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"Basin Analysis of the Mississippi Interior Salt Basin and Petroleum System Modeling of the Jurassic Smackover Formation, Eastern Gulf Coastal Plain"

Second Annual Report
August 23, 1997-August 22, 1998

Problem

Oil and gas producers in the Eastern Gulf Coastal Plain maintain that the accessibility of oil and gas information is the single-most important factor to assist them in finding new hydrocarbon discoveries and in improving production from established fields in the Mississippi Interior Salt Basin.

Project Description

The northeastern Gulf of Mexico remains a vastly underexplored region containing numerous basins with a host of siliciclastic and carbonate formations having a high potential for hydrocarbon accumulations. To date, comprehensive basin analysis and petroleum system modeling have not been performed in these basins. Further, small- and medium-size companies are drilling the majority of the wells in this region, and these companies do not have the resources to independently conduct basin studies or to perform extensive searches of the data available on these basins.

Project Objectives

The project objectives are improving access to information for the Mississippi Interior Salt Basin by inventorying data files and records of the major information repositories in the region, making these inventories easily accessible in electronic format, increasing the amount of information available on domestic basins through a comprehensive analysis of the Mississippi Interior Salt Basin, and enhancing the understanding of the petroleum systems operating in the Mississippi Interior Salt Basin.

Research Accomplishments

Year 1

An industry advisory committee consisting of Dave Cate (Pruet Oil Company), Tom McMillan (Smackco, Ltd.), Julius Ridgway (Ridgway Energy, Inc.), Robert Schneeflock (Paramount Petroleum), Harry Spooner (Spooner Energy, Inc.), and Terry Tigrett (Moon-Hines-Tigrett Operating Company) has been constituted.

The inventory of public data available for the Mississippi Interior Salt Basin has been completed. The inventory consisted of past and current petroleum geology research projects at the major research institutions in the region and at the geological surveys and oil and gas regulatory organizations in the area. Service companies and state agencies were contacted for listings of wells, logs, cores and cuttings, production data, and other drilling and production information and seismic data.

The information has been made available in electronic format through the Website of the Eastern Gulf Region of the Petroleum Technology Transfer Council (EGR) and through the respective state agencies. In addition, links to commercial entities with oil and gas information and data are available through the EGR Website. Base maps illustrating commercially available seismic reflection data have been identified, compiled and are available in electronic format.

Because much of the oil and gas information and data are not available in an electronic format, researchers on this project continue to work with state agencies in Mississippi, DOE and PTTC to make this information available electronically. This effort is a major undertaking and beyond the scope of this project.

To accomplish the objectives of this project, researchers have used oil and gas information and data available in the commercial domain for the basin analysis and petroleum system modeling components of this project.

The oil and gas public data available for the Mississippi Interior Salt Basin has been compiled and published (DOE/BC/14946-3). The report includes a bibliography, a listing of state agency reports and documents, a listing of theses and dissertations, a base map illustrating available seismic

reflection data, a listing of well cores and cuttings and a listing of selected field studies. The report includes information from the Alabama Geological Survey, the Alabama Oil and Gas Board, the Mississippi Office of Geology, the Mississippi Oil and Gas Board, the Florida Geological Survey, and the Louisiana Geological Survey. Theses and dissertations from the following universities are included in the report: University of Alabama, Auburn University, Mississippi State University, University of Mississippi, University of Southern Mississippi, Louisiana State University, University of Southwestern Louisiana, Northeast Louisiana University, Florida State University, and University of Florida.

Workshops were held in Tuscaloosa, Alabama, on September 26, 1997, and in Jackson, Mississippi, on November 6, 1997, to transfer the information compiled during Year 1 of the project and to discuss with producers the research plan for Year 2 of the project.

During the first year of the project, two underdeveloped hydrocarbon plays have been identified. The salt dome play in the central portion of the Mississippi Interior Salt Basin is estimated to have a potential to add 50 to 75 million oil equivalent barrels of new reserves. An underdeveloped reef play in the Upper Jurassic Smackover Formation along the northern extent of the basin has also been identified.

Year 2

Part 2 of the project is to provide a comprehensive analysis for he Mississippi Interior Salt Basin in Years 2 and 3 of the project and to transfer effectively the research results to producers through workshops and topical reports. Workshops were held in Tuscaloosa, Alabama, on March 3, 1998, and September 23, 1998, and in Jackson, Mississippi, on March 4, 1998, to transfer the knowledge gained from Year 2 of the project and to discuss with the producers the research plan for Year 3 of the project. Topical reports on the tectonic and depositional history (see Attachment 1) and the burial and thermal history of the Mississippi Interior Salt Basin are being prepared.

The regional base map for the oil and gas fields, land grip map, field and reservoir productivity tabulation and well location and formation top database (see Attachment 2) have been

prepared. The well database consists of over 3,000 oil and gas wells that penetrated Jurassic strata in the Mississippi Interior Salt Basin area. To interpret the tectonic and depositional history of the basin, five regional cross sections consisting of 48 key wells have been drawn (see Attachment 3). Subsurface structure maps (see Attachment 4) and isopach (see Attachment 5) maps have been constructed on key stratigraphic horizons. A detailed stratigraphic analysis has been performed on one composite section consisting of two wells (see Attachment 6). This stratigraphic information in conjunction with well log patterns and well cuttings and core descriptions have been used for sequence stratigraphic analysis. The structure and isopach maps have been compared to reconstruct the tectonic and depositional history of the basin.

Standard burial and thermal history software has been used to determine the burial (see Attachment 7) and thermal (see Attachment 8) history of each of the 48 wells utilized in the preparation of the regional cross sections. Sedimentation (see Attachment 9) and subsidence rate determinations are being made for each of these wells. Oil and source rock analysis information (see Attachment 10) has been tabulated and the distribution of these data is being plotted on the regional base map. A vitrinite reflectance study produced limited results (see Attachment 11). Thermal alternation indices in combination with bottomhole temperature data are being used in combination with the results of the vitrinite reflectance study to determine geothermal gradients.

Application and Utility of Project Results

The lessons learned from this project have application in other regions where small- and medium-sized companies are the principal operators. New hydrocarbon and improved field recoveries will add to our domestic petroleum resource base and contribute to national energy security. Additional production will add to the economies of Mississippi and Alabama.

Conclusions

The project is on schedule.

The vast amount of the oil and gas data available in the public domain is not in an electronic format and will require a major effort to achieve this goal.

There is a great deal of oil and gas data available in the commercial domain at reasonable costs. Therefore, the basin analysis and petroleum system modeling studies will utilize data from the public and private sectors to be cost effective.

The first part of the basin analysis study has shown that the principal petroleum traps are salt and basement related. These traps may have a stratigraphic component. The key reservoirs are Jurassic carbonates (Smackover and Haynesville) and sandstones (Norphlet and Cotton Valley) and Cretaceous sandstones (Lower Cretaceous, Tuscaloosa and Eutaw). Source rocks include Jurassic (Smackover), Cretaceous (Tuscaloosa) and possible Paleogene (Wilcox). Seal rocks include anhydrites (Buckner, Ferry Lake) and shales (Tuscaloosa). Hydrocarbon generation and migration were initiated during the Cretaceous and continued into the Tertiary. Major structural movement was in the late Jurassic.

Attachment 1

"Discussion of Jurassic History"

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Tectonic and Depositional History of the Mississippi Interior Salt Basin

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Triassic-Jurassic

This report outlines the tectonic and depositional history and defines the stratigraphy of the post-Paleozoic sediments in the general area of the Mississippi Interior Salt Basin (MISB). Also included in the discussion are the Wiggins Arch, the coastal region south of the Wiggins Arch, the region along the regional peripheral fault trend (underlain by thin salt, if any), and the extreme eastern end of the salt basin along the Mobile Graben.

Basement Rocks and Tectonics

There has been little study of the pre-Mesozoic basement rocks in the Mississippi Interior Salt Basin (MISB) due to the paucity of data. Along the updip margin of the MISB in Choctaw County, Alabama, wells that penetrated the basement rocks were described by Neathery and Thomas (1975) as quartzite, chlorite schist, and dolomitic marble of the Talladega Slate Belt of the Piedmont Province. Thomas (1988) described basement rocks in two cross sections in Mississippi, one in the east central and one in the west central part of the state. In east central Mississippi, the age of the basement rocks increases

downdip across the regional peripheral fault trend. For example, in Lauderdale County, in the updip area of the regional peripheral fault trend, Mesozoic rocks overlie upper Paleozoic (Pennsylvanian) rocks. In the middle and downdip areas of the regional peripheral fault trend, Mesozoic rocks overlie lower Paleozoic (Cambrian-Ordovician) carbonate rocks. The cross sections by Fischer (1974; 1978) in Newton and Jasper Counties and in Clarke County, Mississippi, respectively, show undifferentiated Paleozoic rocks and Cambrian-Ordovician dolomite and limestone in the updip areas underlying the Jurassic rocks. A lithologic log from one of the wells included in this study (API number 23-023-00270) encountered several hundred feet of section comprised of limestone, chert, sand, and lignite, which is interpreted as a combination of weathered and fresh lower Paleozoic rocks, with some down-hole contamination. It is likely that the carbonate rocks in well 23-023-00270 are the same as those described by Neathery and Thomas (1975), i.e., lower Paleozoic Talladega Piedmont rocks. There are no descriptions of basement rocks in the deeper portion of the MISB in Mississippi.

Along the southern margin of the MISB, two wells in Jackson County, Mississippi, on the Wiggins Arch, penetrated Paleozoic granite. In addition, Cagle and Khan (1983) reported that 2 wells penetrated phyllite on the arch. Harrelson and Bicker (1979) reported the granite from the Amoco Cumbest well (depth 18,817-18,826) to be 272± 10 m. y. (date given by Amoco Production Company, 1979, personal communication), indicating a late Paleozoic age. Harrelson and Jennings (1990) also described granite from the Champlin No. 1 International Paper Company well in Jackson County, Mississippi. The granitic (continental) crust underlying the Wiggins Arch, therefore, is genetically related to Pangaea, rather than to the Gulf of Mexico.

Sawyer et al. (1988) interpreted the MISB to lie on thick transitional crust. Thick transitional crust generally lies landward of the Early Cretaceous carbonate margin and seaward of the regional peripheral fault trend and is associated with the opening of the Gulf of Mexico. In the northern Gulf of Mexico region, the thick transitional crust is characterized by a series of alternating basement highs and lows (Sawyer et al., 1988). The highs include the Sarasota Arch, the Middle-Ground arch-Southern platform, the Wiggins Arch, the Monroe uplift, and the Sabine uplift. The intervening basins are the South Florida basin, the Tampa embayment, the Appalachicola basin and embayment, the MISB, the North Louisiana Salt basin, and the East Texas basin. Thomas (1988) interpreted the location of the MISB and the Wiggins Arch as

resulting from crustal extension and counterclockwise block rotation associated with a pull-part basin within a wrench system. This interpretation is in the context of the transpressional and transextensional tectonic regimes associated with the separation of Yucatán from North America. MacRae and Watkins (1996), building on the concepts of Thomas (1988), proposed a rift-stage oblique-shear extensional framework for the northeastern Gulf of Mexico margin in which these basement highs and lows were "sandwiched" between two large transfer faults, the Pearl River transfer fault and the Florida-Bahamas transfer fault.

In west-central Mississippi, the "basement" rocks are generally Cretaceous volcanic rocks associated with the opening of the Gulf of Mexico and resulting tectonic disturbances. The Jackson Dome, a buried volcano lying directly underneath Jackson, Mississippi, is a very well defined basement structure. The anticlinal structure of the Jackson area has been known for a long time (Hilgard, 1860). Drilling of the structure for oil and gas began as early as 1917 (Harrelson, 1981). Monroe and Toler (1937) described both extrusive and intrusive igneous rocks from the Jackson Dome. Harrelson and Bicker (1979), Harrelson (1981) and Saunders and Harrelson (1992) subsequently studied these igneous rocks. Harrelson (1981) interpreted that doming of the Jackson structure was initiated in the Jurassic, based ostensibly on stratigraphic relations. The doming, which was due to plutonism, continued through Early and mid-Cretaceous time until several volcanic vents opened to the surface, causing explosive volcanism. The volcanism continued almost to the end of the Cretaceous (Saunders and Harrelson, 1992). The volcano is capped by the Jackson "Gas Rock," a reef consisting of bryozoans, foraminifera, and corals (Harrelson, 1981). K-Ar geochronology indicates that the igneous rocks of the Jackson Dome range from 79.0 ± 2.9 Ma to 69.2±2.9 Ma, although dates as young as 65.8 ± 2.7 Ma (Cook, 1975) and as old as 91.3 ± 3.4 Ma (Sundeen and Cook, 1977) are reported from other areas of Mississippi. These data indicate that the northern margin of the MISB was an area of intense tectonic activity throughout much of the latter part of the Mesozoic Era.

Syn-Rift History

Eagle Mills Formation

Formations that show clear evidence of syn-rift deposition include the Eagle Mills Formation, the Werner Anhydrite, and the Louann Salt, including its Pine Hill Anhydrite Member. Evidence for syn-rift

deposition includes localized source rocks, interbedded continental and volcaniclastic sediments and/or basaltic sills and dikes, irregular or abrupt changes in distribution, and sequence of rock types. The abrupt change in thickness is demonstrated in Arkansas, where the thickness changes from nearly 7,000 feet to zero within approximately five miles (Scott et al., 1961). The paleogeographic maps of Salvador (1987) show that the width of the subcrop belt is much narrower in Alabama and Mississippi than it is in Georgia and the Atlantic Coastal Plain and in southern Arkansas. The Eagle Mills Formation was observed in only 3 wells on the regional cross sections, all in updip areas of Mississippi. This distribution is evidence supporting the interpretation of Thomas (1988) that a large transform fault defined the continental margins of the southern part of the United States. The Atlantic and Arkansas areas were subjected to extensive extensional forces while the Mississippi-Alabama offset area was subjected to more strike-slip movement.

The type well for the Eagle Mills Formation is the Amerada Company No. 1 Eagle Mills well in Ouachita County, Arkansas (Scott et al., 1961). The definition of the Eagle Mills Formation has changed several times since it was first used in 1929. In one of the earliest published reports, Weeks (1938) described 1190 feet of red sand and shale lying above Paleozoic rocks and below Comanche (Lower Cretaceous) rocks in the type well. In other wells in the area, salt was encountered at about the same stratigraphic position as the red beds, leading Weeks (1938) to conclude that the salt was in part equivalent to the red beds. Weeks also described a 60-foot bed of anhydrite lying between the red beds and overlying salt. In another well, 100 feet of anhydrite was observed between the Eagle Mills red beds and the Smackover Formation. Thus, the definition of the Eagle Mills Formation expanded to include not just the red beds, but the superjacent anhydrite and salt. Weeks (1938) also interpreted the Eagle Mills Formation to be of Permian age, due to the lithologic similarity to the abundance of Permian salt and red beds in western Kansas, Oklahoma, and Texas, and the lack of such deposits in any beds of other age in the region of Arkansas.

Hazzard (1939) also interpreted the Eagle Mills to include red shales, mudstones, and sandstones, salt and anhydrite. Hazzard thought the red beds and anhydrite were deposited shoreward while the salt was deposited basinward. However, the formation was considered to be of questionable Jurassic age. By 1947, Hazzard realized that the salt was not the equivalent of any part of the Eagle Mills Formation, and thus recognized the Smackover limestone, Norphlet red, sandy shale, Louann rock salt, and Werner anhydrite

from the Eagle Mills Formation. However, due to lack of any age-diagnostic fossils, the age of the formation was still not known. It was not until Scott et al. (1961) that the age of the Eagle Mills was determined. Specimens of plant impressions observed in a core from a well in Arkansas were identified as the Late Triassic *Macrotaeniopteris magnifolia* (Rogers) Schimper, known at that time only from the Upper Triassic Chinle Formation of Arizona and the Upper Triassic Newark Group of Virginia.

The Eagle Mills Formation is, therefore, the predominantly Late Triassic red bed deposits that generally occur in the half grabens associated with the initial rifting of the Gulf of Mexico Basin. The sporadic distribution of the Eagle Mills Formation and the narrowness of its subcrop pattern in the MISB compared to the very thick and widespread distributions in Arkansas and Louisiana and along the Atlantic Seaboard suggest that the former area was along a transform offset while the latter areas experienced more extensive extension.

Werner Anhydrite

Weeks (1938) described the relatively deep occurrence of anhydrite in two wells in Arkansas. In one well, a 60-foot bed of anhydrite occurred between the Eagle Mills red shale and the overlying salt. In another well, a 100-foot anhydrite bed occurred between the Smackover limestone and the underlying Eagle Mills red shale, thus implying an absence of the salt at that locality. This anhydrite bed was often associated with conglomerates and red siliciclastic sediments. Hazzard et al. (1947c) named this interval the Werner Formation, which consisted of a lower Red Bed member and an upper Anhydrite member. The maximum thickness of the Red Bed member was reported as more than 100 feet, which is the same maximum thickness as the Anhydrite member. The Werner Anhydrite occurs from the East Texas basin, across northern Louisiana and southern Arkansas, and into Mississippi and Alabama. The Werner is now generally considered to be restricted to the Anhydrite member, the red beds being classified as Eagle Mills, although Raymond et al. (1988) stated that subjacent conglomeritic beds might occur locally. The Werner and Louann Salt are generally believed to represent a single cycle of salt precipitation (Salvador, 1991b). Indeed, there is considerable evidence to suggest that anhydrite originally encased the salt, being found below (Werner), above (Pine Hill Member) and in marginal areas of the salt (Rhodes and Maxwell, 1993). Therefore, the Werner may be, in part, age equivalent of much of the Louann Salt.

In the MISB, the Werner is only rarely encountered, as the principal oil and gas producing units are stratigraphically above this formation. Further, Dinkins (1968) concluded that Werner rocks were still associated with grabens and half grabens, suggesting a limited subcrop distribution. According to Ericksen and Thieling (1993), the Werner Formation has not been definitively recognized in the downdip area of southern Mississippi, although one of the wells in the cross sections of Petty et al. (1995), the Betty Joe Anderson well no. 1, from Mobile County, Alabama, shows a thin (50') section of Werner. Tolson et al. (1983) observed the Werner Formation in only 2 out of 30 wells studied in southwestern Alabama, which included the Betty Joe Anderson; however, most drilling stopped above this unit.

Louann Salt

The Louann Salt was considered by Salvador (1991b) to be unsurpassed in its importance in understanding the geology of the Gulf of Mexico basin. The large-scale distribution of the salt offers clues as to the configuration of the Gulf of Mexico (GOM) basin at the time of deposition. Halokinetic structures, ranging in scale from regional faults to individual salt domes, profoundly affect the distribution of oil and gas in the region.

In continuous sequences, the Louann Salt lies conformably on the Werner anhydrite (Salvador, 1991b). The Louann is composed almost entirely of halite, with minor amounts of anhydrite, and small amounts of pyrite, dolomite, quartz, and potassium salts (Salvador, 1991b). The original thickness of the Louann is very difficult to determine, but there is little doubt that the thickness was highly variable. In some areas, such as the MISB, the salt was ostensibly thick, whereas there is no salt at all over the Wiggins Arch (Rhodes and Maxwell, 1993). Andrews (1960b) estimated the Louann to have an original thickness of 4000 to 5000 feet. Oxley et al. (1967) also estimated the Louann's original thickness to have been 5000 feet or more. Salvador (1991b) estimated an original thickness of 1200 to 1500 m (about 3800 to 4700 feet) for the MISB, and more than 3000 m (9420 feet) for the Texas-Louisiana continental slope.

The stratigraphic relationship of the Louann Salt with overlying units is problematical. Some geologists, such as Hazzard et al. (1947c), Andrews (1960a), Bishop (1967), and Tolson et al. (1983) considered the base of the Norphlet Formation to be an unconformity, whereas others, such as Badon (1975), McBride (1981), and Mancini et al. (1981) considered the Pine Hill anhydrite member and black shale facies of the Norphlet to represent transitional facies. The lithology of the underlying or basal unit of

the Norphlet is variable. For example, Badon (1975) described a black shale and red siltstone member of the lower Norphlet that is present in a relatively small area of Clarke County, Mississippi. Badon (1975) interpreted the black shale to represent deposition under stagnant, low-energy conditions in a trough-shaped depression that developed during the terminal phase of Louann deposition. In areas outside of the black shale "trough," the red siltstone facies lies directly on the salt. This black shale unit, although discontinuous in aerial extent, occurs extensively, being described from Alabama (Mancini et al., 1985; Tolson et al., 1983) and Mississippi (Badon, 1975). The Norphlet can also lie on anhydrite (Pine Hill Anhydrite Member of the Louann Salt) or directly on salt (Ericksen and Thieling, 1993; Mink et al., 1990; Rhodes and Maxwell, 1993; Tolson et al., 1983). The variable nature of the lower contact of the Norphlet Formations suggests that it is an unconformable surface.

Pine Hill Anhydrite Member of the Louann Salt

Oxley et al. (1968) first named the Pine Hill Anhydrite Member of the Louann Salt, but did not designate a type well for the member. Raymond et al. (1988) later designated the Brandon Company, W. J. Miller et al. No. 1 well, with depths of 8,764 to 8,772 near Pine Hill, Wilcox County, Alabama, as the type well. Oxley et al. (1968) described the anhydrite bed as having a maximum thickness of 210 feet, although Raymond et al. (1988) reported a maximum thickness of approximately 100 feet. Raymond et al. (1988) described the member as white finely crystalline anhydrite with random reddish inclusions and occasional interbeds of salt. Use of this stratigraphic term has been sporadic; for example, several of the wells described by Tolson et al. (1983) contained anhydrite at the top of the salt, but the term Pine Hill was not used. The cross section of Rhodes and Maxwell (1993) of the Jurassic stratigraphy of the Wiggins Arch shows that anhydrite is present below, on top of, and in marginal areas of the Louann Salt, suggesting gradational evaporitic conditions from sea water to anhydrite to salt (excluding any precursor minerals). This relationship means that the Pine Hill Anhydrite Member can only be defined where it is known that salt underlies it; that is, anhydrite encountered below the Norphlet could be either Pine Hill, anhydrite laterally equivalent to the Louann, or Werner.

The Pine Hill Anhydrite has been described from Alabama (Mink et al., 1985; Raymond et al., 1988; Tolson et al., 1983) and from the offshore region of Mississippi (Ericksen and Thieling, 1993; Petty et al., 1995), but descriptions from the central part of the MISB are lacking. Oxley et al. (1968) noted that

thick anhydrite occurred in some areas of the MISB and was interpreted to be caprock formed when the underlying salt intruded into the overlying sediments containing fresh water (i.e., Cotton Valley). It is not clear, then, if anhydrite only occurs over salt domal structures or if it occurs as a horizon on top of the salt in interdomal areas. Certainly, it does not occur everywhere in Mississippi, such as those localities described by Badon (1975) in Clarke County, where black shales of the Norphlet Formation directly overlie salt. More study is needed to determine the distribution of the Pine Hill in Mississippi.

Post-Rift Stratigraphy

Salvador (1991b) considered the end of the Middle Jurassic or earliest part of the Late Jurassic to be the point in time separating syn-rift from post-rift tectonism. Thick accumulations of salt (Louann) formed in persistently subsiding basins, generally those that were previously active. The salt is thinner over structurally higher basement blocks and absent over the highest blocks, such as the Wiggins Arch (Rhodes and Maxwell, 1993). Following the interval of active rifting, the Gulf of Mexico region was characterized by the prolonged subsidence of the central Gulf region (Salvador, 1991b).

Norphlet Formation

As mentioned previously, early publications, such as Weeks (1938) and Blanpied and Hazzard (1939) placed what is now referred to as the Norphlet Formation into the Eagle Mills Formation. However, even early petroleum geologists (Bingham, 1937) recognized a siliciclastic tongue that occurred between the salt and the limestone of the Smackover Formation. Imlay (1940) defined these red siliciclastic beds as the Norphlet tongue of the Eagle Mills Formation. Several of the wells described by Imlay (1940) included red beds and red, sandy shale lying stratigraphically between the rock salt and limestone, ranging from 18 to 47 feet in thickness. Hazzard et al. (1947c) defined the Norphlet Formation as "…the siliciclastic section which is encountered below the base of the Smackover Limestone in wells in the Tri-State area." Such a poor definition for a formation requires refinement because, for example, the Smackover may overlie Paleozoic siliciclastic rocks, which would then be referred to as "Norphlet." Ostensibly, the reason Hazzard et al. (1947c) did not define a lower boundary was because the Norphlet had been observed to rest on: a) Louann Salt, b) Werner Anhydrite, c) Eagle Mills Formation, or d) undifferentiated Paleozoic rocks. The variable underlying formations led Hazzard et al. (1947c) to conclude the presence of an unconformity

"…of considerable magnitude…" at the base of the Norphlet Formation. Typical lithologies of the Norphlet in the type area are "…composed of red clays, with some gray clays, reddish and gray sands, with or without gravel." The maximum thickness in the type area was approximately 150 feet, although the range was from 13 to 147 feet in thickness.

The Norphlet Formation can consist of four lithofacies: a basal black shale lithofacies, described above by Badon (1975) and Wilkerson (1981b); a red bed lithofacies of Badon (1975), Wilkerson (1981a), and Mancini et al. (1985), which includes sandstones, siltstones, and shales; a low-angle, cross-bedded sandstone; i.e., Denkman Member of Murray (1961); and a conglomeritic sandstone, occurring in the most updip areas of Dinkins (1968), Wilkerson (1981b), Tolson et al. (1983), and Mancini et al. (1985)).

As discussed earlier, the black shale has a discontinuous but regional extent. Badon (1975) described a black shale lithofacies from the lower part of the Norphlet Formation in Clarke County, Mississippi. The shale had an average thickness of 30-40 feet, and was composed primarily of carbonaceous material. The shale was found within a relatively small area, just a few square miles. Wilkerson (1981b) described a shale lithofacies at the base of the Norphlet in Escambia County, Alabama. The shale in Escambia County was also discontinuously distributed. Maximum thickness was 8 feet. This shale was mostly black, with some brown and red shale, and was found to be barren of palynomorphs and kerogen, suggesting deposition under harsh conditions. Tolson et al. (1983) described black shale from the base of the Norphlet Formation in Choctaw and Clarke Counties, Alabama. Mancini et al. (1985) reported the black shale to occur in the offshore regional of Alabama. Badon (1975) considered the black shale lithofacies to have been deposited in isolated depressions on the Louann Salt.

The red bed lithofacies has a much wider distribution than the black shale lithofacies. Mancini et al. (1985) stated that the red bed facies becomes dominant in the updip areas of Alabama. Petrographic analyses by McBride et al. (1987) indicate that the red bed lithofacies is composed mainly of subarkoses and arkoses. Wilkerson (1981a) recognized two subunits of the red bed lithofacies. The lower subunit consisted of red, silty sandstone with occasional thin laminae of medium- to coarse-grained sandstone, and discontinuous non-parallel laminae. This subunit ranged from about 50 to 100 feet thick. The upper subunit was a brownish-gray, very-fine- to very-coarse-grained sandstone with horizontal to slightly inclined planar

laminae of fine- and coarse-grained sandstone. The upper subunit was about 30 feet thick. Petrographic analyses by Wilkerson (1981a) yielded similar results to those of McBride et al. (1987).

The Denkman Member of the Norphlet Formation is generally characterized as quartz sandstone. Murray (1961) defined the Denkman sand on the basis of sediments encountered in the Lion Oil Company's No. 2 Denkman well in Rankin County, Mississippi. The Denkman was considered to possibly be continuous with the Norphlet Formation of the Lou-Ark area, but was said to be "…different lithologically," although this difference was never stated. The Denkman was observed to be at least 279 feet thick in the type well (total depth was still within the unit). Hartman (1968), however, described the Norphlet from a well in Pelahatchie Field, only about 10 miles from the Denkman well. Hartman (1968) concluded that the Denkman sand of Murray (1961) was probably equivalent to the Norphlet in the Pelahatchie Field. In the Pelhatchie Field, the Shell-Love et al. W. D. Rhodes et al. Unit 1 well encountered 716 feet of Norphlet before reaching total depth. McBride et al. (1987) stated that the Denkman was more than 325 m (1020 feet) thick in the Chevron 1 Cox well in northern Rankin County, Mississippi. The Denkman is more than 700 feet thick in Washington County, Alabama (Tolson et al., 1983; Wilkerson, 1981a).

The Norphlet in the type area is "…composed of red clays, with some gray clays, reddish and gray sands, with or without gravel" (Hazzard et al., 1947c). In contrast to the type area, the formation in Rankin County is a light to dark gray, fine- to very-fine-grained sandstone, with very well sorted, subangular to well rounded quartz grains. Shale and/or clay are absent. Wilkerson (1981a) described the Denkman from southwest Alabama as gray to brown, fine grained, well sorted sandstone with rounded and frosted quartz grains. The most distinctive feature of this member is the cross bedding, consisting of thick sets of low to high angle planar cross laminae. Interbedded with the cross-bedded intervals were massive sandstone and horizontally laminated sandstone. At the top of the sequence is a massive interval, apparently the result of marine reworking. The contact between the Denkman and the Smackover is generally sharp, but is gradational in parts of Mobile County (Wilkerson, 1981a).

A conglomeritic sandstone facies occurs in the extreme updip areas of the Norphlet Formation. This conglomeritic facies has been observed in Mississippi (Dinkins, 1968) and in Alabama (Tolson et al., 1983; Wilkerson, 1981a). Fischer (1978) noted cherty clasts in the updip area of Clarke County,

Mississippi, and Choctaw County, Alabama, apparently derived from the adjacent uplifted Paleozoic highlands. Pepper (1982) noted that the conglomeritic facies of the Norphlet reaches a thickness of approximately 400 feet in Monroe County, Alabama, which is east of the eastern limit of the MISB. Rhodes and Maxwell (1993) observed “granite wash” in the Norphlet Formation in areas immediately adjacent to the Wiggins Arch, indicating a source within the granitic basement of the arch. However, most of the Norphlet was composed of eolian sand derived from the north.

The environments of deposition of the Norphlet Formation are fairly straightforward. The conglomeritic sandstone facies occurs in the most updip areas, and was deposited in a series of coalescing alluvial fans (Mancini et al., 1985; Salvador, 1991a; Wilkerson, 1981a). Mancini et al. (1985) suggested debris flow as the primary transporting mechanism, based on such observations as the restricted updip distribution of this lithofacies, the presence of granule to cobble-size clasts of chert, shale, quartzite, granite, and rhyolite, the immature texture of the sandstones, the apparent lack of stratification, and the matrix-supported nature of the deposits. The conglomeritic sandstone facies grades downdip into the red bed facies, which Wilkerson (1981b), Pepper (1982), and Mancini et al. (1985) interpreted as distal portions of alluvial fan and wadi complexes. Further downdip, these wadi complexes gave rise to the dune facies of the Denkman Member. Hartman (1968), Badon (1975), Wilkerson (1981b), Honda and McBride (1981), Pepper (1982), Mancini et al. (1985), Marzano et al. (1988), and Salvador (1991b) concluded an eolian origin of the Denkman. It is this eolian facies that constitutes the bulk of the formation where it is most thick (Hartman, 1968; McBride, 1981; McBride et al., 1987). Pepper (1982) suggested that the high angle, well-sorted cross-laminated intervals are dune deposits, whereas the massive and horizontally laminated intervals were interdune deposits. The upper, massive portion of the Denkman was interpreted by Mancini et al. (1985) to be reworked by marine processes, and represented shoreface deposits. As mentioned previously Badon (1975) and Wilkerson (1981b) concluded that the basal black shale facies was deposited in isolated depressions in the Louann Salt.

The Norphlet Formation thickens considerably going from the Lou-Ark area into Mississippi. The Norphlet Formation in the tri-state area of southwest Arkansas, northwest Louisiana, and northeast Texas ranges from 15 to 70 feet thick, but averages about 50 feet thick, and consists of light-gray to brown, friable, poorly sorted sandstone and conglomeritic sandstone, gray shale, and anhydrite (Dickinson, 1968).

The isopach maps of Marzano (1988), Mink et al. (1990), and Salvador (1991b) show four major depocenters: west central Mississippi in the Rankin County area (just over 1000 feet thick); western Alabama in west-central Washington County (just over 800 feet thick); an area just offshore from Mobile Bay (thicknesses over 500 feet); and offshore panhandle Florida (thicknesses more than 300 feet thick). The Norphlet Formation thins in further downdip areas, and may possibly pinch out into salt (Salvador, 1991b). The cross sections along the coastal area of Mississippi by Petty et al. (1995) show the Norphlet to be fairly thin, generally less than 70 feet thick, except for Mobile County, Alabama where is was 347 feet thick. The Norphlet was also shown to be missing on the Wiggins Arch

Age

Hazzard et al. (1947c) interpreted the Norphlet Formation to be of Jurassic age. The ages of the pre-Smackover stratigraphic units were speculative for many years, due to the lack of age-diagnostic fossils in the red bed-salt interval. As noted above, it was not until 1961 that a reasonable age date could be obtained for the Eagle Mills Formation. Most geologists tentatively concluded that the salt was of the same age as the evaporite deposits of the Permian Basin, an interpretation that was maintained until 1947. Although Hazzard et al. (1947c) interpreted the Norphlet Formation to be non-marine in origin, it was more closely related to the overlying limestone of the Smackover than the underlying salt, from which it was separated by an unconformity. Therefore, the Norphlet was assigned a Jurassic age, while the Louann remained in the Permian. Based on a complex series of regional correlations, principally between the northern GOM region and Mexico, the Norphlet Formation is considered to be of Late Jurassic (Oxfordian) age (Salvador, 1991b).

Norphlet Stratigraphy from Regional Cross Sections

The full thickness of the Norphlet Formation was penetrated in only a few wells examined for this study, thus the full thickness of the formation is not known for most of the wells. The upper part of the Norphlet was, however, penetrated for more than half of the wells, and lithologic and/or sample log descriptions are available for most of these wells. The following descriptions of the formation will proceed from the western portion of the MISB to the eastern portion along section A-A’, and will proceed from downdip to updip areas along the dip sections.

The Norphlet Formation was not penetrated in the Issaquena County wells. In Sharkey County, the Norphlet is only 28 feet thick. The formation is recognized on wireline logs by an increase in gamma ray values and a sharp decrease in resistivity values relative to the overlying carbonate sediments of the Smackover Formation. Sample and lithologic logs from a nearby well indicate that the Norphlet consists of brick-red shale, brownish-gray, dolomitic, and pyritic sand that overlie salt and anhydrite. In extreme southern Hinds County (well 23-049-20032), the siliciclastic-dominated Smackover section (see below) in this region makes recognition of the Norphlet-Smackover contact difficult. On wireline logs, the Norphlet is recognized by a decrease in gamma ray values and an increase in resistivity values relative to the overlying Smackover. A lithologic log from this well indicates that the Norphlet Formation is generally comprised of white, clear, and light gray, very-fine- to fine-grained, slightly calcareous and non-calcareous sandstone; gray, dark gray, and brown, firm, calcareous and slightly calcareous shale; with minor amounts of dark gray, arenaceous, limestone. The Norphlet section is generally sandier than the Smackover Formation, which is predominantly shale. The lithologic log shows that the bottom of the well is in the Norphlet Formation at a depth of 25,460 feet, indicating a thickness of at least 854 feet. Anhydrite is present in minor amounts in the lower part of the Norphlet section. The stratigraphic relations of the Norphlet and Smackover Formations remains problematical for this well, due to the overwhelming predominance of siliciclastic sediments throughout the Jurassic section and lack of paleontological control of the ages of the sediments. The Norphlet Formation was not penetrated in well 23-049-20004, located in southern Hinds County. The Norphlet in well 23-049-20005, located on the Jackson Dome in northern Hinds County, is 220 feet thick. The formation is recognized on wireline logs by an increase in SP values and a decrease in resistivity values relative to the overlying Smackover Formation. A sample log indicates that the Norphlet Formation is comprised of white, gray, pink and red, fine- to medium-grained, moderately cemented to unconsolidated quartz sandstone, with abundant pyrite in parts; reddish-brown and gray, silty and sandy shale; and with traces of whitish-gray limestone in the upper portion.

The Norphlet Formation in well 23-089-20043, located in western Madison County, is 121 feet thick. The formation is recognized on wireline logs by a sharp decrease in resistivity values relative to the overlying Smackover Formation. The bottom of the formation was recognized by well loggers by the first occurrence of salt in the well. The Norphlet Formation in well 23-163-20150, located in southern Yazoo

County, is only 40 feet thick. The wireline log is indistinct for the formation, although the SP values decrease significantly below a depth of 16,700 feet, which is approximately 40 feet above the top of the Norphlet. The upper and lower contacts of the Norphlet for well 23-163-20150 are recognized primarily on the basis of a lithologic log. The log indicates that the Norphlet is comprised of clear, gray, and clearish-white, fine- to medium-grained, unconsolidated, partly calcareous quartz sandstone. The Norphlet Formation is not recognized in the updip portion of section B-B' except for well 23-083-20011, located in southern LeFlore County. The Norphlet is very thin (approximately 25 feet thick), and the electric log signal suggests a shaley lithology. A sample log for a nearby well indicates that the Jurassic sediments overlie igneous rocks.

The Norphlet Formation in well 23-121-20025, located in north central Rankin County, is at least 170 feet thick, although the bottom of the formation was not penetrated. The top of the formation was recognized primarily on the basis of a sample log; the wireline log is indistinct. The lowest occurrence of limestone of the Smackover Formation is recognized as the top of the Norphlet. The sample log indicates the Norphlet Formation is comprised of very-fine to fine-grained, slightly porous and non-porous sandstone.

The Norphlet is recognized in only about half of the wells in section C-C'. The formation is not recognized in the most down dip well, well 23-065-20141, located in Jefferson Davis County. The formation is at least 105 feet thick in well 23-127-20055, located in extreme western Simpson County, but the bottom of the formation was not penetrated. The formation is recognized on wireline logs by a distinct increase in SP values and a sharp decrease in resistivity values relative to the Smackover Formation. The Norphlet was not penetrated in wells 23-129-20122, located in south central Smith County, or in well 23-129-20006, the common well for sections A-A' and C-C', located in central Smith County. The Norphlet in well 23-129-20057, located in northeastern Smith County, is only 71 feet thick. Recognition of the upper and lower contacts is based primarily on a lithologic log, as the wireline log patterns are indistinct for this relatively thin interval. The lithologic log indicates that the Norphlet is comprised of red, sandy, silty, micaceous shale; fine- to medium-grained, unconsolidated quartz sandstone; with traces of reddish-gray mudstone, tan and argillaceous limestone, and gray dolomite (possibly due to down hole contamination). The Norphlet Formation in well 23-129-00015, located in northeastern Smith County, is apparently only

about 40 feet thick. The formation is recognized on wireline logs by an increase in SP values relative to the Smackover Formation. Information from industry indicates that salt occurs at a depth of 15,100 feet. The Norphlet in well 23-101-20005, located in southern Newton County, is 330 feet thick. The formation in this well occurs between the Werner Anhydrite and the Smackover Formation. The lower contact is recognized on wireline logs by a sharp increase in resistivity and SP values of the Werner. The upper contact is recognized by low SP values of the Norphlet relative to the Smackover. A sample log from a nearby well indicates that basement in the area is comprised of Paleozoic carbonate rocks. The Norphlet was not recognized in well 23-101-00014, located in central Newton County.

The Norphlet Formation was recognized in most of the wells along A-A' between sections C-C' and D-D'. The Norphlet Formation in well 23-129-00061, located in extreme eastern Smith County, is apparently only 48 feet thick, although recognition of the unit is questionable. The SP and resistivity patterns from wireline logs are indistinct for the interval. A sample log indicates that very-fine- to fine-grained, non-porous sandstone occurs in the interval between the Louann Salt and carbonate rocks of the Smackover Formation. A lithologic log does not indicate this interval to lack carbonate rocks; therefore, if the Norphlet is present in this well, it is thin and indistinct. The Norphlet is not recognized in well 23-061-20203, located in southwestern Jasper County, in which the Smackover Formation lies directly on the Louann Salt. The Norphlet in well 23-061-20028, located in southwestern Jasper County, is 365 feet thick. On wireline logs, the formation is recognized as a distinct interval of reduced resistivity relative to the Smackover Formation. Sample and lithologic logs indicate the Norphlet is comprised of tan to light-gray, very-fine- to medium-grained, non-porous, micaceous sandstone; red and gray, silty shale; with traces of dark gray, dense limestone that is probably due to caving of sediments from higher in the well. The lower contact of the formation is recognized at the highest stratigraphic occurrence of salt. The Norphlet in well 23-061-20244, located in extreme southern Jasper County, is recognized as a very thin (15-foot) interval of sharply decreased resistivity values relative to the limestones of the Smackover Formation and the underlying salt. Because no lithologic or sample logs were available for this well to verify the predominance or thickness of siliciclastic sediments in this interval, the occurrence of Norphlet in this well is questionable.

The full thickness of the Norphlet Formation in well 23-067-20002, located in northeastern Jones County, is not known because the bottom of the well is in the Norphlet. The formation is at least 95 feet thick. The upper contact of the formation is recognized on wireline logs by sharply decreased resistivity values relative to the Smackover Formation. A sample log indicates that the Norphlet is comprised of white, light-gray and red, very-fine- to medium-grained, lightly porous to non-porous quartz sandstone, with a trace of black, micaceous shale in the lower portion of the well.

The Norphlet is recognized in most of the wells in section D-D', which ranges geographically from Hancock to northern Clarke County, Mississippi. The formation is not, however, recognized in the Hancock County well, which bottoms in the Smackover Formation. The Norphlet in well 23-111-00069, located in extreme southern Perry County, is apparently only 20 feet thick. The formation is recognized by greatly reduced resistivity values and increased SP values relative to the Smackover Formation. Information from industry and from the Mississippi Geological Society Jurassic cross sections (Twiner, unpublished) indicate that the salt occurs at a depth of 20,125 feet in this well. The Norphlet is not recognized in well 23-153-20077, located in southern Wayne County. The formation in well 23-153-01008, the common well for sections A-A' and D-D' located in central Wayne County, is 198 feet thick. The upper contact is recognized on wireline logs by a sharp decrease in both SP and resistivity values. The lower contact is recognized by increases in SP and resistivity. Information from industry indicates that salt occurs at a depth of 14,380 feet. A sample log indicates that the Norphlet is comprised of white and light red, very-fine- to fine-grained, non-porous and slightly porous quartz sandstone underlain by dull black, partly micaceous shale and dark and dull red, micaceous shale. The Norphlet in well 23-153-20232, located also in central Wayne County, is 150 feet thick. The upper contact of the formation is recognized by a sharp decrease in resistivity values. The lower contact is recognized at the top of an erratic resistivity interval. A lithologic log indicates that the Norphlet is comprised of clear and tan to light brown, fine- to medium-grained, loose to moderately cemented quartz sandstone, with traces of tan to brown limestone that may be due to caving of sediments from higher in the well. The Norphlet in well 23-153-20265, located in northern Wayne County, is at least 176 feet thick, although the bottom of the formation was not penetrated. The upper contact is recognized on wireline logs by sharply decreased resistivity values, slightly decreased SP values, and a general blocky SP pattern.

The Norphlet Formation in well 23-153-20042, also located in northern Wayne County, is only 53 feet thick. The upper and lower contacts are recognized primarily on the basis of neutron porosity and formation density logs. The upper contact displays a sharp drop in porosity, a significant drop in gamma ray values, a drop in density, and a slight increase in SP values. The lower contact is recognized on the basis of an increase in bulk density and information from industry. A sample log from a well very close to well 23-153-20042 indicates that the Norphlet is comprised of red, light red, and pink, very-fine- to fine-grained, partly argillaceous quartz sandstone; a trace of red and dark red, sandy, finely micaceous shale; and with cavings of limestone and dolomite from the overlying Smackover Formation. Well 23-023-20114, located in southern Clarke County, is the most updip well in section D-D' for which the Norphlet is recognized. The formation is 244 feet thick in this well. The upper contact is recognized by a sharp drop in resistivity values and a slight drop in SP values relative to the Smackover Formation. The top of the salt was reported by industry. A sample log for a nearby well indicates that the Norphlet is comprised of red, light red and pink, very-fine- to fine-grained quartz sandstone.

The Norphlet Formation is recognized in each of the wells along section A-A' between sections D-D' and E-E'. The formation in well 23-153-20545, located in southern Wayne County, is 199 feet thick. The top of the formation is recognized primarily by a sharp drop in resistivity values relative to the Smackover Formation. The top of the salt is reported to be at a depth of 16,125 feet. A sample log for a nearby well indicates that the Norphlet is comprised of fine- to medium-grained, non-porous sandstone, and dark red and maroon, finely micaceous shale. The Norphlet in well 23-153-20122, located in southeastern Wayne County, is at least 122 feet thick, but the bottom of the formation was not penetrated in the well. The upper contact of the formation was recognized by a sharp increase in gamma ray values and decreased resistivity values relative to the Smackover Formation. A lithologic log indicates that the formation contains abundant light gray, dense anhydrite; white to clear, very-fine- to coarse-grained, unconsolidated to moderately cemented, partly calcareous, quartz sandstone; with abundant traces of dark grayish-brown, dense limestone. Much of the described lithology is probably due to downhole contamination from the overlying Smackover Formation. The Norphlet Formation in well 01-129-20054, located in northwestern Washington County, Alabama, is at least 169 feet thick, but the bottom of the formation was not encountered. The upper contact is recognized by a sharp decrease in resistivity and density values. Only the

very top of the Norphlet is penetrated in well 01-129-20024, located in eastern Washington County. The upper contact is recognized by a sharp increase in resistivity values.

The full thickness of the Norphlet was penetrated only in the common well for sections A-A' and E-E'. Norphlet stratigraphy in southwestern Alabama was described extensively in the literature cited above, and will not be repeated here. Well control for the thickness of the Norphlet was poor for the wells used in this study because the overlying Smackover is the principal target for exploration, and drilling typically ceased at or near the base of the Norphlet. See Tolson et al. (1983) for details regarding thickness and lithology of the Norphlet in southwestern Alabama.

Summary

In summary, the Norphlet Formation, which is of early to middle Oxfordian age, lies unconformably on the salt in relatively downdip areas, and can overlie basal black shale, the Pine Hill Anhydrite Member, the Louann Salt, Werner Formation, the Eagle Mills Formation, Mesozoic volcanic rocks, or Paleozoic rocks in updip areas. The formation is considerably thicker in Mississippi and Alabama than it is in the type area of southern Arkansas and northern Louisiana, attaining thicknesses in excess of 1000 feet in west-central Mississippi. There are four areas of relatively thick Norphlet: the Rankin County area of west-central Mississippi; Washington County, southwestern Alabama; the region just offshore of the mouth of Mobile Bay; and the offshore panhandle area of Florida. Four lithofacies are recognized in the Norphlet, which generally occur along strike from updip to downdip areas: a discontinuously-distributed basal black shale facies, possibly deposited in depressions on the Louann Salt; a conglomeritic sandstone facies present in extreme updip areas, deposited in a series of coalescing alluvial fans; a red bed facies occurring downdip of the conglomeritic sandstone facies, deposited in fluvial and wadi systems; and a cross-bedded, quartz sandstone facies, deposited as dunes in an erg sea. The uppermost part of the Norphlet is often massive, suggesting reworking under marine conditions. The Norphlet thins in downdip areas, possible pinching out into salt. The upper contact of the Norphlet Formation with the Smackover Formation can be abrupt or gradational.

Smackover Formation

The Smackover Formation has been the topic of numerous publications, due to the fact that it has been a major producer of oil and gas in the GOM region since the 1930's (Bingham, 1937; Shearer, 1938;

Weeks, 1938). The type locality is at the Lion Oil Refining Company's Hayes No. 9-A, Union County, Arkansas, in the Smackover Field. The Smackover at the type locality is 700 feet in thickness, with the upper 100 feet being a porous, oolitic reservoir (Bingham, 1937).

The Smackover Formation conformably overlies the Norphlet Formation and is conformably overlain by the Buckner Member of the Haynesville Formation. The Norphlet-Smackover contact can be either gradational or abrupt (Mancini and Benson, 1980). In some areas, such as Mobile County, Alabama, dolomitic sandstone of the uppermost Norphlet Formation grades upsection into silty dolomite of the lowest Smackover. In Escambia County, Alabama, quartzose sandstone of the Norphlet is sharply overlain by carbonate mudstone of the Smackover. A variable contact between the Norphlet and Smackover is also observed in Mississippi, where Dinkins (1968) described difficulty in picking the contact at some localities, such as Rankin County, where there is a transitional zone of about 9 feet between the Norphlet and the Smackover, and a sharp contact at other localities.

The thickness and facies distribution of the Smackover Formation was strongly controlled by the configuration of the incipient paleotopography. For example, the Smackover is thick in the MISB, but thins dramatically (in fact, is missing) over paleotopographic highs such as the Wiggins Arch (Cagle and Khan, 1983; Rhodes and Maxwell, 1993; Tew et al., 1993). Halokinesis was initiated as early as the latter part of Smackover time, uplifting certain areas such as the Pool Creek area in Jones County, Mississippi (Dinkins, 1968). The relatively deeper water sediments of the lower Smackover are also absent over basement highs (Benson, 1988; Benson et al., 1997; Benson et al., 1996; Rhodes and Maxwell, 1993).

In Alabama, the Smackover Formation has been subdivided into three informal members, referred to as the lower, middle and upper members (Benson, 1988). The following discussion on the three members is based on the work of Benson (1988). The lower member is comprised of a relatively thin interval of: (1) algal laminite, (2) intraclastic wackestone/packstone, and (3) peloidal-oncoidal packstone/wackestone. The lower member ranges from a few feet to more than 100 feet in thickness. The member is thinnest near the centers of the depositional basins and thickest in the updip areas.

The algal laminite lithofacies is light-gray to tan mudstone with well-developed algal laminations. Fossils are generally absent, but terrigenous material, including clay minerals, mica, and silt are common. The intraclastic packstone/wackestone lithofacies is typically light-gray to tan, with intraclasts consisting of

tabular fragments of algally laminated mudstone. The peloidal-oncoidal packstone/wackestone lithofacies is typically tan to medium gray in color and is dominated by peloids, which may comprise up to 75% of the lithology. Oncoids in this lithofacies range from 5 to 40 mm in diameter. Bioturbation is common. The lower Smackover member lithologies are commonly dolomitized and very pyritic.

The middle member of the Smackover is characterized by light brown to medium gray skeletal peloidal wackestones interbedded with laminated mudstones. The matrix is typically argillaceous. Bioturbation ranges from nonbioturbated to intensely burrowed. Limestone dominates the member, but dolomite occurs locally. Interbedded with the skeletal/peloidal wackestones are intervals of dark-gray to black, laminated, nonfossiliferous mudstones. These mudstones are organic rich and highly argillaceous. The thickness of the middle member of the Smackover is inverse of the lower member, i.e., the middle member is absent in updip areas and is thickest in the depositional sub-basins, reaching a maximum of 400 feet in the Alabama portion of the MISB.

The upper Smackover member consists of a complex sequence of lithologies, dominated by coarsening upward cycles of peloidal, oncoidal, and oolitic packstones and grainstones. The upper Smackover member, therefore, differs from the lower and middle members by the presence of high-energy facies. Cycle thickness ranges from less than 5 feet to approximately 30 feet, with cycle thickness decreasing upsection. Peloids, including *Favreina*, are abundant in this member, which also contains scattered skeletal grains. The upper part of the cycles consists of light-gray to tan, tabular cross-bedded, oolitic grainstones. Subaerial exposure surfaces occur within the grainstone intervals. The nature of the cycles changes near the top of the Smackover. The uppermost cycles fine upsection instead of coarsen, and contain more micrite. These upper cycles typically grade from a lower interval of cross-bedded oolitic or oncoidal grainstone overlain by peloidal grainstones and packstones which are, in turn, overlain by fenestral, mudcracked dolomitic mudstones commonly containing anhydrite nodules. The cycles are capped in places by thin beds of nodular to massive anhydrite.

The dominant lithologies of the upper member are variable according to location. In the northern updip areas of the Alabama portion of the MISB, the upper member is dominated by peloidal and oncoidal grainstones and packstones interbedded with peloidal and skeletal packstones and wackestones with a restricted invertebrate fauna; algal particles are abundant. The upper member in the Manila embayment

contains significant amounts of terrigenous silt and clay, and consists of argillaceous peloidal wackestones and packstones interbedded with argillaceous mudstones and calcareous shales (Wade et al., 1987). In southwest Alabama and in the northern part of the MISB in Choctaw and Clarke Counties, digitate, laminar, or domal blue-green algal boundstones become conspicuous (Baria et al., 1982). These boundstone reefs developed seaward of ooid shoals around paleotopographic highs. Dolomitization is very common in the upper member of the Smackover, especially in updip areas, and has obliterated original depositional fabric.

The Smackover Formation in Mississippi is significantly different from that in Alabama, especially in the central portion of Mississippi. Historically, the Smackover Formation in Mississippi is subdivided only into an upper and a lower ("Brown Dense Limestone") member (Badon, 1974; Dinkins, 1968). The upper member of the Smackover is generally coarse grained and quite sandy in specific areas, whereas the lower ("Brown Dense") member typically consists of more micritic lithologies, although, again, sandstone can be quite common. Electric logs from Clarke County, in particular, clearly display a bipartite subdivision of the Smackover, with very high resistivities in the lower portion and a less resistive upper portion (Jackson and Harris, 1982). Dickinson (1962), however, used a tripartite subdivision of the Smackover for Mississippi and Alabama, similar to the one later used by Benson (1988), with a lower, dark gray to black, laminated, pyritic limestone, a middle unit consisting of light brown to light gray limestone containing much dolomite, and an upper sandy and/or oolitic unit. Shew and Garner (1986) also used a tripartite subdivision for the Smackover in Rankin County, Mississippi, which included lower, middle and upper informal members. The lower member displays parallel laminated mudstones and was interpreted thin and fine-grained turbidite and/or storm deposits that were deposited as basinal to slope sediments. This lower Smackover interval, therefore, differs considerably from the lower member in Alabama, which, as stated previously, Benson (1988) described as algal laminites, intraclastic wackestone/packstone, and peloidal-oncoidal packstone/wackestone which were deposited in relatively shallow water. The middle Smackover of Shew and Garner (1986) consisted of pelletal and skeletal wackestone to packstone, having laterally continuous siliciclastic layers and mudstone to wackestone with interbedded fine subarkosic sandstone. This member constitutes the "Brown Dense Limestone." The middle member was interpreted to have been deposited in inner to outer shelf to slope paleoenvironments. Again, this middle member differs

considerably from the middle member of Benson (1988), which was comprised of skeletal peloidal wackestones interbedded with laminated mudstone. The middle Smackover in Alabama was interpreted by Benson (1988) to indicate initially more open marine conditions than the lower member, and later to represent deeper water, low energy, poorly oxygenated, basinal deposition. The upper Smackover of Shew and Garner (1986) consisted of cross-bedded subarkosic sandstone, thick oolitic interbeds, and increasing oncolites deposited in inner to outer shoal paleoenvironments. The upper member of the Smackover in Alabama consists of a complex of lithofacies, but all were deposited in moderate to high-energy paleoenvironments. The higher-energy conditions of the upper part of the Smackover Formation, therefore, occurs in both Alabama and Mississippi, the difference being in the nature of the sediments, with carbonate occurring in Alabama and mixed carbonate and siliciclastic sediments in central Mississippi.

In northern and eastern Rankin Counties and in southeastern Scott and northwestern Jasper County, the lower Smackover is very sandy and locally conglomeritic (Fischer, 1974; Olsen, 1982; Oxley et al., 1967; Parker, 1974). The Rankin County area was also the depocenter for an unusually thick Norphlet section, suggesting close proximity to an ancestral Mississippi River (Mann and Thomas, 1968). According to the interpretations of Mann and Thomas (1968), the siliciclastic sediments of the Smackover Formation in Rankin County were derived from a branch of the Mississippi River, whereas the source for the siliciclastic sediments in the Scott and Jasper County area were derived from the Appalachian Mountain drainage system. An area of relatively thin Smackover in south central Scott County separates the two regions of siliciclastic Smackover (Oxley et al., 1967). Olsen (1982) interpreted the siliciclastic sediments in the Smackover Formation to be turbidite channel deposits, based on repeated fining-upward intervals, sharp basal contacts, flame structures, small clasts, soft sediment deformation, and possible water release structures in the siliciclastic sequences. Additionally, no desiccation cracks, algal laminations, flat pebble conglomerates or breccias were present that would indicate a shallow water origin. Shew and Garner (1986) agreed that some turbidity deposits may occur in the lower part of the Smackover, but considered the sands in the middle and upper portions of the formation (using a tripartite subdivision) to be storm deposits. They interpreted the Smackover Formation in Rankin County to have resulted from normal deposition in a shoaling-upward sequence with repeated siliciclastic input.

In Clarke County, Mississippi, the Smackover Formation is composed almost entirely of carbonate rocks (Badon, 1973; Jackson and Harris, 1982; Lieber and Carothers, 1983; Meendsen et al., 1987; Oxley et al., 1967; Weber, 1980). Most authors use the standard bipartite subdivision for the Smackover in Clarke County, Mississippi. The lower member, not being of reservoir quality, has been studied less than the upper member. The lower member is a dark gray to black laminated mudstone and very finely crystalline dolomite, with minor amounts of oncolites, intraclasts, and pellets (Badon, 1973; Jackson and Harris, 1982). This interval is the "Brown Dense Limestone." Jackson and Harris (1982) noted the presence of a sandstone unit at the base of the Smackover in Clarke County, which is a common occurrence in other parts of the state (Dinkins, 1968; Meendsen et al., 1987). This lower zone may be analogous to the marine sandstone at the top of the Norphlet Formation in Alabama described by Mancini et al. (1985). The cross section of Fischer (1978) shows scattered anhydritic zones occurring throughout the lower Smackover in Clarke County, as well as conglomeritic sediments and dolomite (especially in the updip areas). As in Alabama and in central and western Mississippi, the upper Smackover in Clarke County is composed of high-energy packstones and grainstones. Badon (1973) described six lithofacies in the upper Smackover, which included pelloidal micrite, superficial oomicrite, pelmicrite, oosparite, oncolitic superficial oosparite, and dolomitic facies. These six lithofacies occur, in general, in order from the lower to upper portions of the upper Smackover. The porous oolitic rocks are the principal reservoir rocks in Clarke County (Jackson and Harris, 1982; Lieber and Carothers, 1983).

A bipartite subdivision of the Smackover is observed in Perry and Stone Counties, Mississippi (Wakelyn, 1977). This area is north of the Wiggins Arch and in the deepest part of the MISB. The Smackover Formation ranges from approximately 800 to 900 feet thick. With the exception of the basal 1 or 2 feet of the formation, there is no sandstone in the Smackover in this region. This basal sandstone is a calcite-cemented quartzarenite, probably analogous to the upper part of the Norphlet described by Mancini et al. (1985). The lower Smackover member is predominantly an irregularly bedded sequence of very finely laminated, argillaceous-organic micrite, banded micrite, massive micrite, wavy-laminated micrite, and contorted laminated micrite (Wakelyn, 1977). The lower portion of this member contains a relatively large amount of sulfide minerals and organic-argillaceous material. There are a few thin zones of dolomite and intraclastic to brecciated pelmicrites (Wakelyn, 1977). Near the top of the lower member is an interbedded

sequence of grainstones and packstones about 30-50 feet thick, which are lithologically similar to those occurring in the upper member.

Wakelyn (1977) observed six lithofacies in the lower member, with two of the six also occurring in the upper member. A calcite cemented quartzarenite bed occurs at the base of the formation. Wakelyn (1977) included this sandstone bed in the Smackover because it was interpreted to be genetically related to the transgression that formed the Smackover Formation, but it was considered to be the uppermost part of the Norphlet Formation by Mancini et al. (1985). A laminated micrite facies constitutes the bulk of the lower member. This facies occurs in beds from 1 foot to 10 feet in thickness. A high percentage of black, opaque laminae are present, which are rich in sulfide materials and organic and argillaceous materials. Individual laminae are less than 1 cm thick, and are usually less than 1 mm thick. Possible algal filament structures were also observed, suggesting analogy to the algal laminite lithofacies of Benson's (1988) lower Smackover member. Interbedded with the laminated micrite facies is the micrite facies, which occurs in beds ranging from 1 to 6 feet thick. This facies may be structureless, sparse peloid, clotted, blocky to faintly laminate with disseminated organics, or completely recrystallized to microsparite. This facies would not appear to have a comparative bed in the lower Smackover member of Benson (1988). A dolomite facies also occurs in the lower member of the Smackover in Perry and Stone Counties. In this facies, dolomite has replaced the original depositional fabric. This facies occurs only in the upper half of the lower member. Asphaltic hydrocarbons fill the intercrystalline void space. The degree of dolomitization is variable, ranging from a dolomicrite to a completely crystalline dolomite with no trace of the original depositional fabric. The intraclastic peloidal facies, which occurs throughout the upper member, also occurs as thin beds in the lower member. This facies is characterized by a predominance of intraclasts (composed mainly of peloids) and peloids, with minor numbers of a fairly diverse invertebrate fauna. Finally, a peloid mixed allochem facies occurs in the lower member. This is the most abundant facies in the upper member. This lithofacies is characterized by approximately two-thirds allochems (in decreasing order of abundance: peloids, oolites, oncolites, bioclasts, and small amounts of calcispheres and micrite-coated grains). A fossil assemblage similar to the previous lithofacies was also observed.

The upper member of the Smackover in Perry and Stone Counties is distinguished by grain-supported lithologies (Wakelyn, 1977). Peloids are ubiquitous in the upper member. Skeletal packstones

are present in the lower two-thirds of the member. There are also thin intervals of nodules that have been replaced by silica in the lower half to upper quarter of the member. Six lithofacies occur in the upper member, including the last two previously described. An oncolitic facies occurs in a massive bed in the middle of the upper member. This facies is dominated by allochemical components, which include, in decreasing order of abundance, oncolites, peloids, oolites, intraclasts, and fossils. The mixed allochem-sparite facies occurs only in the upper third of the upper member. It is similar to the previously defined lithofacies, being dominated by allochems (with peloids being dominant), but also has sparry calcite cement occurring in the interstices. The oolitic peloid facies is best developed at the top of the Smackover. This facies is similar to the previously defined facies, but oncolites are not present.

The Smackover Formation thins considerably in updip areas, and is missing entirely on portions of the Wiggins Arch (Meendsen et al., 1987; Rhodes and Maxwell, 1993). Where the formation is present on paleohighs, such as the Appleton Field structure in southwest Alabama, it is typically composed principally of the upper, high-energy facies (Benson et al., 1996). The Wiggins Arch is a very important structure in understanding of the stratigraphy of the Jurassic of Mississippi and Alabama. Published papers regarding the Jurassic stratigraphy of the Wiggins Arch area include Cagle and Khan (1983), Meendsen et al. (1987) and Rhodes and Maxwell (1993). This structure formed the southern edge of a carbonate platform or on a distally extended ramp surface, causing temporal circulation restrictions to the north and open marine, siliciclastic-free environments to the south. Individual horst blocks, striking generally northeast, remained emergent during Smackover deposition, and supplied siliciclastic sediment to adjacent areas during restricted intervals (Rhodes and Maxwell, 1993). A series of facies belts surround the structure, grading from anhydrite to oolitic grainstone shoals to shallow subtidal to subtidal in an onshore to offshore direction (Rhodes and Maxwell, 1993). The Smackover thickens rapidly away from the Wiggins Arch, especially in northwestern George and southern Greene Counties, Mississippi, where the formation expands from approximately 300 feet thick to more than 1500 feet thick (Meendsen et al., 1987). The bipartite subdivision of the Smackover becomes apparent within a relatively short distance north of the Wiggins Arch (Meendsen et al., 1987; Rhodes and Maxwell, 1993). Proximal to the arch, where the Smackover is approximately 300 feet thick, the formation is composed almost entirely of sucrosic dolomite (Rhodes and Maxwell, 1993).

Little data are available for the Smackover Formation south of the Wiggins Arch platform margin. Rhodes and Maxwell (1993) stated that the Smackover lithologies are more open marine south off the arch, where it is composed of low-energy limestone. Indeed, further west, in northwestern Hancock County, Mississippi, the entire Smackover and Haynesville interval is carbonate (Petty et al., 1994). Sample logs for the Rhoda Lee Brown well in the Catahoula Field in northern Hancock County describe virtually the entire Smackover Formation as a dark gray, dense, cryptocrystalline to microcrystalline, argillaceous, limestone. The contact between the Smackover and Haynesville at this locality is difficult to discern, due to the carbonate facies of the Haynesville (which may be more appropriately termed the Gilmer Limestone) (Rhodes and Maxwell, 1993). Based on the occurrence of a thin anhydrite as the definition for the upper Smackover, the Smackover Formation is just over 1300 feet thick. Southeast of the Rhoda Brown well, in the State of Mississippi Block 57 well (just off the western end of Cat Island), the Smackover Formation was described as deep water, gray shale by Ericksen and Thieling (1993). The Smackover has either undergone a major facies change in the distance between the Catahoula Creek Field and this inner offshore area, or the latter well was drilled on or near the crest of a Smackover bald structure (Ericksen and Thieling, 1993).

Age

Precise determination of the age of the Smackover in the MISB has been difficult because of the rarity of age-diagnostic fossils in this formation. Studies of the age of the Smackover include Imlay (1940; 1943; 1980), Imlay and Herman (1984) and Young and Oroliz (1993). Considerable work has been published on ammonites from chronostratigraphic equivalent units in Mexico, many of which are in Spanish, which are summarized in Salvador (1991a). Corals from the Smackover Formation of Arkansas were described by Wells (1942). Imlay and Herman (1984) reported wells in the southeastern United States from which ammonites were obtained, including one in Mississippi (Shell McNair #1, in Hinds County). Ammonites from the middle and upper portions of the Smackover include species of *Ochetoceras*, *Proscaphites*, *Dichotomosphinctes*, *Discosphinctes*, *Orthosphinctes*, *Idoceras*, and *Euaspidoceras*, indicating a late middle to late Oxfordian age. The occurrence of *Discosphinctes* at the top of the lower fifth of the Smackover from Morehouse Parish, Louisiana, indicates that the lower portion of the Smackover is also of Oxfordian age. Also reported from the Gilmer Limestone (carbonate equivalent of the

Haynesville Formation, according to Forgotson and Forgotson (1976) is the occurrence of *Idoceras* of late Oxfordian or early Kimmeridgian age. Young and Oroliz (1993) reached a similar conclusion regarding the age of the Smackover, based on fossils occurring in a core collected in the Cotton Valley Field, Webster Parish, Louisiana. Upper Oxfordian ammonites collected from the upper one-third of the Smackover include *Lithacosphinctes?*, *Pseudorthosphinctes*, *Orthosphinctes*, *Ardescia*, *Ochetoceras (Cubaochetocera?)*, *Euaspidoceras* (subgen. indet.), *Orthosphinctes*, *Praeataxioceras?*, *Glochiceras* sp. gr. *Amplicanaliculatum*, and *Passendorferia*. Ammonites collected from the lower two-thirds of the core include *Dichotomoceras* gr. *Anconensis*, *Otosphinctes?*, *Dichotomosphinctes* sp., *Lissoceratoides?* sp., *Ochetoceras* or *Cubaochetoceras* sp., and *"Discosphinctes"* sp. gr. The presence of *Acandai* indicates a middle Oxfordian age. Thus a middle-upper Oxfordian assignment of the Smackover Formation, at least in northern Louisiana, seems firmly established.

Very little data are available for the Smackover Formation in the MISB. Petty et al. (1995) reported the occurrence of a few species of dinoflagellates from the upper Smackover in wells of offshore Alabama and Mississippi. Species of dinoflagellates from the Tenneco Oil Company's Viosca Knoll Block 117 well, located approximately 35 miles south of the coast of Alabama, included *Acanthaulax "senta"* Drugg, 1978 and *?Gonyaulacysta jurassica* (Deflandre, 1938) of Oxfordian age, and *Hystrichogonyaulax cladophora?* (Deflandre, 1938) of early Oxfordian age (ages based on Lentin and Williams (1985). The Smackover in the Conoco Mobile Block 991 well, located about 23 miles offshore of Jackson County, Mississippi, contained the dinoflagellate species *Lithodinia jurassica* Eisenack, 1935 of Callovian age, and species of the genus *Valensiella*, which is a long ranging genus. This Callovian age date for the Smackover on the Conoco well is anomalous, as other age data generally indicate an Oxfordian age.

Smackover Stratigraphy from Regional Cross Sections

The Smackover Formation was encountered in most of the wells used to construct the regional cross sections. The bottom of the Smackover, however, was not penetrated in several wells because the upper, porous Smackover was often the target of exploration; once oil or the "Brown Dense Limestone" was encountered, drilling ceased. Further, the Smackover Formation is very deep in certain areas, such as south and southwest Mississippi, and the target formations for wells in these areas are above the

Smackover. Full thickness data are available, though, for more than half of the number of wells in the cross sections.

As has been published several times, and was described above, the Smackover from Rankin County to the west is quite different than the area east of the point. This western Mississippi region is in the area of high clastic sediment content in the Smackover, due probably to the influence of the ancestral Mississippi River. In this area, the Smackover can be difficult to recognize, but the top was picked at the base of overlying anhydrite of the Haynesville Formation.

The Smackover in well 23-055-00066 is about 300 feet in thickness. The formation consists of gray to dark gray, dolomitic, hard, partly fossiliferous limestone, some siltstone, and gray to green, very-fine- to fine-grained sandstone. The Smackover in Sharkey County is about 730 feet thick, but no detailed lithologic or sample log was available for this study. The electric log signal, however, displays the characteristic pattern of the bipartite Smackover, i.e., a highly resistive lower interval ("Brown Dense") and a less resistive upper portion.

The thickness of the Smackover apparently increases from the updip wells of dip section B-B' towards the south, but, again, several of the wells did not penetrate the entire thickness of the formation. The Smackover in LeFlore County is about 560 feet thick. Although no sample or lithologic logs were available for that particular well (23-083-20011), a sample log was available for a nearby well. That sample log confirmed that the bipartite pattern of the electric log reflects the Brown Dense and upper Smackover stratigraphy. In the nearby well, the upper portion of the Smackover consists of tan and brown, very-fine- to fine-grained, crystalline, slightly sandy, and porous dolomite and pale gray to white and light brown, very fine, crystalline, dolomitic limestone.

The Smackover in the central Holmes County well (23-051-20020) rests on recrystallized volcanic rocks. The formation consists of about 590 feet of section. At the base is a 65-foot interval of light gray, buff, fine-grained, calcareous sandstone that is also hard, red, silicified, and metamorphosed. Sandstone beds occur throughout the Smackover. The lower 200 feet is composed mainly of buff, tan or gray, micritic limestone, oolitic in parts, and the upper 100 feet is dominated by gray, tan or buff, very finely crystalline dolomite.

The bipartite stratigraphy of the Smackover is evident in southern Holmes and northern Yazoo Counties, but this stratigraphy is not applicable in the wells to the south in dip section B-B', due mainly to the influx of siliciclastic sediments. In southern Holmes County, the Smackover is about 730 feet thick, with the lower three-quarters of the formation displaying an electric log signal characteristic of a resistive unit and the upper quarter is characterized by a less resistive signal, indicating the Brown Dense lithologies are overlain by the upper, porous Smackover. The northern Yazoo County well displays similar characteristics, although the lower portion of the Smackover was not penetrated. A lithologic log is available for this latter well. The upper portion (200 of the 470 feet penetrated) is gray, dark gray, and black, fine grained sandstone, and dark gray, finely crystalline, slightly sandy, oolitic, very hard limestone. The lower portion of the section is dark gray, very sandy and silty, very dense, finely crystalline limestone. The southern Yazoo County well displays similar characteristics. The northern Hinds County well records the full thickness of the Smackover, which is 978 feet thick. No bipartite subdivision is apparent in this well. In southern Hinds County, the Smackover is 1053 feet thick, and is composed almost completely of siliciclastic sediment (mainly dark gray and gray, finely silty shale; white and clear, very fine grained to fine grained, calcareous sandstone; and light gray to dark gray, hard, partially dolomitized, sandy limestone). The top of the Smackover in this latter well was recognized by the lowest occurrence of anhydrite in the overlying Haynesville.

The Rankin County well (23-121-20025) marks the eastern boundary of the dominance of siliciclastic sediment in the wells examined for this study, although sand occurs in wells further to the east. The Smackover is approximately 740 feet thick in this well. The upper portion of the formation includes dark brown, dark gray, argillaceous limestone, and light gray, very finely crystalline dolomitic limestone. The middle portion contains dark gray and dark brown, dense, argillaceous limestone, oolitic limestone, and dolomitic limestone. The lower section is comprised mainly of sandstone.

The Smackover in Smith County is generally about 700-800 feet thick; however, near the Smith Jasper County line, the unit thickens rapidly to about 1300 feet. The Smackover is not present in the most updip well in dip section D-D' (Cotton Valley lies directly on Paleozoic basement). The Smackover thickens quickly from about 300 feet to 725 feet between southern Newton County and extreme northeastern Smith County. In southern Newton County, the Smackover is comprised of light and brown,

dense, crystalline, shaley, firm, silty, and sandy limestone, with interbeds of clear, white, or pink, fine- to medium-grained, moderately cemented to unconsolidated quartz sandstone. The limestone becomes oolitic near the top. In central Smith County, the Smackover is about 950 feet thick, although several of the wells do not penetrate the full thickness of the formation. In well 23-129-20057, the Smackover is 945 feet thick, and is comprised, in the lower part, of light gray to tan, sucrosic dolomite, tan, crystalline limestone, and sideritic sand with traces of red and purple shale. The lower part of the formation is the Brown Dense limestone, which also includes interbeds of white, medium grained, unconsolidated sand. The upper part of the Brown Dense includes oolitic limestone beds.

The Smackover in the Simpson County well is probably about 780 feet thick, although recognition of the basal contact is inconclusive. Although no lithologic or sample logs were available for this well, the electric log signal displays a bipartite pattern, with the lower part being much more resistive than the upper part, which probably reflects the lower Brown Dense and overlain by an upper porous and/or sandy unit. The Smackover was not penetrated in the Jeff Davis County well.

As stated above, the Smackover thickens considerably in western and southwestern Jasper County, reaching a maximum thickness (for the wells studied) of nearly 1400 feet. The Smackover in well 23-061-20028 displays a tripartite subdivision, with a 900-foot interval of an upper, brownish-gray or dark gray, dense, crystalline, partially oolitic limestone; a 500-foot interval of the middle Brown Dense limestone; and a 200-foot interval of a lower, dark gray to black, dense limestone with red and silty shale beds.

In northeastern Jones County, the Smackover in well 23-067-20002 does not display the common bi- or tripartite subdivision of the Smackover, but consists of a fairly ubiquitous interval of Brown Dense. No “upper” (i.e., porous) Smackover occurs in the well. The Brown Dense does occur, however, in wells in Wayne County. The extensive faulting in Wayne County renders generalizations regarding thickness trends inconclusive. The Smackover in well 23-153-01008, the tie-in well for the strike section (A-A’) and the eastern Mississippi dip section (D-D’), is about 880 feet thick, but a fault occurs at the top of the formation and the Cotton Valley lies directly on the Smackover Formation. The Smackover in this well displays the bipartite stratigraphy, with the upper portion consisting of light tan, oolitic, and partially dolomitic and dense limestone, and the lower portion consisting of the Brown Dense. In southeastern Wayne County, the Smackover has a tripartite stratigraphy consisting of a lower interval comprised of fine grained, slightly

dolomitized sandstone, with pale gray and white anhydrite and moldic anhydrite; a middle interval of the Brown Dense; and an upper interval of white to tan, dense, peloidal, partially finely crystalline limestone.

The Smackover Formation in the Perry sub-basin is about 885 feet thick. The lower portion of the formation consists of dark gray, silty, sandy shale; dark gray, dense, micritic, argillaceous limestone with thin interbeds of dark gray, sandy, calcareous, partially black laminated, shale. The limestone in the formation is typically dark gray, and very finely crystalline; the upper portion includes interbeds of oolitic and peloidal limestone. The Smackover in the Catahoula Field in Hancock County is comprised chiefly of dark to light gray, dense, micritic to microcrystalline , sucrosic and argillaceous in part, limestone. The formation is approximately 880 feet thick. As noted above, the entire Smackover and Haynesville section is carbonate, and thus the top of the Smackover was recognized at the lowest occurrence of anhydrite in the overlying Haynesville section.

Descriptions of the Smackover Formation in southwest Alabama have been extensively published, as noted above, and will not be repeated here. The formation is considerably thinner in Alabama than in most of Mississippi, probably reflecting decreasing subsidence along the margin of the MISB. Most of the Smackover in southwest Alabama lies directly on basement rocks. The thickest Smackover occurs in Washington County, which part of the deepest part of the salt basin.

Summary

The Smackover Formation represents the earliest carbonate deposition in the MISB, and was deposited during a major cycle of sea level rise and fall. The Wiggins Arch, a major structural feature defining the southern margin of the MISB, possibly defined the platform margin, where open marine conditions existed to the south and more restricted conditions periodically existed to the north. The Smackover Formation can be subdivided generally into two members, a lower micritic interval and an upper, packstone and grainstone interval. The stratigraphy of the lower member may also be considered to be bipartite, with a basal, laminated microbial zone relatively rich in siliciclastic sediment and pyrite, and an upper interval of more massively micritic limestone. This lower member represents the initial Oxfordian transgression and the deepening of the basinal areas of the region. At this time, the rate of relative sea level rise/subsidence exceeded the rate of carbonate sediment accumulation. The lower member is typically absent on the positive basement structures. The upper member of the Smackover comprises a complex suite

of moderate- to high-energy facies, with packstone and grainstone lithologies predominating. These deposits record the change from a catch-up to a keep-up phase of carbonate deposition. Sediment loading of the underlying salt had progressed during Smackover deposition resulting in halokinetic movement, and rapid facies and thickness changes over salt structures. The combined effects of filling in the MISB, relative drop in sea level, and barrier effect of the Wiggins Arch resulted in the cessation of carbonate production, which ended Smackover deposition.

Haynesville Formation

The Haynesville Formation is a highly lithologically variable stratigraphic interval that occurs between the carbonates of the Smackover Formation and the siliciclastic sediments of the Cotton Valley Group. As such, it can include anhydrite, shale, sand, carbonate, or conglomerate in almost any proportion. For example, in the Rankin, Scott, and Jasper County areas, the Haynesville is quite sandy, due probably to the same siliciclastic source that resulted in the unusually thick Norphlet Formation and sandy Smackover in this area. Haynesville anhydrites are often dominant in the areas north of the Wiggins Arch, whereas they are almost absent in the areas south of the arch. Haynesville sections on or near paleotopographic highs are often conglomeritic and/or dolomitic. Overall, however, the Haynesville is characterized as a mixed carbonate-siliciclastic and/or evaporitic unit between the Smackover and the Cotton Valley.

The stratigraphic nomenclature of the Haynesville Formation and its Buckner Anhydrite Member has evolved over many years. Swain and Anderson (1993) presented a good summary of the evolution of the stratigraphic nomenclature of the Jurassic units of Louisiana and Arkansas, from which the following discussion was derived. Prior to 1944, the “Cotton Valley formation” was considered to extend down to the top of what is now referred to as the Alpha Buckner, which is the massive anhydrite overlying the Smackover limestones. It became apparent, then, that the “Cotton Valley” was comprised of two suites of rocks, a lower interval of red bed and anhydritic rocks (“lower Cotton Valley”), and an upper interval of dominantly gray siliciclastic rocks (“upper Cotton Valley”), and that an unconformity separated the two rock types. Subsequently, three changes in the nomenclature were made: (1) the term Cotton Valley was restricted to the gray siliciclastic sequence lying above the unconformity, (2) a new name, the Haynesville Formation, was given to include the evaporitic and red siliciclastic interval below the unconformity and above the Smackover, and (3) the term Buckner was reduced to member status within the Haynesville

Formation. A dual usage of “Haynesville-Buckner” persisted, at least in Mississippi, for many years ((Dinkins, 1968; Fischer, 1974; 1978).

The contact of the Smackover Formation with the overlying Buckner Member of the Haynesville Formation is conformable and is typically picked at the base of the massive anhydrite beds of the Buckner. Where the Buckner is absent, which includes far updip areas, regions overlying local uplifts, and the basinal areas, the base of the Haynesville is picked at the base of an evaporite/siliciclastic interval. Along the coastal area of Mississippi essentially no siliciclastic sediment and very little evaporite deposits occur in this interval, thereby rendering the selection of the base of the Haynesville as very difficult. For the Rhoda Lee Brown well in northwestern Hancock County, the base of the Haynesville was picked at the base of thin anhydrite stringers in a thick carbonate sequence. Rhodes and Maxwell (1993) suggested using the term Gilmer (Forgotson and Forgotson, 1976) for Haynesville equivalent carbonate strata south of the Wiggins Arch.

The Buckner Anhydrite Member of the Haynesville Formation is generally considered to be the massive anhydrite at the base of the Haynesville (Dinkins, 1968; Oxley et al., 1967; Tolson et al., 1983). These evaporitic deposits were probably formed in a restricted paleoenvironment landward of a significant barrier, i.e., the Wiggins Arch. As such, the Buckner occurs along a fairly narrow subcrop belt. The Haynesville isopach map of Oxley et al. (1967) clearly shows the updip and downdip limits of the Buckner in Mississippi. In Mississippi, the downdip limit of the Buckner is generally subparallel to the updip limit of the Haynesville at a distance of approximately 10-15 miles, except for an area in northwestern Jasper County, where the entire Haynesville Formation is anomolously thin. There is no Buckner in this area. Also, in northern Rankin County, the Buckner extends much further downdip (Oxley et al., 1967). In downdip areas, the lower Haynesville becomes an interval of interbedded sandstone, limestone, anhydrite, and shale (Twiner, unpublished).

The Buckner is present throughout southwest Alabama except for the extreme updip and downdip regions (Tolson et al., 1983). The Conecuh Ridge/Wiggins Arch complex probably caused more restricted circulation in southwestern Alabama than in the more open conditions in southern and southwest Mississippi, hence the generally wider distribution of the Buckner subcrop belt. Also, the MISB margin curves from an east-southeast orientation in the vicinity of the Gilbertown-West Bend Fault Zones to a

north-south orientation paralleling the western limit of the Mobile Graben, causing depositional strike to curve in a similar direction. Therefore, it should be expected that north-south cross sections in southwestern Alabama (i.e., Washington and northern Mobile Counties) would show little depositional change within specific units, except those due to local uplifts such as the Chatom and Macintosh salt domes.

According to Oxley et al. (1967), the top of the Haynesville Formation in Mississippi is placed at the first occurrence of anhydritic sediments, carbonates or dark-gray and black calcareous shales stratigraphically below the top of the Pink Sandstone facies of the Cotton Valley Group in the central parts of the state or below massive Cotton Valley sandstones in downdip areas. As such, the Haynesville may consist of any lithology, except sandstone that occurs above the Smackover limestones and below the predominantly sandy Schuler facies of the Cotton Valley Group. Tolson et al. (1983) considered the Haynesville to be a transitional stratigraphic interval between the Smackover carbonates below and the generally coarser grained continental siliciclastic sediments of the Cotton Valley above. The top of the Haynesville, according to Tolson et al. (1983), is picked above the uppermost anhydrite bed at the base of the coarse siliciclastic sequence of the overlying Cotton Valley Group. In this latter definition, the presence of anhydrite is essential to the assignment of beds to the Haynesville, where the presence of anhydrite is not essential in the Oxley et al. (1967) definition.

The variable lithologies included within the Haynesville Formation introduce uncertainties in correlating the interval, in particular selecting the top of the formation. For example, in cross section I of the Mississippi Geological Society (Twiner, unpublished), which extends in a general north-south orientation from LeFlore County to southern Hinds County, Mississippi, the Haynesville is an interbedded sandstone and shale with generally more shale in LeFlore and Holmes Counties. This interval is correlated with thick, massive anhydrite in two nearby wells. In Yazoo County, the Haynesville becomes shaley sandstone, differing little from overlying shaley sandstone of the Cotton Valley, but the Haynesville interval includes a basal anhydrite bed. In the next two wells further south, still in Yazoo County, the lower third of the Haynesville consists of interbedded anhydrite and shale. The interval is interbedded sandstone and shale up section. In Hinds County, the Haynesville includes basal anhydrite and limestone beds overlain by a few hundred feet of shale, with one sandstone unit in the upper portion. The presence of Haynesville in southern Hinds County is questionable. Twiner (unpublished) shows the top of the

Haynesville to be at a depth of approximately 22,000 feet, but that point is in a very thick interval of interbedded sand and shale, with no sign of a thick overlying sand to mark the top of the formation nor any carbonates, evaporites, or shales to suggest Haynesville lithologies.

The preceding descriptions underscore two important observations concerning the Haynesville Formation: (1) It is a highly variable distribution of lithofacies, suggesting a complex mode of deposition; and (2) An uncertain relationship exists between the lithostratigraphy and the chronostratigraphy of the correlations. As typically correlated, the Haynesville interval is not a time-rock unit.

In Rankin County, central Mississippi, the Haynesville contains more carbonate and evaporite deposits and less shale than in the Hinds County area (Oxley et al., 1967; Twiner, unpublished). In northern Rankin County, the Haynesville consists mainly of interbedded sandstone and limestone, with lesser amounts of dolomite and anhydrite. Only one well on the Jurassic cross section III of the Mississippi Geological Society (from southwestern Leake County to southern Rankin County) contained a thick section of anhydrite (Buckner) in the central part of the county. In the southern part of Rankin County, the Haynesville becomes more thinly bedded, has an increased proportion of carbonate rocks, and consists of thin beds of limestone, sandstone and anhydrite. In southernmost Rankin County, the Haynesville consists mainly of limestone with few interbeds of sandstone, which generally increase in number up section. Anhydrite only occurs rarely in this area. Differentiation of the Smackover and Haynesville is very difficult in this well because, according to the lithologic descriptions and selection of the top of the Smackover as reported by (Twiner, unpublished), the contact was placed in an interval devoid of anhydrite and consists of limestone with relatively thin sandstone interbeds. In all the wells in Rankin County, the top of the Haynesville is fairly easy to recognize, where it occurs at the top of a carbonate unit which is at the base of a thick sandstone interval.

Two sets of cross sections have been published for the Jasper County area of Mississippi (Fischer, 1974; Twiner, unpublished). In southeastern Newton and northeastern Jasper Counties, updip of the updip margin of the Louann Salt, the Haynesville Formation contains no anhydrite and consists of red shale, red and pink calcareous sandstone, and upper limestone interbeds. The upper contact of the Haynesville was recognized by Fischer (1974) at the top of a red shale unit lying between the uppermost limestone unit in the Haynesville and a thick sandy sequence in the overlying Cotton Valley Group. South of the regional

peripheral fault trend, the Haynesville includes a substantial number of anhydrite beds in a dominantly limestone interval, with lesser amounts of sandstone and dolomite units, all of which occur below a thick sandy interval of the Cotton Valley. The base of the formation can be difficult to recognize, however, because the characteristic anhydrite beds are not ubiquitous; only careful correlation between adjacent wells that include this basal anhydrite enables correct placement of the contact. Generally, the anhydrite beds become more numerous and laterally persistent in the upper portion of the Haynesville in the Jasper County area. In areas where anhydrite is missing in the lower portion of the formation, miscorrelations have resulted, in which the top of the Smackover is placed at the base of one of these upper anhydrite beds (Fischer, 1974); again, only careful analysis of adjacent wells which include the lower anhydrites allows correct correlations.

The interbedded anhydrite/limestone sequence of the Haynesville is well developed in the updip area of Clarke County, Mississippi (Fischer, 1978). The lithologies of these interbeds produce a high-frequency, serrated resistivity pattern that is characteristic of the Haynesville in much of southwest Alabama and eastern Mississippi. In addition to the limestone/anhydrite, relatively thin sandstone beds occur and, in the upper portion of the formation particularly, red shale becomes quite common. Dolomite beds are present locally. Toward southwest Clarke County, beds of red and gray shale and limestone occur progressively higher in the stratigraphic section (in updip Cotton Valley equivalents), prompting Fischer (1978) to place the Haynesville-Cotton Valley contact at a stratigraphically higher elevation in this area. This observation demonstrates the diachroneity of this contact. It is possible that dip-oriented geophysical surveys will reveal this region to include toplap surfaces that mark a series of higher-order depositional sequences.

The anhydrite/limestone/shale interbeds of the Haynesville of southwestern Alabama also produce a distinctive, high frequency, serrated resistivity pattern on wireline logs. The Buckner Anhydrite Member is also well developed, except in the far updip area of central and northern Choctaw County and downdip area of southern Mobile County (Tolson et al., 1983). In addition, anhydrite is quite common in the upper, unnamed member of the Haynesville. The uppermost portion of the Haynesville is often shaley in southwest Alabama. However, the high-amplitude resistivity peaks in the Haynesville contrast readily with the low-amplitude pattern of the overlying Cotton Valley Group (Tolson et al., 1983). Salt is also common

in the Haynesville in southwestern Alabama. Several wells display a tripartite subdivision of the Haynesville: a lower massive anhydrite (Buckner), a middle, very high frequency, high amplitude interval on wireline logs, and an upper interval of generally decreasing resistivity amplitude and. In general, this upper interval of decreasing resistivity should be included with the Haynesville Formation, rather than the overlying Cotton Valley Group, as anhydrites and carbonates occur.

The Frisco City sand and other Haynesville sands such as the “Megargel sand” and “Haynesville” sand (Mancini et al., 1997), are other facies of the Haynesville Formation. The Frisco City is predominantly a plagioclase arkosic and subarkosic sandstone, comprised mainly of quartz, feldspar, metamorphic rock fragments, chert, muscovite, and biotite (Mann et al., 1989). The formation lies unconformably on the Buckner Anhydrite Member, and is overlain by typical Haynesville interbedded shales and anhydrites. The thickness of the Frisco City sand ranges from about 100 to 200 feet thick (Mann et al., 1989; Paul et al., 1993). The Frisco City only occurs adjacent to basement paleotopographic highs, and is generally thought to be derived locally from them (Baria et al., 1993; Mann et al., 1989). However, Stephenson et al. (1993) observed that a comparison of petrographic data from metamorphic rocks underlying the Haynesville and the sandstones in the Frisco City sand clearly indicated that the local metamorphic rock could not be the sole siliciclastic source for the Frisco City Sand. However, the Frisco City sand on the Wiggins Arch was clearly derived from the underlying basement complex, being formed as alluvial fan deposits (Rhodes and Maxwell, 1993). Petty et al. (1995) reported the Frisco City sand to occur not only in the immediate vicinity of the Wiggins Arch, but also 20 miles south of the Wiggins Arch offshore of Harrison County, Mississippi. The mineralogy of the Frisco City is distinct between the central and western portions of the arch and the eastern side. Sandstones and shales occur on the eastern side of the arch, where the underlying basement is comprised of phyllite and not granite, but coarser siliciclastic sediments predominate on the western side of the arch (Rhodes and Maxwell, 1993). Petty et al. (1995) also indicated the Frisco City to be comprised of clear, white, quartzose sandstone to the southwest of the Wiggins structure.

The Wiggins Arch played a very important role in determining the distributions of the various Haynesville lithofacies. The arch was, in effect probably defining a platform margin, separating offshore carbonate rocks from onshore siliciclastic and evaporitic rocks (Cagle and Khan, 1983; Ericksen and Thieling, 1993; Petty et al., 1994; Rhodes and Maxwell, 1993) or formed a distally-steepened ramp. For

example, Haynesville equivalent strata south of the Wiggins Arch are principally dark gray, micritic limestones. Rhodes and Maxwell (1993) suggested using the term Gilmer Limestone for these carbonate equivalents to the Haynesville.

Age

As with the underlying Smackover Formation, age-diagnostic fossils for the Haynesville Formation in the MISB are very rare, particularly because much of the Haynesville is comprised of evaporitic and nearshore, siliciclastic-dominated facies that were inimical to the production of nektonic species. Mentioned in the previous section on the Smackover Formation were a few ammonite occurrences that have been observed in the lower part of the Haynesville section and in its offshore equivalent, the Gilmer Limestone. Imlay (1940; 1943; 1980), Imlay and Herman (1984) and Young and Oroliz (1993) reported ammonites from the lower portion of the Haynesville and Gilmer, including species of *Idoceras*, *Badenia?*, *Ataxioceras*, and *Nebrodites* of early Kimmeridgian age, and species of *Glochiceras*, *Taramelliceras*, and *T. (Metahaploceras)* of early to late Kimmeridgian age.

Haynesville Stratigraphy from Regional Cross Sections

The Haynesville Formation changes dramatically in thickness and lithology across the MISB. This section will discuss the thickness and lithology changes of the Haynesville as recognized in the wells used to construct the regional cross sections. The discussion will follow the regional grouping previously established.

The Haynesville Formation in most of the western Mississippi region is relatively thin, ranging from 140 to 611 feet thick. In southern Hinds County, however, the Haynesville thickens rapidly to more than 1800 feet. An abrupt thickening is also observed between northern Hinds and Rankin Counties (the unit actually more than doubling in thickness). The formation also more than doubles in thickness between Rankin and northern Smith Counties. From the tie-in well (23-049-20005) between the strike section (A-A') and the western dip section (B-B'), the thickness of the Haynesville is fairly constant, but south and east of this point the Haynesville thickens rapidly.

In the area of relatively thin Haynesville, the formation consists of interbedded shale, anhydrite, limestone, and sandstone. In Issaquena County, the Haynesville is thin, ranging from 207 to 383 feet thick. The lithology of the westernmost well (23-055-00032) is apparently mostly shale, although no sample or

lithologic logs were available for this study. The next well (23-055-00066) consists of dark maroon shale and mudstone, with anhydrite interbeds, some red sandstone, and a trace of dark igneous sediment. In LeFlore County, the Haynesville is only 157 feet thick and appears to be quite shaley. In Holmes County, the Haynesville thickens to about 245 feet. Well 23-051-20020 consists of a lower red, fine- to medium-grained, loosely cemented sandstone and an upper dark gray, silty shale. (The Mississippi Geological Society Jurassic Cross Sections I and II and formational assignments by Theo Dinkins on the sample logs place this lower sandstone in the Smackover and the upper shale in the Haynesville). In southern Holmes County, the thickness of the formation increases to 245 feet and the lithology of the unit changes abruptly, in that the Haynesville consists almost entirely of anhydrite (Buckner). The thickness of the Haynesville in Yazoo County increases to 510 to 595 feet. In general, the lower part of the section consists of more anhydrite than the upper portion. The anhydrite is mottled, colorless, pink or white, and sucrosic, with inclusions of micritic and crystalline, in par oolitic and dolomitic limestone. Shale, which increases upsection, is red, sandy and micaceous, with rare inclusions of anhydrite. Sandstone interbeds are white, clear-white, fine-grained, moderately to well cemented, and slightly calcareous. The tie-in well (23-049-20005) consists of 611 of Haynesville, including a lower 150-foot interval of gray, dense, argillaceous, and oolitic limestone, white and pink crystalline anhydrite, and white and pink, medium grained, well cemented sandstone. The middle portion includes approximately equal amounts of anhydrite, white and pink, medium grained, well cemented sandstone, gray, dense, argillaceous, oolitic limestone and red and gray, firm, silty shale. The upper portion includes reddish-brown shale, white and gray, fine- to medium-grained, very well cemented sandstone, and white, crystalline anhydrite.

The Haynesville increases in thickness from 611 feet in northern Hinds County to nearly 3000 feet in southern Hinds County. In fact, the base of the Haynesville was not reached in the 23-049-20004 well, which included 2976 feet of the formation. The section in this area is mainly shale and sandstone, with interbeds of limestone and anhydrite. The lower portion is dominated by gray, dark gray, and greenish-gray shale and siltstone, with limestone and coal interbeds becoming more common upsection. Anhydrite is generally more common in the lower part. This pattern of lithologies also occurs in the last well of the dip section, in extreme southern Hinds County.

The Haynesville thickens from 611 to 1300 feet in northeastern Hinds County and Rankin County to more than 2600 feet in northern Smith County. In Rankin County, the Haynesville consists of interbeds of limestone, sandstone and shale. The limestone is light gray or light brown, very fine grained to crystalline, and dolomitic in parts, beds oolitic and pelloidal limestone beds. The shale is dark or dull red or maroon in color. The sandstone is very fine-grained, nonporous, and dolomitic. The upper portion of the formation consists mainly of red and maroon shale.

The Haynesville displays rapid thickness increases in the central Mississippi region, apparently along a line parallel to and just north-northeast of cross section A-A'. Well 23-129-00178, in northern Mississippi is anomalously thick at 2635 feet. This latter well, for which lithologic log and core descriptions are available, consists mainly of limestone and anhydrite with a few sandstone interbeds. The limestone is gray, brown, or grayish-black, and dense to sucrosic. The anhydrite is white to gray, and soft. The sandstone is clear, medium-grained, hard, and calcareous. The shale is grayish-green, silty, and calcareous. In general, the upper 700 feet of the formation contains more reddish-gray, sandy, silty, calcareous shale than the lower portion, and the limestone becomes more oolitic and peloidal. The top of the Haynesville was recognized by the highest occurrence of limestone.

The Haynesville in the central Mississippi dip section (C-C') increases in thickness from 0 feet in southern Newton County to 1510 feet in south-central Smith County (the formation is not present in the Simpson County or Jeff Davis wells). The Haynesville is characterized by rapid changes in thickness in Smith County. For example, in the northeast portion of the county, the Haynesville is approximately 800 feet thick, but it is more than 1500 feet thick in central Smith County. The formation also thickens from 400 feet in well 23-129-00061 to 1882 feet in southwest Jasper County (well 23-061-20203). The Haynesville thins to 457 feet and 344 feet in south-central Jasper County. Some of these abrupt changes in thickness are due to the location of the wells being on or adjacent to salt structures, which reflect differential movement during deposition of the Haynesville.

Dip section C-C' extends from southern Newton County to northern Jeff Davis County. There is no anhydrite present in well 23-101-20005 in southern Newton County. The Haynesville consists of interbedded clear, white or gray, very-fine- to fine-grained, partly calcareous sandstone, red, brown or light or dark gray, sandy, silty, blocky, micaceous shale; and tan to gray, moderately firm, crystalline or micritic

limestone. In well 23-129-20057 the formation includes pearly gray, firm, in part, oolitic and sucrosic limestone; gray, fine- to medium-grained, calcareous sandstone; reddish-brown, sandy, micaceous shale, with a few interbeds of anhydrite. The lithologies in well 23-127-20055 are similar to the preceding description.

The Haynesville in the eastern Mississippi region also exhibits very abrupt changes in thickness, due mainly to the north-northwest-trending faults in the Wayne County region (Gazzier and Bograd, 1988). For example, the Haynesville is missing in well 23-067-20002 (eastern Jones County) and well 23-153-01008 (western Wayne County). It is 115 feet thick in well 23-153-20545 (central Wayne County), but the formation is 4655 feet thick in well 23-153-20122 (southeastern Wayne County). An abrupt thickening (4414 feet thick) is also observed for well 23-153-20077 in southern Wayne County.

In the updip area of eastern Mississippi, the Haynesville consists of up to 540 feet of limestone with anhydrite and, more rarely, sandstone and shale interbeds. The limestone is typically gray or light gray, very sandy in part, oolitic and peloidal in part, and dolomitic and dense in part. The upper portion becomes shaley (dark gray, very silty, finely micaceous, and dolomitic in parts). Little data were available for the Haynesville section for wells in central Wayne County. In Perry County, the Haynesville thins to 960 feet, but the change in facies lends uncertainty to this conclusion. As noted above, the Jurassic units are thin or absent over the Wiggins Arch, which may explain the thinning of the Haynesville between the southern Wayne County wells and the southern Perry County well. The Haynesville in a well located in Stone County but near the Perry County well consists mainly of red and greenish-gray sandstone and red shale, but the unit contains red limestone, is lignitic in parts, and has rare anhydrite beds in the lower part. The Haynesville was not recognized in the Hancock County well.

The thickness of the Haynesville in the Alabama wells displays the same overall trend as the eastern Mississippi wells, i.e., an increase in thickness into the MISB, then a decrease toward the Wiggins arch. The Haynesville increases from 566 feet in south-central Choctaw County to 2310 feet in central Washington County. It thins to 1446 feet thick in east-central Mobile County. In general, the Haynesville in wells in Alabama contains more anhydrite than observed in the Mississippi wells. Indeed, the Buckner Member is well developed in southwestern Alabama, attaining thicknesses of several hundred feet, whereas it occurs only as a narrow band in Mississippi with highly variable thickness. This difference in relative

volume of anhydrite is probably due to the influence of the Wiggins Arch, as discussed above. The Alabama sections also include salt, which occurs only in the easternmost portion of Mississippi.

The Haynesville in Alabama typically contains a lower anhydritic section, including the Buckner Anhydrite Member, a mixed limestone/salt/dolomitic middle portion, and a more shaley upper section. See Tolson et al. (1983) for detailed descriptions of the Haynesville in wells in southwestern Alabama.

Summary

The Haynesville Formation of Kimmeridgian age is a heterogeneous stratigraphic unit, representing a transition between the underlying carbonate rocks of the Smackover Limestone and the coarser, continental, siliciclastic sediments of the overlying Cotton Valley Group. The Wiggins Arch defined the carbonate platform margin or distally steepened ramp during the Jurassic, separating dense, dark, micritic limestones offshore from siliciclastic, evaporitic, and carbonate sediments onshore. The formation is subdivided into a lower Buckner Anhydrite Member and an upper, unnamed member. The Buckner Anhydrite Member is a massive anhydrite bed as opposed to interbedded anhydrite and subcrops generally in a narrow band subparallel to and slightly basinward of the regional peripheral fault trend (updip limit of the Louann Salt). In southwest Alabama and eastern Mississippi, the Haynesville is generally comprised of interbedded limestone, anhydrite, sandstone, and shale, with lesser amounts of dolomite, producing a characteristic wireline log signature of high amplitude, high frequency oscillations. Further west, the Haynesville generally becomes shalier and less anhydritic downdip in southern and southwestern Mississippi and it is represented by a carbonate facies. The Frisco City sand and other sand units in the lower part of the upper, unnamed member of the Haynesville, occur locally adjacent to paleotopographic basement highs. Progradation of the continental siliciclastic sediments of the Cotton Valley Group signaled the end of marine deposition that began with the Werner/Louann evaporites, continued with the deposition of the Smackover carbonates, and ended with the evaporitic/siliciclastic sequence of the Haynesville Formation.

Cotton Valley Group

The Cotton Valley Group of Late Jurassic age is the largely paralic deposits occurring between the underlying evaporite/carbonate/siliciclastic sediments of the Haynesville Formation and the coarse, continental, siliciclastic deposits of the overlying Lower Cretaceous Hosston Formation. Shearer (1938)

was the first to use the name “Cotton Valley formation” for marine beds in the Cotton Valley field in Webster Parish, Louisiana. Hazzard (1939) formally defined the unit as the “dark shales, limestones, sands (Schuler facies with red beds shoreward,” of approximately 2000 feet in thickness lying disconformably (?) over the Buckner Formation and disconformably (?) under the “Travis Peak.” As such, this older terminology included what is now considered to be the upper, unnamed member of the Haynesville Formation. Swain (1944) elevated the Cotton Valley to group level, which included the lower Bossier Formation and an upper Schuler Formation. The Schuler Formation consists of two members, a lower Shongaloo and an upper Dorcheat. The Bossier Formation extends south in northeastern Louisiana, but does not occur in the MISB. Forgotson (1954) further formalized the stratigraphic nomenclature of the Cotton Valley Group, following the precedent of Philpott and Hazzard (1949) using the base of the Bossier as the top of the Haynesville Formation (rather than the top of the Buckner to define the base). He did not subdivide the Schuler into upper and lower members. Mann and Thomas (1964) proposed new nomenclature for the Cotton Valley Group in Louisiana and Arkansas, which included, in ascending order, the Bossier Formation, Terryville Sandstone, Hico Shale, and Knowles Limestone. The terms Terryville Sandstone and Hico Shale are little used today, although the Knowles Limestone is used extensively, as is the older term, Bossier Shale. Anderson (1979) later proposed elimination of the term “Schuler,” raising Swain’s (1944) Shongaloo and Dorcheat Members to formational status, due to the greater regional significance of a tripartite subdivision. Generally, for the MISB strata, a bipartite subdivision of the Cotton Valley is recognized (a lower Shongaloo sandier interval and an upper Dorcheat shaley interval). Thus, this report will consider the Cotton Valley Group, in Mississippi, to consist entirely of the Schuler Formation, which includes the lower Shongaloo Member and the upper Dorcheat Member.

Swain (1944) originally defined the Schuler Formation to “…include the nearshore or non-marine pastel, and red-green shales, sandstones, and basal conglomerates and the offshore equivalents of these rocks, which are dark gray fossiliferous shales, limestones, sandstones, and basal conglomerates, lying stratigraphically between the base of the Hosston formation and the top of the Bossier formation.” The Schuler Formation was differentiated from the underlying Bossier Formation because the Bossier contains more siliciclastic sediments and is generally more colorful. Unfortunately, the lower and upper members of the Schuler Formation, the Shongaloo and Dorcheat Members, respectively, were differentiated on the

basis of color, an attribute not discernable with wireline logs. The Shongaloo Member consists of red and red-green shales of a darker color than the Dorcheat shales, of red and white sandstones, and of conglomerates. The Dorcheat was composed principally of pastel, varicolored shales or claystones, siltstones, and white sandstones. Swain (1944) noted that in basinward regions of northern Louisiana, the two members of the Schuler Formation "…pass into dark gray, shell-bearing shales, limestones, and sandstones, but conglomerates persist in the lower part of the Shongaloo member."

Oxley et al. (1967) recognized the bipartite nature of the Cotton Valley Group in central Mississippi, but preferred to refer to the units as "Schuler facies" (lower) and "Dorcheat facies" (upper). The "Schuler facies" is equivalent to the Shongaloo Member. This lower member is a dominantly siliciclastic facies, consisting of a red bed section of red to maroon shales and reddish coarse-grained sandstones. The upper "Dorcheat facies" extended approximately as far west as Yazoo County, beyond which point the interval became entirely dominated by coarser siliciclastic sediments and was undifferentiated. The Dorcheat was also recognized as far east as Clarke County, Mississippi, beyond which point the interval becomes conglomeritic, and again is undifferentiated. This eastern conglomeritic facies extended downdip only as far as Wayne County. South of Wayne County, the interval became sandy. In the Newton County area, central Mississippi, near the updip limit of the Cotton Valley subcrop and adjacent to the Phillips fault zone, the "Dorcheat facies" is also conglomeritic. The clasts of which were derived from Paleozoic limestone on the upthrown side of the fault. The "Dorcheat facies" thickens progressively downdip at the expense of the Schuler facies.

Dinkins (1968) expanded the description of the lower part of the Schuler Formation (which he termed the Shongaloo Member) to "… consist of a sequence of white, red and pink fine to coarse subangular to rounded rarely lignitic occasionally calcareous and commonly conglomeritic sandstones, some dark-red, maroon and purple silty micaceous occasionally sandy shales, minor amounts of vari-colored mudstones and a few thin streaks of lignite." Throughout central Mississippi, the lower two-thirds of the Shongaloo is characterized by a distinctive pink sandstone facies, and is referred to as the "Pink Sandstone." The upper "Dorcheat facies" consisted of nearshore, varicolored shales and fine-grained sandstones. Thus, the Cotton Valley Group in central Mississippi, as recognized by Dinkins (1968), consists of a lower "Pink Sandstone facies," a middle Shongaloo Member, and an upper Dorcheat Member.

Interestingly, Dinkins (1968) noted that the basinward thickening of the Shongaloo between the top of the "Pink Sandstone" and the base of the Dorcheat was due to the presence of younger beds in the top of the Shongaloo. The presence of these beds signals the possibility of a series of toplap surfaces in a sequence stratigraphic framework.

Thus, by the late 1960's, the Cotton Valley Group, in Mississippi, was known to contain three facies in the central part of Mississippi (from the eastern portion of Yazoo County to near the Mississippi-Alabama border): a lower "Pink Sandstone" facies, a middle varicolored upper Shongaloo Member, and an upper shaley Dorcheat Member. To the east, west, and north of this region, the Cotton Valley Group becomes undifferentiated, consisting of coarse siliciclastic sediments.

Moore (1983) studied the Cotton Valley depositional systems in Mississippi. He considered the Cotton Valley to be characterized as "…the predominantly siliciclastic beds between the carbonates, siliciclastics, and anhydrite of the underlying Haynesville (Jurassic) Formation and the siliciclastics of the overlying Hosston (Lower Cretaceous) Formation." The base of the group was recognized either by the shallowest occurrence of a limestone, anhydrite, or dark shale of the Haynesville. Using electric logs, the top of the group was defined by the first shale beneath the Hosston gravel (updip) or sand (downdip). Based on sample descriptions, the top of the group is recognized by the shallowest occurrence of siderite concretions and/or varicolored pastel and purple shales. Moore (1983) found that there are no electric log markers within the Cotton Valley that extend throughout Mississippi.

Moore (1983) subdivided the Cotton Valley into three equal intervals, the "lower," "middle," and "upper" informal members, in order to map sand percentages for determination of depocenters. These three members should not be considered to have any relationship to lithology or e-log character. The lower third of the group contained the greatest percentage of sand (often corresponding closely to the "Pink Sandstone" facies of Dinkins (1968). The middle third contained somewhat less sandstone, and the upper third (which included the Dorcheat Member) contained the least amount of sandstone. Sand percentage maps of the three "members" showed a regressive depositional system, with depocenter locations very similar to those in the underlying Norphlet, Smackover and Haynesville Formations. The western depocenter was no doubt the ancestral Mississippi River delta complex, which had shifted a bit to the west relative to the Norphlet, Smackover and Haynesville depocenters. Three lobes were also recognized in the westerly delta complex,

one in Sharkey and central Issaquena Counties, another in northern Warren and west-central Hinds Counties, and a third in southern Madison and northern Rankin Counties. This latter region had been the primary depocenter for Norphlet and Smackover deposition. The other depocenter was in the Newton, Jones, and Scott County areas. This east-central Mississippi delta lobe complex was possibly the product of a river complex that was different than the one to the west, which was sourced from the Appalachian Mountains (Mann and Thomas, 1968). These two depocenters migrated progressively to the north during deposition of the middle and upper parts of the Cotton Valley section. An expanded interdeltaic region developed between the two deltas. It is in this interdeltaic region that the Dorcheat Member was deposited; the siliciclastic-dominated sections of the deltaic regions are generally the areas of undifferentiated Cotton Valley.

The updip limit of limestone occurrence in the upper Cotton Valley (i.e., Knowles Limestone) was also mapped by Moore (1983). This limit extended due east from southern Claiborne County to eastern Simpson County, then extended south to northern Pearl River County, bulging slightly to the southwest into Jones County. The limit extended southeast into southeastern Harrison County. This configuration was evidently strongly controlled by the deltaic depocenters. The apex of the updip limestone occurs in the interdeltaic region of central Mississippi.

The western deltaic region of the Cotton Valley was studied by Sydboten and Bowen (1987). This area included Issaquena, Warren, Sharkey, Yazoo, Hinds, and Madison Counties. Sydboten and Bowen (1987) also subdivided the Cotton Valley into three informal members, also termed “lower,” “middle,” and “upper” members. The three members were not related to the three members of Moore (1983), nor directly with the tripartite subdivision of Dinkins (1968). These three members graded downdip into progressively finer lithofacies. The three members of Sydboten and Bowen (1987) were based on marker horizons occurring only within this western deltaic complex and are probably not applicable to areas outside of this region. Sydboten and Bowen (1987) interpreted the depositional system of the Cotton Valley to be essentially the same as that proposed by Moore (1983).

Ericksen and Thieling (1993) and Petty and et al. (1995) studied the Cotton Valley Group in southern Mississippi. As alluded to previously, the Cotton Valley contains a significant amount of limestone in this southerly region. At the Catahoula Field in Hancock County, the middle interval consists

of shales, limestones, and sandstones. The lower, hydrocarbon-bearing interval consists of shales, siltstones, and sandstones. The upper Cotton Valley consists of sandstone with interbedded limestone. The occurrence of limestone only in the middle and upper portions of the Cotton Valley indicates a generally transgressive depositional sequence. The cross sections of Petty et al. (1995) reveal the thickness trends of the Cotton Valley in the onshore and offshore region of coastal Mississippi and Alabama. The thickness of the group thins only slightly across the Wiggins Arch, and ranges from approximately 2100 feet thick in Mobile County, Alabama, to approximately 1750 feet thick in northern Jackson County, Mississippi, demonstrating the attenuated effect of the underlying structure. Another cross section line extended from Pearl River County to the Viosca Knoll structure. The Cotton Valley thickness ranged from 2650 to 2850 feet thick in Pearl River, was 2724 feet thick in Hancock County, thinned to 1985 feet in Mississippi Sound, but thickened to 4700 feet in the Viosca Knoll region. The Cotton Valley was the only unit that displays appreciable thickness increase on this structure, which may indicate that the Late Jurassic-earliest Cretaceous was a time of accelerated subsidence in this area.

In Alabama, the Cotton Valley Group consists of moderate- to pale-red, light gray and white, fine- to very coarse-grained to conglomeritic sandstone with angular to subrounded quartz grains. Locally, this sandstone contains chert and abundant metamorphic rock fragments (Tolson et al., 1983). The Cotton Valley is very conglomeritic in updip areas, and generally contains coarser siliciclastic sediments than in nearby Mississippi. Smith (1998) described the Cotton Valley from central Washington County, Alabama, to be similar to the coarse siliciclastic sediments of the overlying Hosston Formation, but he recognized the Cotton Valley by its greater abundance of quartzose silty to sandy, very muscovitic claystones, the occurrence of granular quartz and chert gravel, and the presence of trace amounts of igneous and metamorphic rock fragments and feldspar in the unit. The shaley intervals of the Cotton Valley are mainly red in updip areas and gray in downdip areas; a similar color pattern was observed for the sandstone units. Thickness variations in the Cotton Valley were attributed by Tolson et al. (1983) to be a result of (1) the difficulty in differentiating the Cotton Valley from the underlying Haynesville Formation, and (2) the influence of paleotopography. For example, the Cotton Valley thins over the Wiggins Arch and is thick in the MISB.

Aultman (1975) described the Bay Springs sand unit that occurs in southeastern Jasper to southwestern Scott County, Mississippi. This sand unit is at the base of the Cotton Valley in this area and was considered to be stratigraphically equivalent to the updip massive Pink Sandstone member and the downdip Haynesville siliciclastic, evaporitic and carbonate sediments. Aultman (1975) interpreted the Bay Springs sand to be more marine than the typical Pink Sandstone member that occurred between the regional peripheral fault trend and the region of thick salt accumulation. The Cotton Valley environments of deposition were concluded to range from alluvial-deltaic environments in the lower portion of the unit to coastal environments in the upper portion of the Cotton Valley.

Age

Swain and Anderson (1993) proposed several chronostratigraphic subdivisions for the Cotton Valley Group in the northern Louisiana-southern Arkansas region. The Cotton Valley Group represented a stage, the Cotton Valley Stage, which overlies the Louark Stage and underlies the Durango (Coahuila) Stage. This Cotton Valley Stage was subdivided into three substages, which are in ascending stratigraphic order: Millerton, Shongaloo, and Dorcheat. The Millerton Substage included three chronozones, or members: the lower, middle, and upper. The Millerton is a relatively nearshore tongue of the Bossier Shale. A molluscan assemblage zone, the *Idoceras santarosanum* Zone, was tentatively proposed for the Millerton Substage (Swain and Anderson, 1993). The Shongaloo Substage included five chronozones, the sub-Taylor, Taylor, Sexton, Roseberry, and upper Shongaloo. The entire Shongaloo Substage was assigned to the *Nophrecythere parintermedia* ostracode assemblage zone (Swain and Anderson, 1993). The Shongaloo Substage also included two ammonite assemblage zones, the *Virgatosphinctes* cf. *V. aguilari* Assemblage Zone and the *Salinites grossicostatum* Assemblage Zone (Swain and Anderson, 1993). Finally, the Dorcheat included four chronozones: the Leton, Sentel, Hughes, and Aycock chronozones. The Dorcheat Subzone included five ostracode assemblage zone, with two in the Leton chronozone and one each for the upper three chronozones in this substage. The Leton Member, or chronozone, included the *Prohutsonia rugosa* and the *Dorcheatia nodocaudata* ostracode Assemblage Zones. The Sentell Member was represented by the *Quadraschuleridea melonica* Assemblages Zone. The Hughes Member was represented by the *Hutsonia vulgaris elongata* Assemblage Zone, and the Aycock Member was represented by the

Schuleridea acuminata Assemblage Zone. These substages and chronozones have not been recognized in Mississippi.

According to Swain and Anderson (1993), the Cotton Valley Group ranges from Tithonian (Jurassic) through Berriasian (Early Cretaceous) in age. Cooper (1976) studied nannofossils from the Bossier Shale in southern Arkansas and northern Louisiana. In the downdip area of northern Louisiana, the Bossier comprises essentially all of the Cotton Valley. The nannofossil species *Hexalithus noelae* was believed to occur at the top of the Jurassic in this region. This species occurred near the top of the Bossier in all but one well, the southern-most (downdip) well. At this latter locality, the highest occurrence of *H. noelae* was 4430 feet below the top of the Bossier Shale, indicating the top of the Bossier is considerably younger in the downdip area than the updip area. The highest occurrence of one nannofossil species, *Cruciellipsis cuvillieri*, which had been reported to be of Hauterivian age, was more than 400 feet below the top of the Bossier. However, another species, *Nannoconus colomi*, with a reported range of upper Tithonian to upper Barremian, occurred throughout the shale, indicating either that the reported ranges of *C. cuvillieri* or *N. colomi* were in error.

Rogers (1987) studied the palynological biostratigraphy of the upper Dorcheat and lower Hosston Formations in northern Louisiana. Samples from the lower Dorcheat Formation yielded dinoflagellates indicative of the Late Jurassic. These species included *Cleistosphaeridium ehrenbergi* (Deflandre, 1947) and *Parvocavatus tuberosus* Gitmez, 1970. Palynomorphs extracted from the upper half of the Dorcheat indicate an Early Cretaceous age. Marker dinoflagellates from this interval include *Phoberocysta neocomica* (Gocht, 1957), *Microdinium opaquum* Brideaux, 1971, and *Muderongia simplex* Alberti, 1961. Terrestrial palynomorphs obtained from the upper Dorcheat (Early Cretaceous) include *Trilobosporites* sp., *Pilosisporites* sp., *Neoraistrickia breviclavata* and *Leptolepidites proxigranulatus*. The Hosston Formation also yielded Early Cretaceous species, including the Early Cretaceous marker spore *Cicatricosisporites angicanalis* and the dinoflagellate *Oligosphaeridium* complex. All these data indicate that the top of the Jurassic occurs in the upper part of the Cotton Valley (Dorcheat Formation) and that only the lower of the group is of Tithonian age (Jurassic).

Petty et al. (1995) reported several occurrences of dinoflagellates and calcareous nannofossils from the Cotton Valley Group of the coastal region of Mississippi. Calcareous nannofossils were reported

from the Tenneco well in Viosca Knoll Block 117 well. The species *Hexalithus* cf. *H. beckmanni* was reported from approximately 1/3 up from the base of the formation and was listed as top Tithonian, but the nannofossil guide of Perch-Nielsen (1985) did not list this species. If the identification of *H. beckmanni* is correct, this would indicate that the Jurassic-Cretaceous boundary occurs approximately 1/3 up from the base of the Cotton Valley in this well. The species *Polycostella* cf. *P. senaria* Thierstein, 1971 and *P.* cf. *beckmanni* Thierstein, 1971 were reported from approximately 2/3 up from the base of the group. The former species was reported by Perch-Nielsen (1985) as middle Berriasian and the latter species as Tithonian to lower Berriasian. *Nannoconus steinmanni* Kamptner, 1931 was reported from approximately 570 feet below the top of the Cotton Valley, which Perch-Nielsen (1985) indicated ranged from the Tithonian to the top Barremian. All these data indicate that the Jurassic-Cretaceous boundary occurs somewhere in the middle to lower third of the Cotton Valley Group in this well.

Paleontological data was also reported from the Conoco Mobile Block 991 well. Basal Cotton Valley beds contained the dinoflagellate species *Geiselodinium paeminosum* (referred to as *Subtilisphaera paeminosa* (Drugg, 1978) by Lentin and Williams (1989)), which was listed as middle Kimmeridgian age by Lentin and Williams (1989). This age date is considerably older than Cotton Valley sediments dated at other localities. Specimens of the dinoflagellate species *Gonyaulacysta perforans* (Cookson and Eisenack, 1958) (now assigned to the genus *?Cribroperidinium*) were reported from the middle Cotton Valley, the age of which was given by Lentin and Williams (1989) as Late Jurassic. The dates in this latter well, if accurately identified, indicate that the Jurassic-Cretaceous boundary in this Conoco well is in the upper portion of the Cotton Valley, stratigraphically higher than the comparable time point in the Tenneco well.

Petty et al. (1995) also reported paleontological data from the Chevron Mississippi Sound Block 57 well. The calcareous nannofossil species *Nannoconus bonnmanni* (probably *N. broennimanni* Trejo, 1959) of Tithonian to latest Valanginian age (Perch-Nielsen, 1985) was observed near the top of the Cotton Valley, as was *Schuleridea acuminata* Swartz and Swain, 1946. This latter species, better referred to now as *Schuleridea acuminata* s. l., as several subspecies were described in Swain and Anderson (1993), has long been known to occur at or near the top of the Cotton Valley in Louisiana and Arkansas (Swartz and Swain, 1946).

Cotton Valley Stratigraphy from Regional Cross Sections

Wireline, sample and lithologic logs for forty-three of the wells used to construct the regional cross sections of the MISB contained section assignable to the Cotton Valley Group. In five of the wells studied, the Cotton Valley was not recognized because it was faulted out or no wireline log contact was discernable. Regional stratigraphic trends were delineated on the basis of these logs. In nearly all of the wells, the Cotton Valley displays a bipartite subdivision, with the lower part of the section containing more sandy sediments and generally being more red in color than the upper part, which is shalier and usually very colorful. In some areas, the Cotton Valley can be subdivided into three or more subdivisions, such as in Jasper County where the group includes a lower "Bay Springs sand," a shaley "Bay Springs lime," the Pink sandstone, the upper Shongaloo and the Dorcheat.

Of the fourteen wells in the western Mississippi region, all include part or all of the Cotton Valley Group. Thickness ranges from 625 feet in the updip region of LeFlore County to 4598 feet in southern Hinds County. A bipartite subdivision is recognized only in the western and updip areas of the region; the Shongaloo-Dorcheat contact is not recognized south of northern Yazoo County. The top of the Shongaloo is not a good point for correlation, as noted by Dinkins (1968), as its relative thicknesses are not consistent between wells. In Issaquena County, the Cotton Valley is approximately 3000 feet thick, and includes red, fine-grained, slightly to non-porous sandstone with some red and maroon shale. The upper portion is shalier, including dark red, purple and maroon shale, light gray and light greenish-gray mudstone, with siderite concretions. These are typical Dorcheat lithologies. The 3907-foot section in Sharkey County includes essentially the same lithologies as in Issaquena County but includes carbonaceous material in the lower part of the section. The Cotton Valley is relatively thin in LeFlore and central Holmes County but thickens abruptly between central and southern Holmes County. In the northernmost well, the lower approximately 400 feet is sandier than the upper 200 feet, whereas in the central Holmes County well, the section is approximately evenly divided. In this area, the sandstone is white to gray, red in parts, fine- to coarse-grained, lignitic, and contains abundant chert gravel. The shale is red and gray, micaceous, and slightly silty. The characteristic multi-colored shale and mudstone was not described for this well but is in nearby wells. The Cotton Valley in the southern Holmes County well is 1788 feet thick, with the lower two-thirds recognized as Shongaloo and the upper one-third as Dorcheat. The northern Yazoo County well

displays a tripartite subdivision, with the lower approximately 700 feet being the Pink sandstone, the overlying 850 feet being the Shongaloo, and the upper 800 feet being the Dorcheat. The Cotton Valley increases from 2225 feet thick to 4598 feet thick between northern Yazoo and southern Hinds County. The Shongaloo-Dorcheat contact is not recognized in these areas, but the lithology generally follows the trend of sandier in the lower portion to shalier in the upper portion, including the colorful fine sediments in the upper portion. In southern Hinds County, however, the lower portion of the Cotton Valley includes abundant coal and pyrite, which persists in decreasing amounts in the upper part of the section. Interestingly, abundant coal also occurs in the Cotton Valley in the downdip area of Perry and northern Stone County, Mississippi. To the east, in Rankin County, the Shongaloo and Dorcheat are recognized, with the lower 1400 feet being Shongaloo and upper 1700 being the Dorcheat. Typical Pink sandstone and dark red, micaceous shale occur in the Shongaloo and colorful, sideritic shale and mudstone in the Dorcheat.

The Shongaloo and Dorcheat are recognized in the central Mississippi region, except for the extreme updip well. The full thickness of the Cotton Valley is not present in the Simpson (faulted) and Jeff Davis County (base not reached) wells, nor in the Jones County well (faulted). The Shongaloo and Dorcheat facies are essentially the same as in western Mississippi. In southwestern Jasper County, however, the Cotton Valley differs considerably from the surrounding region, due to the presence of the Bay Springs facies. In well 23-061-20203, the lower 500 feet is very sandy (Bay Springs sand) and the overlying 250 is very shaley, and the group includes limestone near the top. As stated previously, Aultman (1975) considered the Bay Springs facies to be time equivalent to part of both the Haynesville Formation and the Cotton Valley Group. Overlying the Bay Springs lime is the Pink sandstone, which occurs about 970 feet above the base of the group. In this well, the upper portion of the Shongaloo (the top of which is about 2800 feet above the base of the group) and the Dorcheat occur in the upper approximately 1200 feet of section.

The Shongaloo and Dorcheat are recognized in the eastern Mississippi region, except in the far downdip regions. Part or all of the Cotton Valley is faulted out of the section in a few wells in Wayne County. In the Wayne County area, the Shongaloo is typically thicker than the Dorcheat. For example, in well 23-153-20122, the Shongaloo is approximately 2250 feet thick, whereas the Dorcheat is about 800 feet

thick. In this well, the Shongaloo consists of clear and red, fine grained, moderately cemented, slightly micaceous sandstone; of light gray, well cemented chert fragments; and of reddish-brown, silty, micaceous shale. The Dorcheat consists of reddish-brown, purple, gray, mottled, yellow, and lavender, silty, sandy, very micaceous shale, with traces of pyrite. In the updip area of Clarke County, the entire Cotton Valley contains chert, which is abundant in the Shongaloo. The rest of the group includes typical Shongaloo and Dorcheat facies. In Perry County, the bipartite subdivision of the Cotton Valley is not recognized, although the group generally becomes shalier up-section. Also, as stated previously, abundant coal and lignite occur throughout section, with interbeds of red limestone. In Hancock County, the Cotton Valley has changed considerably from the updip area, generally grading from shale and sandstone in the lower portion to limestone/shale/sandstone in the upper portion. The shale in the lower portion is dark gray to black, calcareous and micaceous; the sand is light gray to gray, clear, very fine-grained, well cemented, and very calcareous. The limestone is typically dark gray, dense, micritic, fossiliferous and dolomitic in part. In the upper portions of the unit, the limestone becomes oolitic and sucrosic in part.

The Cotton Valley Group in Alabama is generally similar to that in Mississippi, but it contains more coarse clastic sediment, making recognition of the Shongaloo and Dorcheat difficult to impossible. In several of the wells, a subtle trend of increasing shale upsection was observed, but this trend is not as easily recognized as in the section in Mississippi. The predominant color of the Cotton Valley in Alabama is red (Tolson et al., 1983), but shale composes only about 30 percent of the total thickness of the Cotton Valley. The lower percentage of shale makes recognition of the colorful Dorcheat facies difficult to impossible. In addition, the coarse clastic sediments of the Cotton Valley obscure the upper contact, thus leading to uncertainty regarding formational descriptive assignments.

Summary

The Cotton Valley Group in the Mississippi Interior Salt Basin is comprised entirely of the Schuler Formation. The Bossier is absent in the MISB. In western and eastern Mississippi and Alabama, the Cotton Valley consists of coarse siliciclastic sediments, and the unit becomes increasingly conglomeritic in updip areas. The areas of coarse siliciclastic sediments define where ancient rivers debouched. The western area was possibly the ancestral Mississippi River, and the eastern river probably emanated from the Appalachian Mountains. In central Mississippi, from about Yazoo to Clarke County, the

Schuler can be subdivided into two members, a lower Shongaloo and an upper Dorcheat. The Dorcheat is generally more shaley than the underlying Shongaloo. The lower part of the Shongaloo also contains a distinctive unit, the "Pink Sandstone," which is a fairly massive, pink sand unit. These siliciclastic sediments grade downdip into finer sediments. Interbedded limestone occurs in southwestern and southern Mississippi. Recognizing the upper and lower contacts of the Cotton Valley can be difficult due to lack of regional stratigraphic markers. In addition, color has been used extensively in recognizing the Cotton Valley and its various subdivisions. This attribute is not discernable from wireline logs. Biostratigraphic evidence indicates that the Cotton Valley Group ranges from Tithonian (Jurassic) to Berriasian (Cretaceous) in age.

Lower Cretaceous

Hosston Formation

The Hosston Formation was named by Imlay (1940) for the 2000 foot section of dominantly gray and red shale and sandstone that occurs in the Dixie Oil Company Robertshaw No. 92 (Dillion No. 92) well in Caddo Parish, Louisiana. Prior to Imlay's work, the lower part of the Lower Cretaceous Series (the interval above the Cotton Valley and below the Pine Island Formation) was referred to as the Travis Peak Formation (Hazzard, 1939; Weeks, 1938). Imlay determined that the rocks overlying the Cotton Valley Group were older than the Travis Peak of Texas and stratigraphic equivalents in Arkansas. This determination was based on the occurrence of the ammonites *Dufrenoya* and *Prochelonicerasi*, which occur in the Travis Peak of Texas. However, these species also occur in the lower part of the Pine Island Formation. Imlay (1940) distinguished the Hosston Formation from the Cotton Valley by its dominantly brighter colors, smaller amounts of calcareous material, presence of carbonaceous materials and plant fragments, absence of brownish-black pellets of siderite, and lack of variegated maroon and gray shales. The disconformable contact between the Hosston and Cotton Valley Formations was determined on the basis of widespread conglomerates at the base of the Hosston. In Arkansas, the Hosston consists mainly of red shale with interbedded lenses of white sandstone. Sandstone predominates in the lower 100 feet of the formation, is abundant in the middle portion of the formation, and is uncommon in the upper third (Imlay, 1940). Imlay (1940) also defined the Sligo Formation. The contact between the Hosston and Sligo is

conformable, and defined by the uppermost red beds of the Hosston Formation. The thickness of the Hosston Formation increases from 0 feet at its northern limit in southern Arkansas to more than 2200 feet in northern Louisiana.

Nunnally and Fowler (1954) was one of the first publications to describe the Lower Cretaceous stratigraphy of Mississippi. Also presented in this publication was a regional correlation chart of the Lower Cretaceous formations for Texas, the Louisiana-Arkansas region, and Mississippi. Several factors regarding the difficulty of correlation of these units into Mississippi were stressed in this work. First is the difficulty of differentiating the Washita and Fredericksburg Groups. Second was the impossibility of differentiating the James Limestone and Pine Island equivalents. Third was the absence of the Sligo Formation in Mississippi. These three factors were due to the changes in lithology between the type areas and Mississippi, and the dearth of age diagnostic fossils.

In Mississippi, the Hosston Formation consists of white, pink, red, green, and gray sandstones, red and gray shales, occasional limestone nodules, and traces of lignite (Devery, 1982; Dinkins, 1969; Dinkins, 1971; Nunnally and Fowler, 1954). Devery (1982) also noted the presence of chert, which typically increases in abundance toward the updip limit of the formation. The base of the formation is generally recognized at a change from the vari-colored shales of the Dorcheat Member of the Schuler Formation (Cotton Valley Group) to the red beds of the Hosston Formation. The contact between the Cotton Valley and Hosston is unconformable. The Hosston and Sligo Formations are essentially time equivalents, with the relatively coarse red beds of the Hosston Formation occurring in the updip regions grading into the gray shales and limestones in the downdip areas (Devery, 1981; Devery, 1982; Dinkins, 1969; Dinkins, 1971; Nunnally and Fowler, 1954). Devery (1982) noted that, on electric logs, the top of the Hosston "…is placed at the base of the lowest sandstone and shale section of the overlying Sligo Formation…" and that the contact between the Hosston is gradational and conformable. Dinkins (1971) recognized the top of the Hosston as follows: "…at the top of a sequence of medium- and coarse-grained conglomeratic sandstone generally associated with quartz and chert pebbles below the lowest sandstone and shale sequence of the overlying Sligo formation [sic]." Differentiation of the Hosston from the Sligo was variable, however, because of the lithologic similarities between the two formations. The contact, where recognized, was

usually a general increase in grain size and abundance of sandstone beds when passing from the lower Sligo into the upper Hosston.

The lower portion of the Hosston in the Perry sub-basin was described by Applin and Applin (1953) and correlated with other wells in the region by Maher and Applin (1968). The Hosston Formation in the Perry sub-basin is dominated by dark brownish-red, unfossiliferous, hard, partly silty, micaceous and calcareous shales with occasional beds of sandstone. The red shale was partly mottled and streaked with gray to greenish-gray, silty, micaceous shale and contained inclusions of red limestone. Applin and Applin (1953) noted the difficulty of recognizing the contact between the Cotton Valley Group and the Hosston Formation due to the lack of a distinctive stratigraphic break. This difficulty results in uncertainty regarding the placement of this boundary in southern Mississippi.

Warner (1993) studied the Cretaceous sediments in the subsurface of coastal Mississippi. Warner observed that recognition of the Cotton Valley-Hosston contact is difficult due to the lithologic similarities of the two units. The Hosston in Ansley field, southern Hancock County, is comprised of 1370 feet of white to dark gray, hard, dense, microfossiliferous, micritic limestone, with thin beds of dark gray shale. In Mississippi Sound, the Hosston thickens to 1895 feet thick, and is comprised, in the lower portion, of dark gray to gray to dark brown, hard, microcrystalline, argillaceous limestones interbedded with minor amounts of dark gray shales and very fine-grained sandstones. The upper portion of the Hosston includes much more siliciclastic sediments, being dominated by varicolored, moderately consolidated to firm, calcareous cemented silt, and gray to dark gray, firm to hard, micaceous, arenaceous, slightly calcareous shale. Interbedded with these silts and shales is gray to dark gray, firm to hard, argillaceous, oolitic limestone with abundant microfossils. In the Mississippi state waters area, the Hosston is comprised of an 1810-foot interval of predominantly siliciclastic sediments. These sediments include light gray to dark gray to reddish-brown, firm to hard, micaceous, moderately calcareous shales interbedded with varicolored, very fine-grained to coarse-grained, calcareous cemented sandstones and cream to light gray to white, firm to moderately hard, microcrystalline, oolitic limestones. Along the Mississippi Gulf Coast the Hosston interval changes from predominantly limestones to the west (Hancock County) to fine siliciclastic sediments to the east (Mississippi Sound area) (Warner, 1993).

The Hosston is generally considered to have formed under fluvial-deltaic conditions (Fielder et al., 1985; Jackson, 1990; Thomson, 1978; Weaver and Smitherman, 1978). In southwest Mississippi, in the Jefferson Davis, Lamar, Covington and Marion County areas, the Hosston was interpreted to grade from fluvial/deltaic sandstones to prodelta and into marine shelf sandstones (Fielder et al., 1985) in an updip to downdip progression. The fluvial/deltaic facies was characterized by thick (40-120 foot) channel-fill sandstones that are laterally discontinuous interbedded with thinner sandstones that may represent overbank deposits. The numerous sandstone units that occur in the Hosston, such as those presented by Scherer (1981a; 1981b), probably represent these channel sands. Correlation of these sand units is very difficult or impossible due to their discontinuous distribution. Downdip from the fluvial/deltaic setting, the Hosston is represented by prodeltaic, marine sandstone facies (Fielder et al., 1985). These prodeltaic deposits are composed of well-sorted, fine-grained quartz sandstones with thick intervals of gray and brown shales. The sandstone units displayed three bedding types: small-scale cross beds, faintly laminated or massive sandstones, and thin, bioturbated intervals. A shelf sandstone facies occurs in more downdip areas. The shelf sandstone facies is characterized by very fine-grained quartz sandstone with abundant carbonate grains and matrix (Fielder et al., 1985).

Age

The Hosston Formation is generally devoid of age-diagnostic fossils, thus determining the age of the unit is problematical. Typically, the Hosston Formation is assigned to the lower part of the Coahuila Series (Imlay, 1940). In the Pine Island field of northwestern Louisiana, the top of the Hosston is at or near the base of the *Dufrenoya texana* ammonite zone. As stated previously, Rogers (1987) recovered palynomorphs indicative of the Late Jurassic from the lower part of the Dorcheat Member of the Schuler Formation (Cotton Valley Group) of northern Louisiana, but recovered Early Cretaceous palynomorphs from the upper part of the Dorcheat, indicating that the Jurassic-Cretaceous boundary occurs in the middle portion of the Dorcheat. The Hosston also contained Early Cretaceous palynomorphs. Thus, the Hosston is younger than earliest Cretaceous. Rogers (1987) indicated that the Hosston lies wholly within the Durango Group, which occupies the lower, or earlier, part of the Coahuila Series. Imlay (1944) defined the Durango Group on paleontological criteria, with the lower boundary defined by the lowest occurrence of the ammonites *Neocosmoceras*, *Spiticeras*, and *Himalayites*, and the upper boundary defined by the lowest

occurrence of the ammonites *Pulchellia*, *Barremites*, and *Pseudohaploceras*. This interval was correlated to the Berriasian, Valanginian, and Hauterivian Stages of Europe. Rogers (1987) further noted that the lower part of the Hosston contained the miospore *Cicatricosisporites angicanalis*, which occurs in the Berriasian Stage in Europe. However, later correlations, such as that of McFarlan and Menes (1991), correlate the upper part of the Cotton Valley Group to the top of the Berriasian and the lower part of the Hosston to the uppermost part of the Valanginian Stage; thus, almost all of the Valanginian Stage is missing. The age of the top of the Hosston is variable, as the Hosston and Sligo are time equivalent, with the Sligo being a downdip time equivalent of the updip Hosston. Swain and Anderson (1993) described one ostracode zone for the Hosston, the *Truncofabanella platydorsum* Zone, which occurred their Napper Member of the Hosston, the lowest member of the formation.

Petty et al. (1995) published microfossil occurrences for three wells on their cross sections along coastal Mississippi. A sample from near the base of the Hosston in the Tenneco Viosca Knoll 117 well yielded the dinoflagellate species *Muderongia simplex* Alberti, 1961, which Lentin and Williams (1989) reported as ranging from the Valanginian to early Barremian. This same well yielded specimens of *Choffatella decipiens* Schlumberger, 1904, which has long been known to occur at the top of the Sligo Formation. *Choffatella decipiens* is generally taken to mark the top of the Coahuilan Stage and lower portion of the Aptian Stage (Minerals Management Service, Gulf of Mexico OCS Region Biostratigraphic Chart; Van Hinte (1976)). A sample approximately one-fourth up from the base of the Hosston in the Conoco Mobile Block 991 well contained the dinoflagellate species *Druggindium "A"* of unpublished taxonomic affinity, and *Phoberocysta neocomica* s. l. (Gocht, 1957) (several subspecies were described as belonging to this species) of Hauterivian age. Calcareous nannofossils belonging to the species *Nannoconus steinmanni* of Tithonian to latest Barremian age were observed approximately one-third up from the base of the Hosston Formation in the Chevron Mississippi Sound Block 57 well. All the paleontological data indicate a Hauterivian to early Barremian age for the Hosston Formation and a Barremian age for the Sligo Formation along the Mississippi Gulf Coast.

Hosston Stratigraphy from Regional Cross Sections

The Hosston Formation displays fairly consistent stratigraphic sequence throughout most of the MISB, but changes rapidly in southern Mississippi (dip section D-D') grading from dominantly coarse

siliciclastic sediments (white sands, quartz pebble conglomerates, and red shales) to dark shales (Perry sub-basin) and carbonates (Hancock County region of coastal Mississippi). The Sligo Formation can be recognized only in the southern parts of the dip sections, being characterized by containing more shale than the underlying Hosston. The Sligo Formation is generally noncalcareous in most of the wells observed in this study, consisting of interbeds of shale and sandstone. The Hosston becomes very difficult to recognize updip of the limit of the Pine Island Formation, as the Hosston is lithologically similar to the Rodessa Formation in that area. In the downdip area of the Perry sub-basin and coastal Mississippi, the base of the Hosston is difficult to recognize due to the lithologic similarities between the lower Hosston and upper Cotton Valley Group. The base of the Hosston is distinct in the central and northern parts of the MISB except for the extreme updip limits, where coarse siliciclastic sediments predominate.

In Issaquena County, Mississippi (wells 23-055-00032 and 23-055-00066), the interval between the top of the Cotton Valley and the base of the Gas Rock is referred to as the Lower Cretaceous undifferentiated. This area is updip of any of the finer grained units, and consists of an attenuated section of relatively coarse siliciclastic sediments. The interval is approximately the same thickness in both of these wells, being about 1620 feet thick. A Trowbridge sample log (well 23-055-00066) refers to this interval as the Hosston and, indeed, it is lithologically similar to the Hosston in other areas. The Lower Cretaceous sediments in this well include very fine- to fine-grained, green, porous sandstone, clear, pink and red quartz pebbles, scattered tan siderite concretions and chert. Further to the east in southeast Sharkey County (well 23-125-20004), the base of the Hosston is recognized as an indistinct contact between the relatively shaley interval of the Dorcheat and sandstone of the Hosston. The Hosston in this well is about 1670 feet thick. Sample logs from nearby wells indicate that the Hosston in this region is comprised of fine- to coarse-grained, slightly and non-porous sandstone, quartz pebbles and quartz gravel; dull red and maroon, micaceous shale; and some mottled mudstone. The overlying approximately 400 feet consists generally of more shale than sandstone (based on electric log signature), and is referred to as the Sligo Formation, although the difference between the Hosston and Sligo in this well is not obvious. Trowbridge sample logs from the nearby wells also refer to this upper interval as Sligo.

In describing the Hosston Formation in the dip sections, it is best to begin with the most downdip well location and proceed updip, as the stratigraphic units are better developed and easier to recognize in

the downdip areas. The Hosston Formation is approximately 2100 feet thick in southern Hinds County (well 23-049-20032). The base of the formation, however, is difficult to recognize due to the relatively fine grain size of the upper Cotton Valley and lower Hosston units. The contact was selected at the base of a sandstone unit above a relatively shaley interval (17, 370' depth). Sydboten and Bowen (1987) interpreted this contact to be stratigraphically higher in this well (17, 150'). They placed the contact at the top of a sandstone unit. The overlying 950 feet (up to the base of the Pine Island) is referred to as the Sligo Formation. Lithologic log descriptions indicate that the Hosston in this well includes white and clear, fine- to medium-grained, non-calcareous to slightly calcareous sandstone; red to reddish-brown, finely micaceous, silty shale; and with traces of dense, crystalline limestone, lignite, and pyrite. The Hosston in well 23-049-20004 (a few miles north of 23-049-20032) is also about 2100 feet thick, although the Sligo has apparently thinned to some 800 feet. However, the contact between the Hosston and Sligo is transitional, and therefore indistinct, being recognized as an increase in thickness of shale intervals. In fact, a sample log indicates that the "probable" top of the Hosston is approximately 500 feet higher than where it is selected herein. However, the wireline log character change is more significant in recognizing this contact, and the sample and lithology logs show the presence of nodular limestone in the intervening interval. Sample logs and lithology logs indicate that the Hosston Formation in this well is comprised of white, red, light red and pink, fine- to coarse-grained, very slightly porous to non-porous sandstone, clear quartz pebbles, and dark red and maroon, finely micaceous shale.

The Sligo and Hosston are undifferentiated in well 23-049-20005, which is a common well for the strike section A-A' and the dip section B-B', as there is no appreciable increase in fine siliciclastic sediment in the upper portion of the interval (below the Pine Island). However, the Sligo in the next well updip, 23-089-20043, can be recognized. It is not clear why the Sligo cannot be recognized in well 23-049-20005. In this latter well, for which a sample log is available, the Hosston is comprised of red and light red, fine-grained sandstone, abundant clear quartz gravel and pebbles, and red, dark red and maroon, micaceous shale and sandy shale. The top of the formation is recognized on the basis of the lowest occurrence of the overlying Pine Island shales. The base of the Hosston was recognized by a thick sandstone interval occurring at the top of a relatively thick shale interval. This point (at a depth of 12, 060 feet) was also considered the top of the Cotton Valley by Sydboten and Bowen (1987), although the sample log indicates

the top of the Cotton Valley to be approximately 490 feet higher in the section. Selection of the top of the Cotton Valley at this higher elevation would, in fact, result in a thickness of the combined Sligo/Hosston interval of approximately 2800 feet, which is the same thickness of this combined interval in the wells adjacent to it in the dip section. Using the more distinctive lower elevation results in a combined Sligo/Hosston thickness of approximately 3300 feet, which is about 500 feet thicker than the wells adjacent to it. Thus, there are two anomalies regarding the Coahuilan section in the 23-049-20005 well: 1.) the Sligo is not recognized, although it is in wells adjacent to it; and 2.) the thickness of the Hosston is approximately 500 feet thicker than the adjacent wells. The cause of these discrepancies is not known at this time.

The Hosston in well 23-089-20043, located in western Madison County, is approximately 2100 feet thick, whereas the overlying Sligo is approximately 715 feet thick. Although no sample or lithology log is available for this well, the wireline log signature suggests a dominantly sandy lithology. The lower contact was recognized by the lowest occurrence of a predominantly sandy section above the shale of the Dorcheat; this point was also recognized by Sydboten and Bowen (1987) as the top of the Cotton Valley, but is about 400 feet higher stratigraphically than the top of the Cotton Valley as interpreted by Twiner (unpublished). The higher point is much more distinctive than the lower, and is more consistent with recognized contacts in other wells. The upper contact of the Hosston was recognized by the highest occurrence of relatively thick sandy intervals, above which the shaley intervals are thicker and more numerous.

Well 23-163-20150, located in southern Yazoo County, is the most updip well for which differentiation of the Hosston and Sligo is made and is, in fact, the most updip well for which any of the lower Lower Cretaceous formations (top of Cotton Valley to top of Rodessa) are recognized. The combined thickness of the Hosston and Sligo in the Yazoo County wells is approximately 1958 feet thick, including 1628 feet of Hosston and 330 feet of Sligo. Based on a lithology log, the Hosston in 23-163-20150 is comprised of interbedded sandstones and shales, with the sandstones being white, clear, pink or tan, fine-grained, moderately to well cemented, slightly calcareous, and glauconitic in part, and the shales being reddish-brown, dark gray, flaky, splintery, and moderately firm. The upper approximately 330 feet of the interval is finer grained, and is referred to as the Sligo.

The entire Lower Cretaceous interval in well 23-163-00049, located in northern Yazoo County, is only about 2830 feet in thickness, which is approximately the same thickness as the Hosston Formation in the more downdip wells. The questionable occurrence of the Mooringsport between elevations of 8180 and 8483 feet, is the only recognized Lower Cretaceous marker in this well. The lower 800 feet of the interval between the top of the Cotton Valley and the base of the Mooringsport contains abundant quartz pebble gravels, red and light red, fine- to coarse-grained, slightly to non-porous sandstone, and dark red and maroon shale, with traces of chert and lignite.

Well 23-051-20036, located in southwest Holmes County, also includes a relatively thin Lower Cretaceous section (2260 feet thick). The Mooringsport is fairly distinctive in this well, but the Cotton Valley-Hosston contact is not distinctive. The lower contact for the Lower Cretaceous section was recognized on the basis of nearby wells, including well 23-163-00049 and a well on Cross Section II of Twiner (unpublished). No discernable contact was recognized between the top of the Cotton Valley and the base of the Mooringsport in an interval of 1520 feet thick. Sample logs are available from a nearby well, although the Lower Cretaceous section in this well is much attenuated from well 23-051-20036 (the Lower Cretaceous being only 610 feet thick). The Trowbridge sample log for this well indicates that the lower part of the Lower Cretaceous (all of which was referred to as Hosston) is comprised of coarse-grained, slightly porous and calcareous sandstone, loose, clear, yellow and red quartz pebbles, a trace of dark red shale and red nodular limestone.

The northern two wells in dip section B-B’ include only undifferentiated Lower Cretaceous, consisting predominantly of sandstones and shales. The Lower Cretaceous section in well 23-051-20020, located in north-central Holmes County, is approximately 2460 feet thick and is approximately 1050 feet thick in well 23-083-20011 in southern LeFlore County. A sample log from well 23-051-20020 indicates that the Lower Cretaceous section is comprised of white, red and green, fine-grained, well cemented, micaceous sandstone, glauconitic in part, with traces of pyrite; pink and red quartz pebbles; and red, gray, silty, firm, slightly micaceous shale. A similar lithology is indicated for the Lower Cretaceous section on a sample log from a well near well 23-083-20011.

The Hosston occurs as a distinctive unit in well 23-121-20025 (north-central Rankin County), located between dip sections B-B’ and C-C’. The lower contact of the Hosston is recognized by a change

from the predominantly shaley interval of the Dorcheat to a dominantly coarse grained interval of the Hosston. The contact between the Hosston and Sligo is recognized by an increase in number and thickness of shale units. The Hosston is approximately 1770 feet thick and the Sligo is approximately 420 feet thick. A sample log indicates that the Hosston consists of fine- to medium-grained, porous and non-porous sandstone; clear and pink quartz pebbles; dark red and maroon, micaceous shales; and light gray and purple mudstone, with a trace of lignite.

Well 23-129-00178, located just west of dip section C-C', includes an approximately 1530 foot section of Hosston and a 270 foot section of Sligo, which is somewhat thinner than the well to the west (Rankin County), but about equal to the well a few miles to the east. A lithology log for well 23-129-00178 indicates that the Hosston is white to gray, fine- to medium-grained, loosely to well cemented sandstone, and red, sandy, firm shale. The Sligo is recognized by an increase in shale thicknesses.

The Hosston-Sligo contact can only be recognized in the three downdip wells in dip section C-C'. The Coahuilan section well 23-065-20141, located in northern Jeff Davis County, is approximately 3000 feet thick, with the Hosston occupying the lower 2655 feet and the Sligo the upper 345 feet. The Hosston in this well is predominantly a clear, light gray, white, and occasionally tan and light pink, fine- to medium-grained, well cemented sandstone; reddish-brown, silty, firm, micaceous, partly sandy shale; and traces of lignite and pyrite. A fault occurs in the Hosston in well 23-127-20055, located in extreme eastern Simpson County, in which approximately 2000 feet of section is missing, thus the exact thickness of the Hosston is not known. The top of the Hosston is recognized at the highest occurrence of relatively coarse-grained sediments, and the top of the Sligo is recognized as the top of a sandy unit at the top of a shaley interval. This latter contact also coincides with that published by the Mississippi Geological Society (Davis and Lambert, 1963). No lithology or sample logs were available for this well. Well 23-129-20122 is the most updip well in dip section C-C' for which the Sligo can be differentiated from the Hosston. The base of the Hosston was recognized at the lowest occurrence of coarse-grained sediments overlying a thick shale interval, but the Sligo-Hosston contact was indistinct, being recognized only by a subtle decrease in thickness of sandstone units in the Sligo and the presence of thin limestone beds. The Hosston in this well is approximately 1875 feet thick and the Sligo is approximately 560 feet thick. A lithology log indicates

that the Hosston in well 23-129-20122 is lithologically similar to that in well 23-127-20055, but the Hosston in well 23-129-20122 includes some chert fragments.

Updip of the updip limit of the Pine Island, as in dip section B-B', the top of the Hosston becomes very difficult to recognize, where the Rodessa directly overlies the Hosston, the only stratigraphic markers are the top of the Cotton Valley and the base of the Mooringsport. A sample log from a well near well 23-101-00014 (the most updip well in dip section C-C', located in central Newton County) indicate that the lower part of the Coahuilan section consists of clear, yellow, pink and red, fine-to coarse-grained, slightly and non-porous sandstone, clear and pink quartz pebbles, and maroon, purple, and bright red shale, with traces of pink and buff chert.

The thickness of the Sligo/Hosston interval ranges from 1931 to 2352 feet in the three wells in Jasper County (wells 23-061-20203, 23-061-20028, and 23-061-20244, from west to east). The lower contact of the Hosston is very distinctive in this region, being recognized by a thick sandy interval overlying the shales of the Dorcheat Member (Schuler Formation, Cotton Valley Group). In addition, a distinctive SP deflection occurs approximately 200 feet below the base of the Hosston. The top of the Hosston-Sligo interval is recognized by the lowest occurrence of the shales of the Pine Island Formation. The Hosston/Sligo contact cannot be recognized reliably in the area. Sample and lithology logs for wells in the region indicate that the Hosston/Sligo interval consists of white, red, light red, and pink, very-fine- to medium-grained, unconsolidated to moderately cemented, non-calcareous to slightly calcareous sandstone; dark red, dull red, brown, and maroon, finely micaceous shale; pink quartz pebbles; with traces of pyrite, reddish-yellow chert, and lignite.

Dip section D-D' displays the greatest lithologic variation observed in this series of cross sections, particularly between the wells in Hancock, Perry, and Wayne Counties. As observed by Warner (1993), the Hosston Formation consists largely of carbonate rocks in Hancock County, as confirmed by a lithologic log from well 23-045-20075, in the Catahoula Creek field. Indeed, in this largely carbonate section of rocks, recognition of the formation contacts is difficult. The base of the Hosston was recognized by a shale break at the top of the Cotton Valley, and the top was recognized by the highest occurrence of siliciclastic sediments in the interval. In this offshore area, the top of the Sligo is often recognized on a paleontological basis. The top of the range of the benthic foraminifer *Choffatella decipiens* Schlumberger occurs in this

unit. The Hosston Formation in well 23-045-20075 is approximately 2830 feet thick, and the Sligo Formation is 530 feet thick. A lithology log from this well indicates that the Hosston consists of gray, dark gray, brown, and reddish brown, medium firm to firm, silty, sandy, micaceous, non-calcareous shale; light gray, light brown, white, and clear, very fine grained, shelly in part, consolidated to well cemented, slightly calcareous sandstone; dark gray, gray, tan, dense, microcrystalline and sucrosic, peloidal, argillaceous limestone; and traces of pyrite and carbonaceous material.

The Hosston Formation in the Perry County basin (well 23-111-00069) is 2145 feet thick, and the overlying Sligo Formation is 310 feet thick. Although neither a sample nor a lithologic log was available for this Josephine A-#1 well, such logs are published for the nearby George Vasen Fee well (Applin and Applin, 1953; Maher and Applin, 1968). These descriptions show, in contrast to the carbonate section downdip and the relatively coarse siliciclastic section updip, the Hosston is comprised predominantly of shale with occasional sandstone beds. The shale is dark reddish-brown, hard, mostly unfossiliferous, and in part silty, micaceous, and calcareous. As stated by Applin and Applin (1953), the lower contact of the Hosston is very difficult to recognize, thus adding uncertainty to this contact. According to these authors, the contact is recognized by a change from the reddish-brown color of the Hosston to dark and duller shade of red, and the lenses of sandstone and shale increase in number and thickness. In the Josephine well, the base of the Hosston is recognized by a fairly thick (~180-foot) interval characterized by a reduced deflection in the SP curve and increased resistivity values in the curve for the overlying a thick (~550-foot) shale interval. The sandstone unit marker bed observed approximately 200 feet below the contact in the wells in Jasper County are also observed in the Josephine well. The upper portion of the Hosston contains an increase in the number of sandstone units. The upper contact of the Hosston was recognized by the highest occurrence of the sandstone units, while the top of the Sligo is recognized by the base of the shale of the Pine Island Formation.

The Hosston in well 23-153-20077, southern Wayne County, is 2292 feet thick, and the overlying Sligo is 267 feet thick. Based on wireline log characteristics, the Hosston is comprised of fairly regularly spaced interbeds of sandstone and shale. The lower contact of the formation is recognized by the dominantly sandy Hosston section overlying the predominantly shaley interval of the Cotton Valley. In this well, the top of the Hosston is fairly distinctive, which is recognized as a predominantly shale section

underlying the shale of the Pine Island Formation. The Hosston in well 23-153-01008, the common log for strike section A-A' and dip section D-D', is not present due to faulting.

The Hosston and Sligo are recognized in the three wells updip of the common well, but these two units cannot be distinguished in the Clarke County wells. The middle of the three wells, well 23-153-20265, contains an attenuated Coahuilan and Upper Jurassic section compared to the wells adjacent to it, suggesting the probability of a fault or series of faults in this interval. Well 23-153-20232, located in central Wayne County, includes 1873 feet of Hosston and 274 feet of Sligo. The lower contact of the Hosston is recognized by a thick sandstone package overlying a predominantly shaley interval, whereas the upper contact is recognized by an increase in number and thickness of shale units. The top of the Sligo was recognized at the base of the shale of the Pine Island Formation. The Hosston in this well consists of medium- to coarse-grained, greenish-gray to clear, loosely consolidated, quartz sand, and brick red to dark brown, sandy, brittle shale. The Sligo contains essentially the same lithologies, but includes an increase in shale beds.

The Hosston in well 23-153-20265 is only 738 feet thick and the Sligo is 202 feet thick, compared to 1732 feet and 305 feet, respectively, in well 23-153-20042. The Hosston Formation in these two wells are very similar, consisting of clear, pink, and light tan, very fine-grained to coarse-grained, slightly porous to non-porous sandstone, clear, pink and yellow quartz pebbles, red, dark red and maroon, slightly sandy shale, and white, ochre, buff, and red chert. The Hosston in well 23-153-20265 includes a basal gravel.

The interval between the top of the Cotton Valley and the base of the Mooringsport (top of the Rodessa) in the two Clarke County wells is described as undifferentiated because the key stratigraphic markers could not be recognized in this interval. The lower part of this interval looks like typical Hosston lithologies, but the top of the formation (base of Pine Island Formation) cannot be recognized. The interval between the top of the Cotton Valley and base of the Mooringsport is 1754 feet, which is less than the thickness of the Hosston a short distance downdip. The same interval in the most updip well, well 23-023-00270, is slightly thinner, being 1612 feet thick. There is considerable discrepancy regarding the elevation of the top of the Cotton Valley in this well, which means, of course, there is considerable discrepancy regarding the thickness of both the Cotton Valley and Hosston-Rodessa interval. A Trowbridge sample log indicates the top of the Cotton Valley to be at a elevation of 8560 feet, whereas the elevation reported by

industry is several hundred feet higher than that point. The depth interpreted herein is at an elevation between these interpretations, at a depth of 7235 feet. Considerable uncertainty remains for this contact. The lithology in the lower portion of this well consists of amber, pink, and clear, medium- and coarse-grained sandstone, dark red shale, clear, yellow and red quartz pebbles, white and ochre nodular sandstone, and ochre chert chips.

The Hosston and Sligo Formations are described as undifferentiated in the Alabama wells. Considerable uncertainty exists regarding the top of the Cotton Valley Group, due to the updip position in the basin and concomitant inclusion of relatively coarse-grained sediments in the region. The Hosston Formation is 2016 feet thick in the most downdip well in cross section E-E' (Hatter's Pond field), and thins to 1790 and 1745 feet in thickness in the two wells immediately updip to this well. The thickness of the Hosston cannot be determined for well 01-129-20051 because the top of the Cotton Valley cannot be recognized from the available information. The Hosston Formation in the common well for strike section A-A' and dip section E-E' is 1533 feet thick, and consists predominantly of medium to very coarse quartzose sandstones, with lesser amounts of reddish-brown clays. A thin (125-foot) interval overlying the Hosston Formation is questionably referred to as the Sligo Formation. The Sligo in this well consists of moderate-reddish-brown claystone and subordinate amounts of fine- to coarse-grained sandstone. The top of the Hosston Formation cannot be recognized in the two most updip wells in cross section E-E'. In the next most updip well (01-023-20114), the interval between the top of the Haynesville Formation and the base of the massive sand of the Tuscaloosa Group is described as undifferentiated because the key stratigraphic markers are not recognized.

Summary

The Hosston Formation is comprised essentially of siliciclastic sediments deposited in continental paleoenvironments occurring between the top of the Cotton Valley Group and either the base of the Sligo Formation or Pine Island Formation. The dominant lithologies are white and pink sandstones, red shales, and clear and pink pebble conglomerates. The Hosston Formation is predominantly shale in the Perry sub-basin and the eastern portion of coastal Mississippi, and is largely carbonate along the western portion of the Mississippi coastal region. The Sligo Formation can be differentiated from the Hosston Formation only in the downdip regions of the MISB. The Sligo is recognized generally by an increase in shale. Thickness

of the Hosston is fairly consistent throughout most of the MISB, averaging about 1800-2200 feet thick, except for the updip regions where the unit thins. The thickness of the Hosston Formation cannot be determined for the most updip wells, as the upper contact (base of the Pine Island Formation) cannot be recognized. Paleontological evidence is scarce, but suggests that the Hosston Formation ranges from latest Valanginian or earliest Hauterivian to early Aptian in age. The Hosston and Sligo Formations are time equivalent, with the Sligo being the fine-grained, downdip equivalent of the relatively coarse siliciclastic sediments of the Hosston Formation.

Sligo Formation

The age, stratigraphic relationships, and distribution of lithologies for the Sligo Formation were presented largely in the previous section. The Sligo is a transitional unit between the continental siliciclastic deposits of the Hosston Formation and the shales of the Pine Island Formation. The Sligo can be recognized only in the downdip regions of the MISB, and is recognized by a relative increase in shale bed thickness and number. Except for one well in the Catahoula field, Hancock County, Mississippi, there is essentially no carbonate in the Sligo Formation in the wells studied in the MISB. The Sligo in Louisiana and the offshore area of Mississippi typically contains carbonates. The contact between the Hosston and Sligo is conformable and often gradational, resulting in uncertainty regarding its exact position. It is widely known that the Sligo is the offshore, marine facies time equivalent of the Hosston Formation, thus the contact between the two formations has little time significance.

Pine Island Formation

The term Pine Island Formation was first published by Crider (1938) to refer to red, purple, and greenish shale, siltstone and sandstone, with thin beds of calcareous shale and partly fossiliferous limestone underlying the lower Glen Rose and overlying the Jurassic rocks. This interval is now understood to represent the Hosston Formation. Weeks (1938) identified the Pine Island as a member of the Glen Rose Formation, which included the Pettit oolitic limestone beds in the lower portion, a middle gray to dull brown shale, and James limestone beds in the upper portion. The Pettit limestone, or Pettet as published by Imlay (1940), is now considered to occur in the Sligo Formation, and the James Limestone is considered a stratigraphic unit overlying the Pine Island. The Shreveport Geological Society (Blanpied and Hazzard, 1939) also considered the Pine Island to be a member of the Lower Glen Rose Formation, which was part

of the Glen Rose Sub-Group. At that time, the Lower Glen Rose encompassed the stratigraphic units between the top of the "Travis Peak" (Hosston) and the base of the Glen Rose Anhydrite (now called Ferry Lake). Again, the limestones and shales overlying the "Travis Peak" red beds (Sligo Formation) were considered to be part of the Pine Island Formation, which was a reflection of the incomplete understanding of the facies relationship of the Sligo and Hosston. The Glen Rose Sub-Group also included the Glen Rose Anhydrite (Ferry Lake) and Upper Glen Rose (now called Mooringsport Formation). The Glen Rose Sub-Group occupied a very large interval within the Trinity Group, which encompassed the interval between the top of the Cotton Valley and the base of the Fredericksburg Group. Imlay (1940) recognized the enormity of time expanse of the Trinity Group, and therefore assigned the Hosston to the Coahuila Group (the top of which was defined by the lowest occurrence of the ammonite *Dufrenoya texana*), but still retained the Sligo at the base of the Trinity ("Glen Rose" sub-group). Some subsequent works, including Stricklin et al. (1971), Young (1972), and McFarlan and Menes (1991) retained the more expansive definition of the Trinity Division, which includes the lower Trinity Hosston and Sligo Formations, the middle Trinity Hammett Shale (=Pine Island Formation) and Cow Creek Formation in the middle Trinity, and the Hensel Sand and Glen Rose Formation in the upper Trinity. For this report, the base of the Trinity will be defined at the base of the Pearsall Formation, i.e., Pine Island and the equivalent Hammett Shale.

Forgotson (1957) studied the Comanchean Trinity Group in the Gulf Coastal Plain. Forgotson recognized that the Hosston and Sligo were time-equivalent facies, and thus redefined the base of the Trinity to occur at the top of the Sligo Formation in the downdip regions or at the top of the Hosston Formation where the Sligo does not occur. The "Travis Peak" as recognized in outcrop was determined to be the stratigraphic equivalent of the lower part of the Rodessa Formation, the Pearsall Formation (which included the Pine Island, James Limestone, and Bexar Shale Members, and the upper part of the Sligo Formation). The Pearsall Formation was defined by Imlay (1945) to include the "…dominantly shaley beds lying above the Sligo formation [sic] and below the Glen Rose limestone, and representing the subsurface equivalents of the Travis Peak formation [sic] of the outcrop." This definition of the Pearsall was amended by Forgotson (1957) to include "…a sequence of dominantly shaley beds stratigraphically above the Sligo formation [sic] and below the base of either the Glen Rose limestone or the Rodessa formation [sic]." Forgotson further noted that the Rodessa Formation was not recognizable beyond the limits of the Ferry

Lake Anhydrite. Three members were considered to constitute the Pearsall in Louisiana, Arkansas, and east Texas: the lower Pine Island Shale Member, the middle James Limestone Member, and the Bexar Shale Member. These three members were not recognized in Mississippi, and the interval was referred to as "Pearsall Formation equivalents."

Nunnally and Fowler (1954), in the earliest regional study of the Lower Cretaceous formations of Mississippi, did not recognize the Pearsall Formation in Mississippi, and referred to the interval between the top of the Hosston Formation and the base of the Ferry Lake Anhydrite as the "Rodessa Formation and lower Trinity undifferentiated." Devery (1982), also a regional study of the Cretaceous formations of Mississippi, recognized the Sligo, Pine Island, Rodessa, Ferry Lake, and Mooringsport Formations in the Trinity interval of Mississippi. The Pine Island Formation was recognized only in southern Mississippi, and was characterized, in the updip areas, as gray, fine- to medium-grained sandstones interbedded with shales. In downdip areas, the Pine Island was characterized as red and gray shales and gray limestone nodules, and, in southern Mississippi, the formation was described as black shales, dense gray limestone, dolomite, and gray argillaceous limestone. Dinkins (1971) described the Pine Island in Rankin County as a 340 to 380 foot interval of dark red, maroon, and purple occasionally finely micaceous shales, light gray, pale gray, and light green to pale green mudstones, and very fine- to medium-grained sandstones. The mudstones characteristically contain small siderite concretions. Dinkins (1971) recognized the stratigraphic utility of the Pine Island as being a key stratigraphic marker in wells located beyond the updip limit of the Ferry Lake Anhydrite. Indeed, beyond the updip limits of the Pine Island, the Hosston/Sligo interval becomes indistinguishable from the Rodessa Formation. Dinkins (1971) observed that the sandstones in the lower half of the formation are generally fine- to medium-grained, whereas the upper half includes very-fine- to fine-grained sandstones and more shales and mudstones than the upper half. Dinkins (1969) also described the Pine Island Formation in Copiah County, located downdip from Rankin County. The Pine Island in Copiah County ranged from 230 to 245 feet thick, and was composed of shales, sandstones, siltstones, and argillaceous limestones. The shales were dark-gray and black, flaky and splintery, commonly calcareous and fossiliferous. It is notable that the Pine Island actually thins downdip. The sandstones were white, very-fine- to fine-grained, generally calcareous, and silty. The siltstones were generally calcareous, while the

limestones were light gray to gray, fossiliferous and generally argillaceous and silty. The upper and lower contacts of the Pine Island were conformable.

In coastal Mississippi, the Pine Island ranges in thickness from 140 to 230 feet thick, and consists of white, tan, light gray, gray, and dark gray, hard, cryptocrystalline, microfossiliferous and oolitic in part, limestone (Warner, 1993). In this region the Pine Island is overlain conformably by the James Limestone, which was described by Warner (1993) as a white to tan to light gray, hard, cryptocrystalline limestone. The fact that the Pine Island Formation is thicker in the updip areas and is generally finer grained suggests the possibility that the James Limestone is the downdip time equivalent facies of the upper portion of the Pine Island. Study of the microfossils of the Pine Island in both the updip regions (i.e., Rankin County) and the coastal area could potentially determine the validity of this hypothesis.

Age

The Pine Island Formation has long been known to be of Late Aptian age, due to occurrences of ammonites (Forgotson, 1957; Hazzard, 1939; Imlay, 1940). These ammonites include the genera *Dufrenoya*, *Hypacanthoplites*, *Parahoplites?*, and *Pseudosaynella* (Hazzard, 1939). Young (1972; 1982) reported an Aptian cosmopolitan ammonite fauna from the Hammett Shale including the genera *Cheloniceras*, *Procheloniceras*, *Eodouvilleiceras*, *Burckardtites*, and several species of *Dufrenoya*. However, the cosmopolitan taxa disappear in the overlying Cow Creek Limestone, and include only the endemic species *Dufrenoya justinae* of late, but not latest, Aptian age.

Pine Island Stratigraphy from Regional Cross Sections

The Pine Island Formation occurs only in the downdip regions of the MISB. Strike section A-A' occurs near the updip limit of the formation, and the formation was not recognized in all the wells. The formation was observed generally in the downdip half of the dip sections. Where present, the Pine Island is recognized as a distinctive shaley interval in the predominantly sandy package of the Hosston/Sligo and Rodessa Formations. The formation does not display a typical basinward thickening, and attains its maximum thickness in the middle portions of the dip sections.

The Pine Island was not recognized in the westernmost wells of strike section A-A' (Issaquena County). The formation was observed in each of the strike section wells from Sharkey County to central Smith County. The Pine Island in Sharkey County (well 23-125-20004) is 210 feet thick, and is recognized

as a shaley interval in a predominantly sandy package. A sample log from a nearby well indicates that the formation consists of dark gray, slightly sandy, fossiliferous shale, in part dark red, purple, and black; mottled and ochre mudstone; very-fine-grained, slightly argillaceous and calcareous sandstone; and very finely crystalline, fossiliferous limestone. The formation is 224 feet thick in well 23-049-20011 (northern Hinds County), but thins to 154 feet thick in well 23-049-20005 (common well for sections A-A' and B-B'). A Trowbridge sample log indicates that the top of the Pine Island is in the interval 8420-8440 feet, but this interval is clearly above the distinctive shaley zone. The sample log also indicates that the black shale is highly slickensided in samples from approximately depth 8580 feet in well 23-049-20005, suggesting the possibility that the thinness of the unit may be due to faulting. The Pine Island in this well consists of red, dark red and maroon shale, finely micaceous in part; light gray, pale gray, purple, and ochre mudstone; and very-fine- and fine-grained, slightly porous to non-porous sandstone with some siderite.

The Pine Island is present only in the four downdip wells in dip section B-B'. In well 23-049-20032, located in extreme southern Hinds County, the Pine Island is approximately 200 feet thick and has fairly distinct upper and lower contacts. A sample log for this well indicates that the Pine Island consists of gray, light gray, firm, silty, partly calcareous shale; white, fine grained, well cemented, partly calcareous sandstone; and dark gray and white, partly oolitic and partly micritic and fossiliferous limestone, mainly restricted to the lower part of the formation. The formation thickens to 249 feet in south-central Hinds County (well 23-049-20004). The Pine Island is very distinctive in this well. Sample logs indicate the formation to consist of red, dark red, and maroon, finely micaceous shale; dark gray and gray, and partly black and flaky shale; light gray, light green, and lavender mudstone; and green, fine- to medium-grained, slightly porous and non-porous sandstone. As stated above, the Pine Island is anomalously thin in the common well for sections A-A' and B-B', due possibly to faulting in the Pine Island interval. The formation in well 23-089-20043, located in western Madison County, is 270 feet thick and has a very distinct lower contact and fairly distinct upper contact. In this well, the Pine Island is recognized as a shale interval within a thick sandy package. Well 23-163-20150 is the most updip well in which the Pine Island Formation is recognized. The formation in this well is a fairly distinct. It consists of a 170-foot thick section of reddish-brown, gray, mottled, flaky, splintery, and moderately firm shale interval.

Eastward, the Pine Island thickens to 266 feet in Rankin County. The upper contact is very distinctive, being recognized as a shale bed overlain by a sandy bed. The lower contact, however, is apparently transitional over a 90-foot interval, being recognized by decreasing sand content between the Sligo and Pine Island. Sample logs indicate that the Pine Island consists of dark red, maroon and purple, finely micaceous shale; pale-gray and purple mudstone; red and light red, very-fine to fine-grained, slightly porous to non-porous sandstone; with some siderite concretions. This lithology is essentially the same lithology as observed in Hinds County.

The Pine Island was not recognized in the northern Smith County well (well 23-129-00178). In this well, the lower portion of the Rodessa Formation is relatively shaley, but there is no distinctive shale unit as observed in other wells. Without this distinctive Pine Island bed, the Hosston/Sligo and Rodessa contact is difficult to recognize and perhaps this interval should be referred to as Hosston-Rodessa undifferentiated. In the common well for sections A-A' and C-C' (well 23-129-20006), the Pine Island is only moderately distinctive, being recognized as a generally shaley interval in a thick sand package. The formation is 114 feet thick in this well and consists of reddish-brown, silty shale, and white to pink, very-fine- to fine-grained, unconsolidated to moderately cemented sandstone. The common well is the most updip well for which the Pine Island can be recognized.

The Pine Island was recognized only in the three downdip wells in dip section C-C'. The formation in the most downdip well (well23-065-20141, located in the Gwinville field, Jefferson Davis County), consists of a fairly distinct, 215-foot interval of gray, red, and brown, lightly calcareous, sandy, slightly micaceous shale, and white to clear and light gray, very-fine- to fine-grained sandstone. The formation thickens slightly to 255 feet in well 23-127-20055, located in the Magee field, eastern Simpson County. The lower contact in this well is distinct and is recognized by a shale unit overlying a sandy interval, but the upper contact is gradational and is recognized by an increase in sand content. The Pine Island in well 23-129-20122, located in south-central Smith County, consists of 212-foot section of red, brown, gray, and multi-colored, silty, sandy, micaceous shale, dense, crystalline limestone, and white to gray, pink, fine-grained, well cemented, slightly calcareous sandstone. The electric log signature is distinctive for the Pine Island in this well.

The Pine Island is recognized as a distinct unit in the Jasper County wells. The formation is 168 feet thick in well 23-061-20203. A sample description from this well indicates that the Pine Island consists of a dark red and maroon, finely micaceous shale, light gray, pale greenish-gray, and lavender mudstone, and very-fine-grained, non-porous sandstone. The Pine Island in well 23-061-20028 includes a distinctive 146-foot-thick interval of essentially the same lithology as in well 23-061-20203. The formation thickens to 220 feet in well 23-061-20244, located in extreme south-central Jasper County, and is comprised of essentially the same lithology as in the previously described wells.

The lower contact of the Pine Island in well 23-067-20002, located in northeastern Jones County, is very distinct and is recognized as a shale unit overlying a sandy package. The upper contact in this well is indistinct, thereby resulting in uncertainty as to whether the placement for this contact is correct. For this study, the contact is placed at a depth of 10,485 feet, which is at the base of the first sandstone unit overlying the shale of the Pine Island. This placement results in a thickness of 123 feet for the unit. A Trowbridge sample log, in contrast, indicates that the contact occurs at a depth of 10,095 feet. The placement of the contact at this depth results in a thickness of 513 feet, which is an anomalously thick interval for the formation in this region. The discrepancy in the placement of this contact is due to the predominance of shale in the overlying Rodessa Formation. This unit can be characterized by an electric log pattern like the shale of the Pine Island. A Trowbridge sample description indicates that the Pine Island is comprised of maroon and purple shale; pale gray, partly black and dark-gray mudstone; very-fine- to fine-grained, non-porous sandstone; and red, light red and pink sandstone.

The Pine Island is either indistinct or faulted out of the wells in the strike section in Wayne County and in western Alabama because it was not recognized in wells from these areas. In well 23-153-01008, located in central Wayne County, the Pine Island is indistinct and most of the lower portion of the Lower Cretaceous section is not present due to faulting, including the base of the Pine Island. A sample log indicates that the upper portion of the formation consists of maroon, purple, and lavender shale; light gray, pale gray and ochre mudstone; and very-fine- to fine-grained, slightly porous and non-porous sandstone. The overlying Rodessa Formation displays only a slight increase in sandstone content, leading to low confidence in recognition of the top of the Pine Island. The Pine Island is not present in well 23-153-20545, due to faulting, nor is it recognized in the adjacent two wells (well 23-153-20054, located in southeastern

Wayne County, and well 01-129-20054, located in Washington County, Alabama) in the strike section A-A'. The formation is recognized in well 01-129-20024 in the strike section as a 143-foot shaley interval in a thick sand package (Hosston through Rodessa). The Pine Island is 159 feet thick in well 01-129-20012, the common well for sections A-A' and E-E'. In this well, the Pine Island consists of reddish-brown, very finely muscovitic, noncalcareous clay; clear, white to pink, very-fine- to fine-grained, argillaceous, moderately calcareous sand; and pale reddish brown, dense, very finely crystalline, nonfossiliferous limestone.

The Pine Island Formation changes lithologic character substantially along dip section D-D', as do most of the Lower Cretaceous formations. Indeed, the formation is not recognized in the Hancock County well. The interval is represented by carbonates and is assigned to the Rodessa Formation. In the Perry sub-basin, the Pine Island is overlain by the James Limestone, and consists of a 150-foot section of predominantly shale. The formation is a moderately distinct 186 foot-thick section in well 23-153-20077, located in southern Wayne County, but the upper portion of the Sligo Formation and lower portion of the Rodessa Formation are also shaley. The lithologic character of the Sligo and Rodessa in this part of the MISB casts uncertainty on the elevations of the contacts. No lithologic or sample log was available for this well. The Pine Island is recognized in the common well for sections A-A' and D-D' and this section was described previously. The formation is 138 feet thick in well 23-153-20232, located updip of the common well, and consists of a fairly distinct interval of red to dark brown, brittle, sandy shale; green, gray and clear, coarse grained sandstone; and gray to ran, dense limestone. The formation apparently thickens to approximately 200 feet thick in well 23-153-20265, located in north-central Wayne County. However, the lower contact of the formation in this well is indistinct. The upper portion of the Sligo Formation is quite shaley in this well and, therefore, it is lithologically similar to the Pine Island. A sample log was available for a well adjacent to well 23-153-20265, which indicates that the Pine Island interval (the top of the Pine Island was not identified in the sample log) consists of dark red and maroon, finely micaceous shale, gray, green, ochre mudstone, and some fine- and medium-grained, slightly porous sandstone in this area. Although no sample or lithologic log was available for well 23-153-20042, located near the northern boundary of Wayne County, the Pine Island was recognized as an indistinct shaley interval in a thick sandy package. Due to the lack of sample or lithologic logs for this well and the indistinct electric log

characteristics of the Pine Island, the contacts of the formation are questionable. Well 23-153-20042 is the most updip well for which the Pine Island was recognized.

Summary

The Pine Island Formation of late, but not latest, Aptian age is the shale interval occurring between the predominantly sandstone dominated sections of the Hosston/Sligo interval and the Rodessa Formation in the MISB. The formation is recognized only in the downdip portion of the basin. Wells in strike section A-A' generally are located downdip of the updip limit of the formation. The contacts of the formation are generally distinctive and are marked by the contrast between the shaley lithology of the Pine Island and the sandy lithologies of the Hosston/Sligo and Rodessa intervals. The formation, therefore, serves as a key stratigraphic horizon used to differentiate between the Hosston/Sligo and the Rodessa units. Differentiation of these latter units is difficult in the absence of the Pine Island marker.

The formation, in the MISB, is generally comprised of dark red, red, maroon, or dark gray, finely micaceous shale, and light gray, light green, lavender and ochre mudstone, with lesser amounts of very-fine- to fine-grained, partly calcareous sandstone. Microfossils have been observed from the unit. In updip regions, sand content increases and the formation becomes indistinguishable from the Hosston/Sligo and Rodessa intervals. In the Perry sub-basin, the formation is difficult to differentiate from the underlying Sligo Formation because the Pine Island is represented by carbonate facies in this area. Where the Pine Island is recognizable in the downdip portions of the MISB, it is overlain by the James Limestone. The Pine Island is indistinguishable from the other Lower Cretaceous carbonates in Hancock County and coastal Mississippi because the entire Pine Island interval is comprised of limestone.

Rodessa Formation

The earliest published reference to the Rodessa Formation was by Weeks (1938), who referred to it as the Rodessa Member of the Lower Glen Rose Formation, which was the lower portion of the Glen Rose Sub-Group. The Glen Rose, according to Weeks, included the stratigraphic interval of what is now considered to be from the top of the Hosston Formation ("Travis Peak" of Weeks) to the base of the Ferry Lake Anhydrite ("Massive anhydrite" of Weeks). The lower Glen Rose included what is now the Sligo Formation ("Pettit limestone" of Weeks), Pine Island Formation, and James Limestone. The Rodessa was the upper member of the lower Glen Rose, and was an interval comprised of sandstone, limestone,

marlstone, and shale beds. The stratigraphic framework of Blanpied and Hazzard (1939) and Hazzard (1939) was similar to that of Weeks' (1938), but included the James Limestone as part of the Rodessa Member rather than part of the Pine Island Member. Imlay (1940) raised the Rodessa to formation status, but still retained the James Limestone as its lower member. The Rodessa Formation in the type area, which is near the junction of Arkansas, Louisiana, and Texas, included several tongues and lentils of shale, marlstone, limestone, and anhydrite in a 415-490-foot interval. Forgotson (1957) noted that the James Limestone is not actually present in the Rodessa field, but that geologists had historically considered the Dees and Young zones, present in the lower part of the Rodessa interval, to be time equivalent to the James Limestone. According to correlations by Forgotson (1957), the chronostratigraphic equivalent of the James in the Rodessa field is marlstone and black shale which occur stratigraphically below the porous limestone of the Young zone. Forgotson (1957) therefore redefined the Rodessa "…as those rocks between the base of the Ferry Lake anhydrite [sic] and the base of the Young zone (or its stratigraphic equivalent) as recognized in the Rodessa field." The type well was designated as the Union Producing Company's Caddo Levee Board No. B-1, sec. 26, T. 23 N., R. 16 W., Caddo parish, Louisiana.

As with the Sligo and Pine Island Formations, Nunnally and Fowler (1954) included the Rodessa in the "undifferentiated Sligo, lower Trinity, and Rodessa" interval. The top of the Rodessa could, of course, be recognized in southern Mississippi, which is the base of the Ferry Lake Anhydrite. Nunnally and Fowler (1954) noted that in this area, the Sligo, lower Trinity and Rodessa consists of limestones, shales, and sandstone with several anhydrite stringers approximately 60 feet below the top of the Rodessa. In the updip regions, sandstone content increases, making differentiation of this interval from the Hosston below and the upper Comanche beds above difficult. The Rodessa Formation, James Limestone, and Pine Island Formation also were undifferentiated by Eargle in his (1964) study of the stratigraphy of Mississippi and surrounding regions.

Dinkins (1969), however, did recognize the Rodessa Formation as a distinct unit in Copiah County. The base of the Rodessa was "…placed at the first occurrence, in cuttings, of dark-gray and black flakey and splintery shales and/or gray or light gray fossiliferous limestones with scattered faint ochre colored oxidation or selective fossil replacement below the basal fine and medium grained sandstones of the overlying Rodessa formation [sic]." The top of the Rodessa was placed below the lowest massive

anhydrite of the Ferry Lake. The Rodessa in Copiah County ranged from 600 to 720 feet thick, and consisted of shales, mudstones, limestones, sandstones and siltstones with a thin stringer of anhydrite in the upper part of the formation. The formation was observed to become progressively more marine in the downdip areas. The shales were dark red, dull red, maroon, gray, dark gray and black, and were occasionally fossiliferous. The limestones were pale gray to dark gray, fossiliferous, and partly argillaceous. The limestones were generally restricted to the upper portion of the formation in the updip areas but became more numerous throughout the formation in the downdip area. The sandstones of the Rodessa were red and white, generally very-fine- to fine-grained, micaceous, and variably calcareous, with a few intervals of coarser, sometimes conglomeritic sandstone in the basal part of the formation. The red sandstones were restricted to the lower two-thirds of the formation. The siltstones were finely micaceous and usually calcareous.

Dinkins (1971) also studied the Rodessa Formation in Rankin County, located northeast and updip of Copiah County. The top of the formation was placed at the base of the Ferry Lake anhydrites, where present. Beyond the updip limit of the anhydrite, the top of the Rodessa was placed at the top of the sandstones below the shales and mudstones of the Mooringsport Formation (see discussion below). Dinkins (1971) observed that thin stringers of pale gray to dark gray, fossiliferous and peloidal limestones occurred at the equivalent stratigraphic horizon as the anhydrites north of their updip limit. The formation ranges from 260 to 450 feet thick in Rankin County (thickening to the south) and consists of dark red and maroon to purple, silty, finely micaceous shales, light gray and light green mudstones, red and white, very-fine- to coarse-grained, occasionally calcareous sandstone, and some vari-colored quartz pebbles. In contrast to Copiah County, the Rodessa in Rankin County includes only subordinate amounts of pale gray and red nodular limestones. Also, the grain size of the quartz in the sandstones is coarser, and quartz pebbles are present.

Devery (1982) used the base of the massive anhydrites of the Ferry Lake to mark the top of the Rodessa in the downdip areas, but used the base of the shales of the Mooringsport to mark the top of the formation updip of the updip limit of the Ferry Lake anhydrites. Unfortunately, the base of the shale of the Mooringsport Formation is not the chronostratigraphic nor lithostratigraphic equivalent of the base of the Ferry Lake. The Ferry Lake actually occurs near the middle of a fairly thick shale interval, which includes

the upper portion of the Rodessa Formation and all of the Mooringsport Formation. Therefore, correlations using the base of the shales of the Mooringsport to define the top of the Rodessa (updip areas) are stratigraphically lower than using the base of the Ferry Lake. Devery (1982) described the Rodessa in central Mississippi, a relatively updip region, as red and gray shales, white, fine-grained sandstone, and light gray limestones. The formation gradually changes to dark gray, oolitic limestone and gray shales, with anhydrite stringers.

Warner (1993) studied the Rodessa Formation along the coastal region of Mississippi. In this area, the Rodessa overlies the James Limestone. The top of the Rodessa was difficult to recognize due the general absence of the Ferry Lake Anhydrite and the lithologic similarity to the overlying Mooringsport Formation. The thickness of the Rodessa varied widely, being 2050 feet thick in Hancock County, 148 feet thick in western Mississippi Sound and 197 feet thick in the region offshore of the Mississippi –Alabama state line. The Rodessa was described by Warner (1993) as a gray, arenaceous to argillaceous, partly oolitic limestone containing fossil debris and interbedded with thin, hard, fine-grained sandstone, brown granular dolomite, gray to brownish-red, micaceous shale, and white to buff anhydrite stringers.

Petty and others (1995), on a series of cross sections and accompanying text, showed the Rodessa to be of fairly uniform thickness, averaging 715 to 790 feet thick in George and Jackson Counties and in the near offshore area of Mississippi. He also showed a thickening of the unit to 1066 feet towards the west, south of Hancock County. The Pine Island Formation and James Limestone were not recognized as discrete units in his cross sections.

Eaves (1976) studied the informal “Donovan” unit in the Citronelle field of northern Mobile County, Alabama. Eaves (1976) interpreted the “Donovan” section to be equivalent to the lower Glen Rose (Rodessa, Pine Island, and Sligo) section of Louisiana and Mississippi. The contacts between the Glen Rose (i.e., Sligo) and Hosston and the Hosston and Cotton were the “subjects of disagreement” among geologists, according to Eaves (1976) resulting probably from the lithologic similarity of these units in the relatively updip areas. Eaves (1976) observed a conformable stratigraphic relationship and lithologic similarity between the rocks occurring in the top Hosston and the base Ferry Lake. He concluded that paleoenvironmental conditions remained relatively constant throughout deposition of upper Hosston through the lower Ferry Lake intervals. The oil reservoir rock referred to as the “Donovan” (Rodessa and

Ferry Lake facies) in the Citronelle field was described as poorly sorted siliciclastic sediments, including "tight," micaceous and silty sandstones, and gray to brown broken shale. The siltstones and fine- to medium-grained sandstones were further described as ranging from low-porosity, nonpermeable, slaty siltstone to clean, porous, permeable sandstone. The high mica content in these sediments was attributed to a southern Appalachian Paleozoic and Precambrian source terrain. The siltstones and claystones displayed vertical bedding disturbances caused by plant roots. The presence of oyster shells suggested deposition in a shallow, brackish-water embayment. Eaves (1976) suggested the depositional environment consisted of narrow, irregularly shaped meander belts that cut through a brackish-water embayment area. The irregularity of the meander belts resulted in a complex series of channel sandstones that occur throughout the "Donovan" interval. Eaves (1976) also concluded that the Citronelle field structure formed as a result of salt withdrawal and subsidence primarily on the east and north of the structure.

Raymond (1995) studied the Rodessa-Ferry Lake-Mooringsport interval in southwestern Alabama. The upper portion of the Rodessa was dominantly mudstone or claystone in the northern (generally updip) regions of the study area (southern Washington County, Baldwin County). The Rodessa became mixed carbonate/anhydrite/mudstone in middle parts of Mobile and Baldwin Counties, and was dominantly limestone in the southern parts of these counties in the coastal region of Alabama. Ostracodes and foraminifera were noted in several described wells, suggesting the possibility of future paleontological correlations of this stratigraphic interval.

Age

Blanpied and Hazzard (1939) were among the first authors to correlate the Rodessa Formation (as Rodessa member of the Lower Glen Rose Formation) with European stages. They assigned the unit to the lower part of the lower Albian, based on the suprapositional relationship of the Rodessa with the known age of the Pine Island. Forgotson (1957) reported that the ammonite genus *Dufrenoya* was found in a cored interval of the lower part of the Rodessa. This ammonite is characteristic of the late Aptian. Forgotson (1957) also reported the presence of early Albian ammonites in the upper part of the formation. Forgotson (1957) concluded, therefore, that the Aptian-Albian contact is in the lower part of the Rodessa Formation. Young (Young, 1972; 1982) placed the Aptian-Albian boundary in the basal part of the Glen Rose Limestone, based on the highest occurrence of the ammonite species *Kazanskyella spathi* (Stoyanow,

1949). The Glen Rose is typically subdivided, in Mississippi and Alabama, into the lower Rodessa, middle Ferry Lake, and upper Mooringsport Formations. Therefore, the Rodessa is equivalent to the lower portion of the Glen Rose, which correlates to an early Albian age.

The foraminiferal species *Orbitolina texana* (Roemer, 1849) has long been used as an index species for the Glen Rose Limestone and age-equivalent rocks of the Gulf Coast. Douglass (1960) thoroughly examined specimens of *Orbitolina* from the Glen Rose and chronostratigraphic equivalent rocks in Texas, New Mexico, and Arizona. Eight species of the genus were recognized, seven of the species were not previously described. The species *O. texana* was observed only in the lower part of the Glen Rose, below the "*Corbula* bed" in central Texas. The most common species was *T. minuta* Douglas, 1960, which was restricted to the upper part of the Glen Rose. Thus, these two species provide a reliable means of biostratigraphic correlation of the unit. Differentiation of the various species of *Orbitolina*, however, requires thin sectioning the test of the foraminifera, which is a fairly labor-intensive process. It is likely that identifications listed as *O. texana* are, in fact, one of the other species described by Douglass (1960).

Petty et al. (1995) published microfossil occurrences in a few wells in coastal Mississippi. A sample from near the base of the Rodessa in the Tenneco Viosca Knoll 117 well contained the dinoflagellate *Pseudoceratium pelliferum* Gocht, 1957, which Lentin and Williams (1989) list as a Valanginian-Hauterivian species. Paradoxically, one subspecies, *P. pelliferum solocispinum*, has been listed as middle-late Barremian age. The calcareous nannofossil species *Nannoconus steinmanni* of Tithonian to latest Barremian age and *N. bucheri* Brönnimann, 1955 of Hauterivian to late Aptian age were observed approximately one-third up from the base of the formation. The benthic foraminifer *Orbitolina texana* was found near the top of the Rodessa. A calcareous nannofossil species and a benthic foraminiferal species were observed in the lower portion of the Rodessa in the Chevron Mississippi Sound Block 57 well. These species included the calcareous nannofossil *Nannoconus wassellii* Brönnimann, 1955, of earliest Barremian to Late Aptian age (Perch-Nielsen, 1985) and the benthic foraminiferal species *Choffatella decipiens*, which is considered to be a good marker for the early Aptian (Minerals Management Service Gulf of Mexico Biostratigraphic Chart, 1997 edition). It is probable that the lower part of the Rodessa Formation in this offshore region is chronostratigraphically equivalent to the Pine Island Formation in more updip areas, as the correlation chart of Petty et al. (1995) does not recognize the Pine Island in this offshore region.

Rodessa Stratigraphy from Regional Cross Sections

For this study, in the main part of the MISB, the top of the Rodessa was placed at the top of the sandstones that occur below the Ferry Lake Anhydrite or at the base of the Mooringsport Formation north of the updip limit of the Ferry Lake. As this is not the top of the Rodessa *sensu stricto*, it is referred to as the Rodessa marker. As stated previously, the problem with using the base of the Ferry Lake to mark the top of the Rodessa is its limited distribution. Previous workers have correlated beds occurring at the base of the Ferry Lake in downdip wells to beds found at the base of the shales of the Mooringsport Formation in updip wells. Those two surfaces are neither chronostratigraphic nor lithostratigraphically equivalent. Although the top of the sands of the Rodessa are certainly not synchronous (probably becoming older downdip), the top of the sandstones are lithostratigraphically equivalent. However, in several wells in southern Alabama, no clear sandstone-shale contact was observed below the base of the Ferry Lake anhydrites; thus, the interval between the top of the Pine Island and the base of the Ferry Lake was referred to as the Rodessa Formation.

The Rodessa was not recognized in the two westernmost wells in strike section A-A', wells 23-055-00032 and 23-055-00066. The Lower Cretaceous units in these two wells are difficult to differentiate. A distinct, 551-foot thick sandstone package is recognized as the Rodessa in well 23-125-20004, located in southern Sharkey County. A sample log from a nearby well indicates the Rodessa consists of very-fine- to fine-grained, non-porous to slightly porous, micaceous sandstone, and greenish-gray mudstone with finely disseminated pyrite. The Rodessa in well 23-049-20011, located in northern Hinds County, is approximately 457 feet thick. Although no sample or lithologic log was available for this well, the electric log signature suggests that the Rodessa is a sandy package lying between the shales of the Pine Island and the shales below the Ferry Lake.

The Rodessa is recognized in all but the two most updip wells in dip section B-B', but the full thickness of the formation can only be determined in the five downdip wells due to the absence of the Pine Island Formation in the four updip wells. In the most downdip well, well 23-049-20032 located in extreme southern Hinds County, the Rodessa is recognized as a 487-foot thick interval comprised of shale, with lesser amounts of limestone and sandstone. The shale is red and brown, calcareous, micaceous, and occasionally pyritic; the sandstone is light gray, gray, green, very-fine- to medium-grained, glauconitic, and

calcareous; and the limestone is tan, white, chalky, hard, partly anhydritic. Limestone extends only as far updip as the next well, well 23-049-20004, located in southern Hinds County. The Rodessa in this latter well is a distinctive, but still quite shaley, interval of 601 feet in thickness. The formation in this well is also comprised of interbeds of sandstone, shale, and limestone. The sandstone is white, light red, and pink, very-fine- to fine-grained, generally well cemented, slightly calcareous, lignitic, and micaceous; the shale is red, gray, and black, firm, silty, occasionally with limonite nodules and embedded white anhydrite in gray shale; and the limestone is dark gray, black, brown, and red, very dense, very hard, partly sandy, and with anhydrite stringers. Again, no carbonate rocks are present in the Rodessa updip from this well.

The Rodessa is recognized in well 23-049-20005, the common well for strike section A-A' and dip section B-B' located in northern Hinds County, as a distinctive 699-foot thick sandstone package occurring between the shales of the Pine Island and the shales below the Ferry Lake. A sample log from this well indicates that the Rodessa is comprised of fine- to medium-grained, slightly porous and non-porous sandstone; red, very-fine- to fine-grained sandstone; dark red and maroon, finely micaceous shale and gray and dark gray shale; and occasional mottled, light gray and light red mudstone. The Rodessa is recognized as a distinctive sandstone package bounded by shale units also in well 23-089-20043, located in western Madison County. The Rodessa in this latter well is 530 feet thick. Well 23-163-20150 is the most updip well in section B-B' for which the full thickness of the Rodessa is recognized, as it is the most updip well in which the Pine Island Formation is recognized. In this central Yazoo County well, the Rodessa is comprised of a distinctive, 595-foot sandstone package occurring between the two shale units mentioned previously. The formation becomes progressively sandier up-section. A lithologic log indicates that the sandstone consists of white and clear, fine-grained, moderately to well cemented, partly calcareous sandstone; reddish brown, brown, and gray, silty, sandy, firm shale; and traces of limestone.

The base of the Rodessa cannot be recognized in well 23-163-00049, located in northern Yazoo County, as this well is beyond the updip limit of the Pine Island Formation. Sample logs, however, indicate that the Rodessa is comprised of fine- to medium-grained, slightly porous, partly calcareous sandstone; dark red and maroon shale; and pale gray, red and lavender, mottled mudstone. In well 23-051-20036, located in southern Holmes County, the interval between the top of the Cotton Valley Group and the top of the Rodessa Formation is undifferentiated. Wireline log signatures indicate that this interval is comprised

chiefly of sandstones. The Rodessa was not recognized in the two most updip wells in dip section B-B', wells 23-051-20020 and 23-083-20011, located in northern Holmes and southern LeFlore Counties, respectively.

Well 23-121-20025, located in north-central Rankin County, is useful in correlating wells in dip sections B-B' to those in C-C'. The Rodessa is recognized as a distinctive, 465-foot thick unit similar to that described previously, i.e., as a sandy package occurring between the shales of the Pine Island Formation and the shales below the Ferry Lake Anhydrite. A sample log indicates that the Rodessa is comprised of green and light red, fine- to medium-grained, slightly porous and non-porous sandstone; lesser amounts of dark red, maroon, gray, and dark gray, finely-micaceous shale; and a few small, clear quartz pebbles.

The full thickness of the Rodessa is recognized only in the three most downdip wells in dip section C-C', as the Pine Island is not recognized in the further updip wells. The Rodessa also changes lithology considerably between the downdip and updip areas. In the most downdip well in C-C', well 23-065-20141, located in northern Jefferson Davis County, the Rodessa is relatively fine grained, thus the lower and upper contacts are only moderately distinct. In this well, the Rodessa is 505 feet thick, and is comprised mainly of red, brown, and gray, silty, sandy to very sandy shale. Also occurring in lesser amounts are light gray, clear and white, very-fine- to fine-grained, well cemented sandstone, and gray, tan, crystalline, oolitic, dense limestone. The Rodessa is sandier in the next well, well 23-127-20055, located in extreme eastern Simpson County and is therefore more distinctive. The formation is 400 feet thick in this latter well and, although the formation is sandier than either the Pine Island or the shales below the Ferry Lake, it is still predominantly shale. Sand content increases in the next well, well 23-129-20122, located in south-central Smith County, and the formation is recognized as a distinctive sandy package occurring between the bounding shale units. The Rodessa in this well is 362 feet thick, and is comprised mainly of interbedded sandstone and shale. The sandstone is clear, white, gray, and pink, fine- to medium-grained, slightly calcareous, and unconsolidated to moderately cemented; the shale is red, brown, gray, and yellow, sandy, silty, slightly calcareous, and with a trace of lignite; and there are traces of dense, oolitic limestone.

The Rodessa in the common well for strike section A-A' and dip section C-C', well 23-129-20006 located in central Smith County, is the most updip well in this dip section in which the full thickness of the

Rodessa is known, as it marks the most updip occurrence of the Pine Island. The Rodessa is 341 feet thick. The top of the formation is recognized by the lowest occurrence of shale in the overlying Mooringsport (no Ferry Lake is present in this well), and the lower contact is recognized as the lowest occurrence of sandstone above the shales of the Pine Island. The wireline log indicates that the Rodessa is comprised mainly of interbedded sandstone and shale. A lithologic log describes the sandstone as white, reddish-pink, medium grained, moderately cemented, friable, and slightly lignitic; and the shale as reddish-brown and gray, sandy, and silty. Sand content increases up-section.

The Pine Island is not recognized in any of the three wells in northern Smith County, wells 23-129-20057 and 23-129-00015, occurring on dip section C-C', and well 23-129-00178, occurring on strike section A-A', thus the full thickness of the Rodessa is not known for these wells. The Rodessa in well 23-129-20057 is apparently comprised of an equal amount of shale, limestone, and sandstone, based on the lithologic log. The shale is red, brown, gray, and purple, mottled, flaky, and sandy. The limestone is gray, hard, crystalline, and some soft, white and sandy limestone. The sandstone is fine- to medium-grained, white, cemented, calcareous, and occasionally white, clear and unconsolidated. The Rodessa interval in well 23-129-00015 appears, based on wireline log signatures, to be very sandy. In well 23-129-00178, the interval between the top of the Sligo and the top of the Rodessa is 730 feet thick. The top of the formation was recognized at the base of the shale of the Mooringsport Formation. A sample log from this well indicates that the Rodessa interval is comprised of interbedded sandstones and shales. The sandstones are very-fine- to fine-grained, gray, loose to firm, shaley, and slightly calcareous and glauconitic; the shales are red and gray and sandy. Red and gray, silty shale predominates in the lower part of this interval, which may represent the updip equivalent of the Pine Island Formation. Again, the full thickness of the Rodessa is not known for the two most updip wells in C-C' because the Pine Island is not recognized. In well 23-101-20005, located in southern Newton County, the Rodessa interval is comprised of green, clear, yellow and pink, fine- to coarse-grained sandstone, maroon, dark red and red shale, small clear, yellow and red quartz pebbles, and trace of buff chert.

The Rodessa generally occurs as a distinctive unit in the region along strike section A-A' between dip sections C-C' and D-D'. The thickness of the Rodessa in well 23-129-00061, located in extreme eastern Smith County, is not known, as the Pine Island was not recognized in this well. However, a Trowbridge

sample log places the top of the Pine Island in the interval of 10,800-10,820 feet, which would result in a thickness of the Rodessa of approximately 410 feet. The Rodessa interval in this well is comprised of fine-grained, slightly porous and non-porous sandstone, and dark red and maroon shale. The next three wells in strike section A-A' occur in southwestern Jasper County. Well 23-061-20203 includes 287 feet of Rodessa, which was recognized as a sandy unit between two major shale units (Pine Island and Mooringsport). A sample log from a nearby well indicates that the Rodessa is comprised of red, dark red and maroon, finely micaceous shale, and fine-grained, porous and slightly porous, slightly micaceous sandstone. The Rodessa in the next well, well 23-061-20028, is also recognized as a distinct sandstone package between two major shale units. The formation is 375 feet thick and is comprised of white, clear, light red, pink and light gray, fine-grained, slightly porous, moderately cemented to mostly unconsolidated sandstone; and red, brown and gray, silty shale, with a trace of lignite and pyrite. The other well in Jasper County, well 23-061-20244, includes 425 feet of Rodessa and the formation was recognized by the same criteria as described for the previous wells. A lithologic log indicates that the Rodessa is comprised of white to red and pink, very-fine- to fine-grained, loosely cemented to unconsolidated, partly calcareous sandstone; red and dark brown, silty, firm, partly micaceous shale; and light gray and brown to white, crystalline, dense limestone.

In the well in Jones County, well 23-067-20002, located in the northeastern part of the county, the Rodessa is a fairly distinct sandstone package of 502 feet thick comprised of white and gray, very-fine- to medium-grained, slightly porous, cemented, friable, asphaltic sandstone; red, brown, gray, maroon and purple, waxy, silty shale; and a trace of highly slickensided maroon shale located near a depth of 10,400'. Although slickensides normally indicate faulting, the thickness of the Rodessa does not suggest that appreciable section is missing in this well.

The area of dip section D-D' extends from the Gulf Coast of Mississippi to northern Clarke County, Mississippi. The Rodessa interval in well 23-045-20075, located in the Catahoula field of Hancock County consists totally of carbonates, consisting of dark gray, gray, and light gray, dense, crypto- to microcrystalline, partly chalky and fossiliferous, peloidal limestone. The formation in this well was recognized as the interval between the top of the Sligo and the base of the Ferry Lake Anhydrite. The Pine Island was not found in this well. Indeed, recognition of most of the Lower Cretaceous units in this coastal region is based on criteria different than those used for the onshore regions. The Rodessa in the Perry sub-

basin (well 23-111-00069) includes the interval between the James Limestone (the only occurrence of the James that was recognized in this study) and the base of the Ferry Lake. Although no lithologic or sample logs were available for this well, the wireline log signature indicates that the interval is comprised almost entirely of shale. Therefore, the criterion of using the top of the sandstones of the Rodessa as a stratigraphic marker is not feasible for this well. In southern Wayne County (well 23-153-20077), the Rodessa is a fairly distinct unit. The formation is 402 feet thick and was recognized as a sandy package between the shales of the Pine Island and shales below the Ferry Lake. Sand content increases up section in the formation in this well. The full thickness of the formation in well 23-153-01008, the common well for sections A-A' and D-D', located in central Wayne County, is not known, as a fault occurs somewhere below the base of the Mooringsport to the top of the Smackover. The top of the Rodessa was placed at the base of the shale underlying the Ferry Lake. A sample log indicates that the Rodessa interval is comprised of green, very-fine- to fine-grained, slightly porous and non-porous, partly abundantly micaceous sandstone; dark red and maroon shale; gray and light gray mudstone; with a trace of lignite.

The Rodessa occurs as a distinctive unit in three wells updip from the common well in sections A-A' and D-D'. The formation is 355 feet thick in well 23-153-20232, located in central Wayne County. The section in this well is mainly interbedded sandstone and shale. The sandstone is predominantly gray and clear, medium-grained, partly coarse-grained and silty; the shale is brick-red to dark brown, brittle to soft, sandy, silty, calcareous, and with traces of lignite and pyrite. The Rodessa in well 23-153-20265, located in northern Wayne County, is recognized, as in most other wells, as a sandstone package occurring between the shales of the Pine Island and the overlying Mooringsport interval. In this well, the Rodessa is 480 feet thick and is comprised of red and light red sandstone, dark red and maroon shale, and occasional small, clear, quartz pebbles in the lower part of the section. A sample from a the interval of 9630-9650 indicates highly slickensided strata, suggesting the possibility of a fault. However, the thicknesses of the units in the Rodessa interval do not suggest any substantial missing section. Well 23-153-20042 is the most updip well in which the Pine Island Formation occurs, and therefore the most updip well for which the full thickness of the Rodessa can be measured. The Rodessa occurs as a fairly distinct, 300-foot thick sandstone package lying between the major shale units.

The Pine Island Formation is not recognized in the two wells in Clarke County, Mississippi, thus the full thickness of the Rodessa is not known. In well 23-023-00270, located in northern Clarke County, the Rodessa interval is characterized as fine- to medium-grained, slightly porous and non-porous sandstone, red, bright red, and dark red shale, and with occasional clear, yellow, and red quartz pebbles.

The Rodessa in Alabama is also observed as a sandstone package occurring between shale units, except for the far updip areas. The thickness of the formation in Mobile County is fairly constant, being 647 feet, 578 feet, and 610 feet thick in wells 01-097-20299, 01-097-20141, and 01-097-20134, respectively progressing from south to north. The wireline log from the Rodessa interval in well 01-129-20051, located in southern Washington County, does not display any characteristics suggesting substantial sandstone units, thus the top of the formation was defined by the base of the Ferry Lake Anhydrite. The formation in this well is 479 feet thick. Well 01-129-20012, the common well for sections A-A' and E-E', located in central Washington County, is the only well in section E-E' for which detailed lithologic information is known. The Rodessa in this well is comprised of coarse- to very coarse-grained quartz sandstone, and very-fine- to fine-grained, argillaceous, quartz sandstone. The formation in this well is 570 feet thick. The Pine Island is not recognized updip from the common well, thus the thickness of the Rodessa is not known in this area. The Rodessa interval in well 01-023-20197, located in southern Choctaw County, based on wireline log characteristics, is comprised of interbedded sandstone and shale. The Rodessa was not recognized in the most updip well in dip section E-E', located in central Choctaw County. The entire Lower Cretaceous interval is undifferentiated for this area.

Summary

The Rodessa Formation in most of the MISB is recognized as a distinct sandstone package occurring between the shales of the underlying Pine Island Formation and those occurring below the Ferry Lake Anhydrite. However, both the Pine Island and Ferry Lake pinch out in the updip areas. The base of the Rodessa is not recognized updip from the limit of the Pine Island, as the predominantly sandy section of the Rodessa lies directly on the predominantly sandy section of the Hosston/Sligo, rendering differentiation difficult for these units. Recognition of the upper contact of the Rodessa also presents problems, as the Ferry Lake pinches out updip in the MISB. Traditionally, geologists have used the base of the Ferry Lake to mark the top of the Rodessa in downdip wells and the base of the shales of the Mooringsport Formation

for the updip wells. These two horizons are neither chronostratigraphically nor lithostratigraphically equivalent. For this study, a “Rodessa marker” was used to correlate the Rodessa interval. This marker is the top of the sandstones below the shales underlying the Ferry Lake. To a certain extent, the Ferry Lake can be thought of as anhydrites occurring in the middle of a major shale package, the Mooringsport Formation. Using the base of these shales as a Rodessa “marker” has the advantage of being a lithostratigraphically equivalent surface. However, in areas where there is little sand in the Rodessa interval, such as the Perry sub-basin and in some parts of southwestern Alabama, the top of the sandstone unit is not present; thus the base of the Ferry Lake must be used. However, the sandstones are present in almost all the wells analyzed for this study, and the highest occurrence of these sandstones served as a convenient correlation horizon. Along the coast, recognition of the Rodessa becomes difficult on the basis of wireline logs, as the entire section consists of carbonate. Criteria other than lithology must be used for recognition of several of the Lower Cretaceous formational contacts.

The Rodessa Formation does not display a simple basinward thickening as is observed for most formations in the MISB. In general, however, the formation in the more updip wells is thinner than in the downdip wells. In certain areas, for example in the Perry sub-basin, part of the section in the lower Rodessa interval occurs as the James Limestone. Typically, in the downdip areas where the full thickness of the formation is known, the thickness varies within one hundred feet.

The sandstones of the Rodessa are typically gray, clear or white, very-fine- to fine-grained, unconsolidated to moderately cemented, slightly porous to non-porous. Some small, clear quartz pebbles were observed. The shales are generally dark red, brown or maroon. Lignite and pyrite were observed in certain intervals. Limestone was observed in several of the most downdip wells. The limestone is tan, white, red, brown, and dark gray or black, dense, hard, partly sandy and, in the most downdip areas, included anhydrite stringers. The formation was observed to coarsen up-section in several of the wells. This observation, plus the stratigraphic relationship with the James Limestone, suggests an overall progradation for the interval from the Pine Island through the sandstones of the Rodessa. This progradational interval also suggests that the sediments of the Rodessa Formation represent deposits of a highstand systems tract. The available paleontological data suggests that the Rodessa ranges from late Aptian to early Albian in age.

Ferry Lake Anhydrite

The Ferry Lake Anhydrite is one of the most useful stratigraphic units in the Gulf Coast. The unit has long been used as a datum from which to hang cross sections and to draw structure contour maps. Bingham (1937) was one of the first publications to mention the formation, noting the position of an oil-producing sandstone "…is approximately 240 feet below the anhydrite section." Weeks (1938) described the unit as the Glen Rose anhydrite , or "Massive anhydrite" member, which consisted of approximately 250 feet of white finely crystalline anhydrite with streaks and partings of gray shale and dense limestone and dolomite. Weeks (1938) also recognized the relationship between the subsurface Ferry Lake and the outcropping DeQueen Limestone, although he stated that the Ferry Lake equivalent was below the DeQueen and not precisely equivalent to the DeQueen as subsequent workers, such as Lock et al. (1983) have concluded. The Shreveport Geological Society (Blanpied and Hazzard, 1939) also referred to the unit as the Glen Rose Anhydrite, placing it between the Lower Glen Rose (Pine Island and Rodessa intervals) and the Upper Glen Rose (Mooringsport equivalent unit). The Lower Glen Rose, Glen Rose Anhydrite, and Upper Glen Rose comprised the Glen Rose Sub-Group of the Trinity Group. Hazzard (1939) noted the unit had a thickness ranging from 250 to 500 feet in the Arkansas-Louisiana-Texas area.

Imlay (1940) formally defined the Ferry Lake Anhydrite, replacing the older term Glen Rose massive anhydrite. Imlay (1940) stated that the type section and boundaries of the formation would be described in a forthcoming paper by the Shreveport Geological Society, although that description was apparently never published. Imlay (1940) defined the Ferry Lake as "…about 250 feet of white to gray, finely crystalline anhydrite which contains minor amounts of interbedded gray to black shale, dense limestone, and dolomite." The unit was also described as lying conformably between the Rodessa and the Mooringsport Formations. Thickness variations in the Arkansas-Louisiana-Texas area ranged from about 10 feet to more than 500 feet.

Forgotson (1957) did not consider the term "Mooringsport Formation" to be a valid unit for regional correlation, and thus redefined the Ferry Lake as "…a formation which occupies the stratigraphic interval between the base of the Rusk formation [sic] and the top of the Rodessa formation [sic] as they are recognized in the Caddo Lake (Ferry Lake) area of western Caddo Parish, Louisiana." The Rusk Formation was defined as "..those rocks and their stratigraphic equivalents below the top of the Glen Rose limestone

[sic] as recognized in the subsurface of northeastern Texas and above the top of the Ferry Lake anhydrite [sic].” The top of the Glen Rose occurs at the base of the Paluxy Formation. The term “Rusk Formation” has not been a widely used term; most geologists use the term “Mooringsport Formation” for this interval (see a more complete discussion of the Rusk Formation below under “Mooringsport Formation”). The type well for the Ferry Lake was the Gulf Refining Company’s Caddo Levee Board “O” Gas Unit well No. 1, Jeems Bayou field, sec. 10, T. 20 N., R. 16 W., Caddo Parish, Louisiana. Forgotson (1957) noted that the Ferry Lake grades into shale and limestone northward from the type well into southern Arkansas, and is represented in outcrop by an interval of gypsum within the DeQueen Limestone.

Nunnally and Fowler (1954) described the Ferry Lake Anhydrite in Mississippi as gray shale interbedded with light gray to brownish-gray limestone and anhydrite. Some limestone beds contain fossils and have inclusions of white anhydrite, and other limestone beds are oolitic. The upper and lower contacts were known to be conformable. Nunnally and Fowler (1954) produced an excellent structure contour map of the base of the Ferry Lake, one of the most useful datum levels for regional correlation in the Gulf Coastal Plain. The map showed several important features. The first feature was the northern (updip) limit of the Ferry Lake, which occurs along a line from Issaquena County, through northern Hinds, central Rankin and Smith, southern Jasper, and central Wayne Counties. This line is very close to the strike section A-A’, as some of the wells penetrate the Ferry Lake, but others do not. The second feature is the Jackson Dome, which is clearly outlined by the structure contour map. The third feature is the Perry sub-basin, which is shown as a northwest-southeast trending, elongate structure occurring in the southern half of Perry County and the east-central part of Forest County. The Perry sub-basin is the deepest part of the MISB. The Ferry Lake is shown on the figure of Nunnally and Fowler (1954) to be greater than 14,000 feet deep in the sub-basin. Another feature apparent on the structure contour map of the Ferry Lake is the Wiggins Arch, which is seen as a west-southwest-plunging anticlinal structure in northern George County. Lastly apparent on the contour map is the change in strike of the strata in the northwest region of the MISB, due to the influence of the Sharkey Platform, where strike changes from west-northwest to southwest. The maximum thickness of the Ferry Lake in Mississippi was reported by Nunnally and Fowler (1954) to be 240 feet in Stone County.

Pittman (1985) identified and correlated several anhydrite beds in the Ferry Lake in the Arkansas-Texas-Louisiana-Mississippi region. Eleven anhydrite beds were identified from the Ferry Lake, while four were identified from the Mooringsport and three from the Rodessa. Pittman (1985) described the Ferry Lake as consisting of anhydrite beds alternating with claystones and oolitic/bioclastic lenticular buildups of limestone. The Ferry Lake was described as ranging from 200 to 250 feet thick across much of the area, which suggests that the 500-foot thickness described in the early literature, such as Hazzard (1939), included the anhydrite beds of the Rodessa and Mooringsport as part of the Ferry Lake. Most of the anhydrite beds were correlable across the entire region. Pittman (1985) noted that the Ferry Lake extends from east Texas, across southern Arkansas and northern Louisiana, Mississippi, southern Alabama, and into Florida, where it was correlated with beds of the Punta Gorda Formation. The formation was deposited shoreward of an extensive reef fringing the shelf edge.

Petty (1995b) expanded the nomenclature and correlations of the Ferry Lake into southern Mississippi and Alabama, state waters of Mississippi, Alabama, and Florida, and adjacent federal waters. The eleven anhydrite beds of the Ferry Lake and three from the Rodessa that were defined by Pittman (1985) were correlated to the offshore area by Petty (1995a), which resolved the problem where operators were referring all anhydrite beds to the Ferry Lake. Petty (1995a) recognized as many as twelve anhydrite beds in the Rodessa Formation, numbers RO12, RO11, and RO10 (RO representing Rodessa) correspond to Pittman's (1985) R3, R2, and R1. A gap exists between the anhydrite beds of the Ferry Lake and those of the Rodessa. Petty (1995b) noted that areas which exhibit poor development of anhydrite beds may be regions where patch reefs are likely to occur. These patch reefs are known to produce hydrocarbons.

Raymond (1995) studied the Ferry Lake Anhydrite in detail in several wells in southwestern Alabama, resulting in a series of cross sections. Descriptions of well cuttings indicated that the Ferry Lake consists of massive anhydrite, light-olive-gray to medium-dark-gray oolitic packstone/wackestone, fossiliferous to intraclastic sandy grainstone, and red mudstone, with ostracodes, foraminifera, and shell fragments being common. An isopach map of the Ferry Lake showed that the formation thins over the Citronelle structure, indicating salt movement at depth during deposition. The formation was noted to thicken generally to the south and southwest (downdip) by the addition of anhydrite beds. There are, however, two distinct regions of thick Ferry Lake, separated by an elongate region of relatively thin Ferry

Lake. One thick region is a northwest-trending elongate area extending from northern and central Baldwin County to northern and northwestern Mobile County, where the formation exceeds 240 feet in thickness. The other thick Ferry Lake region is sub-parallel to the coast, in extreme southern Mobile and Baldwin Counties, where the unit thickens to more than 300 feet thick in the offshore area.

Age

Scott (1939) was one of the earliest workers to correlate North American Lower Cretaceous strata to Europe. Scott (1939) assigned the Glen Rose (with anhydrite in the basal part) to the Albian Stage, based on the occurrence of the ammonites *Knemiceras roemeri* (Cragin, 1893) and, in slightly younger units, *K. nodosum* Gayle, 1939, and *K. azlense* Scott, 1939. Imlay (1940) assigned the Ferry Lake (Glen Rose anhydrite [sic] in his terminology) to the middle of the Lower Albian stage, based on stratigraphic relations with units of known age. Pittman (1989), studying the regional stratigraphy of the Glen Rose Formation, concluded that the Ferry Lake equivalent strata in the Glen Rose, located below the regional marker *Corbula* bed, occurs in the *Orbitolina texana* Zone (below the lowest occurrence of *O. minuta*), indicating an early, but not earliest, Albian age (Douglass, 1960). Thus, an Early Albian age is concluded for the Ferry Lake Anhydrite

Ferry Lake Anhydrite Stratigraphy from Regional Cross Sections

As the Ferry Lake Anhydrite is a fairly ubiquitous lithologic unit, descriptions will not be given for individual wells. Several wells just updip from the northern limit of the Ferry Lake display wireline log signatures in the Mooringsport that indicate the presence of sand or limestone that is probably the updip equivalent of the Ferry Lake. Thickness trends and regional extent, principally in the dip sections, will be presented.

The wells in Issaquena County (wells 23-055-00032 and 23-055-00066) do not contain the Ferry Lake. As noted previously, the basin margin (strike) turns abruptly from a northwest to a southwest orientation between Issaquena County and Sharkey County, probably as a result of the Sharkey Platform. The Ferry Lake is present in well 23-125-20004, located in Sharkey County, as recognized on the wireline log and confirmed by nearby sample logs. The formation is approximately 161 feet thick in this well. The wireline log signature for well 23-049-20011, located in extreme northern Hinds County, indicates the

presence of the Ferry Lake in this well, but that interpretation is not verified by lithologic or sample logs. The formation in this well is 145 feet thick.

The anhydrites of the Ferry Lake are present only in the three downdip wells in dip section B-B', which includes the common well for cross sections A-A' and B-B'. The Ferry Lake is 203 feet thick in well 23-049-20032, located in extreme southern Hinds County. A lithologic log confirms the presence of anhydrite in this well. The Ferry Lake is 277 feet thick in well 23-049-20004, located in southern Hinds County. The presence of anhydrite is also confirmed in this well by a lithologic log. The northernmost well that contains anhydrite of the Ferry Lake in section B-B' is the common well for cross sections A-A' and B-B', well 23-049-20005, located in northeastern Hinds County. The formation is 138 feet thick in this well. The presence of anhydrite in this well is confirmed by a sample log. Unfortunately, no lithologic, sample, sonic, or density log was available for well 23-089-20043, located in western Madison County. The wireline log signature in the interval between approximately a depth of 10,650 and 10,540 feet suggests the possibility of anhydrite or stratigraphic equivalents. Neither the Ferry Lake nor electric log signatures suggesting equivalent units was observed in any of the more updip wells in cross section B-B', nor in well 23-121-20025, located in north-central Rankin County.

As in dip section B-B', only the three downdip wells in dip section C-C' contain anhydrite of the Ferry Lake. The formation is 300 feet thick in well 23-065-20141, located in northern Jefferson Davis County. A lithologic log confirms the presence of anhydrite in this well. The Ferry Lake in well 23-127-20055, located in the Magee field of eastern Simpson County, is approximately 122 feet thick. Although no lithologic, sample, sonic, or density logs were available for this well, the very high amplitude peaks on the resistivity curves strongly suggests the presence of interbedded anhydrite and shale. Well 23-129-20122, located in south-central Smith County, is similar to the previously discussed well, in that no supplementary logs were available, but high amplitude resistivity kicks suggests the presence of anhydrite. The Ferry Lake in this well is approximately 86 feet thick. The Ferry Lake is not present in the wells updip of 23-129-20122 in dip section C-C'.

Anhydrite of the Ferry Lake was not recognized in any of the strike section wells (A-A') between dip section C-C' and D-D'.

The Ferry Lake was recognized in the four downdip wells in dip section D-D', including the common well for cross sections A-A' and D-D'. Only remnants of the anhydrite were observed in the common well for the two cross sections, as described on a sample log. The Ferry Lake in well 23-045-20075, located in the Catahoula field of Hancock County, near the Mississippi Gulf Coast, is approximately 172 feet thick. A lithologic log confirms the presence of anhydrite in this well. The Ferry Lake in well 23-111-00069, located in extreme southern Perry County, is 225 feet thick. Although no supplementary logs were available for this well (the Phillips Petroleum Josephine A-#1 well), the very high resistivity signal from the interval between depths of 12,550 and 12,325 feet strongly indicate the presence of anhydrite. A similar case exists for well 23-153-20077, located in southern Wayne County. The Ferry Lake in this well is approximately 90 feet thick. As anhydrite occurs in well 23-153-01008 (the common well for cross sections A-A' and D-D') and in the deeper parts of the basin, it is likely that it occurs in wells 23-153-20077. The Ferry Lake is 140 feet thick in well 23-153-01008. The Ferry Lake was not observed in wells updip of the common well for A-A' and D-D'.

Anhydrite of the Ferry Lake occurs in the four downdip wells in dip section E-E'. No supplementary logs were available for these four wells. The characteristic high-amplitude resistivity values, however, indicate the presence of anhydrite in the wells. In addition, the work of Raymond (1995) confirms the presence of anhydrite in the area of these four wells (northern Mobile County and southern Washington County). The Ferry Lake is 156 feet thick in well 01-097-20299, 119 feet thick in well 01-097-20141, 90 feet thick in well 01-097-20134, and 52 feet thick in well 01-129-20051. Detailed lithologic descriptions of well 01-129-20012, the common well for cross sections A-A' and E-E', verify that anhydrite is not present in that well.

Summary

The Ferry Lake Anhydrite is one of the most distinctive lithologic units in the Gulf Coastal Plain, and has been used as a marker bed for local and regional correlations for many years. The formation has been traced from near Waco, Texas, into the Punta Gorda Anhydrite of Florida. Individual beds within the Ferry Lake are widely distributed. The formation consists essentially of interbedded anhydrite, shale and limestone. The formation crops out in Arkansas, and is known as the DeQueen Formation. The formation is also stratigraphically equivalent to the upper part of the Lower Glen Rose Formation of central Texas,

where it lies just below the *Corbula* bed. Ammonites collected from adjacent stratigraphic units and the presence of *Orbitolina texana* s. s. indicate an early, but not earliest Albian age for the Formation.

In this study, the northern (updip) limit of the Ferry Lake generally occurs just downdip of strike section A-A'. The updip limit of the formation as observed in this study is essentially identical to that observed by Nunnally and Fowler (1954). Some wells just updip of the limit of the Ferry Lake display resistivity peaks within the Mooringsport Formation that appear similar to those in wells in which anhydrite occurs, but lithologic or sample logs indicate that anhydrite is not present. The Ferry Lake ranges from approximately 80 feet to 300 feet in thickness in the MISB.

Mooringsport Formation

The Mooringsport Formation is defined as the interval between the top of the Ferry Lake Anhydrite and the base of the Paluxy Formation. Early petroleum geologists (Blanpied and Hazzard, 1939; Hazzard, 1939; Weeks, 1938) from Louisiana and Arkansas considered this interval to be the Upper Glen Rose Formation. The formation in south Arkansas consists of approximately 475 to 730 feet of gray to dull brown shale and marls with streaks of fine sandstone and anhydrite (Hazzard, 1939; Weeks, 1938). However, Weeks (1938) interpreted these dark shales to grade to red shales of the Paluxy Formation northward and, in outcrop, into the 30-50-foot DeQueen Formation. Thus, Weeks (1938) considered the Mooringsport and Paluxy Formations to be time equivalent. Imlay (1940), who formally defined the Mooringsport Formation, also considered the Paluxy, Mooringsport, and DeQueen to be time equivalent formations. Imlay (1940) defined the Mooringsport Formation as:

> "…the dominantly marine shale and limestone lying above the Ferry Lake anhydrite [sic] and below the red shales and sands of the Paluxy formation [sic], and corresponding to the Upper Glen Rose formation [sic]. Its lower boundary is fairly abrupt; its upper boundary is transitional."

Thickness of the formation ranges from about 60 to 75 feet in outcrop (DeQueen Formation) to approximately 800 feet in the subsurface of northwestern Louisiana. Imlay (1940) further described the Mooringsport to consist, in northwestern Louisiana, of interbedded gray to black, calcareous shales and gray to white, thin-bedded limestones which grade up-section into red, sandy shales and fine-grained sandstones. Anhydrite beds were noted. Imlay (1940) also considered the Mooringsport to grade into the Paluxy Formation, both vertically and horizontally. The upper boundary of the Mooringsport Formation was thus chosen arbitrarily, and was "…generally chosen where the first fossils appear." It must be

assumed that the "first" occurrence of fossils corresponds to the first encounter when drilling and not the first in chronostratigraphic order, as the Mooringsport is generally marine and the Paluxy is non-marine.

Nunnally and Fowler (1954) defined the Mooringsport Formation in southern Mississippi as the interval between the base of the sandstones of the Paluxy Formation (Glen Rose age) and the top of the massive anhydrite beds of the Ferry Lake. Both upper and lower contacts were gradational. Nunnally and Fowler (1954) further stated that the limestones of the Mooringsport become thinner and fewer in number, grading into sandstones and shales indistinguishable from the Paluxy Formation. In the downdip area of Stone County (George Vasen #1 Fee well), the formation consists of fine-grained, silty, and micaceous sandstone, dark red, red, light red, gray, and dark gray shales, and light gray, gray, and brown limestones. The formation in Pearl River County, also in a downdip position, consists of mottled red and gray, silty and sandy shale, red and gray shale with plant remains, limestones, and carbonaceous material. The limestone beds are white, gray, tan, and brown, finely sucrosic, very-finely- and finely-crystalline, glauconitic, fossiliferous, and occasionally anhydritic. In Lamar County, the formation consists of gray and light gray mudstones with inclusions of red and gray, nodular limestones. Limestone content is less in Lamar County than in Pearl River County.

Forgotson (1957) considered the Mooringsport Formation to be only recognizable in northwest Louisiana and southwest Arkansas, and therefore defined the Mooringsport as a member of the Rusk Formation. The Rusk Formation was equivalent to the Mooringsport Formation and part of the Paluxy Formation of Imlay (1940). The Rusk time-stratigraphic unit was defined by Forgotson (1957) as "…those rocks, regardless of lithologic type, below the isochronous surface contemporaneous with the top of the Glen Rose as defined in the Austin area and above the isochronous surface contemporaneous with the top of the Ferry Lake anhydrite [sic] in its type area." The top of the Rusk Formation defined the top of the Trinity Stage time-stratigraphic unit. The top of the Rusk Formation was defined by characteristic electrical log patterns created by limestones in the upper part of the formation. This marker looses its identity as the limestones grade into sandstone toward the "northwest margin of deposition," and the upper sandstones of the Rusk Formation become indistinguishable from the overlying Paluxy sandstones. Where the top of the Rusk Formation is sandy, the top of the Trinity Stage time-stratigraphic unit is defined by an isochronous surface. Similarly, lithologically similar limestones occur in the upper part of the Trinity and lower part of

the Fredericksburg Group in south Texas, in which area the contact between the two units cannot be recognized solely on the basis of lithology. Forgotson (1957) defined the Mooringsport Member "...as that stratigraphic interval and its recognizable equivalent above the Ferry Lake anhydrite [sic] and below the top of the first limestone bed within the Trinity group [sic] in the Mooringsport field area of Caddo Parish, Louisiana." The limestone bed that marks the top of the Mooringsport Formation loses its identity to the west, north, and east of the type well, grading into sandstones and shales. Therefore, Forgotson (1957), considering the Mooringsport to be recognizable only by the presence of the upper limestone units, concluded that the aerial distribution of the formation was limited to a relatively small area, and not appropriate for regional correlations.

Dinkins (1969) studied the subsurface formations of Copiah County, Mississippi. He recognized the base of the Mooringsport as the top of the massive anhydrites of the Ferry Lake Anhydrite. The top of the Mooringsport was placed at "…a marked increase of dark-red and maroon shales and associated pale-gray to light-green mudstones below the lowest sandstones of the Paluxy formation[sic]." The contact between the Mooringsport and the Paluxy was transitional, and thickness variations of up to 400 feet existed within Copiah County. The upper half of the formation consisted of generally dark-red and maroon, silty, and micaceous shales. The lower half of the formation consisted predominantly of interbedded shales, mudstones, sandstones, and limestones. Pale-gray, light-gray and gray, variable fossiliferous, partly oolitic limestones become increasingly abundant towards the base of the formation.

Dinkins (1971) studied the Mooringsport in Rankin County and concluded that the contacts of the formation as recognized in Rankin County were essentially identical to those in Copiah County. In Rankin County, the formation consisted of approximately 300 to 450 feet of shales, mudstones, sandstones, and siltstones with a few basal stringers of fossiliferous and "pseudo-oolitic and spherulitic" (thrombolitic?) limestones.

Devery (1982) defined the Mooringsport similarly to Dinkins (1969; 1971), recognizing the top of the formation at the base of the sandstones of the overlying Paluxy Formation. She described the formation in central Mississippi as consisting of red and gray shales, fine-grained sandstones, vari-colored mudstones, and red and white limestone nodules. In southern Mississippi, the lithology changes to gray, oolitic limestones and gray shales.

Baria (1981) studied the petroleum geology of the Mooringsport Formation in Waveland field, Hancock County, Mississippi. Core and geophysical log information indicated the Mooringsport is comprised of a nearly continuous and massive buildup of coarse rudistid, dictyoconid, and other bioclastic debris, which was interpreted to represent a wide carbonate sand apron proximal to a back reef environment. To the northeast, in Stone County, the Mooringsport consisted of sandstones and red calcareous shales, which were interpreted to represent paralic siliciclastic facies. Between these two wells, the Mooringsport Formation was comprised of a generally uniform interval of miliolid and pellet packstones, mollusk and echinoid mudstones, orbitolinid packstones and grainstones, and occasional rudistid boundstone patch reefs. This sequence was interpreted to represent back-reef and lagoonal shelf deposits. Other wells in the region indicated that the Mooringsport in coastal Mississippi consists of reef, back-reef, and paralic lagoonal facies aligned in east-southeast parallel bands in an offshore-onshore progression, respectively.

Raymond (1995) studied the Rodessa Formation, Ferry Lake Anhydrite, and Mooringsport Formation in southwest Alabama. She observed the Mooringsport to range from approximately 140 feet in the updip regions to more than 300 feet in the downdip areas of coastal Alabama. The updip limit of the formation extends from west-central Washington County east-southeast to southern Escambia County. Thickness of the formation was greatest (more than 240 feet thick) in two areas, one from central Baldwin County to southern Washington County, and the other along the Alabama coast. The greatest thickness of the unit (289 feet thick) was determined to be in Mobile County. The formation is predominantly medium dark gray, olive gray, and grayish red, finely micaceous mudstone and shale in the updip regions (generally in the northern parts of Mobile and Baldwin Counties), and light brownish gray, light gray and white limestone, ranging from oolitic to mudstone in downdip areas (along the Alabama coast). Ostracodes commonly occurred in the calcareous facies of the Mooringsport Formation.

In summary, in contrast to the work of Forgotson (1957), who considered the Mooringsport to be of only local extent, subsequent geologists studying the regional stratigraphy of the Lower Cretaceous units of Mississippi concluded that the Mooringsport Formation is a useful regional stratigraphic term. The formation, according to these subsequent workers, is defined as the stratigraphic interval between the top of the massive anhydrite beds of the Ferry Lake and the sandstones of the Paluxy Formation.

Age

The age of the Mooringsport Formation is determined largely on the basis of its suprapositional position relative to the well-known age of the Ferry Lake Anhydrite and its outcrop equivalent, the DeQueen Formation. Studies of microfossils, although described as common or even abundant in certain regions and intervals, have not been published for rocks in the MISB. Early workers such as Blanpied and Hazzard (1939), indicated a late Early Albian age for the formation. Imlay (1940) reported that the age of the unit must be close to that of the DeQueen, but did not assign the formation to a European stage. Petty (1995) reported the occurrence of the foraminiferal species *Orbitolina texana* from near the top of the Mooringsport in a Chevron well in Mississippi Sound Block 57 and a well in the Viosca Knoll region. It is not certain that this identification is *O. texana* s. l. or *O. texana* s. s., the difference of which was noted in the previous section. Regional correlations by Pittman (1989) indicate that the Ferry Lake is within the *O. texana* range, and the overlying Thorp Spring Formation of Texas is within the range of *O. minuta*. The Thorp Spring Formation was interpreted to be younger than the DeQueen Formation, which would place the upper portion of the DeQueen in the upper part of the range of *O. texana* and/or the lower part of the range of *O. minuta*. These data indicate a late Early or early Middle Albian age. Raymond (1995) reported calcareous nannofossil occurrences from the top of the Mooringsport Formation in southern Baldwin County. The nannoflora was identified by Charles Smith, and included two specimens of *Eprolithus floralis* (Stradner, 1962), indicating a range of Middle Aptian to Early Cenomanian age.

Mooringsport Formation Stratigraphy from Regional Cross Sections

The Mooringsport Formation is one of the most useful stratigraphic units in the MISB because its shaley lithology is generally easy to recognize in wireline logs, and the formation extends almost to the updip margin of the basin. The top of the formation was recognized in 43 of the 48 wells used in the regional cross sections. As mentioned previously, the lower contact of the formation is contingent upon the presence of the Ferry Lake Anhydrite. The base of the Mooringsport is placed at the top of the upper massive bed of the Ferry Lake Anhydrite where present, and at the top of the sandstones of the underlying Rodessa Formation in the areas updip of the limit of the Ferry Lake. It is because of the variable definition of the base of the Mooringsport that the formation thickness increases beyond the updip limit of the Ferry Lake, as the shales below the Ferry Lake are included within the Mooringsport. The upper contact of the

Mooringsport is typically recognized by a well-defined wireline log shift from the shales of the Mooringsport to the sandstones of the overlying Paluxy Formation. The upper part of the formation, although usually distinct, is transitional from the shales of the Mooringsport to the sandstones of the Paluxy. It is apparent that this upper lithologic contact is diachronous, and that the top of the formation is older in updip areas than in downdip areas, as the Paluxy Formation probable late highstand systems tract deposits prograded generally from north to south. In several of the wells, individual sandstone units in the lower part of the Paluxy could be traced only partially downdip, then apparently graded into the shales of the Mooringsport. Limestone commonly occurs in the basal part of the formation. All of these observations indicate that the Mooringsport Formation was deposited during a period of progradation.

The western area of the cross section (Issaquena County) is one of the areas in which the Mooringsport is absent. The formation is present in all wells in dip section B-B' except for the two updip wells. The formation in well 23-049-20032, located in extreme southern Hinds County, is 499 feet thick. The base of the formation is defined by the top of the Ferry Lake Anhydrite, and the top is placed at the base of a 35-foot thick sandstone unit in the overlying Paluxy Formation. One sandstone unit occurs in the upper part of the formation. A lithologic log, available for the lower 75 feet of the formation, indicates the formation consists of shale; white and clear, fine-grained, glauconitic sandstone; and light gray and dark gray, cryptocrystalline, fossiliferous limestone. The Mooringsport in well 23-049-20004, located in southern Hinds County, is approximately the thickness as the previous well, being 498 feet thick. The Mooringsport is recognized as a distinctive shale package between the top of the Ferry Lake Anhydrite and the sandstones of the Paluxy Formation. A sample description indicates that the formation consists of dark red, gray, dark gray and maroon, finely micaceous shale; very-fine-grained to fine-grained, very lightly porous and non-porous sandstone, with occasional red and light red sandstone; and, in the basal part, gray, tan, and dark red, dense, hard, partly fossiliferous, partly "pseudo-oolitic" limestone.

The Mooringsport Formation in well 23-049-20005, the common well for sections A-A' and B-B' located in northeast Hinds County, is 348 feet thick, which is considerably thinner than in southern Hinds County. The formation is recognized as a dominantly shaley section between the top of the Ferry Lake Anhydrite and the base of the sandstones of the Paluxy Formation. The local "Mashburn" sandstone occurs in the lower part of the Mooringsport and the "Gaddis" sandstone occurs in the upper part. A sample log for

the lower 300 feet of the formation indicates that the formation is comprised of dark red and maroon, finely micaceous shale; light gray mudstone; very-fine-grained, very slightly porous and non-porous, calcareous sandstone and siltstone; and, in the basal part, pale-gray, sandy, “pseudo-oolitic” limestone. The shale was described as slickensided in parts, suggesting the presence of small-scale faults. The formation thins to 325 feet in well 23-089-20043, located in western Madison County. Recognition of the formation is by the criteria described previously for the downdip wells. A sandstone unit near the top of the formation is probably equivalent to the “Gaddis” sandstone in well 23-049-20005. No sample or lithologic log was available for this well.

The Ferry Lake is not recognized in well 23-163-20150, located in southeastern Yazoo County; therefore, the Mooringsport is determined to be 415 feet thick in this well. This section includes the shales equivalent to those below the Ferry Lake in downdip areas. A lithologic log indicates that the Mooringsport consists, in the lower part, of reddish-brown, brown, gray, silty, sandy, firm shale; white, clear, fine-grained, tightly cemented, partly slightly calcareous sandstone; with a trace of grayish-white, dense limestone. The upper part includes red, brown, gray, mottled, sandy, splintery, blocky, firm shale. The formation thins to 304 feet in well 23-163-00049, located in northeastern Yazoo County. The top of the Rodessa and the top of the Mooringsport Formation are indistinct in this well. The interval includes upper and lower shale units separated by a 70-foot thick sandstone unit. A sample log indicates that the formation consists of dark red and maroon shale; gray and light gray mudstone; and fine- to medium-grained, slightly porous, sparingly micaceous sandstone. Some quartz pebbles were observed in the middle sandstone unit.

Well 23-051-20036 is the most updip well in which the Mooringsport is recognized. The formation in this well is 209 feet thick and consists of a distinctive shale unit occurring between the sandstones of the Rodessa and Paluxy Formations.

The Mooringsport in well 23-121-20025, a well occurring between dip sections B-B’ and C-C’, is recognized as a 243-foot thick shaley interval between the sandstones of he Rodessa and the Paluxy. The formation consists of red, maroon, and purple, and finely micaceous shale; pale-gray and ochre mudstone; nodular limestone; and very-fine- to fine-grained, light red, calcareous sandstone.

The Mooringsport Formation is recognized in all wells in dip section C-C’. The formation in well 23-065-20141, located in northern Jefferson Davis County, is recognized as a predominantly shaley, 387-

foot thick interval between the top of the Ferry Lake Anhydrite and the sandstones of the Paluxy Formation. A lithologic log indicates that the formation consists of red, brown, gray, splintery, silty, sandy shale; and white, clear, fine-grained, moderately- to well-cemented sandstone. The formation thins to 190 feet in well 23-127-20055, located in eastern Simpson County. The Mooringsport is recognized in this well as a 190-foot interval between the top of the Ferry Lake Anhydrite and the base of the sandstones of the Paluxy Formation. Three sandstone units are recognized in the Mooringsport. This observation is in agreement with the description of the formation as recognized by the Mississippi Geological Society (Davis and Lambert, 1963). The upper contact of the formation in this well is probably at a lower (?older) point than in well 23-065-20141, but was placed, again, at the base of continuous Paluxy sandstones. In other words, the top of the Mooringsport in well 23-127-20055 is probably chronostratigraphically equivalent to a stratigraphic level within the shales of the Mooringsport in well 23-065-20141.

Well 23-129-20122, located in south-central Smith County, is the most updip well in cross section C-C' to contain the Ferry Lake Anhydrite. The Mooringsport Formation is recognized as a 215-foot thick shale interval occurring between the top of the Ferry Lake and the continuous sandstones of the Paluxy Formation. A prominent, 50-foot thick sandstone unit is present approximately in the upper third of the formation. This sandstone is also found in well 23-129-20006 (the common well for sections A-A' and C-C'). Correlation of the top of the Mooringsport between well 23-129-20122 and well 23-129-20006 is questionable. Because well 23-129-20122 includes one sandstone unit in the upper portion of the Mooringsport while the formation apparently contains two sandstone units in well 23-129-20006. The lower of the two sandstones in well 23-129-20006 is probably the same unit as the upper sandstone in well 23-129-20122, but the upper sandstone unit in well 23-129-20006 is probably represented only as a feather edge in well 23-129-20122. The Mooringsport in well 23-129-20006 is 394 feet thick, which is thicker than the more downdip well, well 23-129-20122. The Ferry Lake is not present to separate the upper shales from the lower shales in well 23-129-20006. A lithologic log indicates that the Mooringsport is comprised of reddish-gray, silty, sandy shale; white, very-fine-grained, moderately to well cemented, lignitic sandstone; and a trace of light-gray limestone in the lower part of the formation.

The Mooringsport in well 23-129-20057, located in northeastern Smith County, is recognized as a 212-foot thick, mainly shaley interval between the sandstones of the Rodessa and the Paluxy Formations.

The contacts of the formation in this well are fairly distinct. Two sandstone units occur in the formation in this well, but it is doubtful that they are the same units as in well 23-129-20006, as they occur at different stratigraphic levels. A lithologic log indicates that the formation is comprised of red, brown, and purple, flaky shale; with traces of gray siltstone, fine-grained, green and white, tight, partly calcareous sandstone. The formation thickens to 251 feet in well 23-129-00015, located in extreme northeastern Smith County. The formation in this well is fairly distinctive and is recognized as a shaley unit occurring between the sandstones of the Rodessa and Paluxy Formation. Sandstone occurs in the middle portion of the Mooringsport. The formation thins considerably (108 feet thick) in well 23-101-20005, located in southern Newton County. Sample and lithologic logs from a nearby well indicate that the formation is comprised of bright red, dark red, and purple shale; and purple, lavender, pale-gray and ochre mudstone. From wireline logs, the formation is recognized as a shaley interval occurring between the sandstones of the Rodessa and Mooringsport Formation.

The Mooringsport Formation in well 23-101-00014, located in west-central Newton County, is recognized as a distinctive, 177-foot thick interval between the sandstones of the Rodessa and Paluxy Formations. No lithologic or sample log was available for this well.

The Mooringsport Formation was recognized in each well along strike section A-A' between dip section C-C' and D-D'. The formation in well 23-129-00061, located in extreme eastern Smith County, is recognized as a 370-foot shaley interval between the sandstones of the Rodessa and Paluxy Formations. A sample log indicates that the formation is comprised of dark red and maroon, finely micaceous shale; very-fine-grained, non-porous sandstone; and a trace of limestone. The Ferry Lake does not occur in well 23-061-20203, located in southwestern Jasper County. The Mooringsport is observed generally as a 370-foot shale interval between the sandstones of the Rodessa and Paluxy Formation in the well. A 50-foot thick sandstone unit occurs in the upper part of the formation. The Mooringsport Formation in well 23-061-20028, also located in southwestern Jasper County, is recognized as a distinct, 370-foot shale interval between the sandstones of the Rodessa and Paluxy Formations. Sample and lithologic logs indicate that the Mooringsport Formation is comprised of dark red, red, brown, and gray, silty, sandy shale; light gray and ochre mudstone; gray, white and pink, very-fine- to fine-grained, slightly porous, loosely cemented to unconsolidated sandstone; and, in the lower part, light gray, "pseudo-oolitic" limestone.

The Mooringsport in well 23-061-20244, located in southern Jasper County, is recognized as a generally shaley, 470-foot thick interval between the sandstones of the Rodessa and Paluxy Formations. A 25-foot thick sandstone unit occurs in the upper portion of the Mooringsport. A lithologic log for a nearby well indicates that the formation is comprised of red, gray, brown and dark gray shale, occasionally micaceous; and traces of lignites and white and light gray, dense limestone. The formation thickens in well 23-067-20002, located in northeastern Jones County, to 435 feet thick, an anomalously thick section for the Mooringsport. The interval herein interpreted as Mooringsport includes several thin (10-20') sandstone units, rendering recognition of the contacts (particularly the lower contact) difficult. Only the upper 130 feet of the interval is predominantly shale. A sample log indicates that the Mooringsport is comprised of maroon and purple shale; green, very-fine- to fine-grained, slightly and non-porous sandstone; ochre mudstone; and all slickensided, suggesting the possibility of extensive faulting in the interval. The presence of faults probably accounts for the difficulty in recognizing the formational contacts.

The Mooringsport Formation is distinctive in well 23-045-20075, located in Hancock County and at the downdip limit of dip section D-D'. The formation is, however, lithologically different than in the other wells in the MISB. It consists completely of carbonate sediments. The formation is recognized as the interval between the top of the Ferry Lake Anhydrite and the base of the siliciclastic sediments of the Paluxy Formation. It is likely that the top of the formation in well 23-045-20075 is considerably younger than in more northerly (updip) wells. One line of evidence to support this interpretation is the thickness of 560 feet for the formation, which is almost twice as thick as in most other wells. Such a thickness suggests more time for deposition or a rapid sediment accumulation rate. Also, as mentioned previously, individual sandstone units at the top of the formation in updip areas pinch out in downdip areas, thus the upper contact becomes younger going from updip to downdip areas. A lithologic log for well 23-045-20075 indicates that the formation is comprised of dark gray and white, dense, fossiliferous in part, crypto- to microcrystalline, "pseudo-oolitic" in part, argillaceous limestone; and gray, dark gray and brown, firm, splintery, brittle, silty shale.

The Mooringsport in well 23-111-00069, located in Perry County, is recognized as the predominantly shaley interval between the top of the Ferry Lake and the sandstones of the Paluxy Formation. Even though the Paluxy includes a fairly thick (100-foot) shale interval in the lower part of the

formation, the contact between the Mooringsport and Paluxy is distinctive. The Mooringsport Formation in well 23-153-20077, located in southern Wayne County, is the stratigraphic interval between the top of the Ferry Lake and the base of the sandstones of the Paluxy Formation. The formation is 385 feet thick and is recognized as a distinctive shaley interval. Well 23-153-01008, the common well for sections A-A' and D-D', is the most updip well to contain the Ferry Lake Anhydrite in this dip section. The Mooringsport is recognized in this well as a distinctive, 242-foot thick, predominantly shaley interval between the top of the Ferry Lake and the base of the sandstones of the Paluxy Formation. A sample log indicates that the formation is comprised of light red, dark red, maroon and purple shale; dark gray and black, flaky, and splintery shale; gray green, and ochre mudstone; and light gray, fossiliferous, "pseudo-oolitic" limestone in the lower part of the formation.

The Mooringsport in well 23-153-20232 is a 600-foot thick, predominantly shaley interval between the sandstones at the top of the Rodessa and the base of the Paluxy. The Mooringsport is anomalously thick in this well, partly because of the inability to recognize the Ferry Lake Anhydrite to subdivide the thick shales in the interval. Even though the formation is thick, it is very distinctive on wireline logs. A lithologic log indicates that the formation is comprised of brick red to dark brown, brittle to soft shale; clear, loose, silty sand; and a trace of gray to tan, dense limestone in the lower part.

The Mooringsport in well 23-153-20265 is thin (90 feet) and lithologically indistinct. It is possible that the three lower sandstone units included herein in the Paluxy Formation are assigned to the Mooringsport. Therefore, a depth of 9590 in well 23-153-20265 (300 feet higher in the well) corresponds to the top of the Mooringsport in other wells. However, the sandstone units in question are fairly well developed (30-50 feet thick), which indicates their inclusion in the Paluxy. These sandstones are not present in the wells on either side of well 23-153-20265. A sample log from a nearby well indicates that the Mooringsport Formation consists of dark red and maroon shale, and light gray, light green and ochre mudstone.

The Mooringsport in well 23-153-20042, located in extreme northern Wayne County, is a distinctive, 358-foot thick shaley interval between the sandstones of the Rodessa and the Paluxy Formation. The formation thins to 138 feet in well 23-023-20114, located in central Clarke County and is lithologically comparable to the formation in well 23-153-20042. The Mooringsport in well 23-023-00270, located in

northern Clarke County, is only 126 feet thick and is also recognized as the interval between the sandstones of the Rodessa and Paluxy Formations. Sample and lithologic logs indicate that the formation is comprised of light and dark red, and gray, sandy, silty shale, and gray, fine-grained, well-cemented sandstone.

The Mooringsport Formation is recognized in the wells along strike section A-A' between dip sections D-D' and E-E' as the predominantly shaley interval between the sandstones of the Rodessa and Paluxy Formations. The Ferry Lake is not present in these wells. The Mooringsport is 522 feet thick in well 23-153-20545, located in southern Wayne County. A sample log indicates the formation is comprised of dark red and maroon shale; green and red, slightly porous and non-porous sandstone; and, in the lower part, white, pale-gray and light gray, "pseudo-oolitic" limestone. The formation thins to 420 feet in well 23-153-20122, located in southeastern Wayne County and is recognized as a distinctive shale interval between the bounding sandstone units. The formation thins again in well 01-129-20054, located in northwestern Washington County, Alabama, but is recognized as a distinctive shale interval between the predominant sandstones. The Mooringsport in well 01-129-20024, located in western Washington County, is 290 feet thick. The upper contact of the formation in this well is distinct, but the lower contact is indistinct. The entire Rodessa Formation includes only poorly-developed sandstone units in the well. The Mooringsport is of the same thickness in well 01-129-20012 as in well 01-129-20024, being 290 feet thick, and has an indistinct lower contact, but distinct upper contact. A lithologic description indicates that the formation is comprised of reddish-brown, finely muscovitic, slightly to moderately calcareous clays and claystones. Trace amounts of limestone were observed in the Mooringsport.

The Mooringsport is recognized in the four downdip wells in dip section E-E' as the interval between the top of the Ferry Lake Anhydrite and the base of the sandstones of the Paluxy Formation. The formation in well 01-097-20299, located in Hatter's Pond field, northeastern Mobile County, is only 115 feet thick, due to a fault located 115 feet above the top of the Ferry Lake. The formation is 231 feet thick in well 01-097-20141 and is recognized as a generally shaley interval between bounding sandstone units. Beds of anhydrite are probably present in the lower part of the Mooringsport, based on very high amplitude resistivity peaks in that interval. No sample or lithologic log was available to confirm this interpretation. The formation in well 01-097-20134, located in northern Mobile County, is 216 feet thick and is recognized as a distinctive shale unit occurring between bounding sandstones. The formation in well 01-

129-20051, located in southern Washington County, is lithologically indistinct. The lower contact of the formation (top of the Ferry Lake) is distinctive, but the upper contact is indistinct. The entire Mooringsport interval in this well is a repetitious section of sandstones and shales, with no predominant shale unit. The formation was interpreted to be approximately 344 feet thick in this well. The Mooringsport was described in well 01-129-20012, the common well for section A-A' and E-E', in the previous paragraph. The Mooringsport in well 01-023-20197, located in southwestern Choctaw County, is a lithologically distinct and consists of a 159-foot shale unit between the sandstones of the Rodessa and Paluxy Formations. The Mooringsport was not recognized in well 01-023-20114, located in southern Choctaw County.

Summary

The definition of the Mooringsport Formation depends on the distribution of the underlying Ferry Lake Anhydrite. Where the Ferry Lake is present, the Mooringsport is the predominantly shaley interval between the top of the massive anhydrites and the base of the sandstones of the Paluxy Formation. In the absence of the Ferry Lake, the Mooringsport is the predominantly shaley interval between the sandstones of the underlying Rodessa Formation and overlying Paluxy Formation. Only where the lower contact is defined by the top of the anhydrites of the Ferry Lake do the contacts approach synchroneity. Detailed lithologic correlations show that individual sandstone units at the top of the Mooringsport in updip areas grade into shale in downdip areas, indicating that the contact rises in the section, and thus is younger in downdip areas than in updip areas. The abrupt thickness increase observed in all dip sections north of the updip limit of the Ferry Lake is due to the inclusion of shales in the Mooringsport that occur below the Ferry Lake in the downdip areas. All these observations indicate that the contacts of the Mooringsport are diachronous.

The formation generally consists of red, dark red, or maroon shale with interbeds of very-fine- to fine-grained sandstones. Limestone is present generally only in the lower parts of the formation, either just above the Ferry Lake or above the sands of the Rodessa Formation. The entire formation grades into carbonates along the coast of Mississippi. Lithofacies analyses indicate that the paleoenvironmental conditions along the coast graded from a barrier reef to a back barrier lagoon to a paralic lagoon (Baria, 1981). Numerous wells have been described as containing microfossils, but these have not yet been described. The age of the Mooringsport is probably late Early Albian.

Paluxy Formation

The Paluxy Formation was first described by Hill (1891), based on exposures "…of fine, white packsand, oxidizing red at the surface, about 100 feet in thickness, resembling very much the Trinity sands and hitherto confused with them." The type locality for the formation is along the Paluxy River near the town of Paluxy, Somerville (now Somervell) County, Texas. The Paluxy Formation was placed in the Comanche Division by Hill (1891) because the contact between the Paluxy and the underlying Glen Rose was sharp, whereas the contact between the Paluxy and the overlying Walnut clays was gradational in Texas. South of the type area, the Paluxy sandstones decrease in thickness, whereas they increase in thickness to the north.

Weeks (1938) described the Paluxy Formation in Arkansas to be "…a predominantly non-fossiliferous lithologic unit comprising the upper part of the Trinity group [sic] and grading abruptly into the Fredericksburg group [sic] above." By the time of Weeks (1938), the Comanche Series included all of the Lower Cretaceous stratigraphic units. The Paluxy in south Arkansas had a maximum thickness of 1200 feet, which occurred in the updip areas where the formation was best developed. The formation was divided into three nearly equal informal members. The upper 400 feet consisted of variegated shales and streaks of fine, white sand. The middle 460 feet consisted of red to dull brownish-gray, fossiliferous shales with streaks of dense gray, fossiliferous limestone and fine, white sand. The lower 350 feet was comprised of red shale with streaks of fine, white sand. The entire formation became sandier toward the outcrop. The correlation chart of Blanpied and Hazzard (1939) reflected a similar nomenclature as that of Weeks (1938), with the Paluxy Formation occupying the stratigraphic interval between the top of the Glen Rose Sub-Group (top of the Upper Glen Rose Formation, now the Mooringsport Formation) and the top of the Trinity Group.

Imlay (1940) recognized that the red shales and sandstones of the Paluxy Formation grade downdip into gray limestones and shales, thin sandstones, and some red beds of the Mooringsport Formation, which had been postulated by Weeks (1938). The upper Trinity stratigraphic position was justified by the gradational relationship of the Paluxy with the Mooringsport.

Nunnally and Fowler (1954) described the regional stratigraphy of the Paluxy Formation in Mississippi. The formation was generally described as a sequence of alternating sandstones and shales. The

sandstones were buff, amber, pink, light red, reddish-white, and white, very-fine- to coarse-grained, graveliferous in part, porous to non-porous, silty, micaceous, calcareous, argillaceous, and carbonaceous. The shales were generally red, maroon, gray, and green, micaceous in part, with some being black, flaky and splintery. Mudstones were described as green, greenish-gray, gray, ochre, and mottled, and containing particulate lignite. Charophytes (benthic, calcareous algae) were also noted. The maximum thickness of the Paluxy was 1448 feet, which occurred in a well in Forrest County. Both the upper and lower contacts of the formation were transitional. The upper contact was typically placed at the base of the lowest limestone of the Fredericksburg Group. The base of the formation was defined as the base of the lowest sandstone above the highest limestone of the Mooringsport Formation. These definitions require the presence of limestones in both the Mooringsport Formation and in the Washita-Fredericksburg Group, which are only present in southern Mississippi. Nunnally and Fowler (1954) stated that the Paluxy Formation cannot be distinguished from either the Washita-Fredericksburg Group or the Mooringsport Formation in the central part of Mississippi, where the entire sequence grades into a siliciclastic interval. Nunnally and Fowler (1954) also recognized that the limestones and shales of the Mooringsport Formation in downdip areas are time equivalents of the sandstones and shales of the Paluxy Formation in updip areas.

Dinkins (1969) studied the subsurface stratigraphic units in Copiah County, Mississippi. The Paluxy Formation was described as a sequence of alternating shales and sandstones, with minor amounts of mudstone and nodular limestone. The shales were predominantly dark red, dull red and maroon, silty, micaceous, and occasionally slightly sandy. Also present in subordinate amounts was dark-gray and black, flaky, and splintery shales, being more numerous in the lower half of the formation. Minor amounts of light-gray, gray, and green mudstones and pale-gray and tan nodular limestones were present throughout the formation. The sandstones were typically red, light red, and white, very-fine to coarse-grained, finely micaceous, and occasionally calcareous. Lesser amounts of conglomeritic sandstone were also present in the formation, generally in the upper part. The top of the formation was recognized, in samples, at the top of a sequence of fine- and medium-grained sandstones that occurred below the lowest shale or sandy shale sequence of the Washita-Fredericksburg Group. There is no mention of limestones in the lower part of the Washita-Fredericksburg.

Dinkins (1971) studied the subsurface geology of Rankin County, Mississippi. The Paluxy Formation was described generally as a sequence of alternating sandstones and shales with minor amounts of nodular limestone and mudstone. The Paluxy sandstones were described as white, pink, and red, very-fine- to coarse-grained, but predominantly fine- to medium-grained, commonly micaceous, with some of the sandstones being slightly calcareous. The sandstones in the lower part of the formation are finer-grained than those in the higher parts of the formation. The shales were described as dark red and maroon, silty, micaceous, and sparingly sandy, with minor amounts of dark gray, and black, finely micaceous shales and pale gray, gray and green mudstones. The top of the Paluxy was placed at the top of a sequence of fine- to coarse-grained, generally conglomeritic sandstones below the lowest shale or sandy shale sequence of the Washita-Fredericksburg Group. Again, no mention was made of limestones in the lower portion of the Washita-Fredericksburg.

Coyle (1981) studied a core from Bolton field, just west of Jackson, Mississippi, to determine the environments of deposition. The sedimentary structures, consisting of inclined laminae in the lower part to parallel laminae and ripples in the upper part, a vertical decrease in grain size, and lenticular and discontinuous sand bodies indicated deposition in a fluvial system. Previous workers also concluded that the Paluxy was deposited in a non-marine setting.

Devery (1982) described the Paluxy Formation in central Mississippi as white, fine- to coarse-grained sandstones interbedded with dark red and gray shales deposited in fluvial systems. Gray limestones and shales increased to the south. On wireline logs, the upper contact of the Paluxy was recognized as the top of the first sandstone below the shale-limestone section of the Washita-Fredericksburg Group.

In practice, the upper and lower contacts of the Paluxy Formation are recognized by petroleum geologists working in the MISB on the basis of wireline, typically dual induction, log characteristics. The Paluxy is recognized as the predominantly sandstone interval between the shales of the Mooringsport Formation and the relatively thicker shale units of the Washita-Fredericksburg Group, regardless of limestone content in either of these two bounding formations. This criterion of using the predominance of sandstone in the Paluxy Formation can be seen clearly on the published wireline logs from such fields in the MISB as Bolton, Gitano, Merit, Morgans, Pool Creek, Puckett, Reedy Creek, Summerland, and Wausau (Davis and Lambert, 1963). The regional cross sections of Devery (1982) also illustrated this relationship.

Warner (1993) studied the Cretaceous formations of the subsurface of coastal Mississippi. The Paluxy Formation was recognized in all four wells studied. The formation in wells in the western part of the area, including wells in Ansley field, southern Hancock County, and in the Mississippi Sound area, were comprised in the lower part of siliciclastic sediments and of carbonate sediments in the upper part. The criteria used to define the upper and lower contacts of the formation were not explicitly defined. The siliciclastic sediments included gray to dark gray, firm to hard, brittle, sandy, and partly calcareous shale, and gray to tan, very-fine to medium-grained, firm to hard to friable to unconsolidated, calcareous cemented sandstone. Shales predominated in the Mississippi Sound well. The upper carbonate part of the section was white to tan to light gray, hard, microcrystalline limestone. A microfossils were reported from the Mississippi Sound well. The formation was 770 feet thick in the Ansley field well, and 727 feet thick in the Mississippi Sound block 57 well. The Paluxy Formation in Mississippi Sound, offshore Jackson County (to the east of block 57), consisted of cream to light gray, very hard, microcrystalline dolomite and red to gray to green, firm to hard, micaceous, and partly silty shale, with minor lenses of very-fine-grained sandstone. The full thickness of the Paluxy in Mississippi Sound, off the coast of Jackson County, is not known, as the well total depth was within the Paluxy. The Paluxy in the remaining well, locate offshore of the Alabama-Mississippi state line, was a 790-foot thick, shale dominated section with several prominent sandstone units and some interbeds of limestone. The shales were dark gray to gray to red to dark brown, very firm to moderately hard, slightly calcareous, partly arenaceous, and slightly micaceous. The sandstones were gray to light gray to white, very-fine to fine-grained, loosely cemented, friable, and slightly calcareous, with traces of mica, pyrite, glauconite, and some carbonaceous materials.

Age

The Paluxy Formation is typically non-fossiliferous, and thus the age of the formation is determined by its stratigraphic relationship with units for which the age is known, particularly the Mooringsport Formation. Blanpied and Hazzard (1939), Hazzard (1939), and Imlay (1940) assigned the unit to the uppermost portion of the Lower Albian. Petty et al. (1995) reported occurrences of the ostracode *Eocytheropteron trinitiensis* (Vanderpool, 1928) in the lower and upper parts of the Paluxy Formation in wells in the Viosca Knoll and Mississippi Sound areas. *Eocytheropteron trinitiensis* was originally named by Vanderpool (1928), based on specimens collected from the Glen Rose Formation eight miles west of

Weatherford, Parker County, Texas. The species was also reported to be abundant in the DeQueen Formation of Arkansas, and was described from the Glen Rose of northwest Louisiana (Shaw, 1961). This species was reported as abundant in the Paluxy Formation of southern Oklahoma (Vanderpool, 1928); Trinity deposits of the Texas, Arkansas, and Louisiana region (Calahan, 1939); the Walnut Formation of Travis and Williamson Counties, Texas (Moysey, 1975; 1982); the Trinity (?) and pre-Trinity (?) of the North Carolina subsurface (Swain and Brown, 1964); and in Swain and Brown's (1972) Unit G (=Trinity age) of the Atlantic Coastal Plain. All these occurrences suggest that *E. trinitiensis* ranges from the Glen Rose Formation to the Walnut Formation, which occurs in the upper part of the Aptian and lower part of the Albian, but is most common in the lower part of the Albian. Thus, the Paluxy Formation is assigned to the latest part of the Early Albian.

Paluxy Formation Stratigraphy from Regional Cross Sections

The Paluxy Formation was recognized in most wells in the regional cross sections, except for those in the far updip areas. For example, the formation was not recognized in the wells west of dip section B-B', and not in the four updip wells in section B-B'. The following descriptions will generally progress from downdip to updip wells except, of course, in descriptions of the formation in the strike section A-A'.

The Paluxy Formation in well 23-049-20032, located in extreme southern Hinds County, is recognized as the predominantly sandstone interval between the shales of the Mooringsport Formation and a thick (250-foot) shale unit at the base of the Washita-Fredericksburg. The formation is 1745 feet thick. The lower half of the formation contains fairly thick (40-100-foot) shale units, which generally decrease in thickness up-section, although the uppermost approximately 250 feet of the formation contains two prominent shale beds. The formation in well 23-049-20004, located in southern Hinds County, is of similar thickness to that in the previous well. The thickness is 1720 feet. The same criteria for recognition of formational contacts also apply. Sample and lithologic logs indicate the formation is comprised of clear, white, light red, light brown and green, very-fine- to medium-grained, slight porous and non-porous, unconsolidated sandstone; dark red, brown, maroon, black and gray, silty, finely micaceous shale; and with a trace of limestone. The formation in well 23-049-20005, the common well for sections A-A' and B-B' located in northeastern Hinds County, is 1615 feet thick. The lower contact is very distinctive, being recognized by a 40-foot thick sandstone unit overlying the predominantly shaley interval of the

Mooringsport Formation. The “McAlpin” sandstone occurs in the lower part of the formation. The upper contact is recognized at the base of a 70-foot thick shale unit that is at the base of the Washita-Fredericksburg.

The Paluxy in well 23-089-20043, located in western Madison County, is 1250 feet thick. The lower contact is placed at the top of the thick (150-foot) shale of the Mooringsport Formation, and the upper contact is placed at the base of a 85-foot thick shale bed of the Washita-Fredericksburg. The Paluxy Formation is recognized as a predominantly sandstone section, whereas the Washita-Fredericksburg section includes thick (approximately 80-foot) shale beds. The Paluxy in well 23-163-20150, located in southeastern Yazoo County, is recognized by essentially by the same criteria as well 23-198-20043, but is 980 feet thick. The formation is predominantly white, pink, and clear, fine- to medium-grained, moderately to well cemented sandstone, and brown and reddish-brown, sandy, silty, firm shale, with a trace of limestone.

The upper portion of the Lower Cretaceous section becomes attenuated in well 23-163-00049, located in northeastern Yazoo County, and in well 23-051-20036, located in southern Holmes County. The interval between the top of the Mooringsport and the top of the Lower Cretaceous is 891 feet thick in well 23-163-00049. A sample log indicates this interval is comprised of medium- to coarse-grained, slightly porous and non-porous sandstone; dark red, purple, lavender, ochre, and mottled shale; mottled mudstone; and occasional quartz pebbles. The interval between the top of the Mooringsport and the top of the lower Tuscaloosa Formation in well 23-051-20036 (the Massive sand was not recognized in this well) is 896 feet thick. This interval was referred to in sample logs as the Hosston Formation in a nearby well, but the age of the strata in these wells remains unknown due to a lack of age-diagnostic fossils. A sample log from the nearby well indicates that this interval is comprised of loose, coarse-grained sand; dull red, medium- and coarse-grained, slightly porous, argillaceous sandstone intercalated with white siltstone; and “water-laid” volcanic material. Specific units in the Lower Cretaceous section in well 23-051-20020, located in central Holmes County, and in well 23-083-20011, located in southeastern LeFlore County, are difficult to differentiate.

The Paluxy Formation in well 23-121-20025, located in central Rankin County, is 1287 feet thick. The formation is recognized as the predominantly sandstone interval between the shales of the

Mooringsport Formation and the alternating beds of sandstone and shale of the overlying Washita-Fredericksburg section. The upper contact is indistinct, and was placed at the top of a 100-foot thick sandstone bed. A sample log indicates the Paluxy is comprised of green, red, and light red, very-fine- to coarse-grained, slightly porous to non-porous sandstone; dark red and maroon, finely micaceous shale; light green and pale gray mudstone; and small, clear and light pink quartz pebbles. The formation in well 23-129-00178, located in northern Smith County in proximity to dip section C-C', is recognized by the same criteria as well 23-121-20025. The upper contact is difficult to define, and was placed at the top of a 50-foot thick sandstone bed. The overlying Washita-Fredericksburg section contains relatively thicker shale units than the Paluxy Formation. The formation is 1177 feet thick in well 23-129-00178. A lithologic log indicates the Paluxy is comprised of gray, light gray and white, very-fine- to fine-grained, loose, partly shaley and calcareous sandstones; and red and multi-colored, partly sandy shale.

The full thickness of the Paluxy Formation was recognized in all wells in dip section C-C', except for the two updip wells. The Paluxy Formation in well 23-065-20141 is much shalier than in the updip wells. The base of the formation was recognized at the base of a 65-foot sandstone bed overlying the shales of the Mooringsport Formation. A thick (200-foot) shale bed overlies this basal sandstone unit. The upper contact was placed at the base of a thick (320-foot), predominantly shale interval of the Washita-Fredericksburg sequence. The Paluxy is characterized as a 1288-foot sequence of alternating sandstones and shales. Most of the sandstone units are fairly thin (10-20 feet thick) and only 2 sandstone beds attain a thickness of 50 feet thick. These occur at the base and at the top of the formation. A lithologic log of the lower part of the formation indicates it is comprised of red and brown, silty, slightly calcareous, slightly micaceous shale; white, clear and pink, fine-grained, mostly moderately cemented but some well cemented sandstone; and with a trace of light gray, dense limestone. The Paluxy in well 23-127-20055, located in extreme eastern Simpson County, is 1588 feet thick. The base of the formation is placed at the top of the shales of the Mooringsport Formation. Davis and Lambert (1963) placed the base of the Paluxy Formation approximately 320 feet higher in the well, which would include three very prominent sandstone units within the Mooringsport Formation ("Mooringsport pool"). Lithostratigraphically, however, these sandstone units are not less prominent than those of the overlying Paluxy Formation, and the intervening shale units are no thicker than those of the Paluxy. Thus, in this report these sandstones are assigned to the

Paluxy Formation. The beds of the upper Paluxy are transitional with the overlying Washita-Fredericksburg strata, and therefore the top of the Paluxy was placed at the top of a 70-foot sandstone unit. The shales are generally thicker in the overlying Washita-Fredericksburg section. This upper contact agrees with that of the Mississippi Geological Society (Davis and Lambert, 1963). The lower half of the formation includes several thick (50-80-foot) shale units, and is very similar to the lower part of the Washita-Fredericksburg.

The Paluxy Formation in well 23-129-20122, located in south-central Smith County, is 1830 feet thick. The lower contact is distinct and is recognized at the base of a predominantly sandstone interval overlying the shales of the Mooringsport Formation. The upper contact is difficult to define, and was placed at the base of a 65-foot shale bed. The Washita-Fredericksburg displays only a slight increase in shale content relative to the Paluxy. Based on wireline logs, the Paluxy and Washita-Fredericksburg sequences are similar and difficult to differentiate. The situation is reversed in well 23-129-20006, the common well for sections A-A' and C-C' located in central Smith County. In this well, the lower contact of the Paluxy is difficult to recognize due to the transitional nature of the strata between the top of the Mooringsport and the base of the Paluxy. This relationship was discussed in the previous section on the Mooringsport Formation. The upper contact is recognized at the top of the predominantly sandy interval underlying the shalier interval of the Washita-Fredericksburg. The Paluxy Formation in well 23-129-20006 is 969 feet thick. A lithologic log indicates the Paluxy is comprised of reddish-brown, silty, sandy shale; gray to white, very-fine- to fine-grained, unconsolidated to moderately cemented, partly calcareous, slightly micaceous and glauconitic sandstone, becoming coarser grained up-section; and a trace of lignite in the upper part of the section. These data suggest a shallowing-upward sequence (late highstand systems tract).

The Paluxy in well 23-129-20057, located in northeastern Smith County, is recognized as a distinctive, 1053-foot, predominantly sandy interval between the top of the shales of the Mooringsport Formation and the alternating sandstone/shale sequence of the Washita-Fredericksburg. The upper contact was placed at the base of a thick (115-foot) shale bed in the basal Washita-Fredericksburg. The thickness of the shale units is greater in the lower and upper parts of the formation, with the middle portion of the formation being very sandy. Several coarsening-upward sandstone units are distinctive of the lower part of the section. The Paluxy in well 23-129-00015, located in extreme northeastern Smith County, is similar to that in well 23-129-20057, and is of the same thickness. The lower and upper contacts in well 23-129-

00015 are distinctive. The Paluxy Formation is characterized by regularly-alternating beds of sandstone and shale, with sandstone thickness generally greater than shale thickness. Shale bed thickness is slightly greater in the lower and upper parts of the formation relative to the middle portion.

Sandstone content in both the Paluxy Formation and Washita-Fredericksburg Groups is greater in well 23-101-20005, located in southern Newton County, than in the more downdip wells, and the two units cannot be distinguished in the most updip well in dip section C-C', well 23-101-00014. The lower contact of the Paluxy is recognized at the top of the 110-foot shales of the Mooringsport Formation. The upper contact is recognized at the top of the predominantly sandy section underlying the alternating sandstone/shale sequence of the Washita-Fredericksburg. The Paluxy is 987 feet thick in well 23-101-20005. The lower approximately 350 feet of the formation contains several fairly thick (30-60-foot) shale beds, whereas the upper part consists of sandstone. A lithologic log indicates the formation is comprised of clear, white, tan, and some pink, very-fine- to fine-grained, calcareous, loose to moderately cemented, quartz sandstone; and red, brown, gray, tan, and mottled, silty and firm shale. The Paluxy in well 23-101-00014 cannot be distinguished from the Washita-Fredericksburg. The interval between the top of the Mooringsport and the base of the massive sand of the lower Tuscaloosa Formation is 1587 feet thick. The lower approximately 700 feet of this interval contains relatively less shale, except for the lower 200 feet, than the overlying approximately 800 feet. The lower 700 feet may represent the Paluxy Formation, and the upper 800 feet may represent the Washita-Fredericksburg in this well.

The full thickness of the Paluxy Formation is recognized in each of the wells along section A-A' between dip sections C-C' and D-D'. The formation in well 23-129-00061, located in extreme east-central Smith County, is recognized as a distinct, 1230-foot sandstone interval between the top of the shales of the Mooringsport Formation and the alternating sequence of relatively thicker shales and sandstones of the Washita-Fredericksburg. A sample log indicates that the Paluxy is comprised of pink and white, fine-grained, porous to non-porous sandstone; light and dark red shale; and scattered clear and yellow quartz pebbles. The upper and lower approximately 150 feet of the formation includes thicker shale units. The Paluxy in well 23-061-20203, located in southwestern Jasper County, is very similar to the previously described interval, but is slightly thicker, being 1317 feet thick. The lower part of the Paluxy is lithologically transitional with the upper part of the Mooringsport Formation. Shale bed thickness is greater

in the lower part of the formation than in the upper part. A sample log from a nearby well indicates that the Paluxy Formation is comprised of light red, fine- to medium-grained, very slightly porous to non-porous, partly calcareous sandstone; red and maroon, silty, finely micaceous shale; and with traces of quartz pebbles.

The Paluxy in well 23-061-20028, located also in southwest Jasper County, is recognized as a distinctive, predominantly sandy, 1535-foot interval between the shales of the underlying Mooringsport Formation and the alternating sequence of thickly bedded sandstones and shales of the Washita-Fredericksburg. The top of the formation was placed at the base of a 130-foot shale bed at the base of the Washita-Fredericksburg. Lithologic and samples logs from the lower 250 feet of the Paluxy indicate that the formation is comprised of white and clear, very-fine- to fine-grained, moderately cemented to unconsolidated sandstone; and reddish-brown, very silty, finely micaceous shale. The Paluxy in well 23-061-20244, located in extreme southern Jasper County, is 1151 feet thick. The base of the formation was placed at the base of a continuous sequence of sandstones. The upper boundary was recognized at the base of an alternating sequence of relatively thick sandstones and shales of the Washita-Fredericksburg. The Paluxy is absent due to faulting in well 23-067-20002, located in northeastern Jones County.

The greatest lithologic variability of the Paluxy Formation in the MISB is displayed along dip section D-D'. The Paluxy in well 23-045-20075, located in Hancock County, is a predominantly shaley unit 1110 feet thick. Carbonates of the Mooringsport Formation, or Trinity Lime of Petty et al. (1995) and of the overlying Washita-Fredericksburg are the bounding units. The stratigraphic relationship and lithology of the Paluxy Formation as recognized in this report as a predominantly siliciclastic unit, as opposed to the lithology of the Paluxy of Warner (siliciclastic in the lower part and carbonate in the upper part) is not resolvable at this time because Warner (1993) did not explicitly describe his criteria for recognizing the Paluxy. The Paluxy in this well is comprised of brown, reddish-brown, and gray, firm to moderately firm, splintery, brittle, silty, sandy in part, finely micaceous, non-calcareous shale; and brown, light brown, white, and clear, very-fine- to medium-grained, well cemented sandstone. The Paluxy in well 23-111-00069, located in extreme southern Perry County, is also shaley compared to the lithology of the formation in updip wells. The formation is characterized by alternating beds of sandstone and shale. The lower contact is recognized at the base of the lowest sandstone unit in the interval, and the upper contact is placed

at the base of a thick (140-foot) shale unit at the base of the Washita-Fredericksburg. Sandstone beds in the Paluxy generally increase in thickness up section. Sandstone units in the lower half of the formation are relatively thin (20-30 feet), whereas those of the upper half are much thicker, including one sandstone that is 100 feet thick. The thickness of the shale units is fairly constant throughout the section. This stratigraphic sequence suggests deposition during a progradational event (late highstand systems tract).

The Paluxy in well 23-153-20077, located in southern Wayne County, is 1375 feet thick. The lower contact is recognized at the top of the shales of the Mooringsport Formation, and the top of the formation is recognized at the base of a 100-foot, generally shaley interval at the base of the Washita-Fredericksburg. The Paluxy-Mooringsport contact is distinct, though transitional, and the Paluxy- Washita-Fredericksburg contact is lithologically transitional. The Washita-Fredericksburg generally differs from the Paluxy in containing thicker shale units. The sandstones in the lower approximately 500 feet of the Paluxy are relatively thin, but thicken upsection; the interval between 500 and 1100 feet above the base of the formation is predominantly sandstone, with a few interbeds of shale, and the upper 250 feet includes two thick (40 and 80 feet thick) shale units. This sequence suggests that the lower 1100 feet of the Paluxy represents late highstand deposits, while the upper approximately 250 feet of the formation represent transgressive deposits of an overlying sequence. The contact between the sandstone-dominated interval of the Paluxy and the more thickly-bedded sandstone/shale interval of the uppermost Paluxy and/or lower Washita-Fredericksburg probably represents a sequence boundary.

The Paluxy in well 23-153-01008, the common well for sections A-A’ and D-D’ located in central Wayne County, is 1365 feet thick. The contacts between the bounding formations of the Paluxy are distinct. The lower contact of the Paluxy is recognized at the contact between the shales of the Mooringsport Formation and the sandstones of the Paluxy Formation. The upper contact is placed at the base of a thick (230-foot) shaley interval at the base of the Washita-Fredericksburg. The Paluxy Formation is characterized as a relatively uniform section of sandstones with interbedded shales; a slight increase in shale bed thickness is observed in the lower and upper parts of the formation. A sample log indicates that the Paluxy is comprised of red, very-fine- to medium-grained, non-porous sandstone, and dark red and maroon shale. The Paluxy in well 23-153-20232 is recognized as the predominantly sandy interval between the shales of the Mooringsport and the alternating sandstone/shale interval of the Washita-Fredericksburg. The

formation is 1465 feet thick. The lower approximately 500 feet of the formation is characterized by alternations of sandstone and shale beds of subequal thickness; the middle 550 feet is predominantly sandstone, and the upper 450 feet is characterized by regular alternations of sandstone and shale. The upper contact is placed at the base of a 80-foot shale bed in the basal Washita-Fredericksburg. A lithologic log indicates the Paluxy Formation is comprised of clear and gray, silty, loose to moderately cemented sandstone; brick red, brittle, hard shale; and multi-colored siltstone.

The Paluxy in well 23-153- 20265, located in northern Wayne County, is 1425 feet thick. The lower contact is indistinct and lithologically transitional with the Mooringsport Formation. This transitional zone is approximately 300 feet thick, and contains three sandstone units within a dominantly shaley interval; a 100-foot shale unit occurs at the top of this interval. It is possible that the top of this transitional interval corresponds to the base of the Paluxy in well 23-153-20232 and that the sandstone units within the transitional zone do not occur in the latter well. However, detailed correlations with nearby wireline logs indicate that the base of the Paluxy should be placed at the lower position. Thus, the lower part of the Paluxy in well 23-153-20265 is time equivalent to the upper part of the Mooringsport in well 23-153-20232. A sample log from a well in proximity to well 23-153-20265 indicates that the formation is comprised of fine- to medium-grained, slightly porous sandstone; dark red and maroon shale; and yellow, ochre and red chert. The sample log also indicates gravel deposits about 200 feet above the base of the Paluxy, comprised of clear and yellow quartz pebbles.

The Paluxy Formation in well 23-153-20042, located in extreme northern Wayne County, is a distinctive unit between the shales of the Mooringsport Formation and the regular alternations of subequal thicknesses of sandstone and shale in the Washita-Fredericksburg. The formation is 1385 feet thick. The lower contact is lithologically distinctive. The lower approximately 150 feet of the Paluxy contains slightly thicker shale units than the middle part of the formation. The interval between 150 and 1150 feet above the base of the formation is sandstone dominated, while the upper 200 feet also includes relatively thicker shale units. Thus, although the upper and lower contacts are distinctive, there are lithologically transitional zones in the lower and upper parts of the formation. The Paluxy in well 23-023-20114, located in central Clarke County, is 1232 feet thick. The lower part of the section is also transitional with the Mooringsport Formation, thus the exact placement of the contact is uncertain within a 70-foot interval. The upper contact

is distinct and is recognized at the base of a 200-foot, predominantly shaley interval at the base of the Washita-Fredericksburg. Only the interval between 400 and 800 feet above the base of the formation is a predominantly sandy interval observed. The upper 350 feet of the formation includes several distinct shale units. The Paluxy Formation and the Washita-Fredericksburg cannot be differentiated in the most updip well in section D-D'. The interval between the top of the Mooringsport Formation and the base of the massive sand of the Tuscaloosa is 737 feet thick; this upper portion of the Lower Cretaceous is attenuated relative to downdip wells. A sample log from the interval above the Mooringsport indicates medium- to coarse-grained sandstone; red, light red, and ochre shale; and clear and yellow quartz pebbles. The upper portion of the top of the Mooringsport to the base of the Massive sand interval of the Tuscaloosa is graveliferous with fine- to medium-grained, non-porous sandstone; red, light and dark red shale; and light gray and lavender mudstone.

The full thickness of the Paluxy Formation is recognized in most wells along section A-A' between dip sections D-D' and E-E'. The formation in well 23-153-20545, located in southern Wayne County, is 1048 feet thick. A fault occurs within the Paluxy Formation, thus the full thickness of the formation is not known for this area. The lower part of the formation includes relatively thick shale units and is thus transitional with the underlying Mooringsport Formation. The lower contact of the Paluxy is recognized at the top of a 210-foot shale bed in the Mooringsport Formation. The upper portion of the Paluxy is lithologically transitional with the overlying Washita-Fredericksburg. The upper contact is placed at the base of a 75-foot shale bed in the basal Washita-Fredericksburg. The formation is dominated by sandstone in the interval between approximately 500 and 850 feet from the base of the formation. Apparently, the section that is faulted includes some of the middle, sandstone-dominated interval, as it is generally thicker in other wells in the area. A sample log from a nearby well indicates that the formation is comprised of green and light red, fine- to medium-grained, slightly porous to non-porous sandstone; maroon, micaceous shale; and with scattered quartz pebbles.

The Paluxy Formation in well 23-153-20122, located in southeastern Wayne County, is 1720 feet thick. The lower contact of the formation is not easily distinguished, as the Mooringsport Formation is not a distinct shaley unit as is observed in other wells, and includes several sandstone units. The Paluxy displays a tripartite subdivision, with the lower 500 feet containing a relatively large amount of shale, the middle

portion being sandstone dominated, and the upper portion containing thicker shale units. The upper contact of the Paluxy was recognized at the top of a thick (150-foot) sandstone unit. The Paluxy in well 01-129-20054, located in northwestern Washington County, is a distinct, 1776-foot stratigraphic unit. The lower contact is placed at the top of a shale unit in the Mooringsport Formation. The upper contact is placed at the top of a predominantly sandstone interval, at the base of a 70-foot shale bed in the basal Washita-Fredericksburg.. The alternating beds of subequal thicknesses of sandstone and shale of the Washita-Fredericksburg sequence contrast with the predominantly sandy sequence of the Paluxy. The lower approximate half of the Paluxy contains thicker shale units than the upper half.

The Paluxy Formation in well 01-129-20024, also located in northwestern Washington County, is attenuated relative to other wells in the area. The overlying Washita-Fredericksburg section is relatively thick in this well, suggesting the possibility that the top of the Paluxy in this well is recognized at a stratigraphically lower position than in other wells. However, the Washita-Fredericksburg section is a fairly ubiquitous interval of alternations of sandstone and shale beds of subequal thickness similar to the other wells. The lower contact of the formation is distinct and is recognized at the top of the shale-dominated interval of the Mooringsport Formation. The lower half of the formation is characterized by relatively thicker shale units than the upper half.

The Paluxy Formation is recognized in all but the updip and downdip wells in section E-E'. A fault occurs in the formation in well 01-097-20299, located in the Hatter's Pond field of eastern Mobile County, Alabama. The base of the formation is recognized at the top of the shales of the Mooringsport Formation, but the top of the formation is not recognized. The Paluxy in well 01-097-20141 is 1097 feet thick. The base of the formation is recognized at the top of the shale sequence of the Mooringsport Formation. The upper contact is placed at the top of the predominantly sandy section of the Paluxy and base of a thick (130-foot) shale unit at the base of the Washita-Fredericksburg. The formation, particularly the lower half of the unit, is predominantly shale, with sandstone interbeds not evident in the Mooringsport. The upper portion of the formation is sandier, but still includes prominent shale units.

The Paluxy in well 01-097-20134, located in northern Mobile County, is 1109 feet thick. The lower contact is distinct and is recognized at the top of the shales of the Mooringsport Formation. The upper contact is also distinct, and is recognized at the base of a thick (190-foot) shale bed in the lower

Washita-Fredericksburg. The lower half of the formation generally contains thinner sandstone units and thicker shale units than the upper half of the unit. The formation in well 01-129-20051, located in southern Washington County, is 864 feet thick. The formational contacts in this well are not easily recognized due to the quality of the geophysical logs. The Mooringsport Formation is not recognizable in this well, rendering recognition of the Mooringsport-Paluxy formational contact difficult. The contact is placed at the top of a shale unit. The upper contact is more distinct, and is placed at the base of a 200-foot shale unit at the base of the Washita-Fredericksburg.

The Paluxy in well 01-129-20012, the common well for sections A-A' and E-E' located in central Washington County, is 1070 feet thick. The formational contacts in this well are distinct. The lower contact is placed at the top of the shales of the Mooringsport Formation, and the upper contact is placed at the base of a thick (200-foot) shale unit at the base of the Washita-Fredericksburg. The formation is characteristically shalier (thicker shaley beds) in the lower half of the formation and sandier in the upper half of the unit. A sample description indicates that the formation is comprised of white to very-light gray, fine- to medium-grained, calcareous, quartzose sandstone and non-calcareous clay and claystone.

The Paluxy in well 01-023-20197, located in southwestern Choctaw County, is a distinct sandstone interval 895 feet thick. The Mooringsport Formation is relatively thin and lithologically indistinct in the updip well, and thus the contact between the Mooringsport and the Paluxy Formation is difficult to define. The lower contact is placed at the top of a 70-foot shale bed in the Mooringsport. The upper contact is placed at the base of a 90-foot shale bed at the base of the Washita-Fredericksburg. The upper and lower portions of the Paluxy are generally shalier than the middle portion. A prominent, 40-foot shale bed is present in the upper part of the formation. A fault in well 01-023-20114, located in south-central Choctaw County, makes differentiation between the Lower Cretaceous and Jurassic formations difficult. The section below the base of the Massive sand of the Tuscaloosa is similar to the Washita-Fredericksburg in adjacent wells, but the stratigraphic interval that should correspond to the Paluxy becomes shalier, rather than sandier. The Paluxy is not recognized in well 01-023-20114.

Summary

The Paluxy Formation was recognized in most of the wells used in the regional cross sections of the MISB. In far updip wells, the Paluxy cannot be distinguished from the Washita-Fredericksburg. The

Paluxy is generally characterized as a predominately sandy interval between the shales of the underlying Mooringsport Formation and the relatively thick alternating beds of sandstone and shale of the Washita-Fredericksburg. In most of the wells studied for this project, carbonates are absent from both the Mooringsport Formation and from the Washita-Fredericksburg. Although carbonates have been reported from the Washita-Fredericksburg in southwest Mississippi, they have only been observed in wells from coastal Mississippi in this study. The contacts of the Paluxy are generally lithologically transitional with the bounding formations, although the contacts are often distinctive. The lower and upper portions of the formation typically contain thicker shale units than the middle part of the formation. Many wells exhibit a bipartite subdivision of the Paluxy, rather than a tripartite subdivision. These wells containing thicker shale units in the lower half of the formation relative to the upper half of the unit. The thickness of the Paluxy is greatest in the middle and updip portions of its subcrop. This is the inverse of the underlying Mooringsport Formation. It is likely that the sandstone units in the lower portion of the Paluxy in updip areas are time equivalent to shale units in the upper part of the Mooringsport Formation in downdip areas. The upper portion of the Paluxy or of the Paluxy-Washita-Fredericksburg transitional interval contains a sequence boundary marking the change from the late highstand systems tract deposits of the Paluxy to the transgressive systems tract deposits of the Washita-Fredericksburg. The Paluxy Formation is assigned to the latest portion of the Early Albian Stage.

Washita-Fredericksburg Groups undifferentiated

The contact between the Washita and Fredericksburg Groups is difficult to distinguish in the MISB. These units include the stratigraphic interval between the top of the Paluxy Formation and the top of the Lower Cretaceous. The lower contact of the interval is usually readily recognizable, but the upper contact can be difficult to recognize due to the variable nature of the basal Tuscaloosa (lowest Upper Cretaceous) stratigraphic units. Where the Massive sand is the basal part of the Tuscaloosa Group is present, the upper contact of the Lower Cretaceous is easily recognized. The Massive sand is comprised of white, medium- to coarse-grained, finely micaceous sandstone characterized by its lack of glauconite. The “Massive sand,” however, has a limited regional distribution. Dickas (1962) studied the regional stratigraphy of the Tuscaloosa Group in parts of Louisiana, Mississippi, Tennessee, and Alabama, using

438 wireline logs. He found that the western limit of the Massive sand occurred along a line from Walthall County (due north of Lake Ponchartrain) to Scott County, Mississippi. To the west and southwest of the subcrop limit of the Massive sand, the basal Tuscaloosa is comprised of glauconitic sand, which is a characteristic of the overlying Stringer sand. Recognition of the contact between the top of the Washita-Fredericksburg and the base of the Stringer sand in these areas is difficult.

In northern Texas, the Fredericksburg Group is essentially a carbonate unit. The group is defined as the interval between the top of the Trinity Division and the base of the Washita Division, and includes the Walnut Marl and the Goodland Formation (including the Marys Creeks Marl and Benbrook Limestone Members) (Hendricks, 1967). As noted previously, some authors, such as Hayward and Brown (1967), include the Paluxy Sand as the basal formation in the Fredericksburg Group. The Fredericksburg Group in central and in south central Texas includes the Paluxy Sand, the Walnut Clay, the Comanche Peak Limestone, and the Edwards Limestone (Hayward and Brown, 1967; Young, 1967). The Washita Group in north Texas includes the Kiamichi Formation, Duck Creek Formation, Fort Worth Limestone, Denton Formation, Weno Formation, Paw Paw Shale, Main Street Limestone, Grayson Formation, and Buda Limestone (Hendricks, 1967; Kessinger, 1974; 1982; Young, 1982). The Washita in central Texas is comprised of the Georgetown Limestone, the Del Rio Clay, and the Buda Limestone (Hayward and Brown, 1967; Kessinger, 1974; 1982; Young, 1982). The Washita in south central Texas includes the Kiamichi Formation, the Georgetown Limestone, the Del Rio Clay, and the Buda Limestone. It is important to recognize that most of the units in the Fredericksburg and Washita Groups are carbonate, marl or clay deposits, all predominantly marine units.

The stratigraphic nomenclature regarding the interval generally referred to as the Washita-Fredericksburg Groups undifferentiated in Mississippi is complicated. Nunnally and Fowler (1954) distinguished two units in the subsurface of southern Mississippi between the top of the Paluxy Formation and the top of the Lower Cretaceous rocks. The lower of the two intervals was referred to as the pre-Dantzler Washita and Fredericksburg Groups undifferentiated, and the upper interval was the Dantzler Formation. This differentiation was possible only south of a line from central Greene County to north Claiborne County. The pre-Dantzler Washita and Fredericksburg interval was referred to as the Andrew Formation by Eargle, (1964), based on sample and core descriptions from the Gulf Oil Co. No. 25 J. M.

Andrew well, in sec. 6, T. 1 N., R. 16 W., Baxterville oil field, Lamar County, Mississippi. In the type well, the Andrew Formation consists, toward the top, of

> "…dull- to dark-red, gray and olive-gray shale containing beds of brownish-gray finely sandy limestone, some shell fragments, and some beds of olive-gray dolomite and light cream limestone. This grades down into gray and greenish-gray to dull-red micaceous shale alternating with limestone, minor beds of fine-grained sandstone containing some carbonaceous matter, and grayish-green siltstone. Much of the lower part is dark-gray shale."

The core descriptions also reported that the formation contains abundant bivalves and ostracodes, and parts of the formation contain the benthic foraminifer *Lituola inflata* Lozo, 1944 (referred to as *Lituola subgoodlandensis* (Vanderpool, 1933) by (Frizzell, 1954), species of *Quinqueloculina* and other miliolid foraminifera, and *Plicatula* and other *Pecten*-like bivalves. Nunnally and Fowler (1954) also noted that a Washita microfauna had been reported from the upper part of the unit, but no details were given. The limestones are gray, light gray, white, brownish gray, tan, and brown, generally fossiliferous, and some are sandy, sucrosic, glauconitic, and "pseudo-oolitic." The shales are light red to red, mottled, silty, micaceous, and fossiliferous. The mudstones are gray or greenish gray, mottled, and silty. The sandstones are light red to red, light gray or pale green, and often silty, micaceous, calcareous, fossiliferous (including ostracodes and lignitized plant remains), and carbonaceous. The contacts of the Andrew are recognized on the basis of carbonate content. The subcrop of the Andrew Formation is generally outside of the area of the MISB; thus its presence was not distinguished as a separate stratigraphic unit.

The Dantzler Formation was named by Hazzard et al. (1947a), based on a description of the Humble Oil and Refining Co. B-1 Dantzler Lumber Co. well in sec. 30, T. 5 S., R. 8 W., Jackson County, Mississippi. Eargle (1964) quoted the description of the lithology as:

> "Nonmarine sands, fine- to medium-grained, white to dull-red, and green; shales, dark-purplish-red, generally mottled with white, yellow, ochre, and gray; some shales are dark gray; some are micaceous, slightly chloritic, silty. Some beds are carbonaceous and lignitic, others are calcareous and contain gray, red, or white limestone nodules."

Hazzard et al. (1947b) defined the formation as "…the sand and gray and red-mottled shale section, with fossiliferous zones which intervene between the base of the Lower Cretaceous and the top of the Washita limestone [sic]." Implicit in the definition of the Dantzler is the presence of underlying limestones of the Andrew (="Washita") limestones. The formation was reported by Eargle (1964) to contain oyster shells, ostracodes, and the charophyte *Chara*, and a rare occurrence of the benthic foraminifer *Haplophragmoides*. Nunnally and Fowler (1954) described the Dantzler in Mississippi as a

sequence of alternating sand, mudstone, shale, and siltstone beds. The shales are dark red, dull red, and red and gray mottled in color, and are partly micaceous and silty. The sandstones are buff, light green to greenish-white, and dull red, fine- to medium-grained, porous to nonporous. Some of the sandstones are carbonaceous and lignitic, while others are calcareous and contain limestone nodules. The mudstones range from red to ochre, light green, light gray to gray, and mottled. The contact between the Andrew and Dantzler Formations is transitional and the contact is placed between the lowest sandstone and the highest fossiliferous limestone. The Dantzler is overlain unconformably by conglomeratic sands of the Lower Tuscaloosa. Nunnally and Fowler (1954) considered the first dark and dull red, silty, finely micaceous shale, gray and light gray, ochre and mottled mudstone, and red and white nodular limestone to mark the top of the Dantzler Formation.

Although the Dantzler-Tuscaloosa contact is generally considered to be unconformable in the MISB, Chasteen (1983) interpreted the Lower Tuscaloosa and the Dantzler in southern Mississippi (Perry sub-basin) to be a continuous stratigraphic sequence. Chasteen (1983) interpreted the Perry sub-basin to represent a continental basin separated from the ancestral Gulf of Mexico by the Wiggins Arch-Hancock County High structural complex during the latter portion of the Early Cretaceous. Upon infilling this region (Dantzler Formation), nonmarine sediments of the Lower Tuscaloosa Formation prograded to the south and southwest. Soon after deposition of these nonmarine sediments, the sea transgressed, resulting in a stratigraphic sequence grading up-section from nonmarine deposits to marginal marine deposits (Stringer sands of the Lower Tuscaloosa) to full marine deposits (Middle Tuscaloosa Marine shale). The lower portion of the nonmarine interval consisted of a stacked series of massive channel sands (ostensibly the Massive sand), which were interpreted to represent braided stream deposits. The upper portion of the nonmarine facies consisted of point bar sand deposits. These point bar deposits were characterized by a basal gravel, cross bedding, and ash and clay encased in red, orange, and mottled shales that were interpreted to represent overbank deposits. The upper portion of the Dantzler/Lower Tuscaloosa undifferentiated section is represented by brackish and marine deposits. These brackish and marine sediments are characterized by gray, micaceous shales and thin sands often containing oysters. Isopach maps of the productive sands in this interval display lenticular geometries. Cores of the interval show intense bioturbation, shell fragments, and cross bedding, indicating deposition as a series of marine bars.

The marine facies of the Lower Tuscaloosa is, in turn, overlain by the Marine shale of the Middle Tuscaloosa.

In summary, the units in the interval between the top of the Paluxy Formation and the top of the Lower Cretaceous have a complex nomenclature. The current nomenclature consists of a dual usage system. In southern Mississippi, the lower, carbonate part of the section is called the Andrew Formation and the upper, nonmarine, predominantly siliciclastic interval is called the Dantzler Formation. Updip of the limit of the lower carbonate section, the entire interval is called the Washita-Fredericksburg Groups undifferentiated even though, at least lithologically, the rocks are completely different than the rocks of the Washita and Fredericksburg Groups of Texas. The rocks of the Washita-Fredericksburg Groups undifferentiated are, however, essentially identical to those of the Dantzler Formation. It is suggested herein that the interval between the top of the Paluxy and the top of the Lower Cretaceous be referred to as the Dantzler Formation in those areas in which the interval is predominantly siliciclastic and be recognized as the Andrew Formation in southern Mississippi where carbonates are present in the lower part of the interval. The term Washita-Fredericksburg Groups undifferentiated should not be used. Renaming of the interval should not be done until further study is accomplished, particularly the micropaleontology of the interval and the nature of the upper contact.

Age

Although the ages of the Washita and Fredericksburg Groups in Texas is well known (although certainly not completely consistent), very little data have been published regarding the ages of the interval in the MISB, in spite of the fact that the interval is known to be fossiliferous. Perkins (1960) considered the Fredericksburg Group to be early, but not earliest, Albian in age. Young (1972; 1982), however, considered the base of the Fredericksburg (i.e., basal Walnut Marl) to be in the middle of the middle Albian, based on the occurrence of ammonites of the genus *Oxytropidoceras* and *Manuaniceras*. The top of the Fredericksburg (i.e., Goodland Formation) was considered by Perkins (1960) also to be in the early portion of the Albian, but Young (1972; 1982) considered it to be in the early part of the late Albian. The top of the Fredericksburg Group was considered by both Perkins (1960) and Young (1972; 1982) to be early Cenomanian in age. Young (1972; 1982) considered the Lower Cretaceous-Upper Cretaceous boundary to be in the Georgetown Formation of central Texas and the Main Street Limestone of northern Texas, but

Perkins (1960) considered this systemic boundary to occur in the Grayson Formation of north Texas. Mancini (1982) concurred with Perkins (1960), based on the occurrence of the mantellicerid ammonites *Mantelliceras* cf. *M. cantianum* Spath, 1926, *M. saxbii* (Sharpe, 1857), *Sharpeiceras mexicanum* (Böse, 1928) and a species of *Paracalycoceras*. Mantellicerid ammonites first appear close to the Albian-Cenomanian boundary in the Anglo-Parisian type area and in North America, and are used as a biostratigraphic indicator group for the earliest Cenomanian throughout most of Europe (Mancini, 1982). Based on these observations, the Washita Group ranges in age in Texas from late Albian (later part of the Early Cretaceous) to early Cenomanian (early part of the Late Cretaceous) in age.

Petty et al. (1995) reported the ostracode species *Eocytheropteron tumidum* (Alexander, 1929) to occur in the upper portion of the Washita-Fredericksburg in a well in the Viosca Knoll region of the OCS. Alexander (1929; 1933), Calahan (1939), and Kessinger (1974; 1982) reported the species to range from the upper Goodland to the top of the Kiamichi Formation (lowest formation of the Washita Group), but most commonly in the Kiamichi, although Garrison (1939) and Lozo (1943) reported occurrences of the species in the Duck Creek Formation (lowest Washita). As the Kiamichi Formation is of early Late Albian age and the specimen from Viosca Knoll occurred near the top of the Washita-Fredericksburg Group undifferentiated, this suggests the possibility that a considerable hiatus occurs in the upper portion of the Lower Cretaceous in the area.

Washita-Fredericksburg Stratigraphy from Regional Cross Sections

As stated previously, the Washita-Fredericksburg Groups undifferentiated is the stratigraphic interval between the top of the sandstones of the Paluxy Formation and the base of the Tuscaloosa Group. The Massive sand is recognized east of a line from Walthall County to Scott County, and the upper contact of the Washita-Fredericksburg Group undifferentiated is easy to recognize in that region. West of that line, however, the contact becomes very difficult to recognize on wireline logs. In this western area, the upper contact of the Lower Cretaceous is placed at the contact between underlying reddish shales and overlying glauconitic “Stringer” sands (Dickas, 1962), as observed on sample logs and from information from industry. The Washita-Fredericksburg is not recognized in the updip areas where the Paluxy Formation is not recognized.

The Washita-Fredericksburg is not recognized in the two wells in Issaquena County, where the Gas Rock apparently overlies undifferentiated Lower Cretaceous sediments, as indicated on a sample log from well 23-055-00066. The Washita-Fredericksburg is also not recognized in well 23-125-20004. The top of the Lower Cretaceous in well 23-125-20004 occurs near the top of an interval of alternating sandstones and shales, at the base of a 50-foot sandstone unit questionably regarded as the lower Tuscaloosa Formation. Well 23-049-20011 is similar to well 23-125-20004, in which the Washita-Fredericksburg is not recognized as a distinct unit and the top of the Lower Cretaceous is questionably placed at the base of a series of four sandstone units alternating with shales units. Very little data have been published on the stratigraphy of the Washita-Fredericksburg in the western portion of the MISB.

As with previously described stratigraphic units, discussion of the Washita-Fredericksburg will proceed from downdip to updip areas in dip section B-B'. The Washita-Fredericksburg in well 23-049-20032, located in southern Hinds County, is 1158 feet thick. The Washita-Fredericksburg is a predominantly shaley interval. The base of the unit is recognized at the base of a thick (250-foot) shale unit, and the top is questionably placed at the base of a relatively thin (30-foot) sandstone unit which occurs below the marine shale of the Tuscaloosa Formation. Data published on the subsurface stratigraphy of Copiah County, located immediately south of Hinds County, indicate that the base of the Tuscaloosa Formation is recognized at the base of massive, conglomeritic, porous sandstones (Dinkins, 1969). These sandstones form distinctive wireline log peaks that are readily recognized in the wells in southern Hinds County. The Copiah County data also indicate that Copiah County is updip of the subcrop limit of the Andrew limestones, which indicates that the Washita-Fredericksburg cannot be differentiated into the Andrew and Dantzler Formations in Hinds County.

The Washita-Fredericksburg in well 23-049-20005, the common well for sections A-A' and B-B', is 933 feet thick. The unit differs from the underlying Paluxy Formation only by a slight increase in shale unit frequency and thickness. The base of the Washita-Fredericksburg is recognized at the base of a 70-foot thick shale unit. The top of the formation is questionably placed at the base of a thick (120-foot), massive sand unit that may be near the western limit of the Massive sand of the Tuscaloosa Formation. The sandstone units in the Washita-Fredericksburg increase in thickness up-section, and are generally massive in character, casting doubt on whether the upper sandstone unit is actually the Massive sand of the

Tuscaloosa. This well is west of the western limit of the Massive sand as recognized by Dickas (1962). The Washita-Fredericksburg in well 23-089-20043, located in western Madison County, is 585 feet thick. The contacts of the formation in well 23-089-20043 are indistinct and the interval is recognized only by a slight increase in shale thickness compared to the Paluxy Formation. The base of the unit is recognized at the base of a thick (100-foot) shale unit. The top was recognized at the base of a fairly massive, 130-foot sandstone unit that is probably the same sandstone unit that is observed at the top of the Washita-Fredericksburg in well 23-049-20005. The interval is comprised of alternating beds of sandstone and shale approximately 60-80 feet in thickness.

The Washita-Fredericksburg in well 23-163-20150, located in southern Yazoo County, is 589 feet thick. The interval is distinguished from the Paluxy Formation by an increase in thickness of the shaley intervals. The base of the formation was recognized at the highest occurrence of a predominantly sandy interval of the Paluxy. The top of the formation was recognized at the base of a thick (120-foot), massive sandstone unit that is probably the equivalent of the sandstone unit noted for downdip wells. A lithologic log indicates that the Washita-Fredericksburg is comprised of reddish-brown and gray in part, silty, firm shale; and white, pink, and some red, fine-grained, moderately to loosely cemented, partly argillaceous, partly slightly calcareous sandstone.

The Paluxy and Washita-Fredericksburg are undifferentiated in each well updip of well 23-163-20150 in section B-B'. The interval between the top of the Mooringsport and the top of the Lower Cretaceous in well 23-163-00049 is 891 feet thick. The top of this interval is questionably placed at the base of a thick (100-foot) sandstone unit that is possibly equivalent to the massive sandstone unit observed in the wells further downdip in this dip section. A sample log for this well indicates that the top of the Lower Cretaceous should be placed at a depth of 7010 feet, which is approximately 288 feet higher in the well than where the contact is recognized herein. Considerable uncertainty remains as to the correct position of the top of the Lower Cretaceous in this well. The sample log indicates that the Paluxy-Washita and Fredericksburg interval is comprised of fine- to coarse-grained, porous sandstone, with some pink, fine-grained, porous sandstone; red, dark red and purple, micaceous shale; and gravelly sandstone with clear, amber, red and pink quartz pebbles and small gravel in lower part (basal gravel).

The interval between the top of the Mooringsport and the top of the lower Tuscaloosa (base of the marine shale) are undifferentiated in well 23-051-20036, located in southern Holmes County. This interval is 896 feet and comprised predominantly of sandstone. A sample log indicates that the interval between the top of the Cotton Valley and the top of the first definite Tuscaloosa is comprised of dark-red, slightly sandy shale; white, nodular limestone; pastel mudstone; fine- to coarse-grained, porous, noncalcareous sandstone; and clear and amber quartz pebbles in the lower part (basal gravels). The interval between the top of the Cotton Valley and the top of the Lower Cretaceous is an interval 2461 feet thick that is difficult to distinguish. The upper contact of the Lower Cretaceous is questionably placed at the base of a 120-foot, massive sandstone unit. A sample log indicates that the upper portion of this interval is comprised of light to dark gray, yellow, and purple, soft, silty, sandy shale; and clear, white, and light gray, very-fine- to fine-grained, unconsolidated, partly lignitic sandstone. The interval between the top of the Cotton Valley and the top of the Lower Cretaceous in well 23-083-20011, located in southeastern LeFlore County, is very similar to that in well 23-051-20036. This interval is 1050 feet thick and is comprised essentially of alternating beds of sandstone and shale.

The Washita-Fredericksburg interval in well 23-121-20025, located in north-central Rankin County, is 945 feet thick, and is characterized by alternating beds of subequal amounts of sandstone and shale. The interval is distinguished from the Paluxy Formation by an increase in thickness of the shaley intervals. The lower contact is recognized at the top of a thick (100-foot) sandstone unit in the upper Paluxy. The top of the formation is questionably placed at the base of the first well-developed sandstone unit below the marine shale of the Tuscaloosa Formation. The Massive sand of the Tuscaloosa was not recognized in this well, which represents the eastern-most well for which the Massive sand is not recognized.

The Washita-Fredericksburg in well 23-129-00178, located in northern Smith County, is 900 feet thick. The base of the formation is recognized at the top of the predominantly sandy section of the Paluxy Formation. The contact between the Paluxy and Washita-Fredericksburg is lithologically transitional. The upper contact is recognized at the base of the Massive sand, which is 110 feet thick in this well. Most of the Washita-Fredericksburg is characterized by alternating beds of sandstone and shale of subequal thickness. The upper 300 feet, however, is dominated by sandstones, with 20- to 30-foot sandstone units separated by

10-foot thick shale units, casting some doubt as to the position of the top of the Lower Cretaceous. A lithologic log indicates that the Washita-Fredericksburg interval is comprised of red, sandy shale; and gray, very-fine-grained, loosely consolidated, shaley, calcareous in part, sandstone, with a trace of lignite.

The Washita-Fredericksburg is recognized in most wells in dip section C-C'. The Massive sand is generally well developed in this dip section, thus adding confidence to recognition of the upper contact. One exception is the most down dip well, well 23-065-20141, where the Massive sand is not recognized. The lower contact in this well is recognized at the base of a 320-foot, predominantly shaley interval in the lower Washita-Fredericksburg. The upper contact is not recognized but may occur in the interval between depths of 9280 and 9500 feet. Sandstones occur below the base of the marine shale in this interval. The lower 850 feet of this interval is predominantly shale and may represent the updip equivalent of the Andrew Formation, although no lithologic or sample logs are available to confirm the occurrence of limestone. The upper 1100 feet consists of alternating, thick (60-70 foot) sandstone and shale units, possible correlable with the Dantzler Formation.

The Washita-Fredericksburg in well 23-127-20055, located in extreme eastern Simpson County, is 1530 feet thick. The interval is recognized by the alternation of sandstone and shale units of subequal thickness (40-60 feet thick), particularly the lower 900 feet. The upper 600 feet of this section is generally sandier. This bipartite subdivision is similar to that observed in well 23-065-20141, with a lower, shalier interval overlain by a sandier interval. The lower contact is observed at the top of the predominantly sandstone interval of the Paluxy. The upper contact is recognized at the base of the well-developed Massive sand of the Tuscaloosa Formation. The Massive sand is also well developed in well 23-129-20122, located in south-central Smith County. The Massive sand in well 23-129-20122 is 140 feet thick. The Washita-Fredericksburg is 973 feet thick, which is considerably thinner than in well 23-127-20055, located downdip of 23-129-20122. The Washita-Fredericksburg is an indistinct unit in well 23-129-20122, being recognized by only a slight increase in the thickness of the shale units compared to the Paluxy Formation. The base of the unit is recognized at the base of a 65-foot shale bed, and again, the top is recognized at the base of the Massive sand. The Washita-Fredericksburg is predominantly sandstone, particularly the middle portion, with shale beds thicker in the upper and lower 200 to 300 feet.

The Washita-Fredericksburg in well 23-129-20006, the common well for sections A-A' and C-C' located in central Smith County, is 850 feet thick. The unit is recognized as an interval of alternating beds of sandstone and shale of variable thicknesses overlying a predominantly sandy section of the Paluxy and underlying the Massive sand of the Tuscaloosa. The upper and lower contacts are distinct in this well, with a well-developed section of Massive sand (approximately 350 feet thick). A lithologic log indicates that the Washita-Fredericksburg is comprised of white, clear, and red, very-fine- to medium-grained, unconsolidated to moderately cemented sandstone; red, silty, sandy shale, in part light to dark gray, silty, sandy shale; and with a trace of lignite. The Washita-Fredericksburg is thick (1151 feet) in well 23-129-20057, located also in central Smith County, than in well 23-129-20006. The increase in thickness in well 23-129-20057 compared to the downdip well is due to the decreased thickness of the lower Tuscaloosa Formation. The Massive sand in well 23-1290-20057 is not as distinct as in the downdip well. A sandstone unit below what is interpreted herein as the Massive sand is approximately the same thickness as the Massive sand in the downdip well but includes several distinct shale units which do not typically occur in that unit. The upper contact of the Washita-Fredericksburg in well 23-129-20057 is, therefore, questionable, and is possibly at a stratigraphically higher position than in well 23-129-20006. The Washita-Fredericksburg is characterized by alternating beds of subequal thicknesses (40-100-foot) of sandstone and shale.

The Massive sand in well 23-129-00015, located in extreme northeastern Smith County, is also indistinct. The lower contact of the Washita-Fredericksburg, however, is distinct, and recognized at the base of a 125-foot shale bed. The shale units in the Washita-Fredericksburg are thicker than those in the underlying Paluxy Formation, particularly in the lower half of the formation. The unit is 984 feet thick in well 23-129-00015. The Washita-Fredericksburg in well 23-101-20005, located in southern Newton County, is 1058 feet thick. The unit is recognized by alternating beds of sandstone and shale, as contrasted with the predominantly sandstone interval of the Paluxy. The Massive sand is distinct in this well, being 150 feet thick, thus the contacts of the Washita-Fredericksburg in well 23-101-20005 are easily recognized. A sample log from a nearby well indicates that the Washita-Fredericksburg is comprised of red, light red, dark red, brown and ochre shale and mudstone; fine- to coarse-grained, porous and non-porous sandstone; and clear, yellow, and pink quartz pebbles in the lower part of the section. The interval between the top of

the Mooringsport and the top of the Lower Cretaceous is difficult to differentiate in the most updip well in this dip section, well 23-101-00014, located in central Newton County. The Massive sand is, however, distinct in this well, being approximately 200 feet thick. The interval from the top of the Mooringsport Formation to the top of the Lower Cretaceous is approximately 1587 feet thick and is characterized by alternating beds of sandstone and shale.

The Washita-Fredericksburg is recognized in most of the wells in section A-A' between sections C-C' and D-D'. The Washita-Fredericksburg in well 23-129-00061, located in extreme eastern Smith County, is 1214 feet thick. The upper portion of the Washita-Fredericksburg and the lower portion of the Tuscaloosa Formation are similar to that in the central Smith County wells, in which the Massive sand is only moderately distinct, and sandstone and conglomerates predominate in the upper portion of the Washita-Fredericksburg, thus casting doubt on the exact placement of the base of the Massive sand. The thick (350-foot) sandstone unit in the upper portion of the Washita-Fredericksburg contains several shale units. This is a characteristic not typical of the Massive sand. In addition, the entire coarse siliciclastic interval is approximately 540 feet thick, which is thicker than the maximum thickness of the massive sand as observed by Dickas (1962), which occurs in Greene and George Counties. The Massive sand as recognized in well 23-129-00061 is approximately 140 feet thick. The lower contact is recognized at the base of a 70-foot shale unit at the top of the predominantly sandy section of the Paluxy Formation. The Washita-Fredericksburg is characterized by alternating beds of sandstone and shale.

The Washita-Fredericksburg in well 23-061-20203, located in southwestern Jasper County, is 1328 feet thick. The unit is characterized by alternating beds of sandstone and shale. The upper contact is distinct. The lower contact is recognized at the base of a 65-foot shale unit overlying the predominantly sandy section of the Paluxy. A sample log from a nearby well indicates that the Washita-Fredericksburg is comprised of dark red and maroon, finely micaceous shale; light gray, pale green and ochre mudstone; and very-fine to fine-grained, nonporous, slightly calcareous sandstone. The Washita-Fredericksburg in well 23-061-20028, located also in southwestern Jasper County, is very similar to that in well 23-061-20203. The unit is 1450 feet thick, and is characterized by alternating beds of sandstone and shale. The base of the unit is recognized at the base of a 120-foot shale unit overlying the predominantly sandy interval of the Paluxy Formation. The top of the Washita-Fredericksburg is recognized at the base of the 350-foot, well-

developed Massive sand. The unit is nearly identical in well 23-061-20244, located in extreme south-central Jasper County. The formation in this well is 1564 feet thick. A lithologic log for a nearby well indicates that the Washita-Fredericksburg is comprised of dark gray, light gray, red, and brown, micaceous, silty in part, limonitic in part, shale; and white, clear, fine-grained, unconsolidated, occasionally light gray and very-fine-grained, well cemented sandstone.

The Washita-Fredericksburg in well 23-067-20002, located in extreme northeastern Jones County, is not easily recognized. The lower contact is apparently faulted out of the section (see previous section on Paluxy Formation). The Massive sand is not recognized. The top of the Lower Cretaceous is questionably placed at the base of several sandstone units below the Marine Tuscaloosa. The interval between depths of 9540 to 7575 feet (1965 feet thick) is characterized by alternating beds of sandstone and shale of subequal thickness (ranging from approximately 40 to 70 feet thick), similar to the Washita-Fredericksburg. This interval is, however, much thicker than the Washita-Fredericksburg in other wells in the area.

The Andrew and Dantzler Formations are recognized in the two downdip wells in dip section D-D'. The combined thickness of the two formations is 2729 feet. The Andrew Formation is 1640 feet thick. A lithologic log indicates that the basal part of the formation is comprised of dark gray, gray, and white, dense, chalky, "pseudo-oolitic" in part, limestone. No lithologic or sample log is available for the upper portion of the Andrew or the Dantzler Formation. The Dantzler Formation is 1089 feet thick and is characterized by alternating beds of sandstone and shale. The top of the Dantzler was recognized at the base of the Massive sand. The Andrew and Dantzler Formations are also recognized in well 23-111-00069, located in extreme southern Perry County. The thickness of both units combined is 1970 feet. The lower 1175 feet, herein interpreted as the Andrew Formation, displays SP values close to the base line, and is apparently shaley, but no lithologic or sample log was available for confirmation. The upper 795 feet, interpreted as the Dantzler Formation, includes a much greater amount of sandstone, although the lower half of the interval is still predominantly shale. The top of the Dantzler is recognized at the base of the Massive sand, which is distinct and very thick (approximately 500 feet).

The Washita-Fredericksburg in well 23-153-20077, located in southern Wayne County, is 1868 feet thick. The entire interval is a fairly uniform alternation of sandstone and shale units and is undifferentiated. The lower contact of the Washita-Fredericksburg is lithologically transitional with the

Paluxy Formation. The upper contact is recognized at the base of Massive sand of the Tuscaloosa Formation. The Washita-Fredericksburg in well 23-153-01008, the common well for sections A-A' and D-D', located in central Wayne County, is 1923 feet thick. The lower contact is recognized at the base of a thick (230-foot) shale unit. The upper contact is recognized at the base of the distinctive Massive sand. The lower 450 feet is predominantly shale, with one 80-foot sandstone bed. The middle portion of the Washita-Fredericksburg is predominantly sandstone. The upper 600 of the unit includes several shale beds. A sample log indicates that the Washita-Fredericksburg in well 23-153-01008 is comprised of dark red and maroon shale; light gray and light green mudstone; green, red, and light red, very-fine- to medium-grained, porous to non-porous sandstone; and scattered clear quartz pebbles.

The Washita-Fredericksburg in well 23-153-20232, located in central Wayne County, is 1392 feet thick. The lower contact is not easily recognized because the Washita-Fredericksburg-Paluxy contact is lithologically transitional. The lower contact of the Washita-Fredericksburg was placed at the base of an 80-foot shale unit. The upper contact is recognized at the base of the 300-foot thick Massive sand. The Washita-Fredericksburg interval is sandier and the shale units are thinner (less than 40 feet thick) than in the downdip wells in this section. A lithologic log indicates that the Washita-Fredericksburg is comprised of green, clear, and gray, fine- to coarse-grained, loose to moderately cemented, partly glauconitic sandstone; and brick red, brittle, micaceous, hard shale. The Washita-Fredericksburg in well 23-153-20265 is shalier, including both shale bed frequency and thickness, than in well 23-153-20232. The Washita-Fredericksburg in well 23-153-20265 is 1525 feet thick. The lower contact is recognized at the base of an 80-shale bed. The upper contact is recognized at the base of the Massive sand of the Tuscaloosa. The Washita-Fredericksburg is comprised of alternating beds of sandstone and shale generally 30 to 100 feet thick. A sample log for a nearby well indicates that the Washita-Fredericksburg is comprised of bright red and dark red shale; fine-grained, slight porous to non-porous sandstone; and clear, yellow, and pink quartz pebbles.

The Washita-Fredericksburg in well 23-153-20042, located in northern Wayne County, is 1475 feet thick. The lower contact is recognized at the base of the alternating sandstone and shale section of the Washita-Fredericksburg. The upper contact is placed at the base of the Massive sand. The Massive sand is not easily recognized in this well because a very thick (800-foot) section in the upper portion of the

Washita-Fredericksburg is characterized by several 100-foot thick sandstone units separated by 10- to 40-foot thick shale beds. The Massive sand was interpreted to be the stratigraphically highest of these sandstone units. The lower half of the Washita-Fredericksburg includes thicker and more frequent shale units than the upper half of the unit. The Washita-Fredericksburg in well 23-023-20114, located in central Clarke County, is 1125 feet thick. As in the previous well, the upper portion of the Washita-Fredericksburg is characterized by thick, massive sandstone units separated by relatively thin shale beds. The Massive sand is recognized as the 260-foot thick uppermost massive sandstone unit in this interval, and the top of the Washita-Fredericksburg is placed at the base of this unit. The lower contact of the Washita-Fredericksburg is recognized at the base of a thick (140-foot) shale unit. The Washita-Fredericksburg is not recognized in well 23-023-00270, located in northern Clarke County. The interval between the top of the Mooringsport and the base of the Massive sand is only 737 feet thick. This interval is dominated by sandstone beds separated by shaley units. A lithologic log indicates that the interval between the top of the Mooringsport and the base of the Massive sand is comprised of brown and gray, fine-grained, friable sandstone with abundant shelly fossils, and brown and buff, brittle shale.

The Washita-Fredericksburg is recognized in each well in section A-A' between dip sections D-D' and E-E'. The Washita-Fredericksburg in well 23-153-20545, located in south-central Wayne County, is 1977 feet thick. The base of the unit is recognized at the base of an 80-foot shale unit overlying a predominantly sandy interval of the upper Paluxy Formation. The upper contact of the Washita-Fredericksburg is recognized at the base of the 280-foot thick Massive sand. The Washita-Fredericksburg is characterized by alternating beds of sandstone and shale. The sandstone units are generally thicker than the shale units. Shale beds are generally thicker in the upper and lower portions of the interval. A sample log from a nearby well indicates that the Washita-Fredericksburg is comprised of light red, light reddish-white, and green, fine- to medium-grained, slightly porous and non-porous sandstone; maroon and dark red shale; and pale-gray and light-ochre mudstone. The Washita-Fredericksburg in well 23-153-20122, located in southeastern Wayne County, is not easily recognizable. The unit as interpreted in this study is 1369 feet thick. The lower contact was recognized at the top of a 150-foot sandstone unit at the to of the Paluxy. The Washita-Fredericksburg differs very little from the Paluxy. The upper contact was recognized at the base of the Massive sand. The Washita-Fredericksburg is comprised of alternating beds of sandstone and shale of

variable thicknesses. The sandstone beds are generally thicker than the shale beds. The Washita-Fredericksburg in well 01-129-20024, located in northwestern Washington County, Alabama, is similar to that in well 23-153-20122. The unit in well 01-129-20025 is 1633 feet thick. The base of the Washita-Fredericksburg was recognized at the base of a 250-foot sandstone bed in the upper portion of the Paluxy. The top of the Washita-Fredericksburg was recognized at the base of the Massive sand, which is more easily recognized in 01-129-20025 than in 23-153-20122. The Washita-Fredericksburg is characterized in well 01-129-20024 by alternating beds of sandstone and shale, with the sandstone beds being generally thicker than the shale beds.

The Washita-Fredericksburg in well 01-129-20012, the common well for section A-A' and E-E', located in central Washington County, is 1690 feet thick. The base of the unit is recognized at the base of a 210-foot shale bed above the predominantly sandy section of the Paluxy. The upper contact is recognized at the base of the Massive sand. With the exception of the basal shale unit, the lower two-thirds of the Washita-Fredericksburg is predominantly sandy, whereas the upper one-third is alternating sandstone and shales, with one thick (120-foot) shale unit near the top of the unit. The unit is characterized by white and very light gray to reddish-orange, massive, indurated, moderately to strongly calcareous sandstone, with a trace of limestone; and reddish-brown clay or claystone.

The Washita-Fredericksburg in well 01-097-20299, located in the Hatter's Pond field of northeastern Mobile County, is largely missing due to faulting. The top of the Washita-Fredericksburg is recognized at the base of the Massive sand. The thickness of the Washita-Fredericksburg is not known, as the top of the Paluxy is not recognized. The few hundred feet of section below the base of the Massive sand is comprised of alternating beds of subequal thickness of sandstone and shale. The full thickness of 1945 feet of the Washita-Fredericksburg is recognized in well 01-097-20141, located in northern Mobile County. The base of the unit is recognized at the contact between the predominantly sandy section of the Paluxy and the alternating sand and shale section of the Washita-Fredericksburg. The upper contact is recognized at the base of the distinct Massive sand. The Washita-Fredericksburg interval in well 01-097-20141 is relatively thicker than the Paluxy, suggesting the possibility that the contact between the Washita-Fredericksburg and the Paluxy is at a stratigraphically lower (chronostratigraphically older) level than in the more updip wells. The Washita-Fredericksburg is characterized by alternating sandstones and shales, with most of the section

being comprised of subequal, but variable, thicknesses of sandstone and shale, although no sample or lithologic logs were available for confirmation of this interpretation. A four hundred foot interval in the upper third of the unit, however, is predominantly sandstone.

The Washita-Fredericksburg in well 01-097-20134, located in north-central Mobile County, is 2078 feet thick. The unit displays a bipartite subdivision, with the lower approximately half of the unit being predominantly shaley and the upper half being predominantly sandy. This two-fold subdivision suggests the possibility that the lower half represents the Andrew Formation and the upper half represents the Dantzler Formation. No sample or lithologic logs were available, however, to confirm the presence of carbonate rocks in the Andrew. The lower contact is recognized at the base of a 190-foot shale bed overlying the predominantly sandy section of the Paluxy. The upper contact of the Washita-Fredericksburg was recognized at the base of the Massive sand. The Washita-Fredericksburg in well 01-129-20051, located in southeastern Washington County, is 1845 feet thick. The lower contact is recognized at the contact between the predominantly sandy section of the Paluxy and the alternating sandstone and shale section of the Washita-Fredericksburg. The upper contact was recognized at the base of the Massive sand. The Washita-Fredericksburg is characterized by alternating beds of sandstone and shale, with the lower half containing more shale than the upper half. This bipartite subdivision suggests that the Washita-Fredericksburg interval may be divisible into the Andrew and the Dantzler Formations, although no lithologic or sample log was available to confirm the presence of carbonates in the lower half (Andrew) of the interval. The Washita-Fredericksburg in well 01-129-20012, the common well for sections A-A' and E-E', was described previously.

The Washita-Fredericksburg in well 01-023-20197, located in southwestern Choctaw County, is the most updip well in section E-E' for which the full thickness (1433 feet) of the Washita-Fredericksburg is recognized. The interval displays a tripartite subdivision. The lower approximately half of the unit includes several relatively thick (60-90-foot) shale beds. A 550-foot section in the upper portion of the unit is predominantly sandy, and the upper approximately 300 feet is relatively shaley. The lower contact is recognized at the base of a 90-foot shale bed overlying the predominantly sandy section of the Paluxy. The upper contact is easily recognized at the base of the Massive sand. A large section (top of the Haynesville to base of the Massive sand of the Tuscaloosa) is not recognized in well 01-023-20114, located in central

Choctaw County, due to faulting and the absence of recognizable lithostratigraphic markers. The base of the Massive sand is recognized at the base of a 170-foot, massive sand unit below the Marine shale. There are, however, several thick sandstone units in the 800 feet below the Marine shale. The sandstone unit immediately below the Marine shale, however, displays a fining-upward wireline log pattern, which is not characteristic of the Massive sand. The Massive sand is interpreted to be the second sandstone unit below the Marine shale, which displays the wireline log pattern typical of the Massive sand.

Summary

The Washita-Fredericksburg Groups undifferentiated comprise a heterogeneous of lithologic interval between the top of the Paluxy Formation and the base of the Tuscaloosa Formation. In most of the MISB, the Washita-Fredericksburg is an interval of alternating sandstones and shales of subequal proportions between the top of the predominantly sandy section of the Paluxy Formation and the base of the Massive sand of the Tuscaloosa. West of a line connecting Walthall and Scott Counties, however, the Massive sand is absent, and the sands and shales of the Stringer sand of the Tuscaloosa overlie the sands and shales of the Washita-Fredericksburg, making recognition of the top of the Washita-Fredericksburg difficult. In downdip areas, generally downdip of most of the wells studied for this project, the lower portion of the Washita-Fredericksburg is comprised of carbonate rocks and is referred to as the Andrew Formation. This assignment follows the stratigraphic nomenclature of Eargle (1964). In these areas, the interval from the top of the carbonate to the base of the Massive sand represents the Dantzler Formation. In the areas not far updip from the Andrew Formation, the lower portion of the Washita-Fredericksburg is typically shalier than the upper portion. The Washita-Fredericksburg in areas updip of the limit of the Andrew Formation is referred to as the Washita-Fredericksburg Groups undifferentiated, although the strata in these areas are lithologically identical to the Dantzler. Contingent upon further study, the term Dantzler Formation should be redefined and confined to all the rocks between the top of the Paluxy and the base of the Massive sand, except where the Andrew Formation is present. The Washita-Fredericksburg in the MISB bears little resemblance to the rocks of the Washita and Fredericksburg Groups in Texas, which are predominantly carbonate sediments.

Although the presence of microfossils is described in several sample logs for the Washita-Fredericksburg interval, very little data have been published on the biostratigraphy of the unit in the MISB.

The Washita and Fredericksburg Groups of Texas are Late Albian to Early Cenomanian in age. The age of the Washita-Fredericksburg in the MISB is not precisely known. It is most probable that the unit is of Late Albian age. Published data from the near shelf-edge region of coastal Mississippi suggests that the upper portion of the Washita-Fredericksburg interval is of early Late Albian age, which implies that the upper portion of the Washita-Fredericksburg in the coastal Mississippi area is older than the upper portion of the Fredericksburg in Texas. Future studies of the micropaleontology of the Washita-Fredericksburg in the MISB are suggested to enable a more confident age determination of the unit.

Very little data have been published on the environments of deposition of the Washita and Fredericksburg Groups in the MISB. The Andrew Formation, due to the predominance of carbonate rocks and a diverse fossil assemblage, was deposited under relatively shallow, normal marine conditions, possibly as barrier bar systems. The Dantzler Formation was probably deposited under nonmarine, fluvial conditions, and consists of a stacked series of braided stream deposits. The sequence of lithologies from the Paluxy to the Dantzler Formations suggests that a sequence boundary occurs at the base of the Andrew, a transgressive systems tract occurs in the lower part of the Andrew, a maximum flooding surface occurs within the Andrew, an early highstand systems tract occurs either in the upper part of the Andrew or the lower part of the Dantzler (or both), and a late highstand systems tract is represented by much of the Dantzler Formation. This late Comanchean stratigraphic sequence thus ended Lower Cretaceous sedimentation in the MISB.

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Attachment 2

"Formation Top Database"

Mark Puckett, University of Alabama
David Kopaska-Merkel, Alabama Geological Survey
Steve Champlin, Mississippi Office of Geology

API	Vicksburg marker	Jackson (top Yazoo/ Shubuta)	Moodys Branch	Cook Mountain	Sparta (Kosciusko)	Cane River (Zilpha)	Wilcox	Midway marker (Porters Creek)	Gas Rock	Selma marker (Clayton)	Eutaw	Tuscaloosa marker	Marine shale	Lower Tuscaloosa	Lower Cretaceous (base massive sand)	Wash/Fred	Paluxy	Moorings	Ferry Lake	Rodessa	Pine Island	Sligo/ Hosston	Unconformity	Cotton Valley	Haynesville	Smackover	Norphlet	Louann Salt	Werner	Unconformity	Eagle Mills	Paleozoic
Strike Section A-A'																																
2305500032						1205	1585	2561	**3022**													3095		4713	7770	7977	8100					
2305500066						1253	1605	2702	**3172**				**3218**											4828	7845	8242	8500					
2312520004		163	385	750	860	1825	2320	4012	4532	**4600**		4885	5261	5480	**5713**			6925	7346	7582	8133	8343		10412	14319	14459	15288	15328				
2304920011		194	687	1190	1378	2320	2811	**5320**		6295	6942	7500	8170	8265	**8600**			10200	10635	10891	11348	11572		**14665**		17370	18380	18480				
2304920005*				660	792	1260	1630	2888	3045	3417	**3758**		4320	4475	**4744**		5677	7292	7640	7865	8564	8718		12060	16020	16631						
2312120025		95	420	732	905	1383	1878	**4300**		5092	6343	6883	7555	7888	**8025**		8970	**10257**		10500	10965	11231		13423	16590	18180	18700					
2312900178		75	350	573	830	1195	1590	**3943**		4575	5800	6177	6977	7175	**7697**		8597	9774	9920	10045	10445	10434		12580	15430	**18065**		18760				
2312920006*								**3920**		4597	5820	6165	7181	7312	**7942**		8795	**9764**		9979	10320	10434		**12260**		14432						
2312900061		115	370	606	678	1105	1500	**3955**		4545	5778	6365	7027	7215	**7576**		8790	**10068**		**10390**		11350		13005	15380	15780	17080	17148				
2306120203		315	582	820	970	1280	1677	**4172**		4725	5968	6322	7255	7443	**7830**		9158	**10475**		10845	11132	11300		13231	17218	**19100**		20487				
2306120028	460	495	660	904	975	1395	1860	**4425**		4985	6310	6695	7705	7830	**8270**		9720	**11255**		11625	12000	12146		14498	15948	16405	17573	17925				
2306120244	235	275	440	678	832	968	1440	**3910**		4525	5694	6628	7025	7205	**7628**		9294	**10600**		10915	11340	11560		13822	16406	16750	16855	16870				
2306720002								**3875**		4545	5810	6156	7277	**7420**				9548	9850	9983	10485	**10608**				11490	12285					
2315301008*	540	630	812	**1093**			2170	**4010**		4645	5998	6412	7357	7582	**7928**		9851	11216	11458	**11760**						13305	14182					
2315320545										4495	5825	6150	7050	7230	**7680**		9657	**10705**		**11227**		11810		13872	15680	15796	15926	16125				
2315320122	767	885	950	**1215**			1840	**3738**		4366	5808	6063	6942	7122	**7461**		8830	10550	10687	**10970**				13865	16960	21615	22508					
112920054											5163	5524	6246	6424	**6810**		8530	**10306**		**10504**					14620	16390	16911					
112920024	405	538	615	**820**			1307	**3220**		3830	4969	5316	5914	6094	**6512**		8145	**9030**		9210	9840	9983		11528	14473	16432	16864					
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Dip Section B-B'																																
2309320011								**2133**		2930	**3850**			4543	**4853**									5903	6528	6685	**7247**					7271
2305120020								**2786**		3628	**4545**			5271	**5460**									7921	8620	**8800**					9393	
2305120036								**3380**		4230	5150	5895	6185	6342	**6707**			**7238**		**7447**				8967	10755	**11000**					11730	
2316300049				482	589	1170	1705	**3797**		4660	5650	6345	6812	6962	**7370**			**8179**		**8303**				10195	12420	12930						
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Dip Section C-C'																																
2310100014								**2158**		2750	3686	4080	4983	5038	**5348**			**6700**		**6780**		7113		**8271**								8680
2310120005										3235	4270	4606	5544	5610	**5992**		7500	**8037**		**8145**				10042	11435	11862	**12150**		**12480**		12590	12738
2312900015								**3230**		3868	4980	5290	6223	6358	**6657**		7641	8694	8750	**8945**				11005	13501	14335	15060					
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Dip Section D-D'																																
2302300270								**1608**		2145	3100	3558	4290	4365	**4765**			**5502**		**5628**				7240	8988	**9060**						9165
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Dip Section E-E'																																
102320114										2648	**4015**		5580	5681	**6085**										11658	12224	12635					
102320197										2900	3944	4292	5203	5354	**5759**		7192	**8087**		**8246**				10488	12500	14003						
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112920051							3810	**5725**		6526	8001	8320	9057	9294	**9695**		11540	12404	**12748**		13279	**13452**			17514	19685	19933					
109720134											5887	6174	6864	7133	**7487**		9565	10674	**10890**		11590	11725		13470	16458	18612	18745					
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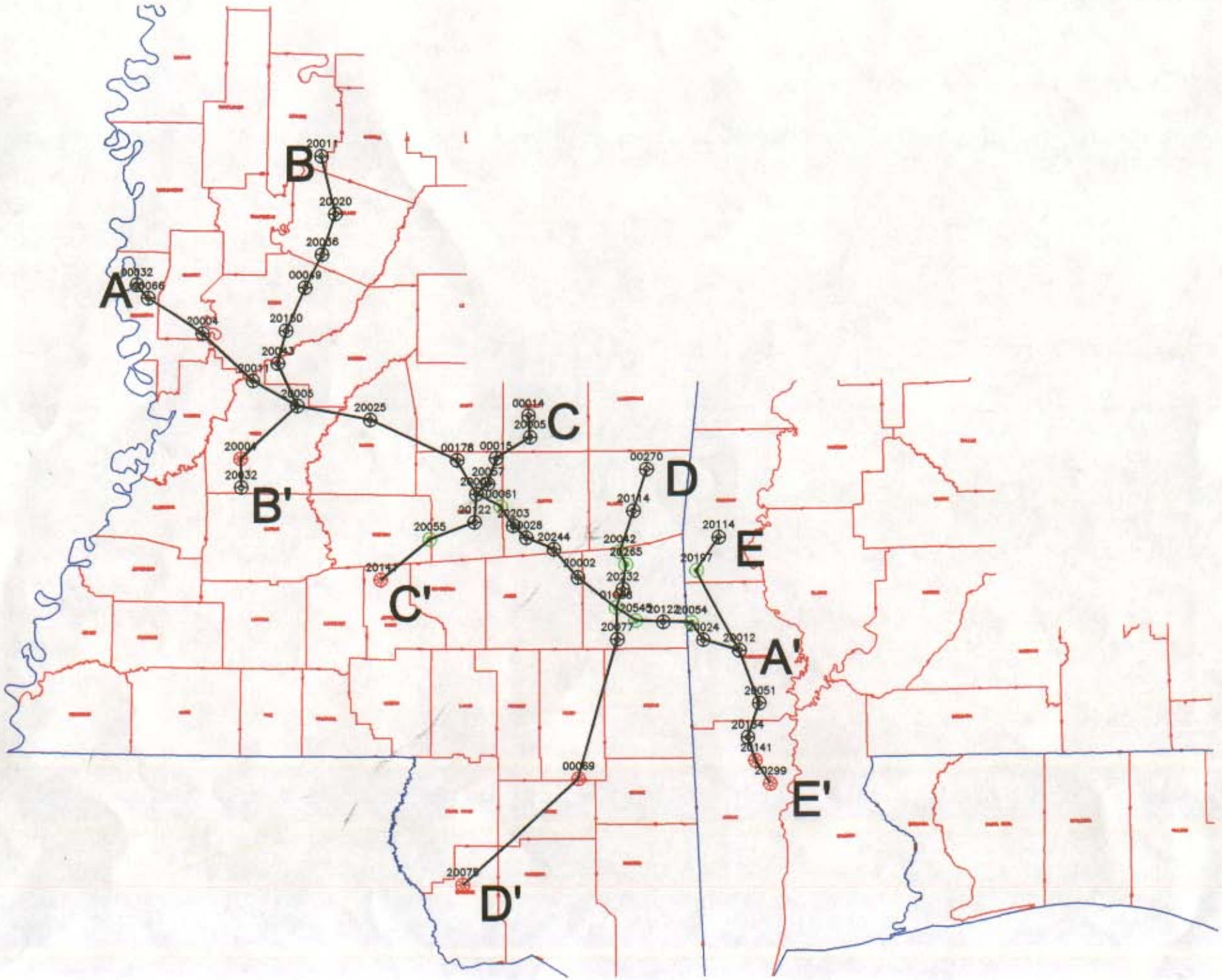
= NOT REACHED OR RECORDED BY LOG

= MISSING INTERVAL OR PICK NOT MADE BOLD ## = VALUE POSSIBLY COMPUTED WITH ADDITIONAL UNPICKED STRATA (UNREALISTIC THICK SECTION)

Attachment 3

"Regional Cross Sections"

Mark Puckett and Brian Panetta
University of Alabama


A
B
B'
C
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E
E'
A'
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20032
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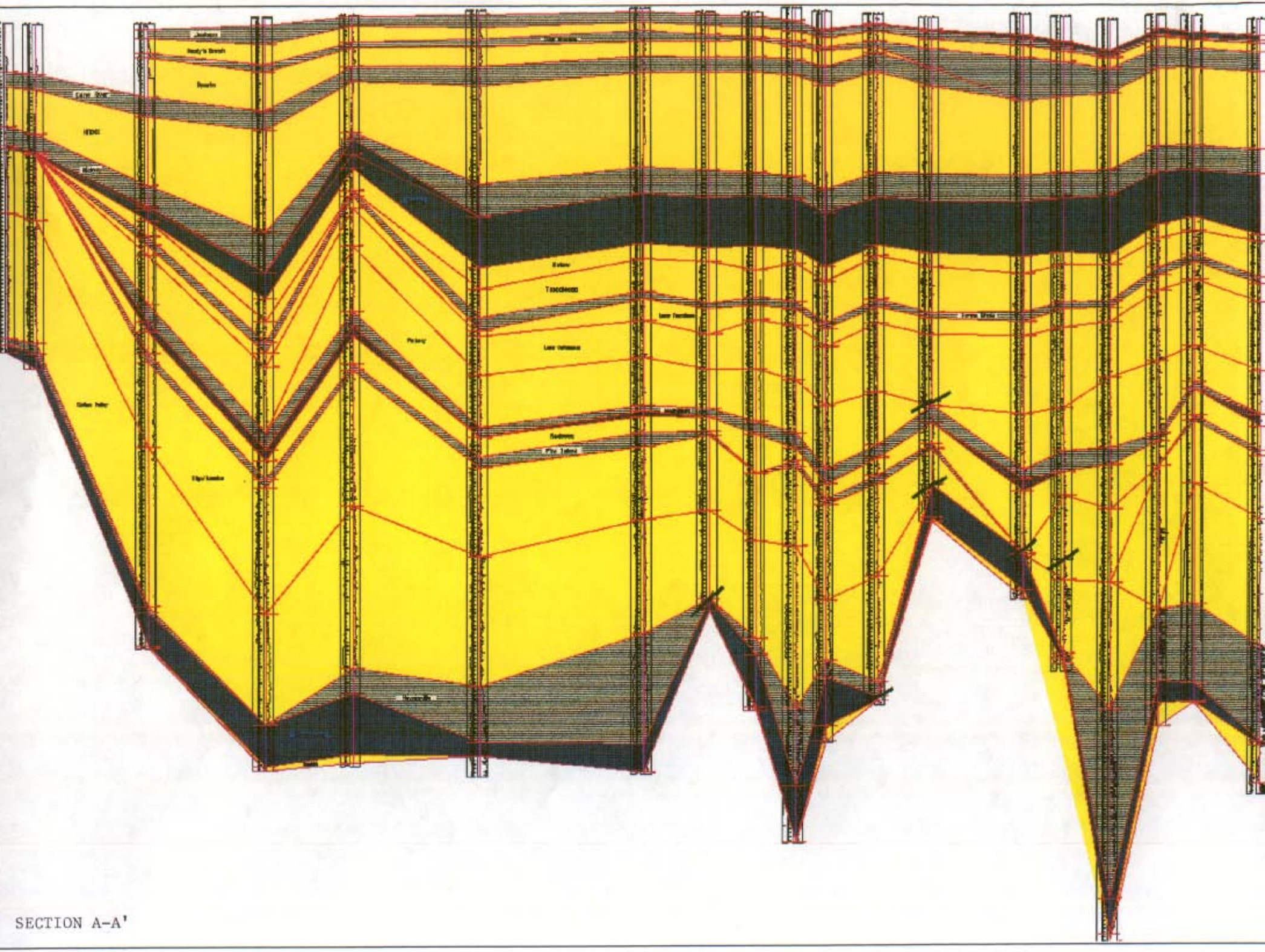
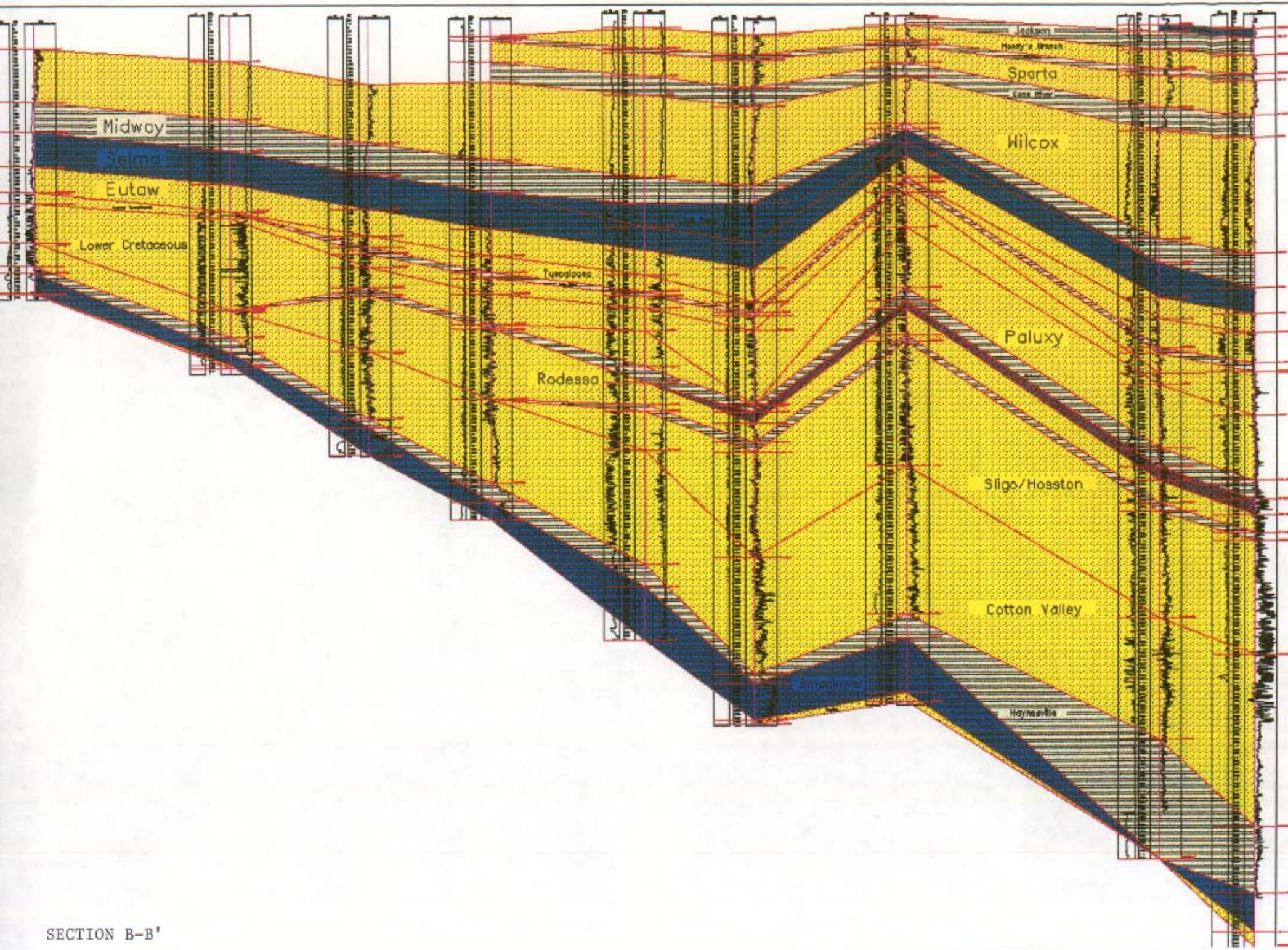
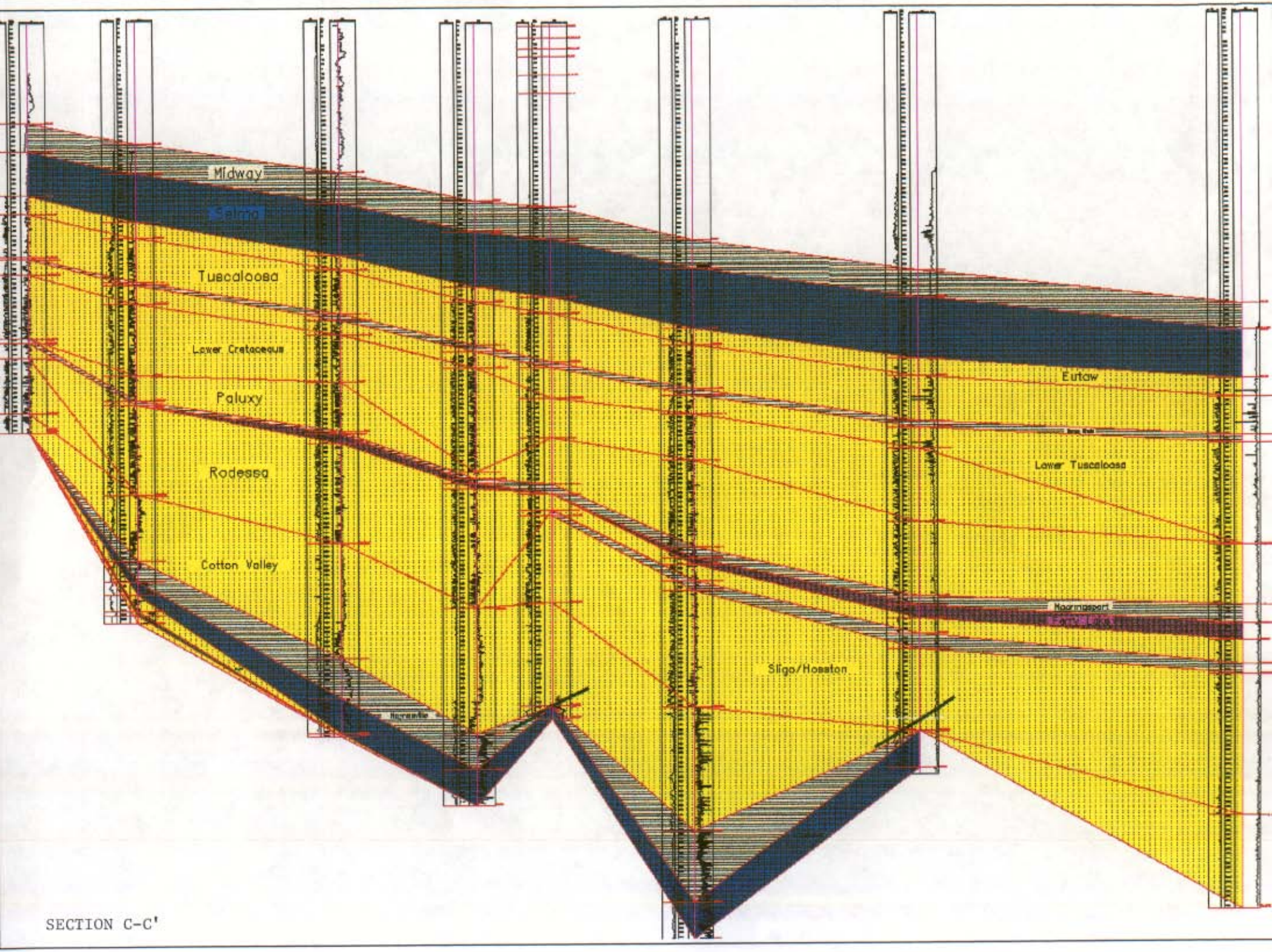


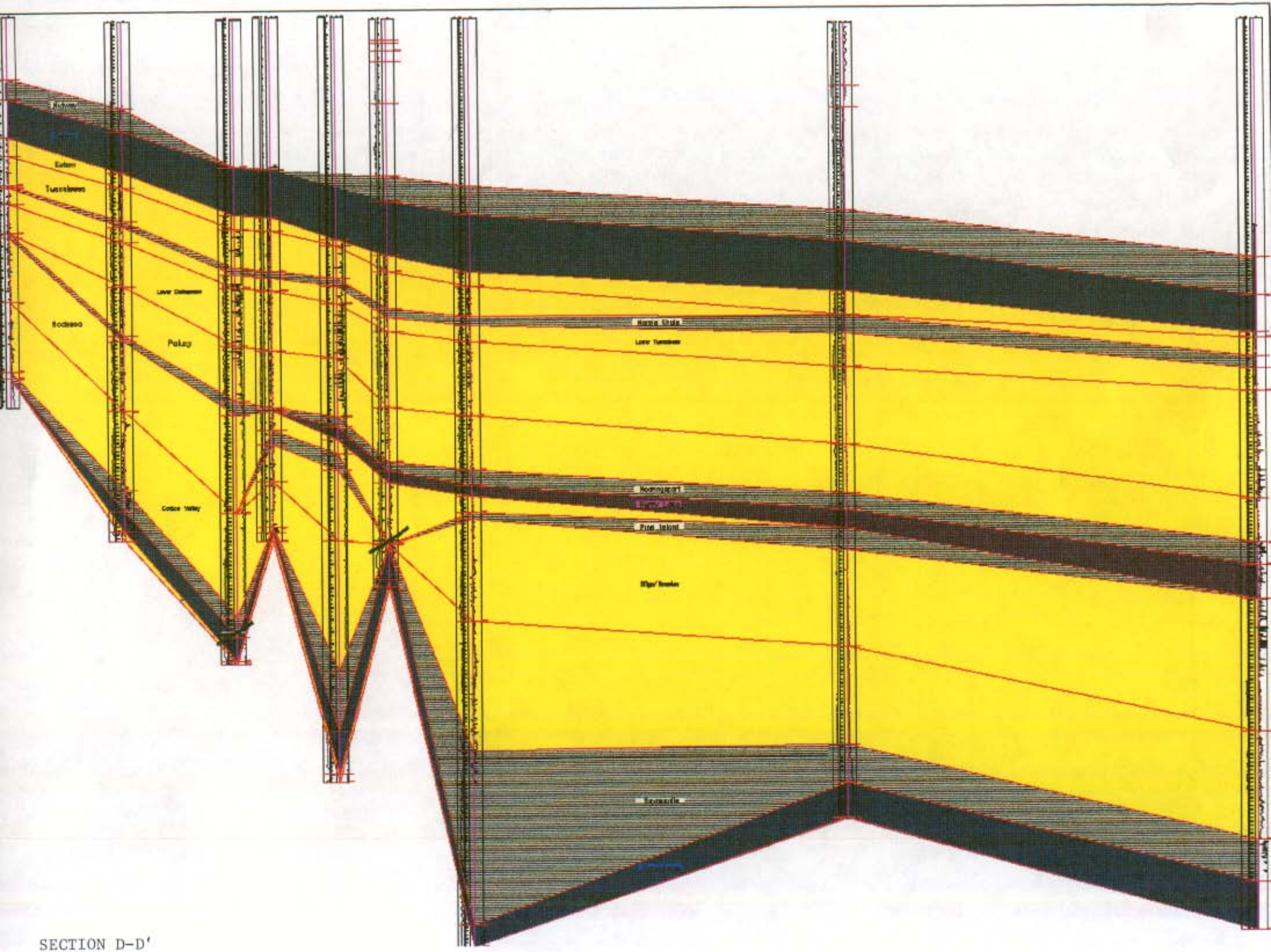
SECTION A-A'


Jackson
Hooty's Branch
Sparta
Cane River
Wilcox
Midway
Selma
Eutaw
Lower Cretaceous
Tuscaloosa
Paluxy
Rodessa
Sligo/Hosston
Cotton Valley
Haynesville

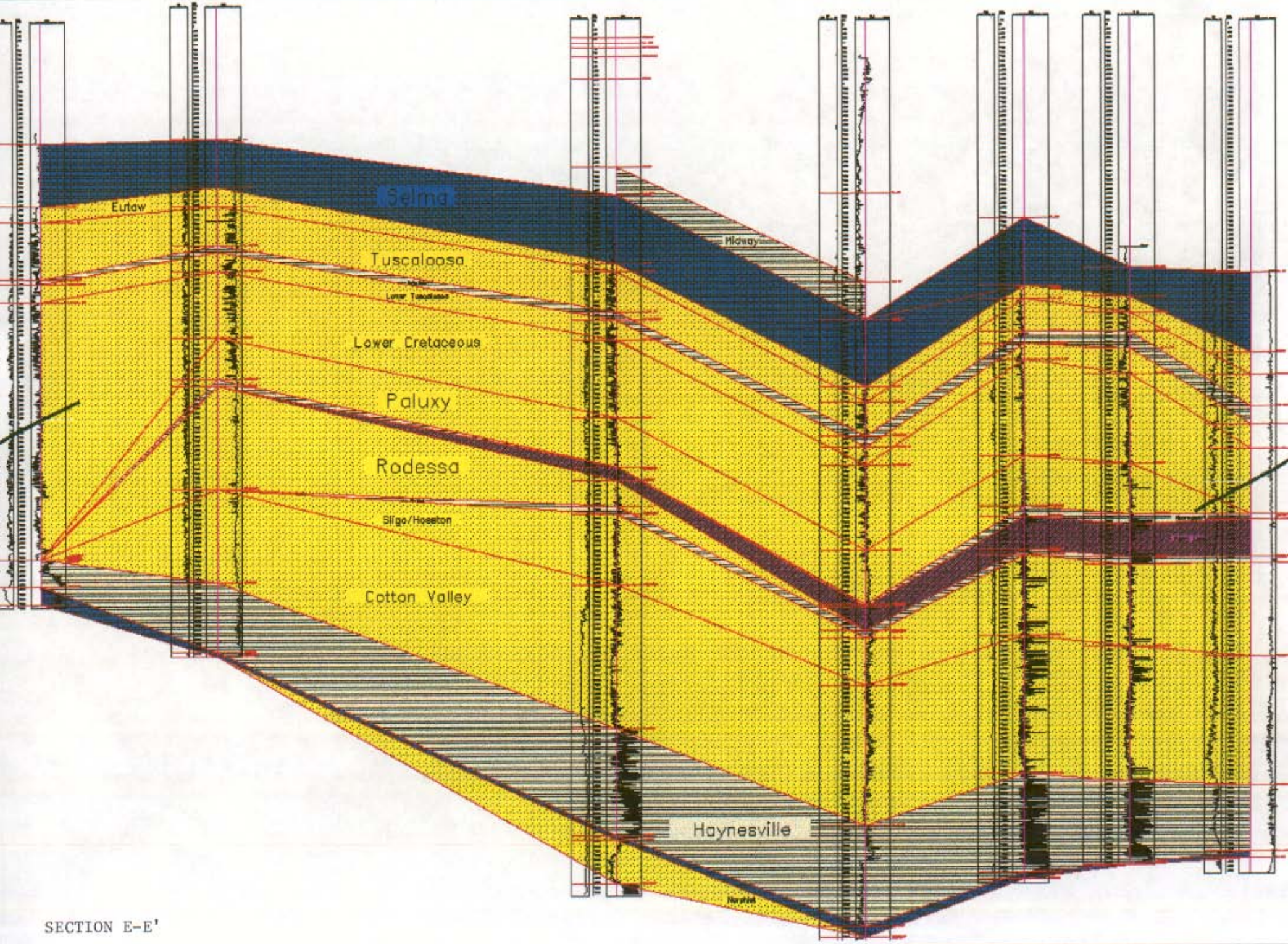
SECTION B-B'


Midway
Selma
Tuscaloosa
Lower Cretaceous
Paluxy
Rodessa
Cotton Valley
Eutaw
Lower Tuscaloosa
Hosston
Sligo/Hosston

SECTION C-C'


Eocene
Tuscaloosa
Lower Cretaceous
Rodessa
Paluxy
Cotton Valley
Hosston Shale
Lower Tuscaloosa
Hosston
Pine Island
Sligo/Hosston
Sunnyside

SECTION D-D'


Selma
Eutaw
Tuscaloosa
Lower Tuscaloosa
Lower Cretaceous
Paluxy
Rodessa
Sligo/Hosston
Cotton Valley
Haynesville
Midway

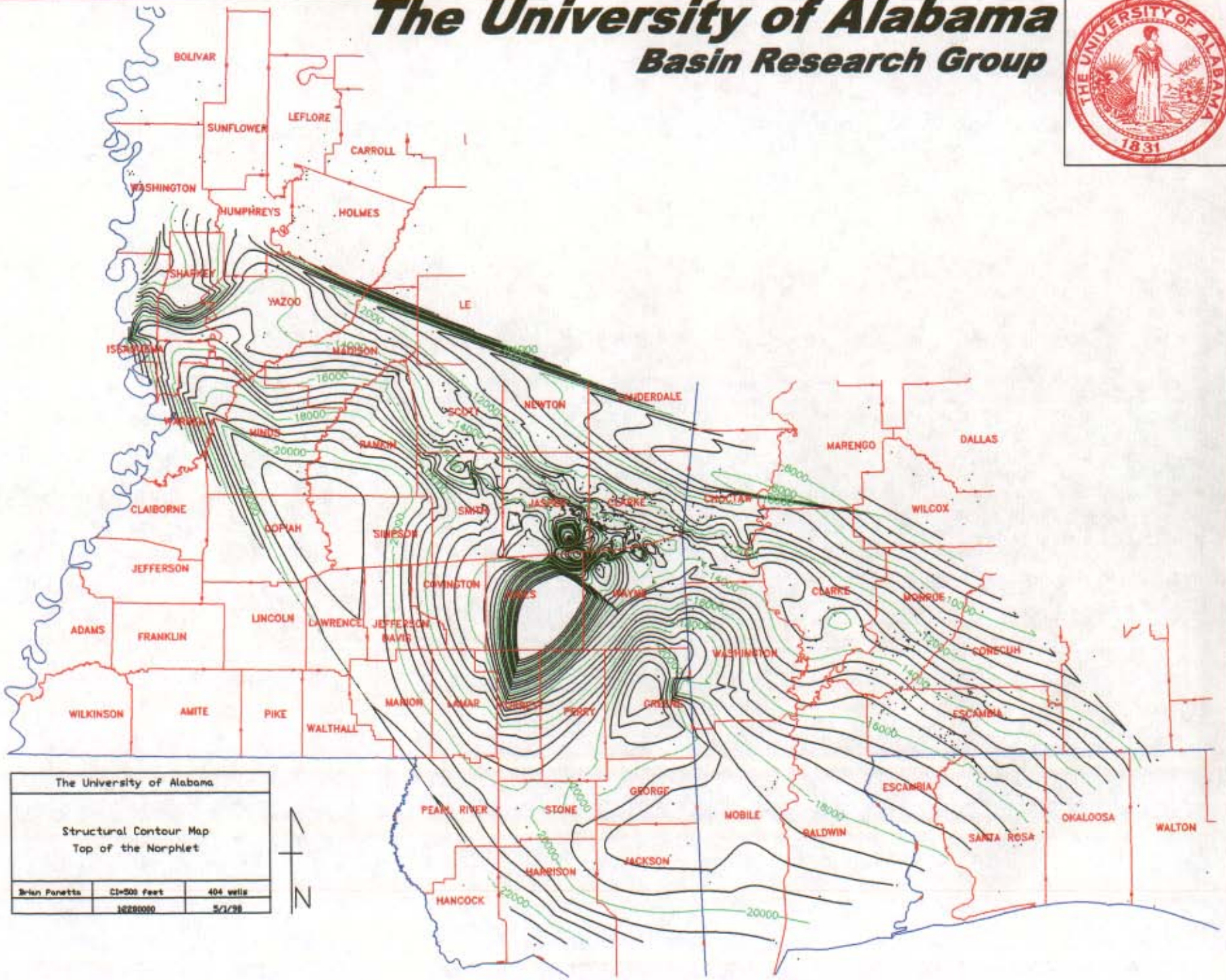
SECTION E-E'

Attachment 4

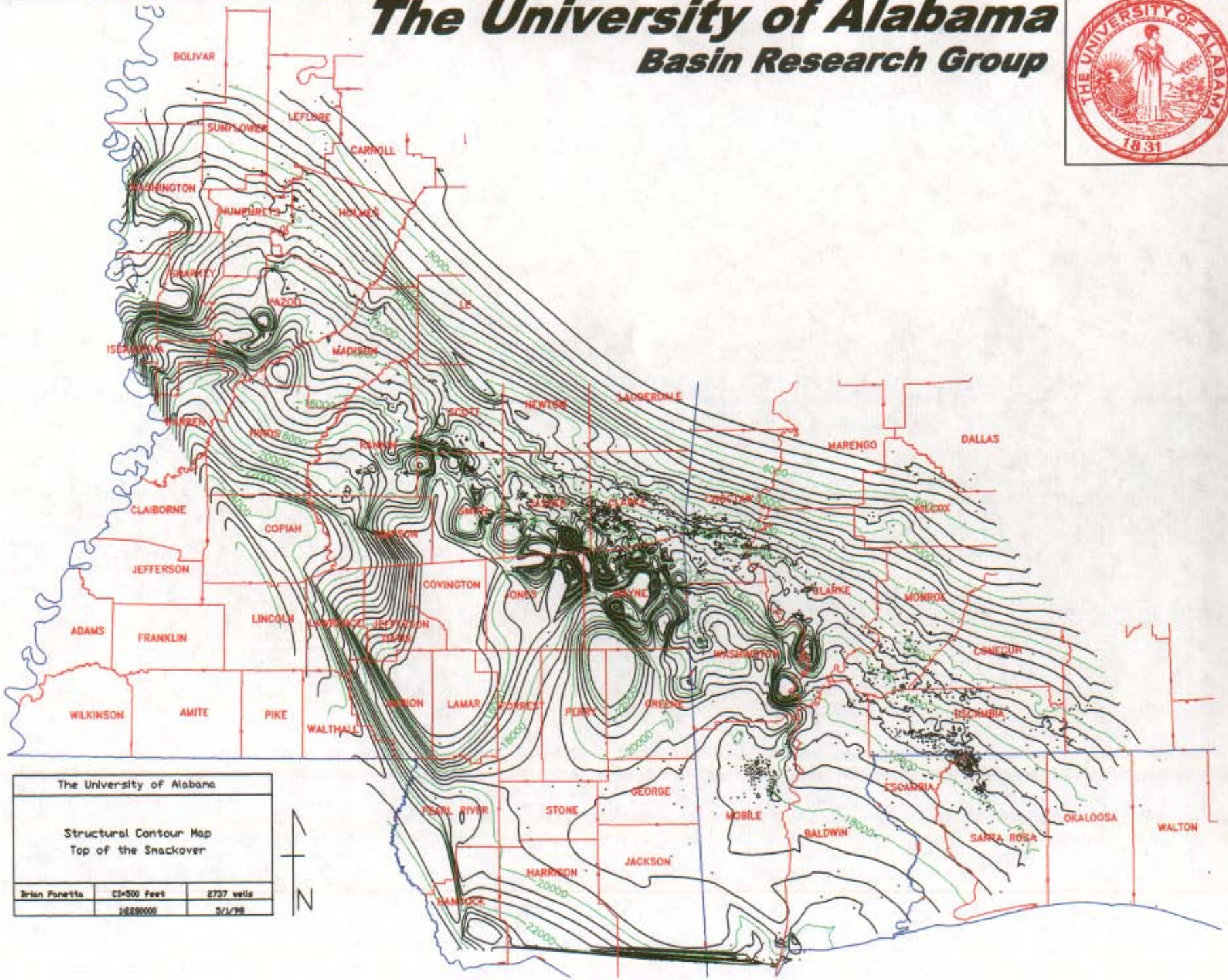
"Structure Maps"

Brian Panetta
University of Alabama

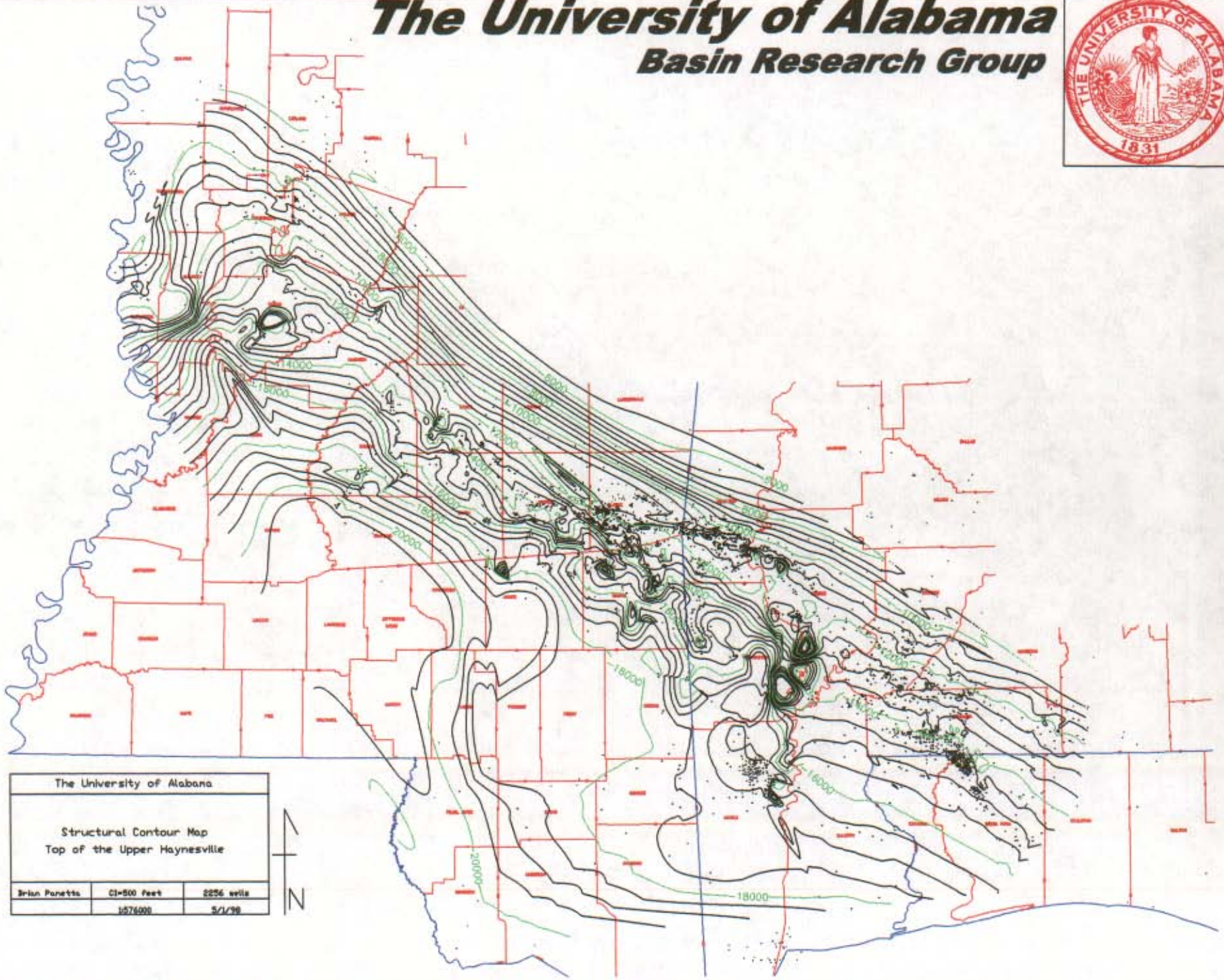
The University of Alabama
Basin Research Group



The University of Alabama
Basin Research Group



The University of Alabama
Basin Research Group



The University of Alabama
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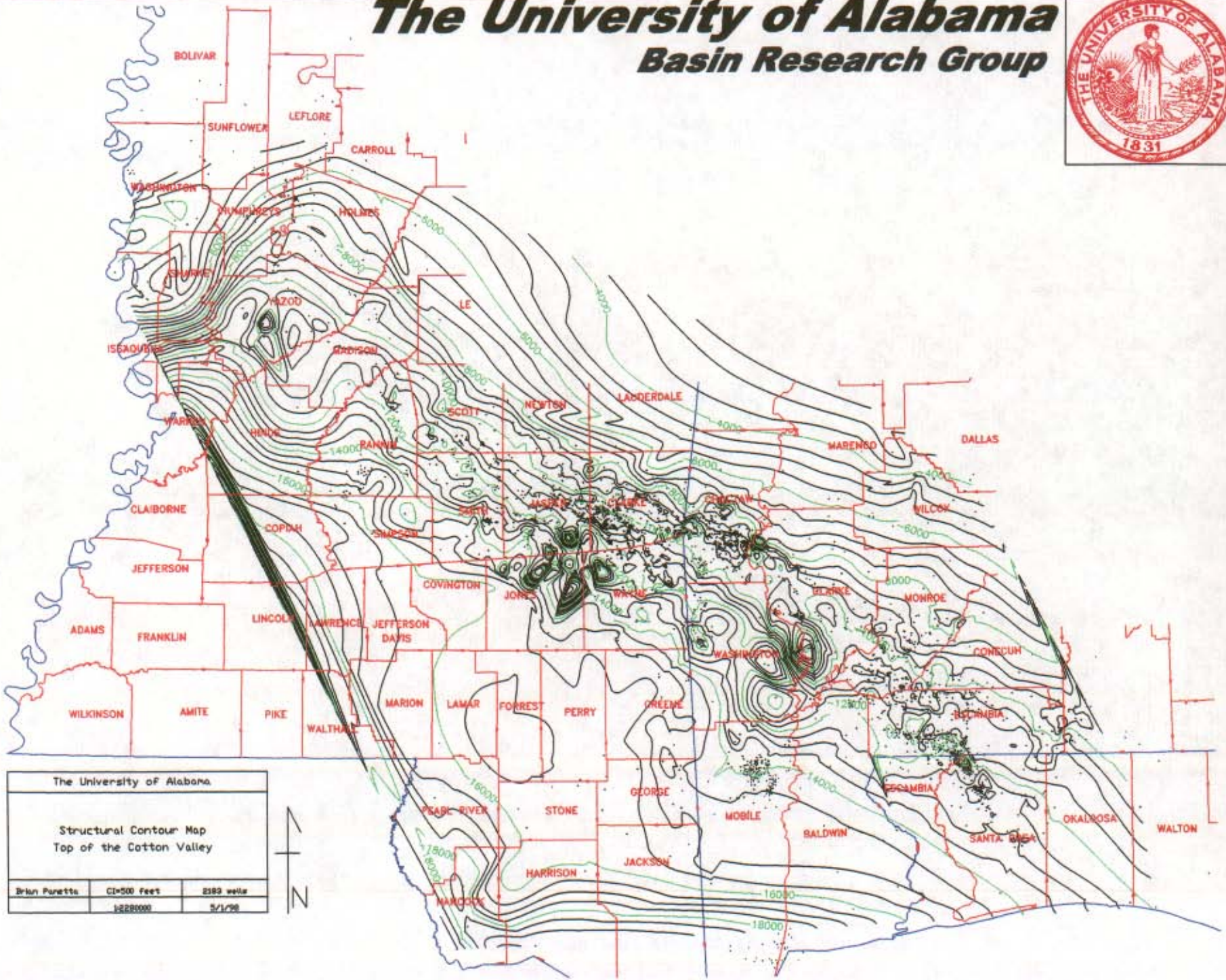
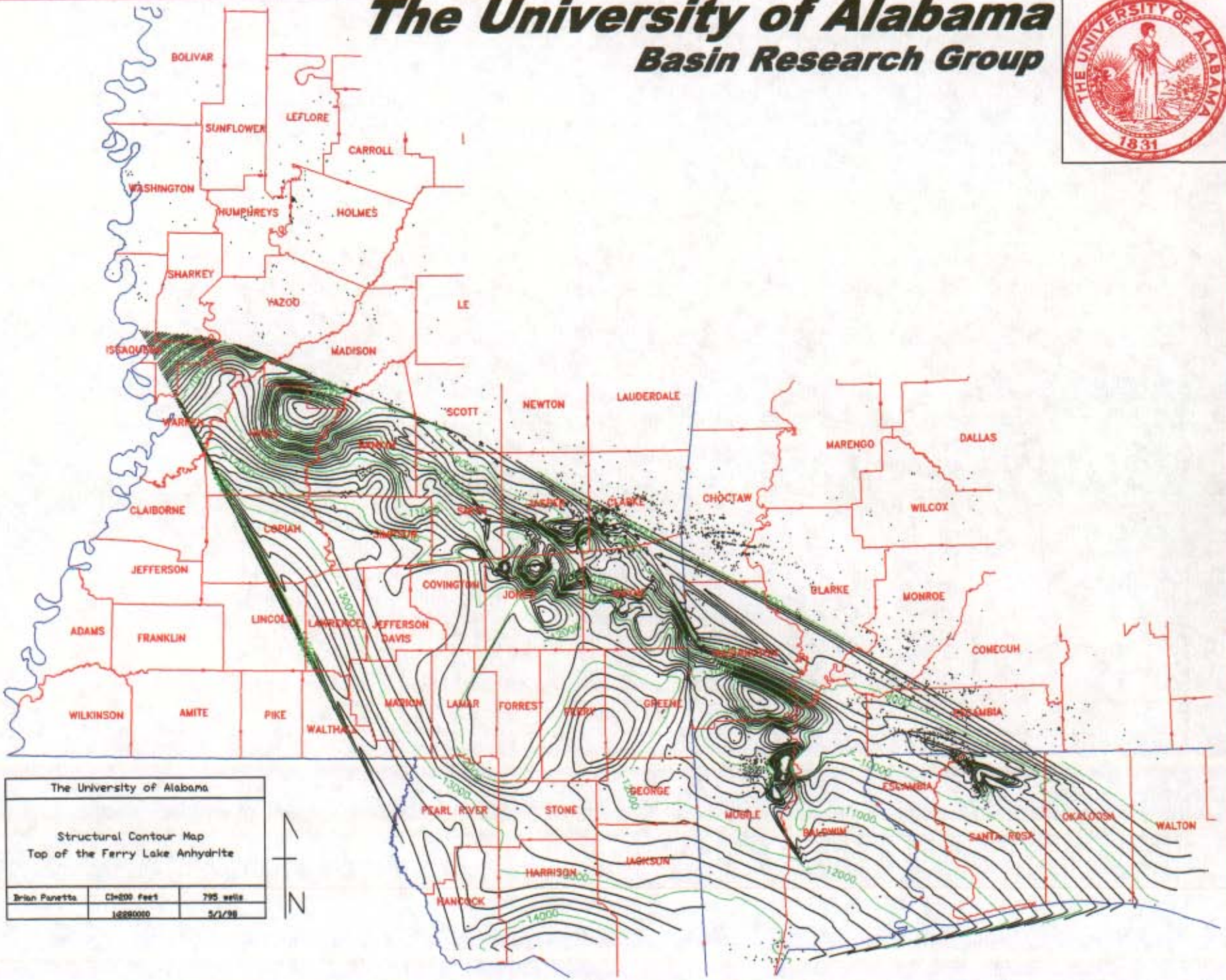


The University of Alabama
Basin Research Group



The University of Alabama
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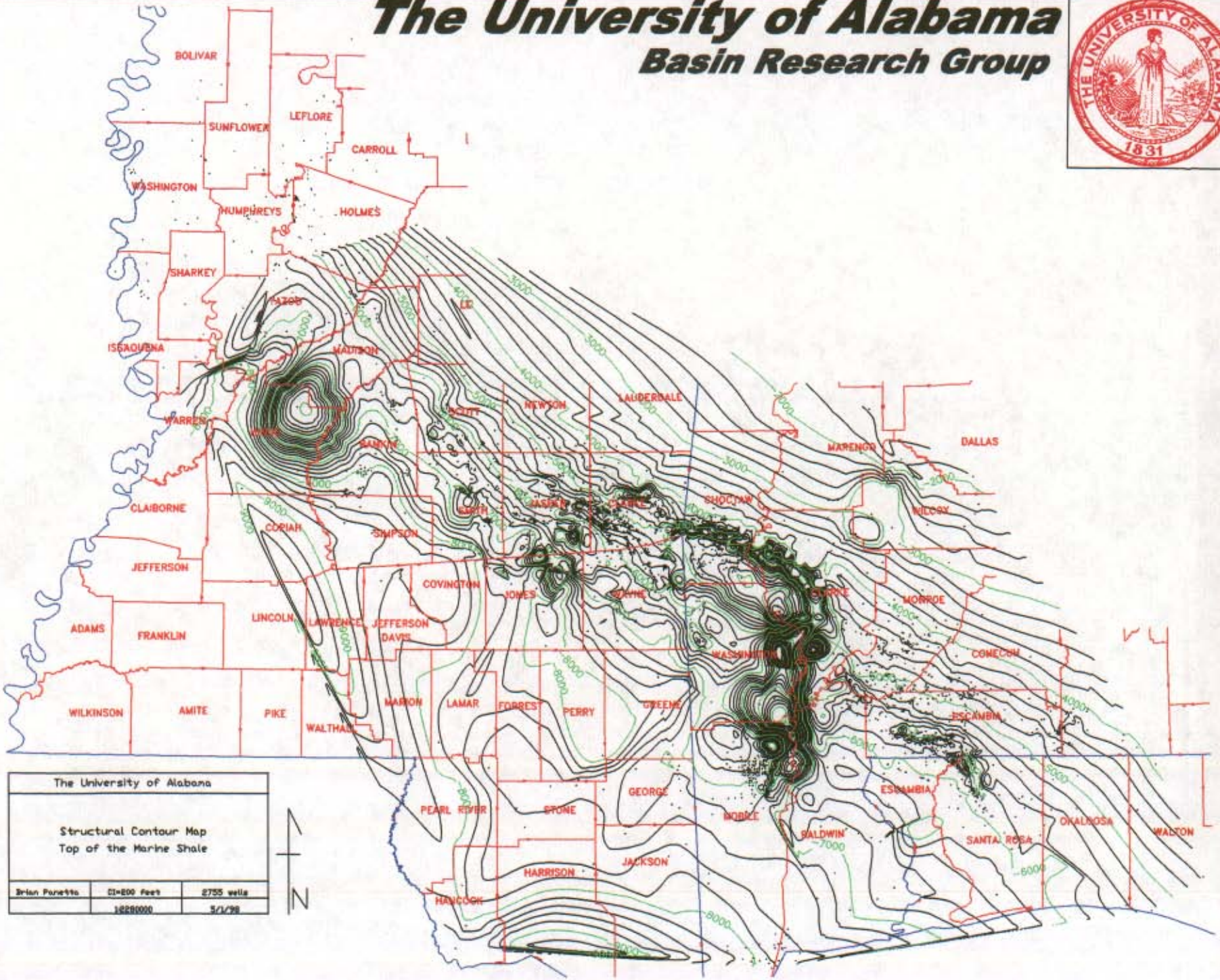

The University of Alabama
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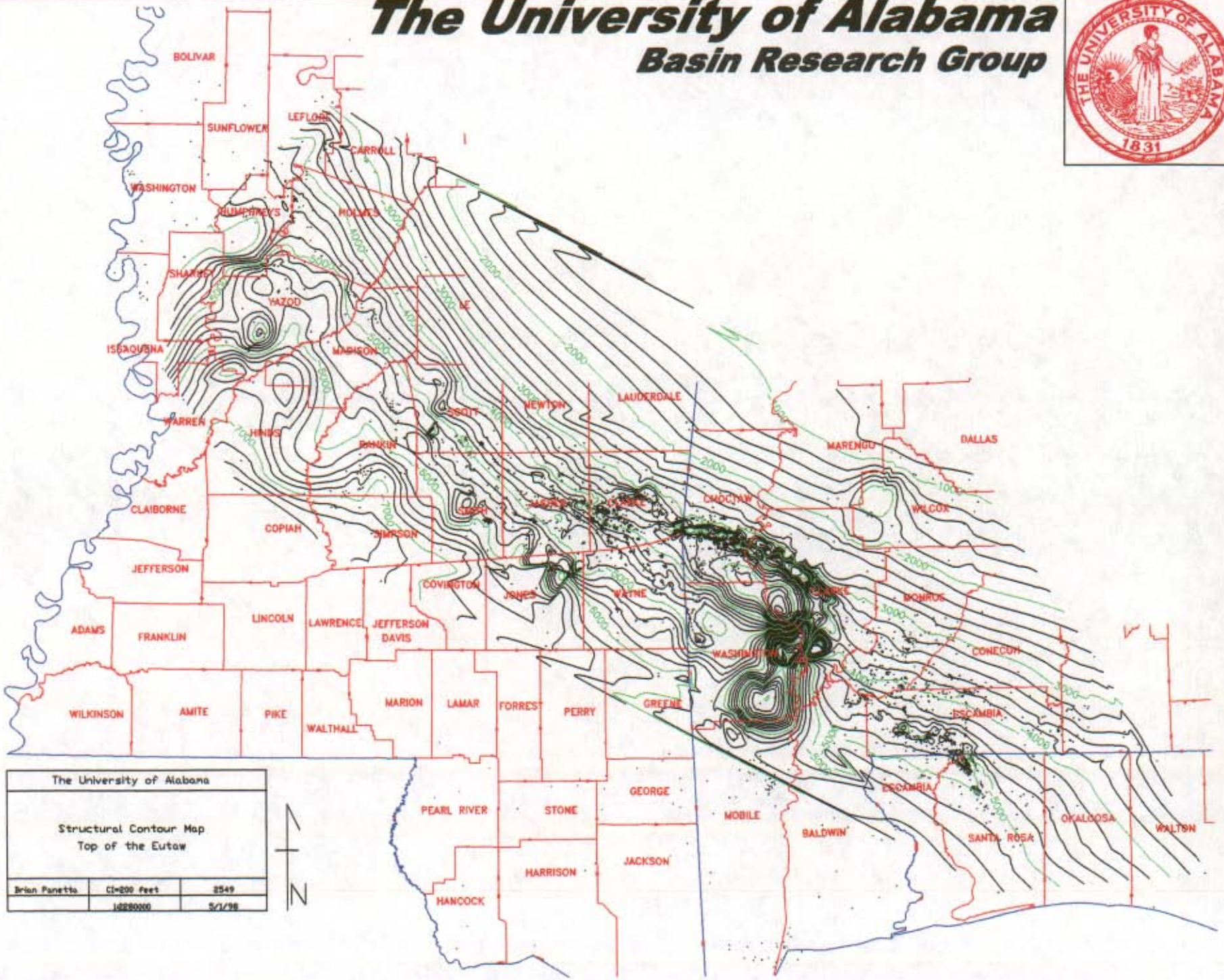
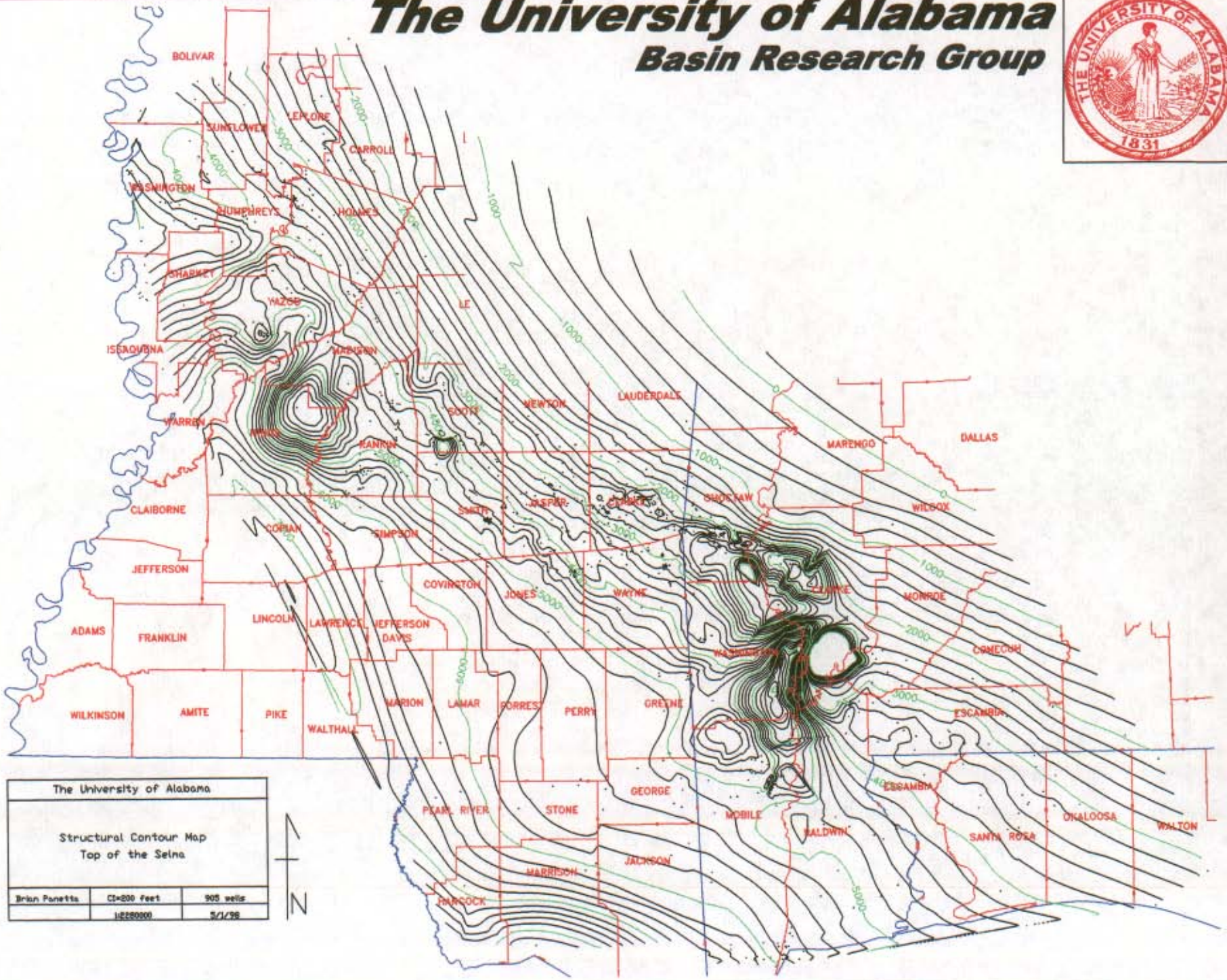
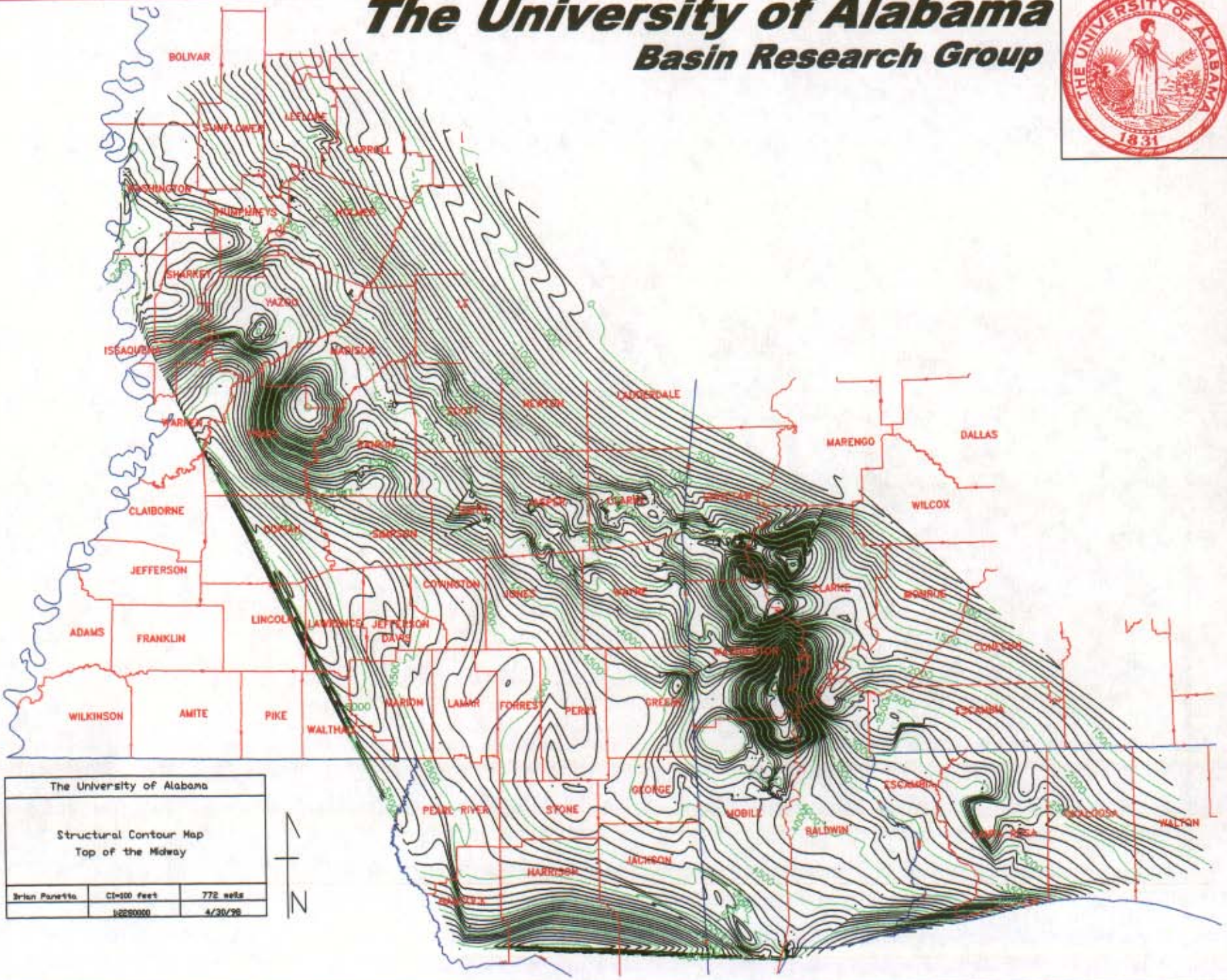


The University of Alabama
Basin Research Group



The University of Alabama
Basin Research Group



The University of Alabama
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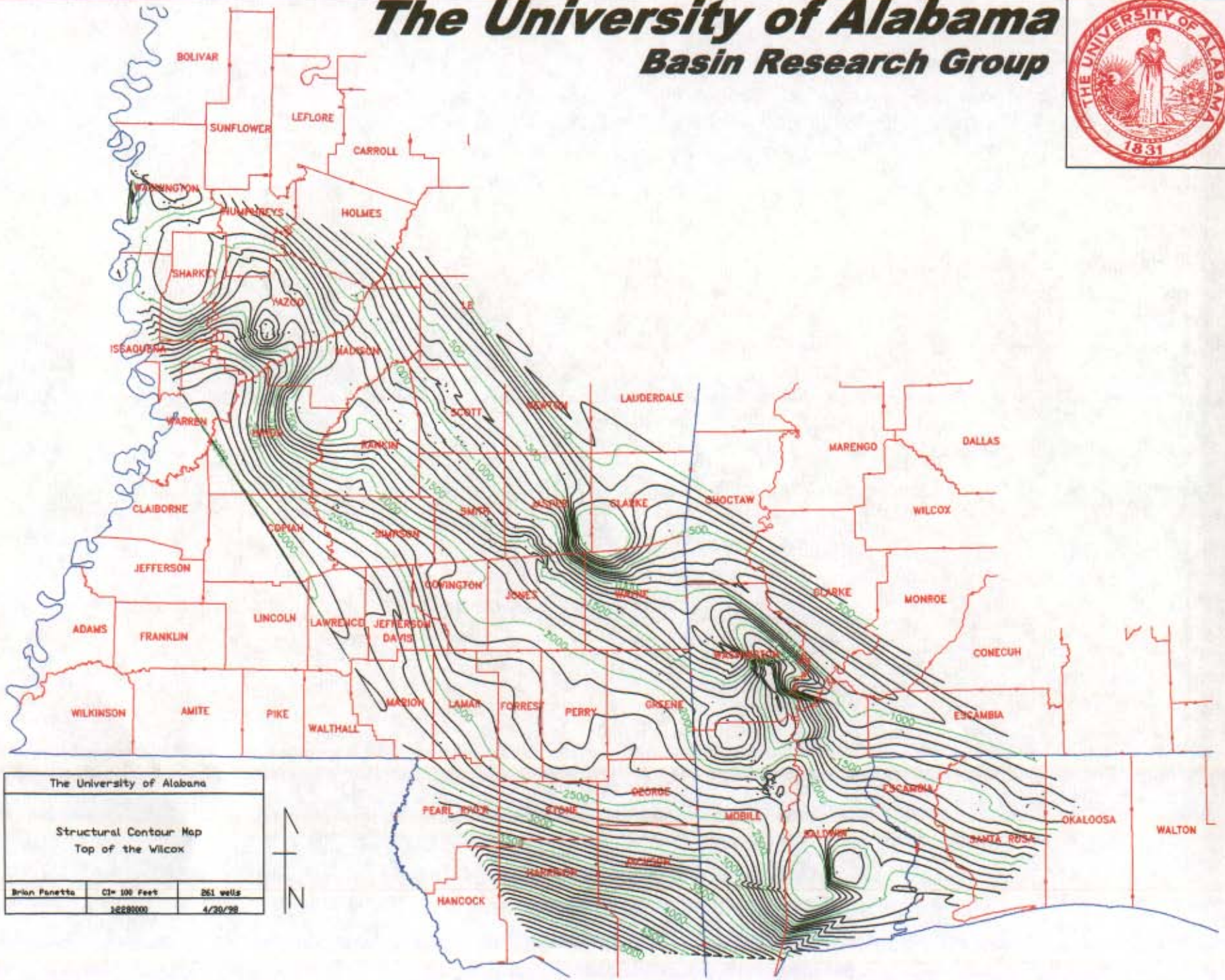


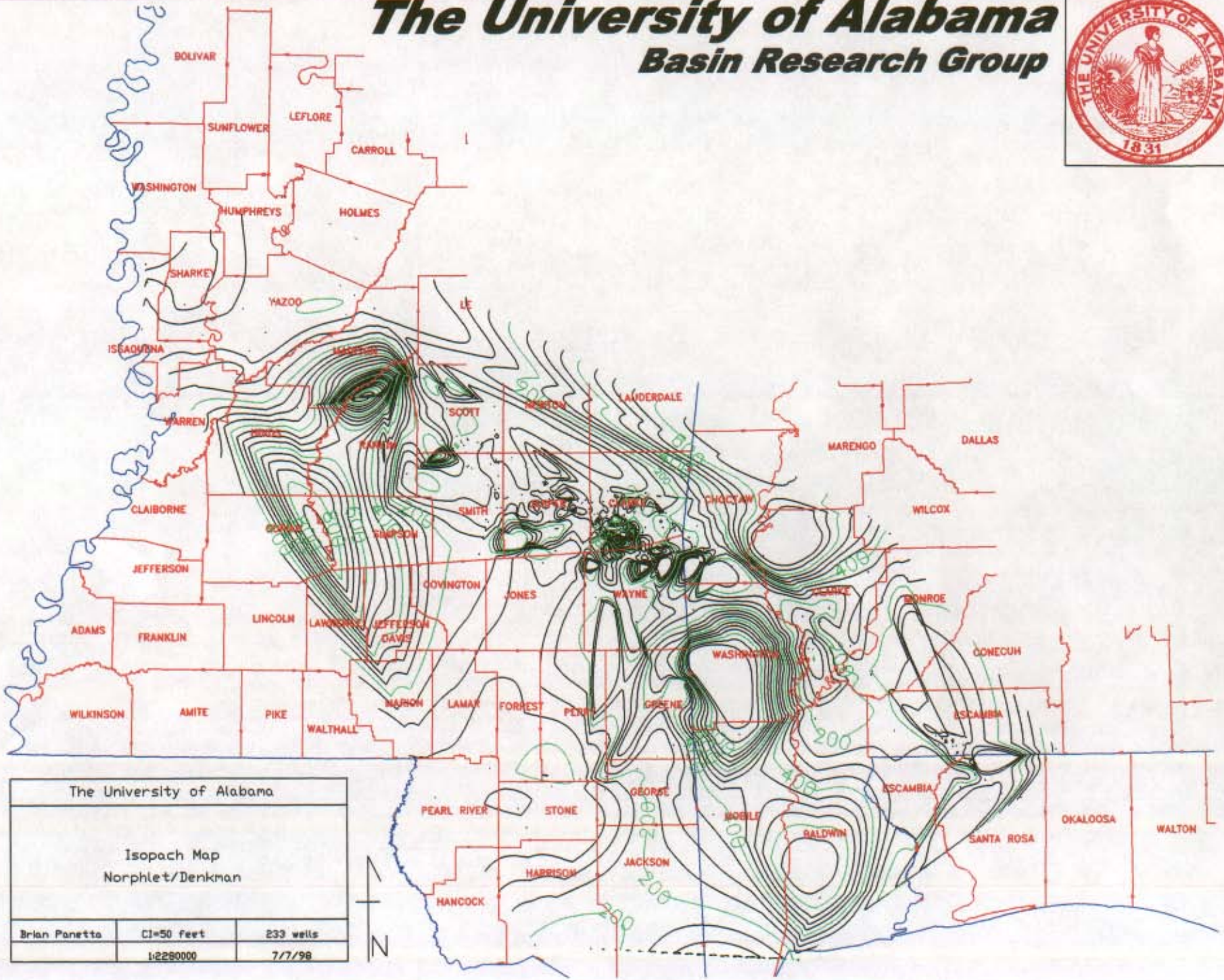
The University of Alabama		
Structural Contour Map Top of the Wilcox		
Brian Panetta	CI= 100 Feet	261 wells
	12280000	4/20/98

Attachment 5

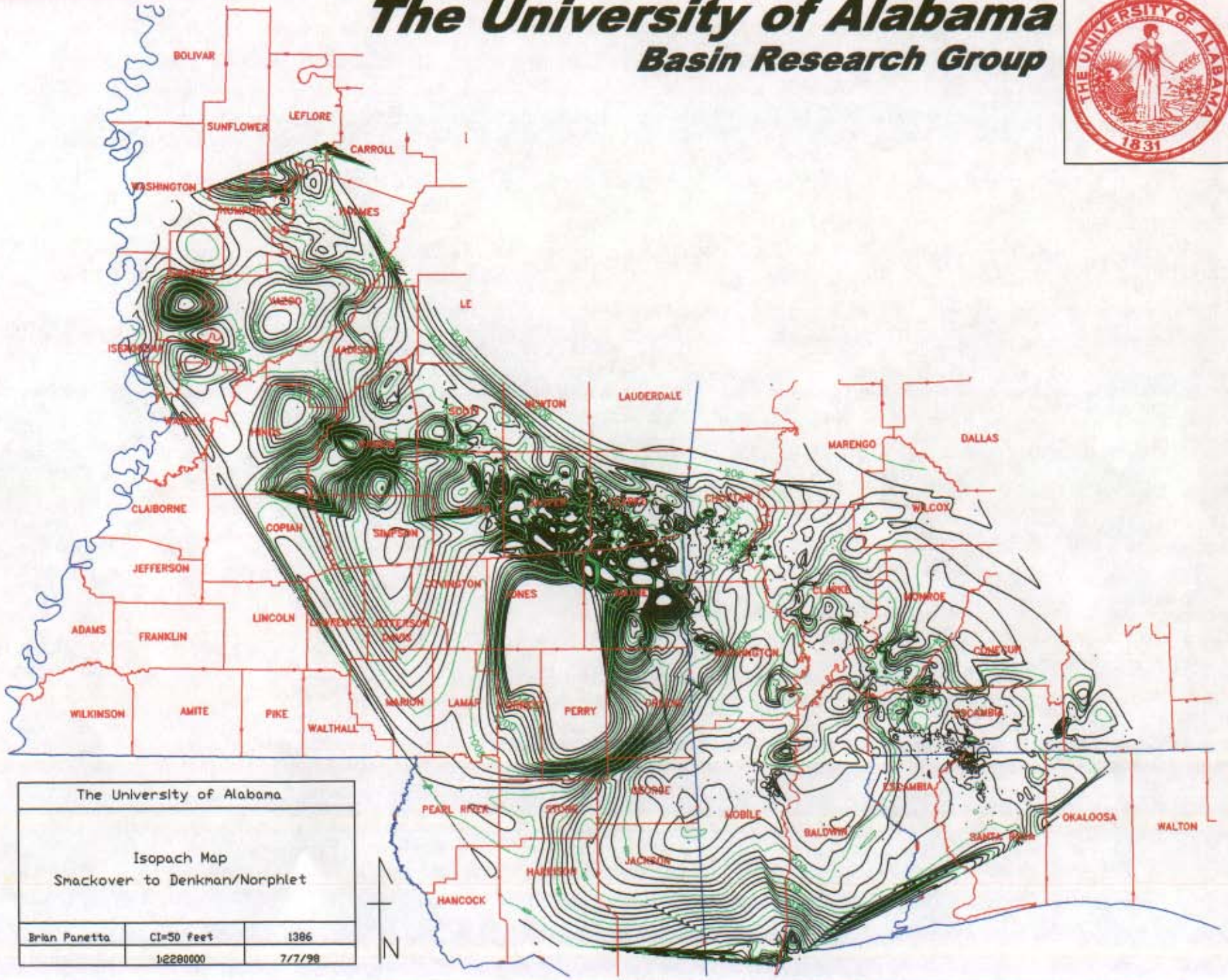
"Isopach Maps"

Brian Panetta
University of Alabama

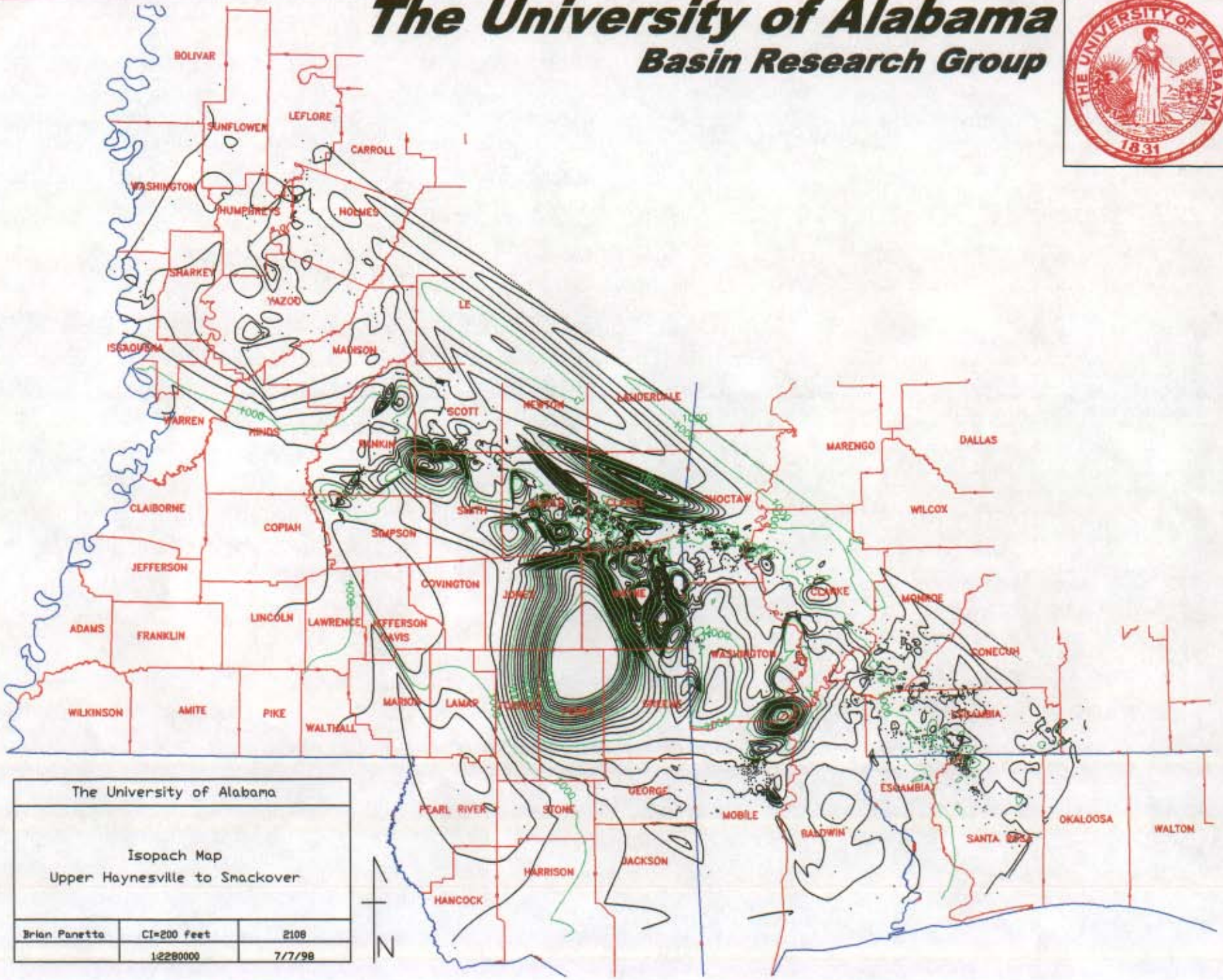
The University of Alabama
Basin Research Group



The University of Alabama
Basin Research Group

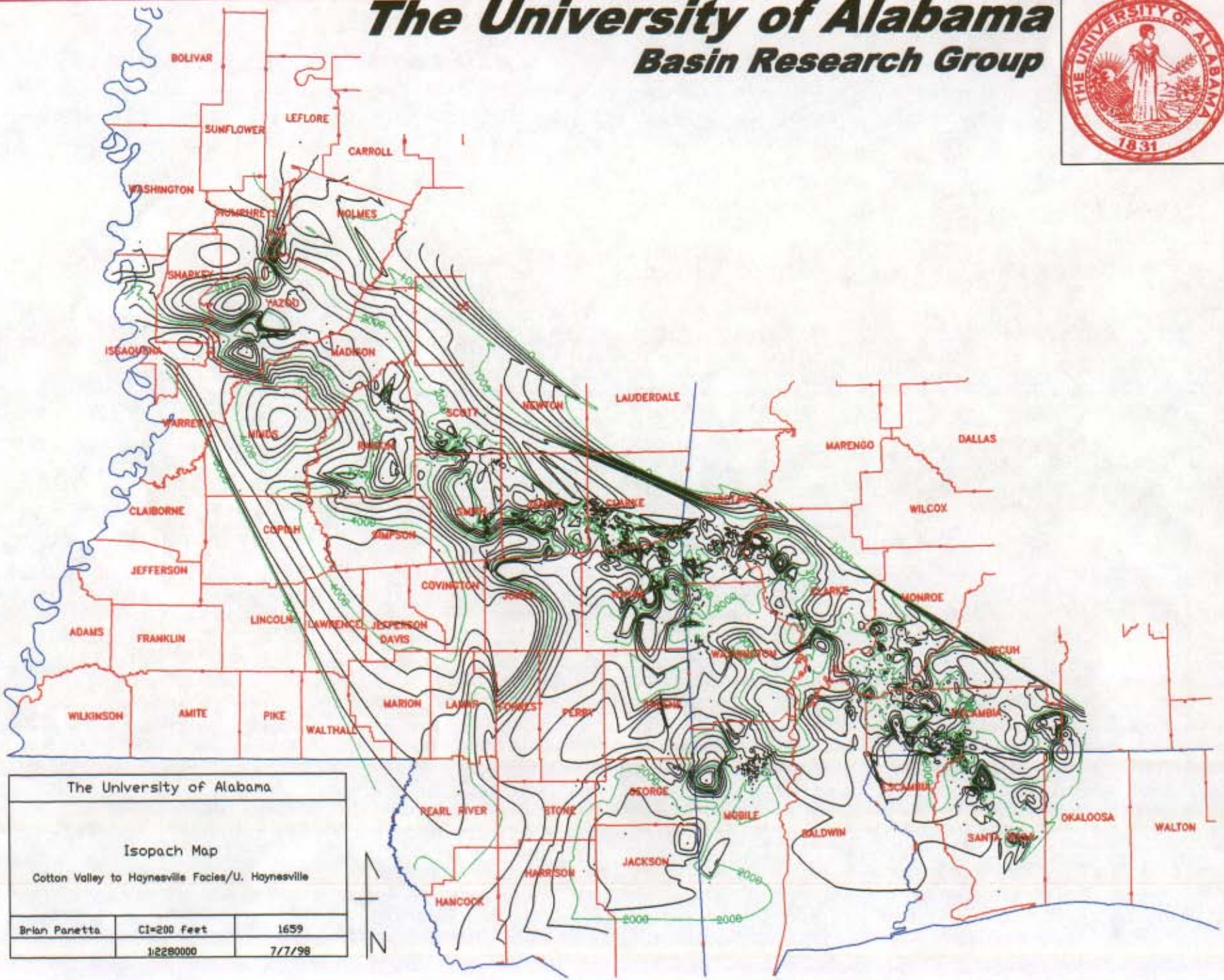


The University of Alabama
Basin Research Group



The University of Alabama		
Isopach Map Upper Haynesville to Smackover		
Brian Panetta	CI=200 feet	2108
	1:2280000	7/7/98

The University of Alabama
Basin Research Group



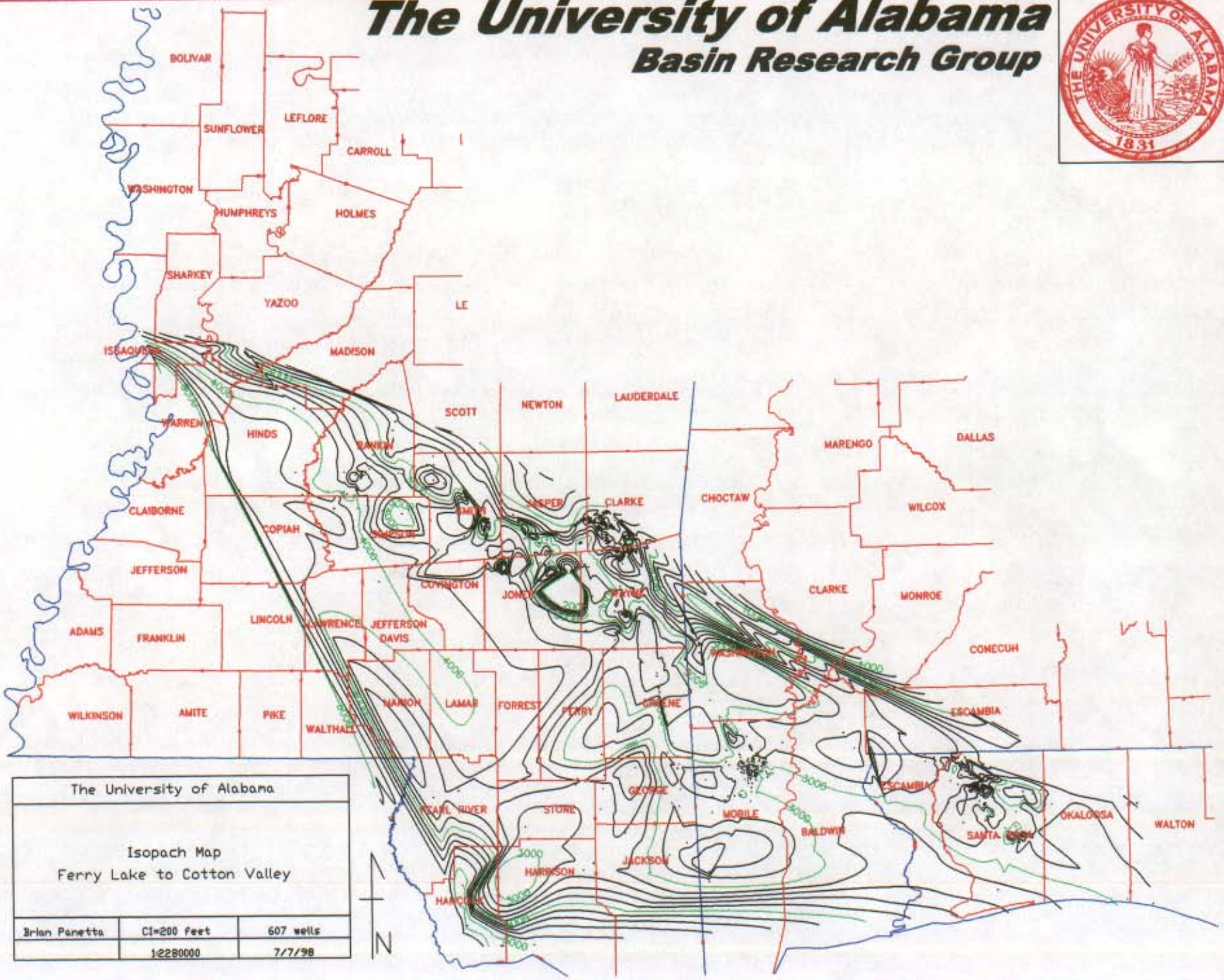
The University of Alabama

Isopach Map

Cotton Valley to Haynesville Facies/U. Haynesville

Brian Panetta	CI=200 feet	1659
	1:2280000	7/7/98

The University of Alabama
Basin Research Group



The University of Alabama		
Isopach Map Ferry Lake to Cotton Valley		
Brian Panetta	CI=200 feet	607 wells
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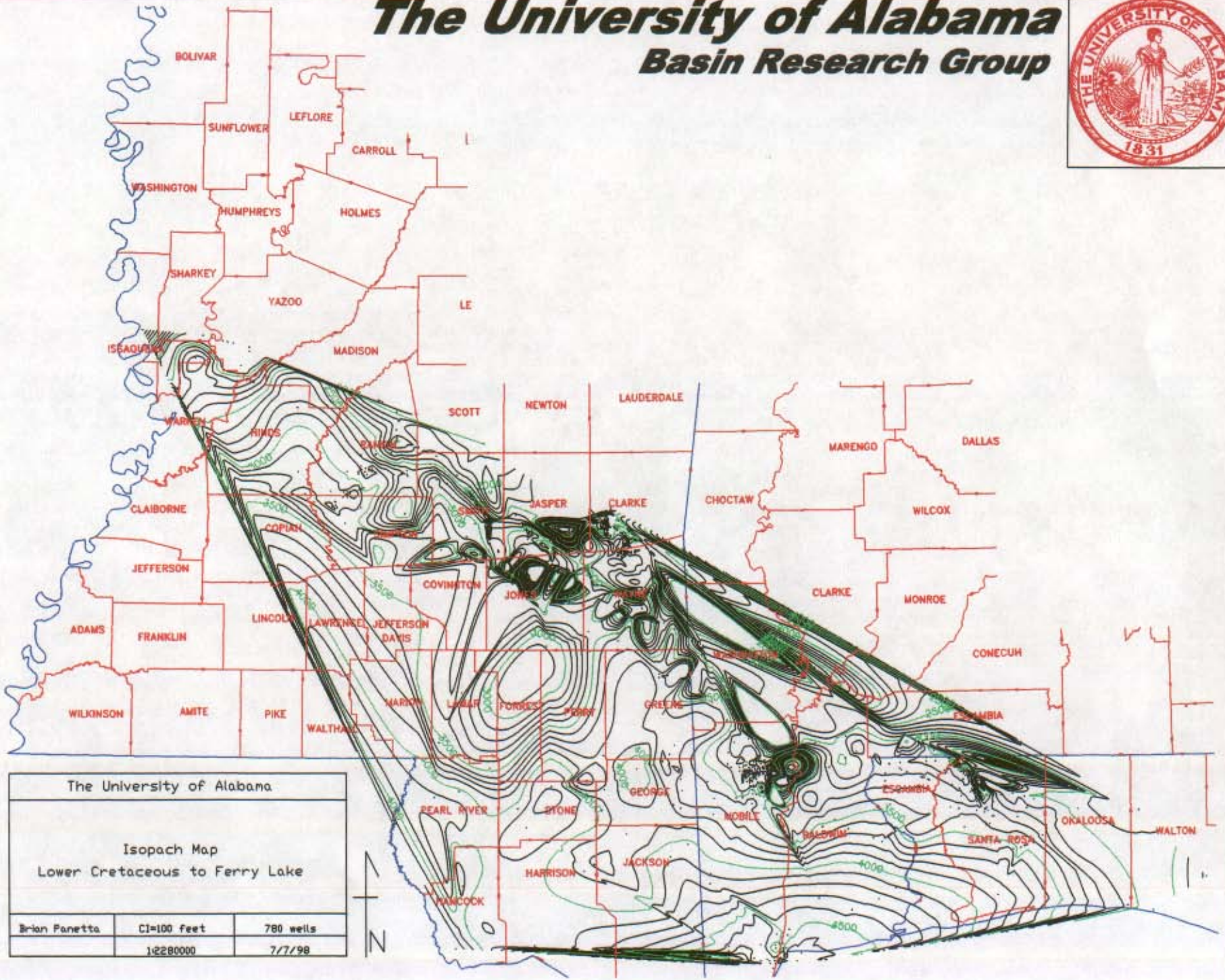
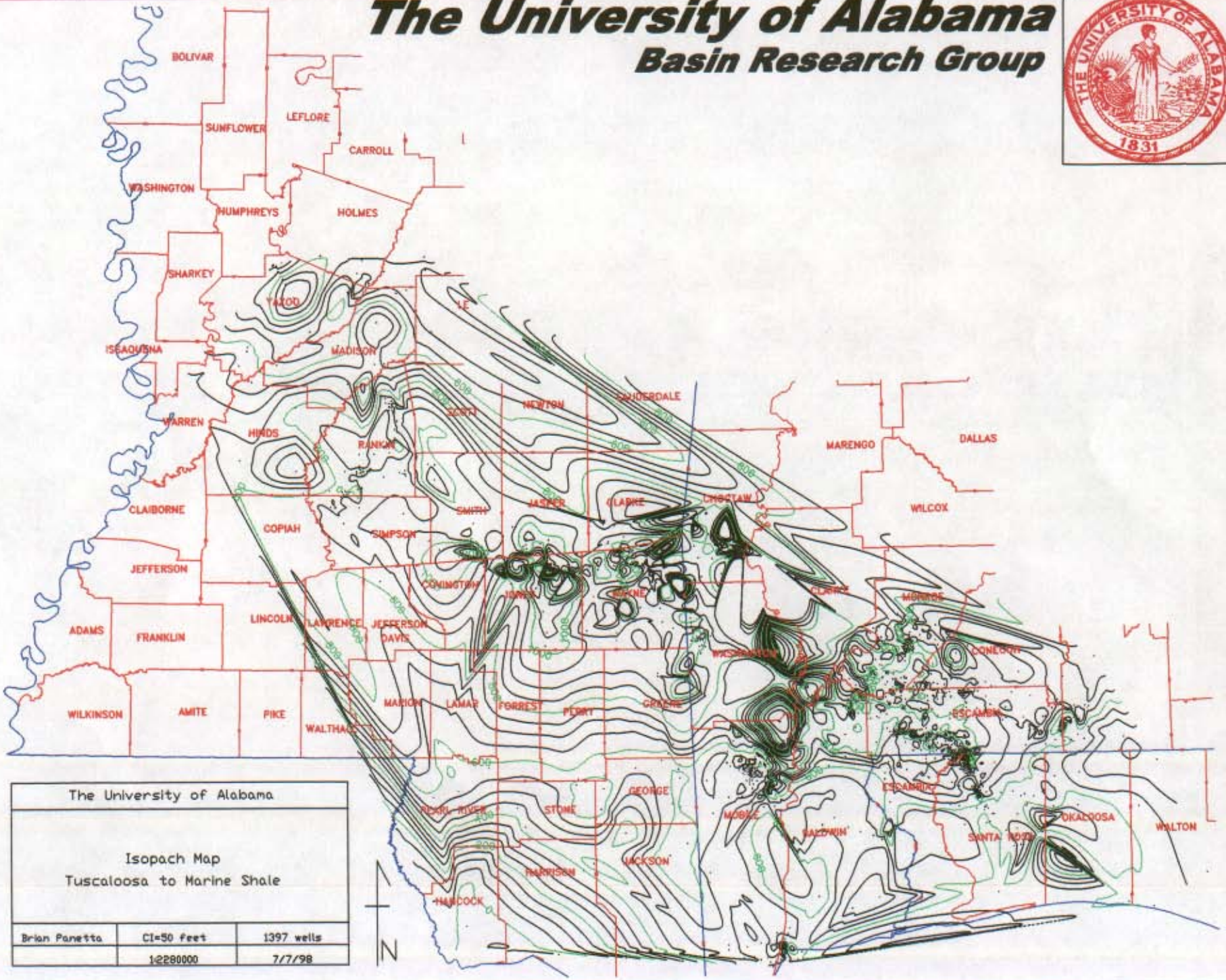
The University of Alabama
Basin Research Group

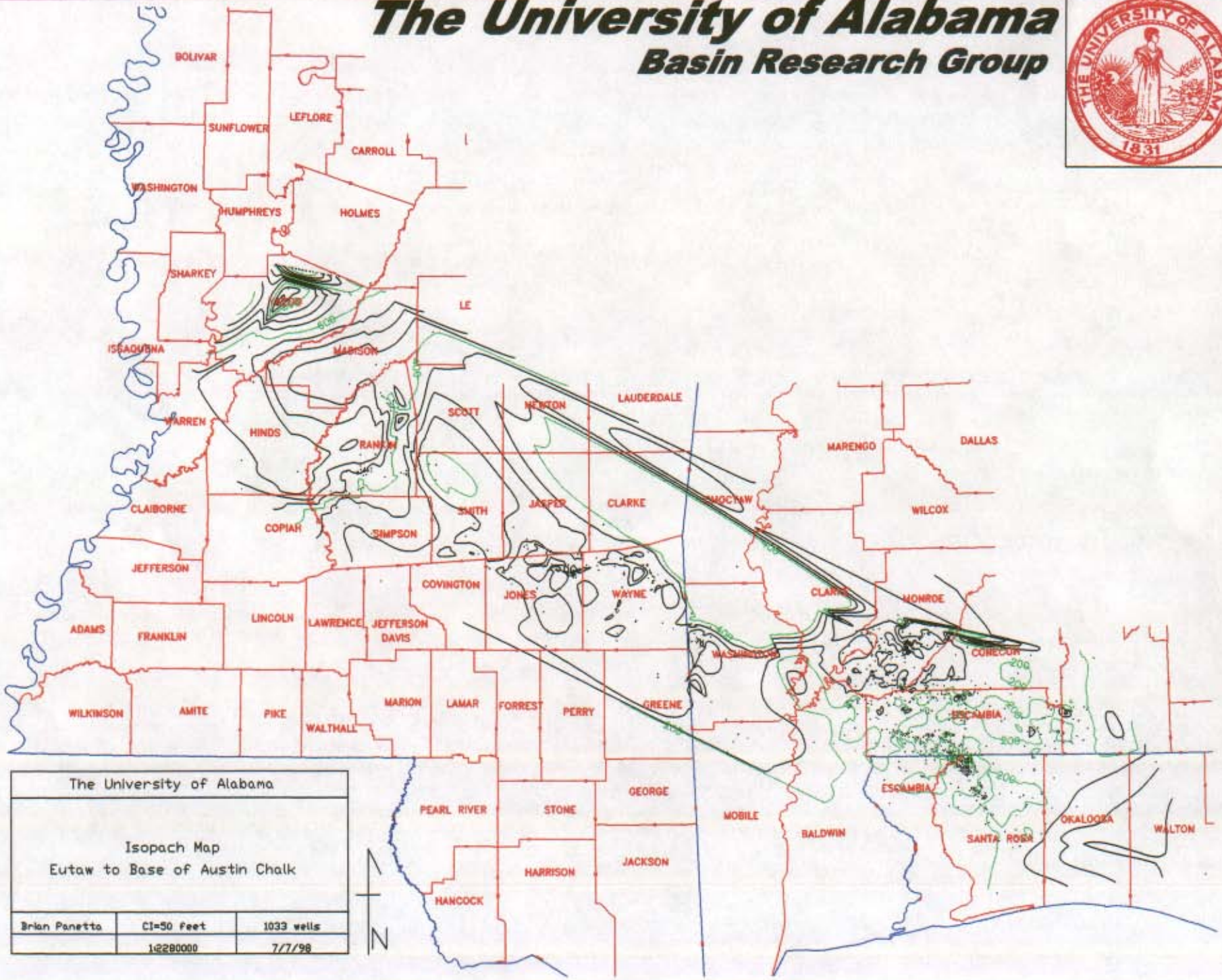


The University of Alabama		
Isopach Map Lower Cretaceous to Ferry Lake		
Brian Panetta	CI=100 feet	780 wells
	1:2280000	7/7/98

The University of Alabama
Basin Research Group

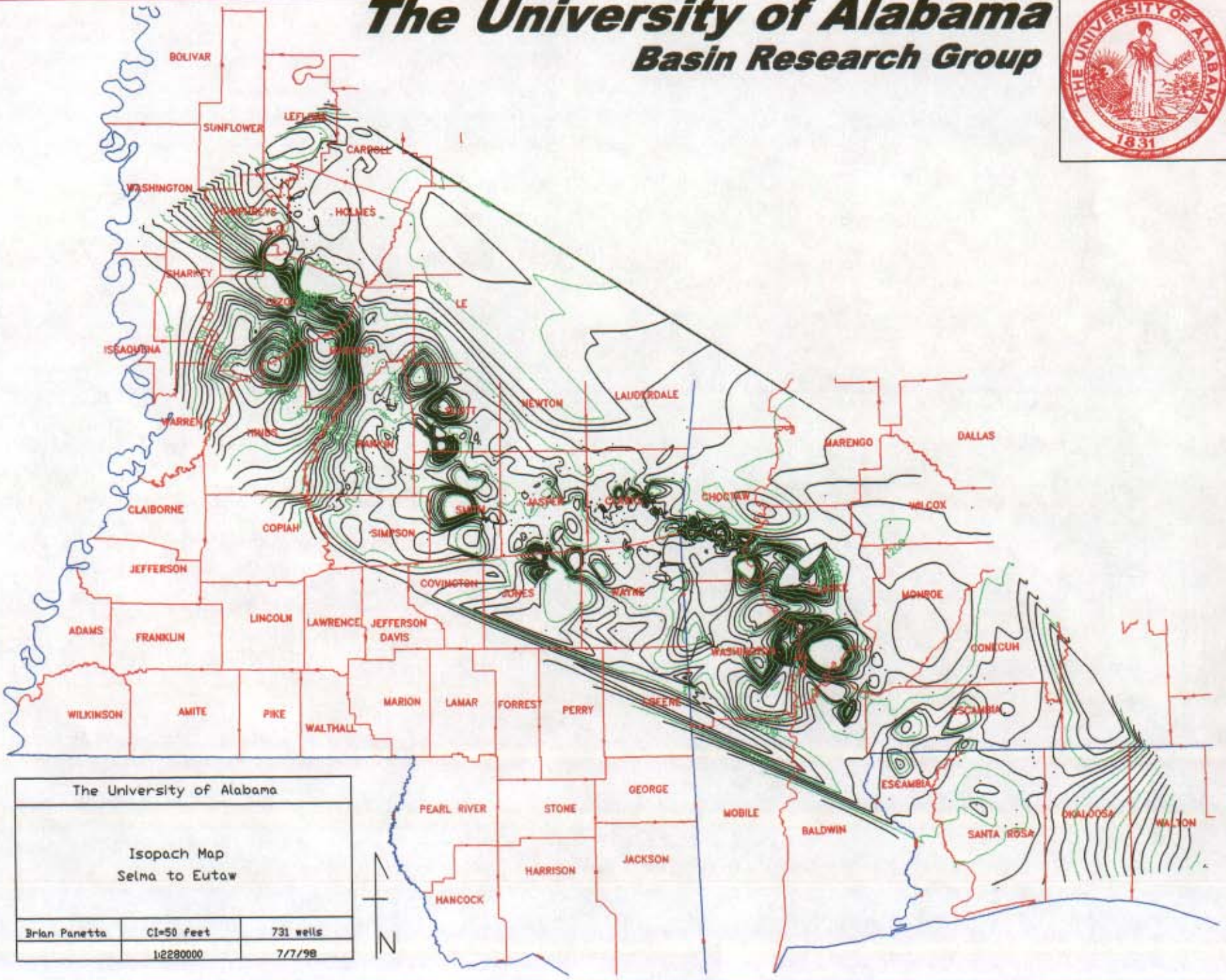


The University of Alabama
Basin Research Group



The University of Alabama		
Isopach Map Eutaw to Base of Austin Chalk		
Brian Panetta	CI=50 feet	1033 wells
	1:2280000	7/7/98

The University of Alabama
Basin Research Group



Attachment 6

"Well Stratigraphic Analysis"

Charles Smith
Alabama Geological Survey

INTRODUCTION

This report consists of lithological descriptions of 292 samples taken from the upper part of the Seaboard Oil Company W. M. Smith No. 1 well, Permit Number 683, GSA No. 1878, located in the NW¼SE¼ sec. 6, T. 5 N., R. 2 W., Washington County, Alabama. These sample descriptions are followed by a one-page summary of the lithostratigraphic intervals and electric-log tops of each encountered geological unit. This report also contains a summary table of the stratigraphy encountered in the well, the generally accepted chronostratigraphic assignment of individual units and their generalized lithology and thickness. Also included is a brief summary report on the lithological and electrical characteristics of each unit, with pertinent comments on the lithic and/or electrical characteristics used in identifying and differentiating stratigraphic units. Low magnification color photographs of typical lithologies of most of the recognized units are included as an aid in further visualizing and understanding the distinctive lithologies encountered in the well. A lithologic log (see pocket), showing both the spontaneous potential and resistivity curves, has been prepared to graphically illustrate encountered lithologies and drill depths of the tops of each identified stratigraphic unit.

In general, overall sample quality was sufficient to adequately characterize individual samples although sample quality was often poor due to extensive down-hole contamination (noted within each sample description). Although these samples were unwashed (in the sense of extraction of microfossils), identified benthonic and planktonic foraminifera are listed within each sample interval. Preparation of nannofossil slides, identity of significant taxa, and comments regarding zonal and age assignments are also included within individual sample descriptions.

DETAILED LITHOLOGIC DESCRIPTION OF SAMPLES

Seaboard Oil Company
W. M. Smith No. 1
NW¼SE¼ sec. 6, T. 5 N., R. 2 W.
Washington County, Alabama

Permit No. 683
GSA No. 1878
Elevation (feet): D.F. 100
G. L. ±85

Depth (feet)	Description
Miocene	
in Miocene undifferentiated	
0-30 Ctgs:	Clay, ferruginous-stained grayish-orange (10YR7/4) to dark-yellowish-orange (10YR6/6), massive, firm, friable, very slightly and finely muscovitic, slightly quartzose silty to very fine quartzose sandy, noncalcareous, 40%; siderite, dusky-red (5R3/4) to blackish-red (5R2/2), in medium to very coarse sand-size spherical to subspherical concretionary masses, 30%; sand, clear to very light-gray (N8), quartzose, subangular to subrounded, moderately well sorted, fine to coarse, 30%. No fossils observed.
30-60 Ctgs:	Sand, same, 50%; siderite concretions, same, but fine to very coarse, 40%; clay, oxidized and ferruginous-stained, same, but with rare fragments fresh and yellowish-gray (5Y7/2), noncalcareous, 10%; pyrite, weathered and oxidized, somewhat sulfurous and fibrous, trace. No fossils observed.
60-90 Ctgs:	Sand, clear to very light-gray, quartzose, subangular to subrounded, very well sorted, fine to medium, 85%; siderite concretions, same, but predominantly medium, 10%; clay, predominantly yellowish-gray to pale-olive (10Y6/2), same, 5%; pyrite, same, trace. No fossils observed. **PHOTO**
90-120 Ctgs:	General lithology same, but with sand somewhat ferruginous-stained, grayish-yellow (5Y8/4) to yellowish-gray and predominately medium to coarse.
Oligocene	
in Tampa Formation—Chickasawhay Limestone undifferentiated	
120-150 Ctgs:	Lithology same, plus trace amounts of limestone (sandy micrite), very light-gray to yellowish-gray, massive, indurated, dense, very fine to medium quartzose sandy, in part recrystallized and somewhat "sugary," highly calcareous. Very rare echinoderm spines, bryozoan fragments and small oyster shell fragments. Contains very rare chalky and poorly preserved *Miogypsina* sp. Noted very rare *Elphidium* sp., small ostracodes, and a single miliolid foraminifera.

150-180 Ctgs: Sand, same, fine to coarse, 90%; limestone (sandy micrite), same, 5%; siderite concretions, same, 3%; clay, same, mixed oxidized and fresh, 2%; pyrite, oxidized and somewhat fibrous, in small nodular masses, trace; clay, pale-yellowish-green (10GY7/2) to pale-olive (10Y6/2), firm yet friable, massive, very slightly quartzose silty, noncalcareous, trace; marl, light-olive-brown (5Y5/6) to moderate-olive-brown (5Y4/4), massive, firm, friable, quartzose silty to very fine quartzose sandy, containing common to abundant fine weathered and chalky unidentifiable fossil fragments, very highly calcareous, trace. Rare echinoderm, bryozoan, oyster, and pelecypod shell fragments. Rare poorly preserved *Miogypsina* sp. and very rare small ostracodes and *Elphidium* sp. **PHOTO**

180-210 Ctgs: Lithology same, but with sand predominantly coarse. Paleontology as above.

Chickasawhay facies (E-log top at 200 feet)

210-240 Ctgs: Limestone (sandy micrite), same, 55%; sand, same, but poorly sorted, fine to very coarse, 40%; siderite concretions, same, 4%; pyrite, same, oxidized, 1%; clay and marl, same, trace. Common to abundant pelecypod, oyster, and echinoderm fragments, rare barnacle plate and crab claw fragments. Abundant to very abundant *Asterigerina* sp. plus rare *Miogypsina* sp. Contains very rare ostracodes, *Elphidium*, and "*Rotalia*" sp. cf. *byramensis*. **PHOTO**

240-270 Ctgs: Sand, clear to very light-gray, quartzose, subangular to rounded, poorly sorted, fine to very coarse, 50%; limestone (sandy micrite), yellowish-gray to pale-greenish-yellow, massive, indurated, relatively impermeable, in part recrystallized and "sugary," slightly fine to medium quartzose sandy, highly calcareous, 48%; siderite, dusky-red to blackish-red, in medium to very coarse subspherical nodular masses, 2%; pyrite, fresh and brassy to oxidized and fibrous, trace. Abundant oyster and pelecypod shell fragments, common echinoderm fragments, and rare barnacle and bryozoan fragments. Contains abundant *Asterigerina* sp., and rare *Miogypsina* sp. and *Elphidium* sp.

E-log top of Vicksburg Group, Bucatunna Clay at 272 feet—Lithology not recognized.

270-300 Ctgs: General lithology same, but with a small portion of limestone fraction consisting of fine calcarenite. Paleontology same, plus observed a single small poorly preserved *Cibicides* sp.

300-330 Ctgs: Sand, same, 50%; limestone (sandy micrite), same, 30%; limestone (calcarenite), very light-gray to yellowish-gray, massive, indurated, in part porous and permeable from solution of fine fossil shell fragments, in part recrystallized, very highly and finely fossiliferous, very slightly calcareous, 19%; siderite, same, 1%; pyrite, dull and oxidized, in coarse to very coarse nodular masses, trace; phosphatic fish tooth and bone fragments, trace. Contains common to abundant echinoderm

plate and spine fragments, oyster and pelecypod shell fragments, common to abundant *Nummulites* sp. and *Asterigerina* sp., and rare *Lepidocyclina* sp., and *Cameria* sp. Noted very rare *Elphidium* sp. and other chalky and poorly preserved calcareous benthonic foraminifera.

Lower Vicksburg Group undifferentiated (E-log top at 330 feet)

330-360 Ctgs: General lithology as above, but with sand, same, 50%; limestone (calcarenite), same, 40%; limestone (sandy micrite), same, 9%; siderite, same, 1%; trace constituents same, plus clay, pale-yellowish-brown (10YR6/2), massive, firm but friable, slightly quartzose silty to very fine quartzose sandy, slightly calcareous, trace. Abundant megafossil shell fragments, same, plus rare barnacle fragments. Noted abundant *Asterigerina*, *Lepidocyclina*, and *Nummulites* spp., and very rare *Nummulites mariannensis*. Noted very rare *Cibicides* sp., *Elphidium* sp., *Rotalia* sp. cf. *R. byramensis*, *Gyroidina* sp., *Uvigerina* sp., *Siphonina* sp., small beaded *Cristallaria* sp. No planktonic foraminifera observed.

360-390 Ctgs: General lithology same. Rare oyster, pelecypod, and echinoderm fragments. Common *Lepidocyclina* sp., *Discocyclina bainbridgensis*, *Nummulites mariannensis*, *Asterigerina* sp., and *Nummulites* spp. Very rare and poorly preserved calcareous benthonic foraminifera as above, plus rare small ostracodes.

Eocene

Jackson Group, Yazoo Clay or Crystal River Formation (E-log top at 395 feet)

390-420 Ctgs: Limestone (fine calcarenite), white to yellowish-gray, massive, indurated, containing abundant very fine to medium fossil fragments with fine micrite cement, in part fine to medium glauconitic, with about 20% of fractions somewhat recrystallized and "sugary," 100%; siderite, dusky-red to blackish-red, in coarse to very coarse spherical nodular masses, trace; pyrite, dull and oxidized, trace; sand, very light-gray, quartzose, subangular to subrounded, medium to coarse, trace; clay, pale-olive, massive, indurated, quartzose silty to very fine quartzose sandy, noncalcareous, trace. Contains abundant bryozoan, echinoderm, oyster, and pelecypod shell fragments. Common *Lepidocyclina* sp., *Nummulites mariannensis*, *Discocyclina bainbridgensis*, and *Nummulites* spp. Common calcareous benthonic foraminifera as above. **PHOTO**

420-450 Ctgs: General lithology as above, but with fine calcarenite, same, 95%; sand, same, moderately well sorted, fine to medium, 5%; trace constituents same. Larger and smaller microfauna same. No planktonic foraminifera noted.

450-480 Ctgs: General lithology as above. Larger foraminifera as above. Noted common calcareous benthonic foraminifera including *Bulimina jacksonensis*.

480-510 Ctgs: Limestone (fine calcarenite), same, 50%; sand, clear to very light-gray, quartzose, angular to subrounded, moderately well sorted, medium to coarse, 50%; siderite concretions, oxidized pyrite, and phosphatic fish tooth and bone fragments are same and present as trace constituents. Noted rare *Nummulites* spp., *Lepidocyclina* spp., and *Discocyclina bainbridgensis*. Sample contains very rare calcareous benthonic foraminifera including *Lenticulina* sp., *Marginulina* sp., *Uvigerina* sp., and few other taxa.

E-log top of Moodys Branch Formation at 510 feet—Lithology not recognized.

510-540 Ctgs: General lithology same. Contains common echinoderm, oyster, and pelecypod shell fragments, and very rare barnacle plates. Noted rare *Nummulites* sp., *Lepidocyclina* sp., *Asterigerina* sp., and very rare *Discocyclina bainbridgensis*. Contains rare and poorly preserved calcareous benthonic foraminifera. Observed a single *Globigerina gortanii*.

Claiborne Group, ?Gosport Sand (E-log top at 560 feet)

540-570 Ctgs: Sand, same, 65%; limestone (fine calcarenite), same, 34%; siderite concretions, same, 1%; pyrite and phosphatic fish tooth fragments, same, trace; clay, dark-yellowish-orange, massive, firm but friable, very slightly quartzose silty to very fine quartzose sandy, noncalcareous, trace. Megafossil fragments same. Noted very rare charophyte oogonia. Noted rare *Nummulites mariannensis*, *Discocyclina bainbridgensis*, *Lepidocyclina* spp., *Nummulites* sp., and *Asterigerina* sp. Very rare *Cibicides* sp., *Gyroidina* sp. *Lenticulina* sp., et al. Noted a single *Bulimina jacksonensis*. **PHOTO**

570-600 Ctgs: Limestone (fine calcarenite), white to very light-gray and yellowish-gray, massive, indurated, in part somewhat recrystallized, consisting of very fine to fine unidentifiable fossil fragments, highly calcareous, 40%; limestone (sandy micrite), yellowish-gray to pale-olive, massive, indurated, recrystallized and somewhat "sugary," moderately very fine to fine quartzose sandy, very slightly calcareous, 30%; sand, clear to very light-gray, quartzose, subangular to subrounded, moderately well sorted, fine to medium, 30%; siderite, dusky-red to blackish-red, in spherical concretionary masses, fine to coarse, trace; clay, pale-olive to light-olive (10Y5/4), massive, firm but friable, very fine quartzose sandy, noncalcareous, trace. Abundant oyster, pelecypod, echinoderm, and bryozoan debris. Noted common *Lepidocyclina* sp. and *Nummulites* spp. Common calcareous benthonic foraminifera include *Bulimina jacksonensis*, very rare and poorly preserved planktonic foraminifera include *Turborotilina cerroazulensis cerroazulensis*.

600-630 Ctgs: General lithology same, plus pyrite, weathered and oxidized, somewhat fibrous and sulfurous, trace. Common oyster and pelecypod shell fragments with rare echinoderm and bryozoan fragments. Rare *Lepidocyclina* sp., *Nummulites* sp., *Discocyclina* sp., *Camerina* sp., and common *Asterigerina* sp. Very rare and poorly preserved calcareous benthonic and planktonic foraminifera.

630-660 Ctgs: General lithology as above. Common to abundant pelecypod, oyster, and echinoderm fragments with rare small gastropod and bryozoan fragments. Common *Lepidocyclina*, *Discocyclina*, and *Nummulites* spp. Contains very rare smaller benthonic foraminifera including *Ceratobulimina eximia*.

Lisbon Formation (E-log top at 640 feet)

660-690 Ctgs: Fossiliferous limestone (fine calcarenite), same, 70%; sand, same, but predominantly medium to coarse, 15%; limestone (sandy micrite), same, 10%; clay, light-olive, same, 4%; siderite concretions, same, 1%; pyrite, weathered and oxidized, somewhat fibrous, trace; glauconite, dark-yellowish-green (10GY4/4) to dusky-yellowish-green (10GY3/2), fresh, in ovate grains, medium to coarse, trace. Abundant megafossils and larger foraminifera as above. Very rare poorly preserved calcareous benthonic foraminifera.

690-720 Ctgs: General lithology and paleontology same. Noted a single fragment of *Lepidocyclina* sp. cf. *L. gardnerae*. Very rare poorly preserved calcareous benthonic foraminifera, including a single individual of *Trifarina* sp. not observed in overlying samples. No planktonic foraminifera observed. **PHOTO**

720-750 Ctgs: Clay, pale-yellowish-brown to light-olive-gray (5Y5/2), massive, firm but friable, very slightly and finely muscovitic, slightly quartzose silty to quartzose sandy, slightly fine to medium glauconitic, moderately to strongly calcareous, 90%; glauconite, fresh and dark-yellowish-green to weathered and light-olive, fine to medium, 6%; sand, clear, quartzose, very highly reflective, angular to subangular, well sorted, fine, 4%; common sandy micrite and fine calcarenite are believed to be caved contaminants. Rare megafossils and larger foraminifera present in this sample contain micrite adhering to their surfaces and are also regarded as caved contaminants. Rare and poorly preserved calcareous benthonic foraminifera. Noted a single *Hantkenina alabamensis*. **PHOTO**

750-780 Ctgs: General lithology same. The considerable amount of sandy limestone and “coquina” are regarded as caved contaminants. Rare smaller foraminifera with no age diagnostic species observed.

780-810 Ctgs: Clay, moderate-greenish-yellow (10Y7/4), massive bedded, firm but friable, very quartzose silty to fine quartzose sandy, very slightly calcareous, 97%; sand, clear, quartzose, very highly reflective,

angular, well sorted, very fine to fine, 3%; glauconite, dark-yellowish-green, fresh, fine, trace; trace amounts of sandy and finely fossiliferous limestone are regarded as caved contaminants. Contains rare *Uvigerina* and *Bulimina* spp., plus very rare *Lenticulina*, *Gyroidina*, and *Eponides* spp.

810-840 Ctgs: Cement from casing set at 814 feet, 100%. No fossils observed.

Tallahatta Formation (E-log top at 810 feet)

840-870 Ctgs: Cement, 30%; clay, yellowish-gray to pale-greenish-yellow (10Y8/2), massive bedded, firm, friable, very slightly and very finely muscovitic, moderately calcareous, 30%; limestone (micrite), white to very light-gray, massive, indurated, sparingly very fine to medium glauconitic, finely fossiliferous, highly calcareous, 25%; siliceous limestone, light-gray (N7), massive, indurated, dense, in part quartzose silty and very finely glauconitic, very slightly calcareous, 13%; siliceous claystone, pale-green (5G7/2) to light-green (5G7/4), very indurated, in part fine to medium glauconitic, massive, dense, noncalcareous, 2%. Rare "tan" pelecypod and involute gastropod shell fragments. No microfossils observed.

870-900 Ctgs: General lithology as above, but with glauconite, dark-yellowish-green, medium to coarse, trace. No microfossils observed.

900-930 Ctgs: General lithology as above, but with finely glauconitic limestone, same, 50%; clay, same, 15%; green claystone, same, 15%; cement, same, 10%; siliceous limestone, same, 10%; glauconite, fresh and dusky-yellowish-green to weathered and moderate-olive-brown, ovate to spherical pellets, coarse, trace; sand, clear to very light-gray, in part glauconite-stained pale-olive, quartzose, subrounded, coarse to very coarse, trace. Very rare pelecypod and gastropod shell fragments. No microfossils observed.

930-960 Ctgs: Siliceous limestone, yellowish-gray, massive, indurated, dense, very slightly and finely muscovitic and glauconitic, very slightly calcareous, 70%; limestone (micrite), white to very light-gray, massive, indurated, dense, fine to medium glauconitic, very finely fossiliferous, highly calcareous, 20%; clay, yellowish-gray, massive, firm but friable, very slightly and finely muscovitic, slightly calcareous, 10%; glauconite, dark-yellowish-green, fine to medium, trace. No megafossils observed. Noted very rare involute and tightly coiled *Lenticulina* sp.

960-990 Ctgs: Lithology same. Sample contains very rare "tan" pelecypod shell fragments. No microfossils observed.

990-1,020 Ctgs: Sand, clear, in part glauconite-stained pale-olive, quartzose, angular to subangular, well sorted, coarse, 60%; limestone (micrite), same, 20%; siliceous limestone, same, 10%; glauconite, dark-yellowish-green, in part weathered and oxidized pale-green (5G7/2), coarse to very coarse,

10%; phosphatic fish tooth and bone fragments, moderate-yellowish-brown (10YR5/4), trace. Very rare "tan" pelecypod shell fragments. Observed a single large *Lenticulina* sp. **PHOTO**

1,020-1,050 Ctgs: Siliceous limestone, same, 60%; limestone (micrite), same, 40%; sand, same, trace; glauconite, same, trace. Very rare pelecypod and gastropod shell fragments. Very rare *Discocyclina advena*. No smaller benthonic or planktonic foraminifera observed.

1,050-1,080 Ctgs: Limestone (sandy micrite), white to yellowish-gray, massive, indurated, dense and impermeable, contains abundant grayish-yellow-green (5GY7/2) glauconite-stained very fine quartzose sand and rare dark-yellowish-green very fine to fine glauconite. Highly calcareous, 85%; siliceous limestone, same, 10%; clay, yellowish-gray, massive, firm, friable, very slightly and finely muscovitic, very slightly calcareous, 5%; glauconite, dark-yellowish-green, in part weathered moderate-yellowish-green, predominantly coarse, trace; pyrite, fresh and brassy, in small coarse to very coarse nodular masses, trace. Common phosphatic fish tooth and bone fragments. Rare to common oyster and "tan" pelecypod and gastropod shell fragments. Observed only a single small fragments of *Discocyclina advena*. No smaller foraminifera observed.

1,080-1,110 Ctgs: Siliceous limestone, yellowish-gray, massive, indurated, dense, very slightly and finely muscovitic and glauconitic, very slightly calcareous, 100%; pyrite, fresh to oxidized, trace; glauconite, same, fresh to weathered, coarse to very coarse, trace. Very rare pelecypod and gastropod shell fragments. No microfossils observed. **PHOTO**

1,110-1,140 Ctgs: General lithology and paleontology same. Noted trace amounts of very fine to fine glauconite in fine sediment fraction.

1,140-1,170 Ctgs: Lithology as above. Noted a single individual of *Lenticulina* and *Siphonina* sp. and a single small *Ceratobulimina eximia*.

1,170-1,200 Ctgs: Lithology same. Observed very rare to rare *Asterigerina lisbonensis*.

1,200-1,230 Ctgs: Siliceous limestone, same, 97%; clay/shale, light-olive-gray (5Y6/1), massive to weakly laminated, firm, friable, very slightly and finely muscovitic and glauconitic, very slightly calcareous, 3%; pyrite, fresh, brassy, trace; glauconite, dark-yellowish-green, fine to coarse, trace. Rare "tan" pelecypod and gastropod shell fragments, plus a single "tan" calcareous worm tube. Rare *Asterigerina lisbonensis*. Observed very rare *Lenticulina* sp. and *Eponides* sp.

Wilcox Group, Hatchetigbee Formation (E-log top at 1,248 feet)

1,230-1,260 Ctgs: Clay/shale, light-olive-gray, same, 60%; siliceous limestone, same, 37% (may be in part or entirely a caved contaminant); glauconite, dark-yellowish-green to dusky-yellowish-green, fresh, fine to very coarse, 3%; carbonized woody fragments, olive-black (5Y2/1) to black

(N1), trace; pyrite, fresh and brassy to oxidized and dull, trace. Contains common to abundant "tan" thin-walled pelecypod and gastropod shell fragments. Observed very rare calcareous benthonic foraminifera and a single individual of *Pseudohastigerina wilcoxensis*. Note: the rinsed residue consists almost entirely of siliceous limestone, with the soft clay/shale having been removed during sample preparation.

1,260-1,290 Ctgs: General lithology and paleontology same. Noted a single small poorly preserved *Acarinina nitida*.

1,290-1,320 Ctgs: General lithology and paleontology as above. Note that the rinsed sample continues to consist almost entirely of siliceous limestone. Observed very rare *Lenticulina* sp. only. No planktonic foraminifera observed.

1,320-1,350 Ctgs: Clay/shale, light-olive-gray, same, 80%; siliceous limestone, same, 13% (caved); glauconite, same, 7%; trace constituents same. Abundant pelecypod and gastropod shell fragments with common "tan" calcareous worm tubes. Rare *Uvigerina*, *Siphonina*, and *Bulimina* sp. are believed to be caved from the overlying section. No planktonic foraminifera observed.

1,350-1,380 Ctgs: Clay/shale, light-olive-gray, weakly fissile, firm, friable, very slightly and finely muscovitic and glauconitic, moderately calcareous, 97%; limestone, (sandy sparite), very light-gray to light-olive-gray, massive, indurated, very highly quartzose silty to very fine quartzose sandy, moderately to abundantly fine glauconitic, matrix consists entirely of spar calcite, very highly calcareous, 2%; glauconite, dark-yellowish-green to dusky-yellowish-green, medium to coarse, 1%; carbonized woody fragments, black, trace; pyrite, fresh and brassy, trace. Abundant "tan" thin-walled pelecypod shell fragments and calcareous worm tubes plus common "tan" gastropods and gastropod fragments. Observed very rare *Eponides lotus*. No planktonic foraminifera observed.

1,380-1,410 Ctgs: General lithology same, but note that the "rinsed" portion of this sample has removed all evidence of clay/shale, leaving a sample consisting almost entirely of small "tan" gastropods and "tan" pelecypod shell fragments. Noted a single small planktonic foraminifera which may belong to *Morozovella subbotinae*.

1,410-1,440 Ctgs: Clay, light-olive-gray to pale-yellowish-brown, massive to very weakly laminated, firm, friable, quartzose silty, very finely muscovitic, very slightly calcareous, 98%; limestone (sandy and glauconitic sparite), same, 1%; glauconite, same, 1%; carbonized woody fragments, black, trace; phosphatic fish bone fragments, trace; pyrite, oxidized and dull, trace. Very abundant "tan" pelecypod and gastropod shell fragments with common calcareous worm tubes. Observed very rare *Lenticulina* sp.

1,440-1,470 Ctgs: General lithology as above. Note that the "rinsed" residue consists almost entirely of pelecypod shell fragments. Noted very rare calcareous benthonic foraminifera including *Cristellaria* sp., *Ceratobulimina eximia*, and *Eponides* sp. No planktonic foraminifera observed. **PHOTO**

1,470-1,500 Ctgs: Note that the "rinsed" residue consists of essentially 100% pelecypod shell fragments. Other than this biologic contribution, the general lithology is as above, a light-olive-gray clay with trace amounts of fine quartzose sandy and glauconitic sparite, glauconite, carbonized woody fragments, phosphatic fish bone fragments, and pyrite. No age diagnostic benthonic or planktonic foraminifera were observed.

1,500-1,530 Ctgs: Clay, light-olive-gray, massive to weakly laminated, firm, friable, quartzose silty, very finely muscovitic and carbonaceous, lignitic, very slightly calcareous, 80%; limestone (sandy and glauconitic sparite), very light-gray, massive, indurated, very highly quartzose silty to fine quartzose sandy, moderately to abundantly fine glauconitic, very highly calcareous, 19%; glauconite, dark-yellowish-green to dusky-yellowish-green, fine to medium, 1%; carbonized woody fragments, olive-black to black, trace; pyrite, fresh to weathered and oxidized, trace. Contains very abundant "tan" pelecypod, gastropod, and oyster shell fragments, with rare calcareous worm tube fragments. Noted a single small *Cristellaria* sp., and small *Eponides* sp., and very rare small *Lenticulina* spp. No planktonic foraminifera observed.

1,530-1,560 Ctgs: General lithology as above, plus phosphatic fish tooth and bone fragments, trace. Abundant pelecypod shell fragments and very rare benthonic foraminifera same.

1,560-1,590 Ctgs: General lithology and paleontology same.

1,590-1,620 Ctgs: Limestone (fossiliferous and glauconitic sparite), light-olive-gray, massive, indurated, recrystallized and somewhat "sugary," abundantly very fine to medium glauconitic, sparingly megafossiliferous, very highly calcareous, 70%; lignitic and carbonaceous clay, same, 28%; glauconite, same, 2%; carbonized woody fragments, same, trace; pyrite, same, trace. Common to abundant oyster fragments and "tan" pelecypod and gastropod shell fragments. Very rare and poorly preserved calcareous benthonic foraminifera.

E-log top of Bashi Marl Member at 1,638 feet—Lithology not recognized.

1,620-1,650 Ctgs: General lithology and paleontology same, plus rare small *Siphonina* sp.

Paleocene

Wilcox Group, Tuscahoma Sand (E-log top at 1,656 feet)

1,650-1,680 Ctgs: Lignitic shale, light-olive-gray, thinly and indistinctly laminated, firm, friable, highly yet finely muscovitic and carbonaceous, noncalcareous, 75%; glauconitic limestone, same, 23%; glauconite, same, but medium to very coarse, 1%; carbonized woody fragments, same, 1%; pyrite, weathered and oxidized, trace. Common oyster and pelecypod shell fragments. Rare large *Lenticulina* sp. cf. *wilcoxensis*. No planktonic foraminifera observed.

1,680-1,710 Ctgs: Lignitic shale, same, 90%; glauconitic limestone, same, 8%; carbonized woody fragments, same, 1%; glauconite, same, 1%; pyrite, same, trace. Common oyster and pelecypod shell fragments which may be in part or entirely caved contaminants. Very rare calcareous benthonic foraminifera only.

1,710-1,740 Ctgs: Lignitic shale, same, 100%; glauconitic limestone, glauconite, carbonized woody fragments, and pyrite, same, as trace constituents. Rare pelecypod shell fragments believed to be caved. No indigenous foraminifera observed.

1,740-1,770 Ctgs: General lithology and paleontology same.

1,770-1,800 Ctgs: Lithology and paleontology as above. Noted a small *Nodosaria affinis* and *Vaginulina* sp. probably caved from overlying sediments.

1,800-1,830 Ctgs: Lignitic and carbonaceous shale, same, 100%; trace constituents and paleontology same. **PHOTO**

1,830-1,860 Ctgs: Lignitic clay/shale, light-olive-gray, massive to weakly and thinly laminated, firm yet friable, very finely muscovitic, finely carbonaceous, noncalcareous, 100%; carbonized woody fragments, black, trace; pyrite, fresh and brassy to oxidized and dull, trace. Note that the "rinsed" sample contains significant contamination from overlying sections, including both Lisbon and Tallahatta lithologies and larger foraminifera. The small residue of fine to medium quartzose sand, glauconite, and pelecypod shell fragments are regarded as caved contamination. No indigenous microfossils observed.

1,860-1,890 Ctgs: Lignitic clay/shale, same, 90%; lignite and carbonized woody fragments, olive-black to black, relatively soft, 5%; sandstone, light-gray to light-olive-gray, quartzose, well sorted, fine to medium glauconitic, calcareously cemented, finely fossiliferous, highly calcareous, very fine- to fine-grained, 5%; pyrite, same, trace.

1,890-1,920 Ctgs: Sandstone, same, but fine- to medium-grained, fine to medium muscovitic and glauconitic, in part pyritic, fossiliferous, highly calcareous, 80%; lignitic clay/shale, same, 20%; carbonized woody fragments, same, trace; phosphatic fish tooth and bone fragments,

trace. Contains common thick-walled oyster shell fragments believed to be in place. No microfossils observed.

1,920-1,950 Ctgs: Lignitic and carbonaceous clay/shale, same, 80%; sandstone, same, 18%; carbonized woody fragments, black, same, 2%; phosphatic fish tooth and bone fragments, trace. Rare oyster shell fragments. No microfossils noted.

1,950-1,980 Ctgs: Lignitic and carbonaceous clay/shale, same, 100%; pyrite, oxidized, trace; carbonized woody fragments, same, trace. The washed residue contains fine to medium sand, glauconite, and sandstone, among other obviously caved lithologies, all regarded as sample contaminants.

1,980-2,010 Ctgs: Lithology same.

2,010-2,040 Ctgs: Lignitic clay/shale, same, 60%; sandstone, medium-light-gray (N6) to light-olive-gray, quartzose, massive, indurated, abundantly fine to medium glauconitic, very finely muscovitic, in part sideritic, containing abundant sparry calcite cement, very highly calcareous, 40%; pyrite, fresh, brassy, trace; carbonized woody fragments, black, trace; phosphatic fish tooth and bone fragments, trace; glauconite, fresh and dusky-yellowish-green to weathered and moderate-yellowish-green, medium to very coarse, trace. Observed common oyster shell fragments. No indigenous microfossils observed.

2,040-2,070 Ctgs: Lignitic and carbonaceous clay/shale, same, 100%; sandstone, same, trace; other trace constituents as above.

2,070-2,100 Ctgs: General lithology same.

2,100-2,130 Ctgs: Lithology as above.

2,130-2,160 Ctgs: Lignitic clay/shale, same, noncalcareous, 100%; pyrite, fresh, brassy, trace. No indigenous fossils observed.

2,160-2,190 Ctgs: General lithology same.

2,190-2,210 Ctgs: Lithology same, plus siderite, dark-reddish-brown (10R3/4), massive, indurated, dense to moderately glauconitic, noncalcareous, trace. No fossils noted.

2,210-2,240 Ctgs: General lithology same.

2,240-2,270 Ctgs: Clay/shale, light-olive-gray to pale-yellowish-brown, massive to thinly and weakly laminated, lignitic, abundantly but very finely muscovitic, fine to medium carbonaceous, noncalcareous, 100%; siderite, same, massive, trace. Pyrite, fresh, brassy, trace. No megafossils or indigenous microfossils observed.

2,270-2,300 Ctgs: General lithology same. Noted a single small *Morozovella aequa* (probably not the top of upper occurrence).

Nanafalia Formation (E-log top at 2,335 feet)

2,300-2,330 Ctgs: Lithology same. Noted only a single small immature beaded *Cristellaria* sp.

2,330-2,360 Ctgs: Clay/shale, same, 92%; sand, clear to very light-gray, quartzose, subangular to subrounded, well sorted, fine, 5%; glauconite, fresh and dusky-yellowish-green to oxidized and moderate-yellowish-green, fine to medium, 2%; sideritic sandstone, dark-reddish-brown, massive, indurated, fine to medium glauconitic, in part finely fossiliferous, noncalcareous, fine-grained, 1%; pyrite, oxidized, trace. Very rare oyster shell fragments. No microfossils observed.

2,360-2,390 Ctgs: Sandstone, yellowish-gray and moderate-yellowish-orange (10R6/6) to moderate-reddish-brown (10R4/6), quartzose, massive, indurated, medium glauconitic, very finely fossiliferous, containing common to abundant fragments of *Discocyclina* sp., medium-grained, cemented with spar calcite, predominantly sideritic, highly calcareous, 85%; sand, clear to very light-gray, quartzose, angular to subrounded, well sorted, fine to medium, 10%; glauconite, dark-yellowish-green, in part oxidized and light-olive, medium to coarse, 5%; pyrite, oxidized and dull, trace. Noted rare isolated fragments of *Discocyclina* sp. Noted several large *Lenticulina midwayensis*, *L. wilcoxensis*, and rare *Dentalina obliquua* and *Nodosaria latejugata*. No planktonic foraminifera observed. **PHOTO**

2,390-2,420 Ctgs: General lithology and paleontology same, plus glauconite, moderate-yellowish-green in very large coarse to very coarse irregular shaped grains.

2,420-2,450 Ctgs: Lithology same. Continue to observe common to abundant fragments of *Discocyclina* sp. incorporated in the fine- to medium-grained sideritic sandstone.

2,450-2,480 Ctgs: Lithology and paleontology as above. Continue to observe significant contamination from the overlying Tuscahoma-Hatchetigbee intervals, as well as from the higher Lisbon and Tallahatta Formations.

2,480-2,510 Ctgs: Clay, very light-gray, massive, firm but friable, very slightly and finely muscovitic, noncalcareous, 98%; sand, clear to very light-gray, quartzose, angular to subrounded, well sorted, fine, 1%; glauconite, fresh and moderate-yellowish-green to weathered and light-olive-brown, fine to coarse, 1%. No indigenous fossils observed. Note that the washed residue of this sample contains considerable down-hole contamination of overlying lithologies, particularly lignitic and carbonaceous shale of the overlying Tuscahoma Sand.

2,510-2,540 Ctgs: Lithology and paleontology same.

2,540-2,550 Ctgs: No sample.

2,550-2,580 Ctgs: Lithology and significant down-hole contamination same.

2,580-2,610 Ctgs: Clay, same, but very slightly and very finely fossiliferous, highly calcareous, 100%. Contamination of overlying lithologies, including common cement from the casing shoe at 814 feet persists through these samples.

2,610-2,640 Ctgs: Lithology same.

2,640-2,670 Ctgs: General lithology same. Observed small amounts of yellowish-gray glauconitic limestone among the other considerable amounts of caved contaminants which may or may not be in place. Noted very rare *Lenticulina wilcoxensis* and a single *Palmula mcglammeryae*, which, to my knowledge, is known only from the Salt Mountain Limestone and updip Nanafalia Formation.

Salt Mountain Limestone (E-log top at 2,710 feet)

2,670-2,700 Ctgs: Clay, very light-gray, finely fossiliferous, same, 85%; limestone (fine calcarenite), yellowish-gray to very light-gray, massive, indurated, very finely porous and permeable, fine to medium glauconitic, quartzose silty to very fine quartzose sandy, consisting predominantly of very finely divided unidentifiable fossil fragments, but with *Discocyclina* fragments on rare fractured surfaces, highly calcareous, 15%. This sample interval continues to contain considerable caved material from overlying sections. No indigenous planktonic foraminifera observed.

2,700-2,730 Ctgs: Limestone (fine glauconitic calcarenite), same, 70%; clay, same, 30%. The rare pelecypod and oyster shell fragments in this sample are believed to represent yet additional contamination from above. Observed very rare isolated *Discocyclina* sp.

2,730-2,760 Ctgs: General lithology same, with rare *Discocyclina* sp.

2,760-2,790 Ctgs: General lithology believed to be as above. Observed several large *Lenticulina midwayensis*.

2,790-2,820 Ctgs: Limestone, same, 70%; clay, finely fossiliferous, highly calcareous, same, 28%; sand, clear to very light-gray and yellowish-gray, quartzose, subangular to subrounded, well sorted, coarse, 2%; glauconite, light-olive, somewhat weathered and oxidized, coarse to very coarse, trace. Contains extremely abundant water-worn and abraded oyster shell fragments which may represent *Odontogryphaea thirsae* Gabb. **PHOTO**

2,820-2,850 Ctgs: General lithology same. The very abundant oyster shell fragments probably constitute up to 80% of the total volume of this sample.

2,850-2,880 Ctgs: Calcareous sandstone or very quartzose sandy limestone, pale-yellowish-brown to light-olive-gray, massive, dense, indurated, fine to medium glauconitic, very highly calcareous, fine-grained, 80%; clay, same, 20%. Contains very abundant oyster shell fragments which may

represent *Odontogryphaea thirsae*. Very heavily contaminated samples same.

2,880-2,910 Ctgs: No sample.

2,910-2,940 Ctgs: Lithology as at 2,850 to 2,880 feet. Sample continues to contain very abundant oyster shell fragments.

2,940-2,970 Ctgs: Clay, light-gray, massive, indurated, dense, very slightly and finely muscovitic, in part finely fossiliferous, moderately to strongly calcareous, 85%; calcareous sandstone, same, 15%; sand, clear to very light-gray, quartzose, subangular to subrounded, coarse, trace. Noted a sharp reduction in oyster shell fragments. Those which are present are believed to be just another component of this very heavily contaminated sample.

2,970-3,000 Ctgs: Heavily contaminated sample, probably consisting of light-gray calcareous clay as above. Only trace amounts of calcareous sandstone were observed. No indigenous fossils observed.

3,000-3,030 Ctgs: General lithology same.

3,030-3,060 Ctgs: Clay, light-gray, finely fossiliferous, same, 60%; limestone (sandy micrite), medium-light-gray, massive, indurated, dense, very fine to fine glauconitic, fine to medium quartzose sandy, highly calcareous, 40%. Note that this sample is very heavily contaminated and any trace constituents, including glauconite, quartzose sand, pyrite, and other material, is impossible to detect. No fossils observed.

3,060-3,090 Ctgs: General lithology same.

Midway Group, Naheola Formation (E-log top at 3,090 feet)

3,090-3,120 Ctgs: Sandstone, yellowish-gray to very light-gray, quartzose, massive, indurated, somewhat micritic, very slightly and finely glauconitic, finely muscovitic, very highly calcareous, very fine-grained, 80%; lignite and carbonized woody fragments, black, 20%. Contains common thick-walled oyster shell fragments believed to be in place. Observed rare *Lenticulina midwayensis*. **PHOTO**

3,120-3,150 Ctgs: Sandstone, same, 85%; lignite, same, 15%. Sample continues to be heavily contaminated.

3,150-3,180 Ctgs: Siltstone to very fine-grained quartzose sandstone, same, 70%; shale, olive-gray (N5) to light-olive-gray, massive, indurated, very highly yet finely muscovitic, lignitic, noncalcareous, 20%; lignite and carbonized woody fragments, black, same, 10%; pyrite, fresh and brassy to oxidized and dull, trace. Noted rare *Lenticulina midwayensis* believed to be in place.

3,180-3,210 Ctgs: General lithology same, but with shale, same, light-olive-gray, lignitic, 50%; siltstone to sandstone, same, 40%; lignite, same, 10%; pyrite, same, trace. No fossils observed. **PHOTO**

3,210-3,240 Ctgs: General lithology as above.

3,240-3,270 Ctgs: Lithology same. Note that these samples continue to be heavily contaminated with cement and both Lisbon and Tallahatta lithologies.

3,270-3,300 Ctgs: General lithology same, but with almost half of very fine sandstone fraction sideritic and light-brown (5YR5/6) to moderate-brown (5YR4/4). Sample is very heavily contaminated, containing abundant Lisbon and Tallahatta larger foraminifera.

3,300-3,330 Ctgs: Sideritic sandstone, light-brown to moderate-brown, massive, indurated, dense, very finely glauconitic, very highly calcareous, very fine-grained, 70%; sideritic limestone (sideritic micrite), moderate-brown (5YR3/4) to dark-reddish-brown, massive, indurated, dense, structureless and somewhat aphanitic, very highly calcareous, 30%. No indigenous fossils observed.

3,330-3,360 Ctgs: This sample is very heavily contaminated but believed to be as above. No microfossils observed.

3,360-3,390 Ctgs: General lithology believed to be as above.

3,390-3,420 Ctgs: General lithology same. Samples are very, very extensively contaminated.

3,420-3,450 Ctgs: Sample consists of 90% caved lithologies yet is believed to be as above.

3,450-3,480 Ctgs: Very extensively contaminated sample, but believed to consist predominantly of sideritic sandstone and siderite as above.

3,480-3,510 Ctgs: General lithology same. Noted common large *Bathysiphon* sp. plus a single small solitary coral tentatively assigned to *Turbolina* sp.

Porters Creek Formation (E-log top at 3,520 feet)

3,510-3,540 Ctgs: This sample consists of 90 to 95% caved lithologies including significant Lisbon, Tallahatta, and Hatchetigbee-Tuscahoma sediments. It does contain perhaps 8 to 10% by volume of lignitic shale, dark-gray (N3), massive to thinly laminated, indurated, very finely muscovitic, highly carbonaceous, and noncalcareous. This is believed to represent Porters Creek lithology. Noted several *Bathysiphon* sp.

3,540-3,570 Ctgs: General lithology same, although the lignitic and carbonaceous shale probably makes up 40% of the sample volume. Noted several fragments of *Bathysiphon* sp. and *Lenticulina midwayensis*.

3,570-3,600 Ctgs: Shale, medium-gray to pale-yellowish-brown, thinly laminated, indurated, very finely muscovitic and carbonaceous, highly lignitic, noncalcareous, 85%; sandstone, yellowish-gray, massive, indurated, fine to medium glauconitic and carbonaceous, micritic, very highly calcareous, fine-grained, 15%; lignite and carbonized woody

fragments, black, trace. Noted rare oyster shell fragments which may or may not be in place. Noted a single small ostracode. **PHOTO**

Beginning at 3,600 feet, samples were collected at 10-foot intervals. Although each sample was microscopically examined, for purposes of this report, lithologically similar samples were "composited" into intervals of varying thickness, as follows:

3,600-3,620 Ctgs: Samples are very heavily contaminated. Lignitic and carbonaceous shale, same, 90%; sandstone, same, fine-grained, 10%; pyrite, oxidized, somewhat fibrous, trace; lignite and carbonized woody fragments, same, trace. Rare to common *Bathysiphon* sp. and *Lenticulina* sp. No planktonic foraminifera observed.

3,620-3,670 Ctgs: Shale, same, 85%; sandstone, same, 10%; sideritic limestone, dark-reddish-brown, in part massive and dense and in part fine quartzose sandy and glauconitic, noncalcareous, 5%; rare to common *Bathysiphon* sp. Note that at least 90% of the sample volume consists of caved lithologies.

3,670-3,690 Ctgs: General lithology same, but with about 10% of shale fraction grayish-black (N2) to black and is very dense and indurated.

3,690-3,710 Ctgs: No samples.

3,710-3,740 Ctgs: Very extensively contaminated sample interval whose general lithology appears to be similar to the 3,670-3,690 foot interval.

3,740-3,840 Ctgs: Shale, medium-light-gray to light-olive-gray, somewhat fissile, very finely muscovitic and carbonaceous, noncalcareous, 80%; siltstone to sandstone, very light-gray, massive, in part firm and friable and in part indurated, very finely glauconitic and carbonaceous, finely muscovitic, noncalcareous, silt to very fine-grained, 15%; shale, grayish-black, thinly laminated, dense, indurated, noncalcareous, 5%; carbonized woody fragments, black, trace; pyrite, oxidized and weathered, trace. Note that these samples are very heavily contaminated. I suspect that only the *Lenticulina midwayensis* and rare *Bathysiphon* sp. may be in place.

3,840-3,890 Ctgs: Shale, medium-gray to medium-dark-gray (N4), thinly fissile and splintery, very finely muscovitic, lignitic, noncalcareous, 100%; pyrite, oxidized and somewhat fibrous and sulfurous, trace. Note that this series of samples is relatively free of contamination, containing only perhaps 10 to 15% caved material by sample volume. No fossils observed.

3,890-3,900 Ctgs: Shale, same, 95%; sideritic limestone, dark-reddish-brown to dusky-brown (5YR2/2), massive, indurated, dense, noncalcareous, 5%. Noted rare *Bathysiphon* sp. and very rare arenaceous *Trochammina* and *Haplophragmoides* sp.

3,900-3,910 Ctgs: Lithology same. This sample contains trace amounts of very light-gray, highly porous and permeable fossiliferous limestone which has

not been noted earlier. Preparation and examination of a nannofossil smear mount proved this lithology to be assignable to Zone NP-16, or to the Eocene Lisbon Formation.

3,910-3,960 Ctgs: Lithology and paleontology as at 3,890 to 3,900 feet. Continue to observe only very rare Paleocene *Trochammina* and *Haplophragmoides* sp. No Cretaceous fossils observed.

Upper Cretaceous

Selma Group, Prairie Bluff Chalk and Ripley Formation undifferentiated (E-log top at 3,903 feet)

3,960-3,970 Ctgs: Shale, same, 85% (believed to be caved from the overlying Porters Creek Formation); chalky limestone (fossiliferous micrite), very light-gray, massive, indurated, dense, containing common clear "spheres" probably representing immature tests or isolated chambers of microfossils, highly calcareous, 10%; sideritic limestone, same, 5%. No megafossils observed, and only rare *Trochammina* and *Haplophragmoides* sp. were observed. A nannofossil preparation proves this chalky limestone to be of Cretaceous, middle Maastrichtian, age. No *Nephrolithus frequens*, *Micula murus*, or *M. prinsii* were observed. The common occurrence of *Lithraphidites quadratus* and absence of overlying taxa indicates this upper Cretaceous chalky limestone to be assignable to the upper half of Zone 25b, or the very uppermost part of the *Arkhangelskiella cymbiformis* Zone, which we regard as being equivalent to the upper part of the *Gansserina gansseri* planktonic foraminiferal zone.

3,970-3,980 Ctgs: Shale, same, 90% (caved); chalky limestone, same, 10%; pyrite, oxidized, trace. No megafossils or Cretaceous microfossils observed. Note that these samples continue to contain bryozoans, echinoderm fragments, and larger foraminifera together with caved lithologies from overlying intervals.

3,980-4,020 Ctgs: Shale, same, 65% (caved); chalky limestone, same, 35%; pyrite, same, trace. No megafossils observed. Noted rare large arenaceous *Lituola* sp. plus common Maastrichtian Globotruncanids, Rugoglobigerinids, Globotruncanellids, Heterohelicids, and Planoglobigerinids.

4,020-4,090 Ctgs: Shale, same, 50% (caved); chalky limestone, same, but very light-gray to light-gray, 50%; paleontology as above, plus this interval contains the very rare brachiopod *Terebratulina* sp. Common planktonic foraminifera including large *Gansserina gansseri*.

4,090-4,170 Ctgs: Shale, same, caved, 50%; chalky limestone, predominantly yellowish-gray to very light-gray or white, massive, indurated, dense, very highly yet very finely fossiliferous, highly calcareous, 50%. Contains common large *Lituola* sp. Noted very rare brachiopods assignable to *Terebratulina* sp. Common to abundant arenaceous and calcareous benthonic foraminifera and abundant planktonic taxa.

E-log top of Demopolis Chalk at 4,150 feet—Lithology not recognized.

4,170-4,260 Ctgs: General lithology and paleontology same, plus very rare to rare inoceramid shell fragments and isolated prisms. The true sample lithology is obviously a chalky limestone, yet dark-gray Porters Creek shale persist as contamination through this interval.

4,260-4,340 Ctgs: General lithology as above, but with a significant amount of caved material from the overlying Lisbon-Tallahatta interval.

4,340-4,470 Ctgs: This interval is very extensively contaminated, consisting of about 85% dark-gray Porters Creek shale, 10% Lisbon-Tallahatta Limestones, and about 5% in place chalky limestone, white to very light-gray, massive, indurated, dense, very highly and finely microfossiliferous, highly calcareous. Contains very rare inoceramid shell fragments and *Lituola* sp. Due to abundance of caved contaminants, benthonic and planktonic foraminifera are rare.

4,470-4,590 Ctgs: General lithology as above, but with chalky limestone, same, 50%; shale (Porters Creek caved material), same, 40%; other contamination (Lisbon-Tallahatta and Hatchetigbee-Tuscahoma), 10%; continue to note very rare *Terebratulina* sp. and very rare large arenaceous *Lituola* sp., with rare Cretaceous smaller calcareous and arenaceous benthonic and planktonic foraminifera. Note that very rare cuttings of chalk contain fine to medium fresh euhedral black biotite mica crystals. This biotite has been observed in the middle and lower portions of the Demopolis Chalk in the outcrop belt of central and western Alabama. **PHOTO**

4,590-4,660 Ctgs: Lithology and paleontology same.

4,660-4,670 Ctgs: No sample.

4,670-4,690 Ctgs: Chalky limestone, white to very light-gray, massive, indurated, dense, very abundantly yet finely fossiliferous, highly calcareous, 50%; chalky marl, medium-gray to light-olive-gray, in part massive and in part weakly and indistinctly laminated, very highly and finely microfossiliferous, very slightly and finely muscovitic, highly calcareous, 25%; clay or marl, light-bluish-gray (5B7/1), thinly laminated, firm yet friable, very highly microfossiliferous, highly calcareous, 10%; shale, brownish-black to black, thinly laminated, indurated, noncalcareous, 10% (Porters Creek contamination); Lisbon, Tallahatta, Hatchetigbee, and Tuscahoma contamination, 5%. Observed rare inoceramid fragments, very rare *Lituola* sp., and very rare calcareous foraminifera.

Mooreville Chalk, Arcola Limestone Member (E-log top at 4,640 feet)

4,690-4,720 Ctgs: General lithology as above, but with chalky limestone, white to very light-gray, same, 50%; chalky marl, medium-gray to light-olive-gray, same, 25%; chalky marl, light-bluish-gray, same, 10%; contaminated

lithologies, 10%; calcisphere limestone (calcisphere-rich micrite), white, massive, indurated, dense, containing very abundant small "clear" calcitic calcispheres, very highly calcareous, 5%. Megafossil and microfossil paleontology as above. A nannofossil preparation was made from the calcisphere-rich Arcola Limestone. The indurated limestone yielded a common flora including *Calculites obscurus*, *C. ovalis*, and *Lucianorhabdus maleformis*. No *Bukryaster hayi* or *Ceratolithoides aculeus* were observed. Although the limestone can be assigned to the *Calculites ovalis* Zone or Zone CC-19, I am unable to relate the material to Subzone 19a or 19b. In the outcrop throughout Alabama, the Arcola indurated beds are assignable to Zone 19a, which appears to be consistent with the subsurface Arcola in central Washington County. These data provide further support for the time-synchronous nature for the Arcola in Alabama.

Mooreville Chalk, unnamed lower member (E-log top at 4,655 feet)

4,720-4,740 Ctgs: Very heavily contaminated interval with 80% of sample volume consisting of black Porters Creek shale. Cretaceous lithologies consist of a mixture of white to very light-gray chalky limestone, medium-gray to light-olive-gray chalky marl, and light-bluish-gray chalky marl. Perhaps 1% of sample volume consists of pale-yellowish-brown thinly laminated, somewhat "speckled" marl. No Arcola calcisphere-rich limestone cuttings are apparent in these samples. No megafossils or microfossils observed.

4,740-4,850 Ctgs: Reduction in Porters Creek contamination to perhaps 15% of sample volume. Cretaceous lithologies are generally as above and consist of "speckled" marl, pale-yellowish-brown, thinly laminated, highly calcareous, 50%; chalky limestone, white to very light-gray, same, 30%; chalky marl, medium-light-gray and light-bluish-gray, same, 20%. Very rare inoceramid fragments and oyster shell fragments. Contains very rare caved *Lenticulina* sp.

4,850-4,970 Ctgs: General lithology as above, but with white to very light-gray chalky limestone, same, 70%; light-gray to light-bluish-gray chalky marl, same, 20%; light-olive-gray chalky marl, same, 10%. Interval contains very rare inoceramid plate fragments and thick-walled oyster shell fragments which may or may not be in place. Note that this interval continues to contain significant amounts of caved contaminants, including cement from the surface casing at 814 feet (!), and considerable amounts of Lisbon, Tallahatta, Hatchetigbee, Tuscahoma, and Porters Creek contaminants, including Paleocene *Bathysiphon* sp. and overlying larger foraminifera. Whether this material is truly caved and incorporated with the sample as it enters the shale shaker, or whether the samples were improperly collected (contaminated?) at the surface is impossible to discern. Regardless, the strong mixing of

lithologies persists making lithological determination within samples and intervals difficult at best.

4,970-5,030 Ctgs: Chalky marl, light-olive-gray, massive, indurated, dense and nonporous, containing very abundant small microfossils and thus somewhat "speckled," very highly calcareous, 80%; chalky limestone, white to very light-gray, same, 20%. Note that this interval continues to be heavily contaminated both with respect to lithology and paleontology.

5,030-5,160 Ctgs: General contaminated lithology as above, but with chalky limestone, same, 50%; chalky marl, same, 50%. Very rare inoceramid plate fragments may be in place. Contains rare to common planktonic foraminifera, which are difficult to evaluate due to extensive contamination. **PHOTO**

5,160-5,180 Ctgs: General lithology same, but with chalky marl, same, 60%; chalky limestone, same, 20%; plus chalky shale, pale-yellowish-brown, thinly and weakly laminated, very slightly and finely muscovitic, very highly microfossiliferous, highly calcareous, 20%. Contamination persists throughout this section.

5,180-5,190 Ctgs: Chalky shale, same, 100%. This interval continues to be contaminated with many mixed lithologies (and fossils) from overlying intervals. A nannofossil preparation was made from the pale-yellowish-brown highly calcareous chalky shale. Included among the very abundant nannofossil flora are common to abundant *Calculites obscurus* in the absence of *Aspidolithus parcus*. This indicates that the chalky shale belongs to the *Calculites obscurus* Zone or Zone CC-17, which we relate to strata of early Campanian age. In terms of planktonic foraminiferal equivalence, Zone CC-17 is believed to lie within the lower one-third of the *Globotruncanita elevata* Zone.

5,190-5,200 Ctgs: No sample.

5,200-5,270 Ctgs: General lithology as at 5,180 to 5,190 feet. Note that these samples continue to contain considerable contamination from overlying beds.

Eutaw Formation (E-log top at 5,278 feet)

5,270-5,280 Ctgs; General very heavily contaminated lithologies as above. Noted trace amounts of sandstone, very light-gray, quartzose, very slightly micritic, slightly fine to medium muscovitic, abundantly glauconitic with glauconite very fine to fine and of an unusual brilliant-green (5G6/6) color, very highly calcareous, very fine-grained, trace. A nannofossil preparation was made from this fine-grained sandstone. Common nannofossils were present, including *Eprolithus floralis*, *Lithastrinus septenarius*, and *Marthasterites furcatus*. No *Calculites obscurus* nor *Lucianorhabdus cayeuxii* were noted. An interpretation of the total flora indicates this sample is assigned to the *Reinhardtites anthophorus* Zone or Zone CC-15, which we regard as of middle

Santonian age. In terms of planktonic foraminiferal equivalents, this zone should straddle the *Dicarinella concavata-Dicarinella asymetrica* zonal boundary.

5,280-5,290 Ctgs: Chalky shale, pale-yellowish-brown, thinly and weakly laminated, very slightly and finely muscovitic, very highly microfossiliferous, highly calcareous, 100%; sandstone, same, trace; glauconite, dark-yellowish-green, fine to medium, trace; sand, clear to glauconite-stained pale-green, quartzose, fine to coarse, trace. This sample contains over 50% contamination by volume.

5,290-5,300 Ctgs: General contaminated lithology as above, but with chalky shale, same, 97% (probably all caved!); sand, same, but fine to coarse, 3%; sandstone, same, trace; glauconite, same, trace. No fossils believed to be in place.

5,300-5,320 Ctgs: Last sample examined. Lithology same, but with caved (?) chalky shale, same, 85%; sandstone, same, 12%; sand, same, 3%. No diagnostic fossils observed. **PHOTO**

Note: The total depth of this well is at 6,610 feet. Samples below 5,320 feet were not examined. For purposes of the current project, sample descriptions will begin in the basal Mooreville Formation and continue downward through the Jurassic in the Placid Oil Company No. 5-12 McClure, Permit No. 1643, located about 0.5 mile toward the east of this well.

Interpretation by
Charles C. Smith
Geologist

SUMMARY OF GEOLOGY AND ELECTRIC-LOG TOPS
W. M. Smith No. 1
Permit No. 683
GSA No. 1878

	Sample interval			E-log top
Miocene	0	-	120	--
Oligocene				
in Tampa-Chickasawhay undifferentiated	120	-	210	--
Chickasawhay facies	210	-	?	200
Vicksburg Group				
Bucatunna Clay	?	-	330	272
lower Vicksburg undifferentiated	330	-	390	330
Eocene				
Jackson Group				
Yazoo Clay or Crystal River Formation	390	-	?	395
Moodys Branch Formation	?	-	540	510
Claiborne Group				
?Gosport Sand	540	-	660	560
Lisbon Formation	660	-	840	640
Tallahatta Formation	840	-	1,230	810
Wilcox Group				
Hatchetigbee Formation	1,230	-	?	1,248
Bashi Marl Member	?	-	1,650	1,638
Paleocene				
Wilcox Group				
Tuscahoma Sand	1,650	-	2,300	1,656
Nanafalia Formation	2,300	-	2,670	2,335
Salt Mountain Limestone	2,670	-	3,090	2,710
Midway Group				
Naheola Formation	3,090	-	3,510	3,090
Porters Creek Formation	3,510	-	3,960	3,520
Upper Cretaceous				
Selma Group				
Prairie Bluff Chalk and Ripley Formation undifferentiated	3,960	-	?	3,903
Demopolis Chalk	?	-	4,690	4,150
Mooreville Chalk				
Arcola Limestone Member	4,690	-	4,720	4,640
unnamed lower member	4,720	-	5,270	4,655
Eutaw Formation	5,270	-		5,278

INTRODUCTION

This report consists of lithological descriptions of 659 samples taken from the lower part of the Placid Oil Company No. 5-12 McClure well, Permit Number 1643, GSA No. 3642, located in the NW¼SW¼ sec. 5, T. 5 N., R. 2 W., Washington County, Alabama. These sample descriptions are followed by a one-page summary of the lithostratigraphic intervals and electric-log tops of each encountered geological unit. This report also contains a summary table of the stratigraphy encountered in the well, the generally accepted chronostratigraphic assignment of individual units and their generalized lithology and thickness. Also included is a brief summary report on the lithological and electrical characteristics of each unit, with pertinent comments on the lithic and/or electrical characteristics used in identifying and differentiating stratigraphic units. Low magnification color photographs of typical lithologies of most of the recognized units are included as an aid in further visualizing and understanding the distinctive lithologies encountered in the well. A lithologic log (see pocket), showing both the spontaneous potential and resistivity curves, has been prepared to graphically illustrate encountered lithologies and drill depths of the tops of each identified stratigraphic unit.

In general, overall sample quality was sufficient to adequately characterize individual samples although sample quality was often poor due to extensive down-hole contamination (noted within each sample description). Although these samples were unwashed (in the sense of extraction of microfossils), identified benthonic and planktonic foraminifera are listed within each sample interval. Preparation of nannofossil slides, identity of significant taxa, and comments regarding zonal and age assignments are also included within individual sample descriptions.

DETAILED LITHOLOGIC DESCRIPTION OF SAMPLES

Placid Oil Company
No. 5-12 McClure
NW¼SW¼ sec. 5, T. 5 N., R. 2 W.
Washington County, Alabama

Permit No. 1643
GSA No. 3642
Elevation (feet): K.B. 130
G. L. 104.45

Note: For purposes of the present investigation, the upper part of this well was not examined due to the lack of an electric log above 4,640 feet. Descriptions of sample lithologies above the basal Mooreville Chalk in the subsurface of this general area have been recorded from the Seaboard Oil Company, W. M. Smith No. 1 Well, Permit No. 683, GSA No. 1878, located in the NW¼SE¼ sec. 6, T. 5 N., R. 2 W., or about 0.5 mile west of the current well.

Depth (feet)	Description
Upper Cretaceous	
Selma Group, in lower Mooreville Chalk	
5,180-5,210 Ctgs:	Marl, light-gray (N7) to medium-gray (N5), massive to thinly and weakly fissile, dense and nonporous, very finely muscovitic, very rarely biotitic, highly and finely microfossiliferous, highly calcareous, 70%; chalky limestone, white (N9), massive, dense, indurated, very highly microfossiliferous, highly calcareous, 30%; pyrite, fresh, brassy, in small nodular masses, trace. Rare inoceramid prisms and inoceramid plate fragments, very rare oyster shell fragments; rare calcareous planktonic and benthonic foraminifera. **PHOTO**
5,210-5,280 Ctgs:	No samples.
5,280-5,310 Ctgs:	Marl, same, but in part light-olive-gray (5Y6/1), very finely muscovitic, 90%; chalky limestone, same, 10%; pyrite, mixed fresh and brassy to oxidized and dull, trace. Paleontology as above.
5,310-5,340 Ctgs:	Lithology and paleontology same, plus glauconite, moderate-yellowish-green (10GY6/4), ovate pellet-like grains, medium to coarse, trace.
Eutaw Formation (E-log top at 5,332 feet)	
5,340-5,370 Ctgs:	Marl, same, 90%; chalky limestone, same, 9%; marly sandstone, very light-gray (N8) to yellowish-gray (5Y8/1), massive, indurated, dense, very slightly and finely glauconitic and muscovitic, highly calcareous, very fine-grained, 1%; sand, clear to very light-gray, quartzose, subrounded, medium, trace; paleontology as above.
5,370-5,400 Ctgs:	Lithology and paleontology same.
5,400-5,430 Ctgs:	Lithology and paleontology same.

5,430-5,460 Ctgs: Lithology and paleontology same, plus carbonized woody fragments, olive-black (5Y2/1), trace.

5,460-5,490 Ctgs: Lithology and paleontology same.

5,490-5,520 Ctgs: Sandstone, white to very light-gray, quartzose, massive, indurated to somewhat friable, very marly, in part very fine to fine muscovitic and glauconitic, very highly calcareous, very fine-grained, 70%; marl, medium-gray, highly microfossiliferous, same, 20% (probably a caved contaminant); chalky limestone, same, 10% (believed to be a caved contaminant); glauconite, same, trace; sand, same, trace; carbonized woody fragments, olive-black to black (N1), medium, trace. Very rare oysters and inoceramid shell fragments with rare to common calcareous planktonic and benthonic foraminifera (believed to be caved). NOTE: The reason that these typical Eutaw sandstones occur in the samples over 150 feet below the electric log marker is impossible to identify. More than likely, drill rates through this interval were fairly high and the samples were not properly "lagged" to correct for circulation times for depth to the surface. Of course, the samples themselves could have been improperly collected, such as bagging five or six samples at one time. Regardless, the sample depth and electric log depth of the top of the Eutaw are in considerable disagreement. A nannofossil preparation was made from several fossil chips of the glauconitic and calcareous sandstone. The slide contains a very rare and extremely etched (dissolved) flora including *Eiffellithus eximius*, *E. turriseiffeli*, *Lucianorhabdus cayeuxii*, *L. maleformis*, *Watznaueria barnesae*, *Zygodiscus diplogrammus*, and several unidentified fragments of *Thoracosphaera*. This flora is restricted to nannofossil Zones CC-16 through CC-21a which we can relate no better than to late Santonian to middle Campanian age. **PHOTO**

5,520-5,550 Ctgs: Lithology, trace constituents, and paleontology same.

5,550-5,580 Ctgs: General lithology as above, but with marl, same, 60%; sandstone, same, 40%; trace constituents and paleontology same.

5,580-5,610 Ctgs: Sandstone, same, 50%; marl, same, 50% (probably caved). Very rare inoceramid and thick-walled oyster shell fragments which are believed to be caved contaminants.

5,610-5,640 Ctgs: This sample is very heavily contaminated with Mooreville Chalk and chalky marl plus it contains abundant cement from the casing shoe set at 4,632 feet. The sample consists of about 80% medium-gray chalky marl, highly fossiliferous and calcareous which is believed to be a caved contaminant, and about 20% very fine-grained quartzose sandstone as above.

5,640-5,670 Ctgs: Heavily contaminated lithology as above.

Tuscaloosa Group, Gordo Formation (E-log top at 5,658 feet)

5,670-5,700 Ctgs: Clay, pale-red-purple (5RP6/2) to pale-red (10R6/2), dark-yellowish-orange (10YR6/6), and light-olive (10Y5/4), massive, soft, somewhat "oily" or "waxy," noncalcareous, 70%; lignitic shale, medium-dark-gray (N4), thinly fissile, very finely muscovitic, finely carbonaceous, noncalcareous, 20%; siderite, light-red (5R6/6) to moderate-red (5R4/6), massive, dense, indurated, noncalcareous, 5%; sand, clear to very light-gray, quartzose, subangular to subrounded, poorly sorted, fine to coarse, 5%; pyrite, oxidized and somewhat fibrous, trace. This sample contains considerable amounts (greater than 50% by volume) of caved lithologies from overlying intervals. **PHOTO**

5,700-5,730 Ctgs: Clay, same, 60%; lignitic shale, same, 40%; siderite and sand, same, in trace amounts only. Sample is heavily contaminated.

5,730-5,760 Ctgs: General lithology as above, but with sand, same, medium to very coarse, in trace amounts.

5,760-5,790 Ctgs: Clay, same, 45%; sideritic sandstone, pale-reddish-brown (10R5/4) to moderate-reddish-brown (10R4/6), in very coarse sand-size to granular gravel-size spherical to subspherical concretionary masses, consisting of fine to medium sand cemented by siderite into small nodules, noncalcareous, 40%; lignitic shale, same, 13%; sand, same, fine to medium, 2%; siderite, same, massive, dense, trace; pyrite, same, trace. Sample contains about 30% by volume of caved material from overlying sections.

5,790-5,820 Ctgs: General lithology same, but with clay predominantly pale-reddish-brown and pale-pink (5RP8/2), 80%; sideritic sandstone, same, 15%; lignitic shale, same, 5%; trace constituents same, plus noted trace amounts of grayish-orange (10YR7/4) coarse to very coarse quartzose sand.

5,820-5,850 Ctgs: Clay, predominantly pale-pink to moderate-reddish-brown but also light-olive and dark-yellowish-orange, massive, soft, very finely muscovitic, "oily" or "waxy," noncalcareous, 85%; lignitic shale, medium-dark-gray, thinly fissile and somewhat splintery, very finely muscovitic, fine to medium carbonaceous, noncalcareous, 13%; sand, clear to very light-gray, in part ferruginous-stained grayish-orange, quartzose, subangular to subrounded, poorly sorted, fine to very coarse, 2%; pyrite, oxidized and dull, trace. Observed rare oyster shell fragments which may or may not be in place.

5,850-5,880 Ctgs: General lithology same, but with a slightly larger percentage of clay dark-yellowish-orange.

5,880-5,910 Ctgs: Waxy clay, same, 90%; lignitic shale, same, 10%; sand, same, but fine to medium, trace.

5,910-5,940 Ctgs: General lithology same.

5,940-5,970 Ctgs: Clay, same, 95%; lignitic shale, same, 5%; sand, same, trace. **PHOTO**

5,970-6,000 Ctgs: Lithology as above.

6,000-6,030 Ctgs: General lithology same, plus sandstone, white to very light-gray, quartzose, massive, indurated, "clean," noncalcareous, medium-grained, trace; siderite concretions, moderate-reddish-brown to dark-reddish-brown (10R3/4), coarse to very coarse, trace.

6,030-6,060 Ctgs: General lithology same.

6,060-6,090 Ctgs: Lithology as above.

6,090-6,120 Ctgs: Clay, pale-pink to moderate-reddish-brown, light-olive, and dark-yellowish-orange, massive, soft, "oily" or "waxy," very finely muscovitic, noncalcareous, 95%; lignitic shale, medium-gray, thinly fissile, firm yet friable, finely muscovitic, slightly quartzose silty, fine to medium carbonaceous, noncalcareous, 3%; sand, clear to very light-gray, quartzose, subangular to subrounded, well sorted, fine, 2%; sandstone, white, quartzose, massive, indurated, "clean," noncalcareous, medium-grained, trace; muscovite mica, fresh, fine to medium, trace; siderite, dark-reddish-brown, massive, indurated, trace. Observed very rare inoceramid and oyster fragments undoubtedly caved.

6,120-6,150 Ctgs: General lithology as above, but with part of clay fraction pale-olive (10Y6/2) to light-olive. This sample is heavily contaminated with multiple lithologies from overlying sections.

6,150-6,180 Ctgs: Lithology same.

6,180-6,210 Ctgs: General lithology same, plus shale, brownish-black (5YR2/1) to black, thinly laminated, firm but friable, somewhat "waxy," noncalcareous, trace. Samples continue to be heavily contaminated.

6,210-6,240 Ctgs: General lithology same.

6,240-6,270 Ctgs: Clay, same, 85%; siderite, dark-reddish-brown to very dusky-red (10R2/2), massive, indurated, dense, 10%; lignitic shale, same, 5%; black shale, fine sand, medium-gray quartzose sandstone, and oxidized pyrite as above in trace amounts.

6,270-6,300 Ctgs: Clay, light-olive-gray, grayish-orange (10YR7/4), light-olive to medium-olive-brown (5Y4/4), dusky-yellow (5Y6/4) to dark-yellowish-orange, and pale-pink to dark-reddish-brown, massive, soft to firm but friable, in part very finely muscovitic, "oil" or "waxy," noncalcareous, 75%; sandstone, white to very light-gray, quartzose, massive, indurated, in part "clean" and in part micritic, moderately calcareous, fine- to medium-grained, 12%; lignitic shale, medium-gray to black, thinly fissile, very finely muscovitic, noncalcareous, 10%; limestone, white to very light-gray, massive, dense to thinly laminated, highly calcareous, 3% (may represent slickensided-calcite vein filling); carbonized woody fragments, black, medium to coarse, trace; siderite,

dark-reddish-brown, massive, indurated, dense, trace; sand, clear, quartzose, subangular, fine to medium, trace. Noted very rare oyster shell fragments, probably caved. This sample continues to be contaminated with overlying Mooreville and Eutaw lithologies.

6,300-6,330 Ctgs: General lithology as above, but with sandstone, same, 15%, and limestone in trace amounts only.

6,330-6,360 Ctgs: General lithology same.

6,360-6,390 Ctgs: No change in lithology.

Middle Marine Shale (E-log top at 6,397 feet)

6,390-6,420 Ctgs: Clay, same, 70%; lignitic shale, same, 10%; sandstone, same, 10%; limestone, same, 10%; very fine to medium quartzose sand, siderite, pyrite, and carbonized woody fragments as trace constituents. Noted rare oyster shell fragments. A nannofossil preparation was made from several small chips of the limestone fraction in this sample. Unfortunately, the preparation was barren of fossils.

6,420-6,450 Ctgs: General lithology same.

6,450-6,480 Ctgs: General lithology same.

6,480-6,510 Ctgs: Clay, varicolored as at 6,270 to 6,300 feet, massive, soft, somewhat "oily" or "waxy," noncalcareous, 80%; lignitic shale, medium-gray to black, thinly fissile, very finely muscovitic, in part quartzose silty to very fine quartzose sandy, noncalcareous, 10%; limestone, white to very light-gray, massive, indurated, dense and very fine to fine quartzose sandy, in part megafossiliferous, highly calcareous, 5%; sandstone, white to very light-gray, quartzose, massive, "clean" to micritic, moderately calcareous, fine- to medium-grained, 5%; carbonized woody fragments, black, trace; sand, clear, quartzose, subrounded, fine, trace.

6,510-6,540 Ctgs: Shale, medium-gray to olive-gray (5Y4/1), thinly laminated and fissile, splintery, very abundantly yet very finely muscovitic, noncalcareous, 95%; clay, same, 4% (caved); siderite, same, 1% (caved); limestone and sandstone, same, as trace constituents.

Coker Formation, "pilot sand" (E-log top at 6,530 feet)

6,540-6,570 Ctgs: Muscovitic shale, same, but in part fine to medium carbonaceous, noncalcareous, 100%. Varicolored clay, fine sandstone, and siderite present in this sample are regarded as contaminants.

6,570-6,600 Ctgs: General lithology same. Noted very little Mooreville or Eutaw contamination. **PHOTO**

6,600-6,630 Ctgs: Shale, same, 95%; siltstone to sandstone, white to yellowish-gray, quartzose, massive, firm, friable, in part very finely muscovitic, chloritic, and glauconitic, moderately to strongly calcareous, siltstone

to very fine-grained sandstone, 5%. Small amounts (2 to 3% by volume) of Mooreville Chalk persist in these samples. A nannofossil preparation was made from fragments of the calcareous quartzose siltstone present in this sample. The material yielded a very rare and poorly preserved, badly etched, flora consisting of *Watznaueria barnesae*, *Zygodiscus diplogrammus*, (?)*Prediscosphaera cretacea*, and *Eiffellithus turriseiffeli*. This flora is assignable to Zones CC-9 through CC-26, a range we regard as being of late Albian through Maastrichtian age. Unfortunately, there are no time significant taxa present.

6,630-6,660 Ctgs: General lithology same.

6,660-6,690 Ctgs: Shale, same, 90%; siltstone to very fine sandstone, same, highly calcareous, 10%; siderite, dark-reddish-brown, massive, indurated, trace.

E-log top of "massive sand" at 6,705 feet—Lithology not recognized.

6,690-6,720 Ctgs: General lithology as above, but with shale, same, 80%; very fine-grained quartzose sandstone, in part finely glauconitic, highly calcareous, same, 20%.

6,720-6,750 Ctgs: Muscovitic and lignitic shale, same, 90%; very fine quartzose sandstone, same, 10%.

6,750-6,780 Ctgs: General lithology as above, but with lignitic shale, same, 90%; sandstone, same, 9%; carbonized woody fragments, olive-black to black, 1%.

6,780-6,810 Ctgs: General lithology same.

6,810-6,840 Ctgs: General lithology same, plus siderite, pale-reddish-brown to moderate-reddish-brown, massive, indurated, dense, trace.

6,840-6,870 Ctgs: Lithology as above, plus shale, medium-gray to light-olive-gray, thinly laminated, splintery, highly yet finely muscovitic, containing microscopic yellowish-gray particles (biologic?) giving the shale a speckled appearance, highly calcareous, trace. Nannofossils were examined from several small fragments of this gray highly calcareous shale. Although the flora is etched, with many taxa undoubtedly removed by solution, identified species include *Watznaueria barnesae*, *Zygodiscus diplogrammus*, *Eiffellithus turriseiffeli*, *Eprolithus floralis*, and *Cylindralithus* sp. As with the overlying preparation from 6,600 to 6,630 feet, this flora consists mainly of long-ranging taxa assignable to nannofossil Zone CC-7b through CC-16, or late Aptian through late Santonian age.

E-log top of "interbedded sand" at 6,865 feet—Lithology not recognized.

6,870-6,900 Ctgs: Lithology same. Note that much of the woody material is oxidized and sulfurous.

6,900-6,930 Ctgs: Lignitic shale, medium-gray to medium-dark-gray, thinly laminated, fissile, splintery, very abundantly yet very finely muscovitic, noncalcareous, in small part "speckled" and moderately calcareous, 85%; sandstone, white to yellowish-gray, quartzose, massive, firm, friable, in part fine-grained and relatively "clean" and in part siltstone and "marly," 14%; carbonized woody fragments, black, sulfurous, 1%; siderite, moderate-reddish-orange (10R6/6), massive, dense, indurated, trace; claystone, pale-olive (10Y6/2), massive, firm but friable, very finely muscovitic, containing silt- to very fine sand-sized dark-reddish-brown siderite concretions, noncalcareous, trace.

6,930-6,960 Ctgs: General lithology as above.

6,960-6,990 Ctgs: General lithology as above, with lignitic shale, same, 80%; sandstone, same, 18%; sand, clear to very light-gray, quartzose, subrounded, well sorted, with individuals grains having dusty overgrowths of tiny siderite crystals, medium to coarse, 2%; carbonized woody fragments, black, same, trace; claystone, same, very finely sideritic, trace.

6,990-7,020 Ctgs: No sample.

7,020-7,050 Ctgs: Lignitic shale, medium-gray to olive-gray, thinly laminated, fissile, splintery, abundantly very fine muscovitic, noncalcareous, 80%; sandstone, white to yellowish-gray, quartzose, massive, firm, in part "clean" and in part micritic, in part finely glauconitic, moderately calcareous, very fine- to fine-grained, 18%; siderite, moderate-reddish-orange to dark-reddish-brown, massive, indurated, dense, noncalcareous, 2%; sand, clear to grayish-orange, quartzose, subangular to subrounded, medium to coarse, trace; carbonized woody fragments, black, trace; pyrite, oxidized and dull, sulfurous, trace. **PHOTO**

7,050-7,080 Ctgs: General lithology as above, but with lignitic and muscovitic shale, same, 90%; sandstone, same, 10%; trace constituents same.

7,080-7,110 Ctgs: General lithology same, but with siderite in part dark-reddish-brown to very dusky-red.

7,110-7,140 Ctgs: Lithology same, plus siltstone, pale-olive, massive, indurated, dense, highly yet very finely muscovitic, in part containing medium sand-size pyrite spherules, noncalcareous, trace.

7,140-7,170 Ctgs: Lithology same, plus noted a single small phosphatized fish vertebra imbedded in a muscovitic lignitic shale cutting.

7,170-7,200 Ctgs: General lithology same.

7,200-7,230 Ctgs: General lithology as above.

Lower Cretaceous

Washita and Fredericksburg Groups (undifferentiated) (E-log top at 7,205 feet)

7,230-7,260 Ctgs: Clay or claystone, moderate-reddish-brown, massive, firm, friable, very slightly and very finely muscovitic, noncalcareous, 60%; lignitic shale, medium-gray, thinly laminated, fissile, splintery, abundantly very finely muscovitic, noncalcareous, 39%; sandstone, white to very light-gray, quartzose, massive, firm, in part "clean" and in part micritic, moderately calcareous, very fine- to fine-grained, 1%; carbonized woody fragments, black, trace; limestone (micrite), grayish-orange-pink (10R8/2) to pale-pink, massive, indurated, dense, very highly calcareous, trace. **PHOTO**

7,260-7,290 Ctgs: General lithology same. Continue to see trace amounts of pale-pink limestone.

7,290-7,320 Ctgs: Clay or claystone, same, 75%; lignitic shale, same, 24%; sandstone, same, 1%; claystone, pale-pink, massive, indurated, dense, noncalcareous, trace; carbonized woody fragments, olive-black to black, trace; siderite, dark-reddish-brown, massive, indurated, trace; limestone (micrite), same, trace.

7,320-7,350 Ctgs: General lithology same.

7,350-7,380 Ctgs: Clay or claystone, same, 90%; lignitic and muscovitic shale, same, 9%; sandstone, same, 1%; trace constituents same. Noted a single poorly preserved *Lenticulina* sp., unidentified, which appears to be in place.

7,380-7,410 Ctgs: General lithology same, plus limestone (micrite), grayish-orange-pink to pale-pink, massive, indurated, dense, very highly calcareous, trace. No fossils observed.

7,410-7,440 Ctgs: General lithology same. A nannofossil preparation was made from several small cuttings of the grayish-orange-pink calcareous limestone. Unfortunately, the slide is barren of fossils.

7,440-7,470 Ctgs: Lithology same.

7,470-7,500 Ctgs: Clay or claystone, moderate-reddish-brown, massive, soft to firm and friable, very slightly and finely muscovitic, noncalcareous, 95%; lignitic shale, same, 4% (probably caved); limestone, same, pale-pink, highly calcareous, 1%; sandstone, same, very fine-grained, trace (probably caved).

7,500-7,530 Ctgs: General lithology as above.

7,530-7,560 Ctgs: General lithology same.

7,560-7,590 Ctgs: Clay or claystone, moderate-reddish-brown to dark-reddish-brown, massive, dense, relatively soft to firm yet friable, moderately very finely muscovitic, noncalcareous, 95%; lignitic shale, same, 3% (probably caved); limestone (micrite), white to very light-gray and

pale-pink, massive, indurated, dense, in part somewhat crystalline and dolomitic, highly calcareous, 2%; sandstone, same, very fine-grained, trace (probably caved); sand, clear, quartzose, angular to subrounded, coarse, trace (probably caved).

7,590-7,620 Ctgs: Lithology same.

7,620-7,650 Ctgs: General lithology as above.

7,650-7,680 Ctgs: Lithology same.

7,680-7,710 Ctgs: No sample.

7,710-7,740 Ctgs: Clay to claystone, same, 99%; limestone (micrite), pale-pink, same, 1%. The small amounts of lignitic shale, sandstone, and medium to coarse quartzose sand, as well as chalky marl and cement, are all regarded as caved contaminants.

7,740-7,770 Ctgs: Lithology same.

7,770-7,800 Ctgs: Lithology same.

7,800-7,830 Ctgs: Clay to claystone, same, 75%; sandstone, white and very light-gray to moderate-reddish-orange, quartzose, massive, indurated, in part "clean" and porous and permeable and in part clayey or micritic and nonporous, both lithologic types moderately to strongly calcareous, very fine- to fine-grained, 22%; limestone (micrite), same, 3%. The 5% or so lignitic and muscovitic shale in this sample is regarded as contamination. A nannofossil slide was prepared from cuttings of the white, calcareous, micritic sandstone in this sample. Unfortunately, the preparation was barren of nannofossils. **PHOTO**

7,830-7,860 Ctgs: Lithology same, but with part of sandstone fraction moderately to strongly muscovitic and chloritic.

7,860-7,890 Ctgs: General lithology as above but with clay to claystone, same, 85%; sandstone, same, 10%; limestone (micrite), same, 5%.

7,890-7,920 Ctgs: Lithology same.

7,920-7,950 Ctgs: General lithology same, but with clay to claystone, same, 75%; sandstone, same, 22%; limestone (micrite), same, 3%.

7,950-7,980 Ctgs: General lithology same but with part of limestone fraction quartzose silty to very fine quartzose sandy and highly calcareous, and about half of clay to claystone fraction moderately calcareous. No fossils noted in limestone cuttings.

7,980-8,010 Ctgs: Lithology same.

8,010-8,040 Ctgs: General lithology same but with clay to claystone fraction noncalcareous.

8,040-8,070 Ctgs: Clay to claystone, same, 80%; sandstone, same, 15%; limestone (micrite), same, 5%.

8,070-8,100 Ctgs: Lithology same, but with clay to claystone fraction moderately calcareous.

8,100-8,130 Ctgs: General lithology same.

8,130-8,160 Ctgs: Clay or claystone, moderate-reddish-brown, massive, firm, abundantly yet very finely muscovitic, very slightly quartzose silty, in part moderately calcareous, 90%; sandstone, clear to very light-gray or pale-pink, quartzose, massive, firm to indurated, in part relatively "clean" and porous and in part micritic and tight, in part muscovitic and chloritic, moderately to strongly calcareous, very fine- to fine-grained, 5%; limestone (micrite), very light-gray to moderate-orange-pink (10R7/4), massive, indurated, dense, in part very finely muscovitic and quartzose silty, highly calcareous, 5%. No fossils observed. Note that these samples continue to contain 5 to 10% lignitic and muscovitic shale caved from overlying Tuscaloosa intervals.

8,160-8,190 Ctgs: General lithology same.

8,190-8,220 Ctgs: Lithology same.

8,220-8,250 Ctgs: Clay or claystone, same, in part noncalcareous, 95%; limestone (micrite), same, 4%; sandstone, same, 1%.

8,250-8,280 Ctgs: Lithology same.

8,280-8,310 Ctgs: General lithology as above.

8,310-8,340 Ctgs: General lithology same.

8,340-8,370 Ctgs: Clay or claystone, same, 92%; limestone (micrite), same, but in part recrystallized (dolomitic?), 5%; sandstone, same, 3%. Note that very finely muscovitic and lignitic shale believed to be a contaminant comprises about 10% of the volume of this sample.

8,370-8,400 Ctgs: General lithology same.

8,400-8,430 Ctgs: Lithology same.

8,430-8,460 Ctgs: General lithology same.

8,460-8,490 Ctgs: Lithology same.

8,490-8,520 Ctgs: General lithology same, but with limestone (micrite) in part consisting of rounded nodular micritic fragments (nodular limestone).

8,520-8,550 Ctgs: Clay or claystone, moderate-reddish-brown to dark-reddish-brown, massive, firm, abundantly yet very finely muscovitic, slightly quartzose silty, moderately calcareous, 97%; nodular limestone (micrite), very light-gray to moderate-reddish-brown, massive, indurated, dense, in part very finely muscovitic and quartzose silty, in part recrystallized and ?dolomitic, very highly calcareous, 2%; sandstone, very light-gray to yellowish-gray, quartzose, massive, firm to somewhat indurated, in part "clean" and relatively porous and permeable and in part micritic and tight, in part highly muscovitic and

chloritic, moderately to strongly calcareous, 1%. Continue to observe 5 to 10% by volume muscovitic lignitic shale regarded as a caved contaminant. A nannofossil preparation was made from the reddish-brown claystone so prevalent in this sample. Unfortunately, the sediment is barren of calcareous nannofossils.

8,550-8,580 Ctgs: General lithology same.

8,580-8,610 Ctgs: Lithology same.

8,610-8,640 Ctgs: Lithology same.

8,640-8,670 Ctgs: Lithology as above.

8,670-8,700 Ctgs: Clay or claystone, same, but entirely noncalcareous, 98%; limestone (micrite), same, 1%; sandstone, same, 1%.

Trinity Group, Paluxy Formation (E-log top at 8,662 feet)

8,700-8,730 Ctgs: Clay or claystone, same, 75%; sandstone, white to very light-gray, quartzose, massive, friable to indurated, predominantly "clean" and relatively porous and permeable, but in part containing a white micritic cement and relatively nonporous, both types moderately calcareous, fine- to medium-grained, 24%; limestone, same, 1%.

8,730-8,750 Ctgs: Clay or claystone, same, 65%; sandstone, same, 30%; limestone (micrite), very light-gray to moderate-reddish-brown, indurated, dense, nodular to massive and uniform, in part finely muscovitic and quartzose silty, very highly calcareous, 5%.

8,750-8,780 Ctgs: General lithology same. **PHOTO**

8,780-8,810 Ctgs: Clay or claystone, same, 80%; sandstone, same, 15%; limestone, mixed lithology, same, 5%.

8,810-8,840 Ctgs: General lithology as above.

8,840-8,870 Ctgs: General lithology same.

8,870-8,900 Ctgs: General lithology same.

8,900-8,930 Ctgs: Clay or claystone, predominantly dark-reddish-brown, massive, firm but friable, finely muscovitic, slightly quartzose silty, noncalcareous, 65%; sandstone, white to very light-gray, quartzose, massive bedded, firm to somewhat indurated, in part relatively "clean" and in part containing a white micritic cement, moderately to strongly calcareous, medium-grained, 15%; sand, clear to very light-gray, quartzose, angular to subangular, well sorted, with many grains having highly reflective "overgrown" crystal facies, medium to coarse, 15%; limestone (micrite), light-gray to pale-reddish-brown, massive, indurated, dense, in part very finely muscovitic, highly calcareous, 5%.

8,930-8,960 Ctgs: General lithology as above, but with clay or claystone, same, 50%; sandstone, same, 25%; sand, same, 20%; limestone, same, 5%.

8,960-8,990 Ctgs:	General lithology same.
8,990-9,020 Ctgs:	General lithology same, but with rare quartz sand grains very coarse.
9,020-9,050 Ctgs:	General lithology as above, but with clay or claystone, same, 45%; sandstone, same, 35%; sand, same, medium to very coarse, 15%; limestone, same, 5%.
9,050-9,080 Ctgs:	Clay or claystone, same, 93%; limestone, same, 5%; sandstone, same, 1%; sand, same, 1%.
9,080-9,110 Ctgs:	General lithology same.
9,110-9,140 Ctgs:	Lithology same.
9,140-9,170 Ctgs:	Lithology as above.
9,170-9,200 Ctgs:	General lithology same.
9,200-9,230 Ctgs:	Clay or claystone, same, 97%; limestone, same, 2%; sandstone, same, 1%; sand, same, medium to coarse, trace.
9,230-9,260 Ctgs:	General lithology as above.
9,260-9,290 Ctgs:	General lithology same.
9,290-9,320 Ctgs:	Clay or claystone, moderate-reddish-brown to dark-reddish-brown, massive, firm, friable, finely muscovitic, in part slightly quartzose silty, noncalcareous, 97%; limestone (micrite), yellowish-gray to moderate-reddish-brown, massive bedded, indurated, dense, in part massive and uniform and in part nodular, very finely crystalline, highly calcareous, 2%; sandstone, white to yellowish-gray, quartzose, massive, in part “clean” and in part containing a fine micritic cement, moderately to strongly calcareous, medium-grained, 1%; sand, clear to very light-gray, quartzose, angular to subrounded, medium to coarse, trace.
9,320-9,350 Ctgs:	Lithology as above.
9,350-9,380 Ctgs:	General lithology same.
9,380-9,410 Ctgs:	General lithology same. Note that this sample contains considerable contamination (±90% of sample volume) from overlying sections, including casing shoe cement (4,632 feet), Mooreville chalk, et al.
9,410-9,440 Ctgs:	General lithology same.
9,440-9,470 Ctgs:	Lithology same. Noted a single large poorly preserved ostracode which could not be identified either by myself or by T. Markham Puckett. No other fossils observed.
9,470-9,500 Ctgs:	General lithology same. No fossils observed.
9,500-9,530 Ctgs:	Clay or claystone, same, 97%; limestone (micrite), same, massive and uniform to somewhat nodular, highly calcareous, 3%; sandstone, same, predominantly marly (micritic), fine- to medium-grained, trace. No fossils observed.

9,530-9,560 Ctgs: General lithology same.

9,560-9,590 Ctgs: General lithology as above, but with clay or claystone, same, 94%; limestone (micrite), same, 5%; sandstone, same, micritic, 1%. Noted a single oyster shell fragment which may or may not be in place. These samples continue to be contaminated with material from overlying sections below the casing shoe at 4,632 feet.

9,590-9,620 Ctgs: General lithology same.

9,620-9,650 Ctgs: General lithology same. Noted a single small fragment of what appears to be a compressed calcareous worm tube.

9,650-9,680 Ctgs: General lithology same. No fossils observed.

9,680-9,710 Ctgs: Clay or claystone, moderate-reddish-brown to dark-reddish-brown, massive, dense, friable to indurated, abundantly very finely muscovitic, in part quartzose silty, rarely very fine quartzose sandy, in part very slightly calcareous, 95%; limestone (micrite), white to yellowish-gray and pale-pink to moderate-reddish-brown, massive and uniformly finely crystalline to somewhat nodular, indurated, nonfossiliferous, very slightly and finely muscovitic, highly calcareous, 4%; sandstone, white to pale-reddish-brown, quartzose, massive, indurated to friable, moderately argillaceous or micritic, and in part finely muscovitic, moderately to strongly calcareous, very fine- to fine-grained, 1%.

Mooringsport Formation (E-log top at 9,730 feet)

9,710-9,740 Ctgs: Clay or claystone, same, 92%; sandstone, same, but in part very fine- to medium-grained, 5%; limestone (micrite), same, 3%. Note that this sample contains very rare fragments of bryozoans and larger foraminifera. They are not in place, and their origin is mysterious. No such fossil material occurs in the Mooreville or below, and overlying beds in the well are behind casing. How this material got into this sample, I do not know.

9,740-9,770 Ctgs: General lithology same. Noted *Nummulites* spp. and *Camerina* spp. from overlying Oligocene and Eocene sections (behind pipe).

9,770-9,800 Ctgs: General lithology same, with rare biologic (inoceramid, echinoderm, pelecypod, and larger foraminifera) contamination.

9,800-9,830 Ctgs: Clay or claystone, same, 97%; limestone (micrite), same, massive to nodular, 2%; sandstone, same, 1%. Continue to observe biologic, but surprisingly little lithologic, contamination.

9,830-9,860 Ctgs: General lithology same.

9,860-9,980 Ctgs: There are no samples covering this stratigraphic interval.

9,980-10,010 Ctgs: Clay or claystone, same, 98%; micritic limestone, same, principally uniformly finely crystalline, highly calcareous, 2%; sandstone, same,

trace. No biologic contamination was observed in this sample. **PHOTO**

10,010-10,040 Ctgs: General lithology same, plus noted a single small cutting of oolitic limestone (packstone), pale-pink to grayish-orange-pink, massive, indurated, dense, highly calcareous.

10,040-10,070 Ctgs: General lithology same. No oolitic limestone noted.

10,070-10,100 Ctgs: Clay or claystone, same, 97%; micritic limestone, same, finely crystalline to nodular, 2%; sandstone, same, 1%. Noted a single small unidentifiable gastropod which appears to be in place.

10,100-10,130 Ctgs: General lithology same.

10,130-10,160 Ctgs: Lithology same.

10,160-10,190 Ctgs: General lithology same.

10,190-10,220 Ctgs: Clay or claystone, moderate-reddish-brown to dark-reddish-brown, massive, indurated to friable, very finely yet abundantly muscovitic, in part quartzose silty, noncalcareous, 94%; limestone (micrite), yellowish-gray to moderate-reddish-brown, massive and finely crystalline to somewhat nodular, indurated, nonfossiliferous, 3%; sandstone, white to pale-reddish-brown, quartzose, massive, indurated to friable, in part argillaceous or micritic and in part "clean," rarely finely muscovitic, moderately to strongly calcareous, 3%. Sample contains rare contamination from about all overlying levels.

?Ferry Lake Anhydrite equivalent (E-log top not recognized)

10,220-10,250 Ctgs: General lithology as above, but with clay or claystone, same, 87%; limestone, same, 10%; sandstone, same, 3%. **PHOTO**

10,250-10,280 Ctgs: General lithology same.

10,280-10,310 Ctgs: General lithology same.

10,310-10,340 Ctgs: Lithology same.

Rodessa Formation (E-log top not recognized)

10,340-10,370 Ctgs: Sandstone, moderate-orange-pink, quartzose, massive, indurated, sparingly argillaceous or micritic, moderately calcareous, fine- to medium-grained, 45%; clay or claystone, same, 35%; sand, clear, pale-pink and very pale-orange (10YR8/2), quartzose, subangular to subrounded, poorly sorted, fine to coarse, 15%; limestone (micrite), same, massive to nodular, 5%. **PHOTO**

10,370-10,400 Ctgs: General lithology same, plus muscovite mica, fresh, coarse to very coarse, trace.

10,400-10,430 Ctgs: Clay or claystone, same, 65%; sandstone, same, 25%; sand, same, but predominantly fine to medium, 5%; limestone, same, 5%; muscovite mica, fresh, coarse to very coarse, trace.

10,430-10,460 Ctgs: General lithology same. Continue to see trace amounts of fresh coarse to very coarse muscovite mica.

10,460-10,490 Ctgs: Clay or claystone, same, 65%; sandstone, same, 20%; limestone, same, 10%; sand, same, 5%.

10,490-10,520 Ctgs: General lithology same.

10,520-10,550 Ctgs: Clay or claystone, same, 75%; sandstone, same, 15%; limestone, same, 10%; muscovite mica, fresh, coarse to very coarse, trace.

?Pearsall Formation, Pine Island Member (E-log top at 10,590 feet)

10,550-10,580 Ctgs: Clay or claystone, moderate-reddish-brown to dark-reddish-brown, massive, firm to indurated, very abundantly but very finely muscovitic, in part quartzose silty, noncalcareous, 40%; sand, clear to grayish-orange-pink, quartzose, subangular to subrounded, well sorted, coarse to very coarse, 35%; sandstone, white and moderate-orange-pink to moderate-reddish-brown, quartzose, massive, indurated, very argillaceous or micritic, in part slightly to moderately calcareous, very fine- to fine-grained, 15%; limestone (micrite), pale-reddish-brown to moderate-reddish-brown, massive, indurated, dense, predominantly very finely crystalline, nonfossiliferous, highly calcareous, 10%.

10,580-10,610 Ctgs: General lithology same.

10,610-10,640 Ctgs: Sand, same, 45%; sandstone, same, but fine- to coarse-grained, 25%; clay or claystone, same, 25%; limestone (micrite), same, 5%. **PHOTO**

10,640-10,670 Ctgs: General lithology same.

10,670-10,700 Ctgs: Clay or claystone, same, 40%; sandstone, same, but predominantly very fine- to medium-grained, 30%; sand, same, 20%; limestone (micrite), same, 5%; siliceous claystone or siltstone, pale-olive to yellowish-olive (10Y4/2), massive, indurated, very slightly and finely muscovitic, noncalcareous, 5%.

Nuevo Leon Group, ?Sligo Formation (E-log top at 10,743 feet)

10,700-10,730 Ctgs: Clay or claystone, moderate-reddish-brown, same, 75%; sandstone, same, 10%; sand, same, predominantly medium, 5%; limestone, same, 5%; siliceous claystone or siltstone, same, 5%. **PHOTO**

10,730-10,760 Ctgs: Clay or claystone, same, 50%; sandstone, same, but mixed very fine- to fine-grained and other fragments medium- to coarse-grained, 25%; sand, same, but predominantly coarse, 10%; siliceous claystone or siltstone, same, noncalcareous, 10%; limestone (micrite), same, 5%.

10,760-10,790 Ctgs: Clay or claystone, same, 70%; sandstone, same, but predominantly fine- to medium-grained, highly calcareous, 10%; siliceous claystone or siltstone, same, 10%; sandstone, same, but predominantly medium-grained, 5%; limestone, same, 5%; muscovite mica, fresh, coarse to very coarse, trace.

10,790-10,820 Ctgs: General lithology same, but with clay or claystone, same, 50%; sandstone, same, 30%; other constituents as above.

10,820-10,850 Ctgs: Lithology as above.

10,850-10,880 Ctgs: General lithology same.

Hosston Formation (E-log top at 10,870 feet)

10,880-10,910 Ctgs: Sandstone, same, predominantly fine- to medium-grained, 40%; sand, same, medium to coarse, 25%; clay or claystone, moderate-reddish-brown, same, 20%; siliceous claystone or siltstone, same, noncalcareous, 10%; limestone, same, 5%. **PHOTO**

10,910-10,940 Ctgs: General lithology same.

10,940-10,970 Ctgs: General lithology same.

10,970-11,000 Ctgs: Lithology as above.

11,000-11,030 Ctgs: General lithology same, plus limestone, pale-olive, massive, indurated, very finely crystalline, slightly muscovitic and quartzose silty, moderately calcareous, trace.

11,030-11,060 Ctgs: General lithology same.

11,060-11,090 Ctgs: General lithology same.

11,090-11,120 Ctgs: General lithology same, plus feldspar (? orthoclase), white to pale-pink, fresh, coarse, trace.

11,120-11,150 Ctgs: General lithology as above, but with sand, same, predominantly coarse to very coarse.

11,150-11,180 Ctgs: Sand, clear and white to grayish-orange-pink, quartzose, subangular to subrounded, moderately well sorted, coarse to very coarse, 40%; sandstone, white to pale-pink, quartzose, massive, indurated, porous and permeable, slightly micritic, slightly to moderately calcareous, medium-grained, 35%; clay or claystone, moderate-reddish-brown, massive, indurated, dense, very abundantly but very finely muscovitic, in part quartzose silty, noncalcareous, 20%; limestone (micrite), predominantly moderate-reddish-orange, massive, indurated, dense and finely crystalline to somewhat nodular, highly calcareous, 3%; siliceous claystone or siltstone, pale-olive to grayish-olive, massive, indurated, noncalcareous, 2%; feldspar (? orthoclase), fresh, highly reflective cleavage faces, coarse to very coarse, trace; pyrite, fresh, brassy, trace.

11,180-11,210 Ctgs: General lithology same but no pyrite observed.

11,210-11,240 Ctgs: General lithology as above but with clay or claystone, same, 50%; sand, same, 25%; sandstone, same, 20%; limestone, same, 3%; siliceous claystone, same, 2%; feldspar, same, trace.

11,240-11,270 Ctgs: Lithology as above.

11,270-11,300 Ctgs: General lithology same.

11,300-11,330 Ctgs: General lithology same, plus muscovite mica, coarse to very coarse, trace.

11,330-11,360 Ctgs: Sand, clear to yellowish-gray, quartzose, angular to subrounded, moderately well sorted, coarse to very coarse, 75%; clay or claystone, same, 15%; sandstone, same, 7%; siliceous claystone or siltstone, pale-olive to grayish-olive, same, 2%; limestone (micrite), same, 1%; muscovite mica, fresh, coarse to very coarse, trace. No fossils observed.

11,360-11,390 Ctgs: General lithology same, plus chlorite schist (?), light-green (5G7/4), massive, indurated, dense, thinly foliated, noncalcareous, trace.

11,390-11,420 Ctgs: General lithology as above.

11,420-11,450 Ctgs: General lithology same.

11,450-11,480 Ctgs: General lithology as above but with sand, same, 85%; clay or claystone, same, 10%; sandstone, same, 3%; limestone (micrite), same, 2%; chlorite schist (?), same, trace; muscovite mica, same, trace.

11,480-11,510 Ctgs: General lithology same.

11,510-11,540 Ctgs: Sand, same, 80%; sandstone, white to very light-gray, quartzose, massive, indurated, argillaceous, noncalcareous, fine- to coarse-grained, 10%; clay or claystone, moderate-reddish-brown, massive, indurated, dense, very abundantly but very finely muscovitic, noncalcareous, 7%; siliceous claystone or siltstone, same, 2%; limestone (micrite), pale-red to moderate-reddish-brown, massive, indurated, dense, uniformly finely crystalline, highly calcareous, 1%; muscovite mica, fresh, coarse to very coarse, trace; chlorite schist (?), same, trace.

11,540-11,570 Ctgs: General lithology same.

11,570-11,600 Ctgs: Lithology same.

11,600-11,630 Ctgs: Lithology as above.

11,630-11,660 Ctgs: General lithology as above, plus chert, light-gray to medium-gray, cryptocrystalline, sharply angled edges, very coarse, trace.

11,660-11,690 Ctgs: General lithology same.

11,690-11,720 Ctgs: General lithology same, with rare chert granules grayish-orange.

11,720-11,750 Ctgs: General lithology same.

11,750-11,780 Ctgs: General lithology same.

11,780-11,810 Ctgs: Lithology as above.

11,810-11,840 Ctgs: General lithology same.

11,840-11,870 Ctgs: Lithology same.

11,870-11,900 Ctgs: General lithology same.

11,900-11,930 Ctgs: General lithology same, plus feldspar (orthoclase?), white to very light-gray, somewhat weathered and chalky, coarse to very coarse, trace.

11,930-11,960 Ctgs: General lithology same, but with part of clay or claystone fraction fine to medium quartzose sandy.

11,960-11,990 Ctgs: General lithology as above.

11,990-12,020 Ctgs: General lithology as above.

12,020-12,050 Ctgs: Sand, clear to very light-gray or yellowish-gray, quartzose, angular to subrounded, moderately well sorted, with white argillaceous material filling grain depressions and irregularities, medium to very coarse, 65%; sandstone, white, quartzose, massive, indurated, poorly sorted, argillaceous, noncalcareous, fine- to coarse-grained, 30%; clay or claystone, moderate-reddish-brown, massive, indurated, dense, abundantly very finely muscovitic, in part very fine to medium quartzose sandy, noncalcareous, 5%; muscovite mica, fresh, coarse to very coarse, trace; limestone (micrite), medium-light-gray (N6), massive, indurated, dense, very slightly and finely muscovitic, highly calcareous, trace; chlorite schist (?), same, trace.

12,050-12,080 Ctgs: General lithology same, plus feldspar (orthoclase?), white, somewhat weathered and chalky, trace; chert, grayish-orange, cryptocrystalline, coarse to very coarse, trace.

12,080-12,110 Ctgs: General lithology same.

12,110-12,140 Ctgs: General lithology same.

12,140-12,170 Ctgs: General lithology same, but with sand predominantly very coarse.

12,170-12,200 Ctgs: General lithology same.

12,200-12,230 Ctgs: General lithology same, but with about 10 to 15% of sand fraction chert, very pale-orange to grayish-orange and moderate-orange-pink to moderate-reddish-orange. **PHOTO**

12,230-12,260 Ctgs: General lithology same.

12,260-12,290 Ctgs: General lithology same.

12,290-12,320 Ctgs: General lithology as above.

12,320-12,350 Ctgs: Claystone, moderate-reddish-brown, massive, dense, abundantly very finely muscovitic, in part quartzose silty to medium quartzose sandy, noncalcareous, 50%; sandstone, moderate-orange-pink, quartzose, massive, indurated, poorly sorted, argillaceous, slightly muscovitic, noncalcareous, very fine- to medium-grained, 25%; sand, clear and pale-pink to moderate-reddish-orange, quartzose, angular to subrounded, moderately well sorted, with white argillaceous material adhering to grain surface irregularities, medium to coarse, 22%;

limestone (micrite), pale-reddish-brown to light-gray, massive, indurated, dense, finely crystalline, very slightly and finely muscovitic, highly calcareous, 3%; gravel, pale-yellowish-orange (10YR8/6) to moderate-yellowish-brown (10YR5/4), chert, entire grains subrounded, broken grains with sharply angled margins, granular, trace; muscovite mica, fresh, coarse to very coarse, trace.

12,350-12,380 Ctgs: General lithology same, plus chlorite schist (?), pale-olive, foliated, in coarse to very coarse sand-size grains, trace.

Lower Cretaceous-Jurassic Cotton Valley Group (E-log top at 12,370 feet)

12,380-12,410 Ctgs; General lithology as above, but with sandstone, same, 40%; sand, same, 35%; claystone, same, 22%; limestone, same, 3%; trace constituents same.

12,410-12,440 Ctgs: General lithology as above.

12,440-12,470 Ctgs: General lithology same, plus feldspar (orthoclase?), white, somewhat weathered and chalky, coarse to very coarse, trace. **PHOTO**

12,470-12,500 Ctgs; General lithology as above.

12,500-12,530 Ctgs: General lithology as above, but with sand, same, 65%; sandstone, same, 20%; claystone, same, 12%; limestone, same, 3%; trace constituents same.

12,530-12,560 Ctgs: General lithology same.

12,560-12,590 Ctgs: General lithology same.

12,590-12,620 Ctgs: General lithology as above.

12,620-12,650 Ctgs: General lithology as above, but with sand, same, but predominantly very coarse, 45%; sandstone, same, 35%; gravel, same, 5%; claystone, limestone, and trace constituents as above. **PHOTO**

12,650-12,680 Ctgs: General lithology as above.

12,680-12,710 Ctgs: Lithology same.

12,710-12,740 Ctgs: General lithology same.

12,740-12,770 Ctgs: Sand, clear to very light-gray, quartzose, subangular to subrounded, moderately well sorted, with white argillaceous or micritic material adhering to grain depressions and surface irregularities, medium to very coarse, 55%; sandstone, white to pale-pink, quartzose, massive, indurated, dense, in part argillaceous and finely muscovitic, medium-grained, 20%; claystone, moderate-reddish-brown, massive, indurated, dense, quartzose silty to very fine quartzose sandy, highly yet very finely muscovitic, noncalcareous, 20%; gravel, very light-gray to grayish-orange, quartz and chert, fractured and highly angular, granular, 3%; chlorite schist (?), pale-olive, massive to thinly foliated, very finely muscovitic and chloritic, 1%; limestone (micrite), medium-

gray, massive, dense, indurated, finely crystalline, nonfossiliferous, highly calcareous, 1%.

12,770-12,800 Ctgs: General lithology same, but with part of limestone fraction yellowish-gray to pale-pink.

12,800-12,830 Ctgs: General lithology as above, but with sandstone, same, noncalcareous, 50%; sand, same, 25%; claystone, same, 20%; gravel, chlorite schist (?), and limestone same.

12,830-12,860 Ctgs: Large cuttings with general lithology as above. Sandstone, same, 60%; claystone, same, 30%; gravel, same, 3%; limestone, same, 3%; sand, same, 3%; chlorite schist (?), same, 1%.

12,860-12,890 Ctgs: Large cutting with general lithology as above. Noted trace amounts of coal, black, massive to very thin bedded, dense and very highly reflective, one piece measuring about 1 cm in length. Also noted several medium to coarse sand-size fragments incorporated in cuttings of sandstone.

12,890-12,920 Ctgs: General lithology same. The lustrous black chips of coal are quite evident in this sample.

12,920-12,950 Ctgs: General lithology as above, but with sandstone, same, 70%; claystone, same, 20%; limestone, gravel, and sand, same, 3% each; chlorite schist (?), 1%; contains rare fragments of highly lustrous coal.

12,950-12,980 Ctgs: General lithology as above.

12,980-13,010 Ctgs: General lithology same. Continue to observe trace amounts of black coal.

13,010-13,040 Ctgs: General lithology as above, but with claystone, same, 50%; sandstone, same, predominantly fine- to medium-grained, 30%; sand, same, predominantly medium to coarse, 17%; limestone, same, 3%; coal, same, trace; gravel, same, trace.

13,040-13,070 Ctgs: General lithology same.

13,070-13,100 Ctgs: Claystone, moderate-reddish-brown, massive, indurated, dense, quartzose silty to very fine quartzose sandy, very highly yet finely muscovitic, noncalcareous, 50%; sandstone, white to very light-gray, quartzose, massive, dense, indurated, argillaceous, noncalcareous, medium-grained, 30%; sand, clear to very light-gray, subangular to subrounded, moderately well sorted, with white argillaceous or micritic material adhering to grain depressions and irregularities, medium to very coarse, 15%; limestone (micrite), light-gray and yellowish-gray to light-olive-gray, massive, dense, indurated, in part very slightly and finely muscovitic, finely crystalline (dolomitic?), noncalcareous, 5%; chert, grayish-orange to dark-yellowish-orange, cryptocrystalline, medium to coarse, trace.

13,100-13,130 Ctgs: General lithology same.

13,130-13,160 Ctgs: Sandstone, same, argillaceous, poorly sorted, medium- to coarse-grained, 45%; sand, same, 20%; gravel, predominantly quartzose, clear to grayish-orange, rounded to broken and sharply angled, granular, 20%; claystone, same, 15%; limestone, same, trace. **PHOTO**

13,160-13,190 Ctgs: General lithology same.

13,190-13,220 Ctgs: Sharp reduction in general grain size. Sand, same, but medium to very coarse, 65%; sandstone, same, predominantly fine- to medium-grained, 20%; claystone, same, 15%; gravel and limestone, same, in trace amounts.

13,220-13,250 Ctgs: General lithology same.

13,250-13,280 Ctgs: General lithology same.

13,280-13,310 Ctgs: Sandstone, white, quartzose, massive, indurated, dense, argillaceous, noncalcareous, medium-grained, 60%; sand, clear to very light-gray, quartzose, subangular to subrounded, moderately well sorted, with white argillaceous material adhering to irregularities in grain surfaces, coarse to very coarse, 20%; claystone, moderate-reddish-brown, massive, indurated, dense, abundantly very finely muscovitic, quartzose silty, noncalcareous, 15%; gravel, predominantly grayish-orange, chert, broken and sharply angular, 3%; limestone (micrite), predominantly light-olive-gray, massive, dense, indurated, uniformly finely crystalline to somewhat pelletiferous, moderately calcareous, 2%; coal, black, fresh, highly vitreous, coarse, trace.

13,310-13,340 Ctgs: General lithology same.

13,340-13,370 Ctgs: Large cuttings with general lithology as above.

13,370-13,400 Ctgs: This interval consists of three 10-foot samples which are obviously out of place. The samples consist of medium- to dark-gray anhydritic limestone and abundant anhydrite. As 10-foot samples were begun only deeper in this well and since this lithology will presumably be encountered deeper in the hole, it is believed that the depths on the cloth sample bags may have been partly illegible and confused during laboratory working of the samples.

13,400-13,430 Ctgs: General lithology as at 13,280-13,310, but with sandstone, same, 50%; claystone, same, 20%; sand, same, 20%; gravel, same, but mixed quartz and chert, 4%; limestone (micrite), same, 3%; shale to siltstone, pale-olive to moderate-yellowish-green (10GY6/4), massive to thinly laminated, indurated, dense to very abundantly muscovitic and very quartzose silty to very fine quartzose sandy, noncalcareous, 3%; coal, same, coarse, trace.

13,430-13,460 Ctgs: Note that this interval contains three 10-foot samples labeled 13,430-13,460 feet. The three 10-foot samples contain dark-gray limestone and anhydrite which are obvious out of place. The 30 feet of samples

included here are similar to the overlying samples at 13,370-13,400 feet.

13,460-13,490 Ctgs: General lithology as above, but with sandstone, same, 50%; claystone, same, 25%; sand, same, 20%; limestone, same, 3%; gravel, quartz and chert, same, granular, 2%; coal, same, trace.

13,490-13,520 Ctgs: Sample consists almost entirely of very large cuttings. Sandstone, same, 40%; claystone, same, 35%; gravel, clear to very light-gray and pale-pink to dark-yellowish-orange, quartz and chert, previously broken and with sharply angled margins, granular, 15%; sand, same, medium to very coarse, 7%; limestone, same, 3%.

13,520-13,550 Ctgs: General lithology as above, with relatively abundant granular gravel.

13,550-13,580 Ctgs: Sandstone, same, predominantly medium- to coarse-grained, 55%; sand, same, 25%; claystone, same, 15%; gravel, same, 3%; limestone, same, 2%; trace of black coal.

13,580-13,610 Ctgs: General lithology same.

13,610-13,640 Ctgs: General lithology same, but with rare chert grains fine to medium oolitic.

13,640-13,670 Ctgs: General lithology same. No oolitic chert observed.

13,670-13,700 Ctgs: General lithology same.

13,700-13,730 Ctgs: Large cuttings with general lithology as above, but with sandstone containing common muscovite, biotite, and chlorite mica plus trace amounts of limestone (?) fragments and pale-olive chlorite schist (?) fragments.

13,730-13,760 Ctgs: Sandstone, same, 50%; claystone, same, 30%; sand, same, medium to very coarse, 10%; gravel, same, but granular to pebbly, 7%; limestone, same, 3%.

13,760-13,790 Ctgs: Very large-size cuttings with general lithology as above.

13,790-13,820 Ctgs: General morphology and lithology of sample same.

13,820-13,850 Ctgs: General lithology as above.

13,850-13,880 Ctgs: Sample consists of very large cuttings. Claystone, moderate-reddish-brown to dark-reddish-brown, massive, dense, indurated, very finely muscovitic, in part quartzose silty to fine quartzose sandy, noncalcareous, 40%; sandstone, white to pinkish-gray or greenish-gray, quartzose, massive, indurated, dense, in part muscovitic and chloritic, argillaceous, noncalcareous, somewhat conglomeratic, predominantly fine- to medium-grained, 40%; sand, clear to very light-gray, quartzose, subangular to subrounded, moderately well sorted, with white argillaceous material adhering to surface depressions and grain irregularities, medium to very coarse, 10%; gravel, white to grayish-orange, predominantly chert, grains broken and sharply

angled, 6%; limestone (micrite), light-olive-gray, dolomitic, massive, indurated, dense, very slightly calcareous, 4%.

13,880-13,910 Ctgs: Sand, same, quartzose, coarse to very coarse, 60%; sandstone, same, predominantly medium-grained, 25%; claystone, same, 14%; gravel, same, 1%; limestone, same, trace; chlorite and muscovite mica, fresh, coarse, trace.

13,910-13,940 Ctgs: General lithology same.

13,940-13,970 Ctgs: General lithology same, plus metamorphic rock fragments (chlorite and muscovite schist), pale-olive, massive, somewhat foliated, very fine to fine quartzose sandy, trace.

13,970-14,000 Ctgs: General lithology same.

14,000-14,030 Ctgs: General lithology as above, but with sand, same, 60%; sandstone, same, 30%; claystone, same, 9%; gravel, same, 1%; limestone, chlorite and muscovite mica, and schist (?) fragments, same, in trace amounts.

14,030-14,060 Ctgs: General lithology same.

14,060-14,090 Ctgs; General lithology same.

14,090-14,120 Ctgs: Sand, same, predominantly coarse, 75%; sandstone, same, predominantly medium-grained, 20%; claystone, same, 5%; gravel, limestone, muscovite and chlorite mica, and schist (?) fragments, same, as trace constituents. **PHOTO**

14,120-14,140 Ctgs: General lithology same.

14,140-14,170 Ctgs: General lithology same. No fossils or fossil fragments of any sort noted.

14,170-14,200 Ctgs: Lithology as above.

14,200-14,230 Ctgs: General lithology same.

14,230-14,260 Ctgs: General lithology same.

14,260-14,290 Ctgs: Sample with very large cuttings. Sandstone, white to very light-gray, quartzose, massive, indurated, dense, argillaceous, in part moderately chloritic and muscovitic, noncalcareous, fine- to medium-grained, 45%; claystone, dark-reddish-brown, indurated, dense, massive bedded, abundantly very fine muscovitic, quartzose silty to very fine quartzose sandy, noncalcareous, 35%; sand, clear, quartzose, subangular to subrounded, moderately well sorted, with white argillaceous material adhering to irregularities in grain surfaces, coarse to very coarse, 10%; gravel, clear, pale-reddish-brown, grayish-orange, and light-brown (5YR5/6), quartz and chert, broken and predominantly angular, granular, 7%; limestone (micrite), light-olive-gray, dolomitic, uniformly microcrystalline, massive, indurated, dense, very slightly calcareous, 3%; oolitic chert, white to grayish-orange, indurated, dense, siliceous, trace.

14,290-14,320 Ctgs: General lithology same.

14,320-14,350 Ctgs: Large cuttings with general lithology same.

14,350-14,380 Ctgs: General reduction in size of cuttings with sand, same, predominantly very coarse, 50%; sandstone, same, 30%; claystone, same, 15%; limestone, same, 4%; gravel, same, 1%; chlorite mica, fresh, in coarse to very coarse sand-size aggregates, trace.

14,380-14,410 Ctgs: General lithology same, plus metamorphic rock fragments (chlorite schist?), pale-olive, indistinctly foliated, trace.

14,410-14,440 Ctgs: General lithology same.

14,440-14,470 Ctgs: Lithology as above, but with sand, same, 60%; sandstone, same, 30%; claystone, same, 5%; limestone, same, 4%; gravel, same, 1%; trace constituents as above.

14,470-14,500 Ctgs: General lithology same.

14,500-14,530 Ctgs: Lithology same.

14,530-14,560 Ctgs: General lithology same.

14,560-14,590 Ctgs: General lithology same, plus feldspar (orthoclase?), white to very light-gray, somewhat weathered and chalky, very coarse, trace.

14,590-14,620 Ctgs: General lithology as above.

14,620-14,650 Ctgs: General lithology same, plus muscovite mica, fresh, coarse to very coarse, trace.

14,650-14,680 Ctgs: Sand, clear to very light-gray, quartz and chert but predominantly quartz, subangular to subrounded, well sorted, with white micritic or argillaceous material (anhydrite?) adhering to grain irregularities, coarse to very coarse, 70%; sandstone, white to yellowish-gray, quartzose, massive, indurated, dense, in part chloritic and muscovitic, very argillaceous (anhydritic?), noncalcareous, in part conglomeratic but predominantly fine- to medium-grained, 20%; claystone, dark-reddish-brown, massive, dense, indurated, finely muscovitic, quartzose silty to fine quartzose sandy, noncalcareous, 5%; gravel, predominantly grayish-orange to dark-yellowish-orange, chert, angular, granular, 4%; limestone (micrite), pale-yellowish-brown (10YR6/2), massive, dense, indurated, uniformly microcrystalline, dolomitic, slightly calcareous, 1%; muscovite and chlorite mica, fresh, medium to coarse, trace. **PHOTO**

14,680-14,710 Ctgs: General lithology same, plus feldspar (orthoclase?), moderate-orange-pink, somewhat weathered, coarse, trace.

14,710-14,740 Ctgs: General lithology as above.

14,740-14,770 Ctgs: General lithology same, but with sand predominantly very coarse.

14,770-14,800 Ctgs: Lithology as above.

14,800-14,830 Ctgs: General lithology same.

14,830-14,860 Ctgs: General lithology same, plus metamorphic rock fragments (chlorite schist?), pale-olive to light-olive, finely foliated, trace.

14,860-14,890 Ctgs: General lithology same.

14,890-14,920 Ctgs: General lithology as above, but with chert in part light-olive-gray (5Y5/2).

14,920-14,950 Ctgs: Sample with very large cuttings. General lithology as above, but with claystone, same, 50%; sand, same, 25%; sandstone, same, 20%; gravel, same, 4%; limestone, same, 1%; muscovite and chlorite mica, feldspar, and metamorphic rock fragments as trace constituents.

14,950-14,980 Ctgs: Sample with small cuttings size. Sand, clear to very light-gray, quartzose, subangular to subrounded, well sorted, with white chalky-like argillaceous material (anhydrite?) adhering to irregularities in grain surfaces, noncalcareous, coarse to very coarse, 65%; sandstone, white to pale-olive, quartzose, massive bedded, indurated to somewhat friable, dense and nonporous, very highly argillaceous (anhydrite?), moderately chloritic and muscovitic, noncalcareous, predominantly medium-grained, 25%; claystone, dark-reddish-brown, massive, indurated, dense, finely muscovitic, in part fine quartzose sandy, noncalcareous, 10%; gravel, yellowish-gray to grayish-orange, quartzose, grains broken and sharply angled, trace; limestone (micrite), pale-yellowish-brown, massive, indurated, dense, uniformly finely crystalline, dolomitic, very slightly calcareous, trace; muscovite mica, fresh, coarse to very coarse, trace; metamorphic rock fragments (chlorite schist?), pale-olive to light-olive, finely foliated, indurated, trace; feldspar (orthoclase?), white to moderate-orange-pink, somewhat weathered and chalky, coarse, trace.

14,980-15,010 Ctgs: General lithology same.

15,010-15,040 Ctgs: Very coarse cuttings. Claystone, same, 50%; sandstone, same, 40%; sand, same, but predominantly very coarse, 7%; gravel, same, predominantly quartzose, 3%; limestone and other trace constituents as above.

15,040-15,070 Ctgs: Very coarse cuttings with general lithology same.

15,070-15,100 Ctgs: Return to sample with small cuttings size. Lithology and composition of samples as at 14,950-14,980.

15,100-15,130 Ctgs: General lithology as above, but with sand, same, coarse to very coarse, 55%; sandstone, same, but in part grayish-orange-pink, well sorted, fine-grained, 35%; claystone, same, 10%; gravel, limestone, metamorphic rock fragments, chlorite and muscovite mica, same, as trace constituents.

15,130-15,160 Ctgs: General lithology same, with sandstone, same, fine-grained, and predominantly moderate-orange-pink.

15,160-15,190 Ctgs: General lithology as above, but with sandstone, same, moderate-orange-pink, fine-grained, 50%; sand, same, coarse to very coarse, 35%; claystone, same, 15%; trace constituents as above.

15,190-15,220 Ctgs: Very coarse and large cuttings with general lithology as above.

15,220-15,250 Ctgs: Return to normal cuttings. Sand, same, coarse to very coarse, 65%; sandstone, same, white to moderate-orange-pink, predominantly fine-grained, in part slightly calcareous, 25%; claystone, same, 10%; trace constituents same.

15,250-15,280 Ctgs: General lithology same.

15,280-15,300 Ctgs: General lithology same.

15,300-15,330 Ctgs: General lithology as above.

15,330-15,360 Ctgs: Sandstone, moderate-orange-pink to white, quartzose, massive, indurated, dense, very argillaceous (anhydritic?), well sorted, noncalcareous, in part very slightly and finely chloritic, fine-grained, 50%; sand, very light-gray, quartzose, subangular to subrounded, moderately well sorted, with white argillaceous (anhydritic?) material adhering to grain depressions and irregularities, noncalcareous, coarse to very coarse, 40%; claystone, dark-reddish-brown, massive, indurated, dense, very finely muscovitic, in part quartzose silty to fine quartzose sandy and finely muscovitic, noncalcareous, 10%; metamorphic rock fragments (chlorite schist?), pale-olive, thinly foliated, trace; muscovite and chlorite mica, fresh, coarse, trace; feldspar (orthoclase?), white to very pale-orange, somewhat weathered and chalky, coarse, trace; limestone (micrite), pale-yellowish-brown, massive, indurated, dense, uniformly finely crystalline, dolomitic (?), very slightly calcareous, trace. **PHOTO**

15,360-15,390 Ctgs: Large coarse cuttings with general lithology as above, but with claystone, same, 45%; sandstone, same, 40%; sand, same, 15%; trace constituents same.

15,390,15,420 Ctgs: General lithology same.

15,420-15,450 Ctgs: General lithology same.

Jurassic Louark Group, Haynesville Formation (E-log top at 15,397 feet)

15,450-15,480 Ctgs: General lithology as above, but with claystone, same, 45%; sandstone, same, 40%; sand, same, 10%; with limestone (oosparite), white to very light-gray, massive, indurated, quartzose silty to fine quartzose sandy, in part fine to medium muscovitic, containing very abundant olive-gray to olive-black fine sand-size rounded oolites, very highly calcareous, 5%; trace constituents same. A nannofossil slide was prepared from several small chips of the very highly calcareous white oosparite from this sample. Regrettably, the slide is barren of calcareous nannofossils. **PHOTO**

15,480-15,510 Ctgs: General lithology same.

15,510-15,540 Ctgs: General lithology same.

15,540-15,570 Ctgs: Claystone, dark-reddish-brown, massive, indurated, dense, very abundantly very finely muscovitic, in part moderately muscovitic and quartzose silty to fine quartzose sandy, noncalcareous, 65%; sandstone, pale-pink to moderate-orange-pink, quartzose, well sorted, massive, indurated, dense, argillaceous (anhydritic?), noncalcareous, 15%; limestone (micrite), medium-dark-gray to dark-gray (N3), massive, indurated, dense, uniformly very finely crystalline, in part anhydritic and medium-light-gray, highly calcareous, 13%; sand, clear to very light-gray, quartzose, subangular to subrounded, well sorted, with white micritic material (anhydrite?) adhering to irregularities on grain surfaces, noncalcareous, coarse to very coarse, 5%; limestone (oosparite), white to very light-gray, massive, indurated, very slightly quartzose silty to very fine quartzose sandy, containing very abundant olive-gray to olive-black fine sand-size oolites, very highly calcareous, 2%; feldspar (orthoclase?), very pale-orange, fresh, coarse to very coarse, trace; gravel, clear to grayish-orange, quartz and chert, angular, broken, trace; anhydrite, white, massive, very finely crystalline, noncalcareous, trace.

15,570-15,600 Ctgs: General lithology same.

15,600-15,630 Ctgs: General lithology as above, but with limestone (micrite), same, microcrystalline, in part anhydritic, 55%; claystone, same, 35%; anhydrite, same, 5%; sandstone, same, 3%; sand, same, 1%; oolitic limestone, same, 1%; trace constituents same.

15,630-15,660 Ctgs: General lithology same.

15,660-15,690 Ctgs: General lithology as above, but with limestone (micrite), same, very anhydritic, 40%; claystone, same, 40%; sandstone, same, 10%; anhydrite, same, soft, 10%; oolitic limestone and sand, same, in trace amounts only.

15,690-15,720 Ctgs: General lithology same.

15,720-15,750 Ctgs: General lithology same, with micritic limestone containing thin irregular lenses of anhydrite.

15,750-15,780 Ctgs: General lithology as above, but with anhydritic limestone (micrite), same, 70%; anhydrite, same, 20%; claystone, same, 10% (caved?); sand, sandstone, and oolitic limestone, same, in trace amounts. **PHOTO**

15,780-15,810 Ctgs: General lithology same.

15,810-15,840 Ctgs: General lithology same.

15,840-15,870 Ctgs: General lithology as above, but with limestone (micrite), same, anhydritic, highly calcareous, 55%; anhydrite, same, 30%; claystone,

same, very quartzose silty to fine quartzose sandy, 15%; oolitic micrite, sandstone, and sand, same, in trace amounts.

15,870-15,900 Ctgs: General lithology same.

15,900-15,930 Ctgs: General lithology same.

15,930-15,960 Ctgs: General lithology same, but with part of micritic limestone fine to medium oolitic.

15,960-15,990 Ctgs: General lithology same. No microscopic fossils or fossil fragments noted in any of the abundant limestone cuttings.

15,990-16,000 Ctgs: No sample.

NOTE: From 16,000 feet down, samples were collected at 10-foot intervals.

16,000-16,010 Ctgs: Anhydritic limestone, very light-gray to medium-light-gray or medium-gray, massive, indurated, dense, uniformly very finely microcrystalline, very anhydritic, with anhydrite often in thin seams and partings, highly calcareous, 75%; anhydrite, white to very light-gray, massive, relatively soft, in part finely crystalline, noncalcareous, 20%; claystone, dark-reddish-brown, massive, indurated, dense, very abundantly but very finely muscovitic, in part quartzose silty to very fine quartzose sandy, noncalcareous, 5%; sandstone, pale-pink, quartzose, massive, indurated, impermeable, argillaceous (anhydritic?), noncalcareous, trace; cement from casing shoe at 15,985, trace; oolitic limestone (oosparite), light-gray, massive, indurated, dense, containing abundant medium to coarse sand-size dark-gray oolites, highly calcareous, trace.

16,010-16,030 Ctgs: Anhydrite, same, 85%; anhydritic limestone, same, but in part light-olive-gray, highly calcareous, 15%; claystone, same, trace; sand, clear to yellowish-gray and grayish-orange, quartz and chert, subangular to subrounded, poorly sorted, medium to very coarse, trace (may have been washed from cement).

16,030-16,040 Ctgs: Anhydrite, same, containing thin seams of dark-gray limestone/shale, 80%; anhydritic limestone, same, but in part finely granular, highly calcareous, 20%; cement, same, trace. No claystone or sand was observed.

16,040-16,050 Ctgs: Dolomitic limestone, light-olive-gray, uniformly finely crystalline, massive, indurated, dense, anhydritic, very slightly calcareous, 90%; anhydrite, same, 8%; anhydritic limestone (micrite), same, 2%.

16,050-16,060 Ctgs: Dolomitic limestone, same, 60%; dark-gray anhydritic limestone, same, 35%; anhydrite, same, 5%; claystone, dark-reddish-brown, massive, indurated, dense, very highly yet finely muscovitic, in part very highly very fine quartzose sandy, noncalcareous, trace.

16,060-16,070 Ctgs: Anhydrite, same, 60%; dolomitic limestone, light-olive-gray, same, 20%; anhydritic limestone, same, 20%; claystone, same, trace. Note that this interval contains about 20% cement by sample volume (from the casing shoe at 15,985 feet).

16,070-16,100 Ctgs: Anhydritic limestone, very light-gray to light-olive-gray and medium-gray, massive, indurated, dense, uniformly very finely crystalline, anhydritic, lighter colors due to greater percentages of contained anhydrite, very slightly to strongly calcareous, 100%; anhydrite, white to very light-gray, massive, soft, very finely crystalline, noncalcareous, trace.

16,100-16,160 Ctgs: General lithology as above, with anhydritic limestone, same, 85%; anhydrite, same, 15%.

16,160-16,170 Ctgs: General lithology as above, but with anhydrite, same, 60%; anhydritic limestone, same, but with a greater percentage of anhydrite lenses and seams, moderately to strongly calcareous, 40%.

16,170-16,180 Ctgs: Anhydritic limestone, same, 95%; anhydrite, same, 5%.

16,180-16,190 Ctgs: Anhydrite, same, 95%; anhydritic limestone, same, 5%. **PHOTO**

16,190-16,210 Ctgs: Anhydritic limestone, same, 90%; anhydrite, same, 10%.

16,210-16,270 Ctgs: Anhydritic limestone, pale-yellowish-brown (10YR7/2) to medium-dark-gray, massive, indurated, dense, impermeable, nonporous, uniformly very finely crystalline, very slightly to very strongly calcareous (determined by percentages of anhydrite in limestone), 100%. **PHOTO**

16,270-16,290 Ctgs: Anhydritic limestone, same, 95%; anhydrite, white to very light-gray, massive, firm but relatively soft, in part finely crystalline, noncalcareous, 5%.

16,290-16,300 Ctgs: Anhydrite, white, soft, 90%; anhydritic limestone, same, 10%.

16,300-16,310 Ctgs: Anhydritic limestone, same, 85%; anhydrite, same, 15%.

16,310-16,330 Ctgs: Anhydritic limestone, same, 50%; anhydrite, same, 50%.

16,330-16,350 Ctgs: Anhydritic limestone, same, 80%; anhydrite, same, 20%.

16,350-16,360 Ctgs: Anhydritic limestone, same, 40%; calcareous shale, light-olive-gray to light-olive-brown (5Y5/6), massive to indistinctly laminated, firm yet friable, finely muscovitic and quartzose silty, highly calcareous, 40%; anhydrite, same, 20%. No megafossils observed. A nannofossil slide was made from several small chips of the light-olive-gray calcareous shale present in this sample. Unfortunately, the slide proved to be barren of calcareous nannofossils, consisting entirely of clay minerals, very finely divided organic detritus, and fine quartzose silt. A nannofossil preparation was also made from the light-olive-brown calcareous shale, and it too was barren of fossils, consisting of clay minerals with lesser amounts of organic debris and quartzose silt.

16,360-16,370 Ctgs: General lithology as above, but with anhydrite, same, 80%; calcareous shale, same, 10%; anhydritic limestone, same, 10%.

16,370-16,400 Ctgs: No samples.

16,400-16,410 Ctgs: Claystone, moderate-reddish-brown, massive, indurated, firm yet friable, very highly yet finely muscovitic, quartzose silty, anhydritic, slightly calcareous, 60%; anhydritic limestone, same, 25%; anhydrite, same, 15%; shale, light-olive-gray, same, trace.

16,410-16,440 Ctgs: No samples.

16,440-16,450 Ctgs: Anhydritic limestone (micrite), medium-gray to light-olive-gray, massive, dense, indurated, containing rare fine to medium sand-size dark-gray unidentifiable clasts, highly calcareous, 70%; anhydrite, white, soft, same, 10%; claystone, yellowish-gray, massive, firm, friable, very highly yet finely muscovitic, very quartzose silty, anhydritic (?), very slightly calcareous, 10%; claystone, moderate-reddish-brown, same, 10%; calcareous shale, same, trace. A nannofossil slide was prepared from cuttings of the very slightly calcareous yellowish-gray claystone in this sample. Regrettably, the slide was barren of nannofossils, consisting of clay minerals with very abundant rhombic anhydrite crystals.

16,450-16,460 Ctgs: General lithology as above, but with anhydrite, same, 70%; yellowish-gray claystone, same, 20%; moderate-reddish-brown claystone, same, 5%; anhydritic limestone, same, 5%.

16,460-16,490 Ctgs: Claystone, yellowish-gray, very finely muscovitic, abundantly quartzose silty, anhydritic, noncalcareous to very slightly calcareous, 75%; anhydrite, same, 20%; moderate-reddish-brown claystone, same, 5%; anhydritic limestone (micrite), same, trace.

16,490-16,500 Ctgs: Yellowish-gray claystone, same, 70%; anhydrite, same, 10%; shale, medium-gray, finely laminated to massive, firm, relatively clean, anhydritic (?), very slightly calcareous, 10%; moderate-reddish-brown claystone, same, 5%; anhydritic limestone, same, 5%. Preparations of the very slightly calcareous medium-gray shale fractions proved the shale to be barren of calcareous nannofossils, consisting entirely of clay minerals, rare very fine organic debris and very rare quartzose silt.

16,500-16,520 Ctgs: Yellowish-gray claystone, same, 65%; anhydrite, same, 30%; moderate-reddish-brown claystone, same, 5%; anhydritic limestone, same, trace; shale, same, trace.

16,520-16,560 Ctgs: Yellowish-gray claystone, anhydritic (?), same, 90%; anhydrite, white, same, 5%; moderate-reddish-brown claystone, same, 5%; anhydritic limestone (micrite), highly calcareous, same, trace.

16,560-16,570 Ctgs: General lithology same, but with yellowish-gray claystone, very quartzose silty to very fine quartzose sandy (almost an argillaceous

(anhydritic) siltstone). Note that samples are very “dirty” and coated with drilling mud (i.e., improperly washed).

16,570-16,590 Ctgs: Anhydrite, white to very light-gray, massive, soft, 90%; claystone, yellowish-gray, massive, firm to indurated, dense, in part very highly quartzose silty to very fine quartzose sandy, very highly calcareous, 10%.

16,590-16,600 Ctgs: Anhydrite, same, 75%; claystone, same, 15%; anhydritic limestone, medium-gray to light-olive-gray, massive, indurated, dense, uniformly and finely microcrystalline, weakly to strongly calcareous, 10%.

16,600-16,670 Ctgs: Anhydrite, same, 40%; anhydritic limestone, same, 35%; claystone, same, 25%. Note that these samples are very “dirty.” Tasting of the unwashed residue suggests the presence of halite.

16,670-16,680 Ctgs: Samples are “dirty” with anhydritic (?) and/or salty mud coating cuttings. General lithology believed to be as above, plus sandstone, light-olive-gray, quartzose, massive, dense, indurated, argillaceous (anhydritic?), well sorted, very highly calcareous, fine-grained, trace.

16,680-16,690 Ctgs: Anhydrite, same, 80%; claystone, same, 15%; anhydritic limestone, same, 5%; sandstone, same, trace.

16,690-16,740 Ctgs: Claystone, light-olive-gray to pale-yellowish-brown, massive, firm but friable, relatively “clean,” very highly calcareous, 75%; anhydrite, white to very light-gray, massive, soft, in part very finely crystalline, noncalcareous, 20%; anhydritic limestone, light-olive-gray, massive, indurated, dense, finely crystalline, very slightly to very strongly calcareous, 5%; sandstone, same, very fine- to fine-grained, trace. A nannofossil slide was prepared from several small chips of the very highly calcareous light-gray claystone from the 10-foot sample between 16,690 and 16,700 feet. Regrettably, the sample is barren of calcareous nannofossils, consisting entirely of very highly birefringent dolomite rhombs with lesser amounts of clay minerals and very rare quartzose silt.

16,740-16,750 Ctgs: Samples continue to be coated with anhydritic drill mud. Anhydritic limestone, same, 60%; claystone, same, 30%; anhydrite, same, 10%.

16,750-16,770 Ctgs: Claystone, same, 80%; anhydrite, same, 15%; anhydritic limestone, same, 5%.

16,770-16,780 Ctgs: Anhydritic limestone, same, 80%; anhydrite, same, 10%; claystone, same, 10%.

16,780-16,790 Ctgs: Anhydrite, same, 75%; anhydritic limestone, same, 15%; claystone, same, 10%.

16,790-16,810 Ctgs: Anhydrite, same, 50%; anhydritic limestone, same, 40%; claystone, same, 10%.

16,810-16,850 Ctgs: Anhydrite, same, 40%; claystone, same, 40%; anhydritic limestone, same, 20%. Note that cuttings have a very distinct salty taste.

16,850-16,860 Ctgs: Halite, moderate-orange-pink, coarsely crystalline, somewhat dissolved during sample washing, 40%; anhydrite, same, 30%; claystone, same, 30%; anhydritic limestone, same, trace.

16,860-16,870 Ctgs: Halite, same, 85% (present only in unwashed sample); claystone, same, 15%; anhydrite, same, trace; anhydritic limestone, same, trace. **PHOTO**

16,870-16,880 Ctgs: Anhydritic limestone (micrite), yellowish-gray to medium-dark-gray (color variation due to varying percentages of anhydrite in the limestone), massive, dense, indurated, brittle, in part uniformly finely crystalline and in part containing fine sand-size pellets, highly calcareous, 75%; halite, same, 15%; anhydrite, same, 5%; claystone, same, 5%.

16,880-16,890 Ctgs: Anhydrite, same, 50%; halite, same, 30%; anhydritic limestone, same, 20%.

16,890-16,910 Ctgs: Halite, same, 60%; anhydrite, same, 20%; claystone, same, 10%; anhydritic limestone, 10%. Note that these lithologies are based on examination of unwashed cuttings. All halite has been removed from the processed samples.

16,910-16,920 Ctgs: General lithology as above, but with anhydritic limestone, same, 35%; anhydrite, same, 30%; halite, same, 20%; claystone, same, 15%.

16,920-16,940 Ctgs: Anhydritic limestone, same, 50%; claystone, same, but in part very abundantly very fine quartzose sandy, 30%; anhydrite, same, 20%; halite, same, trace (in unprocessed sample material only).

16,940-16,960 Ctgs: Anhydrite, same, 50%; anhydritic limestone, same, 40%; claystone, same, in part very quartzose sandy as above, 10%.

16,960-16,980 Ctgs: Anhydrite, same, 40%; anhydritic limestone, same, 30%; claystone, same, 30%.

16,980-16,990 Ctgs: Halite, moderate-orange-pink, coarsely crystalline, 50%; anhydritic limestone, same, 25%; claystone, same, 15%; anhydrite, same, 10%. Note that halite is present only in the unwashed sample.

16,990-17,000 Ctgs: Halite, same, 40%; claystone, same, 30%; anhydrite, same, 25%; anhydritic limestone, same, 5%.

17,000-17,010 Ctgs: Anhydritic limestone, same, 40%; anhydrite, same, 40%; claystone, same, 20%; halite, same, trace (in unwashed sample residue only).

17,010-17,020 Ctgs: Anhydritic limestone, yellowish-gray to medium-dark-gray, massive, indurated, dense, microcrystalline, somewhat brittle, very anhydritic to almost pure calcium carbonate, moderately to strongly calcareous, 85%; claystone, pinkish-gray to light-gray, massive, firm but friable,

very slightly and very finely muscovitic, highly calcareous, 10%; anhydrite, white, soft, friable, 5%.

17,020-17,060 Ctgs: Anhydritic limestone, same, 40%; anhydrite, same, 40%; claystone, same, 20%.

17,060-17,070 Ctgs: Anhydrite, same, 40%; claystone, same, 40%; anhydritic limestone, same, 20%.

17,070-17,080 Ctgs: Anhydrite, same, 70%; anhydritic limestone, same, 20%; claystone, same, 10%.

17,080-17,110 Ctgs: Halite, moderate-orange-pink, coarsely crystalline, 70% (present in unwashed samples only); anhydrite, same, 25%; anhydritic limestone, same, 5%; claystone, same, trace.

17,110-17,120 Ctgs: Anhydrite, white to yellowish-gray, massive, soft to indurated, dense to friable, noncalcareous, 70%; anhydritic limestone, yellowish-gray to medium-dark-gray, massive, indurated, dense, very anhydritic, slightly calcareous, 20%; halite, same, 5% (present in unwashed sample only); claystone, light-brown, massive, firm, friable, very slightly and finely muscovitic and quartzose silty, moderately calcareous, 5%.

17,120-17,130 Ctgs: Anhydrite, same, 65%; anhydritic limestone, same, 20%; claystone, same, but in part light-gray, 15%; halite, same, trace.

17,130-17,150 Ctgs: General lithology as above, but with anhydrite, same, 45%; anhydritic limestone, same, in part medium-gray to medium-dark-gray, dolomitic, slightly to moderately calcareous, 40%; claystone, same, 15%. No halite observed.

17,150-17,170 Ctgs: Halite, same, 75% (in unwashed sample only); anhydrite, same, 15%; anhydritic and dolomitic limestone, same, 5%; claystone, same, 5%.

17,170-17,180 Ctgs: Anhydrite, same, 40%; anhydritic and dolomitic limestone, same, 35%; claystone, same, 20%; halite, same, 5% (in unwashed sample only).

17,180-17,210 Ctgs: Halite, same, 90%; anhydrite, same, 4%; anhydritic and dolomitic limestone, same, 3%; anhydritic claystone, same, 3%.

17,210-17,250 Ctgs: Halite, same, 95%; anhydrite, same, 2%; anhydritic limestone, same, 2%; anhydritic claystone, same, 1%. **PHOTO**

17,250-17,350 Ctgs: Halite, same, 90%; anhydrite, same, 4%; anhydritic claystone, same, 4%; anhydritic limestone, same, 2%.

17,350-17,400 Ctgs: Halite, same, 90%; anhydritic shale, pale-reddish-brown and medium-gray, thinly laminated, semiindurated, very finely muscovitic, moderately calcareous, 6%; anhydrite, white to yellowish-gray, massive, soft to indurated, noncalcareous, 4%.

17,400-17,410 Ctgs: Halite, same, 80%; anhydrite, same, 10%; anhydritic shale, same, but predominantly light-gray to medium-gray, 10%.

17,410-17,420 Ctgs: Halite, same, 70%; anhydrite, same, 20%; anhydritic shale, same, 10%.

Haynesville Formation, Buckner Anhydrite Member (E-log top at 17,380 feet)

17,420-17,500 Ctgs: Anhydritic claystone, medium-gray and rarely pale-reddish-brown, massive, friable to indurated and very dense, very finely muscovitic, dolomitic (?), slightly calcareous, 50%; anhydrite, very light-gray and yellowish-gray to white, massive, soft to indurated, noncalcareous, 45%; anhydritic and dolomitic limestone (micrite), yellowish-gray, massive, dense, indurated, brittle, very slightly calcareous, 5%. **PHOTO**

17,500-17,560 Ctgs: General lithology as above, but with anhydritic claystone in part very highly quartzose silty to very fine quartzose sandy.

17,560-17,590 Ctgs: Anhydrite, same, 40%; anhydritic and dolomitic limestone, medium-gray to pale-yellowish-brown, massive, indurated, dense, in part uniformly micritic and in part containing rare to common pellets and other identifiable fine grains, dolomitic and finely crystalline, slightly calcareous, 40%; anhydritic claystone, same, 20%.

17,590-17,600 Ctgs: General lithology same, but with part of limestone fraction very light-gray (N8) and very highly anhydritic.

17,600-17,650 Ctgs: Anhydritic claystone in part moderate-reddish-brown, same, 50%; anhydrite, same, 40%; anhydritic and dolomitic limestone, same, 10%.

17,650-17,660 Ctgs: General lithology same, with rare limestone (micrite) cuttings containing oolites and pellets.

17,660-17,690 Ctgs: Anhydritic limestone (predominantly micrite), medium-dark-gray to brownish-gray (5YR4/1), massive, indurated, dense, brittle and sharply angled, containing common thin anhydrite seams, in part very anhydritic and light-gray to very light-gray, in part containing very rare to rare very fine sand-size rounded pellets, anhydritic, dolomitic, very slightly calcareous, 75%; anhydrite, same, 15%; anhydritic claystone, same, 10%.

17,690-17,710 Ctgs: Anhydritic limestone, same, 85%; anhydrite, same, 10%; anhydritic claystone, same, 5%. No fossils or fossil fragments observed.

Smackover Formation (E-log top at 17,710 feet)

17,710-17,720 Ctgs: Limestone (very fine calcarenite), predominantly yellowish-gray to very light-gray, massive, indurated, dense, very anhydritic and argillaceous, in part dolomitic and finely crystalline, moderately calcareous, 80%; anhydrite, white to very light-gray, massive, crystalline, indurated to relatively soft, noncalcareous, 15%; anhydritic claystone, same, 5%. **PHOTO**

17,720-17,740 Ctgs: Limestone (micrite or very fine calcarenite), same, 65%; anhydritic claystone, pale-yellowish-green (10Y8/2), massive to very indistinctly and thinly laminated, firm, friable, dense, noncalcareous, 20%; anhydrite, same, 15%.

17,740-17,750 Ctgs: Halite, clear to grayish-orange, crystalline, 60% (in unwashed sample only); limestone (micrite and fine calcarenite), same, 30%; anhydrite, same, 7%; anhydritic claystone, same, 3%.

17,750-17,760 Ctgs: Limestone, same, 45%; halite, same, 35%; anhydrite, same, 15%; anhydritic claystone, same, 5%.

17,760-17,770 Ctgs: Limestone (micrite to very fine calcarenite), pale-yellowish-brown to medium-dark-gray, massive, indurated, dense, brittle, in part very highly anhydritic and thus light-gray, dolomitic, slightly to moderately calcareous, 90%; anhydrite, same, 10%; anhydritic claystone, same, trace; halite, same, trace.

17,770-17,780 Ctgs: Halite, as at 17,740 feet, 60% (observed in unwashed cuttings residue only); limestone, same, 30%; anhydrite, same, 10%; anhydritic claystone, same, trace.

17,780-17,800 Ctgs: Halite, same, 80% (in unwashed sample only); limestone, same, 15%; anhydrite, same, 5%. **PHOTO**

17,800-17,810 Ctgs: Halite, same, 60% (in unwashed residue only); limestone, dolomitic, same, 30%; anhydrite, same, 10%.

Norphlet Formation (E-log top at 17,808 feet)

17,810-17,820 Ctgs: Halite, same, 85% (in unwashed sample; rare to common halite in processed sample); limestone, same, 5% (may be caved); sandstone, white to very light-gray, quartzose, massive, indurated, dense, containing very rare to rare dark-gray to black very fine metamorphic and/or igneous rock fragments, noncalcareous, very fine- to fine-grained, 4%; anhydrite, same, 3%; anhydritic claystone, same, 3%.

17,820-17,840 Ctgs: Sandstone, same, but in part very finely pyritic, 75%; limestone, same, 10%; anhydrite, same, 10%; anhydritic claystone, same, 5%; halite, same, trace (in unwashed sample—probably caved). **PHOTO**

17,840-17,870 Ctgs: Sandstone, same, 85%; anhydrite, same, 10%; anhydritic claystone, same, 5%; limestone, same, trace.

17,870-17,880 Ctgs: Sandstone, same, 80%; anhydrite, same, 15%; anhydritic claystone, same, 5%; limestone, same, trace.

17,880-17,890 Ctgs: Sandstone, same, 50%; halite, clear to grayish-orange, crystalline, 30%; anhydrite, same, 15%; anhydritic claystone, same, 5%; limestone, same, trace.

17,890-17,910 Ctgs: General lithology as above, but with anhydrite, same, but moderately to abundantly fine to medium quartzose sandy, and with about half of

claystone fraction ferruginous-stained (?) light-brown. A nannofossil slide was prepared from several small chips of light-gray anhydritic claystone present in the sample between 17,900 and 17,910 feet. Unfortunately, the sample is barren of calcareous nannofossils, consisting entirely of clay minerals and tiny anhydrite rhombs.

17,910-17,920 Ctgs: Halite, same, 40%; sandy anhydrite, same, 30%; sandstone, same, 25%; anhydritic claystone, same, 5%; limestone, same, trace.

17,920-17,930 Ctgs: Halite, same, 40%; anhydrite, same, in part very fine to fine quartzose sandy, 40%; sandstone, same, 15%; anhydritic claystone, same, 5%; limestone, same, trace.

17,930-17,940 Ctgs: Halite, same, 95% (present in both unwashed and washed residues); anhydrite, same, 3%; sandstone, same, 1%; anhydritic claystone, same, 1%. **PHOTO**

17,940-17,960 Ctgs: Halite, same, 65% (in unwashed sample only); anhydrite, same, 15%; sandstone, same, 15%; claystone, same, 5%.

17,960-17,980 Ctgs: Halite, same, 40%; anhydrite, same, 40%; sandstone, same, 15%; claystone, same, 5%.

17,980-17,990 Ctgs: Sandstone, same, 65%; anhydrite and sandy anhydrite, same, 20%; halite, same, 10%; anhydritic claystone, same, 5%.

17,990-18,020 Ctgs: Sandstone, same, containing common to abundant very fine to fine "dark-gray," "green," and "orange" metamorphic and igneous rock fragments, 75%; anhydrite, same, 20%; anhydritic claystone, same, 5%; halite, same, trace.

18,020-18,040 Ctgs: Halite, same, 40%; anhydrite and sandy anhydrite, same, 40%; sandstone, same, 20%; anhydritic claystone, same, trace.

18,040-18,070 Ctgs: Anhydrite and sandy anhydrite, same, 45%; halite, same, 40%; sandstone, same, 10%; anhydritic claystone, same, 5%.

18,070-18,080 Ctgs: Halite, same, 75%; anhydrite, same, 20%; sandstone, same, 3%; anhydritic claystone, same, 2%.

18,080-18,100 Ctgs: Halite, clear to grayish-orange, coarsely crystalline, 35% (in unwashed sample only); anhydrite, white to very light-gray, massive, firm, friable, very abundantly very fine to fine quartzose sandy, noncalcareous, 30%; sandstone, white to yellowish-gray, massive, indurated, dense, argillaceous (anhydritic), well sorted, containing rare medium-gray and moderate-yellowish-green igneous and metamorphic rock fragments, very rarely very fine to fine pyritic, noncalcareous, very fine- to fine-grained, 25%; anhydritic limestone, light-gray, massive, dense, firm but friable, very abundantly and finely anhydritic, very slightly calcareous, 10%. Note that these samples contain trace amounts of medium-dark-gray to light-olive-gray brittle limestone (micrite) believed to be a caved contaminant.

18,100-18,120 Ctgs: Halite, same, 70%; quartzose sandy anhydrite, same, 15%; anhydritic claystone, same, 10%; sandstone, same, 5%. **PHOTO**

18,120-18,140 Ctgs: Halite, same, 50%; sandstone, same, but in part very fine- to medium-grained, 20%; sandy anhydrite, same, 20%; anhydritic claystone, same, 10%.

18,140-18,170 Ctgs: Sandy anhydrite, same, but grayish-orange-pink, 80%; sandstone, same, 10%; anhydritic claystone, same, 10%. No halite is present in either the unwashed or washed sample residues.

18,170-18,200 Ctgs: Sandy anhydrite, same, 50%; sandstone, same, but predominantly pale-red to grayish-orange, 45%; anhydritic claystone, same, 5%. Continue to observe trace amounts of dark-gray micrite regarded as caved contamination.

18,200-18,240 Ctgs: Sandy anhydrite, same, 70%; sandstone, same, anhydritic, noncalcareous, 25%; anhydritic claystone, same, 5%. A nannofossil slide was prepared from cuttings of the anhydritic claystone in the sample between 18,210 and 18,220 feet. Regrettably, the slide was barren of nannofossils, consisting only of clay minerals, tiny anhydrite crystals, and highly birefringent dolomite (?) rhombs.

18,240-18,270 Ctgs: Halite, as at 18,080 feet, 70% (in unwashed sample only); sandy anhydrite, same, 20%; sandstone, same, 5%; anhydritic claystone, same, 5%.

18,270-18,280 Ctgs: Quartzose sandy anhydrite, same, 80%; halite, same, 10%; sandstone, same, 5%; anhydritic claystone, same, 5%.

18,280-18,300 Ctgs: Quartzose sandy anhydrite, same, 85%; anhydritic claystone, same, predominantly medium-light-gray, noncalcareous, 10%; sandstone, same, 5%.

18,300-18,320 Ctgs: Halite, as at 18,080 feet, 40% (in unwashed sample only); quartzose sandy anhydrite, same, 35%; anhydritic claystone, same, 15%; sandstone, same, 10%.

18,320-18,350 Ctgs: Halite, same, 70%; sandy anhydrite, same, 20%; anhydritic claystone, same, 7%; sandstone, same, 3%.

18,350-18,370 Ctgs: Halite, same, 50%; quartzose sandy anhydrite, same, 40%; anhydritic claystone, same, 7%; sandstone, same, 3%.

18,370-18,380 Ctgs: Halite, same, 80%; sandy anhydrite, same, 10%; sandstone, same, 8%; anhydritic claystone, same, 2%.

18,380-18,400 Ctgs: Halite, same, 50%; sandy anhydrite, same, but very soft and existing principally of very fine to coarse sand-size cuttings, 30%; sandstone, same, 15%; anhydritic claystone, same, 5%.

18,400-18,420 Ctgs: Sandstone, same, but very fine- to medium-grained, very anhydritic, 40%; quartzose sandy anhydrite, same, 30%; halite, same, 20%; anhydritic claystone, same, 7%; sand, moderate-reddish-brown,

quartzose, subrounded, frosted, moderately well sorted, medium to coarse, 3%.

18,420-18,430 Ctgs: Halite, same, 60%; quartzose sandy anhydrite, same, 30%; sandstone, same, 5%; anhydritic claystone, same, 5%; sand, same, trace.

18,430-18,440 Ctgs: Halite, same, 80%; quartzose sandy anhydrite, same, 15%; anhydritic claystone, same, 5%; sandstone, same, trace; sand, same, trace.

18,440-18,450 Ctgs: Halite, same, 90%; quartzose sandy anhydrite, same, 5%; sandstone, same, anhydritic, noncalcareous, 5%; anhydritic sandstone, same, trace.

18,450-18,470 Ctgs: Halite, same, 50% (in unwashed sample only); quartzose sandy anhydrite, same, 45%; anhydritic claystone, same, 5%; sand, same, trace. No "typical" Norphlet sandstone was observed.

18,470-18,480 Ctgs: Halite, same, 80%; quartzose sandy anhydrite, same, 20%; anhydritic claystone, same, trace; sandstone, same, trace; sand, same, medium, trace.

18,480-18,520 Ctgs: Halite, same, 80% (in unwashed sample only); quartzose sandy claystone, same, 10%; sandstone, same, but moderate-reddish-brown and poorly sorted, very fine- to medium-grained, 10%; anhydritic claystone, same, trace; sand, same, trace. **PHOTO**

18,520-18,530 Ctgs: Halite, same, 50% (in unwashed sample only); quartzose sandy claystone, grayish-orange-pink, massive, dense, firm but friable, very anhydritic, moderately very fine to fine quartzose sandy, noncalcareous, 30%; sandstone, pale-red to grayish-orange, quartzose, massive, indurated, dense, very anhydritic, argillaceous (?), noncalcareous, very fine- to medium-grained, in part containing coarse to very coarse sand-size grains of anhydrite, 12%; anhydritic claystone, light-gray, massive, dense, firm, appears to be very finely muscovitic from abundance of fine crystalline anhydrite, noncalcareous, 5%; anhydrite, white to very light-gray, massive, dense to finely crystalline, friable, noncalcareous, 3%; sand, moderate-reddish-orange, quartzose, subrounded, trace.

18,530-18,540 Ctgs: Sandy anhydritic claystone, same, 45%; anhydrite, same, 30%; halite, same, 15%; sandstone, same, 6%; gray anhydritic claystone, same, 4%; sand, same, trace.

18,540-18,570 Ctgs: Sandy anhydritic claystone, same, 60%; anhydrite, same, 30%; sandstone, same, 5%; gray anhydritic claystone, same, 5%; sand, same, trace; halite, same, trace.

18,570-18,590 Ctgs: Sandy anhydritic claystone, same, 45%; sandstone, same, 45%; anhydrite, same, 5%; gray anhydritic claystone, same, 5%; sand, same, fine to medium, trace.

18,590-18,620 Ctgs: Sandy anhydritic claystone, same, 50%; anhydrite, same, 25%; sandstone, same, 20%; gray anhydritic claystone, same, 5%; sand, same, but predominantly medium to coarse, trace.

18,620-18,640 Ctgs: Sandstone, same, 60%; sandy anhydritic claystone, same, 30%; anhydrite, same, 8%; gray anhydritic claystone, same, 2%; sand, same, coarse, trace.

18,640-18,660 Ctgs: General lithology same, with sandstone, same, very anhydritic, containing common medium sand-size grains of white anhydrite and very slightly calcareous (dolomitic?).

18,660-18,670 Ctgs: Sandstone, same, 75%; sandy anhydritic claystone, same, 15%; anhydrite, same, 10%; gray anhydritic claystone, same, trace.

18,670-18,680 Ctgs: Sandstone, same, 75%; anhydritic claystone, same, 15%; anhydrite, same, 5%; halite, clear to grayish-orange, coarsely crystalline, 5%; sand, moderate-reddish-orange, quartzose, subrounded, frosted or pitted, coarse, trace.

18,680-18,700 Ctgs: Sandstone, same, highly anhydritic, 75%; sandy anhydritic claystone, same, 20%; sand, same, coarse to very coarse, 3%; anhydrite, same, 2%.

18,700-18,750 Ctgs: General lithology same, plus dolomite, moderate-reddish-brown, massive, indurated, dense, very highly fine to medium muscovitic, anhydritic, quartzose silty, very slightly calcareous, trace. **PHOTO**

Louann Salt (E-log top at 18,746 feet)

18,750-18,770 Ctgs: Anhydrite, white to grayish-orange-pink, massive, dense, firm to relatively soft, about half of fraction very fine to medium quartzose sandy, noncalcareous, 70%; sandstone, white or yellowish-gray to moderate-reddish-brown, massive, dense, indurated, very highly anhydritic, containing rare to common “black” and “dark-green” fine sand-size igneous and metamorphic rock fragments and white anhydrite grains, noncalcareous, predominantly very fine- to fine-grained but rarely containing medium sand-size quartz grains, 22%; anhydritic claystone, light-gray to medium-light-gray, massive, indurated, dense, very anhydritic, rarely abundantly quartzose silty, noncalcareous, 5%; sand, clear to very light-gray and pale-reddish-brown, quartzose, rounded to subrounded, etched or frosted, coarse to very coarse, 3%. **PHOTO**

18,770-18,780 Ctgs: Muscovitic claystone, dark-reddish-brown, massive to thinly and indistinctly laminated, very highly very fine to medium muscovitic, very anhydritic, noncalcareous, 40%; anhydrite, same, 30%; sandstone, same, 30%; sand, same, trace; anhydritic dolomite, medium-dark-gray, massive, indurated, dense, very fine to fine muscovitic and biotitic, very anhydritic, very slightly calcareous, trace.

18,780-18,790 Ctgs: Anhydrite, same, 30%; red muscovitic claystone, same, 20%; anhydritic dolomite, same, 20%; anhydritic claystone, light-gray, same, 15%; sandstone, same, 15%.

18,790-18,810 Ctgs: Anhydritic and finely quartzose sandy anhydrite, same, 60%; sandstone, same, 15%; gray anhydritic claystone, same, 15%; gray dolomite, same, 5%; red claystone, same, 5%.

18,810-18,880 Ctgs: General lithology same, plus fluorite (?) crystals, pale-olive, with highly polished and very reflective crystal faces, coarse to very coarse, trace.

18,880-18,910 Ctgs: Very large cuttings with general lithology same. Continue to observed unusual fluorite (?) crystals as above.

18,910-18,920 Ctgs: Anhydrite, white to very light-gray and yellowish-gray, massive, dense, soft yet firm, in part quartzose silty to very fine quartzose sandy, argillaceous, noncalcareous, 40%; anhydritic claystone, light-gray to medium-light-gray, massive, indurated, dense, very anhydritic and appears to be finely muscovitic from abundance of finely crystalline anhydrite, rarely quartzose silty, noncalcareous, 25%; halite, clear to grayish-orange, coarsely crystalline, 20% (in unwashed sample only); anhydritic claystone, moderate-reddish-brown to moderate-greenish-brown, massive, dense, indurated to firm, rarely thinly laminated, very anhydritic, noncalcareous, 10%; sandstone, pale-reddish-brown to moderate-reddish-brown, quartzose, massive, dense, indurated, very highly anhydritic, noncalcareous, predominantly fine-grained but with rare medium sand-size grains “floating” in the fine matrix, noncalcareous, 3%; limestone (micrite), medium-dark-gray, massive, dense, indurated, brittle, uniformly finely crystalline, highly calcareous, 2%; fluorite (?) crystals, pale-olive, highly reflective crystal faces, coarse to very coarse, trace. No fossils or fossil fragments observed.

18,920-18,930 Ctgs: General lithology as above, but with anhydrite, same, 45%; gray anhydritic claystone, same, 35%; reddish-brown anhydritic claystone, same, 10%; sandstone, same, 8%; gray limestone (micrite), same, 2%; halite, same, trace.

18,930-18,950 Ctgs: General lithology as at 18,910 feet with halite constituting about 20% of sample volume, plus muscovitic mica, somewhat “milky” and weathered, very coarse.

18,950-18,960 Ctgs: Halite, same, 50%; gray anhydritic claystone, same, 20%; anhydrite, same, argillaceous, 20%; reddish-brown anhydritic claystone, same, 5%; limestone (micrite), same, 3%; sandstone, same, 2%; fluorite (?) crystals, pale-olive, same, trace.

18,960-18,970 Ctgs: Halite, same, 85%; argillaceous anhydrite, same, 7%; gray anhydritic claystone, same, 5%; reddish-brown anhydritic claystone, same, 1%;

sandstone, same, 1%; limestone (micrite), same, 1%; fluorite (?) crystals, same, trace. **PHOTO**

18,970-18,980 Ctgs: Halite, same, 50%; argillaceous anhydrite, same, 30%; gray anhydritic claystone, same, 15%; reddish-brown claystone, same, 2%; limestone (micrite), same, 2%; sandstone, same, 1%; fluorite (?) crystals, same, trace. No fossils or fossil fragments observed.

18,980-18,990 Ctgs: Last sample available for study (driller's total depth of well is at 18,993 feet). Anhydrite, very argillaceous, firm but soft, same, 50%; anhydritic claystone, light-gray to medium-light-gray, same, 40%; anhydritic claystone, moderate-reddish-brown, same, 5%; limestone (micrite), massive, indurated, uniformly microcrystalline, same, 3%; sandstone, same, 2%; fluorite (?) crystals, same, trace.

Interpretation by
Charles C. Smith
Geologist

SUMMARY OF GEOLOGY AND ELECTRIC-LOG TOPS
W. M. Smith No. 1
GSA No. 1878

	Sample interval			E-log top
Upper Cretaceous				
Selma Group				
In Mooreville Chalk	5,180	-	5,340	--
Eutaw Formation	5,340	-	5,670	5,332
Tuscaloosa Group				
Gordo Formation	5,670	-	6,390	5,658
middle marine shale	6,390	-	6,540	6,397
Coker Formation	6,540	-	7,230	6,530
"pilot sand"	6,540	-	6,690	6,530
"massive sand"	--	-	--	6,705
"interbedded sand"	--	-	--	6,865
Lower Cretaceous				
Washita and Fredericksburg Groups (undifferentiated)	7,230	-	8,700	7,205
Trinity Group				
Paluxy Formation	8,700	-	9,710	8,662
Mooringsport Formation	9,710	-	10,220	9,730
? Ferry Lake Anhydrite equivalent	10,220	-	10,340	--
Rodessa Formation	10,340	-	10,550	--
? Pearsall Formation				
Pine Island Member	10,550	-	10,700	10,590
Nuevo Leon Group				
? Sligo Formation	10,700	-	10,880	10,743
Hosston Formation	10,880	-	12,380	10,870
Lower Cretaceous-Jurassic				
Cotton Valley Group	12,380	-	15,450	12,370
Jurassic				
Louark Group				
Haynesville Formation	15,450	-	17,420	15,397
Buckner Anhydrite Member	17,420	-	17,710	17,380
Smackover Formation	17,710	-	17,810	17,710
Norphlet Formation	17,810	-	18,750	17,808
Louann Salt	18,750	-	--	18,746

Attachment 7

"Well Burial History"

Ernest A. Mancini and William Parcell
University of Alabama

Burial History

Mississippi Interior Salt Basin

Understanding burial history is important to interpreting the geohistory of a basin. Burial history is crucial in determining the generation, migration and preservation of hydrocarbons in the basin. This modeling is dependent upon a sound regional model for the geologic history of the basin (Waples, 1994a). Determination of the magnitude of depositional events, such as sedimentation and subsidence rates are critical. The identification of erosion events and times of non-deposition are crucial in interpreting the burial and thermal histories of a basin. Burial history work for the Mississippi Interior Salt Basin has been published by Nunn and Sassen, 1986; Driskill et al., 1988; and Vaughn and Benson, 1988), but no comprehensive analysis has been published to date.

In this study, the tectonic and depositional histories of the Mississippi Interior Salt Basin form the foundation for interpreting the burial history of the basin. Five regional cross sections consisting of 48 key wells comprise the basis for the interpretation. The burial history for each well and cross section was determined. Basinmod software was utilized. Information interpreted from these cross-sections, well logs, and other sources include biostratigraphic (geologic ages of selected units or horizons), paleoenvironmental (water depths), stratigraphic thickness of the units, lithologies, sedimentation and subsidence rates, unconformities and faulting.

To determine the geologic ages of the key stratigraphic horizons as recognized by characteristic well log signatures, the biostratigraphy for this geologic section was studied from well cuttings from a composite type log located in Washington County, Alabama. The results of the biostratigraphic study were inconclusive indicating that the geologic ages of the key stratigraphic horizons in the eastern Gulf Coastal Plain would have to be determined by studying outcrop data for the region and by comparison to the biostratigraphy of these units in the western Gulf Coastal Plain area. The geologic ages for the Tertiary units in the Mississippi Interior Salt Basin were determined using the outcrop work of Mancini and Tew (1991) and for the Upper Cretaceous units using the outcrop work of Mancini et al. (1996) and Christopher (1982) and subsurface work of Mancini and Payton (1981). The geologic ages for the Lower Cretaceous units were determined using the work

performed in the western Gulf by Imlay (1940) and Young (1972). The geologic ages for the Upper Jurassic units were determined using the work done in the western Gulf by Imlay and Herman (1984) and Young and Oloritz (1993). Geologic age data published by Todd and Mitchum (1977) and Salvador (1991) were also used. Utilizing the geologic age data, the stratigraphic section was divided into five intervals: Jurassic (161-137 my), lower Cretaceous (137-99 my), upper Cretaceous (99-65 my), lower Tertiary (65-30 my) and upper Tertiary (30-0 my) for basin modeling. Hiatuses were recognized in the Jurassic (195-176 my) and the lower Cretaceous (137-132 my). Fault displacements of 100 to 2,000 feet were found throughout the section.

The total thickness of the sediment column corrected for compaction for the key stratigraphic horizons was determined using basinmod software. The stratigraphic horizons were recognized by their characteristic well log signatures. Sedimentation rates and subsidence rates were determined using these data. In these determinations, the following constants were used: average mantle density of 3.30 g/cm^3; average water density of 1.02 g/cm^3; average sediment density of 2.64 g/cm^3 for sandstone, 2.60 g/cm^3 for shale, 2.72 g/cm^3 for limestone, 2.98 g/cm^3 for anhydrite and 2.15 g/cm^3 for salts; and paleowater depths ranging from 0 to 400 feet. The mean stratigraphic thickness for the five intervals is as follows: Jurassic (4,736 ft), lower Cretaceous (6,242 ft), upper Cretaceous (3,887 ft), lower Tertiary (4,939 ft) and upper Tertiary (2,926 ft). Mean sedimentation rates for these intervals are: Jurassic (188.2 ft/my), lower Cretaceous (208.6 ft/my), upper Cretaceous (166.1 ft/my), lower Tertiary (174.4 ft/my) and upper Tertiary (101.4 ft/my). Mean sandstone sedimentation rates range from 311.0 ft/my for lower Cretaceous sandstones to 169.8 ft/my for Jurassic sandstones. Mean shale sedimentation rates range from 107.6 ft/my for upper Cretaceous clays to 90.2 ft/my for lower Tertiary shales. Mean limestone sedimentation rates range from 121.6 ft/my for Jurassic limestone to 57.4 ft/my for upper Cretaceous chalk. Mean anhydrite sedimentation rates are 85.0 ft/my for lower Cretaceous anhydrites. Mean tectonic subsidence rates for the intervals are: Jurassic (129.8 ft/my), lower Cretaceous (72.0 ft/my), upper Cretaceous (46.0 ft/my) and upper Tertiary (45.2 ft/my).

UNIT NAME	BASE AGE	TOP AGE	BASE STAGE	TOP STAGE
Vicksburg	33.7	30.3	E. Rupelian	e. M. Rupelian
Yazoo Clay	39.1	33.7	L. Bartonian	L. Priabonian
Moodys Branch	41.1	39.0	E. Bartonian	M. Bartonian
Cook Mountain	43.0	41.0	L. Lutetian	E. Bartonian
Koskiusko Sand	44.4	43.0	l.M. Lutetian	L. Lutetian
Zilpha Clay	52.3	44.4	E. Lutetian	l.M. Lutetian
Wilcox	59.1	52.3	E. Selandian	E. Ypresian
Midway/Porters Creek	61.5	59.1	E. Danian	E. Selandian
Gas Rock	65	61.5	Danian	Danian
Selma/Clayton	84	65	L. Santonian	Maastrichtian
Eutaw	87	84	L. Coniacian	L. Santonian
Tuscaloosa	92	87	E. Turonian	M. Coniacian
Marine Shale	94	92	L. Cenomanian	E. Turonian
Lower Tuscaloosa	96	94	M. Cenomanian	L. Cenomanian
Massive Sand	99	96	E. Cenomanian	E. Cenomanian
Washita and Fredicksburg	103	99	L. Albian	L. Albian
Paluxy	106	103	M. Albian	M. Albian
Mooringsport	109	106	E. Albian	M. Albian
Ferry Lake	112	109	E. Albian	E. Albian
Rodessa	114	112	L. Aptian	L. Aptian
Pine Island	117	114	M. Aptian	L. Aptian
Sligo/Hosston	132	117	Hauterivian	E. Aptian
UnconformityU	137	132	Valanginian	Valanginian
Cotton Valley	150	137	L. Kimmeridgian	Berriasian
Haynesville	154	150	Kimmeridgian	Kimmeridgian
Smackover	159	154	E. Oxfordian	L. Oxfordian
Norphlet	161	159	Callovian	E. Oxfordian
Louann	175	163	Bathonian	Callovian
Werner	176	175	Aalenian	Aalenian
UnconformityL	195	176	Pliensbachian	Toarcian
Eagle Mills	210	195	Rhaetian	Hettangian
Basement	500	210	?	?

ABBREVIATIONS:

L. = late
M. = middle
E. = early

Absolute ages from:
Berggren et al., 1995 [Cenozoic strata]
Gradstein et al., 1995 [Mesozoic strata]

NAME	AGE	*Sea Level (FT)*	*Water Depth (FT)*
Yazoo Clay	39	650	400
Moodys Branch	41	500	30
Cook Mountain	43	300	30
Koskiusko Sand	44.4	500	15
Zilpha Clay	52.3	500	30
Wilcox	59.1	500	5
Midway/Porters Creek	61	500	30
Gas Rock	65	500	0
Selma/Clayton	84	650	200
Eutaw	87	500	15
Tuscaloosa	92	500	0
marine shale	94	650	150
lower Tuscaloosa	95	650	15
massive sand	99	500	5
Wash/Fred	103	650	15
Paluxy	106	650	0
Mooringsport	109	500	30
Ferry Lake	112	500	5
Rodessa	114	300	0
Pine Island	117	300	30
Sligo/Hosston	132	300	80
HIATUS	137	300	-10
Cotton Valley	150	500	0
Haynesville	154	300	5
Smackover	159	300	200
Norphlet	167	250	0
Louann	180	150	15
Werner	181	150	5
HIATUS	195	150	-10
Eagle Mills	210	150	0

API	UPPER TERTIARY		Jackson (top Yazoo/ Shubuta)	Moodys Branch	Cook Mountain	Sparta (Kosciusko)	Cane River (Zilpha)	Wilcox	Midway marker (Porters Creek)	Gas Rock	Selma marker (Clayton)	Eutaw	Tuscaloosa marker	Marine shale	Lower Tuscaloosa	Lower Cretaceous (base massive sand)	Wash/Fred	Paluxy	Moorings.	Ferry Lake	Rodessa	Pine Island	Sligo/ Hosston	Unconformity	Cotton Valley	Haynesville	Smackover	Norphlet	Louann Salt	Werner	Unconformity	Eagle Mills	Paleozoic
rike Section A-A'																																	
2305500032	**1205**						380	976	461	**73**													1618		3057	207	123						
2305500066	**1253**						352	1097	470	**46**				**1610**											3017	397	258						
2312520004	**1825**		222	365	110	965	495	1692	520	68	**285**		376	376	828	**1212**			421	236	551	210	2069		3907	140	829	40					
2304920011	194		493	503	188	942	491	2509	**975**		647	558	670	95	335	**1600**			435	256	457	224	3093		**2705**		1010	100					
2304920005*	**660**				132	468	370	1258	157	372	341	**562**		155	269	**933**		1615	348	225	699	154	3342		3960	611							
2312120025	**420**		325	312	173	478	495	2422	**792**		1251	540	672	333	137	**945**		1287	**243**		465	266	2192		3167	1590	520						
2312900178	**350**		275	223	257	365	395	2353	**632**		1225	377	800	198	522	**900**		1177	146	125	400	2135			2850	2635	**695**						
2312920006*	**3920**								**677**		1223	345	1016	131	630	**853**		969	**215**		341	114	1826		**2172**								
2312900061	**3955**		255	236	72	427	395	2455	**590**		1233	587	662	188	361	**1214**		1278	**322**		**960**		1655		2375	400	1300	68					
2306120203	315		267	238	150	310	397	2495	**553**		1243	354	933	188	387	**1328**		1317	**370**		287	168	1931		3987	1882	**1387**						
2306120028	495		165	244	71	420	465	2565	**560**		1325	385	1010	125	440	**1450**		1535	**370**		375	146	2352		1450	457	1168	352					
2306120244	275		165	238	154	136	472	2470	**615**		1169	934	397	180	423	**1666**		1306	**315**		425	220	2262		2584	344	105	15					
2306720002	**3875**								**670**		1265	346	1121	143	**2128**				302	133	502	123	**882**				795						
2315301008*	**812**		182	281	**2917**		1840	1840	**635**		1353	414	945	225	346	**1923**		1365	242	302	**1545**						877						
2315320545	**4495**										1330	325	900	180	450	**1977**		1048	**522**		**583**		2062		1808	116	130	199					
2315320122	**3738**		65	265	**625**			1898	**628**		1442	255	879	180	339	**1369**		1720	137	283	**2895**				3095	4655	893						
112920054	**5163**											361	722	178	386	**1720**		1776	**198**		**4116**					1770	521						
112920024	538		77	205	**487**			1913	**610**		1139	347	598	180	418	**1633**		885	**180**		630	143	1545		2945	1959	432						
112920012*	**5325**											168	881	156	440	**1690**		1070	**290**		570	152	1533		3125	2310	100	940					
Dip Section B-B'																																	
2309320011	**2133**								**797**		920	**693**			310	**1050**									625	157	562	**24**					7271
2305120020	**2786**								**842**		917	**726**			189	**2461**									699	180	**593**						
2305120036	**3380**								**850**		920	745	290	157	365	**531**			**209**		**1520**				1788	245	**730**						
2316300049	**482**				107	581	535	2092	**863**		990	695	467	150	408	**809**			**124**		**1892**				2225	510							
2316320150	**405**			545	132	626	504	2208	730	595	618	677	431	124	326	**1376**			**154**		1049	170	1055		3050	580	**1425**						
2308920043	**438**			533	149	750	501	2111	468	1075	680	895	279	94	367	**2010**			190	280	530	270	2812		3098	247	978	121					
2304920005*	**660**				132	468	370	1258	157	372	340	**563**		155	269	**834**		1714	348	225	699	154	3342		3960	611	1481	305					
2304920004	400		503	507	188	881	606	2907	**638**		918	579	763	160	550	**280**		1720	498	354	601	249	2823		3260								
2304920032	607		490	503	182	930	592	3109	**922**		695	507	813	1767	2007	**1158**		1745	499	421	487	200	3050		3740	2663	1053						
Dip Section C-C'																																	
2310100014	**2158**								**592**		936	394	903	55	310	**1352**			**80**		**333**		1158		**409**								8680
2310120005	**3235**										1035	336	938	66	382	**2045**	537	537	**108**		**1897**				1393	427	288	**330**		**110**		148	12738
2312900015	**3230**								**638**		1112	310	933	135	299	**984**		1053	56	195	**2060**				2496	834	725						
2312920057	**5597**											308	917	128	356	**1151**		1053	237	113	**2525**				2625	600	945	71					
2312920006*	**3920**								**677**		1223	345	1016	129	635	**850**		969	**204**		352	**1940**			**2172**								
2312920122	**6540**											350	930	130	412	**973**		1830	215	140	362	212	2436		2620								
2312720055	**5474**								**551**		1299	355	971	120	460	**3118**	1588	1588	190	267	320	335	**1720**				780						
2306520141	**6747**										1028	401	809	165	**2135**			1288	370	362	505	215	3000										
Dip Section D-D'																																	
2302300270	**1608**								**537**		955	458	732	75	400	**737**			**126**		**1612**				1748	72	**105**						9165
2302320114	**2220**								**580**		1050	370	863	125	397	**1125**		1232	**138**		**1754**				2034	482	540						
2315320042	**4970**											362	990	153	335	**1475**		1385	**358**		**2479**				2598	705	417						
2315320265	**3880**										1205	350	1015	157	333	**1525**		1425	**90**		480	350	940		**1167**		137						
2315320232	**5825**												832	193	418	**1392**		1465	257	343	355	412	**5077**			1503	1070						
2315301008*	**812**			281	**2917**				**635**		1353	414	945	175	446	**1873**		1365	242	302	**1545**						877						
2315320077	**4990**										1460	342	788	210	402	**1868**		1375	385	285	402	186	2559		3276	4414							
2311100069	**1634**			**533**			**2620**		**766**		1257	**606**		476	828	797	1173	1230	405	**475**		535	2455		2470	960	885	20					
2304520075	**7035**								**967**		925	130	470	310	561	1029	1700	1110	560	**862**			3358		2720								
Dip Section E-E'																																	
102320114	**2648**										1367	**1565**		101	404	**5573**										566	411						
102320197	**2900**										1044	348	911	151	405	**1433**		895	**159**		**2242**				2012	1503							
112920012*	**5325**											168	881	156	440	**1690**		1070	**290**		570	152	1533		3125	2310	100	940					
112920051	**3810**							1915	**801**		1475	319	737	237	401	**1845**		864	344	**531**		173	**4062**			2171	248						
109720134	**5887**											287	690	269	354	**2078**		1109	216	**700**		135	1745		2988	2154	133						
109720141	**6126**											334	404	386	540	**1945**		1097	231	**697**		170	1790		2923	1779							
109720299	**5496**										1714	482	688	405	535	**1410**			117	**803**		134	2016		2803	1446	145						
MAX	**7035**		503	545	257	965	352	3109	730	1075	1714	934	1121	1767	2007	1029	1700	1830	560	421	1049	2135	3358		3987	4655	1481	940				148	12738
MIN	**194**		65	205	71	136	460	976	157	68	340	130	279	55	137	797	1173	537	56	113	287	114	940		625	72	100	15				148	7271
MEAN	**2926**		268	342	146	583	606	2073	423	496	1091	418	772	215	449	913	1437	1283	296	255	501	280	2191		2674	1195	613	264				148	9464

U.TERTIARY (total) 2926

L.TERTIARY (total) = 4939
sandstones = 1000
shales = 361

U. CRETACEOUS (total) = 3858
sandstone = 638
shale = 215
limestone = 1091

L. CRETACEOUS (total) = 6242
sandstone = 1637
shale = 288
anhydrite = 255

JURASSIC (total) = 4746
sandstone = 1469
shale = 1195
limestone = 613

= NOT REACHED OR RECORDED BY LOG

= MISSING INTERVAL OR PICK NOT MADE

	Moodys Branch	Cook Mountain	Kosciusko	Zilpha	Wilcox	Midway/Porters Creek	Gas Rock	Selma/Clayton	Eutaw	Tuscaloosa marker	Marine shale	Lower Tuscaloosa	massive sand	Wash/Fred	Paluxy	Moorings.	Ferry Lake	Rodessa	Pine Island	Sligo/Hosston	Unconformity	Cotton Valley	Haynesville	Smackover	Norphlet	Louann Salt	Werner	Unconformity	Eagle Mills	Paleozoic
Strike Section A-A'																														
2305500032				22.00	31.23	81.51	**14.09**													16.26	16.70	102.69		131.95						
2305500066				18.25	26.85	63.82	**0.32**				******										77.27	114.05	129.21	150.40						
2312520004				5.93	30.34	64.20	60.60			**	15.96		**46.75**			54.70	27.41	11.93	16.40	107.10	265.01	10.46	10.90	98.32	139.98	12.81				
2304920011	49.94	32.60	147.49	23.48	53.18	**68.85**		51.64		36.57	25.97	44.16	******			74.26	******	30.36	29.98	110.96	149.78	**95.19**		237.18	149.93	******				
2304920005*		21.05 H	57.11 H	16.78 H	28.37 H	32.99 H	38.43 H	7.69	******		28.59 H	31.90 H	**84.95**		******	26.42	******	34.63 H	16.28	100.45	132.29	145.15	148.95	319.18						
2312120025	20.10	26.41	52.71	21.68	47.80	**103.75**		**	27.19	32.87	33.98	19.31	**179.19**			**12.64**		31.87	40.83	81.49	104.85	125.27	186.09	92.51	48.54	******				
2312900178	******	******	******	16.92	46.15	**55.12**		40.35	30.35	47.47	37.50	76.70	******			******	6.54	50.84			50.43	89.66	247.62	**175.33**		******				
2312920006*						**33.14**		45.78	32.25	67.50 F	45.19	105.81 L	**38.65**		140.41	**34.31**		64.47			71.69	**92.31**		115.77 F						
2312900061						**26.72**		37.47	30.23		32.44	47.70	**42.68**		146.92	**42.57**		**60.89**			64.89	119.37	125.62	202.30	123.03	******				
2306120203	24.47	22.76	42.60	16.34	44.27	**48.01**		33.54	25.00	39.10	31.78	37.84	**31.85**		97.15	**27.63**		18.87	23.81	65.06	82.44	132.19	213.64	**318.06**		******				
2306120028	16.63	11.28	60.14	19.88	49.11	**54.07**		39.73	29.57	49.59	38.90	49.93	**40.96**		125.90	**31.10**		69.80	23.06	90.75	117.74	59.91	77.95	259.33	168.83	******				
2306120244	21.66	24.96	21.96	20.97	42.04			25.53	29.83	**	41.10	59.00	******		213.07	**28.50**		43.36	38.21	94.94	125.62	129.35	135.53	28.92	15.60	******				
2306720002						**35.62**		49.53	36.56	86.78	54.72	**83.58**				58.59	63.28	107.50	35.85	**55.28**	66.35			**	******					
2315301008*	12.37	**45.98**				**55.52**		45.61	36.86	62.79	48.00	62.98	**98.76**		223.12 F	89.00	30.48	**48.73**			52.68 H			50.50 H	22.97 H					
2315320545								30.99	32.56	56.30	34.64	77.35	**108.58**			**53.94**		**32.93**		94.50	125.27	98.27	86.02	34.16	29.16	******				
2315320122						**25.23**		38.34	28.44	43.88	36.54	45.78	**86.00**			122.44	153.63	**33.82**			32.22	81.02	261.26	226.24	253.43					
1129200054									15.60	30.81	19.25	41.79	**48.09**		158.68	**21.21**		**120.90**			127.08		104.40	136.08	141.51					
1129200024	11.38	**13.76**			28.46	**44.43**		34.70	24.30	28.08	25.57	50.93	**52.50**		89.62	**16.33**		123.63	52.56		68.27	103.93	193.67	111.54	118.03					
1129200124*									14.37	42.41	**	52.68	******		******	**25.87**		54.13	24.81	56.93	70.23	103.41	240.65	24.70 F	64.60	******				
Dip Section B-B'																														
2309320011						**80.78**		29.02	**37.02**				**16.48**								17.23	29.77	38.84	115.56	******					******
2305120020						**83.31**		27.86	**32.57**			**	******								43.32	60.86	**	******					******	
2305120036						**41.58**		53.72	52.08		21.19	32.03	******			**30.72**		**39.08**			41.18	80.83	81.60	**29.29**					33.58	
2316300049		17.92	79.42	**	39.63	**70.81**		56.71	32.83		46.90 F	45.37	******			**19.28**		**48.57**			52.75	105.82 F	124.30 F	193.69 F						
2316320150	******	22.50	100.23	23.28	41.55	107.68	76.33	15.26 H	19.84		43.36	45.29	**21.77**			**57.10**		46.01			48.59	140.61	159.78	**228.95**		******				
2308920043	34.21	23.55 H	103.77	21.67 H	42.59	66.44 H	113.37	13.75 H	16.77		50.21	8.81 H	**9.89**			31.73	******	63.48		108.54	145.99	113.89	**	231.33	137.24	******				
2304920005*		21.05 H	57.11 H	16.78 H	28.37 H	32.99 H	38.43 H	7.69 H	**7.32**		28.59 H	31.90			44.04	26.42	******	34.63 H	16.28	100.45	132.29 F	145.15 F	148.95	319.18	199.91	******				
2304920004	28.59 H	34.87	115.67	**	52.24	**123.13**		17.04 H	20.91 H	27.25	25.76		******		83.26	115.82	11.77	148.61 L	50.07	140.81	201.93	**								
2304920032	38.92	31.12	101.15	**	51.58	**66.17**		44.74 H	18.56 H	29.99	22.26		**24.71**		123.15	80.96 H	******	21.90 H	22.50 H	94.76 H	123.14 H	165.08	218.07	264.04 H	301.25					
Dip Section C-C'																														
2310100014						**54.96**		25.77	47.53		22.72	69.26	**60.07**			**11.41**		**28.52**		73.70	92.97	**7.56**								******
2310120005								25.88	43.15		25.60	88.21	******		******	**17.00**		**49.86**			52.10	62.93	98.86	66.92	**13.65**		**14.00**		31.20	9.12
2312900015						**28.39**		39.12	29.76		34.07	43.87	**39.51**		140.19	16.74	13.40	**48.56**			50.49	97.91	130.51	172.34	187.99					
2312920067									21.77		26.05	52.89	**42.75**		150.03	29.88	7.32	**57.98**			60.95	106.76	133.64	187.44	205.99					
2312920006*						**33.14**		45.78	32.25 F	67.50 L	45.19	105.81 L	**38.65**		140.41	**34.31**		64.47			71.69	**92.31**		115.77 H						
2312920122									23.45	55.99	33.50	65.31	**90.71**		******	39.18	1.09 F	29.33 F	32.64	91.78	118.12	107.66	171.77						
2312720055						**32.52**		44.61	37.17	70.74	52.42	90.67	**129.83**		******	46.80	8.94	82.71	85.23	******	120.68			186.37 F	204.71					
2306520141								27.72	30.86	53.08 L	41.72	**80.81**			159.25	94.74	16.35	**	41.75	146.91	212.22	**								
Dip Section D-D'																														
2302300270						**46.58**		25.02	43.79 F	61.30	61.30 F	60.75 F	**34.87**			**19.66**		**85.30**			95.72	26.17	17.31	******						******
2302320114						**24.40**		34.52	27.69	**	32.75 F	58.01 F	**44.87**		158.90	**20.31**		**43.05**			45.02	85.96	108.72		78.32					
2315320042									21.06	**	24.31	45.17 H	**53.56**		160.35	**47.29**		**129.22**			142.63	**	170.64	144.88 F	155.89 F					
2315320265								29.18	31.99	68.06	37.65	58.48	**74.72**		224.87 L	**16.50**		94.80			114.35			34.99 H	35.62 H					
2315320232										40.21	24.18	51.54	**45.21**		157.10	67.77	18.24	130.41			122.34		367.79 L	254.17 L	288.61 L					
2315301008*	12.37	**45.98**				**55.52**		45.61	36.86	62.79	48.00 F	62.98 F	**98.76**		223.12 F	89.00	30.48	**48.73**			52.68			50.50 H	22.97 H					
2315320077								20.50	28.35	32.95	28.79	42.64	**93.15**		80.62 F	60.33	******	59.80 L	23.24	81.64 H	106.13 H	319.68	**	**	**					
2311100069	**3.01**			**90.20**		**38.51**		19.97 H	**25.82**		25.32 H	105.97 H	60.24 H	45.56 H	177.92	67.47	******		79.16	90.79 H	117.78 H	98.71 H	**	**	**					
2304520075								21.78 H	18.31 H	31.35 H	18.66 H	85.08 H	98.33	106.31	125.78 H	37.68 H	**38.95**			121.40	160.58	**	121.28		**					
Dip Section E-E'																														
1023220114								31.78 F	**40.97**		37.84 F	82.16 F	**73.88**								85.01		179.12 F	98.62 F	103.69 F					
1023220197								16.79 F	25.19 F	53.85 F	36.93 F	62.73 F	**61.97**		128.95 F	**22.29**		**52.36**			53.65 F	78.00 F	147.63 F	506.60 F						
1129200124*									14.37	42.41	**	52.68	******		******	**25.87**		54.13	24.81	56.93	70.23	103.41	240.65	24.70 F	64.60	******				
1129200061					37.75	**55.51**		53.45	34.33	39.17	37.02	55.29	**65.55**		85.26	53.72	******		19.62	**140.74**	161.02		128.79	125.39	71.76					
1097201341									18.99 H	35.63 H	23.97 H	50.30 H	**80.08**		126.31	44.31 H	**6.92**		22.52 H	67.14 H	84.01 H	109.42 H	215.91 H	37.51 H	38.23 H					
1097201411									18.46 H	18.96 H	19.32 H	76.39 H	**73.47**		122.21 H	47.02 H	**6.54**		28.20 H	68.95 H	86.71 H	108.98 H	191.82 H	86.27 H						
1097202991								39.05 H	39.96 H	32.87 H	30.20 H	62.92 H	**11.98**			25.17 F	**9.13**		22.23 H	78.96 F	100.80 F	113.16 H	185.65 H	40.48 H	41.32 H					
MAX	49.94	34.87	147.49	23.48	53.18	107.68	113.37	56.71	39.96	86.78	54.72	105.97	98.33	106.31	224.87	122.44	153.63	148.61	85.23	146.91	212.22	165.08	367.79	319.18	301.25	12.81	14.00		33.58	9.12
MIN	11.38	11.28	21.96	5.93	26.85	32.99	38.43	7.69	14.37	18.96	18.66	8.81	60.24	45.56	44.04	16.74	6.54	11.93	16.28	16.26	16.70	10.46	10.90	28.92	15.60	12.81	14.00		31.20	9.12
MEAN	24.204	24.1725	78.28	18.76615385	39.9670588	64.23047619	66.64	33.1381944	27.13875641	45.7551724	33.3947072	57.628	79.285	75.935	136.98913	59.7817391	32.31958333	58.31382353	32.61272727	89.21428571	90.91549242	98.347931	154.3058081	145.1941667	121.312308	12.81	14		32.39	9.12

L.TERTIARY = 45.18

U. CRETACEI = 46.02330508

L. CRETACEOI = 72.0102227

JURASSIC = 129.7900534

= NOT REACHED OR RECORDED BY LOG

= MISSING INTERVAL OR PICK NOT MADE

** = NOT COMPUTED BY BASINMOD

H = LOCATED OVER STRUCTURAL HIGH (TENDS TO DECREASE SUBS. RATES)

L = LOCATED OVER STRUCTURAL LOW (TENDS TO INCREASE SUBS. RATES)

F = FAULTED SECTION

BO = VALUE POSSIBLY COMPUTED WITH ADDITIONAL UNPICKED STRATA (UNREALISTIC THICK SECTION)

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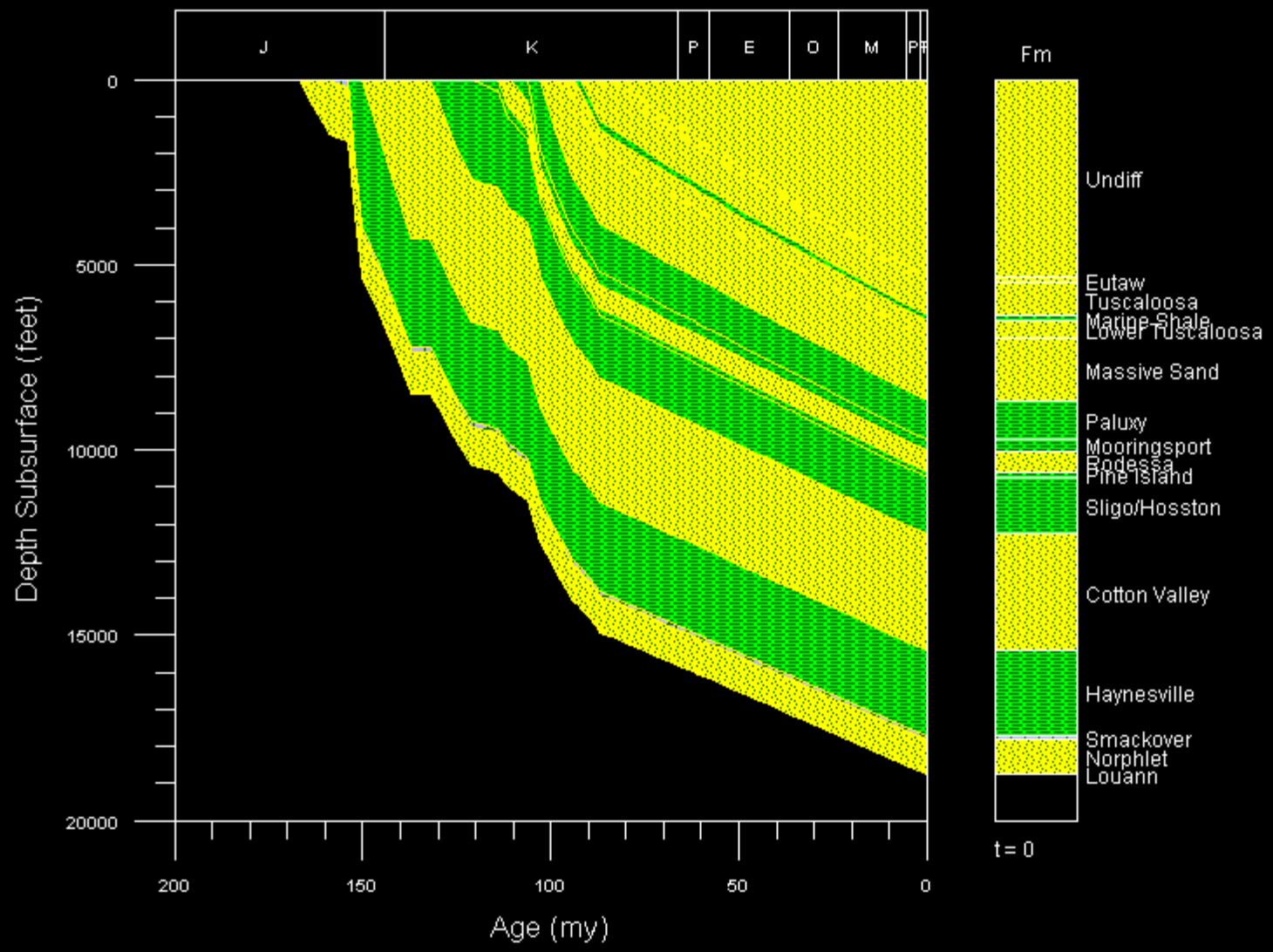

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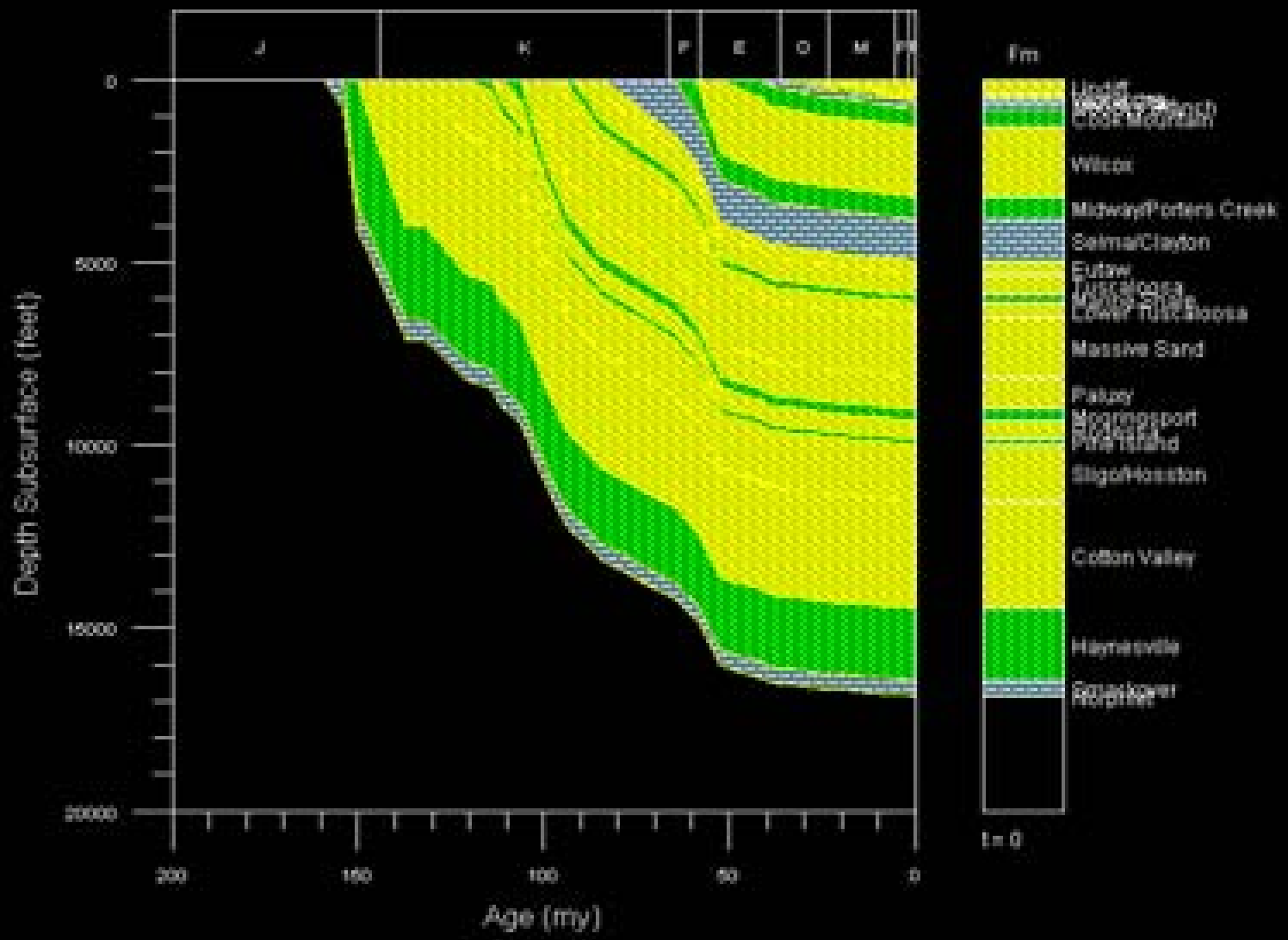
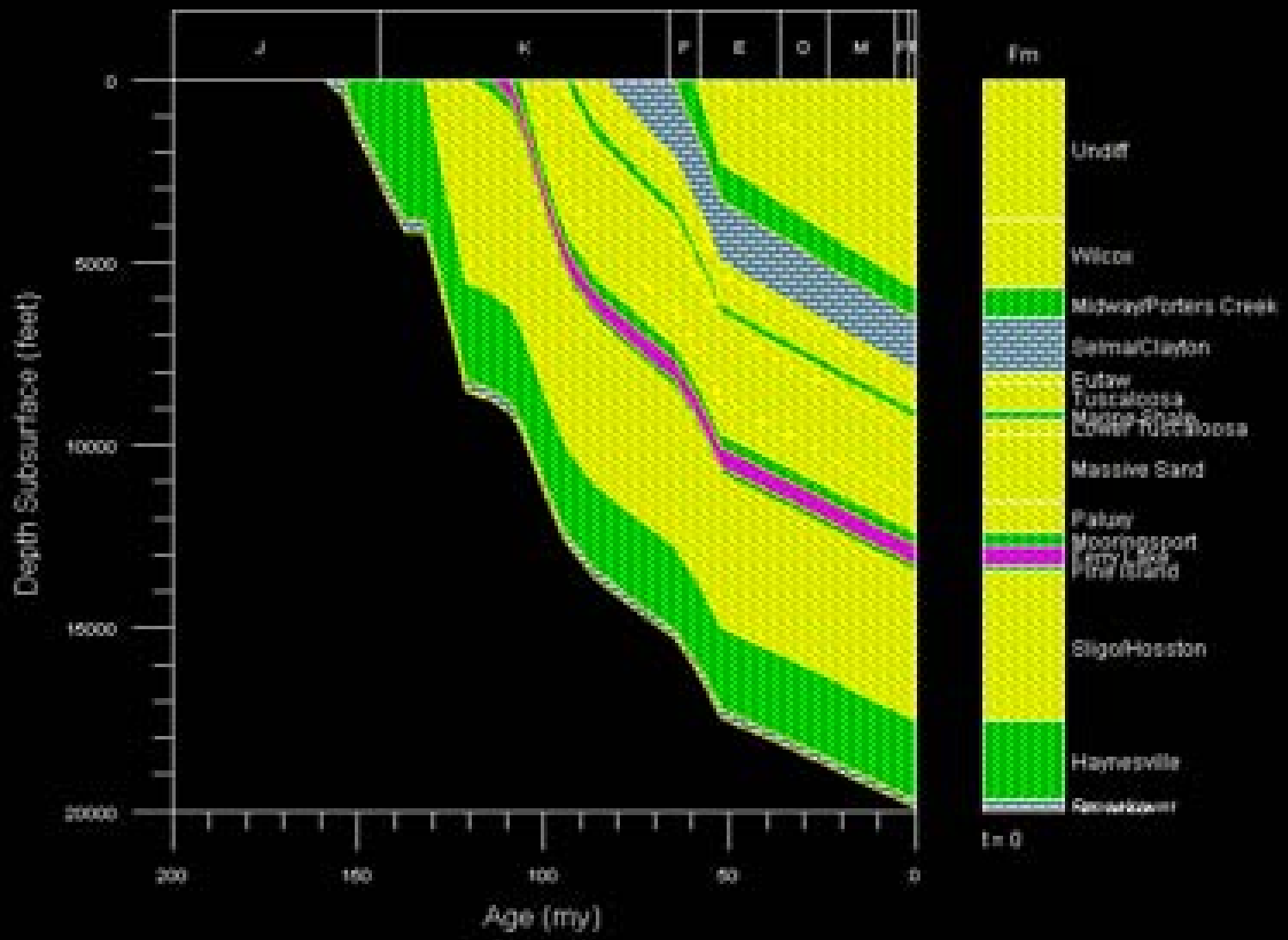
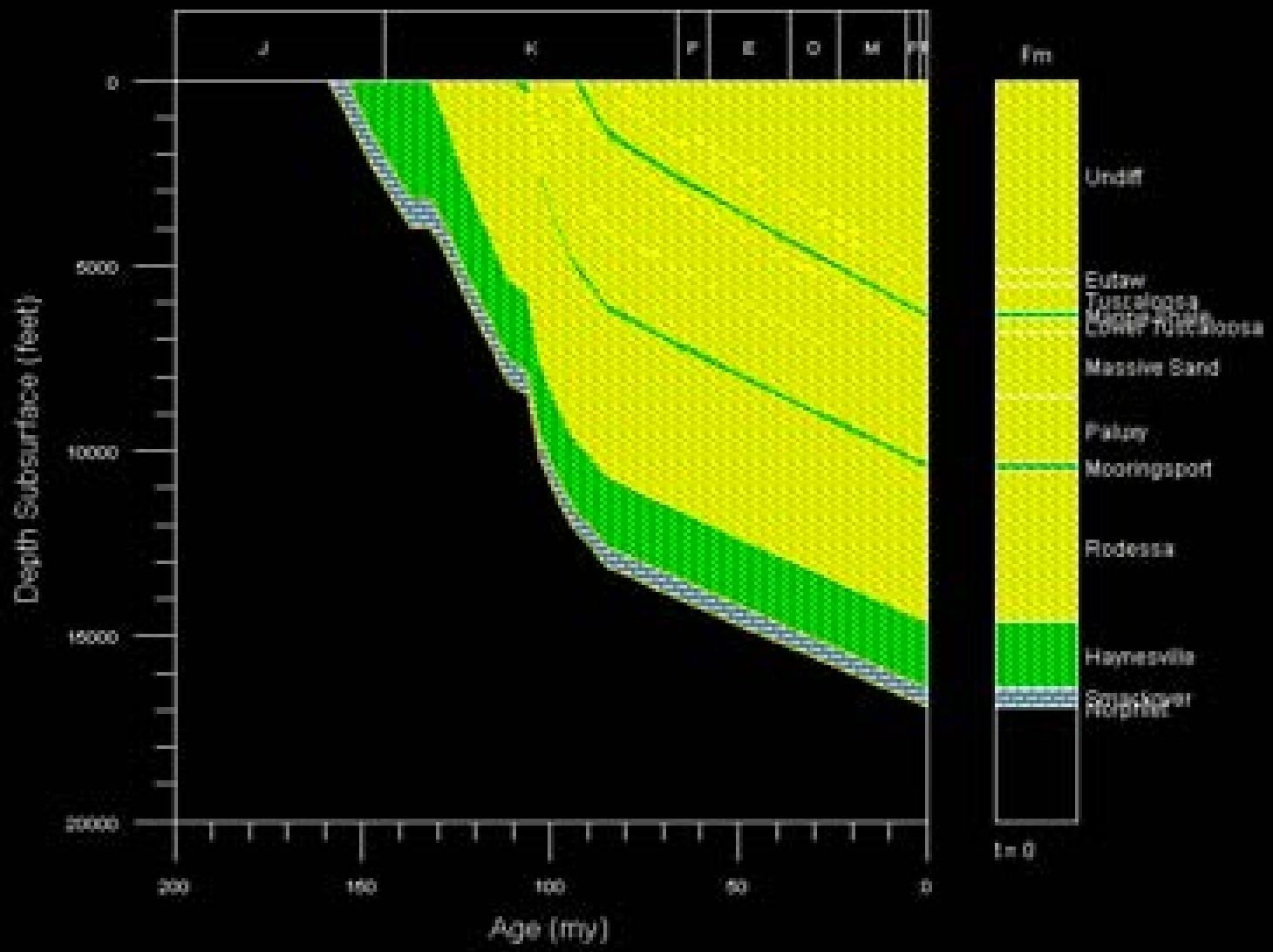


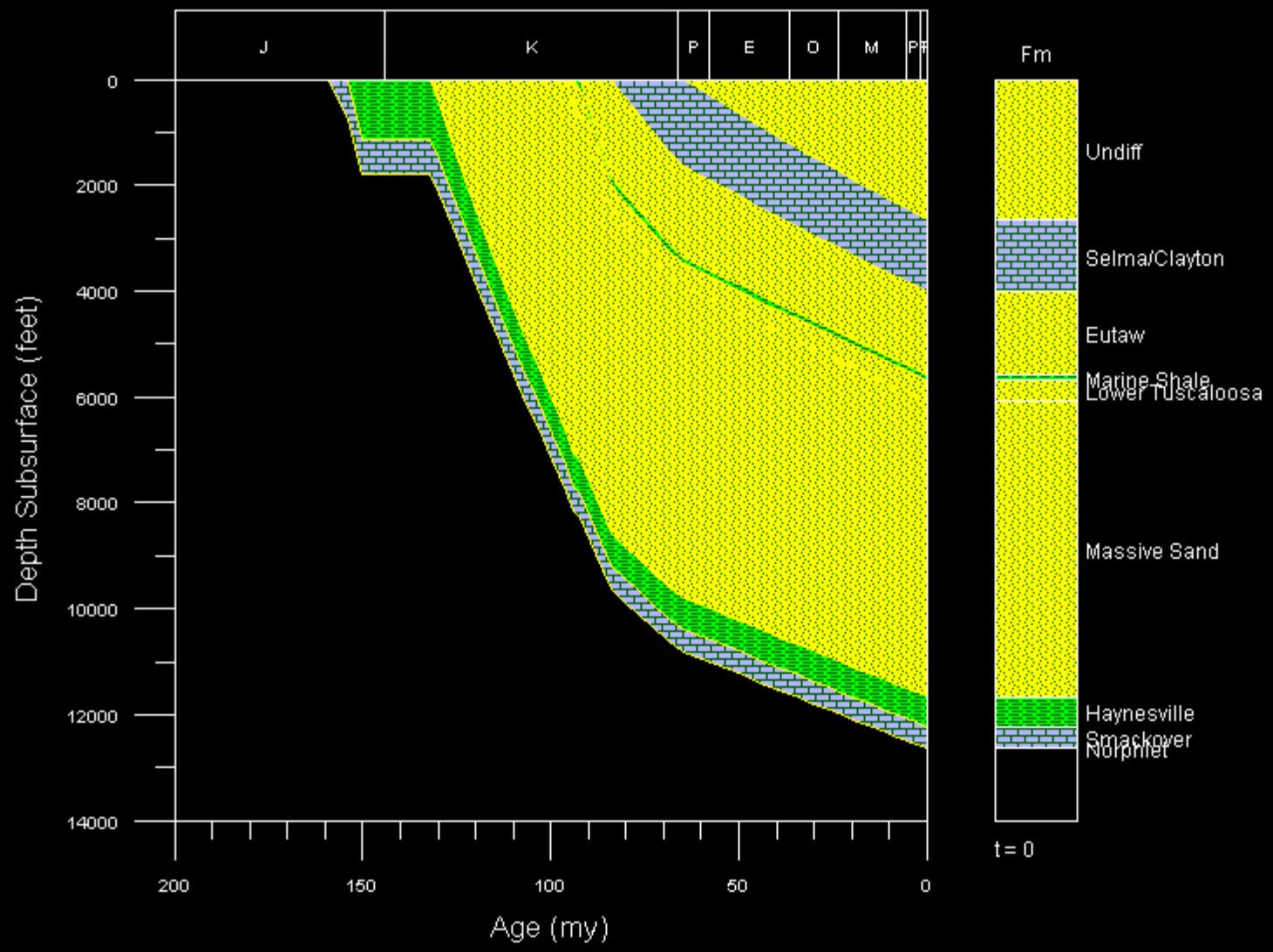
01-129-20051 BUR HIST

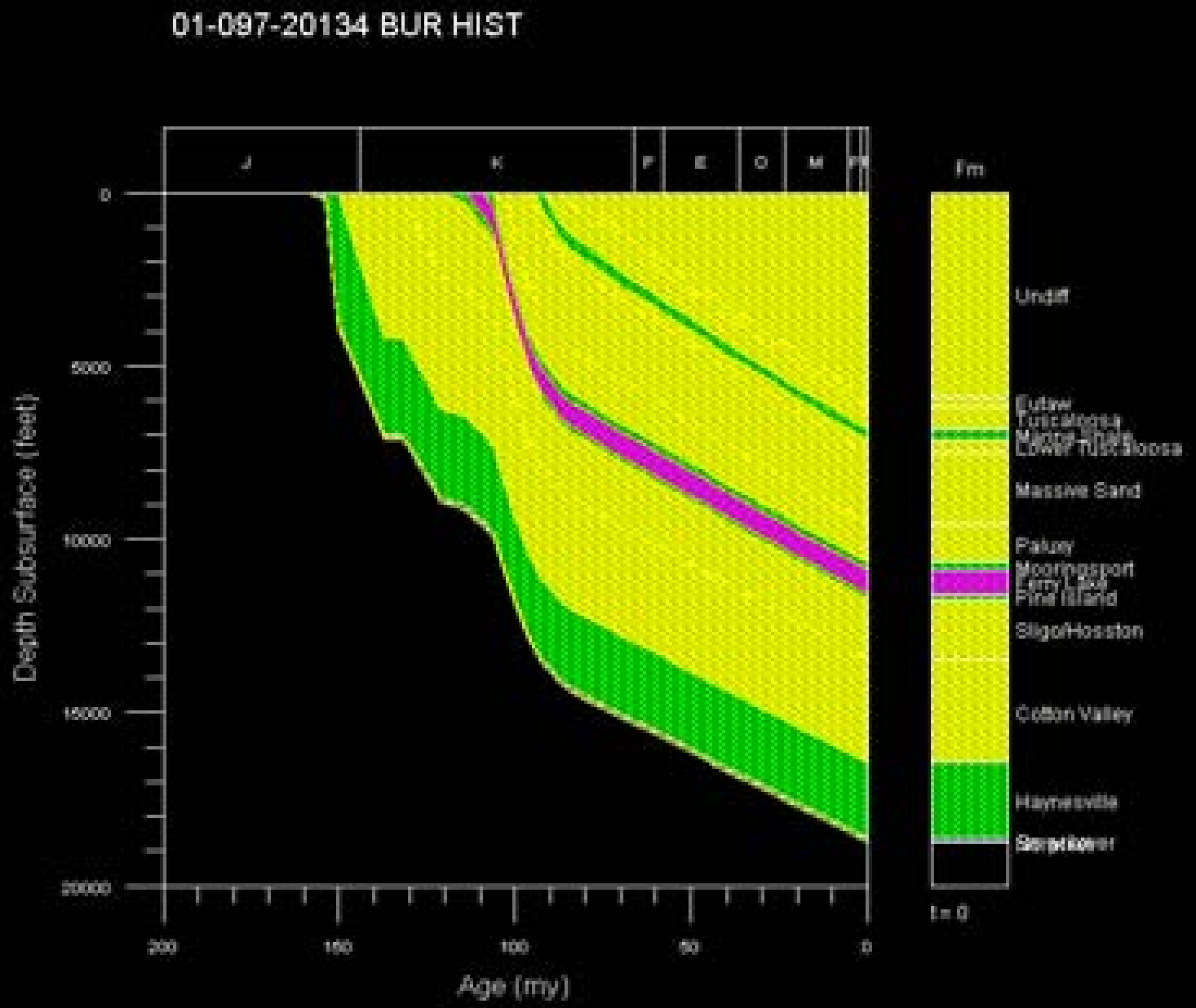


01-129-20054 BUR HIST

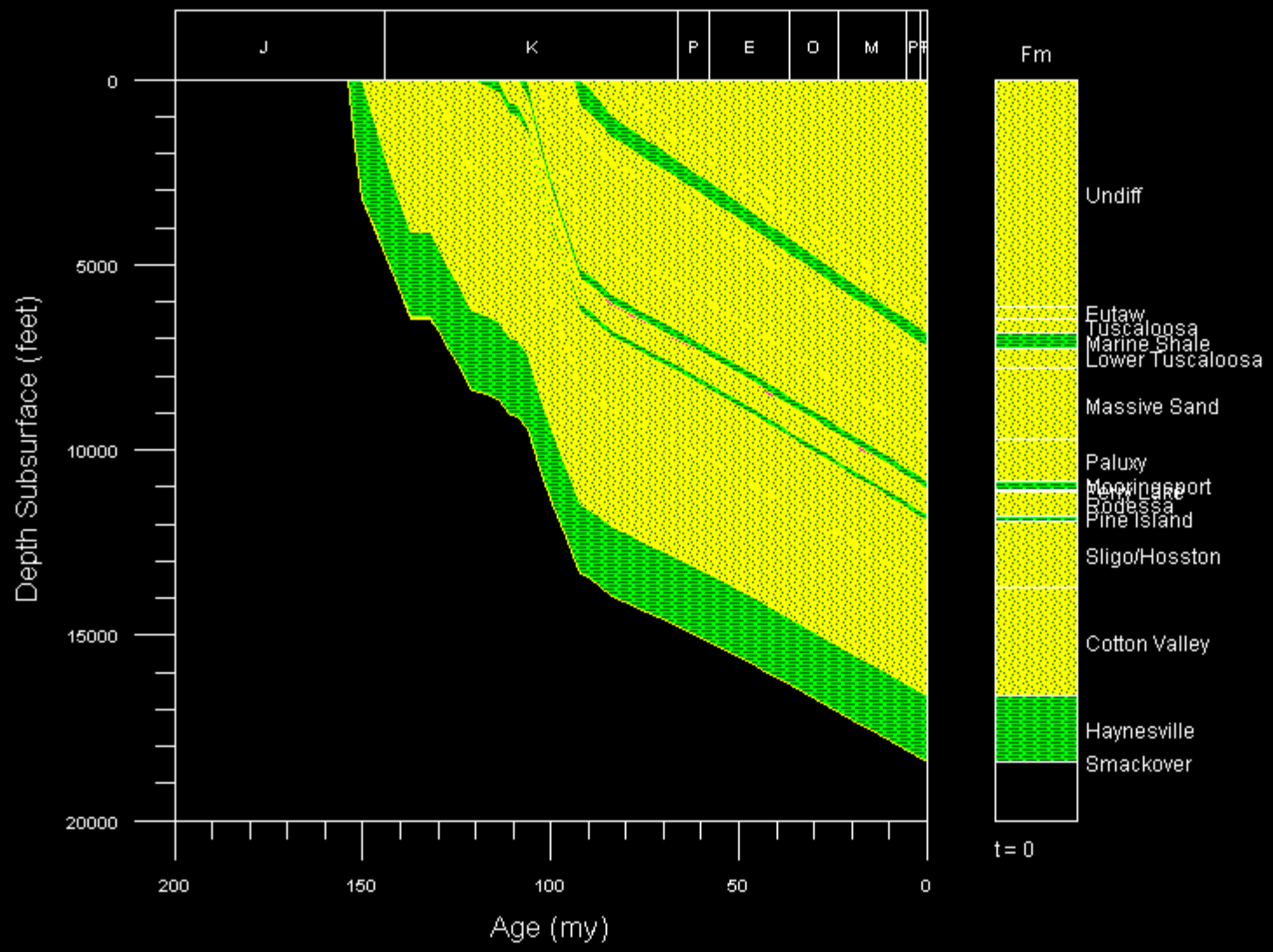


01-232-0114 BUR HIST

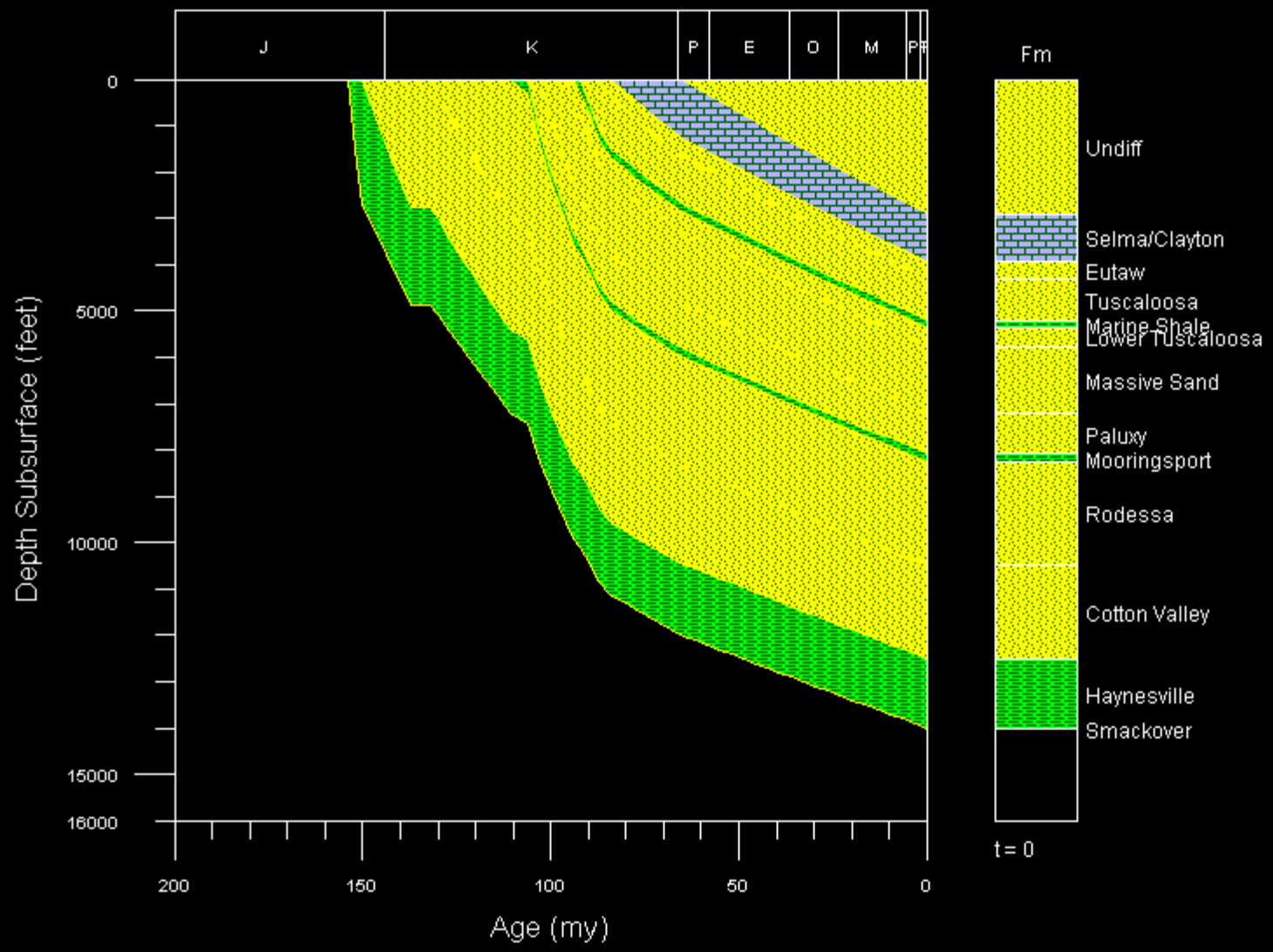


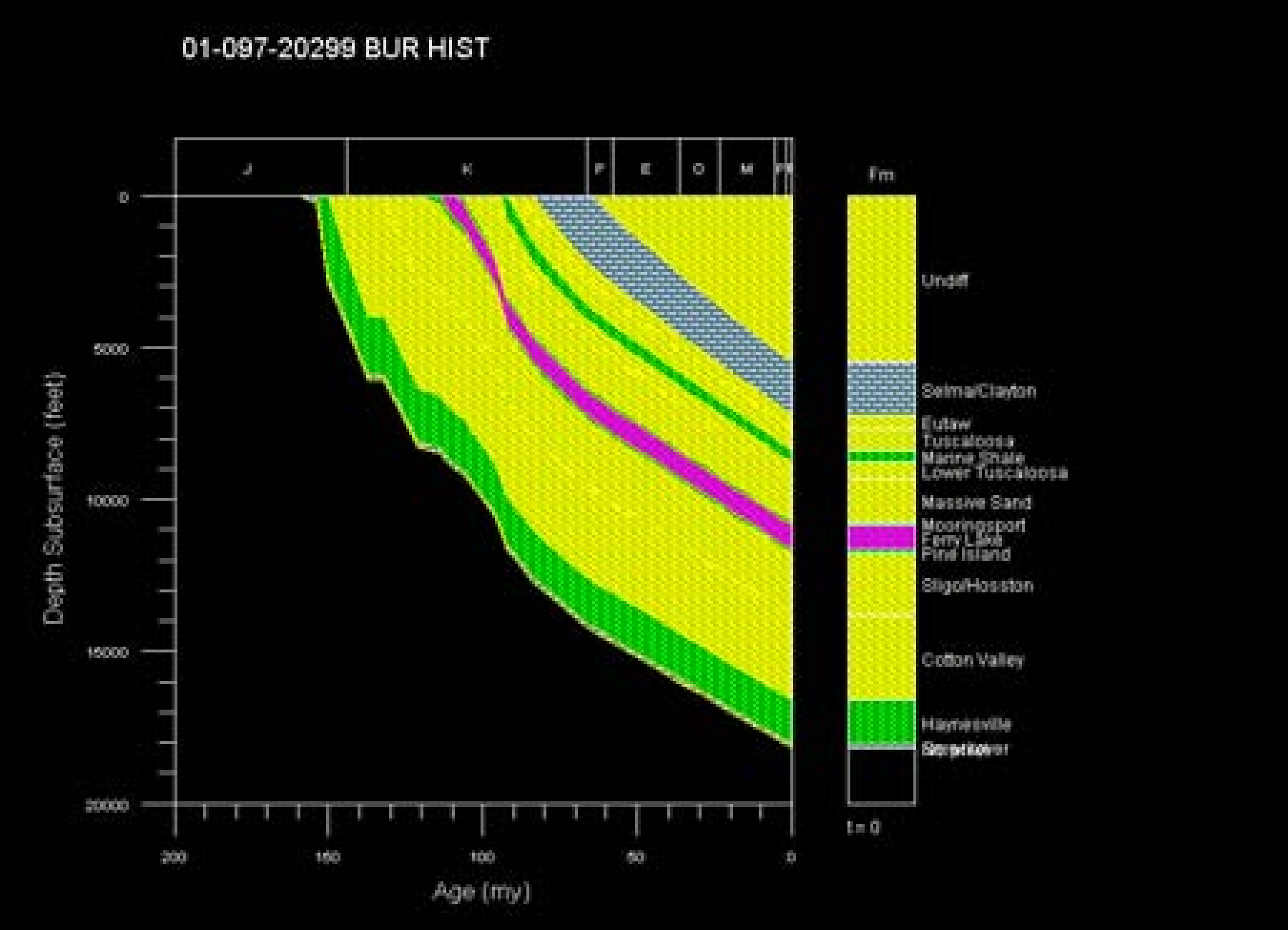

01-097-20134 BUR HIST
J
K
P
E
O
M
Fm
Undiff
Eutaw
Tuscaloosa
Marine Shale
Lower Tuscaloosa
Massive Sand
Paluxy
Mooringsport
Pine Island
Sligo/Hosston
Cotton Valley
Haynesville
t = 0
Depth Subsurface (feet)
0
5000
10000
15000
20000
200
150
100
50
0
Age (my)

01-097-20141 BUR HIST

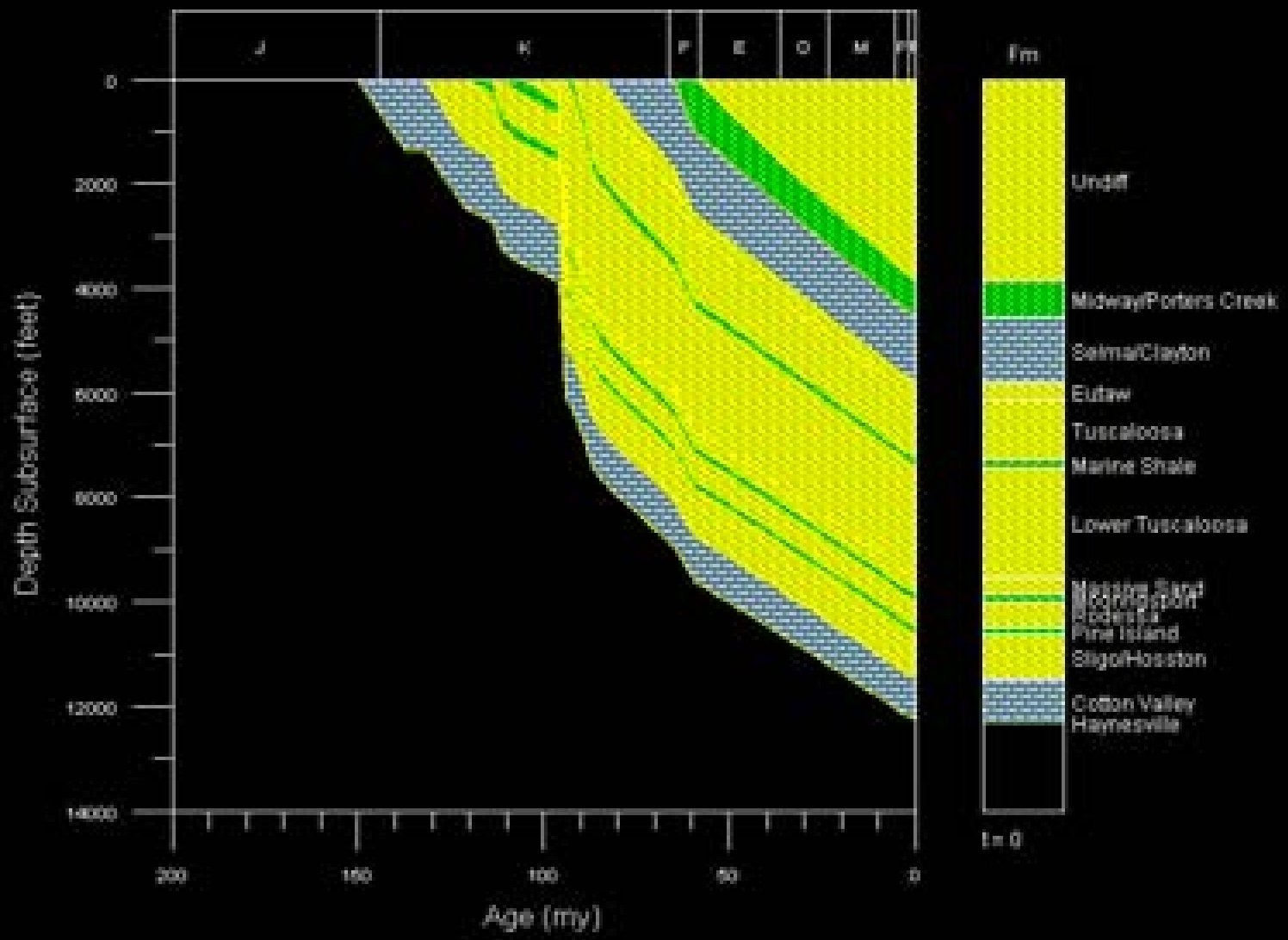


01--23-20197 BUR HIST

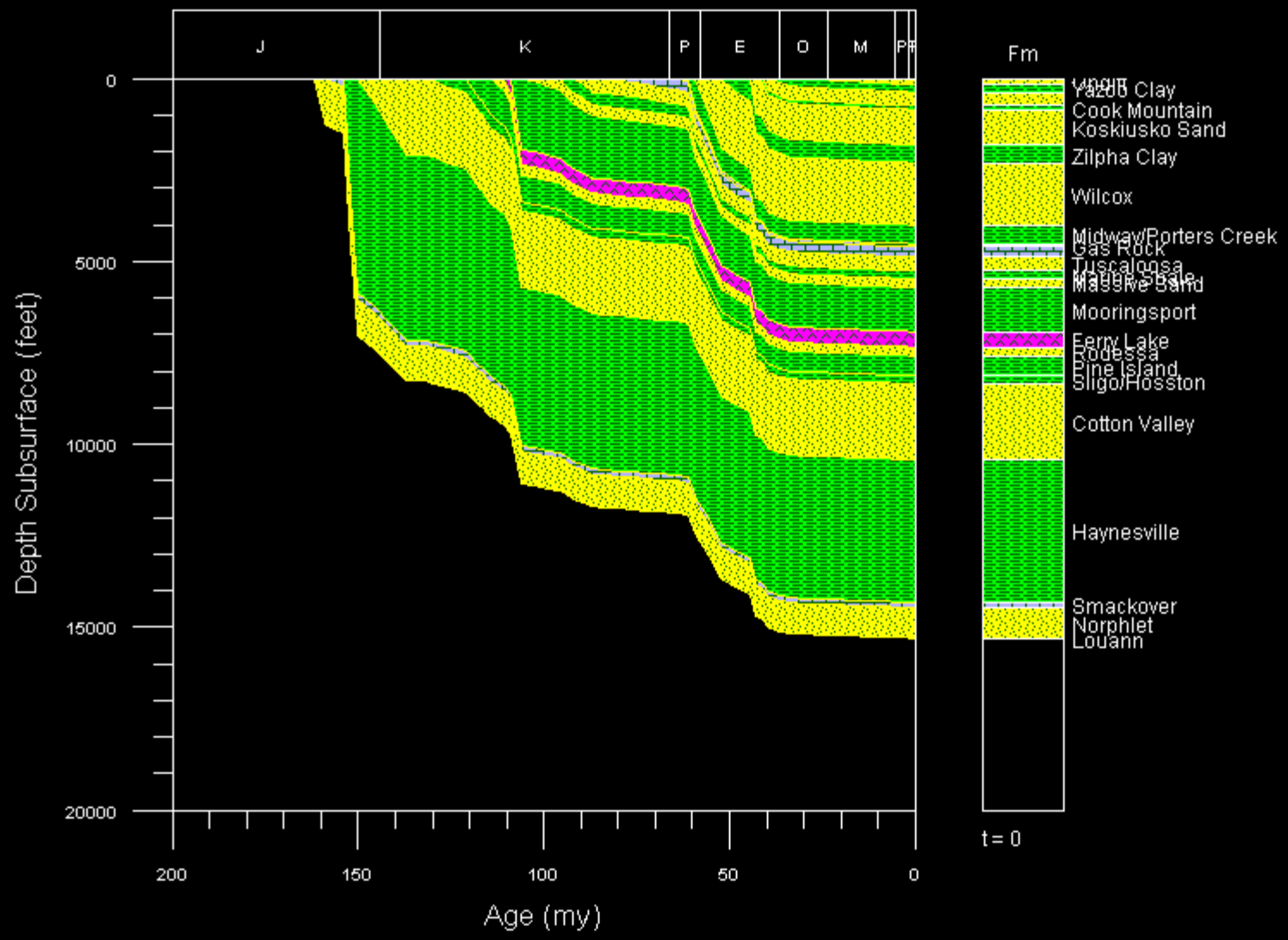



01-097-20299 BUR HIST
J
K
P
E
O
M
Fm
Undiff
Selma/Clayton
Eutaw
Tuscaloosa
Marine Shale
Lower Tuscaloosa
Massive Sand
Mooringsport
Ferry Lake
Pine Island
Sligo/Hosston
Cotton Valley
Haynesville
t = 0
Depth Subsurface (feet)
0
5000
10000
15000
20000
200
150
100
50
0
Age (my)

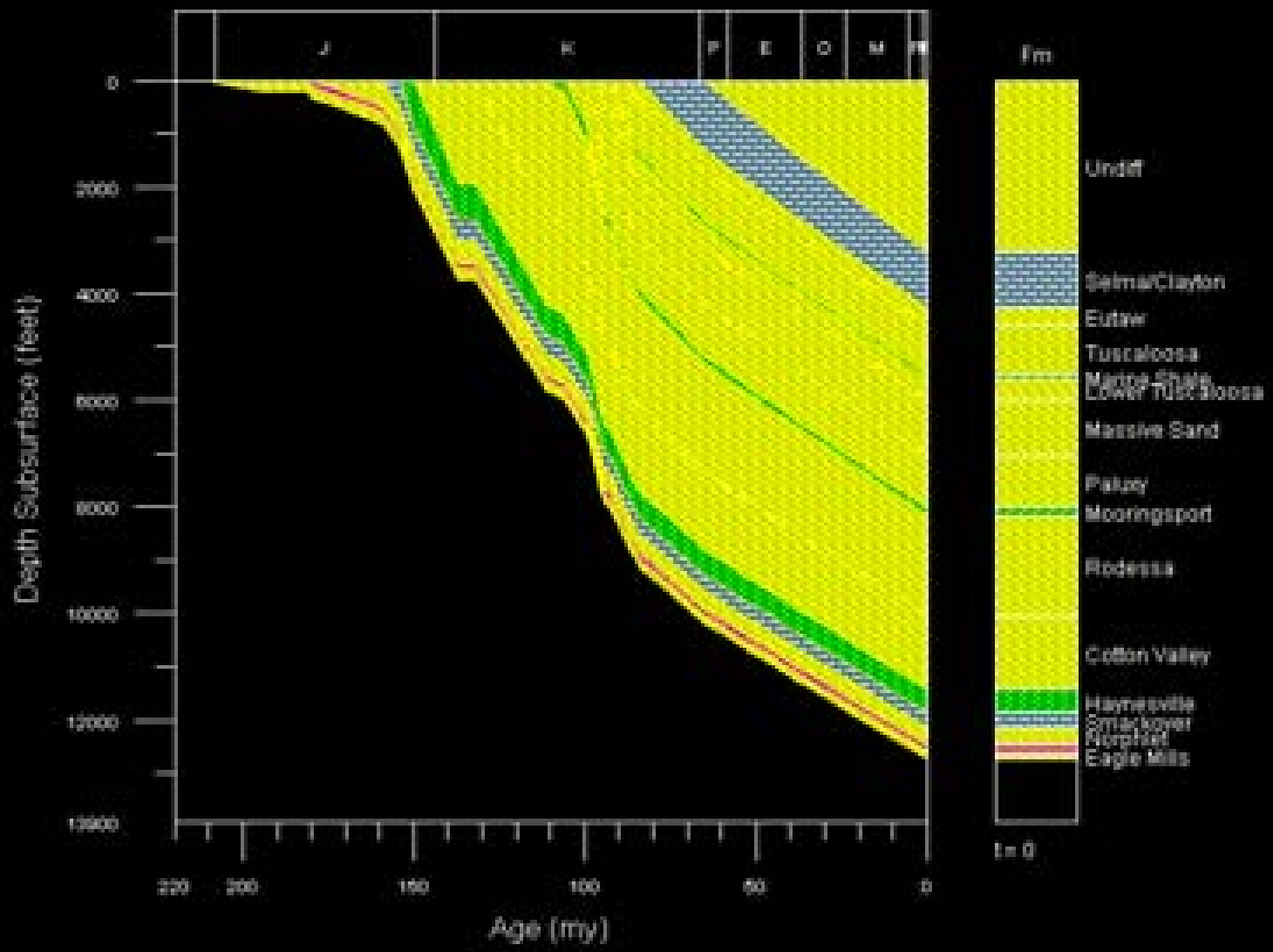
23-067-20002 BUR HIST



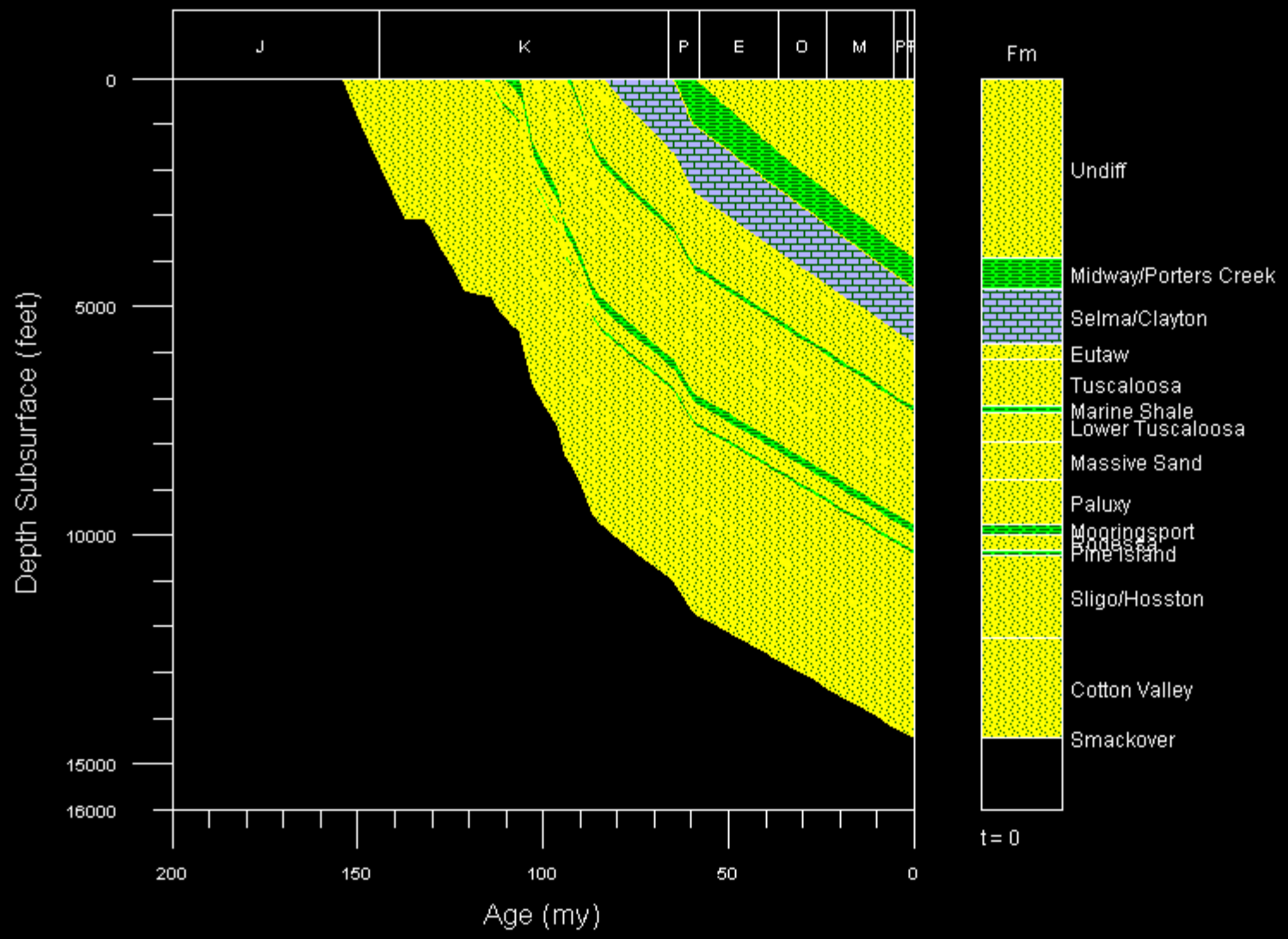
23-125-20004 BUR HIST



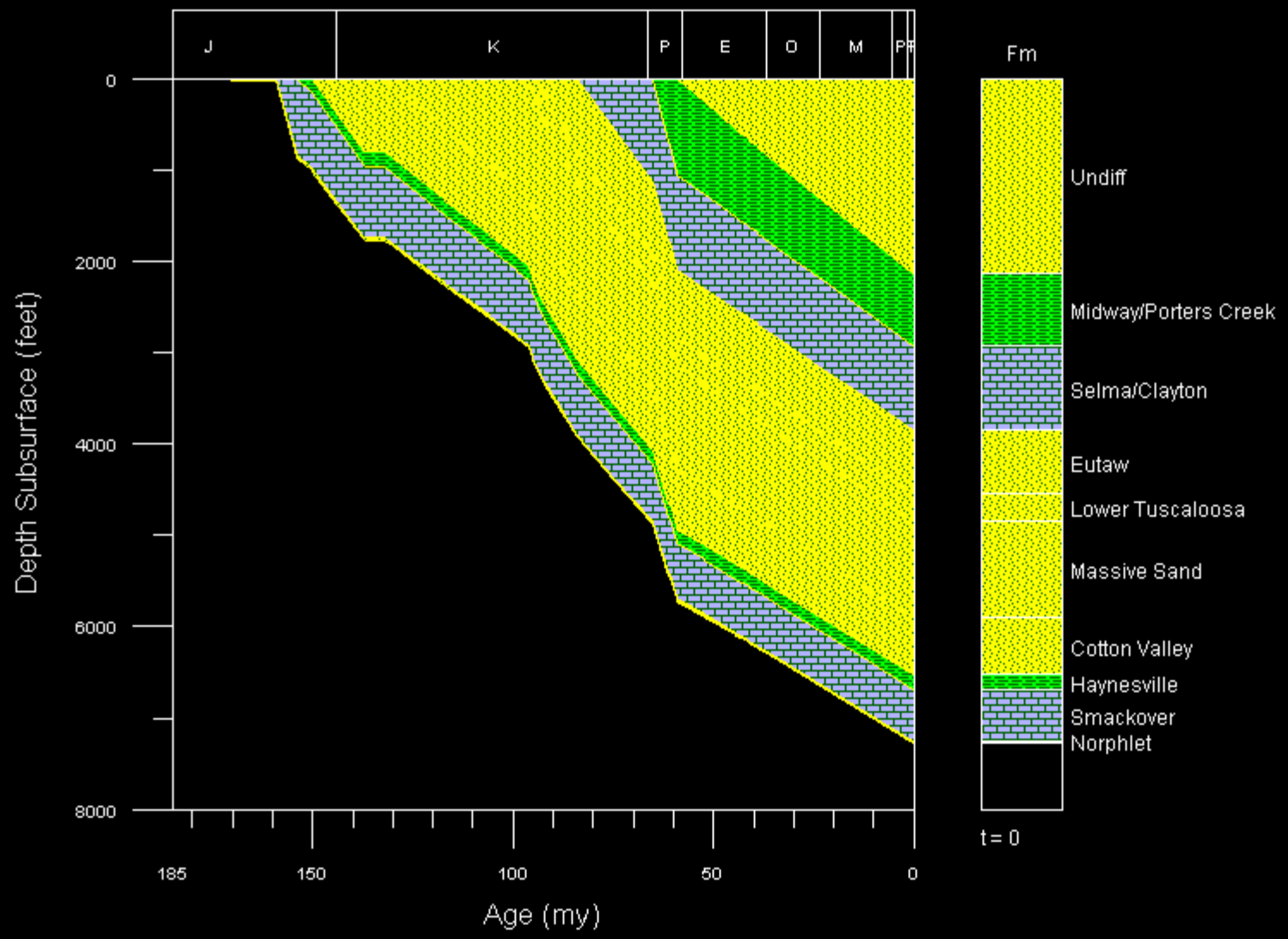
23-101-20005 BUR HIST

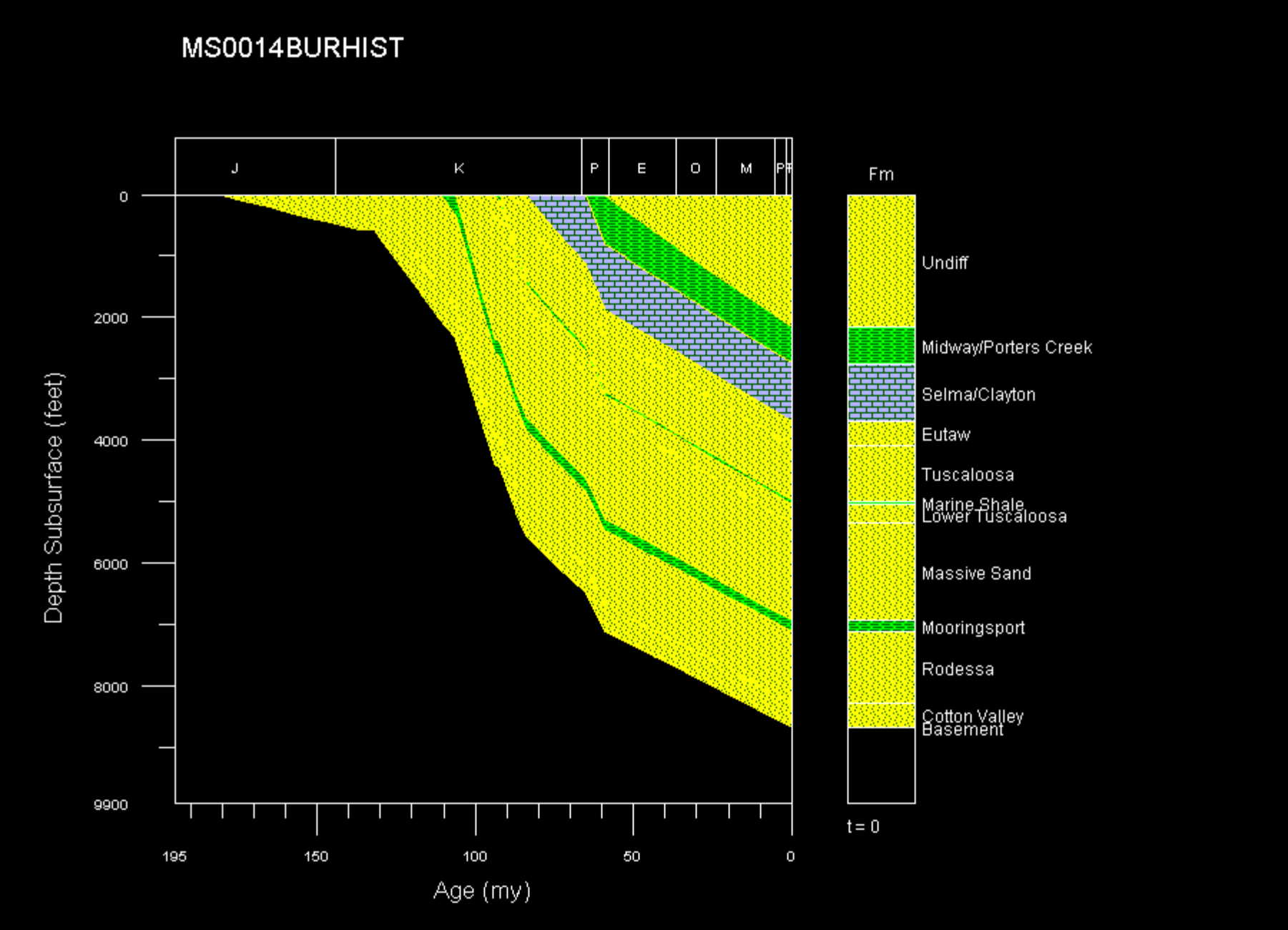


23-129-20006 BUR HIST

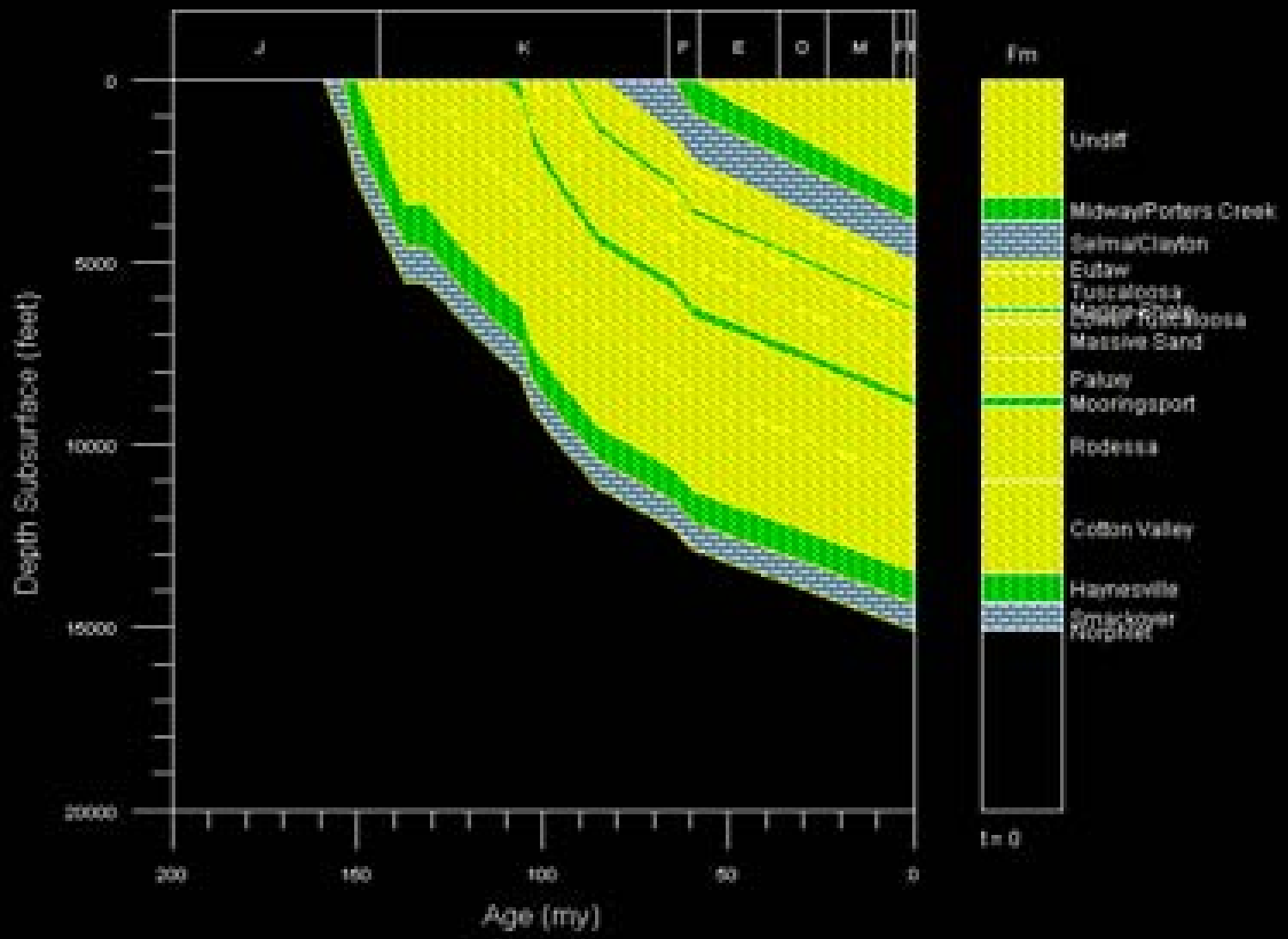


23-093-20011 BUR HIST

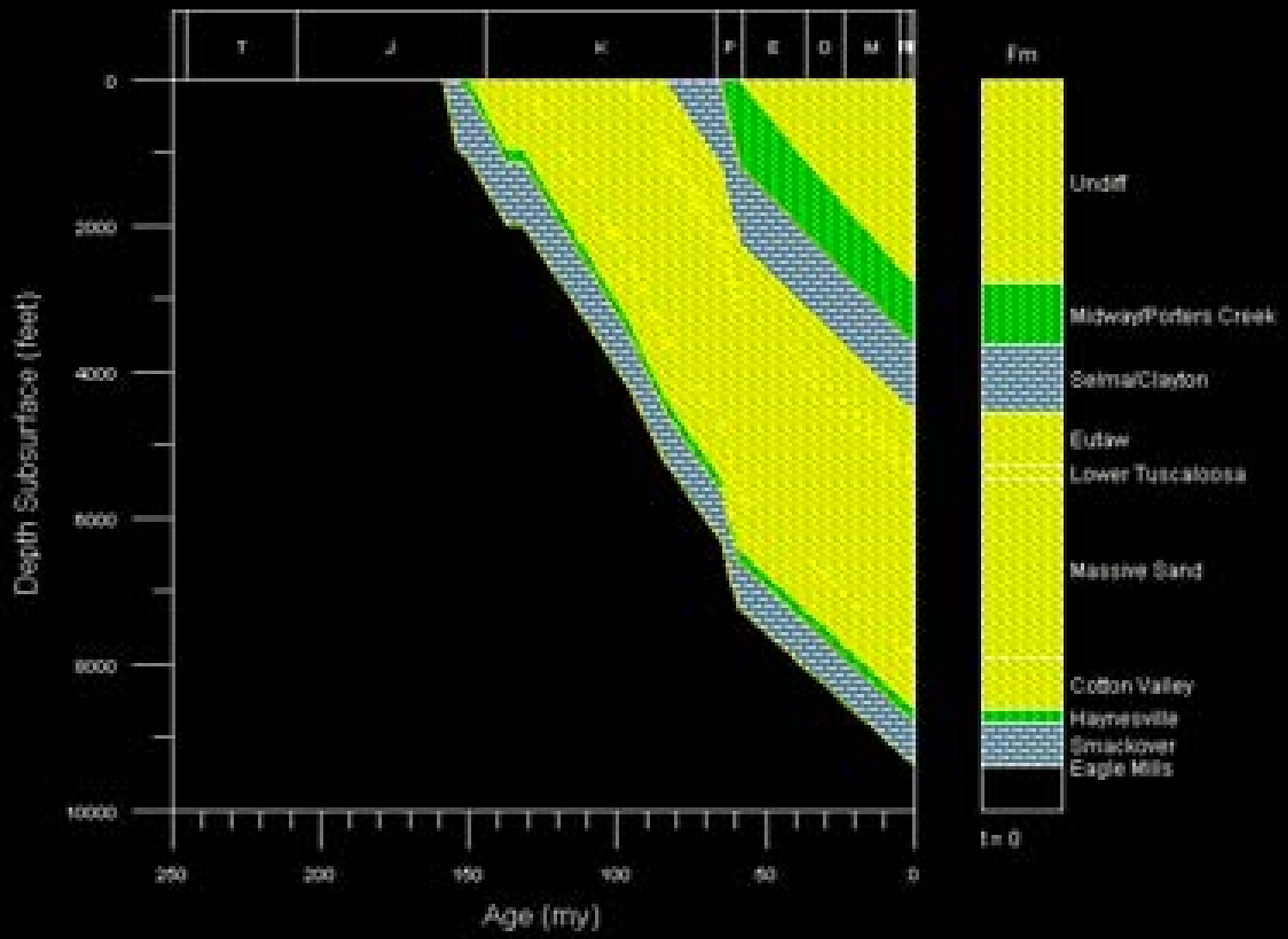



MS0014BURHIST
J
K
P
E
O
M
Pf
Fm
Undiff
Midway/Porters Creek
Selma/Clayton
Eutaw
Tuscaloosa
Marine Shale
Lower Tuscaloosa
Massive Sand
Mooringsport
Rodessa
Cotton Valley
Basement
t = 0
Depth Subsurface (feet)
0
2000
4000
6000
8000
9900
195
150
100
50
0
Age (my)

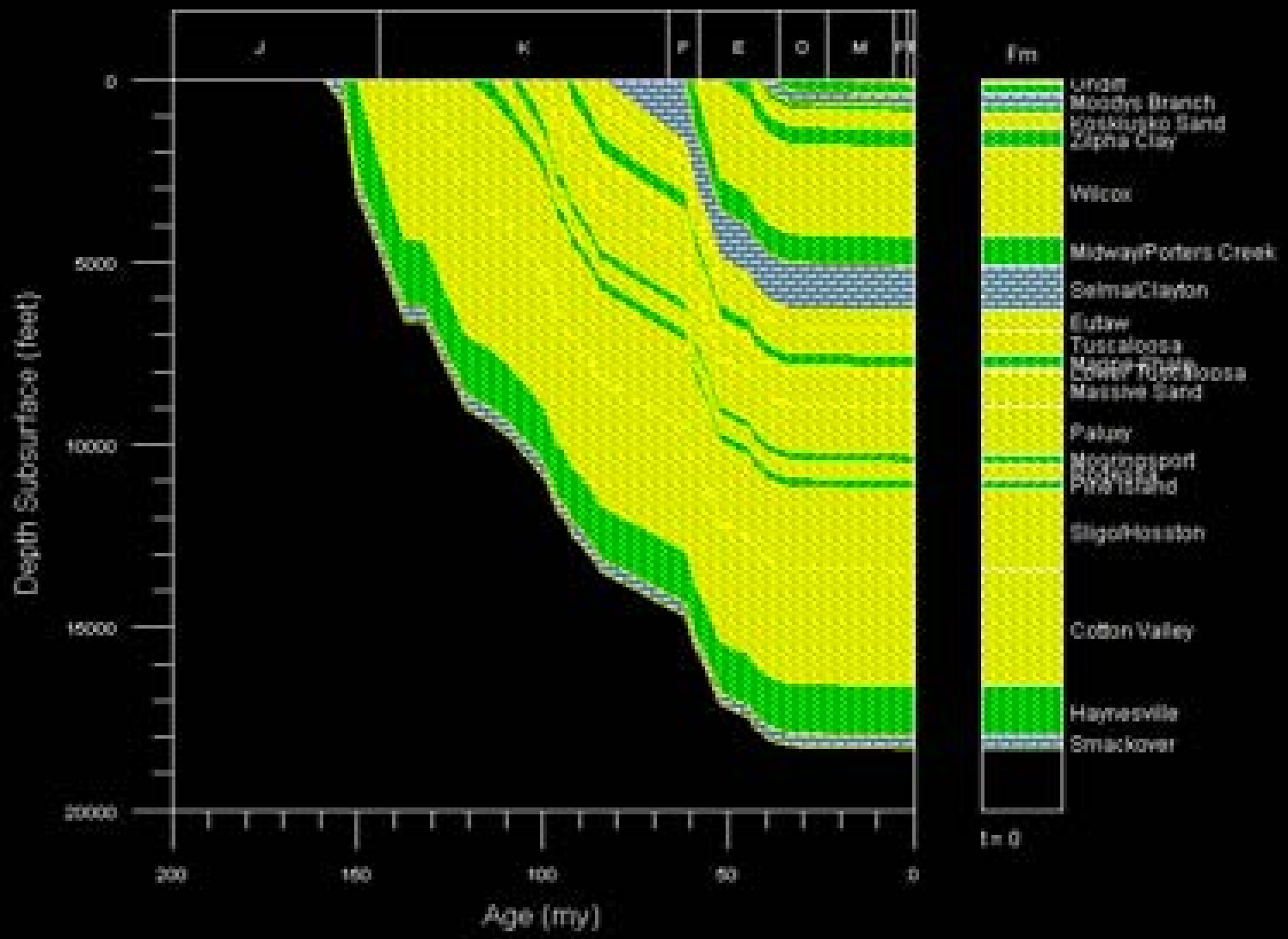
23-129-00015 BUR HIST



23-051-20020 BUR HIST



23-121-20025 BUR HIST



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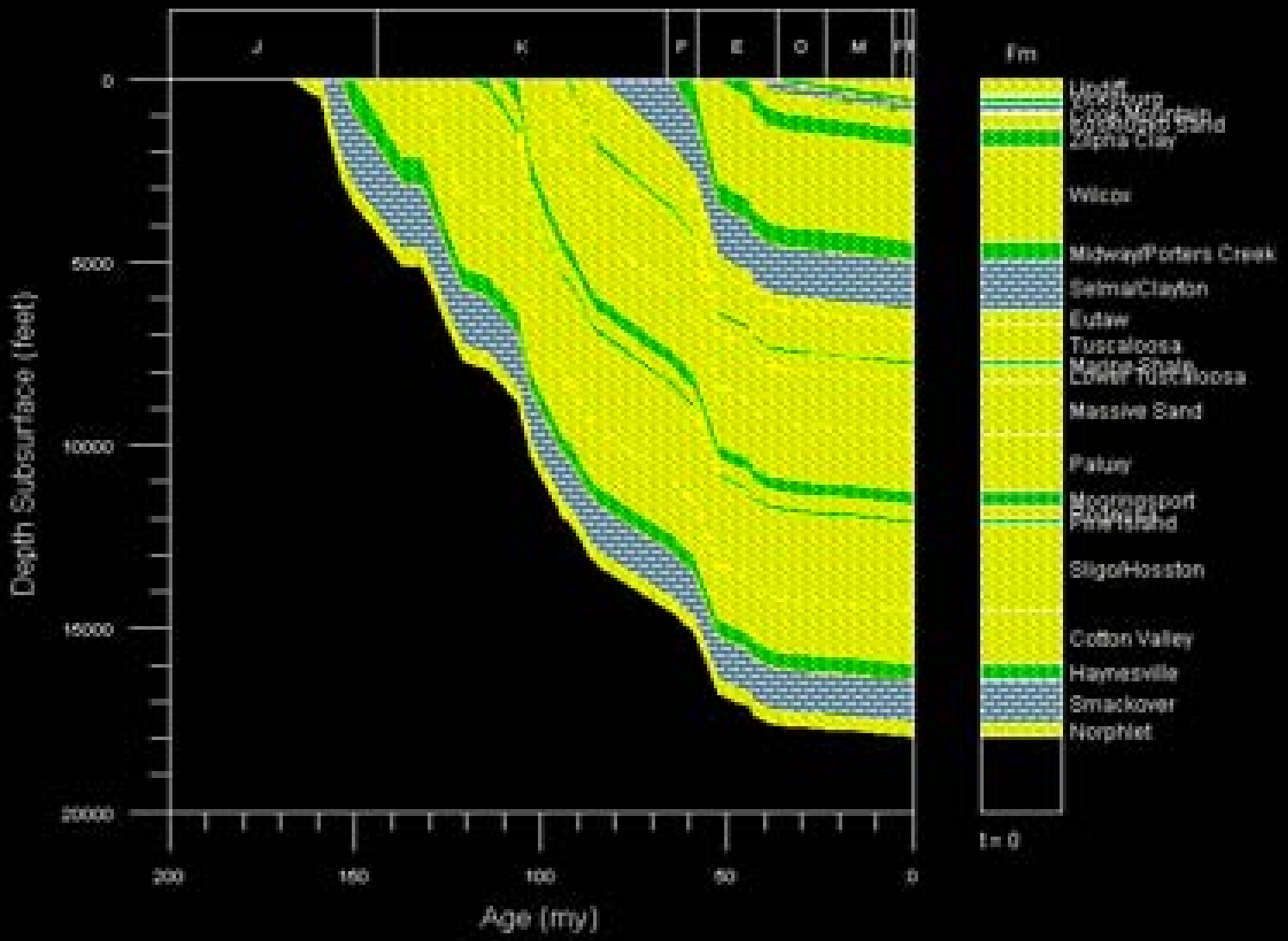

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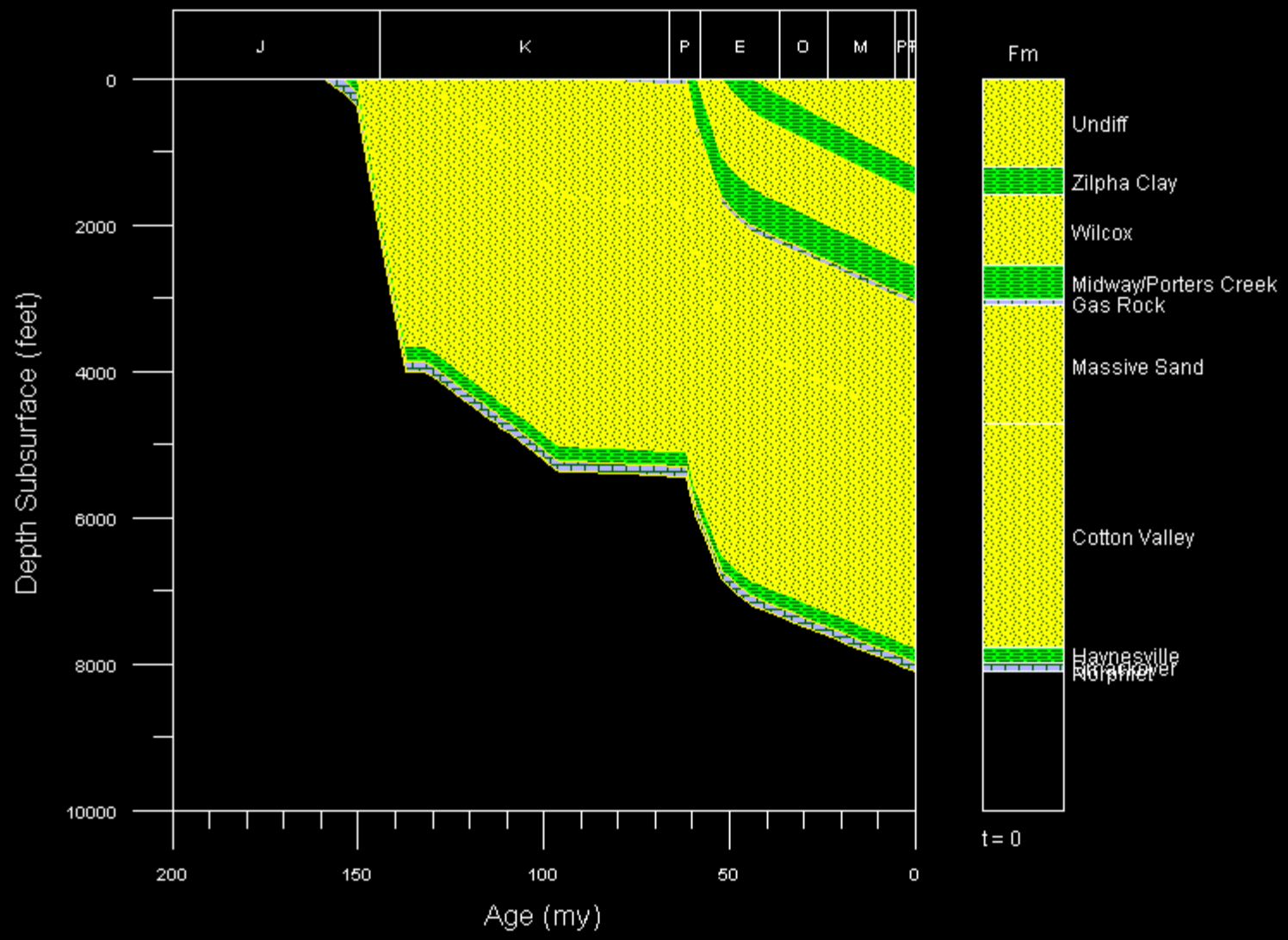
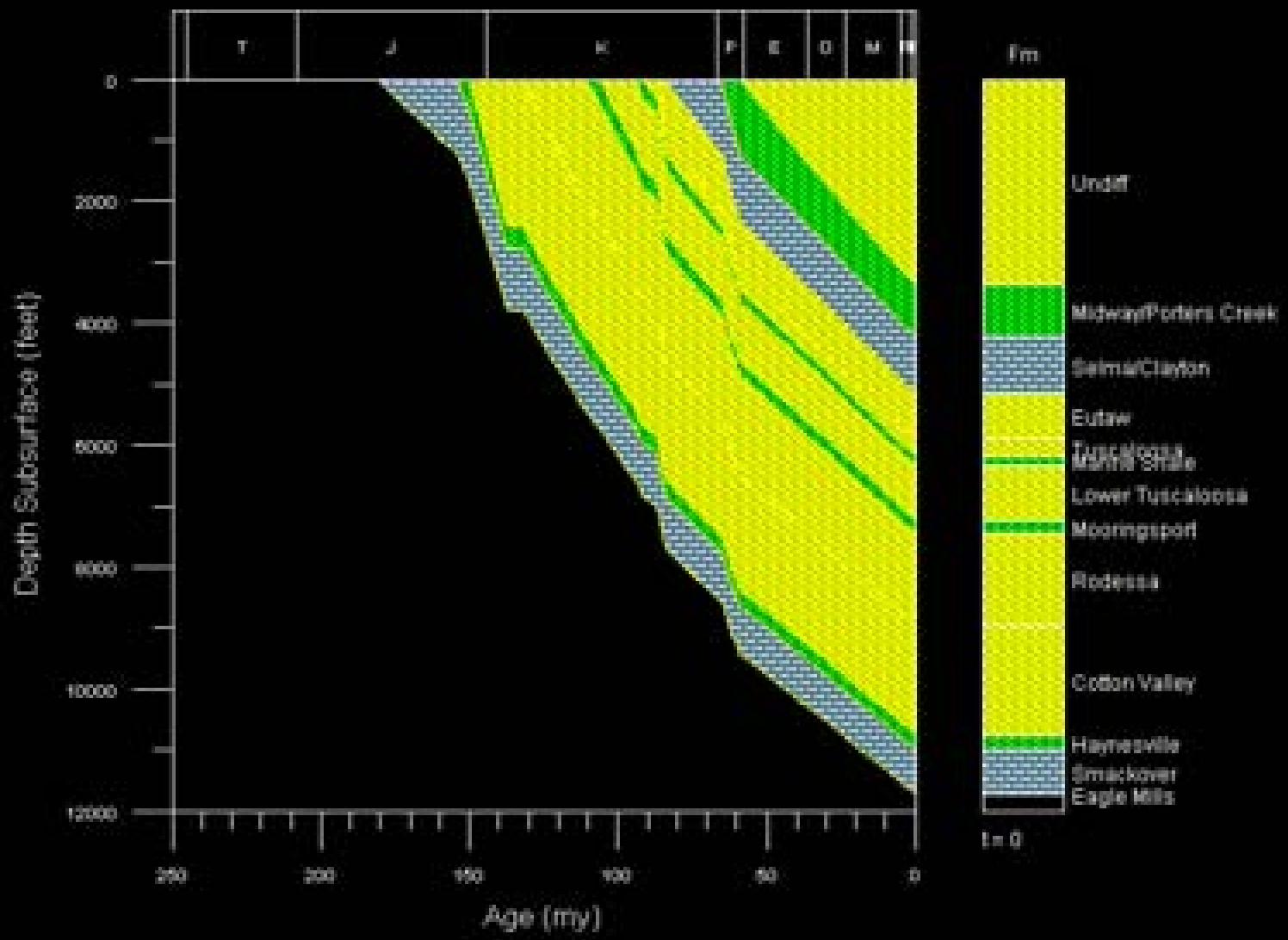
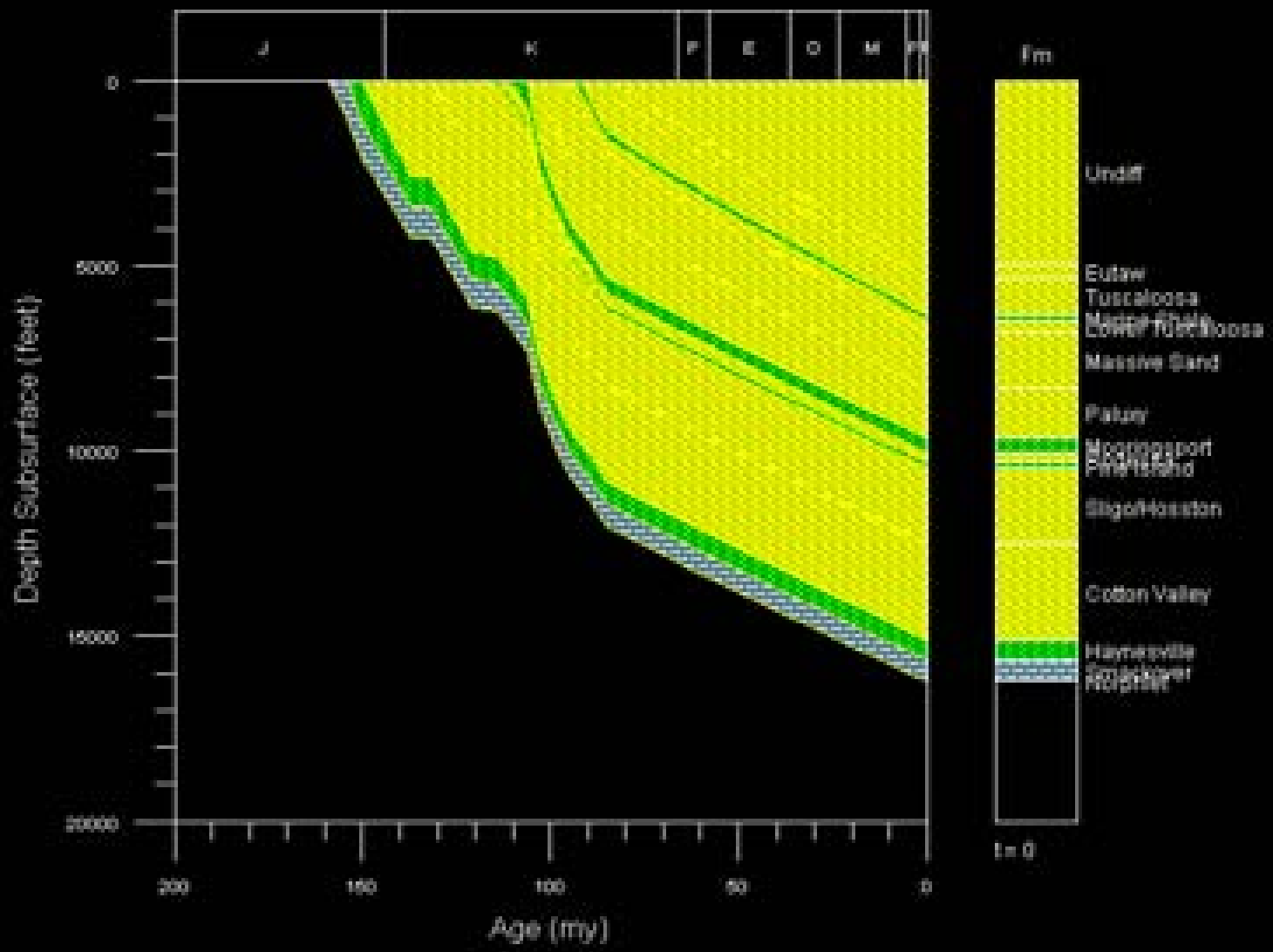


23-051-20036 BUR HIST



23-153-20042 BUR HIST



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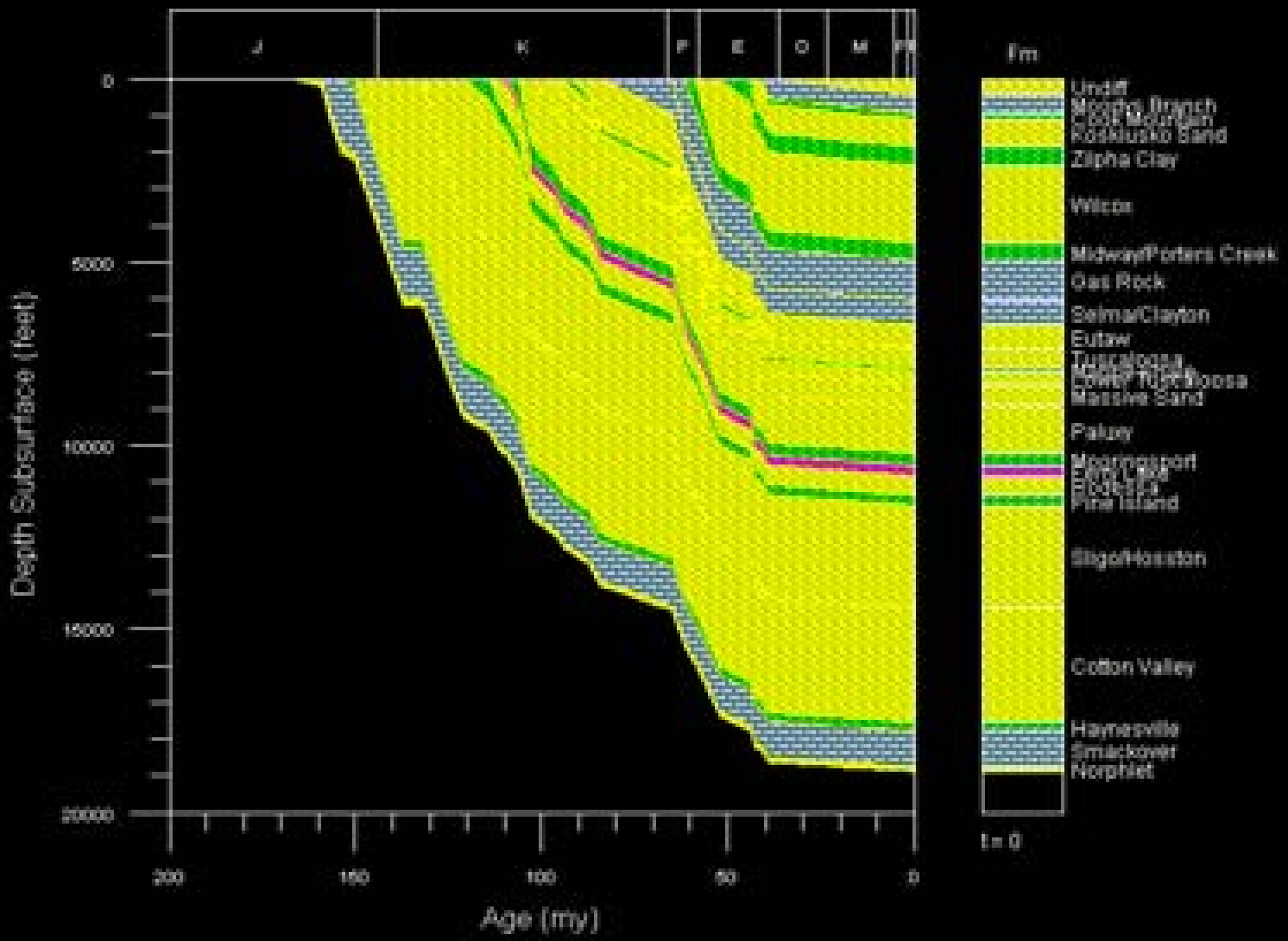
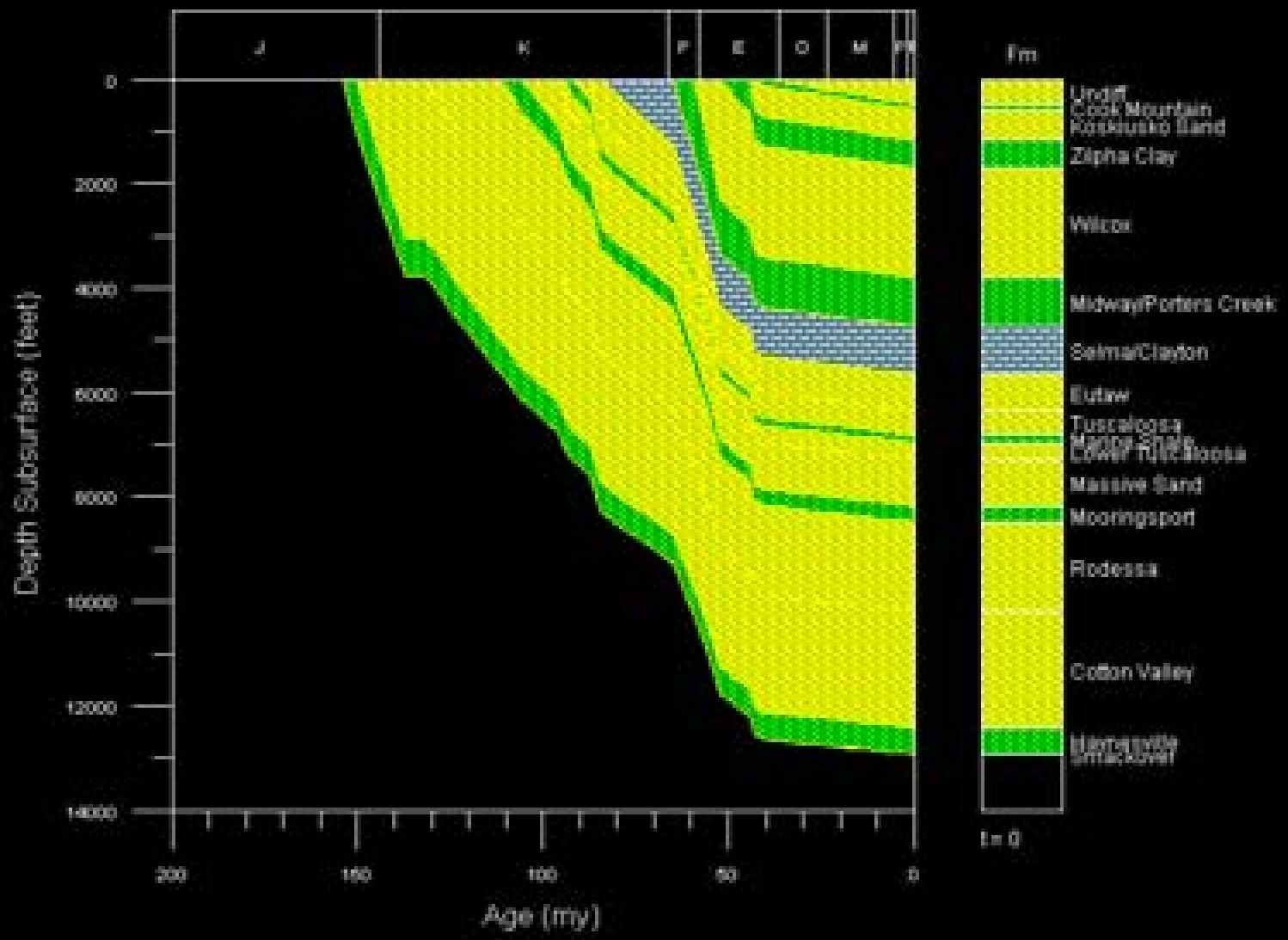


23-163-00049 BUR HIST



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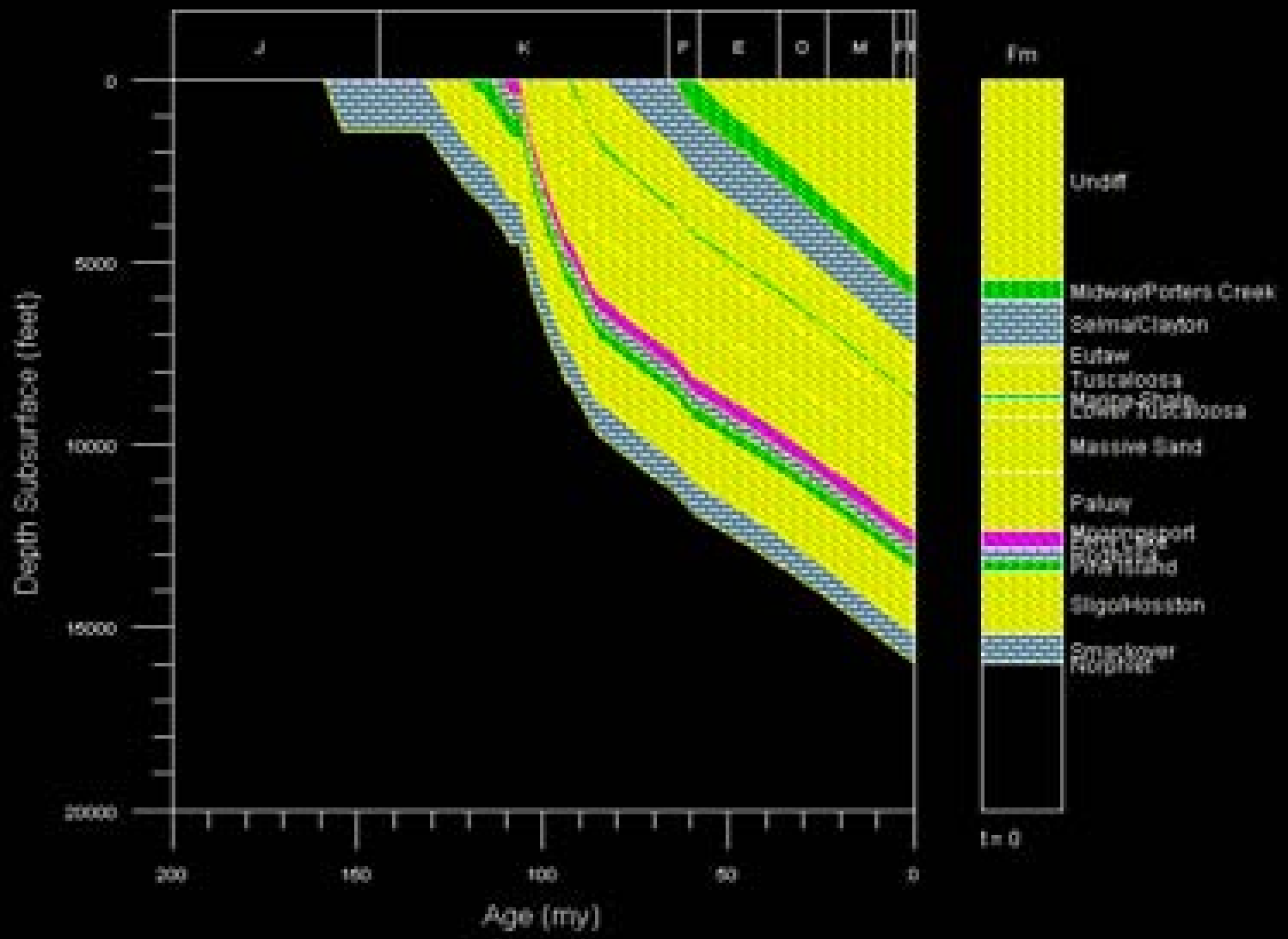

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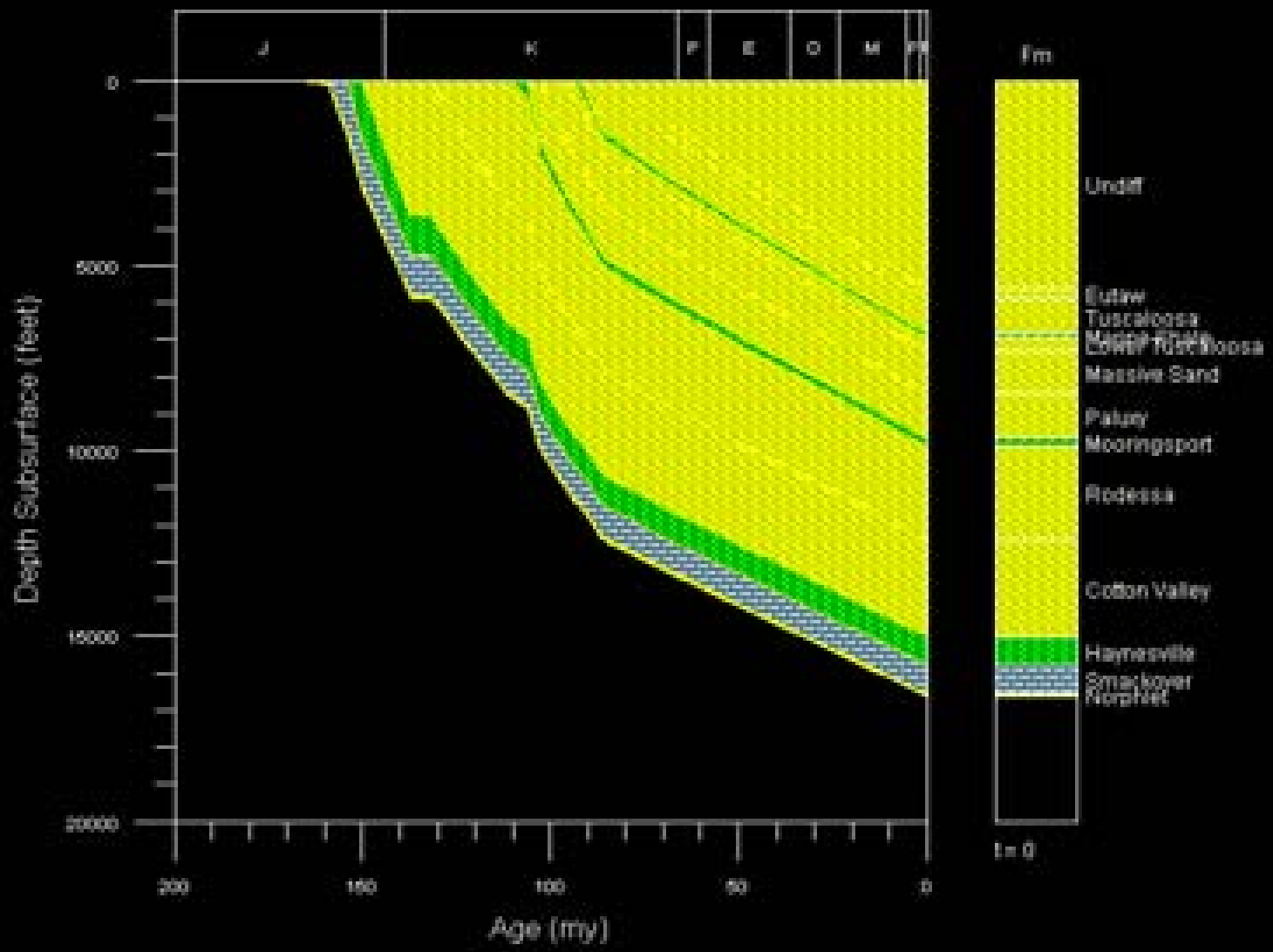

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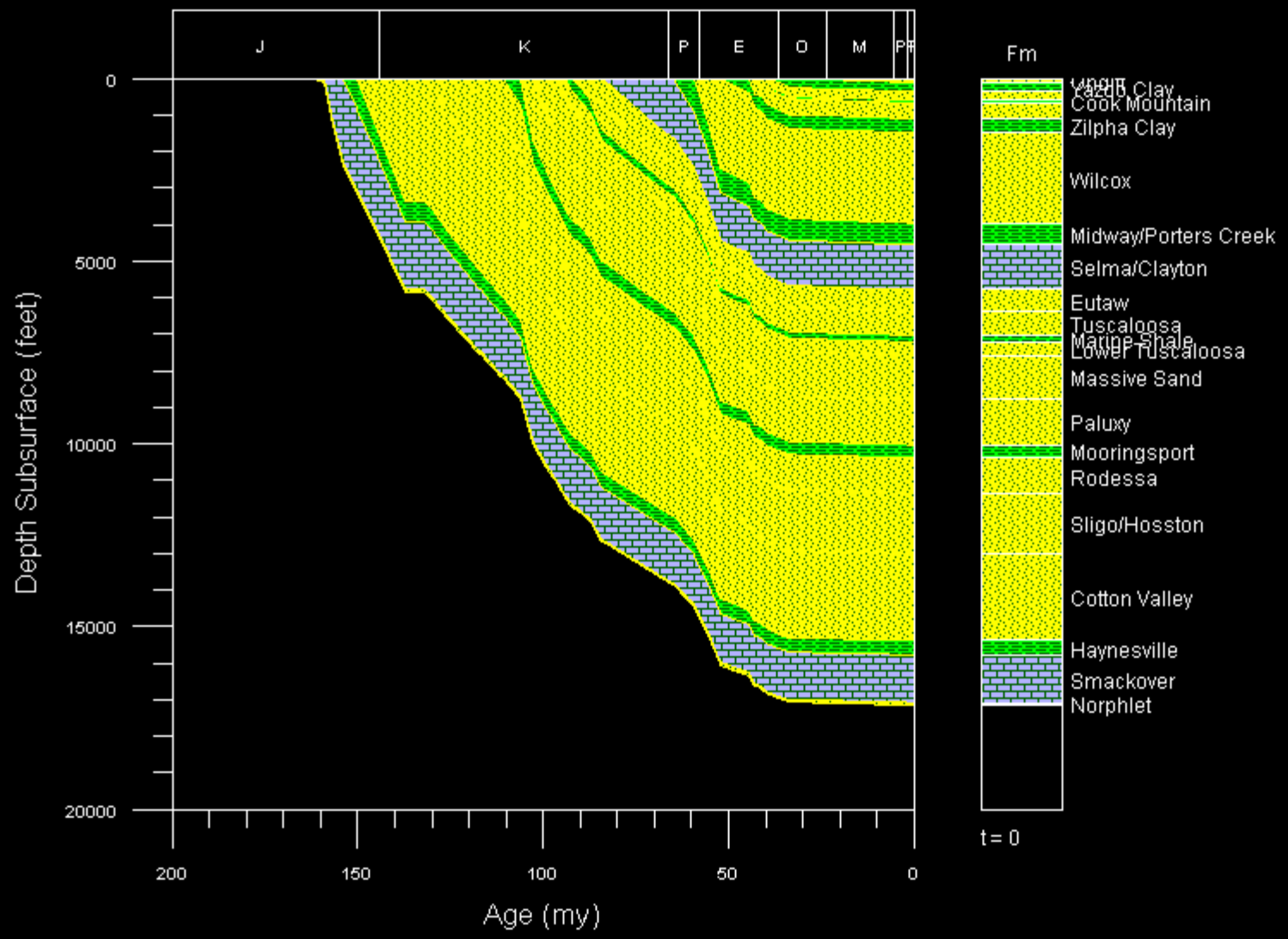
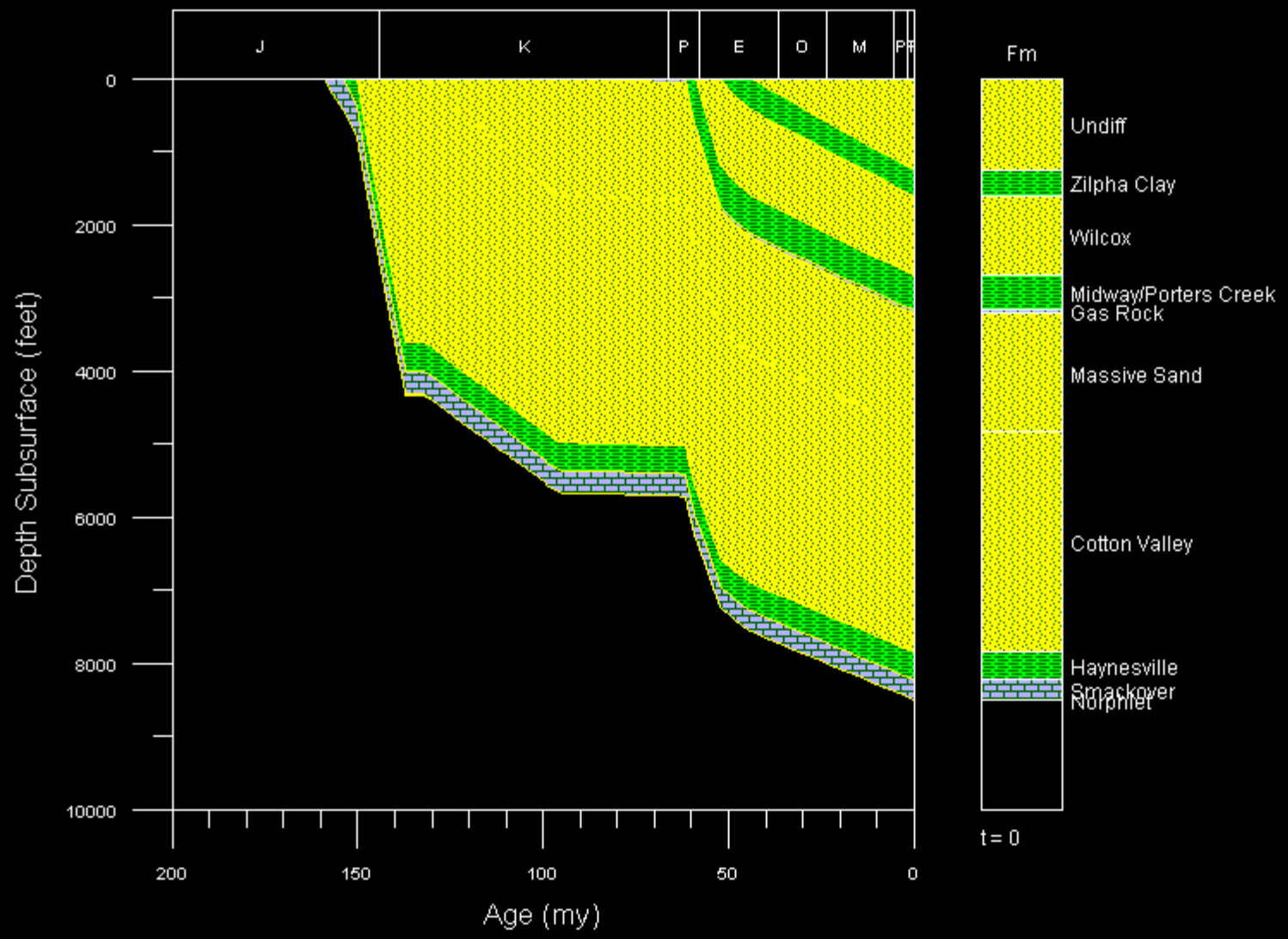


23-055-00066 BUR HIST



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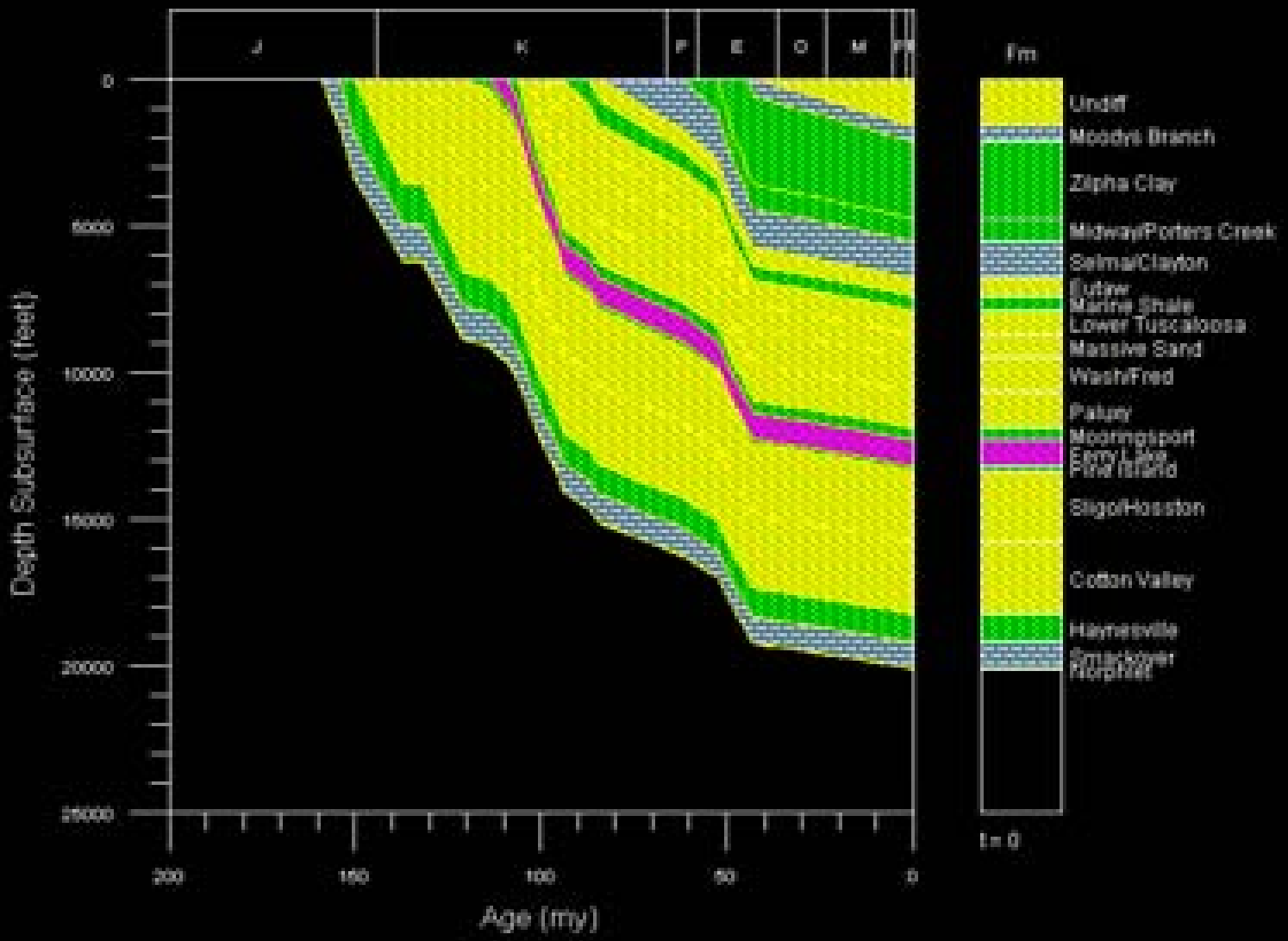

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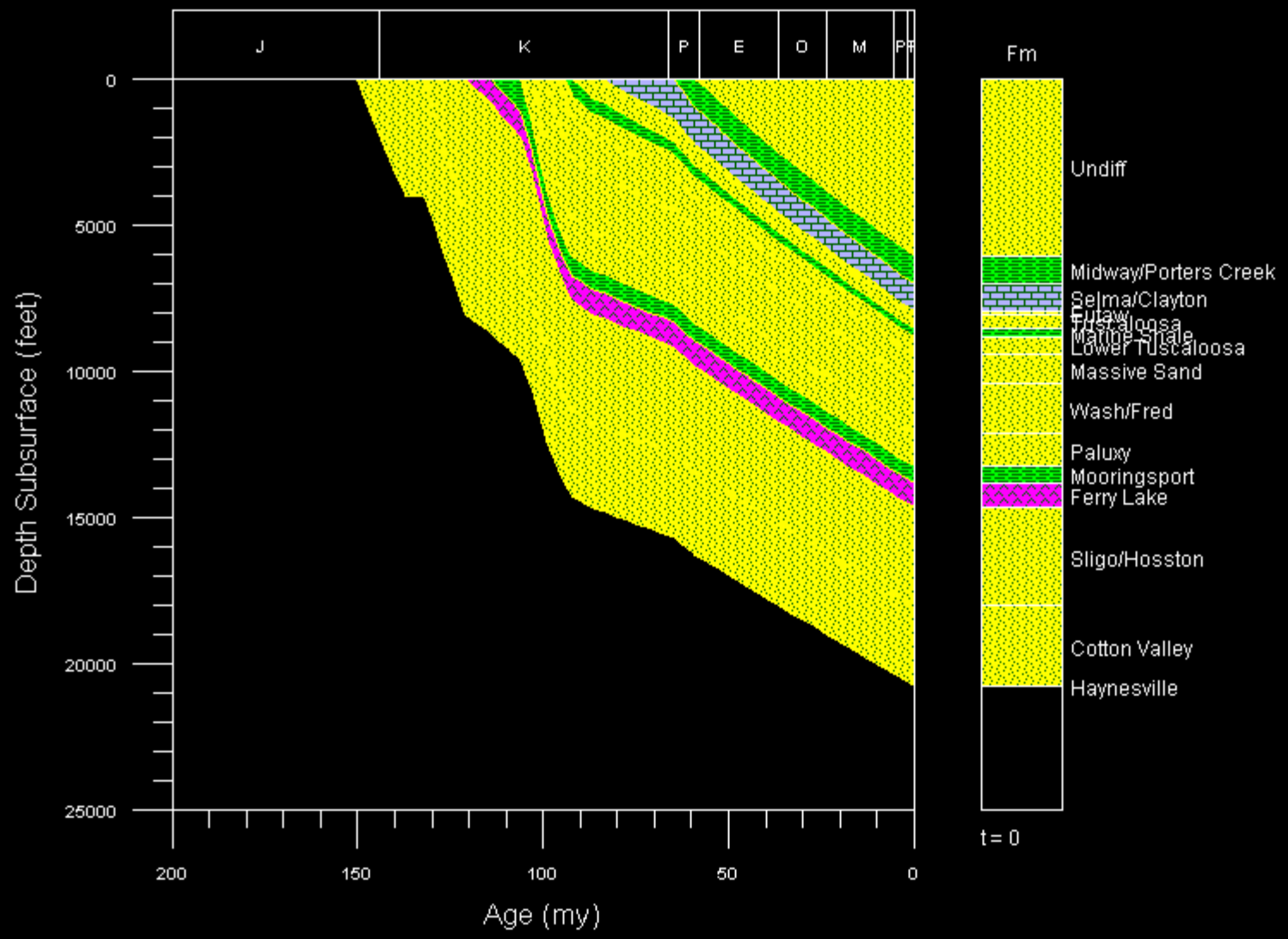

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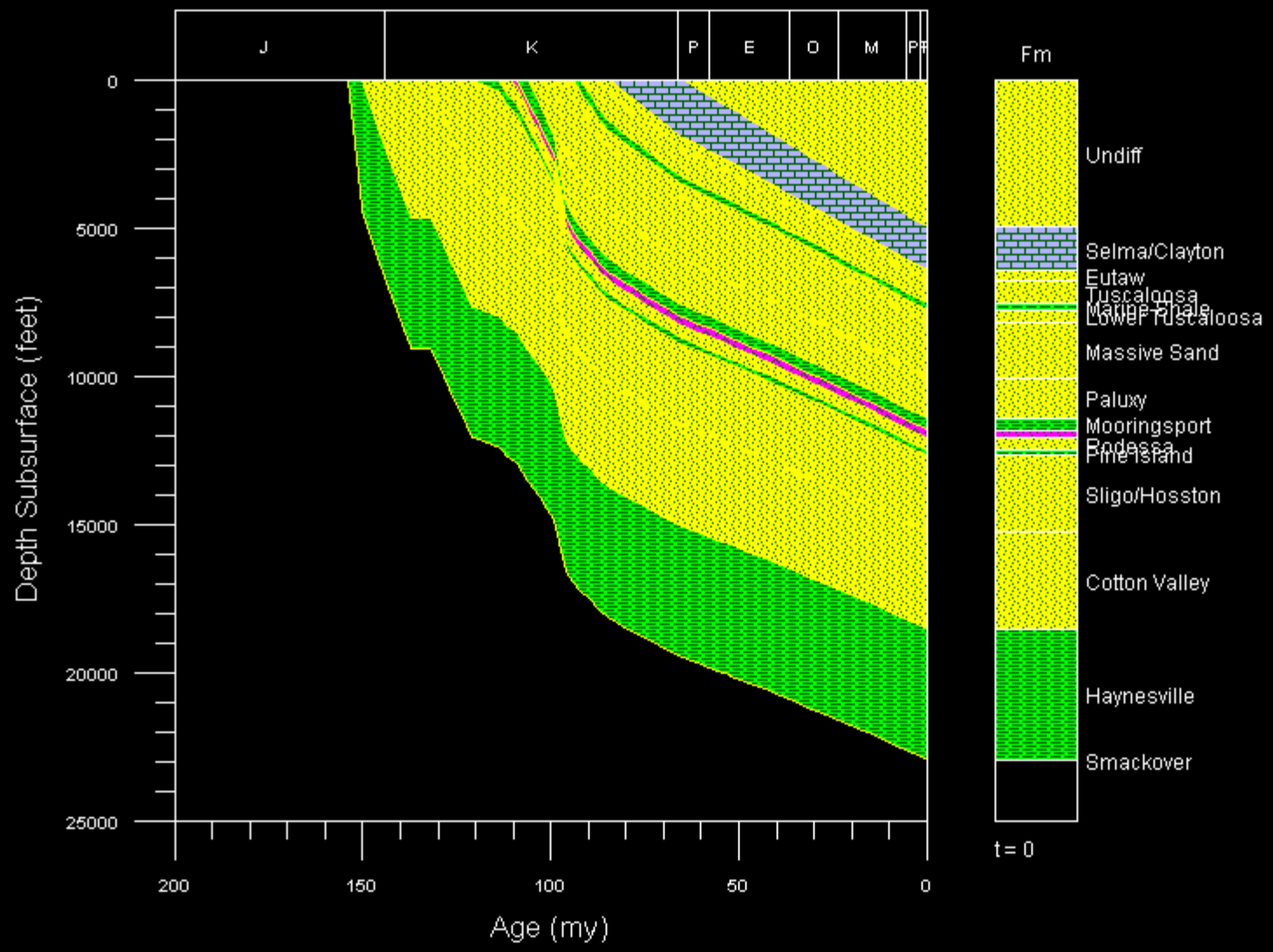

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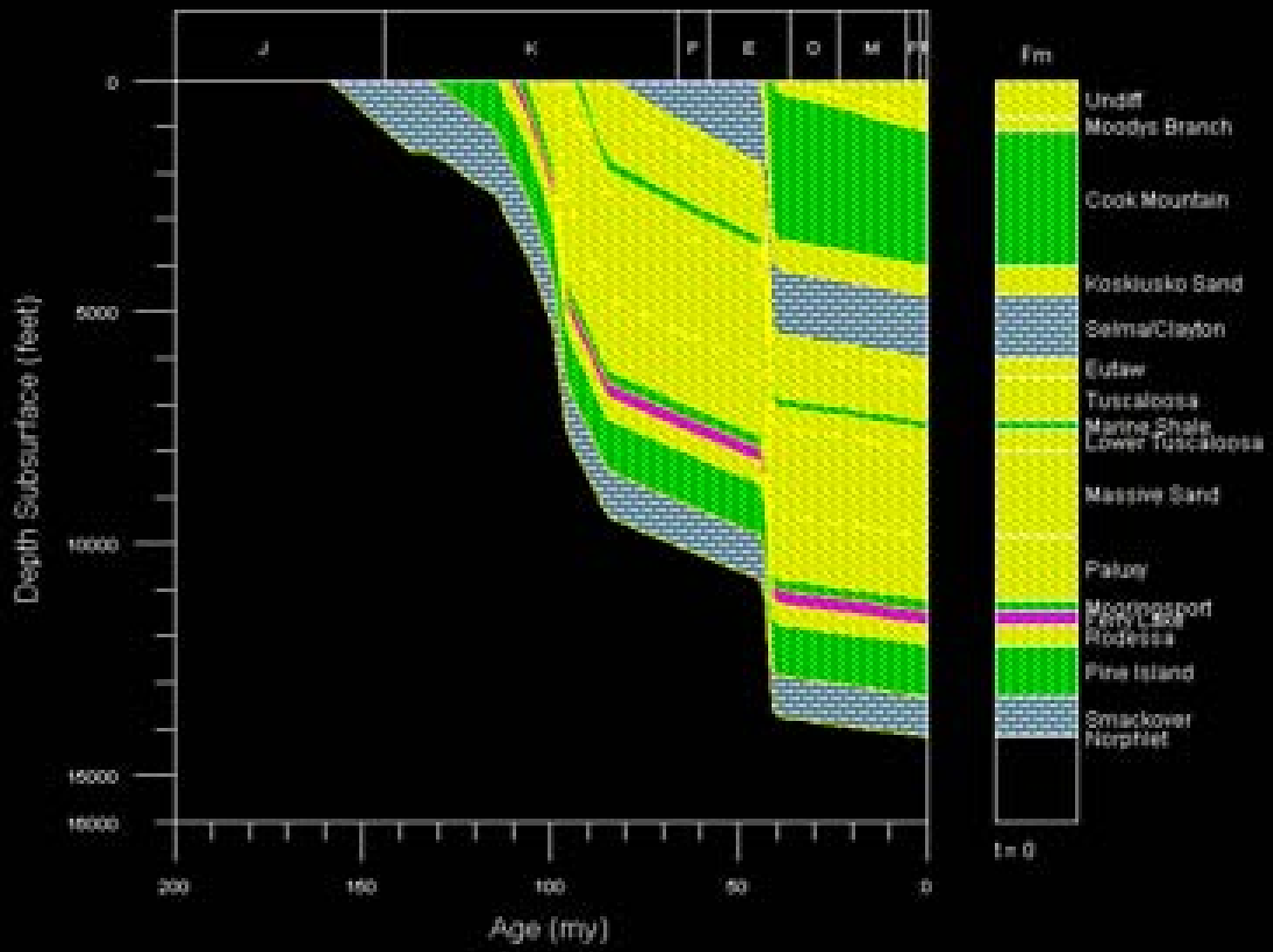

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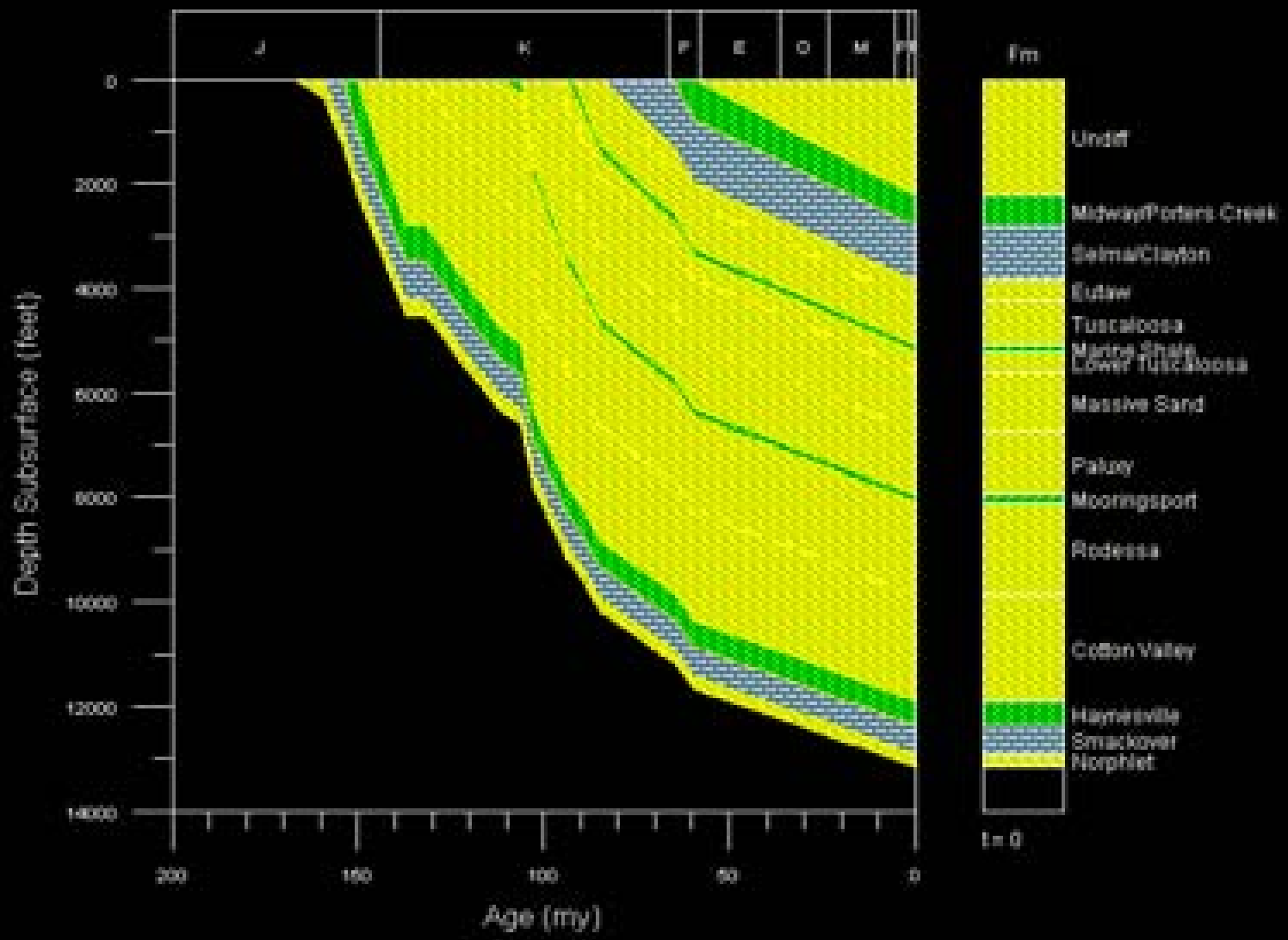

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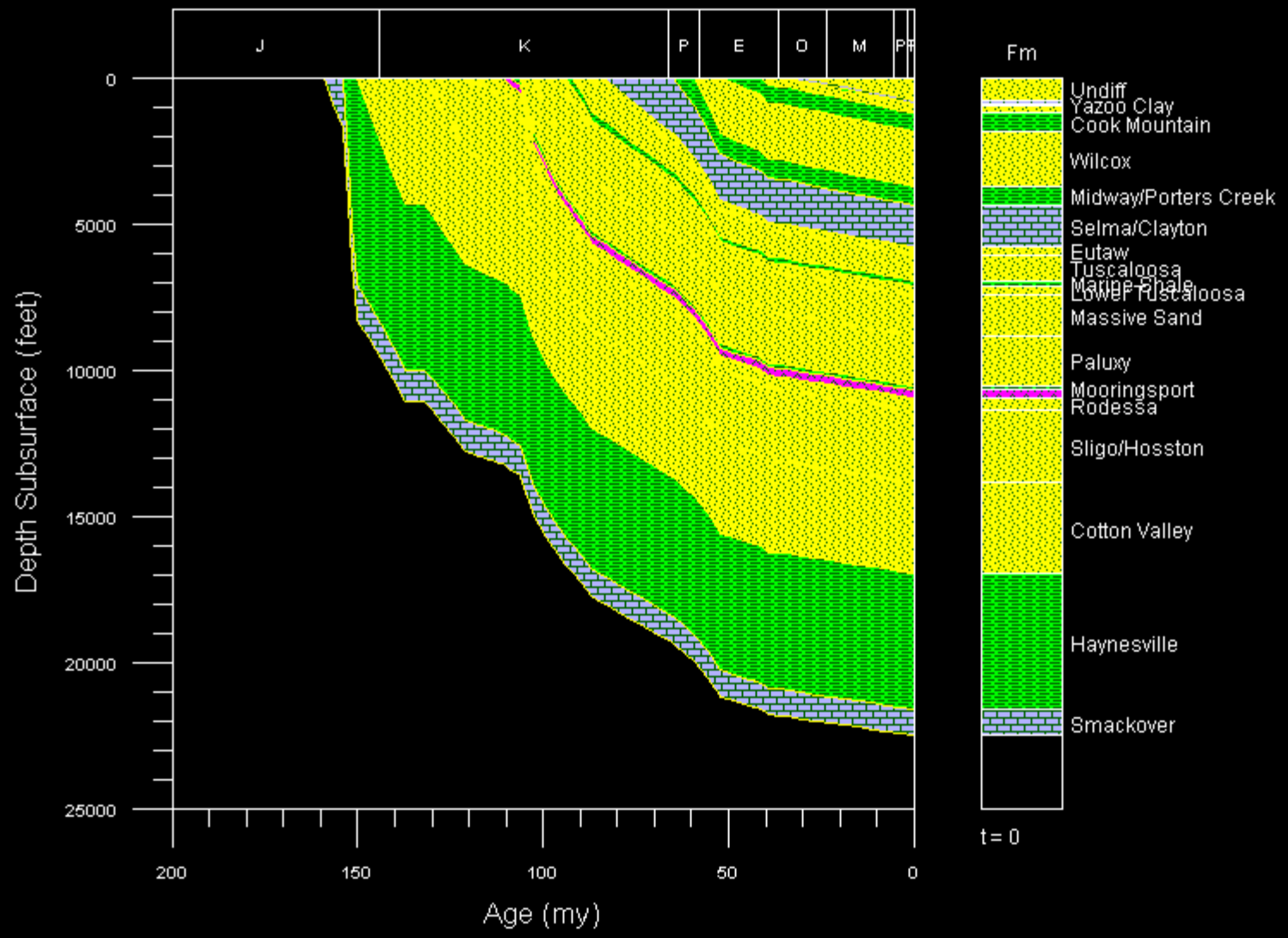

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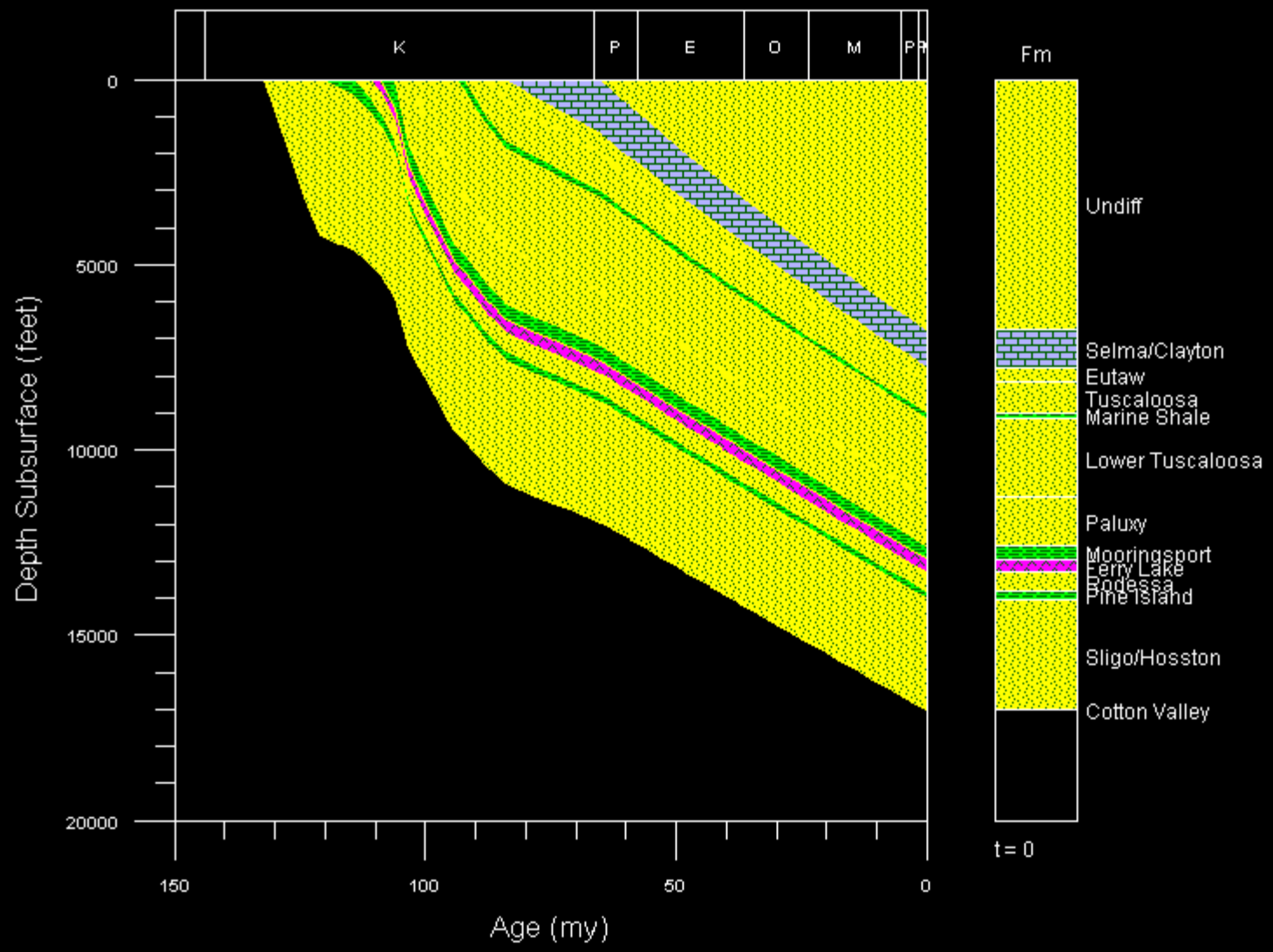

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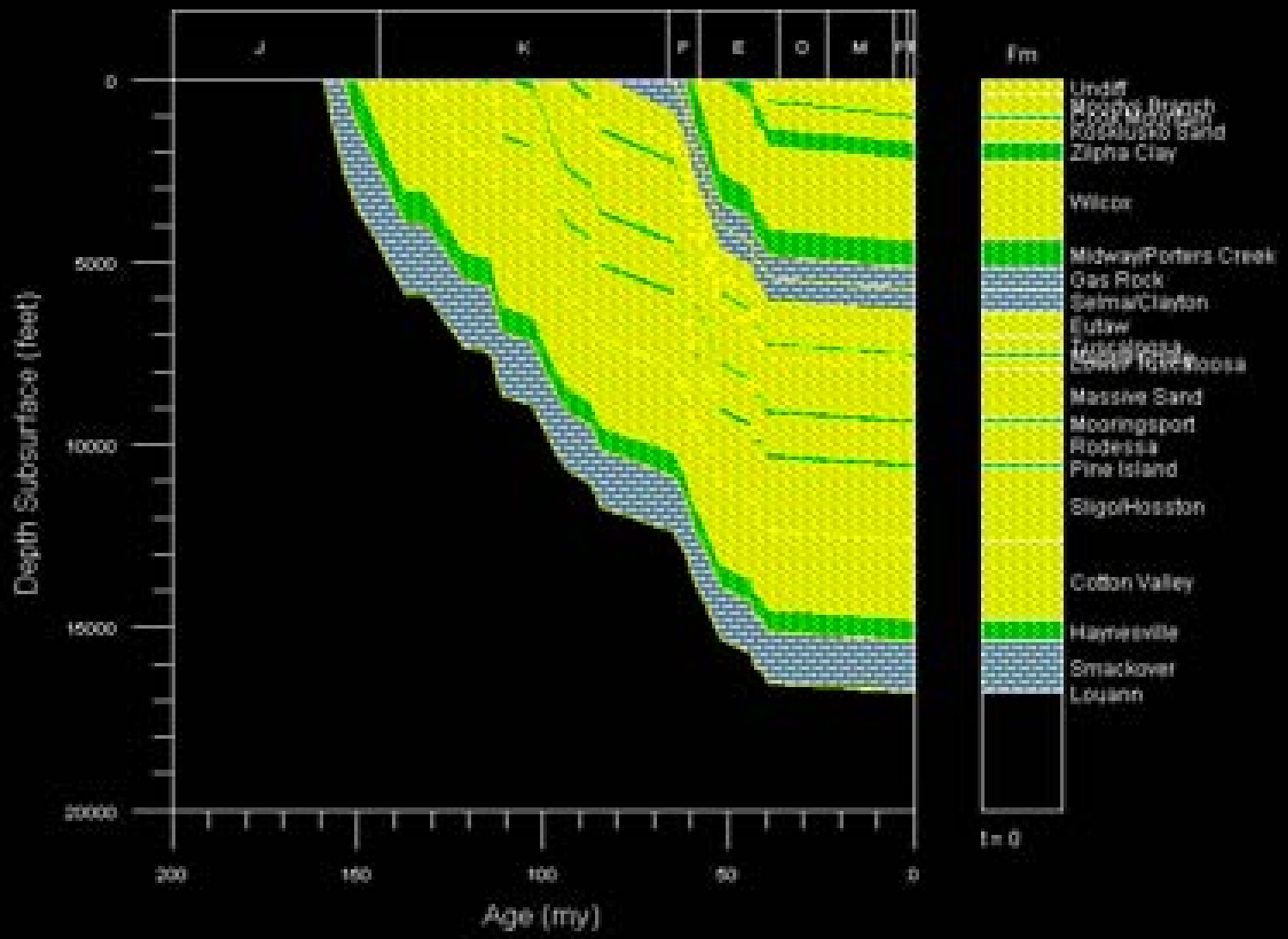

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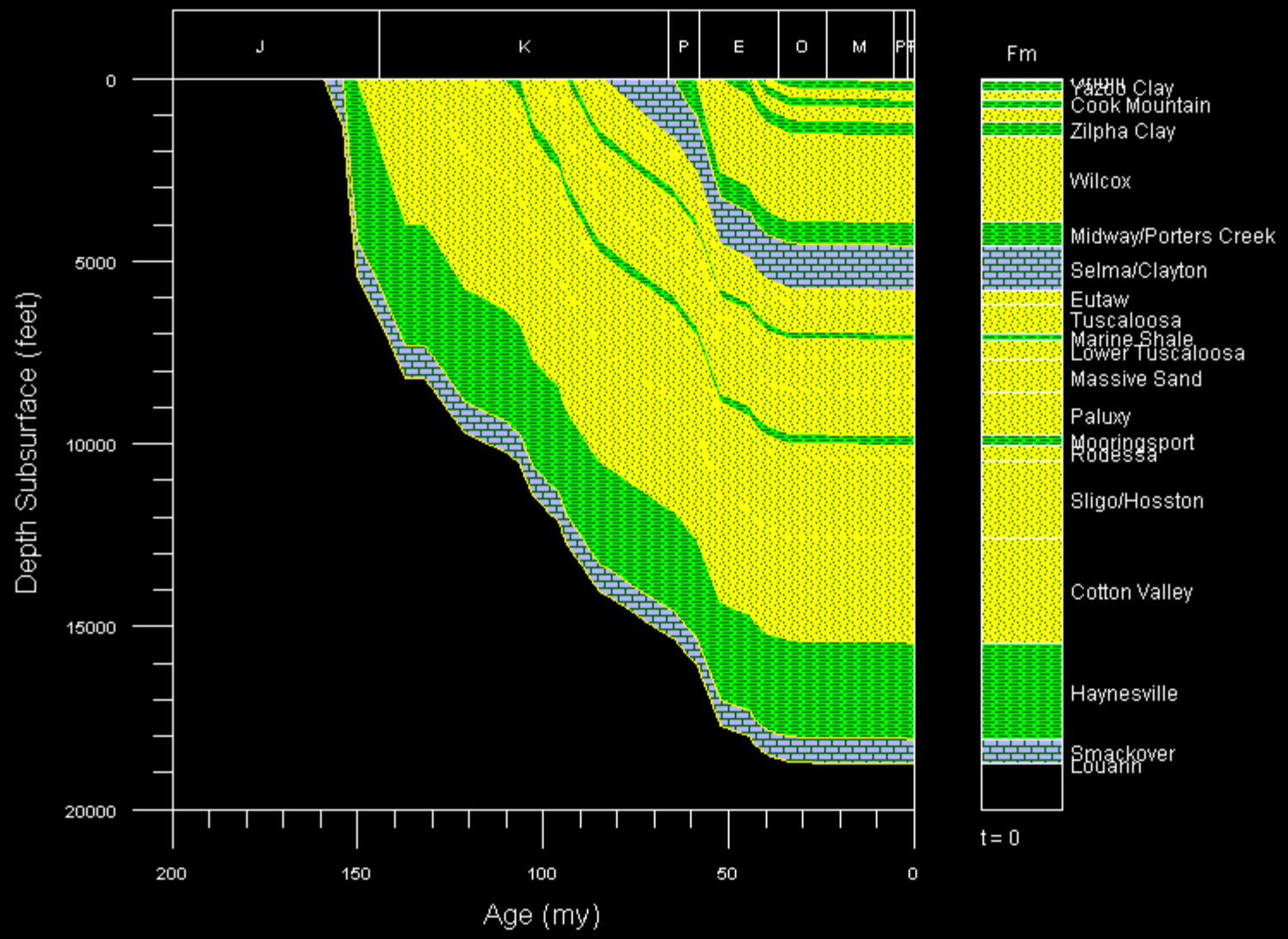

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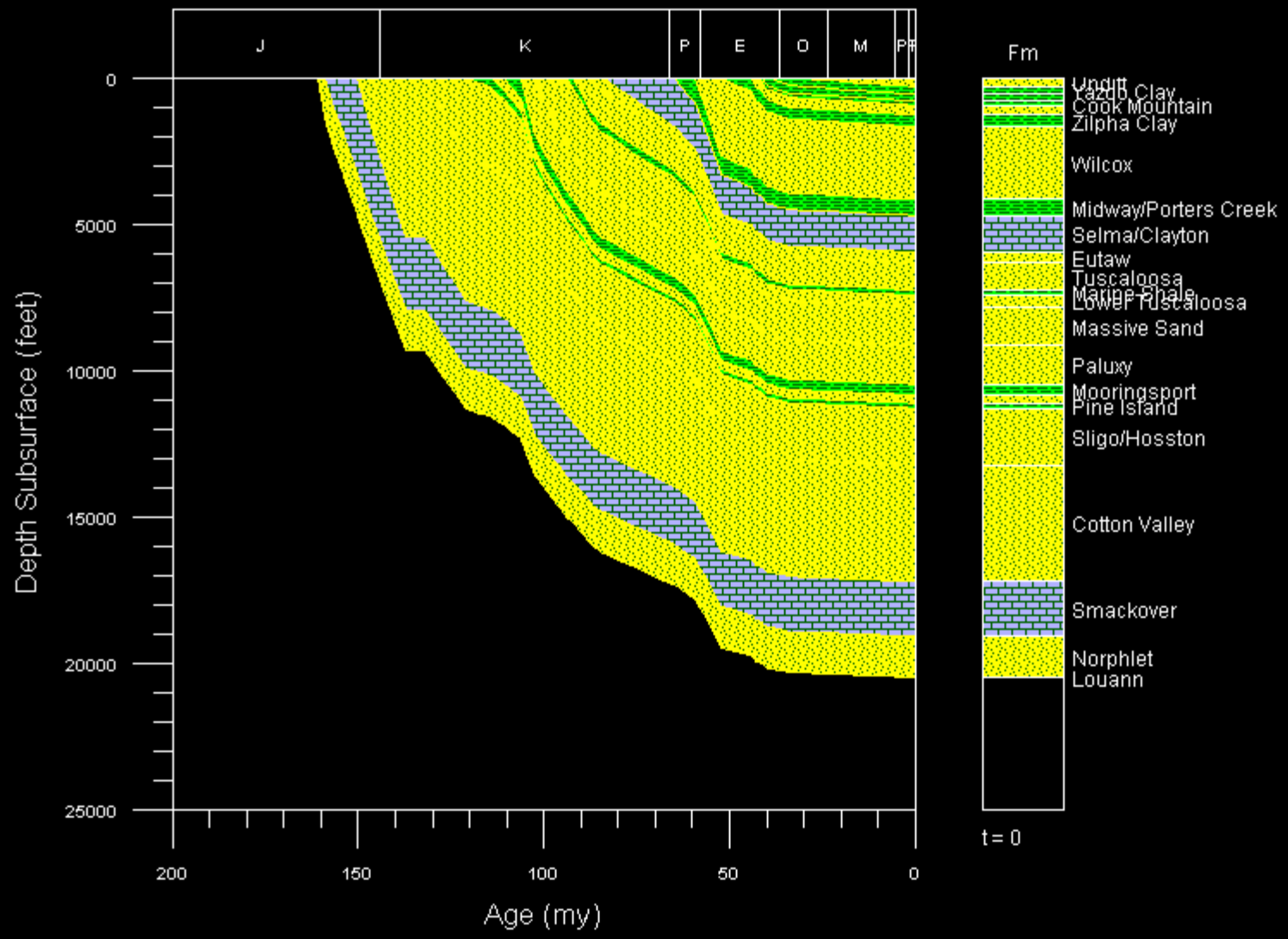

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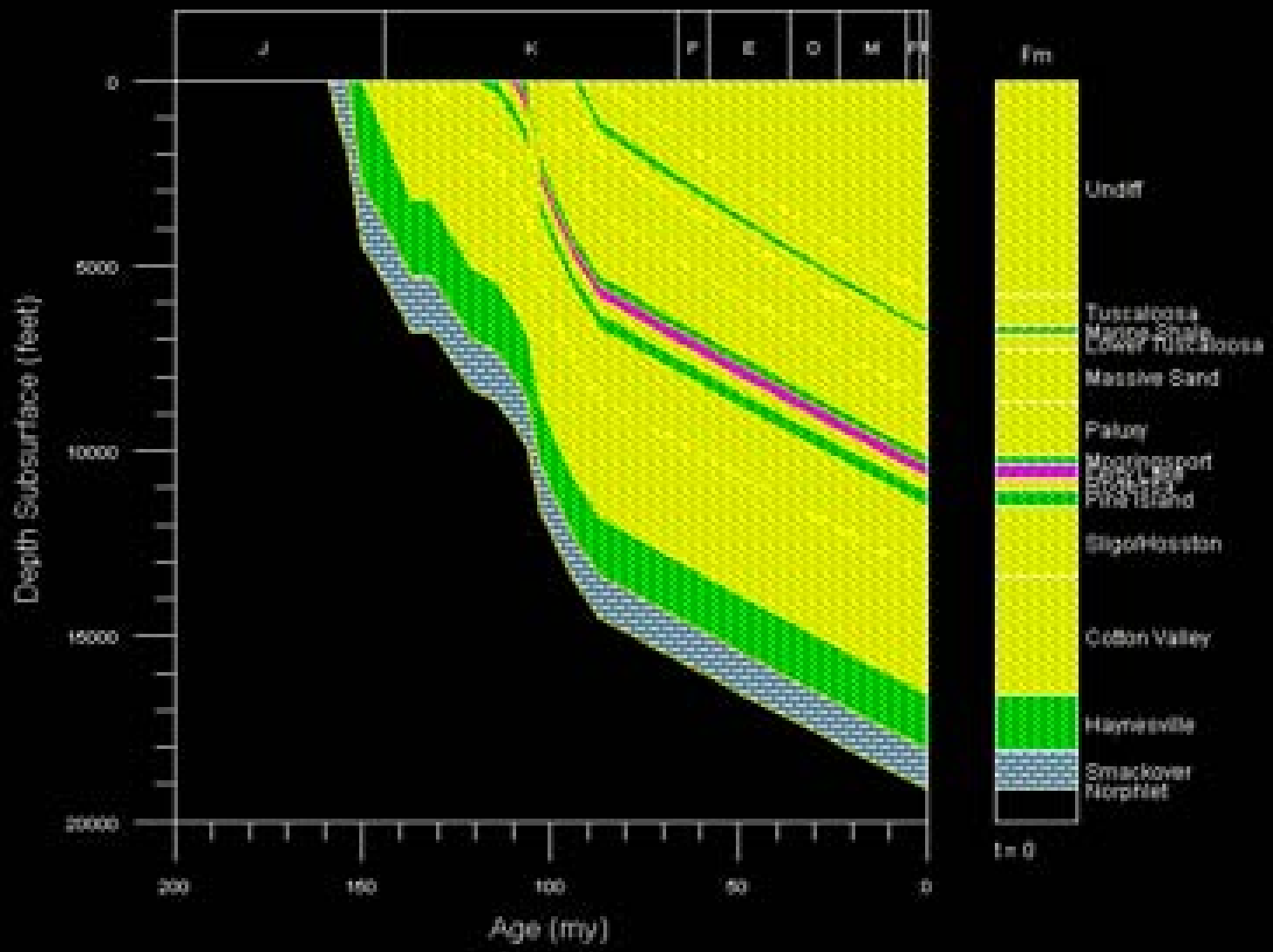

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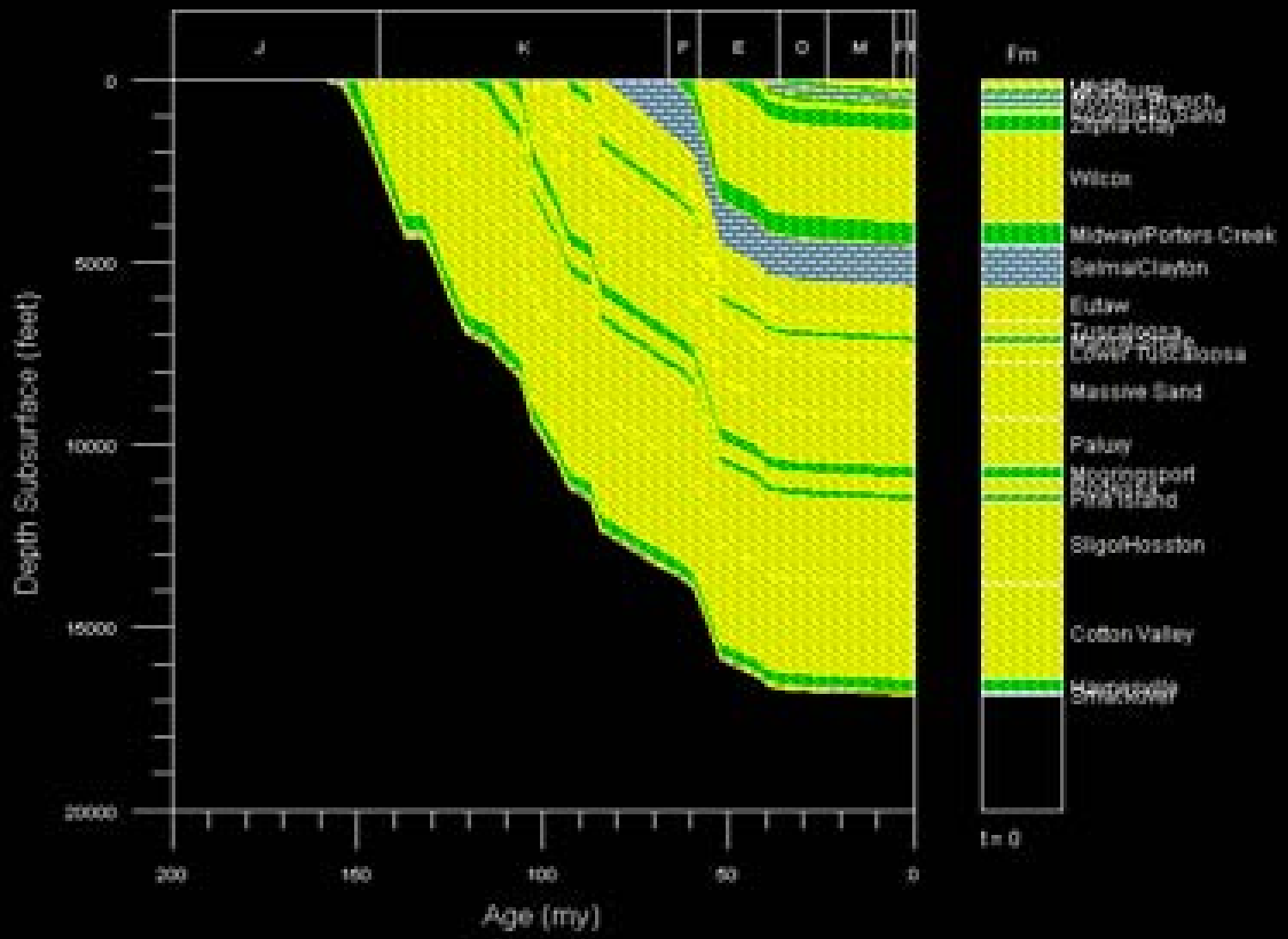

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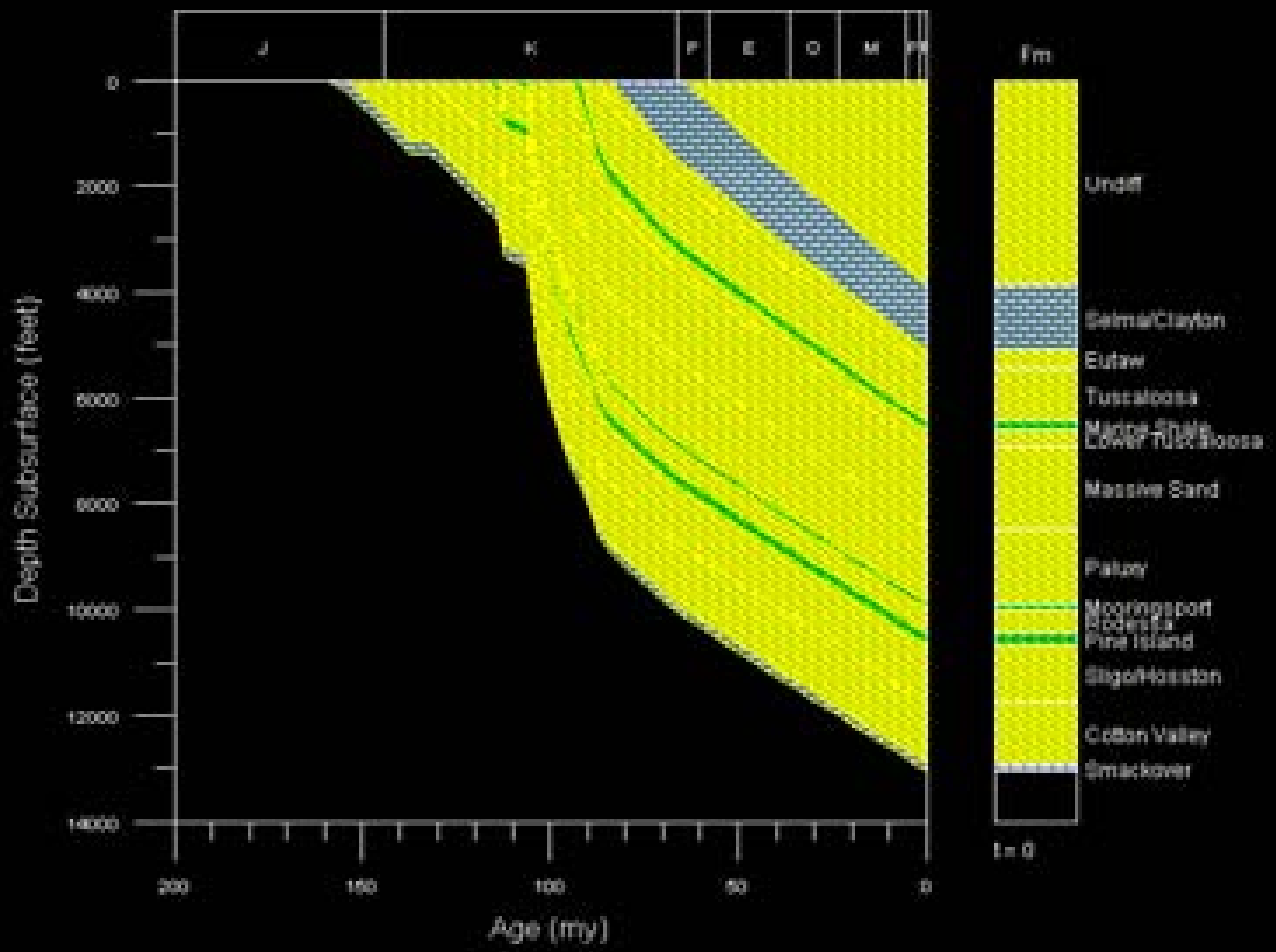

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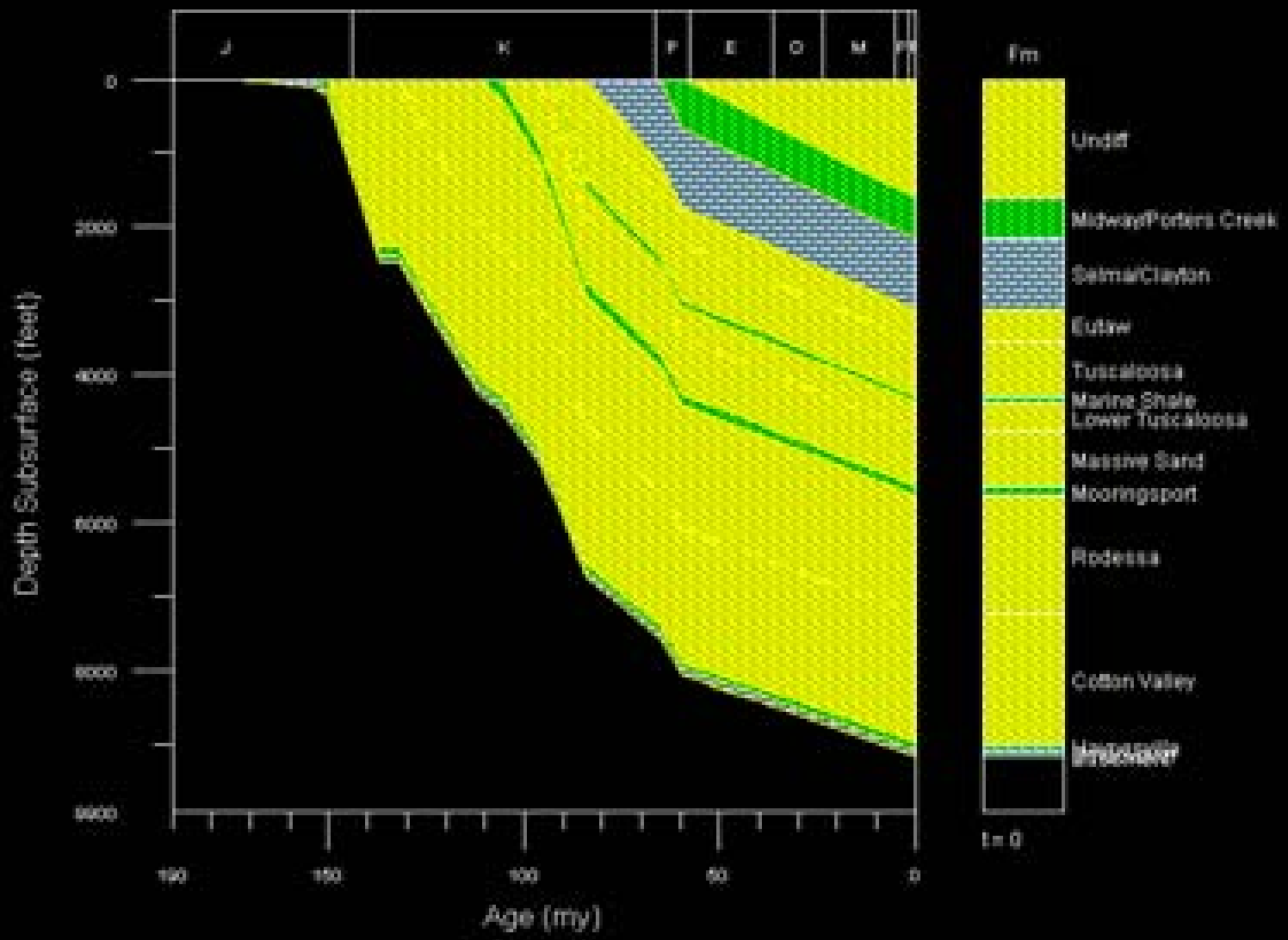

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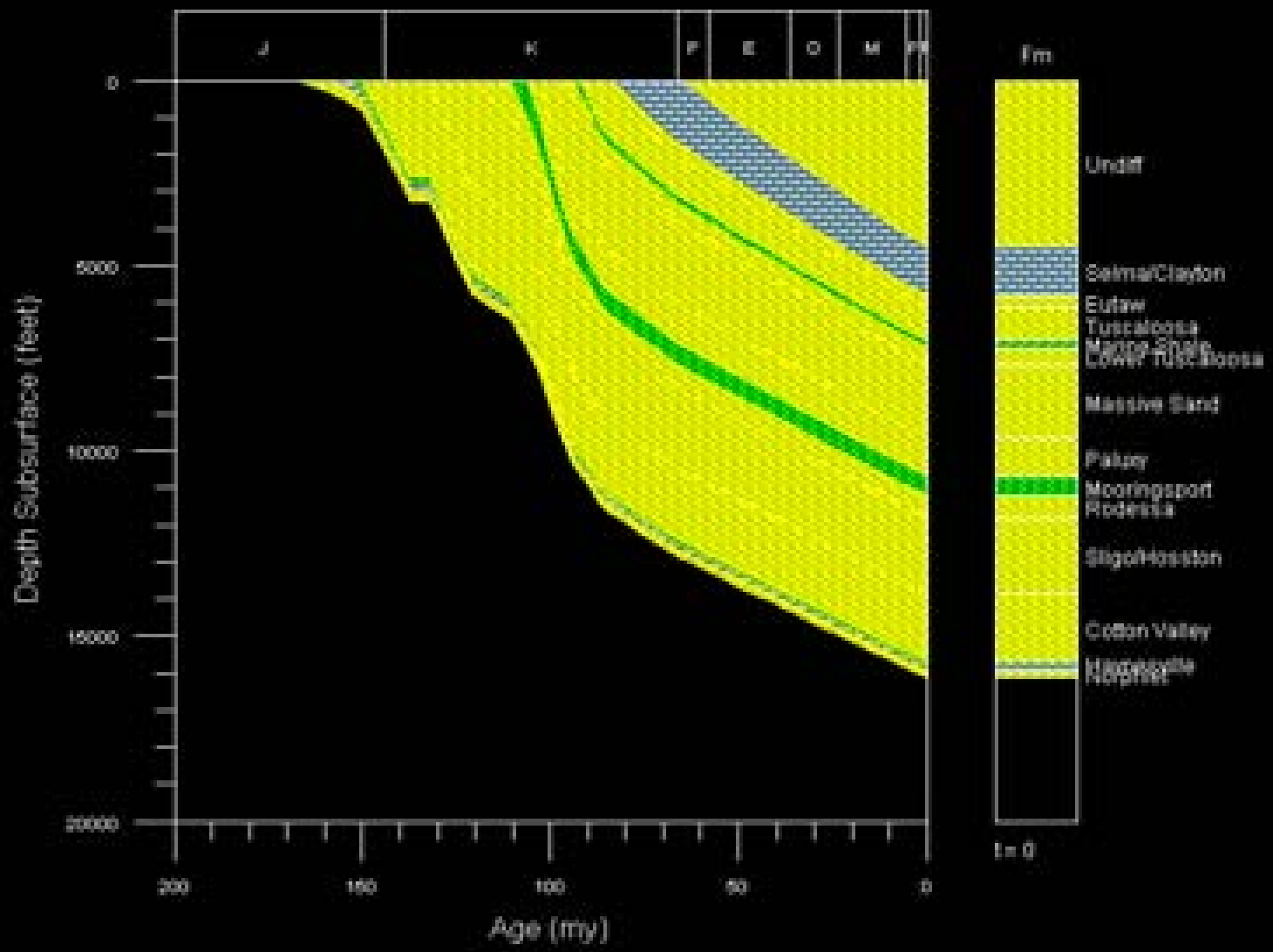


Attachment 8

"Selected Well Thermal History"

Ernest A. Mancini and William Parcell
University of Alabama

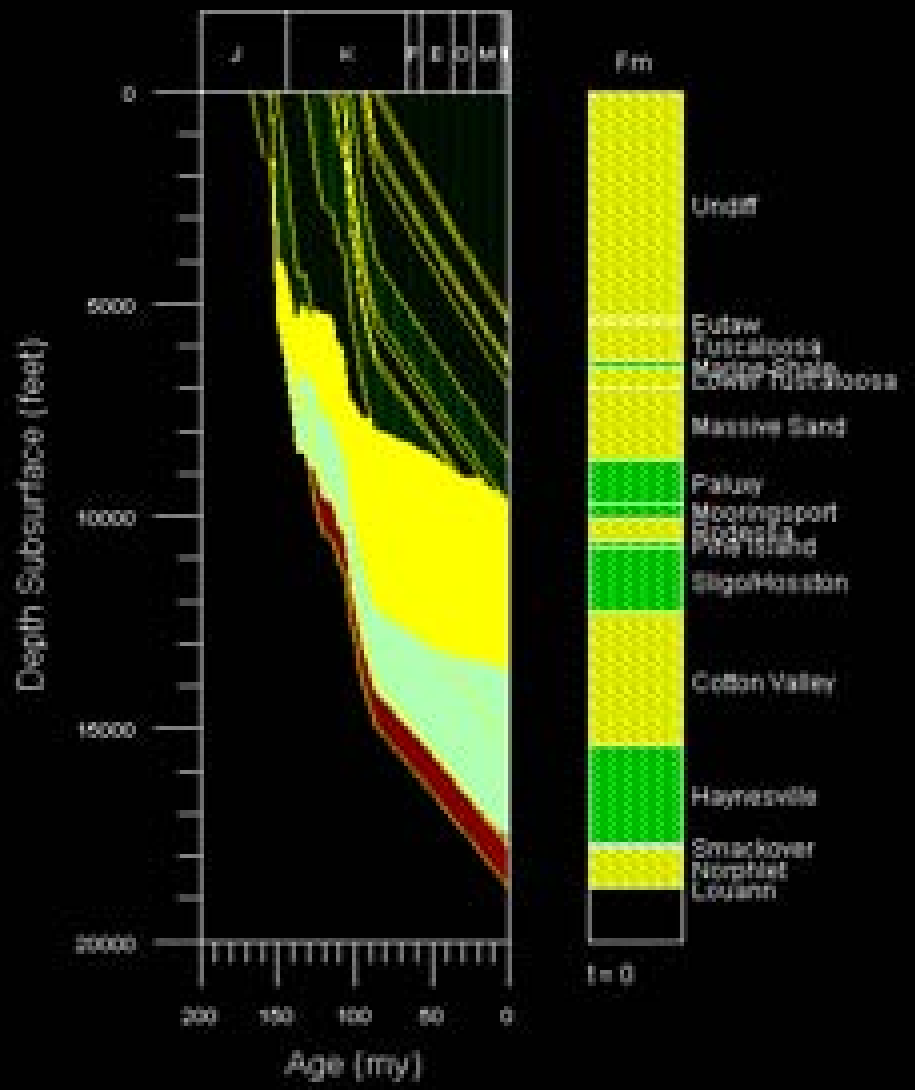
Thermal History

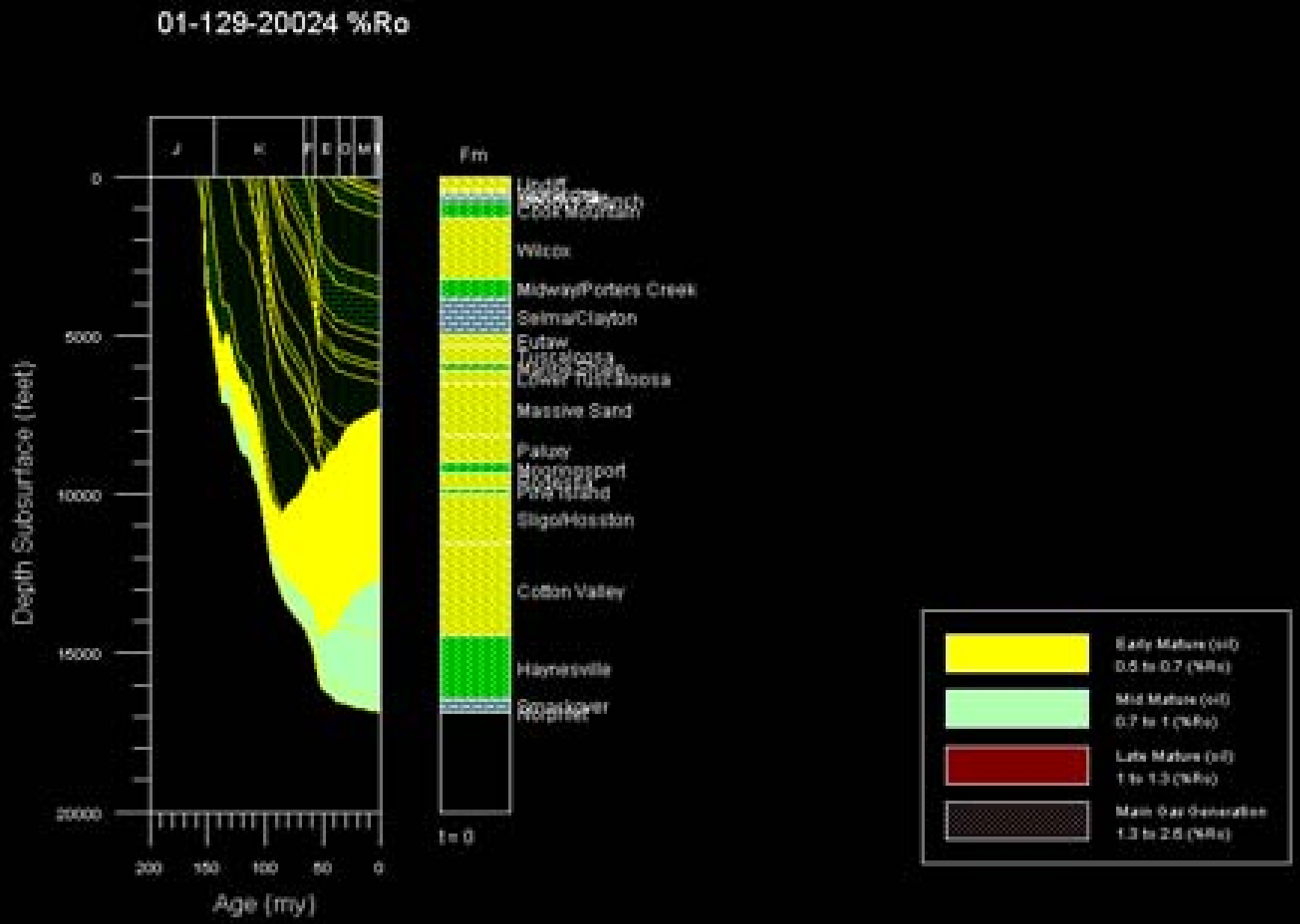
Mississippi Interior Salt Basin

The thermal history of a basin is a crucial element as to whether the basin has hydrocarbons in commercial quantities and as to whether those hydrocarbons are oil, natural gas or both. Thermal maturity modeling has become a standard in basin analysis and petroleum exploration. Maturity modeling builds on burial history modeling. Determination of present-day heat flow, paleoheat flows, and thermal conductivity's are vital criteria along with the amount and type of kerogen and the element of timing (Waples, 1994a). Thermal history work for the Mississippi Interior Salt Basin has been published by Wilson (1975), Koons et al. (1974), Smith et al. (1981), Nunn (1984), Nunn et al. (1984), Oehler (1984), Nunn and Sassen (1986), Sassen (1987, 1989), Sassen et al. (1987), Sassen and Moore (1988), Meendsen et al. (1987), Sofer (1988), Vaughn and Benson (1988), Driskill et al. (1988), Claypool and Mancini (1989), and Mancini et al. (1993), but no comprehensive analysis has been published to date.

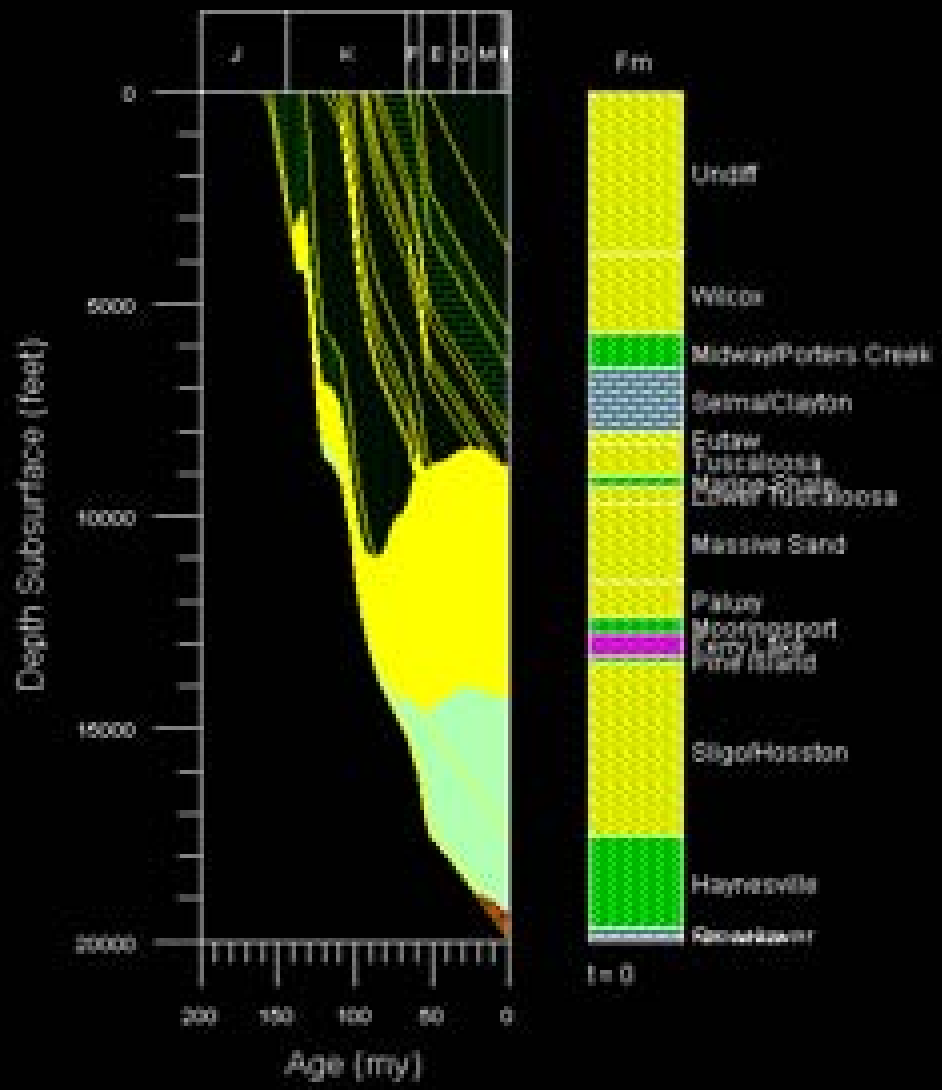
In this study, the tectonic, depositional and burial histories of the Mississippi Interior Salt Basin form the foundation for interpreting the thermal history of the basin. Five regional cross-sections consisting of 48 key wells comprise the basis for the interpretation. The thermal history for each well and cross-sections was determined. Basinmod software was utilized. Information utilized includes bottom hole temperature, present-day geothermal gradient, present-day heat flow, vitrinite reflectance, thermal alteration, Tmax, paleogeothermal gradient, paleoheat flow, thermal conductivity, total organic carbon, and kerogen type.

01-129-20012 %Ro

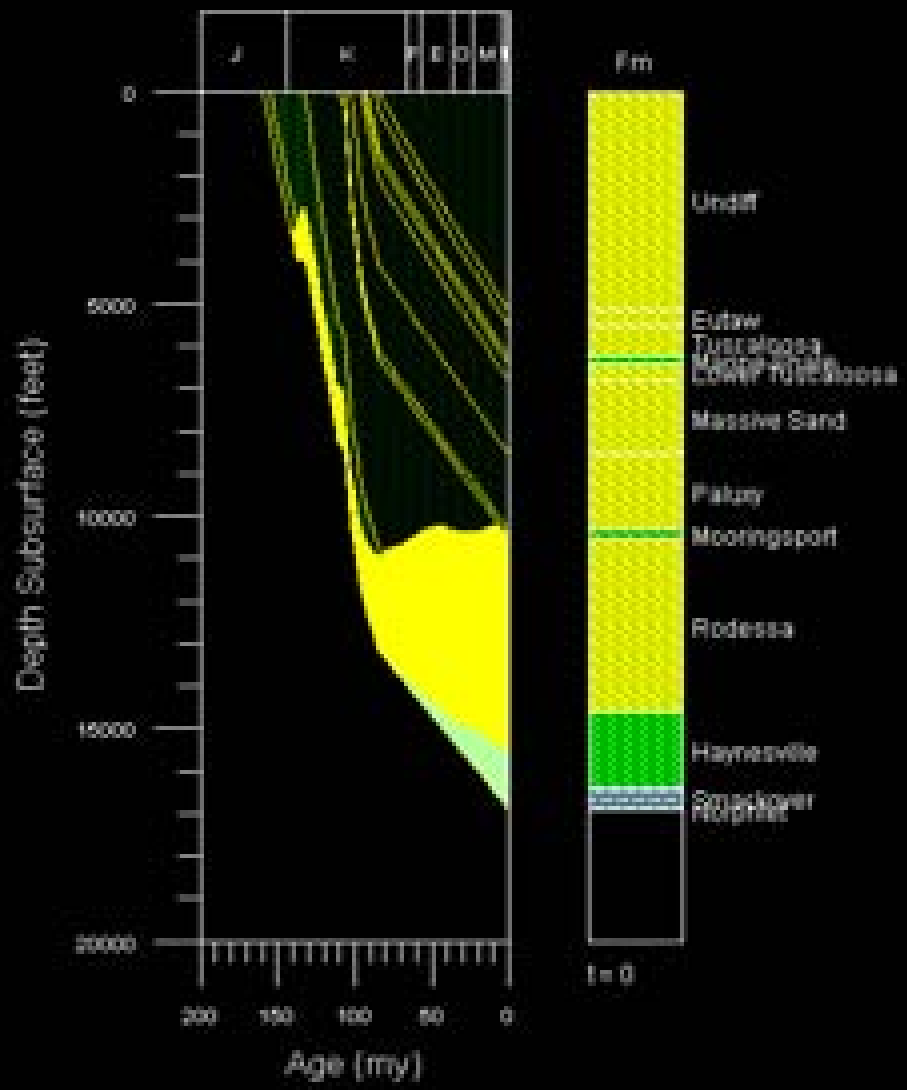



01-129-20024 %Ro
J
K
P
E
O
M
Fm
Coal Mountain
Wilcox
Midway/Porters Creek
Selma/Clayton
Eutaw
Tuscaloosa
Lower Tuscaloosa
Massive Sand
Paluxy
Mooringsport
Pine Island
Sligo/Hosston
Cotton Valley
Haynesville
Smackover
Norphlet
t = 0
Depth Subsurface (feet)
0
5000
10000
15000
20000
200
150
100
50
0
Age (my)
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)

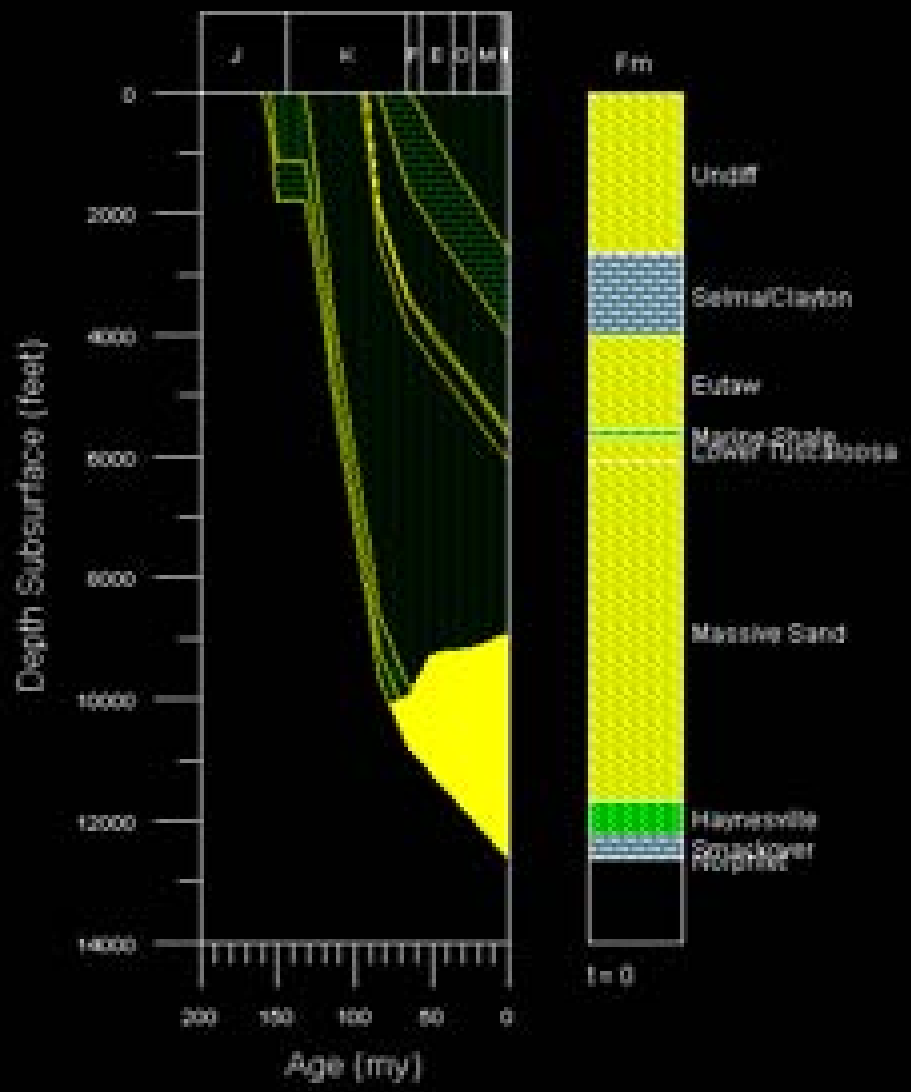
01-129-20051 %Ro



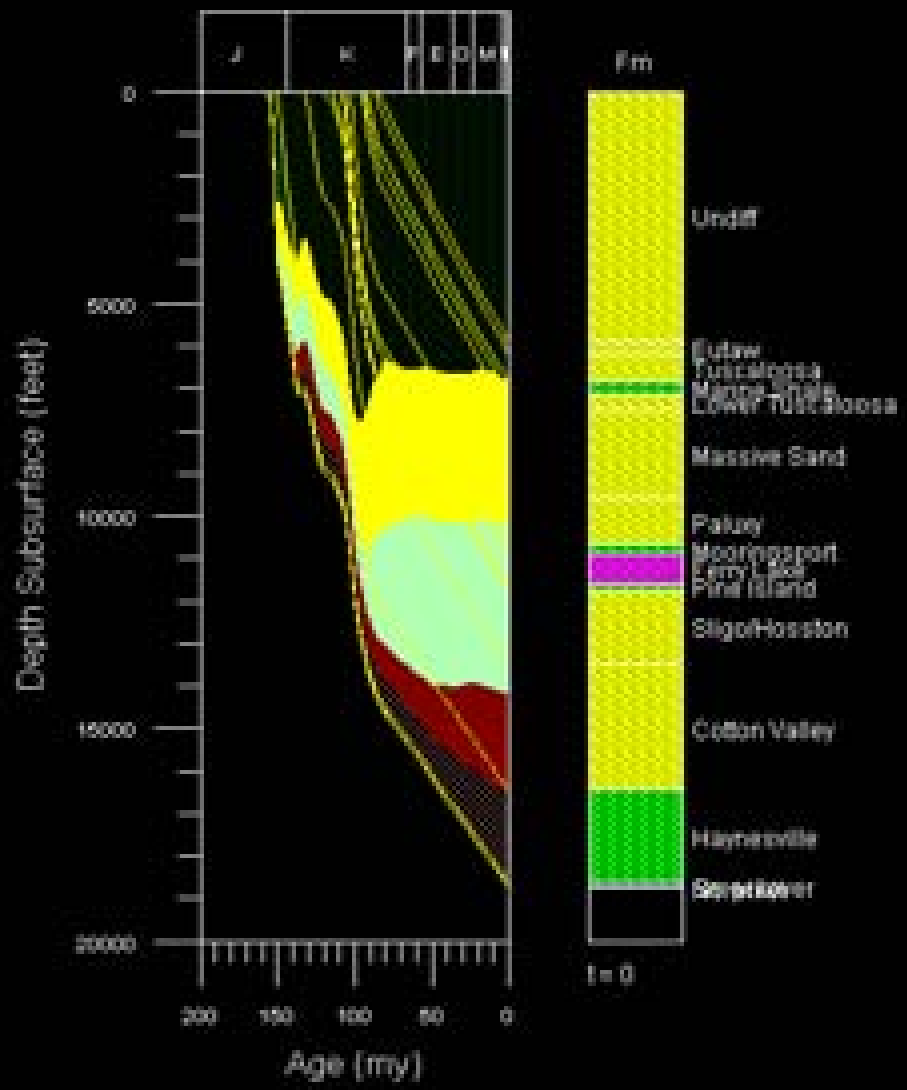
01-129-20054 %Ro



01-023-20114 BUR HIST



01-097-20134 BUR HIST



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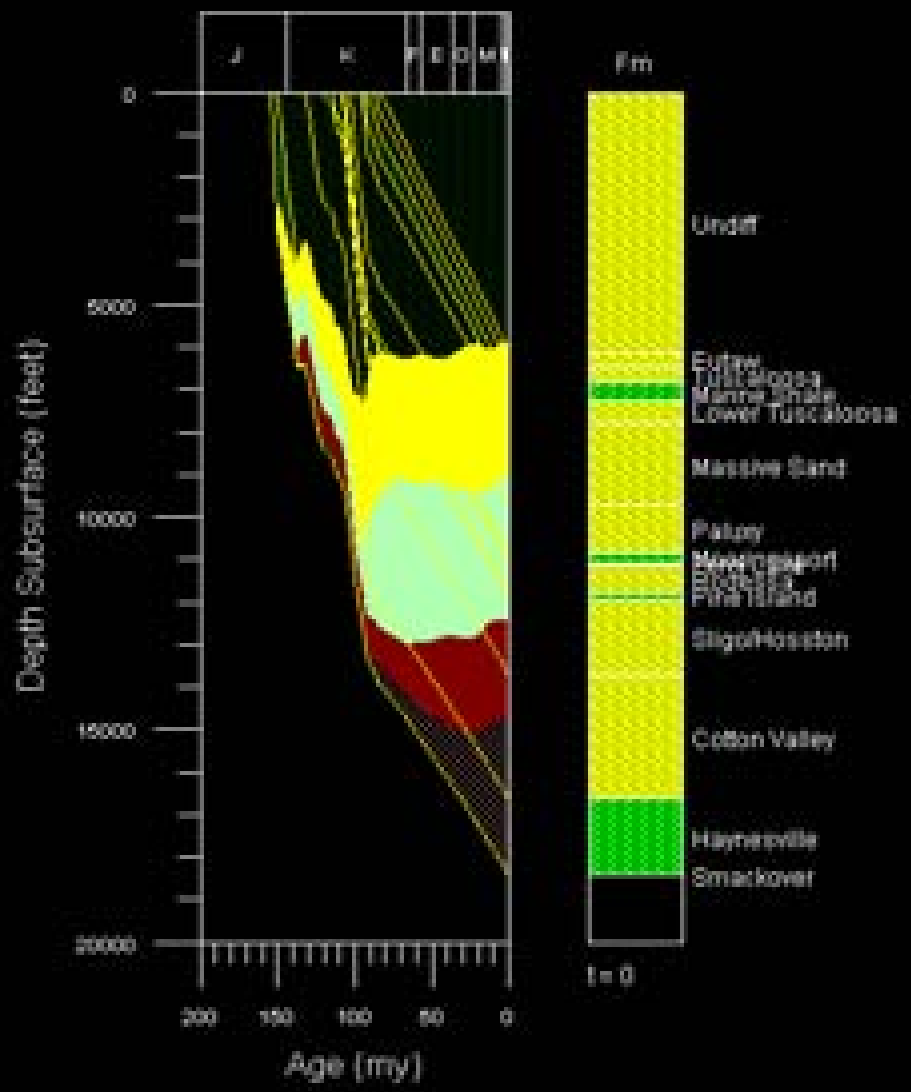
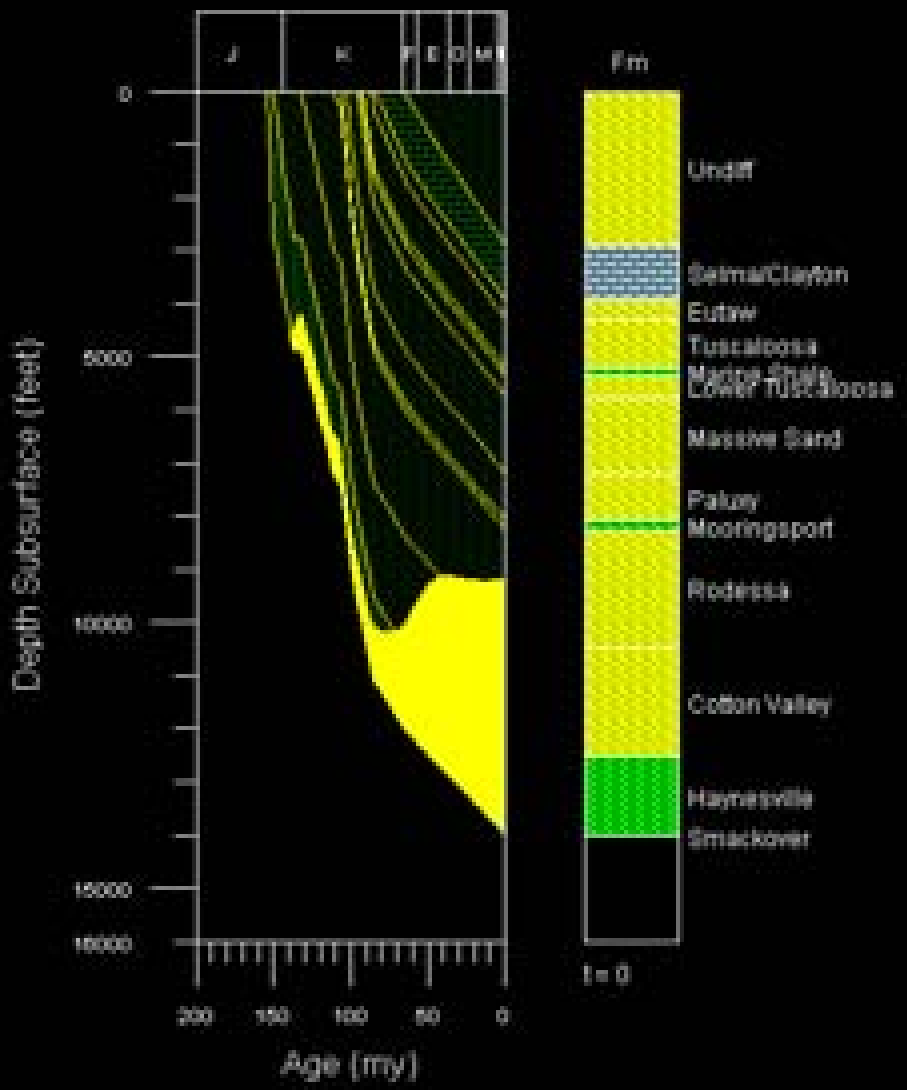
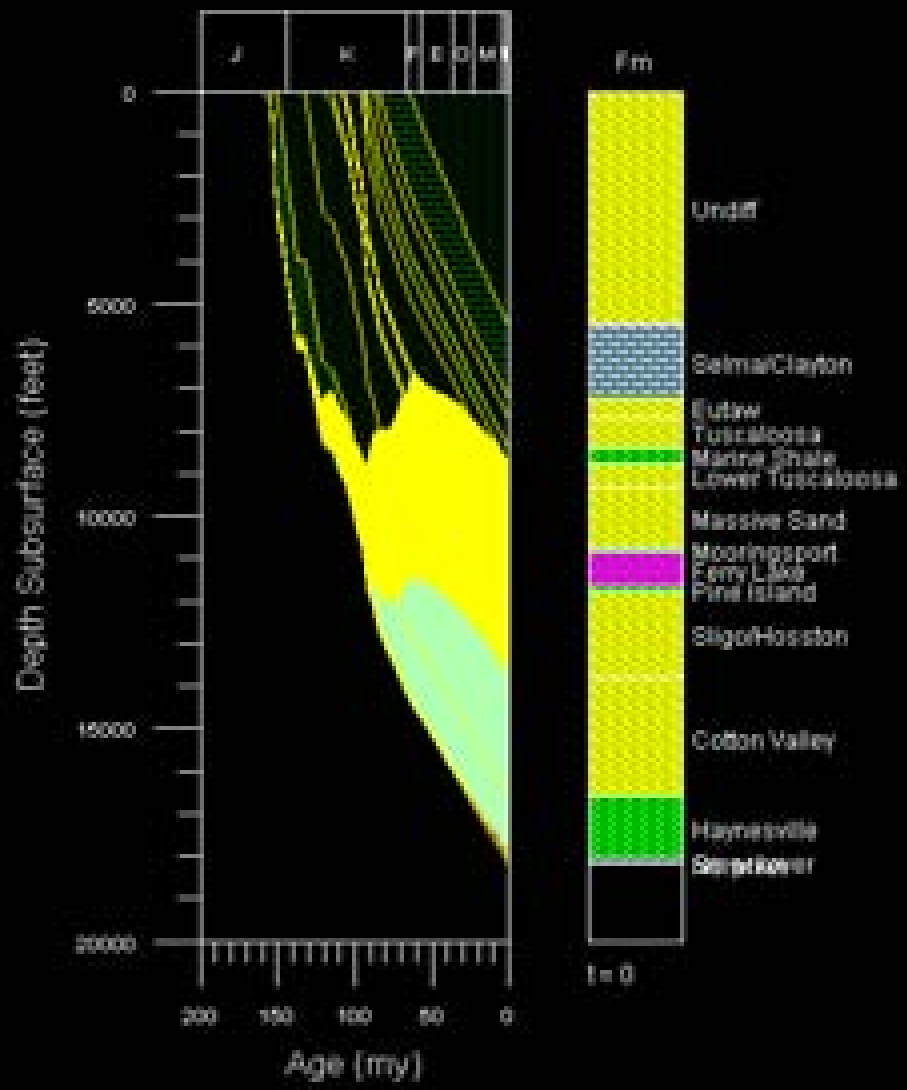
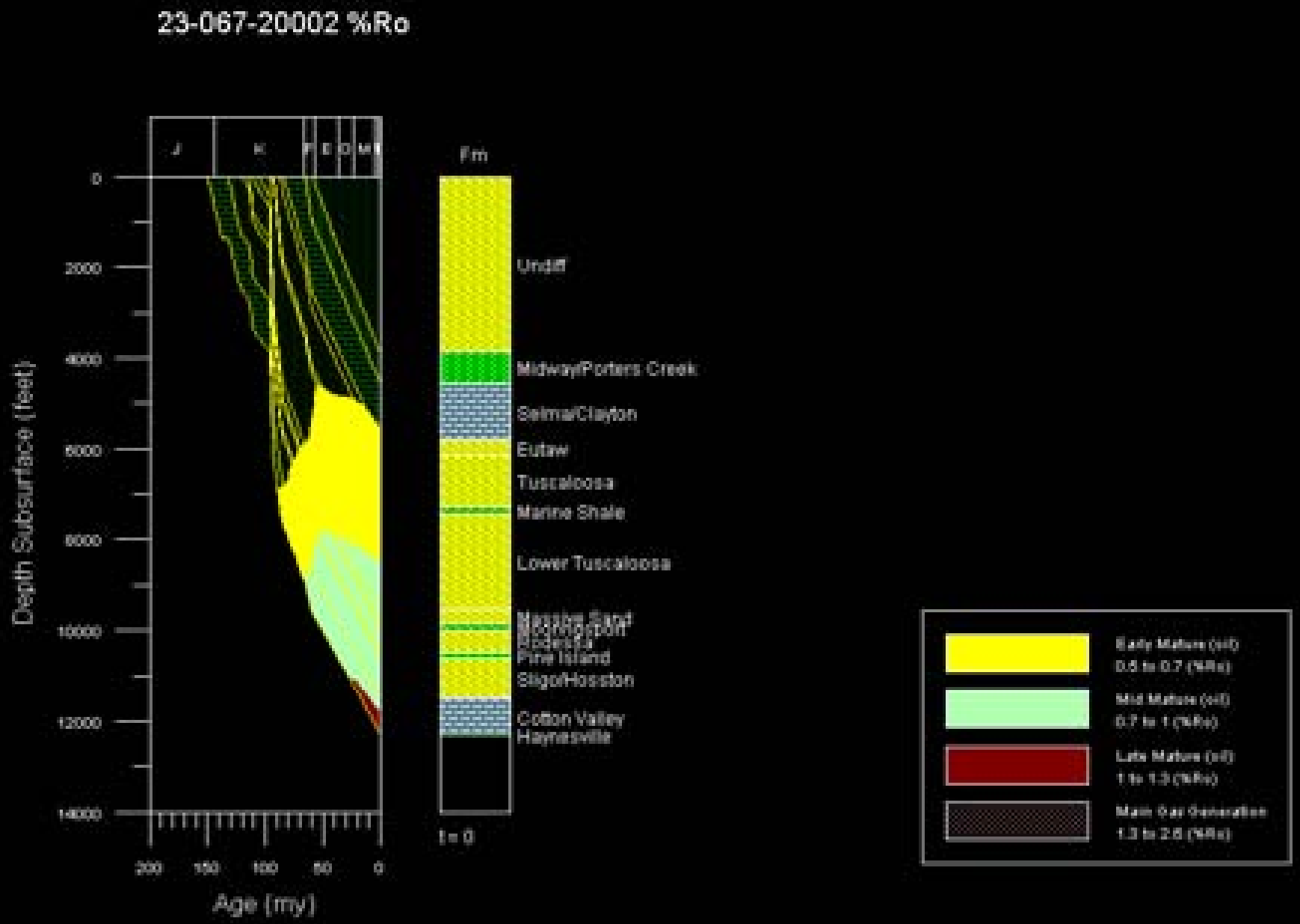


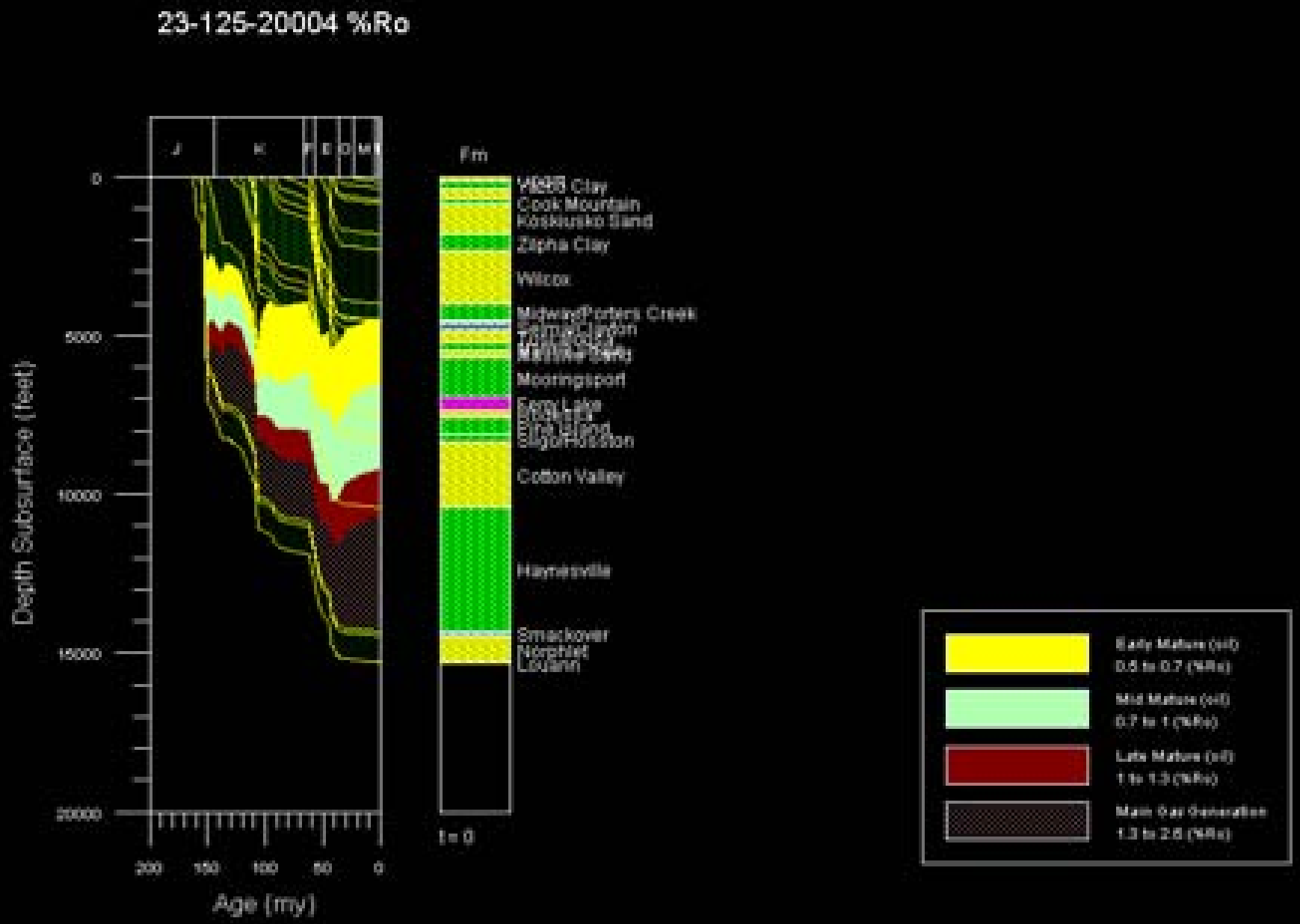
01-023-20197 %Ro



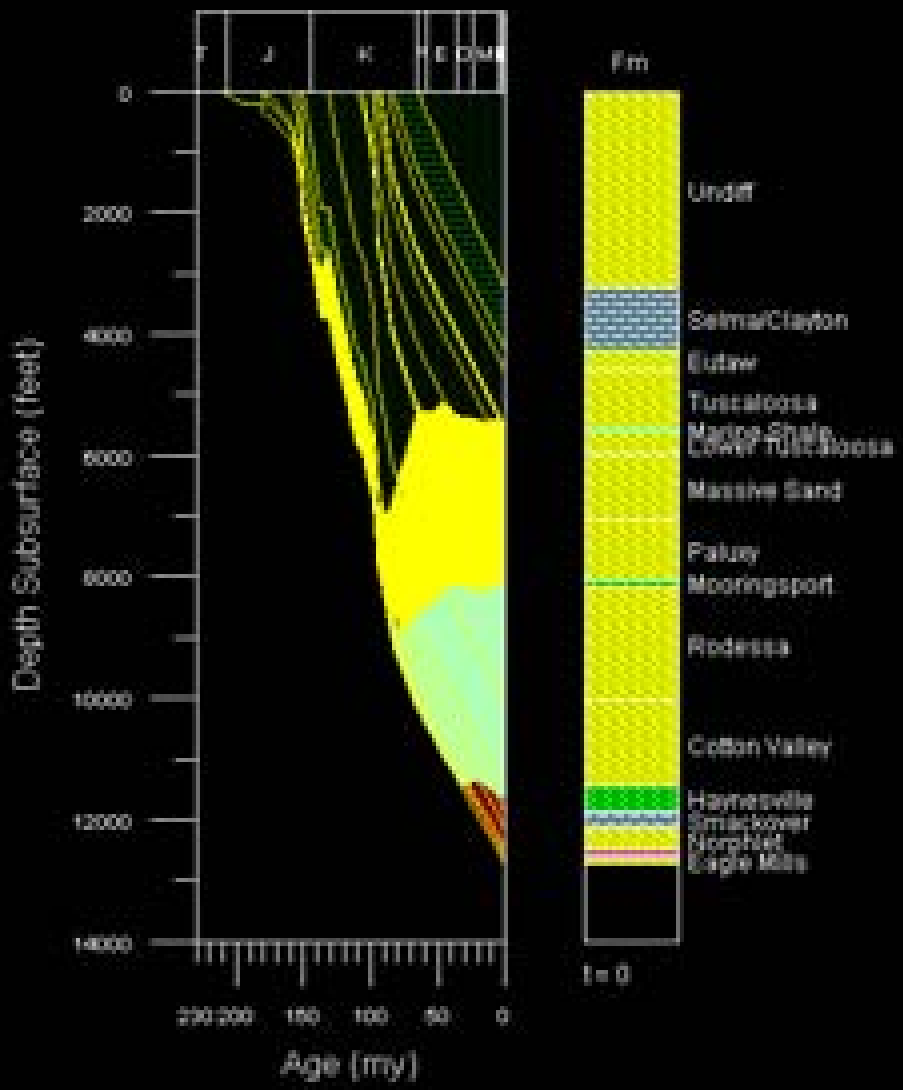
01-097-20299 %Ro

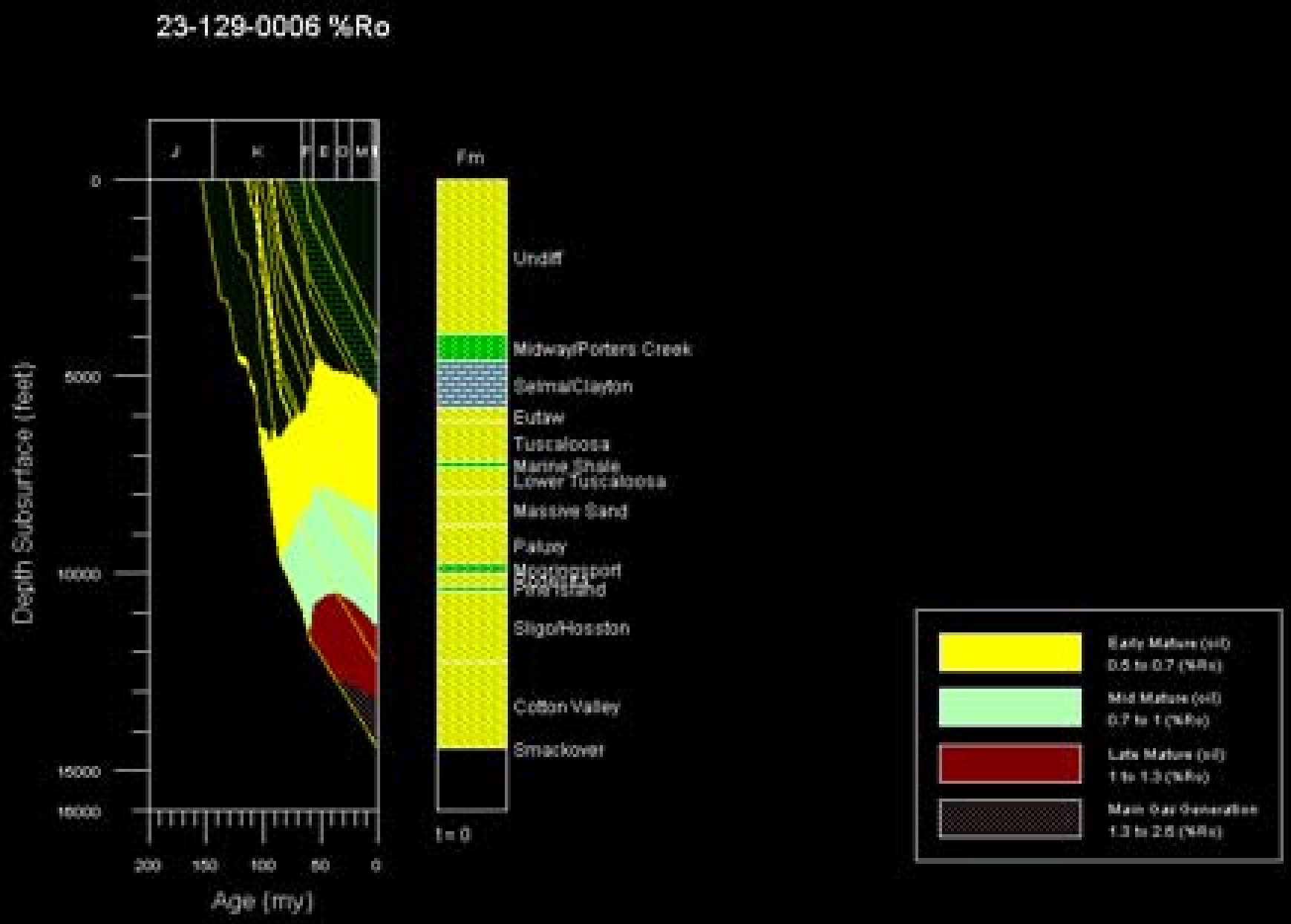



23-067-20002 %Ro
J
K
P
E
O
M
Fm
Undiff
Midway/Porters Creek
Selma/Clayton
Eutaw
Tuscaloosa
Marine Shale
Lower Tuscaloosa
Massive Sand
Pine Island
Sligo/Hosston
Cotton Valley
Haynesville
t = 0
Depth Subsurface (feet)
0
2000
4000
6000
8000
10000
12000
14000
200
150
100
50
0
Age (my)
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)

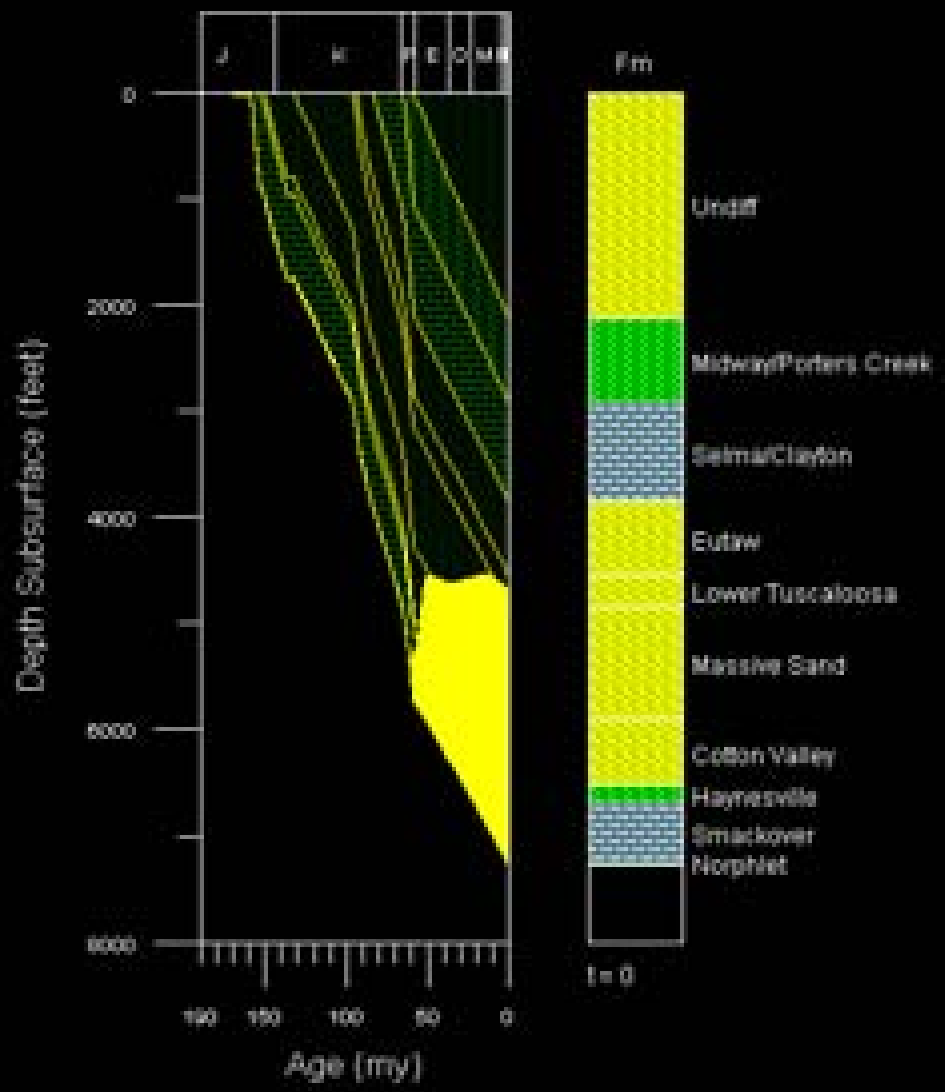

23-125-20004 %Ro
J
K
P
E
O
M
Fm
Clay
Cook Mountain
Kosciusko Sand
Zilpha Clay
Wilcox
Midway/Porters Creek
Mooringsport
Cotton Valley
Haynesville
Smackover
Norphlet
Louann
t = 0
0
5000
10000
15000
20000
Depth Subsurface (feet)
200
150
100
50
0
Age (my)
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)

23-101-20005 %Ro

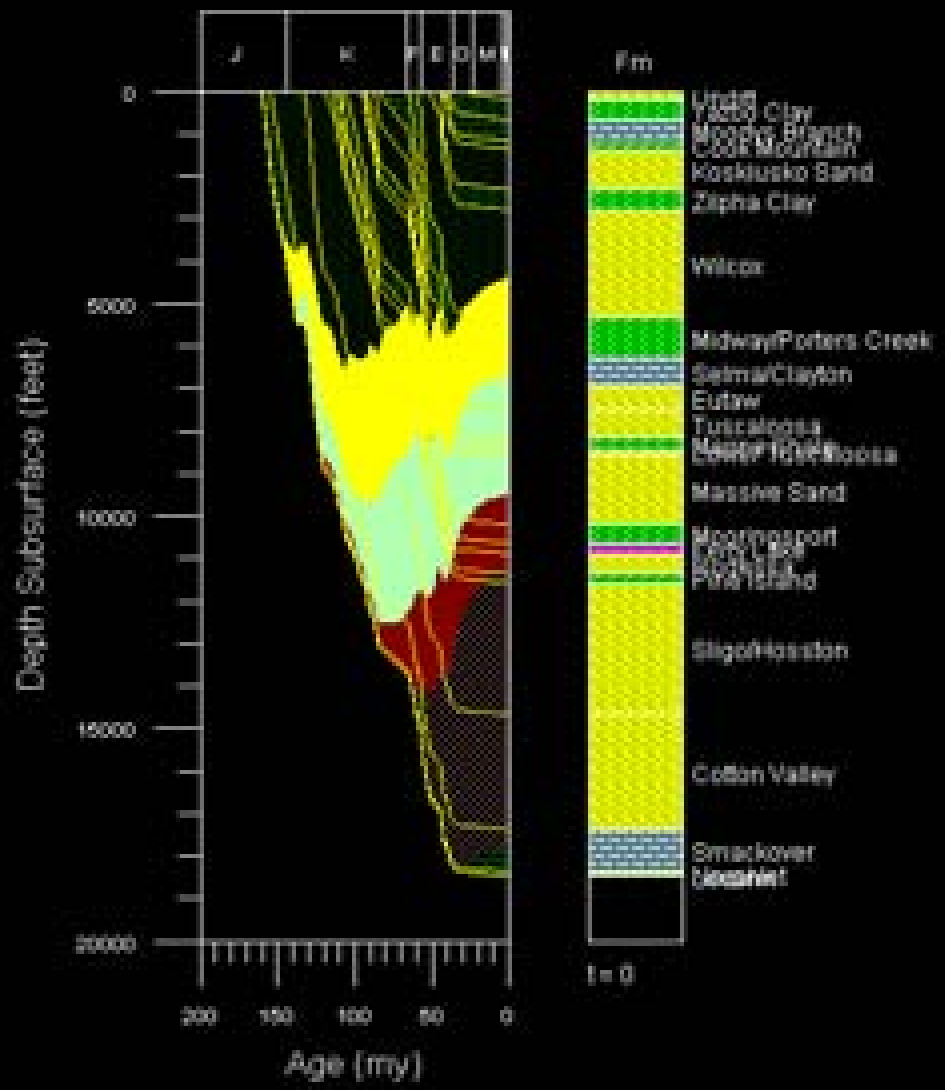



23-129-0006 %Ro
J
K
P
E
O
M
Fm
Undiff
Midway/Porters Creek
Selma/Clayton
Eutaw
Tuscaloosa
Marine Shale
Lower Tuscaloosa
Massive Sand
Paluxy
Mooringsport
Pine Island
Sligo/Hosston
Cotton Valley
Smackover
t = 0
Depth Subsurface (feet)
0
5000
10000
15000
16000
200
150
100
50
0
Age (my)
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)

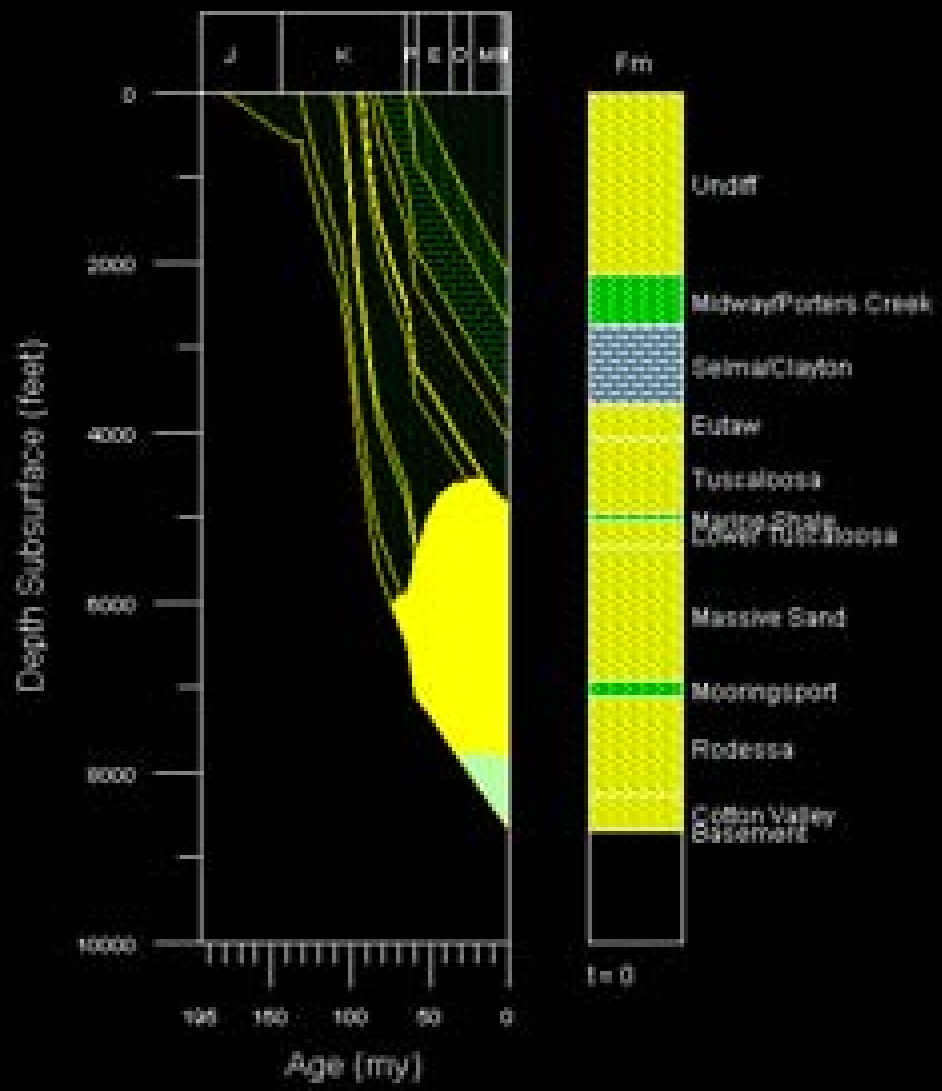
23-093-20011 %Ro

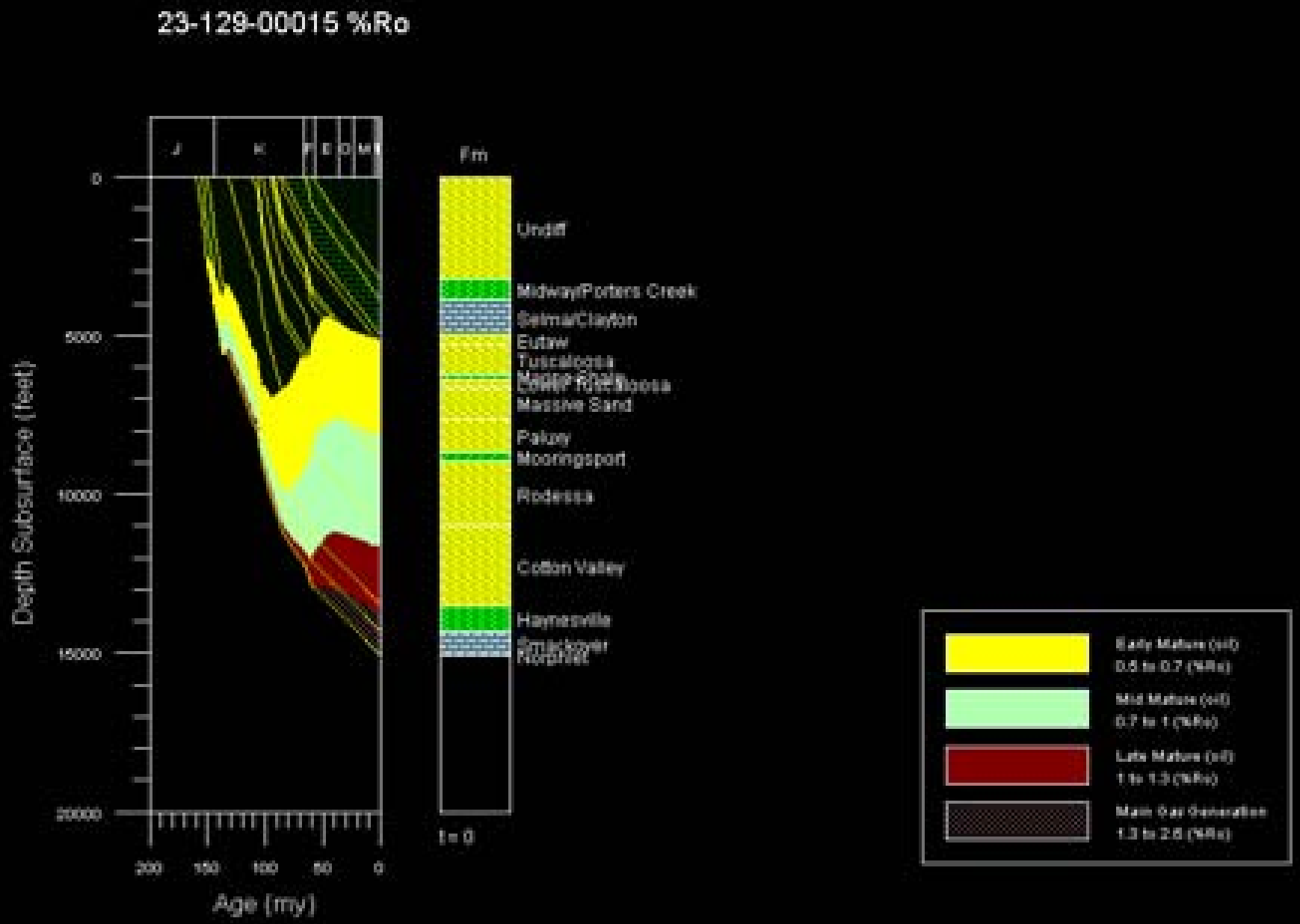


23-049-20011 %Ro

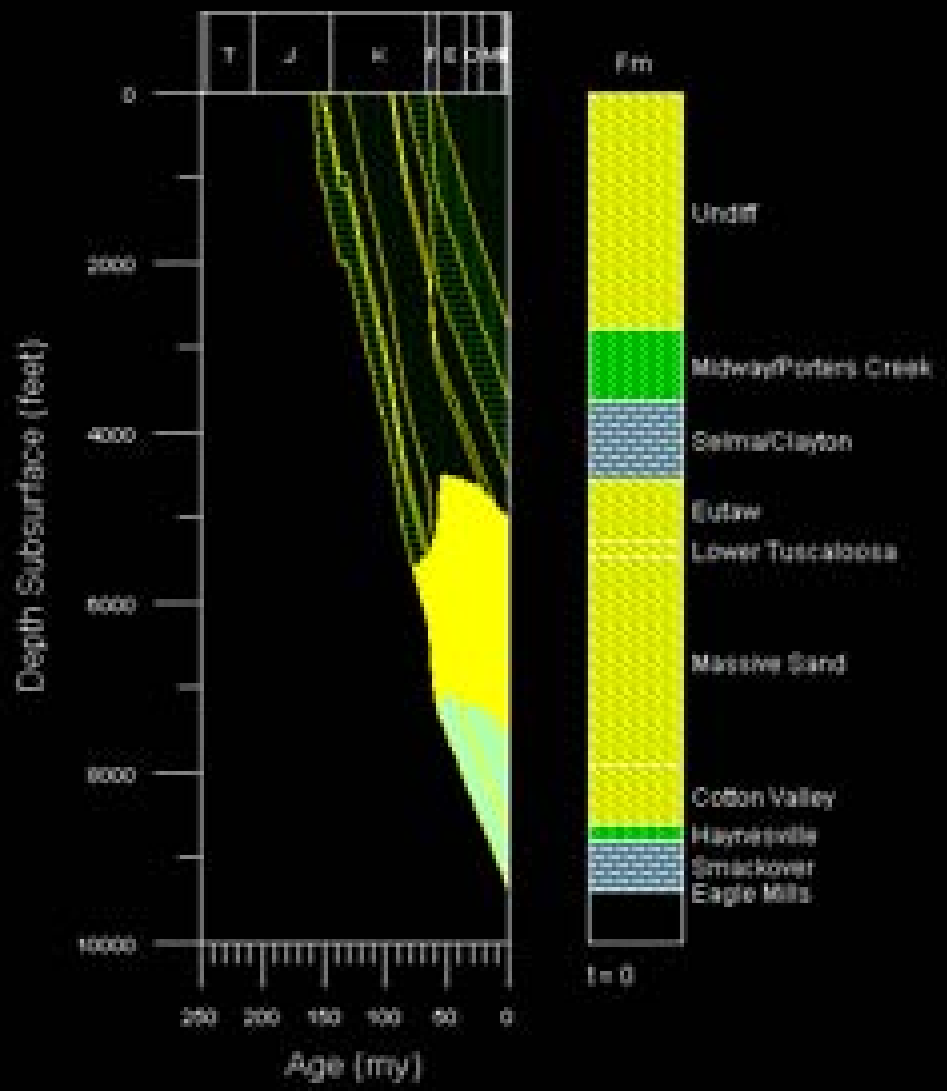


23-101-00014 %Ro

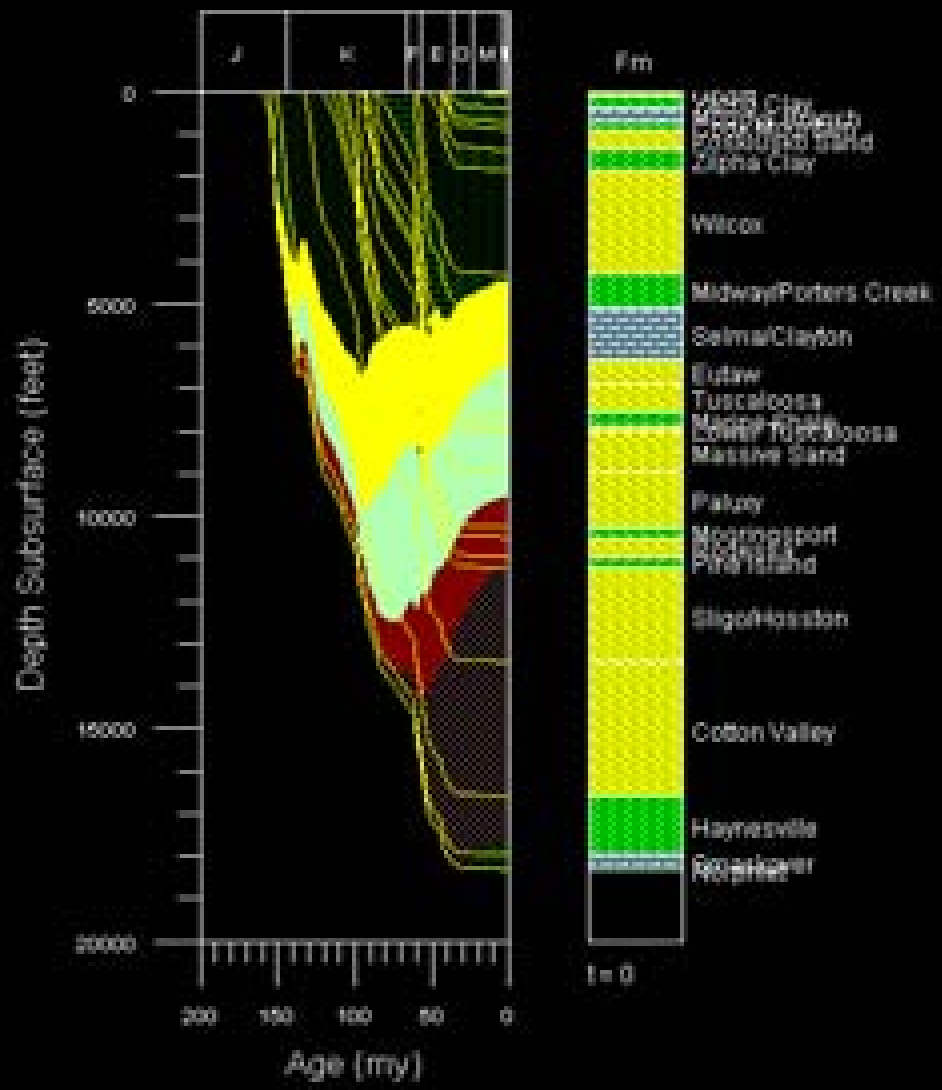



23-129-00015 %Ro
J
K
P
E
O
M
Fm
0
5000
10000
15000
20000
Depth Subsurface (feet)
200
150
100
50
0
Age (my)
Undiff
Midway/Porters Creek
Selma/Clayton
Eutaw
Tuscaloosa
Massive Sand
Paluxy
Mooringsport
Rodessa
Cotton Valley
Haynesville
t = 0
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)

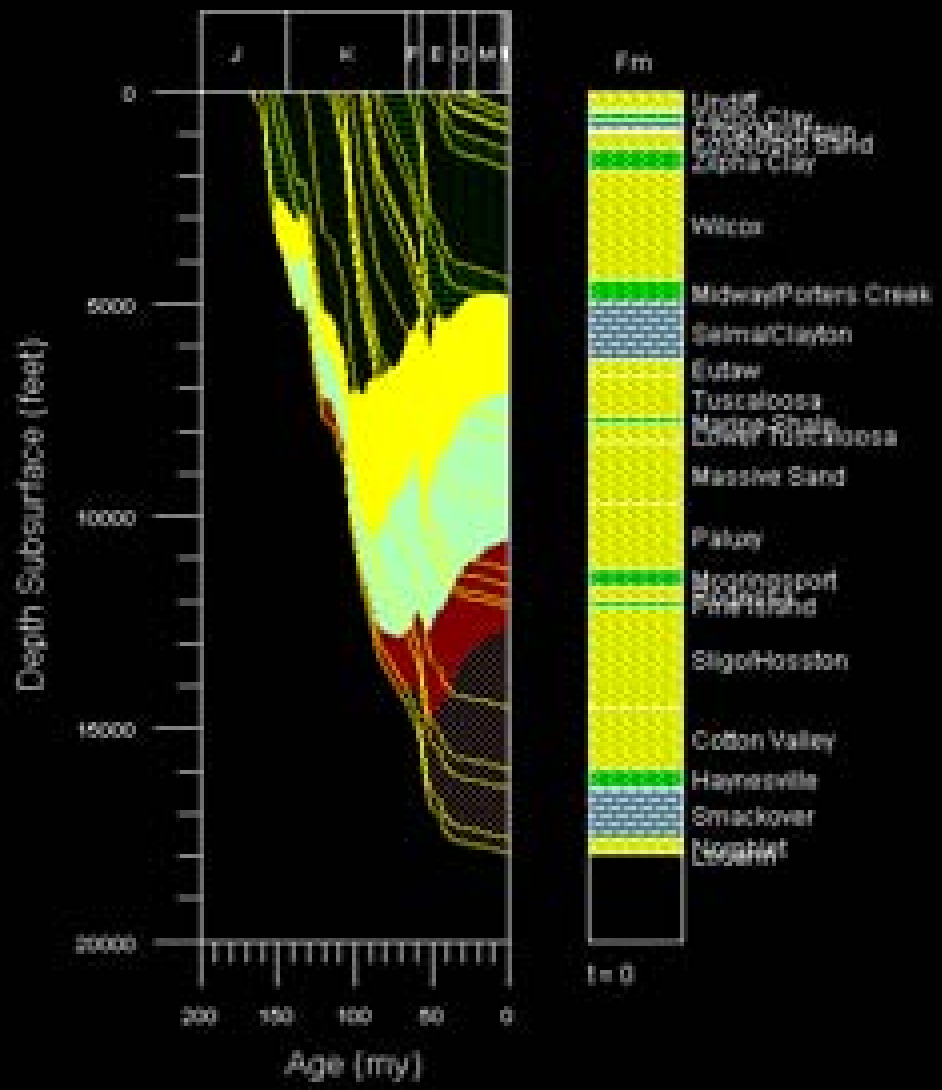
23-051-20020 %Ro



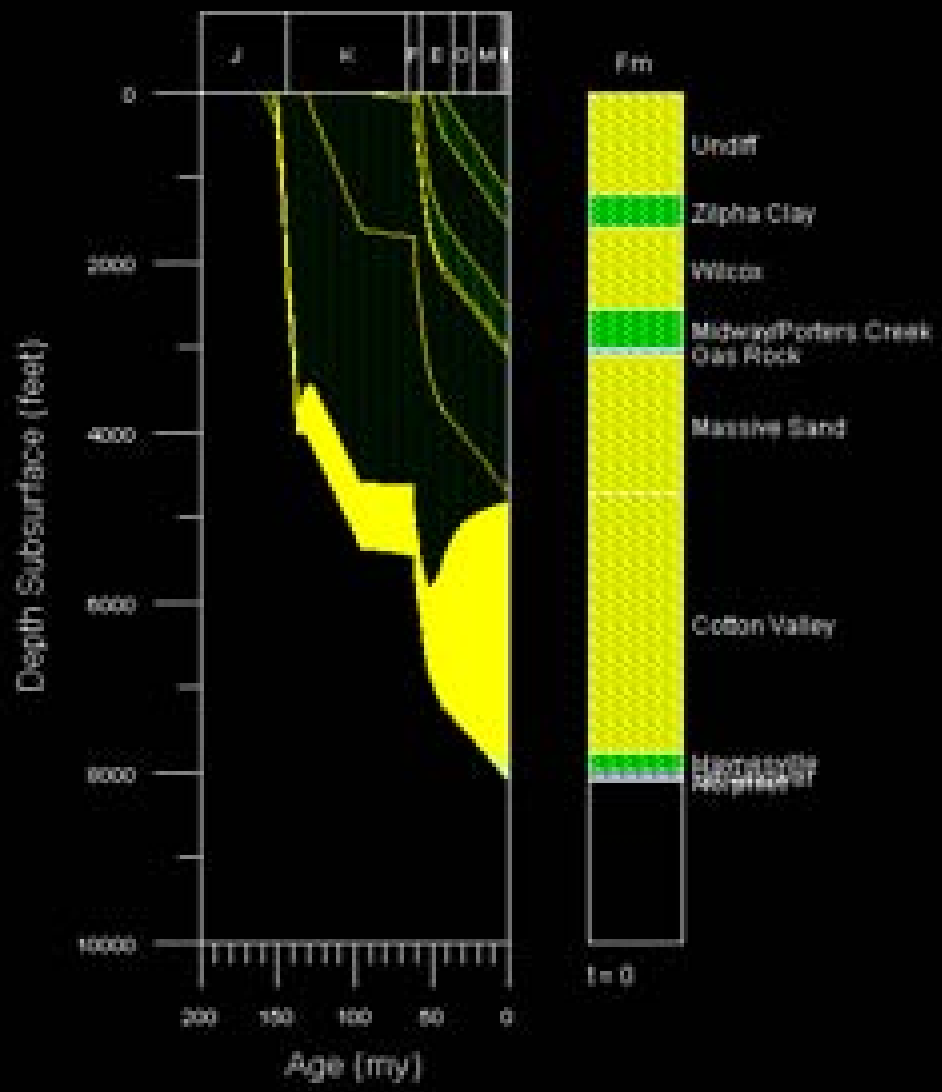
23-121-20025 %Ro



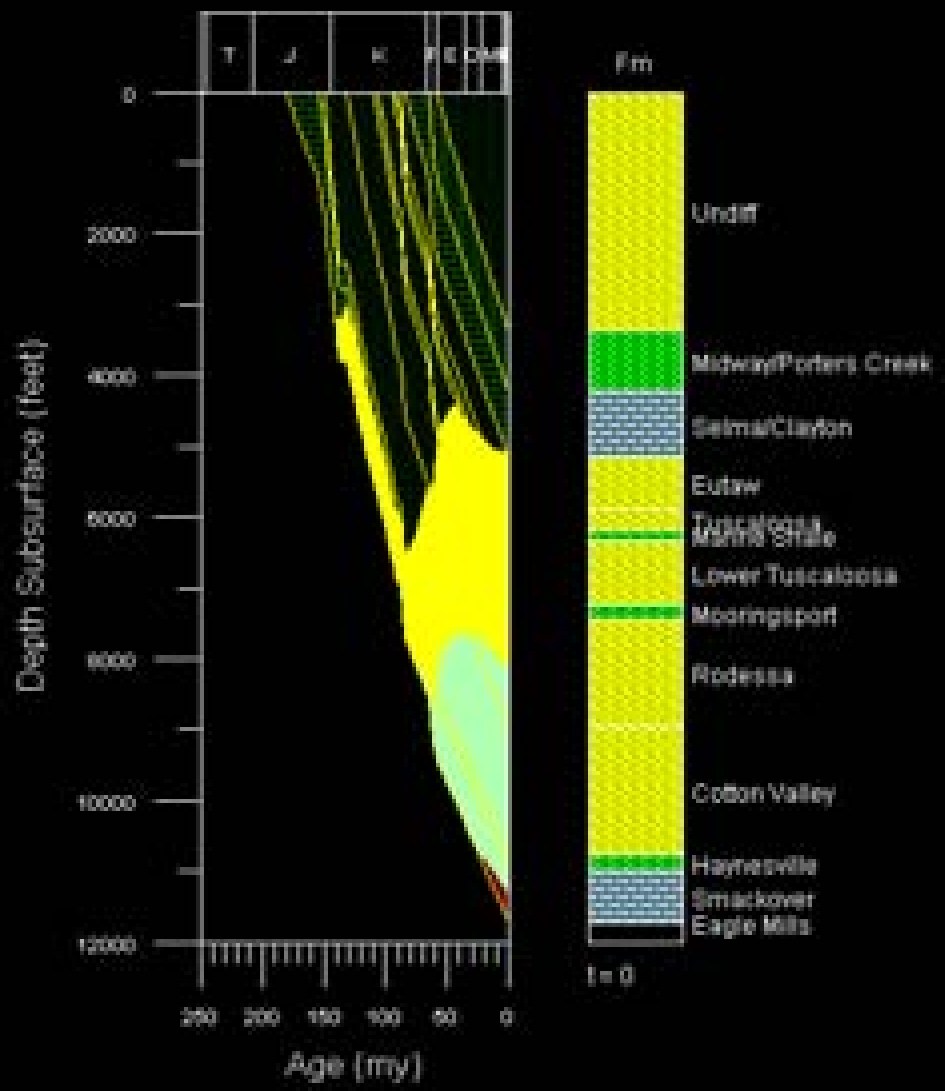
23-061-20028 %Ro



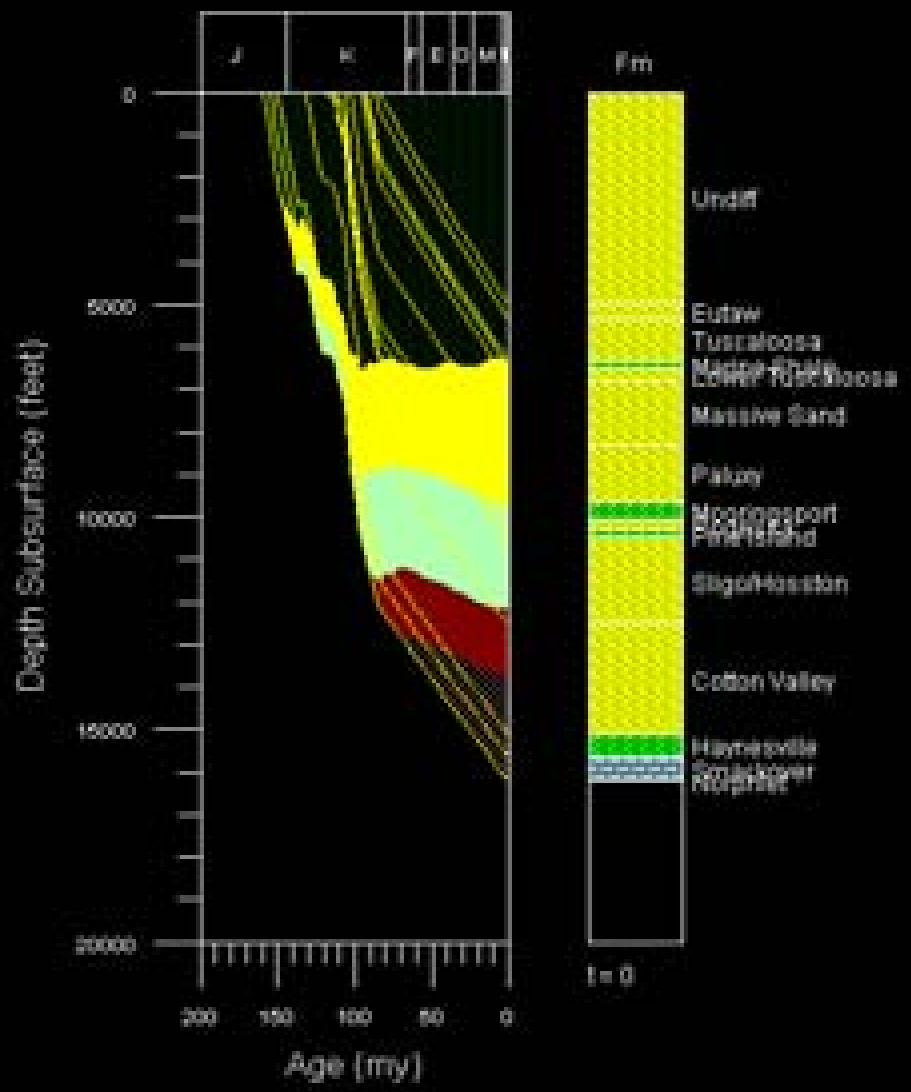
23-055-00032 %Ro

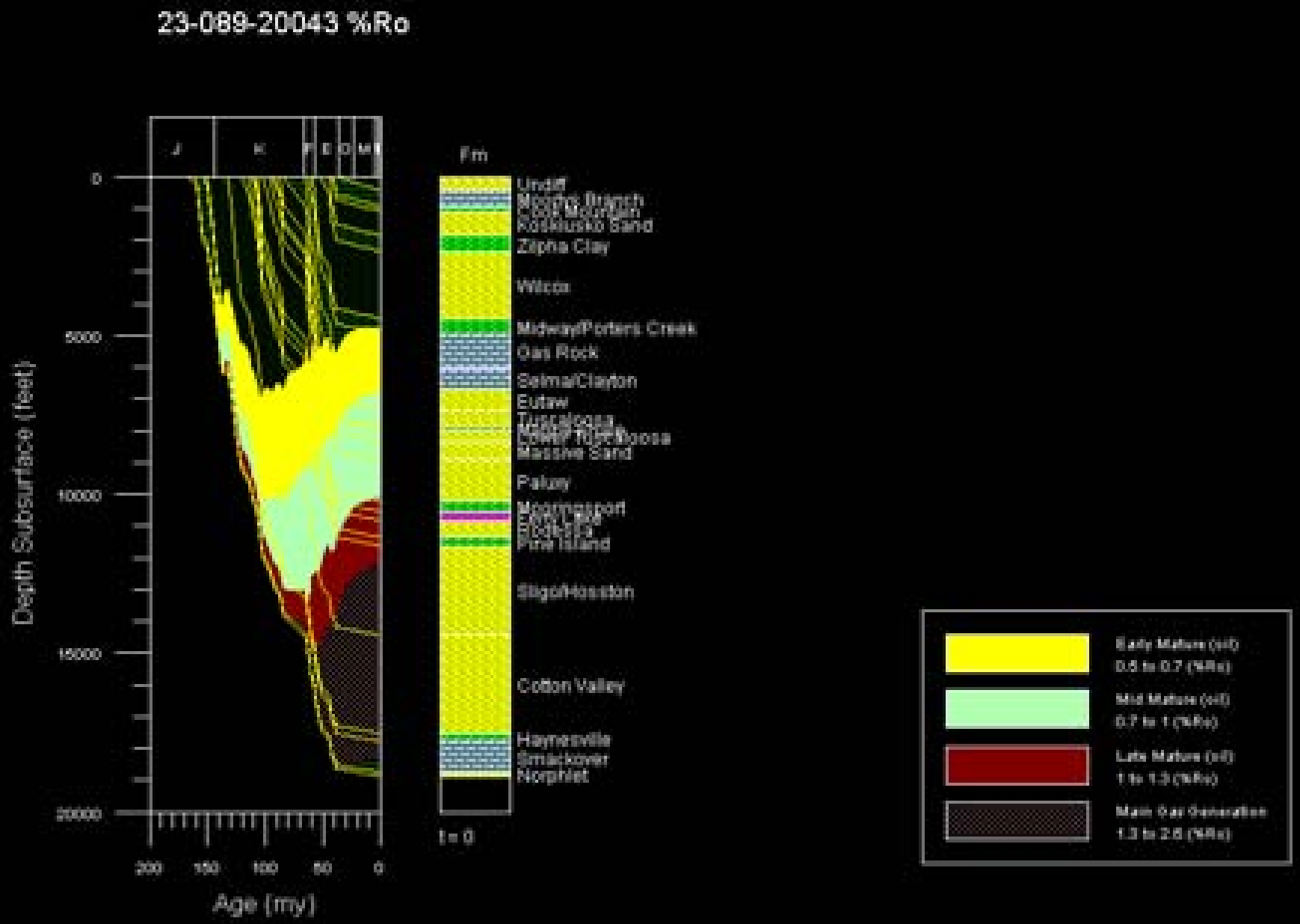


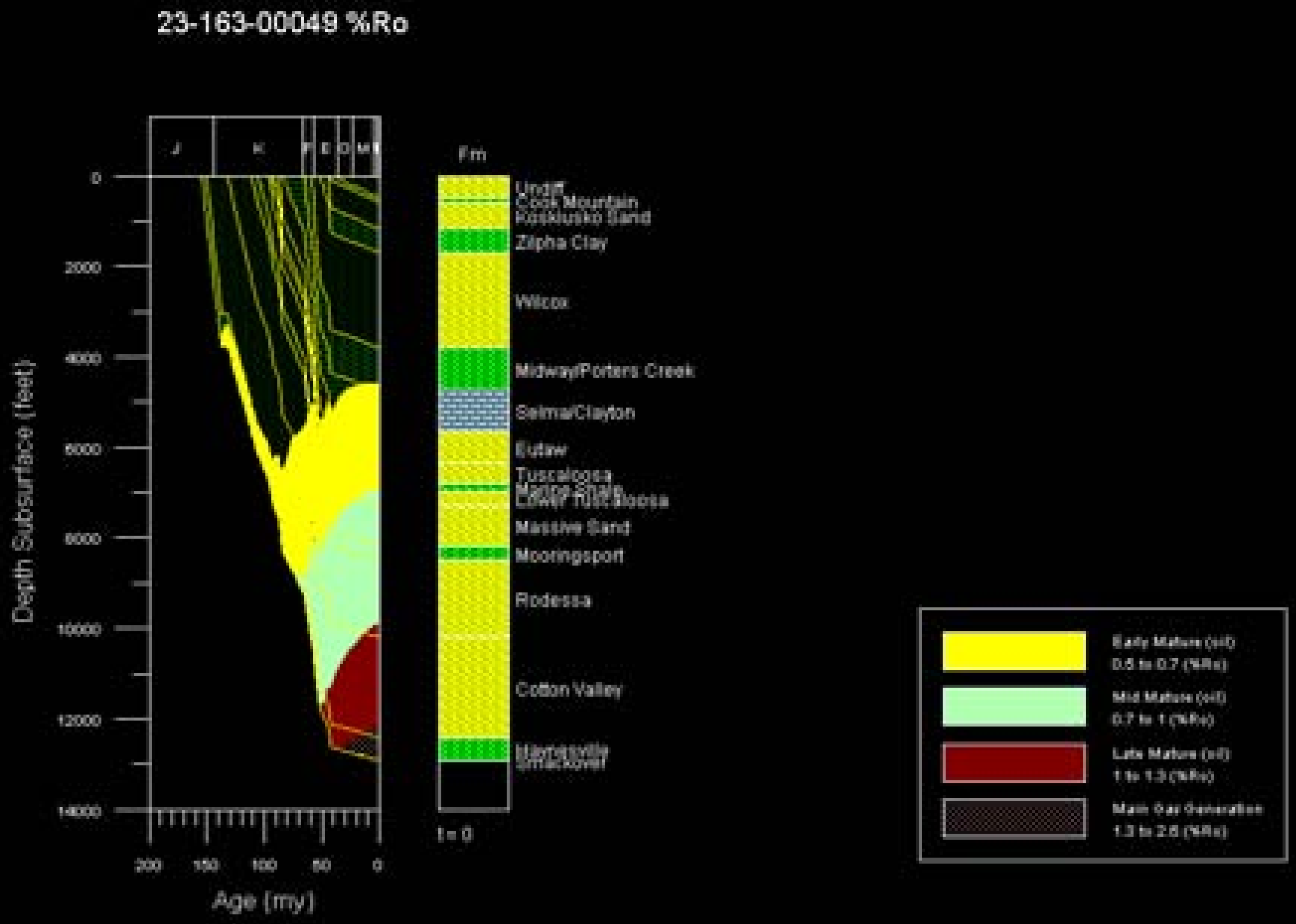
23-051-20036 %Ro



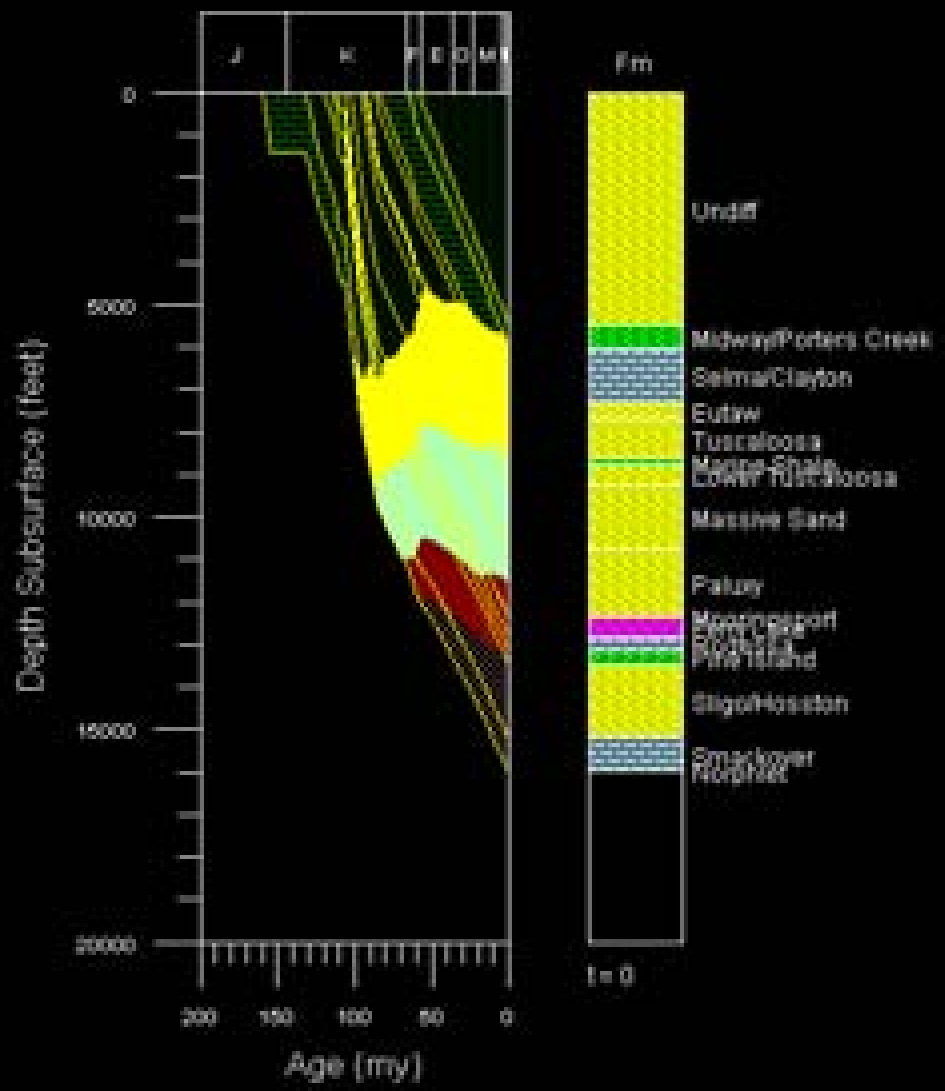
23-153-20042 %Ro



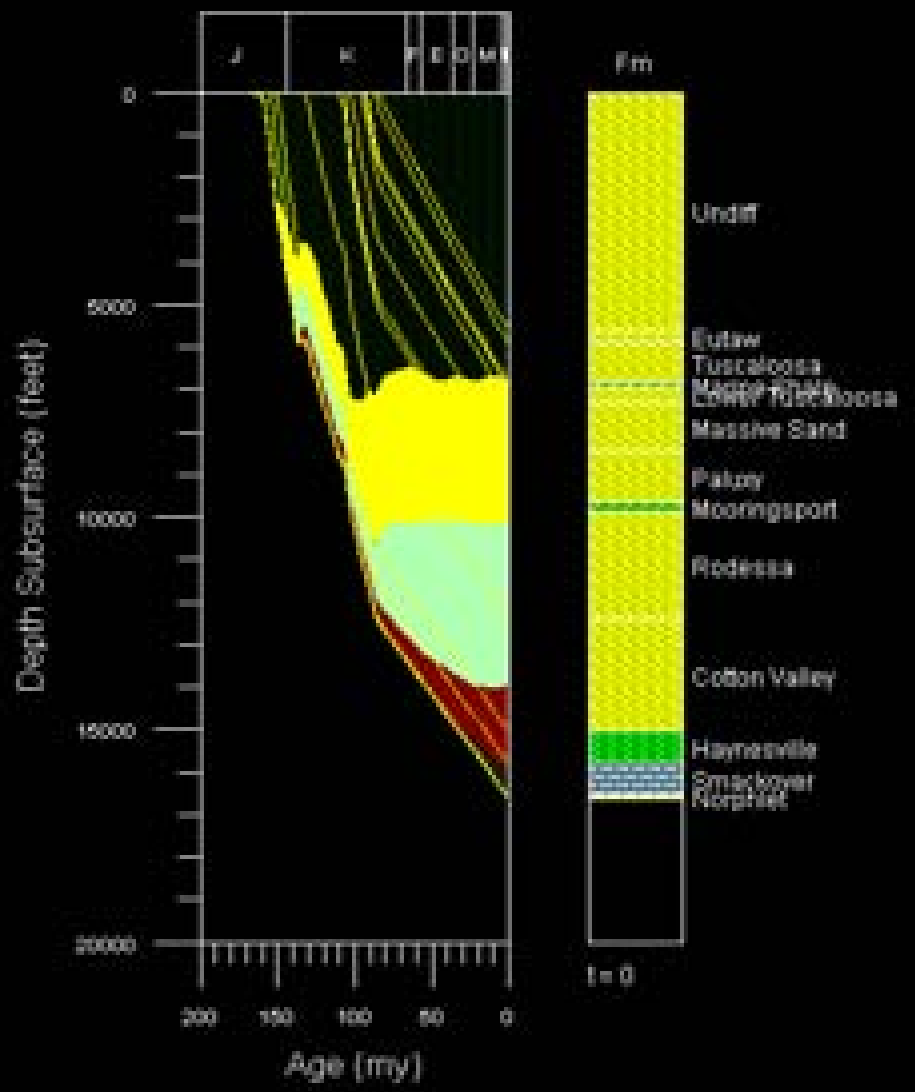

23-089-20043 %Ro
J
K
P
E
O
M
Fm
Undiff
Moorhn Branch
Coal Mountain
Rosklusko Sand
Zilpha Clay
Wilcox
Midway/Porters Creek
Gas Rock
Selma/Clayton
Eutaw
Tuscaloosa
Massive Sand
Paluxy
Mooringsport
Pine Island
Sligo/Hosston
Cotton Valley
Haynesville
Smackover
Norphlet
t = 0
0
5000
10000
15000
20000
Depth Subsurface (feet)
200
150
100
50
0
Age (my)
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)


23-163-00049 %Ro
J
K
P
E
O
M
Fm
Undiff
Cook Mountain
Pointe Coupee Sand
Zilpha Clay
Wilcox
Midway/Porters Creek
Selma/Clayton
Eutaw
Tuscaloosa
Marine Shale
Lower Tuscaloosa
Massive Sand
Mooringsport
Rodessa
Cotton Valley
Haynesville
Smackover
t = 0
Depth Subsurface (feet)
0
2000
4000
6000
8000
10000
12000
14000
200
150
100
50
0
Age (my)
Early Mature (oil)
0.5 to 0.7 (%Ro)
Mid Mature (oil)
0.7 to 1 (%Ro)
Late Mature (oil)
1 to 1.3 (%Ro)
Main Gas Generation
1.3 to 2.6 (%Ro)

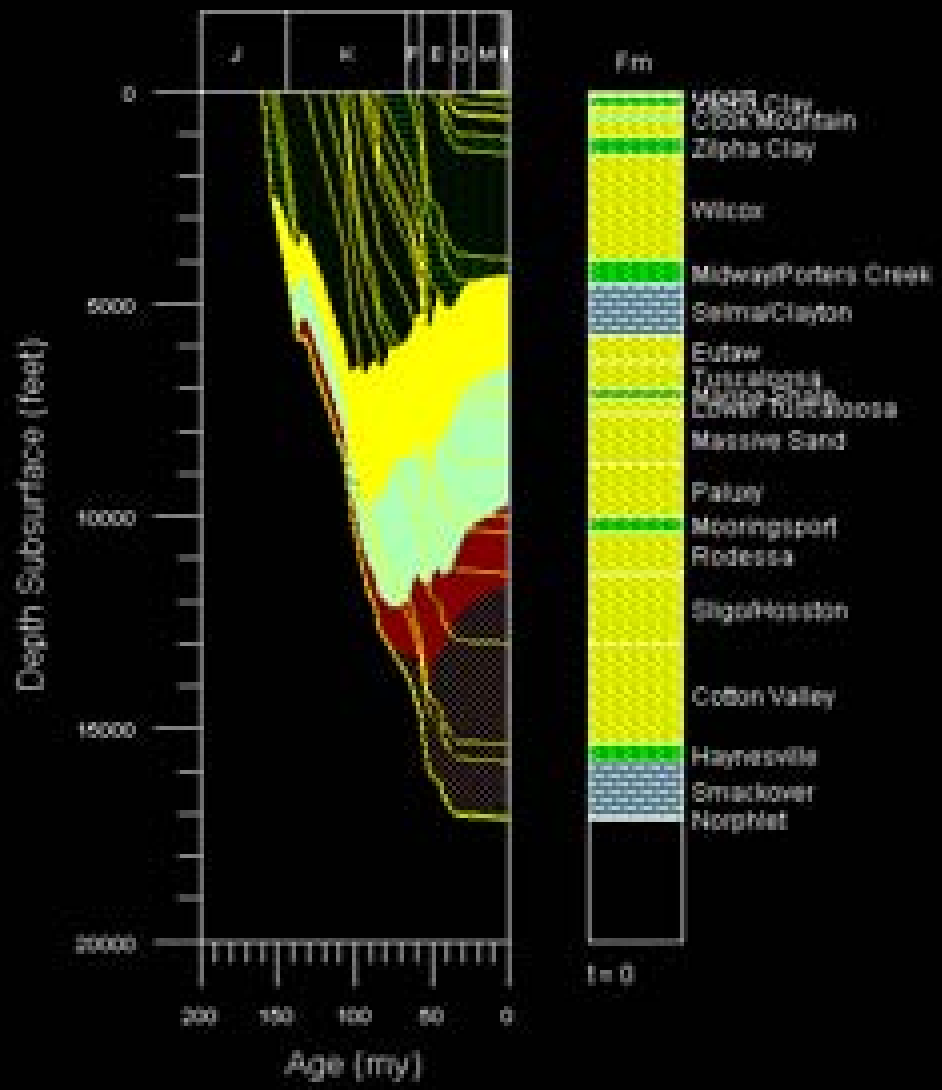
23-127-20055 %Ro



23-129-20057 %Ro



23-129-00061 %Ro



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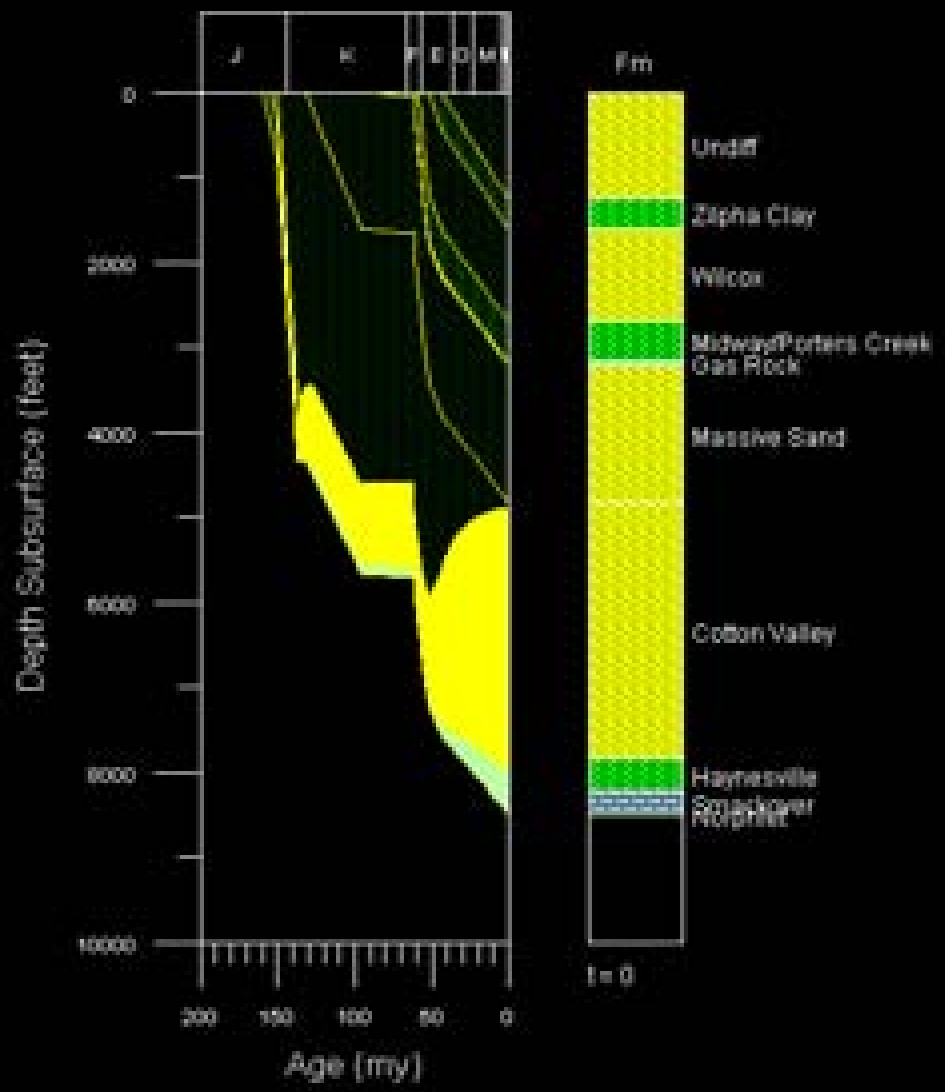

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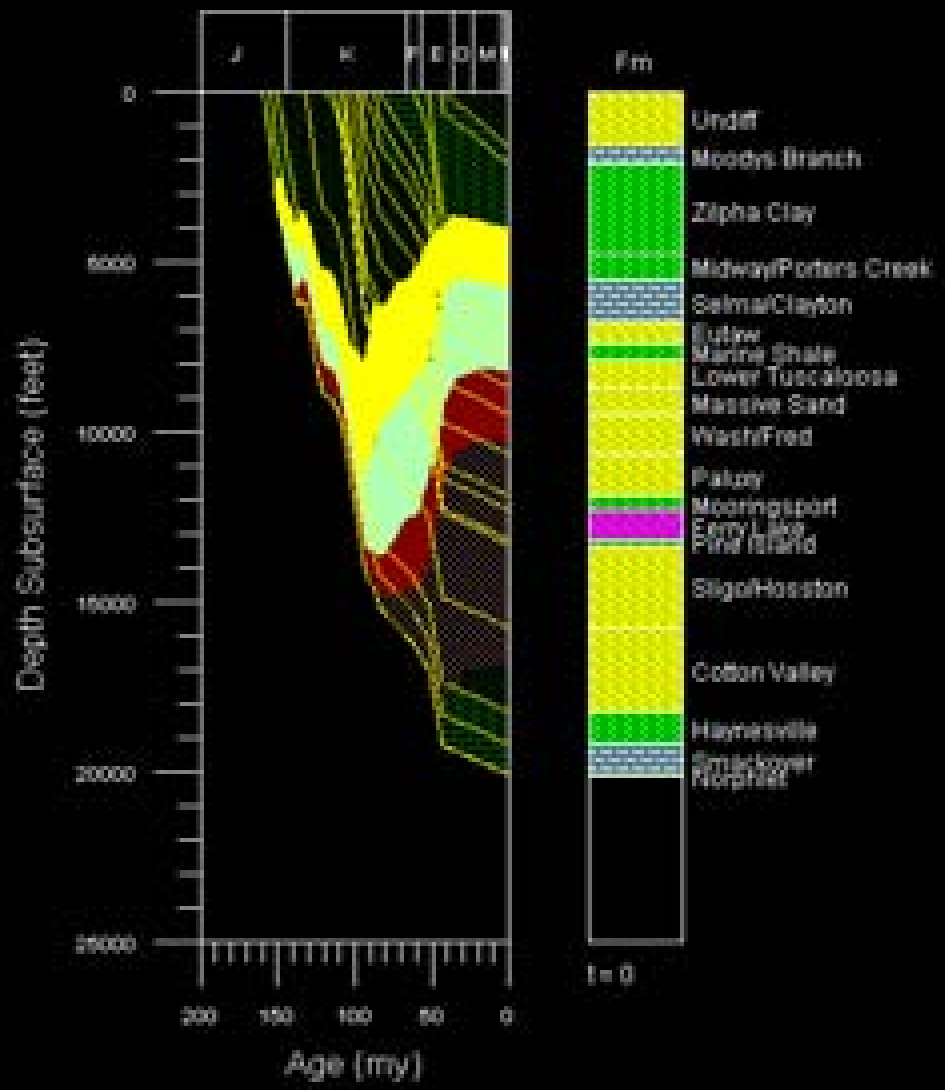

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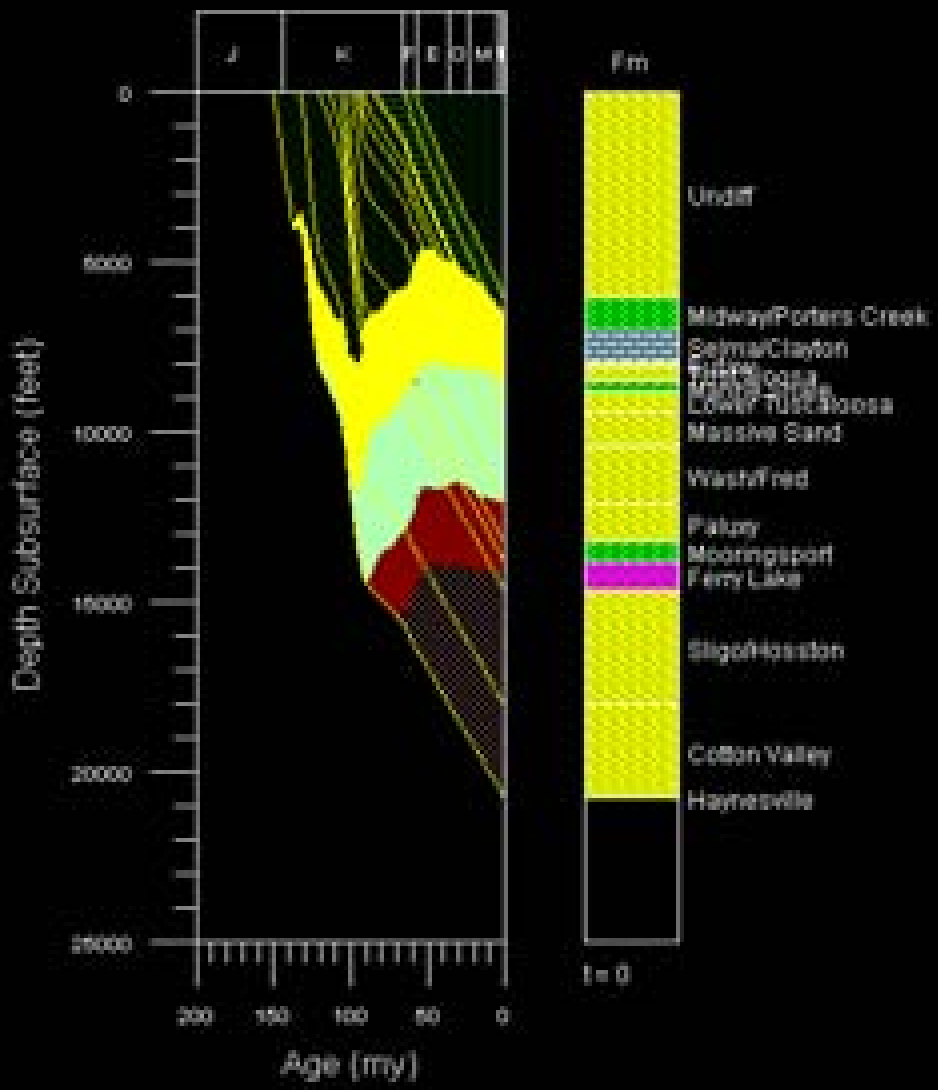

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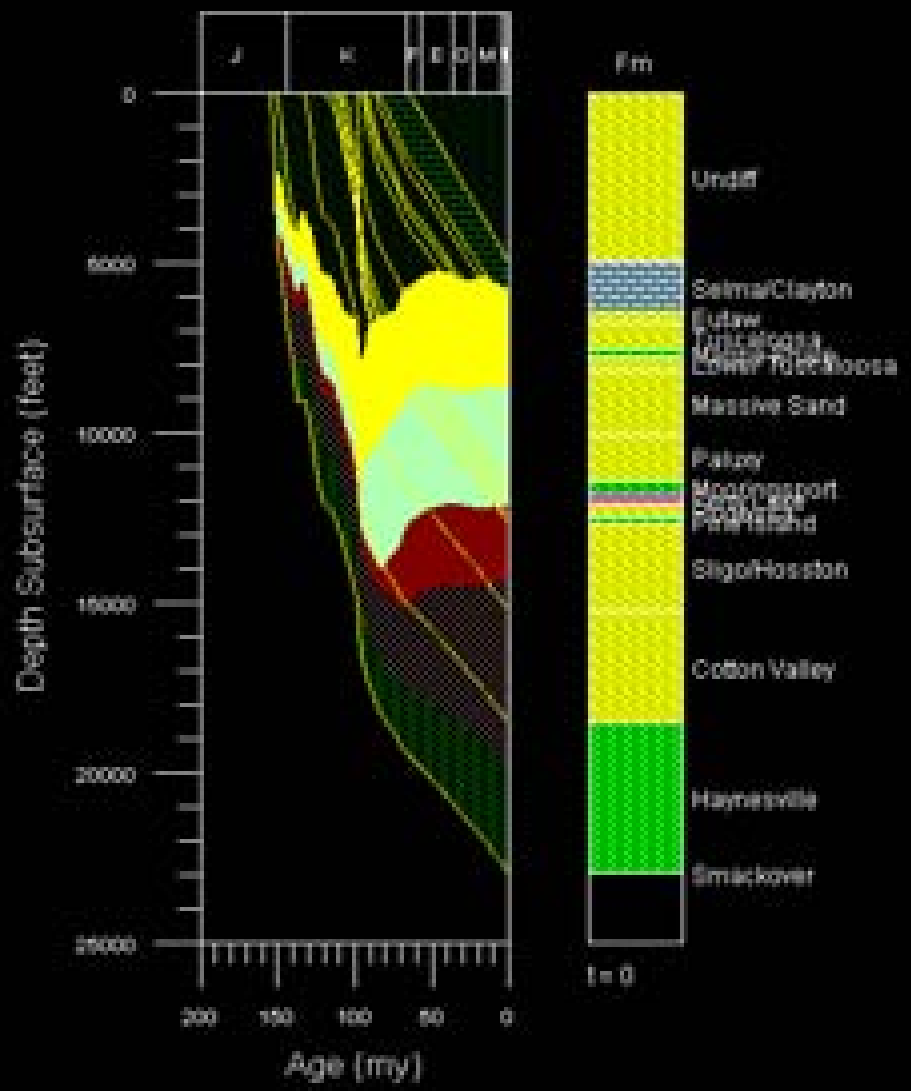

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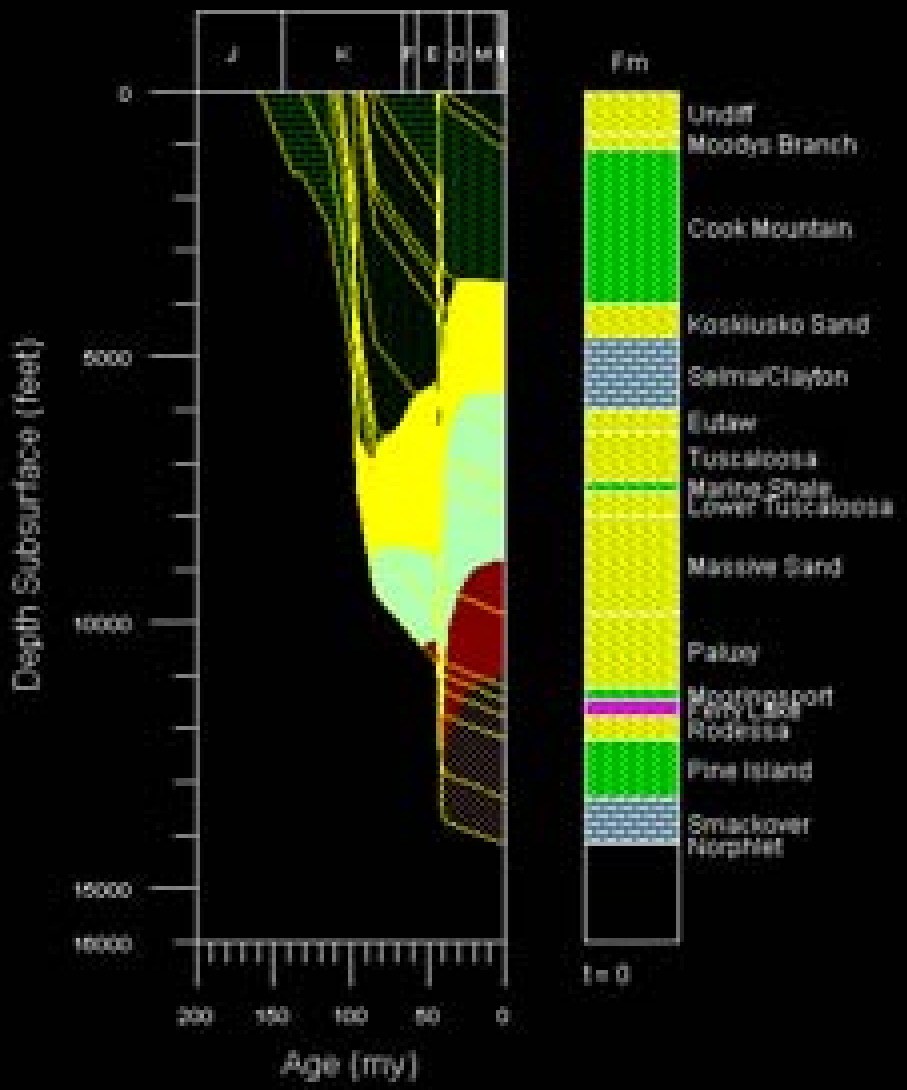

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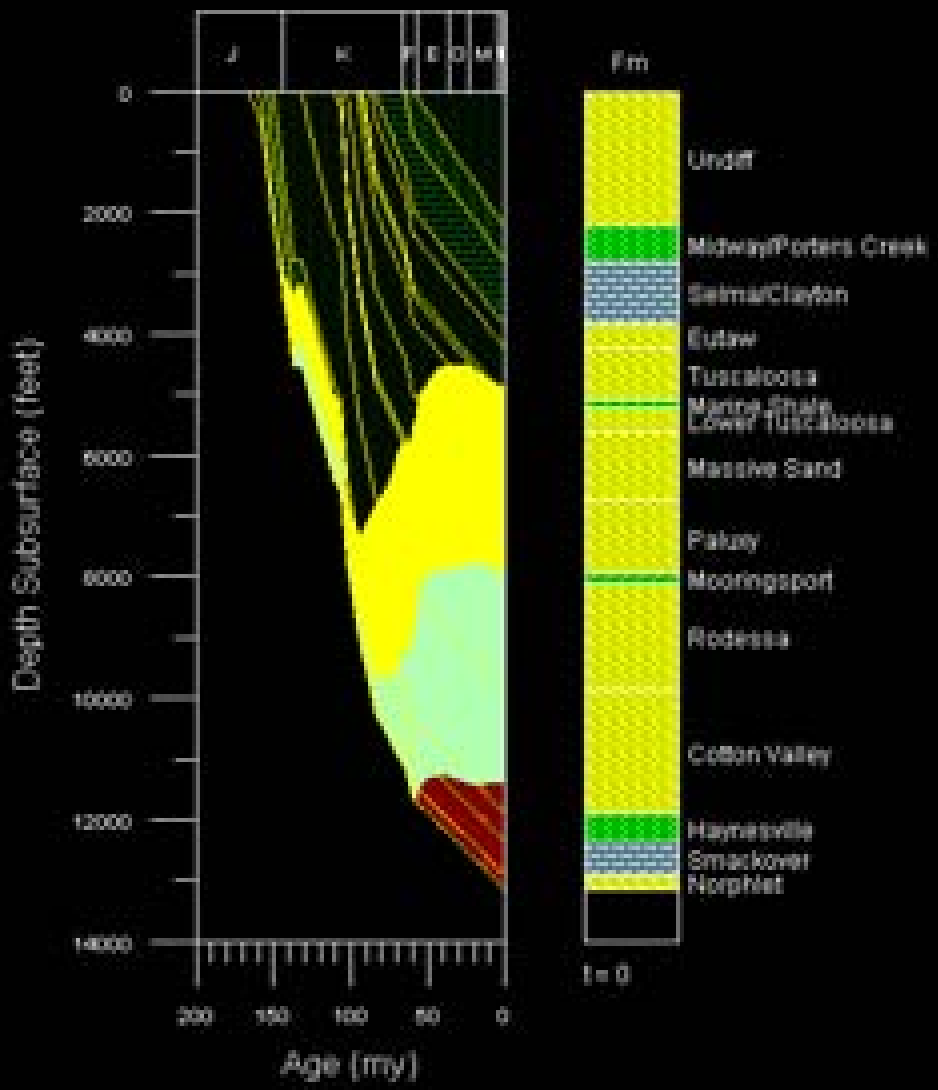

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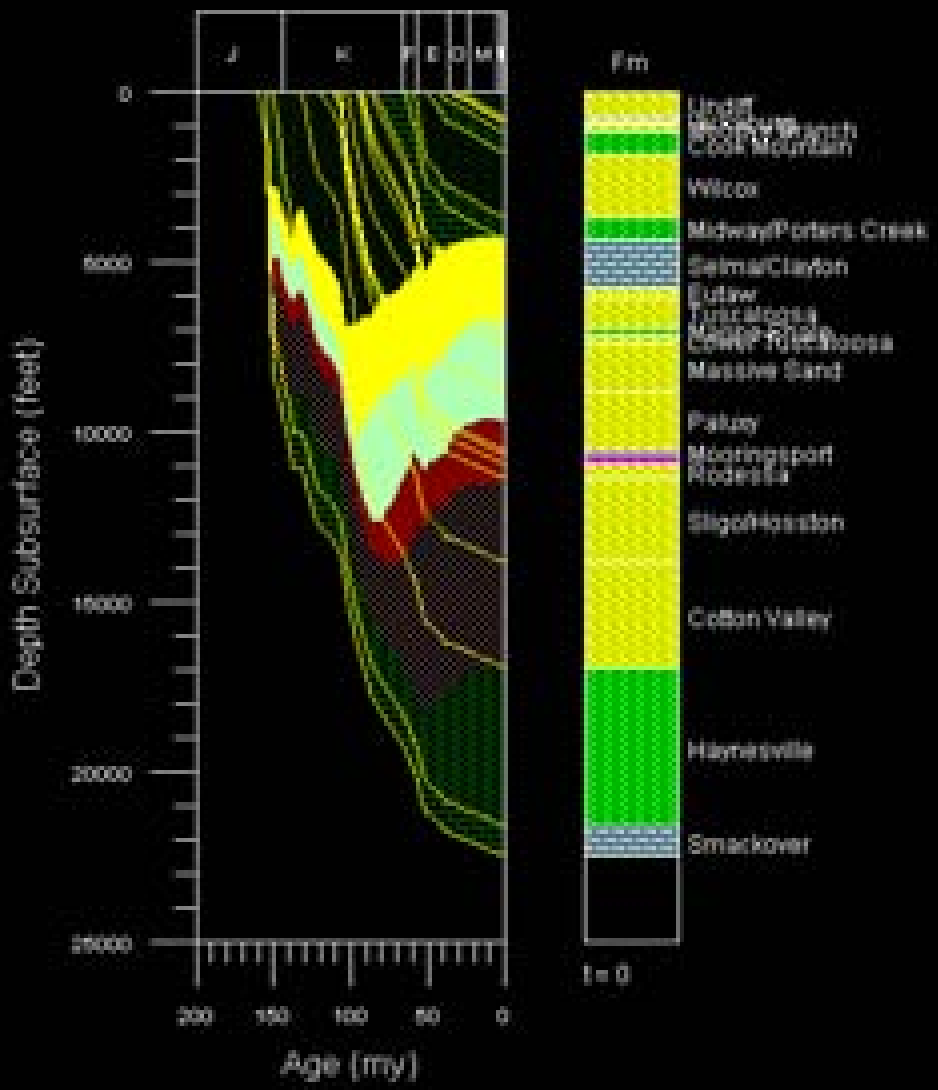

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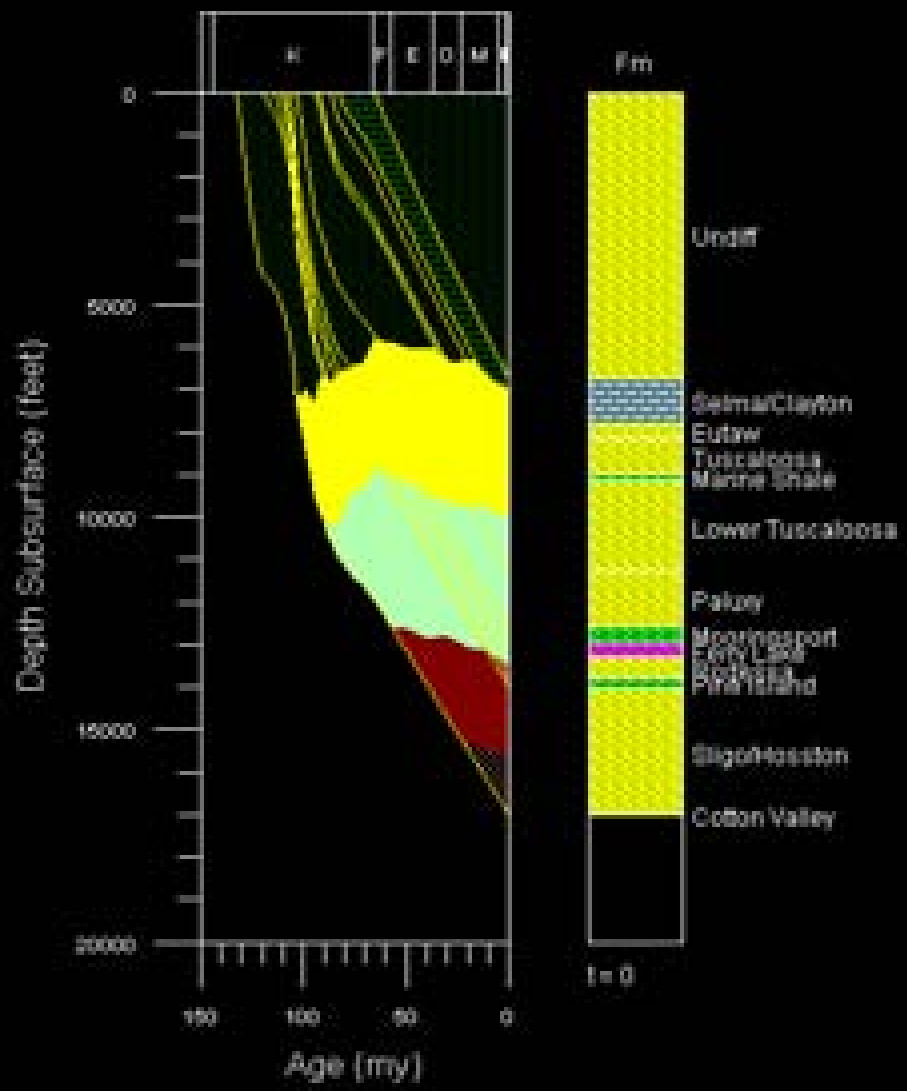

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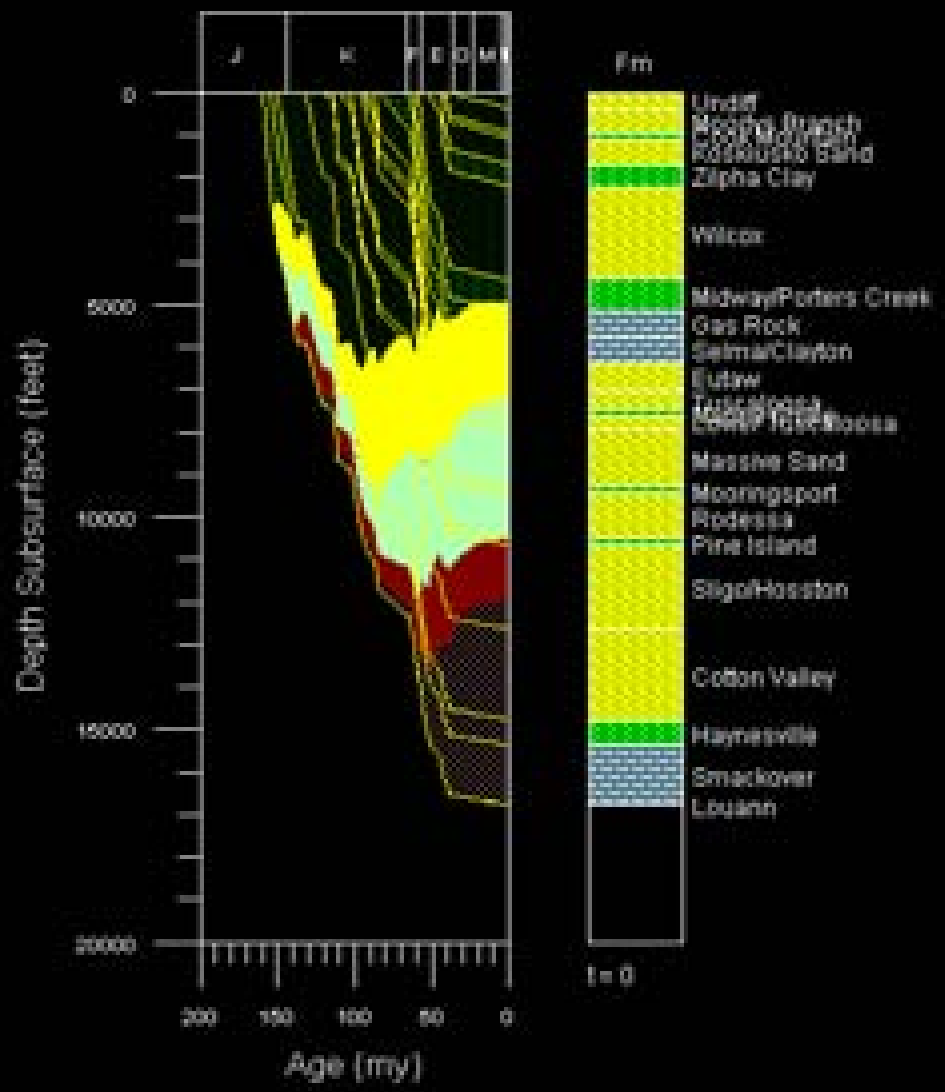

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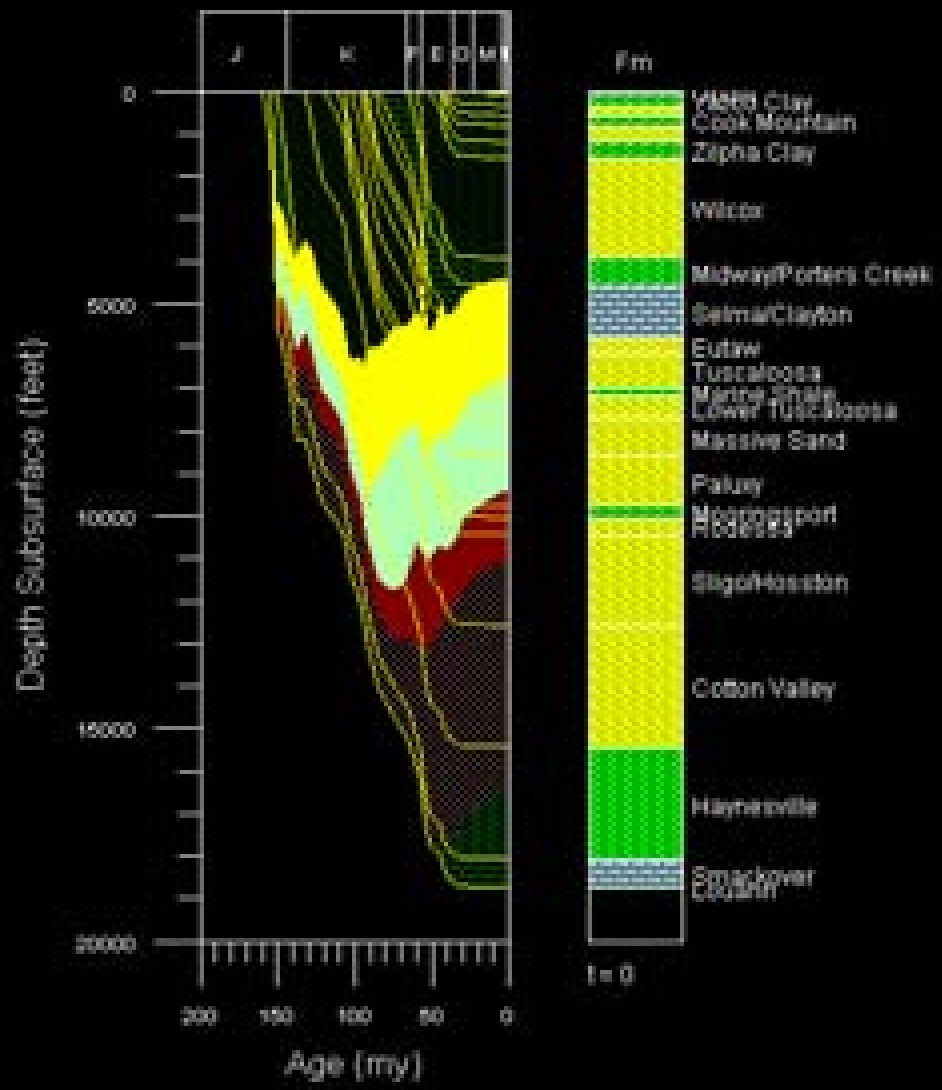

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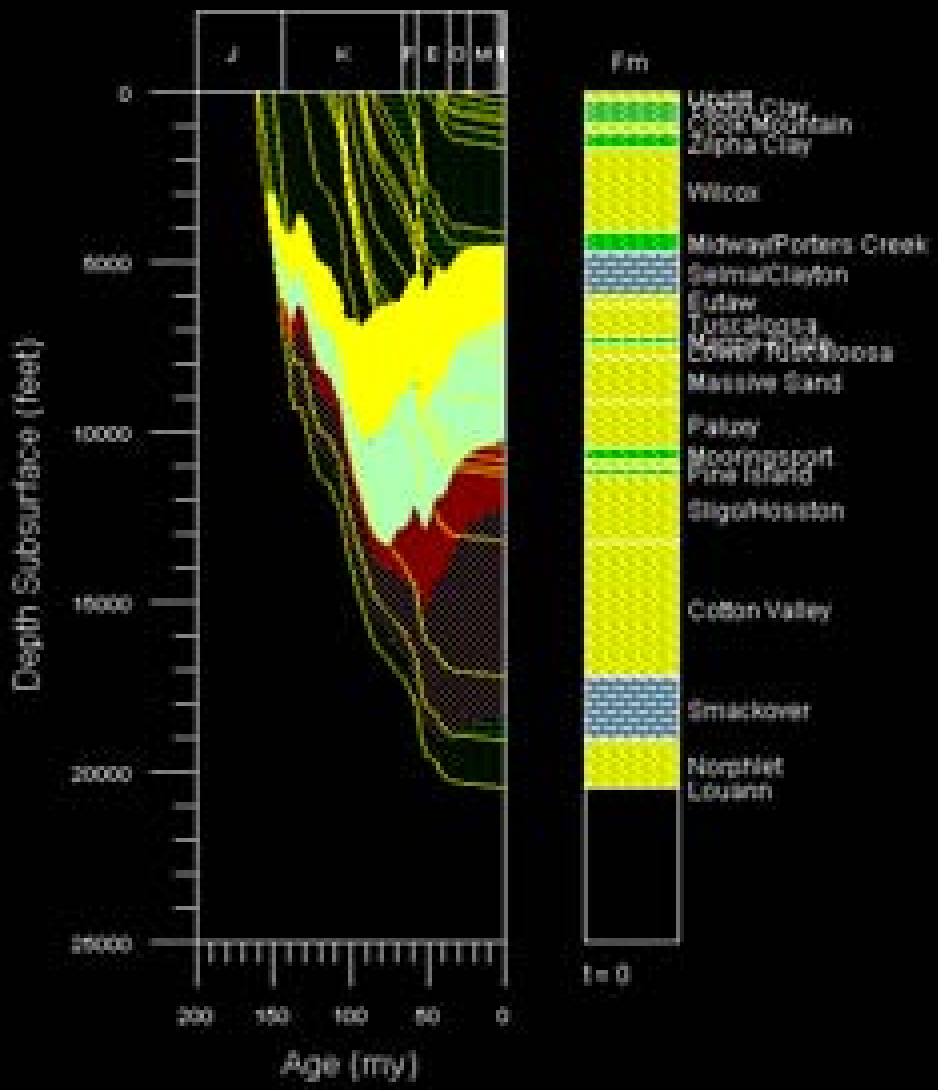

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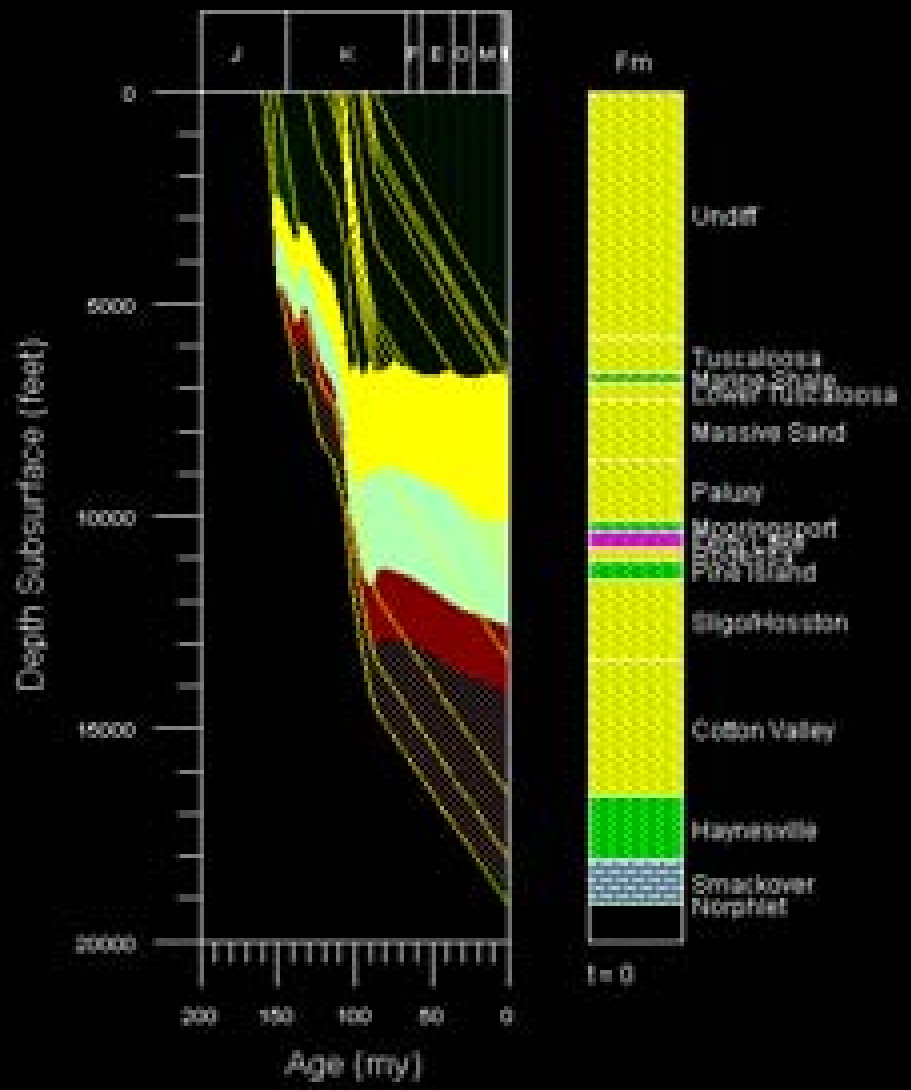

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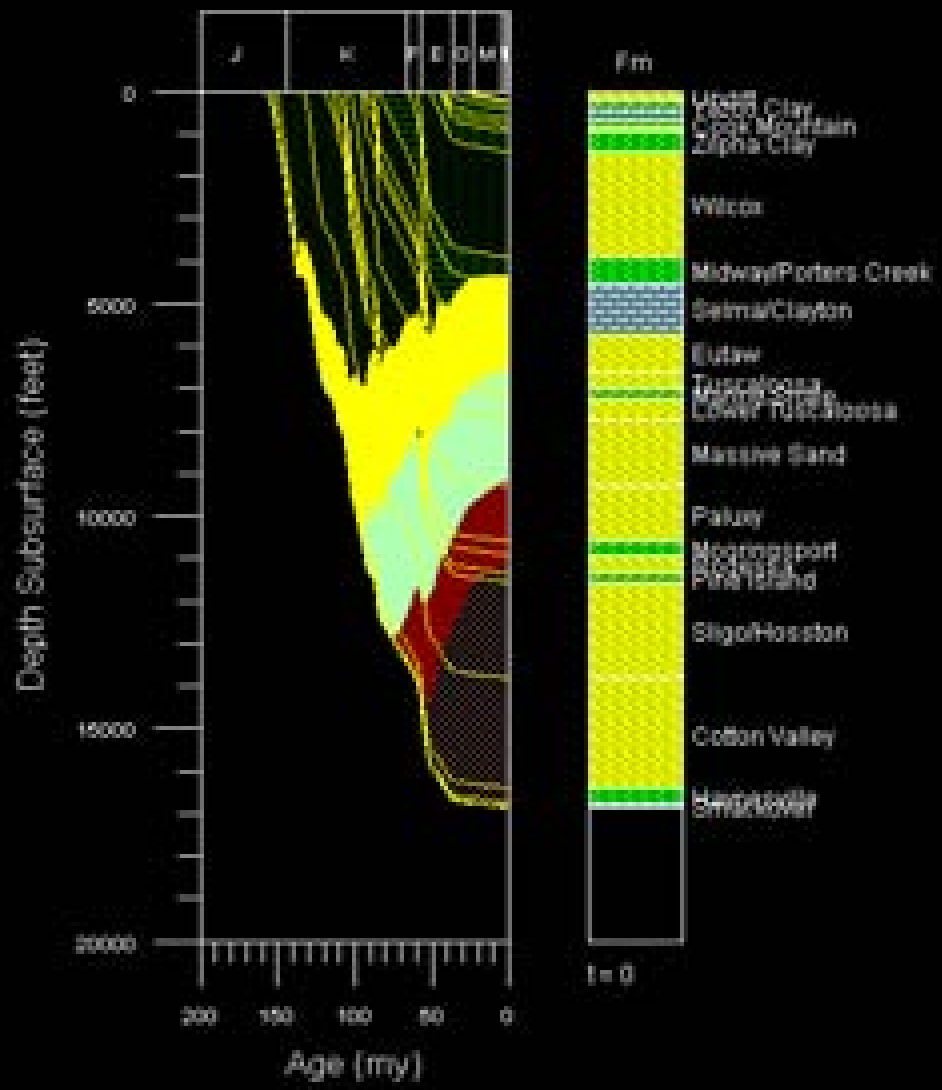

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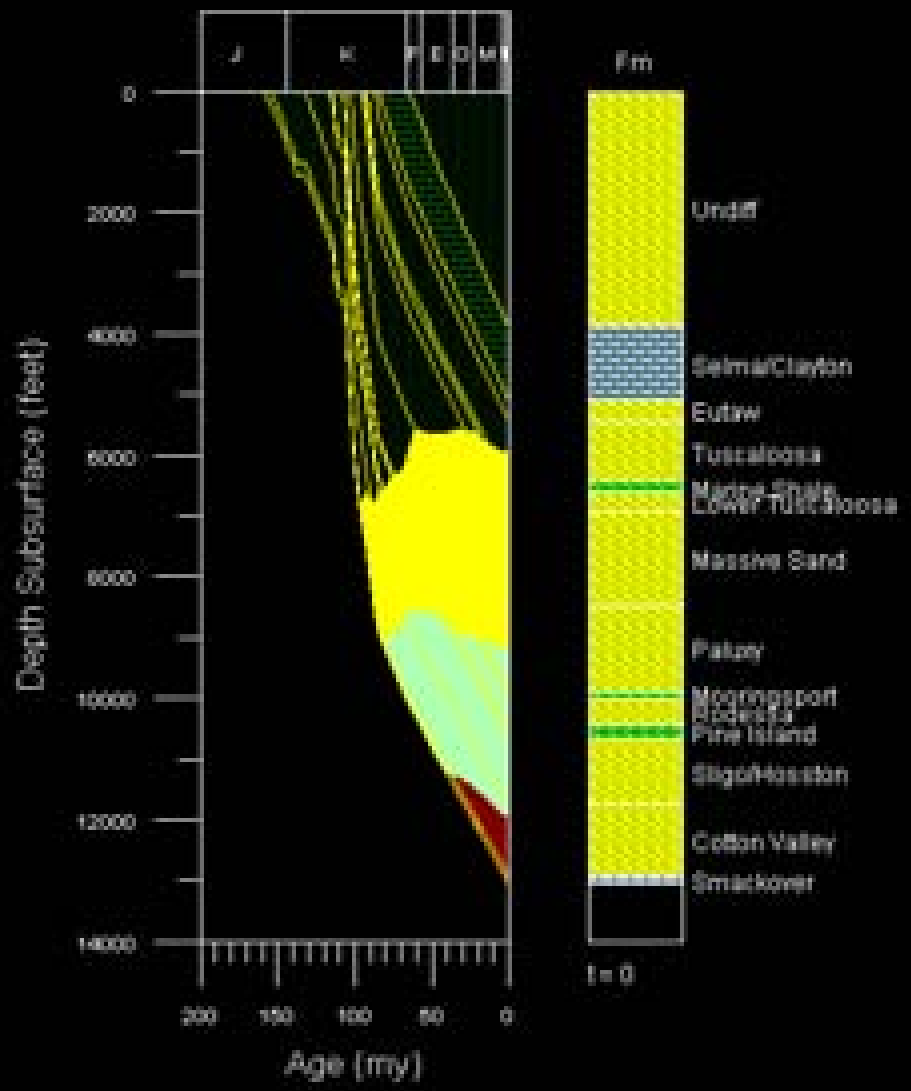

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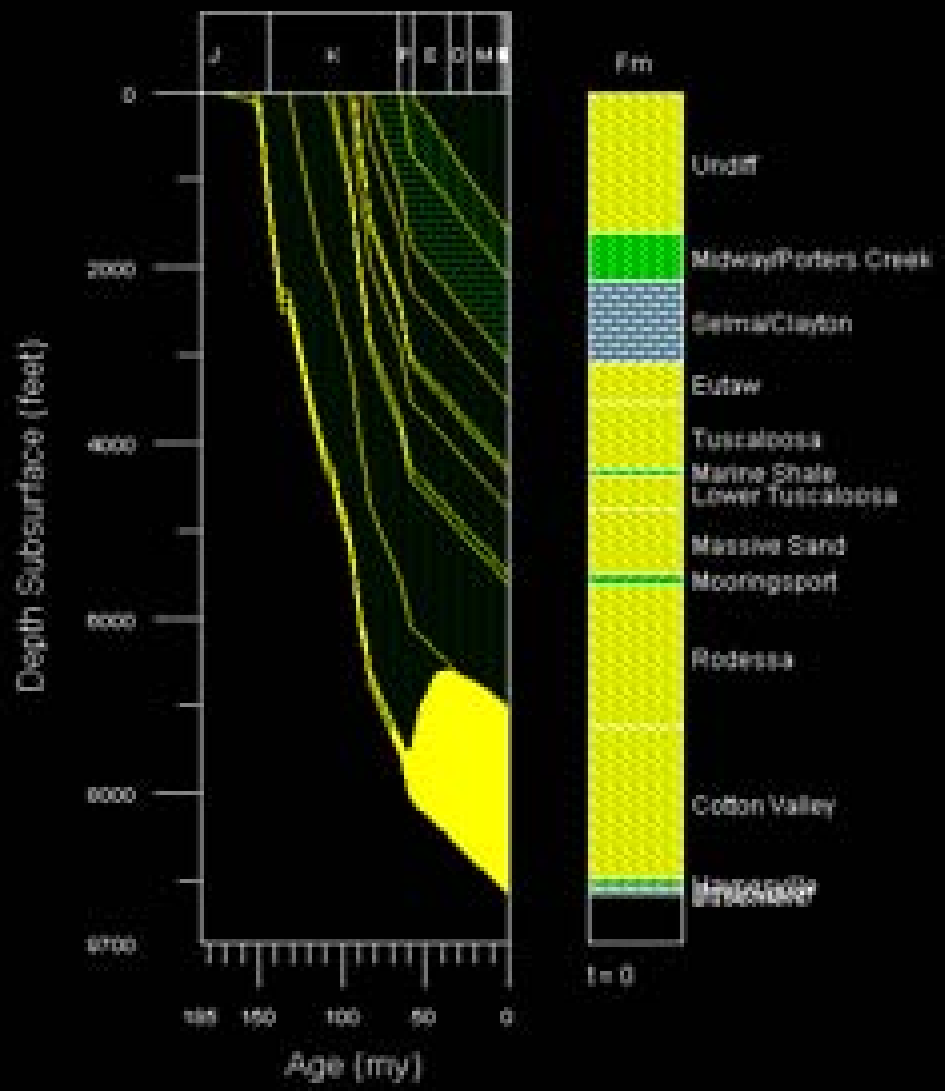

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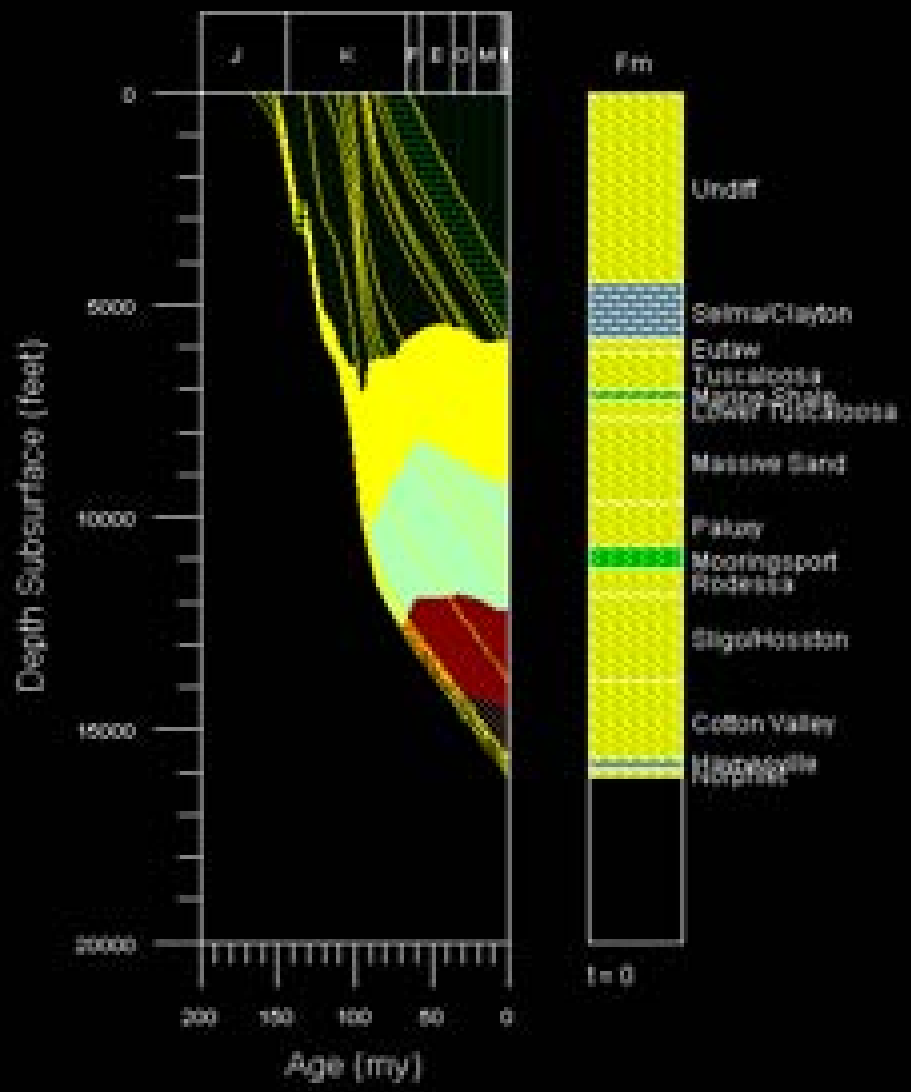

Attachment 9

"Well Sedimentation Rates"

Ernest A. Mancini and William Parcell
University of Alabama

API	UPPER TERTIARY		Jackson (top Yazoo/ Shubuta)	Moodys Branch	Cook Mountain	Sparta (Kosciusko)	Cane River (Zilpha)	Wilcox	Midway marker (Porters Creek)	Gas Rock	Selma marker (Clayton)	Eutaw	Tuscaloosa marker	Marine shale	Lower Tuscaloosa	Lower Cretaceous (base massive sand)	Wash/Fred	Paluxy	Moorings.	Ferry Lake	Rodessa	Pine Island	Sligo/	y	Cotton	Haynesville	Smackover	Norphlet	Louann		y	Eagle Mills	
Begin Age (Ma)	30.3		39.1	41.1	43	44.4	52.3	59.1	61.5	65	84	87	92	94	96	99	103	106	109	112	114	117	132	137	150	154	159	161	175	176	195	210	500
Duration (Ma) ---->		30.3	8.8	2	1.9	1.4	7.9	6.8	2.4	3.5	19	3	5	2	2	3	4	3	3	3	2	3	15	5	13	4	5	2	14	1	19	15	290
Strike Section A-A'																																	
2305500032	39.77						48.10	143.53	192.08	**20.86**													107.87		235.15	51.75	24.60						
2305500066	41.35						44.56	161.32	195.83	**13.14**				**805.00**											232.08	99.25	51.60						
2312520004	60.23		25.23	182.50	57.89	689.29	62.66	248.82	216.67	19.43	**15.00**		75.20	188.00	414.00	**404.00**			140.33	78.67	275.50	70.00	137.93		300.54	35.00	165.80	20.00					
2304920011	6.40		56.02	251.50	98.95	672.86	62.15	368.97	**406.25**		34.05	186.00	134.00	47.50	167.50	**533.33**			145.00	85.33	228.50	74.67	206.20		**208.08**		202.00	50.00					
2304920005*	21.78				69.47	334.29	46.84	185.00	65.42	106.29	17.95	**187.33**		77.50	134.50	**311.00**		538.33	116.00	75.00	349.50	51.33	222.80		304.62	152.75							
2312120025	13.86		36.93	156.00	91.05	341.43	62.66	356.18	**330.00**		65.84	180.00	134.40	166.50	68.50	**315.00**		429.00	**81.00**		232.50	88.67	146.13		243.62	397.50	104.00						
2312900178	11.55		31.25	111.50	135.26	260.71	50.00	346.03	**263.33**		64.47	125.67	160.00	99.00	261.00	**300.00**		392.33	48.67	41.67	200.00	711.67			219.23	658.75	**139.00**						
2312920006*	129.37								**282.08**		64.37	115.00	203.20	65.50	315.00	**284.33**		323.00	**71.67**		170.50	38.00	121.73		**167.08**								
2312900061	130.53		28.98	118.00	37.89	305.00	50.00	361.03	**245.83**		64.89	195.67	132.40	94.00	180.50	**404.67**		426.00	**107.33**		**480.00**		110.33		182.69	100.00	260.00	34.00					
2306120203	10.40		30.34	119.00	78.95	221.43	50.25	366.91	**230.42**		65.42	118.00	186.60	94.00	193.50	**442.67**		439.00	**123.33**		143.50	56.00	128.73		306.69	470.50	**277.40**						
2306120028	16.34		18.75	122.00	37.37	300.00	58.86	377.21	**233.33**		69.74	128.33	202.00	62.50	220.00	**483.33**		511.67	**123.33**		187.50	48.67	156.80		111.54	114.25	233.60	176.00					
2306120244	9.08		18.75	119.00	81.05	97.14	59.75	363.24	**256.25**		61.53	311.33	79.40	90.00	211.50	**555.33**		435.33	**105.00**		212.50	73.33	150.80		198.77	86.00	21.00	7.50					
2306720002	127.89								**279.17**		66.58	115.33	224.20	71.50	**1064.00**				100.67	44.33	251.00	41.00	**58.80**				159.00						
2315301008*	26.80		20.68	140.50	**1535.26**			270.59	**264.58**		71.21	138.00	189.00	112.50	173.00	**641.00**		455.00	80.67	100.67	**772.50**						175.40						
2315320545	148.35										70.00	108.33	180.00	90.00	225.00	**659.00**		349.33	**174.00**		**291.50**		137.47		139.08	29.00	26.00	99.50					
2315320122	123.37		7.39	132.50	**328.95**			279.12	**261.67**		75.89	85.00	175.80	90.00	169.50	**456.33**		573.33	45.67	94.33	**1447.50**				238.08	1163.75	178.60						
112920054	170.40											120.33	144.40	89.00	193.00	**573.33**		592.00	**66.00**		**2058.00**					442.50	104.20						
112920024	17.76		8.75	102.50	**256.32**			281.32	**254.17**		59.95	115.67	119.60	90.00	209.00	**544.33**		295.00	**60.00**		315.00	47.67	103.00		226.54	489.75	86.40						
112920012*	175.74											56.00	176.20	78.00	220.00	**563.33**		356.67	**96.67**		285.00	50.67	102.20		240.38	577.50	20.00	470.00					
Dip Section B-B'																																	
2309320011	70.40								**332.08**		48.42	**231.00**			155.00	**350.00**									48.08	39.25	112.40	**12.00**					25.07
2305120020	91.95								**350.83**		48.26	**242.00**			94.50	**820.33**									53.77	45.00	**118.60**						
2305120036	111.55								**354.17**		48.42	248.33	58.00	78.50	182.50	**177.00**			**69.67**		**760.00**				137.54	61.25	**146.00**						
2316300049	15.91				56.32	415.00	67.72	307.65	**359.58**		52.11	231.67	93.40	75.00	204.00	**269.67**			**41.33**		**946.00**				171.15	127.50							
2316320150	13.37			272.50	69.47	447.14	63.80	324.71	304.17	170.00	32.53	225.67	86.20	62.00	163.00	**458.67**			**51.33**		524.50	56.67	70.33		234.62	145.00	**285.00**						
2308920043	14.46			266.50	78.42	535.71	63.42	310.44	195.00	307.14	35.79	298.33	55.80	47.00	183.50	**670.00**			63.33	93.33	265.00	90.00	187.47		238.31	61.75	195.60	60.50					
2304920005*	21.78				69.47	334.29	46.84	185.00	65.42	106.29	17.89	**187.67**		77.50	134.50	**278.00**		571.33	116.00	75.00	349.50	51.33	222.80		304.62	152.75	296.20	152.50					
2304920004	13.20		57.16	253.50	98.95	629.29	76.71	427.50	**265.83**		48.32	193.00	152.60	80.00	275.00	**93.33**		573.33	166.00	118.00	300.50	83.00	188.20		250.77								
2304920032	20.03		55.68	251.50	95.79	664.29	74.94	457.21	**384.17**		36.58	169.00	162.60	883.50	1003.50	**386.00**		581.67	166.33	140.33	243.50	66.67	203.33		287.69	665.75	210.60						
Dip Section C-C'																																	
2310100014	71.22								**246.67**		49.26	131.33	180.60	27.50	155.00	**450.67**			**26.67**		**166.50**		77.20		**31.46**								29.93
2310120005	106.77										54.47	112.00	187.60	33.00	191.00	**681.67**	134.25	179.00	**36.00**		**948.50**				107.15	106.75	57.60	**165.00**		**110.00**		9.87	43.92
2312900015	106.60								**265.83**		58.53	103.33	186.60	67.50	149.50	**328.00**		351.00	18.67	65.00	**1030.00**				192.00	208.50	145.00						
2312920057	184.72											102.67	183.40	64.00	178.00	**383.67**		351.00	79.00	37.67	**1262.50**				201.92	150.00	189.00	35.50					
2312920006*	129.37								**282.08**		64.37	115.00	203.20	64.50	317.50	**283.33**		323.00	**68.00**		176.00	**646.67**			**167.08**								
2312920122	215.84											116.67	186.00	65.00	206.00	**324.33**		610.00	71.67	46.67	181.00	70.67	162.40		201.54								
2312720055	180.66								**229.58**		68.37	118.33	194.20	60.00	230.00	**1039.33**	397.00	529.33	63.33	89.00	160.00	111.67	**114.67**				156.00						
2306520141	222.67										54.11	133.67	161.80	82.50	**1067.50**			429.33	123.33	120.67	252.50	71.67	200.00										
Dip Section D-D'																																	
2302300270	53.07								**223.75**		50.26	152.67	146.40	37.50	200.00	**245.67**			**42.00**		**806.00**				134.46	18.00	**21.00**						31.60
2302320114	73.27								**241.67**		55.26	123.33	172.60	62.50	198.50	**375.00**		410.67	**46.00**		**877.00**				156.46	120.50	108.00						
2315320042	164.03											120.67	198.00	76.50	167.50	**491.67**		461.67	**119.33**		**1239.50**				199.85	176.25	83.40						
2315320265	128.05										63.42	116.67	203.00	78.50	166.50	**508.33**		475.00	**30.00**		240.00	116.67	62.67		**89.77**		27.40						
2315320232	192.24												166.40	96.50	209.00	**464.00**		488.33	85.67	114.33	177.50	137.33	**338.47**			375.75	214.00						
2315301008*	26.80			140.50	**1535.26**				**264.58**		71.21	138.00	189.00	87.50	223.00	**624.33**		455.00	80.67	100.67	**772.50**						175.40						
2315320077	164.69										76.84	114.00	157.60	105.00	201.00	**622.67**		458.33	128.33	95.00	201.00	62.00	170.60		252.00	1103.50							
2311100069	53.93			**266.50**			**331.65**		**319.17**		66.16	**202.00**		238.00	414.00	265.67	293.25	410.00	135.00	**158.33**		178.33	163.67		190.00	240.00	177.00	10.00					
2304520075	232.18								**402.92**		48.68	43.33	94.00	155.00	280.50	343.00	425.00	370.00	186.67	**287.33**			223.87		209.23								
Dip Section E-E'																																	
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102320197	95.71										54.95	116.00	182.20	75.50	202.50	**477.67**		298.33	**53.00**		**1121.00**				154.77	375.75							
112920012*	175.74											56.00	176.20	78.00	220.00	**563.33**		356.67	**96.67**		285.00	50.67	102.20		240.38	577.50	20.00	470.00					
112920051	125.74							281.62	**333.75**		77.63	106.33	147.40	118.50	200.50	**615.00**		288.00	114.67	**177.00**		57.67	**270.80**			542.75	49.60						
109720134	194.29											95.67	138.00	134.50	177.00	**692.67**		369.67	72.00	**233.33**		45.00	116.33		229.85	538.50	26.60						
109720141	202.18											111.33	80.80	193.00	270.00	**648.33**		365.67	77.00	**232.33**		56.67	119.33		224.85	444.75							
109720299	181.39										90.21	160.67	137.60	202.50	267.50	**470.00**			39.00	**267.67**		44.67	134.40		215.62	361.50	29.00						
MAX	232.18		57.16	272.50	135.26	689.29	44.56	457.21	304.17	307.14	90.21	311.33	224.20	883.50	1003.50	343.00	425.00	610.00	186.67	140.33	524.50	711.67	223.87		306.69	1163.75	296.20	470.00				9.87	43.92
MIN	6.40		7.39	102.50	37.37	97.14	58.19	143.53	65.42	19.43	17.89	43.33	55.80	27.50	68.50	265.67	293.25	179.00	18.67	37.67	143.50	38.00	62.67		48.08	18.00	20.00	7.50				9.87	25.07
MEAN	101.44		30.45	171.22	77.09	416.52	76.71	304.92	176.37	141.83	57.40	139.34	154.49	107.55	224.53	304.33	359.13	427.63	98.55	85.04	250.25	93.18	146.10		205.67	298.67	122.56	132.13				9.87	32.63

U.TERTIARY 101.44

L.TERTIARY = 174.39
sandstones = 297.56
shales = 90.16

U. CRETACEOUS = 164.61
sandstone = 205.67
shale = 107.55
limestone = 57.40

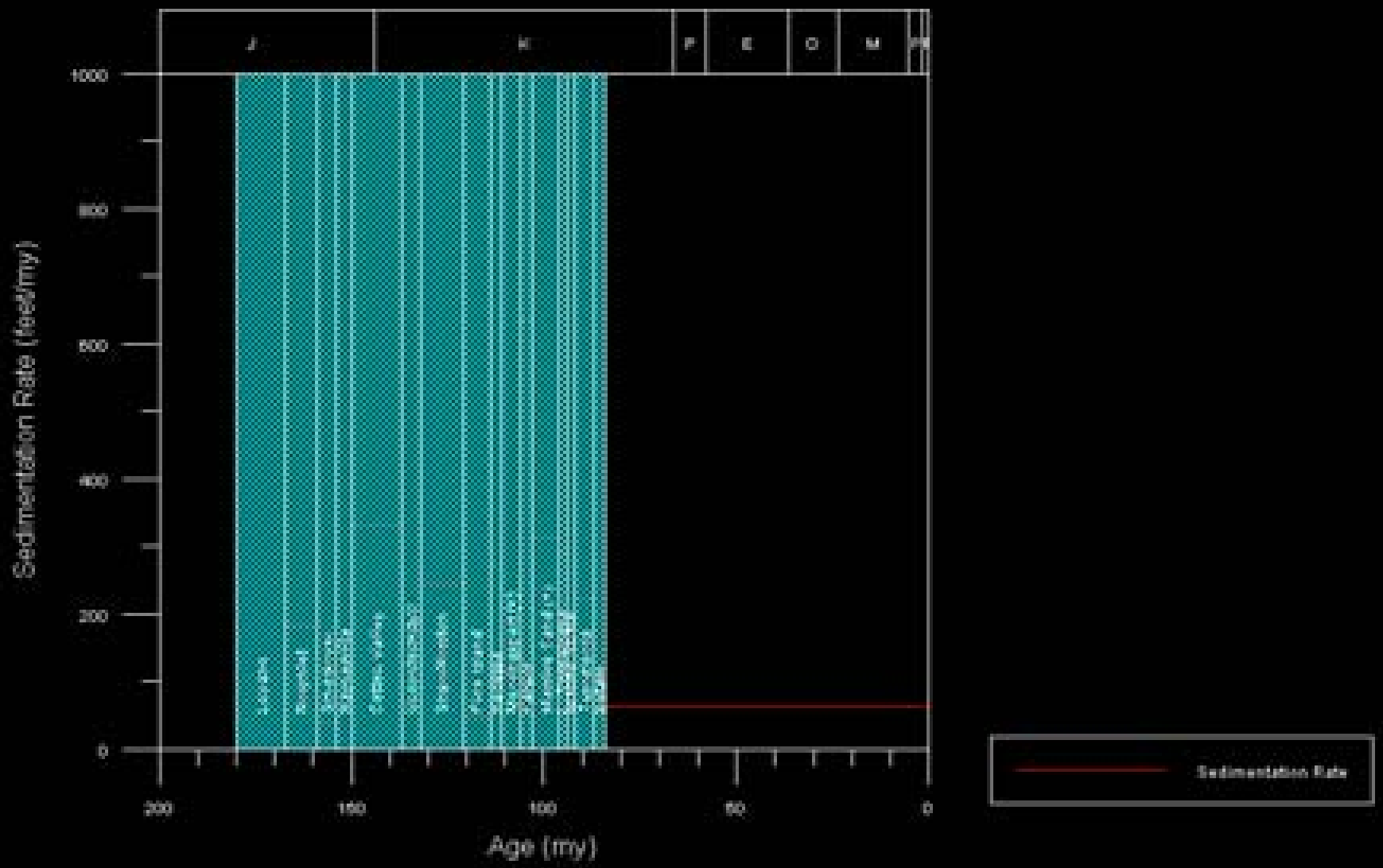
L. CRETACEOUS = 208.55
sandstone = 310.95
shale = 95.87
anhydrite = 85.04

JURASSIC = 189.76
sandstone = 168.90
shale = 298.67
limestone = 122.56

[light blue box] = NOT REACHED OR RECORDED BY LOG

[grey box] = MISSING INTERVAL OR PICK NOT MADE

01-129-20012 SED RATE



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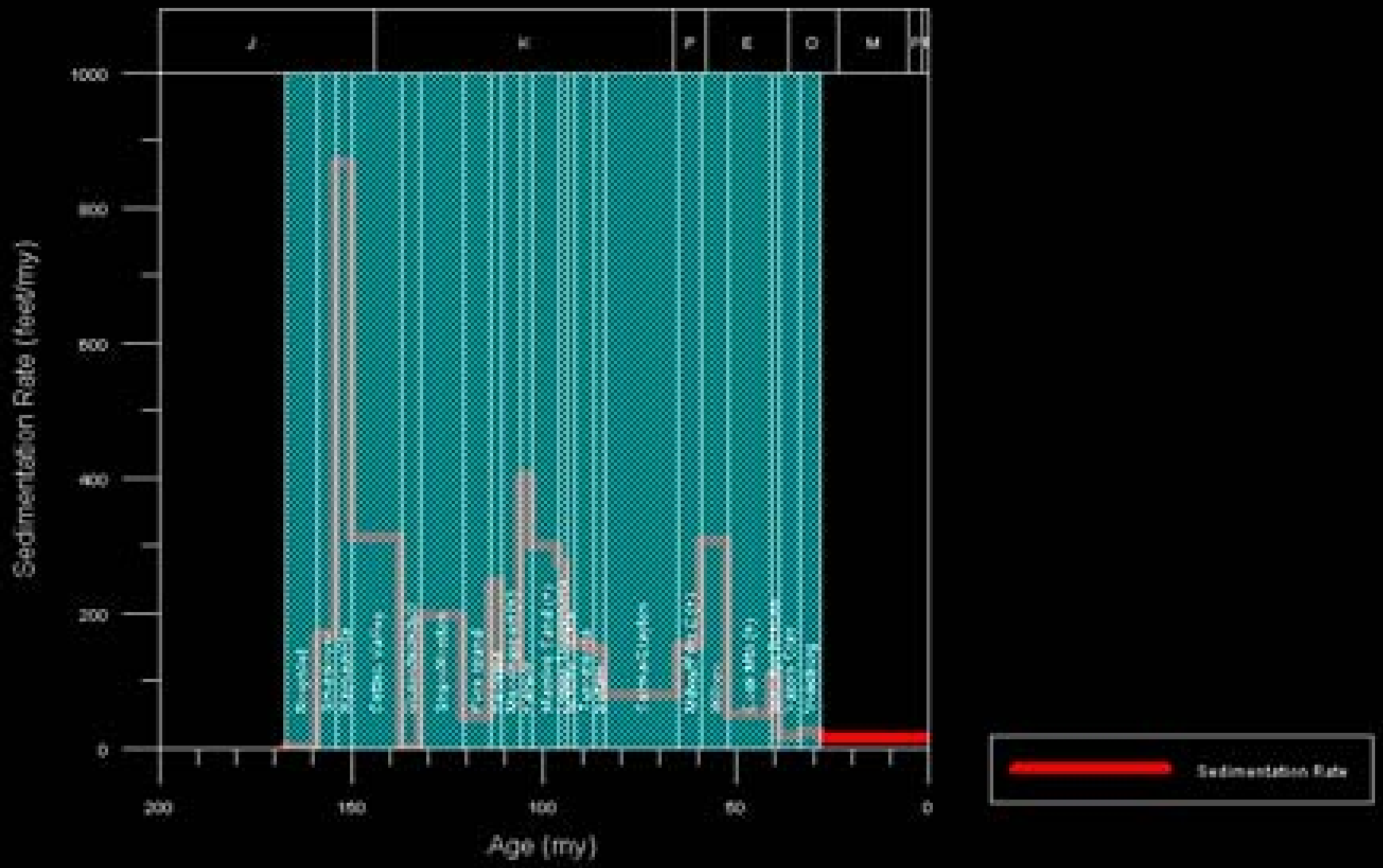

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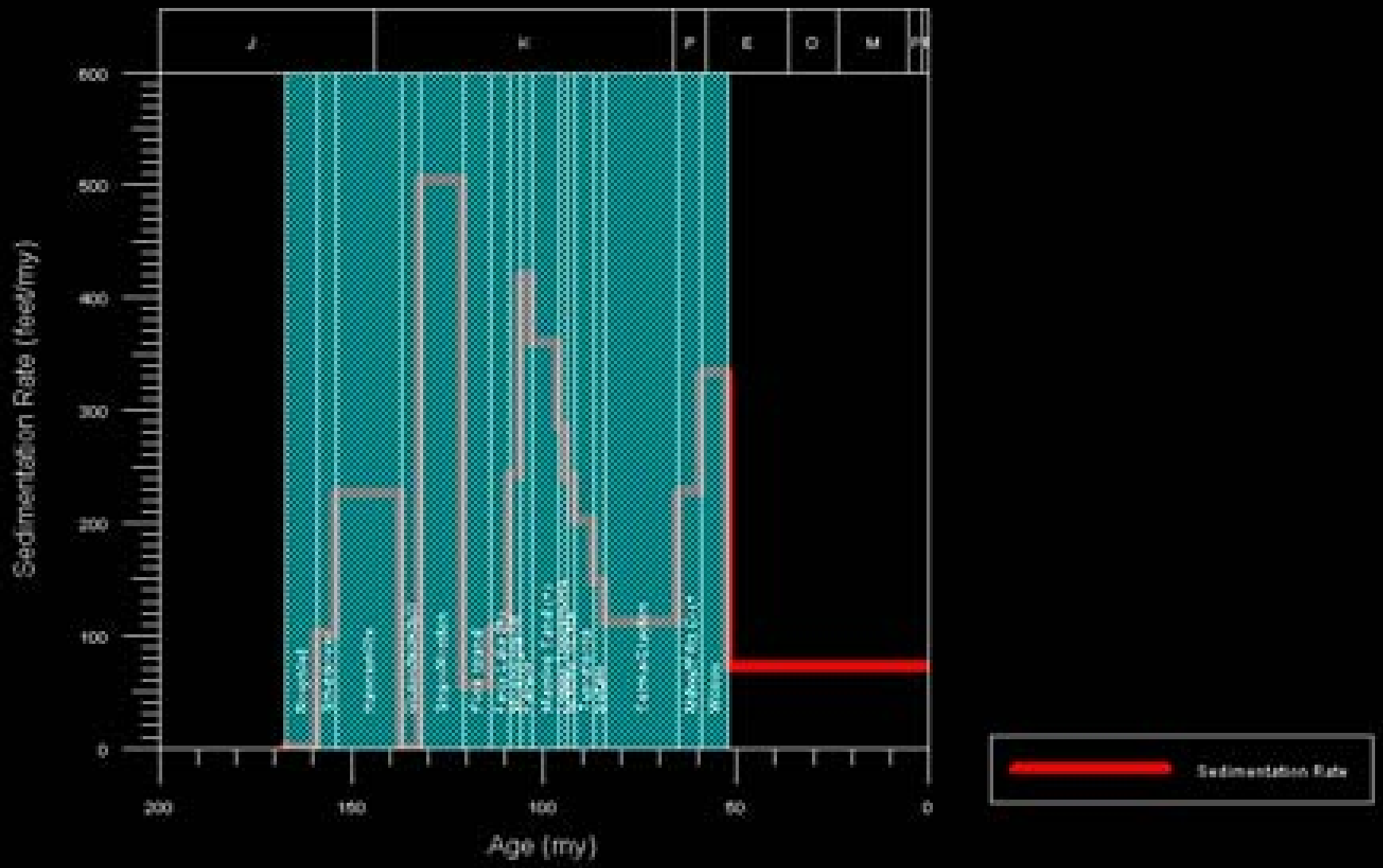

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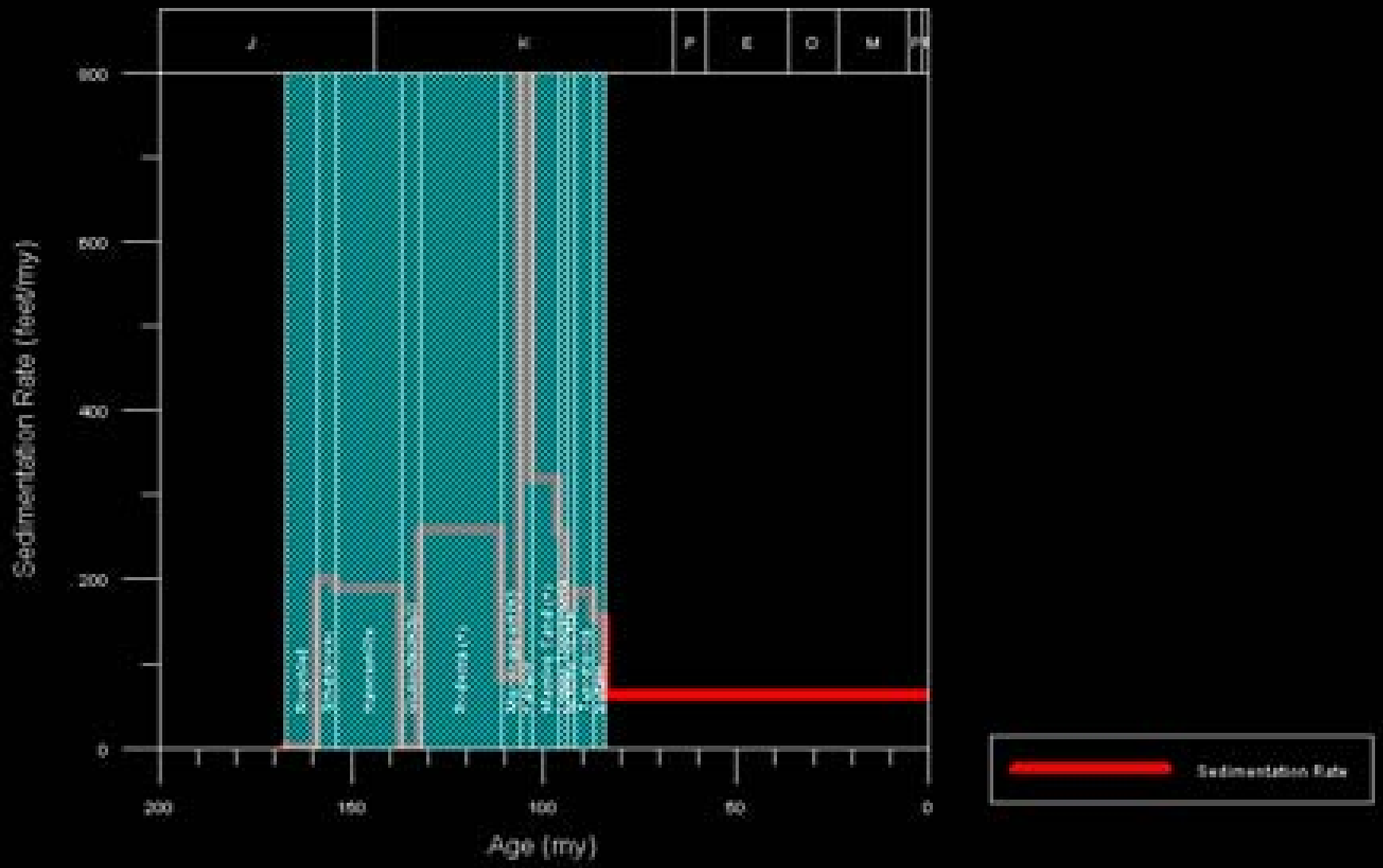
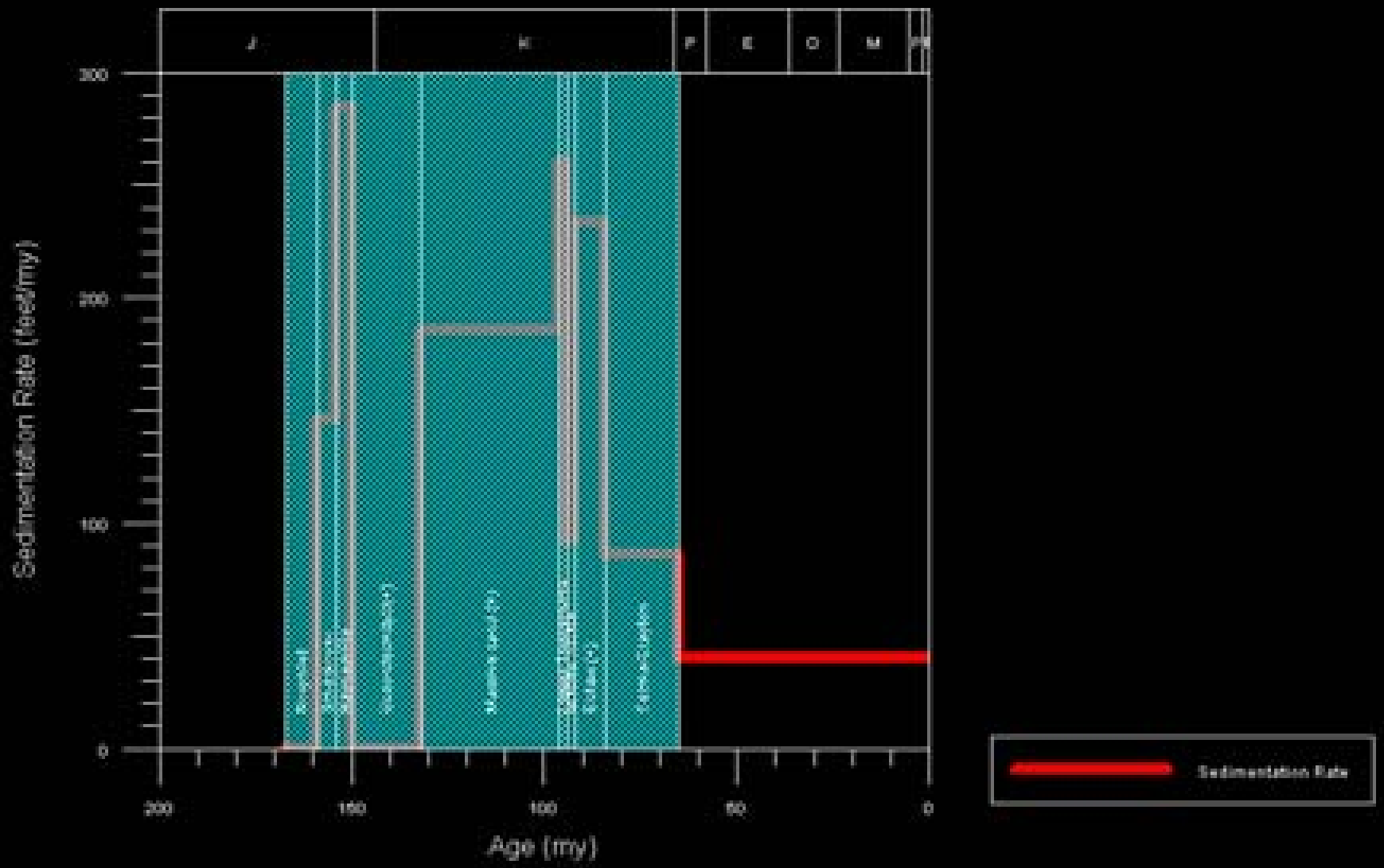
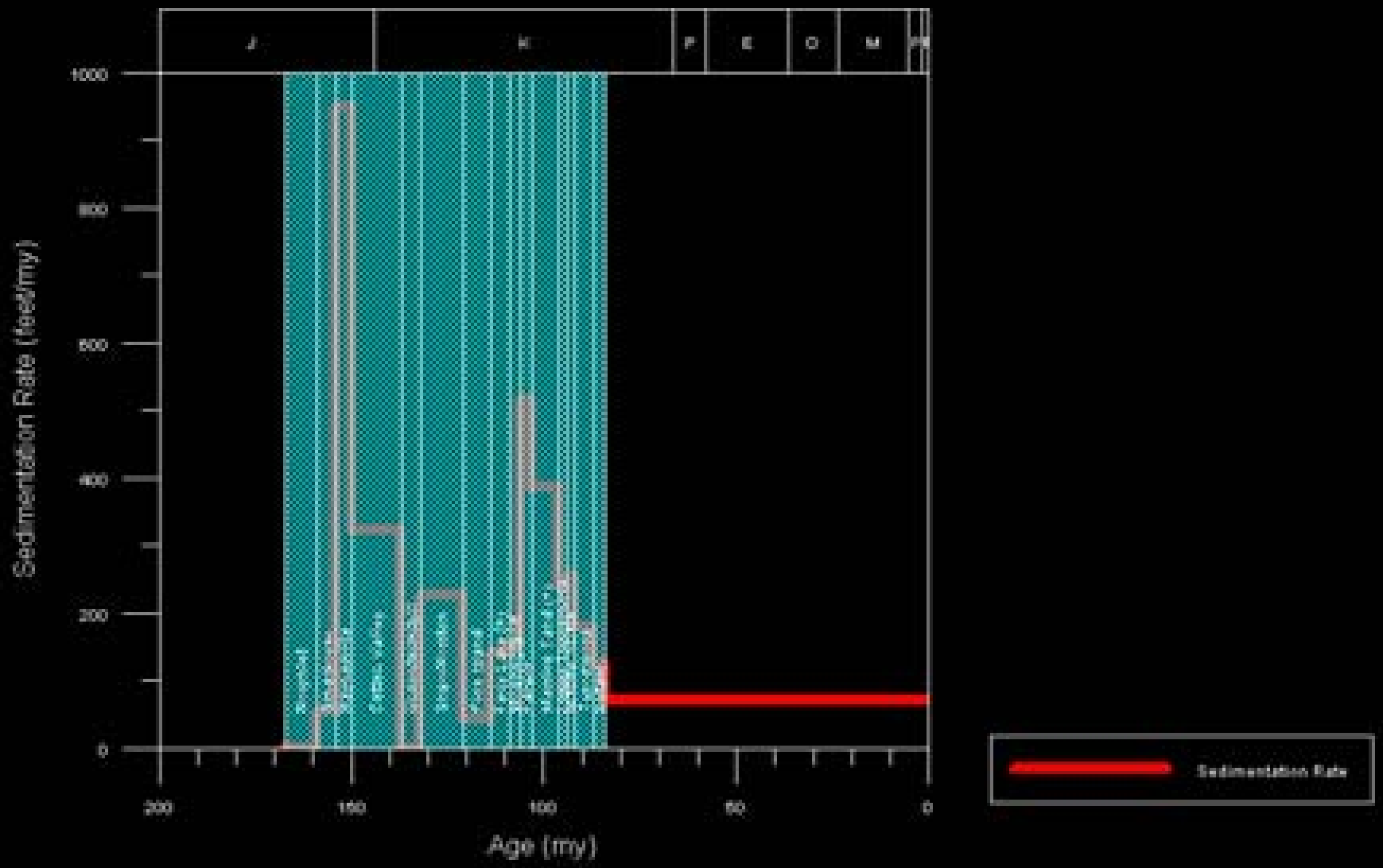


01-023-20114 SED RATE



01-097-20134 SED RATE



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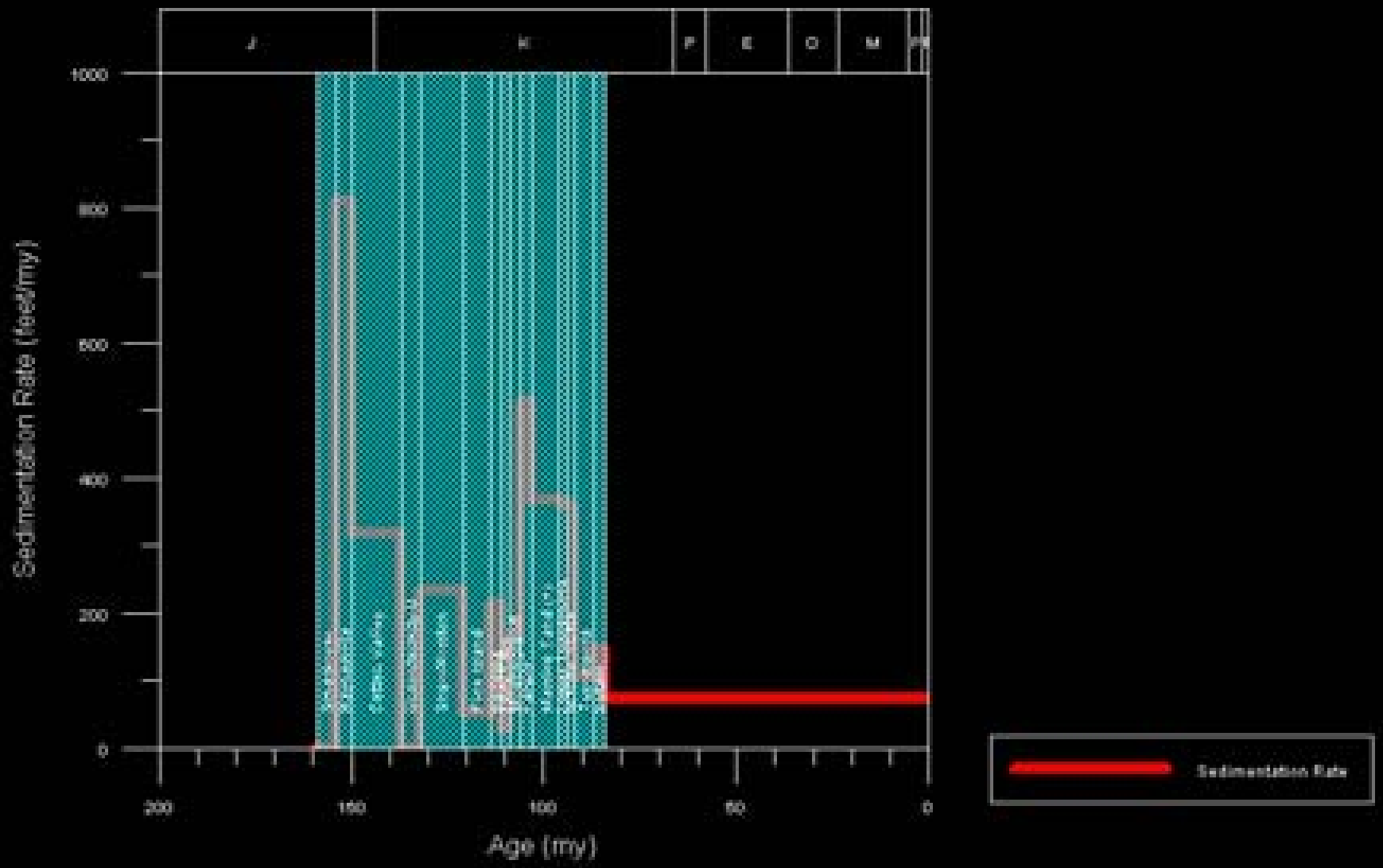

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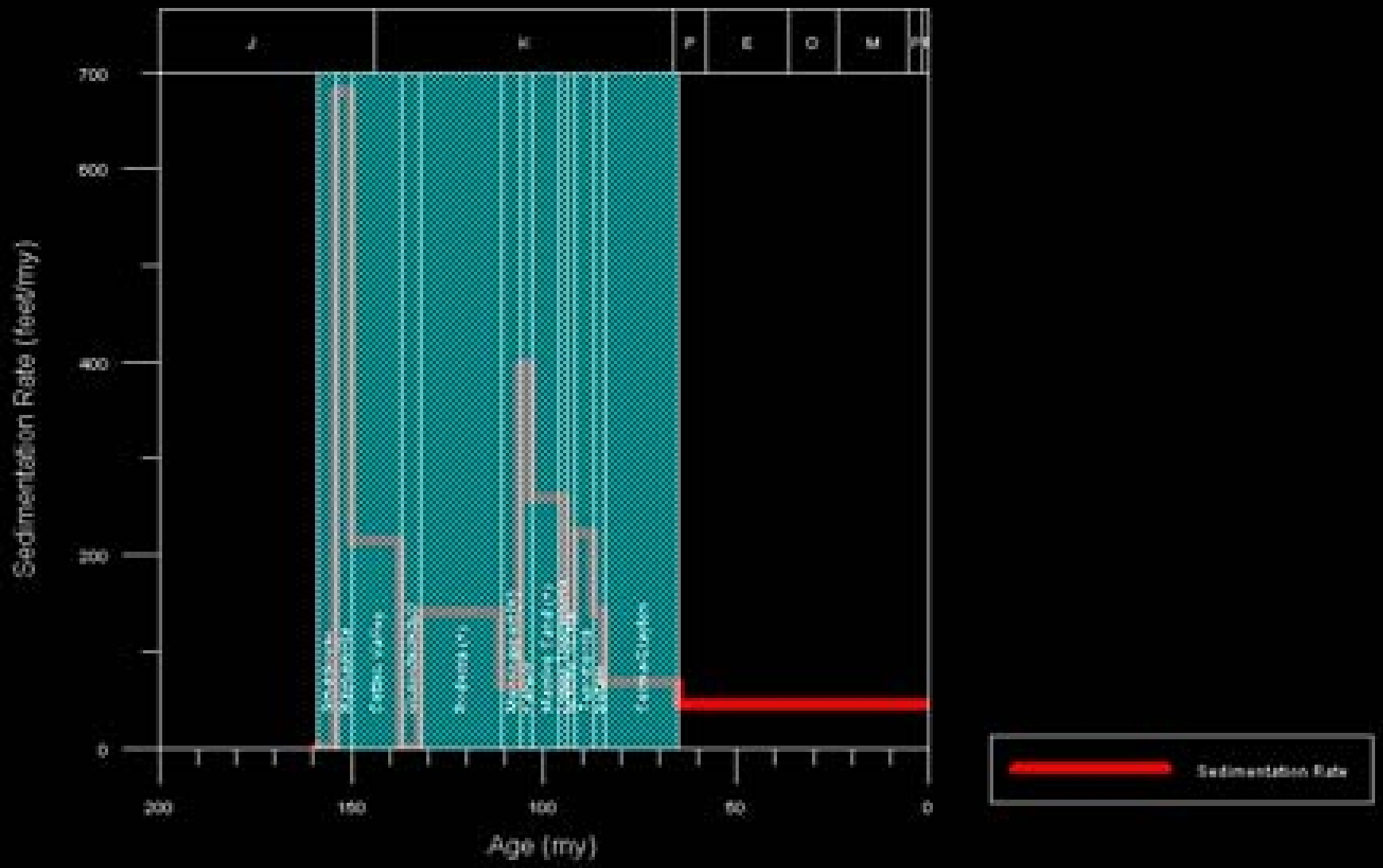

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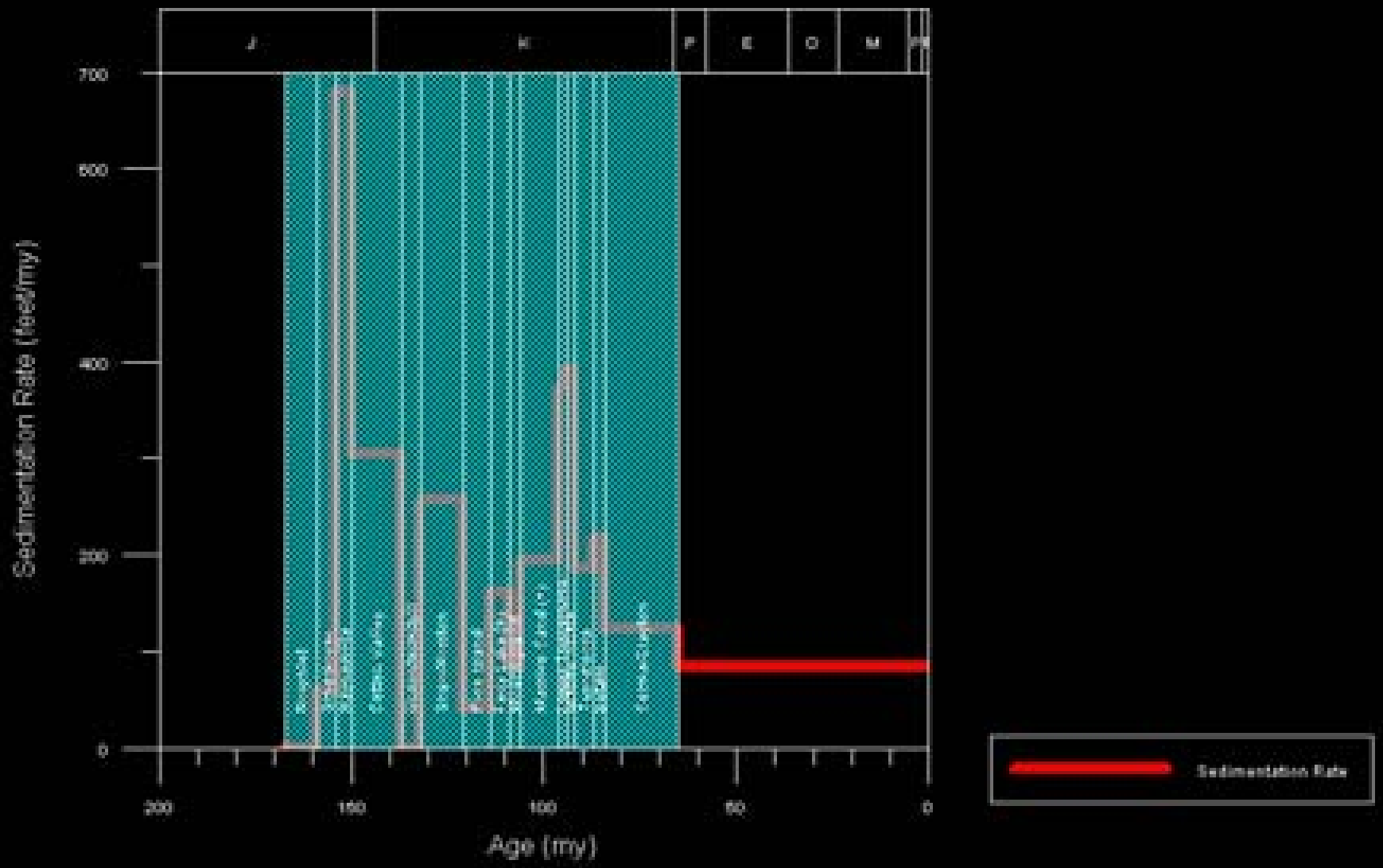

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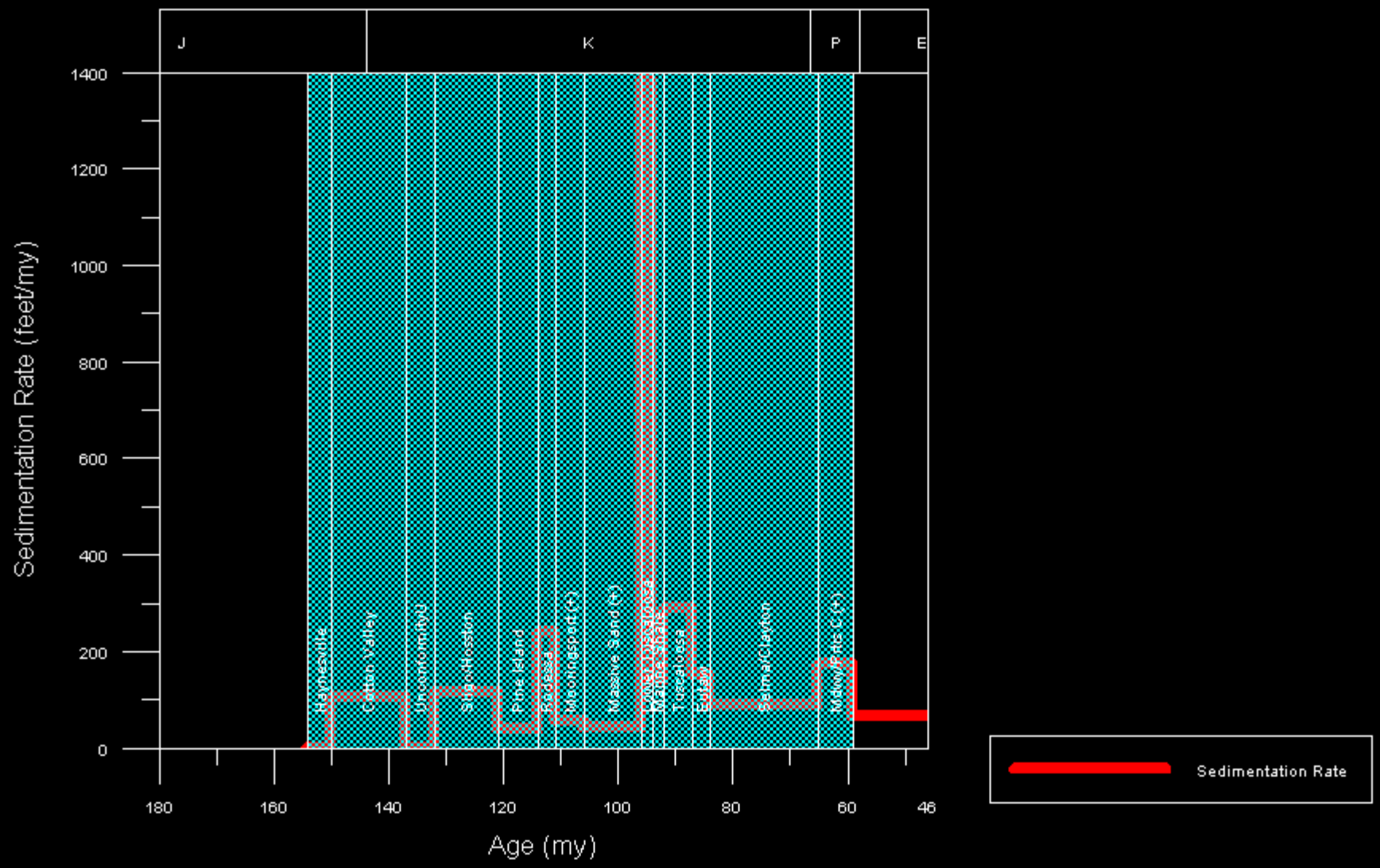
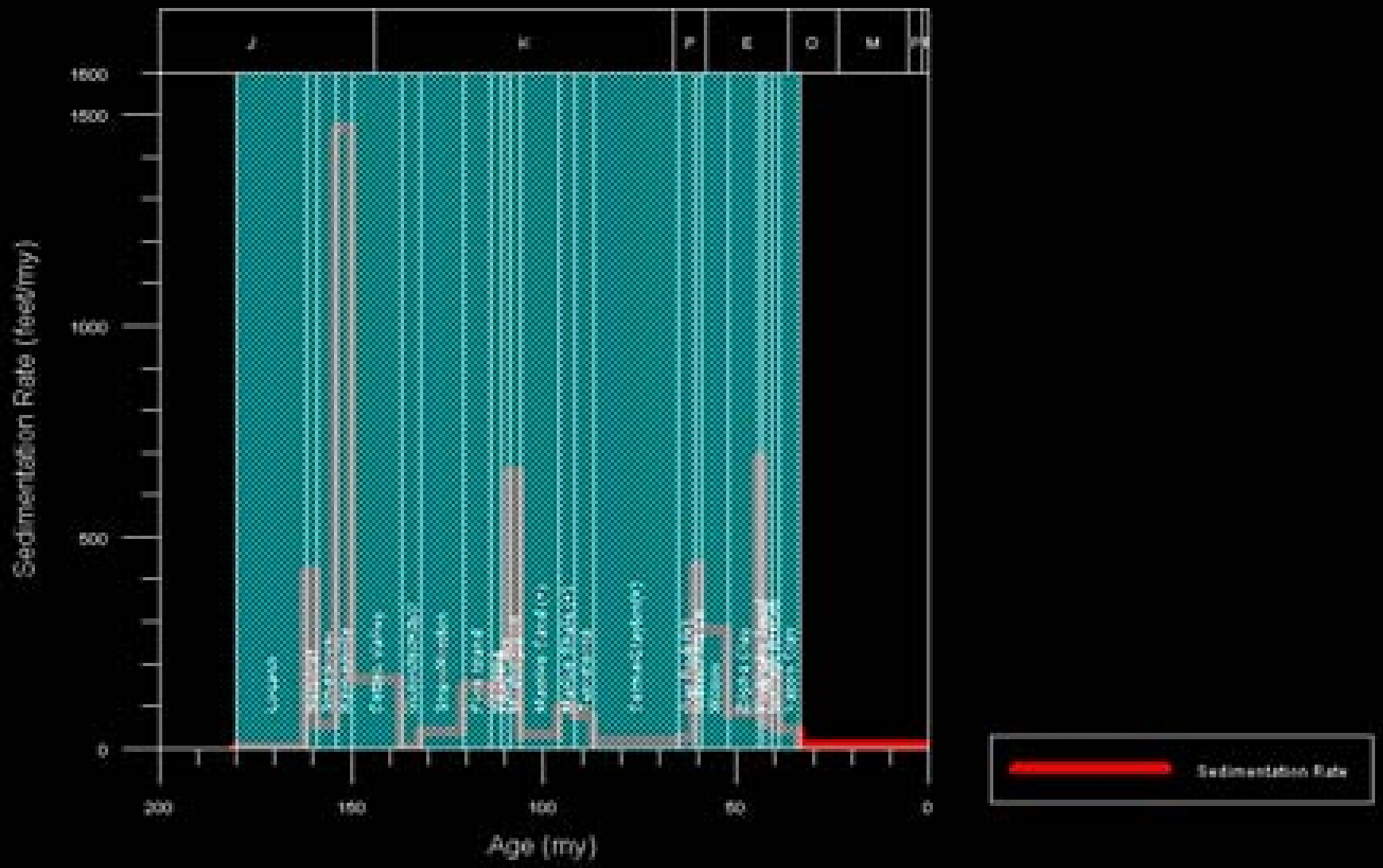
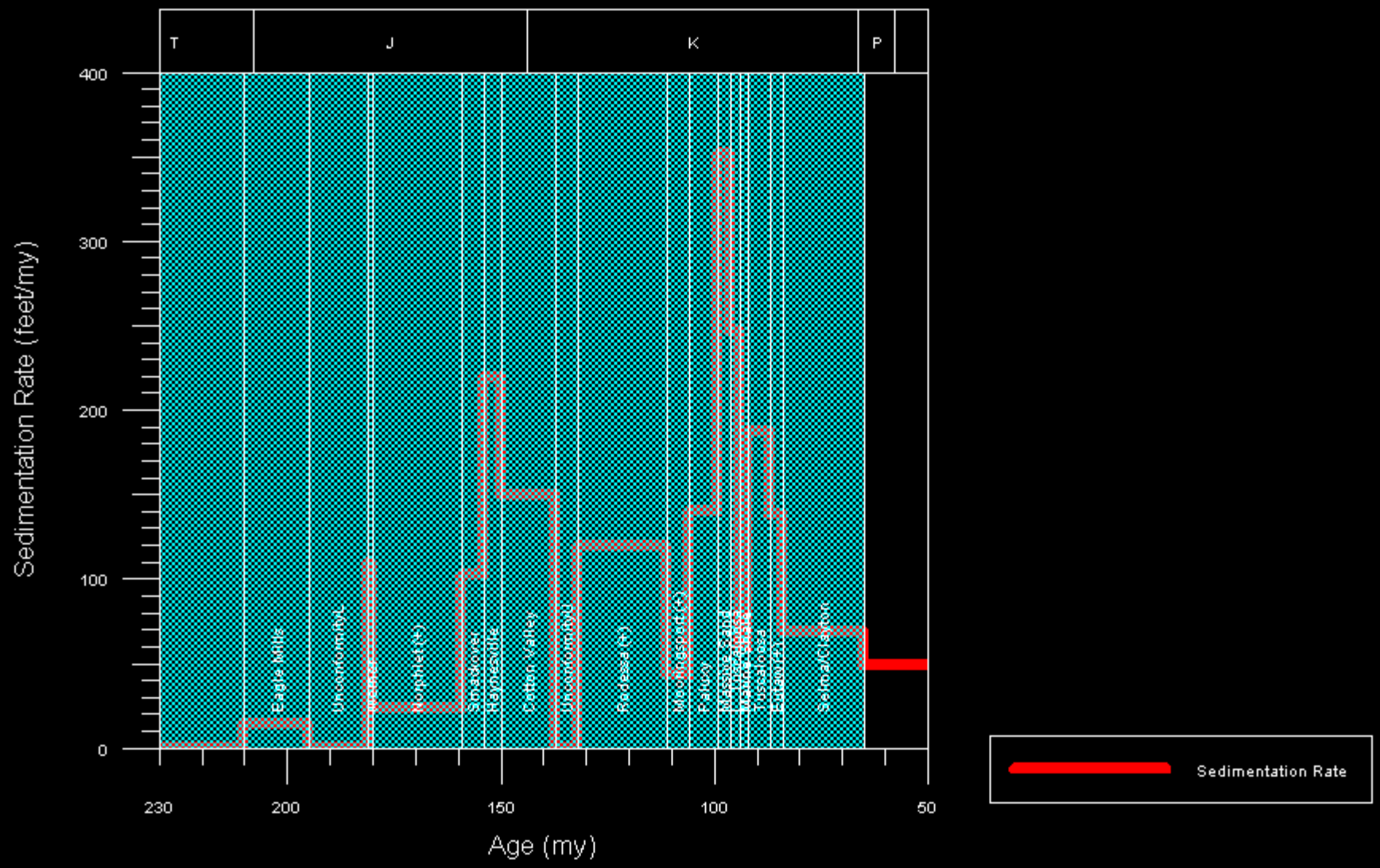


23-125-20004 SED RATE



23-101-20005 SED RATE



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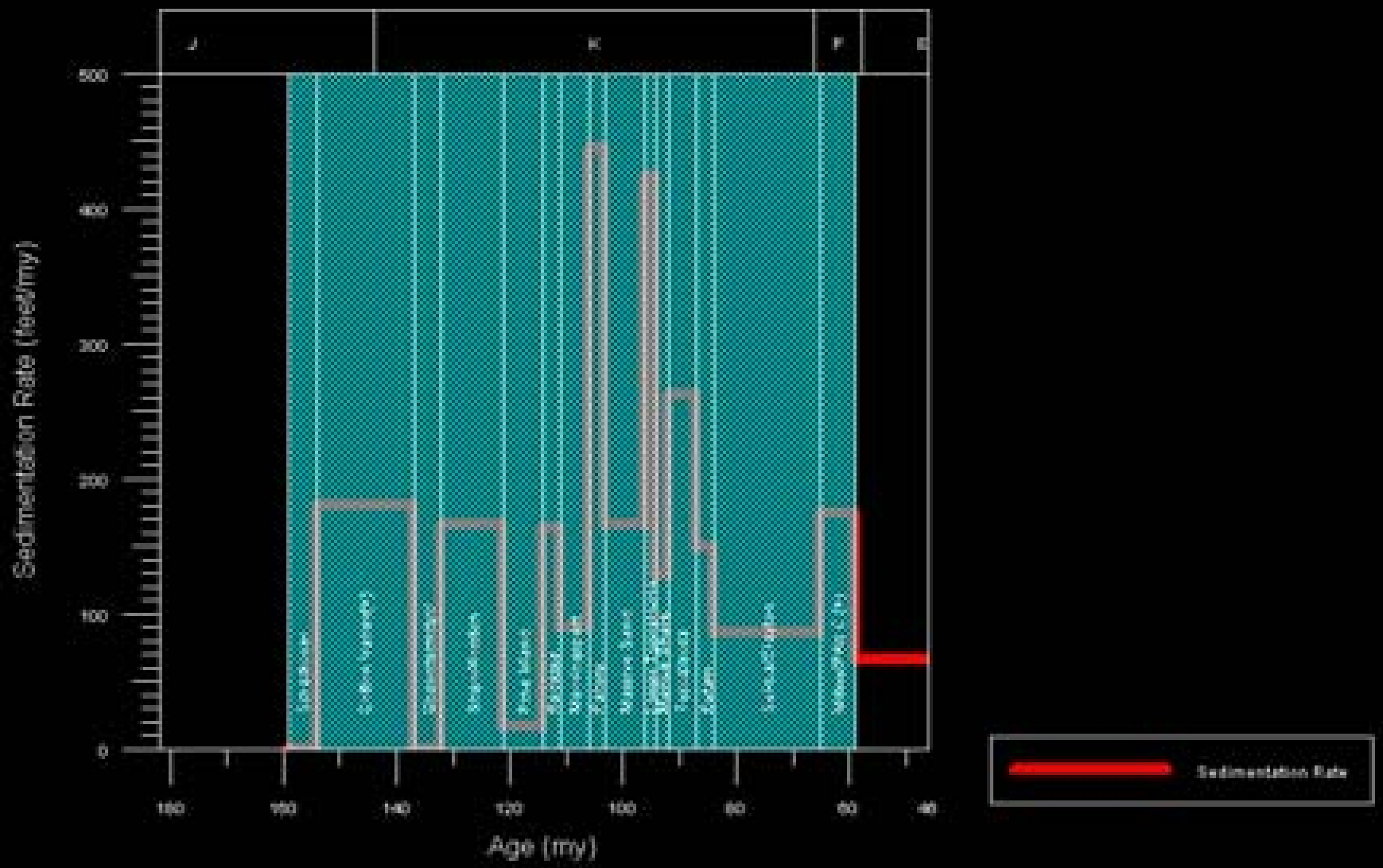

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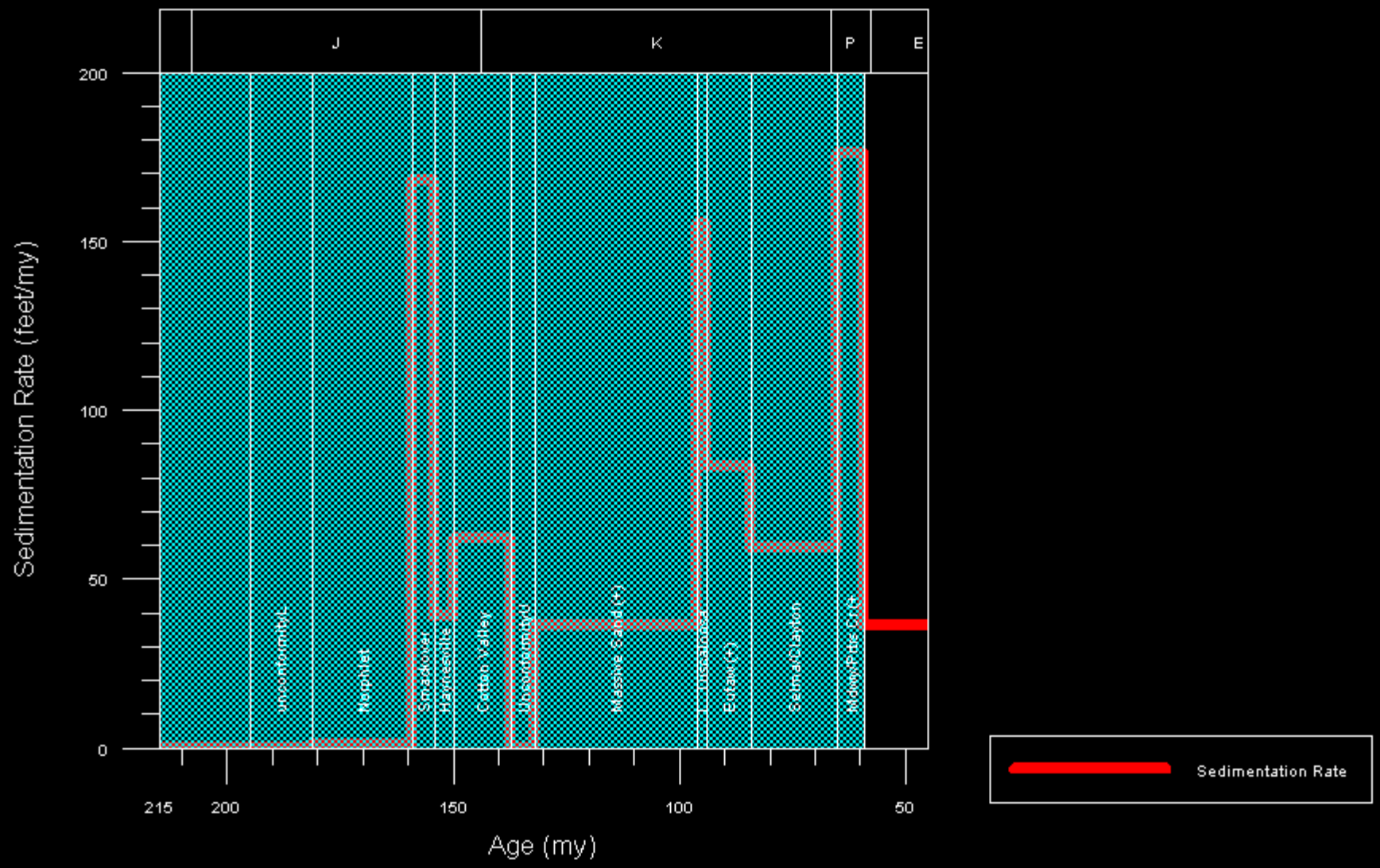

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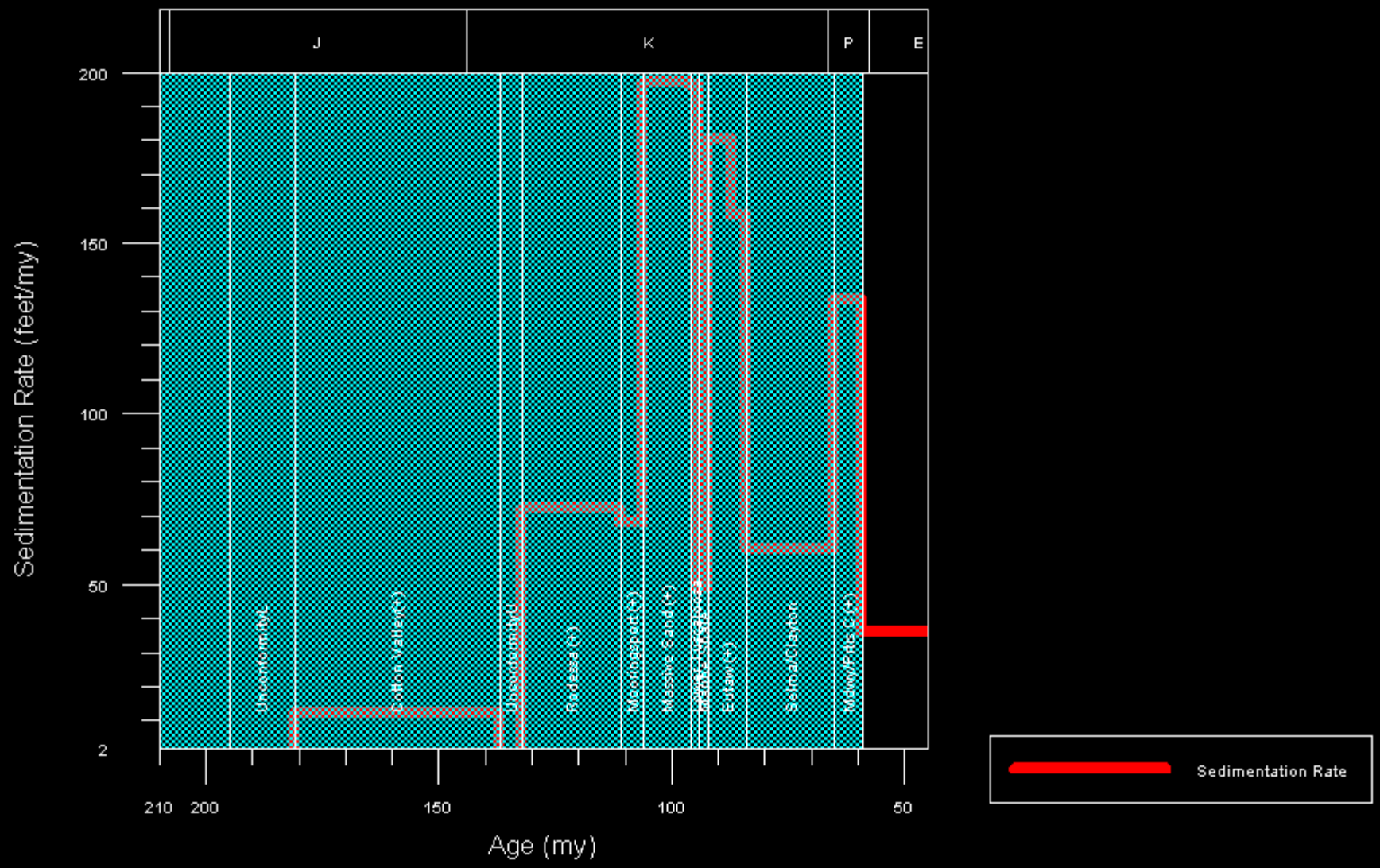

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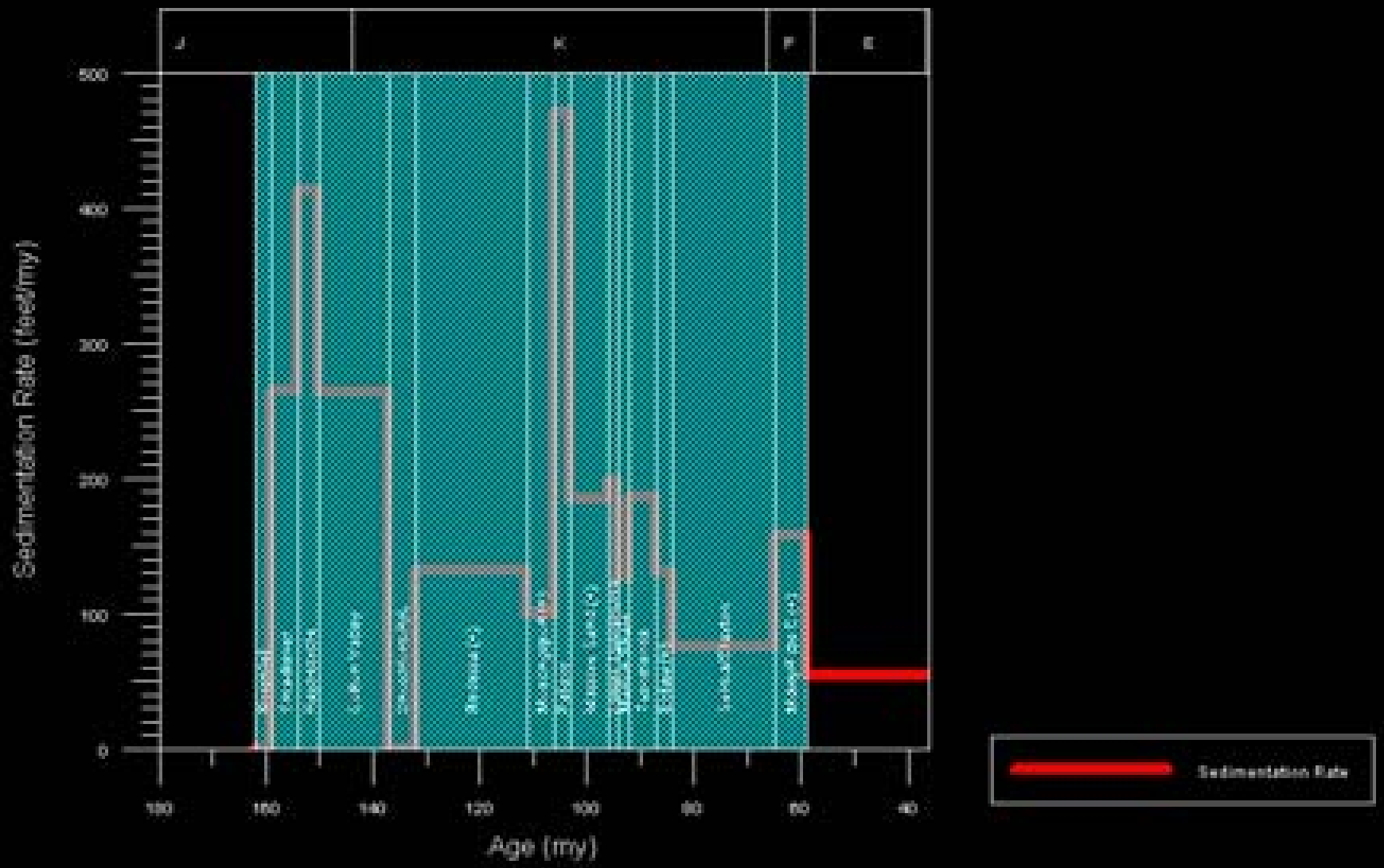

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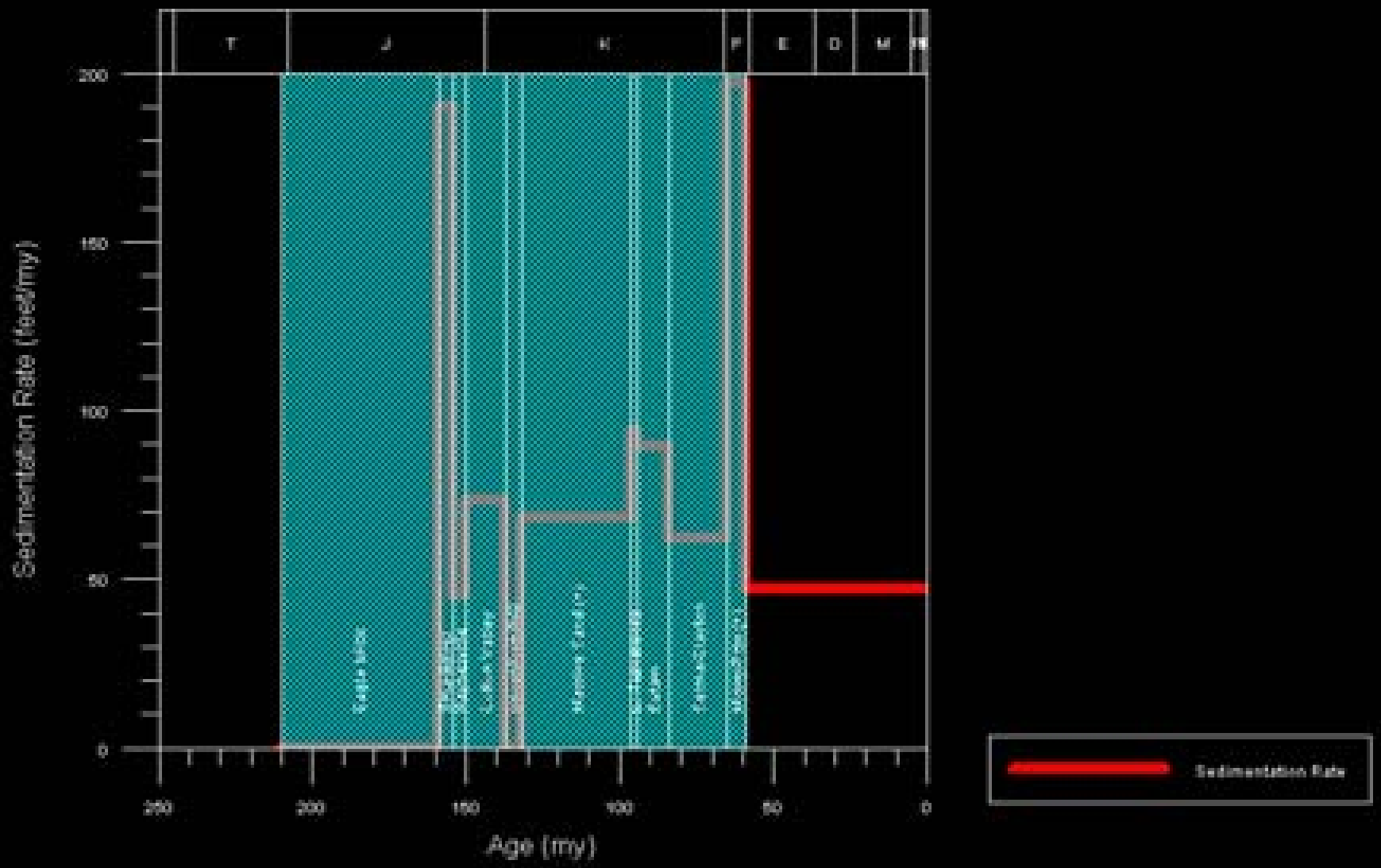
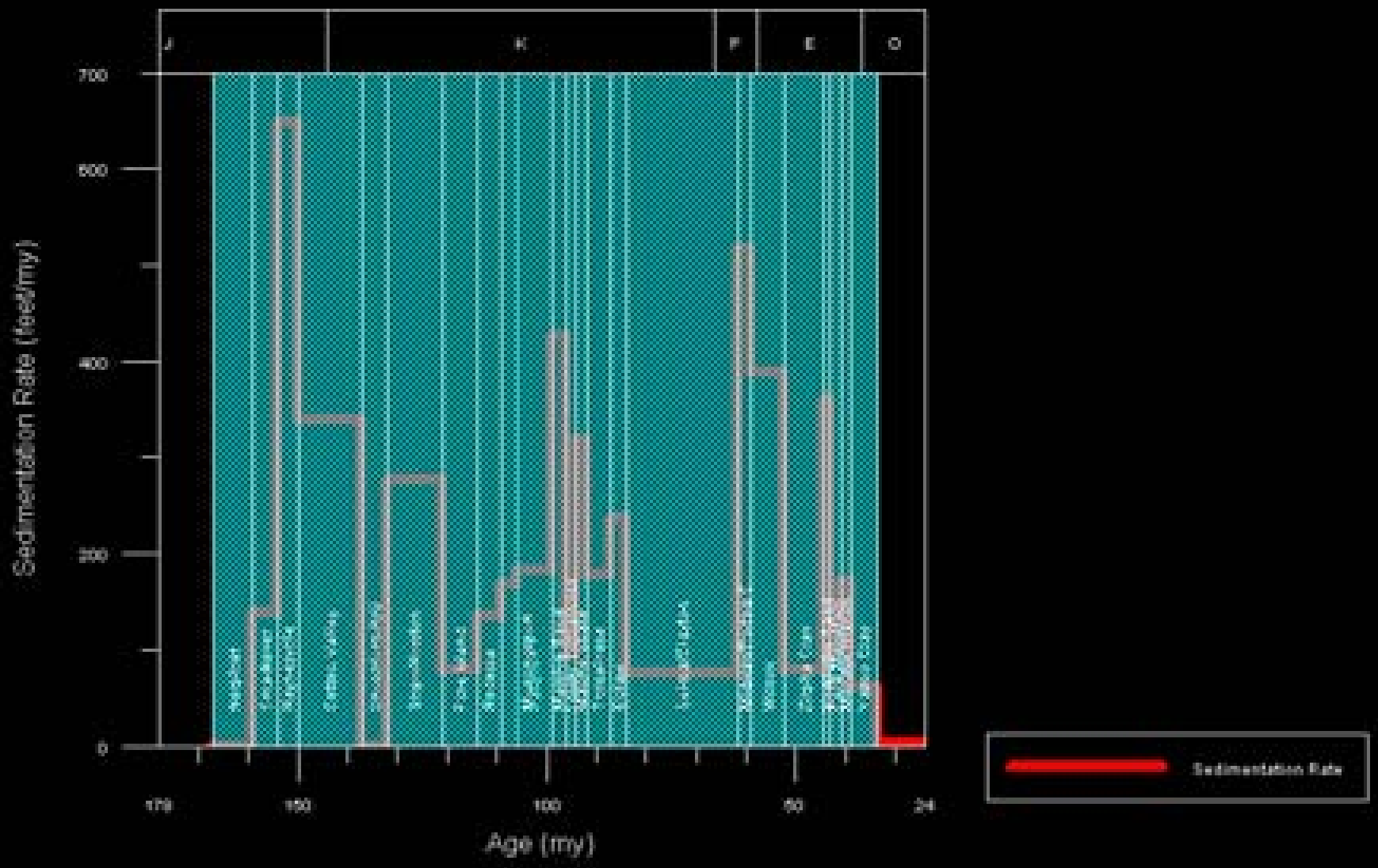
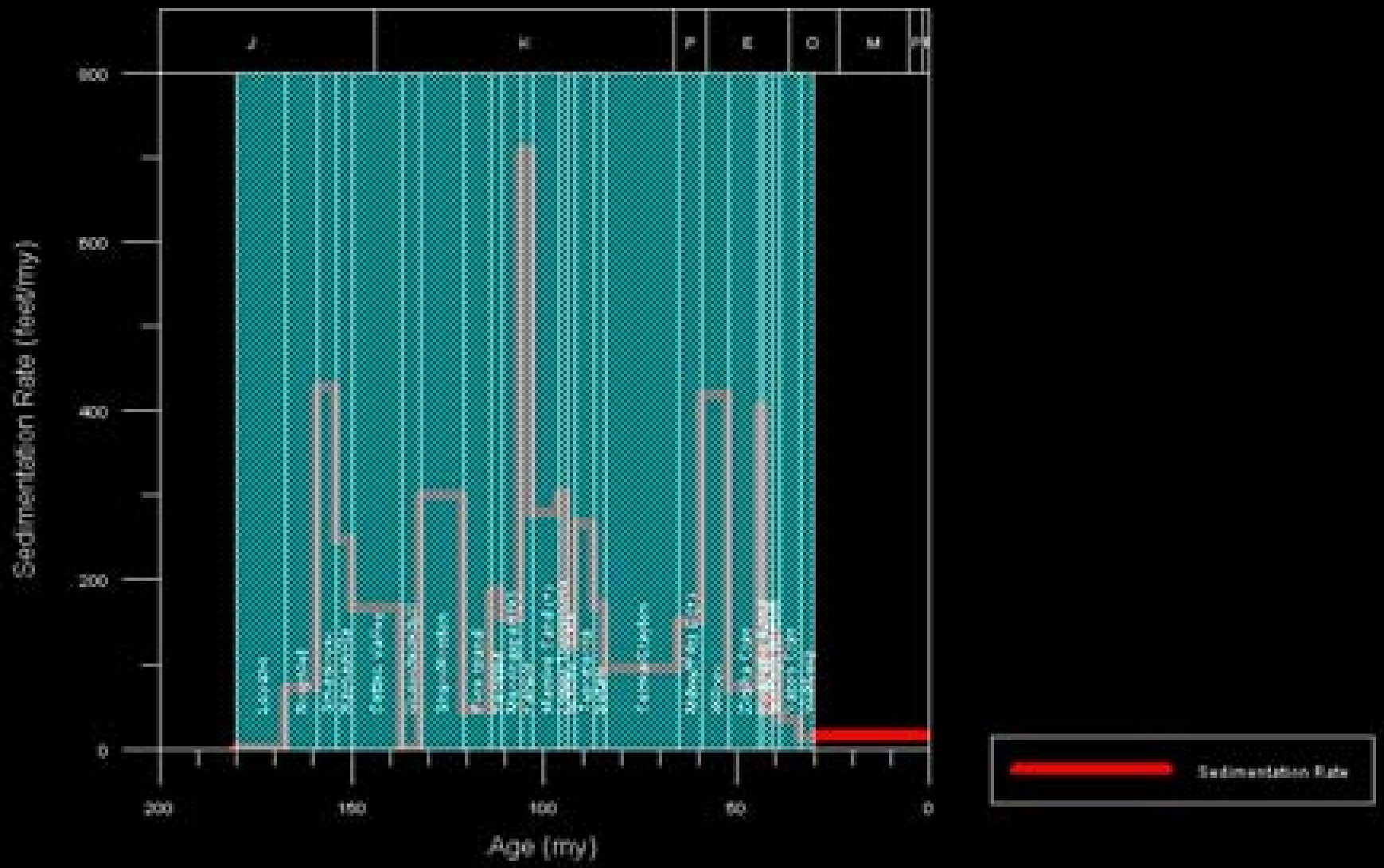


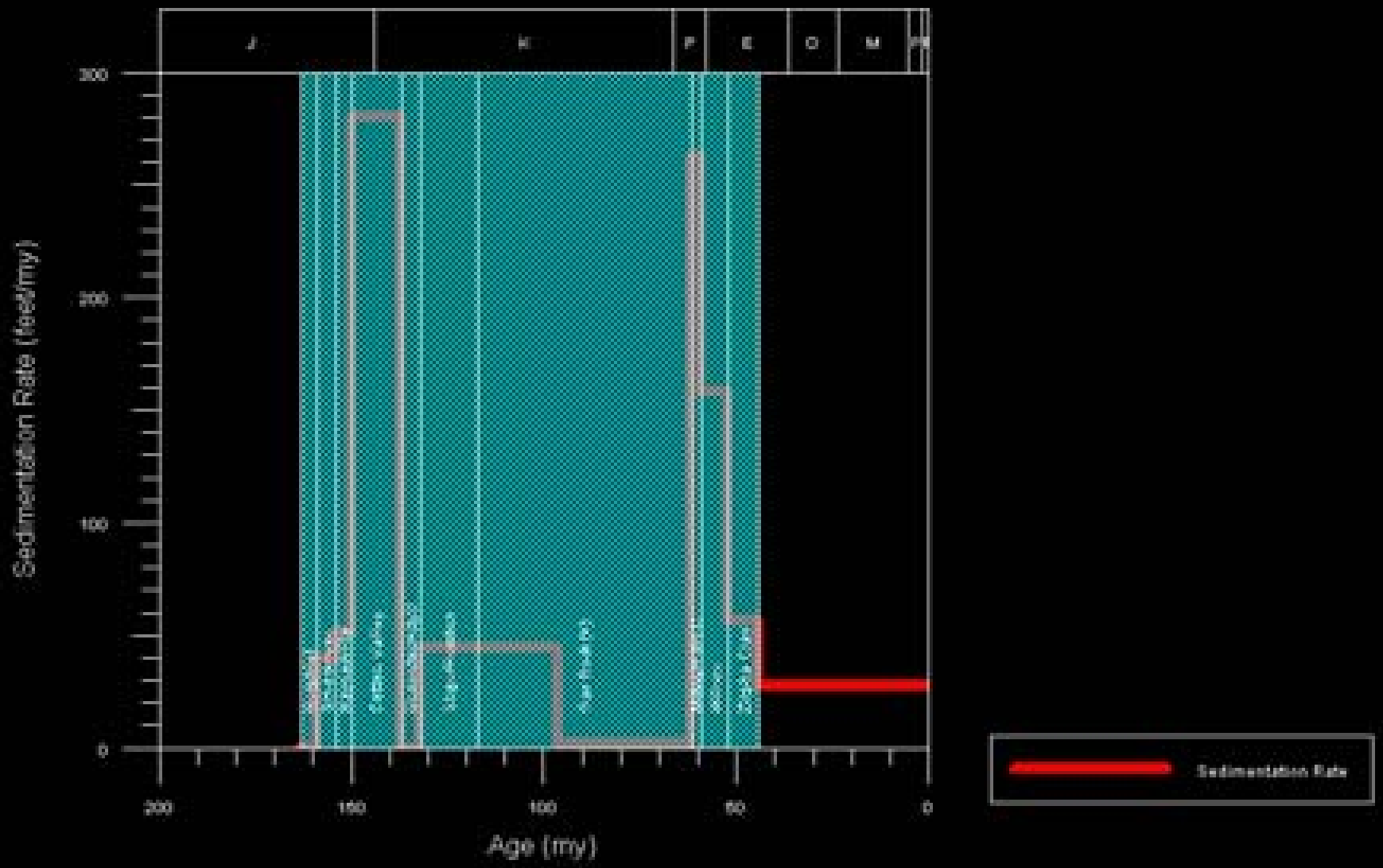
23-121-20025 SED RATE



23-061-20028 SED RATE



23-055-00032 SED RATE



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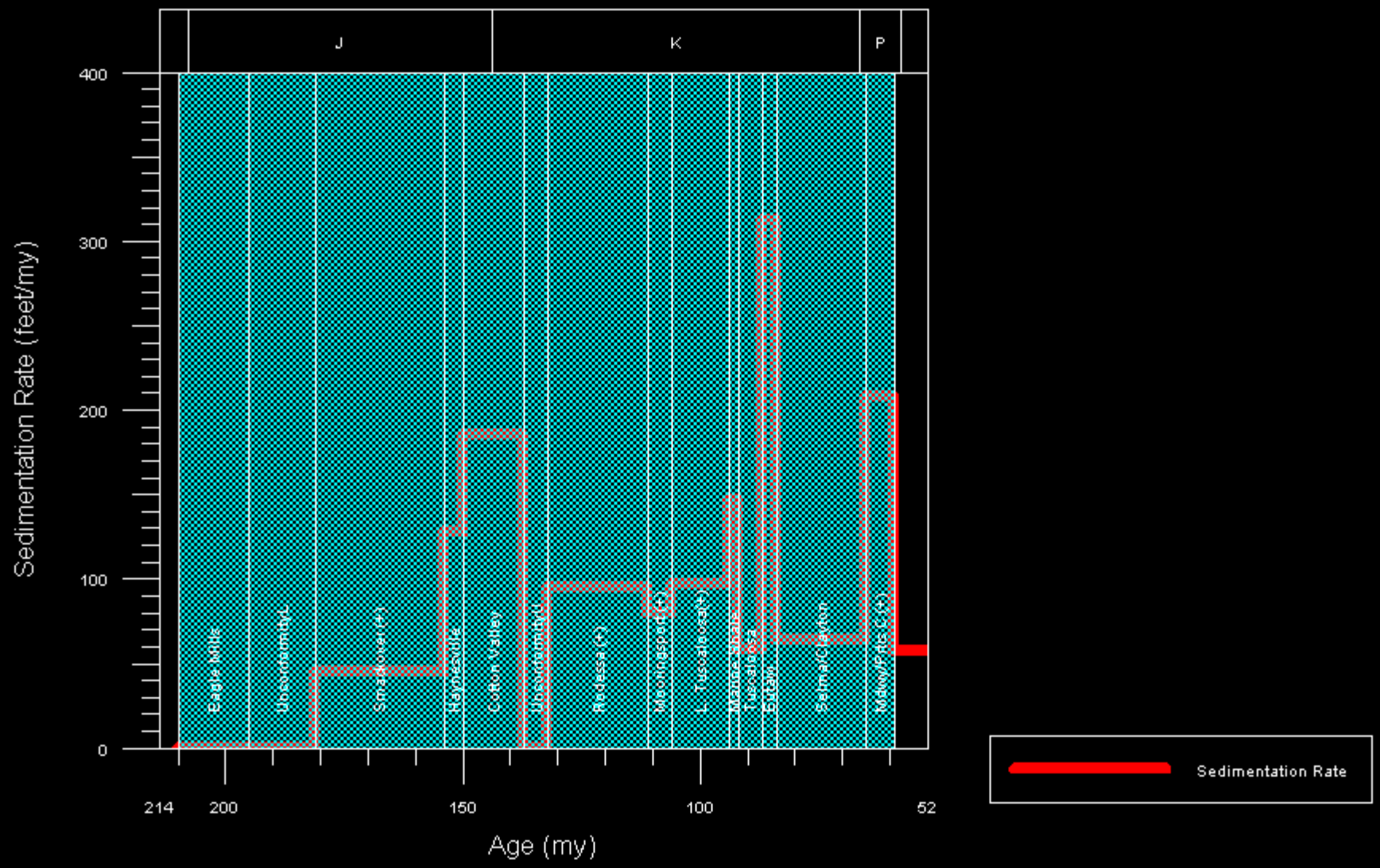
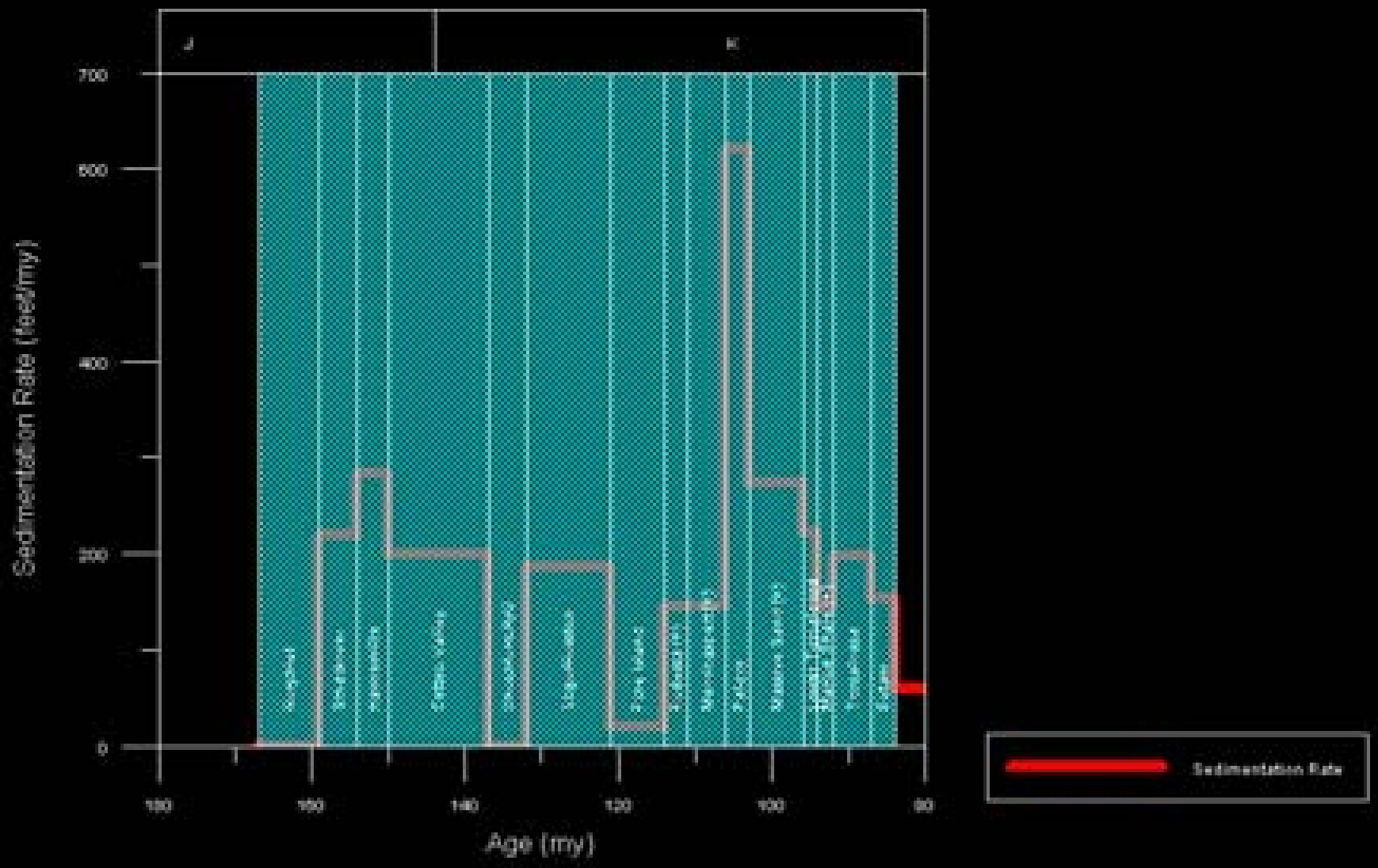
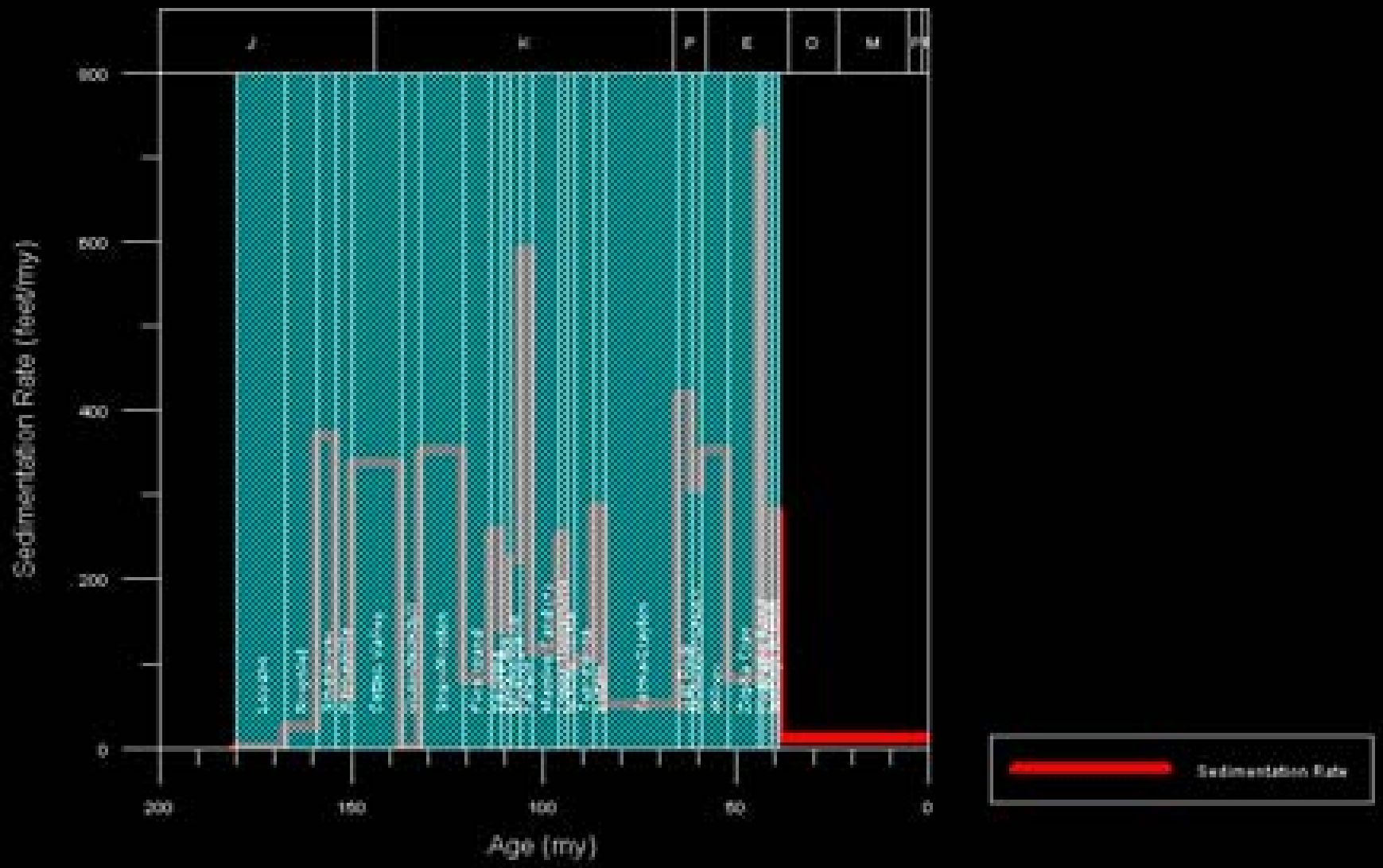


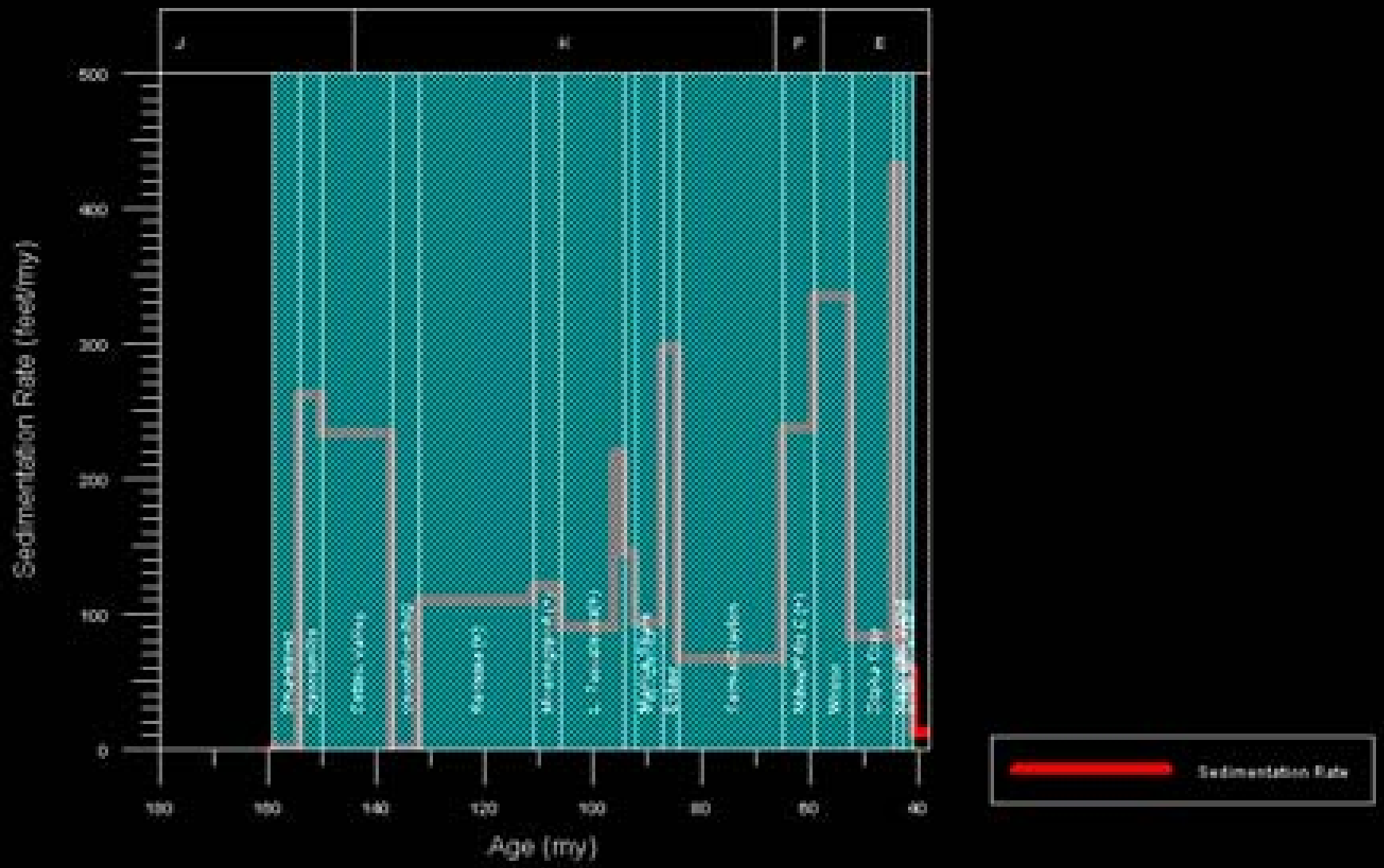
23-153-20042 SED RATE



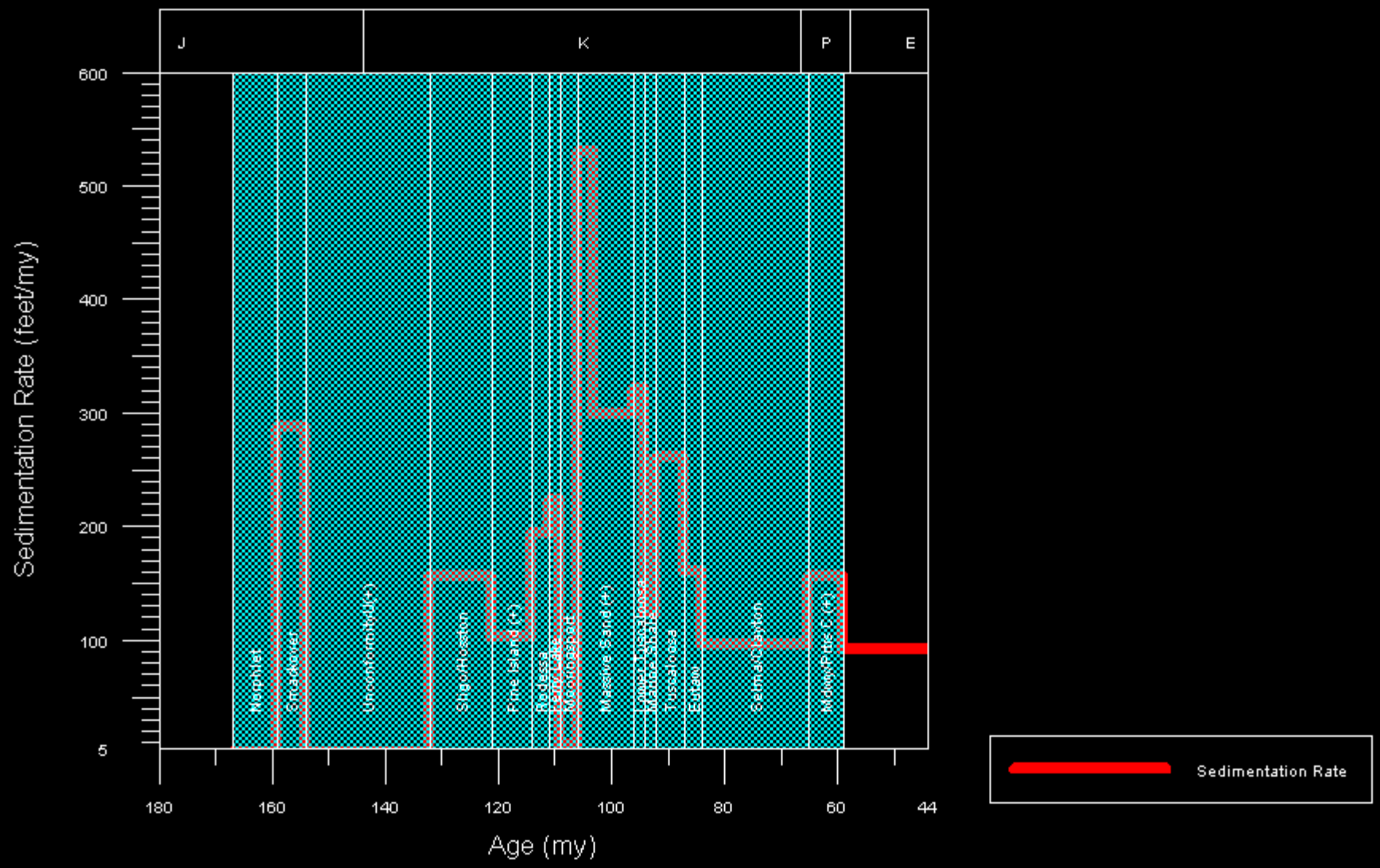
23-089-20043 SED RATE



23-163-00049 SED RATE



23-127-20055 SED RATE



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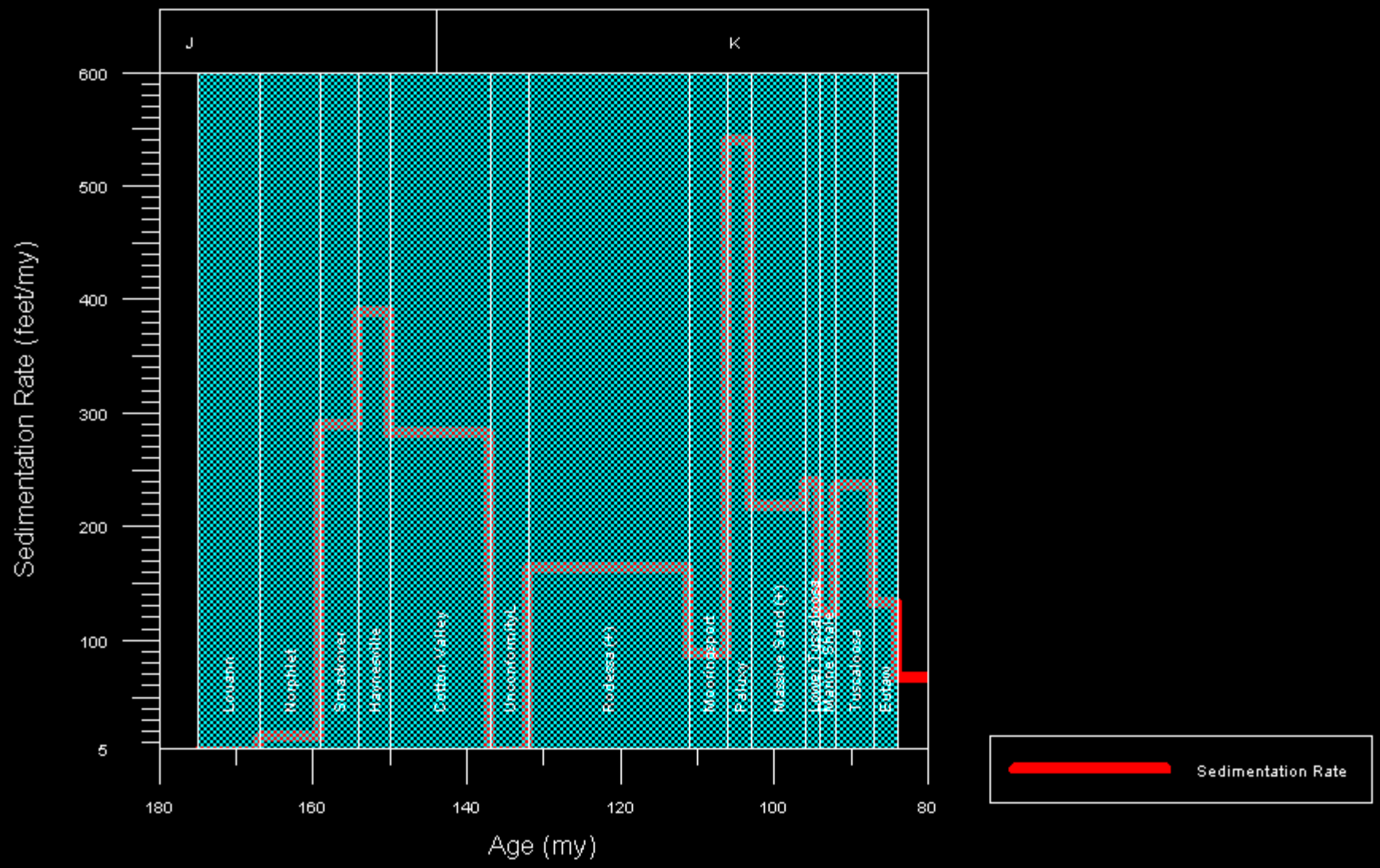

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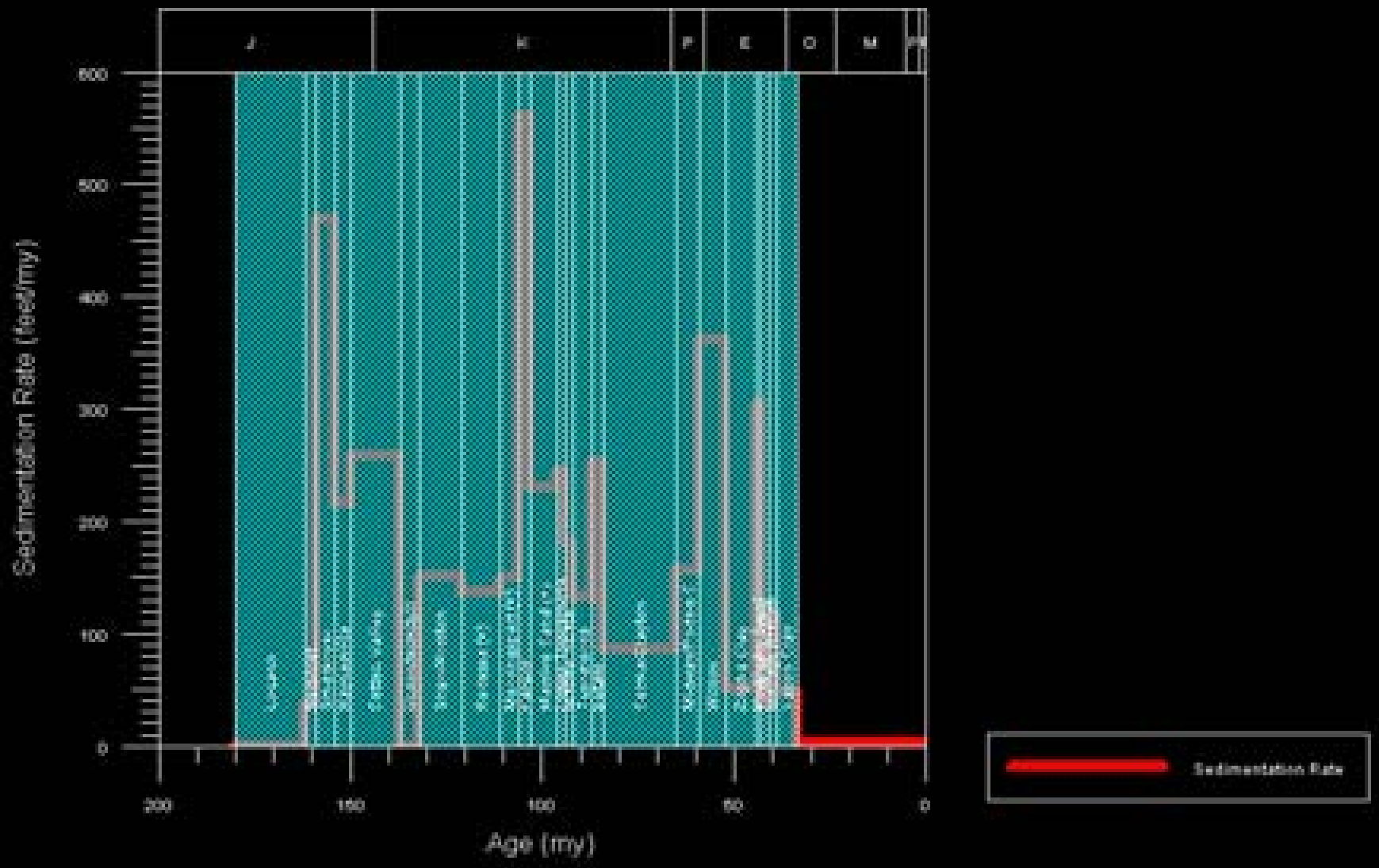

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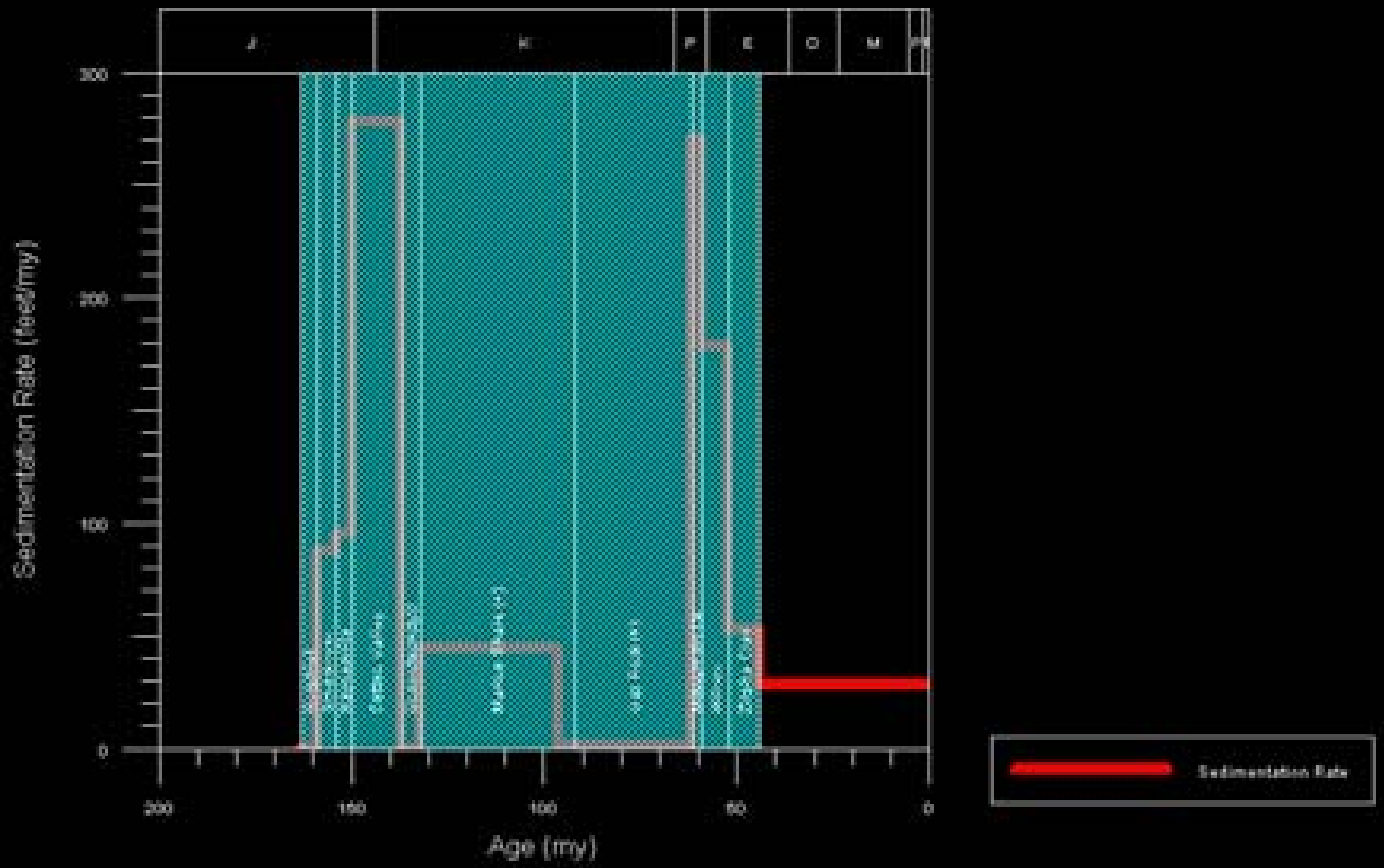
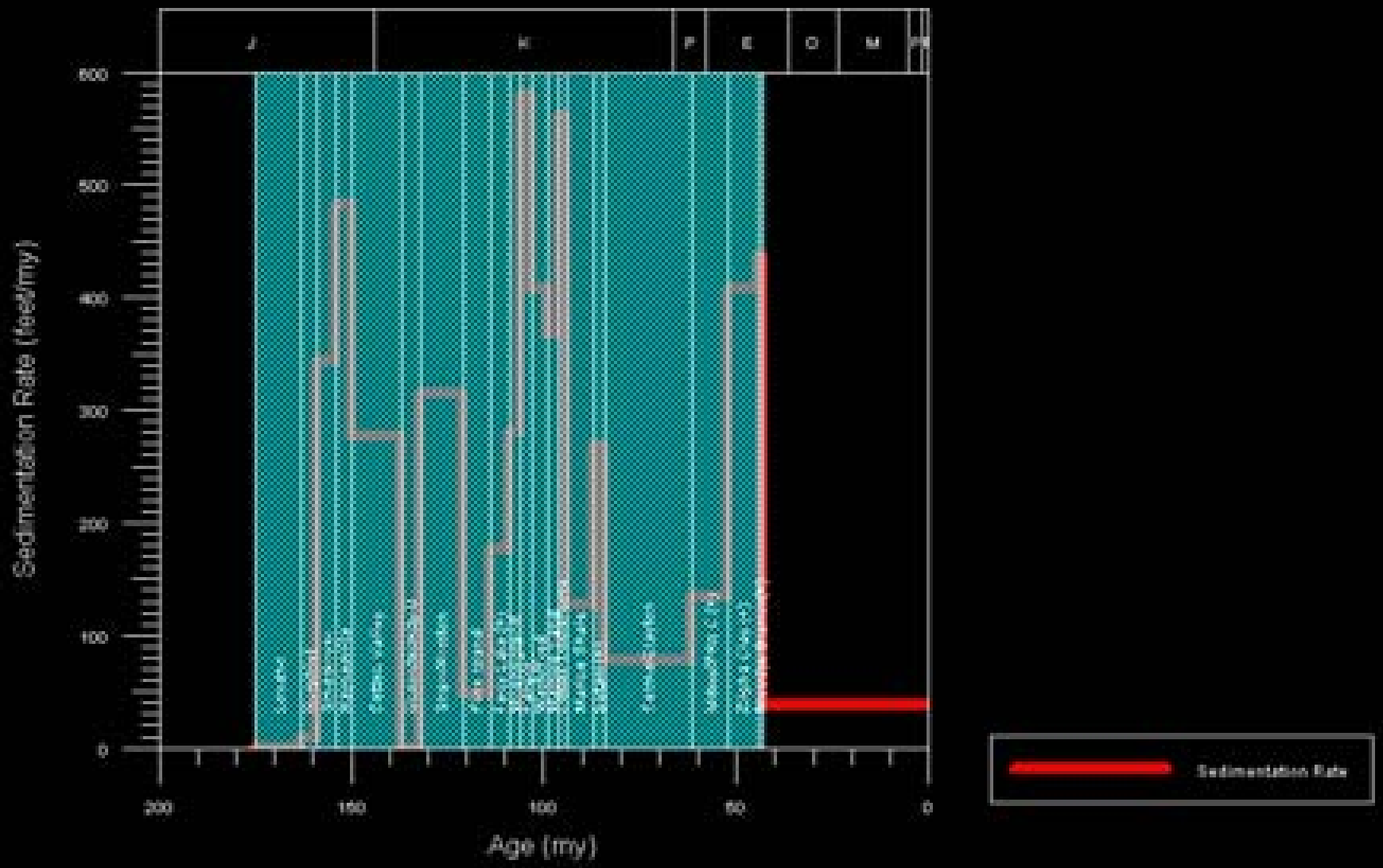


23-111-00069 SED RATE



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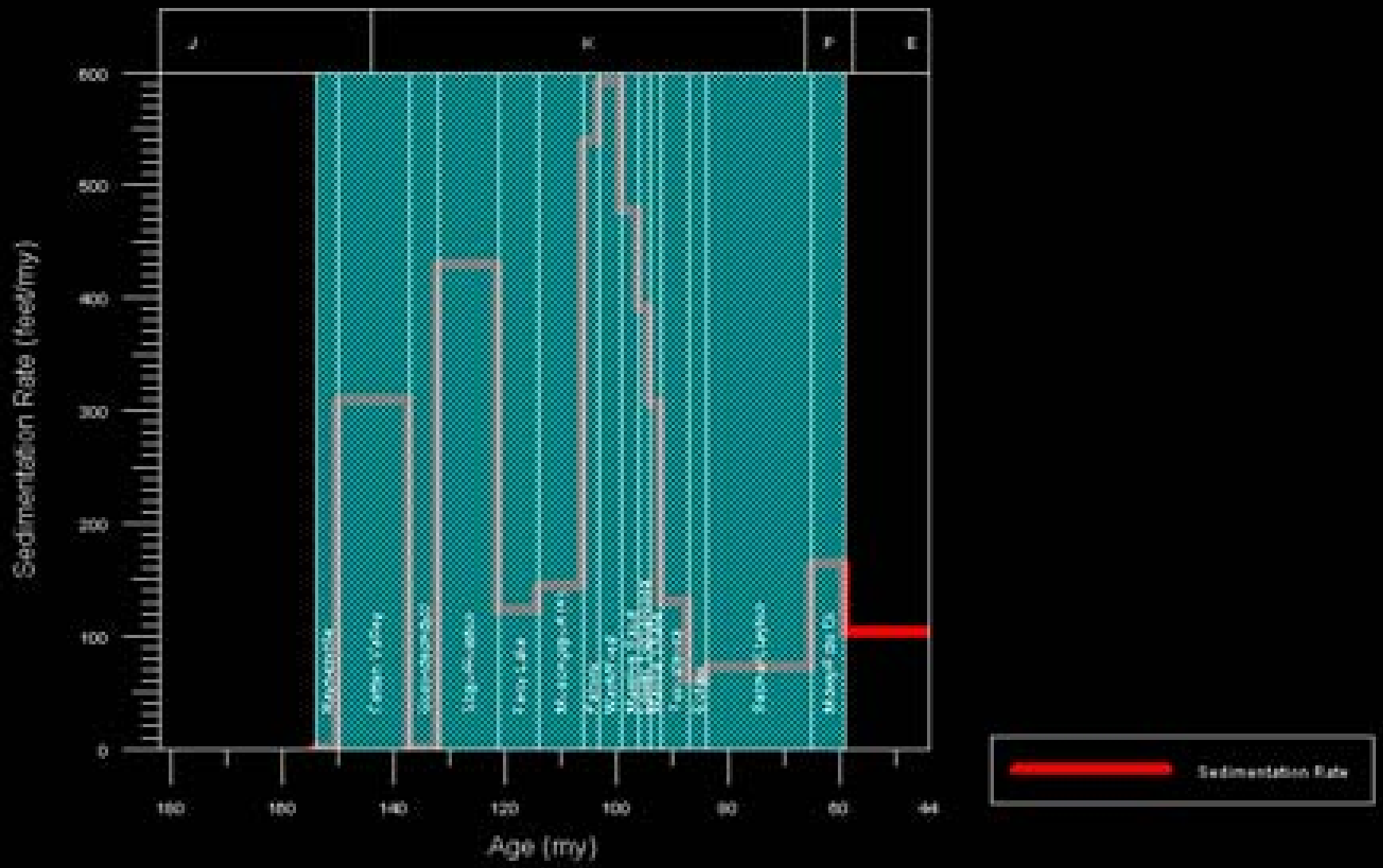
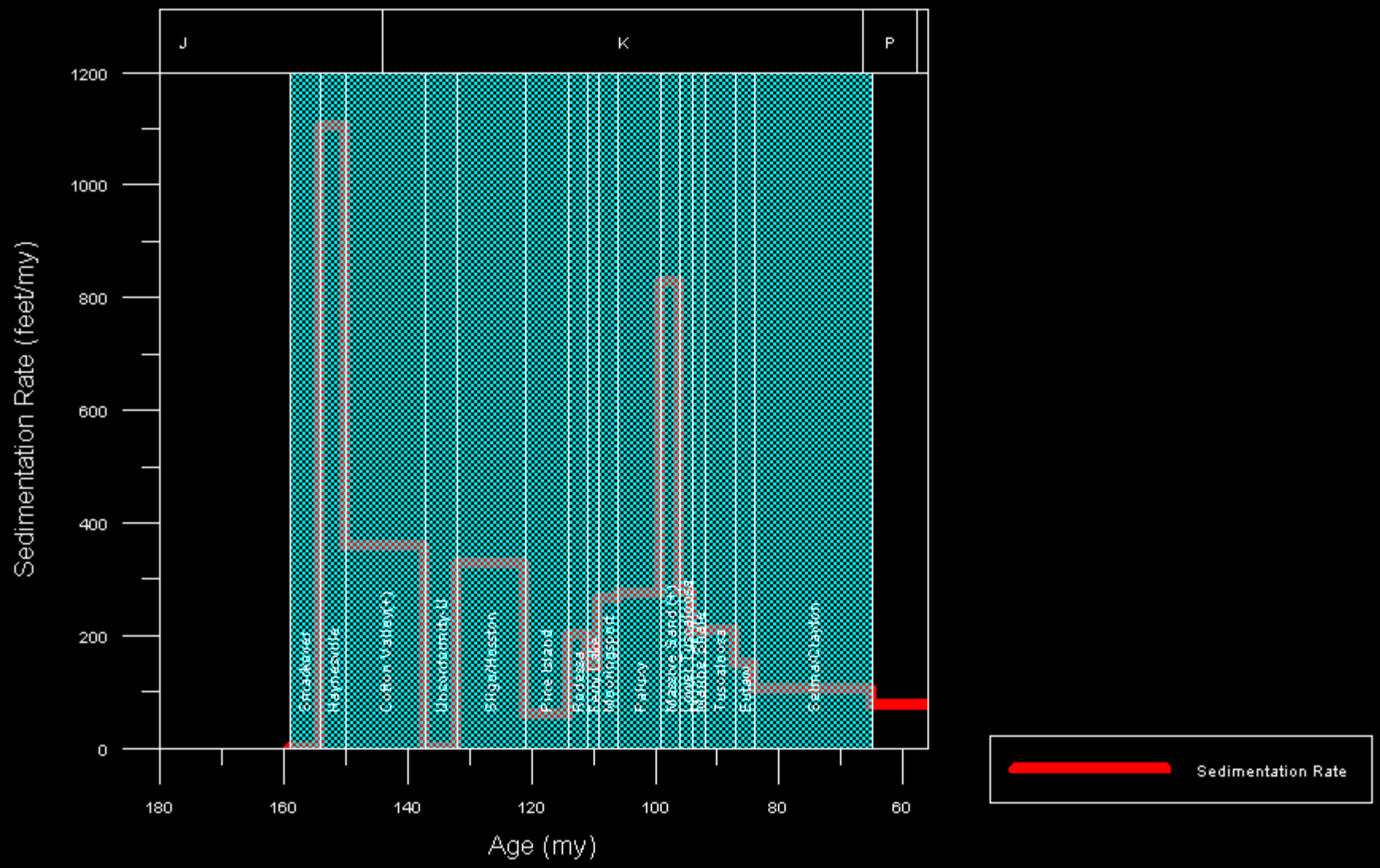


23-153-20077 SED RATE



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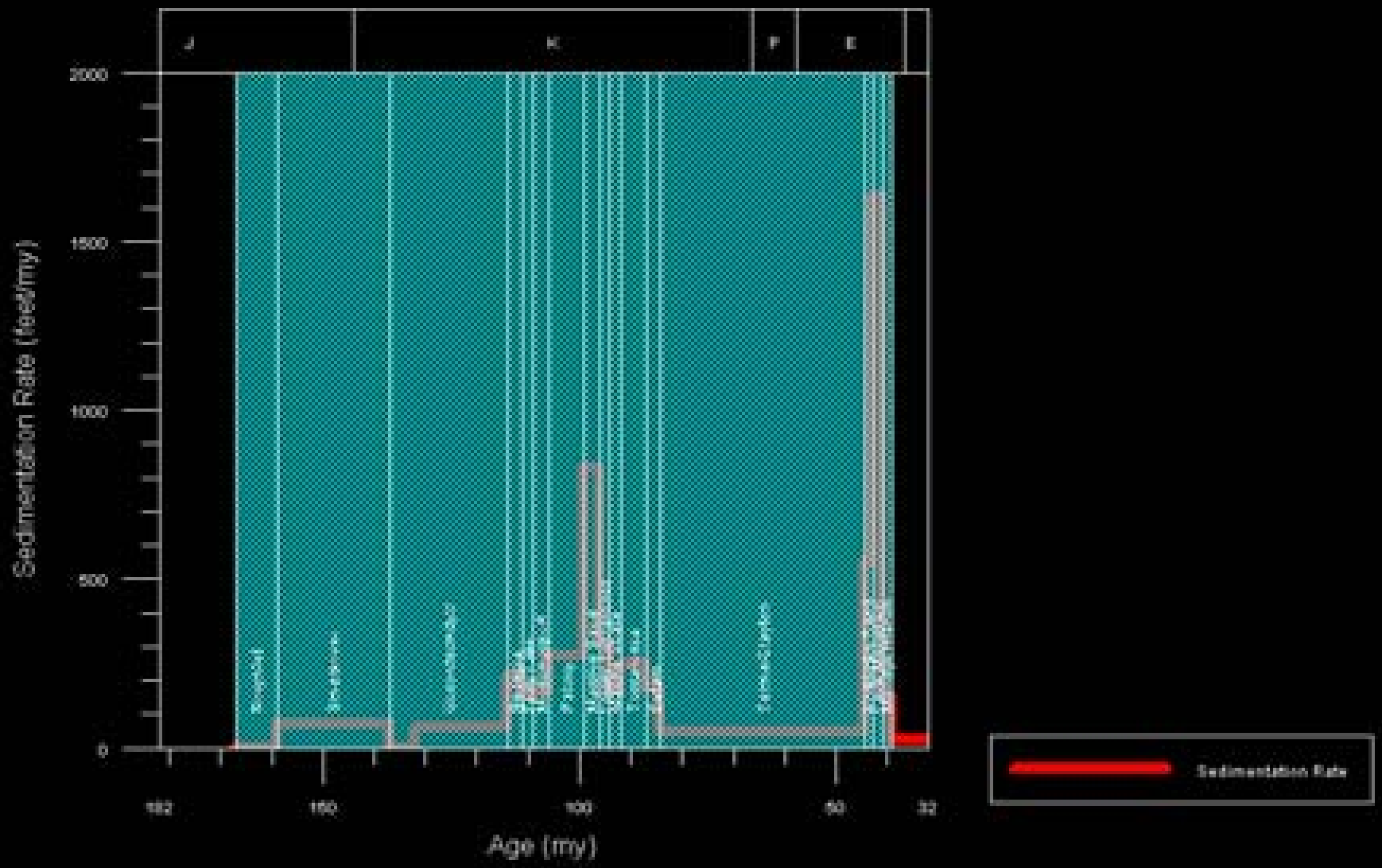
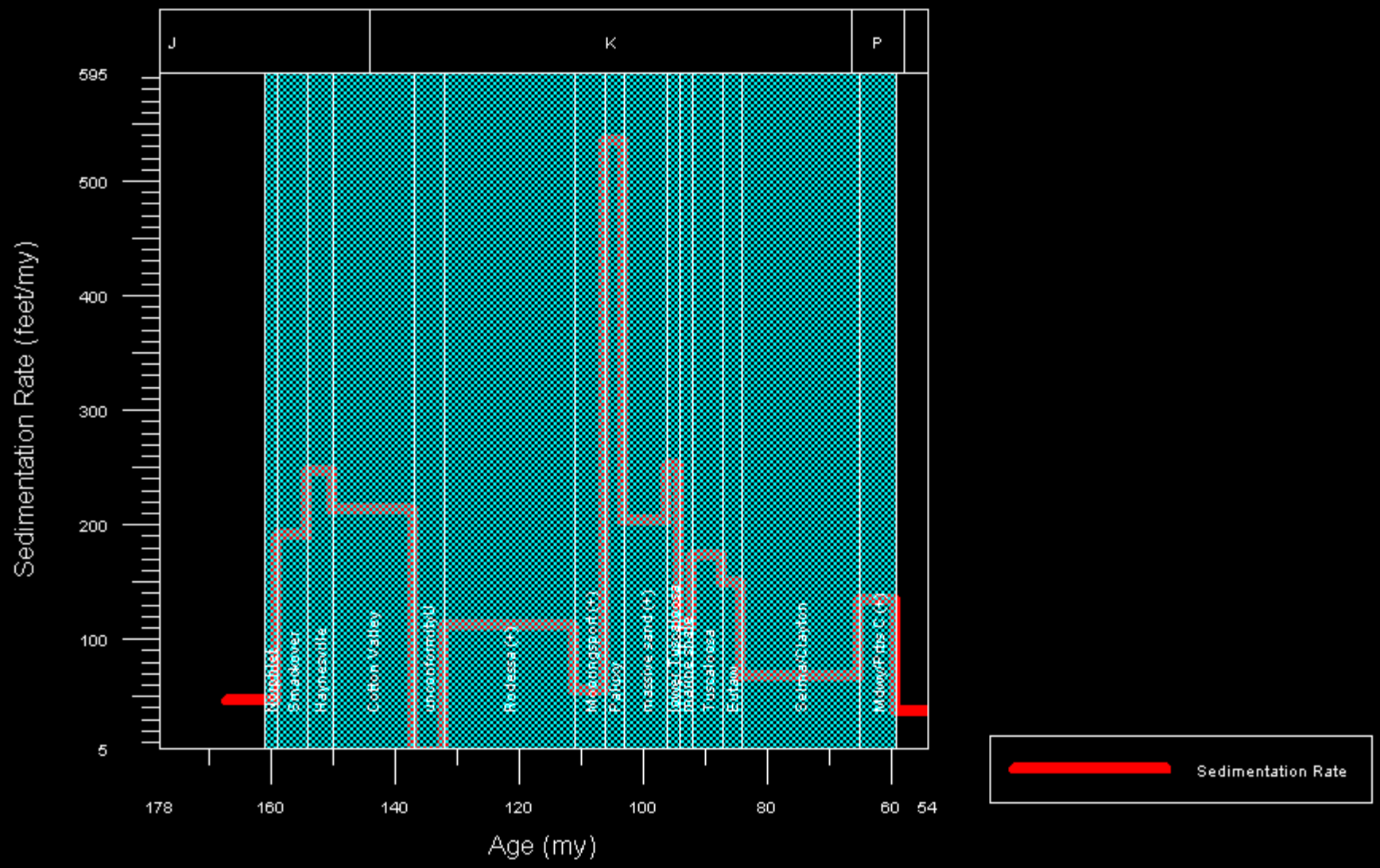
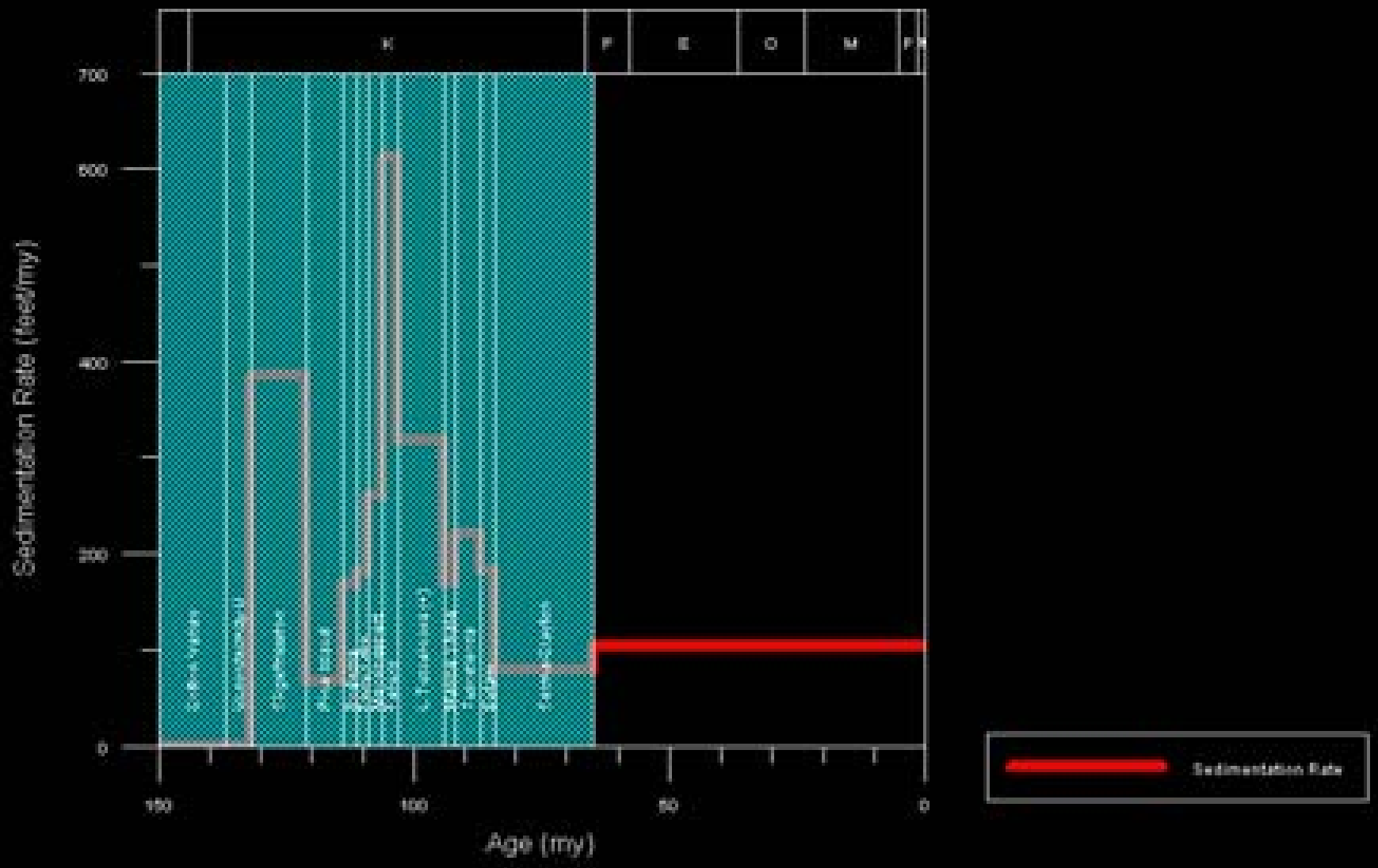


23-023-20114 SED RATE



23-065-20141 SED RATE



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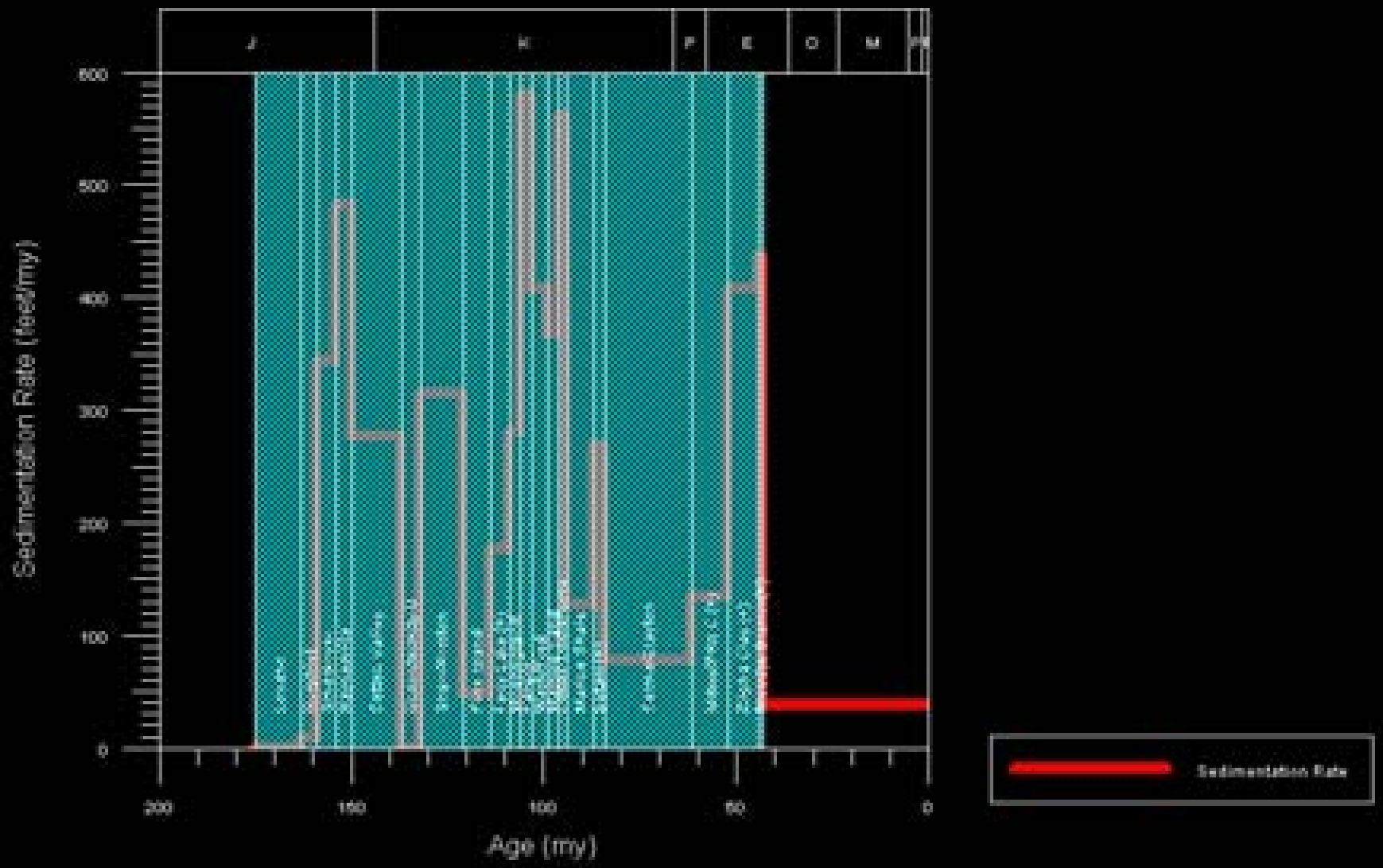

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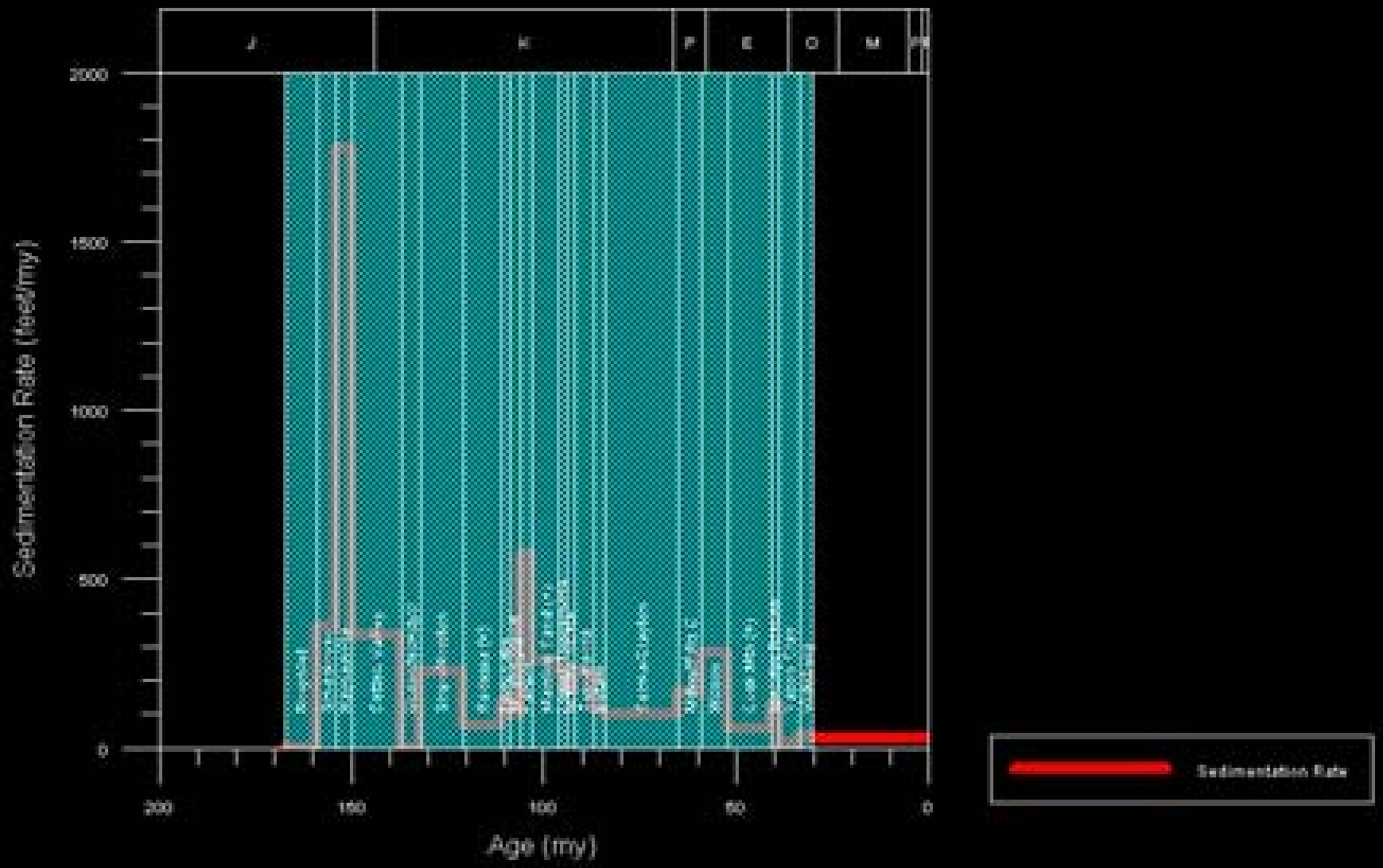
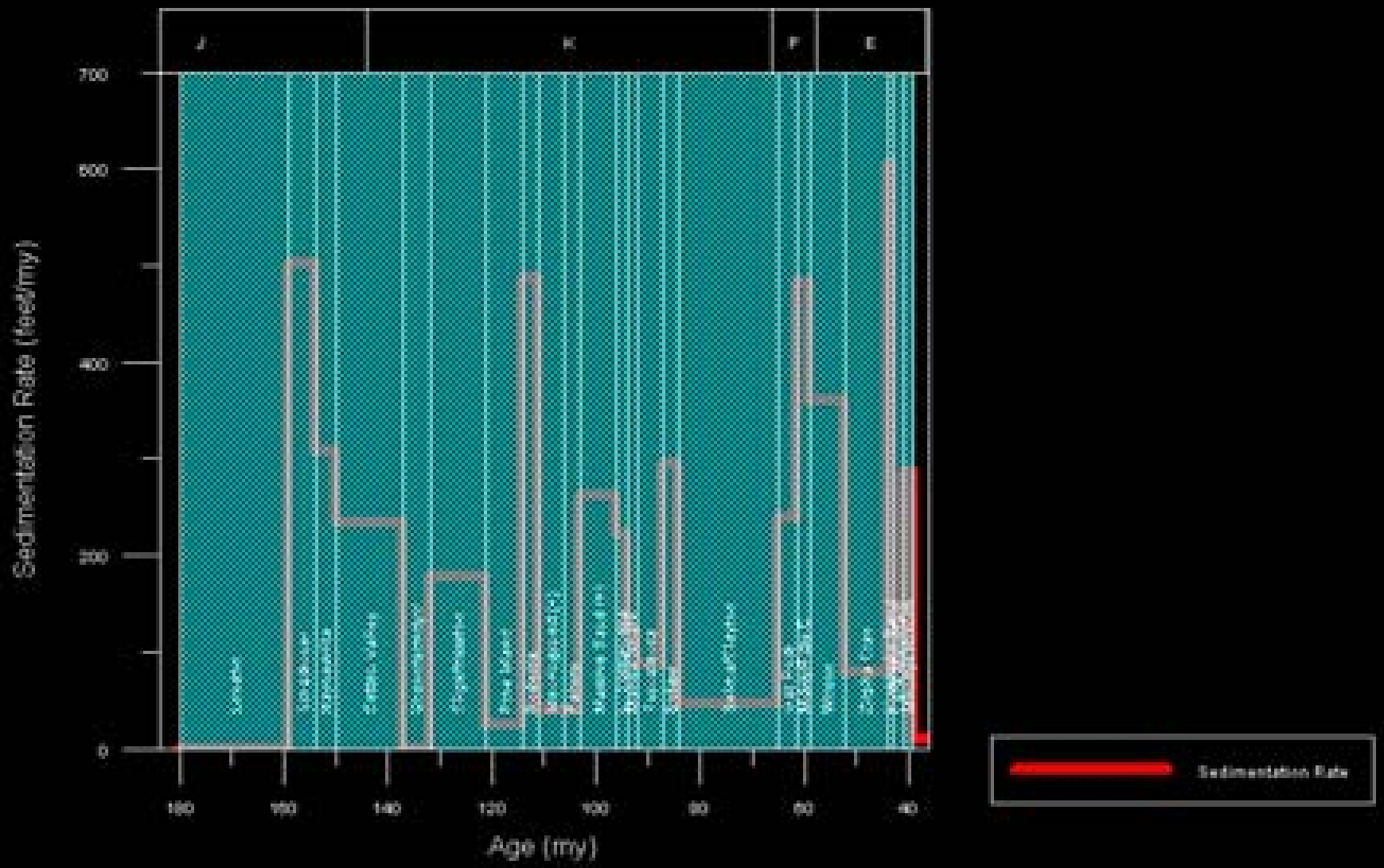
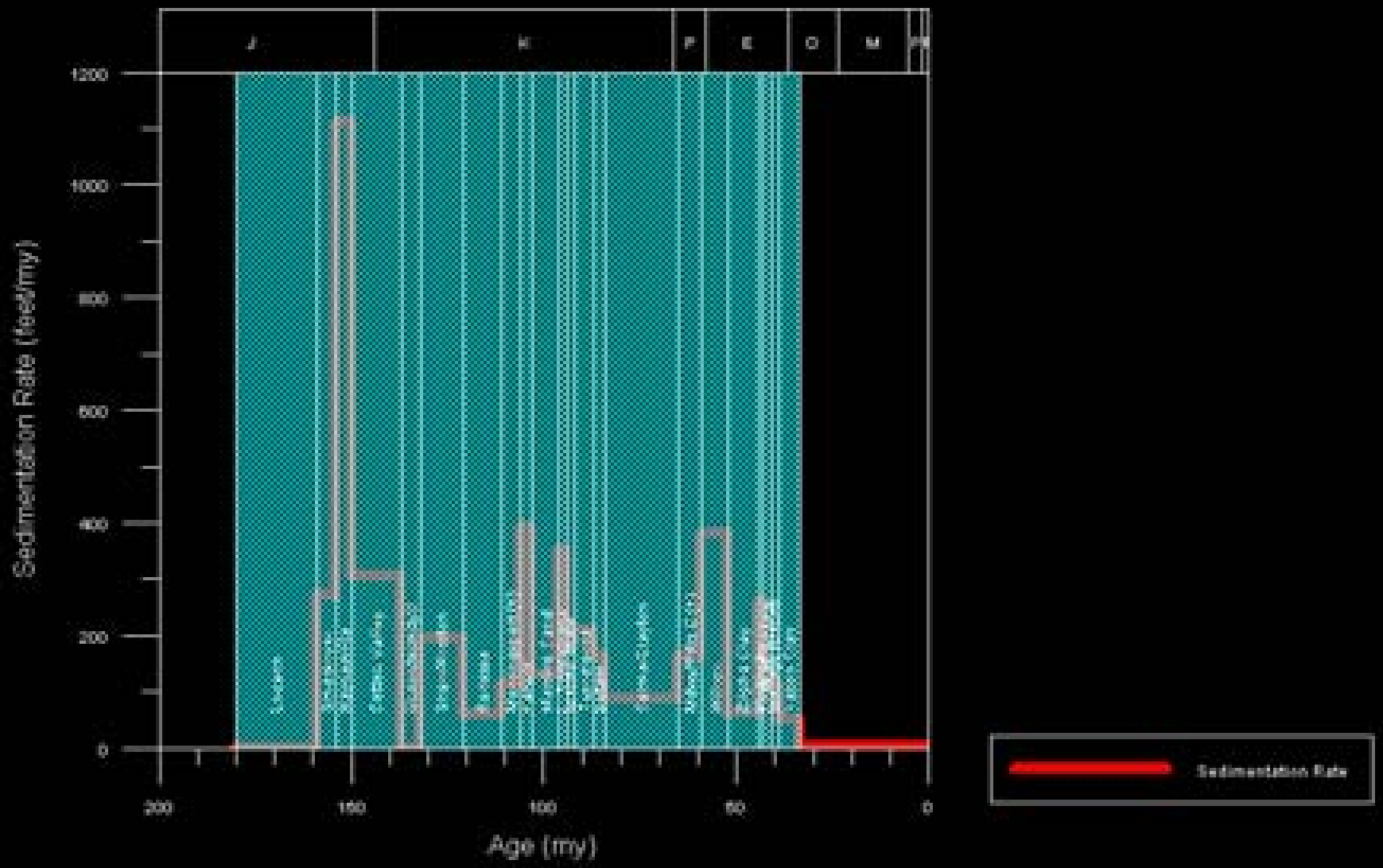


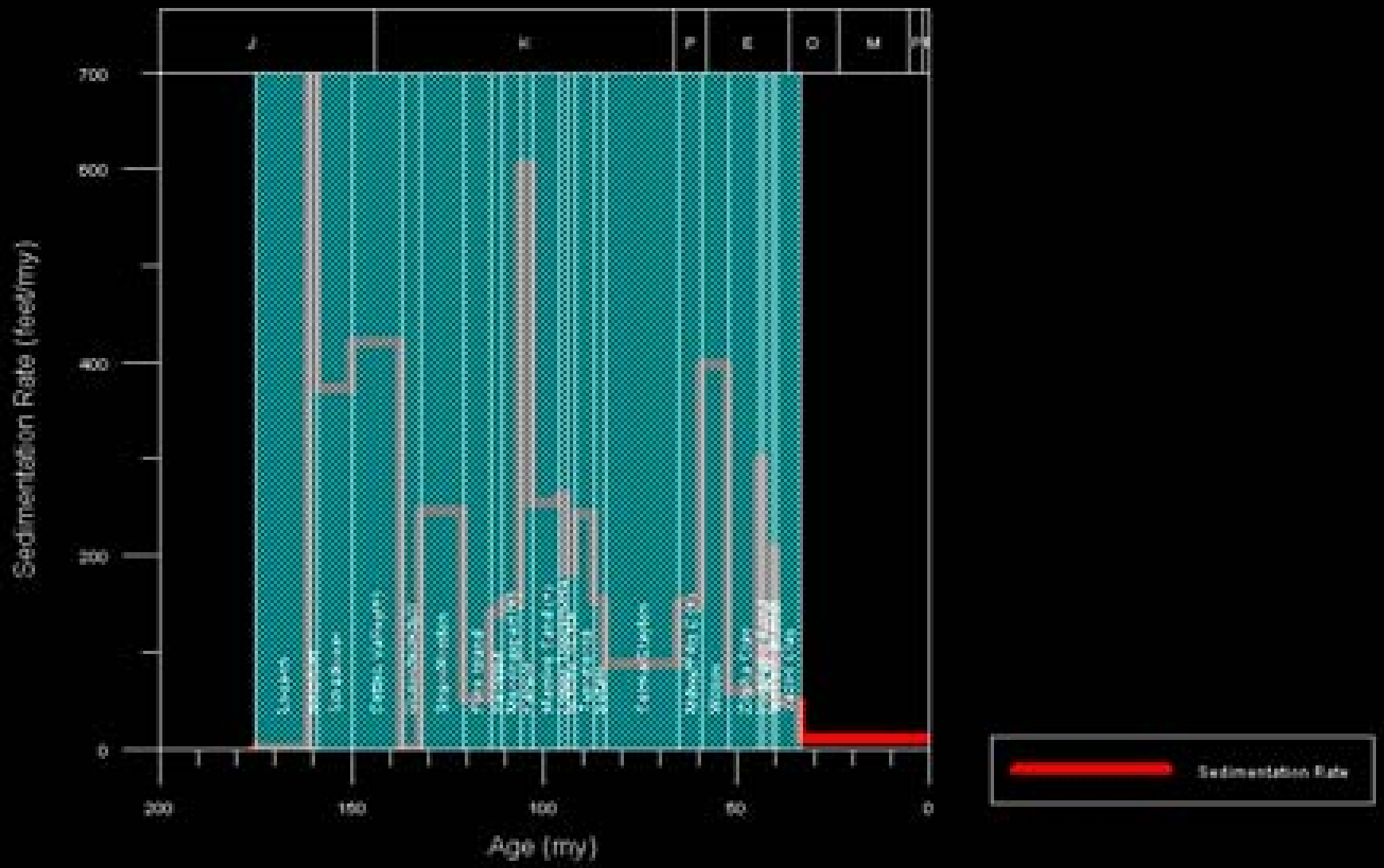
23-163-20150 SED RATE



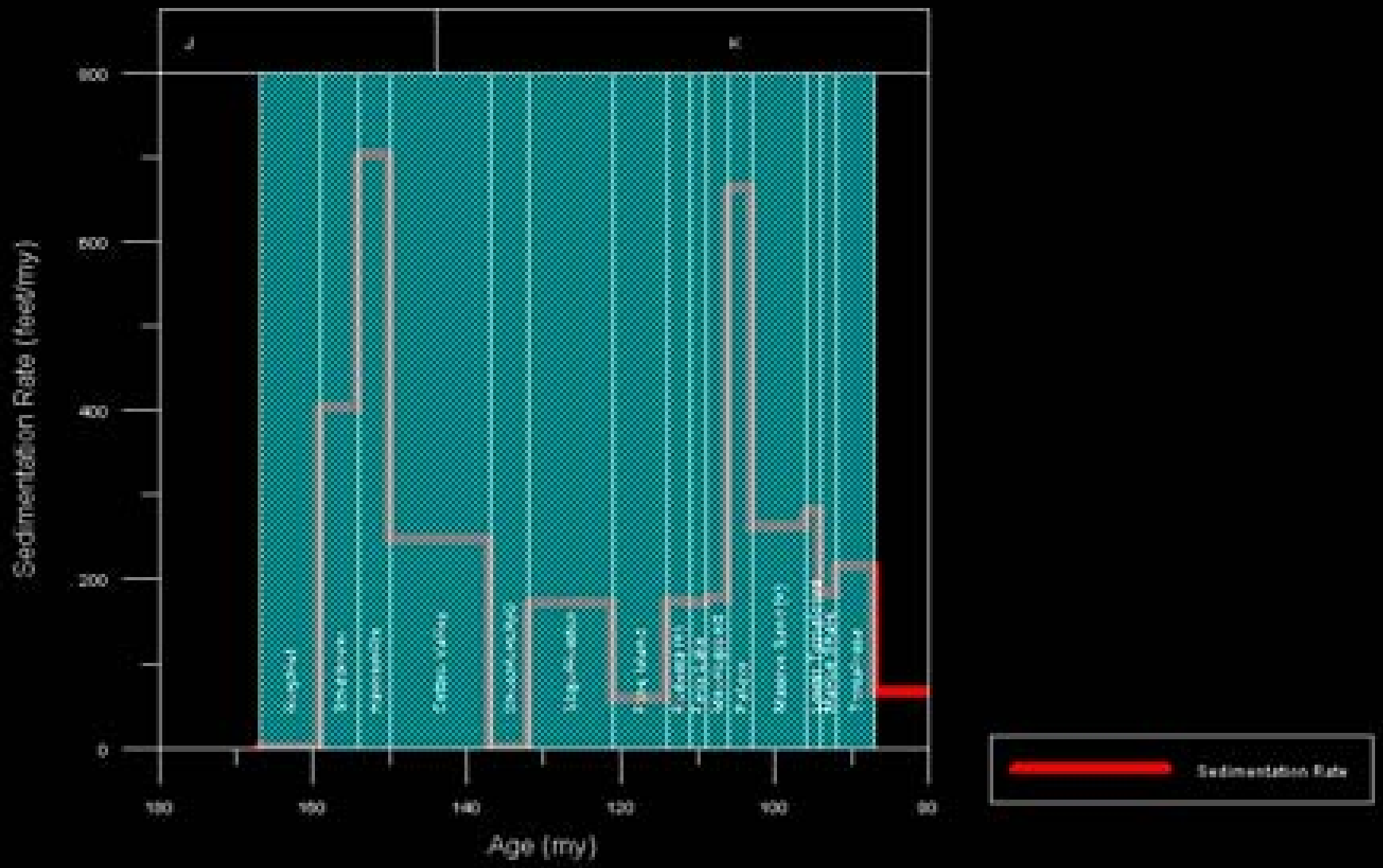
23-129-00178 SED RATE



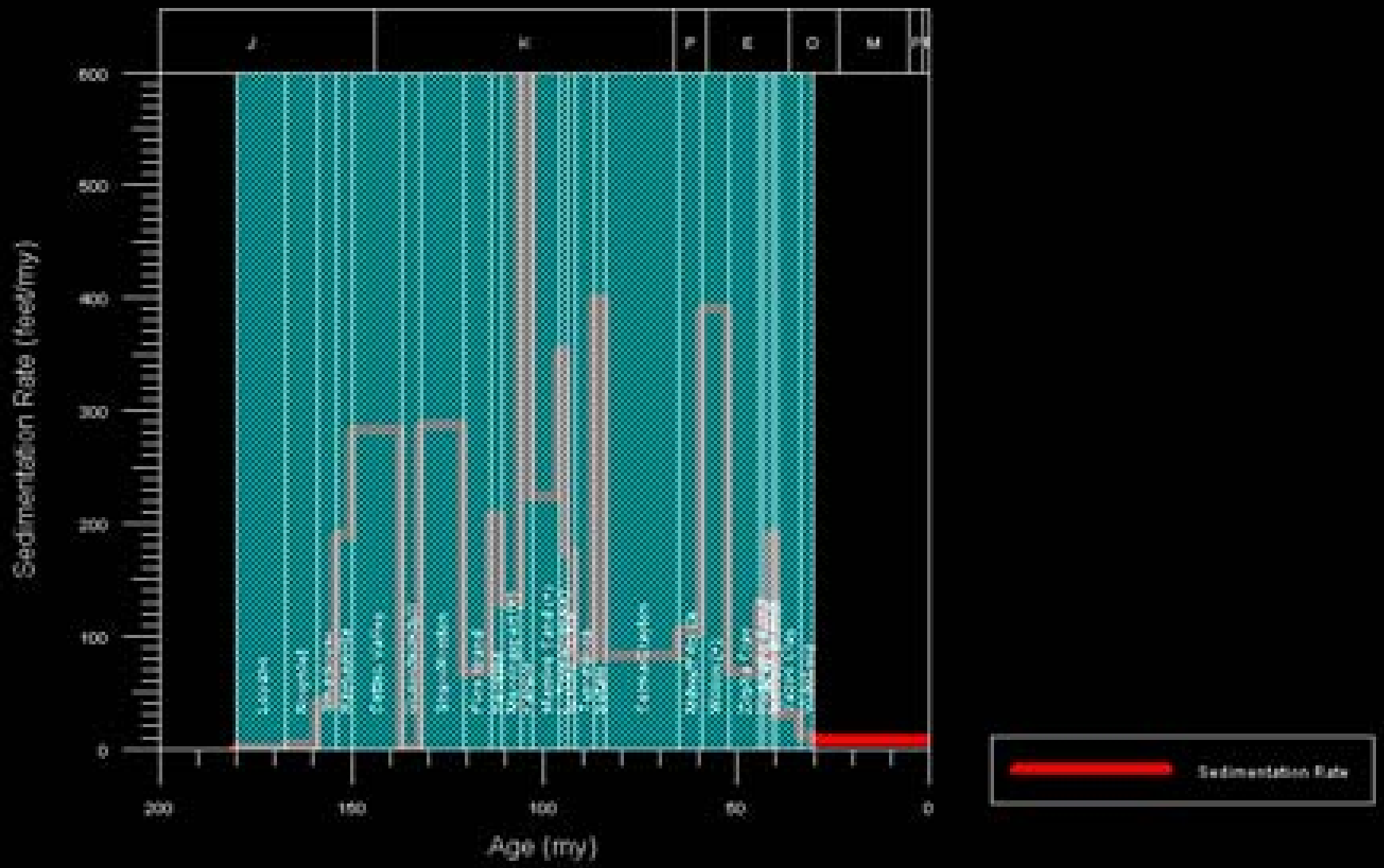
23-061-20203 SED RATE



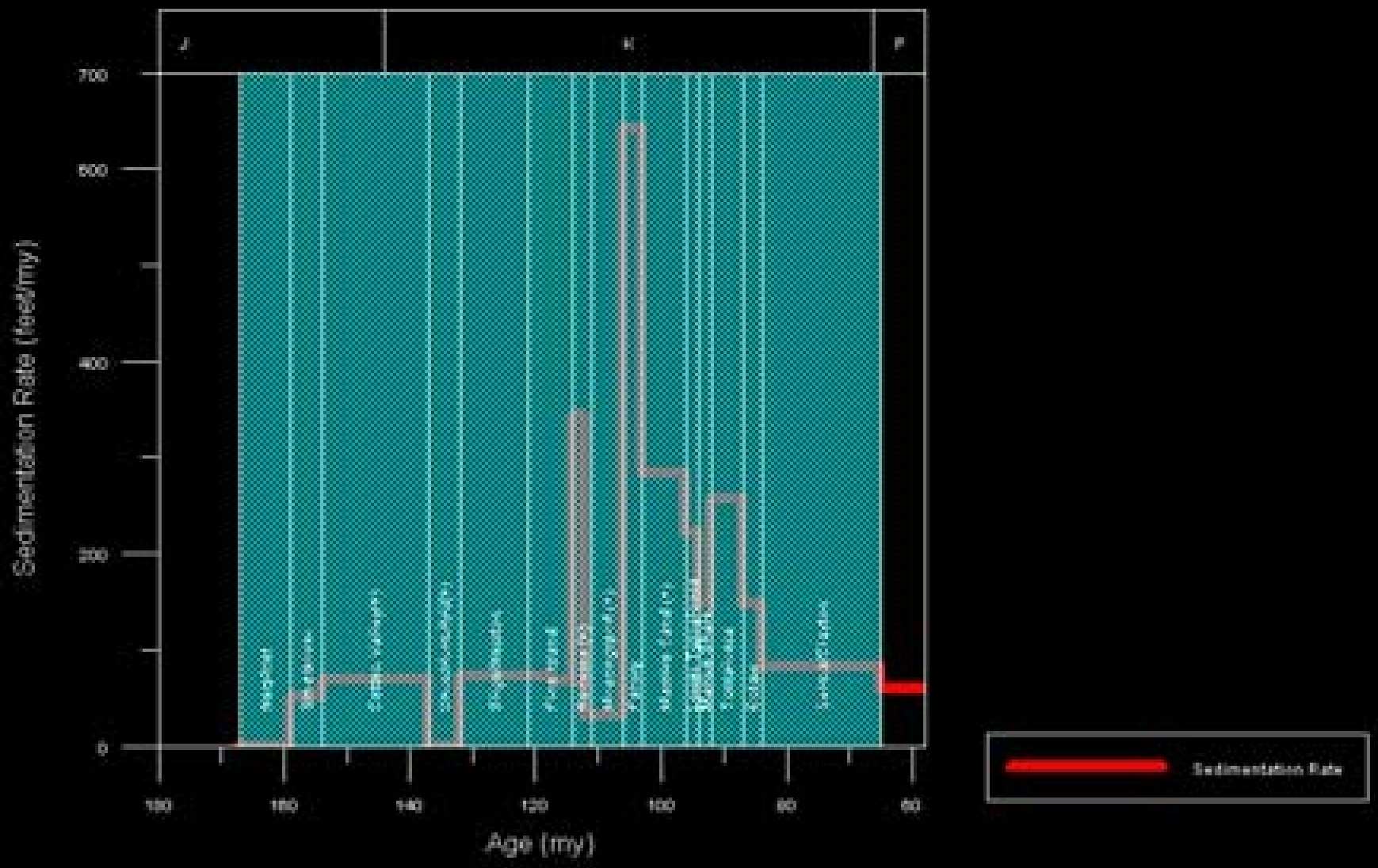
23-153-20232 SED RATE



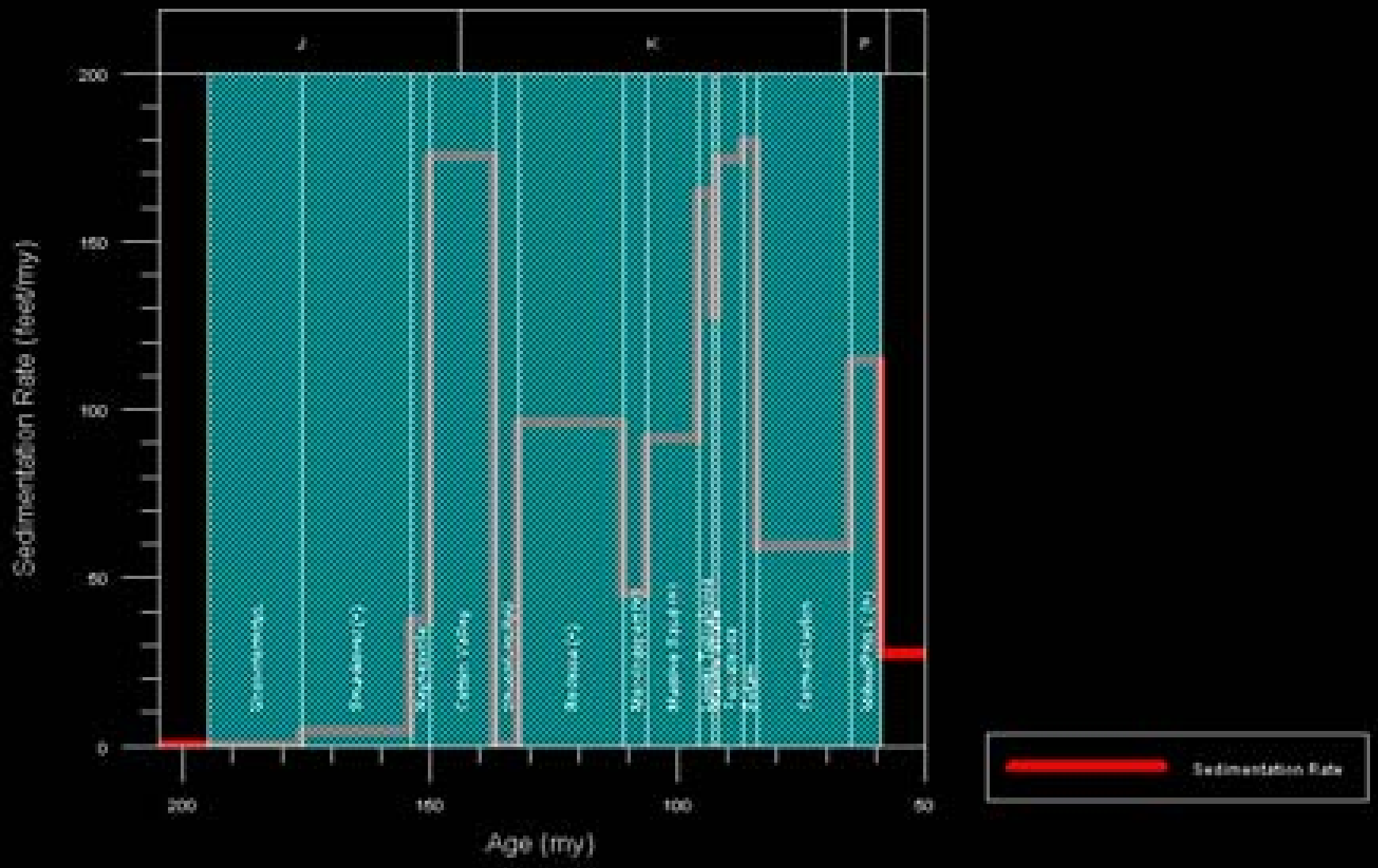
23-061-20244 SED RATE



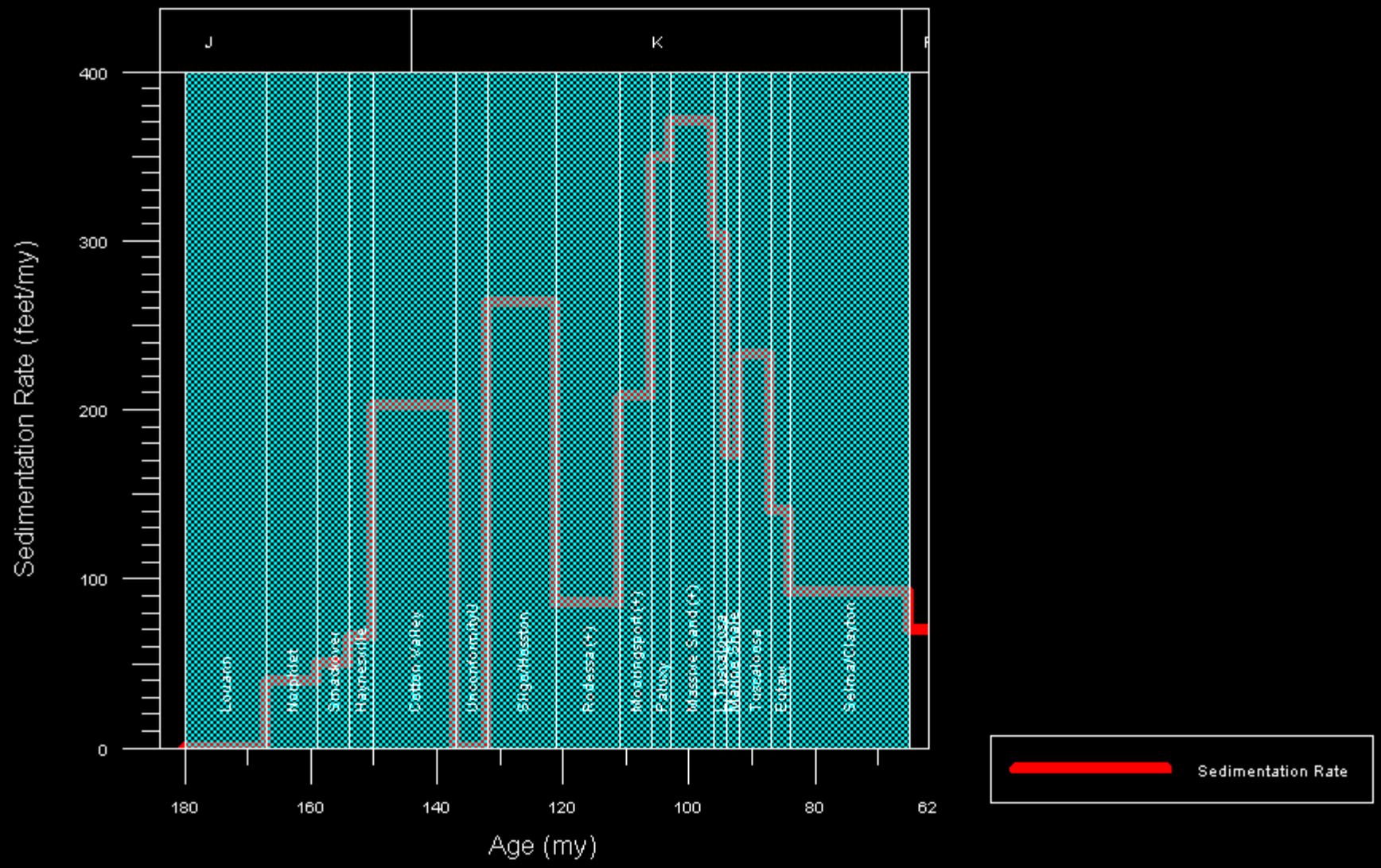
23-153-20265 SED RATE



23-023-00270 SED RATE



23-153-20545 SED RATE



Attachment 10

"Thermal and Source Rock Data"

Ernest A. Mancini and William Parcell
University of Alabama

Bottom Hole Temperature Data (BHT)

API	AL PERMIT #	DEPTH (FT)	DEPTH (M)	BHT (F)	SOURCE	COMMENTS
Strike Section A-A'						
2305500032		8086	2462.7	187	WELL LOG	
2305500066		8502	2589.4	180	WELL LOG	
2312520004		15376	4683.0	286	WELL LOG	
2304920011		17496	5328.7	317	WELL LOG	
2304920005*		18436	5615.0	324	WELL LOG	
2312120025		16393	4992.8	266	WELL LOG	
2312900178		18769	5716.4	281	WELL LOG	
2312920006*						
2312900061		17153	5224.3	264	WELL LOG	
2306120203		17688	5387.2	247	WELL LOG	
2306120028		17994	5480.4	282	WELL LOG	
2306120244		16928	5155.7	240	WELL LOG	
2306720002		12388	3773.0	210	WELL LOG	
2315301008*		14388	4382.1	248	WELL LOG	
2315320545		16127	4911.8	?		
2315320122		22660	6901.5	336	WELL LOG	
112920054	3247	17054	5194.1	280	WELL LOG	
112920024	1872	16891	5144.5	265	WELL LOG	
112920012*		18997	5785.9	310	WELL LOG	
Dip Section B-B'						
2309320011		?		?		
2305120020		9618	2929.3	178	WELL LOG	
2305120036		11777	3586.9	222	WELL LOG	
2316300049		13391	4078.5	260	WELL LOG	
2316320150		16806	5118.6	292	WELL LOG	
2308920043		18878	5749.6	321	WELL LOG	
2304920005*		18446	5618.1	202	WELL LOG	
2304920004		2993	911.6	100	WELL LOG	
		7512-8425	2288-2566	431	WELL LOG	Eutaw
		9016-11380	2746-3466	431	WELL LOG	Tusc
2304920032		25000	7614.2	421	WELL LOG	
Dip Section C-C'						
2310100014		8693	2647.6	160	WELL LOG	
2310120005		12744	3881.4	202	WELL LOG	
2312900015		15104	4600.2	228	WELL LOG	
2312920057		16624	5063.1	240	WELL LOG	
2312920006*						
2312920122		19408	5911.1	290	WELL LOG	
2312720055		16105	4905.1	248	WELL LOG	
2306520141		1901	579.0	730	WELL LOG	
Dip Section D-D'						
2302300270		9881	3009.4	190	WELL LOG	
2302320114		12700	3868.0	190	WELL LOG	
2315320042		16292	4962.0	232	WELL LOG	
2315320265		13192	4017.9	200	WELL LOG	
2315320232		19366	5898.3	334	WELL LOG	
2315301008*		14400	4385.8	248	WELL LOG	
2315320077		4983	1517.7	126	WELL LOG	
2311100069		20138	6133.4	366	WELL LOG	
		19906.9	6063	517	WELL LOG	
		20005.4	6093	590	WELL LOG	
		20067.7	6112	595	WELL LOG	
2304520075					WELL LOG	
Dip Section E-E'						
102320114	1820	12578	3830.9	190	OGR 10	
102320197	2372	14166	4314.5	221	WELL LOG	
112920012*	1643	?	?	?		
112920051	2943	?	?	?		
109720134	2542	18828	5734.4	281	WELL LOG	
109720141	2584	18502	5635.1	292	WELL LOG	
109720299	6846	18542	5647.3	314	WELL LOG	

Tmax Data

API	PERMIT #	DEPTH (FT)	DEPTH (M)	TMAX (^{o}C)	COMMENTS	SOURCE
Strike Section A-A'						
2305500032						
2305500066						
2312520004						
2304920011						
2304920005*						
2312120025						
2312900178						
2312920006*						
2312900061						
2306120203						
2306120028						
2306120244						
2306720002						
2315301008*						
2315320545						
2315320122						
112920054						
112920024						
112920012*						
Dip Section B-B'						
2309320011						
2305120020						
2305120036						
2316300049						
2316320150						
2308920043						
2304920005*						
2304920004						
2304920032			2280-2566	431	projected; Eutaw	Sassen, 1990
			2746-3466	431	projected; Tuscaloosa	Sassen, 1990
Dip Section C-C'						
2310100014						
2310120005						
2312900015						
2312920057						
2312920006*						
2312920122						
2312720055						
2306520141						
Dip Section D-D'						
2302300270						
2302320114						
2315320042						
2315320265						
2315320232						
2315301008*						
2315320077						
2311100069						
2304520075						
Dip Section E-E'						
102320114						
102320197						
112920012*						
112920051						
109720134						
109720141						
109720299			4498	444	Smackover	projected from Driskell et al., 1988
			4500	443	Smackover	projected from Driskell et al., 1989
			4511	441	Smackover	projected from Driskell et al., 1990

Thermal Alteration Index Data (TAI)

API	PERMIT #	DEPTH (FT)	DEPTH (M)	TAI	
Strike Section A-A'					
2305500032					
2305500066					
2312520004					
2304920011					
2304920005*					
2312120025					
2312900178					
2312920006*					
2312900061					
2306120203					
2306120028					
2306120244		15779.7	4806	2	
2306720002					
2315301008*					
2315320545		15897.9	4842	2+	
		14761.9	4496	2	
2315320122					
112920054	3247	14761.9	4927.7	3	proj from #49 in Mancini et al., 1993
112920024	1872	14761.9	4927.7	3	proj from #49 in Mancini et al., 1993
112920012*					
Dip Section B-B'					
2309320011					
2305120020					
2305120036					
2316300049					
2316320150					
2308920043					
2304920005*					
2304920004					
2304920032					
Dip Section C-C'					
2310100014					
2310120005					
2312900015					
2312920057					
2312920006*					
2312920122					
2312720055					
2306520141					
Dip Section D-D'					
2302300270		1456.0	4281	2	
		15287.2	4656	2	
2302320114					
2315320042					
2315320265					
2315320232					
2315301008*					
2315320077		19621.2	5976	3 to 3+	
2311100069		20090.7	6119	3	
		19795.2	6029	4- to 4	
2304520075					
Dip Section E-E'					
102320114	1820	12254.4	3732.3	2-	proj from #34, 31 in Mancini et al., 1993
102320197	2372	12254.4	3732.3	2-	proj from #34in Mancini et al., 1993
112920012*	1643	16179.3	4927.7	3	proj from #49in Mancini et al., 1993
112920051	2943	19373.6	5900.6	3	proj from #51in Mancini et al., 1993
109720134	2542	17321.2	5275.5	3	proj from #52 in Mancini et al., 1993
109720141	2584				
109720299	6846	18323.0	5580.6	3	proj from #53 in Mancini et al., 1993

Vitrinite Reflectance (%Ro) Data

API	PERMIT #	DEPTH (FT)	DEPTH (M)	%Ro (MEAN)	COMMENTS	SOURCE
Strike Section A-A'						
2305500032						
2305500066						
2312520004						
2304920011						
2304920005*						
2312120025						
2312900178						
2312920006*						
2312900061						
2306120203						
2306120028						
2306120244		15779.7	4806	0.8		
2306720002						
2315301008*						
2315320545		15897.9	4842	0.9		
		14761.9	4496	0.7		
2315320122		15897.9	4842	0.9	w/ TOC	
		14761.9	4496	0.6	w/ TOC	
112920054	3247					
112920024	1872	4399.7	1340	0.33	Tallahatta?	Carroll, R.E., 1998
		5581.7	1700	0.37	Tuscahoma	Carroll, R.E., 1998
		7354.7	2240	0.34	Nanafalia?	Carroll, R.E., 1998
		9423.2	2870	0.41	Nanafalia?	Carroll, R.E., 1998
		9521.7	2900	0.35	Naheola	Carroll, R.E., 1998
		9817.2	2990	0.44	Porters Creek	Carroll, R.E., 1998
		14085.5	4290	0.41	Selma?	Carroll, R.E., 1998
		16055.5	4890	0.46	Eutaw	Carroll, R.E., 1998
112920012*	1643	10276.8	3130	0.35	Naheoloa lignite	Carroll, R.E., 1998
		12903.5	3930	0.49	Porters Creek	Carroll, R.E., 1998
		17927.0	5460	0.47	Eutaw	Carroll, R.E., 1998
		21177.5	6450	0.47	Tuscaloosa	Carroll, R.E., 1998
Dip Section B-B'						
2309320011						
2305120020						
2305120036						
2316300049						
2316320150						
2308920043						
2304920005*						
2304920004		7486.0	2280	0.61		Sassen, 1990
		8425.0	2566	0.61		Sassen, 1990
		9016.0	2746	0.28		Sassen, 1990
		11380.0	3466	0.28		Sassen, 1990
2304920032		7486.0	2280	0.61		Sassen, 1990
		8425.0	2566	0.61		Sassen, 1990
		9016.0	2746	0.28		Sassen, 1990
		11380.0	3466	0.28		Sassen, 1990
Dip Section C-C'						
2310100014						
2310120005						
2312900015						
2312920057						
2312920006*						
2312920122						
2312720055						
2306520141						
Dip Section D-D'						
2302300270		14056.0	4281	0		
		15287.2	4656	0.7		
2302320114						
2315320042						
2315320265						
2315320232						
2315301008*						
2315320077		19499.7	5939	1.7		
2311100069		20090.7	6119	1.5		
		19795.2	6029	3		
2304520075						
Dip Section E-E'						
102320114	*1820*					
102320197	2372					
112920012*	1643	10276.8	3130	0.35	Naheoloa lignite	Carroll, R.E., 1998
		12903.5	3930	0.49	Porters Creek	Carroll, R.E., 1998
		17927.0	5460	0.47	Eutaw	Carroll, R.E., 1998
		21177.5	6450	0.47	Tuscaloosa	Carroll, R.E., 1998
112920051	2943					
109720134	2542					
109720141	2584	10539.5	3210	0.36	Tuscahoma?	Carroll, R.E., 1998
		12706.5	3870	0.36	Naheoloa lignite	Carroll, R.E., 1998
		15661.5	4770	0.45	Porters Creek	Carroll, R.E., 1998
		20291.0	6180	0.41	Eutaw	Carroll, R.E., 1998
		20685.0	6300	0.48	Eutaw	Carroll, R.E., 1998
		22359.5	6810	0.5	Tuscaloosa	Carroll, R.E., 1998
		18514.7	5639	1.3	projected	Sassen and Moore, 1988
109720299	6846	18386.7	5600	1.3	projected	Sassen and Moore, 1988

Total Organic Carbon Data (TOC)

API	PERMIT #	DEPTH (FT)	DEPTH (M)	TOC	COMMENTS	SOURCE
Strike Section A-A'						
2305500032						
2305500066						
2312520004						
2304920011						
2304920005*						
2312120025						
2312900178						
2312920006*						
2312900061						
2306120203						
2306120028						
2306120244						
2306720002						
2315301008*		22000.0	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		22100.0	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
2315320545		22000.0	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		22100.0	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
2315320122		22000.0	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		22100.0	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
112920054	3247					
112920024	1872					
112920012*						
Dip Section B-B'						
2309320011						
2305120020						
2305120036						
2316300049						
2316320150						
2308920043						
2304920005*						
2304920004						
2304920032						
Dip Section C-C'						
2310100014						
2310120005						
2312900015						
2312920057						
2312920006*						
2312920122						
2312720055						
2306520141						
Dip Section D-D'						
2302300270		14056.0	4281	1.56	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14069.1	4285	0.72	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14111.8	4298	2.46	isolated kerogen; projected	Sassen and Moore, 1988
		14121.6	4301	6.14	isolated kerogen; projected	Sassen and Moore, 1988
		14131.5	4304	5.88	isolated kerogen; projected	Sassen and Moore, 1988
		14134.8	4305	8.1	isolated kerogen; projected	Sassen and Moore, 1988
		14134.8	4305	0.75	30% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14138.0	4306	9.12	isolated kerogen; projected	Sassen and Moore, 1988
		14141.3	4307	9.3	isolated kerogen; projected	Sassen and Moore, 1988
		14141.3	4307	0.53	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15287.2	4656	0.62	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15290.5	4657	0.87	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14111.8	4298	2.46	isolated kerogen; projected	Sassen and Moore, 1988
2302320114		14056.0	4281	1.56	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14069.1	4285	0.72	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14111.8	4298	2.46	isolated kerogen; projected	Sassen and Moore, 1988
		14121.6	4301	6.14	isolated kerogen; projected	Sassen and Moore, 1988
		14131.5	4304	5.88	isolated kerogen; projected	Sassen and Moore, 1988
		14134.8	4305	8.1	isolated kerogen; projected	Sassen and Moore, 1988
		14134.8	4305	0.75	30% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14138.0	4306	9.12	isolated kerogen; projected	Sassen and Moore, 1988
		14141.3	4307	9.3	isolated kerogen; projected	Sassen and Moore, 1988
		14141.3	4307	0.53	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15287.2	4656	0.62	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15290.5	4657	0.87	100% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		14111.8	4298	2.46	isolated kerogen; projected	Sassen and Moore, 1988
2315320042		15897.9	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15930.7	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
2315320265		15897.9	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15930.7	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
2315320232		15897.9	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15930.7	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
2315301008*		15897.9	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15930.7	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
2315320077		15897.9	4842	0.46	40% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		15930.7	4852	0.58	60% amorphous; projected	Sassen , Moore, and Meendsen, 1987
		19621.2	5976	0.37		Sassen , Moore, and Meendsen, 1987
		20090.7	6119	5.1		Sassen , Moore, and Meendsen, 1987
		19782.1	6025	25.3		Sassen , Moore, and Meendsen, 1987
2311100069						
2304520075						
Dip Section E-E'						
102320114	1820					
102320197	2372					
112920012*	1643					
112920051	2943					
109720134	2542	10968		0.07	Rodessa	projected from wells in Mancini et al., 1993
		17308		0.81	Smackover	projected from wells in Mancini et al., 1993
		18309		0.89	Smackover	projected from wells in Mancini et al., 1993
		19215		1.74	Smackover	projected from wells in Mancini et al., 1993
		19695		0.25	Smackover	projected from wells in Mancini et al., 1993
		20466		0.11	Norphlet	projected from wells in Mancini et al., 1993
109720141	2584	10968		0.07	Rodessa	projected from wells in Mancini et al., 1993
		17308		0.81	Smackover	projected from wells in Mancini et al., 1993
		18309		0.89	Smackover	projected from wells in Mancini et al., 1993
		19215		1.74	Smackover	projected from wells in Mancini et al., 1993
		19695		0.25	Smackover	projected from wells in Mancini et al., 1993
		20466		0.11	Norphlet	projected from wells in Mancini et al., 1993
109720299	6846	10968		0.07	Rodessa	projected from wells in Mancini et al., 1993
		17308		0.81	Smackover	projected from wells in Mancini et al., 1993
		18309		0.89	Smackover	projected from wells in Mancini et al., 1993
		19215		1.74	Smackover	projected from wells in Mancini et al., 1993
		19695		0.25	Smackover	projected from wells in Mancini et al., 1993
		20466		0.11	Norphlet	projected from wells in Mancini et al., 1993

Attachment 11

"Vitrinite Reflectance Study"

Richard Carroll
Alabama Geological Survey

INTRODUCTION AND OBJECTIVE

This volume contains the report on task 1, year 2, of the Mississippi interior salt basin (MISB) analysis project. Task 1 involved the collection of suitable well cutting samples, preparation of whole-rock polished pellets, and recording of vitrinite reflectance measurements from selected wells throughout the interior salt basin. These data have been integrated into a computerized model of burial and thermal maturation history of the Mississippi interior salt basin. Analysis of a basin's burial and geothermal history is critical for assessing potential source rock, hydrocarbon generation potential, and hydrocarbon occurrence.

The objective of this task was to provide thermal maturation data for six wells distributed throughout the basin, and for a stratigraphic range of Jurassic through Tertiary.

METHODS

Suitable wells for study were selected by examining data from the files of the Alabama Oil and Gas Board. Wells were considered for study if they 1) penetrated the Jurassic Smackover Formation, 2) had washed cuttings available over the entire depth of the well, and 3) were without major faults (PN 2297 is faulted, and no samples lower than the Tertiary were recovered). Final selection was made using the above criteria and in collaboration with other workers to correspond with wells selected for the cross sections. Six wells were finally selected and are listed in Table 1. Figure 1 shows the location of these wells.

Washed cuttings were examined for each of the wells, and portions of those intervals which appeared to be carbonaceous and thus favorable for the measurement of vitrinite were

collected. These samples were embedded in epoxy and were polished using standard coal petrographical procedures. All samples were examined using a Nikon Microphot II compound microscope under reflected light. Only samples containing sufficient vitrinite were analyzed for vitrinite reflectance in oil (R_o) using a Nikon P1 photometer attached to the microscope, again using standard coal petrographical procedures. Twenty-five reflectance measurements were to be collected from each sample examined. In many cases, however, this was not possible due to the paucity of vitrinite. Collected data were stored in Microsoft Excel spreadsheets.

RESULTS

The six wells selected for this study are listed in Table 1. Figure 1 shows the location of these wells.

Table 1. Wells selected for inclusion in the thermal maturation task

Permit No.	Cuttings (GSA) No.	County	T&R Location
224	1965	Clarke	Sec. 1, T.7N., R.1W.
3589	5671	Choctaw	Sec. 15, T.10N., R.4W.
1643	3642	Washington	Sec. 5, T.5N., R.2W.
1872	3846	Washington	Sec. 8, T.7N., R.4W.
2297	4388	Washington	Sec. 23, T.5N., R.1E.
2584	4939	Mobile	Sec. 1, T.1S., R.2W.

A total of 81 samples were collected from the six wells. Of these only 41 contained sufficient vitrinite to analyze. The results of the measurements for each well are given in Tables 2 through 7. Reflectance profiles generated by plotting vitrinite reflectance against depth for each well are shown in Figures 2 through 7. These profiles show a general increase of reflectance with depth. Figure 8 combines all samples together and illustrates that, although there is a general tendency for reflectance to increase with depth, the increase is not very great over the stratigraphic interval measured, and the line of correlation is nearly

Table 2. Vitrinite reflectance data for well PN 224 (Sec 1, T.7N., R.1W.)

Depth (ft)	Unit	Mean %R($_o$)	Minimum	Maximum	Count
387	Tuscahoma	0.31	0.28	0.38	25
648	Naheola	0.35	0.29	0.43	25
1,017	Naheola	0.34	0.30	0.45	25
1,467	Porters Creek	0.35	0.28	0.41	17
2,463	Eutaw	0.41	0.33	0.48	21
2,553	Eutaw	0.37	0.31	0.47	24
2,823	Eutaw	0.44	0.36	0.50	15
3,273	Tuscaloosa	0.40	0.30	0.49	19
3,723	Tuscaloosa	0.36	0.29	0.46	25
4,143	Tuscaloosa	0.38	0.28	0.51	22
4,233	Lower Cretaceous	no data	- -	- -	- -
5,533	Lower Cretaceous	no data	- -	- -	- -
7,393	Lower Cretaceous	no data	- -	- -	- -
8,983	Lower Cretaceous	no data	- -	- -	- -
9,723	Lower Cretaceous	no data	- -	- -	- -
10,953	Cotton Valley	no data	- -	- -	- -
11,403	Cotton Valley	no data	- -	- -	- -
11,508	Cotton Valley	no data	- -	- -	- -

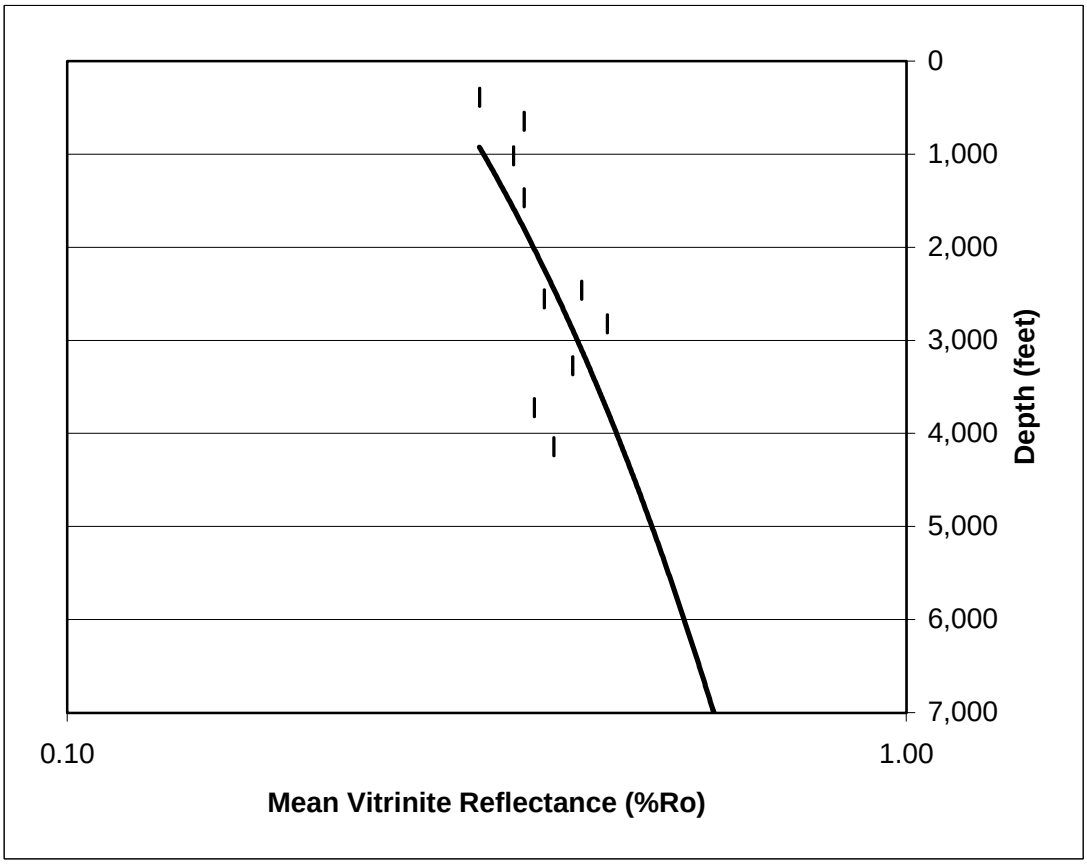


Figure 2.Vitrinite reflectance profile for well PN 224 (Sec 1, T.7N., R.1W.)

Table 3. Vitrinite reflectance data for well PN 3589 (Sec 15, T.10N., R.4W.)

Depth (ft)	Unit	Mean %R($_o$)	Minimum	Maximum	Count
740	Tuscahoma	0.32	0.27	0.39	25
920	Tuscahoma lignite	0.38	0.29	0.46	25
1,670	Naheola	0.36	0.26	0.44	25
2,150	Porters Creek	0.35	0.26	0.47	22
3,762	Eutaw	0.42	0.32	0.51	19
3,823	Eutaw	0.51	0.34	0.56	25
3,883	Eutaw	0.46	0.36	0.50	25
4,554	Tuscaloosa	0.52	0.36	0.59	18
5,510	Lower Cretaceous	no data	- -	- -	- -
6,560	Lower Cretaceous	no data	- -	- -	- -
7,530	Lower Cretaceous	no data	- -	- -	- -
8,490	Lower Cretaceous	no data	- -	- -	- -
9,527	Lower Cretaceous	no data	- -	- -	- -
10,480	Lower Cretaceous	no data	- -	- -	- -
11,560	Cotton Valley	no data	- -	- -	- -
12,100	Upper Haynesville	no data	- -	- -	- -
12,810	Lower Haynesville	no data	- -	- -	- -
13,280	Smackover	no data	- -	- -	- -
13,690	Norphlet	no data	- -	- -	- -
14,140	Louann	no data	- -	- -	- -
15,230	Werner	no data	- -	- -	- -

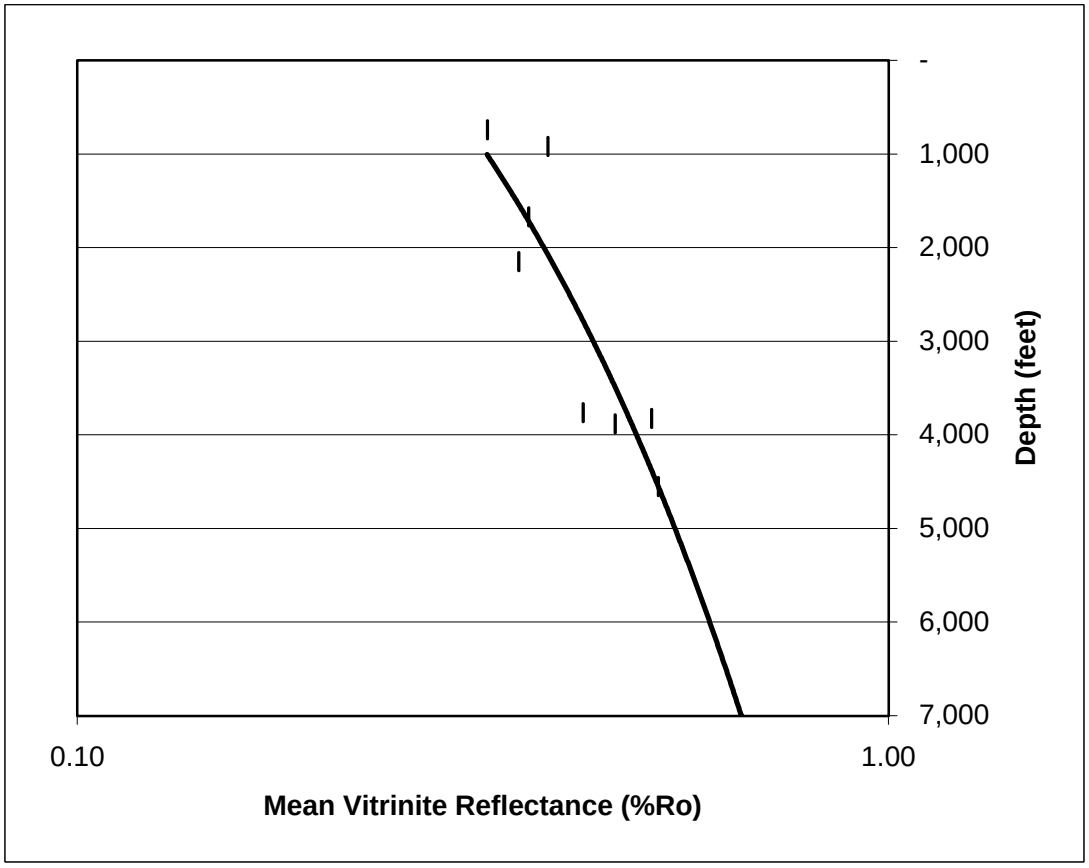


Figure 3. Vitrinite reflectance profile for well PN 3589 (Sec 15, T.10N., R.4W.)

Table 4. Vitrinite reflectance data for well PN 1643 (Sec 5, T.5N., R.2W.)

Depth (ft)	Unit	Mean %R($_o$)	Minimum	Maximum	Count
3,130	Naheola lignite	0.35	0.26	0.46	25
3,930	Porters Creek	0.49	0.32	0.54	20
5,460	Eutaw	0.47	0.36	0.56	17
6,450	Tuscaloosa	0.47	0.34	0.54	15
15,540	Haynesville	no data	- -	- -	- -

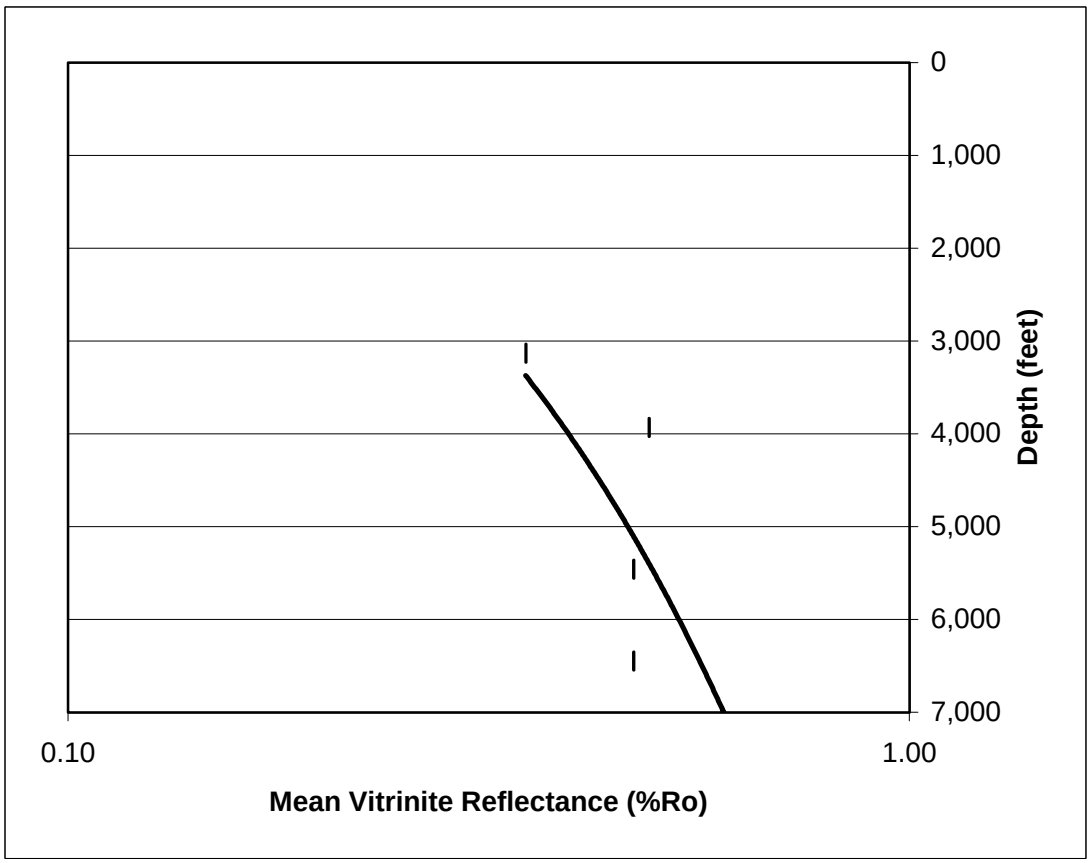


Figure 4. Vitrinite reflectance profile for well PN 1643 (Sec 5, T.5N., R.2W.)

Table 5. Vitrinite reflectance data for well PN 1872 (Sec 8, T.7N., R.4W.)

Depth (ft)	Unit	Mean %R($_o$)	Minimum	Maximum	Count
1,340	Tallahatta?	0.33	0.25	0.46	20
1,700	Tuscahoma	0.37	0.29	0.41	25
2,240	Nanafalia	0.34	0.26	0.38	25
2,870	Salt Mountain	0.41	0.32	0.49	19
2,900	Salt Mountain	0.35	0.27	0.49	25
2,990	Porters Creek	0.44	0.30	0.50	21
4,290	Selma	0.41	0.32	0.52	15
4,890	Selma	0.46	0.36	0.55	25
5,070	Eutaw	no data	- -	- -	- -
6,180	Lower Tuscaloosa	no data	- -	- -	- -
6,450	Lower Cretaceous?	no data	- -	- -	- -
14,500	Haynesville	no data	- -	- -	- -
14,690	Haynesville	no data	- -	- -	- -
14,760	Haynesville	no data	- -	- -	- -
15,630	Haynesville	no data	- -	- -	- -
15,350	Haynesville	no data	- -	- -	- -
16,330	Buckner	no data	- -	- -	- -

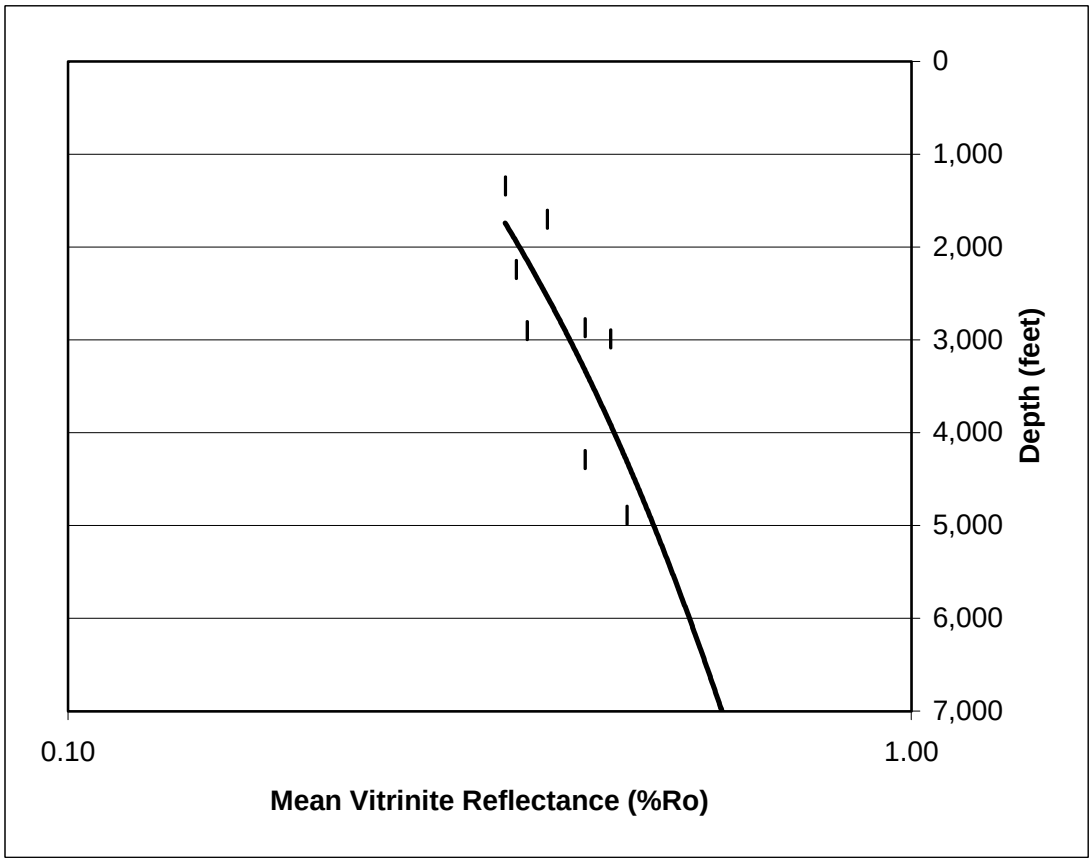


Figure 5. Vitrinite reflectance profile for well PN 1872 (Sec 8, T.7N., R.4W.)

Table 6. Vitrinite reflectance data for well PN 2297 (Sec 23, T.5N., R.1E.)

Depth (ft)	Unit	Mean %R($_o$)	Minimum	Maximum	Count
3,690	?	0.46	0.33	0.52	25
3,990	?	0.42	0.31	0.55	16
4,950	Tuscahoma	0.47	0.33	0.56	25
6,150	Naheola	0.46	0.37	0.53	25
6,800	Porters Creek	0.50	0.35	0.61	20
10,610	Lower Cretaceous	no data	- -	- -	- -
12,000	Lower Cretaceous	no data	- -	- -	- -
14,790	Haynesville	no data	- -	- -	- -
15,280	Haynesville	no data	- -	- -	- -
15,800	Haynesville	no data	- -	- -	- -

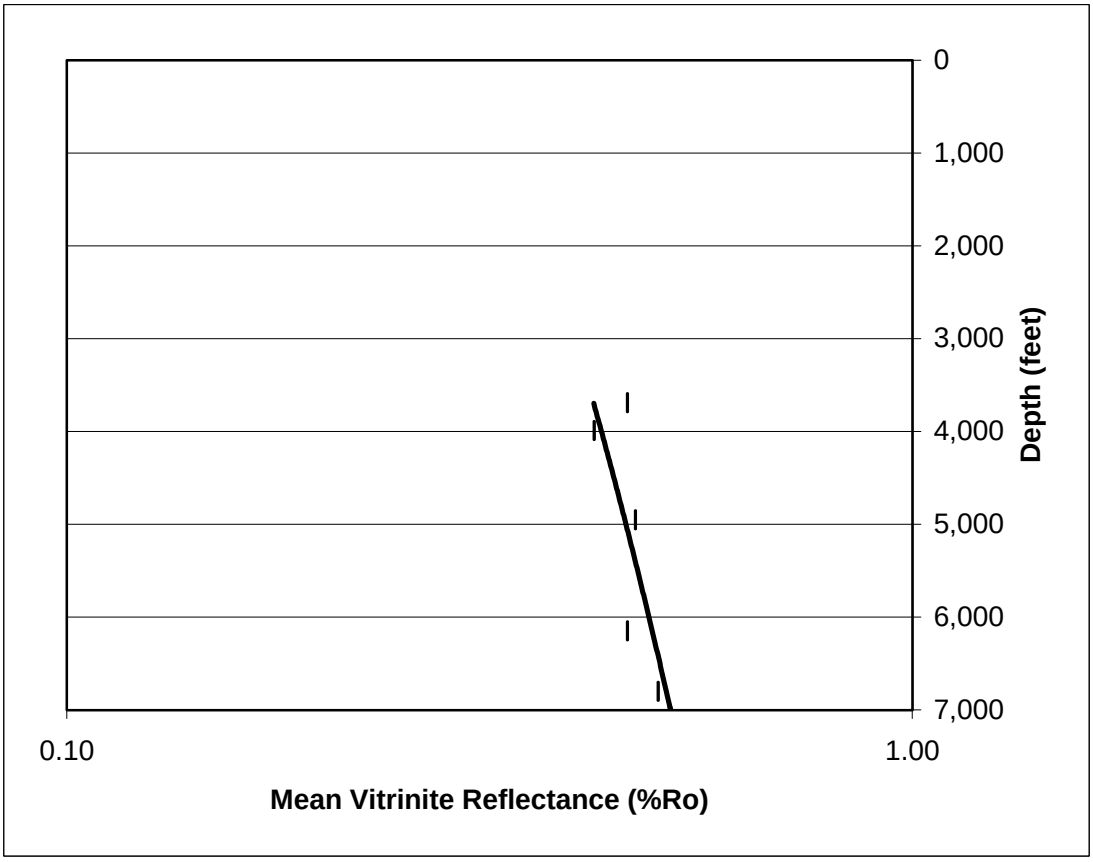


Figure 6. Vitrinite reflectance profile for well PN 2297 (Sec 23, T.5N., R.1E.)

Table 7. Vitrinite reflectance data for well PN 2584 (Sec 1, T.1S., R.2W.)

Depth (ft)	Unit	Mean %R($_o$)	Minimum	Maximum	Count
3,210	Tuscahoma?	0.36	0.26	0.49	25
3,870	Naheola lignite	0.36	0.30	0.46	25
4,770	Porters Creek	0.45	0.28	0.59	25
6,180	Eutaw	0.41	0.33	0.55	25
6,300	Eutaw	0.48	0.36	0.63	21
6,810	Upper Tuscaloosa	0.50	0.37	0.65	17
7,500	Lower Tuscaloosa	no data	- -	- -	- -
16,920	Haynesville	no data	- -	- -	- -
17,550	Haynesville	no data	- -	- -	- -
18,000	Haynesville	no data	- -	- -	- -

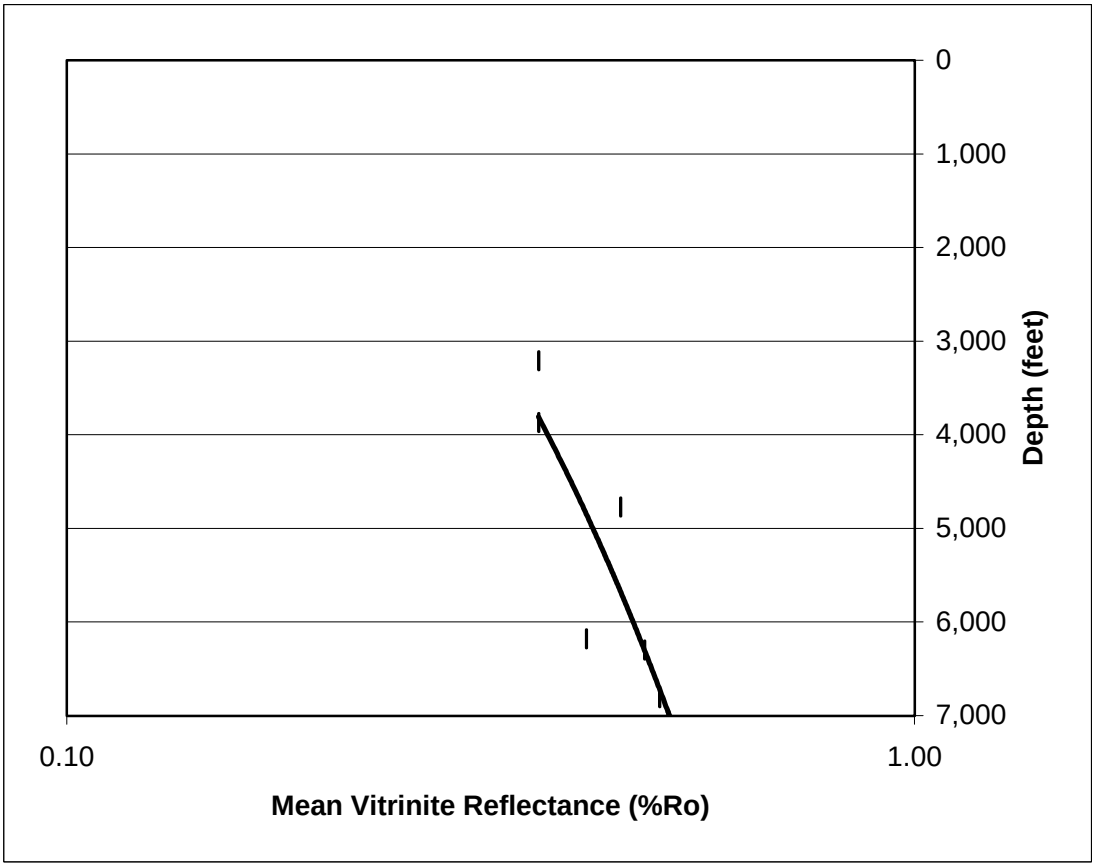


Figure 7. Vitrinite reflectance profile for well PN 2584 (Sec 1, T.1S., R.2W.)

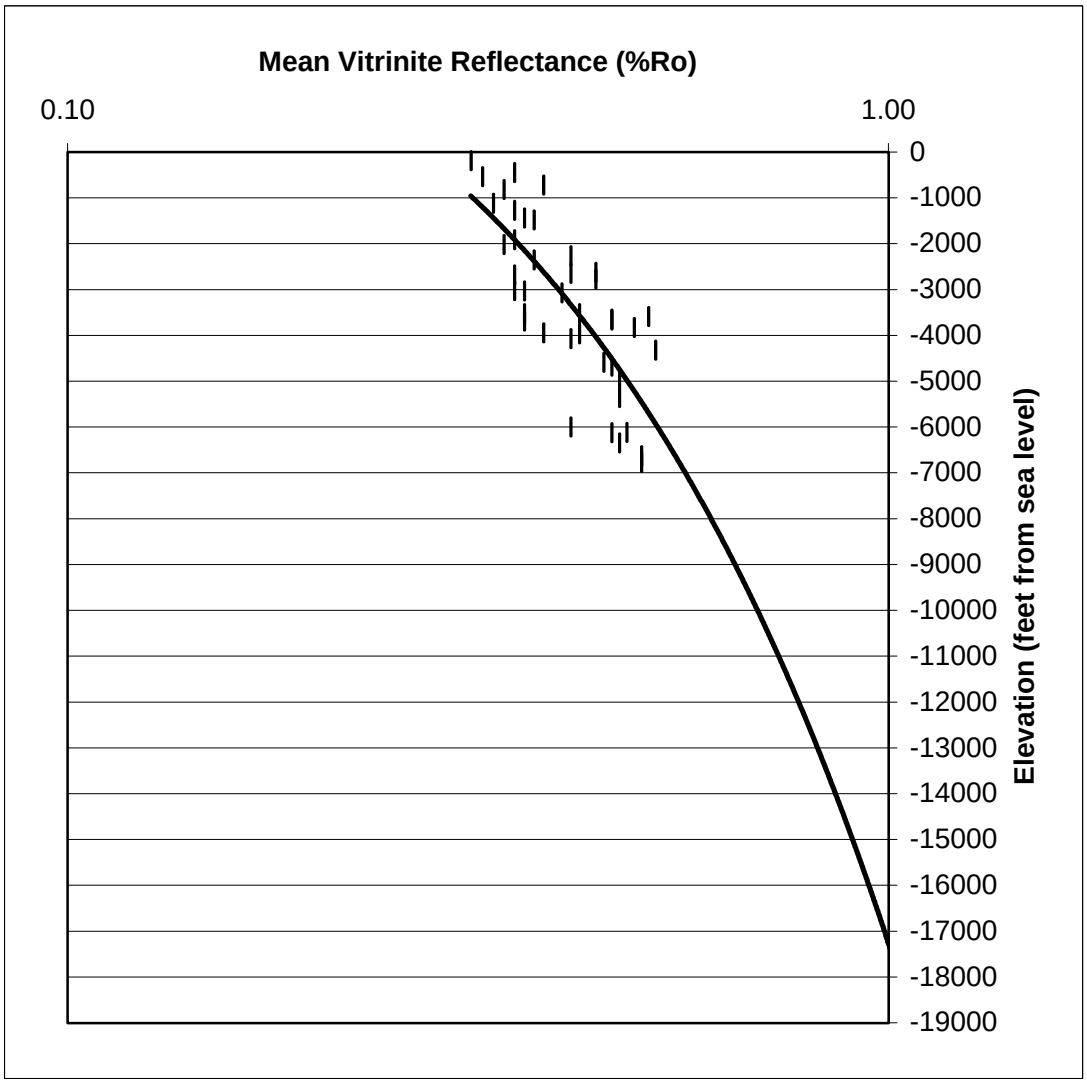


Figure 8. Relationship between elevation and reflectance for all samples.

vertical. Rank of the rocks studied varies from lignite (0.27% to 0.38%) to sub-bituminous (0.39% to 0.52%).

Samples collected from the Lower Cretaceous and deeper did not contain sufficient vitrinite to analyze. This is due mainly to either the oxidized nature of lithologies such as sandstone, siltstone and shale which usually have preserved vitrinite, or to the occurrence of lithologies such as limestone and anhydrite which typically do not contain any vitrinite.