# THE JACKSONIAN STAGE IN SOUTHEASTERN ARKANSAS

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CONTENTS

CONTENTS (Continued)

## ILLUSTRATIONS

ILLUSTRATIONS (Continued)

## ABSTRACT

Although Jacksonian deposits in the Mississippi Embayment have been recognized for many years, no detailed studies of these strata have been undertaken. Marine Jacksonian beds have been identified from small outcrops as far north as the latitude of Memphis, Tennessee, and the presence of upper Eocene strata beneath the alluvium of the Mississippi River Valley has been recorded, but the most accessible and representative Jacksonian section within the embayment occurs at the surface in an area of irregular shape in southeastern Arkansas. The present report is a result of studies of the Jacksonian outcrops in this region.

The outcrop area in southeastern Arkansas is situated in the western portion of the Desha basin, a partially enclosed structural depression formed as a result of the construction of the Mississippi structural trough by the Monroe uplift in the vicinity of the Arkansas-Louisiana boundary. The Jacksonian outcrops are inliers, completely isolated from the main body of Jacksonian sediments, which crop out in a belt roughly parallel to the coastline farther south.

Jacksonian beds containing marine invertebrates overlie typically nonmarine Claiborne sediments in Arkansas. The contact between the two units shows evidence of disconformity in parts of the area, but elsewhere no pronounced break in sedimentation is noted.

Both marine and nonmarine sediments occur in the Arkansas Jacksonian succession. Marine parts of the sequence are classified as the White Bluff formation and nonmarine parts as the Redfield formation. White Bluff beds were deposited under three distinct sets of environmental conditions as indicated by three separate marine facies which are recognized: (1) Pastoria sand member, which includes the coarser clastic elements of the formation, and is characterized paleontologically by a distinctive fauna, chiefly molluscan; (2) Caney Point marl member, which includes the more calcareous and glauconitic elements of the formation, and is characterized paleontologically by a varied fauna consisting of mollusks, foraminifers, ostracodes, corals, bryozoans, and echinoids; and (3) Rison clay member, which includes argillaceous and

subordinate coarser clastic elements, characterized generally by a sparse fauna consisting of arenaceous foraminifers and small mollusks (molds), but locally containing mollusca (molds) concentrated in thin discontinuous beds. The Redfield formation is lithologically variable, consisting principally of sand and silt, well bedded in most outcrops. It contains fossil leaves and other plant remains.

The Caney Point marl and Pastoria sand are stratigraphically equivalent basal members of the Jacksonian section. They are overlain by Rison clay and Redfield beds, which are seemingly correlative units. The Pastoria sand and Redfield formation are best developed in the northern part of the outcrop area whereas the Caney Point and Rison members are best developed in the southern part of the area.

The Caney Point and Pastoria members are interpreted as products of transgressive and innundative phases of a Jacksonian depositional cycle which occurred in the Desha basin. The lithological and paleontological differences between the two units are due to facies variation caused principally by proximity of the delta of a river of medium size. The deltaic deposits are located in the northern part of the basin, near the area where the Pastoria sand member is developed. The Redfield formation and Rison member of the White Bluff formation are regarded as products of the regressive phase of the sedimentary cycle. Nonmarine Redfield deposits accumulated near the source of the sediment, and Rison clay beds were laid down farther from the deltaic influence in a partially isolated body of brackish water.

Comparisons of the invertebrate fauna of the White Bluff formation with fossils of the standard Jacksonian sections, and other stratigraphic and geographic factors, indicate that the southeastern Arkansas sediments were deposited during the latest part of early Jacksonian time.

# THE JACKSONIAN STAGE IN SOUTHEASTERN ARKANSAS

By Louis J. Wilbert, Jr.

## INTRODUCTION

### JACKSONIAN STAGE

Upper Eocene deposits now collectively referred to the Jacksonian Stage[1] are among the most thoroughly studied sediments of the entire Gulf Coastal Plain. A complete bibliography of papers dealing directly or indirectly with parts of this unit would contain more than 500 titles. Geologists have been attracted by the prolific, well-preserved invertebrate fossils contained in the Jacksonian deposits. Cetacean remains are also common at some localities. The predominant marine character of the beds and the ease with which they may be mapped sets them apart from associated Tertiary strata. Finally, the wide geographic extent over which the stage is recognized makes it noteworthy.

Jacksonian strata bearing many local formational names are exposed in a narrow belt roughly parallel to the coastline from Mexico to North Carolina. Farther north, at least to Maryland, they also occur but are concealed beneath younger deposits. Though nearly all beds in this belt are marine, the lithology of the sequence varies considerably throughout this extent; however, a certain constancy in predominant lithologic character permits differentiation of the outcrop belt into three general depositional provinces. In the Atlantic and eastern Gulf Plain, exposed Jacksonian sediments are mainly calcareous; in the central Gulf Plain they are mainly argillaceous; and west of the Sabine River they are mainly arenaceous. The time equivalence of the deposits in these

[1] Until recently, the term Jackson or Jackson group has been employed commonly as a standard Eocene subdivision in the Gulf Coast region. Murray and Wilbert (1950) have pointed out that Jackson deposits thus recognized constitute a time-rock unit for which Jacksonian Stage is a preferable term. By their definition the Jacksonian Stage includes all sediments deposited during the time occupied by the late Eocene marine transgression and later regression in the Gulf-Atlantic Plain. This usage is followed here.

more or less distinct lithologic provinces is established mainly by paleontological criteria.

Jacksonian deposits are also known to occur at and beneath the surface inland from the coastwise outcrop belt over a large portion of the Mississippi Embayment.[2] Special depositional conditions prevailed in this region, and the sediments show more lithologic variation than elsewhere. The Jacksonian section of the embayment is most closely related to the argillaceous province of the central Gulf Plain coastwise belt geographically, lithologically, and faunally.

## JACKSONIAN STAGE IN THE CENTRAL GULF PLAIN

Early geological work by Wailes (1854), Conrad (1856), and Hilgard (1860) on the upper Eocene sequence of Mississippi resulted in the recognition of a distinct sedimentary unit overlying the middle Eocene Claiborne group and underlying the Oligocene Series. The richly fossiliferous deposits in the vicinity of Jackson, Mississippi, first attracted these workers and came to represent the type section of this unit, now known as the Jacksonian Stage. Numerous publications since 1860 discuss various aspects of the Jacksonian sediments in the outcrop belt extending eastward from Jackson. Modern stratigraphers recognize the persistent, thin, abundantly fossiliferous greensand near the base of the Jacksonian—the Moodys Branch formation—as one of the best mappable horizons in the Tertiary section. The overlying thick clay sequence, called Yazoo group, is almost equally well known. It contains most of the cetacean remains which are so characteristic of the Jacksonian.

Geologists have devoted much attention to the Jacksonian strata which crop out on the west side of the Mississippi Alluvial Valley in Louisiana, opposite Jackson, Mississippi. The Moodys Branch formation and the Yazoo

[2] The Mississippi Embayment is a triangular-shaped northward extension of the Coastal Plain, bisected by the Mississippi River. It is approximately 40,000 square miles in area, and extends inland for about 200 miles beyond the northern limit of the central Gulf Plain to the east and west. The apex of the embayment is near Cairo, Illinois; the southern boundary is arbitrarily placed along a line from Murfreesboro, Pike County, Arkansas, to the vicinity of Tuscaloosa, Alabama.

group are recognized here as well as farther east; and a younger formation, Danville Landing, is identified as a distinct upper Jacksonian unit in the outcrop belt between the Ouachita and Sabine Rivers.

In the Mississippi Embayment portion of the central Gulf Plain, studies comparable in detail to those in Mississippi and Louisiana have not been undertaken. Although much is known of the extent of Jacksonian deposits in this region both at and beneath the surface and although most of the organic remains have been reported and described, published accounts reflect reconnaissance work only. The present investigation is devoted to a stratigraphic description of Jacksonian outcrops in the western part of this area, distributed in seven southeastern Arkansas counties.

## PREVIOUS WORK

With exception of a few scattered localities along the edge of the Mississippi Valley in Kentucky and Tennessee, where nonmarine beds contain fossil leaves tentatively identified as Jacksonian by Berry (1915, p. 81; 1924, pp. 99-100), all Jacksonian outcrops reported within the Mississippi Embayment are found in the State of Arkansas. Geological literature concerning the Coastal Plain of Arkansas is not extensive. Papers written prior to 1894 are chiefly of historical interest and contain little data not repeated and more authoritatively discussed in subsequent publications. Lists of the older works, together with short summaries of their contents, are included in the writings of Harris (1894, pp. 1-6), Stephenson and Crider (1916, pp. 15-22), and Spooner (1935, pp. 3-17). No previously published report has been devoted exclusively to the Jacksonian deposits of this region, but treatment of these upper Eocene beds occupies a significant portion of several more inclusive studies. These are summarized in the following paragraphs.

Harris (1894) published the basic work on the Tertiary sediments which crop out in southern Arkansas. The object of his study was to describe the entire Tertiary

section southwest of the Arkansas River. Much of this report (pp. 87-176) was devoted to the "Claiborne[3] and Jackson stages." He gave a brief general discussion of the principal localities in each county, and included a list of fossils gathered from each site visited. The paleontological portion of the work is particularly important.[4] Original descriptions of many Jacksonian molluscan species from Arkansas appear in these pages. The faunal studies demonstrated that marine beds in Cleveland and Drew Counties are Jacksonian in age. Harris later (1902, p. 22) concluded that the mollusks he collected from White Bluff (Jefferson County) and Little Crow Creek (St. Francis County) were likewise Jacksonian. He was then able to establish the approximate limits of the Jacksonian sea in the Mississippi Embayment.

A. C. Veatch (1906), collaborator with Harris on many stratigraphical studies in the central Gulf Plain, published a paper on groundwater resources which added to general knowledge of relationships of the Jacksonian deposits to other sediments of the Mississippi Embayment. Discussion of stratigraphical details of the Tertiary beds in this report is meager, but the cross-sections, well records, and geological map are valuable contributions. These combine to show the attitude of the deposits and general structural features of the embayment. The geologic map (Veatch, 1906, Plate 3) shows essentially the same distribution of Jacksonian sediments in southeastern Arkansas as is found on the current geologic map of Arkansas (Arkansas Geological Survey, 1929).

The most important publication on the geology of the area northeast of the Arkansas River in the northern part of the Mississippi Embayment was written by Stephenson and Crider (1916). The more significant parts

[3] Part of the marine deposits now known to be Jacksonian were identified as Claiborne by Harris' predecessors on the Arkansas Geological Survey. Harris (1894) followed their usage in part, with some doubt, referring the marine facies developed at White Bluff (Jefferson County) to the Claiborne. He later became convinced that all marine beds in this general stratigraphic position were Jacksonian.

[4] The collections of Harris, together with others made in the region since that time, have been restudied recently by Harris and Palmer (1946-47) in preparing a monograph on the Jacksonian Mollusca of the central Gulf Plain.

of this work are discussion of the Tertiary geology of the Crowleys Ridge area, and a geologic map of northeastern Arkansas (used without conspicuous change for that portion of Arkansas on the present state geologic map). The considerable data regarding subsurface occurrances of Jacksonian fossils, and the detailed sections and lists of invertebrates collected from the Little Crow Creek locality add to the usefulness of this paper.

In 1935, Spooner prepared a voluminous report on the oil and gas geology of the Coastal Plain of Arkansas. It contains much information regarding subsurface stratigraphy of the region, especially of the Cretaceous and older Tertiary deposits penetrated in wells. Little new information regarding Jacksonian deposits is presented, but the discussion of structural features of the embayment, and the regional information it contains concerning the "Arkansas syncline" and the Desha basin are important to the present study.

The latest significant work on the geology of the Mississippi Embayment region was published by Fisk (1944). This is the report of a geological investigation of the alluvial valley of the Mississippi River, undertaken for the U. S. Engineers, but it effectively summarises existing knowledge and adds much new information about Tertiary beds in the embayment. The numerous maps, structure sections, and diagrams found in Fisk's report were prepared after study of many samples from deep and shallow borings throughout the Mississippi Alluvial Valley; they graphically present data which have a bearing on most geological problems of the central Gulf Plain. One of the most notable contributions of the work is a map showing the distribution of Tertiary deposits beneath the alluvium of the Mississippi Valley (Fisk, 1944, Plate 10). This is the only source of documented data on the extent of the Jacksonian beds over a large portion of the embayment.

## SCOPE OF THE PRESENT INVESTIGATION

In all publications just mentioned, Jacksonian deposits are treated only in most general terms; they are not differentiated precisely, upper and lower limits are not set, paleontological data are more taxonomic than stratigraphic, and correlations with the standard coastwise sequence are mere approximations. The aim of the present paper is to supply such needed stratigraphic detail as may be gained from a study of Jacksonian outcrops within the Mississippi Embayment.

The major portion of this report comprises discussion of the stratigraphy of the Jacksonian deposits present at the surface in the southwestern portion of the Mississippi Embayment, in Grant, Jefferson, Cleveland, Lincoln, Bradley, Drew, and Ashley counties, southeastern Arkansas. (Figure 4). In this, the only area within the embayment where extensive Jacksonian outcrops occur and where a representative stratigraphic section is exposed, data are available in sufficient detail to support conclusions bearing on late Eocene history of the region.

Field work was largely confined to southeastern Arkansas, and had as its objective the establishment of the stratigraphic succession of beds, and interpretation of the facies variation of the marine deposits represented. No attempt was made to prepare a detailed map of the outcrop area, however. Laboratory studies were principally directed toward identification of fossil invertebrates found in these sediments. A paleontological analysis of the fauna of each stratigraphic subdivision recognized was made for the purpose of evaluating relationships between these subdivisions, and of correlating the section with the Jacksonian succession in Mississippi and Louisiana.

## ACKNOWLEDGMENTS

In the course of work on this project valuable assistance, counsel, and encouragement has been given freely by many associates and friends. Dr. H. N. Fisk, of the

Humble Oil Company, suggested the problem and generally granted me full access to all of the subsurface samples taken in connection with his work on the Mississippi Alluvial Valley. He also made many suggestions which facilitated the completion of the study. Dr. R. C. Moore, University of Kansas, has directed the work and edited the manuscript. He accompanied me on a trip over much of the area of study, and pointed out several important features which previously had escaped notice. Mr. D. P. Meagher, Carter Oil Company, who had done considerable geologic work in southeastern Arkansas, was very helpful in orienting me for the initial field work, in indicating the principal exposures, in discussing stratigraphic problems and in criticizing the completed manuscript. Mr. Meagher first noted the presence of Jacksonian deposits in Grant County, where Claiborne is shown on the Arkansas geologic map. Dr. H. V. Howe, Louisiana State University, identified the ostracodes which are recorded in the present paper, and contributed advice regarding stratigraphic significance of the species recognized. Dr. H. V. Anderson, Louisiana State University, checked identification of the foraminifers and criticized early drafts of the manuscript. Dr. G. E. Murray, Louisiana State University, accompanied me to major outcrops and made helpful suggestions. Messrs. George Belchic and John Lochridge acted as field assistants during part of the summer of 1947, and Mr. William Arper did the same during the month of August, 1949. The Corps of Engineers, Little Rock District, furinshed samples from borings made to investigate dam site foundations near White Bluff; and Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi, furnished samples from other borings made in the Mississippi Alluvial Valley. Mr. D. B. Tait of the United States Geological Survey, Little Rock, Arkansas, supplied data regarding Jacksonian deposits found in wells which he investigated. The assistance of all mentioned above has made the task much easier, and their help is gratefully acknowledged.

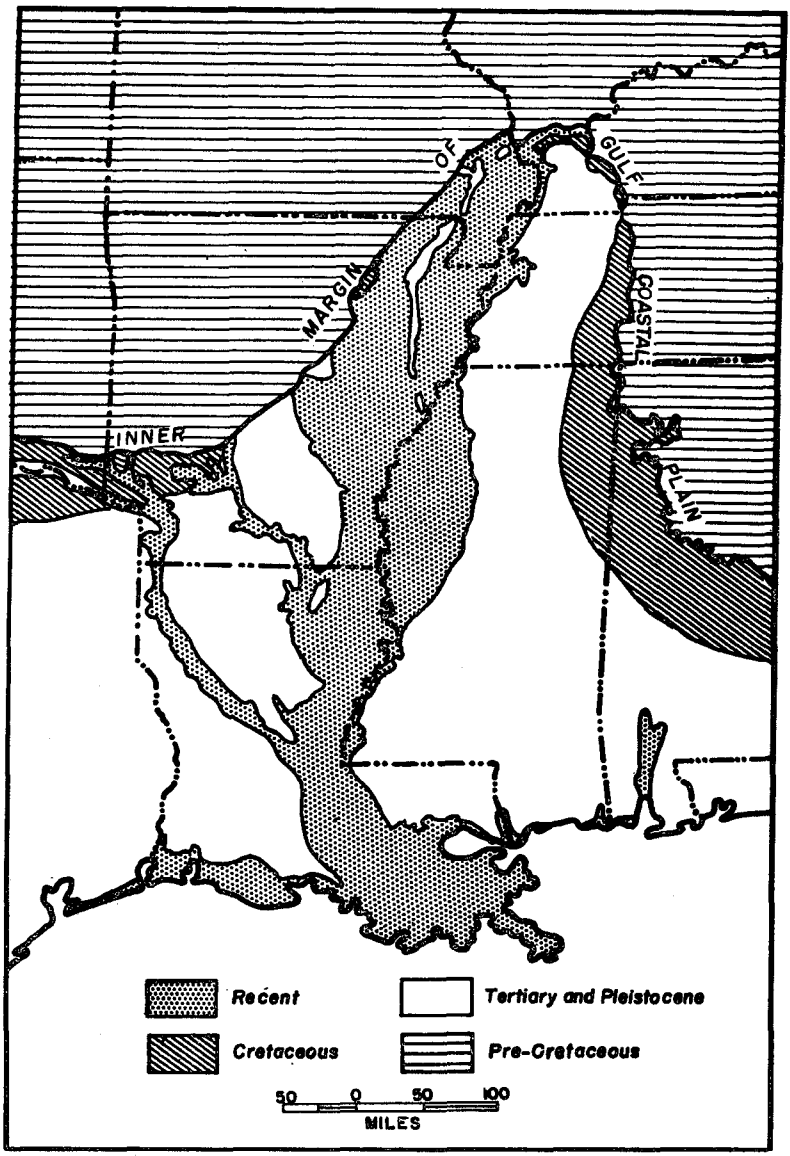



Figure 1. Generalized geologic map of the central Gulf Plain (modified from Fisk, 1944).

# REGIONAL GEOLOGY OF THE MISSISSIPPI EMBAYMENT

## PHYSIOGRAPHIC SETTING

The alluvium deposited by the Mississippi River, its major tributaries, and distributaries (the Mississippi Alluvial Valley) has masked pre-Recent deposits in an elongate area 35 to 125 miles wide extending from the northern end of the Mississippi Embayment to the Gulf of Mexico (Figure 1). Terrace deposits of gravel, sand, and clay, attributed to fluviatile activity during Pleistocene interglacial stages, have covered a considerable portion of the uplands adjacent to the major drainage channels of this region. Within the embayment, Tertiary and Cretaceous sediments crop out in irregular areas on stream divides west of the Mississippi Alluvial Valley, and in more continuous strips east of the valley.

The present course of the Mississippi River in the Coastal Plain Province is, for the most of its length, near the extreme eastern edge of its alluvial valley but near the axis of the Mississippi Embayment. The only conspicuous deviation from this position is in northwestern Mississippi where the Yazoo River (the only major eastern tributary of the Mississippi between the Ohio River and the Gulf of Mexico) occupies the eastern part of the valley. Since the Mississippi River flows through the center of the embayment, the effect of the drainage arrangement on continuity of the outcrop belts of Tertiary and Cretaceous formations is marked. East of the river, it is possible to trace many stratigraphic units of the Upper Cretaceous, Paleocene, and lower and middle Eocene from the coastwise outcrop belt into the embayment. On the west side of the Mississippi River, however, continuous outcrops are lacking, and much of the territory between the coastal belts and the embayment is covered by alluvium or Pleistocene terrace material. Tertiary and Cretaceous outcrops west of the Mississippi River in the embayed portion of the central Gulf Plain are geographically isolated from beds of similar age parallel to the coastline.

## STRUCTURE

The Mississippi Embayment owes its existance to structural movements of Paleozoic rocks of the Central Lowlands. These movements produced a troughlike syncline which plunges southward. The axis of the syncline is traced, with a few deviations, by the present Mississippi River course. This structural corollary of the Mississippi Embayment is called "Arkansas syncline" by Spooner (1935, pp. 136-137) and "Mississippi Structural Trough" by Fisk (1944, p. 64; Figure 5). Distribution of Lower Cretaceous sediments indicates that the trough was not formed prior to the beginning of late Cretaceous time. Thereafter, as Upper Cretaceous sediments accumulated in this region, continued (perhaps intermittent) subsidence occurred.

One of the major positive structural features of the central Gulf Plain is the Monroe uplift.[5] This is a broad dome located beyond the southern limit of the Mississippi Embayment, in northeastern Louisiana and southeastern Arkansas, and adjacent portions of western Mississippi. A long and complicated history is suggested by subsurface data, but simplified, they indicate that movement of the Monroe Uplift commenced prior to the beginning of the Cretaceous Period and continued into the Tertiary Period. The positive movements of the Monroe uplift caused a deflection of the axis of the Mississippi structural trough toward the east near the Louisiana-Arkansas boundary, and also caused the width of the trough at that point to be reduced. A structural basin, partially isolated from the remainder of the Coastal Plain, was thus created in the region north of the Monroe uplift (Figure 3). As the center of this basin is in Desha County, Arkansas, it is sometimes called the Desha basin. Because of its partial isolation, the sediments which accumulated in the Desha basin exhibit some characteristics not shared by equivalent beds in adjacent sectors.

[5] Including "Sharkey Platform" of Mississippi geologists.

## SEDIMENTARY HISTORY

Nonmarine sediments predominate over marine sediments in the Mississippi Embayment. It was only during the most widespread transgressions of the sea that marine beds were deposited extensively within the embayment. However, since marine beds yield the principal evidence of value in dating sediments and establishing correlations in the Gulf Plain, these beds are considered to be of primary importance. Three major marine invasions are recorded in the Mississippi Embayment section: (a) toward the close of late Cretaceous time; (b) in Paleocene time; and (c) in late Eocene time. These are punctuation marks in the sedimentary history of the region.

Upper Cretaceous deposits are exposed around the inner margin of the embayment adjacent to the Paleozoic rocks east of the Mississippi River (Figure 1). In eastern Arkansas, on the opposite side of the valley, only one or two scattered outcrops are noted. The character of the Cretaceous sediments reflects fluctuations of the strand line, but indicates a gradual transgression of the sea toward the head of the embayment. Marine conditions existed farthest inland during the latter portion of the epoch, as manifested in beds of the Ripley formation (Maestrichtian) which contain marine invertebrates in Kentucky, Illinois, and Missouri. On the west side of the Mississippi River, the Nacatoch sand, partially equivalent to the Ripley formation, is identified from fossils found in Independence County, Arkansas, 80 miles northeast of Little Rock (Stephenson, 1939, pp. 543-544; Stephenson et al, 1942, correlation table).

Tertiary deposition began in the Paleocene (Midway group). Marine Midway fossils are found in southern Missouri (Farrar, Grenfell, and Allen, 1935, pp. 20-21) at the northern end of the embayment, indicating complete inundation of the central Gulf Plain. The contact of the Midway beds with the underlying Cretaceous sediments is not marked by distinct angularity in this region, nor is there prominent physical evidence of a stratigraphic break reported.

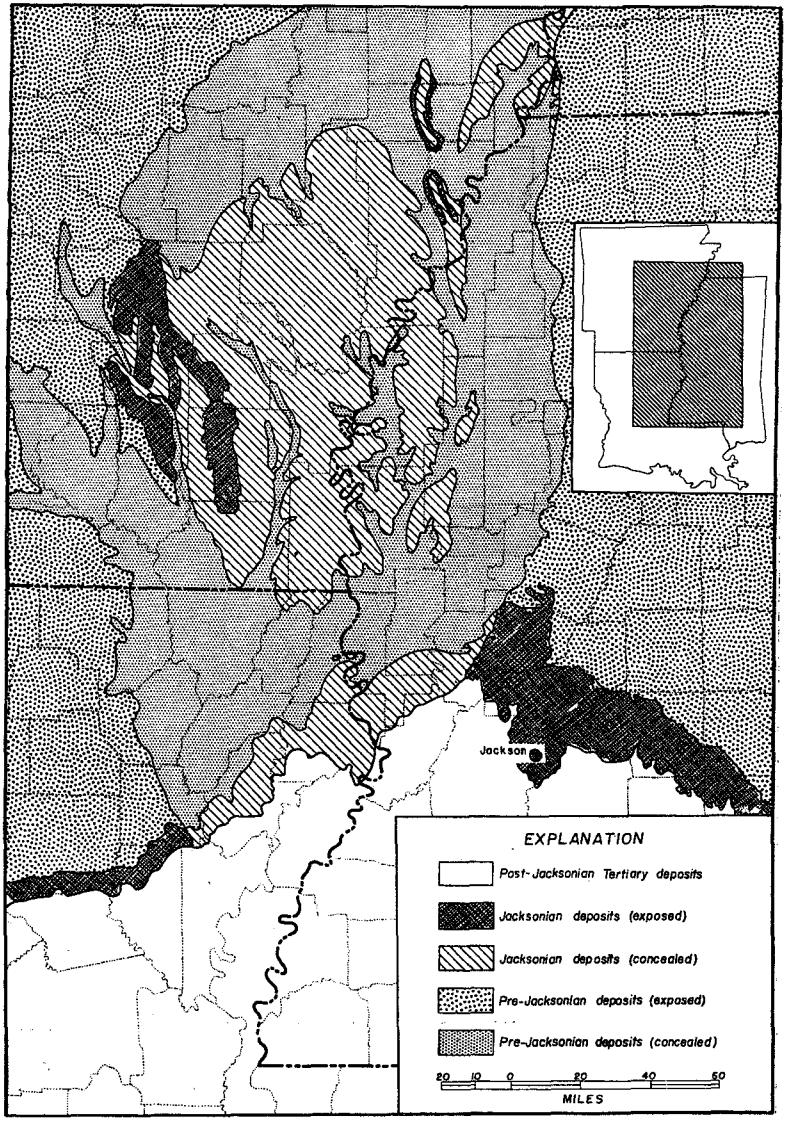



**Figure 2. Pre-Pleistocene paleogeographic map of a portion of the central Gulf Plain, showing the distribution of Tertiary and older sediments with special reference to Jacksonian deposits. Data on sediments beneath Mississippi Valley alluvium were taken from Fisk (1944).**

Nonmarine deposits identified as lower Eocene (Wilcox group) and middle Eocene (Claiborne group)[6] are mapped over a large portion of the embayment. The differentiation of the two units west of the Mississippi River is somewhat arbitrary, and maps which separate them show only approximate distribution. Age determinations are based on stratigraphic position and on identifications of fossil leaves found at scattered localities. East of the Mississippi River, more conclusive basis is offered for recognition of two distinct divisions, since these units may be traced into the coastwise belts where better chronology is established. The combined thickness of the Wilcox-Claiborne section is said to be 2000 to 3000 feet in the Desha basin. This exceeds the combined thickness of the remainder of the Tertiary section.

Deposits of the Jacksonian Stage are the youngest of the Tertiary sediments generally identified in this region. Jacksonian beds are marine throughout most of the embayment, and recognizable marine fossils are found as far north as the latitude of Memphis, Tennessee. Paleobotanical remains indicate that beds in the vicinity of Hickman, Kentucky, may be referable to the stage (Berry, 1924, pp. 99-100). Unlike older Tertiary units, Jacksonian strata are not tracable on the surface from the coastwise belts into the embayment. All marine Jacksonian beds within the Mississippi Embayment crop out as isolated inliers west of the Mississippi River.

No sediments in the area have been identified as Oligocene or Miocene, and reports of Pliocene occurrences are limited to deposits of sand and gravel considered to be Pleistocene by many authors.

Chief features of Quaternary history are: (1) fluviatile activity of Pleistocene time, which is represented by present terrace deposits along the major drainage channels, and (2) development of the Mississippi Alluvial Valley.

[6] Subsurface marine Claiborne (Cook Mountain?) beds are reported by Spooner in Bradley County (1935, p. 123) at the southern margin of the embayment. D. B. Tait (personal communication) reports probable Claiborne fossils from cuttings of a well in Arkansas County at depths of 860 to 950 feet. No marine Claiborne beds have been found at the surface within the embayment.

## SUMMARY

As a result of downwarping of the Mississippi structural trough and upwarping of the adjacent Monroe uplift, the Desha basin was formed. This basin acted as a center of deposition within the Mississippi Embayment, and constituted a somewhat separate depositional province, partially isolated from the remainder of the Gulf Plain. Here accumulated a section of Upper Cretaceous and Cenozoic deposits in which nonmarine beds form a larger percentage of the whole than in comparable sequences in the coastwise outcrop belt. Only the most widespread transgressions of the sea over the Coastal Plain are marked by marine deposits in this area. After successive marine invasions of the embayment in Late Cretaceous and Paleocene times, thick nonmarine deposits of the Wilcox and Claiborne groups were laid down. Final inundation of the Mississippi Embayment occurred during part of the Jacksonian Age. Shortly after marine Jacksonian sediments were deposited, the Desha basin ceased to exist as a depositional center. Quaternary fluviatile activity produced alluvium and other deposits which mask older sediments over large parts of the embayment adjacent to the Mississippi River and its tributaries. Upper Cretaceous, Paleocene, and lower and middle Eocene deposits may be traced from the coastwise belt into the Mississippi Embayment on the east side of the river, but west of the Mississippi Alluvial Valley this is not possible. All Jacksonian outcrops within the embayment are isolated.

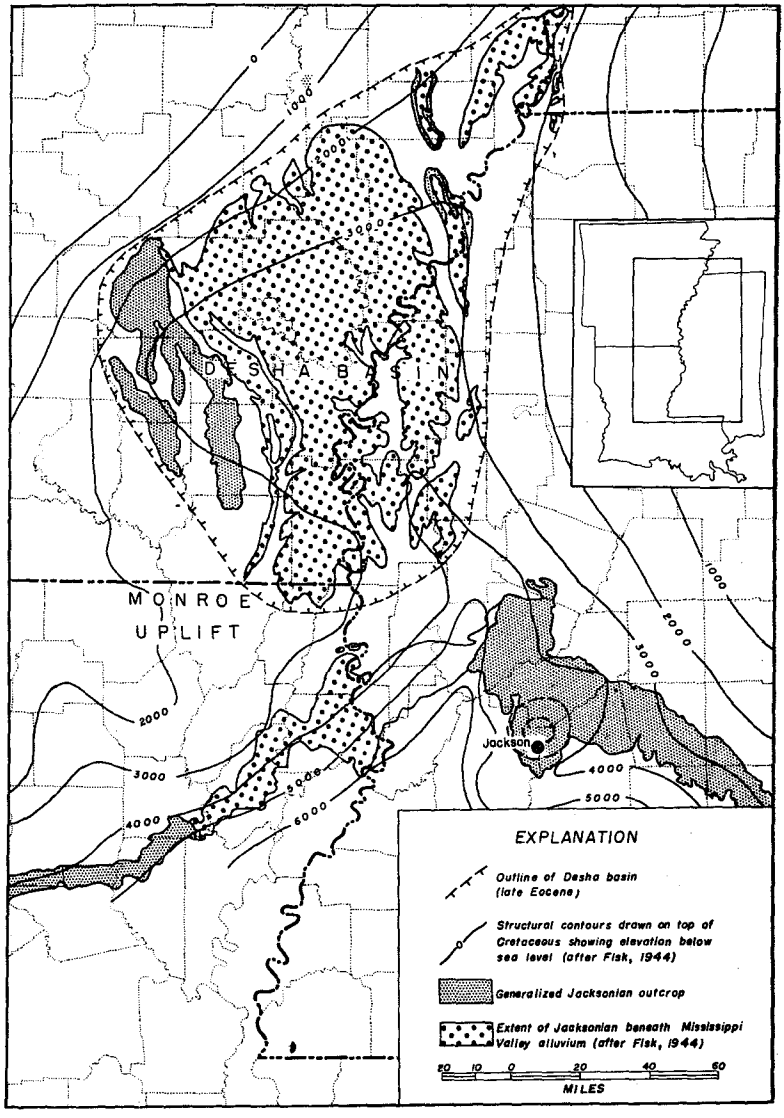



**Figure 3. Relationship between distribution of Jacksonian deposits and major structural features of the central Gulf Plain.**

# STRATIGRAPHY OF THE JACKSONIAN STAGE IN SOUTHEASTERN ARKANSAS

## GENERAL DISCUSSION

The extent of Jacksonian sediments within the Mississippi Embayment is shown by Figure 2. Most of these deposits are covered by alluvium of the Mississippi River Valley, and are known only from borings. Outcrops occur in two widely separated areas, near the northern and western limits of Jacksonian deposition in this region.[7] In the northern area, a few outcrops are found along the flanks of Crowleys Ridge[8], in Phillips, Lee, St. Francis, and Cross Counties. Only one outcrop where marine beds may be observed is significant; this is the well-known Little Crow Creek locality (Stephenson and Crider, 1916, pp. 76-78). Although this exposure is important in fixing the northern extent of Jacksonian marine transgression, and although the occurrence of *Basilosaurus cetoides* (Owen) at the locality (Palmer, 1939) aids in correlating the embayment section with the coastwise belt, the locality is of very limited stratigraphic value for determining the succession of deposits and geological history of the embayment in late Eocene time.

The other outcrop area occupies a much larger tract in Jefferson, Grant, Cleveland, Lincoln, Drew, Ashley, and Bradley counties, in southeastern Arkansas. Exposures available in this district provide a representative marine section of Jacksonian beds, and yield important data bearing on Jacksonian stratigraphy of the central Gulf Plain. These outcrops are the object of the present study.

The southeastern Arkansas outcrop area is a minimum distance of 60 miles from the nearest Jacksonian exposure in the coastwise belt. The area is located near the western

[7] The nonmarine deposits tentatively referred to the Jacksonian on the basis of fossil leaves (Berry, 1915; 1924) found at several localities north of Memphis are disregarded.

[8] Crowleys Ridge is a narrow upland within the Mississippi Alluvial Valley, aligned parallel to the valley axis, extending from Commerce, Missouri, to Helena, Arkansas. It is a remnant of the pre-Recent surface of the Mississippi Embayment preserved due to its position as a divide between major drainage channels (Fisk, 1944, p. 6).

margin of the Mississippi Embayment, and it lies in the western portion of the Desha basin. The distribution and attitude of Jacksonian beds here conforms closely to the overall structure of the region as revealed by subsurface studies, and confirms the presence of the Desha basin. The relationship between distribution of Jacksonian deposits and major structural features of the central Gulf Plain is shown by Figure 3.

Outcrops occur on divides between the Arkansas, Saline, and Ouachita Rivers. A gently rolling topography is developed on the easily eroded silts and clays which form the bulk of the Jacksonian section in this area. In contrast to the prevailing topographic expression of Jacksonian sediments of the coastwise belt, no conspicuous lowland is evident, for there are no resistant units above or below the sequence in southeastern Arkansas. Instead, these deposits occupy a topographic position intermediate between the older Tertiary beds of greater elevation, which are adjacent to the Paleozoic rocks of the Ouachita Mountains, and the wide, flat, alluvial surface of the Mississippi River Valley.

### Influence Of Streams On Outcrops

One of the actions of the Mississippi River and subordinate streams in the Mississippi Embayment during recent geologic time has been the masking of Jacksonian sediments by alluvium over three-fourths of the area of their known extent. Tributary streams of the Mississippi River have modified the outcrop area in southeastern Arkansas as well, and have produced the irregular pattern of Jacksonian deposits shown by the areal geologic map of Arkansas (Figure 4).

The alluvial valley of the Arkansas River and the alluvial valley of the Mississippi River are confluent in the Coastal Plain Province. The present course of the Arkansas River, and that of Bayou Bartholomew which occupies an abandoned channel of the Arkansas River (Fisk, 1944, p. 45), together with the Pleistocene terrace deposits found in the uplands adjacent to these streams,

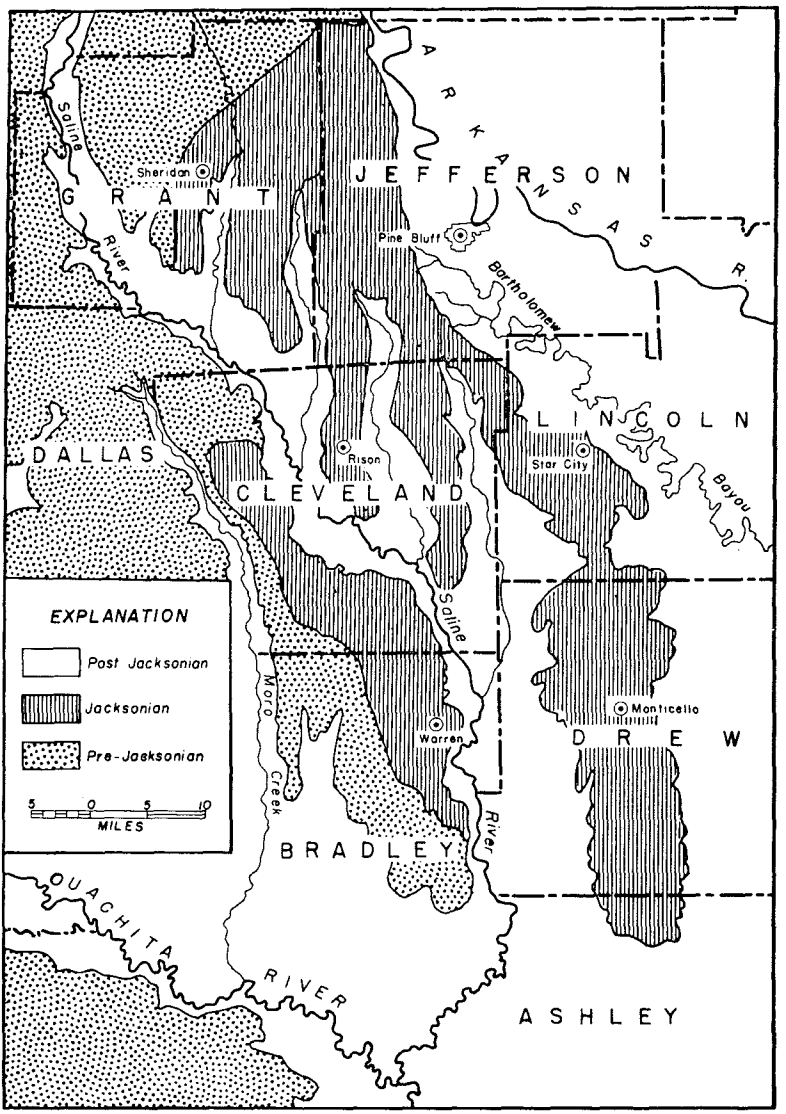



**Figure 4. Jacksonian outcrop area of southeastern Arkansas (modified after geologic map of Arkansas, 1929).**

limit the Jacksonian exposures on the east. The Saline River cuts diagonally across the outcrop area. This river and its tributaries account for most of the irregularities in the outcrop pattern (Figure 4). The northern and west-

ern margins of the outcrop area are not so dependent upon stream position, but are stratigraphically controlled by the location of the contact between the basal unit of the Jacksonian sequence and underlying beds.

One rather close relationship between stream position and structural attitude of Jacksonian sediments deserves special mention. The course of the Saline River is approximately parallel to the strike of the Tertiary beds in Cleveland County and in the northern portion of Bradley County. Accordingly, different parts of the Jacksonian section are present on opposite sides of the river. The basal marine member of the Jacksonian Stage is exposed throughout the area of outcrop west of the Saline River, and a few beds of stratigraphically higher subdivisions are seen. The angle of dip of this basal marine unit is about the same as the angle of slope of the upland toward the Saline River. In the upland on the east side of the river, younger Jacksonian beds are encountered, and the basal marine member is at minimum 50 feet below the surface over much of the area south of the latitude of Pine Bluff, Arkansas. Near water level along the left bank of the Saline River several exposures of the basal marine beds containing well preserved fossils are known.

## Nature Of The Exposures

Good individual outcrops of the Jacksonian deposits in southeastern Arkansas are not common. Excepting the few good sections seen in bluffs along the Arkansas River in northern Jefferson County, it is difficult to find a locality where more than 10 feet of continuous section may be viewed. Over much of the outcrop area small exposures of Tertiary sediments in roadcuts are the sole source of geologic information. Commonly these are either too widely separated or lack sufficiently distinctive beds of moderate thickness to permit close correlation. Slumping, high water alluviation along streams, soil and other covering, and heavy vegetation all combine to make stratigraphic detail difficult to obtain.

The few places where representative sections are encountered have furnished the basic information upon which much of the report is based. For example, 5 to 10 feet of marine Jacksonian beds are visible above low water level at several points along the left bank of the Saline River. At two of these (Caney Point, Locality 29, and Cornish Ferry, Locality 38) well-preserved megafossils are found, and collections made at these places yield the only easily studied larger invertebrate remains encountered in the southern portion of the region.

In a few local areas where relief is greater than normal, small creeks and gulleys are actively extending themselves headward. Under these circumstances erosion is very rapid, and good exposures result. In several instances visits to such spots after a year or more revealed significant changes in the exposed section. A mediocre outcrop of the basal marine member was measured in a roadside drainage ditch (Locality 36). When visited two years later this outcrop furnished one of the best examples of the basal contact found in the entire outcrop area.

It is much more common to find a few feet of stratified beds (generally less than 5 feet) exposed in road-cuts on the slopes of the hills. These hills, for the most part, have a graveliferous remnant of Pleistocene terrace cover on their crests, and a small stream of gently sloping valley walls at their feet. The soft Jacksonian clay slumps badly, and the active colluviation is a detriment to good exposures. Measurable sections are seen most often beneath the gravel and sand of the hill-top and above the colluvial cover at the foot of the hill. The best roadcuts are found along the Warren-New Edinburg-Kingsland road, the Kingsland-Rison-Pine Bluff road, and local roads in the vicinity of Rye, Pansy, and Herbine in Cleveland County, and Grapevine and Lamont in Grant County. Parts of the stratigraphic column were determined by piecing together small fragments of the section exposed along such roads, using topographic profiles prepared from Paulin altimeter traverses. Conclusive results were not always obtained by this method. Proof of some of the stratigraphic rela-

tionships which are obscurely expressed in exposed sections would require additional data from properly spaced borings.

The most spectacular locality in the entire region is at White Bluff in northern Jefferson County. There, the Arkansas River is adjacent to its western valley wall for a distance of about two miles and is actively eroding the upland against which it flows. A steep bluff is produced, which rises 40 to 60 feet above low water level. Continuous exposures of Tertiary sediments are seen throughout most of the two-mile length. Slumping is active, and large masses weighing many tons have fallen to the foot of the bluff. Red Bluff and South Red Bluff, formed in the same way as White Bluff, are located one and one-half to two miles (map distance) to the north, and they provide other good exposures.

## Upper And Lower Limits

Previous writers usually employed the lithologic (rock) terms "Jackson formation" or "Jackson group" to apply to marine beds which contain fossils similar to those found in the vicinity of Jackson, Mississippi. Such marine beds present in southeastern Arkansas have been called Jackson. In this area the marine deposits constitute a mappable unit, underlain by nonmarine, carbonaceous sediments, and overlain in places by nonmarine strata. Over much of the outcrop area the marine unit has a well-defined base, and a less distinct upper contact. The beds upon which it rests have been referred to the Claiborne group; the locally developed nonmarine section above it is normally included within the Jackson group of previous writers.

With the reclassification of upper Eocene strata through the recognition of the Jacksonian Stage as a time-rock unit, it is necessary to reconsider the partition of this part of the section. Sediments identified as Jacksonian in southeastern Arkansas must be shown to have been deposited during the time occupied by the advance and

subsequent retreat of the late Eocene sea in the Coastal Plain province.

It is easy to demonstrate paleontologically that the marine beds termed Jackson in this area were laid down during the same marine cycle as were beds of the Jacksonian type section near Jackson, Mississippi. This correlation is already well established. However, problems of age relationship arise when the nonmarine beds below and above the marine unit are considered.

Regional studies have shown that a thick section of carbonaceous sand, silt, and clay underlies the marine Jacksonian in Arkansas. Stratigraphic position and identifications of fossil leaves have led to the classification of this mass as belonging to the Claiborne group. It is separated with difficulty from similar Wilcox deposits below it. We are here concerned with that part of the section which immediately underlies the marine Jacksonian. The inclusion within the Jacksonian Stage of nonmarine beds below the marine strata needs to be considered, for there is a strong possibility that at least part of them were deposited during Jacksonian time. The geographical position of this area, far inland from the region where the earliest effects of Jacksonian transgression are recognized, makes it conceivable that during the advance of the Jacksonian sea over the Coastal Plain to the south, nonmarine beds such as these may have accumulated in southeastern Arkansas.

Present knowledge of nonmarine sediments in this area and in the coastwise outcrop belt does not permit demonstration of such a time relationship. Paleobotanical studies which may lead to the establishment of a more detailed chronology of the nonmarine segments of the Tertiary column are not sufficiently advanced to yield definitive data. Decision regarding the age of these beds, and the placement of the base of the Jacksonian Stage in this region must await such data.

The oldest beds which definitely can be classed as Jacksonian are the lowermost marine beds which contain

a Jacksonian fauna. On the basis of existing knowledge, it seems advisable, tentatively, to exclude older sediments from the stage, reserving ultimate judgment until additional information is available. The base of the marine unit is here considered to be the base of the Jacksonian; underlying sediments are referred to the Claiborne group, as by previous authors.

We face also the problem of classifying the nonmarine sediments which overlie marine Jacksonian beds in the northern portion of the outcrop area. These are carboniferous sands and silts which contain some fossil leaves. The leaves collected from White Bluff, where this nonmarine unit is best developed, are identified as Jacksonian species by Berry (1924, p. 103). Other evidence cited in support of this age assignment include observations that (a) regional relationships indicate at least partial equivalence of the nonmarine beds to marine Jacksonian sediments downdip; and (b) the well exposed contact between the nonmarine beds and marine Jacksonian beds at White Bluff is gradational, showing no signs of stratigraphic discontinuity. The Jacksonian Stage as here recognized, includes this nonmarine sequence.

No Tertiary beds found in the area require assignment to younger units. The stratigraphically highest Jacksonian beds encountered are either subaerially exposed or are covered by Pleistocene terrace deposits. In either case the upper limit of the stage in southeastern Arkansas is an erosion surface.

### Stratigraphic Subdivisions

The Jacksonian deposits in southeastern Arkansas include both marine and nonmarine strata. The requirements of stratigraphic description are best served by considering these segments of the section as separate formations. Each is a mappable unit with the requisite physical objectivity. The name *White Bluff formation*[9] is given

[9] The name "White Bluff marl" (from White Bluff on the Arkansas River) was used by Dall (1898, p. 343, and table opposite p. 334) as a stratigraphic unit "at top of Claibornian and above 'Claiborne sand'." The section at White Bluff is now known to be Jacksonian. The term has not been used by later authors. Dall's name is here resurrected and emended as indicated.

the marine unit; the name *Redfield formation* is given the nonmarine unit.

The White Bluff formation is thicker and more extensive than the Redfield formation over most of the outcrop area. The latter unit is best developed in the northern part of the area, and may be predominant in more northerly parts of the embayment. At the White Bluff locality where relationships are easily seen, Redfield beds overlie the White Bluff formation. Farther south, parts of the Redfield are probably the time equivalents of some of the upper beds of the White Bluff formation seen in Drew and eastern Cleveland Counties.

The White Bluff formation is not a homogenous unit having a single dominant lithology. Three facies are developed in the outcrop area. These are designated here as members of the White Bluff formation.[10] The *Caney Point marl member* is a calcareous glauconitic clay or argillaceous greensand, containing an abundant and varied invertebrate fauna, and resembling lithologically the Moodys Branch formation of Louisiana and Mississippi. The *Pastoria sand member* is a dark gray argillaceous sand enclosing many molluscan remains, but lacking many of the other invertebrate forms found in the Caney Point beds. The *Rison clay member* is a variable unit in which thin-bedded silty clay and blocky clay beds predominate, characterized by discontinuous, thin, molluscan concentrates, spasmodically developed in an otherwise sparsely zoolitic section. Lignitic fragments and fossil leaves are present locally in the beds of the Rison clay member.

The Redfield formation exhibits the lithologic variation characteristic of nonmarine-type sedimentation in the Gulf Coastal Plain. Thin-bedded lignitic silts, commonly containing well preserved fossil leaves, cross-bedded sands, and discontinuous thin beds of lignite are diversely

[10] Designation of facies as separate named subdivisions of larger stratigraphic units has been judged to be unnecessary and undesirable (Moore, 1949, p. 33; discussion by P. B. King in Longwell et al, 1949, p. 167). Classification following the pattern of facies differentiation is adequately expressed through the use of one or another of existing rock terms as appropriate in individual situations. Accordingly, the three facies recognized in the marine Jacksonian section of southeastern Arkansas are treated as members of the White Bluff formation.

developed within the unit. All possible combinations may appear in local exposures.

The inferred correlation of these units with the standard divisions of the Jacksonian Stage in Mississippi and Louisiana is shown by Figure 5.

It was considered advisable to erect the new formations listed above in preference to extending any existing stratigraphic names from the adjacent coastwise outcrop belt to apply to these deposits. The geographic isolation of the outcrops in Arkansas makes it difficult to demonstrate continuity with units farther south. This area is in many ways a separate depositional basin, distinct from the coastwise belt to the southeast and southwest, and is not without its sedimentary peculiarities. Finally, facies variation within the Arkansas outcrop area makes unadvisable the unit treatment of the marine Jacksonian under an existing formational name which carries a different lithologic connotation elsewhere, and unit treatment of the marine Jacksonian of this area is desirable.

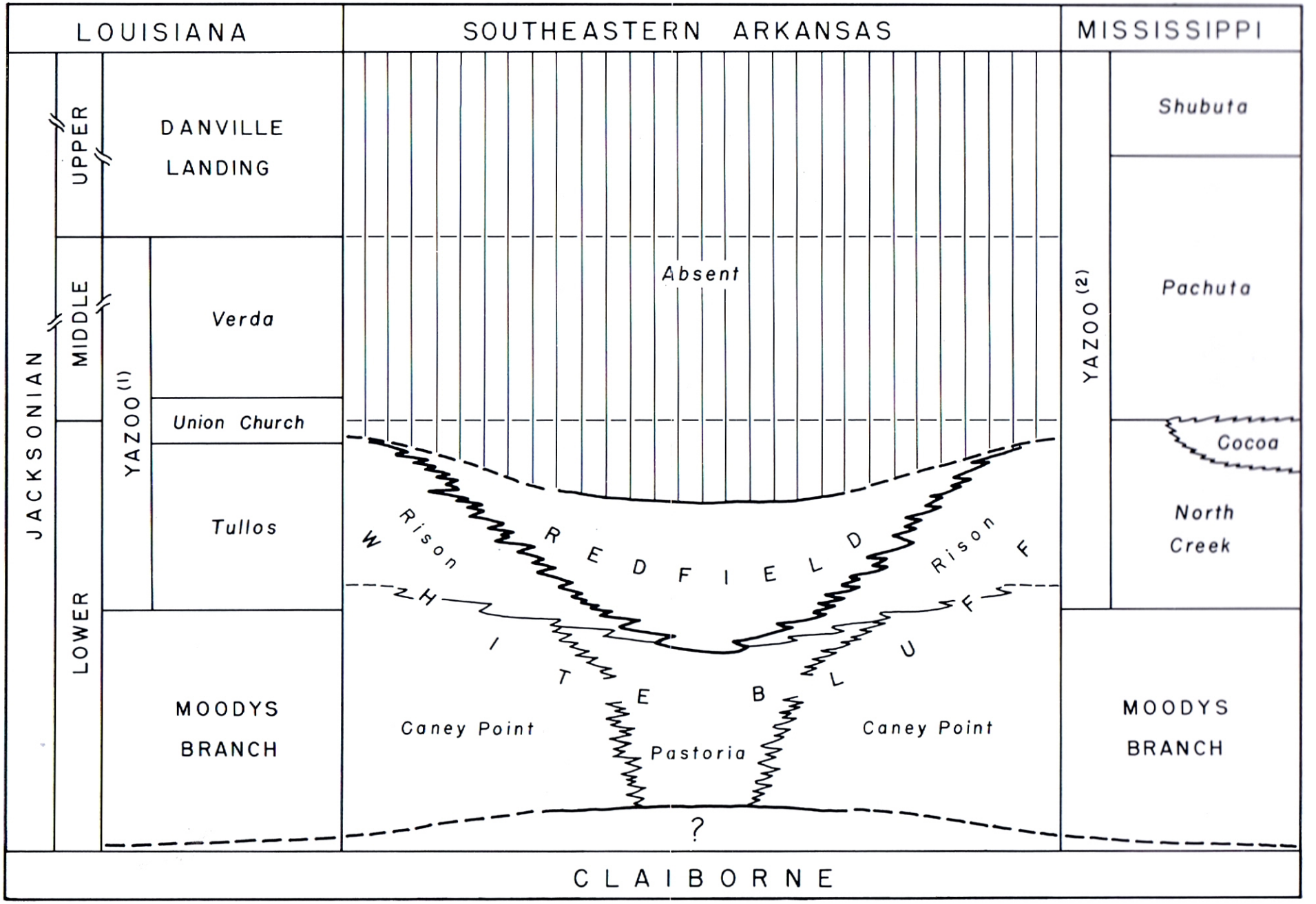
Though each of the members of the White Bluff formation is mappable, their designation as separate formations is unwarranted. Not only is each somewhat local in extent, but the members are all products of the same set of geological conditions, and the differences of lithology and fossil content are differences of degree rather than of kind.

# LOWER BOUNDARY OF JACKSONIAN DEPOSITS

## Basal Contact In Mississippi And Louisiana

Before examining evidence bearing on the nature of the basal Jacksonian contact in southeastern Arkansas, it is pertinent to review current opinion regarding this contact in the coastwise belt. As in Arkansas, marine lower Jacksonian beds lie above (generally) nonmarine beds of the Claiborne group in the rest of the central Gulf Plain. The contact between the two units has not been interpreted alike by all observers. Lack of agreement is resolved into a question of whether or not a hiatus of considerable magnitude is signified by the contact.

Discussion centers on the interpretation of the section found in the excellent exposures at Montgomery Landing on the Red River, Grant Parish, Louisiana, and the Jacksonian type section, Jackson, Mississippi. At both places the distinctive Moodys Branch formation, a very fossiliferous calcareous greensand, lies above carbonaceous silts and clays of the Cockfield formation (Yegua of some authors) which is the uppermost unit of the Claiborne group in that belt. In a zone extending 5 or 6 feet below the clearly marked base of the Moodys Branch formation are masses of glauconitic fossiliferous material which are enclosed by strata lithologically identical to the Cockfield beds below. This is the "transition phase" or "transition zone" of authors (Veatch, 1902, p. 165; Fisk, 1938, p. 95; Hunter, 1939, Fig. 7; and others), so termed because it is judged to represent a transition from Cockfield to Moodys Branch lithology. Stenzel (1939) finds evidences of stratigraphic discontinuity at the base of the Moodys Branch formation at these localities and at others he has examined in eastern Texas. He concludes that there is no transition between the units, and that the basal Jacksonian contact indicates (p. 861) ". . . a widespread, regional disconformity possibly representing a large time interval." The "transition phase" and other beds in the upper part of the Cockfield (Yegua) "which contain unmistakable




(1) Undifferentiated in western Louisiana

(2) Undifferentiated in western Mississippi

Figure 5. Correlation of subdivisions of the Jacksonian Stage in the central Gulf Plain.

marine indicators, such as marine fossils, glauconite, limestone layers or fucoids," are separated from the rest of the formation and designated "Creola member" by Stenzel (1939, p. 881). The marine fossils of the Creola member are closely related to those of the Jacksonian, and there is little paleontologic basis for separation of the two. Among the fossils present in this member is *Nonionella cockfieldensis,* Cushman and Ellisor, a foraminifer to which special stratigraphic significance has been attributed.

Most authors place a disconformity at the base of the Moodys Branch formation, but few stress, as does Stenzel, the magnitude of the hiatus. The problem of explaining some of the apparently contradictory evidence regarding the nature of the contact at various places in the Coastal Plain is one which requires careful re-examination of all available exposures.

## Aspects Of The Basal Contact In Southeastern Arkansas

There are no exposures of the basal contact in Arkansas which compare with the sections seen at Montgomery and Jackson. However, certain features of the contact discernible at several localities scattered over parts of the outcrop area permit formulation of some conclusions regarding its nature.

Precise location of the base of the White Bluff formation is easily accomplished only in Bradley and Cleveland Counties. There, where the calcareous greensand and clay of the Caney Point member lie directly on lignitic silts and clays, lithologic contrast is marked, and the boundary may be placed definitely. Elsewhere the Pastoria sand constitutes the basal unit of the White Bluff formation, and the contact is not so well expressed. The lower beds of the Pastoria member contain carbonaceous matter, thin glauconite stringers, and only scattered Mollusca. At the White Bluff locality mollusks are very prolific in the middle and upper portions of the member but they become sparse in the sandy beds near the base of the exposed section.

At South Red Bluff, invertebrate remains (molds) gradually disappear as the base is approached. In the cored section traversed by dam-site borings at the south end of White Bluff, a similar gradual diminution of fossils is noted near the base.

Much the same sort of indefinite contact is present in Grant County. A special development of the White Bluff formation is seen in roadcuts around Sheridan, where a few thin beds of cross-bedded glauconite containing some molds of mollusks are exposed. No fossils are seen in surface outcrops below these glauconite beds, but a few water wells dug on the western outskirts of Sheridan penetrate sediments containing abundant mollusks to a depth of 27 to 30 feet. Deeper holes encounter a typical Claiborne section. The contact here is placed more or less arbitrarily at the lowest occurrence of marine fossils, even though this is not a well-marked horizon.

### Nature Of The Contact In Bradley And Cleveland Counties, Arkansas

The uplands on the west side of the Saline River in Bradley and Cleveland Counties are formed of Claiborne sediments overlain by deposits of the Caney Point marl member of the White Bluff formation. Here and there, the river is immediately adjacent to its valley wall and sections of Tertiary beds are exposed as bluffs or as thin outcrops near water level. Claiborne deposits crop out in a strip extending from southeastern Bradley County to western Cleveland County, west and south of the upland belt mapped as Jacksonian on the state geologic map, and in places east of this belt. One of the best upper Claiborne exposures in this area is at Long View Bluff (Harris, 1894, pp. 125-126) where a discontinuous section 75 feet thick, containing evenly bedded lignitic clays and sands, occurs above the Saline River floodplain. Harris (1894, pp. 122-123) refers to other upper Claiborne localities at Alga Bluff, Sulphur Springs, and Crawfords Bluff in the right bank of the Saline River south of Warren. Two beds of lignite (18 and 13 inches thick) are present at Alga Bluff.

The fossiliferous glauconitic clay beds of the Caney Point member contrast sharply with the carbonaceous silts and clays of the Claiborne. The fact that relatively few fresh exposures occur in the area does not prevent approximate location of the boundary between the two units, for the glauconite-rich Caney Point member, which weathers into red ironstone nodules containing molds of Mollusca, is quite different from the underlying barren silts and sands which are light gray when weathered.

The general relationship of the Caney Point to the Claiborne in this area is shown on Figure 17. Caney Point deposits simply cap the part of the upland over which they occur.

Evidence bearing on the nature of the contact is provided by exposures in two roadcuts along Arkansas State Highway Number 8, between Warren and New Edinburg (Localities 36 and 37). Near the tops of these cuts occur fossiliferous ironstone nodules, which are the weathered representative of the Caney Point marl member. The lowest beds exposed are massive yellowish gray silts, mottled with moderate reddish orange stains, which constitute the uppermost Claiborne deposits in this local area. Between the two units are beds consisting of yellowish brown glauconitic sandy clay, approximately 4 feet thick, intricately traversed by irregular cylindrical bodies of reddish brown ironstone, one to one and one-half inches in diameter. The marine nature of these beds, as indicated by their glauconite content and by the fact that lithologically similar beds containing fossils are found in a comparable stratigraphic position at other outcrops, marks them as Jacksonian. Although the exposures of these intermediate beds, here and elsewhere, permit only a general evaluation of relationships to adjacent units, it seems clear that they are the basal deposits of the Caney Point member.

The cylindrical ironstone bodies, which are prominent at these localities in the basal Caney Point deposits, are solid concretion-like structures (Figure 6). Their orienta-

Figure 6. Basal beds of Caney Point marl member of White Bluff formation, showing irregular cylindrical clay-ironstone bodies, 5.7 miles northwest of Warren, Bradley County, Arkansas (Locality 36).

*Figure 7.* *Claiborne beds just below contact with Caney Point marl* member of White Bluff formation, showing tubes filled with glauconitic clay derived from overlying Jacksonian deposits 5.7 miles northwest of Warren, Bradley County, Arkansas (Locality 36).

tion is not constant, and they branch many times, but usually they can be traced upward to where they are lost among the ironstone nodules of higher Caney Point beds, and downward several feet into Claiborne deposits where they occur as tubes filled with loose glauconitic sandy clay (Figure 7), lithologically similar to the overlying strata.

Other data are gathered from the type locality of the Caney Point member (Locality 29). Near water level, numerous solid clay-ironstone cylindrical bodies are developed in the typical fossiliferous marl beds of the Caney Point marl member exposed there (Figure 8). Many of these bodies extend downward into less fossiliferous glauconitic sands at the base of the member. The Caney Point-Claiborne contact is not well exposed at this locality, and the same is generally true of the beds immediately above the contact. However, in a few spots along the outcrop, slab-like lignitic clay inclusions several inches in length are found in the basal glauconitic sand beds of the Caney Point member. These lignitic clay inclusions resemble closely the uppermost Claiborne deposits seen at Cornish Ferry (Locality 38). Clay-ironstone bodies are found at Cow Ford (Locality 30), 4½ miles downstream from Caney Point, but stratigraphic associations cannot be made out.

At the base of the exposed section in some of the gulleys on the property of Mr. Van Mann in eastern Bradley County (Locality 39), a somewhat better view of the beds just above the contact is provided. Here the Caney Point member is less weathered than elsewhere, and cylindrical ironstone bodies are not noted. Samples of the greenish gray glauconic sand taken from a few feet above the bottom of the gulleys contain slabs of gray lignitic silty clay similar to those found at the base of the section at Caney Point (Figure 9). Claiborne beds are not well exposed, but the probability is strong that they are buried by only a thin veneer of sediments. Sandy clay deposits, questionably in place, seen imperfectly in a few places near the gulley bottoms may be Claiborne.

In evaluating the contact great importance is attached to the clay-ironstone cylinders, and to the slabs of lignitic

Figure 8. Irregular cylindrical clay-ironstone bodies developed in lower portion of Caney Point marl member of the White Bluff formation at its type locality at Caney Point on Saline River, approximately 5½ miles northwest of Crossroads at Rye, Cleveland County, Arkansas (Locality 29).

clay present in the basal Caney Point beds. The ironstone bodies are almost certainly the result of borings made by organisms, later filled with glauconitic clay, weathered, and rendered hard. Identification of these structures as borings is strongly indicated by their continuation into underlying Claiborne strata as tubes filled with material derived from basal Caney Point deposits (Localities 36 and 37). The prominence of the bodies in beds several feet above the Caney Point-Claiborne contact at the Caney Point locality suggests that the boring organisms inhabited the Jacksonian sea, and continued their boring activity while Caney Point deposits accumulated. The presence of such borings at contacts has been cited as evidence of stratigraphic discontinuity.

The lignitic slabs noted immediately above the contact doubtless were deposited originally under nonmarine conditions similar to those which produced the uppermost Claiborne beds in parts of this region. There is no question that they are associated lithologically with the Claiborne, not with the Caney Point deposits. The appearance of the slabs in the marine sediments suggests that they were reworked from underlying beds by the waters of the advancing Jacksonian sea. The disposition of the slabs is somewhat irregular, in some respects like an edgewise conglomerate, though the dominant orientation is parallel to the indistinct bedding planes of the Caney Point member (Figure 9). Perhaps this lignitic clay was deposited originally on a tidal flat where mud cracks developed after exposure, later to become incorporated into the marine formation. In any event, the explanation of the presence of such foreign material in the basal part of the Caney Point member requires the existence of an environmental situation in which pre-Caney Point beds were within reach of surface erosional processes, subaerial or submarine. This is a further sign of stratigraphic discontinuity at the base of the member.

## Summary And Conclusion

The sharp, well-marked contact between the base of the White Bluff formation and the underlying Claiborne

Figure 9. Sample from basal beds of the Caney Point marl member of the White Bluff formation, showing reworked clay inclusions, collected in gulley on farm of Mr. Van Mann, approximately 8 miles south of Warren, Bradley County, Arkansas (Locality 39).—Photo by J. P. Morgan.

beds is noted only where the Caney Point member is developed. Where other facies of the White Bluff rest on Claiborne beds, no abrupt lithologic break is seen, and instead, gradual transition from nonmarine deposits characterizes the contact.

Inspection of the Caney Point-Claiborne contact reveals: (a) borings filled with Caney Point material extending into the upper Claiborne, and (b) reworked lignitic Claiborne material in the lower few feet of the Caney Point member.

Interpreted, these data indicate stratigraphic discontinuity at the base of the Caney Point member. No such discontinuity is found at the base of the Pastoria member, but its seeming absence may be the result of failure to recognize the break. Even so, physical evidence of a stratigraphic break is not sufficiently prominent to indicate that the contact is a major disconformity representing a long time interval. On the contrary, one gains the impression that the sedimentary interruption was not prolonged, and that the term "diastem" might be applied more appropriately.

This conclusion has important bearing upon the controversy regarding evaluation of the Jacksonian and pre-Jacksonian contact in Mississippi and Louisiana. If an extended period of erosion preceded Jacksonian transgression in the latitude of Jackson, Mississippi, the effects of this erosion should be even more pronounced farther north in the Mississippi Embayment. This does not seem to be the case.

## WHITE BLUFF FORMATION

### Definition

The White Bluff formation includes all marine Jacksonian deposits exposed in southeastern Arkansas. It is a heterogeneous formation, embracing lithologically distinct elements, all of which contain recognizable marine fossils. The unit treatment of these different entities is justified, since the formation is easily recognized in the field, and is mappable over a considerable area. They are classed as subdivisions of a single formation because the component parts are intimately related. No other classification of these marine beds is so convenient.

Beds of the Claiborne group underlie the White Bluff formation. Deposits of the nonmarine Jacksonian unit, the Redfield formation, are present above it over parts of the outcrop area. Elsewhere no overlying Tertiary beds are known.

### Extent

The formation is typically exposed at White Bluff, a prominent bluff on the right bank of the Arkansas River, 4 miles east of the village of Redfield, in northern Jefferson County, Arkansas. White Bluff is a classic locality which has been mentioned prominently in nearly every paper treating the Coastal Plain of Arkansas since 1860. It is the site of the best exposures of marine Jacksonian deposits in the Mississippi Embayment, and provides a good section of the Redfield formation as well. South Red Bluff, 2½ miles (map distance) north of White Bluff is a second good locality of the formation in this vicinity.

The outcrops in northern Jefferson County lie near the northern limit of the Jacksonian outcrop area in this part of the embayment. To the north the White Bluff formation thins and disappears. To the south it dips beneath the Redfield formation. Southwest of White Bluff the formation may be traced along the strike into Grant County only with difficulty. There are no good exposures

along this belt and the lower, updip edge of the formation which occurs at the surface does not support distinctive soils or other indirect signs of its presence. Only scattered ferruginous masses containing molluscan molds mark the member. In the vicinity of Sheridan, more easily recognizable fossiliferous beds are seen at the surface. Sheridan is near the western limit of the Jacksonian outcrop, and special depositional conditions indicating proximity to a source of coarser clastic materials affect the appearance of the unit there. Data from water wells in the area confirm the limited evidence available from surface exposures. In the territory between White Bluff and Sheridan, the Pastoria member of the formation is developed, and the difficulty experienced in tracing the unit along this line is a reflection of its lack of a sharp basal contact and its landward interfingering with equivalent nonmarine deposits.

The strike of the White Bluff formation changes at Sheridan, and beds near its base are encountered again in southeastern Grant County. In roadcuts around Grapevine and Lamont, small exposures containing a limited number of molds of Jacksonian Mollusca are found. From this area the basal contact can be traced and studied with much less difficulty to eastern Bradley County except where covered by Saline River flood plain deposits.

In the portion of the Jacksonian outcrop area located in Cleveland, Bradley, Lincoln, and Drew counties, the formation thickens and exhibits a more distinctly marine character, resembling certain portions of the Jacksonian section in Mississippi and Louisiana. Stratigraphic differentiation of lower beds (Caney Point marl member) and higher strata (Rison clay member) is possible.

### Structural Attitude

The Jacksonian beds of southeastern Arkansas were deposited in the western portion of the Desha basin. This is confirmed by tracing the White Bluff formation over its outcrop area. The dip of the formation at White Bluff has a strong south component; at Sheridan the dip is east;

in Bradley County it is northeast. Projection of these dip directions indicates that the center of the basin is in northern Desha County. Relationships between Jacksonian deposits and regional structural features of this area are shown by Figure 3.

## Facies

The lithologic heterogeneity of the White Bluff formation is due to variation in the environment which controlled the accumulation of this genetically related body of sedimentary materials. The constituent elements are products of non-uniform depositional conditions in a single basin during one marine cycle, or part-cycle. The different lithologic entities are not sharply set-off from one another; all have gradational boundaries, and all include beds which vary to a considerable degree. The relationships between these parts of the White Bluff formation are such that they fit perfectly the definition of the term "facies."

The three facies here recognized as members of the White Bluff formation are characterized as follows:

1. *Pastoria sand member*
   Includes the more clastic elements of the formation; typically developed at White Bluff; coextensive with the formation in northern portion of outcrop area; typical lithology—argillaceous sand containing glauconite and molluscan remains.
2. *Caney Point marl member*
   Includes the more calcareous elements of the formation; limited to the lower portion of the formation; best developed in Cleveland and Bradley counties; present beneath Rison member in Drew and Lincoln counties; typical lithology—calcareous glauconitic clay containing a varied invertebrate fauna including molluscans, echinoids, bryozoans, corals, etc.
3. *Rison clay member*
   Includes argillaceous and subordinate coarser clastic elements variable; limited to upper por-

tion of formation; best developed in Drew, southern Lincoln, and eastern Cleveland counties; present beneath the Redfield formation in central part of outcrop area; typical lithology—silts and blocky clay containing arenaceous foraminifers, scattered molluscan molds, local thin lenticular concentrations of molluscan molds.

## PASTORIA SAND MEMBER

### Extent And Thickness

The Pastoria sand member is confined to the northern portion of the outcrop area, and is co-extensive with the White Bluff formation over most of the former's known extent. The upper, middle, and part of the lower beds of the member are well exposed at White Bluff. Stratigraphically lower beds are seen at South Red Bluff. South of these outcrops, the unit dips beneath the surface, and is covered by the Redfield formation. It is traceable with difficulty along the strike southwest of the Arkansas River bluffs to the vicinity of Sheridan, Grant County. The member is probably present beneath younger Jacksonian deposits over most of Jefferson and Grant Counties south and east of the outcrop. It is replaced by other facies of the White Bluff formation in Cleveland, Lincoln, Bradley, Drew, and northern Ashley counties.

At White Bluff the Pastoria member is approximately 65 feet thick (estimated; base not exposed), but it thins to about 20 to 25 feet at South Red Bluff. Nearly 100 feet of Pastoria beds were encountered in borings made just south of the outcrops at White Bluff.

### Type Locality

The name Pastoria is derived from the Pastoria Quadrangle (outline shown on Figure 10), issued by the U. S. Engineers, Mississippi River Commission. The quadrangle encompasses all of the area where this member is best exposed, including the White Bluff and South Red Bluff

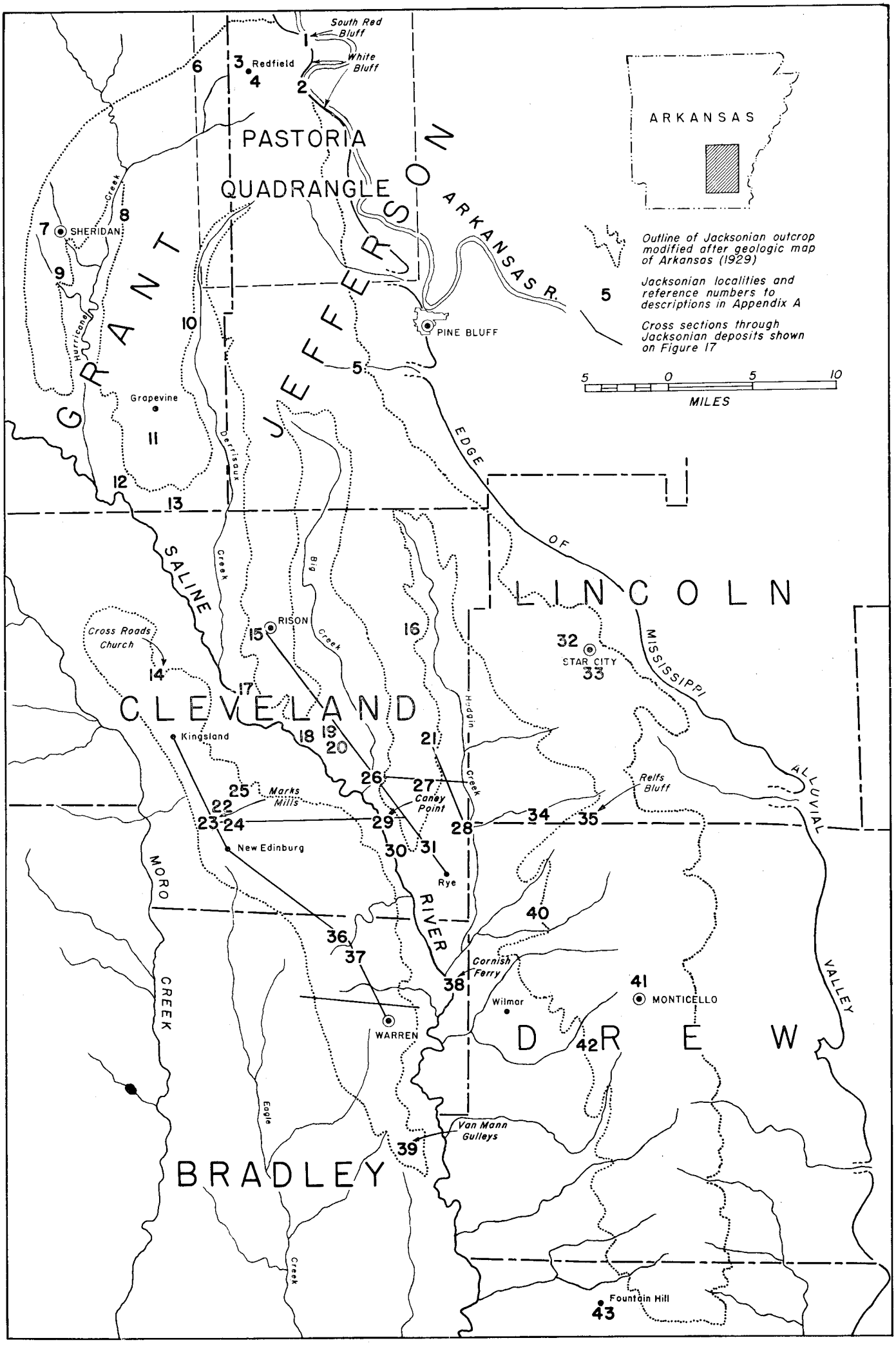



Figure 10. Locality map.

localities. The type locality is at White Bluff, and is precisely the same section which serves as type locality for the White Bluff formation. The section exposed here is much more complete, contains better preserved and more abundant fossils, and is more uniformly marine than at any other outcrop of the member.

The cliff face of White Bluff (Locality 2) rises an average height of 70 feet above the low water level of the Arkansas River and extends for a distance of approximately 2 miles along the stream. Continuous exposures of Jacksonian beds are seen for nearly the entire length. These beds have a moderate dip in a southerly (downstream) direction. Of the total stratigraphic section exposed, the lower 55 feet are marine beds of the Pastoria member, above which approximately 90 feet of nonmarine beds of the Redfield formation occur.

These two units are conspicuously different and easily distinguished at this outcrop. Argillaceous sands containing glauconite and abundant, well-preserved fossil shells, contrast noticeably with the overlying more definitely bedded, leaf-bearing lignitic silts. Due to the dip of the beds, the thickest section of the Pastoria member is found in the northern part of the bluff, whereas the Redfield formation is more prominent farther south. The dip can be demonstrated best by following a thin persistent bed of lignite which occurs about 30 feet above the base of the Redfield formation.

### Exposures at At White Bluff

The marine beds exposed near the middle of White Bluff are perhaps the most uniform and typical of the member. In the following section, measured at this part of the bluff, the upper contact is drawn above unit (b); the base is not exposed.

Figure 11. The Pastoria sand member of the White Bluff formation at its type locality, White Bluff on the Arkansas River, 3½ miles east of Redfield, Jefferson County, Arkansas (Locality 2).

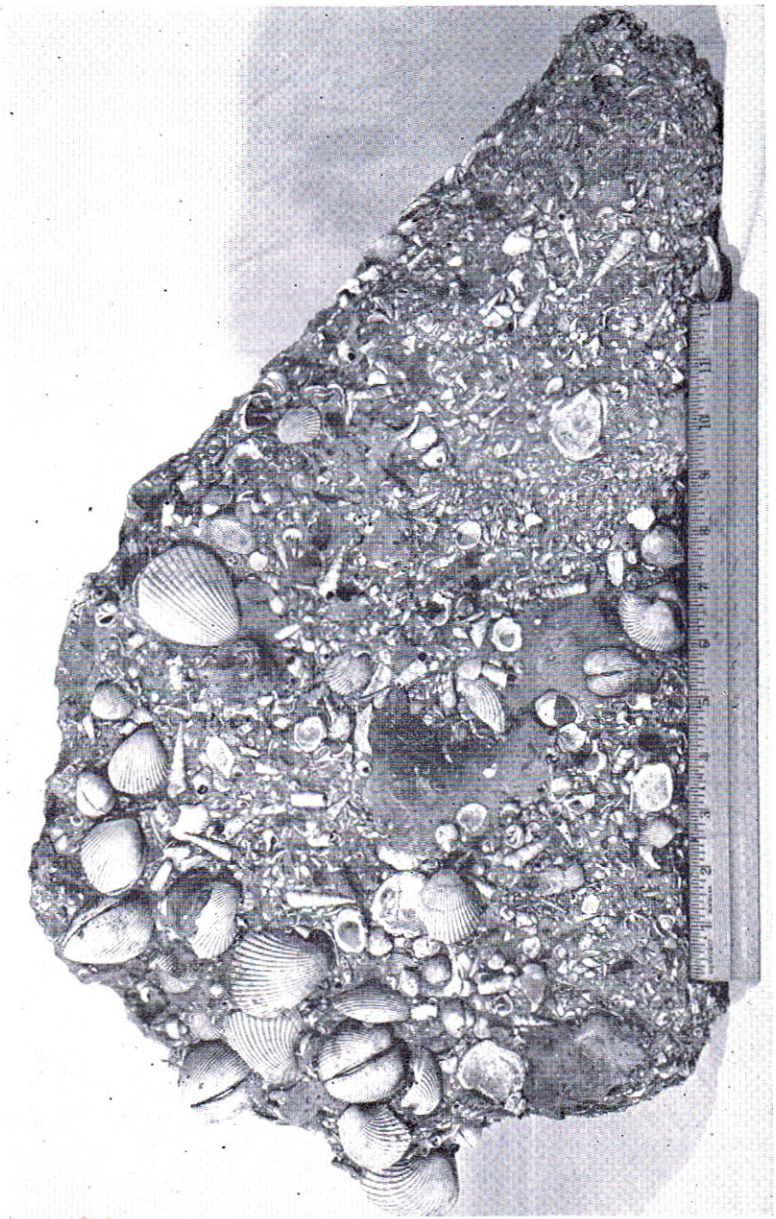


Figure 12. Fossiliferous calcareous concretion from the Pastoria sand member of the White Bluff formation collected at White Bluff on the Arkansas River, 3½ miles east of Redfield, Jefferson County, Arkansas (Locality 2). —Photo by J. P. Morgan.

**Section Near Middle Of White Bluff, Jefferson County, Arkansas (Locality 2)**

Measured at approximately the same part of the bluff as section given by Harris (1894, pp. 90-91).

| | Thickness Feet |
|---|---|
| Redfield formation | |
| f. Silt, yellowish gray, evenly bedded, coarse, intercalated with thin beds of silty clay; sandier near base; numerous imprints of leaves present; top not exposed | 17.0 |
| e. Lignite | 0.4 |
| d. Sand, light gray, crossbedded, containing irregular beds and lenses of lignitic silt and clay | 20.0 |
| c. Sand, light gray, thin-bedded, alternating with dark gray silty clay, lignitic; leaf impressions present | 10.0 |
| White Bluff formation, Pastoria sand member | |
| b. Silty clay, medium gray, with thin stringers of very-fine sand containing *Glottidia* | 2.0 |
| a. Argillaceous sand, dark greenish gray, containing glauconite and abundant well-preserved molluscan shells; species of *Venericardia* and *Turritella* particularly numerous; more argillaceous beds encountered locally; base not exposed | 30.0 |

The strata marked (a) are nearly homogeneous argillaceous sand. The greenish cast is imparted by glauconite, but the mineral is only a minor constituent. When the clay content is removed from a sample of this material by washing on a 200-mesh screen, the residue consists of angular quartz grains of very-fine-sand size, many fragments of mollusks, a little glauconite, and a few foraminifers and ostracodes.

Well preserved molluscan shells are scattered throughout the unit. *Venericardia* occurs in profusion, locally packed tightly together in layers, with both valves joined

in natural position (Figure 12). The genus *Turritella* is also very common. Many other forms may be collected; some robust and easily recovered, others very fragile and difficult to separate from the matrix. A number of delicate small forms are present, and care must be exercised to obtain identifiable specimens.

Unit (b) differs from the part of the member just described. Lithologically it combines the characteristics of unit (a) and the Redfield formation. In the sandy, slightly glauconitic stringers are a number of isolated valves of the linguloid brachiopod *Glottidia,* plus a few molluscan molds. The darker silty clay beds contain no megafossils. Both upper and lower contacts are gradational. Though they clearly represent a transition between the marine sediments below them and the nonmarine sediments above them, these beds are placed in the Pastoria member because of the recognizable invertebrate fossils they contain. The fossils are indicative of very near-shore marine or estuarine conditions.

Farther north along the bluff stratigraphically lower beds are exposed near water level. The following section was measured near the northern end of White Bluff:

**Section Near Northern End, White Bluff, Jefferson County, Arkansas**

**(Locality 2)**

| | Thickness Feet |
|---|---|
| Redfield formation | |
| f. Silt, yellowish gray, coarse, evenly bedded (beds 3 inches to 6 inches thick), intercalated with thin beds of darker silty clay; numerous imprints of leaves present | 18.0 |
| White Bluff formation, Pastoria member | |
| e. Clay, medium gray, with thin sand stringers containing *Glottidia* | 2.0 |
| d. Argillaceous sand, dark greenish gray, containing glauconite and abundant well-pre- | |

served molluscan shells; species of *Venericardia* and *Turritella* particularly numerous 21.0

c. Clay, dark gray, blocky, with silt and very-fine sand stringers, containing molluscan remains; spherical concretions locally present ---------- 15.0

b. Silty and sandy clay, dark gray, lignitic; concentrations of glauconite, molluscan remains (*Nuculana albirupina* especially common), and otoliths at bedding planes, shells fragmentary; carbonized wood particles noted ---------- 7.0

a. Silt, greenish gray, interbedded with very fine sand; calcareous concretions locally present in sand beds; sparse molluscan fauna noted in upper 2 feet; base no exposed ---------- 7.0

The correlation between this section and the previous one is aided by recognition of the identity of the *Glottidia* beds. Unit (d) here represents the upper part of (a) of the former section. The beds of unit (c) have a higher clay content than strata above them and the fossils are more concentrated in some strata or lenses. Spherical concretions 4 to 5 inches in diameter are distributed irregularly through these beds. Many of the concretions enclose molluscan shells.

Unit (b) represents a modification of the typical argillaceous sand lithology of the member. Clay is predominant, but between many of the beds are partings of glauconite-rich sand containing many specimens of *Nuculana albirupina* (Harris), otoliths, and, a few other mollusks. In some of these partings the fossil content is limited to masses of badly fragmented shells, evidently broken prior to burial. The character of the sediment and the fossils suggest that deposition took place very close to the margin of the marine basin.

The base of the member is not exposed at White Bluff, but unit (a) has the same lithologic constitution and sparse fauna noted in the basal beds at South Red Bluff.

## Exposures At South Red Bluff

There are no good exposures between White Bluff and South Red Bluff, 2 air miles farther north. The latter locality is similar in topographic position to the former, but is not as long; the beds are more deeply weathered; and fossils are less abundant, preserved only by molds. Because stratigraphically lower beds are exposed, the South Red Bluff section is useful in supplementing stratigraphic data supplied by the type section.

**Section At South Red Bluff, Jefferson County, Arkansas**

**(Locality 1)**

| | Thickness Feet |
|---|---|
| Redfield formation | |
| i. Silty clay, light gray, evently bedded; top not exposed | 3.0 |
| h. Silt and silty clay, light to medium gray, thin bedded; ferruginous partings evident | 8.0 |
| g. Silty clay, blue gray, containing silt stringers | 1.0 |
| f. Silt and very-fine sand, light gray, crinkly bedded; more argillaceous near base | 8.0 |
| White Bluff formation, Pastoria sand member | |
| e. Clay, pale yellowish brown, blocky, containing grayish yellow silt partings and a few thin beds and lenses of very-fine sand; sand more common in upper portion; local beds of glauconite near base, in some places weathered into thin (1 inch) beds of ironstone containing molds of mollusks (*Nuculana albirupina* very common); fossils found in lower 12 feet only | 21.0 |
| d. Argillaceous sand, fossiliferous, glauconitic, weathered into ferruginous ledge | 1.0 |
| c. Sand, dark gray (where freshly exposed), lignitic, containing a few fossils (more commonly in upper portion); pockets of glauconite form ferruginous masses upon weath- | |

| | |
|---|---|
| ering; large selenite crystals common in upper portion | 7.0 |
| b. Sand, fossiliferous, glauconitic, weathered into ferruginous ledge | 1.0 |
| a. Sand, gray, lignitic, containing clay stringers; some glauconite noted in upper portion; ferruginous concretions develop locally; no zoolites noted; base not exposed | 10.0 |

In the area intervening between White Bluff and South Red Bluff, marked changes in the Pastoria member must have occurred, for it is difficult to establish continuity of any units by comparing sections from the two locations. Assuming a constant dip, the base of the exposure at South Red Bluff is at least 15 feet lower (stratigraphically) than anything seen at White Bluff, and yet the thickness of beds in which recognizable invertebrate fossils are noted is only 21 feet (lower portion of unit (e) to unit (b) inclusive). The beds included within (f), (g), (h), and (i) are nonmarine and must be classified as the Redfield formation, though they are undoubtedly the stratigraphic equivalent of marine beds at White Bluff.

The top of the Pastoria member is placed at the top of unit (e), which is rather thick. The lower 12 feet contain molluscan molds, concentrated in thin layers or as isolated specimens, and thin glauconite-rich beds, an arrangement not unlike the *Nuculana*-bearing clays of the White Bluff section. Strata of the same distinctive yellowish brown ("chocolate") clay, but lacking glauconite stringers, continue for 9 feet above the highest mollusks found. A few arenaceous foraminifers were collected from these beds, but are by no means abundant. This upper portion of the unit is traditional between the Pastoria member and the Redfield formation.

Sufficient recognizable molluscan molds were recovered from (d), (c), and (b) to identify these units with the Pastoria member. The lignitic content of these beds is noticeable, leaving little doubt that they were deposited very near the shore line.

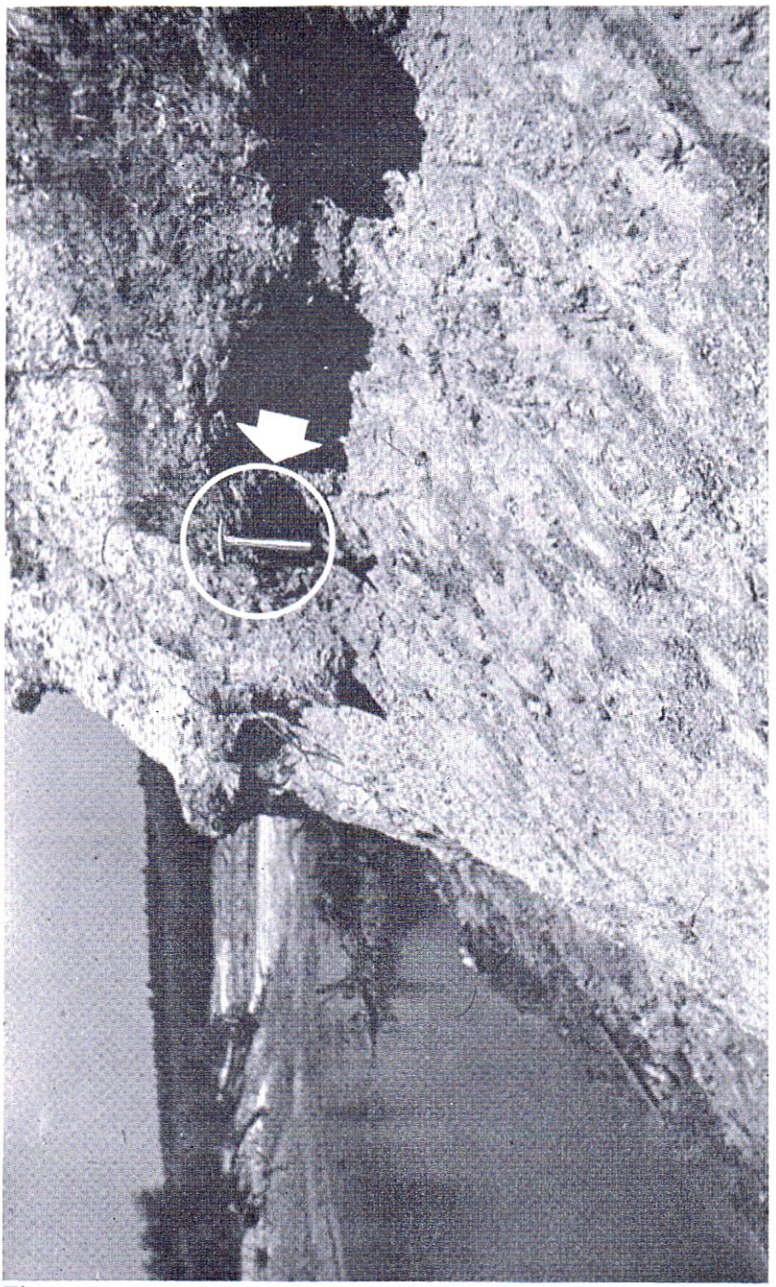


Figure 13. Ferruginous ledge at South Red Bluff near base of the Pastoria sand member of the White Bluff formation, approximately 4½ miles east of Redfield, Jefferson County, Arkansas (Locality 1).

Fossils were not found below the lower fossiliferous ledge (b). The presence of glauconite in the upper portion of unit (a) suggests the prevalence of marine conditions as it was laid down. Since by definition the White Bluff formation includes all marine beds in this stratigraphic position, the basal contact is drawn below the lowest of the marine indicators; it belongs at an undetermined position somewhere within this unit.

From the data presented by the South Red Bluff section, it may be inferred that the Pastoria member thins rapidly up dip from White Bluff, and interfingers with the Redfield formation at the landward edge of the area invaded by the Jacksonian sea.

### Borings At South End Of White Bluff

The Pastoria member cannot be traced on the surface very far south of the middle part of White Bluff, for the unit dips beneath the water of the Arkansas River, and only the Redfield formation is exposed. About 1½ miles farther south, however, at the southern end of White Bluff, dam-site test borings made by the U. S. Engineers, Mississippi River Commission, yield valuable data concerning the section down dip from the outcrop. The borings penetrated approximately 50 feet of nonmarine Redfield beds, and about 100 feet of marine strata. The lithologic character of the marine beds is much the same as that of the Pastoria member exposed at White Bluff (dominantly sands containing Mollusca and some glauconite). The fossils recovered from a few of the boring samples show somewhat more variety than at the outcrop. For example, material taken from 34 feet above the bottom of the deepest boring yielded a fauna in which foraminifers and ostracodes were more abundant and varied than seen elsewhere in the member. Representative collections of the megafossils in these beds could not be made because of the small amount of material available.

The Pastoria-Claiborne contact was not reached by the borings. Glauconite and a few mollusks were found

in the lowest sample examined. Mollusca are much less abundant in the lower part of this section, and judging from the character of the beds near the base of the member at South Red Bluff, it is probable that the basal contact of the Pastoria sand is not many feet below the bottom of the hole.

Relationships and correlation between the Jacksonian deposits encountered in the borings, at White Bluff, and at South Red Bluff are shown by Figure 14.

### Occurrence In Grant County

The Pastoria member is not well exposed except at the localities along the Arkansas River mentioned above. The relatively steep dip exhibited by the Jacksonian beds in this area limits its potential outcrop width. We have seen from the exposure at South Red Bluff that the member thins owing to interfingering with nonmarine Redfield deposits at the up-dip edge. This further restricts the outcrop width. In the absence of topographic situaitons which result in the development of such exposures as are seen along the Arkansas River, the member would be difficult to trace along strike southwest from the river.

At the roadcut on U. S. Highway 65, 0.7 miles north of Redfield, northern Jefferson County (Locality 3), a weathered section of silts and silty clay is visible. A few molluscan molds were detected in ferruginous partings near the top of the exposure. Some weathered ferruginous masses containing a few fossil molds occur in a small drainage ditch beside a local road southeast of the Orion crossroads (Locality 6), about three miles west of Redfield. No other evidence of the presence of the member was noted between this spot and Sheridan, in central Grant County, although closer investigation of streams and local roads may lead to the discovery of additional minor exposures. According to the state geologic map of Arkansas, the Jacksonian outcrop extends only a few miles into the eastern portion of Grant County. Revision of this part of the map is necessary, as stratigraphic relationships

prove the presence of Jacksonian deposits as far west as Sheridan.

A number of small sections are seen in roadcuts around Sheridan. Several occur just west of the city limits on U. S. Highway 270 (Locality 7), and also about 4 miles south of the town on U. S. Highway 167 (Locality 9). The following sequence is typical of these outcrops:

**Section At Roadcut Along U. S. Highway No. 270, 0.4 Miles West Of Town Square, Sheridan, Grant County, Arkansas**

**(Locality 7)**

| | Thickness Feet |
|---|---|
| White Bluff formation, Pastoria member | |
| d. Sand, moderate brown cross-bedded, glauconitic, weathered, rather loosely cemented, containing a few molds of Mollusca | 1.5 |
| c. Sand, reddish brown, very-fine, cross-bedded (thickness varies) | 1.0-3.0 |
| b. Concretions, ferruginous, forming small ledge, passing eastward into cross-bedded glauconitic sand containing a few molluscan molds | 1.0 |
| a. Sand, very fine, reddish brown, irregularly interbedded with moderate gray silty clay | 12.0 |

A near-shore sedimentary environment is again indicated by this succession of beds. The molds collected from units (b) and (d) are not specifically identifiable, but the genera which can be determined are all common at White Bluff.

Several shallow water wells dug in the outskirts of Sheridan encountered fossil shells at depths of 20 to 30 feet below the surface. Some of the material taken from two such wells was examined and found to contain shell fragments, and a few complete specimens. All are species common at White Bluff (Locality 2). Well records of strata below these fossils show lignitic silts and clays—

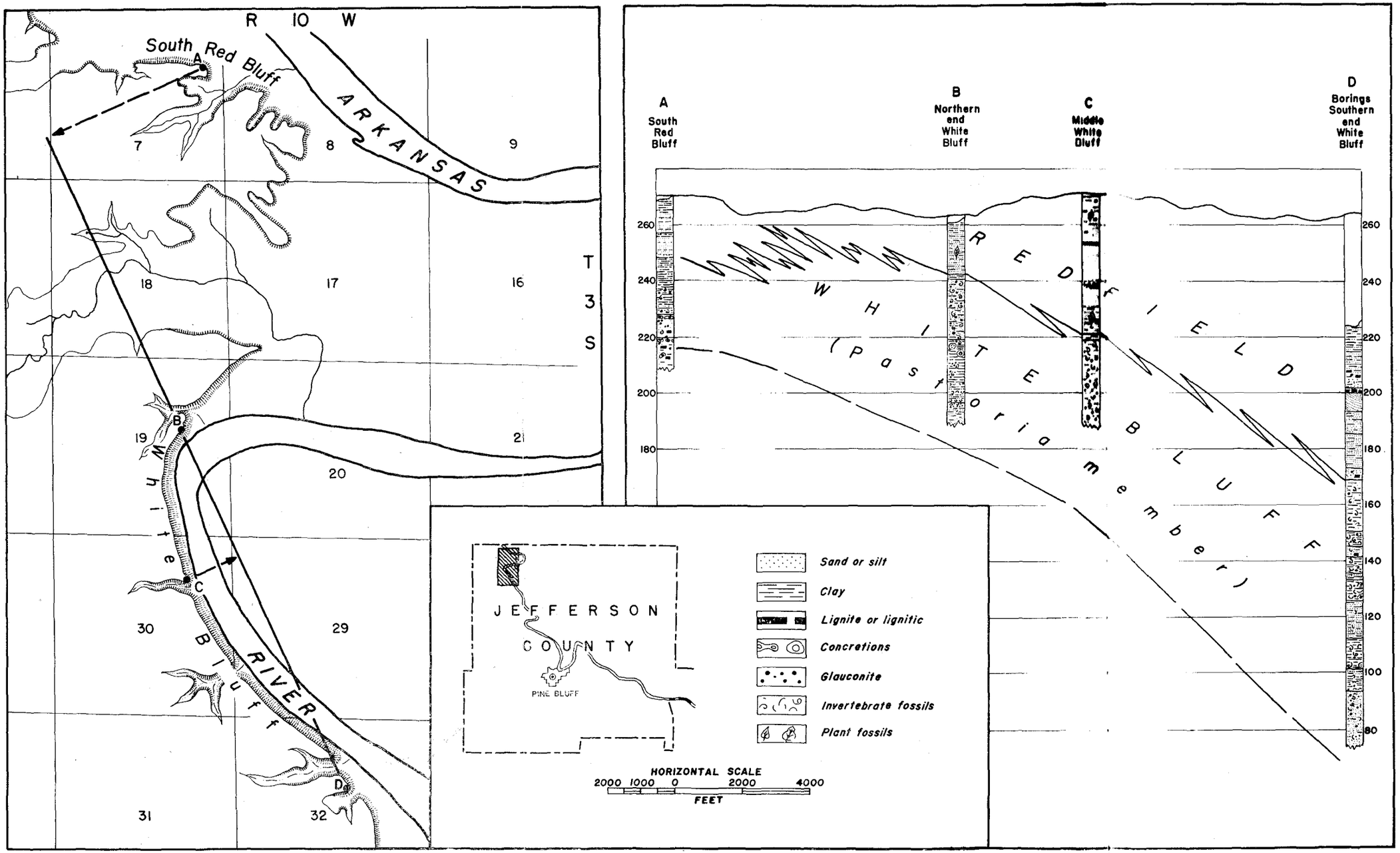



Figure 14. Stratigraphic sections at White Bluff and vicinity.

Figure 15. Cross-bedded glauconitic sand and associated beds in the Pastoria sand member of the White Bluff formation just west of Sheridan, Grant County, Arkansas (Locality 7).

typical Claiborne lithology. Although outcrops are insufficient to permit accurate location of the basal contact at the surface, it must be present within a few miles west of Sheridan.

A short distance east of Sheridan, Redfield deposits occur at the surface, and the Pastoria member is buried.

The strike of the White Bluff formation changes from a general northeast direction to a northwest trend near Sheridan. The continuity of outcrop is interrupted by Hurricane Creek, and representative outcrops of Jacksonian beds are next encountered in cuts along local roads south of Grapevine in southwestern Grant County. The marine deposits here exposed are not like those typical of the Pastoria member, but begin to take on some aspects of the Rison member. This is the area of transition between the two facies, and will be discussed with the latter unit. The southern limit of the Pastoria member is somewhere between Grapevine and Sheridan.

### Organic Remains

Fossils are common in the Pastoria member. Mollusca, foraminifers, ostracodes, and some vertebrate remains such as otoliths, shark teeth, and fish vertebrae are found at some localities, but the preponderence of the Mollusca makes all the others insignificant by comparison. The marine beds at White Bluff contain at least 14 species of Pelecypoda, 1 species of Scaphopoda, and 24 species of Gastropoda. Many of these are found in abundance, making the White Bluff locality one of the better collecting sites in the central Gulf Plain.

A check list of invertebrates identified from the White Bluff formation is given in Appendix B. No corals, bryozoans, or echinoderms are reported from the Pastoria member. Foraminifera are represented by relatively few species at the surface, but are more common in samples taken from the borings at the southern end of White Bluff. Ostracodes are easily obtained from some of the boring samples, but not at the outcrop.

Mollusca are dominant. The most prominent species are *Venericardia* (*Venericor*) *planicosta densata* Conrad[12] and *Turritella arenicola branneri* Harris. These occur in great numbers throughout most of the beds of this member, and are the most characteristic species of the entire assemblage. In certain beds of somewhat local extent, the pelecypod *Nuculana albirupina* Harris and other nuculacean species abound, accompanied by unusually large numbers of otoliths. *Mazzalina inaurata oweni* (Dall) and other varieties of *M. inaurata* are common at White Bluff. The great development of this form is noted elsewhere in the embayment (Little Crow Creek) in beds seemingly deposited under similar environmental control. Other species common in the member and widespread in Tertiary formations of the Gulf Plain are *Athleta petrosa* (Conrad), *Pseudoliva vetusta perspectiva* Conrad, *Pitar trigoniata* (Lea), and *Turritella clevelandia* Harris. *Fusimitra conquisita* (Conrad)[13], which is present but not abundant, is represented by a variant having a maximum length of about 35 mm., less than one-half the length attained by the typical form common in the Moodys Branch formation (Plate 2).

The presence of the brachiopod *Glottidia* in the upper few feet of the member is noteworthy. Specimens are not rare, but are extremely fragile. The internal laminae which distinguish this genus from *Lingula* are not well preserved, but considering the known Tertiary and Recent distribution of these brachiopods (Hertlein and Grant, 1944, pp. 11-12), it is probable that *Glottidia* is the genus in question. More significant is the ecological connotation of the presence of this lingulid. According to Schuchert (1911, p. 264), ". . . the immediate shoreline, and often the estuarine bays and deltas, will be indicated especially

[12] The individual variation shown by White Bluff venericardiids makes them difficult to classify under the scheme proposed by Gardner and Bowles (1939) for splitting the "*Venericardia planicosta* group" into a number of distinct species. A discussion of the Jacksonian forms is given by Harris and Palmer (1946-47, pp. 65-68) who conclude that *Venericardia apodensata* (Gardner and Bowles) is not specifically distinct from V. *planicosta densata* (Conrad). The more liberal view of Harris and Palmer seems best to allow for the variation noted in the White Bluff species, and is here accepted.

[13] *Mitra millingtoni* Conrad of most previous authors. Harris and Palmer (1946-47, pp. 339-401) refer it to synonymy with the Vicksburg species *F. conquisita*.

by the large lingulids imbedded in muds and sands with an otherwise sparse fauna." *Glottidia* occurs in beds transitional between the Pastoria member and the Redfield formation, in clay beds containing sand stringers and a few molluscan molds. Its presence supports other stratigraphic evidence of gradual withdrawal of the Jacksonian sea, and filling of the Desha basin with nonmarine deposits during later Jacksonian time.

## CANEY POINT MARL MEMBER

### Extent And Thickness

Throughout much of Jefferson and Grant Counties, south and east of the narrow outcrop of the Pastoria sand member, the White Bluff formation is covered by the Redfield formation. Redfield deposits are thin or have been removed from more southerly parts of the Jacksonian outcrop area, and the White Bluff formation is again exposed in most of Cleveland and Drew Counties, the southern part of Lincoln County, and northeastern Bradley County. The sediments in this sector do not bear a close resemblance to the Pastoria member. In place of the mollusk-bearing argillaceous sands seen at White Bluff, the formation consists principally of clay. Two separate stratigraphic divisions of the formation are here distinguished. The lower clay beds are calcareous and glauconitic and contain a varied invertebrate fauna. These comprise the Caney Point member. The much thicker section above them is made up of blocky clay and silty clay beds, lacking a conspicuous glauconite or calcareous content, and showing fossils concentrated in locally developed thin beds or lenses. This is the Rison member.

The Caney Point member is seen at the surface only around the western border of the area. Outcrops are largely restricted to the upland which parallels the Saline River on the west, extending from east-central Bradley County to northwestern Cleveland County. Exposures are also noted at several places along the left bank of the Saline River, a few feet above low water level. Farther

east (down dip) the member lies beneath Rison beds. Caney Point deposits are encountered in water wells in northern Ashley County, within 20 to 30 feet of the surface, beneath alluvial and terrace deposits.

Unweathered exposures are not common. None possesses all the attributes desirable in a type locality. The best stratigraphic detail is provided by outcrops in a series of gulleys on the property of Mr. Van Mann, in eastern Bradley County (Locality 39), but megafossils are too fragile to be collected and identified in quantity. The best fossil collecting site is at Caney Point on the left bank of the Saline River. Here, a cover of Pleistocene sand and gravel and alluvium deposited by high water make relationships between the beds difficult to observe. However, the data gathered from these two localities permit the establishment of all the principal characteristics of the member. The section at Caney Point is chosen as the type locality. The section exposed in gulleys on the Van Mann farm is cited as a standard section for comparison and substitution of stratigraphic information supplied by the type locality.

Since the Saline River is parallel to the strike of the Jacksonian deposits along the portion of its course in Cleveland and northern Bradley Counties, Caney Point beds crop out wherever the river is impinged against its valley wall. Besides Caney Point, small exposures are seen at Cornish Ferry (Locality 38), Cow Ford (Locality 30), and a few other places. These outcrops yield little data not better shown at the type locality.

Strata seen at upland localities are almost invariably deeply weathered. Small outcrops are common along local roads and highways where the presence of the member is recognized by the appearance of moderate yellowish brown ironstone occurring in beds or as isolated nodules, containing molds of fossils. The ironstone is derived from the weathering of the glauconite-rich deposits of the member. The area to the north of New Edinburg, Cleveland County, is known at the "Red Lands" because of the prominence of this ironstone at the surface.

The member is sharply separated from underlying Claiborne beds by a contact which exhibits evidence of disconformity. The contact with the Rison member is much more gradational. The upper beds gradually become less glauconitic and contain fewer fossils, and finally merge into the blocky, sparsely fossiliferous Rison silt and clay. In northern Cleveland County, the Caney Point beds contain more sand and less calcareous matter, seemingly due to proximity to the area of Pastoria deposition.

Measurements made at the Van Mann gulleys show the member to be 18 to 20 feet thick, whereas at Caney Point the thickness is only about 11 feet. The latter figure is average for most of Cleveland County. Probably the unit thickens toward the center of the Desha basin, but this is not detected by surface studies.

### Exposure At Caney Point

Harris (1894, pp. 107-108) reports the occurrence of fossiliferous clays and marls "three-fourths of a mile above Vince Bluff, Saline River, Arkansas." This is at a spot (Locality 29) on the river bank sometimes used as a picnic grounds, and referred to by local residents as "Caney Point." It was chosen as type locality of the member principally because of the well-preserved invertebrate remains which are present.

The following section was measured during low water level in 1946, and was remeasured in 1950:

**Section At Caney Point, Saline River, Arkansas**
**(Locality 29)**

| | Thickness Feet |
|---|---|
| White Bluff formation, Rison clay member | |
| d. Clay, pale yellowish brown, blocky, containing arenaceous foraminifers and a few scattered molds of small mollusks | 2.0 |
| White Bluff formation, Caney Point marl member | |
| c. Clay, yellowish gray, blocky, glauconitic, calcareous, fossiliferous, large calcareous concretions developed locally; gradational with beds below | 6.0 |

b. Sand, argillaceous, yellowish gray, glauconitic, calcareous, very fossiliferous, intricately traversed by cylindrical reddish brown clay ironstone bodies, 1 to 1½ inches in diameter, some of which extend into underlying beds ---------- 3.0

a. Sand, dark greenish gray, glauconitic, fossiliferous, containing rounded slabs of very dark gray lignitic silty clay; some cylindrical bodies from overlying beds extend down into this unit; base not exposed---------- 2.0

The lower part of the section is poorly exposed. Near water level, unit (a) may be seen where the colluvial cover can be dug away. Most of the material comprising these beds is similar to the typical Caney Point deposits above them, but is more sandy. The slablike lignitic clay inclusions are quite prominent, and are more numerous as the basal contact is approached. The significance of these clay slabs and the pipelike bodies which traverse the unit has been discussed on previous pages.

Unit (b) is the most characteristic part of the member. Here occur most of the megafossils found at the locality. They are well distributed throughout the unit, and are easily collected where they have weathered out of the matrix. The best collection was made at the time of my first visit to the locality. Successive later visits resulted in the recovery of only a few additional forms. Several years seem to be required for the weathering out of a fresh supply of specimens. The unit is riddled with the irregular tubular clay-ironstone bodies described earlier (Figure 8). It is curious that these are present so far above the base of the unit, but many of the best fossil specimens were collected in situ from glauconitic sandy clay between these concretions.

The beds of unit (b) pass into the underlying deposits without conspicuous break. The upper contact is likewise gradational. Near the top, the sand gradually diminishes and the calcareous clay content increases until the beds become a blocky yellow glauconitic clay. Although few of the larger molluscan species are found in this clay, it

is definitely fossiliferous and contains a good foraminiferal assemblage. The large oval calcareous concretions present are also noted in similar beds at Van Mann gulleys.

The beds marked (d) are classified as belonging to the Rison member. They lack the calcareous content and the varied invertebrate fauna of the Caney Point deposits.

Little additional data is provided by other exposures along the river. At Cow Ford (Locality 30), the presence of the member is indicated only by the pipeline clay ironstone bodies which form a shallow reach of the river where stock may cross during low water. At Cornish Ferry (Locality 38), the uppermost Claiborne beds are exposed below the fossiliferous Caney Point deposits, but the contact is concealed, and other details are complicated by abnormally steep dips. Significantly, the Claiborne deposits here are dark gray lignitic silty clay, similar in many respects to the rounded slabs found in the basal beds at Caney Point.

### Exposures In The Van Mann Gulleys

The section exposed in the steep banks of small intermittent streams located on the Van Mann farm in eastern Bradley County (Locality 39), was pointed out to me by Mr. D. P. Meagher, of the Carter Oil Company. This locality is the only place found in the entire upland area where significant thicknesses of unweathered Caney Point beds are visible. The following composite section shows beds encountered in the banks of the three or four gulleys where best exposures are found.

**Composite Section At Van Mann Gulleys, Bradley County, Arkansas (Locality 39)**

| | Thickness Feet |
|---|---|
| White Bluff formation, Rison clay member | |
| d. Clay, blocky, pale yellowish brown, containing grayish yellow silt partings locally; arenaceous foraminifers and a few scattered molds of mollusks present; thin discontinuous beds of glauconitic clay occur, especially in the lower 10 feet | 20.0 |

White Bluff formation, Caney Point marl member

| | |
|---|---|
| c. Clay, dusky yellow, glauconitic, calcareous, fossiferous; large calcareous concretions developed locally; bentonite bed occurs 4 feet above base; gradational with beds below | 15.0 |
| b. Clay, sandy, pale olive, glauconitic, very fossiliferous; gradational with beds below | 5.0 |
| a. Sand, argillaceous, greenish gray, glauconitic, fossiliferous, containing rounded slabs of gray silty clay; poorly exposed | 2.0 |

The essential similarity between this section and that of the Caney Point locality is immediatley evident. No cylindrical ferruginous bodies are found in the lower beds, but the reworked lignitic matter at the bottom of the exposure indicates a close correlation with the basal beds at Caney Point. Above this is the same succession of calcareous beds, capped by the blocky Rison clay containing arenaceous foraminifers. The greatest discrepancy between the two sections is the increased thickness of the Caney Point beds at the Van Mann gulleys.

Mollusca are not well preserved in these beds, and the shells crumble at the slightest touch. This is probably because the banks of the gulleys are always damp and the specimens are not subjected to the hardening effect of solar radiation. It is possible, however, to recover from beds (b) and (c) a good quantity of foraminifers, ostracodes, corals, and bryozoa by collecting the material in bulk and washing it on a fine-mesh screen.

This locality is the best place to observe the contact between the Caney Point member and the Rison member. Yellow glauconitic clay changes upward into blocky chocolate clay within a vertical distance of approximately 2 feet. Intervening clay beds are of intermediate color, and are generally free of glauconite. The thin glauconite beds which occur above the contact are clearly different from the beds of the Caney Point member.

Figure 16. Calcareous glauconitic clay beds of the Caney Point marl member, White Bluff formation, in gulley on farm of Mr. Van Mann, approximately 8 miles south of Warren, Bradley County, Arkansas (Locality 39).

### Occurrence In The Upland West Of The Saline River

The only good fresh exposure in the entire upland area west of Saline River is in the Van Mann gulleys, at the southern limit of the Jacksonian outcrop in this region. Tracing the unit northwestward is accomplished by following small roadside outcrops of ironstone nodules and beds which contain conspicuous molluscan molds. Little stratigraphically significant detail is gained from these outcrops, but they are useful in determining the structural attitude of the Jacksonian deposits. By plotting the occurrences of the fossiliferous ironstones on a road profile an idea of the relative position of the isolated outcrops may be gained. The annotated road profiles prepared in this and other areas were combined in modified form and made into a panel diagram (Figure 17), which shows the distribution and disposition of the Caney Point marl in that part of the upland between Kingsland and Warren, and an estimation of its position east of Saline River. The location of the lines along which profiles were constructed is shown on the locality map (Figure 10).

Ironstone nodules seem to be developed only in the basal part of the unit, where coarser clastic beds are found. The overlying clays are either eroded away or are obscured by thick soil or colluvial cover.

North of the latitude of New Edinburg, ironstone is found over a much wider area, owing to the decrease of the regional dip of the Jacksonian beds. Roadside outcrops display better stratification, and the weathered ironstone material is a deeper red color and is considerably sandier in texture than farther south (Figure 18). This area is known as the "Red Lands of Cleveland County" (Harris, 1844).

The site of the Civil War battle of Marks Mill is in the midst of the Red Lands. In a roadside drainage ditch just south of the monument marking the battlefield (Locality 23), is exposed a section very helpful in establishing the nature of the Jacksonian succession in this part of the outcrop area.

Figure 18. Weathered exposure of the Caney Point marl member, White Bluff formation, showing typical ironstone development in the "Red Lands" of Cleveland County, 2.75 miles northeast of New Edinburg, Arkansas (Locality 25).

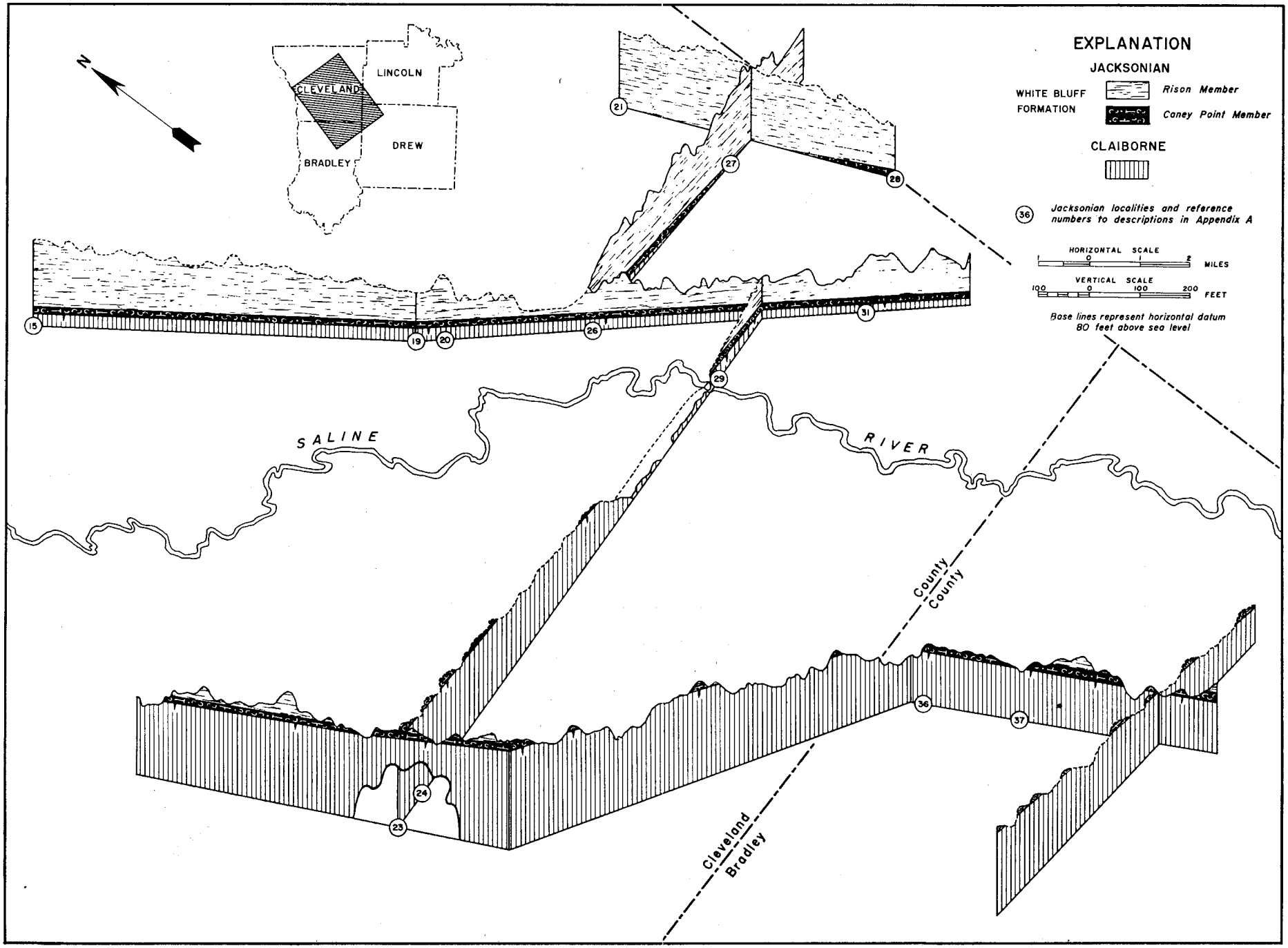



**Figure 17. Panel diagram of parts of Cleveland and Bradley Counties, Arkansas, showing the disposition of Jacksonian sediments.**

**Section At Marks Mill Monument, Cleveland County, Arkansas**

**(Locality 23)**

| | Thickness Feet |
|---|---|
| White Bluff formation, Rison clay member | |
| e. Clay, blocky, light gray, containing scattered molds of small mollusks; nonfossiliferous spherical ferruginous concretions developed locally | 4.0 |
| d. Bentonite | 0.2 |
| c. Clay, blocky, pale yellowish brown, containing arenaceous foraminifers | 4.0 |
| b. Clay, blocky, light gray, containing yellow partings between some of the bedding planes; arenaceous foraminifers and a few scattered molds of small mollusks present | 7.0 |
| White Bluff formation, Caney Point marl member | |
| a. Ironstone, moderate yellowish brown, containing numerous mollusks, some with shell material preserved; base not exposed | 2.0 |

Only unit (a) may properly be assigned to the Caney Point member. The clay section above it possesses all the characteristics of the Rison member. Fossiliferous ferruginous nodules reported by Harris (1894, p. 100) as scattered over the surface at Marks Mill are evidently remnants of one of the molluscan concentrates which develop in the Rison section.

Unit (a) is poorly exposed at the bottom of the drainage ditch. Many fragments of its beds are seen as float. One-tenth mile to the south, weathered greensand layers containing numerous fossiliferous molds are seen in place at about the same elevation.

The nature of the deposits below unit (a) may be determined from an exposure in the steep left bank of a small stream (Locality 24), 300 to 400 yards due east of the Marks Mill locality (Figure 19). A section 10 feet thick consists of fossiliferous greensand, well cemented by calcium carbonate. Numerous molluscan shells are present, but most of them are either too firmly attached to their matrix or, where loosely held, are too fragile to be collected

easily. Significant is the presence of numerous specimens of the disk-shaped echinoid *Periarchus lyelli* (Conrad). This fossil is important in the lower Jacksonian beds of Mississippi and Alabama, but the species has not been reported previously from Arkansas.

North of the Red Lands, the Caney Point outcrop width is reduced and the member is less conspicuous. Much of the region between Marks Mill and Kingsland is covered by beds of the basal part of the Rison member, but good exposures are few. The northernmost locality of the Caney Point member is at Cross Roads Church (Locality 14), and about 3½ miles north of Kingsland. There, fossiliferous ironstone covers the surface. North of this point the Saline River valley interrupts the outcrop. Beyond that the Pastoria member is developed.

The lithology of the Caney Point beds at Locality 24 and the noticeably sandy aspect of the equivalent ironstone beds throughout the Red Lands area indicate that in this part of Cleveland County the member has a reduced clay content, a higher percentage of clastic material, and is somewhat better stratified than at the type locality or at the Van Mann gulleys. Unweathered material taken from a hand-dug water well on the property of Mr. Clyde Brazelton (Locality 22), in the same general area, included glauconitic sand containing fossils, penetrated within 15 feet of the surface. At Cross Roads Church, the increased sand content of the member is noticeable even in badly weathered beds. Clearly, in this part of the upland, the influence of Pastoria-type deposition, dominant in more northerly sectors of the Jacksonian outcrop area, is being expressed.

### Occurrence East Of The Saline River

The only Caney Point outcrops seen east of the Saline River occur in the river bank near water level. In the upland region, the member is buried beneath younger deposits, notably those of the Rison member. The approximate position of the Caney Point beds in this part of the

Figure 19. Fossiliferous glauconitic beds of Caney Point marl member, White Bluff formation, rendered hard by secondary calcareous cement, 2 miles north of New Edinburg, Cleveland County, Arkansas (Locality 24).

upland is shown by Figure 17. Regional relationships, projection of the strike of beds found west of the river, and other structural data indicate that outcrops should occur in southern Drew County and northern Ashley County. However, most of the upland surface in that vicinity is covered by Pleistocene terrace material which obscures all the Tertiary beds. The relief, and with it the number of potential outcrops, diminishes as the upland merges with the alluvial valleys of the Ouachita and the Mississippi Rivers.

One bit of information gained from a water well 50 feet deep, dug on the property of Mr. Hester at Fountain Hill, northern Ashley County, is important in establishing the presence of Caney Point beds near the surface, and in confirming the deduced regional stratigraphic and structural relationships. The well was dug one week before my latest visit to the area in August, 1950, and the material removed from the hole was available for examination. Light greenish gray fossiliferous glauconitic clay and yellow glauconitic clay were encountered from the surface to a depth of approximately 30 feet (according to Mr. Hester). Samples of this material were collected and found to contain mollusks, foraminifers, and ostracodes such as are common in the Caney Point member. Beneath this was dark gray lignitic silty clay, undoubtedly part of the Claiborne group.

### Organic Remains

Paleontologically, the Caney Point member is characterized by the variety of its contained invertebrates. In addition to Mollusca, comparable in number of species, but not in number of individuals with the Pastoria member, it yields a much better foraminifer and ostracode fauna than is found in the marine deposits at White Bluff. The several species of corals, echinoids, and bryozoans which occur, mark the Caney Point beds as products of a sedimentary environment relatively free from the influence of any nearby source of coarse clastics, and thus unique in the Jacksonian section of southeastern Arkansas.

The check-list (Appendix B) shows the species identified from those localities where well-preserved specimens were obtained. Few of these species are more abundant than their fellows.

It was on the basis of the molluscans present in the Caney Point member that the Jacksonian Stage was originally recognized in Arkansas. Not until later were the well-known fossils from the White Bluff locality definitely proved to be Jacksonian. The specific identity of specimens gathered from Caney Point and other localities in Cleveland County with gastropods and pelecypods described from the Moodys Branch formation was cited by Harris (1894). Such forms as *Fusimitra conquisita* (Conrad), *Calyptraphorous velatus stamineus* (Conrad), *Clavilithes humerosus* (Conrad), *Crassatella flexura* (Conrad), *Pecten* (*Eburneopecten*) *scintillatus* (Conrad), and others are prominent in the type Jacksonian section, and at Caney Point.

The corals include *Flabellum wailesi* (Conrad), *Endopachys maclurii* (Lea) varieties, *Aldrichiella elegans* (Vaughan), and others; all known from the Moodys Branch formation at Jackson, Mississippi, or at Montgomery, Louisiana.

The echinoid *Periarchus lyelli* (Conrad), found at locality 24, is common throughout Mississippi and Alabama in the lower part of the Jacksonian sequence. *Schizaster* remains discovered at the Van Mann gulleys are not sufficiently well preserved to permit specific identification. However, the echinoderm from Cornish Ferry pictured by Harris (1894, Pl. 6, Fig. 11) was later identified by Cooke (1942, p. 40) as *S. armiger* (Clark), a characteristic Jacksonian species. It is probable that the specimens from the Van Mann gulleys are the same.

The difference between the Caney Point fossils and those of the Pastoria member is as impressive as is the similarity between the Caney Point and Moodys Branch assemblages. That this difference and similarity is the result of facies control of organic population is an inescapable conclusion.

## RISON CLAY MEMBER

### Extent And Thickness

All marine Jacksonian beds developed above the Caney Point member in the southern part of the outcrop area of the White Bluff formation are referred to the Rison member. The deposits so classified are principally clay, but in places silty and sandy beds occur. These beds contain arenaceous foraminifers, and a sparse molluscan fauna, mostly present as molds. Local, thin, discontinuous beds containing abundant molluscan remains are developed throughout a large part of the member, but are most common in the lower portion.

Rison sediments are present at the surface over a much larger area than any other part of the White Bluff formation. They occur as a relatively thin cover above the Caney Point member at several places west of the Saline River, and are extensively developed on the east side of the river south of a line extending from northern Cleveland County to southern Lincoln County. Beds which seem to represent modifications of the Rison lithology crop out in southeastern Grant County.

Accurate measurements of the thickness of the member have not been made, since there are no persistant key horizons in the Rison sequence to permit the assembling of a detailed stratigraphic column from the scattered outcrops. Estimates based on projections of the regional dip of the Caney Point member indicate a maximum thickness of approximately 140 feet in eastern Cleveland County. The member thickens toward the east. The very generalized log of the city water well at Monticello indicates a thickness of approximately 140 feet in central Drew County. The unit thins to a feather edge at the southern margin of the outcrop area in northern Ashley County, in the vicinity of Fountain Hill. Redfield deposits interfinger with the Rison member and overlap it north of the Drew-Lincoln County line, and also in the area a few miles north of the town of Rison in northern Cleveland County.

The best outcrops occur in roadcuts and adjacent drainage ditches along major highways and local roads in the region of relatively high relief in eastern Cleveland County. Reduced relief and Pleistocene terrace deposits and other covering material makes the member difficult to study in adjacent areas.

## Type Locality

The following is a composite section measured at several roadcuts (Figure 20), and an excavation pit west of the city limits of Rison (Locality 15).

**Section Along U. S. Highway No. 79, Near Junction With With Arkansas State Highway No. 35, West Of Rison City Limits, Cleveland County, Arkansas**

**(Locality 15)**

| | Thickness Feet |
|---|---|
| White Bluff formation, Rison clay member | |
| h. Clay, mottled reddish brown and light gray, silty; scattered small glauconitic silty sand lenses; at least four separate thin discontinuous beds of limonitic sandy clay enclosing many molluscan molds | 14.0 |
| g. Clay, light gray, containing thin sand laminae; locally thicker lenticular beds of sand; locally blocky clay beds containing molds of small Mollusca; small ferruginous silty sand lenses | 13.0 |
| f. Silt, pale yellowish brown, lignitic, containing many good impressions of leaves and grasses; possibly local development exposed near base of excavation pit only; not found in adjacent road cut | 3.0 |
| e. Sand and silt, light gray, alternating beds | 3.0 |
| d. Silt, yellowish brown, sandy, stained by limonite; containing scattered molds of Mollusca | 2.0 |
| c. Sand and silt, light to medium gray, argillaceous | 3.0 |

Figure 20. Upper part of the type section of Rison clay member, White Bluff formation, ¼ mile west of Rison, Cleveland County, Arkansas (Locality 15). Prominent thin beds are ferruginous fossil concentrates.

| | |
|---|---|
| b. Clay, yellowish brown, sandy, containing minor amounts of weathered glauconite, molluscan molds | 2.0 |
| a. Clay, pale yellowish brown, silty, grayish yellow partings between some beds; becomes sandier near base | 4.0 |

The dominant lithology of the Rison member is clay. In the type section there is a larger proportion of coarser clastic constituents than is characteristic of most other sections. Otherwise all of the important features of the unit are well illustrated. The beds are rather evenly stratified, and thin silty partings occur at the bedding planes. Several beds are stained various shades of brown and red by limonite or other iron minerals. Ferruginous matter is locally concentrated as concretions. Sandy lenses, sometimes accompanied by minor amounts of glauconite, are encountered. Sand is a much more important constituent of the upper part of the member as may be seen in roadcuts north of the type locality.

Rison beds are mostly devoid of plant remains which can be observed megascopically. A notable exception to this generalization is seen in the excavation pit, where in a series of beds about 3 feet thick near the bottom of the pit, leaf and grass imprints are common along bedding planes of yellow brown silt.

Perhaps the most characteristic feature of the unit is the distribution of the Mollusca. Although molluscan molds are found in most of the clay beds, they occur in abundance only in thin, discontinuous beds, rendered hard by secondary ferruginous cement. Such beds are well illustrated by unit (h) of the type Rison section. Molluscan concentrates are invariably thin. They develop indiscriminantly in certain strata throughout the units, apparently not restricted to any certain horizon. They appear most commonly in the lower part of the member. The ferruginous cement which contributes to the prominence of these beds is derived from the small amount of glauconite found in association with the mollusks.

## Occurrence Elsewhere In Cleveland County

In the numerous exposures found in the area to the south of Rison, the section is more homogenous, clay is much more prominent, and sand and silt are only minor constituents. In sections at the Van Mann gulleys and Marks Mill, for example, the entire exposed thickness of the Rison member is represented by pure blocky clay (Figure 21). This lithology persists into higher horizons. Characteristic of the development of the unit in eastern Cleveland County is the section exposed in a drainage ditch, 2.1 miles northwest of Rye (Locality 31).

**Section Exposed Along Local Road, 2.1 Miles Northeast Of Rye, Cleveland County, Arkansas**

**(Locality 31)**

| | Thickness Feet |
|---|---|
| White Bluff formation, Rison clay member | |
| a. Clay, light gray (yellowish gray when dry), blocky, containing some beds of silty clay; arenaceous foramin fers and molds of small Mollusca present; three thin (1½ to 2 inches thick) discontinuous beds of ferruginous clay containing molluscan molds packed as tightly together as possible---- | 25.0 |

The fossils concentrated in the thin ferruginous clay beds are exceedingly numerous. Many of the shells were broken prior to final incorporation into the bed and dissolution of the calcium carbonate, and only the molds of fragments remain. Figure 22 is a photograph of fossiliferous material taken at this locality.

Beds of blocky clay are noted along the highways and local roads in the upland area in the southeastern part of Cleveland County. Most of the other sections measured in this area do not exhibit the prolific molluscan concentration just described, but nearly all contain ferruginous masses (concretions or lenses) in which molds are larger and more common than elsewhere in the member.

No molluscan shells have been found at the surface. Numerous water wells drilled in the eastern part of the

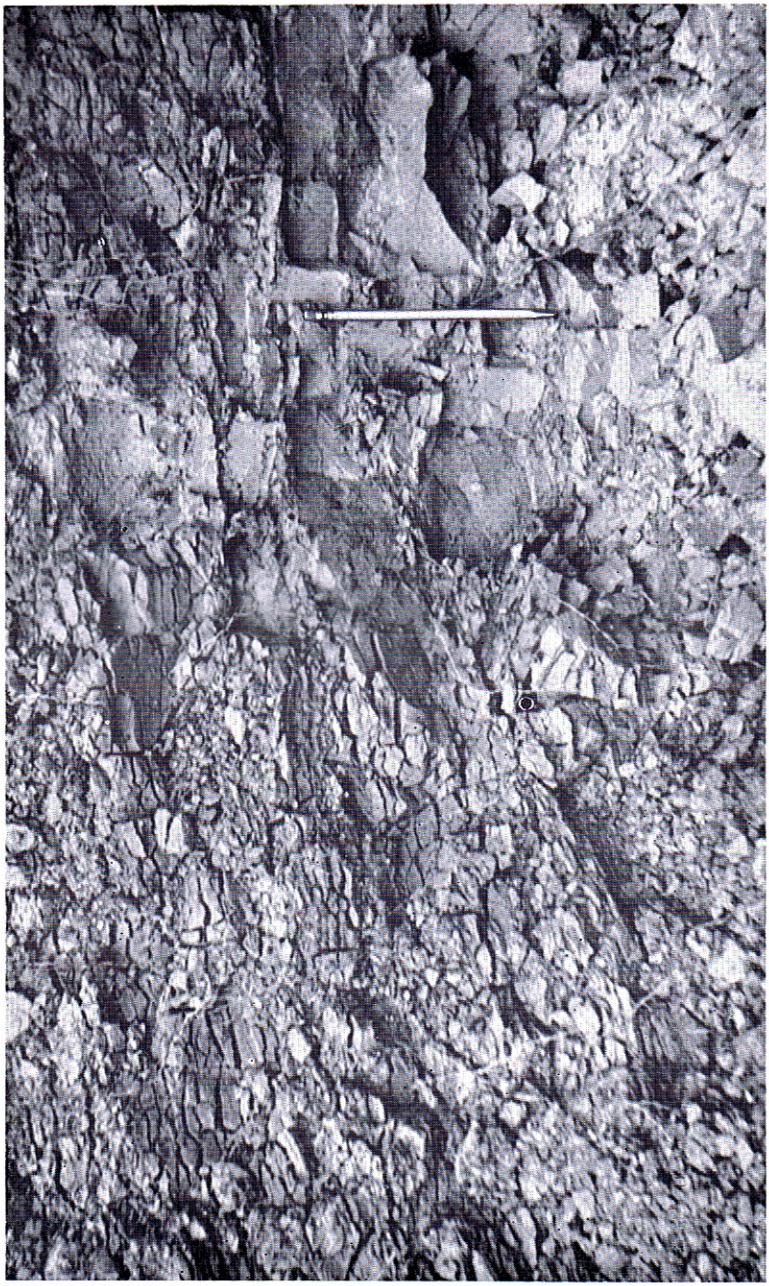


Figure 21. Blocky clay beds of the Rison clay member, White Bluff formation, just south of Marks Mill battlefield monument, approximately 2 miles north of New Edinburg, Cleveland County, Arkansas (Locality 23).

county encounter well-preserved shells at shallow depths. Harris (1894, pp. 95-97) reports such occurrences from water wells in the vicinity of Rison at depths of 30 to 60 feet. I have identified specimens of *Venericardia planicosta densata* and *Turritella arenicola branneri* obtained by Mr. J. Harris from a well dug on his property between Rye and Pansy (Locality 28).

### Occurrence In Drew And Lincoln Counties

Upland areas east of Cleveland County are covered by Pleistocene terrace deposits, and outcrops are inadequate to determine satisfactorily the nature of the member. The upland extending north and south from northern Ashley County through Drew County and into Lincoln County is mapped as Jacksonian on the state geologic map, but terrace sands and gravels cover a considerable portion of it. In Drew County, only one or two small sections of silts and clays containing a few molds of small mollusks were noted; these are sufficient only to permit recognition of the Rison member in this area.

In Lincoln County just north of the Drew County line, near the crossroads known as Relfs Bluff, ferruginous fossiliferous nodules are seen in the banks of several roadcuts (Locality 35). These do not seem to be in place, and the associated section exhibits no stratification planes. The nodules resemble weathered Caney Point material more closely than any part of the Rison member encountered elsewhere. Their classification as Rison is questionable, supported only by inferred stratigraphic position.

North and east of Relfs Bluff, the Tertiary deposits which are visible beneath terrace material are all nonmarine, and are referred to the Redfield formation, which resembles the Rison member in this area, as it contains a considerable amount of clay. Distinction between the two units is based on the absence of molluscan molds and the presence of lignitic material and plant fragments in the Redfield formation.

The Rison-Redfield contact is not well exposed in this upland. North of Rison in Cleveland County, where out-

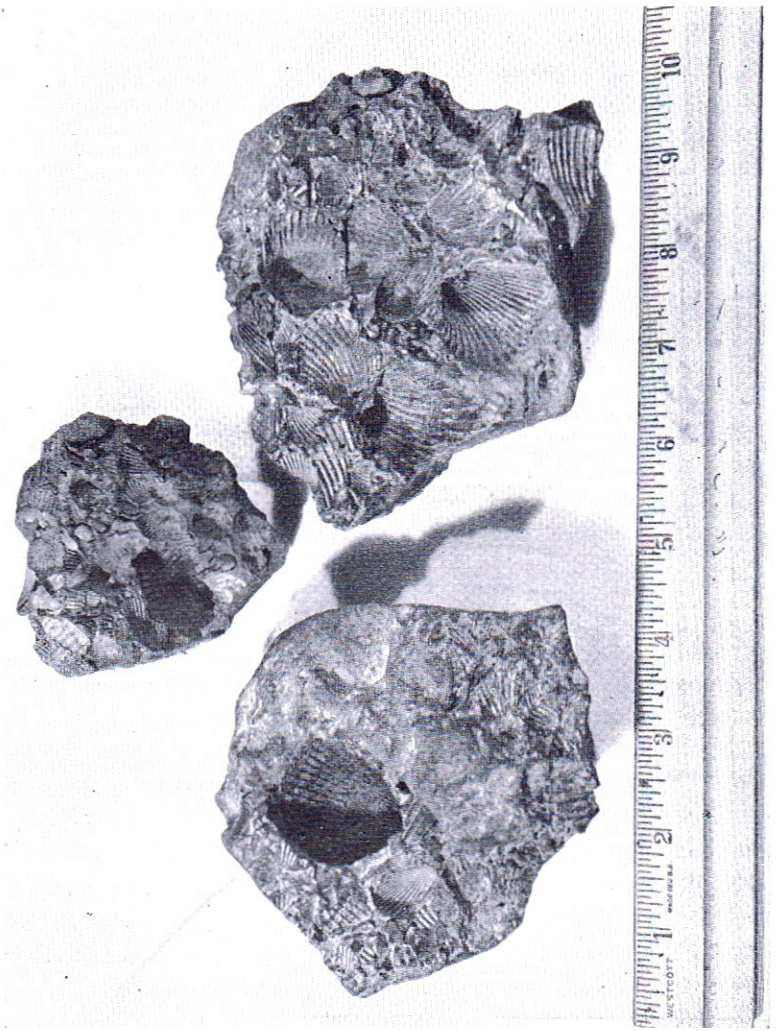


Figure 22. Sample taken from thin bed in the Rison clay member, White Bluff formation, containing numerous molluscan molds, 2.1 miles northwest of crossroads at Rye, Cleveland County, Arkansas (Locality 31). Photo by J. P. Morgan.

crops are somewhat more numerous, the upper silty clay beds of the Rison are gradually replaced by lignitic clay and cross-bedded sand. Regional relationships suggest interfingering of the two units.

### Occurrence In Southeastern Grant County

The Jacksonian outcrops in southeastern Grant County are located in an area where the Redfield formation and the Pastoria and Rison members of the White Bluff formation are closely associated. It is not surprising that the marine deposits which accumulated here are influenced lithologically by the intermingling of the several facies, and lack many of the distinctive properties used elsewhere to identify the individual units. Classification of these transitional sediments as the Rison member presents fewer complications than any other course. The net effect of deposition under these conditions is a modification of the typical development of the Rison member through a reduction in thickness, more common occurrence of fossiliferous strata of the Pastoria type, and a general increase in clastic constituents.

Representative exposures occur at the escarpment above the Saline River floodplain at the end of an abandoned local road southwest of Grapevine (Locality 12), and along Arkansas State Highway No. 35, approximately 2 miles south of Grapevine (Locality 11, Appendix A), and 0.5 miles north of the Grant-Cleveland County line (Locality 13). At the first of these (Locality 12) is a section of 30 feet of blocky clay containing arenaceous foraminifers and a few ferruginous masses. These beds bear the closest resemblance to the typical Rison sediments of any seen in the area. On the hilltops 15 to 20 feet above the clay appear ironstone nodules containing fossil molds. The nodules are not in place, but are concentrated locally on the surface. They are not like the clay-ironstone beds found in the member farther south, but seem to have formed in a much sandier matrix.

The exposures along the highway south of Grapevine reveal stratigraphically higher beds. The section is noticeably coarser, consisting principally of very fine sand, commonly quite massive, interbedded with silt and silty clay strata. Thin ferruginous sandy clay ledges develop locally in this section, and contain molluscan molds (three such

ledges occur in a section 12 feet thick at Locality 11). Isolated ferruginous masses enclosing a few molds are also noted. Other occurrences of fossiliferous nodules both loose and in place are seen in small exposures along many of the local roads.

The fossils collected from this area exhibit peculiarities. Most of the molluscan species are small. A notable exception is the pelecypod *Periploma collardi turgida* (Harris), represented at this locality by individuals larger than specimens of this species collected from White Bluff, and nearly as large as type specimens described from Little Crow Creek. A few molds of *Mytilus* (*Hormomya*) *hamatoides* (Call), another species characteristic of the Little Crow Creek beds, were collected.

### Organic Remains

The similarity between the molluscan assemblage of the Rison and Pastoria members is as remarkable as the difference between the Pastoria and Caney Point faunas. Detailed reporting of Rison Mollusca is made difficult by the absence of well preserved shells at the surface, but it is probable that if fresh material were available in sufficient quantity, few Pastoria species would be lacking in it. All of the common larger forms collected from White Bluff are recognized from the molds present in the thin ferruginous fossil beds. The abundance of *Venericardia planicosta densata* (Conrad) in some of these horizons is illustrated by Figure 22. Numerous specimens of *Turritella arenicola branneri* (Harris) are found at the Rison type locality, along with *Mazzalina inaurata oweni* (Dall), *Pseudoliva vetusta perspectiva* (Conrad), *Athleta petrosa* (Conrad), *Nuculana albirupina* (Harris), *Pitar trigoniata* (Lea), and others. It was impossible to determine accurately the smaller mollusks present.

The molds found in most of the blocky clay beds principally represent species of *Corbula, Venericardia, Nuculana,* and *Yoldia.* The venericardiids are invariably minute, averaging only 8 to 10 millimeters in width. Fossils are nowhere abundant in this matrix, but usually can be

found without undue difficulty. In every clay bed where molluscan molds were found, arenaceous foraminifers are also present. These microfossils are quite small, but are easy to recover on a 200-mesh screen by thorough washing. The Foraminifera are retained on the screen to the virtual exclusion of anything else. Most of these arenaceous forms are badly distorted, and attendant taxonomic problems preclude specific identification. Present are two species of *Trochammina,* two species of *Haplophragmoides,* questionable specimens of *Ammobaculites* and *Ammodiscus,* and some textulariids. The textulariids were specifically determined as *Textularia hockleyensis* (Cushman and Applin), *T. dibollensis* (Cushman and Applin), and *Spiroplectammina mississippiensis* (Cushman). The presence of *T. hockleyensis* and *T. dibollensis* in these beds is interesting, since the first appearance of these species in wells is used by commercial geologists to indicate respectively middle and lower Jacksonian horizons.

The fauna of the Rison member identified in the course of this study is incomplete owing to the absence of well preserved shell material at every outcrop visited.

## REDFIELD FORMATION

### Definition

The Redfield formation embraces the nonmarine Jacksonian deposits which overlie and are partially equivalent to the White Bluff formation. From north to south the Redfield formation successively overlies the Pastoria member and the Rison member. Regional relationships suggest that it interfingers with both of these marine units in parts of the outcrop area. No younger Tertiary beds are known to occur above the formation. The upper boundary is an erosion surface, which is either subaerially exposed or is overlain by Pleistocene terrace deposits.

The usefulness of the Redfield formation as a practical mappable unit is dependent on the recognition of its stratigraphic position with respect to the White Bluff

formation. Only where relationships to that easily recognized marine unit can be demonstrated is it possible to identify the Redfield formation without undue difficulty. Where the White Bluff formation is not developed, there are few field criteria which will permit separation from nonmarine Claiborne beds. Future paleobotanical studies may make it possible to recognize the formation beyond its present known extent.

### Extent And Thickness

The name Redfield is taken from the village of Redfield located in northern Jefferson County, Arkansas. Several exposures occur in the immediate vicinity of Redfield where small sections of nonmarine sediments typical of the formation are seen, but the best locality is at White Bluff, 4 miles east of the village. There, the Redfield formation extends the length of the bluff, and has an aggregate thickness of nearly 90 feet.

The unit is restricted to the northern portion of the Jacksonian outcrop area. It is present at the surface over most of Jefferson and Lincoln Counties, and is prominent in the eastern part of Grant County. The southeastern limit is marked approximately by the Drew-Lincoln County-line.

Precise data on thickness are not available. Estimates of maximum thickness in the area of known outcrops are of the magnitude of 150 to 200 feet in northwestern Lincoln County.

### Lithology

The nonmarine nature of the unit is indicated by the general absence of marine fossils and other marine indicators, such as glauconite, and by the presence of lignitic and carbonaceous matter, and abundant plant remains. Cross-bedded sand is found at many places in the formation. A superficial resemblance between the Redfield formation and the Rison clay member of the White Bluff formation may be noted where blocky clay beds are devel-

oped in the former unit. Close examination normally will reveal minutely divided carbonaceous matter and plant fragments in Redfield clay, whereas Rison beds nearly everywhere contain small molluscan molds.

The well developed stratification exhibited by most of the Redfield beds indicates an aqueous depositional environment. Thinly laminated (containing many irregular wavy bedding planes) silts and silty clays are common. Thicker beds of argillaceous silt, 1 to 2 inches in thickness, are noted at White Bluff and elsewhere.

A representative section may be viewed near Redfield (Locality 4), where light gray thinly laminated silts and silty clay, and irregularly bedded silty sand dominate an exposure approximately 20 feet in thickness found in a stream bank and roadcut (Figure 23). A few hundred yards farther south similar beds are found in another roadcut.

Equivalent and stratigraphically lower beds are exposed at White Bluff. The sections near the northern and middle portion of the bluff have been given in previous parts of this report and are shown in graphical form on Figure 13. The gradational contact with the Pastoria member is well exhibited by the White Bluff section. Above the *Glottidia*-bearing beds, the marine character of the sediments is gradually lost, invertebrates disappear, and plant fossils become common. Approximately 10 feet above this contact, a thick section of cross-bedded sand, containing some very irregular discontinuous lignitic silty sand beds, presents a characteristic nonmarine depositional pattern (Figure 24). A thin bed of lignite just above the cross-bedded sand can be followed for at least a mile along the bluff, and furnishes the best key for determining the downstream dip of the beds.

In a unit characterized by such a variable lithology as the Redfield formation, detailed measured sections have little stratigraphic value beyond very local areas. No widespread distinctive beds permit detailed correlation between exposures. The lignite bed at White Bluff, for example,

becomes lignitic clay in the samples obtained from borings at the southern end of the bluff. In tracing the formation at the surface over its outcrop area one learns to be content with recognition of exposed beds as Redfield, and to expect any type of nonmarine lithology.

Sections exposed at the following selected localities are illustrative of the development of the Redfield formation in various parts of the area of outcrop:

**Sections Of The Redfield Formation**

| | Thickness Feet |
|---|---|
| Southern Jefferson County (Locality 5) | |
| Blocky clay and sand, containing plant fragments | 14 |
| Eastern Grant County (Locality 8) | |
| Fine sand and silty clay | 38 |
| Eastern Grant County (Locality 10) | |
| Silts, blocky clay, and sand; leaf imprints and lignitic material noted in some beds | 16 |
| Eastern Cleveland County (Locality 16) | |
| Clay and sand beds, containing leaf and grass impressions | 8 |
| Central Lincoln County (Locality 32) | |
| Blocky clay and sand beds, some containing plant fragments | 25 |
| Central Lincoln County (Locality 33) | |
| Blocky clay and silt beds, containing a few plant fragments | 12 |
| Southwestern Lincoln County (Locality 34) | |
| Sand, silt, and blocky clay; some beds contain impressions of plant fragments; thin bentonite bed near base of section | 14 |

The bentonite present at Locality 34 is a potential key bed, but unfortunately it has not been found at any other Redfield locality. Other occurrences of bentonite near the base of the Rison member at Localities 17 and 23, and in the Caney Point member at Locality 39 were noted. Stratigraphic relationships indicate that at least two separate bentonite beds are represented. The bed at Locality

Figure 23. Silt and silty sand beds of the Redfield formation 0.25 miles south of caution light at Redfield, Jefferson County, Arkansas (Locality 4).

Figure 24. The Redfield formation at White Bluff on the Arkansas River, 3½ miles east of Redfield, Jefferson County, Arkansas (Locality 2), showing cross-bedded sand beds, irregular lignitic clay beds and lenses, and thin persistent lignite bed.

39 is about 11 feet above the base of the White Bluff formation. It is overlain and underlain by typical Caney Point deposits. At Locality 23, bentonite occurs in the basal portion of the Rison clay member, a minimum distance of 20 feet above the base of the White Bluff formation. The geographic proximity and the general similarity of the stratigraphic situation at Locality 17 leaves little doubt that the bentonite bed exposed there is identical to the one at Locality 23. The bed at Locality 39 may be the same as well, for we know that the Caney Point member is thinner in central Cleveland County than in Bradley County, and its distance above the base of the formation is comparable in both areas. Definite proof of the correlation must be furnished by more detailed stratigraphic study.

It is very unlikely that bentonite in the section at Locality 34 is the same bed as the others. Regional structural data derived from the attitude of the basal beds of the White Bluff formation in Cleveland County, stratigraphic classification of the section exposed between Locality 34 and the Saline River, and the nature of the lithology of the beds above and below the bentonite all point to the conclusion that the bentonite at Locality 34 is 50 to 80 feet higher stratigraphically than recorded at other bentonite localities.

Inasmuch as bentonite beds have not been encountered at localities other than those mentioned, they have not proved useful beyond very local areas.

### Organic Remains

The only fossils found in the Redfield formation are plant remains. Imprints of leaves are seen at a number of localities, but the best preserved specimens come from White Bluff. No attempt was made to identify this flora. Berry (1924, p. 103) reports only three species from White Bluff: *Pisonia jacksoniana, Cedrela jacksoniana,* and *Meselodaphene texana.* He states that the plant remains are fragmentary, and few identifiable specimens are found

at White Bluff. The well preserved leaves present in abundance in several beds must have been overlooked. They occur high on the face of the bluff, and are not easily collected in place. At the time of all my visits to the locality, however, many specimens could be obtained from the large masses which had slumped from higher levels, and accumulated as debris at the foot of the bluff. Undoubtedly a larger flora than reported by Berry occurs here.

Leaves and grasses found at most other Redfield localities are not as well preserved, and are quite fragmentary. Commonly one may find small plant particles between the bedding planes of silt and clay beds. Such remains are widely distributed throughout the formation.

## CONDITIONS OF DEPOSITION[14]

### General Relations

The Jacksonian sediments which crop out in southeastern Arkansas were laid down in the western part of the Desha basin. They record a depositional cycle which began with the invasion of the basin by marine waters and which ended with the withdrawal of the sea and the resumption of nonmarine sedimentation (in at least part of the area), such as had been prevalent prior to the marine invasion.

During Jacksonian time the Desha basin was partially surrounded by regions of higher evaluation on three sides; south, west, and north. Being part of the tectonically negative Mississippi Structural Trough, it was a focal point for deposition in the Mississippi Embayment, and had been receiving sediments of one kind or another since it was formed. The upper Claiborne deposits which accumulated along the western embayment margin show lithographic

[14] Since submitting this report for publication I have written a short summary (Wilbert, 1951) of relationships between faunas and facies in members of White Bluff formation. Some of the same ground is covered in that article as is found below, but the material here presented is organized differently to reach a somewhat different objective.

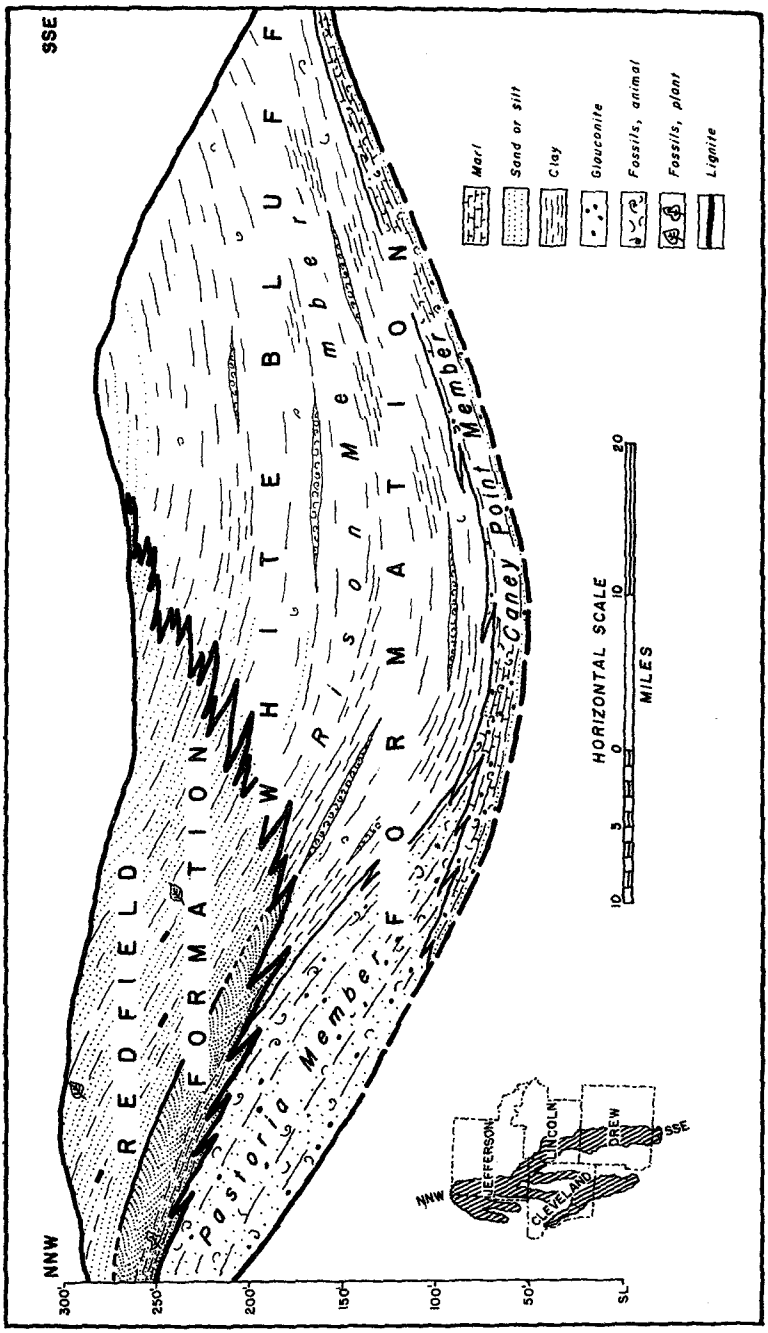



**Figure 25. Stratigraphic diagram of Jacksonian deposits in southeastern Arkansas.**

variation characteristic of nonmarine sediments, but are rather uniformly bedded in such a manner as to suggest that they were laid down in some body of water. If not conclusively shown by the texture of the Claiborne sediments themselves, physical characteristic of the next younger beds indicate that the region now identified geographically as Jefferson and eastern Grant Counties, Arkansas, in the northern portion of the area under consideration, was the site of active deposition just prior to inundation of this part of the Desha basin by the Jacksonian sea. It is probable that a stream of moderate size flowed into this low region from adjacent higher ground. The perpetuation of clastic deposition in this locale is an important factor in explaining the facies which developed during Jacksonian time. A few reworked Cretaceous foraminifers found in uppermost Claiborne strata furnish a possible clue to the source of the sediments.

A second major consideration of environmental significance is the relationship between sedimentation and subsidence in the western part of the Desha basin. After a short period during which this area was a marine depositional province, there was a marked tendency toward a return of the more normal nonmarine depositional conditions. The Jacksonian sea gradually withdrew to the east. The withdrawal was occasioned by sedimentation which pushed the sea entirely out of the northern part of the area, and, farther south, restricted it to a shallow bay or similarly confined water body of less than normal salinity. Subsidence in the Desha basin continued during this phase, for sediments deposited under this environmental control attain thickness of more than one hundred feet.

During Jacksonian time four different facies developed in the southeastern Arkansas area. While normal marine conditions prevailed (the innundative phase), deposits characterized by clastic constituents (Pastoria facies) accumulated in the northern sector, as calcareous deposits (Caney Point facies) were laid down farther to the south. As the sea withdrew eastward (the regressive phase), nonmarine deposits were formed in the north (Redfield facies),

and sediments of a lagoonal, estuarine, or similar marginal marine environment (Rison facies) were deposited in the south. The stratigraphic diagram (Figure 25) illustrates the relationship between these facies.

### Initial Effects Of Marine Transgression

Jacksonian deposition began in an advancing sea which slowly covered the Desha basin, extending at least as far west as the present outcrops of the White Bluff formation. Clastic deposition, which had begun earlier in Jefferson and Grant Counties, continued. The influence of the marine environment was gradually expressed in the sediments of this northern part of the area; first by the addition of glauconite to the clastic constituents, and later by the incorporation of numerous invertebrates. The Claiborne-Jacksonian contact in this region is not sharp.

In more southerly parts of the area there was a different reaction to the marine transgression. Here, in an area perhaps of somewhat greater elevation than farther north (i. e., closer to the positive Monroe uplift), little sediment, if any, was deposited just prior to the inundation, and the Jacksonian sea brought into existence an entirely different environment. The uppermost Claiborne beds were reworked and mixed with marine products. Tidal flats were developed and afterwards were covered by the sea, during which slabs of clay, possibly derived from dried mud cracks, were incorporated into the basal beds of the marine deposit. Marine organisms began their boring activity on the newly made sea bottom. The basal Jacksonian contact shows signs of disconformity in Cleveland and Bradley Counties.

### Inundative Phase

The deposits of the lower part of the White Bluff formation reflect a continuation of the two basic sedimentary environments (coarser deposition in the north, finer clastic deposition in the south) during the time the area was covered by the sea. The coarser facies is repre-

sented by the Pastoria sand member, and the finer clastic facies by the Caney Point marl member. The difference in lithology, thickness, and fossils of the two members is pronounced. All the characteristic properties of the Pastoria member are indicative of deposition in a near-shore area of active sedimentation. Notable among these are the marine-nonmarine interfingering, and the cross-bedded glauconitic sand noted in the vicinity of Sheridan, the prominence of sand in all the marine beds at White Bluff, and the quantity of lignitic material associated with the sediments at several outcrops. Paleontological evidence also supports this conclusion (Wilbert, 1951).

Caney Point marl deposits accumulated outside the region of coarser clastic deposition. Time-equivalence to the Pastoria member is indicated by the common marine character and stratigraphic position of the units, and by their kindred, though generally dissimilar, fossils. After the initial reworking of the uppermost Claiborne beds, only the finer material which entered the basin found its way into these deposits. Calcareous matter, glauconite, and clay are the typical constituents. The member has most of the characteristics which textbooks attribute to "off-shore deposition," but which in reality signify only the remoteness of active coarse clastic deposition. The total thickness of the Caney Point member is much less than that of the Pastoria member.

The difference in depositional environments had an effect on the faunas. Echinoids, bryozoans, and corals seem to be poorly suited generally to life in areas of clastic sedimentation of the Pastoria type, or cannot endure the reduced salinity of sea water in the immediate vicinity of a river mouth, but they thrive in the relatively quiet waters of more normal marine salinity where calcareous glauconitic sediments are laid down. The Caney Point beds enclose a much more varied ostracode and foraminifer faunule for similar reasons. No such generalization is applicable to Mollusca. Some forms, such as *Venericardia* and *Turritella,* are adapted to either condition; but, as shown by the number of individuals found incorporated

in the sediment, they apparently prefer one or the other of the ecologic settings. These genera and others like them are prolific in the Pastoria deposits. Other Mollusca, such as *Fusimitra conquisita,* express the suitability of the environment by size which they attain. Specimens of *F. conquisita* in the Pastoria member are less than one-half as large as Caney Point forms. Less tolerent molluscans are restricted to one environment or the other.

### Regressive Phase

The marine waters did not remain in the area for a very long time. The continued clastic deposition finally resulted in the building of a sedimentary mass extending out from the Pastoria area toward the southeast, driving the sea from this region and at least partially isolating the area where Caney Point beds had been accumulating. The marine Pastoria deposits were replaced by nonmarine Redfield beds, and transitional sediments marked by lingulid brachiopods occur, at least locally, between the two. The Redfield formation contains fossil leaves, cross-bedded sands, and lignitic matter. In most places, the beds are well stratified and thus must have been laid down in some aqueous medium. No marine indicators are found, and it is logical to assume that the medium was relatively fresh water. Sedimentation in a deltaic environment probably would produce such deposits. The Redfield beds seen at the outcrops probably accumulated in shallow water on the western side of a delta, away from marine influence.

This deltaic outbuilding, or some other unknown sedimentary or tectonic activity, reduced the southern region to a broad shallow baylike area, having only a restricted connection to the main marine body farther east. The fresh water of the Redfield sector mingled freely with this bay, producing sub-saline, brackish, or possibly sub-brackish water there. Most of the fine material (but very little of the coarse material) from the Redfield depositional area was carried into the bay and deposited as the pure blocky clay beds of the Rison member.

Relatively few organisms could live in the Rison depositional environment. Arenaceous foraminifers in moderate quantity, *Corbula,* a few nuculids, and a minute venericardiid comprise the complete known assemblage of forms. Periodically there was an influx of Mollusca from adjacent areas where Pastoria-like sediments were still being deposited, and these were incorporated into the Rison member as thin, discontinuous beds and lentils.

The persistence of these two environments for the time necessary to accumulate the observed and computed thickness of the Redfield formation and the Rison member is surprising. It is difficult to find an explanation which does not involve continued subsidence of the Desha basin after open marine waters had been excluded from its western portion. Evidently sedimentation and subsidence in this area were delicately adjusted.

# PALEONTOLOGY OF THE JACKSONIAN STAGE IN SOUTHEASTERN ARKANSAS

## General Discussion

Correlation of the Jacksonian inliers of southeastern Arkansas with the standard Jacksonian section must be based mainly on comparisons of fossils. The geographic isolation of outcrops and distinctness of facies developed within the Mississippi Embayment, coupled with scanty knowledge of sediments beneath the Mississippi Valley alluvium which connect the inliers to the coastwise Jacksonian farther south, make other stratigraphic criteria difficult to apply. Paleontology, therefore, assumes a special importance in this region.

Although both plant and animal remains are present in the Jacksonian beds of Arkansas, only the invertebrates are discussed here. The very incomplete knowledge of paleobotanical features of Gulf Coast Cenozoic deposits does not indicate present stratigraphic usefulness of study of the flora found in Jacksonian beds of Arkansas. Vertebrate fossils are not common; and fish teeth, vertebrae, otoliths, and the few batoidean plates which do occur have little or no stratigraphic significance at this time. The White Bluff formation contains a good faunal assemblage, in which most of the invertebrate phyla are represented. My studies have been restricted to these forms.

In Appendix B are listed 175 species, subspecies, and varieties of invertebrate fossils from the three members of the White Bluff formation. These are arranged so as to accentuate the stratigraphic distribution of the forms in each major taxonomic division. Most of the fossils listed are sufficiently abundant to be present in collections made with moderate care at localities specified.

The assemblage of fossils reported from the Pastoria and Caney Point members is reasonably complete. This is not true of the Rison member. Calcareous matter has been leached from the Rison beds at all outcrops visited, and accordingly all of the fossils with calcareous hard

parts are present only as molds. The faunal list includes those molluscan species from the Rison member which could be identified easily from these molds. Arenaceous foraminiferal tests are the only organic remains in this member which have approximately their original fossil condition.

## Foraminifera

Tests of Foraminifera are common and varied in the Caney Point member; they are less common and much less varied in the Pastoria member. In a few of the cores taken from the borings made at the southern end of White Bluff, a more abundant foraminiferal assemblage than was recovered from samples at the outcrop was noted, but the variety of species is not much greater. The Rison member yields only arenaceous forms at the outcrop.

All of the foraminifers which were identified specifically are present in Jacksonian beds of Louisiana and Mississippi. Those reported without specific name are mostly types which present special taxonomic problems, making positive identification difficult. Species of some of the arenaceous genera, such as *Ammobaculites* and *Trochammina,* are not well known in the coastwise Jacksonian deposits.

The foraminiferal assemblage of the southeastern Arkansas Jacksonian outcrop area has not been listed previously. Fisk (1939, pp. 1797-99) records foraminifers and ostracodes recovered from borings which penetrated Jacksonian sediments at Greenville, Mississippi, near the axis of the Mississippi structural trough, about 40 miles east of the Jacksonian exposures in Drew County, Arkansas. Although the fauna at Greenville contains nearly twice as many species as are found in the White Bluff formation, species from the White Bluff formation are present at Greenville without notable exception. The beds at Greenville are considered by Fisk to be of middle and lower Jacksonian age (*Textularia hockleyensis* and *Textularia dibollensis* zones of authors).

There is a similar identity of species in the White Bluff formation of Arkansas and lower Jacksonian beds near Jackson, Mississippi, and near Montgomery, Louisiana. The fauna in Arkansas is less varied, however.

Special stratigraphic importance has been given certain Foraminifers, which are used as zone indicators by paleontologists engaged in subsurface studies in the area south of the Jacksonian outcrop belt. The first appearance of these species in wells is used to identify parts of the Jacksonian section, as indicated:

Upper Jacksonian *Massilina pratti* Cushman and Ellisor
*Valvulineria texana* Cushman and Ellisor

Middle Jacksonian *Textularia hockleyensis* Cushman and Applin

Lower Jacksonian *Textularia dibollensis* Cushman and Applin

*Valvulineria texana* and *Textularia dibollensis* occur in the Caney Point member. Also present in the Caney Point beds is a *Massilina*, here identified as *M. goniopleura*, which might easily be mistaken for *M. pratti* if examined casually. In the Rison member, *T. hockleyensis* and *T. dibollensis* both are present (Plate 1).

Since the stratigraphic significance of these species is based on the upper limit of their range, it is not necessarily anomalous to find them together in a restricted stratigraphic interval. Bergquist (1942, p. 85) reports *Valvulineria texana* from the lower part of the Yazoo clay in Scott County, Mississippi. Renick (1936, p. 22) has recorded the occurrence of *Textularia hockleyensis* in the Caddell formation, the basal Jacksonian unit in Texas.

The occurrence of *Textularia hockleyensis* and *T. dibollensis* together in the Rison member requires elaboration. *T. hockleyensis* is the more common form, and is represented by a number of specimens (at most localities)

which are well preserved and easily identified. *T. dibollensis*, on the other hand, is more imperfectly preserved, and although one or two specimens were found which show all specific characteristics, most of the others cannot be classified positively as *T. dibollensis* (H. V. Andersen, personal communication). Identification of T. *dibollensis* specimens from the Caney Point member is definite. Seemingly, either *T. dibollensis* declined in importance and *T. hockleyensis* became well established during a relatively short time interval between the deposition of Caney Point and Rison sediments, or the development of the two species is ecologically controlled. Prevailing opinion in the Gulf Coastal Plain regarding the stratigraphic distribution of these textulariids supports the former interpretation.

The foraminifers of the Pastoria members seem to have a greater ecologic than stratigraphic significance. Three species comprise three-fourths of an assemblage of about 15 species. These are *Discorbis jacksonensis texana* Cushman and Applin, *Nonion advenum* (Cushman), and *Glandulina ovata* Cushman and Applin. All of these species have a rather wide geographic and stratigraphic range.

## Mollusca

Representative molluscan populations in the Jacksonian deposits of Mississippi and Louisiana occur spasmodically. The basal Jacksonian rock unit usually identified in the central Gulf Plain, the Moodys Branch formation, contains one of the largest molluscan assemblages in the entire Tertiary System. Relatively few representatives of the phylum have been reported from the Yazoo clay in western Mississippi, and even in the eastern part of the State, well preserved pelecypods and gastropods from middle Jacksonian strata are generally not very plentiful. Though the Yazoo clay section of Louisiana contains a number of beds from which mollusks have been reported, hardly more than 10 forms have been identified specifically from these deposits. Foraminifera and Ostracoda are common in the Yazoo clay both in Louisiana and Mississippi. The Danville Landing formation (Louisiana),

usually considered to be upper Jacksonian, contains a good molluscan assemblage at the type locality and on Bayou Toro, Vernon Parish, Louisiana.

Comparison of the mollusks collected from the Jacksonian outcrops in southeastern Arkansas with fauna from equivalent deposits in Louisiana and Mississippi is essentially limited to determining relationships between the Arkansas fossils and assemblages of early and late Jacksonian time. The resultant correlations are potentially less precise than those based on fossils which are more uniformly distributed throughout the thickness of the standard sections.

The difference between the molluscan remains in the Caney Point and Pastoria members is striking. Though specimens are numerous in both, only 17 of 81 molluscan species listed in Appendix B are common to the two units. Many of these show either conspicuous difference in size or different relative abundance in the two members, further accentuating the faunal distinction between these facies.

The Rison fauna is not sufficiently well known to permit any generalizations, but the Rison mollusks seem to be closely allied to those of the Pastoria assemblage.

A number of the fossils of the White Bluff formation are probably restricted to the Arkansas Jacksonian deposits.[15] These are:

*Mytilus* (*Harmomya*) *hamatoides* Call

*Periploma collaridi turgida* Harris

*Yoldia psammotaea rubamnis* Harris

*Barbatia corvamnis* Harris

*Mactra* (*Spisula*) *albirupina* Harris

*Dentalium* (*Antalis*) *vincense* Palmer

[15] This probability is based on distribution of species given in the Jacksonian molluscan monograph by Harris and Palmer (1946-47). Since the area covered by their publication is restricted to the region between Sabine and Alabama Rivers, occurrences of these species elsewhere would not be recorded. Some of these species also occur at the Little Crow Creek locality on the east flank of Crowleys' Ridge.

*Mazzalina inaurata humerosa* Harris

*Bulla altilis subglobosa* (Conrad)

*Cylichnina jacksonensis exta* (Harris)

*Hopleurotoma? albirupsis* (Palmer)

With the exception of the scaphopod *Dentalium* (*Anatalis*) *vincense* Palmer which is present in Caney Point and Pastoria beds, all of the species peculiar to the Jacksonian deposits of Arkansas occur only in the Pastoria member. Forms closely related to most of these species occur elsewhere in Jacksonian sediments.

The Caney Point molluscan faunule is most like that of the Moodys Branch formation of Louisiana and Mississippi. All of the Caney Point mollusks (except the *Dentalium* mentioned above and *Corbula* (*Caryocorbula*) *willistoni arkansia* Harris are found at Jackson, Mississippi, and Montgomery, Louisiana, or at other localities where Moodys Branch beds crop out. The Moodys Branch formation, however, contains more than three times as many described molluscan species as the entire White Bluff formation.

The close correspondence between the Moodys Branch and the Caney Point assemblages does not necessarily indicate that the two units are exact stratigraphic equivalents. The marked contrast between the Caney Point and Pastoria faunas underlines the strong influence of environment on molluscan populations in adjacent areas and the similarity of the Caney Point and Moodys Branch probably signifies a similarity in ecological factors which control the respective populations. This conclusion is supported by the lithologic similarity between the two units.

Though the prime control may be ecologic, the general absence of specifically distinct Caney Point mollusks from the Moodys Branch formation is not without stratigraphic importance, for if these deposits represented different parts of Eocene time, this difference should be reflected clearly in their contained faunas.

Close relationship between the Caney Point deposits and the Danville Landing formation is not indicated by the Mollusca. The prominence of the gastropod genus *Mazzalina* at Danville Landing and at White Bluff is a point of similarity between the two faunas; also, *Turritella arenicola branneri* Harris, *T. clevelandia* Harris, *Levifusus branneri* Harris, *Conomitra hammakeri* (Harris), *Latirus (Dolicholatirus) leaensis* Harris, and a few other species occur in both units (Plate 2). All of these also occur in the Moodys Branch formation and they seem to range throughout the Jacksonian, relative abundance being controlled by ecologic factors. The only form which is restricted to the Danville Landing and White Bluff formations is *Corbula (Caryocorbula) willistoni arkansia* Harris, the prototype of which is *C. willistoni* Meyer, described from the Moodys Branch formation at Jackson, Mississippi. Most Caney Point mollusks are not found at any of the Danville Landing localities, and there is little faunal evidence to support a correlation of the two units.

### Ostracoda

As in the case of the Foraminifera, ostracodes reported by Fisk (1939, pp. 1397-99) from borings near Greenville, Mississippi, represent the nearest approach to the ostracode assemblages of the White Bluff formation, geographically and stratigraphically. A few species collected from southeastern Arkansas are not reported from Greenville, but these are known from lower Jacksonian deposits in Louisiana and elsewhere in Mississippi. One undescribed species of *Brachycythere* and one of *Cythereis* were found in the White Bluff formation, and are possibly restricted to it. No characteristic upper Jacksonian forms were encountered in Arkansas.

Samples examined from the Rison member of the White Bluff formation yielded no ostracodes. This is not surprising, since all calcareous matter seems to be leached from sediments at the outcrops of this member, and molds of these minute organisms would not be noticed ordinarily.

Ostracodes are most abundant and varied in material collected from the Caney Point deposits. The best sample of Pastoria ostracodes was taken from borings made at the south end of White Bluff (Locality 2).

### Other Fossils

Occurrence of the inarticulate brachiopod *Glottidia* near the top of Pastoria beds at White Bluff is significant only because it supports interpretation of the Redfield-White Bluff formational boundary as a conformable contact. It has no known geochronic value.

The fact that corals, bryozoans, and echinoids are found exclusively in the Caney Point deposits of this region strongly supports argument that faunal variations reflect facies differentiation within the White Bluff formation.

These fossils are among the less conspicuous elements of the White Bluff fauna as a whole, but they are by no means rare in the Caney Point member.

The larger coral species, such as *Astrangia harrisi* Vaughan, *Flabellum cuneiforme* var. *wailesi* Vaughan, and *Balanophyllia inorrata* (Conrad) may be collected individually at some outcrops. The other species are quite small, and are generall seen only in material prepared for microfaunal examination. All species listed are known from the Moodys Branch formation in Louisiana and Mississippi, except *Astrangia harrisi*. *A. harrisi* is reported from the lower part of the Danville Landing formation by Chawner (1936, p. 90).

Bryozoa are not numerous, but fragmentary zoaria of the species listed in Appendix B are found in washed Caney Point samples. Most of these species have been reported from widely separated stratigraphic horizons within the Jacksonian Stage, and some occur in Claiborne and Vicksburg deposits. *Otionella perforata* Canu and Bassler is not reported by these authors (Canu and Bassler, 1941, pp. 106-7) or McGuirt (1941, pp. 47-8) above lower Jacksonian.

Echinoids are common only at Locality 24, where specimens of *Periarchus lyelli* (Conrad) are moderately abundant. A few imperfectly preserved specimens of *Schizaster armiger* Clark were found at Locality 39, and Harris (1894, pl. 6, Fig. 11) reports the species (later identified by Cooke) from Locality 38. *Periarchus lyelli* is abundant in the lower Jacksonian deposits of Mississippi and Alabama, where it marks a conspicuous zone (*"Scutella* bed" of authors). The upper Jacksonian representative of this species, *P. lyelli pileussinensis* Ravenel is not found in Arkansas. *Schizaster armiger,* though perhaps more common in middle and upper Jacksonian deposits, is reported by Cooke (1942, p. 39) from "8 feet above *'Scutella'* bed."

### Age Of White Bluff Fauna

The evidence gathered from a study of each of the major invertebrate phyla indicates that the White Bluff formation is the stratigraphic equivalent of lower Jacksonian deposits of the standard section in Mississippi. Although much of the paleontological similarity between the most fossiliferous part of the formation (Caney Point member) and the Moodys Branch formation of Mississippi may be attributed to a similarity of facies rather than chronological identity, the absence of fossils having stratigraphic range limited to middle and upper Jacksonian horizons minimizes the possibility that there is any great difference in the age between the two units. This is confirmed by the fact that all of the Caney Point forms, with only minor exceptions, are duplicated specifically in the lower Jacksonian beds of Mississippi and Louisiana.

The geographic location of the White Bluff formation is a factor bearing on the relative time during which the sediments accumulated. The basal Jacksonian marine beds were deposited in a sea which was advancing from the south. Since the Jacksonian strata of southeastern Arkansas are some distance inland from the latitude of Jackson, Mississippi, we should expect the White Bluff formation to be somewhat younger than the Moodys Branch formation. The fossils indicate that this difference in age is

slight. The youngest age assignment consistent with paleontological data now available which can be applied to the White Bluff formation, is latest early Jacksonian, equivalent to the lower part of the Yazoo clay of Mississippi.

Such a placement of the White Bluff formation helps to explain the presence of *Textularia hockleyensis* in the Rison member (a species characteristic, but seemingly not restricted to the middle Jacksonian) and the presence of *Schizaster armiger* (lowest reported stratigraphic occurrence in the lower Yazoo clay) in the Caney Point member, while still preserving the relatively close time relationship to the Moodys Branch formation indicated by the Mollusca. This age estimate is supported, in general, by the conclusion reached by Fisk (1939, p. 1400) as to age of the Jacksonian deposits penetrated in the Greenville, Mississippi borings.

It must be emphasized that age relationships here suggested apply to the White Bluff formation in the southeastern Arkansas outcrop area only, and not necessarily to Jacksonian beds elsewhere within the Mississippi Embayment. An indication that the deposits at Little Crow Creek may be younger is provided by the presence of *Basilosaurus* (*Zeuglodon*) *cetoides* (Owen) reported by Palmer (1939); and borings made near Memphis, close to the common corner of Arkansas, Mississippi, and Tennessee, are said to have encountered strata containing upper Jacksonian fossils (H. N. Fisk, personal communication). Stratigraphic evidence that the Jacksonian sea withdrew from the southeastern Arkansas outcrop area, in the direction of the axis of the Mississippi structural trough, is available. The sea may have remained in that vicinity or may have extended northward along the structural axis after withdrawal from the western part of the Desha basin, where the outcrops here discussed are located.

### Effects Of Geographic Isolation

The accumulation of marine Jacksonian sediments now seen in the southeastern Arkansas outcrop area took

place in a region partially isolated from the main Jacksonian sea. Structural evidence and existing distribution of Jacksonian sediments indicate that the connection between the Mississippi Embayment and the open sea was restricted to a relatively narrow strait in the vicinity of the Monroe uplift. The deepest part of the embayment probably extended north from this inlet, closely following the axis of the Mississippi structural trough (marked by the course of the Mississippi River). Marine waters covered the area of the Desha basin as well, at least as far west as the present limits of the White Bluff formation. This geographic situation explains some of the distinctive characteristics of the White Bluff fauna.

The basic similarity between the fossils of the Caney Point member and those of the Moodys Branch formation has been pointed out on previous pages. The principal difference in the faunas is the fact that at least one half of the fossils reported from the Moodys Branch formation are not found in Arkansas. The absence of some of the Mollusca may be explained partially by the relatively few localities which yield identifiable Caney Point megafossils. On the other hand, the more completely known microfaunas are less varied in southeastern Arkansas than in the coastwise Jacksonian belt. The combined effect of partial geographical isolation and facies control of the fauna undoubtedly accounts for the reduced Moodys Branch component in the White Bluff invertebrate assemblage.

Most of the demonstrable peculiarities of speciation in the White Bluff fauna are referable to the Mollusca of the Pastoria member. Pastoria deposits seem to have accumulated at the margin of a delta, under depositional conditions not duplicated exactly elsewhere in the central Gulf Plain. The probable restriction of certain molluscan species to the Mississippi Embayment seems more adequately explained as the combined effect of facies control and geographic isolation, facies control being the more important.

## REGIONAL IMPLICATIONS OF THE STUDY

The study of the Jacksonian outcrops in southeastern Arkansas and their relationships to other late Eocene deposits within the Mississippi Embayment provides additional information and supports some ideas already advanced concerning the history of the central Gulf Plain during late Eocene time. These include the following:

1. Stratigraphic data gathered from southeastern Arkansas are in harmony with interpretation of marine Jacksonian deposition as the product of a late Eocene transgression and regression of the sea.

2. Marine waters advanced into the Mississippi Embayment during early Jacksonian time through a relatively narrow strait and over a shallow threshold located in western Mississippi, approximately at the latitude of the Arkansas-Louisiana Boundary. The positive movements of the Monore uplift were responsible for restricting the opening of the embayment and creating a partially isolated basin, the Desha basin, within the embayment.

3. Most of the sediments which accumulated in the Desha basin during the marine occupation were contributed by a stream of moderate size, which built a delta in the northwestern portion of the basin. Continued sedimentation derived from this source caused the delta to be extended southeastward, driving the sea toward the axis of the Mississippi structural trough, and partially isolating the western part of the Desha basin. This took place during the latest part of early Jacksonian time.

4. If marine waters remained in the Mississippi Embayment during middle and late Jacksonian time they were confined to the region east of the outcrops here discussed. Thereafter the sea withdrew completely. No subsequent marine record is known.

# EXPLANATION OF PLATE 1

*Nonion advenum* (Cushman)

1. Specimen from Pastoria sand member, White Bluff formation, Locality 2 (core taken from test borings made at southern end of White Bluff). Lateral view, x80.

*Textularia dibollensis* Cushman and Applin

2. Specimen from Caney Point marl member, White Bluff formation, Locality 39. Lateral view, x80.

*Textularia hockleyensis* Cushman and Applin

3. Specimen from Rison clay member, White Bluff formation, Locality 39. Lateral view, x40.

*Bolivina gracilis* Cushman and Applin

4. Specimen from Caney Point marl member, White Bluff formation, Locality 39. Lateral view, x60.

*Trochammina sp. 1*

5. Specimen from Rison clay member, White Bluff formation, Locality 39. Ventral view, x70.

*Discorbis? hemisphaerica* Cushman

6. Specimen from Caney Point marl member, White Bluff formation, Locality 39. *a*, ventral view, x90; *b*, dorsal view, x90.

*Massilina goniopleura* Hadley

7. Specimen from Caney Point marl member, White Bluff formation, Locality 39. Lateral view, x40.

*Discorbis jacksonensis texana* Cushman and Applin

8. Specimen from Pastoria sand member, White Bluff formation, Locality 2 (core taken from test borings made at southern end of White Bluff). *a*, dorsal view, x70; *b*, ventral view, x70.

*Valvulineria texana* Cushman and Ellisor

9. Specimen from Caney Point marl member, White Bluff formation, Locality 29. Ventral view, x90.

*Astrangia harrisi* Vaughan

10. Topotype from Caney Point marl member, White Bluff formation, Locality 29. *a*, view of corallum, x1; *b*, view of calice of one corallite, x4.

*Aldrichiella elegans* (Vaughan)

11. Specimen from Caney Point marl member, White Bluff formation, Locality 39. *a*, ateral view, x10; *b*, view of calice, x10.

*Cythereis montgomeryensis* Howe and Chambers

12. Specimen from Pastoria sand members, White Bluff formation, Locality 2 (core taken from test borings made at southern end of White Bluff). Lateral view of left valve, x40.

*Cythereis grigsbyi* Howe and Chambers

13. Specimen from Pastoria sand member, White Bluff formation, Locality 2 (core taken from test borings made at southern end of White Bluff). Lateral view of right valve, x40.

*Cythereis jacksonensis* Howe and Pyeatt

14. Specimens from Pastoria sand member, White Bluff formation, Locality 2 (core taken from test borings made at southern end of White Bluff). Lateral view of left valve, x40.

*Cytheretta alexanderi* Howe and Chambers

15. Specimen from Caney Point marl member, White Bluff formation, Locality 39. Lateral view of left valve, x40.

*Cythereis florienensis* Howe and Chambers

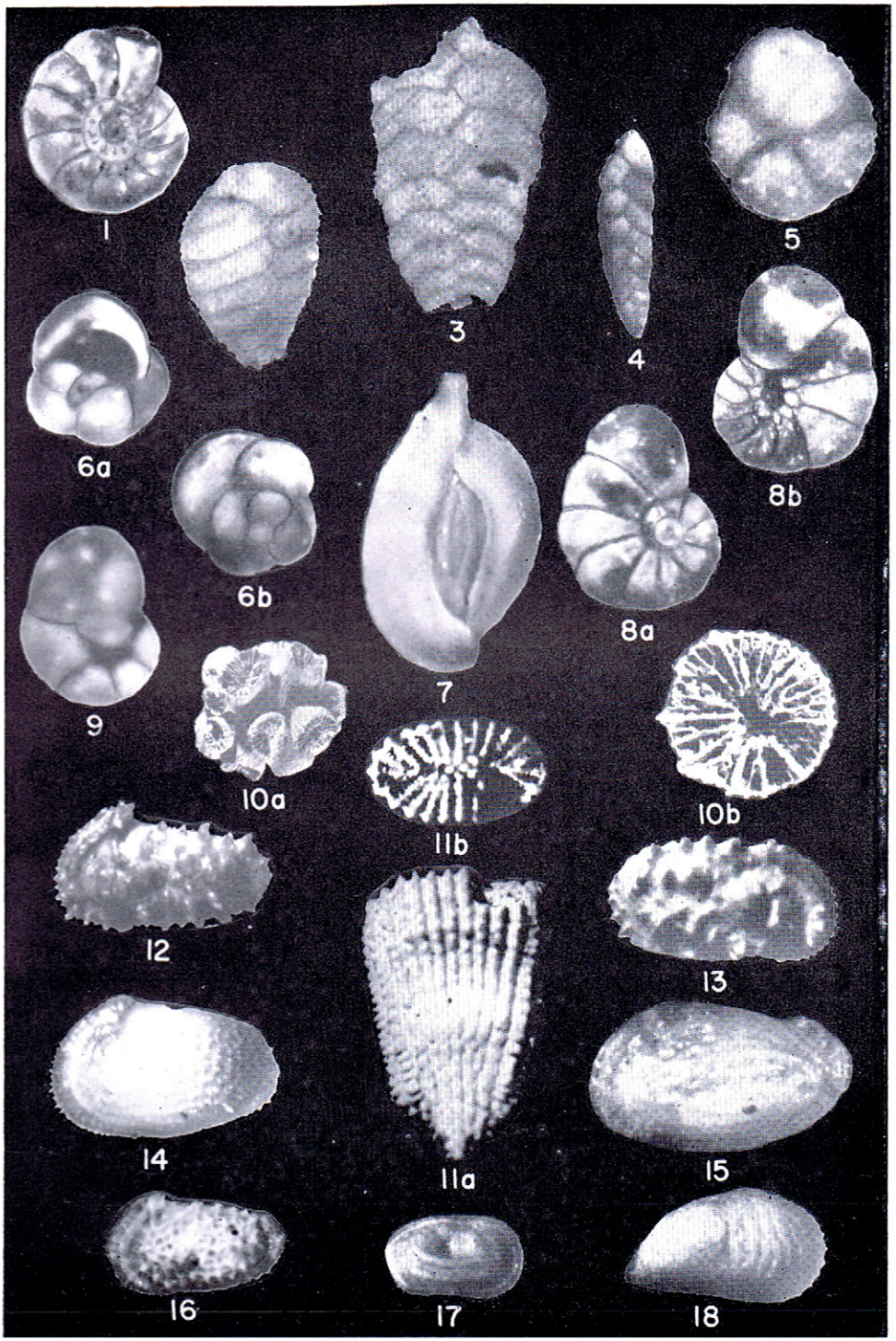
16. Specimen from Caney Point marl member, White Bluff formation, Locality 29. Lateral view of left valve x40.

*Cytherelloidea danvillensis* Howe

17. Specimen from Caney Point marl member, White Bluff formation, Locality 43. Lateral view of right valve, x40.

*Haplocytheridea montgomeryensis* Howe and Chambers

18. Specimen from Pastoria sand member, White Bluff formation, Locality 2 (core taken from test borings made at southern end of White Bluff). Lateral view of right valve, x40.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## EXPLANATION OF PLATE 2

(All figures x1 except as otherwise indicated)

*Venericardia (Venericor) planicosta* c. f. *V. (V.) planicosta densata* Conrad

1. Specimen from Pastoria sand member, White Bluff formation, Locality 2. *a*, view of interior of left valve; *b*, view of exterior of left valve.

*Clavilithes humerosa* Conrad

2. Gerontic specimen from Caney Point marl member, White Bluff formation, Locality 29. *Astrangia harrisi* attached to labrum. Lateral view.

*Pitar trigoniata* (Lea)

3. Specimen from Pastoria sand member, White Bluff formation, Locality 2. *a*, view of exterior of right valve; *b*, view of interior of right valve.

*Turritella clevelandia* Harris

4. Topotype from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.

*Turritella arenicola branneri* Harris

5. Topotype from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.

*Levifusus branneri* Harris

6. Specimen from Caney Point marl member, White Bluff formation, obtained from water well drilled one-half mile south of Monticello, Drew County, Arkansas, depth 150 to 320 feet, donated by Mr. M. S. Sigman. Lateral view.

*Nuculana albirupina* (Harris)

7. Topotype from Pastoria sand member, White Bluff formation, Locality 2. Exterior of right valve, x4.

*Fusimitra conquista* (Conrad)

8. Specimen from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.
9. Specimen from Caney Point marl member, White Bluff formation, Locality 29. Lateral view.

*Pseudoliva vetusta perspectiva* Conrad

10. Specimen from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.

*Latirus (Dolicholartirus) leaensis* Harris

11. Specimen from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.

*Athleta petrosa* (Conrad)

12. Specimen from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.

*Periarchus lyelli* (Conrad)

13. Specimen from Caney Point marl member, White Bluff formation, Locality 24. Aboral view.

*Mazzalina inaurata oweni* (Dall)

14. Topotype from Pastoria sand member, White Bluff formation, Locality 2. Lateral view.


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1b
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3a
3b
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# APPENDIX A

# DESCRIPTION OF LOCALITIES

Jefferson County

1. *South Red Bluff.* Steep bluff on right bank of Arkansas River at old ferry landing, near end of local road, 5 miles east of Redfield, approximately center of SE¼, NE¼, Section 7, T. 3 S., R. 10 W., Jefferson County, Arkansas. *Redfield formation and White Bluff formation (Pastoria sand member) including basal contact.* 70 foot section of nonmarine sands and silts above lignitic, slightly fossiliferous, clay and sand.

2. *White Bluff.* Steep bluff on right bank of Arkansas River, extending for about 2 miles downstream from a point 1/3 mile below mouth of Tar Camp creek, in E½ of Sections 19 and 30, T. 3 S., R. 10 W., Jefferson County, Arkansas. *Redfield formation and type locality, White Bluff formation (Pastoria sand member).* 145 feet of beds consisting of nonmarine silty sands, sand and lignite, above fossiliferous glauconitic argillaceous sand.

3. Drainage ditch and roadcut along U. S. Highway No. 65, 0.7 miles north of Redfield, approximately NE¼, SE¼, Section 16, T. 3 S., R. 11W., Jefferson County, Arkansas. *Interfingering of Redfield formation and White Bluff formation (Pastoria sand member).* 20 foot discontinuous section of clay and silt, some beds containing molds of Mollusca.

4. *Redfield.* Stream bank and roadcut on U. S. Highway No. 65, 0.25 miles south of caution light across highway at Redfield, approximately in center of Section 22, T. 3 S., R. 11 W., Jefferson County, Arkansas. *Type locality, Redfield formation.* 20 feet of laminated silts and silty sand containing carbonaceous material.

5. Drainage ditch on south side of local road between Pine Bluff and Sulphur Springs, 1.55 miles west of its junction with U. S. Highway No. 79, approximately in center of Section 23, T. 6 S., R. 10 W., Jefferson County, Arkansas. *Redfield formation.* 14 feet of blocky clay sand containing plant fragments.

Grant County

6. Small roadcut and drainage ditch along local road 0.7 miles southeast of Orion Crossroads, approximately N. W. corner, Section 19, T. 3 S., R. 11 W., Grant County, Arkansas. *White Bluff formation (Pastoria sand member).* 6 feet of sand containing silt stringers, bearing fossiliferous ferrouginous concretions.

7. Series of roadcuts and drainage ditches beside U. S. Highway No. 270 beginning 0.4 miles west of town square at Sheridan, approximately in center of S½ Section 4, T. 5 S., R. 13 W., Grant County, Arkansas. *White Bluff formation (Pastoria sand member) interfingering with Redfield formation.* Composite section 25 to 30 feet thick consisting of crossbedded glauconitic sand with few fossil molds, sand, and silty clay.

8. Roadcut along U. S. Highway No. 270, 4.3 miles east of Sheridan just east of Hurricane Creek, approximately in S½ SW¼ Section 32, T. 4 S., R. 12 W., Grant County, Arkansas. *Redfield formation.* 38 feet of fine sand and silty clay.

9. Drainage ditch along U. S. Highway No. 167, 4 miles south of Sheridan, approximately in center of S½ Section 27, T. 5 S., R. 13 W., Grant County, Arkansas. *White Bluff formation (Pastoria sand member) interfingering with Redfield formation.* 17 feet of cross-bedded glauconite sand containing a few fossil molds, sand, and silty clay.

10. Drainage ditch beside local road between Sheridan and Pine Bluff, 4 9 miles east of its junction with Arkansas State Highway No. 35 at village of Ain, approximately in center of E½, Section 1, T. 6 S., R. 12 W., Grant County, Arkansas. *Redfield formation.* 16 feet of silts, blocky clay, and sand; leaf imprints and lignitic material noted in some beds.

11. Drainage ditch on west side of Arkansas State Highway No. 35, 4.7 miles north of Cleveland-Grant county line, 1.8 miles south of Grapevine, approximately in NE¼, SW¼, Section 10, T. 7 S., R. 12 W., Grant County, Arkansas. *White Bluff formation (Rison clay member).* 15 feet of silts and sand containing some clay; several thin fossiliferous hardened ledges of ferruginous sandy clay occur.

12. Gulley developed beside local abandoned road, 4½ miles S W. of Grapevine at face of escarpment above flood plain, approximately in center of S½, Section 20, T. 7 S., R. 12 W., Grant County, Arkansas. *White Bluff formation (Rison clay member).* 30 feet of blocky clay containing scattered molds of Mollusca, sparsely fossiliferous ferruginous concretions.

13. Drainage ditch beside Arkansas State Highway No. 35, 0.4 miles north of Grant-Cleveland County line, approximately center of S½, Section 35, T. 7 S., R. 12 W., Grant County, Arkansas. *White Bluff formation (Rison clay member).* 17 feet of thinly bedded silty clay and very fine sand, ferruginous fossiliferous layers containing scattered molds of Mollusca found throughout section.

Cleveland County

14. *Cross Roads Church.* Drainage ditches and small roadcuts in radius of 100 yards from crossroads, 3.5 miles north of Kingsland on local road, approximately in center of SW¼, Section 23, T. 9 S., R. 12 W., Cleveland County, Arkansas. *White Bluff formation (Caney Point marl member).* Fossiliferous ironstone nodules on surface.

15. *Rison.* Roadcuts and excavation pit along U. S. Highway No. 79, ¼ mile west of Rison, approximately SW¼, Section 1, T. 9 S., R. 11 W., Cleveland County, Arkansas. *White Bluff formation (Rison clay member), type section.* 44 foot composite section of clay and silty clay beds, local molluscan concentrates.

16. Drainage ditch along Arkansas State Highway No. 15, 1.4 miles north of Calmer, in approximately the SW¼, SE¼, Section 4, T. 9 S., R. 9 W., Cleveland County, Arkansas. *Redfield formation.* 8 feet of clay and sand beds containing leaf and grass impressions.

17. *Saline River.* Low escarpment face, above flood plain on east side of Saline River 50 yards upstream from bridge on U. S. Highway No. 79, 6.2 miles southwest of Rison, in approximately SW¼, SE¼, Section 27, T. 9 S., R. 11 W., Cleveland County, Arkansas. *White Bluff formation (Rison clay member).* 7 feet of blocky clay containing molds of Mollusca; 2-inch bentonite bed.

18. Ditch along local road between old crossroads called Mt. Elba and Saline River, 7 miles southeast of city limits of Rison, in approximately center of NE¼, Section 8, T. 10 S., R. 10 W., Cleveland County, Arkansas. *White Bluff formation (Rison clay member).* 20 foot discontinuous section of clay, silt and sandy silt, in which ferruginous concretions containing glauconite and fossiliferous molds are found.

19. Drainage ditch beside Arkansas State Highway No. 35, 6½ miles northwest of village of Herbine, in approximately NE corner, NW¼, Section 10, T. 10 S., R. 10 W., Cleveland County, Arkansas. *White Bluff formation (Rison clay member).* 7 feet of silty clay; richly fossiliferous (molds) ferruginous bed near top of exposure.

20. Drainage ditch beside Arkansas State Highway No. 35, 6 miles northwest of village of Herbine, approximately in SW corner, SE¼, NE¼, Section 10, T. 10 S., R. 10 W., Cleveland County, Arkansas. *White Bluff formation (Rison clay member).* 11 feet of blocky clay containing scattered molds of small Mollusca.

21. Roadcut beside Arkansas State Highway No. 15, 3 miles north of Pansy, approximately in center of N ½, Section 10, T.

10 S., R. 9 W., Cleveland County, Arkansas. *White Bluff formation* (*Rison clay member*). 22 feet of blocky clay; sand lenses locally present.

22. *Clyde Brazeleton's Well.* Hand dug well, 15 feet deep, on property of Clyde Brazeleton, approximately in SW corner, Section 33, T. 10 S., R. 11 W., Cleveland County, Arkansas. *White Bluff formation* (*Caney Point marl member*). 15 feet of fossiliferous glauconitic sandy clay.

23. *Marks Mill.* Roadside drainage ditch and roadcut, just south of Marks Mill battleground monument at junction of Arkansas State Highways No. 8 and No. 97, approximately in SE¼, Section 5, T. 11 S., R. 11 W., Cleveland County, Arkansas. *White Bluff formation* (*Caney Point marl and Rison clay members*). 17 feet of blocky clay above fossiliferous ironstone.

24. *Marks Mill Stream.* Left bank of small stream in woods 100 yards north of local road and 350 yards east of Marks Mill monument, approximately in NW Corner, SW¼, Section 4, T. 10 S., R. 11 W., Cleveland County, Arkansas. *White Bluff formation (Caney Point marl member).* 10 feet of fossiliferous greensand cemented by calcium carbonate.

25. *Red Lands.* Roadcut along local road 2.75 miles northeast of New Edinburg, approximately in SE corner, SW¼, Section 27, T. 10 S., R. 11 W., Cleveland County, Arkansas. *White Bluff formation (Caney Point marl member).* 8 feet of ferruginous sand and ferruginous concretions, containing many Mollusca.

26. Drainage ditch beside local road connecting Rye and Arkansas State Highway No. 35, near Big Creek, about ¼ mile south of junction with Arkansas State Highway No. 35, in approximately NW¼, SW¼, Section 19, T. 10 S., R. 9 W., Cleveland County, Arkansas. *White Bluff formation* (*Rison clay member*). 11 feet of blocky clay containing thin fossiliferous ferrouginous beds and some ferruginous concretions.

27. *Herbine.* Drainage ditch beside Arkansas State Highway No. 35, 1/5 mile east of Herbine, in approximately SE Corner, Section 21, T. 10 S., R. 9 W., Cleveland County, Arkansas. *White Bluff formation* (*Rison clay member*). 12 feet of blocky clay, silt partings containing scattered molds of Mollusca.

28. *Harris, Well.* Water well at farm of Mr. J. Harris, ¾ miles east of Arkansas State Highway No. 15, 3 miles south of Pansy, in approximately center of NE¼, Section 1, T. 11 S., R. 9 W., Cleveland County, Arkansas. *White Bluff formation* (*Rison Clay member*). 40 feet of blocky gray clay containing molds of Mollusca; sandy clay bearing well preserved fossil shells at base.

29. *Caney Point.* Left bank of Saline River, 3 miles downstream from mouth of Big Creek at Caney Point, approximately in the NE corner of the NW¼ of Section 6, T. 11 S., R. 9 W., Cleveland County, Arkansas. *White Bluff formation (Caney Point marl member), type locality.* 11 feet of fossiliferous argillaceous glauconitic sand and fossiliferous blocky clay. Two feet of Rison clay member at top of exposure.

30. *Cow Ford.* Left bank of Saline River 3 miles downstream from Caney Point at Cow Ford, approximately in the SW¼, Section 8, T. 11 S., R. 9 W., Cleveland County, Arkansas. *White Bluff formation (Caney Point marl member).* Fossiliferous cylindrical clay ironstone concretions.

31. Ditch beside local road connecting Rye and Arkansas State Highway No. 35, near Big Creek, 2.1 miles northwest of Rye, in approximately NE Corner, SW¼, Section 10, T. 11 N., R. 9 W., Cleveland County, Arkansas. *White Bluff formation (Rison clay member).* 25 feet blocky clay, locally sandy; several thin beds of limonitic clay containing abundant molds of Mollusca present.

Lincoln County

32. Drainage ditch beside local road, 2 miles northwest of town square at Star City, approximately center of NW¼, Section 7, T. 9 S., R. 7 W., Lincoln County, Arkansas. *Redfield formation.* 25 feet of blocky clay and sand; some beds containing plant fragments.

33. Drainage ditch and gully on north side of local road at its intersection with Arkansas State Highway 81, 1.5 miles south of town square at Star City, approximately SW¼, SE¼, Section 17, T. 9 S., R. 7 W., Lincoln County, Arkansas. *Redfield formation.* 12 feet of blocky clay and silt containing a few fragments of plant remains.

34. Drainage ditch on east side of local road, 4.1 miles southeast of village of Cornerville. approximately SW Corner, SE¼. NE¼, Section 35, T. 10 S., R 8 W., Lincoln County, Arkansas. *Redfield formation.* 14 feet of sand, silt, and blocky clay; some beds contain impressions of small fragments of leaves and grass; 3 inch bed of bentonite near base of section.

35. *Relfs Bluff.* Small roadcuts and drainage ditch along Arkansas State Highway No. 81, starting 100 yards north of Drew, Lincoln County line, approximately SE Corner, SE¼, Section 32, T. 10 S., R. 7 W., Lincoln County, Arkansas. *White Bluff formation (Rison clay member?).* Fossiliferous ferruginous nodules occur on surface.

Bradley County

36. Roadside ditch and roadcut on east side of Arkansas State Highway No. 8, 5.7 miles northwest of Warren City limits, in NW Corner, Section 11, T. 12 S., R. 9 W., Bradley County, Arkansas. *White Bluff formation (Caney Point marl member), basal contact.* Borings filled with glauconitic clay extend into Claiborne silt beds.

37. Roadside ditch and roadcut on east side of Arkansas State Highway No. 8, 3.8 miles northwest of Warren City limits, approximately in the NE Corner, SE¼, Section 14, T. 12 S., R. 9 W., Bradley County, Arkansas. *White Bluff formation (Caney Point marl member), basal contact.* Borings filled with glauconitic clay extend into Claiborne silt beds.

38. *Cornish Ferry.* Left bank of Saline River, 1 mile downstream from mouth of Basin Creek at old Cornish Ferry, approximately in SW¼, Section 24, T. 12 S., R. 9 W., Bradley County, Arkansas. *White Bluff formation (Caney Point marl member).* 11 foot discontinuous outcrop consisting of fossiliferous glauconitic sand above lignitic Claiborne clay. Contact not well exposed.

39. *Van Mann gulleys.* Banks of several small intermittent streams beginning 50 feet east of local road connecting Carmel and Johnsville, 4 miles south of junction of above road and Arkansas State Highway No. 15 at Carmel, 200 to 250 feet east of house on farm of Mr. Van Mann, approximately in NE¼, Section 17, T. 14 S., R. 9 W., Bradley County, Arkansas. *White Bluff formation (Caney Point marl and Rison clay members).* 42 feet of blocky clay and glauconitic calcareous fossiliferous sand and clay. Base of section is near lower formational boundary.

Drew County

40. Roadcut and drainage ditch along Arkansas State Highway No. 35, 7.8 miles northwest of city limits of Monticello, approximately NW¼, SE¼, Section 35, T. 11 S., R. 8 W., Drew County, Arkansas. *White Bluff formation (Rison clay member).* 8 feet of silt and clay beds containing scattered molds of Mollusca.

41. Roadcut along Arkansas State Highway No. 35, 0.3 miles northwest of Monticello city limits, approximately in SW¼, Section 23, T. 12 S., R. 7 W., Drew County, Arkansas. *White Bluff formation (Rison clay member).* 9 feet of blocky clay; sand and silt partings.

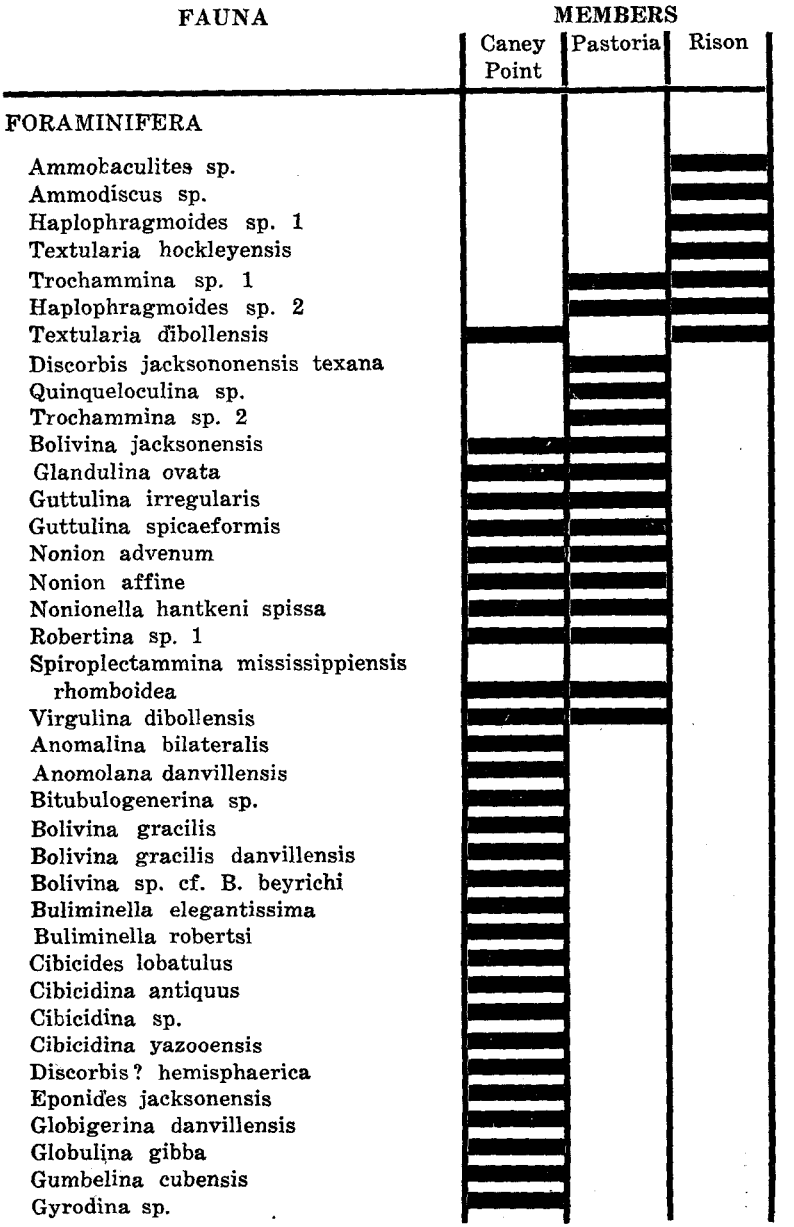
42. Drainage ditch along local road from Monticello to Green Hill, 3 miles southwest of Monticello city limits, approximately in center of NW¼, Section 8, T. 13 S., R. 7 W., Drew County, Arkansas. *White Bluff formation (Rison clay member).* 8 feet of silts and clays containing scattered molds of Mollusca.

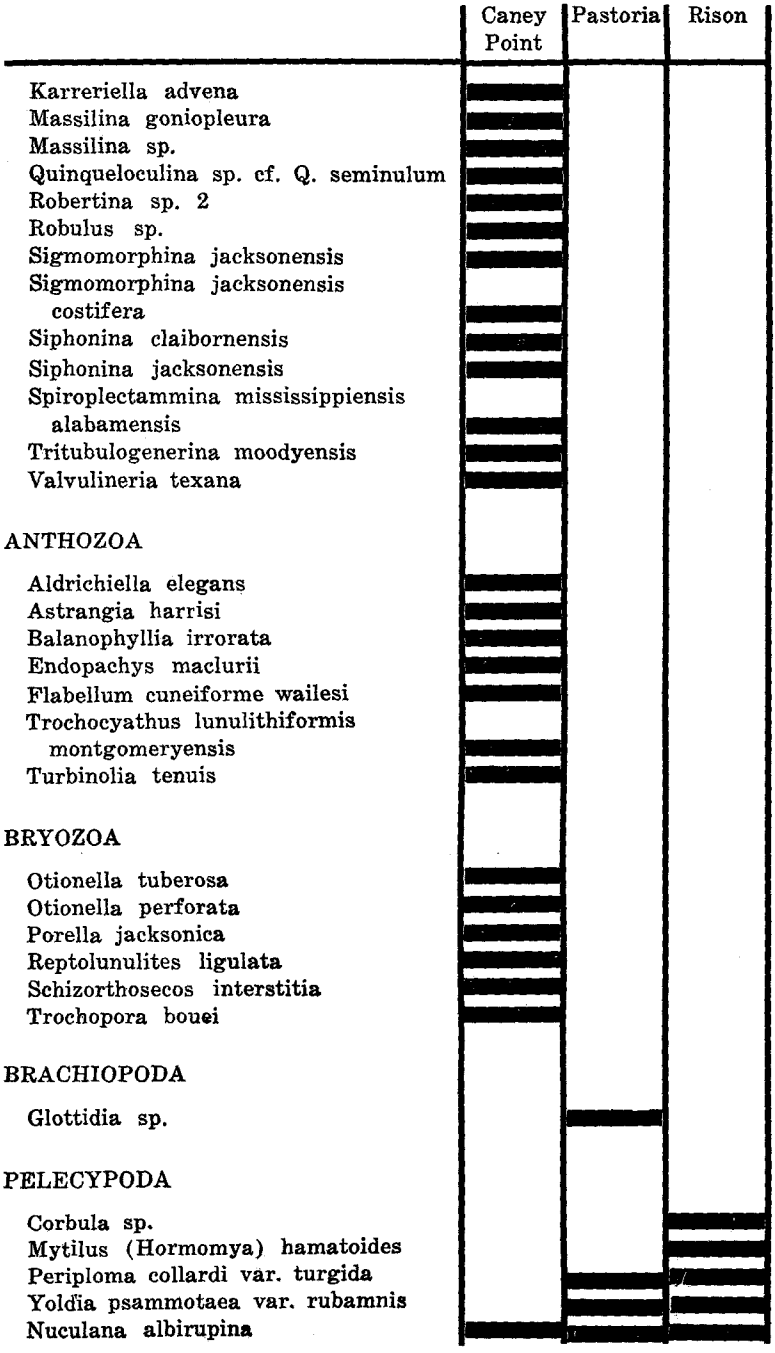
Ashley County

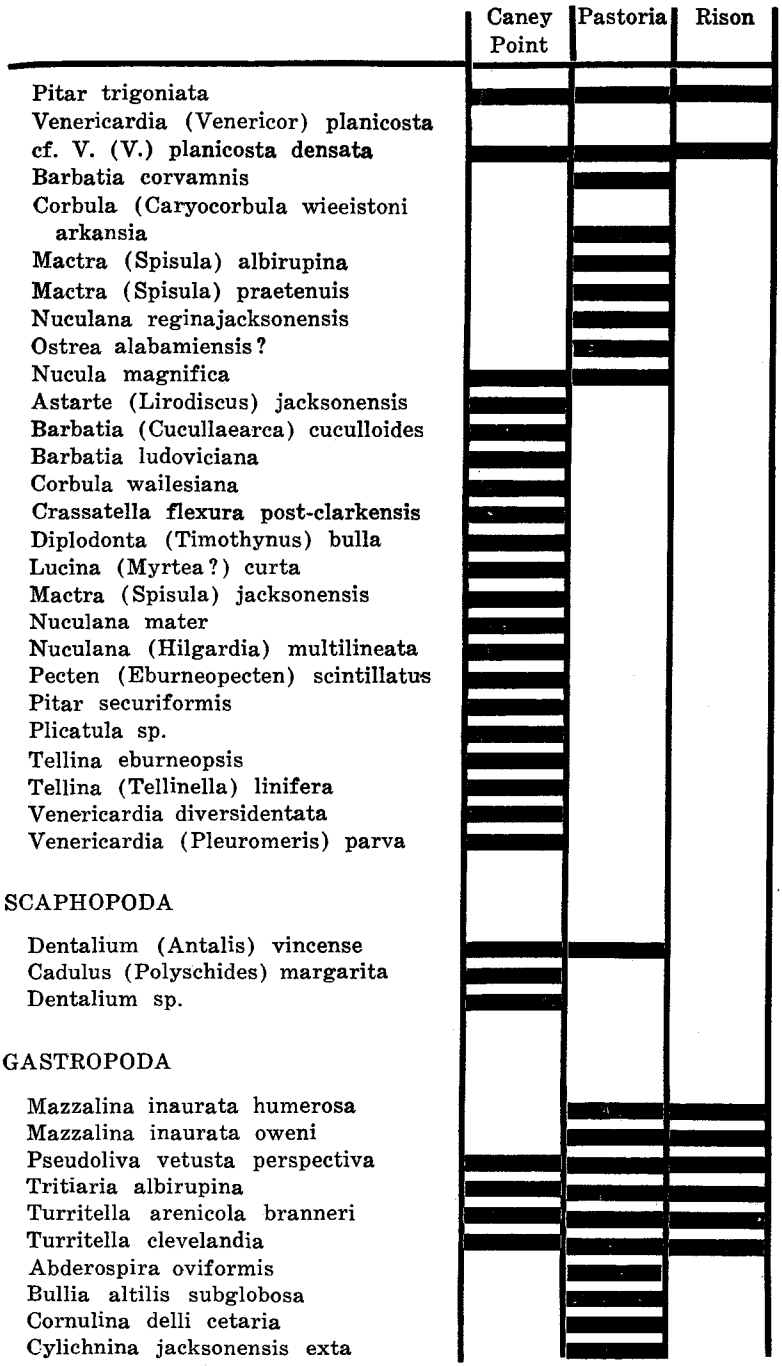
43. *Hester's Well.* Hand dug water well 50 feet deep on property of Mr. Hester, within corporate limits of village of Fountain Hill, approximately SW¼, Section 32, T. 15 S., R. 7 W., Ashley County, Arkansas. *White Bluff formation* (*Caney Point marl member*). Approximately 15 feet of glauconitic fossiliferous clay. In lower 20 to 40 feet of well Claiborne beds were encountered.

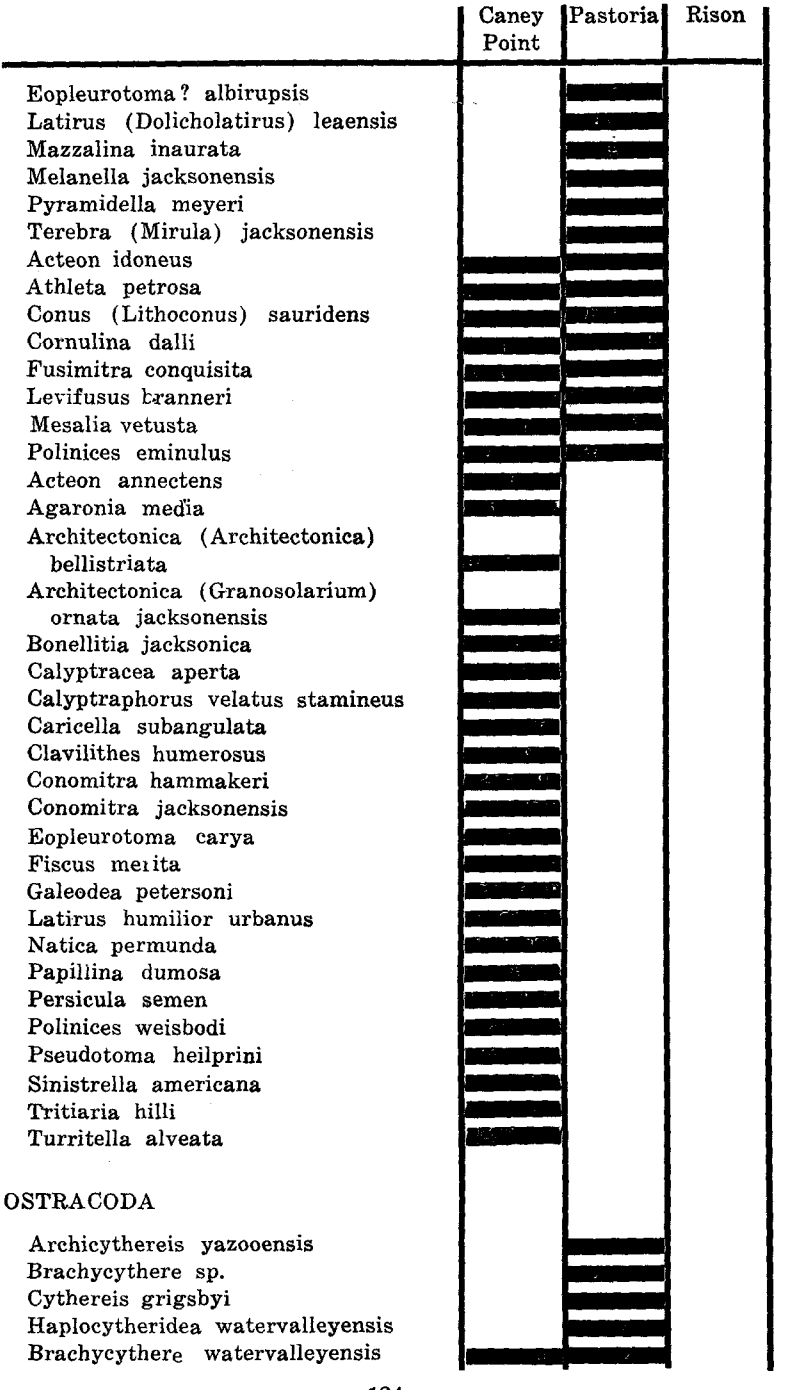
# APPENDIX B

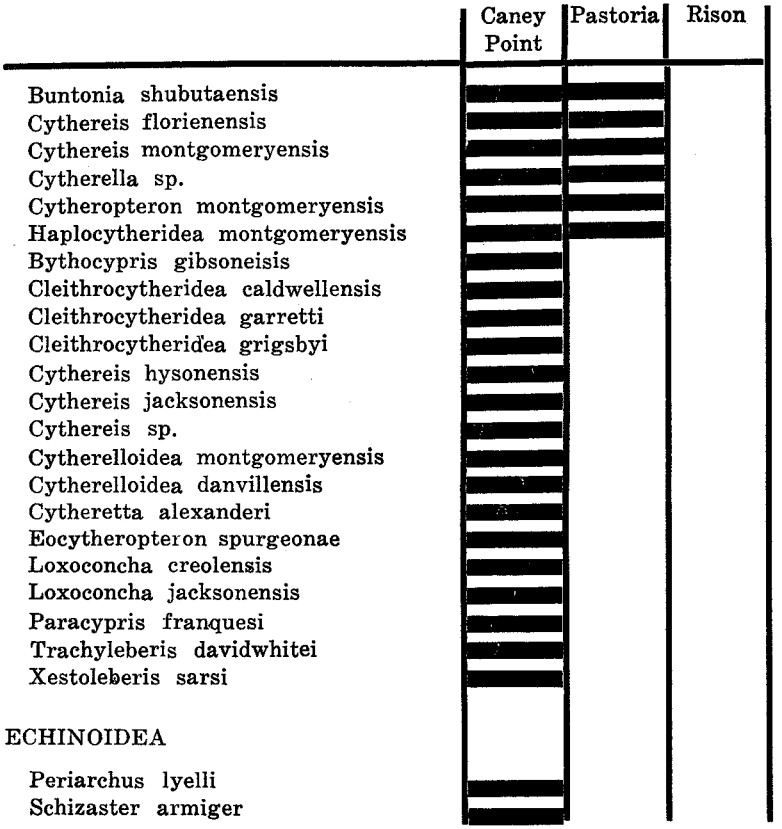
## INVERTEBRATES OF THE WHITE BLUFF FORMATION SHOWING STRATIGRAPHIC DISTRIBUTION




Caney Point
Pastoria
Rison
Karreriella advena
Massilina goniopleura
Massilina sp.
Quinqueloculina sp. cf. Q. seminulum
Robertina sp. 2
Robulus sp.
Sigmomorphina jacksonensis
Sigmomorphina jacksonensis costifera
Siphonina claibornensis
Siphonina jacksonensis
Spiroplectammina mississippiensis alabamensis
Tritubulogenerina moodyensis
Valvulineria texana
ANTHOZOA
Aldrichiella elegans
Astrangia harrisi
Balanophyllia irrorata
Endopachys maclurii
Flabellum cuneiforme wailesi
Trochocyathus lunulithiformis montgomeryensis
Turbinolia tenuis
BRYOZOA
Otionella tuberosa
Otionella perforata
Porella jacksonica
Reptolunulites ligulata
Schizorthosecos interstitia
Trochopora bouei
BRACHIOPODA
Glottidia sp.
PELECYPODA
Corbula sp.
Mytilus (Hormomya) hamatoides
Periploma collardi var. turgida
Yoldia psammotaea var. rubamnis
Nuculana albirupina


Caney Point
Pastoria
Rison
Pitar trigoniata
Venericardia (Venericor) planicosta
cf. V. (V.) planicosta densata
Barbatia corvamnis
Corbula (Caryocorbula wieeistoni arkansia
Mactra (Spisula) albirupina
Mactra (Spisula) praetenuis
Nuculana reginajacksonensis
Ostrea alabamiensis?
Nucula magnifica
Astarte (Lirodiscus) jacksonensis
Barbatia (Cucullaearca) cuculloides
Barbatia ludoviciana
Corbula wailesiana
Crassatella flexura post-clarkensis
Diplodonta (Timothynus) bulla
Lucina (Myrtea?) curta
Mactra (Spisula) jacksonensis
Nuculana mater
Nuculana (Hilgardia) multilineata
Pecten (Eburneopecten) scintillatus
Pitar securiformis
Plicatula sp.
Tellina eburneopsis
Tellina (Tellinella) linifera
Venericardia diversidentata
Venericardia (Pleuromeris) parva
SCAPHOPODA
Dentalium (Antalis) vincense
Cadulus (Polyschides) margarita
Dentalium sp.
GASTROPODA
Mazzalina inaurata humerosa
Mazzalina inaurata oweni
Pseudoliva vetusta perspectiva
Tritiaria albirupina
Turritella arenicola branneri
Turritella clevelandia
Abderospira oviformis
Bullia altilis subglobosa
Cornulina delli cetaria
Cylichnina jacksonensis exta


Caney Point
Pastoria
Rison
Eopleurotoma? albirupsis
Latirus (Dolicholatirus) leaensis
Mazzalina inaurata
Melanella jacksonensis
Pyramidella meyeri
Terebra (Mirula) jacksonensis
Acteon idoneus
Athleta petrosa
Conus (Lithoconus) sauridens
Cornulina dalli
Fusimitra conquisita
Levifusus branneri
Mesalia vetusta
Polinices eminulus
Acteon annectens
Agaronia media
Architectonica (Architectonica) bellistriata
Architectonica (Granosolarium) ornata jacksonensis
Bonellitia jacksonica
Calyptracea aperta
Calyptraphorus velatus stamineus
Caricella subangulata
Clavilithes humerosus
Conomitra hammakeri
Conomitra jacksonensis
Eopleurotoma carya
Fiscus merita
Galeodea petersoni
Latirus humilior urbanus
Natica permunda
Papillina dumosa
Persicula semen
Polinices weisbodi
Pseudotoma heilprini
Sinistrella americana
Tritiaria hilli
Turritella alveata
OSTRACODA
Archicythereis yazooensis
Brachycythere sp.
Cythereis grigsbyi
Haplocytheridea watervalleyensis
Brachycythere watervalleyensis


Caney Point
Pastoria
Rison
Buntonia shubutaensis
Cythereis florienensis
Cythereis montgomeryensis
Cytherella sp.
Cytheropteron montgomeryensis
Haplocytheridea montgomeryensis
Bythocypris gibsoneisis
Cleithrocytheridea caldwellensis
Cleithrocytheridea garretti
Cleithrocytheridea grigsbyi
Cythereis hysonensis
Cythereis jacksonensis
Cythereis sp.
Cytherelloidea montgomeryensis
Cytherelloidea danvillensis
Cytheretta alexanderi
Eocytheropteron spurgeonae
Loxoconcha creolensis
Loxoconcha jacksonensis
Paracypris franquesi
Trachyleberis davidwhitei
Xestoleberis sarsi
ECHINOIDEA
Periarchus lyelli
Schizaster armiger