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Arthur M. Emmerling, Executive Director

DIVISION OF GEOLOGY

Norman F. Williams, Director

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SUBSURFACE GEOLOGY AND RELATED OIL AND GAS POSSIBILITIES OF NORTHEASTERN ARKANSAS

By

William M. Caplan

Little Rock, Arkansas

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SUBSURFACE GEOLOGY AND PETROLEUM POSSIBILITIES OF NORTHEASTERN ARKANSAS

by

William M. Caplan

ABSTRACT

The twenty-seven counties studied have an aggregate area of 17,000 square miles, containing 418 exploratory wells for a drilling density of one well to 40 square miles. No oil or gas is produced in these counties. The area lies in the upper Mississippi embayment of the Gulf Coastal Plain. Presumably the embayment is of post-Comanchean age, formed by differential movements along pre-existing lines of weakness inherent in early Paleozoic or basement rocks.

No Comanchean sediments are believed present in the embayment north of Township 9 or 10 South. Upper Cretaceous (Gulf) sediments of Austin, Taylor and Navarro ages exhibit a normal marine cycle in the embayment, being represented by a basal marginal sand, a series of onlapping beds, and regressive deposits resulting from an apparently complete withdrawal of the sea. These sediments aggregate 1100 feet in thickness in the Desha basin which centers in Desha and Lincoln Counties. Progressive loss of formations updip results from onlap rather than from thinning of individual beds. In a narrow zone parallel and adjacent to the Fall Line, pre-Midway erosion has removed all Cretaceous deposits. Downdip, near the embayment trough, Ripley, Selma and Eutaw facies of western Tennessee and northwestern Mississippi dominate the Cretaceous section. The basal marginal unit, varying in age from Austin, near the embayment trough to Navarro, updip, is the most prospective post-Paleozoic reservoir in northeastern Arkansas.

The next most likely post-Paleozoic reservoir is the Nacatoch sand. Reef-type limestones are present in the Nacatoch in Crittenden and Poinsett Counties. In Desha County, the "Monroe gas rock" facies occurs sporadically in the Nacatoch section. Faulting may have affected the Nacatoch in Woodruff County. Tertiary and younger sediments overlie the Cretaceous in the embayment but are not prospective reservoirs.

The embayment lies within the structural and stratigraphic influences of the Ozark uplift, the Arkansas basin and the Ouachita Mountains. Correlations of pre-Atoka rocks with equivalent rocks of adjacent states indicate that treatment of the embayment on a regional rather than a local basis is valid. Ozark facies rocks in the embayment rise structurally to the north and are truncated in that direction so that northward progressively older Paleozoic rocks immediately underlie Cretaceous rocks present. Maximum development of the Ozark uplift in the embayment is indicated by a truncated belt of Siluro-Devonian rocks, thought to be overlapped downdip by the Chattanooga shale. The base of the Chattanooga marks a major unconformity of regional dimensions.

Porous, truncated Ordovician and Siluro-Devonian rocks wedged out beneath the Chattanooga would make excellent reservoirs. The St. Peter sandstone is considered prospective in the embayment. Cambro-Ordovician rocks present, inclusive of Powell, are presumed equivalents of the Knox dolomite, recently reported as productive of oil in north-

eastern Mississippi. Sands in the Atoka formation, as projected from the Arkansas Valley into the embayment, may be prospective for gas. The Atoka produces dry gas from high carbon ratio areas in western Arkansas. Ouachita facies rocks in the embayment are not now considered potential reservoirs.

INTRODUCTION

This report presents a current interpretation of data derived from a continuing study of the Paleozoic and Cretaceous formations occurring in the subsurface of northeastern Arkansas. The study, which is being sponsored by the Arkansas Resources and Development Commission, Geology Division, has as its ultimate goal the location of stratigraphic or structural features in the subsurface of northeastern Arkansas that may be conducive to the accumulation of oil or gas in commercial quantities.

The area included in this report (Fig. 1) lies in the Gulf Coastal Plain province of Arkansas and consequently in the western portion of the upper Mississippi embayment.

Data from twenty-seven counties were used in the course of this study. These counties aggregate some 17,000 square miles within which 418 exploratory wells and stratigraphic tests have been drilled to the present time. The resulting drilling density of one well to approximately 40 square miles fails to present the exploration pattern in northeastern Arkansas in its proper perspective. The well location map (Plate I) indicates diagrammatically both the relative scarcity of total drilling in the area and the preponderance of drilling in certain counties within the area.

Neither oil nor commercial gas production has resulted to date from exploratory drilling in northeastern Arkansas, although a number of shows of each have been reported. Such oil and gas shows have been attributed to formations ranging in age between Pennsylvanian (Atoka) and Eocene (Wilcox). With few exceptions these reported shows have not been specifically treated herein, as the writer has not been able to substantiate them.

Of the 418 wells in these counties, approximately one-third have been deep enough to encounter a formation of Paleozoic age. The majority of wells drilled to the Paleozoic have been abandoned at, or slightly below, the point at which Paleozoic rocks were first encountered. Only eight wells have penetrated more than one Paleozoic formation.[1]

[1] Benedum-Trees Oil Company No. 1 Mack, sec. 3, T. 15N, R. 12E, Mississippi County; T.D. 4535 ft.

Tennark, Inc. No. 1 Martin, sec. 35, T. 14N, R. 3E, Craighead County; T.D. 5092 ft.

Arkansas Oil Ventures, Inc. (Deardorf) No. 1 Doggett, sec. 31, T. 10N, R. 3W, Jackson County; T.D. 3029 ft. This well is presently being deepened.

R. L. Jones (Tubular Service) No. 1 Norris, sec. 17, T. 12N, R. 4W, Independence County; T.D. 670 ft.

M. E. Davis No. 1 DeMange, sec. 28, T. 8N, R. 7E, Crittenden County; T.D. 5020 ft.

Manning and Martin No. 1 Park-Gieseck, sec. 4, T. 6N, R. 5E, Cross County; T.D. 4451 ft. Plattin lime one was encountered at 3275 ft., followed by 1176 ft. of dolomitic limestone that may include Plattin, Rock Levee, Joachim and Dutchtown.

C. R. Craft Associates Co. No. 1 J. A. Hinkle, sec. 23, T. 11N, R. 4W, Independence County. This proposed 5000 ft. test is now drilling.

Magnolia Petroleum Co. No. 1 Roy Sturgis, sec. 30, T. 9N, R. 3W, Woodruff County. Now drilling.

The number of wells usable for control purposes in this area has been considerably limited by the failure of early operators to preserve well samples or data; however, more care has been exercised in this respect during the last few years. In drilling an area such as this, where every well has a wildcat status, adequate steps should be taken to insure the recovery of as much subsurface data as is practical from a well. This is especially important to operators who are planning a multiple well drilling program within a relatively limited area.

The Cretaceous sediments present, being predominantly chalks and marls, are prone to washing out during drilling. As a result, well cuttings from the Cretaceous section may be interpreted as coming from a rubble zone, thereby suggesting unconformities which are not present. Electrical logs are of particular value in helping to delimit the Cretaceous and younger formations. Core drilling may be used to considerable advantage through the younger sedimentary sections to aid in the establishment of key beds whose presence might otherwise be obscured in well cuttings by caved material. Magnetometer surveys can be of value in this region for generally localizing prospective drilling areas or for determining the locations of traverses for more detailed surveys by seismograph profiling. Insofar as seismic prospecting is concerned, the upper Mississippi embayment has been classed by the Society of Exploration Geophysicists as an area where reflections of good quality may be obtained by methods in general use (Murphee, 1952, p.119).

Magnetometer, seismograph and gravimeter surveys have been and are currently being run in northeastern Arkansas by various companies. Although their specific results have not been made available, the continuance of such surveys appears to denote usable results.

As can be seen on the Paleozoic Contour Map, Plate II (in pocket), a slim-hole drilling program could be used over a fairly extensive region. Wells of this type are not only cheaper to drill but could be converted to production.

Certain unsubstantiated and, at least in part, erroneous ideas have hindered petroleum exploration in this area to a large extent. Outstanding among these are: (1) the tendency to accept carbon ratio values based upon regional patterns as absolute measures of productive ability within limited areas, (2) the presumption that no source beds are present within the Cretaceous section, (3) the assumption that the presence of fresh water, found sporadically in the Cretaceous Nacatoch formation, condemns that formation as a potential reservoir, and (4) the prevalent idea that the attainment of a Paleozoic formation in a northeastern Arkansas well is equivalent to encountering basement rock and is a signal for abandonment. With regard to the

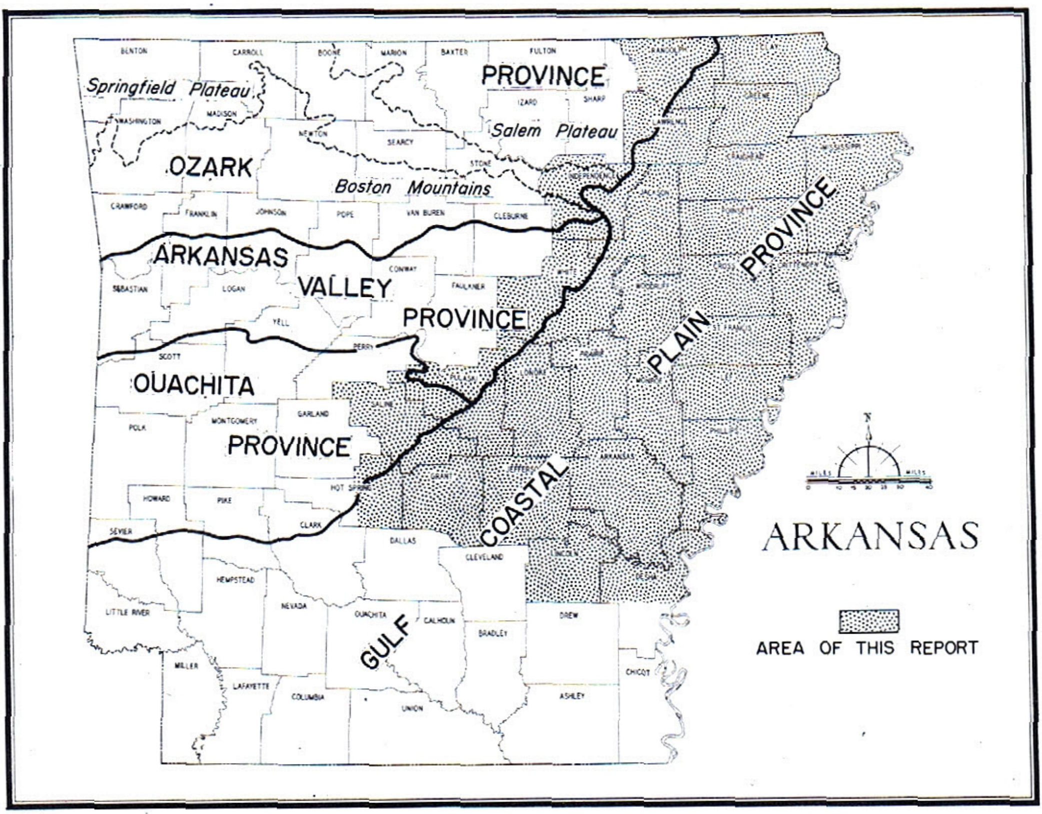

Figure 1. Index map showing area of report and physiographic provinces of Arkansas.

latter point it is true that Paleozoic black shale sections undoubtedly achieve large aggregate thicknesses under portions of northeastern Arkansas. The assumption that they will persist beyond reach of the drill wherever encountered is not justifiable, even on the basis of the limited definitive data now available. The negative attitude toward such areas fails to realize the possibilities for production from sands or other potential reservoir beds contained within these shale sections.

Because of the limited nature of existing subsurface well control in northeastern Arkansas, it has been necessary in this report to treat the area as part of a regional pattern rather than to attempt comprehensive localization of subsurface features. This treatment is considered valid in view of similarities in structural and stratigraphic relationships occurring between Arkansas and adjacent states. The Cretaceous and Tertiary formations can be traced across the embayment into adjoining states with considerably more assurance than can be accorded the Paleozoic sediments. Paleozoic formations encountered in wells drilled in northeastern Arkansas indicate that the pattern of outcrops from the vicinity of Batesville, in Independence County, eastward to the Fall Line, may be the key to a considerable number of problems complicating the Paleozoic section in the embayment. Since it is anticipated that some readers of this report may not be familiar with the expression "Fall Line" as just used, and as will be used throughout the following text, it seems appropriate to define it at this point. As can be seen on the Arkansas State Geological Map, a well defined line of demarcation trends generally northeast-southwest across the state from Sevier County to Clay County, dividing the state approximately in halves. This "Fall Line" serves to separate the region of Paleozoic outcrops of various ages, on the west, from the unconsolidated, younger sediments of the Gulf Coastal Plain, on the east.

In the preparation of the text and associated data, well samples were examined in conjunction with electrical logs whenever possible. Drillers' logs have been used to some extent but only where they could be interpreted with reasonable assurance by comparison with more valid data from near-by wells.

Most of the well samples, electrical logs, drillers' logs, core logs and the variety of additional data used in the preparation of this report were drawn from the files of the Division of Geology.

The interpretations presented herein are tentative and subject to revision as additional information becomes available. Correlations of the Cretaceous and younger sediments shown on cross section A-A' (Plate V) are based essentially on the Phillips Petroleum Company No. 1 Perthshire well, Bolivar County, Mississippi, which is well Number 7 on the section. The geologic tops shown in the Perthshire well are somewhat modified after those of the Shreveport Geological Society (1945, Pl. 2) which were generally used as a guide in this well. Correlations of the Cretaceous and younger sediments shown on cross sections B-B' (Plate VI), C-C' (Plate VII) and D-D' (Plate VIII) are those of the writer. Lithology in the Clay County Oil Company No. 1 Norred (well No. 1, Pl. VIII) is modified slightly after that shown on Missouri Geological Survey Log No. 8698, by Grohskopf and Ostrander.

ACKNOWLEDGMENTS

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The writer is indebted to C. A. Renfroe, formerly of the Division of Geology, whose published and unpublished data on northeastern Arkansas have been invaluable guides, and to Earl McCracken of the Missouri Geological Survey, whose unpublished report on the Paleozoic rocks of the area has been used as a general reference.

Acknowledgment is also made to the numerous oil companies and variously affiliated individuals who provided information or otherwise aided in the preparation of this report.

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REGIONAL STRUCTURAL RELATIONSHIPS

A. Mississippi embayment: The Mississippi embayment is a structural depression whose narrow, northern tip extends to Cairo, Illinois, and whose southern expression opens into the Gulf Coastal Plain, dipping toward the Gulf of Mexico. The upper Mississippi embayment, within which northeastern Arkansas lies, is bounded approximately on the south by the 34th parallel and on the north by the mouth of the Ohio River (Schneider, 1947, p.626). The periphery of the upper Mississippi embayment can be traced on the surface through eastern Arkansas, southeastern Missouri, southern Illinois, western Kentucky, western Tennessee, northeastern Mississippi and northern Alabama by following the respective Fall Lines in those states. Dips of the poorly consolidated Cretaceous and younger formations forming the surface of the embayment are essentially toward the southeast from Arkansas to Illinois, toward the south from Illinois, and toward the southwest from Kentucky to Alabama. Dips along the extent of the Fall

Line through these states range upward to one hundred feet or more per mile into the embayment, but lower dips, in the range of thirty feet or less per mile, predominate. The upper Mississippi embayment is bordered on the west by the Ozark and Ouachita structural provinces, on the north by the Eastern Interior basin, and on the east by the Appalachian Mountain region.

The formation of the Mississippi embayment is believed to have been initiated during the Cretaceous period at some time prior to the deposition of earliest Upper Cretaceous sediments. Probably the first stage of development was the southward downwarping of the entire area now comprising the embayment. This was followed by westward downwarping east of the present course of the Mississippi River. The latter movement may be attributable to structural adjustments resulting from the Appalachian orogeny. Subsequent eastward downwarping in northeastern Arkansas resulted in the formation of the Arkansas Coastal Plain and led ultimately to the present configuration of the upper Mississippi embayment. The structural axis or trough of the embayment, which now approximates the course of the Mississippi River, is indicated as having been some distance to the east initially, reaching its present position through progressive westward movement of depositional centers. This indication is based primarily on the occurrences and relative thicknesses of Cretaceous sediments older than Austin age in Mississippi, Tennessee, Kentucky and Alabama while sediments comparable in age are apparently missing in northeastern Arkansas. East of the Mississippi River the basal Upper Cretaceous Tuscaloosa formation has been found as far north as Kentucky, while to date no sediments of Tuscaloosa age have been positively identified in the subsurface of northeastern Arkansas. Tuscaloosa age sediments may eventually be encountered under the Coastal Plain in the area here concerned, but they will probably be confined to the deeper portions of the Desha basin in Desha County. The absence of Tuscaloosa sediments in wells drilled in western Tennessee suggests limitation of the encroaching Upper Cretaceous sea further to the east. Therefore, deposits of Tuscaloosa age sediments would not be expected in portions of northeastern Arkansas adjacent to western Tennessee.

The prevalence of basal Upper Cretaceous sedimentation in the eastern portion of the upper Mississippi embayment, as opposed to the apparent lack of it in the western portion of the embayment, is taken here as an inference that the eastward component of dip had not been initiated in the embayment area as late as Upper Tuscaloosa time. Not until Tokio-Eutaw (Austin) time did Upper Cretaceous deposits appear to transgress northeastern Arkansas to any extent.

The previously noted migration of depositional centers toward the west may have initiated eastward downwarping that resulted in the development of the upper Mississippi embayment in northeastern Arkansas. It is the belief of some geologists that the eastward component of dip of the Arkansas Coastal Plain is due to small but persistent downwarpings along a northeast trending zone of weakness previously established in the basement rocks during early Paleozoic time. Although downwarping of the embayment area continued into the Tertiary period, the westward shifting of depositional centers apparently ceased at some time prior to deposition of the older sediments of the Midway group. Both the Midway and Wilcox groups achieve their maximum thicknesses in the embayment area essentially along the present axis of the trough. Born (1935) indicated the rapid thickening of these groups toward the center of the embayment and also noted that the Ripley sand in western Tennessee thickens to the west, probably indicating that the axis of the embayment had generally reached its present position during Ripley time. In general, the trough of the Mississippi embayment trends toward the northeast. From present indications the axis of the embayment is not directly under the course of the Mississippi River but is a few miles removed to the west, at least in the vicinity of Memphis, Tennessee.

There is some possibility that Lower Cretaceous and Jurassic rocks related to those deposited in southwestern Arkansas and northern Louisiana may have been deposited in northeastern Arkansas. If this occurred, they must have been removed completely, or nearly so, during the post-Lower Cretaceous (Comanchean), pre-Upper Cretaceous (Gulf) erosion interval following the orogeny at the end of Comanchean time. Evidences of nearshore facies in much of the pre-Austin Mesozoic section of southwestern Arkansas and northern Louisiana seem to preclude the deposition of sediments of Jurassic and Lower Cretaceous ages in northeastern Arkansas. According to Spooner (1935, p.xxix), the strand lines of the Comanchean sea were generally determined by the trend of the Ouachita Mountains. Therefore, sediments of Comanchean age would not generally be expected under the Upper Cretaceous and younger rocks of the Coastal Plain north of Township 9 or 10 South.

The Upper Cretaceous was essentially a period of crustal stability during which marine deposition was predominant. However, continued downwarping of the Arkansas Coastal Plain was taking place slowly along both its eastern and southern components of dip, as evidenced by the progressive marine onlapping of successively younger Upper Cretaceous formations both toward the west and toward the north within the embayment. The thinning of the Upper Cretaceous column northward and westward, toward the head of the embayment and the Fall Line, respectively, is related more to the transgressive overlapping of younger formations than to the thinning of individual beds within the Upper Cretaceous section (Plates V, VI, VII, VIII). Transgressive overlap was apparently the rule in the Mississippi embayment during Upper Cretaceous time, although minor regressive phases may be more numerous than now recognized. Possibly the best example of a deposit attributable to regression in northeastern Arkansas during this period is found in the Nacatoch formation. In the northern portions of the embayment the upper member of the Nacatoch (Plates V and VIII) contains non-fossiliferous, lignitic, sandy clays which grade southward into marine strata.

Disconformities are present within the Upper Cretaceous section near the Fall Line, as evidenced by the appearance of progressively older Upper Cretaceous formations immediately beneath basal beds of the Midway group as the Fall Line is approached. These disconformities are the results of truncation of the Upper Cretaceous formations by erosion following emergence at the end of the Cretaceous period. The disconformities appear to be of local significance only, as they are not consistent for any appreciable distance along the strike of the formations nor do they persist downdip. Plate V will serve as an illustration of the latter condition. The removal of sediments during the post-Upper Cretaceous, pre-Lower Midway erosion interval does not appear to have been as extensive in northeastern Arkansas as would be expected in view of the relative length of the erosional period. The extent of this interval has been estimated on the basis of pronounced evolutionary changes in fauna between Arkadelphia time and Lower Midway time.

Facies changes within the Upper Cretaceous section are to be expected in proceeding from the shallower to the deeper portions of the embayment. These lithologic changes are the resultants of changes in depositional environments and the gradation of sediments of varied geographical and geological origins.

Little is known of the structural attitudes of the downwarped, and possibly faulted, Paleozoic rocks lying immediately beneath the Cretaceous or Tertiary sediments in the embayment, making up its floor. Possibly the word "floor", as used here, should be clarified before proceeding, since it appears frequently in the following portions of the report. The undifferentiated Paleozoic rocks at the base of the unconsolidated, younger Coastal Plain sediments represent the top of the Paleozoic section in the embayment and the floor on which the oldest Cretaceous or Tertiary sediments rest. It should not be inferred that the term applies to a basement complex underlying the Coastal Plain sediments in northeastern Arkansas.

The apparent structural configuration of the embayment floor is shown on Plate II, which is a contour map based on the elevations of undifferentiated Paleozoic rocks encountered in wells drilled in the embayment. Three anomalous conditions are in evidence on this map: (1) a southeast trending nose across Woodruff County, (2) a southeast plunging nose across Arkansas County, (3) a downwarping, known as the Desha basin, whose deepest portions lie essentially in Desha and eastern Lincoln Counties. All of these configurations are seen to persist on Plate III, which is an isopachous map of the Upper Cretaceous sediments found in northeastern Arkansas. Each of these anomalies will be treated in a later section of this report.

Included herein as Plate IV is a paleogeologic map of northeastern Arkansas drawn on the Paleozoic floor of the embayment, showing the outcrop pattern in this area prior to the deposition of Cretaceous and younger sediments. Primarily this map substantiates the previous knowledge that rocks of the Ozark and Quachita facies, or of related facies, extend into the embayment. Further, it reflects the swing in strike of these formations from essentially east-west in the Paleozoic outcrop area west of the Fall Line to northwest-southeast beneath the younger sediments of the Arkansas Coastal Plain. In general configuration this map agrees with the pre-Cretaceous areal map accompanying Mellen's report (1947, p.1802) on the Black Warrior basin. Plate IV has been constructed essentially to show actual formations penetrated. It should not be inferred, however, that the formations appearing on this paleogeologic map have been established between firm areal boundaries and that they thereby preclude the possibility of other formations appearing on this surface when more data are available.

Crowley's Ridge: On occasion questions have arisen concerning the possible subsurface structural significance of a topographic feature in northeastern Arkansas known as Crowley's Ridge. This ridge is strikingly apparent above the surrounding lowlands. At its southern extremity, in Phillips County, it stands approximately 400 feet above sea level. At its northern Arkansas extremity, in Clay County, the ridge has risen to 500 feet above sea level. Contrary to popular belief Crowley's Ridge is not confined to Arkansas but trends arcuately some 200 miles from Thebes, Illinois, to Phillips County, Arkansas, terminating its southern end near Helena, Arkansas. In Arkansas the ridge traverses the Coastal Plain in a general north-south arc passing through portions of Clay, Greene, Craighead, Poinsett, Cross, St. Francis, Lee and Phillips Counties. The width of the ridge varies between one and twelve miles. It is not continuous along its entire length, but is broken by a number of wind and water gaps. The formation of the ridge has been the subject of considerable investigation in the past. Branner (1889), among others, concluded that the Mississippi River at one time followed a course west of the ridge while the Ohio River flowed southward, east of the ridge, in the area now called the Mississippi lowlands.

Presumably the Mississippi and the Ohio Rivers joined somewhere south of Helena, Arkansas. During Late Pleistocene time the Mississippi River is considered to have breached the ridge along its northerly portions. As a result the Mississippi River joined the Ohio River, leaving Crowley's Ridge as an erosion remnant separating the valleys cut out along the previous courses of the two rivers.

Cross section D-D' (Plate VIII), which trends generally north-south across the Coastal Plain, follows the easterly portion of Crowley's Ridge from the Clay County Oil Company No. 1 Norred (well No. 1 on the section) to the Scott No. 2-A Nelson (well No. 3). From the Nelson well to the Forest Oil Company No. 1 Shirley (well No. 4) the section essentially follows the westerly portion of the ridge. South of the Shirley well the section deviates to a course generally west of the ridge. From the limited data available it appears that the Arkansas portion of Crowley's Ridge is a topographic feature unattended by major structural anomalies in the subsurface. Further investigation would be required, however, especially along the segment of the ridge lying in Clay County, before the ridge could be considered absolutely without structural significance in Arkansas.

In a report on Crowley's Ridge in southeastern Missouri, Matthes (1933) describes a bed of ferruginous, clayey sand, four feet thick, containing many imprints of Ripley mollusks, occurring in the southeast facing bluff of the ridge near Ardeola, Stoddard County, Missouri. On the basis of paleontological evidence this bed was assigned to the top of the Ripley formation (Owl Creek tongue). Immediately overlying it is a bed of greenish, glauconitic clay, four or five feet thick, containing molds of marine shells, including both Eocene and Cretaceous forms. The latter bed was assigned to the Clayton formation (lower part of Midway group). According to Matthes, Crowley's Ridge, near Ardeola, contains an appreciable representation of Upper Cretaceous sediments that reach almost to the summit of the ridge, which in this area is roughly 500 feet above sea level. Slightly more than one-half mile northwest of the Cretaceous outcrop in the bluff, the Ripley was found some fifty feet higher than its outcrop in the bluff. Therefore, it was assumed to have a southeastward dip of 75 to 80 feet per mile. The Cretaceous-Eocene contact was found to parallel the dip. Matthes states further that the bluff of Crowley's Ridge at Bell City, two miles northeast of Ardeola, is made up chiefly of indurated sand of possible Wilcox age, and three miles farther south, near Zeta, the bluff is made up of Porters Creek clay. Matthes goes on to conclude that a deformation of some magnitude might be indicated, especially in view of the fact that Crowley's Ridge is generally considered to consist principally of Wilcox, Claiborne and Jackson age sediments. Matthes was not able to determine whether the postulated deformation resulted from folding or faulting.

B. Ouachita Mountain region: The Ouachita Mountains, trending westward for some 225 miles from the vicinity of Little Rock, Arkansas, to Atoka, Oklahoma, represent exposed elements of an extensive, buried mountain belt. The subsurface continuation of the belt is believed to trend generally southeastward from Little Rock, under the Coastal Plain sediments, through southeastern Arkansas and northeastern Louisiana into Mississippi and Alabama. From the Oklahoma exposures the buried extension trends generally southwestward to the Central Mineral region of Texas then swings westward to the Marathon region of southwest Texas (Fig. 2). The exposed elements of the Ouachita Mountains have a maximum width of approximately 50 miles. Westward across Oklahoma the Ouachita Mountains are succeeded structurally along trend by the Arbuckle Mountains and the Wichita Mountains successively. The Ouachita Mountains were formed during the Pennsylvanian period, through the destruction of a Paleozoic geosyncline (Ouachita geosyncline) lying an unknown distance southward from the presently exposed frontal elements. Structurally the Ouachita Mountains and the Appalachian Mountains show similarities, although stratigraphically they do not appear to be related.

With the exception of a few alkaline igneous intrusions of Cretaceous age, the exposed rocks in the Ouachita Mountains are primarily shales and sandstones, with siliceous shale, chert, novaculite and conglomerate being represented. Isolated occurrences of dark colored limestones are known. The rocks making up these exposed frontal elements range in age from probable Cambrian to Pennsylvanian. The character and thickness of the younger rocks are suggestive of their original deposition in a geosynclinal environment. The total thickness of sediments is estimated to be in excess of 20,000 feet.

The ages of some formations have been determined on the basis of faunal evidence. An example is the graptolitic Upper Ordovician Polk Creek shale. The ages of certain of the formations, such as the Stanley shale and the Jackfork sandstone, are debatable because the meager fossil assemblages present are open to various interpretations. Both the Stanley and the Jackfork are made up chiefly of dark-colored, detrital material which appears to have been derived from a near by, progressively uplifted source and deposited in deltaic form. The lower part of the Stanley contains considerable bedded tuff, suggesting that volcanic activity accompanied the uplifting.

The Ouachita orogeny responsible for the creation of the mountain system in Arkansas presumably was initiated by intense lateral compression from the south. As a result, extensive overthrust faulting toward the north took place. According to Van der Gracht (1931), no crystalline core has been found in the Ouachita

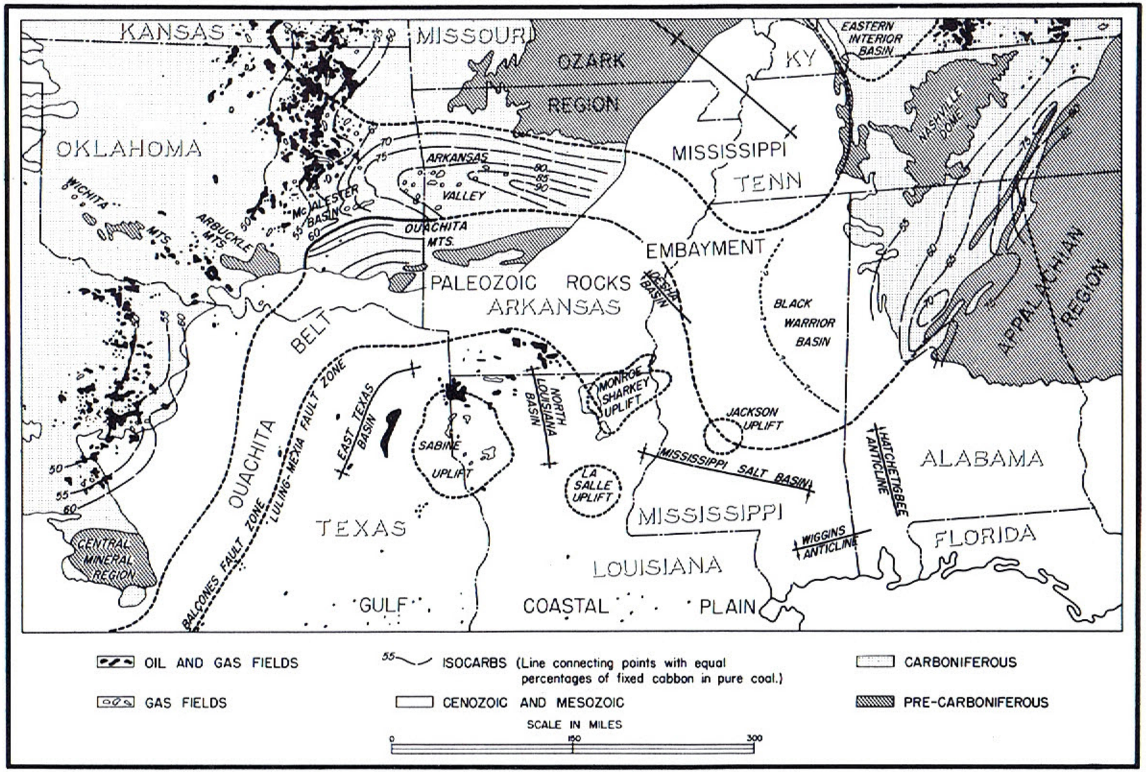

Figure 2. Geological map of southern Mid-Continent and adjacent areas showing relation of metamorphism of Pennsylvanian coals to Ouachita belt of Paleozoic rocks and to oil and gas fields. Regional structural relationships are also shown. Map modified after: Miser, H. D., A. A. P. G. Bull., Vol. 18, No. 8, p. 1076 (August, 1934) and others.

Mountain folds, suggesting the possibility that successive stages of thrusting may have overridden earlier stages so as to result in a vertical assemblage of considerable thickness. A short distance north of the Ouachita Mountain thrust front a generally east-west trending series of close, parallel folds were formed, many of which are overturned toward the north. A number of these folds contain high-angle reverse faults. Further northward from the outer limit of extensive thrusting the tight, asymmetrical folds give way to less closely folded structures. Faults associated with the latter folds are commonly normal, with the downthrown sides being predominantly to the north. The low order metamorphism associated with the orogeny apparently is also progressively reduced northward from the thrust front, although it may be incipient over a considerable area.

Structurally the Ouachita Mountains and the Arkansas Valley are related. Both are included under the expression "Ouachita structural province". In describing the Ouachita Mountains Croneis (1930, p.337) makes use of the term "Novaculite uplift" in reference to the central portion of the Ouachitas. This uplift can be noted on Plate IV as the portion of the Ouachita structural province that is essentially enclosed by arcuate east-west trending ridges of novaculite. The Ouachita Mountain region in Arkansas, when treated as a unit, is in effect an anticlinorium which contains numerous, smaller anticlines and synclines within its confines. The oldest and youngest rocks exposed in the Novaculite uplift are the Collier shale of presumed Cambrian age and the Stanley shale of Carboniferous age, respectively. The age of the novaculite, or at least of certain portions of it, is questionable. The lower part is considered to be Middle Devonian in age. The middle part may be either Upper Devonian or Lower Mississippian in age, or may contain beds of each age. The upper part is Lower Mississippian in age.

The occurrence of asphalt along the frontal margin of the Ouachita Mountains in western Arkansas probably cannot be attributed to seepage from presumed reservoir rocks within the Ouachita Mountain trend. The asphalt seems more likely to be related to that found along the Ouachita Mountain front in southeastern Oklahoma, about which the Tulsa Geological Society (1951, p.193) had the following to say:

> If Arbuckle-Ozark type beds are the most likely source of oil, the numerous seeps and asphalt deposits of the frontal zone of the Ouachita Mountains in Oklahoma suggest that here, at least, the Ouachita thrusts have overridden rocks of Arbuckle type and that the overridden rocks still contain some oil. This indicates that eventually oil in commercial quantities may be produced from traps beneath the frontal overthrusts in Oklahoma.

Miser (1934, p.1065) noted that the Little Rock structural salient at the east end of the Ouachita Mountains, including the arcuately arranged structural trends in the region between Little Rock and Hot Springs, and presumably the portion concealed by the Cretaceous and younger deposits of the Gulf Coastal Plain, resembles in form the Oklahoma structural salient. Rocks of the Ouachita facies may, or may not, have overridden rocks of the Ozark-Arbuckle facies along the extension of the mountain front under the Coastal Plain sediments in northeastern Arkansas. Since this point is not known in fact, it should be given no more validity than the opinion that Ouachita and Ozark facies rocks grade laterally into each other at some general location between the Ouachita Mountains and the Ozark uplift in the subsurface of northeastern Arkansas. Even the existence in the subsurface of an ancient, though now possible destroyed, barrier which served to separate the two facies abruptly in this area cannot be ruled out absolutely.

Continuation in the subsurface of northeastern Arkansas: Much of the controversy centering around the extension of the Ouachita Mountains under the younger sediments of the Coastal Plain lies in the failure of geologists to reconcile two alternate theories, (1) that the Ouachita Mountains and the Appalachian Mountains actually represent one structural system whose trend arcs acutely across southern Mississippi, or (2) that the two mountain belts are separate orogenic entities which intersect east of the Mississippi-Alabama line in the vicinity of the Hatchetigbee anticline (Fig. 2). Despite these differences of opinion, however, there is general agreement among geologists that the trend of the Ouachita Mountains in northeastern Arkansas is essentially northwest-southeast beneath the Coastal Plain sediments, in variance with the almost east-west strike of the belt west of the Fall Line.

Very little factual information is available to aid in determining accurately the northern limits of the Ouachita Mountain front in northeastern Arkansas, although certain inferences may be drawn from well data. On this basis the extensions of rocks of Ouachita facies and the Arkansas Valley region into the Arkansas portion of the Mississippi embayment have been tentatively separated by the boundary shown on Plate IV. The placement of this boundary near the Fall Line was based upon an alignment with the northern limit of intense folding in the Jackfork sandstone, Stanley shale and Atoka shale sections outcropping north of the Novaculite uplift in Pulaski County. Southwest of this boundary, in the embayment, the A. L. Kitselman No. 2 well (T.D. 4080 ft.), section 2, T. 1S, R. 13W, encountered Ouachita facies rocks.

The extension of this tentative boundary line eastward across the embayment is based only on speculative evidence obtained from three wells drilled in Arkansas County. The writer was unable to obtain well samples from the Paleozoic sections of two of these wells[1]; however, available data in the Arkansas Geology Division files concerning these wells are considered here as reliable enough to cite. The Miller well encountered Paleozoic rocks at 4540 feet. A core cut from 4550 to 4560 feet recovered ten feet of rock described as gray slate and schist, graphitic in spots. The writer has tentatively assigned the immediate area of this well to the Ouachita Mountain region because of the relative intensity of metamorphism in evidence.

The Fox well encountered the Paleozoic at 4337 feet. According to the record the formation penetrated was a chert. There is some possibility that the chert may actually have been either novaculite or a very fine grained, quartzitic sandstone. The data indicate a possible vertical sequence of Paleozoic rocks in the Fox well consisting of three feet of shale, ten feet of chert, four feet of shale, sixteen feet of chert and two feet of shale from 4337 feet to total well depth of 4372 feet. The Fox well is assumed here to have been abandoned in the Atoka section since the presence of chert or novaculite in place has not been determined with assurance.

The third well in Arkansas County used for determining tentatively the northern limits of Ouachita facies rocks in the embayment was the Youngblood and Crow No. 1 West (T.D. 4183 ft.), section 24, T. 4S, R. 2W. This well encountered dark-gray shale and dark-gray to black, quartzitic sandstone of possible Atoka age at 4160 feet. A circulation sample from 4183 feet yielded black, brittle shale, black, micaceous shale and what may be either black, very fine grained quartzitic sandstone or black novaculite. The writer is inclined toward the novaculite interpretation. The Paleozoic cuttings from the West well are somewhat iron-stained, suggesting that they may have come from an erosion surface. The novaculite fragments are angular, implying nearness to the source of supply, although sediments of this character could be transported a considerable distance without noticeable rounding.

The Paleozoic section in the West well has been included tentatively with the Arkansas Valley region rather than with rocks of the Ouachita facies by the writer. It is possible to infer a number of circumstances that could account for the presence of novaculite in both the Fox and the West wells. With a variety of conditions to choose from, the novaculite could be interpreted as being underlain either by rocks of Ozark of Ouachita facies.

[1]Fohs-Loffland No. 1 Miller, section 33, T. 5S, R. 4W, Arkansas County, T.D. 4560 ft.

Blackwell (C. W. Robinson) No. 1 Fox, section 23, T. 5S, R. 3W, Arkansas County, T.D. 4372 ft.

The writer has assumed from the information at hand that the Fox and the West wells lie outside the Ouachita Mountain structural front, but were close enough to it to receive eroded, Ouachita type sediments requiring little transportation.

C. Arkansas basin: The Arkansas basin is a downwarped trough of geosynclinal dimensions. The basin trends generally east-west for some 250 miles across Arkansas and into southeastern Oklahoma where it is related both structurally and stratigraphically to the McAlester basin and is known as the McAlester-Arkansas Valley geosyncline. Elsewhere the Arkansas basin is referred to commonly as the McAlester Coal basin, the Arkansas syncline, and the Arkansas Valley. The latter designation has a certain value in that it localizes the Arkansas basin geographically. The basin varies in width between 25 and 35 miles. On the north it is bounded by the gentle folds of the Ozark uplift and on the south by the thrust front of the Ouachita Mountains. Lithologically the rocks of the Arkansas basin belong with those of the Ozark uplift and the Arbuckle Mountains. Structurally it is related to the Ouachita Mountains. In effect the Arkansas basin is a synclinorium whose southern boundary parallels the northern boundary of the Ouachita anticlinorium.

Within the boundaries of the Arkansas basin numerous anticlines and synclines have surface expression. Several of these are indicated on Plate II. Northward from the Ouachita Mountain front the folding is progressively less intense. Near the southern boundary of the Arkansas basin, faulting is represented by northward overthrusts. Normal faults, downthrown to the north, become the predominant type of fault with removal toward the north from the Ouachita Mountain front. In the more northerly portions of the Arkansas basin faulting is also predominantly of the normal type, although the downthrown sides are principally to the south in those areas.

The surface formations of the Arkansas basin consist for the most part of shales and sandstones of Pennsylvanian (Atoka) age. In general, rocks of Pennsylvanian age increase in thickness from a feather edge in the Ozarks to an estimated 20,000 feet or more in the Ouachitas. In addition to the essentially noncalcareous Atoka formation, the Pennsylvanian system in the northern portions of the basin is represented by the Morrow group, consisting chiefly of black shales with subordinate beds of limestone.

In the western portion of the Arkansas Valley dry gas is produced from sands of Atoka age and locally from the Bloyd and Hale formations of the Morrow group. This production is associated with anticlinal or fault-trap structures. The gas is distinguished by an unusually high methane content (95-98%), low percentages of the higher hydrocarbons and nitrogen, and a relatively high percentage of oxygen. In addition, the gas is unusual in its occurrence since the production is obtained from an area in which the carbon ratios reach the upper eighties (Croneis, 1935).

As stated previously in this report, accurate boundaries between rocks of Ozark and Ouachita facies are unknown in the subsurface of the Arkansas basin, both west and east of the Fall Line. The occurrences, distribution and general relationships of rocks of the two regions at depth are undoubtedly more complex than is indicated on Plate IV. Since no evidence appears to be available to the contrary, it seems reasonable to assume that the Ouachita geosyncline intermittently received sediments in greater quantities than could be matched by a differential rate of subsidence. Consequently, during deposition of the pre-Atoka Carboniferous section, tongues of Ouachita type sediments may have encroached upon areas considerably to the north. The Lion Oil Company No. 1 Nalley well, section 33, T. 8N, R. 7W, White County, may have penetrated a section of rocks attributable to such an occurrence. In a study of the pre-Atoka rocks in the Arkansas Valley, both surface and subsurface, Maher and Lantz (1953) concluded that the Nalley well contains beds representing both the Jackfork sandstone and the Stanley shale of the Ouachita Mountain region. The tentative correlations of these formations were based upon lithology, interval and stratigraphic succession. One of the common disagreements with placement of the Jackfork sandstone in this well is the fact that the 960-foot section so designated contains considerably less aggregate sandstone than the typical Jackfork of the Ouachita region. This argument may possibly be countered, however, by assuming a lessening of clastic material in the area near the Nalley well because of its greater distance from the source of supply.

An alternate hypothesis might be advanced to explain the presence of pre-Atoka sediments of this nature in the vicinity of the Nalley well. The fact that they are atypical rocks when compared with the Ozark facies generally expected in the Arkansas Valley does not in itself relate them to the Ouachita Mountain region. They may represent thickened facies of undifferentiated Morrow-Mississippian sediments related northward and westward to equivalent rocks that are more typical of the sequence found near the Ozark region. While the Morrow-Mississippian section in the Nalley well has thickened considerably when compared with wells to the west, north and northeast, the Atoka formation, as tentatively delimited in the Nalley, has apparently thinned in regard to those wells.[1] The Atoka in the Nalley has a thickness

[1]Lion Oil Company No. 1 Griggs, section 23, T. 10N, R. 13W, Van Buren County.

Deep Rock Oil Company No. 1 Sample, section 4, T. 10N, R. 6W, White County.

Arkansas Oil Ventures, Inc. (Deardorf) No. 1 Doggett, section 31, T. 10N, R. 3W, Jackson County.

Killam and McMillan No. 1 Curl, section 10, T. 9N, R. 5W, White County.

of approximately 780 feet according to the aforementioned study by Maher and Lantz. (This writer has tentatively assigned a thickness of 935 feet to the Atoka in the Nalley well, picking the base of the Atoka at the bottom of a bed of fine grained, argillaceous sandstone, containing what may be reworked chert. The bed persists from 920 to 935 feet).

The Griggs well is considered here to have some 1260 feet of Atoka present, the Sample well about 1350 feet, the Curl well about 1318 feet and the Doggett well about 1060 feet; therefore, a thinning of both Atoka and undifferentiated Morrow-Mississippian sediments appears to be indicated from west to east, crossing the Fall Line. An appreciable thinning of the Atoka formation southward toward the Nalley well is indicated, although this well would be expected to have a relatively thicker Atoka section than the designated wells further to the north. If the Nalley well lies in a Morrow-Mississippian basin, considerable differential upwarping along a hinge line located generally north of the Nalley could account for the apparent thinning of the Atoka in this well. Since the Nalley well was drilled near the axis of the Searcy anticline some of the thinning in the Atoka section probably can be attributed to the effect of local structure. The entire thinning might be accounted for by the structural position of the well. A normal fault, downthrown to the north, whose trace was north of the Nalley well, might also be used to explain this circumstance. This appears to violate the regional structure pattern; however, normal faults downthrown to the north have been mapped in the area immediately south and east of Batesville by Gordon and Kinney (1944).

Both a contour map drawn on the base of the Atoka and an isopachous map of the Atoka formation, including wells west and east of the Fall Line, may be broadly interpreted to infer the existence of a partial barrier along the present trend of the Fall Line during Atoka deposition and possibly prior to it. It is possible, of course, that the Atoka-Morrow contact is actually a considerable distance below that generally indicated here for the Nalley well. If future work proves this to be the case, then the Atoka will not only contain more calcareous material than is usually attributed to it in this area, but it may be shown to thicken appreciably from north to south near the Fall Line, in which case it would conform structurally with the underlying formations.

In comparing the stratigraphy in the Lion Oil No. 1 Griggs well and the Nalley well, a point of possible significance may be noted. In Maher and Lantz' Stanley shale section in both of these wells, a single, thin sandstone bed occurs in the upper part of the section. It is considerably closer to the top of their Stanley in the Griggs well than in the Nalley. It can be assumed that these sands are equivalent since the interval between the top of this sand and the top of any given pre-Mississippian formation in the Griggs closely coincides with the same interval in the Nalley well. From this, it appears reasonable to infer that both the Boone and the St. Peter are represented in the Nalley well, but that they are present in changed facies. The fact that there is so little thinning in the section below this sandstone in the Griggs and Nalley wells, indicates that most of the downwarping in the area resulting in the greatly thickened Morrow and Mississippian section took place after this sand was deposited.

The downwarping involving these wells may have been influenced by deposition of the thick Stanley and Jackfork sections further to the south, the implication being that the subsidence in the Ouachita geosycline may have caused compensating differential uplifts northward, which in turn would tend to create subsiding areas of probable lesser dimensions along the northern flanks of such uplifts.

Continuation in the subsurface of northeastern Arkansas: The approximate northern limits of Atoka-Morrow age sediments under the younger deposits of the Coastal Plain in northeastern Arkansas are shown on Plate IV. The lack of means for ready differentiation among the various black shales of Mississippian and Pennsylvanian ages makes exact location of the boundary line questionable. A possible answer may result in the future from the research work on fossil pollen and related studies being carried on by the Carter Oil Company and other organizations.

In plotting the extension of the Arkansas basin under the poorly consolidated sediments of the Coastal Plain, the aforementioned Arkansas Oil Ventures, Inc. No. 1 Doggett well in Jackson County and the Jones No. 1 Norris well in Independence County have been used to aid in drawing the tentative northern boundary line between sediments of Mississippian and Pennsylvanian ages near the Fall Line in the embayment. Samples above 605 feet from the Doggett well were not available. The black shale and gray siltstone occurring at this depth were taken to represent sediments of possible Atoka age. Personal communication with the operators indicated that the well had initially encountered Paleozoic rocks, presumably of Atoka age, at 525 feet. The shallowest sample available from the Norris well came from a depth of 370 feet. Black to brownish-black shales and slightly fossiliferous, limy, black shales, penetrated from 370 to 500 feet, were taken to represent an undifferentiated Batesville-Ruddell-Moorefield interval of Mississippian age. On the basis of these samples, the tentative northern limit of Pennsylvanian age sediments in the embayment area, adjacent to the Fall Line, was drawn between the Doggett and the Norris wells (see Plate IV). Further east in the embayment the Smith and Cockburn No. 1 Robinson well (sec. 14, T. 2N, R. 1E, Lee County, T.D. 3643 ft.)

was used to establish the tentative northern limits of the belt within which rocks of Pennsylvanian age would be expected to occur immediately beneath the Cretaceous and younger sediments of the Coastal Plain. The initial Paleozoic rocks encountered in this well were assigned tentatively to the Atoka formation by the writer.

As noted previously in this report, two noses are apparent in the embayment trending southeastward across Woodruff County and Arkansas County, respectively (Plates II and III). The fact that these noses occur on contours of the Paleozoic floor leads initially to the conclusion that they are true, structural features and that they maybe related to the general folding in the Arkansas basin synclinorium as projected under the Coastal Plain sediments. An alternate interpretation is possible, however, in view of the peneplanation suffered by the undifferentiated Paleozoic rocks comprising the embayment floor following the Ouachita orogeny. These apparent structural noses might then be only the results of differential erosion and therefore reflect no underlying structural attitudes. In contouring or profiling involving the undifferentiated Paleozoic floor of the embayment, it should be kept in mind that a topographic surface may dominate and that its entire effect might be structurally significant only in the overlying Cretaceous and younger sediments. Quartzitic sandstones or novaculite, such as previously described in the Youngblood No. 1 West well in Arkansas County are potential ridge builders, through agencies of erosion, in an area where shales are the predominant sediments.

Honess (1923, p.264) made the following observations about buried hills along the Paleozoic-Cretaceous contact in southeastern Oklahoma which may be applicable in principle to the embayment area in northeastern Arkansas:

> The Comanchean sea floor was not an absolute plain nor was it perfectly level. Minor undulations, produced by resistant sandstone, have been noted in favorable places along the northern feather edge of the outcropping Trinity. The shore of the advancing sea must therefore have been somewhat irregular. There were rocky headlands, and a few large islands and archipelagoes off shore, as shown in High Hill Mountain south of Corrine and west of Sobol . . . These mountains at the present time rise 100 feet or more above the Trinity sandstone plains which completely encircle them. The weathering away of the Trinity has uncovered a rocky headland along the east side of Signal Mountain. That this cliff may have been formed by waves of the Comanchean sea is suggested by the fact that there are large blocks at its foot cemented in the basal conglomerate of the Trinity. North of the main ridge, which forms High Hill Mountain, seven miles long, there are numerous small outcroppings of Paleozoic rocks surrounded by Trinity, showing that peneplanation was not complete in this region and that archipelagoes existed. Certain other mountains (for example Williams Mountain in sec. 35-3S-26E and the high points in sections 24, 25, 35, 36, T.2S, R. 25E) are certainly monadnocks on the Comanchean peneplain and may have been islands in the Trinity ocean.

Buried, isolated hills formed by Paleozoic rocks which are now found embedded in Cretaceous sediments have also been described in portions of Pulaski and southern Massac Counties, Illinois, by Weller (1940).

Generally speaking, the Paleozoic rocks of the Arkansas basin, as extended under the unconsolidated Coastal Plain sediments in northeastern Arkansas, will be found to rise structurally toward the north and to be truncated in that direction, so that progressively older Paleozoic rocks will be found underlying the Cretaceous sediments northward.

Fixed carbon ratio: The percentage of fixed carbon in a coal, determined on an ash and moisture free basis, gives the fixed carbon ratio of the coal. A basic premise of the carbon ratio theory is that the percentage of fixed carbon is directly related to the degree of metamorphism suffered by rocks associated with the coal. By this theory, commercial quantities of oil and gas are claimed to be limited to areas where carbon ratios are below about 65 and 70, respectively. Figure 2 indicates carbon ratios in western and northern Arkansas based on work done by Croneis (1927) a number of years ago. The validity of the isocarbs shown on this map, and the carbon ratio theory in general, are seriously questioned by the fact that gas is produced in commercial quantities from areas in western Arkansas having carbon ratios near 90. In addition, numerous oil seeps are found in portions of the state where carbon ratio values are considered prohibitive. In Oklahoma, Pennsylvania and Virginia oil or gas is produced from areas condemned by carbon ratios. Such examples emphasize the danger of regarding fixed carbon ratios as absolute measures of productive ability.

General structure and physiography of the Ozark region: Structurally the Ozark region of southern Missouri and northern Arkansas is a broad, irregular, flattened dome whose core is exposed in the pre-Cambrian granite of the St. Francis Mountains in southeastern Missouri. Formations lying on the flanks of the dome dip everywhere away from the apex. Consequently, northern Arkansas, which forms the southern and southwestern portions of the dome, has prevailing dips in those respective directions.

In general the dips in the Arkansas Ozark region are of such low order that the beds are considered to be essentially horizontal. Locally the regional dip is obscured by the occurrence of minor folds. South of the Ozark region, as the northern limits of the Arkansas Valley are approached, the folding becomes more noticeable, the angle of dip is intensified and faulting becomes more prominent. Normal faulting predominates, with the downthrown sides being south of the fault traces in most cases. No clearly defined boundary line separates the Arkansas Ozark region from the Arkansas Valley.

From north to south across the Ozark region of Arkansas three physiographic divisions have been designated. These are known, respectively, as the Salem Plateau, the Springfield Plateau and the Boston Mountains. The Salem Plateau comprises most of the northeastern portion of the Ozark region in Arkansas, covering in part an area from Boone County eastward to the Fall Line. Primarily its surface formations are Ordovician dolomites, with lesser amounts of limestones and sandstones. Surface elevations within the area of the Salem Plateau range from about 1250 feet in Carroll County to 250 feet at the Fall Line.

The Salem Plateau and the Springfield Plateau are separated by a generally east-west trending, northward-facing escarpment which consists of sediments of Mississippian age. Although this escarpment is prominent in the western portion of the area, it becomes less so in an easterly direction. Near the Fall Line it tends to lose its identity. The surface formations of the Springfield Plateau are essentially limestones and cherts of Mississippian age, with the Boone formation being predominant. The surface elevations within the area of the Springfield Plateau range between 1000 and 1500 feet.

The Boston Mountain province is separated from the Springfield Plateau by an east-west trending, northward-facing escarpment which is generally a more prominent topographic feature than the escarpment between the Salem and Springfield Plateaus. The Boston Mountain-Springfield Plateau escarpment is capped by a basal sandstone of Atoka age. Rocks of the Morrow group of Pennsylvanian age and the Chester group of Mississippian age are also found outcropping in the escarpment. The surface formations of the Boston Mountain province are essentially sandstones and shales of Pennsylvanian age. Surface elevations vary considerably within the Boston Mountain region since deep gorges are relatively common. The highest elevation in the region is about 2200 feet. Southward dipping terraces serve to connect the Boston Mountains with the Arkansas Valley.

Ozark uplift: Structurally and stratigraphically the Ozark dome represents the surface expression of a much more extensive configuration. In order to present the Ozark dome in its proper perspective, both the surface and subsurface expressions are combined and discussed here as the Ozark uplift. Rocks of the Ozark facies have been identified in the subsurface of southeastern Kansas, western Missouri, western Kentucky, southwestern Illinois, western Tennessee and northern Mississippi. The axis of the Ozark uplift trends from northwest to southeast across portions of southeastern Kansas, southern Missouri and western Tennessee indicating that the uplift is more a linear than a domal feature (Fig. 2).

A number of years ago Wilson (1939) postulated the existence of a structural connection between the Ozark dome and the

Nashville dome of the Cincinnati arch. Subsequent work by Freeman (1945) indicated a subsurface high, masked by younger sediments of the Mississippi embayment, between the Ozark uplift and the Nashville dome. This high proved to be a nose southeastward from the then known limits of the Ozark uplift rather than a separate structure. In extending the limits of the Ozark uplift to include this nose, the trend of the uplift was found to change from east-west in northern Arkansas to northwest-southeast in the embayment area of northeastern Arkansas so that its trend conformed roughly with that of the Ouachita Mountain region as extended into the embayment area.

Although the Ozark uplift apparently never attained mountainous heights during its geologic history, it is generally considered to have persisted throughout most of the Paleozoic as a stable, emergent feature. Despite evidence that the Ozark uplift was not continuously emergent during the Paleozoic, it was a relatively stable and positive feature throughout enough of its geological history to profoundly influence sedimentation in the various areas with which it is identified.

The maximum expression of elevation of the Ozark uplift is considered to be marked by a truncated belt of Siluro-Devonian rocks encircling the uplift. Where the fairly persistent Sylamore sandstone, the basal member of the Chattanooga shale, is missing, the black, bituminous shale itself is the oldest sediment immediately overlying the truncated edges of these Siluro-Devonian rocks. The Sylamore sand is here considered to be equivalent to the basal Mississippian sand of McKnight (1935). The maximum extent of the Ozark uplift can be dated accurately only through clarification of the ages of the Chattanooga shale and the Sylamore sand member. If they are of Upper Devonian age, as postulated by some geologists, the youngest rocks participating in the major movement of the Ozark uplift would, of necessity, be pre-Upper Devonian in age. If the Chattanooga shale and the Sylamore sand are Lower Mississippian in age, the maximum extent of the uplift probably occurred during or at the end of late Devonian time. This idea has many adherents among geologists, including the writer. In any event, the base of the Chattanooga shale (whether the shale itself or the Sylamore sandstone member) which is known to rest variously on all formations from pre-Cambrian to Devonian, marks the most important unconformity in the Ozark region.

Intermittent periods of shallow submergence during the Paleozoic resulted in the deposition of sediments over the Ozark uplift, although contemporaneous deposition was not necessarily the rule throughout its areal extent. Subsequent to periods of submergence the Ozark uplift was differentially elevated above sea level and subjected to truncation toward its apex. Low angle truncation resulted from the relatively low order of these uplifts. Because of this pattern of subsidence, emergence and truncation, sediments in northern Arkansas lying on the flanks of the Ozark uplift are found to thin toward the north and to lose progressively older members updip by transgressive overlap. Downdip from the apex of the Ozark uplift, these disconformities become less noticeable and of less consequence. In deep basin areas of Ozark facies deposition, where more complete sedimentary sections are likely to be present, period breaks will even be difficult to distinguish.

In the Coastal Plain areas of those states bordering on the upper Mississippi embayment, sediments of the Ozark facies are buried beneath poorly consolidated Cretaceous and Tertiary sediments. On the southern and southwestern flanks of the Ozark uplift, typical rocks of the Ozark facies are covered by Mississippian and Pennsylvanian sediments. In the western portion of the area, pre-Mississippian erosion removed rocks down to the Cotter. Farther east, in the area immediately adjacent to the Fall Line, rocks younger than Cotter are exposed. Close to the Fall Line, in the Paleozoic outcrop area, the northern limits of Mississippian and Pennsylvanian sediments are found further downdip on the flanks of the Ozark uplift than are those of their equivalent formations in the western part of the state. This condition may have resulted from more complete erosion of sediments in the eastern portions of the state, following Mississippian and Pennsylvanian deposition.

Continuation in the subsurface of northeastern Arkansas: Despite the limited subsurface control in the embayment area, it is possible to indicate generally the areal distribution of truncated belts of rocks of the Ozark facies beneath the Coastal Plain sediments. In the zone marked Mississippian-Devonian-Silurian on Plate IV, only two wells have been drilled to a Paleozoic formation. Both of these wells, the aforementioned Jones No. 1 Norris, section 17, T. 12N, R. 4W, Independence County, and the LeGrande No. 1 Jacobs, section 34, T. 9N, R. 1W, Jackson County, supposedly encountered Mississippian age sediments as the initial Paleozoic rocks in the wells. There is some question as to the validity of the designation in the Jacobs well, however.

Although no other wells in this belt have actually penetrated Mississippian, Devonian or Silurian rocks, it is inferred here that truncated rocks of those respective ages will be found in that sequence toward the north, beneath Cretaceous or Tertiary sediments. The northern limits of this zone in the embayment, adjacent to the Fall Line, have been placed on the basis of formational trends occurring west of the Fall Line in the Paleozoic outcrop area of Independence County. Eastward into the embayment the northern limits of this belt have been tentatively determined on the basis of a group of wells that encountered rocks identified as Plattin limestone immediately beneath the oldest Cretaceous sediments present in the wells. It can be noted on Plate IV that the eastern portion of the area over which truncated Plattin limestone is found extends from section 16, T. 8N, R. 8E (Dobbs No. 1 Bond, Crittenden County, T. D. 3380 ft.) to section 20, T. 5N, R. 5E (Manning and Martin No. 1 Gregg, St. Francis County, T.D. 3988'). This wide occurrence gives further evidence of the pronounced swing in the strike of formations from east-west adjacent to the Fall Line to northwest-southeast across the embayment, roughly paralleling the Ouachita Mountain front as extended into the embayment.

This relatively greater pre-Cretaceous areal extent of the Plattin limestone in the eastern part of the embayment may indicate a lesser dip of the sediments off this flank of the Ozark uplift in comparison with the dip closer to the Fall Line, and consequently a greater area subjected to low angle truncation. Ordovician formations younger than the Plattin limestone, such as the Fernvale and Kimmswick limestones, together with rocks of Siluro-Devonian age, were not necessarily eroded completely from the belt marked Plattin by post-Devonian, pre-Mississippian peneplanation. Therefore, remnants of these younger Ordovician rocks and of Siluro-Devonian rocks may be found preserved either in association with faults or in relatively downwarped areas within the belt designated as Plattin on Plate IV. In either event it may be inferred that such occurrences within this zone would be sporadic.

In the more northerly portions of the embayment area in northeastern Arkansas the belt of truncated rocks indicated as being Everton in age has been located essentially from data obtained in two wells.[1] The establishment of rocks of Everton lithology beneath the Cretaceous section in the Johnson well is based on scattered samples obtained from the Paleozoic section penetrated. The identification of Paleozoic formations encountered in the Martin well has been the cause of considerable controversy. The initial Paleozoic rock, a dolomitic limestone, found in this well at 1675 feet has been variously assigned to Joachim, Everton and post-Black Rock-pre-Everton ages by geologists examining the samples. On the basis of lithology and insoluble residues the writer favors the assignment of this rock to the Everton formation. The silty, pyritic residue, containing a small percentage of St. Peter type, rounded, frosted quartz grains, is not unlike that from the Joachim limestone occurring in the

[1]C. E. Walters et al No. 1 Johnson, sec. 10, T. 13N, R. 1E, Craighead County, T.D. 1608 ft.
Tennark, Inc. No. 1 Martin, sec. 35, T. 14N, R. 3E, Craighead County, T.D. 5092 ft.

subsurface of western Arkansas. Within the belt of truncated rocks marked Everton on Plate IV, neither the Joachim limestone nor the St. Peter sandstone can be deleted with assurance. Their absence from this map may be accounted for as readily by the meagerness of subsurface control as by their disappearance through truncation.

The extension of Ordovician rocks older than Everton into the embayment was accomplished near the Fall Line by tying into the pertinent outcrops in the area west of the Fall Line in Lawrence and Randolph Counties. Farther eastward, subsurface control for the extension of these older Ordovician rocks was provided by two wells in Clay County and one well in Mississippi County.[1] The first Paleozoic formation encountered in the Sallee well is considered to be the Jefferson City dolomite, and in the Gordon and Mack wells the Cotter dolomite. Some geologists have assigned the first Paleozoic formation encountered in the Mack well to the Jefferson City instead of the Cotter, but the writer favors the latter identification.

An interesting and pertinent outcrop configuration is shown on the Arkansas State Geological Map in Sharp, Lawrence and Randolph Counties. The Black Rock, Smithville and Powell formations, immediately west of the Fall Line, all trend northeast toward the Fall Line, from which they disappear under the Coastal Plain sediments of the embayment. The St. Peter-Everton outcrop west of the Fall Line, in southern Sharp and northern Independence Counties, trends roughly east-west and intersects the outcrops of the Black Rock, Smithville and Powell formations at approximately right angles. This outcrop pattern suggests the presence of a basin in the embayment area during the time of deposition of the Black Rock, Smithville and Powell formations. Further, it indicates that such a basin would have been subjected to orogenic forces and subsequent erosion at some time prior to deposition of the St. Peter sandstone. If the outcropping beds called St. Peter-Everton just west of the Fall Line had been deposited under conditions conformable with those governing deposition of the Black Rock, Smithville and Powell, all of these formations would have had essentially parallel strikes on the outcrop.

Several other factors indicate the presence of an Ordovician or Cambro-Ordovician basin in the area now occupied by the upper

[1] A. L. Ginther No. 1 Gordon, sec. 22, T. 19N, R. 7E, Clay County, T.D. 1309 ft.

Texas Piggott Oil Co. No. 1 Sallee, sec. 11, T. 20N, R. 8E, Clay County, T.D. 1233 ft.

Benedum-Trees Oil Co. No. 1 Mack, sec. 3, T. 15N, R. 12E, Mississippi County, T.D. 4535 ft.

Mississippi embayment. In the extensions of the Everton, Black Rock, Smithville, Powell, Jefferson City and Cotter formations into the embayment there is a marked divergence in the strike of these formations just east of the Fall Line (Plate IV) where they are at variance in part with the general northwest-southeast strike of younger formations extended into the embayment. From this change in strike it can be inferred that these older Ordovician sediments were being deposited within a basin east of the Fall Line. Ordovician formations such as the Jefferson City, Cotter, Roubidoux and Gasconade, as found in the embayment in northeastern Arkansas, have thickened in comparison with their counterparts further to the north. The existence of this basin as far back as pre-Bonneterre time is indicated by a progressive thickening below the top of the Bonneterre formation from about 500 feet in Washington County, Missouri, to 2400 feet in Pemiscot County, Missouri, on the southeast, without penetration of granite (Freeman, 1949). To the present time the Bonneterre has not been penetrated by a well in northeastern Arkansas, but a considerable thickness of this formation is indicated.

The existence of an older basin in the present site of the upper Mississippi embayment necessitates an inference of correlation between Cambro-Ordovician rocks of the Ozark facies in northeastern Arkansas and the Knox dolomite of Mississippi, Tennessee, Kentucky and adjacent states. In general the Knox dolomite is considered to be undifferentiated Cambro-Ordovician in age because of the difficulties encountered in attempting to zone it from one area to another. The lithologic similarity of most of the subsurface Knox section has caused some geologists to question the insertion of a period break within the column. However, certain sections within the Knox dolomite have been convincingly correlated with Ordovician rocks of the Ozark facies such as the Roubidoux and Gasconade, which are found only in the subsurface in Arkansas. McQueen (1931) has presented detailed descriptions of the formations comprising the Knox group and their insoluble residues used in correlating the Ozark facies with the Knox dolomite section in the Cincinnati arch region. Galey (1948) made the following statement concerning in part the possible equivalency of the Knox dolomite:

> The attention of geologists has recently been directed to the practicability of exploring the untested possibilities of Ordovician and lower rocks in the deeper parts of the Appalachian basin by the following factors . . . the interesting showings encountered in the few widely scattered wildcat wells in the deeper parts of the basin; the importance of the production of oil and gas from the Ellenburger group of Texas and from the Arbuckle group of Oklahoma and Kansas, which corresponds with the Knox group (sub-Trenton) of the Appalachian area, in mass, lithologic character and in stratigraphic position; and the demonstration of the ability to drill these rocks to the world's record cable-tool depth of 10,096 feet in relatively short time and at comparatively low cost.

Galey's statement may also be pertinent to northeastern Arkansas in view of the stratigraphic relationships between rocks of the Arbuckle and Ozark facies. It is inferred here that the Knox dolomite of the Cincinnati arch region can, in general, be correlated with Ozark facies rocks ranging in age from Upper Cambrian through Lower Ordovician (Upper Canadian-Beekmantown). This writer is not in agreement with the present assignment of the Black Rock and Smithville formations in Arkansas to an Upper Canadian age and is of the opinion that they would be better placed in Lower Ordovician Buffalo River (Chazyan) time. In that event, the Powell limestone would be the youngest Knox dolomite equivalent among rocks of the Ozark facies in northern Arkansas.

In applying this opinion to the Cambro-Ordovician basin previously discussed, the following assumptions have been made by the writer. From Cambrian through Powell time the Black Warrior basin of Mississippi and Alabama was interconnected with a basin in the present embayment area of northeastern Arkansas and with a basin in the present site of the Arkansas Valley (Fig. 2). While the Black Warrior basin received sediments of Knox age, the embayment area and the Arkansas Valley region received equivalent sediments of Ozark facies from Upper Cambrian through Powell in age. Following deposition of the Powell limestone in Arkansas and the youngest Upper Canadian age sediments in the areas of Knox dolomite accumulation, the entire region was subjected to extensive changes in its patterns of sedimentation. The close of Knox time was marked by this occurrence.

The writer infers that the orogeny had a pronounced depositional, if not structural, effect on the basins occupying both the embayment area in northeastern Arkansas and the present site of the Arkansas Valley. In order to attempt an interpretation of events affecting deposition in these later areas during Knox time, attention is called to two principal sources from which inferences have been drawn by the writer: (1) the trend of the Black Rock, Smithville and Powell outcrops in Sharp, Lawrence and Randolph Counties, and (2) the occurrence of some 1340 feet of partially undifferentiated dolomites and limestones, in part sandy and argillaceous, in the Deep Rock Oil Co. No. 1 Sample well, section 4, T. 10N, R. 6W, White County, from 3670 feet to total well depth of 5010 feet.

Irrespective of the controversy concerning the depth to the top of the Everton formation in this well, rocks of Everton lithology are believed to be recognizable from 3670 feet to approximately 3900 feet. Below this depth, to total depth, the well is in carbonate rocks of the description given above. A combined Everton and Powell thickness of approximately 700-800 feet might normally be expected in this well; however, that thickness is inconsistent with the actual conditions in the Sample well, since no Cotter dolomite is recognizable. Therefore, the writer assumes that this section in the Sample well contains not only rocks of Everton age but Black Rock, Smithville and possibly Powell as well.

In assigning Black Rock and Smithville sections to the Sample well the question arises as to the ages of these formations. For a considerable length of time a controversy has existed concerning both their ages and correlations. McKnight (1935, p.28), as a result of his field work in the Yellville quadrangle, concluded that the Black Rock and Smithville may be facies of the Everton. On the basis of graptolites found in the Smithville and Black Rock; a large molluscan fauna occurring in the Smithville; and sponges, bryozoans and brachiopods found in the Black Rock, Ulrich (1911) concluded that the Smithville and Black Rock were older than the Everton but younger than the Powell.

Subsequent to the orogeny marking the close of Powell time, the Black Rock and Smithville formations were deposited in the embayment area in northeastern Arkansas; however, counterparts of the same lithology were not deposited contemporaneously throughout the Arkansas Valley region. There is no evidence from which to assume that erosion was taking place in the Arkansas Valley while deposition was occurring in the embayment. Consequently, it is postulated here that the Black Rock and Smithville were being deposited in the embayment contemporaneously with progressively younger beds of the Everton formation being deposited over most of the Arkansas Valley region. The Black Rock and Smithville would then be facies of the Everton which were influenced lithologically by transgressions from the Cincinnati arch area following the orogeny at the end of Knox time.

It is possible to conceive of north-south trending differential upwarping during or prior to deposition of the Black Rock, Smithville and older Everton beds. This would serve to isolate, relatively, the Black Rock and Smithville facies from the typical Everton beds between the embayment and the Arkansas Valley region. However, these facies changes can be visualized readily without such inference. The presence or absence of accompanying differential upwarping being conjectural, it still can be assumed that a north-south re-entrant was formed between the embayment area and the Arkansas Valley separating the Black Rock and Smithville facies on the east from the contemporaneous Everton beds on the west. This re-entrant would have to penetrate the Arkansas Valley deeply enough laterally to encompass the aforementioned Deep Rock No. 1 Sample well.

The assumption of a re-entrant does not necessarily imply a structural configuration. The re-entrant might be represented only by facies changes occurring along an arcuate course between the embayment and the Arkansas Valley. This trend would parallel roughly the aforementioned trend of the Black Rock and Smithville outcrop patterns west of the Fall Line. It is necessary to take this hypothesis one step further in order to account for the presence of beds of typical Everton lithology presumed to overlie the Black Rock formation in the embayment area. This could be reconciled by assuming changes in sedimentation patterns subsequent to the deposition of the Black Rock in the embayment in such a manner as to allow deposition of typical Everton sediments both in the embayment and in the Arkansas Valley region. It is believed that rocks of typical Everton lithology overlie the Black Rock in the embayment as shown on Plate IV.

Following this line of thought, the opinions of McKnight and Ulrich might be somewhat reconciled in regard to the Smithville and Black Rock. Older beds of typical Everton would be expected to grade into Smithville or Black Rock facies from west to east across the Fall Line. Because of the changes in facies, implying different conditions of deposition, the faunal assemblages would be expected to show differences. Among other indications drawn from stratigraphic studies in Kentucky, Freeman (1949, p.1669) concluded that detailed work might reveal the Smithville-Black Rock of Arkansas, the Buffalo River of the Ozarks and the Chazy of the Appalachian basin to be essentially correlative and to mark deposits following an orogeny. Under those circumstances, Freeman was of the opinion that some faunal differences should be expected because of the differences in the environments of deposition.

On east-west cross section E-E' (Plate IX) trending from the Arkansas Valley into the embayment, the Arkansas Oil Ventures No. 1 Doggett well can be seen to run structurally higher than the Deep Rock No. 1 Sample well on all geologic tops down to the Everton. The appearance of a number of unconformities between these wells and the indiscriminate thickening or thinning of the formations between them apparently indicates periods of relative uplift and subsidence. The persistent structural anomaly between the Sample and Doggett wells may have had its origin as far back as the orogeny at the end of Powell time. It appears more likely, however, that the uplifting originated after Everton deposition and prior to or during St. Peter deposition. The writer is of the opinion that such uplifting, whatever its date, did not consist entirely of one simple, linear flexure but of a series of low, elongate, dome-like features separated by saddles, aligned in a trend roughly paralleling the approximate position which the Fall Line has at present. How extensive such a hypothetical unwarping might be laterally is not known. In general the structural configuration may resemble the southeastern portion of the LaSalle anticline of the Eastern Interior Coal basin, which, according to Mylius (1927), consists of a series of elongate domes connected by saddles and in part arranged en echelon, with axes varying somewhat in direction. The Matador arch of the southern Panhandle of Texas also consists of a similar series of small, related uplifts rather than one continuous feature. In July, 1951, the United States Geological Survey released a preliminary total intensity aeromagnetic map of the Strawberry, Newport, Augusta, Bald Knob, Pleasant Plains, Batesville and Cave City, Arkansas quadrangles. This contour map includes portions of White, Woodruff, Jackson, Independence, Lawrence, Sharp and Izard Counties. The map is not specifically called upon here to corroborate the upwarping postulated previously in portions of the area covered by it. However, an interesting series of apparent structural anomalies, including domal features separated by lows, is indicated both west and east of the Fall Line.

Differential movements along an arch of this nature in northeastern Arkansas would result in numerous unconformities in the subsurface, both at right angles to the Fall Line and parallel to it. Sediments flanking the arch would provide possible stratigraphic or structural traps for the accumulation of oil or gas present. Drill-stem test records from the Deep Rock No. 1 Sample well in White County indicate shows of gas from 3512-74 feet (possible all St. Peter) and slightly gas-cut mud from 4165-4205 feet and 4820-50 feet. The two latter tests were performed within the section previously noted as being of possible Everton-Black Rock-Smithville-Powell ages. If faulting is present in conjunction with the postulated upwarping in this area, there are no indications of it.

Desha basin: An erroneous impression is fairly prevalent that the designations "Desha basin" and "Mississippi embayment" can be used interchangeably in reference to northeastern Arkansas. The Desha basin is merely a distinctive feature within the Mississippi embayment and is by no means equivalent to it.

The Desha basin is an asymmetrical, downwarped, structural basin lying within Arkansas and Mississippi. In Arkansas the area of its deepest development is essentially in Desha and eastern Lincoln Counties. The basinal configuration can be noted on a contour map of the undifferentiated Paleozoic floor of the embayment in northeastern Arkansas (Plate II). An isopachous map showing Cretaceous thicknesses in the embayment (Plate III) suggests that the Desha basin was instrumental in controlling Upper Cretaceous deposition in the extreme southeastern portion of northeastern Arkansas. Although the Desha basin is generally considered to have originated in Upper Cretaceous time, possibly during or at the end of Tuscaloosa time, its maximum development probably did not take place until the

Tertiary period. This is evidenced by the thicknesses of Wilcox and Claiborne sediments. The possibility exists that this basin is older than now assumed. If so, any sediments of post-Paleozoic, pre-Upper Cretaceous age present in the embayment area of northeastern Arkansas would more likely be encountered in the deeper portions of the Desha basin than in any other part of the Arkansas Gulf Coastal Plain, as limited to this report.

Near the northern rim of the Desha basin the regional southeastern dip of the Upper Cretaceous sediments can be seen to deviate to a southward dip. Near the western edge of the basin the southeastern dip changes to an eastward dip, and on the southern rim of the basin the dip is to the north, into the basin. These deviations from the prevailing southeastern regional dip in northeastern Arkansas are evidences of influences exerted on deposition in the Desha basin by the Monroe uplift of northeastern Louisiana, southeastern Arkansas and adjacent parts of Mississippi. According to Spooner (1935); the Monroe uplift is situated on a northwest-southeast trending line of weakness which coincides with the projected trend of the Ouachita Mountains under the Coastal Plain sediments. As a localized structural feature the Monroe uplift began to take form in Upper Cretaceous time and persisted as an upwarp into the Tertiary period.

The Desha basin is generally considered to be a downwarping within the Arkansas Valley (basin), as extended into the embayment. However, Plates II and IV and Fig. 2 indicate that the northwest-southeast trending major axis of the basin may lie within the Ouachita Mountain region, as projected under the Coastal Plain sediments, and that only the northern rim of the basin may be underlain by Paleozoic rocks identified with the Arkansas Valley. In this event the Desha basin should be considered primarily as a downwarping within the Ouachita anticlinorium. Faulting in the Desha basin has not been indicated to the present time, but faults may be present in view of the apparently close association with the Ouachita Mountain structural front.

Considerable controversy exists concerning the relative ages of many of the formations penetrated by wells drilled in the deeper portions of the Desha basin. A reconstruction of the depositional history of this area cannot be accomplished readily with the limited and widely scattered subsurface information available, but certain generalizations appear to be feasible. Formations encountered in wells drilled in the extreme southeastern portion of northeastern Arkansas will probably bear no marked lithologic resemblance to the equivalent formations drilled elsewhere within the Arkansas Coastal Plain region covered by this report. There is more likelihood that sediments encountered in the Desha basin that are older than the Taylor group will show closer lithologic affinity for sediments of equivalent ages occurring in Mississippi. Sediments of Taylor and Navarro ages that appear to be more closely related lithologically to southwestern Arkansas-northeastern Louisiana equivalents than to Mississippi equivalents will probably not be of typical lithology.

Although the Desha basin is considerably removed from the axis of the Monroe uplift it lies on a northerly flank of that feature. Therefore, deposition in the basin will be expected to reflect the differential movements of the uplift to the extent that clastic sediments may predominate in formations that are more typically shales or marls elsewhere in the subsurface of northeastern Arkansas. In addition, formations characteristic of the Monroe uplift area, such as the Monroe "gas rock", might be encountered in the Desha basin.

The gas rock is a platform reef-type limestone deposit of Navarro age covering the Monroe uplift. In basin areas off the highs the gas rock becomes sandy. A possible example of development of the gas rock in Desha County can be seen in samples from the Lion Oil Company No. 1 Bickham well, section 35, T. 10S, R. 3W (T.D. 4881 ft.). In that well, a tan, finely crystalline, porous, sandy limestone penetrated between 4160 and 4180 feet was attributed to the Monroe gas rock (Plate VIII). Immediately underlying this formation were 20 feet of silty shale followed by 50 feet of white, sandy, porous, crystalline limestone and limy sandstone which were considered tentatively as portions of the Nacatoch sand facies rather than as gas rock on the basis of correlations with wells further to the southwest. In areas of maximum development the Monroe gas rock facies may be found to replace in entirety both the Nacatoch and Arkadelphia formations.

As a result of such changes in sedimentation within the Desha basin area, formation identities and age interpretations will probably be more dependent upon stratigraphic position than upon the recognition of typical lithology in many of the wells drilled. This can be illustrated by referring again to Plate VIII, which is a cross section of Cretaceous and younger formations drawn along a north-south line from Clay County to Desha County. The Columbian Fuel Corp. No. 1 Victoria Cross well, section 34, T. 8S, R. 3W (T.D. 4912 ft.), Desha County, and wells further to the north, encountered formations whose ages are shown with some degree of assurance. However, the aforementioned Lion Oil Co. No. 1 Bickham well contains considerably more sand in the undifferentiated Saratoga-Marlbrook-Annona section than would be expected in these formations elsewhere in northeastern Arkansas. Assured identifications of the Ozan and older formations in this well have been complicated by the appearance of a massive sandstone which persists between 4369 and 4538 feet with only minor shale breaks. Immediately underlying the sandstone, in succession downward, are an 89-foot section of dark shale containing significant beds of lignite, bentonite and sand; a 70-foot section of alternating dark shale and sand; and a 13-foot basal section of coarse, angular sandstone. From the bottom of the latter sandstone (4710 ft.) to the total depth of 4881 feet, the well is assumed to be in the basal portion of the Eagle Mills formation. The aforementioned sandstone, encountered from 4369 to 4538 feet, is a coarse-grained, poorly sorted, predominantly angular, slightly glauconitic and ashy sandstone varying in color from red and yellow to white. The lighter colors become more apparent with depth.

Initially the tendency is to identify this sandstone and the underlying sections with the Tokio-Eutaw or Tuscaloosa formations. However, upon attempting to trace the massive, red sandstone into wells toward the northeast, it appears to grade rather rapidly into a gray, fine-grained, slightly tuffaceous, slightly fossiliferous and pyritiferous, finely glauconitic sandstone. In the Hunt Oil Co. No. 1 Thornton well, section 23, T. 7S, R. 1E, Desha County, an equivalent sandstone is not readily identified. The interval where it would be expected to appear is occupied by shales and sands of possible Ozan age. The section in the Bickham well underlying the massive red sandstone and overlying the 13-foot basal bed of coarse, angular sand also appears to have lost its identity between the Bickham and the Thornton wells and to have graded laterally into either Ozan or Tokio-Eutaw formation equivalents between these wells.

While such inadequately substantiated stratigraphic changes do not necessarily rule out a Tokio age for the massive, red sandstone section in the Bickham well, they suggest that this sandstone may have been deposited contemporaneously with the Ozan formation, or with an Ozan equivalent, to the northeast. If this supposition is valid, the section in the Bickham well between the base of the massive, red sandstone and the Eagle Mills formation may be either Tokio-Eutaw or Tuscaloosa in age.

In regard to the David-McCauley No. 1 Lucas well, section 2, T. 12S, R. 5W, Drew County, Hazzard[1] expressed the opinion that a section containing gravelly sand and some red shale, occurring between 4278 and 4455 feet, might be basal Cotton Valley, underlain by the Eagle Mills formation. Although Drew County is not specifically included in this report, the Lucas well may be pertinent to the identification of certain formations occurring in Desha County wells. The Lucas well is approximately 14 miles southwest of the previously discussed Lion Oil Co. Bickham well. The sand section tentatively identified by Hazzard

[1]Hazzard, Roy T., Gulf Refining Company. Contained in a letter to the Arkansas Division of Geology, August 24, 1950.

as Cotton Valley in the Lucas well appears generally to correlate, both lithologically and by electrical log characteristics, with the massive red sandstone section found between 4369 and 4538 feet in the Bickham well. Lithologically these sandstone beds conform somewhat to the Schuler facies of the Cotton Valley near the presently held northern limits of that formation. Northward from southern Arkansas and northwestern Louisiana the Schuler facies becomes increasingly sandy, with the sands being predominantly red and white. Along the tentatively held northern limits of the Schuler facies, red and gray shales known further south in this facies are absent or inconspicuous.

Imlay (1940) had concluded previously that a marked thinning of the Cotton Valley near its then apparent northern limits indicated that it never extended much farther north. He placed the northern limits as a northwest-southeast trending line crossing the central portions of Hempstead, Nevada, Ouachita, Calhoun and Bradley Counties and the extreme southwestern corner of Drew County. Imlay's conclusions closely parallel those of Weeks (1938).

FAULTING

Paleozoic rocks: Paleozoic faulting of considerable magnitude is recognized in northern Arkansas, west of the Fall Line, and in southern Illinois and Mississippi, adjacent to or within the embayment portions of those states. Few factual data are available for the placement of Paleozoic faults within the embayment in northeastern Arkansas. On the basis of well sample examinations, the writer has found only one well in this part of Arkansas that appears to contain a fault affecting Paleozoic strata. The Davis No. 1 DeMange well, sec. 22, T. 8N, R. 7E, Crittenden County, lies within a group of wells that all penetrated recognizable Plattin limestone immediately beneath the Cretaceous sediments present. At 3180 feet the DeMange well passed from the Cretaceous basal sandstone into 140 feet of white, weathered, porous, slightly tripolitic, brecciated chert. The lower portions of the section also contained lavender chert but in subordinate amounts. The writer considers this entire interval to be Devonian (Plates IV and VII).

From 3320 to 3390 feet the well was found to contain greenish-white, soft, slightly pyritic dolomite and some opaque, brecciated, lavender chert. This 70-foot section has been tentatively assigned to the Silurian by the writer. From 3390 feet to the total well depth of 5020 feet the rocks penetrated were essentially limestones and dolomites, shaly and sandy in part. This entire interval must be treated as undifferentiated Ordovician at present since no typical Ordovician formations could be recognized. This may be attributable to faulting prior to Plattin deposition with the result that Plattin, Kimmswick and

Fernvale formations are present in the DeMange well in changed facies. At 4730 feet a sandy rubble was encountered, consisting of free, poorly sorted, in part rounded, frosted quartz grains and in part subangular, transparent, quartz grains, plus traces of pyrite and black fissile shale. The sand persisted vertically for only 30 feet and may represent a rubble zone along a fault plane. It is possible that the well passed through the fault trace at this depth range.

Since no repetition of section was found in the well it is assumed to have revealed a normal fault which could be downthrown in any direction. The direction of strike of this fault is not known, although a postulated northeast-southwest direction is shown on Plate IV. It is interesting to compare this apparent fault in the DeMange well with a fault found in the Union Producing Co. No. 1 Withers well, section 18, T. 2S, R. 9W, DeSoto County, Mississippi (Well No. 7 on section B-B', Plate VI). The Withers well, at a depth of 3546 feet, went from a detrital sandstone of possible Tokio-Eutaw age into 650 feet of white, porous, tripolitic chert of possible Mississippian or Devonian age. This writer is inclined toward the latter. Below the chert, 85 feet of red, earthy limestone of probable Silurian age were penetrated. This latter section has been correlated tentatively with the Lafferty limestone in Arkansas and the Dixon formation in western Tennessee, and indicates the presence of rocks of Ozark facies in the sub-surface of northwestern Mississippi. Repetition of the tripolitic chert section in this well, below the red, earthy limestone, possibly indicates that the well was drilled through the trace of a reverse fault. The directions of the trace of this fault are not known here, nor are the directions toward which the respective sides were displaced relative to each other. As in the DeMange well, the trace is possibly northeast-southwest.

Within the extension of the Ozarks in northeastern Arkansas, zones of weakness, developed as far back as pre-Cambrian, may have caused intermittent structural adjustments throughout the Paleozoic era. From studies in Missouri, Graves (1938, p.161) concluded that the Paleozoic and the pre-Cambrian rocks in that state have the same general trend, and that the alignment is attributable to movement along pre-Cambrian faults. He further concluded that the Ozark uplift may represent a complex of rectangular blocks of pre-Cambrian rocks uplifted through the overlying formations. More specifically, Graves has indicated that the dominant structural trend in the pre-Cambrian rocks of Missouri is N 50°W with a less pronounced N 40°E trend being in evidence. These facts and conjectures cannot be coupled specifically to the Arkansas portion of the embayment at this time, but they suggest the possibilities of faulting along similar trends. Downwarping of the Mississippi embayment may be attributable to such movements in the basement complex.

The Rough Creek-Shawneetown fault zone of southern Illinois, which is shown on the A.A.P.G. Tectonic map of the United States, may be found eventually to set a pattern for faulting in northeastern Arkansas. Although this fault zone is developed on the northeastern flank of the Ozark uplift, similar structural relationships on the southeastern flank may have given rise to the development of related fault systems under the northern portion of the Arkansas Coastal Plain. In a study of southern Illinois, Weller (1940, pp.50-51) related the Rough Creek-Shawneetown faults to a deep-seated igneous intrusion that arched the overlying strata in a manner permitting wedge-shaped blocks peripheral to the uplift to drop below the level of adjacent rocks. He located the intrusive mass a short distance to the southwest of the fault pattern, beneath the Coastal Plain. The relationship of such an intrusive mass to faulting in northeastern Arkansas, which is some distance to the southwest, is conjectural.

In northeastern Oklahoma the dominant fault trend is northeast. In a discussion involving faulting in eastern Oklahoma, Colton (1935) had the following to say:

> It is significant that every fault of major importance, with the exception of the fault at McAlester, is normal, downthrown toward the south and east . . . It is suggested that the Arkansas basin as originally formed was definitely related to (1) uplift in the Ozark and Tulsa-Okmulgee fault areas, or (2) subsidence due to successive step faults down toward the basinal area and genetically related to faulting in evidence on the surface in the Ozarks but partly concealed by overlap of the Younger beds.
>
> The writer believes that the major part of Atoka divergence is due to the fact that the principal movement and greatest throw of the master fault planes occurred during the deposition of this series and that the divergence is not uniform but reflects directly the throw and tilting of each step-fault block.
>
> It is interesting to note that the increase in thickness of rocks occurs along a cross section which intersects seven known (probably eight) strike faults of considerable throw on the surface. Four of these faults are definitely related to a fault system originating in the Ozarks, which shows every evidence of faulting contemporaneous with, or subsequent to, the deposition of the Morrow group. The faults are all downthrown southeast. It is possible that the major portion of the thickening occurs at the old faults and that those faults localized the present surface folds which grew out of the Choctaw fault overthrusting movement.

A generally similar pattern may have been created in the Arkansas basin in response to the aggregate thicknesses of Mississippian and Pennsylvanian sediments deposited in a progressively subsiding trough. Continued tension normal to the hinge line or lines, might have been relieved eventually through normal faulting in which downthrown sides would be generally basinward. An extensive fault distribution resulting from such circumstances, if coupled with a similar, though not necessarily related, fault pattern along the southern boundary of the Arkansas basin would result in a graben-like structure of regional dimensions.

McKnight (1935, pp.94-96) examined all faults mapped in the northern tier of 30 minute quadrangles from the northwest corner of the state eastward through the Yellville quadrangle, including faults in the Winslow and Batesville quadrangles. His study revealed that in general the faults showed an elongation of their major axes parallel to the dominant southeasterly trend. Within the Yellville quadrangle, not only the faults but many of the domes and basins indicated this same general system of alignment.

Surface and subsurface control indicate a normal fault of considerable throw in Johnson and Pope Counties. This fault is downthrown to the south and has a slightly southeastward trend. The westerly portion of its trace lies between section 17, T. 11N, R. 24W and section 15, T. 10N, R. 24W, in Johnson County. The easterly portion of its trace lies between section 23, T. 10N, R. 21W and section 6, T. 10N, R. 20W, in Pope County. The extent of the fault trace both west and east of the locations cited is not known. Evidences of this fault can be seen on a cross section of the Arkansas Valley prepared by Maher and Lantz (1953). Faults are rare in the vicinity of Batesville, but those present trend generally in a northeasterly direction

Although none of the faults in the Paleozoic outcrop area west of the Fall Line can be traced into northeastern Arkansas, they emphasize the fact that two general fault trends may occur in the northern portions of the embayment, one being essentially northwest-southeast and the other northeast-southwest. Faults following either trend will probably be normal and downthrown toward the south. Further south in the embayment faulting will probably have been influenced not only by old, established zones of weakness but by the intense, compressive forces related to the Ouachita orogeny. Within the extension of the Arkansas basin under the Coastal Plain sediments, faulting might be expected which is similar in nature to that occurring in the Arkansas basin west of the Fall Line. In this case, normal faults, downthrown toward the north, might predominate in the southerly portions of the Arkansas basin, as projected into the embayment. Closer to the Ouachita structural front in the embayment, normal faults might become subordinate to thrust faulting.

In western Tennessee igneous rocks encountered in wells to the present time lie within a narrow, linear, northeastward trending zone and may be indicative of a fault or fault system. Jenny (1937) concluded, on the basis of two magnetic fault indications, that a possible fault zone runs parallel to and about five miles east of the Mississippi River. The northern indication, according to him, is supported by surface evidence in the form of a 30-foot bluff on the east or upthrown side of the suspected fault. Jenny stipulated, however, that the field data are not sufficient to establish this fault zone definitely. An extension of this possible fault zone, if projected northward along the embayment trough, might connect with the Rough Creek-Shawneetown fault system of southern Illinois.

According to Mellen (1947, p.1816) many faults have been mapped in the Black Warrior basin of Mississippi and Alabama. In general these faults show a strike roughly normal to the axis of Appalachian folding. Mellen states further that grabens in Lauderdale and Colbert Counties, Mississippi, have displacements ranging from 100 to about 300 feet, where blocks of Chester sediments have been dropped into the lower Mississippian cherty limestones. He also states that almost all of the faults found in the Black Warrior basin are normal, except within the belts of Ouachita and Appalachian thrusting.

<u>Coastal Plain sediments</u>: The generally unconsolidated character of the post-Paleozoic sediments occurring in northeastern Arkansas makes faulting difficult to distinguish. Faulting that has taken place will be obscured easily by slumping. In areas where faults are not actually present, slumping and differential compaction may lead to the placement of faults erroneously. Unless substantiated by data from deeper zones, the placement of faults involving older Upper Cretaceous rocks, or Paleozoic rocks, cannot be undertaken with assurance solely on the basis of anomalies between Wilcox or Midway sections in adjacent wells. Faults involving sizable displacements of Cretaceous rocks will probably be related to deep-seated adjustments along zones of weakness in Paleozoic or pre-Cambrian rocks.

Faulting, slumping and general evidences of crustal displacement may be expected in those portions of the embayment affected by the New Madrid earthquake of 1811-1812. According to Fuller (1912) the epicenter of this earth movement was in northeastern Arkansas and southeastern Missouri, between Crowley's Ridge and the Mississippi River. Evidence examined by Fuller indicated the existence of a fault or fault system trending northeast-southwest across the general area affected, but actual areal placement of the fault or fault system could not be made with the information available. The maximum expression of faulting and related adjustments attributable to the New Madrid earthquake in Arkansas is likely to be found in the region between Crowley's Ridge and the Mississippi River, from the general vicinity west of Memphis, Tennessee, to the Missouri line. The fault system postulated might extend from Memphis to the head of the embayment at Cairo, Illinois.

Because of the tendencies of unconsolidated sediments to readjust easily by slumping or differential compaction, numerous difficulties may attend the interpretation of subsurface structure from surface mapping or aerial photography in the embayment. In an investigation of the development of a fracture pattern in the Central Gulf Coastal Plain, Fisk (1944) concluded that faulting in the Mississippi embayment occurs in a definite rectangular fracture pattern with one set of faults trending northeast-southwest throughout the region and the other trending northwest-southeast. Also, he indicated parallelism of the fracture system in the Central Gulf Coastal Plain to faulting in the Appalachian region on the east, the Ozark-Ouachita region on the west, and to faulting of the adjacent coastal plain areas. Further, he concluded that the orientation of the faulting indicated the results of adjustments along previous lines of weakness, presumably developed in the basement complex.

Fisk's fracture pattern within the Central Gulf Coastal Plain was determined essentially from a study of aerial photographs, utilizing the presence of scarps offsetting meander scars of abandoned stream courses, apparent changes in the areal patterns of soils, and changes in drainage attributed to land adjustments. Field studies, borings and other data were used in certain instances. In regard to the origin of this fracture system, Fisk stated:

> A direct correlation can be drawn between the warping of the fracture pattern and the gradual change in trend of the axes of successive deltaic accumulations in the Central Gulf Coastal Plain. The trend of the axes of the deltaic masses diagonally crosses the rectangles formed by the intersection of the two principal fracture sets. The fault zones trend approximately N 50°E (and at right angles) within the Mississippi Embayment area and are warped to N 35°E near the coastline. The trend of the axes of successive deltaic masses makes a comparable angular shift between the southern limit of the Mississippi Embayment and the present axis of the Gulf Coast Geosyncline . . . The fracture pattern appears, therefore, to be directly related to the distribution of the Mesozoic and Cenozoic sediments and may result from the release of stresses set up in the earth's crust as thick masses of deltaic sediments accumulated.

No exception is taken here to Fisk's preceding conclusions concerning the formation and trends of the fault systems and fracture patterns in the embayment. However, this writer is of the opinion that the fracture mosaic placed in northeastern Arkansas by Fisk appears to be premature in the light of the meager subsurface control data available.

In several areas within the Arkansas Coastal Plain possible faults affecting Upper Cretaceous sediments may be present. In the Cotton Plant area of Woodruff County apparent structural discrepancies can be noted between the J. N. Watkins No. 1 Nathan well, section 18, T. 5N, R. 2W and the Tatum and Watkins No. 1 Miller well, section 7, T. 5N, R. 2W. The Nathan well, being south of the Miller well, would normally be expected to have structurally lower formation tops in each case. The top of the Porters Creek shows such a relationship between these wells; however, the Clayton, Arkadelphia and Nacatoch tops are structurally higher in each case in the Nathan well than in the Miller well. The Nacatoch tops show a 50-foot difference. The Porters Creek, Clayton and Arkadelphia are 63 feet, 12 feet and 2 feet thicker, respectively, in the Miller well than in the Nathan well. These data suggest either a normal fault, downthrown to the north, trending northwest-southeast between these wells, or a narrow graben, of the same general trend, within whose bounding faults the Miller well was drilled. Drillers' logs from other wells drilled in the Cotton Plant area suggest a structural anomaly in the area but are not detailed enough to permit its placement with assurance. If faulting is present, it appears to have been initiated during Arkadelphia or Clayton time.

An alternate to faulting between the Nathan and Miller wells is the possibility of a sharp nosing which trends toward the southeast. Such a configuration would be progressively more pronounced with depth if contoured on the Porters Creek, Clayton, Arkadelphia and Nacatoch formations. A larger anomalous feature in Woodruff County, contoured as a southeast trending nose, can be seen on Plates II and III. Small shows of gas and salt water have been reported from the Nacatoch formation in the Cotton Plant area.

Indications of another fault involving possible Cretaceous sediments can be noted on Plate III and on the Arkansas State Geological Map. The only outcrop found to the present time in northeastern Arkansas which is attributed to the Cretaceous occurs along the western edge of the Mississippi embayment in eastern Independence and western Lawrence Counties. Here deposits of glauconitic sand and gray clay have been called Nacatoch, although they may prove to be of Clayton age or younger. On Plate III contour lines close to the Fall Line have been diverted somewhat from their prevailing trend in order to provide for these outcropping Cretaceous sediments. Unless a very gentle dip is inferred for the Cretaceous strata, from the Fall Line basinward until they have achieved an aggregate thickness of several hundred feet, it would be necessary to swing the contour lines considerably westward from their existing configuration in the Independence and Lawrence County areas. This has not been done on Plate III since no data are available to justify more deviation of the contour lines than has been shown.

To further complicate the structural configuration of this area, the so-called Nacatoch formation is not found outcropping south of the White River in Independence County, although it is present to the north where it persists into the southwest corner of Township 13 North, Range 5 West. In southeastern Independence County the Nacatoch is absent, and the outcropping lower beds of the Midway group lie unconformably on shales and sands of Pennsylvanian (Atoka) age. The preservation of the Nacatoch on the outcrop might conceivably be attributed to a northwest-southeast trending, downfaulted block whose northern margin would trend from Lawrence County southeastward into Craighead County and whose southern margin would lie along a southeast trending line, serving to isolate the Midway and Nacatoch outcrops on opposite sides of the White River. In view of the lack of data to support a fault pattern of this magnitude, and the attendant differential erosion required to achieve the existing outcrop pattern in this area, such faulting is merely indicated here as a possibility rather than being advanced as a conclusion.

Faulting involving Cretaceous and younger sediments may exist in the meagerly explored northern portions of the embayment as a result of movements along lines of weakness inherent in the Paleozoic or older rocks in the Ozark region. Faults of generally small displacement have been found in the Cretaceous and younger sediments of Kentucky (Roberts, 1929, pp.298-299, 307-308), western Tennessee (Wells, 1933, p.29), southeastern Missouri (Farrar, 1935, p.28), and southern Illinois (Weller, 1940, p.51).

IGNEOUS ROCKS

Occurrence and distribution in northeastern Arkansas: Although numerous wells in the Gulf Coastal Plain province of Arkansas have encountered igneous rocks, only seven such occurrences are noted to the present time within the area covered by this report. Three of the seven wells are in Desha County, two are in Grant County, and the two remaining are in Pulaski and Cross Counties, respectively (see Appendix). The latter well, the Manning and Martin No. 1 Park-Gieseck, section 4, T. 6N, R. 5E, is reported to have encountered igneous rock, possibly a sill, between 3720 and 3730 feet. The depths from which this igneous rock has been reported in the Park-Gieseck well lies far down in the Ordovician column, since Paleozoic rocks (Plattin) were initially encountered at 3275 feet in the well. Subsurface evidences of igneous activity may not be unusual in the general area in which this well was drilled as it lies within the possible zone of weakness discussed previously. If igneous activity in this area is related to the northeast-southwest trending fault system believed to parallel the trough of the embayment, and if it is further related to igneous activity occurring east of the trough, in Tennessee, then igneous intrusions may be found in additional wells in northeastern Arkansas, between Crowley's Ridge and the Mississippi River, in a pattern similar to that developed in Tennessee.

The wells in Desha, Grant and Pulaski Counties in which igneous rocks were encountered all lie within the apparent extension of the Ouachita Mountains as projected under the Coastal Plain. There is some possibility that the area in Desha County in which intrusives have been found may be related structurally to the Monroe-Sharkey uplift area (Fig. 2). The presently known distribution of intrusives in Arkansas Coastal Plain wells indicates an increase in igneous activity toward the Monroe-Sharkey uplift area.

In attempting to date the igneous intrusives in the Coastal Plain, Moody (1949, p.1427) concluded that they were related to two periods of magmatic activity, one occurring during mid-Upper Cretaceous time and the other possibly as early as the Triassic period. The former he believed to consist essentially of basaltic material and the latter of alkaline and basaltic material.

In western Tennessee igneous rocks have been found in three wells. The Lion Oil Company No. 1 Bateman, located approximately 3.8 miles south of Millington (10 miles northeast of Memphis, Tennessee) went from Cretaceous sediments of probable Selma age into normal syenite. The Pure Oil Company McGregor well, Tipton County, Tennessee, located approximately ten miles east of Osceola, Arkansas, drilled into a weathered normal syenite beneath Cretaceous sediments of Ripley age. The Henderson No. 1 Markham well, Lake County, Tennessee, located just across the Mississippi River from the extreme southeastern corner of New Madrid County, Missouri, drilled through several dark-gray (possibly mica-peridotite) dikes in the Cambrian section.

Effect of igneous intrusives on oil and gas possibilities: If the areas in northeastern Arkansas revealing igneous activity contained oil bearing reservoirs prior to such activity, the hydrocarbons therein would be expected to have volatilized upon contact or close association with the intrusives. The extent of volatilization would depend largely upon the type and magnitude of the intrusive. If regional metamorphism resulted, the possibilities for oil production would be almost nil. If contact metamorphism was the predominant result, however, the curtailment of production might be limited to a very small area. As noted by Hager (1938, pp.141-142), the productive pools in the Mexican oil fields are often closely associated with intrusions of basic rocks. The dikes apparently have not disturbed the surrounding beds appreciably nor have they changed the character of the beds to any extent. For this reason, Hager draws the general conclusion that small dikes in favorable prospective areas need not be considered as detrimental, and as has been discovered in Mexico, are positively of assistance in localizing oil accumulations.

The following conclusions, somewhat more pertinent to northeastern Arkansas at this time, have been set forth by Moody (1949, pp.1425-1427):

> Exploratory experience in the northern Gulf Coastal Plain leads to the sweeping conclusion that igneous activity has exerted no baneful influence whatever on the regional processes which operated to bring about the prodigious concentration of Mesozoic oil and gas in that province. The reasons for this observational conclusion are not far to seek. In the first place, no tangible evidence has been adduced which demonstrates that any oil existed in the present producing areas before the cessation of Mesozoic magmatic activity. Secondly, the igneous masses are of such small volume compared with the total volume of Mesozoic sediments that deleterious effects during the early thermal history of the intrusives were surely negligible.
>
> In the Delhi oil field of northeastern Louisiana, on the other hand, the Holt sandstone, believed to be of Paluxy (Lower Cretaceous) age, is a good oil reservoir though a considerable volume of mid-Cretaceous magma was forced through it in three or more vents within the area which is now a prolific oil field. The wells which were drilled into igneous rock were non-producing, but normal oil production was obtained in 40-acre offset locations. The lack of adverse effect on the permeability of the Holt sandstone is explained by the fact that the volcanic vents of the Delhi field are small; it may be postulated that the intrusion of a stock would have played havoc with the Holt sand.

According to Powers (1932) numerous occurrences of hydrocarbons are known in igneous rocks, although production from such sources is not large. Among the examples most often cited in regard to the commercial production of oil from intrusives are the various fields in the Texas Gulf Coastal Plain which produce oil from altered basaltic rocks (the Thrall field in Williamson County, etc.). The igneous activity which resulted eventually in the formation of the serpentine producing in these fields has been placed in the Cretaceous period, as the altered igneous material is found embedded in the lower portions of the Taylor marl. The porosity responsible for these accumulations is probably the resultant of primary porosity owing to the initial character of the intruded material and to secondary porosity produced by alteration of the material. Landes (1951, p.203) has noted that over 17 million barrels of oil have been produced from igneous rock reservoirs in Texas.

The Lion Oil Company No. 1 Bateman well, Shelby County, Tennessee (Plate VII), contains an example of the manner in which intrusives may localize possible traps. The Upper Cretaceous Eutaw formation is either absent over the intruded syenite or has graded into a sandy shale immediately above the syenite. The Selma beds can be seen to thin over the intrusion. Since there are no evidences of metamorphism in the wall it is assumed here that intrusion of the syenite occurred prior to Eutaw time and served to control both Eutaw and Selma deposition. Any oil or gas formed within the Eutaw section, or migrating into it, might find the combined structural-stratigraphic conditions along the flanks of the syenite excellent for localizing hydrocarbon accumulation. There is no reason to believe that like relationship between igneous activity and sedimentary deposits in northeastern Arkansas would not result in like possibilities. The creation of traps by differential compaction of sediments over an igneous intrusion should not be ruled out in considering possible areas of hydrocarbon accumulation.

In Arkansas oil and gas shows have been reported from igneous rocks in the Texas-Seaboard No. 1 Fee well, section 28, T. 17S, R. 4W, and the Texas-Seaboard No. 1 Bynum Cooperage well, section 34, T. 17S, R. 4W, both in Ashley County, and from the Lisbon Gas Company No. 1 Thudium well, section 9, T. 15S, R. 2W, Chicot County (see Appendix).

In speculating on the possibilities of hydrocarbon accumulations in igneous rock in the northern Coastal Plain, Moody (1949, p.1427) reached the following conclusions:

> All of the far-flung exploratory activity in the northern Coastal Plain province has failed to find an igneous rock oil reservoir. Serpentine has not been found in large masses such as occur in the fields of Texas in which it is the reservoir rock. The plutonic and hypabyssal alkaline rocks are too dense, the volcanic rocks are too impermeable to accomodate migrant oil. The buried stocks are therefore not now highly regarded as prospects for oil and gas. Gas and small quantities of oil have been found in late Cretaceous beds unconformably overlying three of the eruptive centers. They are the Jackson gas field and the Carey oil field (abandoned) of Mississippi, and the Epps gas field of northeastern Louisiana.

PALEOZOIC STRATIGRAPHY

Few wells drilled in northeastern Arkansas have penetrated the Paleozoic section deeply enough to afford stratigraphic detailing of the rock units; however, certain generalizations can be drawn. In attempting the following stratigraphic descriptions, the meager subsurface information realized from the area has been used in conjunction with data drawn from the more typical sections of equivalent rocks occurring on the surface and in the subsurface of the Arkansas Valley, west of the Fall Line, and from equivalent units found in the central Missouri Ozark region.

It is apparent from comparison among all of these data that numerous Paleozoic units identifiable with reasonable assurance on the outcrop and in the subsurface of the Arkansas Valley will be obscured basinward in northeastern Arkansas by facies changes. Relatively thicker sections of some of the formations will be developed in the embayment progressively downdip from the apex of the Ozark uplift. Formations such as the Rock Levee and Dutchtown, which are not exposed in the state and which have not been encountered in any wells west of the Fall Line, will probably be found as considerably thick units within deeper portions of the embayment.

In general it might be stated that Paleozoic units occurring in the embayment area of northeastern Arkansas will be expected to be of less typical lithology progressively downdip, when compared with equivalent units west of the Fall Line. This will be apparent in the decreasing coarseness of clastic contents and corresponding increases in the percentages of fine-grained limestones and dolomites present. Dark-colored, silty and shaly phases of these rocks may become more prominent. Unconformities, including period breaks, will be more difficult to distinguish. These lithologic changes are predicted from indications that the embayment will contain transitional groups and general facies changes attendant to a depositional basin environment. It is estimated that the embayment may attain a total thickness of some 18,500 feet of Paleozoic sediments of which about 9000 feet are attributable to Cambro-Ordovician rocks, 1800 feet to Siluro-Devonian-Mississippian rocks and 7700 feet to Pennsylvanian rocks.

For obvious reasons the following stratigraphic discussion must rely considerably for factual data on outcrops and subsurface information obtained from areas as close to the embayment province as possible. Such information is supplemented, wherever feasible, by subsurface data obtained from wells drilled in the embayment. In the preparation of the following section, published material has been relied upon chiefly for descriptions of rock units occurring on the surface and in the subsurface of the

STRATIGRAPHIC CHART
SHOWING
PALEOZOIC FORMATIONS IN NORTHEASTERN ARKANSAS

SYSTEM	SERIES	STAGE	FORMATION	THICKNESS IN FEET*	ESTIMATED THICKNESS IN FEET IN THE SUBSURFACE	DESCRIPTION AND REMARKS
PENNSYLVANIAN	POTTSVILLE		Atoka	0–7000±	0–7000±	Gray to black, coarse- to fine-textured, splintery, finely to coarsely micaceous shale containing siltstone lenses. Gray to tan, fine- to coarse-grained, shaly sandstone with some quartzitic zones. Calcareous material may be present in the shales and sandstones, apparently along bedding planes or as vein filling.
		MORROW GROUP	Bloyd-Hale (Undiff.)		0–725+	
			Upper Shale Member	84–164		**Brown to dark-gray to black fissile shale with beds of gray, sandy limestone and sandstone.
			Sandy Limestone Member	38		Brownish-gray, fossiliferous, shaly, sandy limestone.
			Black Shale Member	46		Brown to black, fissile shale with thin sandy shale beds.
MISSISSIPPIAN	CHESTER		Pitkin	230–250	0–600+	**Gray to black, fossiliferous, finely crystalline limestone beds containing a few thin layers of black shale.
			Fayetteville			
			Black Shale Member	30–55		**Black, platy shale containing fine-grained, black limestone and interbedded layers of black, fissile shale in the upper part.
			Limestone Member	20–40		Brownish- to dark-gray, fine- to coarse-grained, fossiliferous limestone with interbedded black shale. The limestone may be sandy, oolitic, conglomeratic or encrinal.
			Black Shale Member	260–280		Dark-gray to black, fissile shale containing nodules and thin layers of pyrite and pyritized fossils.
			Batesville	62–76	0–510+	These formations are not readily differentiated in the subsurface and are described here as a unit. This unit consists of a sequence of gray, oolitic limestone, black shale, gray to tan, silty shale and black, fossiliferous, silty limestone beds.
			Hindsville	0–12		
	MERAMEC		Ruddell	120–272		
			Moorefield	25–199		
	OSAGE		Boone	102–195	0–450	Brown and brownish-gray to dark-gray or black, dense, angular chert with some white to brownish-gray, granular, shaly limestone. Some pyrite in the upper part of the formation.
			St. Joe	0–100		Thin-bedded, pink to maroon, fossiliferous, coarse to very finely crystalline limestone; has not been identified in the subsurface.
	KINDERHOOK		Unnamed green shale	1–4	0–30	Olive green, slightly silty shale.
			Chattanooga	0–38	0–30	Black to brownish-black, flaky to fissile, bituminous, spore-bearing, slightly pyritic shale.
			Sylamore	2–5	?	Gray, brown or white, fine- to coarse-grained, slightly shaly, angular to sub-rounded, pyritic sandstone. Generally contains dark phosphate pebbles. May be glauconitic.
DEVONIAN	MIDDLE DEVONIAN		Clifty	0–3	?	Gray to blue, compact, sandy limestone with some quartz.
			Penters	0–91	0–100	Brownish-gray to gray, mottled, dense to translucent chert with thin-bedded dolomitic limestone. Some spicular, blebby, gray-blue chert may be present in the upper part of the formation. Downdip the chert may be black.
SILURIAN	NIAGARAN		Lafferty	0–85	0–115	**Red, earthy limestone with beds of red to gray, medium-crystalline to dense limestone containing scattered orange, medium-sized, calcite crystals and crinoid segments. Silicified fossils may occur in basal portions of the formation.
			St. Clair	0–100		Gray to pinkish-white, coarse- to medium-grained, crystalline limestone containing pinkish-white fragments of crinoid columnals.
	LOWER SIL.		Brassfield	0–26		**Light-gray to pinkish-orange, medium- to coarsely crystalline limestone, possibly glauconitic.
ORDOVICIAN	CINCINNATIAN	RICHMOND	Cason	0–23	0–20	Black and gray to green, fissile, calcareous shale with thin-bedded, pyritic, glauconitic, fine-grained sandstone. Phosphatic or ironstone nodules, chert or manganese pellets may be present.
			Fernvale	0–125	0–125	White, with pink tinge, to gray, coarsely crystalline limestone containing pyrite blebs, pink crinoid fragments and pink calcite crystals. The crinoids are characterized by barrel shapes.
	MIDDLE ORDOVICIAN	BLACK RIVER	Kimmswick	0–60	0–275	White, gray or brownish-gray, dense, saccharoidal to medium-crystalline, fossiliferous limestone. May contain a small percentage of white, tan or gray-black chert.
			Plattin	0–240	0–400	Brown to gray, fine-grained, dense limestone with some zones of lithographic stone. The limestones may contain calcite veinlets, pyrite, quartz grains, fossil molds.
	LOWER ORDOVICIAN	BUFFALO RIVER	Rock Levee	0	0–275	Gray to brown, dense, dolomitic limestone.
			Joachim	0–150	0–365+	Gray to brown, fine- to medium-grained, slightly saccharoidal dolomitic limestone with embedded coarse sand grains.
			Dutchtown	0	0–150	Dark-gray to brown, silty, dolomitic limestone.
			St. Peter	0–175	0–175	Frosted, rounded, fine- to coarse-grained sandstone containing minor, granular, sandy, dolomitic zones in which the sand grains are frosted.
			Everton	0–600	0–650+	Gray to brown, dense, very finely crystalline, slightly sandy, dolomite and dolomitic limestone. Beds of St. Peter type sandstone may be found near the top, middle or bottom of the formation.
		UPPER CANADIAN	Black Rock	0–55	0–425±	Dark-gray, fossiliferous, slightly sandy, dolomitic limestone with much brown and tan, translucent chert.
			Smithville	0–65	0–600±	Dark-gray, fine-grained, fossiliferous, clayey limestone.
			Powell	0–200	360–1130	Gray to light-brown, micro- to medium-crystalline dolomite and dolomitic limestone with thin, oolitic chert zones; green, silty shale in the lower part.
			Cotter	500+		Gray, finely crystalline to finely granular dolomite containing much white to milky, translucent, oolitic chert.
			Jefferson City	300–400	300–425	Gray to brown, medium-crystalline dolomite with some gray to white, translucent, smooth and oolitic chert.
			Roubidoux	0	125–250	Dark-gray to black, sandy, oolitic limestone containing much oolitic and smooth, transparent, gray and black chert.
			Gasconade-Van Buren	0	600–900	Black, cherty, clayey limestone.
CAMBRIAN			Eminence	0	600–700	These formations are not readily separable in the subsurface and are treated here as a unit. The unit consists of medium- to coarsely crystalline, light-gray dolomite, free of chert and quartz except in the lower Potosi which becomes increasingly cherty.
			Potosi			
			Derby-Doerun	0	2000±	These formations have not been penetrated in Arkansas.
			Davis			
			Bonneterre			
			Lamotte			

*The thicknesses in this column are of measured outcrop sections at or near the Fall Line with the exception of the Clifty limestone which has been found only in Benton County.

**Formation has not been differentiated in the subsurface; therefore, an outcrop description is given.

Ozark region and the Arkansas Valley. Since it is difficult to acknowledge each individual reference in a discussion such as the following, only those publications used to assist in making a particular point will be cited.

CAMBRIAN SYSTEM

The Lamotte sandstone, Bonneterre, Davis, and Derby-Doerun limestones are not found outcropping in Arkansas nor have any of them been penetrated to date in any wells drilled in the state. However, they are probably not beyond reach of the drill in the northernmost portions of the area included in this report. They are given only a cursory treatment here based on their lithologies as known in Missouri and the general Cincinnati arch area.

Lamotte Sandstone

This formation has achieved a thickness of some 400 feet in the central Missouri Ozark section although it has not been penetrated in the embayment area of that state, or at least not recognizably so. In Missouri the Lamotte consists principally of medium-grained, rounded, frosted, arkosic sand. In the embayment area of northeastern Arkansas this formation might be expected to achieve considerable thickness and to consist principally of silt to coarse sand.

Bonneterre, Davis and Derby-Doerun Limestones

These units will probably be differentiated with difficulty in the embayment in Arkansas. In the Missouri embayment area they aggregate some 700 feet or more of shaly, fine-grained, dark gray-black limestones with infrequent dolomite streaks. Their total thickness in northeastern Arkansas may achieve several thousand feet. Facies changes within this section may occur laterally within relatively short distances. In the normal Ozark section the Bonneterre is a medium-to coarsely crystalline, white to pale-gray dolomite generally free of shale, although streaks of green clays occur with it occasionally. It is relatively sand and silt free. Sand-sized glauconite grains are not uncommon. Glauconite may persist within this unit into the basinal facies in the embayment and render some assistance toward recognition. These limestones probably correlate with lower portions of the Knox dolomite of the Cincinnati arch area.

Potosi-Eminence Dolomites

The Potosi and Eminence formations are treated here as a unit. They are separated with difficulty in the subsurface where no well defined stratigraphic break is in evidence between them.

Distribution: Neither of these formations outcrops in Arkansas. The unit has been encountered in wells north of Township

14 North both in the Paleozoic outcrop area of Arkansas (Independent Oil and Gas Co. No. 1 Banks well, NE¼ NE¼ sec. 6, T. 16N, R. 27W, Madison County) and within the embayment area (Benedum-Trees No. 1 Mack well, SW¼ SW¼ sec. 3, T. 15N, R. 12E, Mississippi County). In both of these wells only the Eminence formation was tentatively identified. The Potosi may or may not be represented.

Thickness: In the Banks well 310 feet of dolomites, in part cherty, designated as Eminence, immediately overlie pre-Cambrian rhyolite. In the Mack well 235 feet of dolomites considered Eminence were penetrated. However, the Mack well bottomed in this formation so that the thickness indicated may not represent the total thickness present in the vicinity of the well. In the normal section of Potosi-Eminence in the central Ozark region, an aggregate thickness of about 500 feet is found. In the embayment area of northeastern Arkansas a total thickness of 600 to 700 feet is predicted for the Potosi-Eminence section.

Character: The Potosi formation in the Missouri section is a crystalline dolomite, generally brown, containing characteristic drusy chert. The Ozark Eminence formation is typically a fine to coarsely crystalline, light-gray dolomite containing only traces of gray, quartzitic chert. This latter formation is somewhat characterized by its low silica content in comparison with the formations both overlying and underlying it. In the Arkansas embayment, or at least in the northern portions, the Potosi-Eminence is expected to conform in general with the above descriptions except that the drusy chert may not be as abundant in the lower (Potosi) section. However, the Potosi-Eminence unit should show relative increases in chert from top to bottom.

Correlation: The Potosi-Eminence sequence may correlate with the Royer dolomite-Signal Mountain limestone section of the Arbuckle group of Oklahoma and with portions of the Knox dolomite of western Tennessee, Mississippi and Alabama.

Productive possibilities: The dolomites in the Potosi-Eminence unit contain in part appreciable intergranular porosity. With other requisite conditions being satisfied, this unit would be a potential oil and gas reservoir.

ORDOVICIAN SYSTEM

LOWER ORDOVICIAN SERIES

Gasconade Dolomite and Van Buren Dolomite (with Gunter basal sandstone member)

Distribution: These formations do not outcrop in Arkansas. Like the Potosi-Eminence, the Gasconade-Van Buren (and Gunter) have been encountered in Arkansas only in wells north of Township

14 North in both the Paleozoic outcrop area and the embayment. Additional drilling southward in these areas will be needed to further define the distribution of these units. To date the Gasconade-Van Buren has been identified in the Independent Oil Co. No. 1 Banks well, sec. 6, T. 16N, R. 27W, Madison County; the Benedum-Trees No. 1 Mack well, sec. 3, T. 15N, R. 12E, Mississippi County; the Town of Marshall No. 3 water well, sec. 25, T. 15N, R. 16W, Searcy County; the Town of Mountain Home No. 3 water well, sec. 8, T. 19N, R. 13W, Baxter County, and the Town of Eureka Springs No. 1 water well, sec. 15, T. 20N, R. 26W, Carroll County.

Thickness: The aggregate thickness of these units ranges from 300 feet in the Banks well to 595 feet in the Mountain Home water well to 905 feet in the Mack well, indicating distinct thickening both toward the east and south. In a normal section in the central Missouri Ozark region these formations total some 300 feet. In the northern portions of the embayment in Arkansas these units may attain a total thickness of 600 to 900 feet.

Character: In the Paleozoic outcrop area of Arkansas the Gasconade-Van Buren section consists of medium-crystalline, white to brown dolomites containing sand lenses, some pyrite and considerable white to gray oolitic chert, the latter being found especially in the lower portions of the section. The Van Buren contains a basal sand member (Gunter sand) which consists of medium to coarse, rounded to subangular, frosted quartz grains. In the western portions of the Paleozoic outcrop area the Gunter is about 40 feet thick; however, it appears to decrease in thickness eastward toward the embayment in which it has not yet been identified. It is possible this sand has been lost in the embayment through a facies change. In general the Gasconade-Van Buren unit in northeastern Arkansas appears to be composed of a series of black, cherty, argillaceous limestones with few or no sands being present. These formations will be separable with difficulty in the embayment.

Correlation: The Gasconade-Van Buren section may correlate with the McKenzie Hill formation of the Arbuckle group in Oklahoma and with portions of the Knox dolomite of western Tennessee, Mississippi and Alabama.

Stratigraphic relations: The Van Buren is unconformable with the underlying Eminence dolomite. The Gasconade lies unconformably on the Van Buren.

Productive possibilities: This unit appears to lack prospects as a potential oil and gas reservoir in the embayment of northeastern Arkansas because of its apparent lack of porosity and poorly developed or absent coarse clastic beds. Chert concentrations, if present in conjunction with the additional requirements for hydrocarbon accumulation, might afford adequate reservoirs, but this condition does not seem likely to occur. Wells drilled in the Paleozoic outcrop area of Arkansas frequently contain traces of asphaltic-type material within the Gasconade-Van Buren unit.

Roubidoux Formation

Distribution: The Roubidoux formation does not outcrop in Arkansas. Its distribution in the subsurface, like that of the Potosi-Eminence and the Gasconade-Van Buren, is unknown because of the scarcity of well control. The Roubidoux has been identified in all of the wells previously mentioned as having penetrated the Gasconade-Van Buren section in Madison, Searcy, Baxter, Carroll and Mississippi Counties.

Thickness: From west to east across the northern portions of the Paleozoic outcrop area and the embayment, the Roubidoux formation is expected to have a thickness ranging between 135 and 190 feet. In northeastern Arkansas the Tennark No. 1 Martin well, sec. 35, T. 14N, R. 3E, Craighead County, encountered some 270 feet of Roubidoux. In the Benedum-Trees No. 1 Mack well, Mississippi County, the formation was 245 feet thick, indicating a thickening toward the south within the embayment. A typical central Missouri section of the Roubidoux formation totals about 125 feet in thickness.

Character: In the subsurface of north Arkansas, west of the Fall Line, the Roubidoux consists essentially of light-colored, cherty and sandy dolomites. The chert ranges in color from white through gray to black. Sand intervals occur in general at the top, near the middle and at the base of the formation. In the lower portions of the formation the chert frequently contains numerous dolomite rhombs. In the embayment the Roubidoux is expected to consist principally of dark-gray to black, sandy, oolitic limestone containing considerable gray to black, oolitic chert. Sandy limestones or limy sandstones will likely be present both in the middle of the formation and at the base, and less frequently near the top of the formation also. A normal Missouri section of the Roubidoux contains more sand than any other pre-St. Peter Ordovician formation. This relative characteristic is presumed to persist into the embayment area of northeastern Arkansas.

Correlation: The Roubidoux formation is tentatively correlated with portions of the McKenzie Hill formation of the Arbuckle group of Oklahoma and with parts of the Knox dolomite of western Tennessee, Mississippi, Kentucky and Alabama.

Stratigraphic relations: The Roubidoux unconformably overlies the Gasconade dolomite and is unconformably overlain by the Jefferson City dolomite.

Productive possibilities: The presence of porous zones in the sands and sandy limestones of the Roubidoux would render this formation a potential reservoir in the embayment. In the Ozark region the formation has well developed porosity in the sand zones, making it a good aquifer. Traces of asphaltic-type material are commonly found within this formation in wells drilled in the Paleozoic outcrop area of Arkansas.

Jefferson City Dolomite

Distribution: The Jefferson City dolomite is the oldest formation recognized in exposures in the State of Arkansas, north of the Arkansas River. In the Paleozoic outcrop area, west of the Fall Line, it has been identified on the surface in Marion, Fulton and Sharp Counties. In the embayment area of northeastern Arkansas it has been identified in wells only as far south as Township 14 North because of limited subsurface control.

Thickness: In the Tennark No. 1 Martin well, sec. 35, T. 14N, R. 3E, Craighead County, a 420-foot section of Jefferson City was tentatively identified between 4400 and 4822 feet by McCracken (1950). In the Benedum-Trees No. 1 Mack well, sec. 3, T. 15N, R. 12E, Mississippi County, a controversy exists concerning the depth and thickness of this formation. Some geologists consider a 345-foot section between 2805 and 3150 feet to be Jefferson City while others favor delimiting the formation between 2920 and 3150 feet and assigning the section between 2805 feet and 2920 feet to the Cotter dolomite. The writer is inclined toward the latter view at present.

Character: In northeastern Arkansas the Jefferson City is a gray to brown, medium-crystalline dolomite containing some gray to white, translucent, smooth chert and oolitic chert. It is not generally known to be fossiliferous although Maher and Lantz (1953) reported the fossil *Archaeoscyphia* in tan, oolitic chert contained in beds of buff, finely to medium-crystalline dolomite occurring at or near the top of the Jefferson City dolomite in the Town of Marshall No. 3 water well, sec. 25, T. 15N, R. 16W, Searcy County. Unlike its exposed counterpart in the Paleozoic outcrop area of Arkansas, the Jefferson City encountered in the embayment to the present time has contained no sands.

Correlation: The Jefferson City is treated as being of (Lower Ordovician) Upper Canadian age and may correlate with the McKenzie Hill formation of the Arbuckle group of Oklahoma and with the Knox dolomite of western Tennessee, Mississippi, Alabama and Kentucky.

Stratigraphic relations: The Jefferson City is reported to lie unconformably on the Roubidoux formation and to be separated from the overlying Cotter dolomite by a disconformity in places.

Productive possibilities: The Jefferson City, in its deeper aspects in the embayment, cannot be ruled out as a potential reservoir although the existence of porous sands or of porosity in the dolomite is conjectural. Wells penetrating this formation west of the Fall Line have encountered frequent traces of asphaltic-type material.

Cotter Dolomite

Distribution: The Cotter dolomite is present in exposures over a considerable area in northern Arkansas, forming most of the surface of the Salem Plateau. Its distribution in the embayment is not known since it has been identified in only one well, the Tennark No. 1 Martin, Craighead County.

Thickness: The thickness of the Cotter in the embayment is unknown, since it was not separable with assurance from the overlying Powell dolomite in the Martin well. In some of its exposures in the Paleozoic outcrop area, the Cotter dolomite achieves a thickness slightly in excess of 500 feet. In the embayment area it may reach a thickness of some 700 feet. A combined thickness ranging between 360 and 1130 feet has been presumed for the Powell and Cotter dolomites in the embayment.

Character: In the subsurface both west and east of the Fall Line, the Cotter has been found as a buff to gray, finely crystalline to finely granular dolomite containing considerable white to milky, translucent to dense, oolitic chert. Both dolomite rhombs and small, well developed, cubic pyrite crystals are found in association with the chert at various levels within the formation. The Cotter is generally thought of as being unfossiliferous, but a few characteristic fauna have been found. *Cryptozoon* reefing may be found sporadically in the Cotter and underlying Ordovician dolomites. The distinctive types of oolitic cherts in this formation are of considerable stratigraphic value, since such cherts are not found in relative abundance either in the overlying Powell or the underlying Jefferson City. In the area of outcrop west of the Fall Line, the Cotter contains two types of dolomite which are found principally as alternating beds. One type exhibits definite crystalline structure while the other is an argillaceous, fine-grained "cotton rock". The latter weathers to a light-colored, soft, chalky material. Nodular chert is characteristic of the Cotter on the outcrop with some of the chert exhibiting remarkably developed banding.

Correlation: The Cotter dolomite is correlated tentatively with upper portions of the Arbuckle group of Oklahoma and the Knox dolomite of western Tennessee, Mississippi, Alabama and Kentucky.

Stratigraphic relations: Although the Cotter is distinguished from the underlying Jefferson City dolomite with difficulty in many places, it has been found to rest disconformably on the Jefferson City in some areas of exposure and is overlain disconformably by the Powell dolomite.

Productive possibilities: The Cotter, in its down dip facies, may be a potential reservoir if porosity is found to be adequately developed.

Powell Dolomite

Distribution: The Powell dolomite is widely exposed over the Salem Plateau area of northern Arkansas. Like the Cotter, the distribution of the Powell in the embayment is unknown, since it has been tentatively identified in only one well, the Tennark No. 1 Martin in Craighead County.

Thickness: A maximum thickness estimated at 400 feet is inferred for the Powell in the embayment area. This is some 200 feet thicker than the occurrences of Powell found in wells drilled west of the Fall Line and in the areas of exposure of the formation. The Powell and Cotter are not expected to be readily separable in the embayment area.

Character: In the embayment the Powell is composed of a gray to light-brown, micro-to medium-crystalline dolomite and dolomitic limestone with thin oolitic cherts. A small amount of green, silty shale has been found in the lower portions of the formation. The type of oolitic chert in the Powell is significant since it has not been found occurring in younger formations in northeastern Arkansas.

Correlation: On the basis of its small faunal assemblage the Powell dolomite is correlated with the upper part of the Beekmantown of the New York section. The Powell is also correlated with the upper part of the Arbuckle group of Oklahoma. It is tentatively considered here to be the youngest formation of the Ozark facies in Arkansas' equivalent to the Knox dolomite of western Tennessee, Mississippi, Alabama and Kentucky.

Stratigraphic relations: In its various areas of exposure the Powell has been found to rest disconformably upon the Cotter dolomite. In certain of its exposures the Powell is unconformably overlain either by the Smithville-Black Rock-Everton formations, the St. Peter sandstone, or the Chattanooga shale.

Productive possibilities: The potentialities of this formation as an oil and gas reservoir in the embayment are inferred to be considerably less than those of the older Ordovician dolomites underlying it. Porosity is expected to be poorly developed. Deeper in the embayment the Powell is expected to become progressively more argillaceous.

Smithville Limestone

Distribution: In Arkansas this limestone has been tentatively identified in surface exposures in Lawrence, Randolph and Sharp Counties only. The trend of its outcrop is noteworthy in relation to the trends of outcropping formations younger than and including St. Peter-Everton and older than Powell in these counties, since the Smithville outcrop lies approximately at right angles to outcrops of these other formations.

Thickness: The Smithville is considered here to have an approximate thickness of 65 feet on the outcrop, although it has been estimated by some geologists previously as being up to 200 feet thick in part of its exposures. In general its thickness and distribution in the embayment are unknown. A 600-foot section of limestone encountered approximately between 2668 and 3269 feet in the Tennark No. 1 Martin well, sec. 35, T. 14N, R. 3E, Craighead County, has been tentatively identified as Smithville (McCracken, 1950).

Character: In the embayment in northeastern Arkansas the so-called Smithville is a dark-gray, fine-grained, argillaceous limestone in which a moderate representation of silicified bryozoa has been found. On the outcrop the Smithville is principally a fine-grained, gray, magnesian limestone or dolomite, weathering to a drab or white color, containing graptolites and a considerable number of cephalopods and gastropods. The Smithville and the overlying Black Rock limestone are distinguishable with difficulty on the outcrop, and it is possible that in the embayment they cannot be separated on the basis of lithology alone.

Correlation: As discussed previously in this report some geologists consider the Smithville to be a facies of the Everton formation while others consider it to be of post-Powell, pre-Everton age. The writer reiterates his opinion, given elsewhere in this report, that the Smithville is of Chazy age and is equivalent to older beds in the Everton formation.

Stratigraphic relations: It is not known what stratigraphic relationship occurs between the Smithville and the underlying Powell. However, if the Powell marks the end of deposition of beds equivalent to the Knox dolomite, it is assumed here that the Powell-Smithville contact may be marked by an unconformity.

Productive possibilities: Relatively low porosity is indicated for the Smithville in deeper portions of the embayment, lessening its potentialities as a possible reservoir.

Black Rock Limestone

Distribution: In Arkansas the Black Rock limestone has been found outcropping only in Independence, Lawrence, Randolph and Sharp Counties. Like the Smithville, its subsurface distribution is unknown since it has been tentatively identified in only one well, the Tennark No. 1 Martin, Craighead County. The surface exposures of the Black Rock are found to parallel those of the Smithville and Powell.

Thickness: On the outcrop the Black Rock has a thickness of approximately 55 feet, although it has previously been considered by some geologists to reach a thickness of some 200 feet in its exposures. In the Martin well a 425-foot section penetrated between 2243 and 2668 feet has been tentatively identified as Black Rock (McCracken, 1950). In general the Smithville and Black Rock may have to be treated as a unit in the deeper parts of the embayment since a stratigraphic break between them, if present, will probably be very difficult to detect.

Character: In the embayment the Black Rock limestone is tentatively described as a dark-gray, fossiliferous, slightly sandy, dolomitic limestone containing considerable brown and tan translucent chert and fragments of sponge spicules and brachiopods.

Correlation: The Black Rock, like the Smithville, is variously considered to be either a facies of the Everton or a limestone of post-Powell, pre-Everton age. The writer is of the opinion that the Black Rock is of Chazy age and is equivalent to beds within the Everton formation.

Stratigraphic relations: It is not known whether the Black Rock overlies the Smithville conformably or disconformably in the embayment.

Productive possibilities: The development of zones of adequate porosity in this formation, in the deeper portions of the embayment, does not appear to be indicated from the few data available.

Everton Formation

Distribution: The Everton formation is exposed throughout the Salem Plateau of north central Arkansas. It has been identified in a number of wells north of Township 9 North, in the embayment. Since the Everton has been identified definitely in wells west of the Fall Line, in the Paleozoic outcrop area, south of Township 9 North, it is inferred that the formation has a considerable extent southward in the embayment also.

Thickness: The Everton ranges upward to 600 feet in thickness in its areas of exposure. In the embayment a maximum thickness of 650 feet or more appears likely. West of the Fall Line, the Cosden Oil Co. No. 1 Shackleford well, sec. 13, T.,9N, R. 19W, Pope County, penetrated some 622 feet of Everton.

Character: The Everton consists essentially of gray to brown, dense, very finely crystalline, slightly sandy dolomites and dolomitic limestones. St. Peter type, rounded, frosted quartz grains are frequently found embedded in the dolomite and are referred to as "floating" sand grains. Beds of St. Peter type sandstone may be found near the top, middle or bottom of the formation. The Calico Rock sandstone, as exposed in eastern and southern

Baxter County, northern Stone County, and eastward in Izard, western Fulton and western Sharp Counties, lies in the lower part of the Everton formation, according to Giles (1930, p.115) and is separated from the St. Peter sandstone by an interval that varies rapidly within short distances. The interval between the St. Peter and Calico Rock sandstones on the outcrop contains beds of massive, white, coarse-grained sandstone alternating with massive to thin, gray to blue magnesian beds. The sandstone layers are indistinguishable from the St. Peter and Calico Rock sandstones. In measured outcrops the Calico Rock varies from a feather edge to 150 feet in thickness. In Izard, Fulton, and Sharp Counties it averages about 100 feet.

Some controversy exists as to the delimiting of the Everton formation and the St. Peter sandstone in the Deep Rock Oil Co. No. 1 Sample well, sec. 4, T. 10N, R. 6W, White County, west of the Fall Line. The top of the St. Peter has been picked, from the well samples, at 3510 feet, at which depth gray to white, coarse-grained, rounded, frosted quartz sand grains were encountered. This sand was assumed to persist to 3540 feet, although well samples were not available from the last 14 feet of the interval. From 3540 feet to an estimated 3630 feet the column consists essentially of dolomite, in part sucrosic and sandy. This dolomitic section overlies some 40 feet of white, finely crystalline sandstone which terminates at 3670 feet. The interval from 3670 feet to the total well depth of 5073 feet is occupied by dolomites and limestones. Some geologists, including the writer, favor placing the lower limit of demarcation of the St. Peter sandstone at 3670 feet, assigning the latter depth as the top of the Everton, while others favor designating 3640 feet as the base of the St. Peter and the top of the Everton, considering therefore that the sands below 3640 feet are part of the Everton formation. The Everton formation exhibits appreciable changes in lithology from west to east in the subsurface of the Paleozoic outcrop area, west of the Fall Line, and it is inferred that it may show more pronounced facies changes in the embayment, indicative of basinal deposition.

Correlation: On the basis of its faunal assemblage, Purdue and Miser (1916, p.6) state that the Everton is Lower Ordovician, of post-Beekmantown and pre-Chazy age. Dott (1941, p.1639), however, refers to the Everton as being of Chazy age. The writer, in previous discussions within this report concerning the tentative ages and correlations of the Black Rock, Smithville, and Everton formations, classified the Everton in accordance with Dott's designation, although Dott's (1939, p.1639) Beekmantown age designations for the Black Rock and Smithville are not used.

The Everton may correlate with lower beds of the Simpson group of the Wichita-Arbuckle Mountains.

Stratigraphic relations: In certain of its exposures west of the Fall Line the Everton overlies the Powell unconformably, and a basal breccia is present. In well samples, however, this relationship is obscure, and the Everton and Powell appear to be separable only by a change from sandy dolomites (Everton) to shaly or silty dolomites (Powell).

Productive possibilities: The Everton contains both sands and sandy dolomites susceptible to the development of porosity, in which event suitable reservoir conditions for oil or gas accumulation might exist. However, in accordance with subsurface evidence, the Everton appears to contain less coarse clastic material both toward the east and the south in the region west of the Fall Line. If this condition follows into the embayment, as it likely does, the chances of the Everton being a prospective reservoir may be lessened considerably.

St. Peter Sandstone

Distribution: The St. Peter sandstone is generally exposed throughout the northern counties in Arkansas, from Range 18 west to the Fall Line. Only one well in the embayment, the Arkansas Oil Ventures (Deardorf) No. 1 Doggett, sec. 31, T. 10N, R. 3W, Jackson County, has encountered beds tentatively identified as St. Peter (see Plate IX). However, the Ramsey Petroleum Company No. 1 Poinsett Lumber Co., sec. 35, T. 9N, R. 4E, Cross County, may have been less than 200 feet above the St. Peter sandstone at its abandonment depth of 3512 feet. West of the Fall Line, in the Lion Oil Company No. 1 Nalley well, sec. 33, T. 8N, R. 7W, White County, the St. Peter is possibly absent either through faulting or truncation. Some geologists are of the opinion that the Nalley well lost the entire interval between the Boone formation and pre-St. Peter Ordovician beds by erosion. However, the extensive differential movement required to accomplish such erosion would be difficult to justify. Since pre-Boone, post St. Peter formations such as the Plattin appear to be identifiable in this well, the disappearance of the St. Peter by truncation could be accomplished as the result of differential uplift either at the end of St. Peter or Joachim deposition. The possibility also exists that the St. Peter is represented in this well by a sandy limestone or dolomite, since facies changes in the St. Peter may occur in proceeding from the Paleozoic outcrop area west of the Fall Line toward and into the embayment. The St. Peter has been identified in most of the deep wells drilled in the Arkansas Valley. Immediately west of the Fall Line, in the Killam and McMillan No. 1 Curl well, sec. 10, T. 9N, R. 5W, White County, the St. Peter was tentatively identified, although no line of demarcation was readily distinguishable between the Joachim and St. Peter formations in the well.

Thickness: The St. Peter varies in thickness in its exposures in the Arkansas Valley through differential erosion. In the subsurface of the Arkansas Valley some thickening of the St. Peter is noted toward the southeast. Based on projections into the embayment, it is inferred that the St. Peter may achieve a maximum thickness of some 175 feet in northeastern Arkansas, although it is not possible to predict what percentage of such thickness would consist of beds of the typical sands.

Character: On the outcrop in Arkansas the St. Peter is a fine-to medium-grained, white sandstone made up principally of well rounded, frosted, quartz grains. Thin beds of gray to green sandy shale and gray sandy dolomite may be present. In the subsurface the porosity of the sandstone varies in accordance with the relative presence of dolomitic cement or secondary silicification. An increase in sand grain size may occur both in the upper and lower parts of the St. Peter.

Correlation: The St. Peter sandstone of Arkansas has been correlated with the St. Peter of Missouri, Illinois, Iowa, Minnesota and other Mississippi Valley states. It is also correlated with the Burgen sandstone of northeastern Oklahoma which Cram (1930) believed may be equivalent to part of the Oil Creek fromation of the Simpson group. According to Dott (1941, p.1640), the "Wilcox" sand, which is the most important economic unit of the Ordovician in Oklahoma because of its high yields of oil per acre, belongs to the Simpson group. He states that the "Wilcox" sands in different producing areas may be of different ages; consequently, correlation of the St. Peter and the so-called "true Wilcox" sand of Oklahoma cannot be made definitely at this time.

Stratigraphic relations: There has been considerable disagreement concerning the stratigraphic relationships of the St. Peter-Everton sequence in northern Arkansas. Dake (1921, p.24) considered a major unconformity to be present at the base of the Everton rather than at the base of the St. Peter. Ulrich (1911) considered the contact between the two formations as being gradational. Glick and Frezon (1953, p.6) noted an apparent unconformity between the St. Peter and the Everton in northeastern Newton and northern Searcy Counties. Wells in the Arkansas Valley which encountered both St. Peter and Everton beds indicated an unconformable relationship between them. The stratigraphic relations of these formations are unknown in the embayment, but unconformities present will possibly be difficult to detect.

Productive possibilities: Based on a study of porosity in twelve samples from Ordovician sandstones of Arkansas, Giles (1932, p.100) indicated that the St. Peter has a porosity ranging between 3.6 and 17.8 percent. This would result in an average porosity of 10.7 percent. Considering the lack of knowledge regarding the subsurface distribution, thickness and stratigraphic relations of this formation it is difficult to make a valid estimate concerning its reservoir potentialities. In a study of four gas fields near Kansas City, Missouri, Bartle's (1941) calculations of the space required for the gas indicated that the effective porosities for these fields varies between 7 and 18 percent. In North Texas, Pennsylvania and other areas, sands with porosities as low as 7 percent have produced oil, although this may be approaching the lower limit of porosity for oil production unless fracturing is present. If a sandstone has not lost too much effective porosity through cementation, a fracture system may greatly enhance its capabilities as a reservoir without such fractures being readily apparent from cores or well samples. Finn (1949) considered that the permeability of the Oriskany sandstone in Pennsylvania and New York was aided in numerous producing areas by the occurrence of small, open fractures or slightly open joint planes and that such fracturing or jointing may have been responsible for the large open flows and high productive capacity of this sandstone. According to Torrey (1935, p.949), some gas bearing portions of the Oriskany sandstone have porosities ranging between 9 and 11 percent, which is equivalent to Giles' average for the St. Peter.

In the Arkansas Valley, the Deep Rock No. 1 Sample well, sec. 4, T. 10N, R. 6W, White County, drill-stem tested an interval from 3512 to 3574 feet which includes the St. Peter section in the well and possibly extends some 34 feet into the Everton formation depending on the placement of the Everton top. According to data on file with the Arkansas Division of Geology, this four hour test recovered an estimated 50 to 100 Mcf of gas and 105 feet of gas-cut mud. The gas is reported to have been non-inflammable.

Until ruled out by comprehensive data to the contrary, the St. Peter sandstone should be considered one of the more prospective Paleozoic producing formations in the embayment.

Dutchtown Limestone

Distribution: The Dutchtown limestone is not exposed in Arkansas and has been tentatively identified in only one well, the Manning and Martin No. 1 Park-Gieseck, sec. 4, T. 6N, R. 5E, Cross County, in the embayment. This formation has not been identified in any wells drilled in the Arkansas Valley. In the embayment the Dutchtown will probably be encountered only at a considerable distance down the flank of the Ozark uplift as a southward-thickening wedge between the overlying Joachim and the underlying St. Peter.

Thickness: The formation tentatively identified as Dutchtown in the Park-Gieseck well was encountered at approximately

4335 feet. However, the well, upon abandonment at 4452 feet, was apparently still in the Dutchtown so that no actual thickness can be given for the formation. Based on this 117-foot section, it is estimated that a maximum of 150 feet of Dutchtown may be encountered in the deeper portions of the embayment.

Character: This formation is a dark-gray to brown, silty, dolomitic limestone.

Stratigraphic relations: The Dutchtown will probably appear to be conformable with the underlying St. Peter sandstone and overlying Joachim dolomite, especially in the deeper portions of the embayment. (See Grohskopf, 1948.)

Productive possibilities: It is assumed that this formation will be too impermeable to act as a reservoir.

Joachim Limestone

Distribution: The Joachim limestone is absent in the western part of the Paleozoic outcrop area, but it is exposed from Newton County eastward to Lawrence County where its maximum outcrop thickness is achieved. Its distribution in the embayment and in the subsurface of the Arkansas Valley, west of the Fall Line, is unknown.

Thickness: In its exposures the Joachim ranges in thickness from a few feet in the westerly portions of the state to about 150 feet in Lawrence County. In Independence County it achieves a thickness of some 100 feet. The Deep Rock No. 1 Sample well, sec. 4, T. 10N, R. 6W, White County, penetrated a 115-foot section of gray to tan, very fine grained dolomite, in part sandy, from 3395 to 3510 feet, tentatively identified as Joachim. The Killam and McMillan No. 1 Curl well, section 10, T. 9N, R. 5W, White County, encountered a 60-foot section of light-colored limestones and dolomites, in part sandy, from 3905 to 3965 feet, assigned to the Joachim. In the embayment the Arkansas Oil Ventures (Deardorf) No. 1 Doggett, sec. 31, T. 10N, R. 3W, Jackson County, penetrated 96 feet of white to brown, medium-crystalline, saccharoidal limestone, highly pyritiferous in part, from 2542 to 2638 feet, considered to be Joachim. In the Manning and Martin No. 1 Park-Gieseck well, sec. 4, T. 6N, R. 5E, Cross County, a 365-foot section of fine-grained dolomitic limestone occupying the interval between 3970 and 4335 feet was tentatively identified as a thickened Joachim facies. On the basis of these data, it is assumed that the Joachim will have a maximum thickness in excess of 365 feet in the embayment.

Character: The Joachim is a gray to brown, fine-to medium-grained, saccharoidal (in some occurrences), dolomitic limestone containing embedded rounded, frosted quartz grains of the St. Peter sandstone type. Thin zones of dolomitic sandstones, and occasionally lithographic limestones, may be found interbedded with the dolomites and sandy dolomites in the Joachim section. Insoluble residues may show light-colored silts, small clusters of pyrite crystals and a few percent of the St. Peter type sand grains. The Joachim and the Everton may be mistaken for each other in the subsurface, especially where the normal stratigraphic succession is not present to aid in identification. These circumstances might be encountered under conditions such as shown on Plate IV where the belt of rocks marked Everton may also include St. Peter or Joachim beds. In the case illustrated, if the St. Peter is absent but the Joachim is present, it would be difficult to tell whether Joachim or Everton beds were being encountered immediately beneath the Cretaceous sediments present in the well. This problem has been encountered in the Tennark No. 1 Martin well, sec. 35, T. 14N, R. 3E, Craighead County.

Correlation: The Joachim has not been correlated definitely with the standard section. It represents the lower portion of the old Izard limestone and may be found eventually to be equivalent to the upper portion of the Simpson group of the Wichita-Arbuckle Mountains.

Stratigraphic relations: The Joachim is gradational into the underlying St. Peter. In the deeper portions of the embayment they will probably appear as conformable formations.

Productive possibilities: Both the crystalline dolomitic and the sandy phases of this formation have potentialities as reservoir beds if porosity and permeability are adequately developed. In the Fitzpatrick No. 1 Pryor well, sec. 32, T. 13N, R. 6W, Independence County, vuggy porosity was in evidence in the lower, sandy dolomite beds appearing as leaching between the embedded sand grains. Asphaltic-like material was found in some of these pores. Downdip in the embayment the Joachim may become increasingly argillaceous, in which case it will be less attractive as a possible reservoir.

Rock Levee Limestone

Distribution: This formation has not been identified in wells drilled west of the Fall Line nor does it outcrop at any place in the state of Arkansas. It has been tentatively considered to be present in the Manning and Martin No. 1 Park-Gieseck well, sec. 4, T. 6N, R. 5E, Cross County, as the lower portion of a 694-foot section of dense, gray to brown, dolomitic limestone occurring between 3276 and 3970 feet. The upper portion of this section is assumed to be a basinal facies of the Plattin limestone.

Thickness: The Rock Levee is estimated to attain a maximum thickness of about 275 feet in the embayment.

Character: This is a dense, gray to brown, dolomitic limestone which will probably contain considerable argillaceous material in its areas of deeper development.

Stratigraphic relations: The formation probably will appear to be conformable with the underlying Joachim and the overlying Plattin downdip in the embayment. (See Grohskopf, 1948.)

Productive possibilities: It is assumed that this formation will be too impermeable to act as a reservoir.

MIDDLE ORDOVICIAN SERIES

Plattin Limestone

Distribution: The Plattin limestone is widely exposed in the Salem Plateau of northern Arkansas, being found over a large area in Stone, Izard, Sharp, Searcy and Independence Counties. West of the eastern part of Newton County it is absent. In the embayment the Plattin may generally be expected to occur south of the northern boundary of the area marked "Plattin" on Plate IV. Within this area, the formation is assumed to be found immediately beneath the oldest Cretaceous sediments present, except in the area indicated as containing a possible fault.

Thickness: The Plattin reaches a maximum thickness of about 240 feet on the outcrop. Wells drilled into or through the Plattin both west and east of the Fall Line indicate that the formation thickens from west to east and from north to south, giving as a resultant a general thickening toward the southeast from the Paleozoic outcrop area into the embayment. In the Lion Oil No. 1 Nalley well, sec. 33, T. 8N, R. 7W, White County, the Plattin is about 235 feet thick. In the Stanolind Oil and Gas No. 1 Brinkman well, sec. 6, T. 10N, R. 20W, Pope County, it is only 60 feet thick. About 210 feet and 240 feet, respectively, were found in the Fitzpatrick No. 1 Pryor well, sec. 32, T. 13N, R. 6W, Independence County, and the Killam and McMillan No. 1 Curl well, sec. 10, T. 9N, R. 5W, White County.

Approximately 192 feet of Plattin were found in the Arkansas Oil Ventures No. 1 Doggett well, sec. 31, T. 10N, R. 3W, Jackson County, and some 310 feet were penetrated in the Deep Rock No. 1 Sample well, sec. 4, T. 10N, R. 6W, White County. The thickest Plattin section encountered to this time has been tentatively identified in the Manning and Martin No. 1 Park-Gieseck well, sec. 4, T. 6N, R. 5E, Cross County, where a development slightly in excess of 400 feet is indicated for the formation. Since data are not available from wells further downdip in the embayment, a maximum thickness of 400 feet has been assigned tentatively to the Plattin in northeastern Arkansas.

Character: The Plattin is a gray to buff, fine-grained, dense, limestone containing small veins of calcite and occasional pyrite crystals. In some occurrences the limestone has a lithographic texture. Thin beds of dolomitic limestone or shaly dolomite may be present in the formation. In the deeper portions of the embayment the Plattin will probably become more argillaceous and contain fewer limestone beds which approach lithographic quality.

Correlation: The Plattin comprises the upper portion of the formation known previously in Arkansas as the Izard limestone. The Plattin of Arkansas is correlated with the Plattin of Missouri and may be equivalent to the Bromide formation of the Simpson group and to the Platteville formation of the upper Mississippi Valley.

Stratigraphic relations: The Plattin overlies the Joachim unconformably west of the Fall Line. Updip in the embayment the Plattin is probably unconformable on the Rock Levee where that formation is present as a southward thickening wedge between the Plattin and the Joachim. Where the Rock Levee is absent, the Plattin probably overlies the Joachim unconformably. In wells in the deeper portions of the embayment, where Plattin, Rock Levee, Joachim and Dutchtown may all be present, these formations are likely to appear in conformable relationship making them almost inseparable in the section.

Productive possibilities: Downdip in the embayment the porosity of the commonly dense Plattin limestone may be enhanced by facies changes resulting in the development of more granular textures. However, there will probably be an increase in argillaceous material in the deeper areas so that the net result will still be a low effective porosity. Consequently, the possibilities for production from the Plattin do not appear to be promising.

Kimmswick Limestone

Distribution: This formation is exposed chiefly in Izard, Stone and Independence Counties. It is not known to outcrop west of Searcy County. The distribution of the Kimmswick in the embayment is not known. In the subsurface of the Arkansas Valley, west of the Fall Line, the Kimmswick has not definitely been identified; however, beds of dark-gray to black, slightly shaly, finely to medium-crystalline limestone containing dark gray to black chert, which overlie the Plattin limestone in several wells drilled in Franklin, Johnson, Pope and White Counties, have been considered by Maher and Lantz (1953) as being of possible Kimmswick age.

Thickness: The Kimmswick has a maximum thickness of about 60 feet on the outcrop. In the Fitzpatrick No. 1 Pryor well, Independence County, 50 feet of Kimmswick are present. An estimated 70 feet of Kimmswick were found in the Deep Rock No. 1

Sample well, White County. The Jones No. 1 Norris well, Independence County, penetrated about 20 feet of Kimmswick but bottomed in the formation so that a total thickness was not available. However, this well is located far enough up the flank of the Ozark uplift to expect the presence of a relatively thin section of Kimmswick through truncation or pinchout of the formation.

The Lion No. 1 Nalley well, White County, tentatively contains some 135 feet of Kimmswick. The absence or presence of the Kimmswick in the Arkansas Oil Ventures No. 1 Doggett well, Jackson County, has been the subject of considerable controversy, since the stratigraphic sequence in this well may offer important clues in regard to structural and depositional relationships between the areas west and east of the Fall Line. A 195-foot section of white, fine-grained limestone and gray to white chert, between 2155 and 2350 feet in the Doggett well, has been tentatively assigned by the writer to the Kimmswick. In consequence of such assignment it may be noted in the well (see Plate IX) that the Kimmswick immediately underlies black shales of undifferentiated Morrow and Mississippian ages, indicating the loss of the entire interval normally occupied by rocks ranging in age from Fernvale through Boone.

In the Killam and McMillan No. 1 Curl well, White County, the Kimmswick is considered to be represented by a 110-foot section of cherty limestone occurring between 3565 and 3675 feet. Based on projections from the data indicated, a maximum thickness of 275 feet is inferred for the Kimmswick in the embayment. An isopachous map of this formation based on the aforementioned wells, shows marked thinning toward the northwest from the embayment into the Arkansas Valley.

Character: This formation is a white, gray or brownish gray, fine to medium-crystalline, in part saccharoidal, fossiliferous limestone which may contain a small percentage of white, tan or gray-black chert. In the deeper portions of the embayment the Kimmswick may be separable with difficulty from the underlying Plattin limestone. The relative chert content of the Kimmswick may increase downdip in the embayment.

Correlation: The Kimmswick has been correlated with the lower division (Trenton) of the Viola limestone occurring in the Wichita-Arbuckle Mountains.

Stratigraphic relations: This formation appears to be conformable and gradational with the underlying Plattin limestone. It is overlain by the Fernvale limestone, possibly unconformably.

Productive possibilities: The Kimmswick offers fair possibilities for production if adequate porosity and permeability are present. A small oil producer was recently completed in the Kimmswick near St. Louis, Missouri by the Laclede Gas Company.

UPPER ORDOVICIAN SERIES

Fernvale Limestone

Distribution: The Fernvale is widely exposed in the Salem Plateau of northern Arkansas, being found on the surface in Izard, Stone and Independence Counties. West of Jasper, in Newton County, it has not been found exposed. On the outcrop the Fernvale ranges up to about 125 feet in thickness, with the thickest exposures being found eastward in the Arkansas Valley, near the Fall Line. The distribution of this limestone in the embayment is unknown. It has been tentatively identified in the Jones No. 1 Norris, sec. 17, T. 12N, R. 4W, Independence County. The correlative Fernvale formation of western Tennessee has been found outcropping in the northern part of Hardin County, Tennessee, where it is composed of an upper green shale member and a lower light gray, coarsely crystalline limestone member which aggregate 20 to 40 feet in thickness. The occurrence of this formation in Tennessee, in a facies at least in part identifiable with that of the Fernvale of the Arkansas Valley, indicates the probable presence of the Fernvale within the embayment. The absence of this limestone in the Arkansas Oil Ventures No. 1 Doggett well, Jackson County, suggests that the Fernvale distribution in the embayment will be sporadic, at least in the northern portions, possibly because of pre-Chattanooga beveling of the area.

Thickness: To the present time the thickest section tentatively identified in the subsurface as Fernvale, both west and east of the Fall Line, has been penetrated in the Lion Oil No. 1 Nalley well, White County, where some 85 feet were encountered. In the Jones No. 1 Norris well, the Fernvale may achieve a maximum thickness of 40 feet, in the interval between 610 and 650 feet, although the lower 10 feet of this section may be of Kimmswick age. It is estimated that the Fernvale may reach a maximum thickness of 125 feet in the embayment.

Character: The Fernvale is a gray to white with a pinkish tinge, coarsely crystalline limestone containing blebby pyrite, pink calcite crystals and pink crinoid fragments, the latter being characterized in certain instances by segments which are barrel shaped.

Correlation: The Fernvale is correlated with the Richmond of the Mississippi Valley section. It is commonly referred to as Viola limestone, although it overlies the Viola in the Wichita-Arbuckle Mountain region.

Stratigraphic relations: The Fernvale is possibly unconformable on the Kimmswick. Where the latter has been removed by erosion the Fernvale overlies the Plattin unconformably. The Fernvale is unconformably overlain by the Cason shale.

Productive possibilities: The Fernvale may have considerable possibilities as a prospective reservoir in the embayment. If the coarse texture characteristic of this limestone west of the Fall Line continues in the embayment, appreciable intergranular porosity might be found. This condition, in conjunction with the development of traps through structural adjustments or pre-Chattanooga beveling, might be conducive to the accumulation of oil or gas. The Fernvale is a producing formation in Kansas and Oklahoma.

Cason Shale

Distribution: Small outcrops of the Cason have been found in the southern part of the Salem Plateau, principally in Izard, Stone and Independence Counties. In the subsurface of the Arkansas Valley it has been found as far east as White County. The Cason has been tentatively identified in only one well in the embayment, the Jones No. 1 Norris, Independence County, to the present time.

Thickness: The Cason on the outcrop has been found in thicknesses up to about 23 feet. In the subsurface of the Arkansas Valley the maximum thickness of Cason encountered to this time occurs in the Arkansas-Louisiana Gas Company No. 1 Barton well, sec. 27, T. 9N, R. 28W, Franklin County, where 46 feet of the formation were present. In the above mentioned Norris well, a possible 10 feet of Cason were found. A maximum Cason thickness of 20 feet is estimated for the embayment.

Character: The Cason consists of black and gray-green, fissile, calcareous shale containing pyrite and possibly phosphatic nodules, chert, ironstone nodules or manganese pellets. Thin-bedded, pyritic, glauconitic, fine-grained sandstone may be present. The 10-foot section tentatively assigned to the Cason in the Norris well is occupied by a sand of the above description. In the Town of Marshall No. 3 water well, sec. 25, T. 15N, R. 16W, Searcy County, the upper one foot of the 14 feet of Cason identified in the well consists of very fine grained, gray-green, pyritic, glauconitic, slightly limy sandstone. The Cason may serve as an excellent marker bed because of its variegated components, in contrast with the formations generally confining it.

Correlation: The Cason is the youngest Ordovician formation present in northeastern Arkansas. It is correlated with the Sylvan shale of the Wichita-Arbuckle Mountains and is the equivalent, or partial equivalent, of the Maquoketa shale of northeastern Iowa, Illinois and Missouri.

Stratigraphic relations: The Cason lies unconformably on the Fernvale limestone and is unconformably overlain by the Brassfield limestone, where the latter is present.

Productive possibilities: This formation is not considered favorably as a possible reservoir.

SILURIAN SYSTEM

Brassfield Limestone

Distribution: The distribution of the Brassfield in the embayment is unknown since it has not been identified in any wells drilled therein. This limestone has been found only in a few exposures in Searcy County. In Independence County, northeast of Cushman, fossils found in a residual clay indicate the former presence of the Brassfield in that area. It is presumed to be present in portions of the embayment in view of the fact that the Brassfield found in southeastern Missouri and southwestern Tennessee have been correlated with the Brassfield occurring west of the Fall Line in Arkansas.

Thickness: Where it is exposed in the Paleozoic outcrop area of the state, the Brassfield ranges in thickness from a feather edge to 26 feet. Its thickness in the embayment, if represented there, is not known at this time. The Arkansas-Louisiana Gas Company No. 1 Barton well, sec. 27, T. 9N, R. 28W, Franklin County, penetrated 42 feet of Brassfield.

Character: In its exposures the Brassfield is a light-gray to pinkish-orange, medium-to coarsely crystalline limestone containing irregular vugs of white or colorless, crystalline limestone. Blue-green glauconite grains are considered characteristic of this limestone. The Brassfield is abundantly fossiliferous in some of its exposures. On the outcrop it resembles the Fernvale and the St. Clair limestones, but the Brassfield generally contains fewer large crystals than the former and a larger percentage of calcite fragments than the latter. If present in the embayment the formation will probably be a gray, glauconitic limestone.

Correlation: On the basis of fossil evidence the Brassfield is correlated with the formation of the same name in Kentucky. It is correlated also with the Brassfield of southeastern Missouri and central southwestern Tennessee and is equivalent, or partially equivalent, to the Chimneyhill formation of the Hunton group in the Arbuckle Mountain region.

Stratigraphic relations: In its exposures the Brassfield rests unconformably on the Cason shale. It is variously overlain, unconformably, by the St. Clair limestone or younger beds.

Productive possibilities: If present in the embayment the Brassfield might have sufficient porosity and permeability to act as a reservoir. However, if the areal extent and thickness of this formation west of the Fall Line are indicative of conditions in the embayment, the Brassfield cannot be very highly regarded as a potential producing formation.

St. Clair Limestone

Distribution: Outcrops of the St. Clair are of small areal extent in the state. It is exposed in portions of Izard, Stone, Searcy and Independence Counties. The subsurface distribution of this formation in the embayment is unknown, but its presence in the Fitzpatrick No. 1 Pryor well, sec. 32, T. 13N, R. 6W, Independence County, and the Deep Rock No. 1 Sample well, sec. 4, T. 10N, R. 6W, White County, only a few miles west of the Fall Line, indicate its probable presence in the embayment.

Thickness: On the outcrop the St. Clair reaches a maximum thickness of about 100 feet. Its thickness in the embayment is not known at this time. In Johnson and Pope Counties, west of the Fall Line, wells have encountered undifferentiated St. Clair-Lafferty sections some 200 feet in thickness. The Arkansas-Louisiana Gas Company No. 1 Barton well, Franklin County, penetrated approximately 212 feet of St. Clair-Lafferty section, which is the thickest combined section of those formations found in the Arkansas Valley to the present time.

Character: The St. Clair is a gray to pinkish-white, coarse- to medium-grained, crystalline limestone containing pinkish-white crinoid segments similar to those found in the Fernvale limestone. The St. Clair is similar to the Fernvale in general appearance but is usually of lighter color and contains fewer fossils. In the embayment these formations may have to be differentiated on the basis of stratigraphic position rather than lithology.

Correlation: The St. Clair is correlated with the Laurel limestone of Tennessee and is a partial equivalent of the Chimneyhill formation of the Arbuckle Mountains.

Stratigraphic relations: The St. Clair unconformably overlies various units, such as the Brassfield, Cason or Fernvale, by virtue of its occurrence as an overlapping formation.

Productive possibilities: The St. Clair, if present in the embayment as predicted, has good potentialities as a reservoir. Its coarsely crystalline character and random crystal orientation may lend themselves to the development of intergranular porosity. Pre-Chattanooga beveling may have been responsible for the creation of weathered zones in the St. Clair, porous and permeable enough to satisfy reservoir requirements. Through subsequent overlap of the St. Clair by an impermeable formation, such as the Chattanooga shale, adequate traps might be established.

Lafferty Limestone

Distribution: The Lafferty has been found exposed in southeastern Izard County, northeastern Searcy County and possibly in Independence County. It is considered to be widely distributed in the subsurface of the Arkansas Valley; however, few attempts are made to delimit it accurately in wells where the underlying St. Clair limestone is present. In such cases the Lafferty-St. Clair section generally is treated as an undifferentiated unit. The Lafferty has been identified, on the basis of lithology, with a red, argillaceous limestone occupying an interval approximately between 4195 and 4280 feet in the Union No. 1 Withers well, DeSoto County, Mississippi (Plate VI). It may also be represented in the section tentatively assigned by the writer to the Silurian in the Davis No. 1 DeMange well, Crittenden County. Although the Lafferty has not been identified in the embayment in northeastern Arkansas, its subsurface occurrences west of the Fall Line, in the state, and in Tennessee, are indicative of its probable presence in the embayment. It is likely to occur in the embayment sporadically, however, in consequence of pre-Chattanooga beveling.

Thickness: The Lafferty outcrop has a thickness of 85 feet in Izard County and 30 feet in Searcy County (Maher and Lantz, 1952, p.6). No thickness range has been established for it in the subsurface west of the Fall Line. Its thickness in the embayment is unknown. In view of the limited knowledge of the Brassfield, St. Clair and Lafferty in the embayment, a thickness ranging upward to 115 feet is assumed at this time for the undifferentiated Silurian sequence projected into the northern portions of the embayment from the Arkansas Valley. Downdip, away from the more pronounced effects of pre-Chattanooga truncation, the undifferentiated Silurian interval may become appreciably thicker in the embayment.

Character: The Lafferty is a red, earthy limestone containing beds of red to gray, medium-crystalline to dense, crinoidal limestone, in which orange, medium-sized calcite crystals may be scattered. In the basal portions of the Lafferty a silicified faunal assemblage may be present. Downdip from the apex of the Ozark uplift, the Lafferty equivalent in Tennessee loses its red color. Downdip in the embayment in Arkansas the same condition might prevail. If the Lafferty is present in the DeMange well in Crittenden County, it may be represented by a non-red facies.

Correlation: The Lafferty may be equivalent, or partially equivalent, to the Henryhouse shale of the Arbuckle Mountains and to the Bainbridge formation of Missouri.

Stratigraphic relations: A disconformity may be present between the Lafferty and the underlying St. Clair limestone.

Productive possibilities: Indications of limited areal extent and poorly developed porosity make the Lafferty appear unfavorable as a potential producing formation.

DEVONIAN SYSTEM

Penters Chert

Distribution: The Penters is exposed at Penters Bluff in Independence County, which is its type locality, and in part of eastern Stone County, along the White River. It has considerable distribution in the subsurface of the Arkansas Valley, west of the Fall Line, where its thickest development appears to be in Pope County. The Penters is present in the embayment, but its extent is unknown. It has been identified in only one well in the embayment, the Jones No. 1 Norris, Independence County, although it may be represented in the chert section immediately underlying beds of Cretaceous age in the Davis No. 1 DeMange well, Crittenden County. The Union No. 1 Withers well in DeSoto County, Mississippi, also contains a chert section which is a possible Penters equivalent.

Thickness: In its exposure at Penter's Bluff, near Batesville, the Penters is 91 feet thick. In the subsurface, west of the Fall Line, its thickness varies from a few feet in Madison County to a maximum of about 260 feet in Pope County. Closer to the Fall Line, the Deep Rock No. 1 Sample well, White County, and the Fitzpatrick No. 1 Pryor well, Independence County, contain some 60 and 50 feet of Penters, respectively. In the embayment, the Norris well has approximately 30 feet of Penters. A maximum thickness of 100 feet is tentatively assigned to the Penters in the embayment.

Character: The Penters is a brownish-gray to gray, mottled, dense to translucent chert containing thin-bedded dolomitic limestones. A small amount of spicular, blebby, gray-blue chert is generally present in the upper part of the formation which may help to differentiate between the Boone and Penters cherts in the event the Chattanooga shale is absent, as is the case in the Pure Oil Company No. 1 Low Gap unit, sec. 17, T. 11N, R. 24W, Johnson County. The Penters chert is often fractured and brecciated. This condition has been noted in cherts equivalent in age to the Penters in Tennessee and Missouri and in possible Penters equivalents in the Union No. 1 Withers well, DeSoto County, Mississippi, and the Davis No. 1 DeMange, Crittenden County. Downdip in the embayment, older Devonian formations equivalent to the Frisco limestone of northeastern Oklahoma may occur as northward-thinning wedges beneath the Penters. The Penters may contain black cherts and shales downdip.

Correlation: The Penters correlates with the Clear Creek chert of southeastern Missouri, the Camden chert of Tennessee and is a possible equivalent of the Sallisaw sandstone of northeastern Oklahoma.

Stratigraphic relations: The Penters is unconformable on underlying formations, whether of Silurian or Ordovician ages.

Productive possibilities: The fractured and brecciated cherts may have some possibilities as potential reservoirs. Pre-Chattanooga planation, where it did not remove all of the Penters, may have been responsible for the development of porous zones within the formation. Subsequent overlap by the Chattanooga shale or younger impermeable formations might result in the establishment of oil and gas traps.

Clifty Limestone

The Clifty is a gray, sandy limestone exposed only in southeastern Benton County where it is less than 3 feet thick. It is considered to be of Middle Devonian age on the basis of fossil evidence. Its presence in the embayment has not been established.

MISSISSIPPIAN SYSTEM

Sylamore Sandstone

Distribution: The Sylamore is exposed throughout the Springfield Plateau area which extends from Benton County eastward to the Fall Line in Independence County. Although it is absent on the surface over large portions of the Plateau, it is known for its persistence throughout the region in general. No Sylamore has been identified in the embayment. It has been identified, however, in a few wells drilled west of the Fall Line.

Thickness: The Sylamore ranges upward to about 75 feet in thickness on the outcrop, achieving the maximum near Springdale, in Washington County. If it is present in the embayment, its thickness cannot be estimated at this time.

Character: The Sylamore is a gray, brown or white, fine-to coarse-grained, slightly shaly, pyritic sandstone made up of angular to sub-rounded quartz grains. It is generally characterized by the presence of dark-colored phosphate pebbles. Glauconite has also been found in well samples identified as Sylamore. On the outcrop the Sylamore is generally either calcareous or conglomeratic.

Correlation: It is correlated with the Misener sandstone of Oklahoma and the Hardin sandstone of Tennessee.

Stratigraphic relations: The Sylamore, as the oldest member of the Chattanooga shale, appears to be a transgressive marginal unit which varies in age according to its location. Where present, the Sylamore variously overlies beds ranging in age from Devonian to Cotter so that its base marks a regionally important truncating unconformity. Updip along the Ozark uplift, where the Chattanooga shale is lost by overlapping younger beds, the Sylamore underlies the Boone formation. The Sylamore is gradational and conformable with the overlying black shale beds of the Chattanooga.

Productive possibilities: It can be inferred that the Sylamore would be a highly prospective reservoir if present over a reasonable area within the embayment. Equivalents of the Sylamore are productive in Oklahoma and Kansas. Shallow gas production has recently been found in this unit in Washington County, Arkansas.

Chattanooga Shale

Distribution: The Chattanooga is widely but sporadically exposed over the Springfield Plateau area, having its best outcrops in Benton, Washington, Madison and Carroll Counties. It has not been found on the surface east of Carroll County with the exception of a few isolated patches in the vicinity of Batesville, in Independence County. The Chattanooga has been found in most of the wells drilled to the present time west of the Fall Line, occurring in its normal sequence between the Boone and the Penters formations. It has not been identified in the Lion No. 1 Nalley well or in the Killam and McMillan No. 1 Curl well, both near the Fall Line in White County.

In the embayment the Chattanooga has been identified tentatively in the Jones No. 1 Norris well, Independence County, but is absent in the Arkansas Oil Ventures No. 1 Doggett well, Jackson County. Since it has been found in only one well in the embayment to date, and especially since that well is just east of the Fall Line, the distribution of the Chattanooga in the embayment cannot be determined at this time. It is assumed to be present downdip in the embayment. The Chattanooga has not been identified very far up the flanks of the Ozark uplift in northeastern Arkansas. The possibility exists that a thin, green shale unit found overlying the Chattanooga, or constituting its upper portion in certain areas of Chattanooga occurrence, may be found eventually to represent the Chattanooga updip in the embayment. According to Mellen (1947, p.1811), the Chattanooga is absent almost everywhere in the subsurface in Mississippi. In that state the thin Maury green shale or sandstone, often correlated as the upper member of the Chattanooga, is considered to be basal Mississippian, probably Kinderhook, by Mellen, based on the relationship of the glauconite in the Maury to that contained in overlying Mississippian beds. Mellen states that the Chattanooga becomes progressively sandier toward the west from the outcrop in the northeast corner of Mississippi. In the Arkansas Valley the Chattanooga appears to become progressively silty toward the east.

Thickness: The Chattanooga ranges upward to 85 feet in thickness in the western portion of the Springfield Plateau; however, its average thickness is about 30 feet. In the subsurface, west of the Fall Line, the maximum thickness penetrated to this time has been about 50 feet. In the embayment, the Jones

No. 1 Norris, Independence County, contains an estimated 10 feet of Chattanooga. In northern Alabama, northeastern Mississippi and on the western Highland rim of the Nashville Dome the Chattanooga reaches a maximum thickness of about 35 feet.

Character: This is a black to brownish-black, flaky to fissile, bituminous, slightly pyritic shale containing microscopic, disc shaped plant spores (Sporangites) and conodonts. Thin limestone and sandstone layers have been reported within the Chattanooga section in several wells drilled in the area west of the Fall Line. Freshly broken surfaces of the Chattanooga give off a petroleum odor. In some areas where the Chattanooga is absent the above-mentioned green shale occupies its interval.

Correlation: Previously in this report mention has been made of the controversy concerning the ages of the Sylamore sandstone and Chattanooga shale. Although both Devonian and Mississippian fauna have been recognized in the Chattanooga in various localities, most Mid-Continent geologists consider it to be entirely of Mississippian age. The basal sand member of the Chattanooga, having been a marginal unit which transgressed the post-Devonian peneplaned surface, is of varying ages depending upon its geographic location. In the columnar section of Plate IX, and elsewhere in this report, the writer has treated the Chattanooga as being of Lower Mississippian age. Likewise, the Sylamore is considered here to be of Lower Mississippian age in its oldest occurrences, becoming somewhat younger progressively updip.

Considerable work has been done on the age of the Chattanooga. Croneis (1930, pp.41-42) believed that the Chattanooga shale, at least in northwestern Arkansas, must be of Mississippian age, since it overlies the Sylamore sandstone, which he indicated to be of the same basal Mississippian age in Arkansas and Missouri. Levorsen (1934, p.765) regarded the Chattanooga shale, or its equivalent, the Woodford shale in southern Oklahoma, to be the basal formation of the Mississippian system throughout much of Oklahoma and Kansas, indicating that it transgressively overlaps all of the pre-Mississippian formations from the Hunton limestone of Devonian and Silurian age to the Arbuckle limestone of Cambro-Ordovician age.

In Tennessee, the Chattanooga shale formation is made up of a basal sandstone and an overlying black shale facies which is treated by Smith and Whitlach (1940, p.29) as being entirely of Mississippian age, at least insofar as that portion of the formation occurring south of the Nashville dome is concerned. In northern Tennessee the lower part of the black shale facies is not only separated from the upper part by an unconformity but contains Devonian fossils; however, according to Bassler (1932, pp.136-143), the Devonian portion of the shale does not appear to extend southward over the Nashville dome for any appreciable distance. Ulrich (1911, p.307) and Swartz (1924, pp.24-30) also correlate the Chattanooga of the Central Basin of Tennessee as being of Lower Mississippian age. Since the Chattanooga is so treated in portions of Oklahoma, Kansas, and Tennessee, it seems logical to apply this age determination to Arkansas in view of the pronounced presence of pre-Chattanooga planation and subsequent Chattanooga overlap in the state.

Stratigraphic relations: The base of the Chattanooga, whether represented by the Sylamore member or by the black shale facies in the absence of the Sylamore, marks a truncating unconformity of regional significance.

Productive possibilities: The Chattanooga black shale facies is not considered favorably as a reservoir because of its impermeable character, but this same property makes it potentially valuable as a seal for porous and permeable limestones or sandstones which may underlie it. Coarse grained limestones such as the Fernvale or St. Clair, where they have been truncated by pre-Chattanooga planation and subsequently covered by the Chattanooga shale, might be excellent reservoirs. The Chattanooga is considered to be a prime source bed by numerous geologists, and much work has been done throughout its region of occurrence to equate it directly to producing beds. Although inferences may be drawn as a result, the work cannot be considered conclusive. The Chattanooga shale is generally rich enough in organic material to burn. In addition some oil can be distilled from it.

Boone Chert

Distribution: The Boone formation makes up most of the surface of the Springfield Plateau. Its distribution is also widespread in the subsurface of the Arkansas Valley, where most of the deep wells drilled have encountered it. In the embayment the distribution of the formation is unknown, since it has been tentatively identified in one well only, the Jones No. 1 Norris, Independence County. As previously mentioned in the discussion of the Kimmswick limestone, the Arkansas Oil Ventures No. 1 Doggett well, Jackson County, contains a cherty limestone section between 2155 and 2350 feet, which was tentatively assigned by the writer to the Kimmswick. This assignment is not necessarily held generally. In view of the relative abundance of chert in that particular section of the Doggett well, some geologists consider it to be of Boone age, while others regard it to be Penters. The Boone may be represented in the porous, weathered chert sections found underlying the Cretaceous in the Davis No. 1 DeMange well, Crittenden County, and the Union No. 1 Withers well, DeSoto County, Mississippi.

Thickness: On the outcrop, slightly west of the Fall Line, the Boone formation ranges in thickness between 102 and 195 feet. Elsewhere, exposures of the formation may be as thick as 450 feet. In the subsurface of the Arkansas Valley up to 375 feet of Boone have been found in wells. In the Jones No. 1 Norris well 60 feet of Boone were penetrated.

Character: In northeastern Arkansas the Boone formation consists of brown and brownish-gray to dark gray, dense chert, and white to brownish-gray, granular, shaly limestone. Pyrite may be present in the upper part of the formation. The chert is sometimes spicular and glauconitic. Thin-bedded oolitic limestones and green, limy shale may occur in the formation. The St. Joe lower member of the Boone formation has not been identified in the embayment but consists of thin-bedded, pink to maroon, fossiliferous, coarse to very finely crystalline limestone in the vicinity of Batesville. The Boone chert section above the St. Joe, which is essentially non-cherty, is made up of beds of Kinderhook, Burlington, Keokuk and Warsaw ages. The relative amounts of chert in the Boone vary considerably, both vertically and laterally. Eastward along the outcrop, from Oklahoma into north central Arkansas, the proportion of chert to limestone in the Boone increases, although the relative changes in ratios are not consistent throughout the region concerned. Progressively toward the southeast within the embayment the Boone formation may be found to undergo facies changes and become generally darker colored, both in its limestone and chert phases, and to become considerably more shaly.

Correlation: The Boone chert is correlated with the Fort Payne chert of western Tennessee, the Keokuk-Burlington sequence of southern Missouri and southern Illinois, and the Keokuk-Burlington-Reed Springs limestones of the southwestern Ozark region. The St. Joe limestone correlates with the Fern Glen formation of the Mississippi Valley section.

Stratigraphic relations: Where the Chattanooga shale is present the contact between it and the overlying Boone formation is conformable. In contacts where the Boone directly overlies Silurian or Ordovician formations the relationship is unconformable. A thin sandstone, probably the Sylamore, sometimes occurs at the base of the Boone in the absence of the Chattanooga shale.

Productive possibilities: Equivalents of the Boone are producing formations in Kentucky, Oklahoma and Kansas, where the porosity and permeability are probably attributable primarily to weathered beds in the sections concerned. The Boone formation may attain considerable porosity through fracturing, such as is the case with its equivalent, the Fort Payne chert, in western Tennessee. Where porosity and permeability are developed, whether by fracturing or other processes, the Boone formation may be considered a potential reservoir. If present indications are substantiated, the Boone formation may become progressively argillaceous downdip in the embayment tending to lessen its chances as a prospective reservoir in its deeper aspects.

Moorefield Formation

Distribution: The Moorefield formation has its best exposure in Independence County. It is absent on the surface in Arkansas west of Searcy County but reappears in northeast Oklahoma. In the subsurface of the Arkansas Valley, west of the Fall Line, the formation is thought to have considerable distribution, but it is difficult to separate from the overlying Ruddell shale. The areal extent of the Moorefield in the embayment is unknown. East of the Fall Line it has been identified, tentatively, in one well only, the Jones No. 1 Norris, in Independence County.

Thickness: On the outcrop in Arkansas the Moorefield has a thickness ranging up to 199 feet. In the subsurface west of the Fall Line no thickness can be given with assurance. The Jones No. 1 Norris well, in the embayment, contains a minimum of 130 feet of section attributable, at least in part, to the Moorefield. The top of this section is not known because of the absence of pertinent well samples; consequently, the total interval concerned may approach a thickness of 500 feet in the well. The Moorefield is not considered here to constitute the entire black shale section found in the Norris well but instead is thought to be present with undifferentiated beds of the Ruddell and Batesville formations. The Batesville, Ruddell and Moorefield formations, as a unit, are estimated to attain a maximum thickness in excess of 500 feet in the embayment.

Character: The Moorefield is typically a brownish-black, gritty shale containing dark granular limestones. The base of the Moorefield may be marked by a pyritic, glauconitic zone similar to that found in eastern Oklahoma at the base of the Mayes formation, which the Moorefield generally resembles lithologically. Available data indicate a thickening of the Moorefield formation southeastward toward the embayment from the Arkansas Valley with an accompanying loss of characteristic lithology. The Batesville, Ruddell and Moorefield formations, treated as an undifferentiated unit in the embayment, may consist of a sequence of gray, oolitic limestone, black shale, gray shale, gray to tan, silty shale and black, fossiliferous, silty limestone beds.

Correlation: The Moorefield may be equivalent to the St. Louis limestone of the central Mississippi Valley and a partial equivalent of the Caney shale of the Arbuckles.

Stratigraphic relations: The presence of pyrite, glauconite and occasional conglomerate at the base of the Moorefield suggest an unconformable relationship with the underlying Boone formation.

Productive possibilities: The Moorefield cannot be considered favorably in the embayment as a potential producing formation since there are no indications that porous beds should be expected. Elsewhere in its occurrences, petroleum hydrocarbons have been distilled from the Moorefield suggesting that it might constitute a favorable source bed, at least in accordance with the commonly held opinions as to what may constitute source beds.

Ruddell Shale

This formation was originally considered as part of the Moorefield. Outcrops in the eastern portions of the Arkansas Ozarks range in thickness between 120 and 272 feet. Northwestward from the Batesville district the Ruddell overlaps the Moorefield and lies directly on the Boone formation. Since it is difficult to differentiate in the subsurface of the Arkansas Valley no valid subsurface thicknesses can be given for the formation. Possibly it is represented in the Jones No. 1 Norris well, Independence County, in which case that well would contain the only Ruddell tentatively identified to this time in the embayment. It may have considerable distribution in the subsurface of northeastern Arkansas but will probably have to be treated as part of an undifferentiated Batesville-Ruddell-Moorefield unit tentatively described under the Moorefield discussion above. The Ruddell is considered here as too impermeable to constitute a potential producing formation. However, it would provide an adequate seal for underlying reservoir beds and might be revealed eventually as a source bed.

Batesville Sandstone

Distribution: The Batesville outcrops throughout the northern counties in Arkansas. Its distribution in the embayment is unknown since it has not been identified to date in any wells drilled east of the Fall Line. The Jones No. 1 Norris well, Independence County, may have penetrated a Batesville section, but well samples from the pertinent interval are missing. The formation is assumed to have a fairly wide distribution in the subsurface of the Arkansas Valley, west of the Fall Line, but is generally treated, of necessity, as part of an undifferentiated Batesville-Ruddell-Moorefield unit so that no individual thicknesses can be given readily.

Thickness: The Batesville achieves a maximum outcrop thickness of 76 feet in Independence County. A general thickening toward the southeast, into the embayment, is indicated.

Character: Typically the Batesville is a gray to brown, medium-grained, calcareous sandstone containing dark-gray shale lenses. Generally the cementation of the sandstone is considerably advanced, resulting in a tight formation; however, zones of porosity are known in the sandstone, especially in the lower portions of the formation. Near the Fall Line a thin, dark, oolitic limestone, known as the Hindsville member, appears in some areas at the base of the Batesville. Near Garfield, in Benton County, asphaltic material has been found in the Hindsville. A chert conglomerate may appear locally at the base of the Batesville formation.

Correlation: The Batesville is an equivalent, or partial equivalent, of the Gasper limestone of western Tennessee, the Paint Creek-Renault sequence of southern Missouri and southern Illinois, and the Caney shale of the western McAlester basin.

Stratigraphic relations: In portions of northwestern Arkansas the Fayetteville shale directly overlies the Boone formation, and the Batesville is absent, possibly through non-deposition. West of St. Joe the Batesville rests disconformably on the Boone. In the eastern portions of the Arkansas Valley the Batesville is conformable on the Ruddell-Moorefield.

Productive possibilities: The Batesville should not be ruled out as a potential reservoir in the embayment as long as its character and distribution in that area are unknown. If the formation is present in a reasonably well developed sand facies, zones of porosity might render it a fair prospect.

Fayetteville Shale

Distribution: The Fayetteville has wide surface distribution in the southern Springfield Plateau region and the northern Boston Mountain region. West of the Batesville district the Wedington sandstone member is present as a fine-to medium-grained, porous sandstone; however, this member is not known in the vicinity of Batesville or eastward toward the Fall Line. It is possible that the sand has undergone a facies change and is represented as the "middle" limestone member of the Fayetteville just west of the Fall Line. The Fayetteville shale has been tentatively identified in only one well in the embayment, the Le Grande No. 1 Jacobs, sec. 33, T. 9N, R. 1W, Jackson County, as the Paleozoic formation immediately underlying the Cretaceous sediments present in the well. In the subsurface of the Arkansas Valley, west of the Fall Line, the Fayetteville has wide distribution. Wells in Crawford and Madison Counties have penetrated white, limy, fine-to medium-grained sandstone beds up to 15 feet thick which may be the Wedington member, near the middle of the formation.

Thickness: On the outcrop, close to the Fall Line, the Fayetteville formation has been found to range between 340 and 375 feet in thickness. Further west in the state, exposures range upward from a few feet to about 400 feet in thickness. Just west of the Fall Line the formation is made up of three members, an upper and lower black shale and a middle limestone. These achieve thicknesses of 30 to 55 feet, 260 to 280 feet, and 20 to

40 feet, respectively, in that vicinity (Gordon and Kinney, 1944). In the embayment the Fayetteville is expected to be separable with difficulty from the overlying Pitkin limestone; consequently, it will probably be necessary to treat the two formations as an undifferentiated unit. In the northern portions of the embayment this unit is estimated to aggregate a maximum of some 600 feet in thickness, possibly becoming thicker toward the southeast. In wells drilled through the Fayetteville west of the Fall Line, the formation has ranged up to 280 feet or more in thickness.

Character: In the Batesville district the upper member is essentially a black, fissile shale with fine-grained, black, limestone partings. The middle member is a brownish to dark-gray limestone which is variously oolitic, encrinal, sandy or conglomeratic. It is considered to resemble the Pitkin limestone lithologically. This is the member referred to above as a possible equivalent, through facies changes, of the Wedington sandstone member found in the Fayetteville further to the west. The lower member of the formation is principally a black, fissile shale containing subordinate amounts of dark brownish-black, granular limestone. Pyrite and pyritized fossils have been found in this member. It is similar lithologically to the Ruddell and Moorefield shales. These divisions of the Fayetteville are not typical of the formation further to the west and may represent facies changes attendant to basin deposition.

Correlation: The Fayetteville is an equivalent, or partial equivalent, of the Caney shale of the western McAlester basin and the Glen Dean limestone of southern Missouri, southern Illinois and western Tennessee. Paleontologically the Fayetteville is closely related to the upper Gasper, Golconda and Bangor formations of Alabama and to parts of the Caney shale of Oklahoma.

Stratigraphic relations: The lower shale member of the Fayetteville is conformable with the underlying Batesville sandstone, where the two are found together.

Productive possibilities: The Fayetteville cannot be considered as a potential reservoir if the generally impermeable character of the formation, as it is known just west of the Fall Line, persists into the embayment. It may be found to be a source bed, however. At almost all of its exposures the formation gives off a petroleum odor when freshly broken. Petroleum hydrocarbons can be distilled from this shale.

Pitkin Limestone

Distribution: The Pitkin is widely exposed in the southern Springfield Plateau region and the northern Boston Mountain region of northern Arkansas. Outcrops extend from Batesville, in Independence County, to Muskogee, Oklahoma. The Pitkin has not been identified to the present time in any wells drilled in the embayment; however, it has fairly wide distribution in the subsurface of the Arkansas Valley, west of the Fall Line.

Thickness: On the outcrop in the vicinity of Batesville the Pitkin reaches a maximum thickness of 250 feet. In the subsurface of the Arkansas Valley a maximum thickness of approximately 200 feet has been recorded for the formation in Franklin and Johnson County wells where it was readily identifiable. Further toward the southeast in the subsurface, toward the Fall Line, the Pitkin loses its typical identity. Although it may be represented by thicker sections near the Fall Line they cannot be delimited with assurance. In the embayment no thickness can be assigned to the Pitkin. Since the Pitkin and Fayetteville in northeastern Arkansas may have to be treated as an undifferentiated, southeastward thickening unit, a tentative thickness of 600 feet is inferred for such unit in its northern occurrences in the embayment, close to the Fall Line.

Character: Typically the Pitkin is a light-gray, medium-crystalline, fossiliferous limestone, in part encrinal, oolitic and sandy. On the outcrop, near the Fall Line, the formation is a gray to black, fossiliferous, finely crystalline limestone containing a few thin layers of black shale. In the subsurface of the Arkansas Valley the Pitkin limestone appears to have undergone facies changes southeastward toward the Fall Line where it is inferred to be represented essentially by black shales. The Pitkin is generally expected to maintain this latter character in the embayment.

Correlation: The Pitkin is considered to be of upper Chester age and is a partial equivalent of the Caney shale of Oklahoma. It is also equivalent to late Chester formations of southern Missouri, southern Illinois and western Tennessee.

Stratigraphic relations: The Pitkin rests conformably on the underlying Fayetteville shale, at least in places where the upper black shale member of the Fayetteville is present. Elsewhere the Pitkin may overlie the middle or lower members of the Fayetteville with apparent disconformity.

Productive possibilities: If the Pitkin persists in the embayment in the character attributed to the formation in the subsurface just west of the Fall Line, it cannot be considered optimistically as a potential producer. It does, however, suggest possibilities as a source bed, according to the common inferences as to what may constitute a source bed. In the western portions of the state solid hydrocarbons have been found in the formation. Near Fayetteville, Arkansas, fossil shells and concretionary masses in the Pitkin have been found to contain small amounts of fairly high gravity oil. In the SW¼ NE¼ of section 29, T. 15N,

R. 21W, Newton County, on Shop Creek, 2.3 miles south of the post office at Parthenon, black, oolitic limestone beds in the outcropping Pitkin are saturated with hydrocarbons according to Easton (1942, p.40).

PENNSYLVANIAN SYSTEM

Morrow Group

Distribution: The Morrow is generally considered to be a group in western Arkansas where it is subdivided into the Bloyd shale and the Hale formation, in descending order. These divisions are not recognizable in the Batesville district. West of the Fall Line, in the vicinity of Batesville, the Morrow is generally divisible into three lithologic units. These constitute an upper shale, a middle sandy limestone and a lower shale. The Morrow is expected generally to thicken toward the southeast, into the embayment, and to exhibit facies changes in that direction.

In the subsurface of the western portions of the Arkansas Valley, not only is the Morrow conceded to be a group, but its component formations, the Bloyd and Hale, are further divisible into definite lithologic units. The Kessler and Brentwood limestones of the Bloyd formation and the Prairie Grove and Cane Hill members of the Hale formation are not recognizable near the Fall Line, however, and are not expected to be definable in the embayment. The Morrow has its type area near Morrow, in Washington County. It is widely exposed in the northern Boston Mountains with the areal extent of Hale outcrops predominating over the Bloyd.

Thickness: The Morrow ranges upward to 725 feet in thickness in its area of maximum surface development. Near the Fall Line its outcrops range upward to about 252 feet in thickness. In the western portions of the Arkansas Valley sections up to about 730 feet in thickness have been identified in wells. No Morrow section has yet been delimited in the embayment where it is now necessary to treat the general black shale interval between the base of the Atoka and the top of the Boone, or pre-Mississippian formations recognizable in the wells, as Morrow-Mississippian undifferentiated.

Character: Immediately west of the Fall Line the Morrow is made up of three lithologic units which are described, respectively, in descending order, as a brown or dark-gray to black, fissile shale containing beds of gray, sandy limestone and sandstone; a brownish-gray, fossiliferous, shaly, sandy limestone; and a brown to black, fissile shale containing thin, sandy shale beds (Gordon and Kinney, 1944). Generally southeastward the black shale beds will probably predominate, with thin beds of sandstones and dark-colored limestones being present in varying abundance.

Correlation: The Morrow is the possible equivalent of the Wapanuka formation of the Arbuckle Mountains in Oklahoma, the lower Dornick Hills formation of the Ardmore basin and the upper Barnett shale and Marble Falls limestone of North Texas.

Stratigraphic relations: Locally the Morrow rests disconformably on the underlying Pitkin formation, marking the break between the Mississippian and Pennsylvanian systems in this area.

Productive possibilities: The Morrow is considered here as too impermeable to represent a potential producer in the embayment. Conglomerates present at the base of the Morrow in other states have not been recognized in Arkansas, except locally. The appearance of such members in the embayment would render the Morrow a possible reservoir. There is some indication that the Morrow may contain relatively more clastic material in a progressive southeasterly direction within the embayment.

Atoka Formation

Distribution: The Atoka is the most widely distributed surface formation of the Boston Mountain and the Arkansas Valley regions. In the embayment, immediately underlying the oldest Coastal Plain sediments present, the Atoka is expected to have a greater areal occurrence than any other Paleozoic rocks discussed in this report (Plate IV).

Thickness: Since no well has penetrated the Atoka completely in the deeper portions of the embayment its maximum thickness in northeastern Arkansas is unknown. It is estimated here as achieving some 7,000 feet in thickness in that area, but this figure is subject to considerable revision either upward or downward. In Perry County, west of the Fall Line, about 9500 feet of section on the outcrop were assigned to the Atoka by Croneis (1930, pp.119-132) who reported that neither the top nor the bottom was present. Although it is inferred to thicken generally toward the south in the Arkansas Valley and the embayment, evidence indicates local thinning of the Atoka in the vicinity of the Fall Line, possibly because of differential structural adjustments during or prior to Atoka deposition.

The Lion No. 1 Nalley well, sec. 33, T. 8N, R. 7W, White County, for example, appears to contain approximately 935 feet of Atoka where some 2,500 feet or more might be expected normally. Along a line trending from west to east across the Arkansas Valley, the Arkansas-Louisiana Gas Company No. 1 Barton well, sec. 27, T. 9N, R. 28W, Franklin County, encountered about 4,450 feet of Atoka; the Cosden Oil Company No. 1 Shackleford well, sec. 13, T. 9N, R. 19W, Pope County, penetrated slightly more than 2,100 feet of Atoka; the Lion Oil Company No. 1 Griggs, sec. 23, T. 10N, R. 13W, Van Buren

County, encountered an estimated 1,260 feet of the formation; and the Killam and McMillan No. 1 Curl well, sec. 10, T. 9N, R. 5W, White County, contained approximately 1,318 feet of Atoka. The Arkansas Oil Ventures, Inc. (Deardorf) No. 1 Doggett well, sec. 31, T. 10N, R. 3W, Jackson County, penetrated between 775 and 1,060 feet of Atoka depending on the interpretations of various geologists.

Presumably the Atoka thickens again in the embayment along an extension of the above traverse, taking into consideration the general change in strike of the formation from east-west in the Arkansas Valley to northwest-southeast in the embayment. If the inference as to alternate thinning and thickening of the Atoka is valid, either differential uplift or faulting essentially parallel to the Fall Line would be required to explain the circumstances.

Character: The Atoka is a gray to black, coarse-to fine-textured, splintery, finely to coarsely micaceous shale containing lenses of white, tan or gray siltstone and fine-to medium-grained shaly sandstone. The latter becomes generally more dense and quartzitic toward the Ouachita Mountain front, in which direction the black shale members become more coarsely micaceous. The Atoka may contain some calcareous material, presumably deposited along bedding planes or as vein filling. Dark-colored chert may be found in the lower portions of the formation. A conglomerate found at the base of the Atoka in some occurrences has not been identified to the present time in the embayment. Fossils are rarely found in the formation. Wells drilled to the Atoka in the embayment may encounter an interval of medium-to dark-gray, flaky shale between the base of the oldest Cretaceous sediments present (generally represented by a detrital sandstone) and the top of the black, hard shale considered representative of the Atoka. This may be a soil mantle developed at the top of the Atoka during the long erosion interval prior to Upper Cretaceous deposition. A maximum thickness of about 50 feet is indicated for this weathered Atoka zone. The Sohio Producing Company No. 1 Gann well, sec. 22, T. 3N, R. 3W, Monroe County, contains approximately 15 feet of shale between 2,645 and 2,660 feet attributable to such a soil mantle.

Correlation: The Atoka is Pottsville in age.

Stratigraphic relations: In northeastern and north central Arkansas the Atoka overlies the Morrow with probable disconformity. In the Ouachita Mountain region the Atoka overlies the Jackfork sandstone with apparent conformity. In the embayment the Atoka is the youngest Paleozoic formation known to be present.

Productive possibilities: The Atoka formation is the principal gas producer in the western portions of the Arkansas Valley, with the production being chiefly from lenticular sands within the shale section. Insufficient Atoka footage has been drilled in the embayment to determine the productive possibilities of the formation in that area; however, there are no factors generally applicable for ruling out Atoka possibilities universally in northeastern Arkansas at this time. Certain localities have indicated tight sands or lack of good sand development in the portions of the Atoka penetrated, but these few wells cannot readily be used to condemn such a widely distributed formation.

CRETACEOUS STRATIGRAPHY

In the upper Mississippi embayment in northeastern Arkansas the relatively unconsolidated Coastal Plain sediments of Upper Cretaceous age overlie Paleozoic rocks present with pronounced unconformity. No Permian, Triassic, Jurassic or Lower Cretaceous (Comanchean) sediments have been found in any part of the area covered by this report with the possible exception of Desha County. There the Eagle Mills, Cotton Valley and younger, pre-Upper Cretaceous sediments may be represented in the deepest development of the Desha basin in this area. Although the possibility exists that post-Paleozoic, pre-Upper Cretaceous sediments were deposited further northward than Townships 9 or 10 South in the embayment area andremoved subsequently by erosion, available evidence indicates they were probably not deposited generally beyond the northern limits tentatively assigned to them at the present time.

The maximum aggregate thicknesses of Upper Cretaceous rocks found in northeastern Arkansas occur along the trough of the Mississippi embayment which essentially parallels the present course of the Mississippi River. Westward and northward from the trough, the Cretaceous section becomes progressively thinner through non-deposition of older beds as a result of marine onlap. In a relatively narrow zone paralleling most of the Fall Line in northeastern Arkansas the Cretaceous is absent in its entirety as the result of post-Upper Cretaceous, pre-Midway erosion (Plate III). In the deeper portions of the embayment facies changes are evidenced throughout the Cretaceous formations. Depositional environments near the embayment trough were generally more closely related to those of Tennessee and Mississippi than to the conditions governing sedimentation in southwestern Arkansas and northern Louisiana; consequently the Taylor and Navarro age sediments identified in the shallower portions of the embayment grade basinward into the Selma and Ripley formations of these other states.

It is not possible at this time to draw lines of demarcation too finely in regard to such facies changes. In Desha County, for example, the Hunt Oil Company No. 1 Thornton well, sec. 23, T. 7S, R. 1E, appears to be related stratigraphically to sedimentation in Mississippi. In contrast, the Lion Oil Company No. 1 Bickham well, sec. 35, T. 10S, R. 3W, is more closely related stratigraphically to deposits occurring southwestward in Drew County, and possibly Ashley County, suggesting the influence of the southwestern Arkansas-northern Louisiana depositional environment over at least a portion of Desha County. Although the structural configuration which we recognize today as the upper Mississippi embayment was formed during post-Comanchean time, the structural grain considered responsible for the occurrence probably dates back to early Paleozoic or pre-Cambrian time. Therefore, the present embayment is apparently a relatively young expression of readjustment along pre-existing lines of weakness deep in older Paleozoic rocks or in the basement complex.

CRETACEOUS SYSTEM

GULF SERIES

Austin Group

Tokio-Eutaw Formation

Distribution: A basal detrital or marginal unit can be seen on Plates V, VI, VII, and VIII essentially overlying the entire Paleozoic floor of the embayment in northeastern Arkansas. Insofar as the writer has been able to determine to the present time, only four wells drilled to the Paleozoic in the embayment have failed to find some representation of this basal sandstone, those wells being the Petroleum Products No. 1 Engler, sec. 17, T. 4N, R. 1W, St. Francis County, and the Youngblood No. 1 West, sec. 24, T. 5S, R. 2W, the Flesh No. 1 Rosencrantz, sec. 2, T. 3S, R. 6W, and the Blackwell No. 1 Fox, sec. 23, T. 5S, R. 3W, all in Arkansas County.

Since this basal sandstone is of variable age, being in general progressively younger updip, only a limited sector of it can be attributed to the Tokio-Eutaw formation. The 600-foot contour line on the Cretaceous isopachous map (Plate III) has been tentatively determined as marking the northern and western limits of the Tokio-Eutaw phase of the basal unit. Subsequent work may reveal, however, that this phase is considerably more restricted in areal extent. There is some evidence at this time suggesting placement of the boundary line considerably closer to the trough of the embayment. In this event the portion of the basal unit occupying the area between such new boundary line and the 600-foot contour line would have to be assigned an Ozan age in conformity with the delineation of the Ozan formation in the next following portion of this report. In the deeper portions of the Desha basin, and along segments of the embayment trough, the basal unit may be overlain by additional sediments of Tokio-Eutaw age, but this condition does not appear likely to persist for any appreciable distance northward or westward.

Thickness: The basal unit has been found to date to have a maximum thickness of 125 feet in northeastern Arkansas. In general it thickens toward the southeast; however, the depositional pattern of the sandstone appears to follow structural or erosional variations of the Paleozoic floor rather closely so that indiscriminate predictions as to the thicknesses to be expected in any locality might be considerably in error. It is safe to assume that areas of known topographic highs on the Paleozoic floor of

STRATIGRAPHIC CHART
SHOWING
POST-PALEOZOIC FORMATIONS IN THE SUBSURFACE OF NORTHEASTERN ARKANSAS

ERA	SYSTEM	SERIES	GROUP	FORMATION	THICKNESS IN FEET	DESCRIPTION AND REMARKS
CENOZOIC	QUATERNARY	PLEISTOCENE & RECENT			0–200	Alluvium, gravel and loess.
CENOZOIC	TERTIARY	EOCENE	JACKSON*		0–575	Gray to dark blue-gray, fossiliferous, lignitic clays, in part glauconitic. Coarse-grained sandstones. Oyster beds in St. Francis County.
			CLAIBORNE	Cockfield —Cook Mountain —Sparta	0–1090	Undivided in the subsurface updip—dark chocolate brown, silty clay with thin lenticular beds.
				Cane River	0–375	Light-brown, glauconitic sandstones. Brown and gray sandy shales containing some lignite.
			WILCOX		0–1200	Brown shale, gray, micaceous shale, gray and gray-green siltstones and clays, thick sand beds, lignitic and sideritic zones and some pyrite. Ironstone layers near the top and bottom.
		PALEOCENE	MIDWAY	Porters Creek	0–630	Blue-gray to dark-gray, fissile, flaky shale with siderite concretions. Usually unfossiliferous.
				Clayton	0–120	Soft, gray, calcareous, fossiliferous shale with lenses of white limestone near the base. Occasionally glauconitic and phosphatic near the base.
MESOZOIC	CRETACEOUS	GULF	NAVARRO	Arkadelphia	0–200	Light- to dark-gray, marly, fossiliferous shale, sparingly glauconitic and containing occasional chalk fragments. Medium- to dark-gray, finely micaceous shale near the base.
				Nacatoch	0–380	Light-gray to white, fossiliferous, calcareous, phosphatic, glauconitic sandstone with thin layers of white, sandy, crystalline limestone. Light-gray glauconitic, micaceous, sandy marls. Near the Fall Line, lenses of non-calcareous, phosphatic, ferruginous, highly glauconitic, coarse-grained, clayey sandstones may occur. Dark, clayey, lignitic, non-marine beds may be found locally near the Fall Line and in northern portions of the embayment.
			TAYLOR	Saratoga	0–125	Gray, calcareous, fossiliferous, fissile shale which is finely micaceous and chalky in places. May contain marls, thin-bedded limestones or sandstones. Glauconitic or phosphatic in part.
				Marlbrook	0–150	Gray, calcareous, fossiliferous, micaceous, very fissile shale. Chalks, marls, thin-bedded limestone or sandstones may be present. Glauconitic or phosphatic in part.
				Annona	0–85	Medium- to dark-gray, finely micaceous, non-calcareous shale. Light-gray, calcareous, sparingly fossiliferous shale or marl. Contains glauconitic chalk and thin beds of calcareous, fine-grained sandstone in places. Glauconitic, phosphatic, pyritic zone near base.
				Ozan	0–150	Tan to dark-gray, silty to sandy, micaceous, calcareous marl, shaly in part. In deeper parts of the Desha basin (Desha County) the Ozan may be considerably thicker than indicated here.
			AUSTIN	**Basal Detrital Unit	0–125	Medium- to coarse-grained, glauconitic, quartzitic sandstone. Gray, fissile, micaceous shale. The sandstone is pyritic, phosphatic, lignitic and sideritic with greenish quartz grains increasing in size toward base. Ash may be present.
				Pre-Ozan	?	It is possible that post-Paleozoic, pre-Taylor formations are present downdip in the extreme southeastern portion of the area.

*Also designated as Jacksonian Stage (Wilbert, 1953, p. 1).
**This is a transgressive marginal unit ranging in age from Austin, near the embayment trough, to Navarro, updip.

the embayment will have a generally lesser representation of basal unit toward the crests of such features either through non-deposition or through erosion subsequent to deposition of the basal unit.

Character: The basal detrital unit is a medium-to coarse-grained, glauconitic, quartzitic sandstone. Pyrite, siderite, phosphatic nodules and lignite, the latter often being found both at the top and at the bottom of the formation, are characteristic of the basal unit. The quartz grains comprising the sandstone frequently have a greenish tinge and become coarser toward the base of the unit. Being a transgressive marginal unit deposited on a peneplaned surface, the sandstone tends to show a relationship to the terrain it has overlapped; consequently, rounded, frosted quartz grains may be found in the basal unit where the St. Peter, Everton or Joachim make up the pre-Cretaceous areal surface. In like fashion black shale fragments should be present in the unit where Atoka, Morrow or Mississippian shales form the Paleozoic floor of the embayment. Cherts may occur in the basal unit, or constitute it, where cherty Ordovician limestones and dolomites have been transgressed.

In the deeper portions of the embayment, adjacent to western Tennessee and northwestern Mississippi, ash is found incorporated in the basal unit, possibly as the result of volcanic activity associated with the Monroe uplift. Occurrences of the ash are generally more pronounced toward the Monroe-Sharkey platform area. A shale section, consisting of 40 feet of gray, fissile, micaceous shale, is present in the basal unit, between confining sandstones, in the McAlester Fuel Company and Cox No. 1 Welch well, sec. 24, T. 4S, R. 2E, Phillips County. In this instance the upper sandstone may be Ozan in age, correlatable with the Tupelo tongue of the Mississippi section. The underlying shale may be equivalent either to the Brownstown of southwestern Arkansas or to Tokio-Eutaw age sediments, and the lower sandstone may be of Tokio-Eutaw age. Similar, although thinner, shale intervals are also found between bounding sand beds in the basal unit in wells located in Lee and Cross Counties. This middle shale unit has essentially the same areal distribution as the portion of the basal unit attributed above to a Tokio-Eutaw age; namely, from the trough of the embayment westward and northward to the 600-foot contour, as shown on Plate III.

Correlation: The basal detrital unit can only be correlated locally, since it becomes progressively younger updip. Therefore, its age may range from Tokio-Eutaw in the deeper parts of the embayment to Nacatoch along the Fall Line to Saratoga in Clay County. The expression "basal detrital unit" will in itself lend no connotation of specific age. The age of the unit will, therefore, have to be expressed in terms of the formation immediately overlying it. Variously the basal unit has been called Tokio, Ozan, Tuscaloosa, Meakin, Buckrange, Blossom or Graves by geologists working the embayment. Both the Eutaw of the western Tennessee and northwestern Mississippi sections can be correlated with the basal unit as it appears adjacent to the embayment trough in northeastern Arkansas.

Stratigraphic relations: The basal detrital unit, wherever found in the embayment, overlies with pronounced unconformity the Paleozoic rocks forming the embayment floor. Since various Austin, Taylor and Navarro age sediments which are present in the deeper portions of the embayment are lost progressively updip by onlap rather than by actual thinning of the individual formations through truncation, the basal unit should be overlain in most instances by formations which are gradational and conformable with it. It may be noted that the terms "basal" and "marginal" have both been applied to this unit in the preceding discussion. The designation of the sandstone as a basal unit may be somewhat more favorable for the purposes of this report in order to impress the fact that it marks initial Upper Cretaceous deposition in the various local areas concerned. However, the unit is probably better defined ultimately as being marginal, since it is actually marginal to other sediments, lying at different stratigraphic levels in the section as viewed regionally, and since it, therefore, transects time diagonally.

Productive possibilities: The basal detrital unit is considered here to be the best potential reservoir among the Cretaceous rocks present in northeastern Arkansas.

Taylor Group

Ozan Formation

Distribution: The pre-Annona transitional unit regarded here as Ozan is generally limited to the area eastward and southward from the 600-foot contour line on Plate III. This formation, as it appears in northeastern Arkansas, may be an Ozan equivalent rather than an actual areal continuation of the Ozan formation of southwestern Arkansas since the latter is considered to lens out in southeastern Union, southeastern Bradley, northeastern Calhoun, and southwestern Dallas Counties, where it is overlapped by the Marlbrook formation.

Thickness: The thickness of the Ozan in the embayment ranges between 0 and 150 feet, although it may be found eventually to achieve thicknesses in the deepest portions of the Desha basin which are appreciably greater than the maximum indicated here.

Character: The Ozan is a tan to dark-gray, silty to sandy, micaceous, calcareous marl. Shale breaks may be present. In the southern portions of Desha County the Ozan may be made up principally of clastics, owing to the proximity of the area to the Monroe uplift. In general the updip, shoreward equivalents of this formation may tend to contain relatively more clastic sediments than the areas of deeper development. Near the embayment trough the formation is generally related to the Selma facies and is not readily separated as a lithologic entity.

Correlation: The formation which is called Ozan in this report is tentatively correlated with the Ozan of southwestern Arkansas and northern Louisiana, and with lower portions of the Selma Chalk of northwestern Mississippi and western Tennessee.

Stratigraphic relations: The Ozan is considered to be the basal formation of the Taylor group in northeastern Arkansas. It is probably transitional with its bounding formations. Its insertion in the northeastern Arkansas columnar section is based upon stratigraphic position as well as lithology.

Productive possibilities: Irrespective of the basal detrital unit, where it is of Ozan age, and the possibility of well developed clastic members occurring in the formation in southern Desha County, the Ozan is not considered here as a potential reservoir in northeastern Arkansas.

Annona Formation

Distribution: The formation referred to herein as Annona may be found as far westward and northward as the 500-foot contour line on Plate III.

Thickness: This formation ranges from 0 to 85 feet in thickness in the northeastern Arkansas embayment area.

Character: The Annona of this area is a medium-to dark-gray, finely micaceous, non-calcareous shale which may contain zones of light-gray, calcareous, sparingly fossiliferous shale or marl. In places glauconitic chalk and thin beds of calcareous, fine-grained sandstones may be found within the formation. In well samples the base of the Annona is generally found to be marked by a zone containing a considerable representation of free pyrite, glauconite and phosphatic nodules. This zone has its greatest value in permitting establishment of the lower limit of the "chalk section" in the embayment, since the Saratoga-Marlbrook-Annona sequence comprising the "chalk section" may otherwise not be separable within itself or from the underlying Ozan formation, where it is present. Although such a distinction among these formations may not appear to have commercial significance at this time, it is of value in helping to detail the stratigraphy of the area. A study of electrical logs in the embayment, in conjunction with sample work, indicates that the base of the Annona can be picked fairly accurately from electrical logs alone when no samples are available. The formation frequently contains iridescent shell fragments, *Inoceramus* prisms, and sharks teeth which may help to delimit it.

Correlation: This formation has been called Annona in northeastern Arkansas primarily because of its apparent stratigraphic position rather than its lithology, which is considerably different from the Annona of the outcrop and the subsurface in southwestern Arkansas. Although the formation is tentatively designated here as Annona, it appears more likely to be an Annona equivalent rather than a continuation of the formation of that name in the northeastern Texas-southwestern Arkansas region. Much additional subsurface work remains to be done in the embayment before the so-called Annona, Ozan, and Tokio-Eutaw formations can be viewed in their proper perspectives.

Stratigraphic relations: The zone of pyrite, glauconite and phosphatic nodules frequently found at the base of this formation, together with the generally observable changes in lithology, may be indicative of a disconformable relationship between the Annona and the underlying Ozan in the embayment, possibly occasioned by an interruption of sedimentation between deposition of the two formations.

Productive possibilities: With the possible exception of clastic sediments developed in the southern parts of Desha County, the Annona formation in northeastern Arkansas is not considered to be a potential reservoir.

Marlbrook Formation

Distribution: The Marlbrook has been tentatively identified in the embayment eastward and southward from the 400-foot contour line on Plate III. Locally it may extend westward beyond the 300-foot contour. Actual areal placement of the Marlbrook limits are difficult because of its lithologic similarity to the overlying Saratoga. Electrical logs are of considerable aid in delimiting the Marlbrook in its updip occurrences.

Thickness: This formation will be found to range between 0 and about 150 feet in thickness.

Character: The Marlbrook of the embayment is made up of gray, calcareous, fossiliferous, micaceous, very fissile shale; however, chalks, marls, thin-bedded limestones or sandstones may be present. In part the formation may contain glauconite pellets or phosphate nodules.

Correlation: The Marlbrook is correlated with the formation of the same name in southwestern Arkansas and with part of the Selma chalk section of western Tennessee and northwestern Mississippi.

Stratigraphic relations: Conformable and gradational with the overlying Saratoga and underlying Annona. Westward and northward from the 600-foot contour line on Plate III, which marks the approximate limits of Ozan and Annona deposition, the Marlbrook would be expected to overlie the basal detrital unit directly.

Productive possibilities: This formation is not considered prospective as a producer in northeastern Arkansas.

Saratoga Formation

Distribution: The Saratoga should be found as far north and west in the embayment as the 100-foot contour line on Plate III. As the youngest formation of Taylor age in northeastern Arkansas it has the greatest areal extent of the formations making up the "chalk section" by virtue of the transgressive overlapping of these formations progressively updip.

Thickness: Ranges between 0 and 125 feet in thickness.

Character: This formation is made up of gray, calcareous, fossiliferous, fissile shale which is finely micaceous and may be chalky locally. Thin-bedded limestones or sandstones may be present in the deeper portions of the embayment. Glauconite pellets or phosphate nodules sometimes occur in the formation.

Correlation: The Saratoga in northeastern Arkansas is correlated with the formation of the same name in southwestern Arkansas, and with the upper portion of the Selma chalk of western Tennessee and northwestern Mississippi. Some geologists consider it to be equivalent to the Coon Creek tongue of western Tennessee which is the oldest member of the Ripley formation in that region. The Saratoga is considered here to be the youngest formation of Taylor age in northeastern Arkansas in conformity with the southwestern Arkansas designation.

Stratigraphic relations: The Saratoga is conformable and gradational with the underlying Marlbrook and conformable with the overlying Nacatoch formation. In Monroe, Woodruff and St. Francis Counties, the contact between the Saratoga and Nacatoch is marked by a transitional zone of gray shale some 20 to 40 feet thick. Near the Fall Line, where post-Upper Cretaceous, pre-Midway erosion was relatively more pronounced, the entire Navarro section may have been removed by truncation locally resulting in the appearance of the Saratoga formation immediately beneath the oldest Midway sediments present.

Productive possibilities: Although chalks and marls have produced some oil and gas in the Gulf Coast region, the Saratoga and related formations of the Taylor section in northeastern Arkansas are not considered here as being prospective producers.

Navarro Group

Nacatoch Formation

Distribution: With the exception of a narrow belt adjacent to the Fall Line, the Nacatoch formation is present throughout the embayment in northeastern Arkansas. It is well represented by surface exposures in southwestern Arkansas. In Clark County, north of Arkadelphia, the Nacatoch outcrop passes under the Tertiary sediments present and is not found again on the surface northward or eastward in Arkansas except for a narrow band some 25 miles long in Independence and Lawrence Counties. The identification of this outcrop as Nacatoch in these latter counties is open to question. Subsequent work may show it to be Clayton or younger in age. The absence of the Nacatoch between the Fall Line and the tentative zero contour line on Plate III is attributed here to complete removal of the Upper Cretaceous section by pre-Midway erosion rather than by non-deposition. The appearance of the Nacatoch on the outcrop in one vicinity only in northeastern Arkansas has been discussed previously in this report as a possible indication of faulting; however, pre-Midway doming affecting portions of the state west of the Fall Line, within the Ouachita structural province, may have resulted in the preservation of this Nacatoch outcrop as an erosional remnant. The zero contour line on Plate III does not necessarily coincide with the western limits of deposition of the Nacatoch in the embayment. Therefore, this contour line cannot be assumed at this time to mark the location of the Nacatoch strand line.

Thickness: The Nacatoch formation has been found to range between 0 and 380 feet in thickness. Along the trough of the embayment, where the Nacatoch grades into the Ripley of western Tennessee and northwestern Mississippi, it may achieve greater thicknesses, but its general loss of individuality makes this difficult to determine.

Character: As in the outcrop area of the Nacatoch in southwestern Arkansas, this formation can generally be divided lithologically into three units in northeastern Arkansas. The upper and lower units are similar in appearance, both being essentially sandy clays, shales and marls. The latter unit, however, appears to contain relatively more marl than the former. The middle member of the formation (see Plates V and VIII) is its most distinctive lithologic unit, being principally a light-gray to white, fossiliferous, calcareous, phosphatic, glauconitic, poorly sorted sandstone. Light-gray, glauconitic, micaceous sandy marls may be present indiscriminately in this unit in addition to thin-bedded, white, sandy, crystalline limestone.

In the deeper portions of the embayment, such as in Crittenden and Poinsett Counties, reef-type limestones are found in the

Nacatoch formation. In southern Desha County, beds of sandy limestone and limy sandstone suggestive of the "Monroe gas rock" facies are developed within the Nacatoch. The quartz grains comprising the sand of the middle member are frequently coarse and angular and may be found to decrease in grain size downward. This latter condition, which would not generally be expected in transgressive deposits, possibly results from a reworking of the upper portion of the middle member by a regressive sea, in which event the finer sand grains would have been removed and redeposited southward.

In the northern portions of the embayment the upper member contains lignitic clays and fine-grained clastics which may represent non-marine deposits. These factors would then indicate at least a partial withdrawal of the sea subsequent to deposition of the middle sand member. This is probably the most pronounced indication of regression during Upper Cretaceous time in northeastern Arkansas. The indications that the upper portion of the middle sand member was reworked by a retreating sea suggest a change in the pattern of downwarping of the embayment at that time. As previously mentioned in this report, the westward migration of the embayment trough apparently stopped with deposition of the Navarro group. Possibly downwarping ceased temporarily or the rate of subsidence was exceeded by the rate of deposition. In either event, circumstances causing withdrawal of the sea following deposition of the middle member, resulted in a considerable redistribution of sediments toward the south.

The outcrop of the Nacatoch in Independence and Lawrence Counties contains concretionary layers of coarse, glauconitic, calcareous, phosphatic sandstone attributed to the middle sand member. These layers are discontinuous and give some evidence of the lithologic variability characteristic of the Nacatoch formation. Sand lenses may occur sporadically throughout the Nacatoch, both vertically and laterally. In the subsurface of southwestern Arkansas the Nacatoch, according to Spooner (1935, p.101), may be found to consist of sands over structurally high areas, grading quite rapidly into sandy clays, clays and thin, interbedded lensing sands on the flanks of the structures. The occurrence of similar patterns of sedimentation in northeastern Arkansas may reveal structural anomalies in that area also.

In Crittenden County, Arkansas, and in Shelby County, Tennessee, reef-type, fossiliferous, sandy, crystalline limestones have been found within the Nacatoch-Ripley sections. Similar limestones are also present, at least locally, in Poinsett County, Arkansas. Since these limestones are presumably of the "Monroe gas rock" type they may have been deposited over structurally high areas and are, therefore, worth further investigation. The Ramsey No. 1 Sanderson well, sec. 15, T. 6N, R. 7E, Crittenden

County, the Lion Oil No. 1 Bateman, Shelby County, Tennessee, and the Scott No. 2-A Nelson, Poinsett County, contain sections representative of such reef-type limestones.

Correlation: The Nacatoch formation in northeastern Arkansas is correlated with the formation of the same name in southwestern Arkansas, with the McNairy sand member of the Ripley formation of western Tennessee, and with part of the Ripley formation of northwestern Mississippi.

Stratigraphic relations: In the embayment in northeastern Arkansas the Nacatoch appears to be conformable with the underlying Saratoga, where that formation is present. Near the Fall Line, approximately west of the 100-foot contour line on Plate III, the Saratoga is absent as the result of overlap by the Nacatoch, and the latter formation overlies either the Paleozoic floor or the basal detrital unit. In this area the basal unit appears, at least locally, as a gravel deposit of variable thickness. This gravel is assumed to occur in discontinuous patches since its actual distribution in the subsurface is unknown. Similar gravels, in related stratigraphic positions, have been reported in Missouri (Farrar, 1935, p.14), Illinois (Weller, 1940, p.43), and Kentucky (Lamar and Sutton, 1930, p.849).

In the deeper portions of the embayment the Nacatoch grades eastward and northeastward into the Ripley formation of western Tennessee. Along the embayment trough, adjacent to northwestern Mississippi, the Nacatoch grades into the Ripley of Mississippi, which in turn constitutes the upper portion of the Selma in the northern part of that state. The Nacatoch is overlain conformably and gradationally by the Arkadelphia formation throughout their areas of occurrence in the northeastern Arkansas embayment area. It is possible that both the Nacatoch and Arkadelphia formations may be represented in the deeper portions of the Desha basin by the "Monroe gas rock" facies.

Productive possibilities: With the possible exception of the basal detrital unit, the Nacatoch is rated here as the most prospective producing formation in the Cretaceous section in northeastern Arkansas.

Arkadelphia Formation

Distribution: The Arkadelphia is found throughout northeastern Arkansas except for a narrow strip paralleling the Fall Line, where the formation has been removed by pre-Midway truncation.

Thickness: Ranges between 0 and 200 feet in thickness. With the exceptions of those areas close to the Fall Line and the embayment trough, where the Arkadelphia is found in its minimum and maximum development, respectively, the formation has a fairly constant subsurface thickness of about 50 feet.

Character: The Arkadelphia is typically a light-to dark-gray, marly, fossiliferous shale which may be glauconitic and chalky in part. Frequently a medium-to dark-gray, finely micaceous shale is found in the basal portion of the formation.

Correlation: The Arkadelphia is correlated with the formation of the same name in southwestern Arkansas, with the Prairie Bluff of the Mississippi section, and with the Owl Creek of the western Tennessee section.

Stratigraphic relations: Conformable and gradational with the underlying Nacatoch. The Arkadelphia is the youngest formation of Upper Cretaceous age occurring in northeastern Arkansas.

Productive possibilities: This formation is not a prospective producer.

TERTIARY STRATIGRAPHY

PALEOCENE SERIES

Midway Group

Distribution: The Midway group is found throughout the subsurface of the embayment in northeastern Arkansas. In White and Independence Counties a thin strip of Midway outcrops along the configuration of the Fall Line.

Thickness: The group has been found to range between 0 and 630 feet in thickness in the subsurface. It is noted for its general consistency in thickness, averaging some 400 to 500 feet, throughout most of northeastern Arkansas.

Character: The Midway group is made up of two members, an upper blue-gray to dark-gray, fissile, flaky shale, containing sideritic, concretionary layers, and a lower unit of soft, gray, calcareous, fossiliferous shale with lenses of white limestone near the base. Occasionally a glauconitic, phosphatic layer separates the lower Midway unit from the underlying Arkadelphia formation. The calcareous lower Midway unit ranges between 0 and 120 feet in thickness, averaging between 50 and 100 feet, in the embayment. It thickens abruptly, however, in the vicinity of the Ouachita Mountains and exceeds the maximum thickness given here by several times, outside the areal confines of this report. The upper shale member of the Midway is essentially non-calcareous and unfossiliferous although a few arenaceous forams have been identified within it. The lower unit is identified by the appearance of calcareous material and highly fossiliferous zones.

Correlation: The Midway is correlated with the group of the same name in southwestern Arkansas. The upper unit of the Midway in northeastern Arkansas, known as the Porters Creek clay, or shale, is correlated with the Porters Creek of northern Mississippi and western Tennessee. The lower, calcareous unit in northeastern Arkansas is correlated in its entirety by some geologists with the Clayton formation of western Tennessee, while other geologists prefer to consider only those occasional lenses of limestone found at the base of the lower unit to represent the Clayton formation in northeastern Arkansas.

Stratigraphic relations: Despite the lithologic similarity between the calcareous, lower Midway unit and the underlying Arkadelphia formation, a complete withdrawal of the sea took place at the end of Upper Cretaceous time. By observing the outcrop pattern along the Fall Line on the Arkansas State Geological Map, the Midway can be seen to lie unconformably on a variety of formations, including the Nacatoch and Arkadelphia of Upper Cretaceous age and Paleozoic rocks of Ouachita and

Arkansas Valley facies. South of Little Rock, along the trend of the Fall Line, the Midway overlies the Ouachita facies rocks, and apparently the Cretaceous sediments, with divergent strike. These are evidences of post-Upper Cretaceous, pre-Midway differential movement.

Productive possibilities: The Midway group is not considered a potential producer in northeastern Arkansas.

EOCENE SERIES

Wilcox Group

The Wilcox group occurring in northeastern Arkansas is mentioned here only because of the unfortunate association of its name with the oil prolific, Ordovician age "Wilcox" of Oklahoma. The group of this name in the region covered by this report is obviously much younger geologically and is related to the Wilcox of the Gulf Coastal region, where it is a sporadic, unreliable oil and gas reservoir. In northeastern Arkansas the Wilcox is made up of brown shale, gray micaceous shale, gray and gray-green siltstones and clays and thick sand beds, some of which are excellent aquifers. Lignitic and sideritic layers occur frequently in the Wilcox. Ironstone layers are found both near the top and bottom of the group. The Wilcox may be absent locally. It achieves a maximum thickness of some 1,200 feet downdip in the embayment.

The base of the Wilcox and the top of the Porters Creek (Midway) generally lie within a silty, shaly transition zone; however, for convenience in working with electrical logs in the area, an arbitrary Midway top is called by most geologists at the base of the last well developed resistivity kick in the Wilcox section, above the Midway shale interval on the log. The Wilcox is not considered with optimism as a prospective producer in northeastern Arkansas. It is conceivable that small quantities of gas or even oil might be encountered in the group in its extreme southern development in the area; however, these occurrences would likely be insignificant at best. The writer found asphaltic material in well samples from the Wilcox section in the Youngblood No. 1 West well, sec. 24, T. 4S, R. 2W, Arkansas County. They could not be related to any particular portion of the Wilcox section and may either have been deposited from formation water or introduced as contamination during drilling. Sediments younger than Wilcox in northeastern Arkansas are classified in Figure 4, which is a post-Paleozoic stratigraphic chart of the region concerned, but they are not discussed here in view of their lack of possibilities as producing formations.

OIL AND GAS POSSIBILITIES

Throughout the previous sections of this report most of the formations discussed, whether Paleozoic, Mesozoic or Tertiary, have been tentatively evaluated as prospective reservoirs or producing formations. No particular attempt was made to segregate formations which were assumed to be porous and permeable enough to act merely as carrier beds from those which might constitute or contain traps in addition to providing reservoir conditions. The intention has been to imply that those formations physically able to constitute reservoirs would also become prospective producers if adequate traps prevailed and if hydrocarbons were present, whether by migration into, or by generation within, the formations concerned. Despite the localization of areas where a combination of reservoir conditions and trap development may occur, the presence or absence of the hydrocarbons remains the prime variable.

Paleozoic rocks: As may be noted on Figure 5, which is a "Paleozoic Oil and Gas Possibilities" map of northeastern Arkansas, the portion of the embayment concerned has been zoned roughly to follow Plate IV. Within the northernmost area rocks of Cambro-Ordovician ages present considerable thicknesses of untested dolomites, limestones and probably lesser developed sandstones. In the extreme northern portion of this area a 5,000- or 6,000-foot well would probably penetrate the Bonneterre and possibly the Lamotte formations of Cambrian age. The Potosi-Eminence formations of the central Ozark region show considerable intergranular porosity which may be found to persist in the embayment. The typical Roubidoux section contains well developed, porous sand zones which may be present within this belt. Little can be said here of possibilities for production from Cambrian through Powell age formations other than to reiterate that considerable asphaltic material is present in the older Ordovician rocks and that the column, in descending order from the Powell, is probably equivalent to the Knox dolomite of Mississippi which has recently yielded a small, producing oil well in the northeastern portion of that state.

Possibly the most prospective formation to be found initially within this area is the St. Peter sandstone. It would appear to be least attractive where it might be found immediately underlying the Cretaceous basal detrital unit, especially if both formations exhibited porosity and permeability. In this case any local hydrocarbon accumulation in the St. Peter would have been dissipated either prior to or subsequent to deposition of the basal unit. The St. Peter may be more prospective downdip and closer to the Fall Line, where structural activity may have resulted in the formation of traps sufficient to impede updip migration of oil or gas contained in the formation. The persistence of the St. Peter throughout the embayment as a sandstone is unknown.

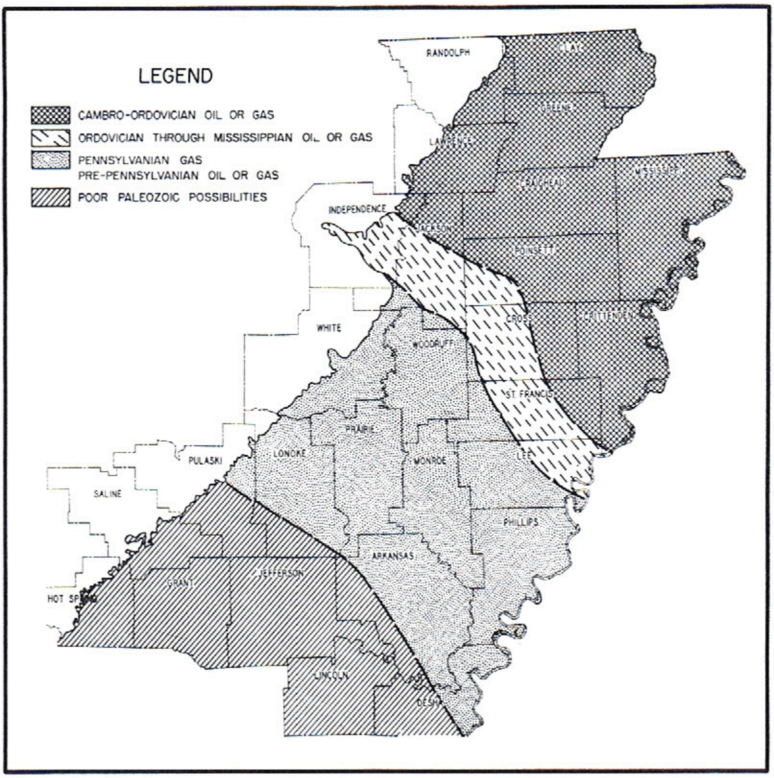

Figure 5. Paleozoic oil and gas possibilities map.

The possibilities for production near the Fall Line may apply to the entire Paleozoic column present, since the embayment area has probably been subjected to differential movement intermittently, along a pre-existing line or zone of weakness essentially paralleling the Fall Line, since early Paleozoic or pre-Cambrian time. The general presence of faulting within the northernmost area shown in the embayment in Figure 5 is conjectural. In Crittenden County, the preservation of Devonian or Mississippian cherts in the DeMange well suggests faulting. This may be related to a regional fault pattern extending at least as far eastward as the Union Withers well in DeSoto County, Mississippi, and an undetermined distance westward from the DeMange well in northeastern Arkansas. The existence of such a fault system would probably be important to oil or gas accumulation in the region.

The Cambro-Ordovician column in the deeper parts of the embayment may be considered generally to contain less coarse clastic material progressively downdip and to become more shaly, silty and dominantly fine-grained in that direction. Unknown factors such as fracturing, dolomitization of limestone, and the introduction of reservoir beds in formations that are basinward thickening wedges but which pinch out or are truncated northward appreciably below the pre-Cretaceous areal surface, must all be considered, although they cannot be applied to any particular vicinity at this time.

The area marked "Ordovician through Mississippian" on Figure 5 represents the tentative northern boundary of the most potential portion of the embayment. Within this zone, and downdip from it, formations such as the Silurian St. Clair, the Ordovician Fernvale and Kimmswick, and Devonian and Mississippian limestones and cherts may all be represented by porous facies, overlain by an impermeable seal and possible source rock such as the Chattanooga shale. From this zone southward numerous unconformities may be present in the section as the result of pre-Chattanooga planation.

Historically, unconformities in the Mid-Continent region have been related in numerous instances to producing zones. The porosity in carbonate rocks is largely secondary, in many cases through solution. Since such leaching activities take place essentially above the water table while the rock is generally exposed to erosion, limestones and dolomites exhibiting solution porosity may often underlie unconformities. As mentioned previously, repeated differential movement along the Fall Line may have provided even a more complex stratigraphic picture in that vicinity, causing local unconformities which are not represented in the deeper portions of the embayment.

The presence and extent of the Chattanooga in the embayment are not known. These may be important factors in downdip production. The Chattanooga is considered by some geologists to rank as the outstanding source rock in Kentucky and Tennessee, since oil and gas are found in rocks both overlying and underlying it. Ordovician, Silurian, Devonian and lower Mississippian formations in contact with the Chattanooga have all yielded production. In those states production is primarily from limestones and dolomites, although the St. Peter sandstone has been found to contain some oil.

The area marked "Pennsylvanian and pre-Pennsylvanian" on Figure 5 represents an area in which progressively thicker Pennsylvanian and Mississippian black shale sections can be expected in a basinward direction. This area is approximately within an extension of the Arkansas Valley under the Coastal Plain sediments of the embayment. At this time the Atoka shale section is considered to be the most prospective producer in this zone, although gas rather than oil would be expected to result from successful drilling. The Atoka cannot be ruled out as a potential producing formation, since the occurrence of well developed sand zones and structural configurations, related to those in the Arkansas Valley, have been neither substantiated nor disproved, other than locally. Carbon ratios have not been established for this region. Undifferentiated Morrow-Mississippian rocks occurring in this area may contain clastic zones which are productive. The Sylamore sandstone, recently found to be productive of gas in Washington County, Arkansas, has excellent potentialities if developed as a sandstone in the embayment.

The area indicated as having poor Paleozoic possibilities is expected to yield Ouachita facies rocks immediately beneath the Cretaceous section present. The occurrence of Ozark facies rocks within this area, overridden by typical Ouachita rocks, is conjectural, and the drilling depths would be prohibitive at this time if they were present. Therefore, this area is not highly regarded currently as a potential Paleozoic producing region.

Cretaceous rocks: Of the Cretaceous sediments present in the embayment the basal detrital unit and the Nacatoch sandstone are considered to constitute the prospective formations. The development of porous sand zones within the Taylor and Tokio-Eutaw sections in the deeper portions of the embayment cannot be evaluated at this time. The basal or marginal unit may be a continuous sand, despite its variable age, having been deposited by a transgressing sea as a blanket formation. If this is the case, the basal unit shares a similarity with some of the prolific Gulf Coast reservoirs. According to Malkin and Jung (1941), the deposition of such sands along the strand line may have been contemporaneous with the accumulation of organic muds seaward, with the result that oil generated in the organic sediments could migrate into the adjacent sandstone with relative ease. Some form of trapping would be necessary, however, whether structural or stratigraphic, to prevent the oil accumulated in this fashion from being migrated updip and dissipated on the surface.

The absence of the basal unit from areas of known topographic highs suggests the value of further detailing of the Paleozoic floor in the embayment, since the sands flanking such highs would probably offer possibilities for accumulation of hydrocarbons. As noted previously in the Phillips, Cross and Lee County areas, the basal unit is separated into two sands by a shale bed. This shale may actually be an overlapping formation rather than a local sedimentary condition within the basal unit, in which case the sandstone lying beneath the shale might be wedged-out against it updip, providing a possible oil or gas trap.

The basal unit may be productive in conjunction with faulting, such as may be present in the Crittenden County area. An accumulation of hydrocarbons might then be attributable to upward migration along the fault plane from Paleozoic rocks involved in the faulting. The flanks of such apparent noses as those indicated in Woodruff and Arkansas Counties might yield excellent traps for production from the basal unit.

The Nacatoch sand will require carefully detailed work in order to determine its lateral and vertical gradations for possible commercial advantage. Because of these changes in character the formation should have good to excellent chances for the stratigraphic trapping of any hydrocarbon materials present. The middle sand member, in effect, is probably a lensing of considerable extent. Both the upper and lower members, though not noted as being typically sands, may contain well developed sand lenses throughout. The Nacatoch may be productive against a possible fault in Woodruff County. Like the basal unit, the Nacatoch may be found responsive to the topography of the Paleozoic floor, in which event accumulation might take place through a combination of structural and stratigraphic conditions associated with underlying anomalies.

In the northern portions of the embayment and in the vicinity of Memphis, Tennessee, the Nacatoch contains water that is essentially fresh, but the extent of encroachment of this water throughout northeastern Arkansas is unknown. The lithology of the formation does not suggest a role as a carrier bed of large areal dimensions. In addition, salt water has been reportedly recovered from the Nacatoch as far north as Woodruff County and southward from the approximate latitude of Township 3 South. There is no evidence, in any event, that the Nacatoch has been entirely breached by any type of water, nor is there any established evidence in any region to rule out absolutely the possibility of production from formations which contain fresh water, unless the region has been entirely water flushed.

The presence of reef-type limestones in Crittenden County, Desha County and Poinsett County suggests the need for more intensive investigations of those areas. Some concern is evidenced over the apparent lack of source beds within the Cretaceous column. The fact that a source bed cannot now be properly defined is in itself an argument against such a supposition. From the literature it is apparent that most writers discussing production from the Nacatoch of southwestern Arkansas and Louisiana favor the productive sands themselves, or adjacent shales, as being the most likely source rocks. These opinions appear to be supported by the fact that each producing horizon, generally speaking, is characterized by a certain type of water and oil. Where faults occur, however, the oil is attributed chiefly to upward migration from deeper sources. Marls, such as occur so abundantly within the Cretaceous column in northeastern Arkansas, may be of sufficient organic content to qualify as source beds.

Igneous rocks: Igneous rocks occurring in the embayment in northeastern Arkansas are not expected to achieve enough areal extent or to be porous enough in themselves to constitute commercial reservoirs. Their principal contributions toward possible oil or gas accumulations might be either as indicators of structural adjustments, such as faulting, or as uplifted masses around which sediments may be draped in such fashion as to result in trap formation. The occurrence of tuffaceous beds or eroded material around such uplifted igneous masses might provide reservoirs against the flanks of the intrusive. If these intrusives are prominent enough locally, the overlying beds present prior to the igneous activity might be arched by the intrusives in such manner as to provide suitable traps. If the overlying beds are deposited subsequent to intrusion, they are likely to undergo thinning or differential compaction over the uplifted area, or pinch-out along its flanks, such as in the Lion No. 1 Bateman well in Shelby County, Tennessee. Igneous intrusions may be found along the projection of the Ouachita Mountain system into the embayment area and along the trough of the embayment generally northward from the vicinity of Memphis, Tennessee.

It is obvious from the foregoing attempt to reconstruct the geological history of northeastern Arkansas that conjecture far outweighs factual data in regard to the area. The most important point to be made is the fact that the entire portion of the state covered by this report is virtually untested, including the Cretaceous as well as the Paleozoic column. Guided by insufficient evidence, premature judgments have been the greatest detriment to exploratory activity in this part of Arkansas.

BIBLIOGRAPHY

Bartle, Glenn G. (1941), Effective Porosity of Gas Fields in Jackson County, Missouri: Bull. Amer. Assoc. Petrol. Geol., Vol. 25.

Bassler, R. S. (1932), The Stratigraphy of the Central Basin of Tennessee: Tenn. Div. Geol. Bull. 38.

Born, Kendall E. (1935), Notes on the Upper Cretaceous and Tertiary Sub-surface Stratigraphy of Western Tennessee: Jour. of the Tenn. Acad. of Science, Vol. X, No. 4.

Branner, J. C. (1889), Ark. Geol. Survey Annual Report for 1889, Vol. II.

Colton, E. G. (1935), Natural Gas in Arkansas Basin of Eastern Oklahoma: Geology of Natural Gas, A.A.P.G. Symposium.

Cram, Ira H. (1930), Cherokee and Adair Counties: Okla. Geol. Survey Bull. 40, Vol. III.

Croneis, Carey (1927), Oil and Gas Possibilities in the Arkansas Ozarks: Bull. Amer. Assoc. Petrol. Geol., Vol. II, No. 3.

__________(1930), Geology of the Arkansas Paleozoic Area with Especial Reference to Oil and Gas Possibilities: Ark. Geol. Survey Bull. 3.

__________(1935), Natural Gas in Interior Highlands of Arkansas: Geology of Natural Gas (A.A.P.G. symposium).

Dake, C. L. (1921), The Problem of the St. Peter Sandstone: Technical Series, Vol. 6, No. 1, University School of Mines and Metallurgy, Rolla, Missouri.

Dott, Robert H. (1941), Regional Stratigraphy of Mid-Continent: Bull. Amer. Assoc. Petrol. Geol., Vol. 25, No. 9.

Easton, W. H. (1942), The Pitkin Limestone: Ark. Geol. Survey Bull. 8.

Farrar, Willard (1935), The Geology and Bleaching Clays of Southeast Missouri: Appendix I, 58th Biennial Report, Missouri Geol. Survey.

Finn, Fenton H. (1949), Geology and Occurrence of Natural Gas in Oriskany Sandstone in Pennsylvania and New York: Bull. Amer. Assoc. Petrol. Geol., Vol. 33, No. 3.

Fisk, Harold N. (1944), Geological Investigation of the Alluvial Valley of the Lower Mississippi River: conducted for the Mississippi River Commission, Vicksburg, Mississippi (War Dept., C. of E., U. S. Army).

Freeman, Louise Barton (1945), chapter on Paleozoic Geology in Geology and Mineral Resources of the Jackson Purchase Region, Kentucky, by Joseph K. Roberts and Benjamin Gildersleeve: Kentucky Dept. Mines and Minerals, Ser. 8, Bull. 8.

__________(1949), Regional Aspects of Cambrian and Ordovician Subsurface Stratigraphy in Kentucky: Bull. Amer. Assoc. Petrol. Geol., Vol. 33, No. 10.

Fuller, Myron L. (1912), The New Madrid Earthquake: U. S. Geol. Survey Bull. 494.

Galey, John T. (1948), (Foreward) Appalachian Basin Ordovician Symposium: Bull. Amer. Assoc. Petrol. Geol.; Vol. 32, No. 8.

Giles, A. W. (1939), St. Peter and Older Ordovician Sandstones of Northern Arkansas: Ark. Geol. Survey Bull. 4.

__________ (1932), Textural Features of the Ordovician Sandstones of Arkansas: Jour. of Geol., Vol. XL, No. 2.

Glick, Ernest E., and Frezon, Sherwood E. (1953), Lithologic Character of the St. Peter Sandstone and the Everton Formation in the Buffalo River Valley, Newton County, Arkansas: U. S. Geol. Survey Circ. 249.

Gordon, Mackenzie, Jr., and Kinney, Douglas M. (1944), The Mississippian Formations of the Batesville District, Independence County Arkansas: U. S. Geol. Survey Oil and Gas Investigations Preliminary Map 12.

Graves, H. B., Jr. (1938), Pre-Cambrian Structure of Missouri: Washington University Doctoral Dissertations, Publications of Washington University, St. Louis, Missouri.

Grohskopf, John G. (1948), Zones of Plattin-Joachim of Eastern Missouri: Bull. Amer. Assoc. Petrol. Geol., Vol. 32, No. 3.

Hager, Dorsey (1938), Practical Oil Geology. McGraw-Hill.

Honess, C. W. (1923), Geology of the Southern Ouachita Mountains of Oklahoma, Part 1: Oklahoma Geol. Survey Bull. No. 32.

Imlay, Ralph W. (1949), Lower Cretaceous and Jurassic Formations of Southern Arkansas and Their Oil and Gas Possibilities: Arkansas Div. of Geology Circ. 12.

Jenny, W. P. (1937), Oil and Gas Possibilities in Northeastern Arkansas and Western Tennessee: Oil Weekly, July 5, 1937, pp. 26-32.

Lamar, J. E., and Sutton, A. H. (1930), Cretaceous and Tertiary Sediments of Kentucky, Illinois and Missouri: Bull. Amer. Assoc. Petrol. Geol., Vol. 14, No. 7.

Landes, Kenneth K. (1951), Petroleum Geology. Wiley & Sons, Inc.

Levorsen, A. I. (1934), Relation of Oil and Gas Pools to Unconformities in the Mid-Continent Region: Problems of Petroleum Geology (A.A.P.G. symposium).

Maher, John C., and Lantz, Robert J. (1952), Described Sections and Correlation of Paleozoic Rocks at Gilbert, Carver, and Marshall, Arkansas: U. S. Geol. Survey Circ. 160.

__________ (1953), Correlation of Pre-Atoka Rocks in the Arkansas Valley, Arkansas: U. S. Geol. Survey Oil and Gas Investigations Chart OC-51.

Malkin, Doris S., and Jung, Dorothy A. (1941), Marine Sedimentation and Oil Accumulation on Gulf Coast. I. Progressive Marine Overlap: Bull. Amer. Assoc. Petrol. Geol., Vol. 25, No. 11.

Matthes, F. E. (1933), Cretaceous Sediments in Crowley's Ridge, Southeastern Missouri: Bull. Amer. Assoc. Petrol. Geol., Vol. 17, No. 8.

McCracken, Earl (1950), Paleozoic Rocks of the Northern Embayment Region of Arkansas (unpublished).

McKnight, E. T. (1935), Lead and Zinc Deposits of Northern Arkansas: U. S. Geol. Survey Bull. 853.

McQueen, H. S. (1931), Biennial Report of the State Geologist: Missouri Bureau of Geol. and Mines, Appendix I.

Mellen, Frederic F. (1947), Black Warrior Basin, Alabama and Mississippi: Bull. Amer. Assoc. Petrol. Geol., Vol. 31, No. 10.

Miser, H. D. (1934), Relation of Ouachita Belt of Paleozoic Rocks to Oil and Gas Fields of Mid-Continent Region: Bull. Amer. Assoc. Petrol. Geol., Vol. 18, No. 8.

Moody, C. L. (1949), Mesozoic Igneous Rocks of the Northern Gulf Coastal Plain: Bull. Amer. Assoc. Petrol. Geol., Vol. 33, No. 8.

Murphee, E. V. (1952), Where Will Tomorrow's Oil Come From?: The Oil and Gas Journal, Nov. 3, 1952, p. 119.

Mylius, L. A. (1927), Oil and Gas Developments and Possibilities in East-Central Illinois: Illinois State Geol. Survey Bull. 54.

Powers, Sidney, et al (1932), Symposium on Occurrences of Petroleum in Igneous and Metamorphic Rocks: Bull. Amer. Assoc. Petrol. Geol., Vol 16, No. 8.

Purdue, A. H., and Miser, H. D. (1916), U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (No. 202).

Renfroe, Charles A. (1949), Petroleum Exploration in Eastern Arkansas with selected Well Logs: Arkansas Div. of Geol. Bull. 14.

Roberts, J. K. (1929), Cretaceous Deposits of Trigg, Lyon and Livingston Counties, Kentucky: Kentucky Geol. Survey Bull., Ser. XI, Vol. 31.

Schneider, Robert (1947), Ground Water Conditions and Problems in the Upper Mississippi River Embayment: Economic Geology, Vol. XLII, No. 7.

Shreveport Geological Society, 1945 Reference Report, Vol. 1, Plate No. 2, Well No. 23, Shreveport, Louisiana.

Smith, Richard W., and Whitlach, George I. (1940), The Phosphate Resources of Tennessee: Tennessee Div. Geol. Bull. 48.

Spooner, W. C. (1935), Oil and Gas Geology of the Gulf Coastal Plain in Arkansas: Arkansas Geol. Survey Bull. 2.

Swartz, J. H. (1924), The Age of the Chattanooga of Tennessee: Amer. Jour. Science, 5th ser., Vol. 7.

Torrey, Paul D. (1935), Summary of Geology of Natural Gas Fields of New York and Pennsylvania: Geology of Natural Gas (A.A.P.G. symposium).

Tulsa Geological Society (1951), Mid-Continent Region (Southeastern Oklahoma-Northwestern Arkansas): Possible Future Petroleum Provinces of North America (A.A.P.G. symposium).

Ulrich, E. O. (1911), Revision of the Paleozoic Systems: Geol. Soc. Amer. Bull., Vol. 22.

Van der Gracht, W. A. J. M. van Watershoot (1931), Permo-Carboniferous Orogeny in South-Central United States: Bull. Amer. Assoc. Petrol. Geol., Vol. 15, No. 9.

Weeks, W. B. (1938), South Arkansas Stratigraphy with Emphasis on the Older Coastal Plain Beds: Bull. Amer. Assoc. Petrol. Geol., Vol. 22, No. 8.

Weller, J. M. (1940), Geology and Oil Possibilities of Extreme Southern Illinois: Illinois Geol. Survey, Report of Investigations, No. 71.

Wells, F. G. (1933), Ground Water Resources of Western Tennessee: U. S. Dept. of Interior, Water Supply Paper 656.

Wilbert, Louis J., Jr. (1953), The Jacksonian Stage in Southeastern Arkansas: Arkansas Div. of Geology Bull. 19.

Wilson, Charles W., Jr. (1939), Probable Connection of the Nashville and Ozark Domes by a Complementary Arch: Jour. Geol., Vol. 47, No. 6.

APPENDIX

IGNEOUS ROCKS ENCOUNTERED IN WILDCAT WELLS
EASTERN ARKANSAS

Information from C. L. Moody, Division Geologist, The Ohio Oil Company; Carter Oil Company; and analyses by Clarence S. Ross, Chief Petrologist, U.S.G.S., in A.D.G. (Ark. Div. of Geol.) files.

Ashley County

Well: Ark-10 Company (J. P. Bell), Cone Estate No. 1
Location: 23-16S-5W
Date drilled: 1948
Remarks: Igneous encountered at 4755 feet. A.D.G. card.

Well: Lion Oil and Refining Company, Betty No. 1
Location: 29-17S-4W
Date drilled: 1944
Remarks: Igneous rock at 3001 feet. A.D.G. card.

Well: March, K. R., et al, E. J. Williams No. 1
Location: 8-18S-4W
Date drilled: 1934
Remarks: Igneous rock at 3287 feet. A.D.G. card.

Well: A. Plummer, Crossett Lumber Company No. 1
Location: Sec. 25-17S-6W
Date drilled: 1946
From report by A. L. Kidwell, Walker Museum, Chicago, Illinois.
Remarks: Igneous rock encountered at 3282 feet and at 3375 feet. A.D.G. card. This well encountered what appears to be a breccia-filled volcanic pipe.

Geologic Setting: The volcanic material occurs in the Cotton Valley Group of Upper Jurassic age and is overlain by the Monroe Gas Rock which is the youngest Upper Cretaceous formation of the area. The well is located on the Monroe uplift near the northeastward pinchout of the Werner, Louann, Norphlet, and Smackover formations onto the Eagle Mills formation. The well bottomed in 1148 feet of pyroclastic material.

Description: The description is based principally upon core samples from the 3530-3540 foot interval. Cuttings from depths of 4445 and 4535 feet were found to be practically identical with the upper sample.

The rock is composed of sedimentary and igneous rock fragments and individual mineral grains in a fine-grained matrix of calcite, limonite, serpentine, and comminuted rock fragments. The igneous rock fragments are subangular to rounded and range in size from about 5 mm. down to .25 mm. Most of them have a trachytic texture and consist of augite and altered olivine phenocrysts surrounded by laths of chloritized feldspar. In some of the well-rounded fragments these feldspar laths are oriented roughly parallel to the periphery of the fragment, sometimes around a phenocryst as nucleus. These are probably true lapilli, formed by the solidification of blown out drops of a crystal-bearing magma.

Crystals and crystal fragments of augite, diopside, and serpentinized olivine are scattered throughout the rock. These probably represent crystals which were present in the magma at the time of the explosive activity. Some of the crystal fragments are possibly from rocks which had already crystallized and were shattered by the explosion. Orthoclase crystals, which are abundant in many of the tuffs from the Monroe uplift, are conspicuously absent.

Sedimentary rock fragments are rare. A few small pieces of fine-grained limestone and silty shale were observed. Neither of them show any evidence of metamorphic action. There are no admixed sand grains which are so characteristic of the normal water-laid tuffs.

Origin: The Crossett well has undoubtedly encountered a buried volcanic pipe of explosive origin. Evidence for this is the great thickness (1148 feet without passing through it), the presence of lapilli which had to fall back into the hole after their formation, and the lack of any known volcanic activity which could have formed a normal tuff in Cotton Valley time. The pipe is thus probably a diatreme, analogous to those in Perry and Conway Counties, Arkansas; southeastern Missouri; and southern Illinois. These pipes were probably formed as a result of tremendous gas pressure, attendant upon the crystallization of local magma cupalos. After the explosion, fragments of the country rock and drops of the partially crystallized magma were hurled upward and then settled back into the opening. A rotational motion imparted to many of the magma droplets caused the already crystallized feldspar laths to orient themselves parallel to the periphery of the drop, thus forming the typical lapilli. The magma was probably able to rise only a limited distance into the tube before being cooled by the fragmental debris with which it came into contact.

Age: The age of the igneous activity is known to be post-Jurassic and pre-Monroe Gas Rock. It was probably a part of the Upper Cretaceous igneous activity which took place in this part of the country.

Well: The Texas Company, C. L. Gay No. 1
Location: 33-16S-4W
Date drilled: 1928
Remarks: A quartz-bearing syenite was found unconformably underlying late Upper Cretaceous beds. The rock is composed of microcline and biotite with quartz, augite, apatite, and magnetite as accessories. Some of the quartz occurs in granophyric intergrowth which suggests that assimilation of siliceous country rock has occurred. Igneous encountered at 3166 feet.
C. L. Moody

Well: The Texas Company, Keifer No. 1
Location: 11-18S-4W
Date drilled: 1929
Remarks: Core below -2901 appears metamorphosed. Igneous plug near? A.D.G. card.

Well: Texas-Seaboard, Fee No. 1
Location: 28-17S-4W
Date drilled: 1935
Remarks: Oil and gas shows in igneous at -2295. Igneous at 2410 feet. A.D.G. card. Quartz-bearing syenite was cored which approaches a granite in composition; it consists of orthoclase, microperthite, oligoclase, biotite, and hornblende with small amounts of quartz and magnetite. Here too, some of the quartz is granophyric, but some of it is also seemingly a primary constituent.
C. L. Moody

Well: Texas-Seaboard, Bynum-Cooperage No. 1
Location: 34-17S-4W
Date drilled: 1935
Remarks: Oil and gas shows in Syenite at -2350 feet. Igneous at -2296 feet to T.D., 2460 feet. A.D.G. card.

Well: Union Producing Co., Crossett Lumber Co. No. E-1
Location: Sec. 12-19S-7W
Date drilled: ?
Remarks: Igneous dikes in Eagle Mills at 7290, 7340, 7800, 7970, 8240, 8500, 9330, 9650, 10,090, 10,210 feet.
Carter Oil Company

Calhoun County

Well: Ohio Oil Company, Stout Lumber Company No. 1
Location: 31-14S-12W
Date drilled: ?
Remarks: Sample of core obtained at 3383 feet contains abundant fragments of phonolitic volcanic material, feldspar and possibly badly altered glassy tuff fragments. With this is abundant novaculite, and laminated rock fragments. Some of these latter almost resemble schist although most of them are probably fragments of shale. The rock fragments are similar to the material that has been described from the Woodbine of Arkansas and adjacent regions in Texas and Oklahoma.
C. S. Ross, August 17, 1929.

Chicot County

Well: Basin Oil Co., J. H. Dowdle No. 1
Location: 17-18S-1W
Date drilled: 1947
Remarks: Igneous encountered at 3245-3255 feet. Second igneous at 3305 feet. In igneous at T.D. A.D.G. card.

Well: Lisbon Gas Co., Thudium No. 1
Location: 9-15S-2W
Date drilled: 1945
Remarks: Igneous sill at 4090 feet. Oil and gas shows in igneous sill at -3957 feet. A.D.G. card.

Well: The Texas Company, J. R. Hammond, Jr. No. 1
Location: 23-17S-2W
Date drilled: 1928
Remarks: Penetrated igneous rock from 3,412 to 3,296 feet. The specimen from a depth of 3,414 feet originally had the following mineral composition.

Mineral composition of pyroxenite:

Diopside	75
Red-brown hornblende	10
Biotite	3
Magnetite	7
A little titanite	

The diopside has been partly altered to a fine-grained aggregate which is now dominantly biotite epidote and small irregular residual areas of diopside. The hornblende and biotite are partly altered to chlorite, calcite and a serpentine like mineral.

The abundant magnetite is fractured and small veinlets of secondary minerals cut across the grains.

It seems evident that the most conspicuous alteration is not the result of weathering, but is a deuteric phenomenon.

Another specimen from nearly the same horizon is similar to the rock just described but contains plagioclase near bytownite in composition. The original mineral composition was as follows:

The mineral composition of gabbro:

Plagioclase	31
Biotite	23
Augite	27
Magnetite	19

Apatite is abundant and titanite has been altered to leucoxene. The ferro-magnesian minerals are somewhat fresher than in the last rocks but have been partly altered to the same minerals. The plagioclase is partly altered to a very fine-grained indeterminable material.

The first rock would be classified as a pyroxenite and the second as a gabbro very low in plagioclase. A rock of this type has close affinity with peridotite although no olivine is present. Both specimens show deuteric alteration but no evidence of regional or dynamic metamorphism.

The fine-grained specimen from a depth of 3,414 feet is closely allied to the gabbro, but its texture is that of a volcanic flow or a hypabyssal intrusive. The mineral composition is as follows:

Interstitial glass	34
Red-brown hornblende	41
Olivine phenocrysts altered to serpentine	5
Magnetite	11
Analcite	9

The rock is nearly fresh except for the alteration of the olivine and the deposition of a little calcite in vesicular cavities. This rock is best described as an analcite basalt rich in hornblende.
C. S. Ross

A coarse plutonite, cut by a minette dike, was cored. It is composed of augite, alkali feldspar and biotite; large apatites, a little garnet, and euhedral magnetite are accessory.
C. L. Moody

Cleveland County

Well: Arkansas Natural Gas Corp., Mrs. D. J. Tate, No. 1
Location: 4-9S-11W
Date drilled: 1928
Remarks: Peridotite encountered at about 3,561 feet. Completed in a dark, granular intrusive rock found under about 250 feet of somewhat metamorphosed Paleozoic sediments which lie unconformably beneath late Upper Cretaceous strata. It is a peridotite made up of serpentinized olivine, some augite, phlogopite, magnetite, and the rare mineral perovskite.
C. L. Moody

3310-3312 Is a fine-grained shale

3363-3372 The rock is dominantly calcite but contains the remains of completely altered ferro-magnesian minerals and large areas of intergrown magnetite and ilmenite. The ferro-magnesian minerals were biotite and probably diopside. Intergrown magnetite and ilmenite are uncommonly abundant as the rock now contains 28 per cent of these minerals and 15 per cent of leucoxene derived from ilmenite.

3466-3473 The dominant material of the rock is quartz with the fine-grained structure of chert or tripoli. This is cut by abundant veinlets of calcite. Titanium minerals are abundant in veinlets of calcite. Titanium minerals are abundant as the rock now contains 15 per cent of leucoxene and 1 per cent of ilmenite.

3555-3560 Similar to the last but is cut by calcite veinlets that contain diopside.

3561-3563 A rock composed of serpentine that is cut by innumerable veinlets of calcite.

3600 Is a rock that is nearly black in hand specimen and contains conspicuous magnetite. The mineral composition is as follows:

Mineral composition of perovskite peridotite:

Olivine altered to (serpentine	24
(magnetite	29
Primary magnetite	13
Perovskite	31
Mica	3
Very small amounts of diopside	

3616 This mineral composition is as follows:

Mineral composition of peridotite

Calcite	8
Olivine	2
Diopside	4
Mica	11
Magnetite	32
Serpentine	34
Perovskite	9

Part of the calcite forms irregular areas where it has replaced serpentine and large rounded poikilitic areas that inclose mica or diopside. Olivine occurs as small residual areas inclosed in serpentine. Diopside is rounded by corrosion by calcite or is partly altered serpentine but is very much less altered than olivine.

The mica is colorless in thin section but appears to be a very pale phlogopite. Part of it forms large crystals 1 mm or more in diameter that seems to have crystallized at about the same time as olivine and diopside; and part forms zones that are the alteration production of olivine where it is evidently a result of reaction between residual solutions and olivine.

Part of the magnetite forms large irregular crystals up to 2 mm in diameter and part is disseminated through serpentine where it has formed during the alteration of olivine.

Most of the serpentine has formed from olivine but a small part may be due to slight corrosion of diopide and mica.

Perovskite forms large irregular crystals that are unaltered.

The olivine has been almost completely altered to serpentine and a little calcite but the other minerals are fresh and so the rock has not been highly altered. The alteration is all of the hydrothermal or deuteric type.

The rocks from a depth of 3,310 to about 3,563 feet appear to be sedimentary rocks (shale, limestone and possibly chert) that have been partly altered and ferromagnesian minerals developed by contact metamorphism of the peridotite.

Peridotite seems to have been encountered at about 3,561 feet where a serpentine derived from a nearly pure olivine rock was encountered. Below about 3,600 feet the rock is a peridotite of variable composition. Some parts are characterized by abundant magnetite and perovskite and others by mica, diopside and magnetite.

The rock from Rison, Cleveland County, is probably most closely allied in mineral composition with the diamond-bearing peridotite of Pike County, Arkansas. The gabbro-pyroxenite of Chicot County may also be related. Both rocks show hydrothermal metamorphism but no evidence of regional or dynamic alteration. This may mean that the rocks are later than pre-Cambrian and are related to the Cretaceous peridotites of Pike County in age as well as mineral composition.
C. S. Ross

Well: Lion Oil Company, Reap No. 1
Location: 25-11S-9W
Date drilled: 1943
Remarks: Igneous at 4204. A.D.G. card.

Cross County

Well: Manning and Martin No. 1 Park - Gieseck
Location: 4-6N-5E
Date drilled: 1937
Remarks: A sample of igneous rock obtained from 3720 feet was found to consist of basaltic rock, somewhat calcitized and otherwise altered. Minute but well defined intersertal or diabasic structure was present, with principal minerals being labradorite and augite. The material is inadequate to justify more than a rough guess as to structural relationships, but since no flows are known in this area in Ordovician rocks, this sample may be from a dike of intermediate age intruding the Ordovician rocks with which it is associated.
C. L. Moody, August 15, 1950

Desha County

Well: Columbian Gas Company, Victoria Cross Lumber Co. No. 1
Location: 34-8S-3W
Date drilled: 1938
Remarks: Drilled into a normal syenite at a depth of 4,875 feet. The rock consists of sericitized alkali feldspar, oligoclase, brown hornblende, and pale biotite with accessory magnetite and abundant euhedral apatite.
C. L. Moody

Granite encountered at 4875 feet. A sample taken from 4904 feet is composed of plagioclase, brown hornblende, biotite, and a little magnetite and apatite. No quartz or potash feldspar was observed. The feldspar is greatly altered, and contains a large proportion of calcite and sericite. Hornblende is partly altered to magnetite and other secondary materials. The rock is, therefore, best described as a diorite.
C. S. Ross, May 3, 1938.

Well: Carter Oil Company, L. Isom No. 1
Location: 33-9S-1W
Date drilled: 1947
Remarks: Igneous (?) or basal gravel at 4723. A.D.G. card.

Well: W. S. Goodwin, S. A. Banks No. 1
Location: 32-9S-4W
Date drilled: 1945
Remarks: Igneous at 4830 feet. T.D. in igneous. A.D.G. card.

Drew County

Well: Curtis Kinard, T. C. Deal No. 1
Location: 29-11S-7W
Date drilled: 1945
Remarks: Igneous at 4350. A.D.G. card.

Well: The Ohio Oil Company, Jerome Lumber Company No. 1
Location: 13-15S-4W
Date drilled: 1929
Remarks: Igneous encountered at 3454 and 3540 feet. Lava found from 3558 to 3748 feet. Cores cut in this well from depths between 3,445 and 3,742 feet reveal a perfect gradation from red, lateritic, augitic volcanic rock to fresh monchiquite. Later Upper Cretaceous sand lies unconformably on the weathered upper surface of the igneous rock. A typical monchiquite is a black, hypocrystalline, porphyritic rock consisting of pyroxene and olivine phenocrysts distributed through a groundmass of small pyroxenes and interstitial glass. A common dike-rock type in the alkaline province is the black, olivine-free monchiquite which has been named fourchite from Fourche Cove, where it occurs as a central augitic core in the nepheline syenite of Fourche Mountain, Arkansas. Dikes of fourchite have been penetrated in six more Mississippi wells.
C. L. Moody

Grant County

Well: Shafer Oil and Refining Company, Longbell No. 1
Location: 36-5S-12W
Date drilled: ?
Remarks: Igneous rock at 2770 to 2775 feet

Well: Shafer Oil Refining Company, Youngblood No. 1
Location: 34-4S-13W
Date drilled: 1927
Remarks: Igneous (Pyroxenite) encountered at -2254 feet. Igneous also from 2268 to 2284 feet. A.D.G. card.

The first plutonic rock discovery in a Coastal Plain well was made in this well in 1927. It is a greenish black, lustrous rock which, under the microscope, is seen to be composed almost entirely of augite and diallage with a little magnetite.
C. L. Moody

Pulaski County

Well: Wonder State Development Company, Wilson No. 1
Location: 21-2S-11W
Date drilled: 1929
Remarks: Clay and shale from 1450 to 1544 feet. Struck Paleozoic or basement rock at 1547 feet and stopped drilling. Igneous rock at 1544 feet.
George Branner.

Sample of rock obtained from 1544 feet is a coarse-grained granitic or pegmatitic rock that was originally composed dominantly of microcline. Part of the microcline is nearly fresh, but large, sharply bounded areas are completely altered to a micaceous mineral, calcite and a little purple fluorite. The micaceous mineral is composed of fairly coarse radial groups and is uniaxial or nearly so. Such material would ordinarily be called sericite but the habit and optical properties suggest very strongly that it is cookeite. The calcite has clearly replaced microcline. The association of cookeite, secondary calcite and fluorite suggests that the granite or pegmatite has been hydrothermally altered.
C. S. Ross

Igneous at 1544 feet. A.D.G card.

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