Upper Jurassic Stratigraphy of Some Adjacent Parts of Texas, Louisiana, and Arkansas

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Upper Jurassic Stratigraphy of Some Adjacent Parts of Texas, Louisiana, and Arkansas

By KENDELL A. DICKINSON

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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A discussion of the nomenclature, lithologic character, thicknesses, and the relation of lithofacies to paleotectonic elements of Upper Jurassic rock strata

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CONTENTS

ILLUSTRATIONS

TABLE

UPPER JURASSIC STRATIGRAPHY OF SOME ADJACENT PARTS OF TEXAS, LOUISIANA, AND ARKANSAS

By Kendell A. Dickinson

ABSTRACT

The Smackover and Buckner Formations and the Cotton Valley Group, which is composed in ascending order of the Bossier and Schuler Formations, are of definite Late Jurassic age. The Norphlet Formation, although considered to be of Late Jurassic age, is unfossiliferous and its age is unproven. The Haynesville Formation, which is composed of part of the Cotton Valley Group and the Buckner Formation, is not used here.

The Upper Jurassic rocks are found only in the subsurface at depths generally ranging from 1,000 feet along the north edge of the gulf coast embayment to 12,000 feet in Louisiana. Their thicknesses and lithologic characteristics were affected by contemporaneous regional movement along the Sabine uplift and the north Louisiana basin and by local movement of anticlines and faults along the margin of the gulf coast embayment. The Smackover and Buckner Formations and the Cotton Valley Group are characterized by varied lithology and by lack of lateral continuity. No regional unconformities are apparent in the Upper Jurassic rocks.

The Smackover Formation is divided into three informal members—lower, middle, and upper. The lower member consists predominantly of dark-brown silty to argillaceous limestone that is commonly laminated. It is recognized over a much wider region, particularly in downdip areas, than the middle and upper members. The middle member, which is predominantly dense limestone, and the upper member, which is predominantly oolitic limestone, are confined to the north margins of the gulf coast embayment in the report area. Southward from downdip areas the middle and upper members grade laterally into the Bossier Formation.

The Buckner Formation, which in the report area is confined to the north margin of the gulf coast embayment, is divided informally into lower and upper members. The lower member, which consists mostly of anhydrite and anhydritic mudstone, was deposited in a narrow basin that paralleled the margin of the embayment. It is apparently limited along its south side by a series of salt-cored anticlines that were forming at the time of deposition and were partly responsible for restricting the outflow of hypersaline water from the marginal basin. The upper member, which consists mostly of mudstone and shale, is found throughout the area of the lower member and even farther south where it is thickest. It is apparently limited on the south by a second series of anticlines. An earlier concept that reef growth within the Smackover Formation was the principal cause of evaporite deposition in the Buckner Formation now seems to be incorrect.

The Bossier Formation is here redefined to include all dark-gray shale above the lower member of the Smackover Formation and below the basal sandstone of the Schuler Formation. It thus includes equivalents of the middle and upper members of the Smackover Formation, all the Buckner Formation, and part of the Schuler Formation. A thin upper part of the Bossier extends northward into the lower part of the Schuler Formation and is here informally termed the Q tongue of the Bossier Formation.

The Schuler Formation is here redefined to include all rocks between the top of the Buckner Formation and the base of the Cretaceous rocks, except for the Q tongue of the Bossier Formation. A sandstone and shale tongue that underlies the Q tongue of the Bossier is here informally termed the P tongue of the Schuler. In updip areas the Schuler Formation is largely near shore or nonmarine in origin, and in downdip areas to the south it is marine. The near-shore or nonmarine facies consists of lenticular light-gray, pink, or reddish-brown fine-grained sandstone and pastel varicolored and reddish-brown shale. The normal marine facies consists of light-gray fine-grained sandstone, dark-gray fissile fossiliferous shale, and some limestone. Two conspicuous unconnected conglomeratic facies are found in the lower part of the Schuler Formation; one is updip in the nonmarine facies and the other is downdip in the marine facies.

INTRODUCTION

The Upper Jurassic rocks are entirely subsurface units that underlie much of the gulf coast embayment in eastern Texas, southern Arkansas, Louisiana, central and southern Mississippi, and southwestern Alabama (fig. 1). The Smackover and Buckner Formations and the overlying Cotton Valley Group which is comprised of the Bossier and Schuler Formations are definitely of Late Jurassic age. The Norphlet Formation is also generally believed to be of Late Jurassic age, but its lack of fossils makes determination more difficult. It overlies the Louann Salt of Jurassic(?) age. The Cotton Valley Group is overlain by the Hosston Formation of Early Cretaceous age.

The Upper Jurassic rocks lie at depths of 1,000–3,000 feet at their north edge in southern Arkansas and northeastern Texas, at about 12,000 feet in northern Louisi-

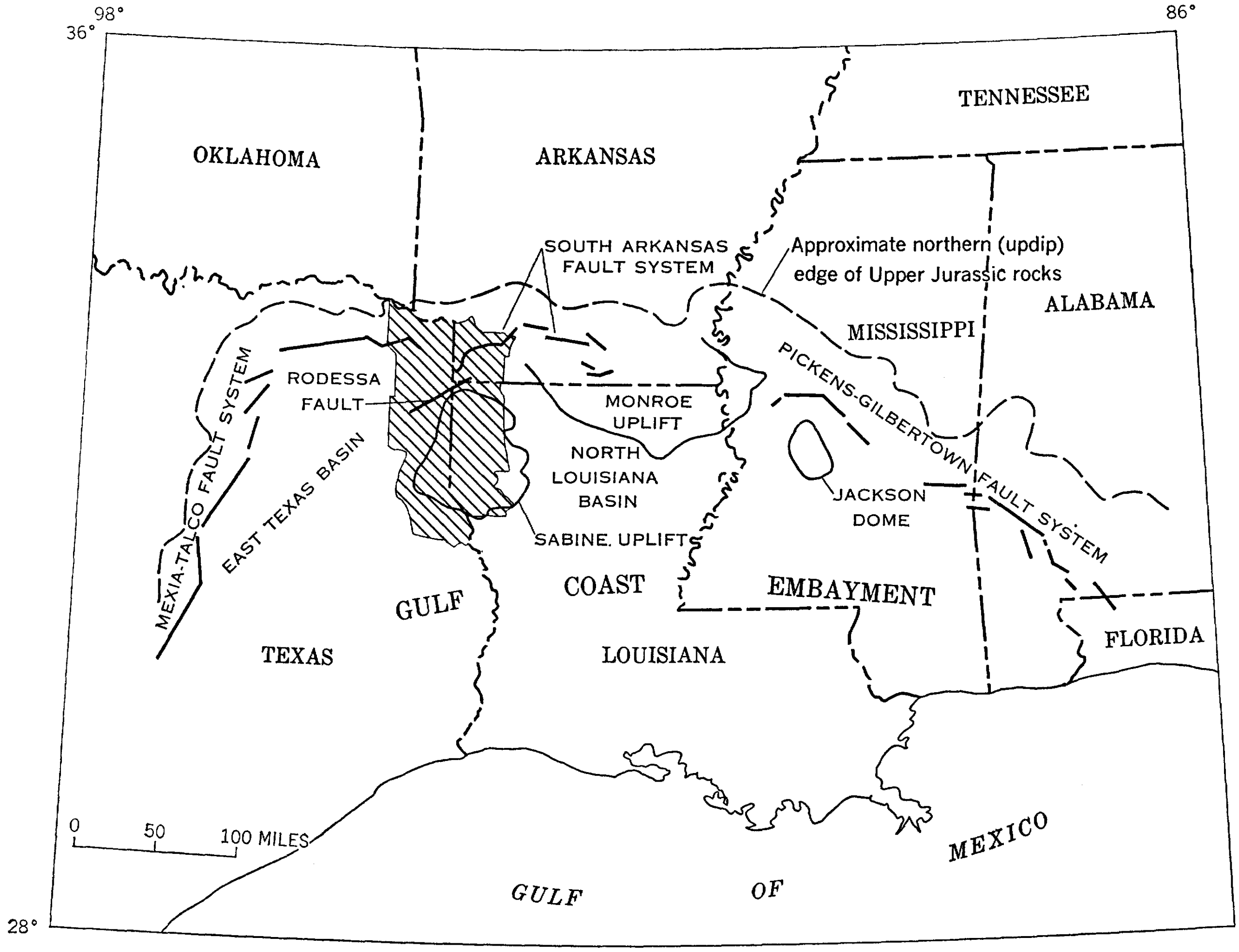

FIGURE 1.—Area of report (crosshatched) in relation to approximate updip limit of Upper Jurassic rocks and to present major structural features of gulf coast embayment.

ana and eastern Texas, and at even greater depths in central Louisiana and southeastern Texas where they have not been penetrated by drilling. In southern Mississippi rocks of Late Jurassic age have been found below 20,000 feet. The Upper Jurassic rocks maintain relatively uniform thicknesses in downdip areas, but they thin to a featheredge along the northwest, north, and northeast margins of the gulf coast embayment. The thickness of the Upper Jurassic rocks in the report area is shown in figure 2, and the structural and stratigraphic relations between the northern (updip) and the southern (downdip) parts of the report area are shown in figure 3. The nearest outcrops of Upper Jurassic rocks are in the Malone Mountains of southwestern Texas, and in Mexico and Cuba.

PURPOSE AND SCOPE

This report presents a revised nomenclature and some new stratigraphic interpretations made on the basis of new data, the reevaluation of old data, and the application of new structural concepts. Further investigations into the petrography and origin of each unit are underway, and reports on these subjects are planned. The revision of stratigraphic nomenclature in this report includes a rank change of one unit and the redefinition of several formations. The impracticability of using the same formational names for widely different sedimentary facies is demonstrated. No new formal terms are proposed and an attempt is made to follow original definitions.

The nomenclature used here is based primarily on a study of rocks in the western part of the ancestral north Louisiana basin and of rocks on the ancestral Sabine uplift and, therefore, may not be entirely suitable for use in the east Texas basin or in other parts of the gulf coast embayment. Each basin within the gulf coast embayment has a somewhat distinctive depositional and lithologic character. Formational unit names, such as Smackover and Schuler, may be generally applied throughout the embayment, but to a large

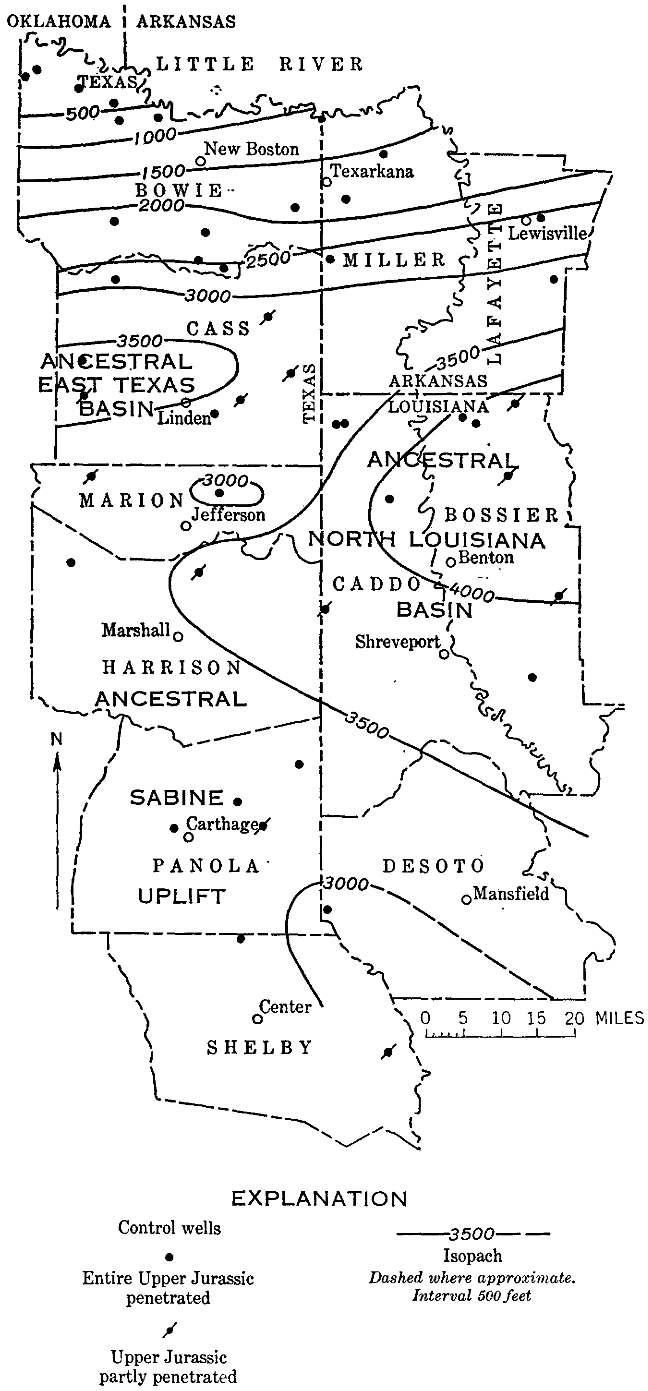

FIGURE 2.—Isopach map of Upper Jurassic rocks and locations of major ancestral structural features.

extent they must be redefined in each local basin or other names must be applied (Murray, 1961, p. 290).

The area of this report lies in the northwestern and north-central parts of the gulf coast embayment (fig. 1) and includes Bowie, Cass, Marion, Harrison, Panola, and Shelby Counties, Tex.; Lafayette and Miller Counties, Ark.; and Bossier, Caddo, and De Soto Parishes, La. The total area is approximately 9,800 square miles.

STRUCTURAL SETTING

The tectonic elements that existed in the gulf coast embayment during Late Jurassic time have remained unchanged to the present, except that their axes have shifted. During the Late Jurassic Epoch the Sabine uplift occupied the west half of the present report area and the north Louisiana basin occupied the east half. The axis of each tectonic feature shifted eastward, however, so that the present Sabine uplift occupies most of the report area and the north Louisiana basin lies directly to the east of the uplift (fig. 1). Both the ancestral and present Sabine uplifts are separated from the north margin of the gulf coast embayment by a northeast-trending extension of the east Texas basin.

Smaller basins have been formed along the margins of the gulf coast embayment because of the concurrent growth of synclines and anticlines. According to Bornhauser (1958), gravitational flowage of the underlying Louann Salt formed many of these folds, but some folds, according to Fowler (1964), resulted from other tectonic activity.

Parts of the Mexia-Talco and south Arkansas fault systems and other normal faults are present in the report area (fig. 1). The Mexia-Talco fault system borders the north margin of the east Texas basin and apparently extends into the report area from the west in southern Bowie County, Tex. The south Arkansas fault system extends from the southwest corner of Arkansas, east and northeast across Miller and Lafayette Counties in the report area, and then eastward across south-central Arkansas. These fault systems and the Pickens-Gilbertown fault system of Mississippi and Alabama are generally parallel to and south of the northern limit of Upper Jurassic rocks in the gulf coast embayment.

Many of these faults bound grabens that formed near the crests of anticlines. Movement along these faults was associated with the formation of salt domes or salt-cored anticlines during the Late Jurassic. Another large fault, the Rodessa, strikes northeastward across Marion County, Tex., and adjacent parts of Louisiana and Arkansas (fig. 1).

METHODS

Rotary drill cuttings and (or) cores were examined from 40 wells. Electric logs from 39 of these wells and from an additional 150 wells were studied. For well names and locations see Dickinson (1968). Supplementary data were obtained from commercial sample logs, especially if samples were not available to the author. Where interpretive sample logs based on commercial

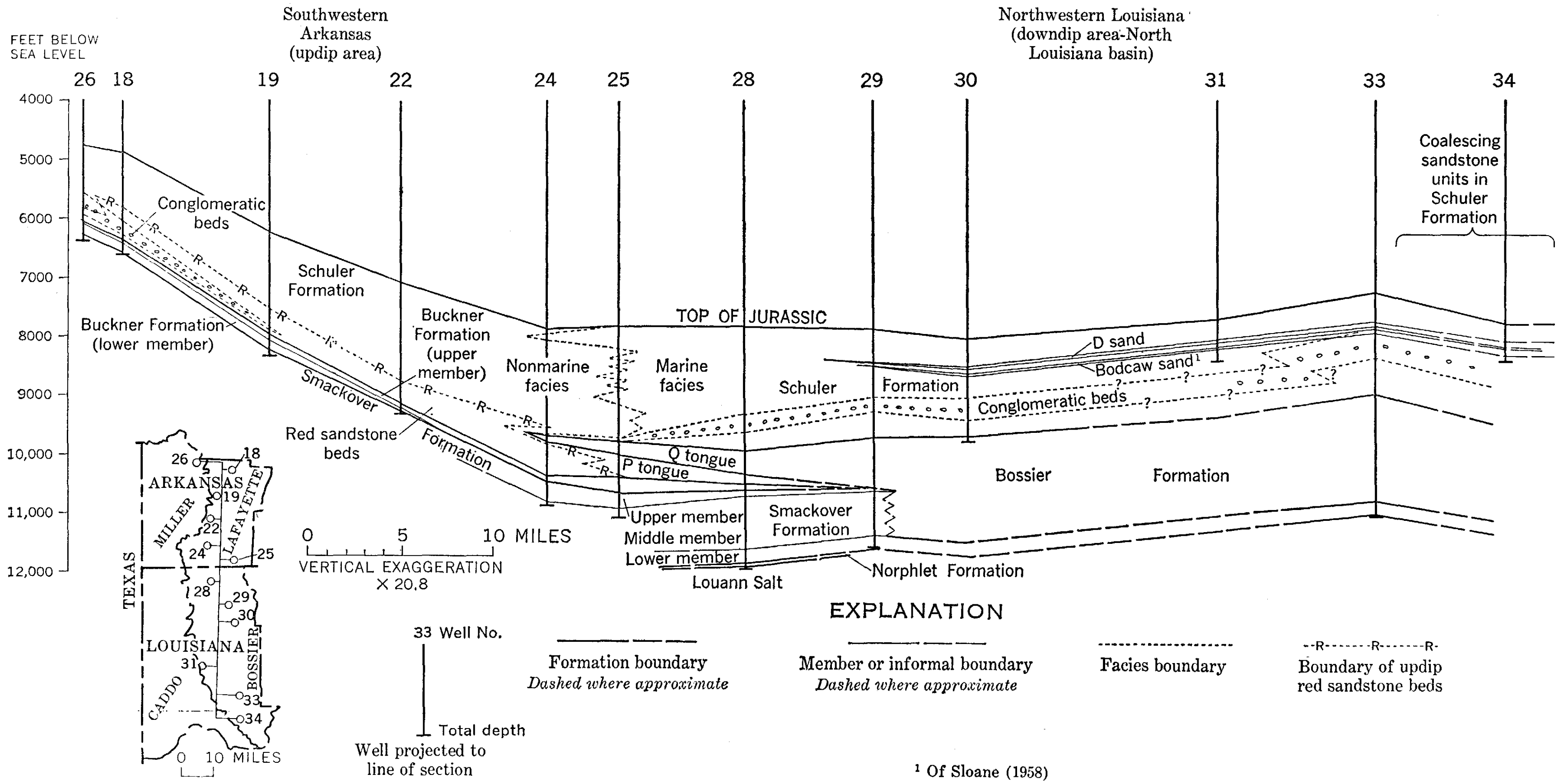

Figure 3.—Diagrammatic cross section of Upper Jurassic rocks showing structural and stratigraphic relations from margin to deeper part of gulf coast embayment.

percentage logs are presented in the illustrations of this report (pl. 1*A*, *B*, *C*), the interpretations shown are those of the author. All rotary drill cuttings from wells in the report area were contaminated from caving farther up the hole; consequently, logs made from these samples are highly interpretive and may not be logged in the same way by other geologists. Little credence was given to those samples that appeared to be excessively contaminated. The wells from which data were taken for plate 1 and figure 3 are listed in table 1.

TABLE 1.—*Names and locations of some wells in adjacent parts of Texas, Arkansas, and Louisiana*

No. on pl. 1 and fig. 3	Company	Well name and No.	Location			Derrick floor elevation (feet above sea level)
		TEXAS				
		Bowie County				
1	W. M. Coats	S. H. Hall 1	Bowie County School Land.			376
2	W. T. Phillips and others	T. & P. Railroad 1	J. Kittrell A–329			374
3	Ray and others	P. S. Cork 1	M.E.P. & P. RR. Co.			368
4	Cities Service Petroleum Co	Johnson "Y" 1	John Maulding A–399			343
5	Tidewater Oil Co	I. G. Talley 1	J. S. Herring A–263			291
6	Gulf Oil Corp	J. Veatch 1	Jacob McFarland			240
		Cass County				
7	Shell Oil Co	J. M. Lasater 1	H. R. Latimer A–650			354
8	Trunkline Gas Co	C. M. McWhorter and others 1	W. Wimberly A–1133			346
9	H. L. Gist and Herring Drilling	T. R. Harrell 1	J. Styles A–939			364
10	Texaco, Inc	M. C. Thompson 1	B. M. Dorriss			455
11	Sunray Mid-Continent Oil Co. and others.	T. J. Mays 1	W. Sonaho A–250			309
12	Humble Oil & Refining Co	South Atlanta Gas Unit 1	Ciriaco Conti A–238			304
13	Pan American Petroleum Corp	Giraud Gas Unit 1	G. S. Young A–1161			347
		Harrison County				
14	Pan American Petroleum Corp	Davis Gas Unit A–2	L. Watkins A–750			283
		Marion County				
15	San Jacinto Oil & Gas Co	M. Cowherd 1	C. Massenton A–289			311
		Panola County				
16	Chicago Corp	Allison Bros. 1	J. Hughes A–278			297
		ARKANSAS				
		Lafayette County				
			Section	Township S.	Range W.	
17	Arkansas Louisiana Gas Co	H. F. Russell 1	3	15	25	251
18	T. M. Evans and others	Osborne 1	16	15	24	281
19	D. Crow and G. B. Christmas	Alford 1	25	16	25	234
20	L. Taubel and others	Tatum 1	18	16	22	255
21	Coulston Drilling Co	Cornelius Est. 1	32	16	23	271
22	Janlyn Oil Co	Barker 1	34	17	25	227
23	Janlyn Oil Co	Cabe 1	1	18	24	264
24	Tennessee Gas Transmission Co	M. Friend	9	19	25	255
25	Austral Oil Co., Inc., and Olin Gas Transmission Co.	International Paper Co. 1	34	19	24	248
		Miller County				
26	McAlester Fuel Co	S. Hervey A–1	Sec. 1, T. 15 S., R. 26 W.			252

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TABLE 1.—*Names and locations of some wells in adjacent parts of Texas, Arkansas, and Louisiana*—Continued

No. on pl. 1 and fig. 3	Company	Well name and No.	Location			Derrick floor elevation (feet above sea level)
		LOUISIANA				
		Bossier Parish				
			Section	Township N.	Range W.	
27	Carter Oil Co	E. Smith 1	2	23	13	262
28	Barnsdall and Sohio Oil Cos	Carter Burton 1	26	23	13	368
29	Feazel Interests and others	L. English 1	33	22	12	341
30	Carter Oil Co	Crystal-Whited 1	26	21	12	241
31	Union Producing Co	Modica 1	32	19	13	231
32	Phillips Petroleum Co	Kendrick 1	22	19	11	231
33	Union Producing Co	Section 13 Unit 1	13	17	12	200±
34	Gulf Refining Co	Hodges 20	24	16	12	172
		Caddo Parish				
			Section	Township N.	Range W.	
35	Arkansas Louisiana Gas Co	M. Pitts 5	11	23	16	244
36	R. W. Norton	Paynes 1	27	23	16	231

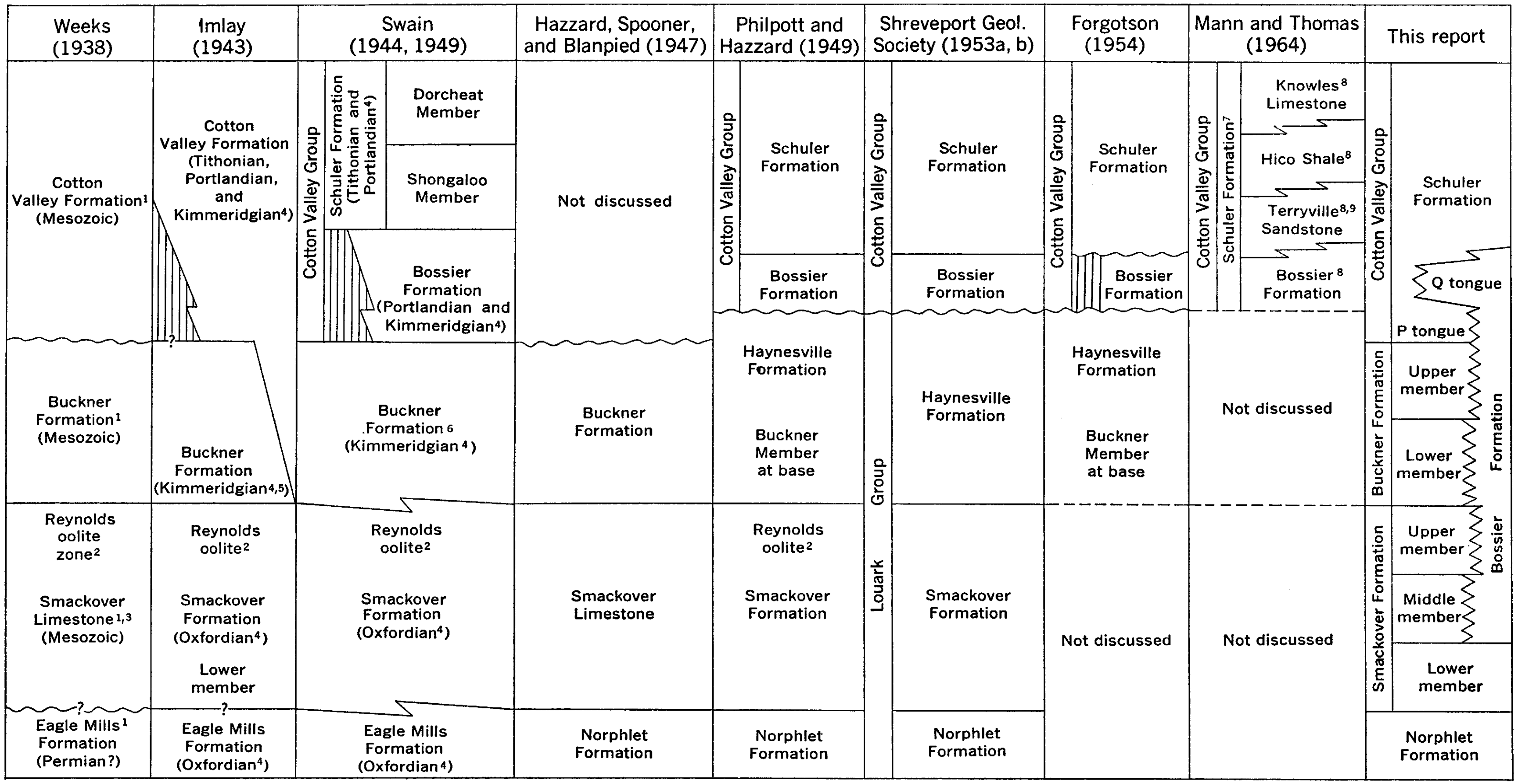
ACKNOWLEDGMENTS

Discussions of the stratigraphy with several geologists were helpful in the formulation of concepts presented in this paper. Many others lent substantial aid by providing well information and samples. Especially helpful were Robert W. Eaton, independent geologist; James W. Harrison, Pan American Petroleum Corp.; Jim H. Cox, Phillips Petroleum Co.; and William W. Brewton, Humble Oil & Refining Co.

NOMENCLATURE

The nomenclature of Upper Jurassic rocks in this area has been controversial and has been subject to periodic revision because new drilling continually produces more information. The history of nomenclature together with that used here is shown in figure 4. The usages adopted for this paper and the justification for changes are presented as follows:

1. The Norphlet Formation is used here as originally defined by Hazzard, Spooner, and Blanpied (1947) to include strata overlying the Louann Salt and underlying the Smackover Formation.
2. The term Smackover Formation is used here for the unit originally defined by Weeks (1938, p. 964) as the Smackover Limestone. In the present report the Smackover Formation includes strata overlying the Permian(?) Eagle Mills Formation and underlying the Buckner Formation; the Smackover is herein divided into three informal members—lower, middle, and upper. The lower and middle members are approximately equivalent to the lower and middle parts of the formation as described by Weeks; the upper member is generally the same as his Reynolds oolite zone except that it locally contains additional oolitic beds and dolomite. Only the lower member can be recognized throughout the report area. In the ancestral north Louisiana basin and on the ancestral Sabine uplift, strata equivalent to the middle and upper members consist of dark-gray shale and are in the present report included in the Bossier Formation.
3. The Buckner Formation is used here as described by Weeks (1938) and not as a member of the Haynesville Formation as proposed by Philpott and Hazzard (1949). The Buckner includes those rocks overlying the Smackover Formation and underlying the Cotton Valley Group as these units are defined herein. The Buckner is divided into two informal members—an upper member that is predominantly red mudstone and a lower member that is predominantly anhydrite. The members are easily separable on sample and electric logs except in the eastern part of Lafayette County, Ark., where the entire formation is thin, and along the downdip limit of the lower member in Cass County, Tex., where the upper member is more evaporitic. The term Buckner will not be applied to beds of equivalent age of offshore marine origin because the evaporites, which characterize the Buckner, were deposited only in linear basins around the margin of the Gulf Coast embayment.



[1] Preliminary description published by Shearer (1938) after approval by Shreveport Geological Society
[2] Of local usage
[3] Term first appeared in Bingham (1937)
[4] European Upper Jurassic stages
[5] Imlay (1952) put the Buckner in the Oxfordian as a Smackover equivalent
[6] Considered the Buckner Formation as passing downdip into the upper part of the Smackover Formation
[7] Recognized Dorcheat and Shongaloo Members of Schuler Formation, which is restricted to the northern or near-shore part of the area
[8] Restricted to the southern or offshore area
[9] Includes proposed Cadeville, Bodcaw, Vaughn, McFearin, and Justiss Tongues

FIGURE 4.—History of nomenclature of Upper Jurassic rocks in gulf coast embayment. Dashed lines are used for contacts not discussed.

4. The Haynesville Formation of Philpott and Hazzard (1949), as defined by them, is not used because (1) it includes a widespread identifiable unit, the Buckner Formation, (2) its upper part is lithologically more like rocks of the Cotton Valley Group, (3) apparently no regional unconformity or distinct lithologic break is present at its top, and (4) the Buckner Formation is not equivalent to any part of the upper rocks originally included in the Haynesville Formation. The Haynesville was defined to include the Buckner Formation of Weeks (1938) as a member and the lower part of the overlying Cotton Valley Group (Goebel, 1950; Chapman, 1951). The rocks included in the Haynesville Formation are here separated into the Buckner Formation and the Cotton Valley Group in accordance with Week's original usage (fig. 4).

Retention of the Buckner as a formational unit is desirable because it is lithologically more persistent and is recognizable over a much wider area than is the Haynesville Formation. Characteristic sections of the Buckner Formation have been described in central Mississippi by Dickinson (1963) and on the west side of the East Texas basin by Swain (1949), both sections being far removed from the present report area.

The predominant lithology of the Haynesville Formation, except the Buckner Member, is white, light-gray, or pink fine-grained sandstone and gray shale very similar to parts of the overlying Cotton Valley Group. That the red color of the Haynesville rocks can be used to differentiate them from overlying rocks of the Cotton Valley Group as claimed by Goebel (1950) and Chapman (1951) can be true only locally. For example, at the type section of the overlying Schuler Formation (Swain, 1944), a basal red sandstone of the Schuler overlies white to gray sandstone of the Jones sand (local usage) which according to Goebel (1950) is part of the Haynesville Formation. White and gray sandstone was reported by Swain (1944, p. 593) just above the Buckner Formation in the Ohio Oil Co. Taylor well 15, sec. 15, T. 23 N., R. 8 W., Claiborne Parish, La. No red sandstone in one well and only 40 feet of red sandstone in another well was reported in the Haynesville Formation in Webster Parish, La., by Martin, Hough, Raggio, and Sandberg (1954, p. 33–34). A preponderance of white, light-gray, and tan sandstone and only a minor amount of red sandstone were found in the Haynesville Formation in several wells in the vicinity of the Haynesville oil field.

According to Chapman (1951) and Goebel (1950), the color change, steep dips in at least one well, faulting that seems to be confined to beds older than the Cotton Valley, and the extreme range of thickness of beds older than the Cotton Valley indicate that a regional unconformity exists at the top of the Haynesville Formation. As discussed above, the colors are not stratigraphically consistent and the other conditions are better explained by the growth of salt-cored anticlines concurrent with deposition (Bornhauser, 1958; Dickinson, 1963). As was recognized by Sloane (1958, p. 6), the variable thickness of the Haynesville Formation need not be the result of post-Haynesville erosion. Bornhauser (1958, p. 352) stated, "All anticlinal folds in the western Gulf Coast show a marked thinning over their crests and a corresponding thickening of section down their flanks into adjacent synclinal areas." He also stated that "this thickening may increase as rapidly as 200 to 300 percent per mile."

The faulting which, according to Chapman (1951), characterizes pre-Cotton Valley strata is found only in the crestal grabens of salt-cored anticlines in the East Haynesville and nearby Colquitt oil fields (Shreveport Geological Society, 1953b, p. 63; 1958, p. 186). These anticlines are known to have formed because of flowage of contained salt. The upper limit of the faulting is controlled, therefore, by the time of salt movement, as pointed out by Bornhauser (1958, p. 360), and is not directly related to a regional tectonic episode.

Correlation of electric and sample logs shows that the updip parts of the Buckner Formation underlie, and are not equivalent to, the downdip clastic rocks of the Haynesville Formation (pl. 1*A*, *B*). In some areas the Buckner Formation is missing, but this is apparently due to nondeposition or local erosion at the end of Buckner deposition (Goebel, 1950).

For all the foregoing reasons the name Haynesville ought to be abandoned for regional use as a rock-stratigraphic unit. Such action is not taken now, however, because the name may be useful locally and because correspondence with E. G. Anderson, Louisiana Geological Survey, indicates that he believes the name is useful.

5. The Bossier Formation is redefined to comprise the original formation as defined by Swain (1944, p. 591) and the underlying sequence above the lower member of the Smackover Formation as used in the present report (pl. 1*B*). This interval of rocks lies between depths of 8,140 and 8,627 feet in the type well, Phillips Petroleum Co. Kendrick well 1, sec. 22, T. 19 N., R. 11 W., Bossier Parish, La. (pl. 1*B*, no. 32 on cross section). Redefinition is

necessary because the added basal sequence consists of dark-gray calcareous shale very similar lithologically to the overlying Bossier Formation in the type well and because the added sequence is easily differentiated from the Buckner Formation or the underlying lower member of the Smackover Formation. The basal sequence, herein added to the Bossier, was referred to by Swain (1944, p. 592) as the Buckner Formation, by Imlay (1943, p. 1429) as "marine beds probably equivalent to the Buckner Formation," and by Arper (1953) as the Smackover Formation. The redefined Bossier Formation is virtually the same as that proposed by Mann and Thomas (1964).

The tongue of the Bossier Formation that extends updip into the Schuler Formation is informally referred to here as the Q tongue (fig. 4, pl. 1*A*, *B*).

6. The Schuler Formation is redefined to include the original formation as defined by Swain (1944, p. 598) and an additional underlying sequence. In the type well, Lion Oil Refining Co. and Phillips Petroleum Co. Edna Morgan 1, sec. 18, T. 18 S., R. 17 W., Union County, Ark., the original Schuler Formation extends from depths of 5,410 to 7,475 feet; in the present report it is extended to a depth of 7,600 feet. The added sequence, which is mostly light-gray sandstone and dark-gray shale, extends to the south beneath the Q tongue of the Bossier Formation; this unit is informally referred to here as the P tongue of the Schuler Formation. It was included in the Bossier Formation by Swain (1944), and part of it was included in the Haynesville Formation by Goebel (1950). The Jones sand of local usage is included in the P tongue. The present nomenclature provides a clear lithologic separation; it places nearly all interbedded sandstone and shale in the Schuler and all dark-gray marine shale that is devoid of sandstone in the Bossier Formation. The Shongaloo and Dorcheat Members proposed for the Schuler Formation by Swain (1944) are not used in this report.

The downdip marine part of the Schuler Formation to the south (pl. 1*A*, *B*) was divided into three formations—the Terryville Sandstone, the Hico Shale, and the Knowles Limestone—by Mann and Thomas (1964). They also named five tongues of the Terryville Sandstone, which are, in ascending order—the Justiss, the McFearin, the Vaughn, the Bodcaw, and the Cadeville. These terms are not being used in this report because of the complex intertonguing between some of them and because they are not present or are not easily recognized on the ancestral Sabine uplift. Also, the double usage of some names has caused confusion. The name applied by Mann and Thomas for each tongue of the Terryville, except the Bodcaw, was taken from one of several informal units within the tongue. The Cadeville Tongue, for example, is not the same stratigraphic unit as the Cadeville sand of informal usage, and, further, the Cadeville Tongue is found in areas where the Cadeville sand is not present. The term Bodcaw was proposed prior to the work of Mann and Thomas by Sloane (1958).

7. The Cotton Valley Group is used here as originally defined by Swain (1944) to include the Bossier and Schuler Formations.

8. The Louark Group is not used here because it is not adequately defined. In the original usage by the Shreveport Geological Society (1953b, p. 63), the Louark Group consisted of the Norphlet, Smackover, and Haynesville Formations.

STRATIGRAPHY

NORPHLET FORMATION

The Norphlet Formation consists of 34 feet of red and gray shale in red and gray partly conglomeratic sandstone at the type section in the Gulf Refining Co. Werner Saw Mill Co. well 49, sec. 5, T. 16 S., R. 16 W., Union County, Ark. In the report area, although sample data are sparse, it consists of light-gray to brown, friable, poorly sorted sandstone and conglomeratic sandstone, gray shale, and anhydrite. The Norphlet Formation ranges in thickness from 15 to about 70 feet in the area but it is generally about 50 feet thick. According to Hazzard, Spooner, and Blanpied (1947), it unconformably overlies the Louann Salt and conformably underlies the Smackover Formation. The relation of the Norphlet to the updip sections of the Eagle Mills Formation of Weeks (1938) is unknown.

SMACKOVER FORMATION

The Smackover Formation consists of gray to brown dense and oolitic limestone (pl. 1*A*, *B*). Fossils—mostly algae, forams, and mollusks—are common but not abundant in the Smackover. The lower member is dark-gray argillaceous silty limestone, the middle member is brown dense limestone, and the upper member is light-brown to dark-gray oolitic, pisolitic, and intraclastic limestone that is commonly porous. The upper member, from which much petroleum is produced, has been dolomitized to various degrees in the northwestern part of the report area. A reference section of the Smackover from the report area follows.

Reference section of the Smackover Formation and partial sections of adjacent formations

[Logged from cuttings; Pan American Petroleum Corp., Giraud Gas Unit well 1, George S. Young Survey A-1161, Cass County, Tex. Derrick floor elevation, 347 feet above sea level]

	Depth (feet)	*Thickness (feet)*
Buckner Formation—upper member (lower part):		
Shale, reddish-brown, silty, anhydritic; white to reddish-brown, finely crystalline anhydrite	10, 915–11, 060	145
Dolomite, tan to gray, dense	11, 060–11, 075	15
Smackover Formation—upper member:		
Limestone, medium-dark-gray, nonporous, oolitic, pisolitic, and very dolomitic with fine dolomite rhombs in matrix having a trace of sparry cement and intraclasts; medium-dark-gray, sugary dolomite containing a few relict oolites	11, 075–11, 119	44
Limestone, medium-brown, dense, arenaceous, pelletoid; containing abundant scattered fine dolomite rhombs, a few oolites, and a few anhydrite inclusions	11, 119–11, 202	83
Smackover Formation—middle member:		
Limestone, medium- to dark-gray, dense, silty, fossiliferous, containing scattered fine dolomite rhombs and anhydrite nodules	11, 202–11, 230	28
Limestone, grayish-brown to dark-grayish-brown, slightly fossiliferous, dense, slightly arenaceous, pelletoid; containing some anhydrite, dolomite, and a few euhedral quartz grains	11, 230–11, 437	207
Limestone, mottled brown, dense, platy, somewhat arenaceous, fossiliferous, containing very delicate concave shells and argillaceous partings	11, 437–11, 733	296
Smackover Formation—lower member:		
Limestone, tan to dark-brown, platy, partly laminated, partly pelletoid, containing foraminifers	11, 733–11, 890	157
Limestone, light-gray to dark-brown, dense, silty, laminated, containing much pyrite and a little native sulfur	11, 890–12, 007	117
Total, Smackover Formation		932
Norphlet Formation (upper part):		
Sandstone, tan, unconsolidated, generally fine-grained and angular but containing a few coarse subrounded grains	12, 007–12, 030	23

THICKNESS AND DISTRIBUTION

The Smackover Formation generally thickens from its updip edge southward to the north margins of the ancestral Sabine uplift and the North Louisiana basin, except where it thins locally over anticlines (fig. 5). Southward from the north margins of the North Louisiana basin and the ancestral Sabine uplift the upper and middle members of the Smackover grade rapidly into the Bossier Formation and only the lower member persists (pl. 1*A*, *B*). The maximum recorded thickness of the Smackover in the report area is 1,292 feet in northern Bossier Parish, La. (fig. 5). The north edge of the formation trends eastward across northwestern Bowie County, Tex., and north of the report area it trends eastward to northeastward (Vestal, 1950; Arper, 1953).

STRATIGRAPHIC RELATIONS

The Smackover Formation conformably overlies the Norphlet Formation in most places, but it may disconformably overlie the Eagle Mills Formation of Hazzard,

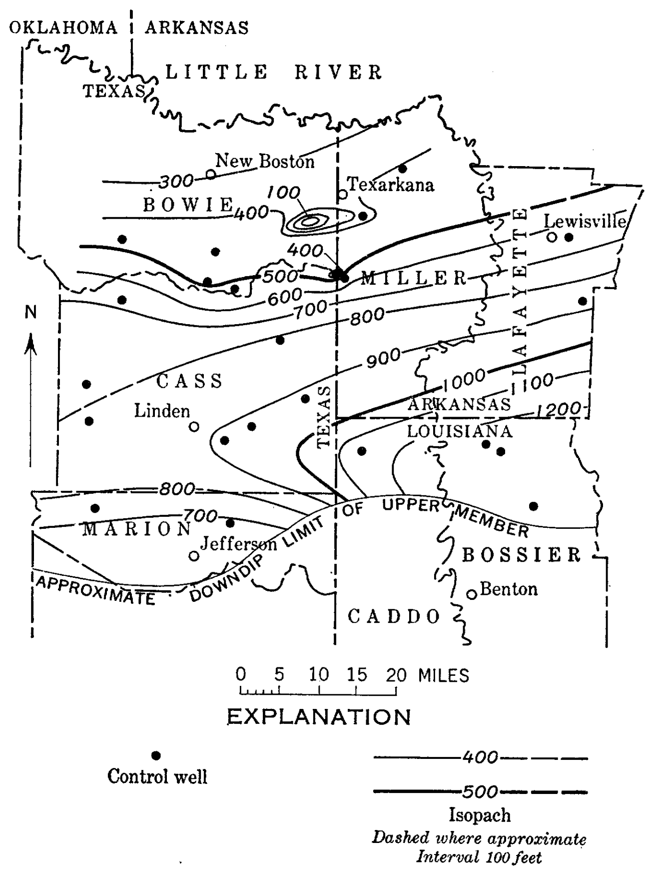


FIGURE 5.—Isopach map of Smackover Formation in area where upper member is present.

Spooner, and Blanpied (1947) in some updip areas. The Smackover is conformably overlain by the Buckner Formation in much of the updip area. In most downdip areas the Bossier Formation conformably overlies the lower member of the Smackover Formation; in a narrow belt along the north margin of the ancestral North Louisiana basin the Bossier lies directly on the upper member of the Smackover.

The hypothesis that the Buckner Formation is a back-reef deposit of the Smackover Formation has long been popular (Hazzard, 1939; Ballard, 1964). This hypothesis embodies the following concepts:

1. The deposits of the reef zone are represented by the upper part of the Smackover Formation itself.
2. Both the upper part of the Smackover and the lower member of the Buckner are progressively younger basinward.
3. During the deposition of the lower member of the Buckner its depositional basin migrated seaward.
4. The Smackover "reefs" restricted the flow of sea water that resulted in the deposition of the Buckner evaporites.

The back-reef hypothesis is now believed by the writer to be incorrect for the following reasons:

1. The relatively uniform thickness of the Smackover Formation is not consonant with reef growth (fig. 5).
2. The Smackover Formation does not consist of reef-type rock. Only a small part of the total volume of the rock consists of fossils. According to Wells (1942), the few corals that have been found in the Smackover are not reef corals.
3. A typical evaporite basin has an inner salt facies surrounded by an anhydrite facies and an outer carbonate facies (Briggs, 1958). This distribution of lithofacies is the result of deposition in a stationary basin rather than in a migrating basin. The lithofacies in the lower member of the Buckner Formation approximates this distribution (fig. 7), and it is therefore concluded that the Buckner was not deposited in a basin that was migrating seaward as the reef hypothesis demands.
4. The barrier that restricted the flow of sea water, which resulted in the deposition of evaporites, apparently was a series of salt-cored anticlines that formed concurrently with deposition (fig. 9).

LOWER MEMBER

The lower member of the Smackover Formation is composed of dense dark-brown silty to argillaceous slightly fossiliferous limestone and calcareous siltstone that is commonly laminated and pelletoid. The lamination is difficult to recognize in rotary drill cuttings and was not found in every well, but where laminated limestone is not found, the lower member can be recognized because of its dark-brown color and silty or argillaceous character.

The thickness of the lower member ranges from 49 feet in southern Bowie County, Tex., to 369 feet in southwestern Bossier Parish, La. The thickness is somewhat arbitrarily determined in a few wells, because the member grades upward into the dense limestone of the middle member of the formation or into the Bossier Formation.

The lower member is recognizable over a much wider region, particularly downdip, than the middle and upper members. Although its limits west of the project area are unknown, it is recognized as far east as southeastern Mississippi.

MIDDLE MEMBER

The middle member of the Smackover Formation consists predominantly of dense brown limestone that commonly contains anhydrite. It is also locally dolomitic, pelletoid, stylolitic, fossiliferous, oolitic, or silty. The upper part of the middle member is dolomitized in the northwestern part of the report area where the upper member is also dolomitized. The middle member varies in color from light to dark brown to dark gray. It is usually lighter in color in the upper part and in updip areas.

The middle member includes an updip and a downdip clastic facies. The updip facies is found in the vicinity of the Eylau field in eastern Bowie County, Tex., where it consists of pink, tan, gray, and reddish-brown sandstone and reddish-brown siltstone and mudstone (Swain, 1949, p. 1213–1214). The downdip clastic facies is found in northeastern Bossier Parish, La., near the downdip limits of the member. This facies consists of light- to dark-gray fine-grained somewhat calcareous sandstone, dark-gray silty platy to fissile fossiliferous calcareous shale, gray hard silty fossiliferous siltstone, and gray hard silty fossiliferous limestone. In Kinsey and Kinsey C.A. Antrim well 1, sec. 30, T. 22 N., R. 11 W., Bossier Parish, La., 512 feet of core from the middle member consists of 36 percent sandstone, 35 percent shale, 19 percent limestone, and 10 percent siltstone. The middle member grades into the Bossier Formation, south of Marion County, Tex., and south of northern Caddo and Bossier Parishes, La.

The sparse data available indicate that the middle member makes up about two-thirds to three-fourths of the total thickness of the Smackover Formation. The thickness trends of the middle member are about the same as those of the total Smackover. From an edge in northern Bowie County, Tex., the member thickens southward to a maximum of 790 feet in northern Bossier Parish, La. It is only 319 feet thick on the north flank of the ancestral Sabine uplift in central Marion County, and it apparently is also thinner over local anticlines.

UPPER MEMBER

The upper member of the Smackover Formation is characterized by oolitic limestone that also commonly contains intraclasts, pisolites, anhydrite, solid hydrocarbons, native sulfur, and various local sulfides and sulfates. A dolomitized facies and four depositional facies of the upper member are mapped in the project area (fig. 6).

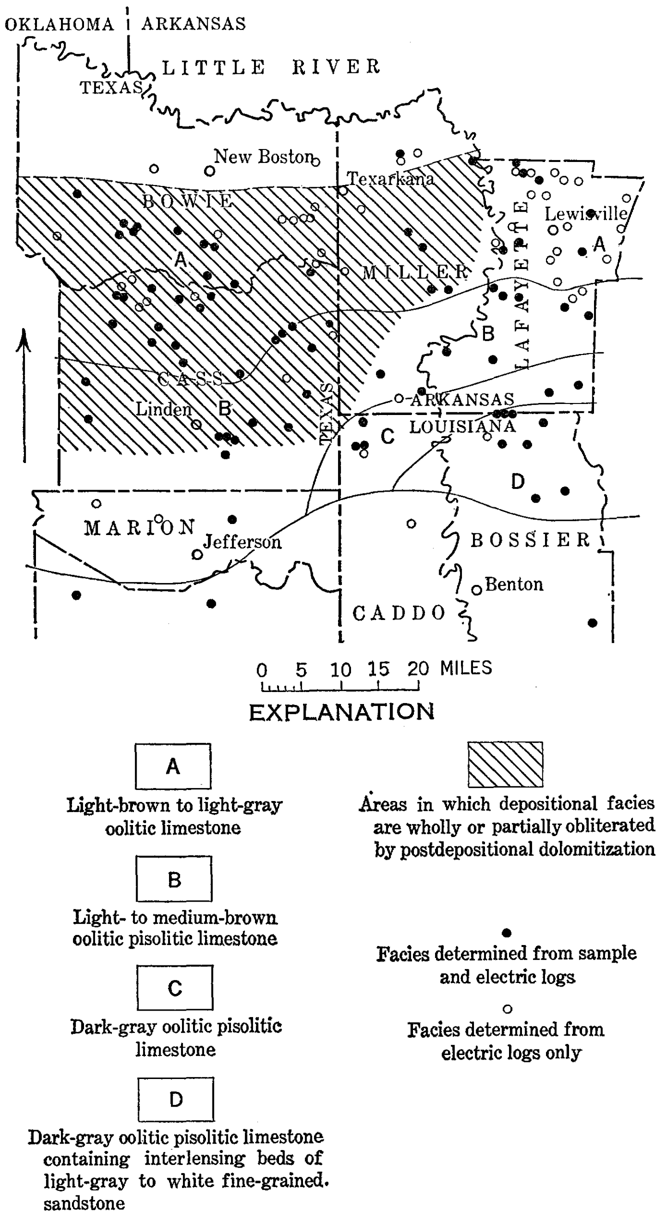


FIGURE 6.—Lithofacies map of upper member of Smackover Formation.

The depositional facies roughly parallel the margin of the gulf coast embayment. These facies, from north to south, are as follows: A, a light-brown to light-gray oolitic limestone facies; B, a light- to medium-brown oolitic, pisolitic limestone facies; C, a dark-gray oolitic, pisolitic limestone facies; and D, a dark-gray oolitic, pisolitic limestone facies containing interlensing beds of light-gray to white fine-grained sandstone. A fifth facies, north of facies A, may be an arenaceous nearshore facies, but few data are available.

The dolomitized facies underlies most of Cass and Bowie Counties, Tex., and northwestern Miller County, Ark. (fig. 6). The boundaries of this facies are indistinct and small amounts of dolomitization are found outside the prescribed facies area. Most of the dolomite consists of fine secondary rhombs in the matrix of oolitic rock. The oolites are generally not dolomitized, but some samples are entirely dolomitized. Some of the dolomitized rock is nonporous and some has a cellular porosity that apparently formed where the calcitic oolites that remained after dolomitization were dissolved. The extent of dolomitization in the Smackover Formation corresponds approximately to the extent of the thick evaporite deposits of the overlying lower member of the Buckner Formation and may be genetically related to it (Halbouty, 1966).

The thickness of the upper member of the Smackover Formation in the report area ranges from zero on the north to at least 261 feet in northern Bossier Parish, La., but it is generally less than 100 feet (pl. 1*A*, *B*, *D*). The upper member makes up about one-tenth to one-fourth of the total thickness of the formation in this area, but greater proportions have been reported elsewhere (Swain, 1949, p. 1214). In the Smackover oil-field locality the upper member constitutes about one-seventh of the total thickness of the formation (Weeks, 1938, p. 965).

PALEOTECTONIC RELATIONS

The lithology and the thickness of the Smackover Formation were affected by local and regional structural features that formed at the time of deposition. The effect of local features is difficult to determine because of few closely spaced wells that penetrate the entire formation, but some conclusions can be made. According to Arper (1953) the anticline at Texarkana oil field (fig. 9) began to rise prior to the deposition of the Smackover Formation. The formation is apparently thin over anticlines in southern and eastern Bowie County, Tex. (fig. 5). The effect of the ancestral Sabine uplift on the thickness of the Smackover can be seen in Marion County, Tex., where a total thickness of only 678 feet was penetrated (pl. 1*A*). The facies distribution was also affected by the uplift. The dark-gray oolitic-pisolitic limestone facies and the sandstone facies do not extend across the uplift (fig. 6).

BUCKNER FORMATION

According to Weeks (1938), the Buckner Formation as described from the Buckner oil field is composed of three parts: a lower part that is predominantly anhydrite but includes some red shale and dolomite, a middle part that is red shale and anhydrite in various proportions, and an upper part that is predominantly red shale. In this report the upper part in general is taken to form the upper member and the middle and the lower parts are taken to form the lower member (pl. 1*D*).

THICKNESS AND DISTRIBUTION

The Buckner Formation occupies a linear arcuate belt around the gulf coast embayment from southwestern Alabama to the western part of east Texas. In the report area the depositional axis trends eastward through Cass County, Tex., and north-central Miller and Lafayette Counties, Ark., and parallels the edge of the embayment (figs. 7, 8). In a north-south cross section the Buckner Formation is approximately lens shaped, thinning northward to its depositional limit and southward to an edge where it grades into other units or where it was eroded away (pl. 1*A*, *B*, *D*). The thickness is as much as 773 feet in west-central Cass County, Tex., 890 feet in the west side of the east Texas basin (Swain, 1949), and 774 feet in central Mississippi (Dickinson, 1963). Exceptionally large thicknesses are found in some narrow grabens that were growing during deposition, such as the graben reported in the East Haynesville oil field (Shreveport Geological Society, 1953b, p. 63).

STRATIGRAPHIC RELATIONS

The Buckner Formation overlies the Smackover Formation with apparent conformity. It has been suggested that the Buckner interfingers with the Smackover Formation in downdip areas (Imlay, 1943; Swain, 1949; Goebel, 1950). The evidence at hand indicates that the Buckner also interfingers with the Bossier Formation (pl. 1 *A*, *B*, *D*). The uniform thickness of the upper member of the Buckner Formation in updip areas (pl. 1*C*) suggests conformity with the overlying Schuler Formation. This conformable relationship is supported by recognition of a gradational contact between the two formations in some places. Locally, over anticlines, the Buckner is thin or absent and the contact is probably unconformable.

LOWER MEMBER

The lower member of the Buckner Formation consists largely of nodular and bedded anhydrite, anhydritic nodular red mudstone, and dolomite, but it also contains some salt, siltstone, sandstone, and some gray and greenish-gray mudstone. The bedded anhydrite, which is characteristic of the lower member, is light gray, microcrystalline to cryptocrystalline, and dolomitic. The lower member is commonly more anhydritic near the bottom and more argillaceous near the top, and in some places it contains a thin dolomitic shale layer near the base. Salt was cored in the lower member of Gulf Oil Corp. Veatch well 1, J. McFarland Survey, in southern Bowie County, Tex. (fig. 7).

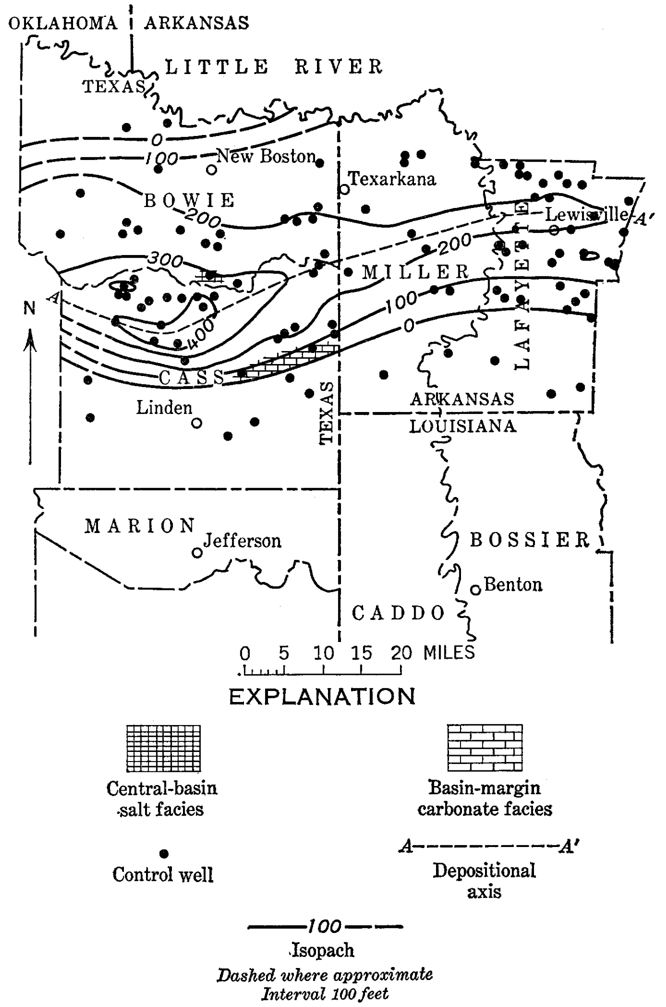


FIGURE 7.—Isopach map of lower member of Buckner Formation showing local lithofacies.

The lower member has a salt facies near the thickest part of the unit in northern Cass and southern Bowie Counties, Tex., and a carbonate facies in a narrow part near the southern edge of the unit in southern Cass County, Tex. (pl. 1*A*, *D*; fig. 7). This distribution approximately conforms to the spatial relationships for facies in a typical evaporite basin which, according to Briggs (1958), has an inner salt facies in the deepest

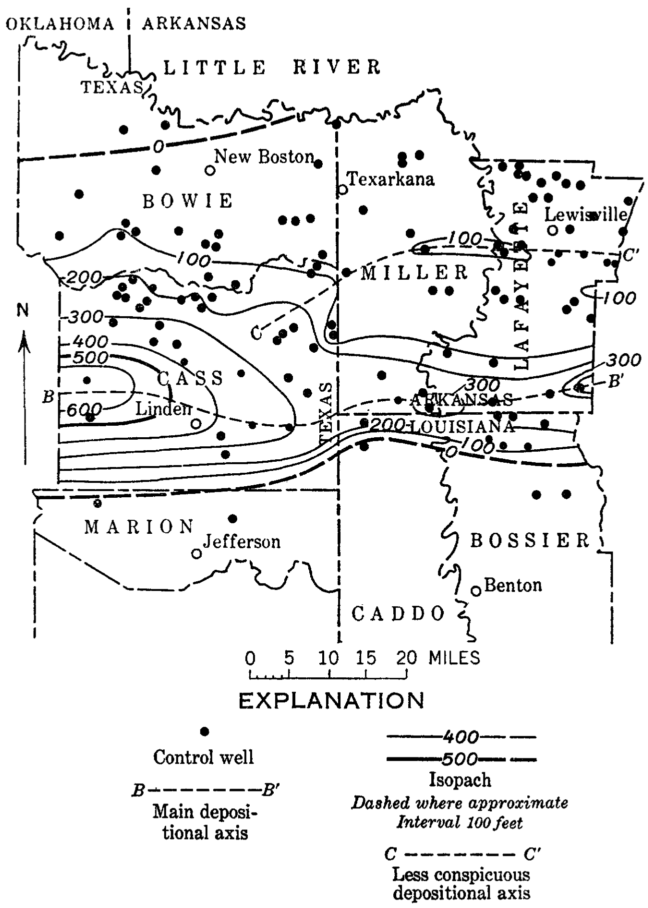


FIGURE 8.—Isopach map of upper member of Buckner Formation.

part of the basin where the greatest thickness of sediments is deposited, an anhydrite facies surrounding the salt facies, and an outer carbonate facies around the margins of the basin.

A maximum thickness of 424 feet is reached by the lower member of the Buckner Formation near a local depositional center in north-central Cass County, Tex. (fig. 7). The depositional axis of the lower member trends generally eastward through northern Cass County, Tex., and central Miller and northern Lafayette Counties, Ark. (fig. 7, *A–A′*). The northern limit apparently extends from west-central Bowie County, Tex., along the northern border of Miller County and through southern Hempstead County, Ark. The southern limit extends through central Cass County, Tex., and south-central Miller and Lafayette Counties, Ark.

The lower member of the Buckner Formation rests with apparent conformity on the Smackover Formation and is overlain, as far as is known, by the upper member of the Buckner.

UPPER MEMBER

The upper member of the Buckner Formation consists largely of nodular anhydritic red mudstone at the Buckner oil field in northeastern Lafayette County, as well as in northern Lafayette and Miller Counties, Ark. Southward in the report area in southern Cass County, Tex., and near the Arkansas-Louisiana State line, the member contains various amounts of anhydrite, dolomite, limestone, sandstone, and gray mudstone. It also contains a persistent bed of oolitic limestone, the A zone of local usage. The A zone, which is lithologically somewhat similar to the upper member of the Smackover Formation, is interbedded in the upper member of the Buckner near its downdip limits. This bed, or several lenticular carbonate and sandstone beds at about the same horizon, can be traced northwestward nearly to the northern border of Cass County, Tex. (pl. 1*D*). Gray shale and carbonate increase in abundance in the upper member toward the downdip edge of the member. In southern Cass County, Tex., the A zone divides the upper member into an upper gray mudstone part and a lower red mudstone part; in the southwestern part of Cass County the shale in the entire upper member is gray.

Partial section of the lower member of the Buckner Formation and the upper part of the Smackover Formation

[Logged from cores; Tidewater Oil Co. I. G. Talley well 1, J. S. Herring Survey A-263, Bowie County, Tex. Derrick floor elevation, 291 feet above sea level]

	Depth (feet)	*Thickness (feet)*
Buckner Formation—lower member (lower part):		
Anhydrite, light- to medium-gray and pink, very finely crystalline to microcrystalline, having a felty appearance	8, 954–8, 957	3
Shale, reddish-brown, interbedded with light-gray dense anhydrite and dolomite	8, 957–8, 959	2
Anhydrite, light-gray, microcrystalline, argillaceous, dolomitic	8, 959–8, 962	3
Anhydrite, light-gray, having discoidal anhydrite nodules separated by thin layers of gray silty shale	8, 962–8, 964	2
Dolomite, light-brown, containing detrital grains(?) and nodules of anhydrite	8, 964–8, 965	1
Mudstone, light-reddish-brown, dolomitic	8, 965–8, 966	1
Anhydrite, light-gray to light-brown, cryptocrystalline, dolomitic, pyritic, having a waxy luster, partly laminated	8, 966–8, 973	7
Siltstone, gray, hard, dolomitic	8, 973–8, 974	1
Anhydrite, brownish-gray, microcrystalline, having a waxy luster	8, 974–8, 975	1

Partial section of the lower member of the Buckner Formation and the upper part of the Smackover Formation—Continued

	Depth (feet)	Thickness (feet)
Buckner Formation—lower member (lower part)—Continued		
Dolomite, light-gray, dense, containing fine detrital(?) grains of anhydrite	8, 975–8, 977	2
Anhydrite, medium-gray, microcrystalline to cryptocrystalline, dolomitic, silty	8, 977–8, 986	9
Total described		32
Smackover Formation—upper member (upper part):		
Limestone, light-brown, oolitic, porous, containing much secondary dolomite and anhydrite in the upper part	8, 986–9, 027	41

The upper member of the Buckner Formation reaches a thickness of 692 feet near an apparent local depositional center in west-central Cass County, Tex., a few miles southwest of the main depositional center of the lower member (figs. 7, 8). It reportedly is more than 714 feet thick in Teneco and Barnhart Barker well 1, sec. 4, T. 20 S., R. 25 W., Lafayette County, Ark., but this thickness is apparently found only in a narrow graben and is not plotted on figure 8. The unit thins northward to an edge that trends northeast through northwestern Bowie County, Tex. The main depositional axis of the upper member (fig. 8, *B–B′*) is south of that of the lower member and trends east from west-central Cass County, Tex., through south-central Miller and Lafayette Counties, Ark. Another less conspicuous depositional axis (fig. 8, *C–C′*) is north of the main depositional axis and more closely coincides with the depositional axis of the lower member. The upper member extends 12–15 miles farther downdip than the lower member. Near the updip edge the upper member is very uniform in thickness (pl. 1*C*).

The upper member is coextensive with the lower member except along the downdip margins where the upper member lies directly on the Smackover Formation. The contact with the Smackover may be unconformable along this narrow belt, but evidence to support a widespread unconformity is lacking. The member is probably conformable with the overlying Schuler Formation.

PALEOTECTONIC RELATIONS

The thickness and distribution of the Buckner Formation are closely related to local and regional structural features. The formation is absent on the ancestral Sabine uplift and in the ancestral north Louisiana basin. Its greatest thickness in the report

Section of the upper member of the Buckner Formation and part of adjacent formations

[Logged from cores; Arkansas-Louisiana Oil Co. M. Pitts well 5, sec. 11, T. 23 N., R. 16 W., Caddo Parish, La. Derrick floor elevation, 287 feet above sea level]

	Depth (feet)	Thickness (feet)
Schuler Formation—P tongue (lower part):		
Sandstone, medium- to light-gray, noncalcareous, somewhat anhydritic; dark-greenish-gray and red shale	10, 563–10, 568	5
Buckner Formation—upper member:		
Shale, reddish-brown and dark-greenish-gray, noncalcareous, hard, containing a few thin layers of anhydrite and dense gray dolomite, bearing *Cyzicus* sp	10, 568–10, 619	51
Shale, grayish-red, containing nodules of white to pink anhydrite and small amounts of dense grayish-brown hard dolomite	10, 619–10, 680	61
Limestone, brown, partly oolitic, containing some fine rhombs of dolomite; medium-gray, very calcareous, nonporous siltstone containing scattered oolites	10, 680–10, 693	13
Shale, dark-grayish-red, green, and gray, containing anhydrite nodules	10, 693–10, 702	9
Siltstone, medium-gray, containing interbedded layers of white anhydrite and dense gray dolomite	10, 702–10, 708	6
Shale, dark-grayish-red and green to gray mottled, containing noddules or beds of anhydrite as much as 1 inch thick	10, 708–10, 800	92
Shale, dark-gray; gray, hard, very slightly calcareous mudstone containing a few dark nodules of pyrite	10, 800–10, 818	18
Total, upper member (lower member absent)		250
Smackover Formation (upper part):		
Limestone, medium-dark-gray, slightly porous, finely oolitic	10, 818–10, 822	4

area is in an extension of the ancestral east Texas basin north of the ancestral Sabine uplift in western Cass County, Tex. The formation also is found around the margins of the ancestral north Louisiana basin where its distribution is apparently related to the locations of salt-cored anticlines.

The lower member is found only on the north or shoreward side of a series of salt-cored anticlines. These anticlines formed concurrently with desposition and were probably largely responsible for restricting the outflow of hypersaline water from marginal basins and for the deposition of evaporites within. This series of

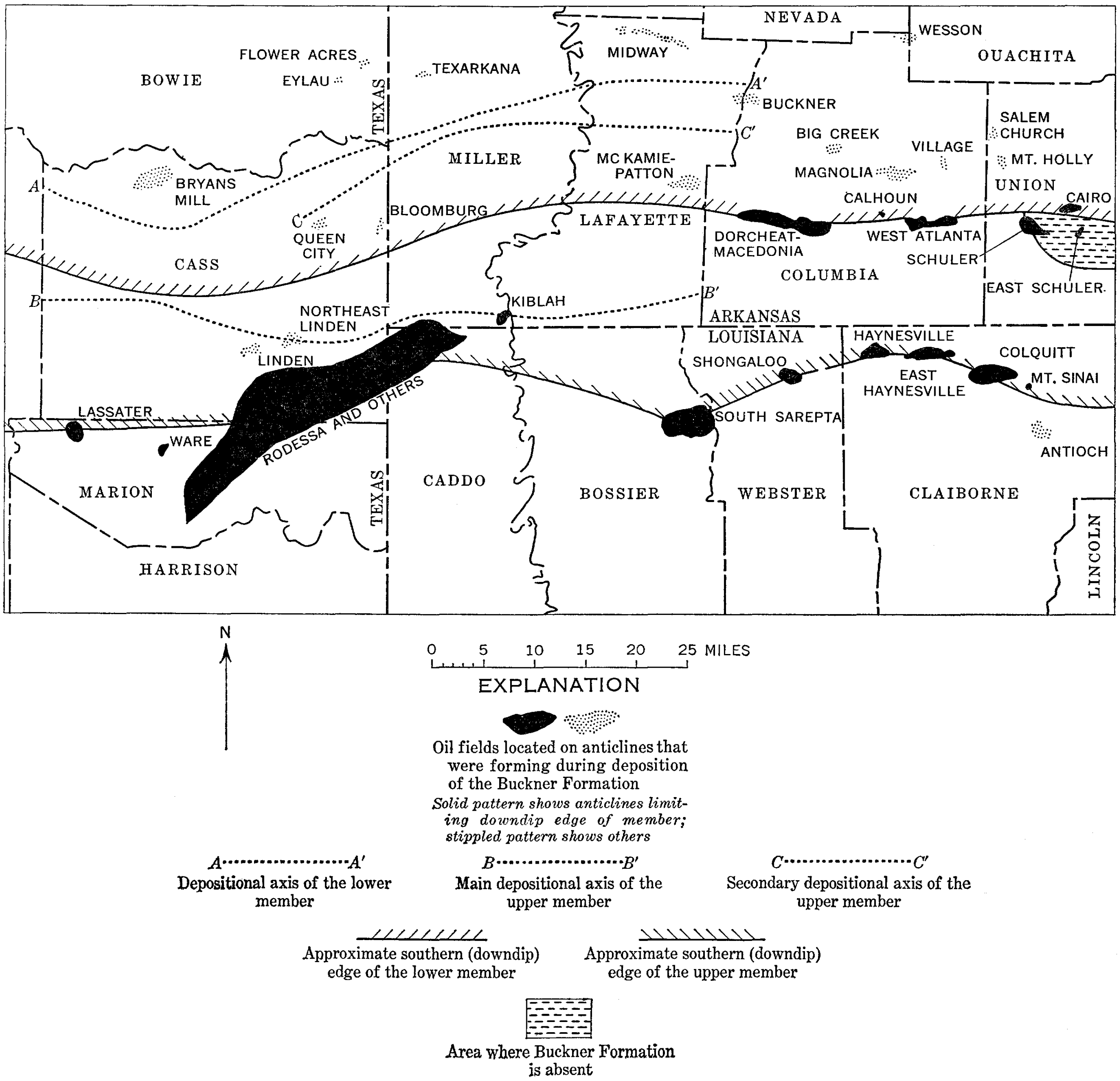


FIGURE 9.—Map showing relations of anticlines to southern (downdip) edges and depositional axes of lower and upper members of Buckner Formation.

anticlines extends eastward from central Miller County, through Lafayette, Columbia, and Union Counties, Ark. Several oil fields that are located on these anticlines include McKamie oil field in Lafayette County; Dorcheat, Macedonia, Calhoun, Atlanta, and West Atlanta oil fields in Columbia County; and Schuler, East Schuler, and Cairo oil fields in Union County, Ark. (fig. 9).

The upper member of the Buckner Formation thins or is absent over the series of the anticlines mentioned in the preceding paragraph but extends farther south, and its downdip limit seems to be related to another series of anticlines (fig. 9). The A zone expands southward into a carbonate facies of the upper member and extends for some distance south of this second anticlinal trend, but the evaporite-red shale facies is largely restricted to the north or shoreward side. Oil fields found along this trend are the Lassater in Marion County, Tex.; the Rodessa in Marion and Cass Counties, Tex., Miller County, Ark., and Caddo Parish, La.; the Kiblah in Miller County, Ark.; the South Sarepta in Bossier Parish, La.; the Shongaloo in Webster Parish, La.; and the Haynesville, East Haynesville, Colquitt, and Mount Sinai in Claiborne Parish, La.

Other anticlines such as the Antioch in Claiborne Parish, La., and the McKamie-Patton in Lafayette County, Ark., were forming concurrently with the deposition of the Buckner and probably also affected to some extent the circulation of water and hence the distribution of the evaporites.

COTTON VALLEY GROUP

The Cotton Valley Group, as used here, consists of the Bossier and Schuler Formations.

BOSSIER FORMATION

The Bossier Formation is predominantly dark-gray fossiliferous calcareous marine shale. It also contains small amounts of limestone, particularly in updip areas (pl. 1*A*, *B*). A reference section of the Bossier for the ancestral North Louisiana basin follows.

Reference section of the Bossier Formation and partial sections of adjacent formations

[Logged from cores except as indicated by asterisk (logged from cuttings); Union Producing Co. Section 13 Unit well 1, sec. 13, T. 17 N., R. 12 W., Bossier Parish, La. (pl. 1*B*). Derrick floor elevation, approximately 200 feet above sea level]

	Depth (feet)	Thickness (feet)
Schuler Formation (lower part):		
Siltstone, dark-gray, mottled, calcareous, fossiliferous; gray, nonporous sandstone; dark-gray to black shale	9, 015–9, 200	185
Bossier Formation:		
Shale, dark-gray, flaky, fossiliferous, calcareous, partly interbedded with thin layers of calcareous dark-gray siltstone	9, 200–9, 468	268
No record of samples	9, 468–9, 514	46
Shale, dark-gray, calcareous	9, 514–9, 614	100
Shale, dark-gray, silty, platy to blocky fracture, very finely micaceous, calcareous, fossiliferous, interbedded with a few thin layers of dark-gray fossiliferous limestone*	9, 614–9, 800	186
Shale, dark-gray, calcareous to noncalcareous, somewhat silty, splintery to blocky fracture, fossiliferous, pyritic, containing white calcite in veins near base, and pyritized spores*	9, 800–10, 800	1, 000
Shale, dark-gray, calcareous, partly laminated; unit contains a few thin interbeds of dark-gray limestone*	10, 800–11, 018	218
Total, Bossier Formation		1, 818
Smackover Formation—lower member:		
Limestone, dark-brown, dense, silty, pyritic, partly laminated*	10, 974–11, 390	416

The lithology of the Bossier Formation on the ancestral Sabine uplift is substantially the same as it is in the ancestral North Louisiana basin. A reference section of the Bossier from the ancestral Sabine uplift follows.

Reference section of the Bossier Formation and partial sections of adjacent formations

[Logged from cuttings; Chicago Corp. Allison Brothers well 1, James Hughes Survey A-278, Panola County, Tex. (pl. 1*A*). Derrick floor elevation, 297 feet above sea level]

	Depth (feet)	Thickness (feet)
Schuler Formation (lower part):		
Sandstone, light-grayish-brown, fine-grained, noncalcareous	9, 446–9, 510	64
Bossier Formation:		
Shale, dark-gray, calcareous to noncalcareous, fossiliferous, chloritic, very finely micaceous, silty, having splintery to blocky fracture and a few thin interbeds of dark-brown argillaceous limestone	9, 510–10, 614	1, 104
Shale, dark-gray to brown, very calcareous, very finely micaceous, chloritic, having blocky fracture; gray, dense, nonporous, argillaceous limestone, containing a little oolitic limestone	10, 614–10, 754	140
Shale, dark-gray, chloritic, noncalcareous to calcareous, very finely micaceous	10, 754–10, 928	174
Total, Bossier Formation		1, 418
Smackover Formation—lower member:		
Limestone, light-gray to dark-gray or dark-brown, dense, silty to arenaceous, partly laminated	10, 928–11, 001	73

THICKNESS AND DISTRIBUTION

The Bossier Formation is thickest in the ancestral north Louisiana basin; it thins somewhat over the ancestral Sabine uplift to the west and thins abruptly northward because of facies change into other formations (figs. 3, 10; pl. 1*A*, *B*). A thin tongue of the Bossier, the Q tongue, extends northward into the updip shelf area as far as north-central Cass County, Tex., and south-central Miller and Lafayette Counties, Ark. The formation reaches a thickness of as much as 2,352 feet in east-central Bossier Parish, La. The recorded thicknesses over the ancestral Sabine uplift range from 1,204 feet in the central part to 1,475 feet on the flanks. The formation apparently continues downdip into the deeper parts of the gulf coast embayment to the south, but it has not been penetrated in this part of the embayment south of Shelby County, Tex.

STRATIGRAPHIC RELATIONS

The Bossier Formation conformably overlies the lower member of the Smackover Formation offshore in the gulf coast embayment in Marion, Harrison, and Panola Counties, Tex., and in Caddo and Bossier Parishes, La. The Q tongue of the Bossier Formation lies directly on the upper member of the Smackover Formation in a narrow belt along the near-shore margins of the north Louisiana basin and the ancestral Sabine uplift in southern Marion County, Tex., and northern Caddo and Bossier Parishes, La. North of this narrow belt, the Q tongue lies directly and with apparent conformity on the P tongue of the Schuler Formation.

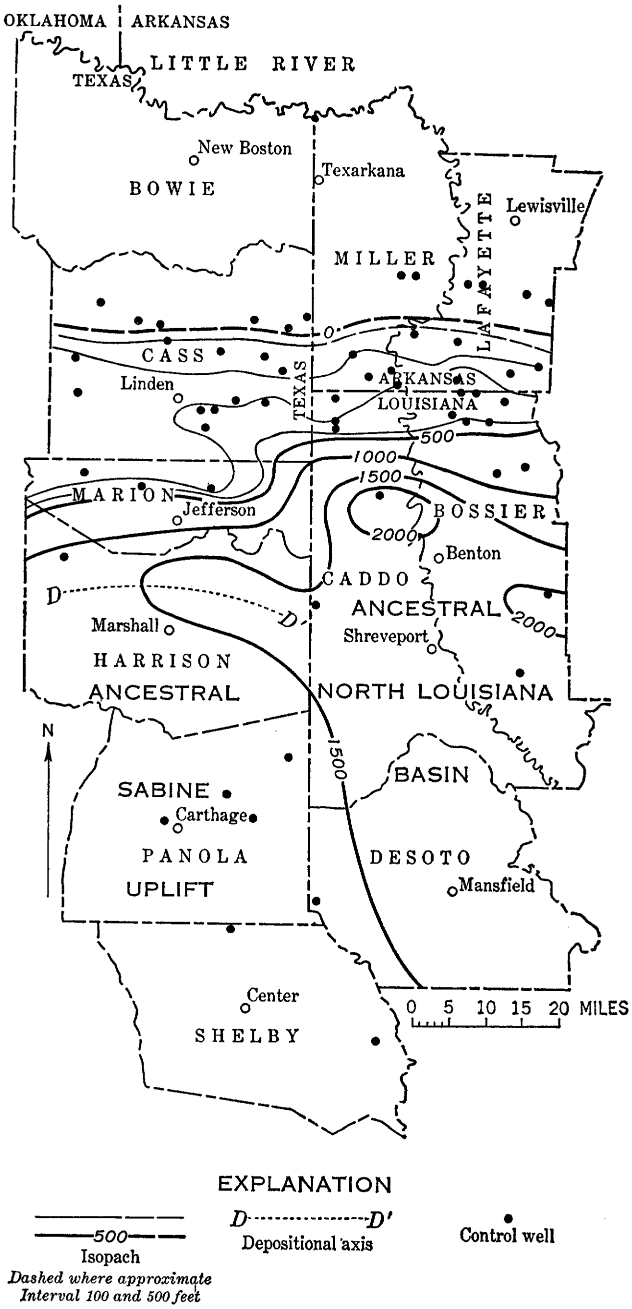


FIGURE 10.—Isopach map of Bossier Formation.

The Bossier Formation is overlain conformably by and intertongues with the Schuler Formation (pl. 1*A*, *B*).

Q TONGUE

The Q tongue is largely dark-gray marine fossiliferous shale. The lower part of the tongue is more calcareous than the main part, and in southern Cass County, Tex., it contains oolitic limestone. The tongue ranges in thickness from 400 feet along the north edge of the ancestral north Louisiana basin to a featheredge north of the basin.

Section of the Q tongue of the Bossier Formation and parts of the Schuler Formation

[Logged from cores; Arkansas-Louisiana Oil Co. M. Pitts well 5, sec. 11, T. 23 N., R. 16 W., Caddo Parish, La. Derrick floor elevation, 287 feet above sea level]

	Depth (feet)	Thickness (feet)
Schuler Formation (main body, lower part):		
Sandstone, light-gray to white, well-sorted, fine-grained, somewhat calcareous, containing carbonized wood and shale fragments	10, 164–10, 185	21
Bossier Formation—Q tongue:		
Shale, dark-gray, slightly calcareous, containing carbonized plant remains and small pelecypods; medium-gray, slightly calcareous mudstone having irregular fracture	10, 185–10, 210	25
Sandstone, medium-light-gray, very fine grained, hard, thinly bedded, nonporous, dolomitic	10, 210–10, 216	6
Shale, medium- to dark-gray, calcareous to noncalcareous; some parts very fossiliferous, containing mollusks; in the upper part, a few thin beds of brown, hard, somewhat argillaceous limestone, containing mollusks; one thin bed of gray, calcareous mudstone near the bottom, containing "oysters" and some solid hydrocarbon	10, 216–10, 402	186
Shale, dark-gray, fossiliferous, silty, very calcareous, having blocky fracture	10, 402–10, 453	51
Total, Q tongue of Bossier Formation		268
Schuler Formation— P tongue (upper part):		
Sandstone, medium-gray, fine-grained, calcareous, silty, containing solid hydrocarbon; tan, fossiliferous limestone; dark-gray, partly laminated, noncalcareous shale containing a few fossils	10, 453–10, 478	25

PALEOTECTONIC RELATIONS

The Bossier Formation is about 500 feet thinner over the ancestral Sabine uplift than in the ancestral north Louisiana basin (fig. 10). This thinning is apparently due to differential deposition because no evidence of erosion has been found. The Q tongue of the Bossier Formation is of uniform thickness over the anticline at East Haynesville oil field, Claiborne Parish, La. (Shreveport Geological Society, 1953b, p. 63). In this and possibly other places the salt-cored anticlines, which had such a pronounced effect on sedimentation during the deposition of the Buckner Formation and part of the P tongue of the Schuler Formation, had little effect during the deposition of the Q tongue.

SCHULER FORMATION

In updip areas marginal to the gulf coast embayment the Schuler Formation is composed in general of lenticular fine-grained, red, pink, or light-gray sandstone and of shale or mudstone of various colors. According to several geologists (Imlay, 1943; Swain, 1944; Forgotson, 1954), the rocks of the Schuler Formation were deposited in a near-shore or nonmarine environment in updip areas. Although a discussion of the evidence is beyond the scope of this report, the updip unfossiliferous part of the Schuler will be referred to as the near-shore or nonmarine facies and the downdip part, which contains marine fossils, will be referred to as the normal marine facies. In the downdip offshore part of the embayment the rock is predominantly light-gray, fine-grained sandstone and dark-gray fissile fossiliferous shale.

For the purpose of describing in greater detail the lithofacies of the Schuler Formation, the report area has been divided into seven sectors as shown in figure 11.

Sectors A and B are parallel updip marginal areas; sector C is transitional between the updip basin-margin areas and the downdip basinal areas and extends southward partly over the ancestral Sabine uplift; sector D is an extension of the ancestral east Texas basin; sector E is coincident with the west end of the ancestral north Louisiana basin; sector F is transitional between the ancestral north Louisiana basin and the main body of the gulf coast embayment; and sector G is apparently within the main body of the embayment.

The near-shore or nonmarine facies includes nearly the whole Schuler Formation in sectors A and B and approximately the upper half of the formation in sectors C and D. The near-shore or nonmarine rocks generally consist of light-colored fine-grained calcareous to noncalcareous sandstone that contains some carbonized wood or other carbonaceous material and red, gray, or pastel varicolored shale or mudstone. The sandstone is commonly white to light gray or pink except in the lower part of the formation in sectors A and B where it is reddish brown. In sector A the sandstone is conglomeratic especially near the bottom of the formation but it is nonconglomeratic in sector B. The shale or mudstone is characterized by various pastel colors, by a waxy to crinkly texture, and by the presence of siderite spherulites (pl. 1*A*, *B*). A reference section from sector A follows.

Reference section of the Schuler Formation and partial sections of adjacent formations

[Logged from cuttings; McAlester Fuel Co. S. Hervey well A-1, sec. 1, T. 15 S., R. 26 W., Miller County, Ark. Derrick floor elevation, 252 feet above sea level]

	Depth (feet)	*Thickness (feet)*
Hosston Formation (lower part):		
Sandstone, white, pink, or reddish-brown, fine- to medium-grained, angular, silty, containing thin interbeds of red and gray shale	4, 954–5, 035	81
Schuler Formation:		
Sandstone, pink and tan, fine-grained; gray, calcareous siltstone; dark-reddish-brown, splintery shale	5, 035–5, 080	45
Shale, light-gray to pink with some yellow-brown mottling, noncalcareous, pyritic	5, 080–5, 110	30
Sandstone, pink to light-gray, fine-grained, argillaceous, noncalcareous	5, 110–5, 152	42
Shale, light-gray to pink, noncalcareous, silty, containing a trace of sideritic spherulites	5, 152–5, 218	66
Sandstone, pink, medium-grained, noncalcareous, well-sorted	5, 218–5, 246	28
Shale, pink to light-gray	5, 246–5, 260	14
Sandstone, pink, medium-grained, noncalcareous, well-sorted	5, 260–5, 278	18
Shale, light-gray to pink, containing sideritic spherulites	5, 278–5, 310	32
Sandstone, pink, medium-grained, noncalcareous, well-sorted	5, 310–5, 333	23
Shale, pastel varicolored, red, sideritic	5, 333–5, 366	33
Sandstone, white, very fine to fine-grained, noncalcareous	5, 366–5, 408	42
Shale, light-gray to pink, waxy-textured, containing sideritic spherulites	5, 408–5, 430	22
Sandstone, light-gray, medium to fine-grained, argillaceous, noncalcareous	5, 430–5, 480	50
Sandstone, fine-grained, white, slightly porous; pastel varicolored, waxy-textured shale	5, 480–5, 550	70
No record	5, 550–5, 580	30
Sandstone, tan to pink, fine-grained, noncalcareous, porous, containing a few thin interbeds of reddish-brown shale	5, 580–5, 698	118

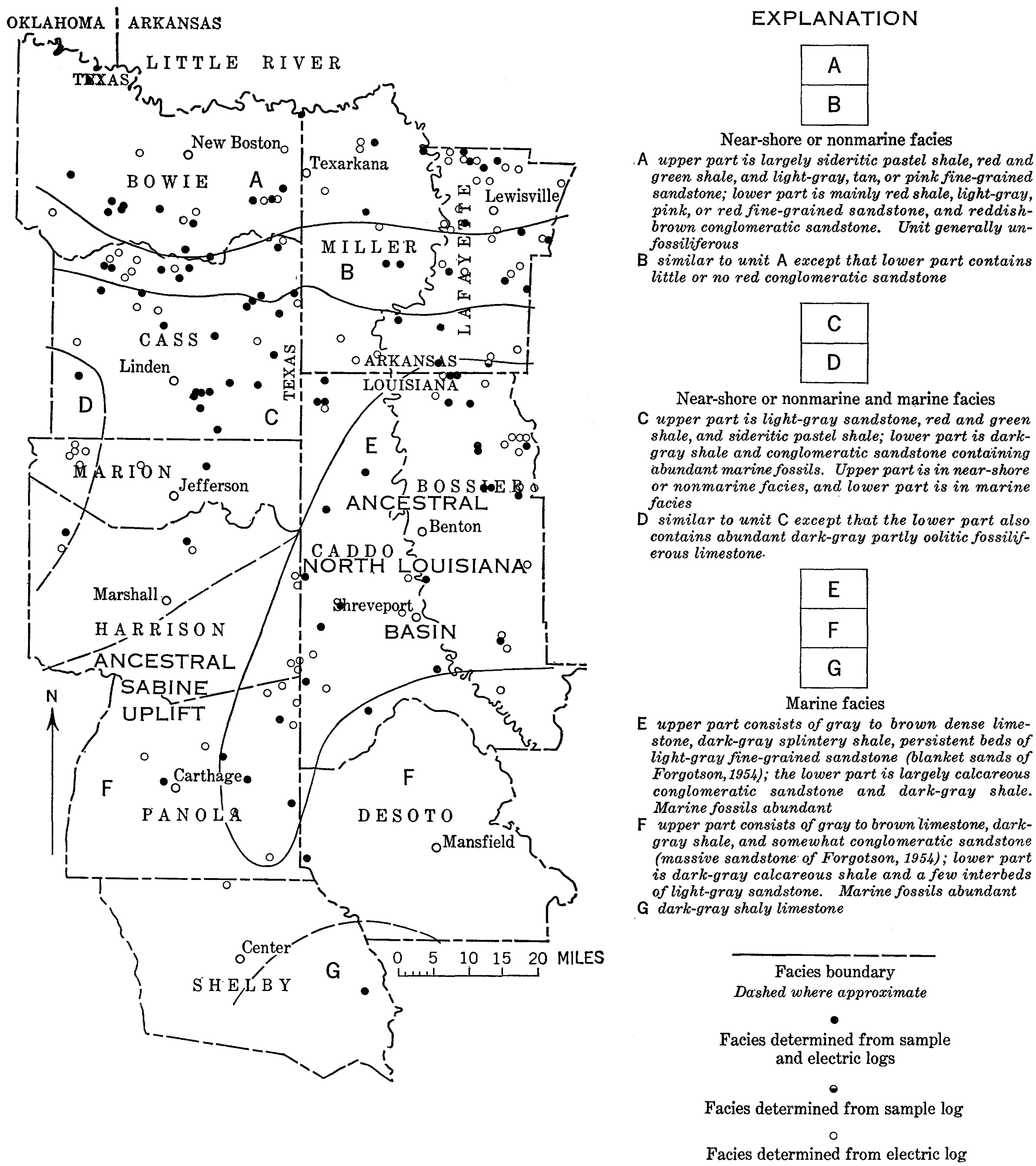


FIGURE 11.—Lithofacies map of Schuler Formation.

Reference section of the Schuler Formation and partial sections of adjacent formations—Continued

	Depth (feet)	Thickness (feet)
Schuler Formation—Continued		
Mudstone, reddish-brown, finely micaceous	5, 698–5, 715	17
Sandstone, tan to pink, fine-grained, noncalcareous	5, 715–5, 768	53
Mudstone, reddish-brown, finely micaceous, containing some interbeds of fine-grained sandstone	5, 768–5, 800	32
Sandstone, fine- to medium-grained, white, silty, noncalcareous, partly conglomeratic; containing a few thin interbeds of pastel varicolored shale, gray fissile shale, and reddish-brown mudstone	5, 800–6, 105	305
Sandstone, reddish-brown, silty, calcareous to noncalcareous, somewhat conglomeratic, containing thin interbeds of reddish-brown mudstone and gray fossiliferous shale	6, 105–6, 320	215
Total, Schuler Formation		1, 285
Buckner Formation—upper member:		
Shale, reddish-brown, silty, finely micaceous, noncalcareous	6, 320–6, 360	40

The normal marine facies includes approximately the lower half of the Schuler Formation in sectors C and D and the entire formation in sectors E, F, and G. A thin marine tongue, the Wesson Tongue of Swain (1944), that consists of fossiliferous medium-gray shale and limestone, also extends into the upper otherwise near-shore or nonmarine facies of the formation throughout most of sector C. The normal marine facies consists mostly of fine-grained light-gray sandstone that is commonly calcareous and conglomeratic and is interbedded with fossiliferous medium-gray to black shale and gray limestone. In sector E several thin persistent light-gray fine-grained sandstone beds, such as the Bodcaw sand of Sloane (1958) and the D sand, are correlatable in the upper part of the Schuler Formation over much of north Louisiana (fig. 3, pl. 1*B*). These sandstone bodies maintain a thickness of about 40 to 50 feet over wide areas and are generally called blanket sandstones. They are separated by dark-gray splintery fossiliferous shale. To the south and west in sector F, the sandstone bodies thicken and coalesce to form a somewhat massive partly conglomeratic sandstone, which according to several geologists was deposited in the form of barrier beaches or islands (Forgotson, 1954, p. 2496; Sloane, 1958, p. 22; Thomas and Mann, 1966). They do not extend or are not recognizable over the ancestral Sabine uplift, and they are not in the updip near-shore or nonmarine facies. According have been informally named in northern Louisiana, but to Mann and Thomas (1964) 22 blanket sandstone units many of them do not extend into the report area. The names are generally well known because of the great economic importance of the sands as oil or gas producers. In the north part of sector E the lower half of the Schuler is mostly fine-grained light-gray calcareous to noncalcareous somewhat fossiliferous sandstone together with lesser amounts of dark-gray shale, limestone, and very calcareous conglomeratic sandstone. Some of these beds are correlatable over wide areas, but most are lenticular. Farther south in sector E and in sector F, the lower part of the Schuler is mostly dark-gray calcareous shale, but it also contains a few nonconglomeratic sandstone beds there. The entire Schuler Formation is dark-gray shaly limestone in sector G, as represented by one well, Humble Oil & Refining Co. Pickering Lumber Co. well 1. A reference section from the ancestral north Louisiana basin (sector E) follows.

Reference section of the Schuler Formation and partial sections of adjacent formations

[Logged from cores except as indicated by asterisk (logged from cuttings) and by dagger (logged from cuttings and cores); Carter Oil Co. Crystal-Whited well 1, sec. 26, T. 21 N., R. 12 W., Bossier Parish, La. Derrick floor elevation, 241 feet above sea level]

	Depth (feet)	Thickness (feet)
Hosston Formation (lower part):		
Sandstone, white and pink, fine-grained, hard	8, 281–8, 307	26
Schuler Formation:		
Shale, light-gray to pink, waxy-textured, containing siderite spherulites	8, 307–8, 345	38
Sandstone, light-gray, fine-grained, noncalcareous, containing inclusions of carbonized wood	8, 345–8, 371	26
Shale, medium-gray, splintery, slightly calcareous, fossiliferous	8, 371–8, 495	124
Sandstone, light-gray, fine-grained, calcareous	8, 495–8, 511	16
Shale, medium-gray, splintery, slightly calcareous, fossiliferous	8, 511–8, 570	59
No record of samples	8, 570–8, 765	195
Shale, medium-gray, laminated with siltstone near base	8, 765–8, 791	26
Sandstone (D sand), light-tan, medium-grained, very calcareous	8, 791–8, 814	23
No record of samples*	8, 814–8, 850	36
Shale, medium-gray, calcareous, fossiliferous*	8, 850–8, 881	31
Shale, gray, slightly calcareous, containing ostracodes and pelecypods, partly laminated, arenaceous in lower 2 feet	8, 881–8, 900	19

Reference section of the Schuler Formation and partial sections of adjacent formations—Continued

	Depth (feet)	Thickness (feet)
Schuler Formation—Continued		
Sandstone (Bodcaw sand of Sloane (1958)), light-gray, mottled with dark-gray, fine-grained, angular, argillaceous, crossbedded; containing a few quartz overgrowths, magnetite, carbonized wood fragments, and pelecypods	8, 900–8, 950	50
Shale, dark-gray splintery to fissile; containing ostracodes, gastropods, and pelecypods†	8, 950–9, 160	210
Limestone, dark-gray, coquinoid, very argillaceous, consisting of pelecypod shells in a matrix of clayey material; dark-gray, calcareous, arenaceous, fossiliferous shale	9, 160–9, 174	14
Sandstone (Davis sand), light-gray with darker beds, fine-grained somewhat calcareous, containing thin dark-brown shale beds	9, 174–9, 210	36
Shale, dark-brown, fossiliferous, calcareous, silty, partly laminated	9, 210–9, 267	57
Sandstone, light- to medium-gray or pink, fine-grained, very calcareous, well-bedded, fossiliferous, containing shale partings	9, 267–9, 305	38
Limestone, dark-gray, fissile, argillaceous, coquinoid, having a matrix of dark-gray clay	9, 305–9, 313	8
Sandstone, gray and reddish-gray, calcareous, fine-grained, having red shale partings and irregular bedding	9, 313–9, 324	11
Shale, gray, arenaceous, containing a few small fossils	9, 324–9, 328	4
Sandstone, light-gray to pink, fine-grained, slightly calcareous with some reddish-brown shale partings; conglomerate containing pebbles of yellowish-brown chert and soft reddish-brown shale and having a matrix of very calcareous fine-grained sandstone	9, 328–9, 395	67
Limestone, light-gray mottled with medium-gray, very silty, dolomitic	9, 395–9, 401	6
Shale, dark-gray, soft, fissile, fossiliferous and arenaceous at intervals, containing a few thin interbeds of dark-gray fossiliferous limestone	9, 401–9, 436	35

Reference section of the Schuler Formation and partial sections of adjacent formations—Continued

	Depth (feet)	Thickness (feet)
Schuler Formation—Continued		
Sandstone, light- to medium-gray, fine-grained, very calcareous, partly conglomeratic, containing interbeds of limestone and conglomerate	9, 436–9, 480	44
Shale, dark-gray, calcareous, very fossiliferous, partly laminated; brown, hard, arenaceous, conglomeratic limestone containing some sparry cement and mollusks	9, 480–9, 504	24
Sandstone, light-gray, fine-grained, very calcareous, micaceous, fossiliferous, irregularly bedded, partly conglomeratic; dark-gray, micaceous, noncalcareous shale; conglomerate having pebbles of clear quartz, milky quartz, and igneous rock and sparry calcite cement	9, 504–9, 580	76
Limestone, gray, fossiliferous, dense; gray, fossiliferous, conglomeratic limestone, having sparry calcite cement	9, 580–9, 594	14
Sandstone, light-gray, slightly calcareous, conglomeratic, fossiliferous; dark-grayish-brown, hard, micaceous, fossiliferous shale	9, 594–9, 608	14
Conglomerate, having pebbles of smoky and milky quartz and a matrix of fine-grained calcareous sandstone	9, 608–9, 620	12
Sandstone, light-gray, very fine grained, irregularly bedded, calcareous, containing worm burrows, interbedded with a few thin layers of arenaceous clastic limestone and dark-gray fissile shale	9, 620–9, 645	25
Limestone, light-grayish-brown, conglomeratic, fossiliferous, having solution porosity	9, 645–9, 658	13
Sandstone, light-gray to dark-brownish-gray, fine-grained, containing some argillaceous partings; dark-brownish-gray argillaceous, arenaceous siltstone	9, 658–9, 683	25
Sandstone, light-gray to dark-brownish-gray and pink, very fine to fine-grained, calcareous, partly laminated; dark-gray to brownish-gray, somewhat fissile, fossiliferous, calcareous shale	9, 683–9, 866	183

Reference section of the Schuler Formation and partial sections of adjacent formations—Continued

	Depth (feet)	*Thickness (feet)*
Schuler Formation—Continued		
Sandstone, light-gray, fine-grained, slightly calcareous to calcareous, fossiliferous, irregularly bedded, partly conglomeratic, containing shale partings and a few thin interbeds of shale; light- to dark-gray, clastic, conglomeratic, fossiliferous limestone, having scattered shale partings and sparry cement	9, 866–9, 966	100
Total, Schuler Formation		1, 659
Bossier Formation (upper part):		
Shale, dark-gray and dark-brownish-gray, slightly calcareous to noncalcareous, finely micaceous, fossiliferous, silty to arenaceous, containing a few interbeds of siltstone	10, 076–10, 147	71

THICKNESS AND DISTRIBUTION

The Schuler Formation ranges in thickness from zero north of the project area to more than 2,000 feet in its thickest part in southern Lafayette and Miller Counties, Ark., and in northern Caddo and Bossier Parishes, La. (fig. 12). The updip edge probably strikes northeastward across northwestern Bowie County, Tex., and north of Miller and Lafayette Counties, Ark. No depositional axis was plotted for the Schuler Formation because the P tongue was mapped separately from the main body, but the general location of a depositional axis can be seen by comparing the maps of the tongue and the main body of the formation (figs. 12, 13).

STRATIGRAPHIC RELATIONS

The Schuler Formation intertongues with and overlies the Bossier Formation in downdip areas and overlies the Buckner or Smackover Formation in updip areas. The basal contact of the Schuler Formation in the updip areas has generally been thought to be disconformable (Swain, 1944; Forgotson, 1954). However, conformity in most places is indicated by the uniform thickness of the upper member of the underlying Buckner Formation in places where erosion would most likely have occurred and by the fact that at some places the Schuler appears to grade downward into underlying rocks (fig. 7, pl. 1*C*). The contact may be disconformable over most anticlines, especially along the structural trend (fig. 9) where the Buckner Formation is either thin or absent, although much of this thinning is thought to be a result of differential deposition (Goebel, 1950, p. 1975).

The contact between the Schuler Formation and the overlying Hosston Formation of Early Gretaceous age is generally thought to be conformable in downdip areas and disconformable in updip areas (Forgotson, 1954; Swain, 1944).

P TONGUE

The P tongue consists predominantly of light-colored fine-grained sandstone and subordinate amounts of interbedded gray shale. It contains some red sandstone and shale near the base and it grades laterally into red sandstone and shale in updip areas where it joins the

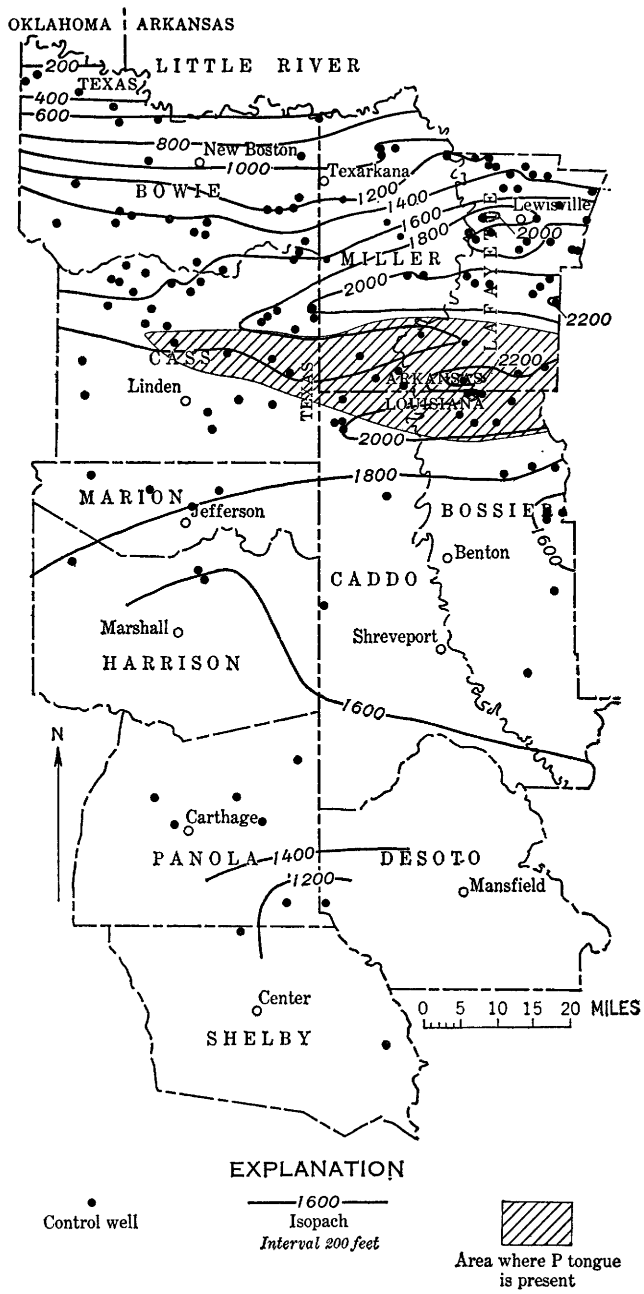


FIGURE 12.—Isopach map of Schuler Formation except P tongue at base.

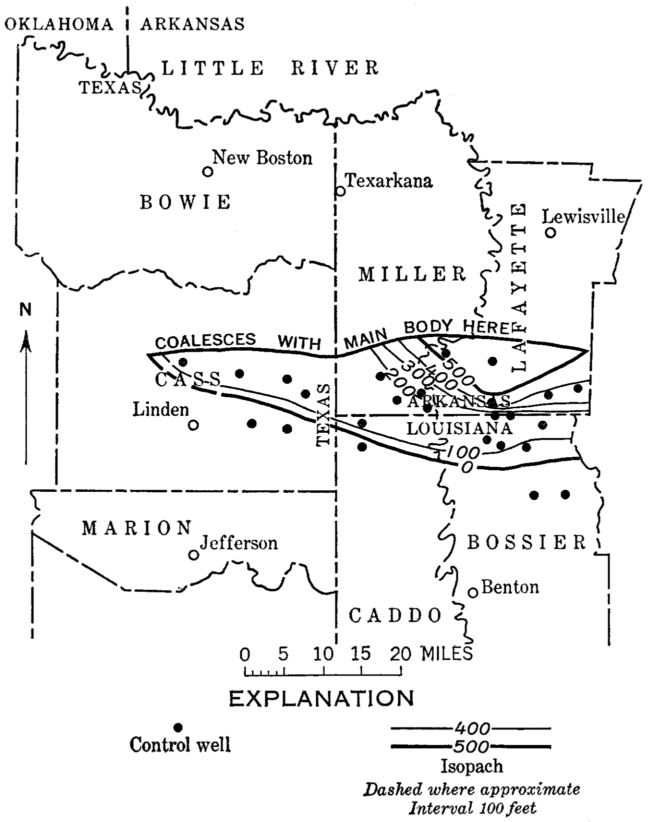


FIGURE 13.—Isopach map of P tongue of Schuler Formation.

main body of the Schuler Formation. Locally it contains some dolomite and anhydrite, especially near the base of the unit where it is in contact with the underlying Buckner Formation. It also characteristically contains some solid hydrocarbons. The tongue reaches a maximum thickness of at least 580 feet in southern Lafayette County, Ark., near its junction with the main body of the Schuler and it thins southward to a featheredge in northern Caddo and Bossier Parishes, La. (fig. 13). A section for the P tongue follows.

Section of the P tongue of the Schuler Formation and parts of adjacent formations

[Logged from core; Arkansas-Louisiana Oil Co. M. Pitts well 5, sec. 11, T. 23 N., R. 16 W., Caddo Parish, La. Derrick floor elevation, 287 feet above sea level]

	Depth (feet)	*Thickness (feet)*
Bossier Formation—Q tongue (lower part):		
Shale, dark-gray, fossiliferous, silty, calcareous, having blocky fracture	10, 402–10, 453	51
Schuler Formation—P tongue:		
Sandstone, medium-gray, fine-grained, calcareous, silty, containing solid hydrocarbon; tan, fossiliferous limestone; dark-gray, noncalcareous, partly laminated shale containing a few fossils	10, 453–10, 478	25
Schuler Formation—P tongue—Continued		
Shale, dark-gray, unfossiliferous; reddish-brown, mudstone containing nodules or subangular fragments of pink anhydrite	10, 478–10, 512	34
Sandstone, medium-gray, hard, very fine grained, noncalcareous, containing dark shale partings	10, 512–10, 520	8
Mudstone, reddish-brown, silty noncalcareous	10, 520–10, 531	11
Sandstone, grayish-brown, very fine-grained, hard, dolomitic, partly laminated	10, 531–10, 539	8
Shale, dark red; gray to green siltstone	10, 539–10, 542	3
Sandstone, dark-gray, dolomitic, very fine grained containing a few red shale inclusions	10, 542–10, 555	13
Sandstone, dark-gray, fine-grained, noncalcareous, containing a few thin beds of dark-gray shale	10, 555–10, 563	8
Sandstone, medium- to light-gray, noncalcareous, somewhat anhydritic; dark greenish-gray and red shale	10, 563–10, 568	5
Total, P tongue of Schuler Formation		115
Buckner Formation—upper member (upper part):		
Shale, reddish-brown and dark greenish-gray, noncalcareous, hard, containing a few thin layers of anhydrite and fine-grained gray dolomite, bearing *Cyzicus* sp	10, 568–10, 619	51

PALEOTECTONIC RELATIONS

The ancestral Sabine uplift apparently rose in relation to the surrounding basins during deposition of the youngest of the Upper Jurassic rocks. This is shown by thickness variations and by the distribution of facies (figs. 10, 11, 13). The Schuler Formation is about 400–500 feet thinner on the uplift than in the north Louisiana basin. This difference in thickness could be explained by slower deposition on the uplift or by subsequent erosion, but for either explanation to be valid, the uplift would have had to have risen by or during Late Jurassic time. Futhermore, near-shore or nonmarine beds in the upper part of the Schuler Formation reach farther south into the gulf coast embayment over the uplift (Sector C, fig. 11) than they do in the north Louisiana basin to the east.

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