

STRATIGRAPHY OF THE WOODBINE AND EAGLE FORD,
WACO AREA, TEXAS

By W. S. ADKINS and FRANK E. LOZO

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Stratigraphy of the Woodbine and Eagle Ford, Waco Area, Texas

By W. S. ADKINS* and FRANK E. LOZO†

INTRODUCTION

In the last twenty years, very little detailed stratigraphy of this area has been published. Meanwhile there have been significant advances in this field: the aims of modern stratigraphic research have been somewhat clarified; much new information pertinent to the stratigraphy of this area has been accumulated from the study of other areas; and a considerable amount of detailed information on the surface and subsurface geology of this area has come to light as a result of detailed outcrop work, extensive drilling of oil tests and water wells, and new techniques of bore-hole logging.

The scope of this work is mainly the study of beds located near the Lower-Upper Cretaceous boundary, from the Lower Washita to the base of the Austin chalk. This includes very detailed investigations of the Upper Washita beds and the Woodbine and Eagle Ford groups. The lithologic division and the fossil zonation of these strata are outlined, isopach and boundary maps of the various units presented, and the outcrop is tied into the subsurface. It is hoped that these results throw light on the division, definition, zonation, and stratigraphic behavior of both the Woodbine and the Eagle Ford in this area.

REVIEW OF GEOLOGIC REFERENCES

EARLY WORK, TO 1888

Spanish expeditions which delineated old Spanish roads and the paths of various *entradas* into Texas territory, including the area under discussion, were described by Baron Alexander von Humboldt, and in the accounts of various eighteenth-century expeditions — that of the Marques de Aguayo in 1721, de Mézières in 1779, and Vial in 1786 (summarized in Adkins and Arick, 1930, p. 5). William Kennedy in 1841 published the first intelligible geographic description of the region and noted its physiographic and geologic outcrop subdivisions, including the Woodbine Cross Timbers belt (Fig. 1). Kennedy gave the best enumeration, to his day, of the early Spanish, Mexican, and French explorations in the territory of Texas.

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German colonization efforts. Aside from the early publications of G. A. Schoepf, Prince Carl von Solms-Braunfels and Victor Bracht, knowledge of the geography and geology of central Texas was first crystallized by Ferdinand Roemer (1849, 1852). He noted physiographic features and outlined the "Azoic," Paleozoic, Mesozoic, and Tertiary outcrop strips in the area (Fig. 2), published a travel diary and descriptions of numerous Paleozoic and Cretaceous fossils, and is rated as the "Father of Texas Cretaceous Geology." A map of his trip from Torrey's Trading Post (below Waco) to the Caddo Indian village at the mouth of Nolan's River is given in figure 3.

Government Surveys until 1858. The area under consideration cannot be extricated geologically from the general region, hence the following explorations are locally important: Exploration of Captain R. B. Marcy, El Paso to Fort Washita (Marshall County, Oklahoma), and Exploration of the Red River, 1849-1852; the Mexican Boundary Survey, 1848-1855; and the Pacific Railway surveys.

First Texas Geological Survey. The first state survey (1858-1861) directed by B. F. Shumard, "constructed an accurate section of the country between Austin and Grayson County"; Professor Riddell made "final surveys" (not since located) of McLennan and Coryell counties and most of Bosque County. From the unfortunate debacle of the Shumard Survey were rescued only the descriptions of certain Cretaceous fossils by B. F. Shumard and C. A. White, a report on Grayson County by G. G. Shumard, and maps of scattered counties, including Brown, Comanche, and Hamilton, published by A. R. Roessler (New York, 1876). The Glenn-Buckley survey (1873-1875) accomplished nothing in this area.

DUMBLE SURVEY TO R. T. HILL

(1888-1901)

The third Geological Survey of Texas (1888-1893) under E. T. Dumble includes the Cretaceous work of J. A. Taff, S. Leverett, Cragin, Dumble, Cummins, von Streeruwitz, and others and relates to the early work of R. T. Hill. Taff, entrusted with the work on the Cretaceous of Central Texas, arrived at the following conclusions:

(1) In both north Texas and south Texas, Cretaceous deposition was continuous from Lower Cretaceous into Upper Cretaceous. Therefore, every formation has to be accounted for at every place in the area. Taff (1893, p. 299) stated: "the bedding planes of the Eagle Ford/Buda are perfectly parallel;" therefore "the land area [unconformity?] in mid-Cretaceous [Buda/Eagle Ford] time was located to the N/NW of the Brazos River;" therefore "the Dakota has a representative in time and in sediment in a part of the Eagle Ford or Fish Bed Shale south of the Brazos River." This presumably means that all of the Woodbine is present south of the Brazos River.

(2) To Taff, nodular upper Grayson as in Denton County, represented the Buda following the idea above mentioned. Hence Taff's correlation was:

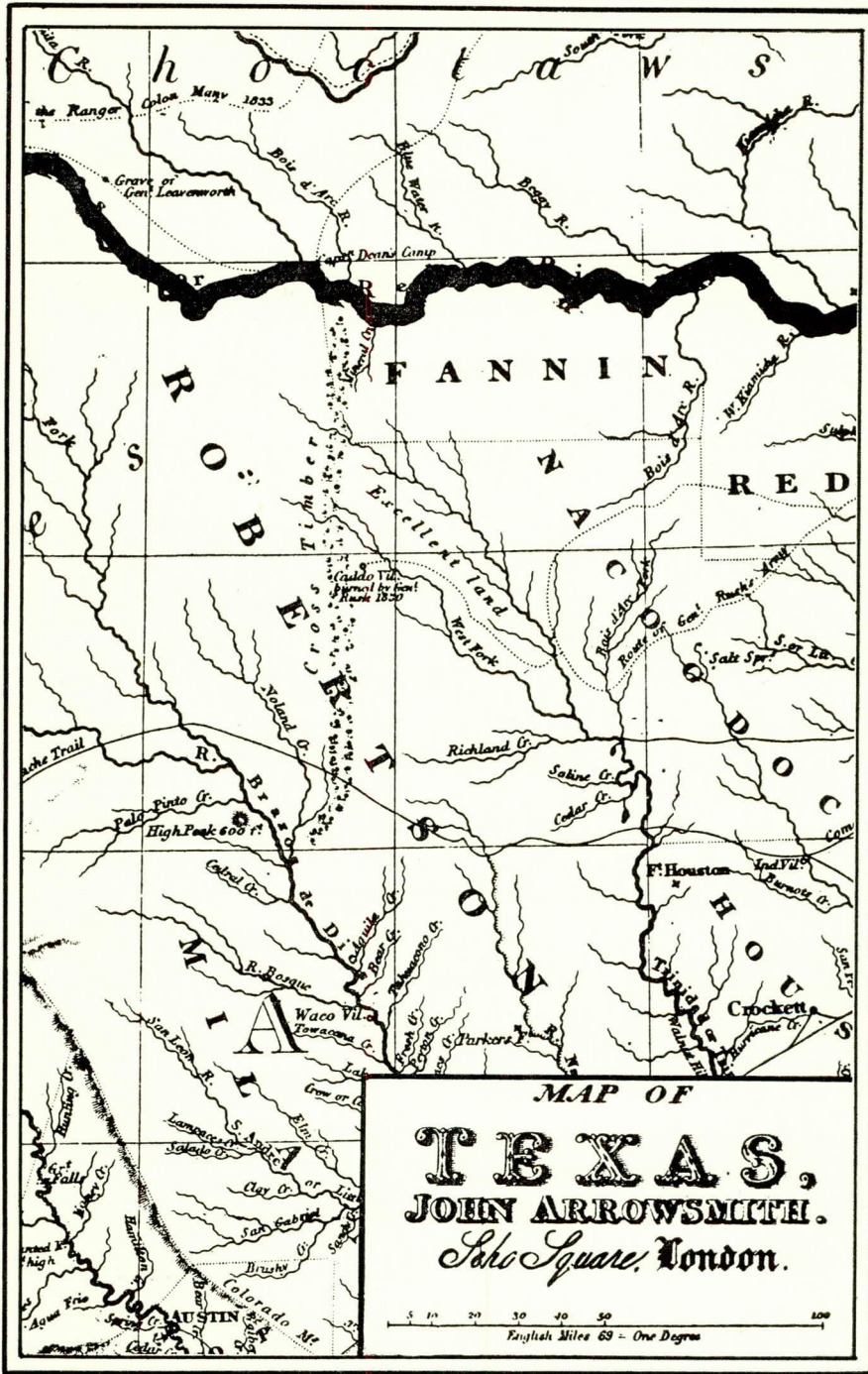


Fig. 1. Portion of 1840 map of Texas showing Cross Timbers, from William Kennedy's "Texas," London. 1841.

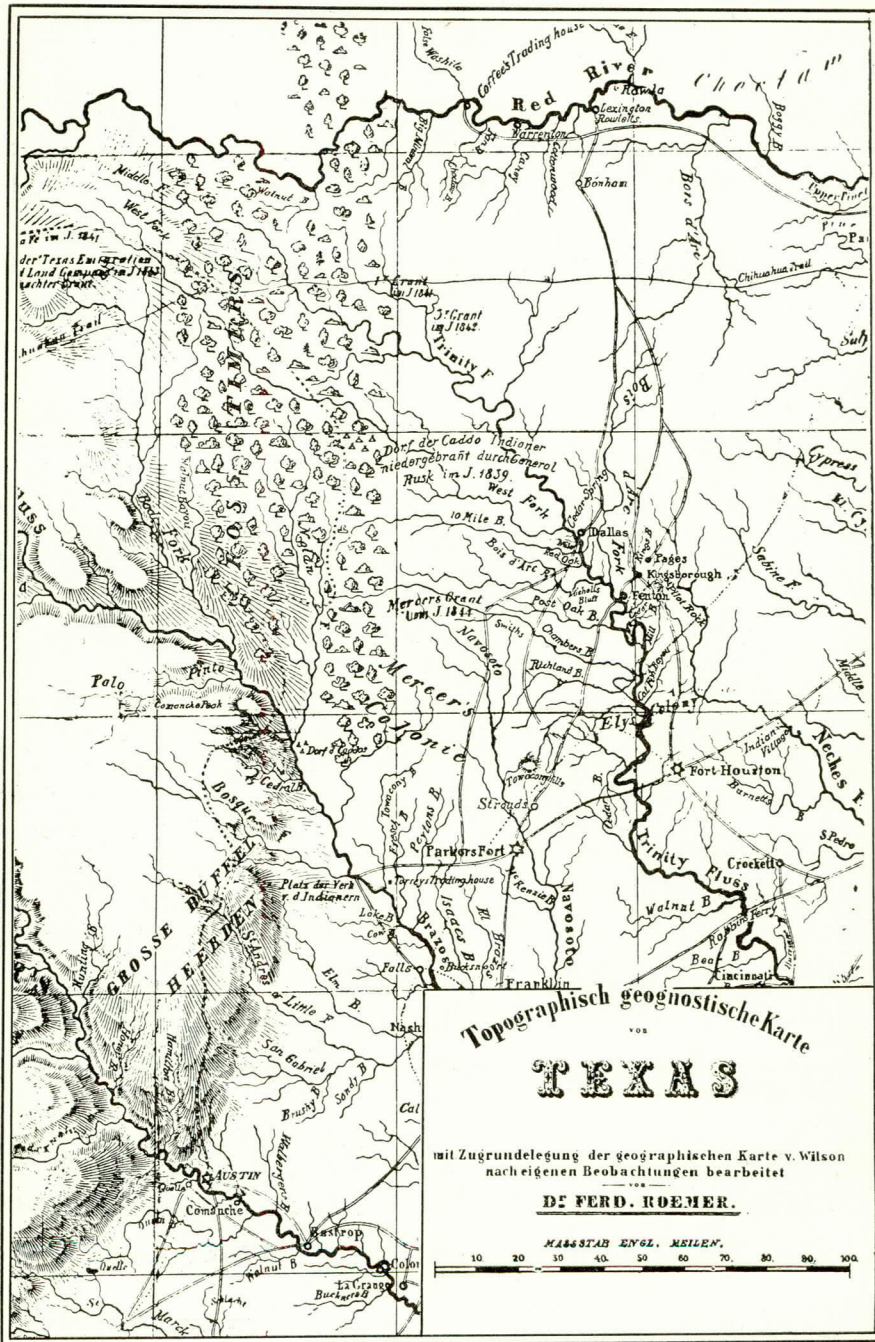


Fig. 2. Portion of 1846 map of Texas showing Cross Timbers and other features, from F. Roemer's "Texas," Bonn, 1848.

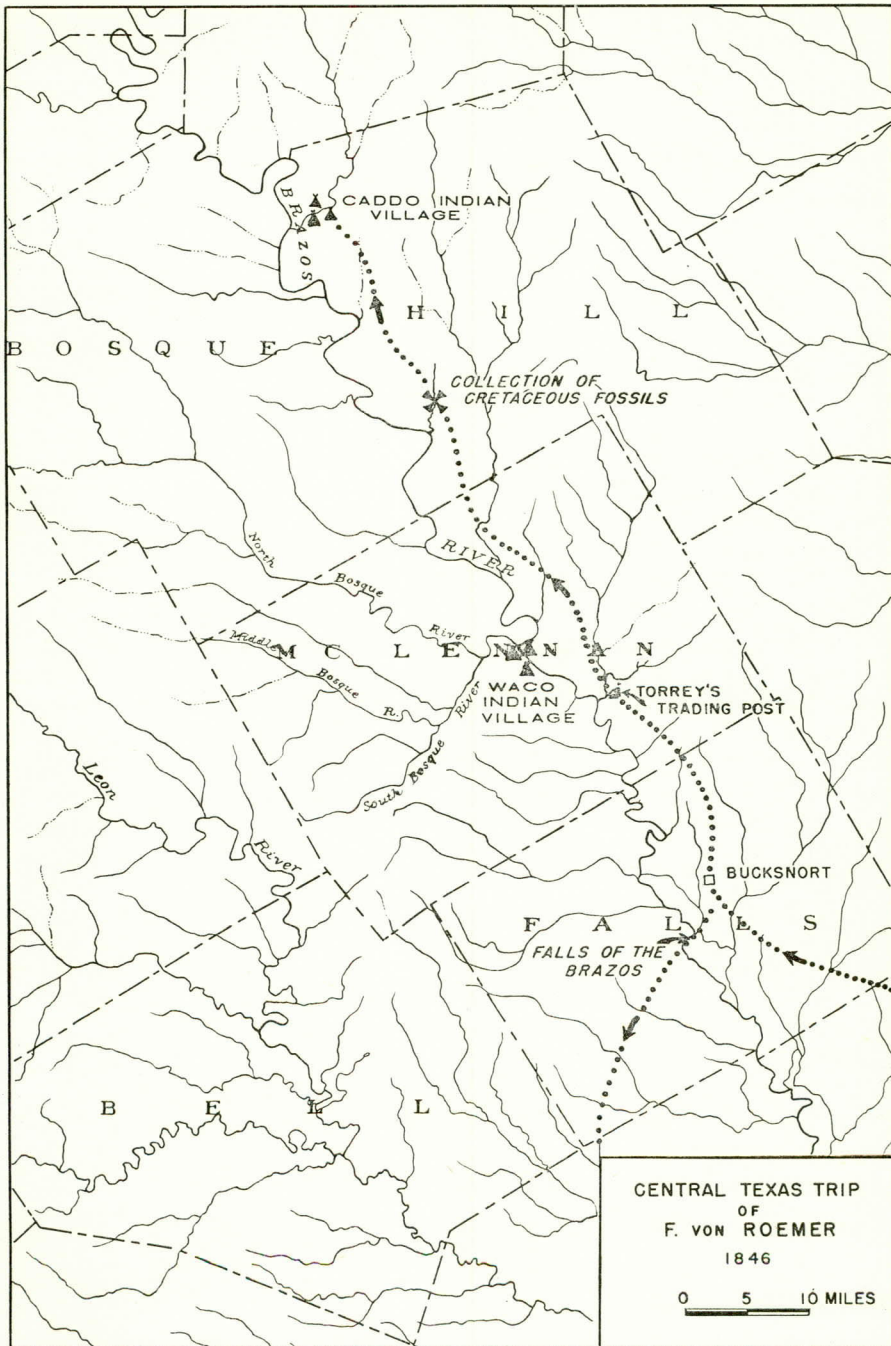


Fig. 3. Route of Roemer's trip to Torrey's Trading Post and Caddo Indian village in 1846.

NORTH TEXAS	SOUTH TEXAS
WOODBINE	= ?Pepper (lower part of "Eagle Ford" shale)
Nodular Grayson	= BUDA
Lower Grayson	= DEL RIO
MAIN STREET	= MAIN STREET

Hill in some early papers (as Hill, 1894), unduly influenced by Taff and by the sporadic ranges of *Kingena wacoensis*, failed to recognize Grayson in Grayson County (it is obscure because there it is thin and at most places overwashed), and considered the Del Rio of South Texas the equivalent of the Main Street in Grayson County, and the Grayson and Buda were considered absent at Denison. Cragin, after the discontinuation of the appropriations for the Dumble Survey in March, 1893, did field work in Grayson County, to clarify the Taff ideas, which he rejected outright (1893, p. 243). From this situation it resulted that Cragin named the Grayson formation. Cragin's correlation was as follows:

NORTH TEXAS	SOUTH TEXAS
EAGLE FORD	= EAGLE FORD
WOODBINE	= (absent; 1893, p. 243)
???	= BUDA
GRAYSON	= DEL RIO (named by Hill and Vaughan in 1898)

In Hill's later papers, including the "Black and Grand Prairies" (1901) the Main Street and Grayson were considered continuous from North Texas to South Texas, the Buda was essentially absent north of the Brazos, and the Woodbine essentially absent south of Brazos; which remained the popular opinion until recently. Such simplified geology resulted from insufficiently detailed field work, ignorance of the zonation, and lack of appreciation of the relations between structure and stratigraphy. It perhaps occasions surprise to note that the fifty years since Hill's report have seen so little stratigraphic progress in this area. From 1902 to 1921 nothing was written on the area.

LATER WORK, 1901-1951

Böse (*in* Udden, Baker and Böse, 1916, pp. 65, 71) believed that the Buda in South Texas is equivalent to the Woodbine in North Texas, apparently because of stratigraphic position. In recent years essentially all possible speculative correlations have been published by divers authors, such as (a) no Buda in north Texas, no Woodbine in south Texas; (b) both Buda and Woodbine present (the Buda not necessarily continuous) throughout; (c) Woodbine present in south Texas, no Buda in north Texas. It may be noted that Hill's definitive conclusions, as expressed in the "Black and Grand Prairies" report (1901) were:

NORTH TEXAS	SOUTH TEXAS
WOODBINE	= (absent)
GRAYSON marl	= BUDA limestone (p. 288, 245, fig. 29)
MAIN STREET limestone	= DEL RIO clay (p. 283)

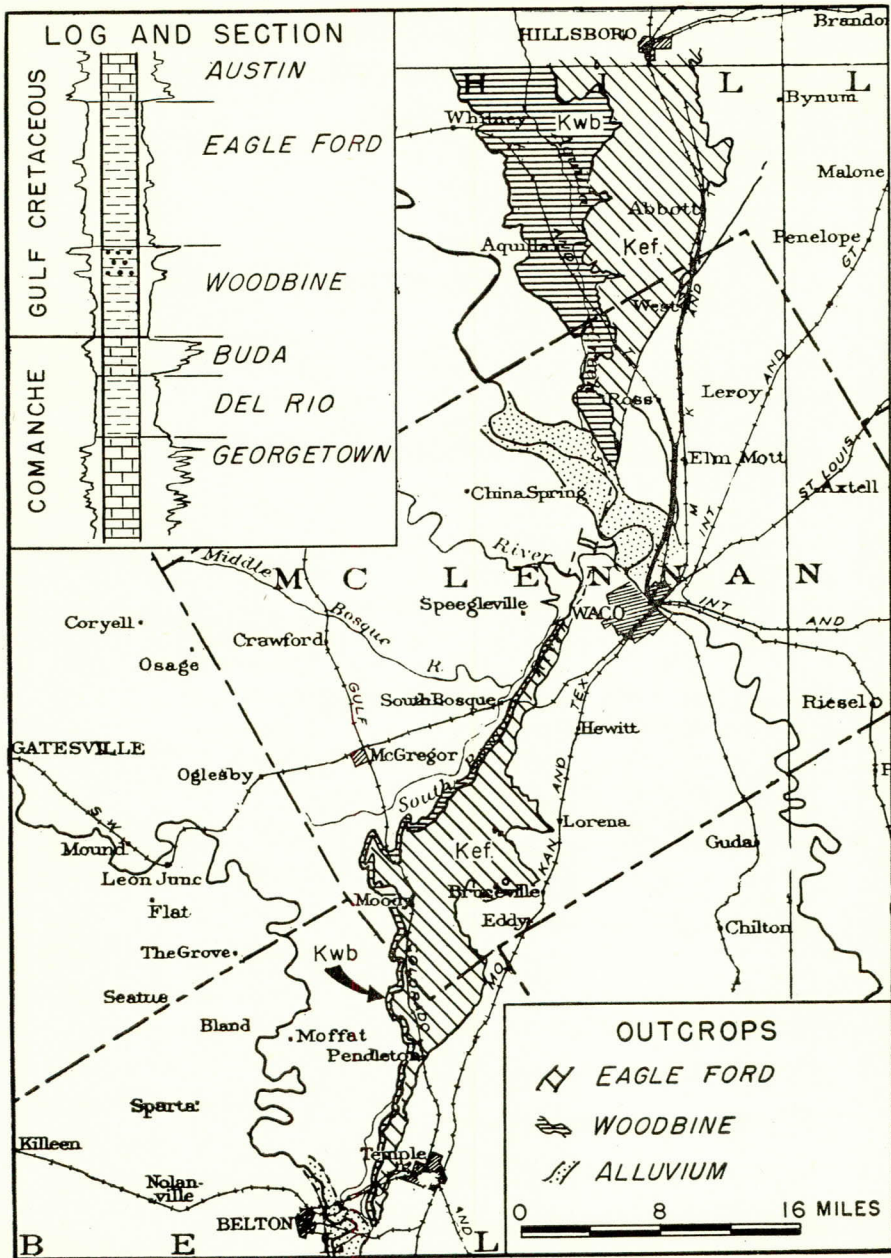


Fig. 4. Geologic map of Woodbine and Eagle Ford, central Hill County to central Bell County, Texas.

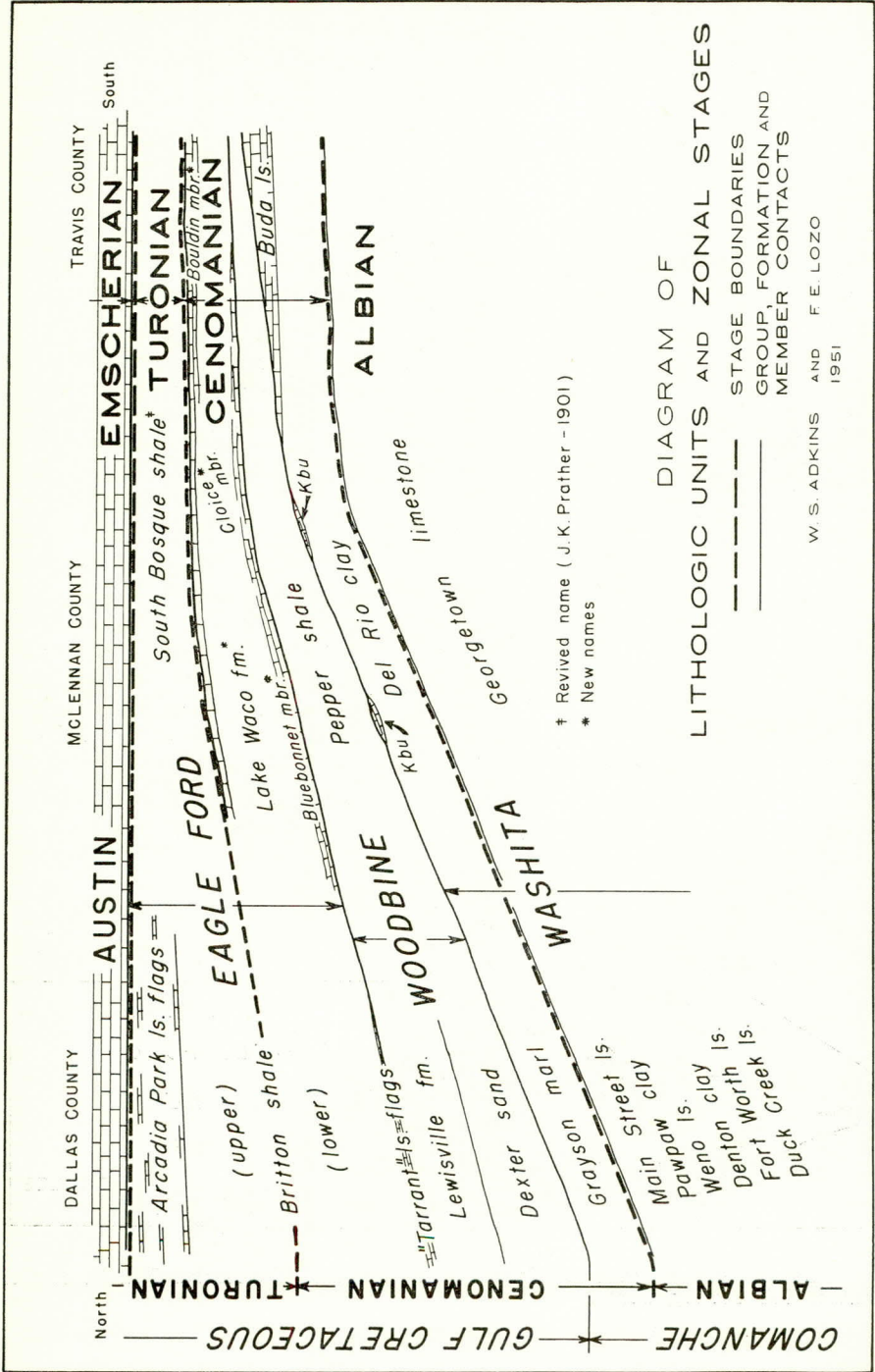


Fig. 5. Diagram of lithologic units and zonal stages.

Adkins and Arick (1924, McLennan County; 1930, Bell County) established the intermittent northward extension of the Buda (with good marker fossils) north of the last continuous outcrop of Buda near Salado, and attempted with the available well data to trace the margin of the subsurface Buda (for better information, see Fig. 22). Since in these bulletins the Pepper shale was included as the basal member of the Eagle Ford, the Woodbine margin questionably portrayed by Adkins (1924, p. 65) had meaning only as a sandstone facies margin, not as a Woodbine group margin. Intermittent Buda outcrop is now known at several places in Bell County (Adkins and Arick, 1930, pp. 48-59, pl. 1), including the "rolled boulder" locality near the McLennan-Bell county line (*ibid.*, p. 52); at Bosqueville, McLennan County; at the Hill-Johnson county line (Adkins, 1936, p. 142); at Modlin Cemetery (Winton, 1925, Hill 1923), Grayson Bluff and nearby localities, Denton County (Bailey, Evans and Adkins, 1945; Stephenson, 1944); and Cherry Mound, Grayson County (Bergquist, 1949, and others). By now the Buda and Woodbine sand subsurface margins in the Embayment are well known and well certified.

The Pepper shale (Adkins, 1933, p. 417) is supposed by the writers to be the southward continuation of a part of the Upper Woodbine group (Lewisville formation) in north-central Texas. Evidence for this correlation is presented in this paper. We have detected no Woodbine equivalents south or west of the south boundary of Travis County; the "Dakota" at El Paso turns out to be characteristic high Cenomanian Eagle Ford.

Since the earliest misunderstandings, the continuity of the Eagle Ford has been clear to all geologists. New data on its behavior, zonation and lithic subdivisions are here presented. The notion of a condensed zone at the top of the Eagle Ford in the southern area was first proposed by Adkins (1933, pp. 435, 436).

As late as 1928, Dr. Stanton expressed doubt that the Grayson and the Del Rio are zonally exactly equivalent, and with justice. Much has been done on this zonation, but the question would carry us far outside the area under consideration here. It is possible that basal Buda may be represented in the Upper Grayson of north Texas (cf. Taff and Winton).

STRATIGRAPHY

GENERAL STATEMENT

THE REGIONAL OUTCROP; RELATIONS WITH SUBSURFACE

The outcrop map and composite electric log (Fig. 4) show the gross lithologic units in this part of the geologic column, in the area under consideration. Probably most of these rocks were deposited in marine waters at some distance from the shores of their respective seas; their depth relations suggest inner-middle neritic, as inferred from litho- and biofacies. At practically no stratigraphic level in the

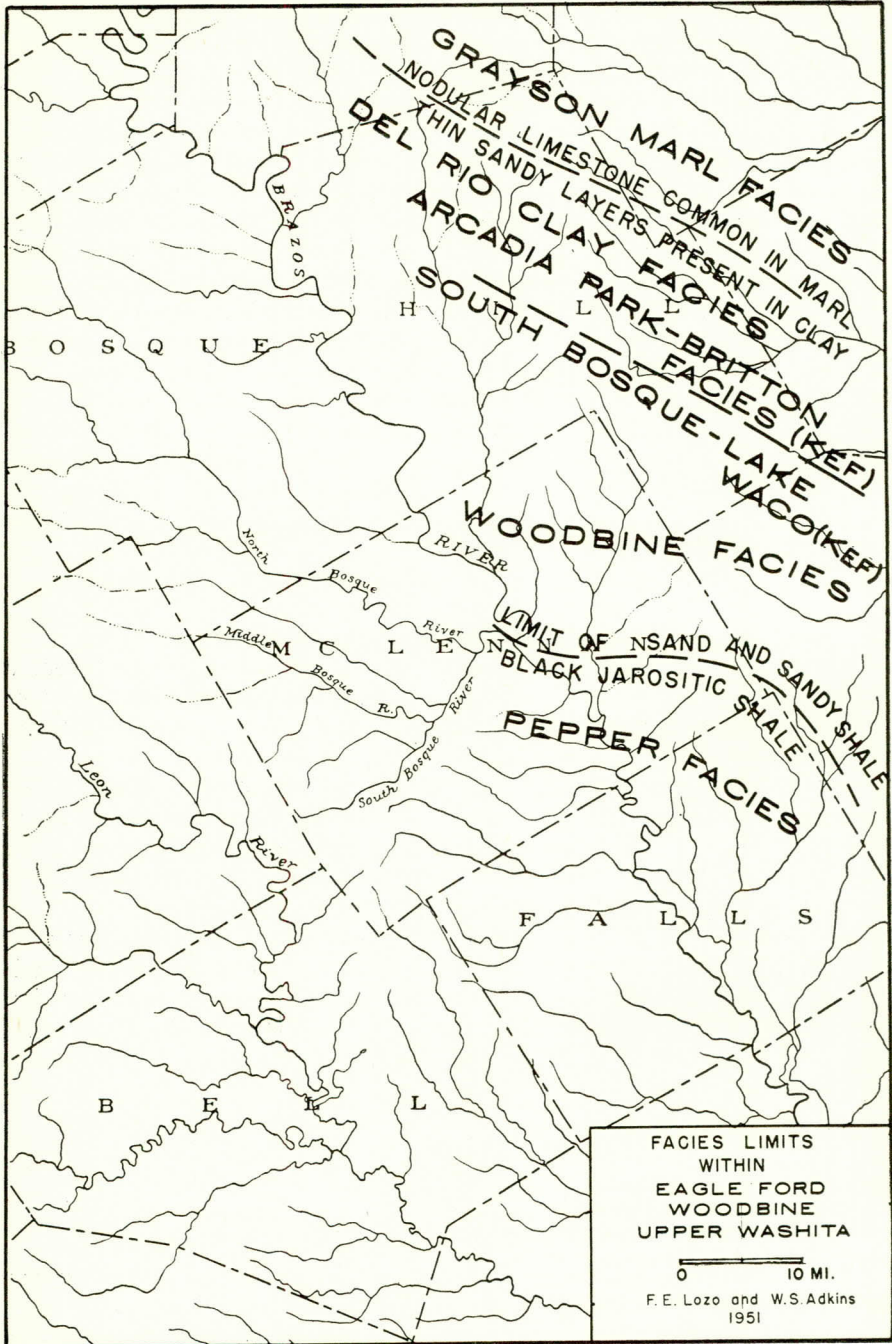


Fig. 6. Boundaries of facies in the Eagle Ford, Woodbine, and Washita.

area, in the formations discussed, is there distinct evidence of sub-aerial erosion; hence some of the stratigraphic relations at the lithic boundaries, as later discussed, remain obscure and puzzling.

It is well known that from Fort Worth to Austin, there is a Comanchean neritic shelf area, which forms the western border of the East Texas Embayment. This border is roughly marked by the westernmost Jurassic deposits which have been preserved, and by the location of the Balcones and Mexia fault systems and of the graben-like strip which lies between them. In the general Fort Worth area south of the Red River Uplift is the Fort Worth syncline; and in the Austin-San Antonio area is the broadly rounded San Marcos arch.

The present outcrop strike runs a little east of north. The isopachal strike is variable but may be seen at different ages from an inspection of figures 22, 23, and 24. The lithofacies strike differs with the formation, but tends toward the southeast. Since the formations (except parts of the Woodbine) are inner-middle neritic, obviously the parts most recently removed are like the outcrop, hence the tie of outcrop to subsurface is immediate. The present structural dip is toward the East Texas Embayment, but with subsidiary differences.

LITHOFACIES; THE PRINCIPAL LITHIC UNITS

Under "lithofacies" are included the facts of the principal rock types, and their stratigraphic arrangement and partition. Lithic units (groups, formations, members) are named for stratigraphic convenience according to personal judgment, and are in no sense absolute (Fig. 5).

For divers reasons, a convenient span of the geologic column is from the Georgetown to the base of the Austin chalk. Neither the rock types nor their descriptions have been standardized, hence any treatment of them remains only approximate. One rough field approximation is to refer to certain gross rock types by well known examples, as "nodular Grayson," "Grayson marl," "type Del Rio," "Pepper-type," "Eagle Ford bentonitic fish-scale shale," "salt-and-pepper shale," etc. With occasionally some question, some of these gross types can be recognized by electric log characteristics, and many are well known from cores and cuttings (Fig. 6).

Upper Georgetown. It is generally light gray-weathering limestone in thin to medium irregularly continuous strata, alternating irregularly with thin to medium strata of whitish-weathering, very calcareous marl. Chert, quartz, and glauconite are rare or absent; large and microscopic fossils are generally common; on the outcrop, the fossil zonation is generally good.

Del Rio. In this area the outcrop is a marl or clay, often high in lime; pyrite, gypsum, and hydrated iron oxides are common. There may be rarely scattered thin limestone seams, ferruginous seams, and shelly strata, and near the top a few very limy, whitish, nodular,

thin limestone seams (more prominent farther north), or thin, buff-weathering platy seams of fine sandstone or siltstone (much more prominent to the south, especially in the middle Rio Grande Embayment). North of Johnson County, bodies of whitish, very limy, nodular, soft limestone mark the upper part of the Grayson. The fossil zonation is generally good.

Buda. In Bell County, as far north as Salado, the main Buda outcrop is a very thin, continuous, hard to porous, coquina-like limestone, at places notably coralliferous, and everywhere ferruginous-stained. North of this point the outcrop is intermittent, and the lithology is much the same but minus the corals, and at places much indurated. Elsewhere in Texas the Buda has very different lithology, including marl strata and diverse limestone types, including dense ("porcellaneous") limestone. The fossil zonation is spotty.

Woodbine. In the area north of the Brazos, strata of porous and crumbly to friable, locally indurated, ferruginous sandstones occur, alternating with Pepper-type black, non-calcareous shales. Southward these sandstones thin and disappear laterally within the body of the shale formation, which is composed thereafter entirely of the Pepper facies. This is a non-calcareous, non-carbonaceous (except for ferrous carbonate and thin shells), black, locally glistening shale which contains pyrite and on the outcrop develops gypsum, celestite, siderite, jarosite, and other minerals. The outcrop is poor in soil and vegetation. The fossil zonation is spotty, but at levels fossils occur, as shale ammonites at Alligator Creek; in fossiliferous limy seams at Haunted Hill.

Eagle Ford. The Eagle Ford contains diverse rock types: (a) black or bluish-black, non-carbonaceous shale or clay, locally glistening, generally somewhat calcareous (as at South Bosque cement plant shale pit); (b) bentonites or related rock types; (c) thin, indurated limestone flagstones, often salmon-colored, with fish and reptilian remains and lignitized wood, and generally containing invertebrates; (d) thin, calcareous, shaly limestones to limy shale especially in the upper ("*Prionotropis*," Arcadia Park) portion; and (e) thin, whitish, limy siltstone or silty limestone layers (as at Blue Cut).

NOMENCLATURE AND HISTORY OF THE GEOLOGIC UNITS

Since no generally accepted procedure exists concerning the naming of lithic units, individual judgment but not priority has generally prevailed; and with the increasing refinement and complexity of modern stratigraphic work, the proposal of new names has increased enormously, contrary to certain earlier expectations.

UPPER WASHITA

B. F. Shumard (1860) first used the term "Washita" for essentially the Georgetown limestone as now understood, since he had in mind a limestone, the lower Georgetown which is "finely developed at Fort Washita" (northwestern Marshall County, Oklahoma). Marcou's (1862) "Washita" definitely excluded the "*Exogyra arietina*"

marl. R. T. Hill's "Broadside sheet," December 23, 1886, made mention of the "Upper or Washita division;" but the definition of its top was so confused as to make entirely questionable whether it included the Grayson or not. The same is true of C. A. White (1887b, p. 40). Hill (1889, pp. xiv, xxi) and others later extended the "Washita" to include the Del Rio and Buda. Synonym: Indian Territory division of R. T. Hill (1891, p. 504).

Georgetown. Hill (1901, p. 262). Defined to include Kiamichi to Main Street, inclusive; approximately the same as Marcou's Washita (see above). First reported in T. W. Vaughan's (1900) Uvalde folio. Named for exposures at Georgetown, Williamson County. Synonymous in part with limestone formerly called Fort Worth limestone.

Main Street. Hill (1894, p. 302, pl. 13). Meaning unaltered; top member of Georgetown. Type locality: near railway stations at Denison, Grayson County. Synonyms: Choctaw limestone of Cragin (1894); Bennington limestone of Taff, (1902).

"*Transition zone*" at Georgetown-Del Rio boundary. Adkins (1933, pp. 386, 387). Not a formation name.

Grayson. Cragin (1894, pp. 40, 43). Type locality: northeastern Denison, Grayson County. Synonyms: Vola clay, Vola limestone of Taff.

Del Rio: Hill and Vaughan (1898, p. 236). Type locality: conical hill in the clay flats south of Del Rio, Val Verde County. Synonyms: *Exogyra arietina* clays or marls of various writers; gelbliche Kalkmergel of Roemer (1849, 1852).

Buda: Vaughan (1900, p. 18). Synonyms: Shoal Creek limestone (name preoccupied), "Burnt limestone," and Vola limestone of various authors (not Taff).

"*Bosqueville rock:*" Adkins (1924, p. 58). Buda plus Woodbine plus topmost limestone of the Del Rio; not a formation name.

Maness: Bailey, Evans and Adkins (1945, p. 176). Overlies the Buda in the subsurface of the East Texas Embayment. Type section: Shell Oil Co., S. H. Maness No. 1, Cherokee County, depth 4705 to 4766 feet.

South Tyler: Hazzard, Blanpied and Spooner (1947, p. 476). A subsurface subdivision of questionable age consisting in part of the "Lower" or Dexter" Woodbine of various authors plus the Maness in the basal portion. Type section: Phillips Petroleum Co., Mrs. W. T. McMinn No. 1, South Tyler field, Smith County, depth 5675 to 6065 feet.

WOODBINE

Until Hill (1901, p. 292) proposed the term Woodbine, taken from the town of Woodbine in eastern Cooke County, the eastern timbered belt of the Cross Timbers (topographically lower than the western belt on the Trinity sands) had been mapped or described as the Lower Cross Timbers, Hill ("Broadside sheet," 1886); Timber Creek group, Hill (1887, p. 298), name preoccupied; Timber Creek beds,

C. A. White (1887b), name preoccupied; "Dakota" of various authors (apparently not type Dakota); and as the Silo formation of Oklahoma by Taff (1902).

Lewisville: Hill (1901). Upper, more calcareous portion of outcrop Woodbine, locally with volcanic material. Type locality: along Timber Creek, Denton County.

Dexter: Hill (1901). Lower portion of Woodbine, generally poor in fossils, sands massive and "clean," i.e., relatively free of volcanic material. In the subsurface of the East Texas Embayment there exist an Upper Woodbine (more argillaceous and volcanics-bearing) section, and a Lower Woodbine section (clean, friable, porous and permeable). Type locality: near Dexter, northeastern Cooke County.

Pine Bluff volcanics: Hazzard (1939). Local name applied to some "cannon ball" volcanics in northeastern Texas. Type locality: Pine Bluff ferry (abandoned), Lamar County.

Pepper: Adkins (1933, p. 417). Outcrop Woodbine shale south of Brazos River in McLennan County; age, Upper (Lewisville) Woodbine. Type locality: along Pepper Creek, Bell County. Type section: Bird Creek, just east of Belton-Temple highway, Bell County. Synonym: "Lower Eagle Ford shale" of Adkins and others.

EAGLE FORD

C. A. White's usage of the term Eagle Ford in 1887 (p. 40) antedated that of R. T. Hill (1887, pp. 296, 298). The type locality is in Dallas County near the village of Eagle Ford. Prior to the above reference, the outcrop shale had been called the "Marly Clay or Red River Group," "blue marl with *Inoceramus problematicus*," and "Fish bed shale" by B. F. Shumard (1860) and Marcou (1862). Roemer, (1852) included the Eagle Ford as a portion of "formations at the foot of the highland" in the faulted New Braunfels region.

Arcadia Park: Moreman (*in* Adkins, 1933, p. 425). Upper 100 feet or less of Eagle Ford in northeast Texas, marked by thin limestone flagstones and marl. Type locality: near Arcadia Park, western Dallas County.

Britton: Moreman (*in* Adkins, 1933, p. 425). Essentially all of the Eagle Ford shale below the Arcadia Park. Type locality: area near Britton, northwestern Ellis County.

Tarrant: Moreman (*in* Adkins, 1933, p. 425). Basal few feet of sandy clay, sandstone, and sandy platy limestones of Moreman's Eagle Ford. Type locality: east of Tarrant Station, eastern Tarrant County. The writers have abandoned the term as a lithic unit.

South Bosque marl: Prather (1902). Name revived for the upper 120 feet of clay or marl of the Eagle Ford in the type area of South Bosque, McLennan County. The best exposure is the Eagle Ford shale pit of the Universal Atlas Cement Company a mile east of South Bosque.

Lake Waco formation: new name, defined and described in following pages.

Bluebonnet member: new name, defined and described in following pages.

Cloice member: new name, defined and described in following pages.

Bouldin member: new name, defined and described in following pages.

OUTCROP DATA

DESCRIPTIONS OF LITHIC UNITS

The Del Rio clay, Buda limestone, Pepper shale, and Woodbine (undifferentiated) sand have been adequately described in the literature and summarized in preceding pages. Formal descriptions of the divisions of the Eagle Ford group recognized in the outcrop area of Bell, McLennan, and Hill counties are here given, in descending order.

SOUTH BOSQUE FORMATION. In 1902 J. K. Prather was concerned with an attempt to identify the marl "which is spoken of by Dr. Hill as 'the marl at the base of the Austin chalk.'" Since Hill did not clearly state what was meant by the "marl at the base of the Austin chalk," but recorded in wells a passage from Austin directly into Eagle Ford shale (as did Prather), Prather was attempting to isolate and identify a marl unit intervening between the Austin chalk and Eagle Ford shale. The latter's final paragraph summarized his study:

. . . In the two well sections . . . the white limestone, or Austin chalk, lies directly upon the Eagle Ford shale, and there is no trace of this marl between the two. In certain localities large areas occur, composed entirely of this marl, and there is no evidence that the Austin chalk once lay above it. It seems to be a separate and distinct formation for the following reasons.

(1) It has characteristic fossils which are not found in the Austin chalk, and

(2) It differs stratigraphically from the Austin chalk. I think this marl should be given a distinct name, and I propose the name of "*South Bosque Marl*," on account of the fine exposures found around South Bosque Station, McLennan County, Texas.

Prather's type section of the South Bosque marl was composed of an upper 107 feet of marl and a lower 33 feet of alternating limestone and marl, a total of 140 feet. Results of the writers' investigations indicate the following correlations:

R. T. Hill, 1901	J. K. Prather, 1902	Present
AUSTIN.....	AUSTIN.....	AUSTIN
	SOUTH BOSQUE	Upper Eagle Ford
	140 ft.	120 ft.
	-----	-----
EAGLE FORD		Lower Eagle Ford
195 ft.		75 ft.

[Continued on next page]

EAGLE FORD

Pepper
55 ft.

DEL RIO

DEL RIO

DEL RIO

It may be noted that Hill's Eagle Ford was based on field work by S. Leverett, J. A. Taff's assistant, in 1892. From transcriptions of Leverett's original field notes, it may be stated that his Eagle Ford section was correctly compiled in interval from two isolated sections but he failed to recognize the Pepper interval and to note its thickness.

Description: The term South Bosque is here revived and emended to exclude the basal 20 feet of the original section. So emended, the South Bosque formation consists of an upper predominantly clay portion, well exposed in the cement plant shale pit east of South Bosque, and a lower portion of platy, salmon-colored, thin-bedded limestones alternating with "bentonitic" shales. The South Bosque formation is overlain by the Austin chalk and underlain by the uppermost member (Bouldin) of the Lake Waco formation. The basal contact is characterized by a change from the platy limestones and "bentonitic" shales to more blocky, grayish, silty limestones interbedded with dark shales and bentonite seams.

Type area and section: Bosque Escarpment, from Waco westward to South Bosque, where there are full but overwashed exposures. A typical and well exposed section is in the Universal Atlas Cement Company shale pit and along Cloice Branch, one mile east of South Bosque.

Thickness: about 120 feet.

Fossils: Eagle Ford Zones 6-9 (see "Zonation").

LAKE WACO FORMATION. A new formation name, the Lake Waco is here proposed for the section underlain by the Woodbine sand or Pepper shale and overlain by the emended South Bosque formation. The formation consists of grayish white to brownish wavy bedded limestones and dark silty shales with bentonite layers.

Description: The Lake Waco formation is described in following pages and graphically illustrated in figure 18.

Type area and section: West-facing Bosque Escarpment from Lake Waco Dam spillway south to the Moody Hills between McGregor and Moody, McLennan County. The type section is in Cloice Branch, from the cement plant to the old South Bosque brickyard pit (see Figs. 10 and 18).

Thickness: 60 to 80 feet.

Fossils: Zone 4, approximately, of the Eagle Ford (see "Zonation").

BOULDIN MEMBER. A new name, the term is here proposed for the upper member of the Lake Waco formation. In the McLennan County area it is composed of interbedded grayish white to brownish silty limestones and silty shales with bentonites. Local details are pre-

sented in figure 18 and in the pages pertaining to the Cloice Branch section.

Type locality and section: Bouldin Creek and diversion cut near the M.P.-M.K.T. railroad, between Milton Street and Barton Springs Road, Austin, Travis County, Texas.

Description: In the type area of the Bouldin limestone, the Eagle Ford is approximately 42 feet thick and divisible into three parts: an upper shale unit of 20+ feet, a middle limestone unit with bentonite layers about 9 feet thick, and a lower shale unit of 11+ feet. The detailed sections by Dan E. Feray and Keith Young (1949, pp. 51-56, pl. 14) of the middle limestone unit are repeated below.

Locality 226—T-45

(Bureau of Economic Geology)

Upper Shale Unit of Eagle Ford

	Feet
t. Blue-gray to black, massive to bedded (weathers as fissile clay) clay with scattered iron-stone or pyrite nodules.....	

Middle Limestone Unit of Eagle Ford = BOULDIN MEMBER

s. Buff to white bentonite.....	0.5
r. Gray to gray-brown, thin-bedded, undulating, silty, slightly fossiliferous limestones. This bed forms ledge and "paves" the creek bottom at the upper waterfall at pipeline crossing.....	1.0
q. Gray to gray-brown, bedded, slightly nodular, calcareous clay.....	0.65
p. Gray, thin-bedded, silty, fossiliferous limestone with pyrite and fish remains.....	0.25
o. Gray, thin-bedded, silty clay with two bentonite layers; lower layer 0.2 foot thick, upper layer 0.1 foot thick. The latter is 0.1 foot above base.....	0.8
n. White to light gray, slightly undulating, slightly silty, massive limestone, weathering rounded.....	0.27
m. Dark gray, thin-bedded, silty clay with interbedded bentonites and thin limestones.....	1.35
l. Gray to buff, thin-bedded, silty, calcareous clay and nodular limestone.....	0.5
k. Gray to rust-colored bentonite.....	0.2
j. Gray, thin-bedded, silty, calcareous clay and limestone nodules with numerous <i>Inoceramus</i>	1.0
i. Gray-white to rust-colored bentonite and underlying gray silty clay.....	0.7
h. Gray, massive to bedded, silty, slightly fossiliferous limestone with two large ammonites in place—one a cast, the other a mold. Large concretions may contain carbonized logs.....	0.4
g. Gray, thin-bedded, fossiliferous (oysters), undulating, silty limestone and clay with "fish bed" conglomerate at base. Yields petroleum odor on fresh break.....	0.85
f. Light gray nodular, undulating, massive, silty limestone, weathering rounded, slightly discontinuous.....	0-0.8

Lower Shale Member of Eagle Ford

e. Gray-black, massive clay, thin-bedded upon weathering and yielding odor of petroleum on fresh break.....	
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Locality 226-T-31

(Bureau of Economic Geology)

Upper Shale Unit of Eagle Ford

u. Soft, weathered, calcareous clay.....	
--	--

Middle Limestone Unit of Eagle Ford = BOULDIN MEMBER

	Feet
t. Bentonite (= bed s of Locality 226-T-45/.....	0.5
s. Hard, gray-brown, silty limestone.....	0.9
r. Soft, massive to bedded, dun-colored, calcareous, fossiliferous, silty clay with interbedded limestone.....	1.7
q. Hard, dense, light gray, fine-grained, silty limestone. This limestone forms a conspicuous bed.....	0.1-0.3
p. Soft thin-bedded, dun-colored, calcareous silt and interbedded limestone	1.1
o. Soft, thin-bedded, dun-colored, calcareous silts with two 1-inch layers of bentonite which merge laterally to form one layer....	0.6
n. Slightly indurated, massive to bedded, calcareous silts.....	0.2
m. Bentonite, weathered brown.....	0.3
l. Soft to indurated, interbedded, calcareous silts and limestone....	1.1
k. Hard, gray-brown, slightly bedded to massive, fossiliferous limestone	0.5
j. Soft to hard, gray-brown, thin-bedded, fossiliferous silts and limestone with base cemented with pyrite; contains numerous fish remains, sharks' teeth, etc. in base.....	0.7
i. Massive, hard, gray-brown, silty limestone with fossiliferous (clams) band in center. This is a very conspicuous bed (= bed f of Locality 226-T-45/.....	0.5

Lower Shale Member of Eagle Ford

- h. Soft, dark gray, thin-bedded, silty clay.....

Thickness: In the type area, the Bouldin limestone is about 9 feet thick. Northward from Travis County, a flagstone member near to or identical with the stratigraphic position of type Bouldin flags occurs at scattered localities across Williamson, Bell, and McLennan counties. As exposed in Blue Cut north of Moody and along Cloice Branch east of South Bosque, this limestone flag unit is approximately 14 feet thick.

Fossils: The Bouldin member contains numerous widespread marker fossils of Eagle Ford Zone 4. There is the possibility that the following fossils may be found to be nearly or entirely restricted to the Bouldin and its equivalents: "*Mantelliceras*" of the *sellardsi* and *vicinale* types, and others; various *Calycoceras*; *Eucalycoceras bentonianum* and other species; and other ammonites. At the type locality so far as discovered, the fossils of the Bouldin are exclusively Cenomanian. The above assemblage with other ammonites occurs at and near Bouldin Creek in Austin, at Blue Cut and Cloice Branch in McLennan County, and at Hackberry Creek and the C.&R.I. bridge (California Crossing) in western Dallas County.

CLOICE MEMBER. This new name is applied to the middle member of the Lake Waco formation. The unit consists of dark, silty, calcareous shales with subordinate limestone beds. The section is indicated in figure 18 and described under the Cloice Branch locality.

Type area and section: Along the Bosque Escarpment southwest to Moody Hills; the type section is in Cloice Branch.

Thickness: 35 feet.

Fossils: A wide assortment of Eagle Ford Zone 4 species (see "Zonation").

BLUEBONNET MEMBER. This term is introduced for the basal member of the Lake Waco formation. The unit consists of limestone flag-

stones interbedded with calcareous shale and bentonites. Confused in the past with the Bouldin member occurring above and the "Tarrant member," a fictitious lithic unit at the Eagle Ford-Woodbine contact in Tarrant and Dallas counties to the north, this unit is distinct stratigraphically and paleontologically along the outcrop.

Type area and section: Along the Bosque Escarpment from the old South Bosque brickyard southwest into the Moody Hills, then southward past Moody, McLennan County. The type section is opposite Baggetts Station on the east side of the McGregor-Moody road (State Highway 317), about 4.5 miles south-southeast of McGregor.

Description: See description under "Moody Hills, Bluebonnet Type Locality," and figures 17 and 18.

Thickness: 12-18 feet in McLennan County.

Fossils: Like the overlying Cloice and Bouldin members, the Bluebonnet flags contain a wide assortment of Eagle Ford Zone 4 fossils. From provisional zonal work, there is a possibility that the following are either very abundant in, or practically restricted to, the Bluebonnet member: *Borissiakoceras* spp., *Acanthoceras* "aff. *confusum*", var. *tunetanum*," *Eucalycoceras* n.sp. 3, and other ammonites.

In summary, reference is again made to figure 6 showing limits of lithofacies. The divisions of the Eagle Ford group described above are of local utility south of an areal band crossing the central portion and southeastern corner of Hill County. North of this band (and in the adjacent subsurface) the local Ellis and Dallas County lithofacies of Arcadia Park limestone flags and Britton shales replace the South Bosque and Lake Waco lithofacies of the area under investigation. Presumably, tectonic relationships are associated with this band of lithofacies change and the similar bands for the Woodbine sand-Pepper shale and Grayson-Del Rio changes.

LOCALITY DESCRIPTIONS AND LOCAL SECTIONS

Localities and sections representative of the Upper Washita, Woodbine, and Eagle Ford in the Waco area of central Texas are presented in the following pages. With the field examination of these sections, conducted as the 1951 field trip of the East Texas Geological Society, it is believed that the major features and characteristics of the local stratigraphic section will be amply demonstrated.

Figure 7 is a reduced road map of the area and serves as an index to the five following geologic maps (Figs. 8-12). The field trip is confined to these five sheets. Each of the eight localities is detailed and then summarized graphically in a corresponding figure (Figs. 13-21).

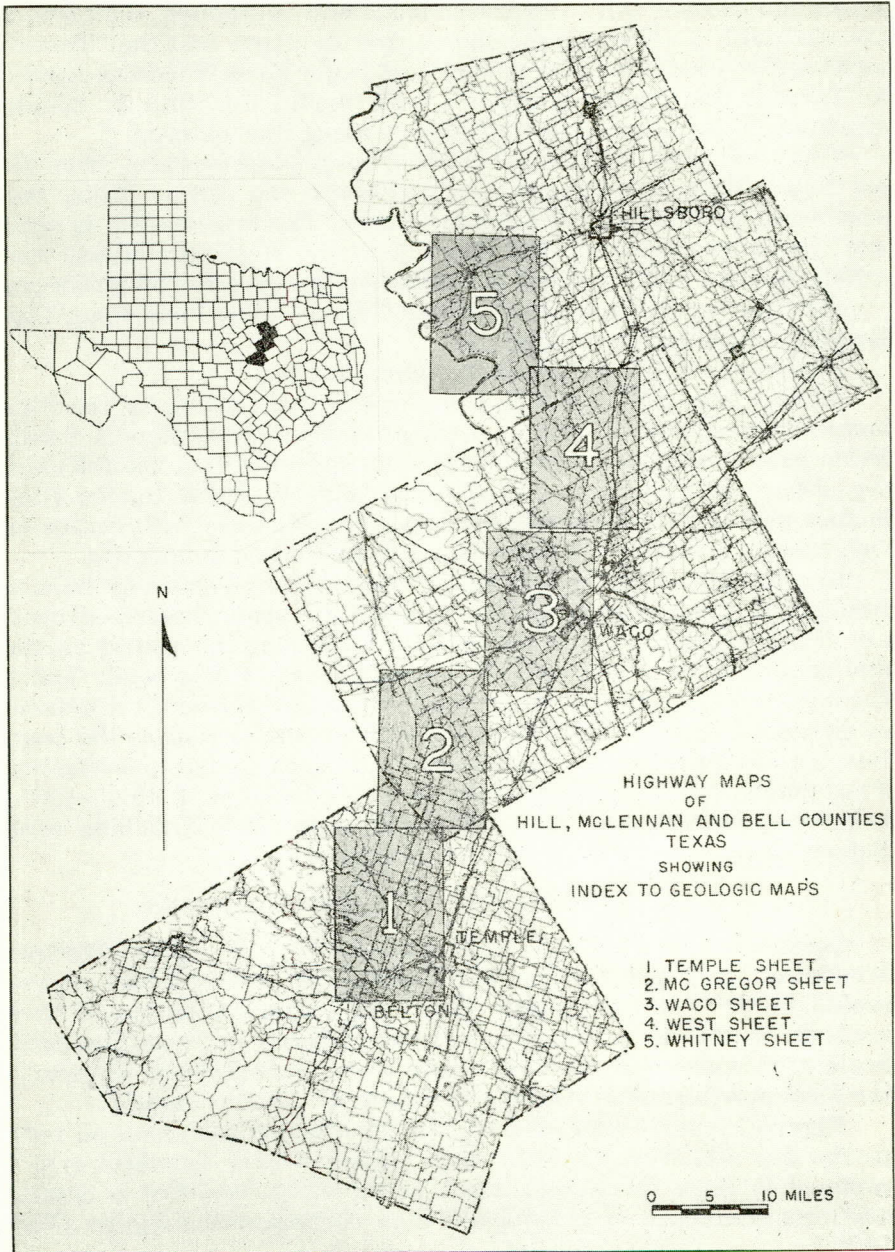


Fig. 7. Index map to geologic sheets.

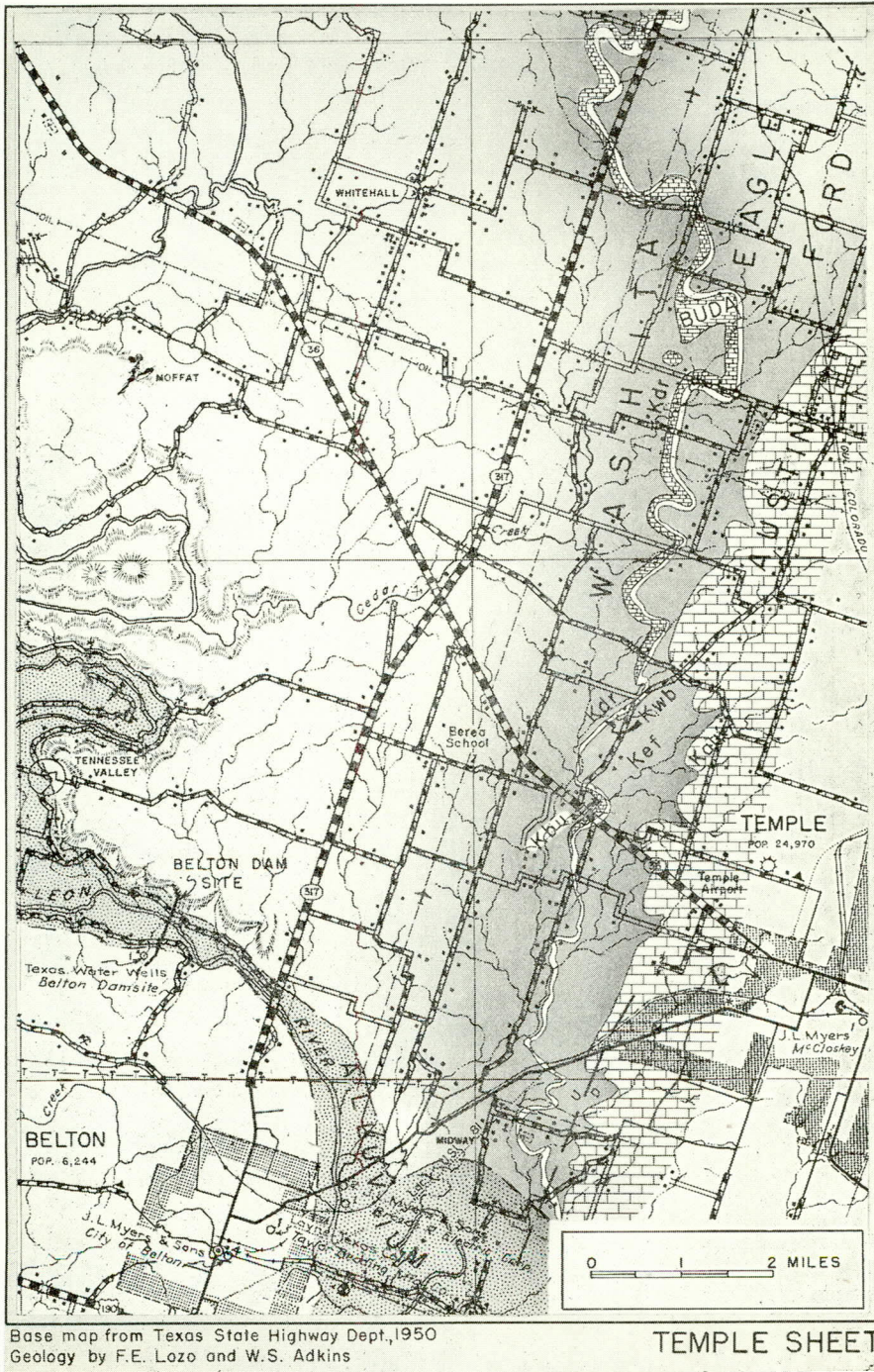


Fig. 8. Geologic map: Temple sheet.

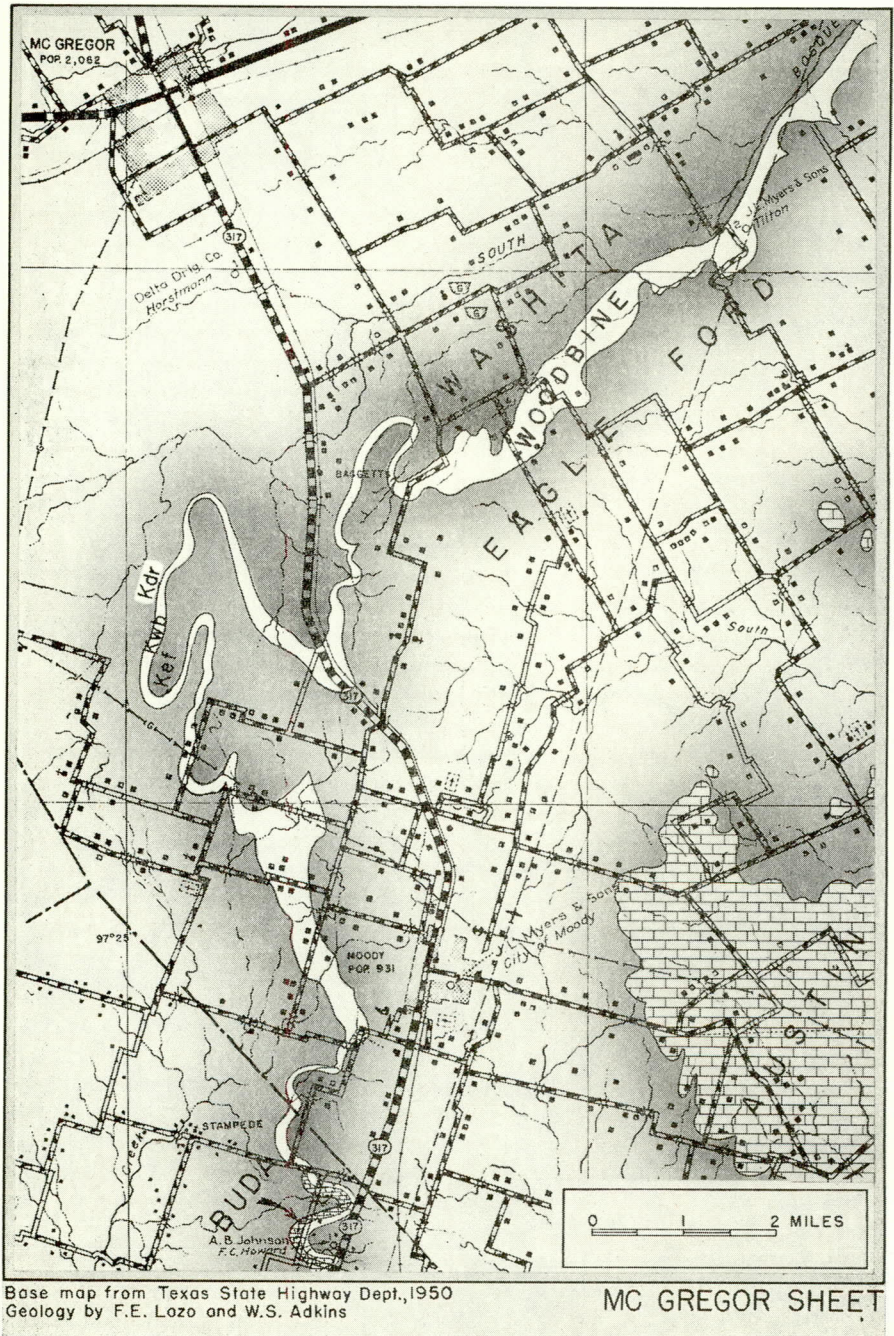


Fig. 9. Geologic map: McGregor sheet.

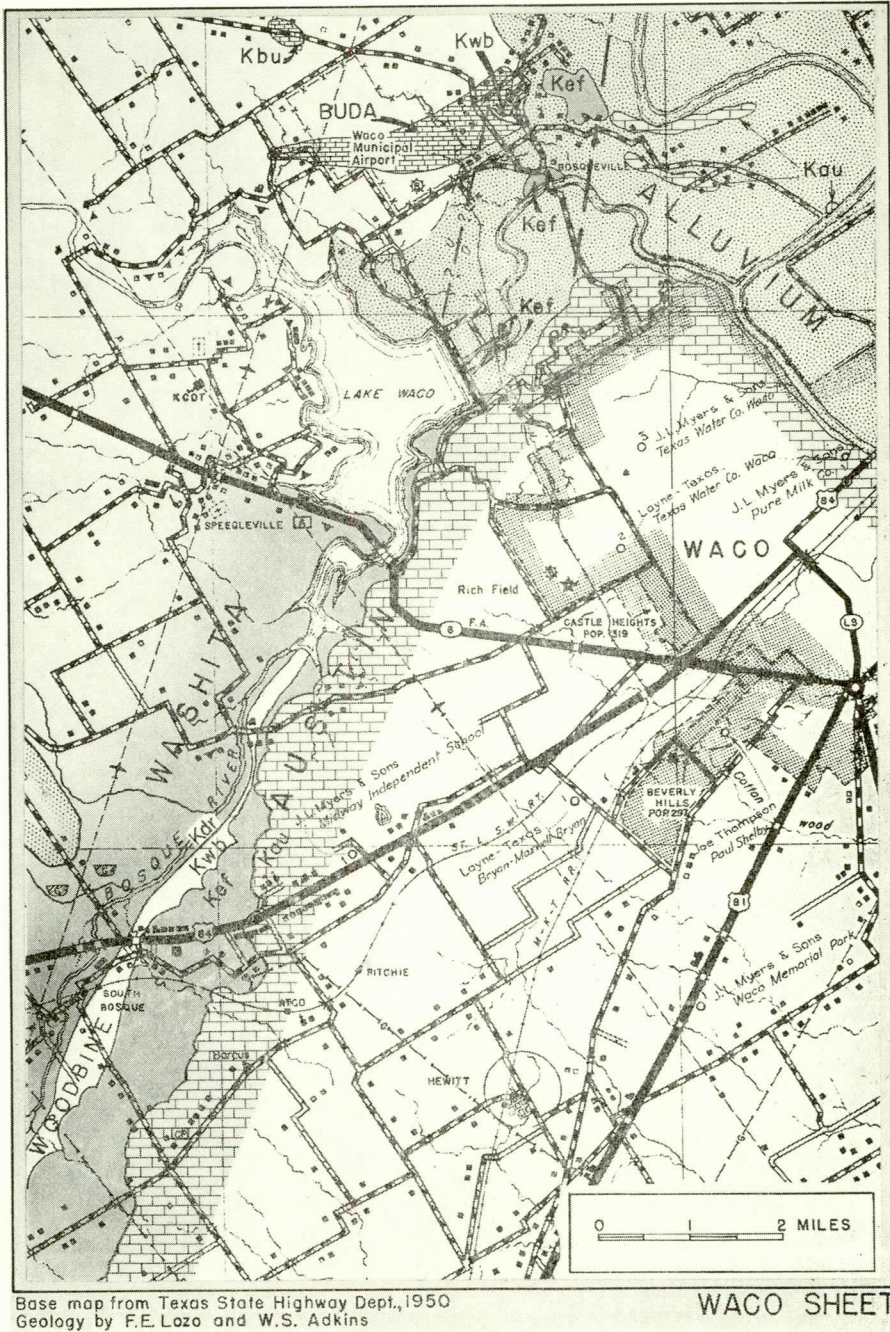


Figure 10. Geologic map: Waco sheet.

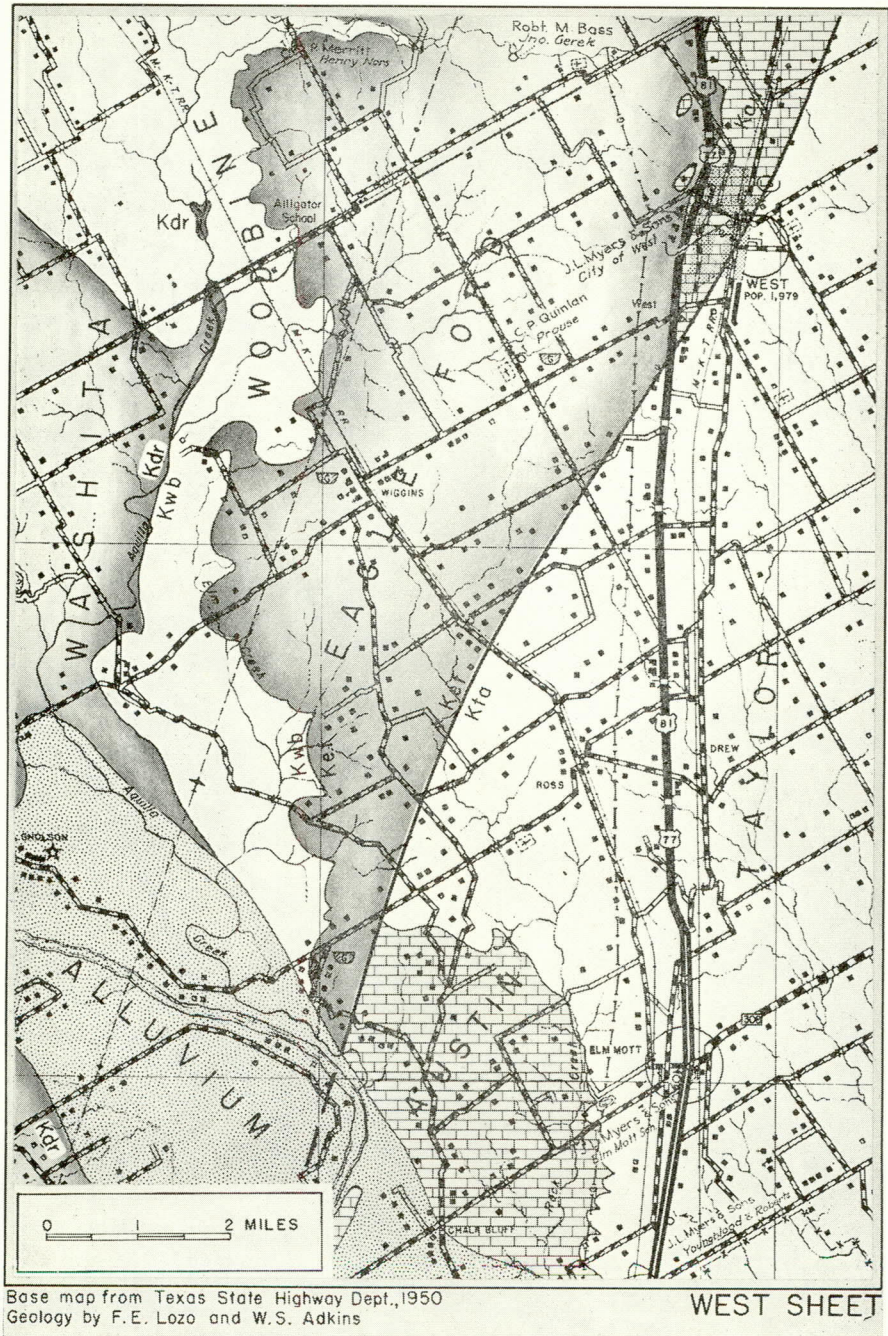


Fig. 11. Geologic map: West sheet.

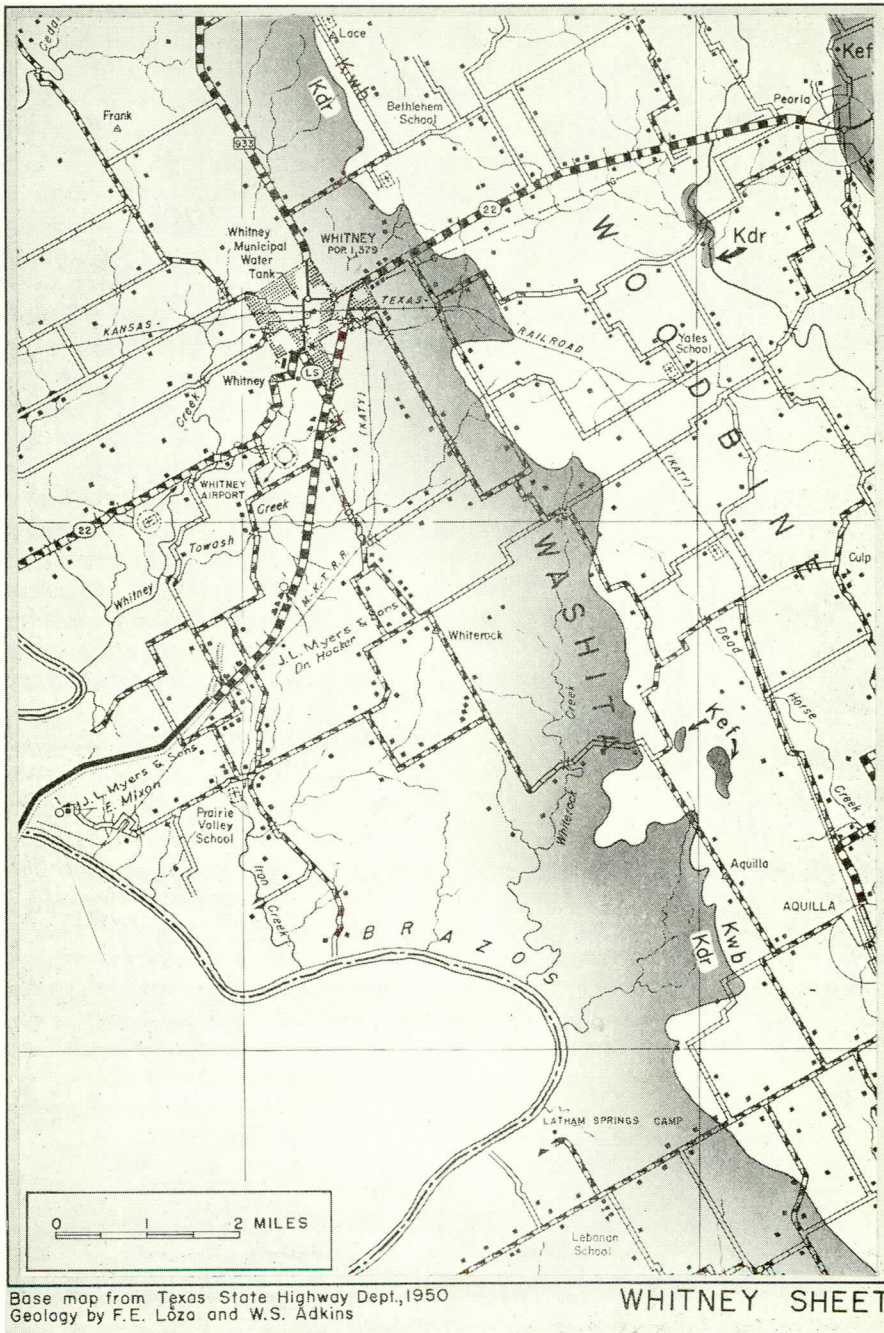


Fig. 12. Geologic map: Whitney sheet.

The type section of the Woodbine Pepper shale is in small west-facing bluffs along Bird Creek, about 500 feet southeast of the Belton-Temple highway (US 81) two and three-fourths miles northeast from the Leon River bridge. The locality was first described by Adkins and Arick (1930, pp. 53-54) with careful detail at the contact with the underlying Del Rio. The basal contact is unconformable and marked by a pebble conglomerate and reworked zone. The total interval of the Pepper was given (Adkins, 1933, p. 417) as 50 feet, but this figure is in error. Hand level measurement to an emended upper contact is 23.5 feet with 1.5 feet of Eagle Ford shale intervening between the top of the Pepper and the base of the ammonite-bearing limestone flag member of the Eagle Ford. The upper contact marks a sharp break in sedimentation; the uppermost Pepper is plastic, unctuous, non-calcareous clay with an impoverished arenaceous foraminiferan fauna, while the lowermost Eagle Ford is well-laminated, brittle shale with abundant globigerinids and other calcareous Foraminifera. From the lower portion of the Pepper here have been collected ammonites examined by Dr. L. F. Spath, foraminiferans reported by Helen J. Plummer (*in* Adkins, 1933, p. 419), and the species described by A. R. Loeblich (1946, refigured in this publication, pl. 4). A number of ammonites in part here and in the gullies and slopes about 0.2 miles westward across the highway (Adkins, 1928; Moreman, 1942).

The measured section at the type locality of the Pepper shale is as follows:

EAGLE FORD (*Bluebonnet member of Lake Waco formation*)

	Feet
h. Limestone, wavy bedded, yellowish-brown, coquinoïd and massive to platy and thinly bedded with a stratum of bentonite near the middle. Locally very fossiliferous with ammonites, inocerami, and other molluscs.....	2+
g. Shale, black, fissile, slightly calcareous, with abundant globigerinids and other calcareous shelled fossils.....	1.5

PEPPER

f. Shale, purplish-black, lustrous, non-calcareous, with yellow jarosite films and streaks in the weathered material and common selenite crystals. Contains arenaceous foraminiferans and thin nacreous shells and impressions of molluscs.....	22.5
e. Shale as above gypsiferous, abundant euhedral selenite crystals	0.6
d. Reworked zone: sandy, carbonaceous, gypsiferous clay with quartz and phosphate pebbles, fish remains, lignitized wood, and reworked Del Rio fossils.....	0.45

DEL RIO

c. Clay, gray, fossiliferous, calcareous, massive.....	1.5
b. Limestone, gray, gritty, clayey, soft.....	0.3
a. Typical Del Rio clay, exposed downstream.....	25+

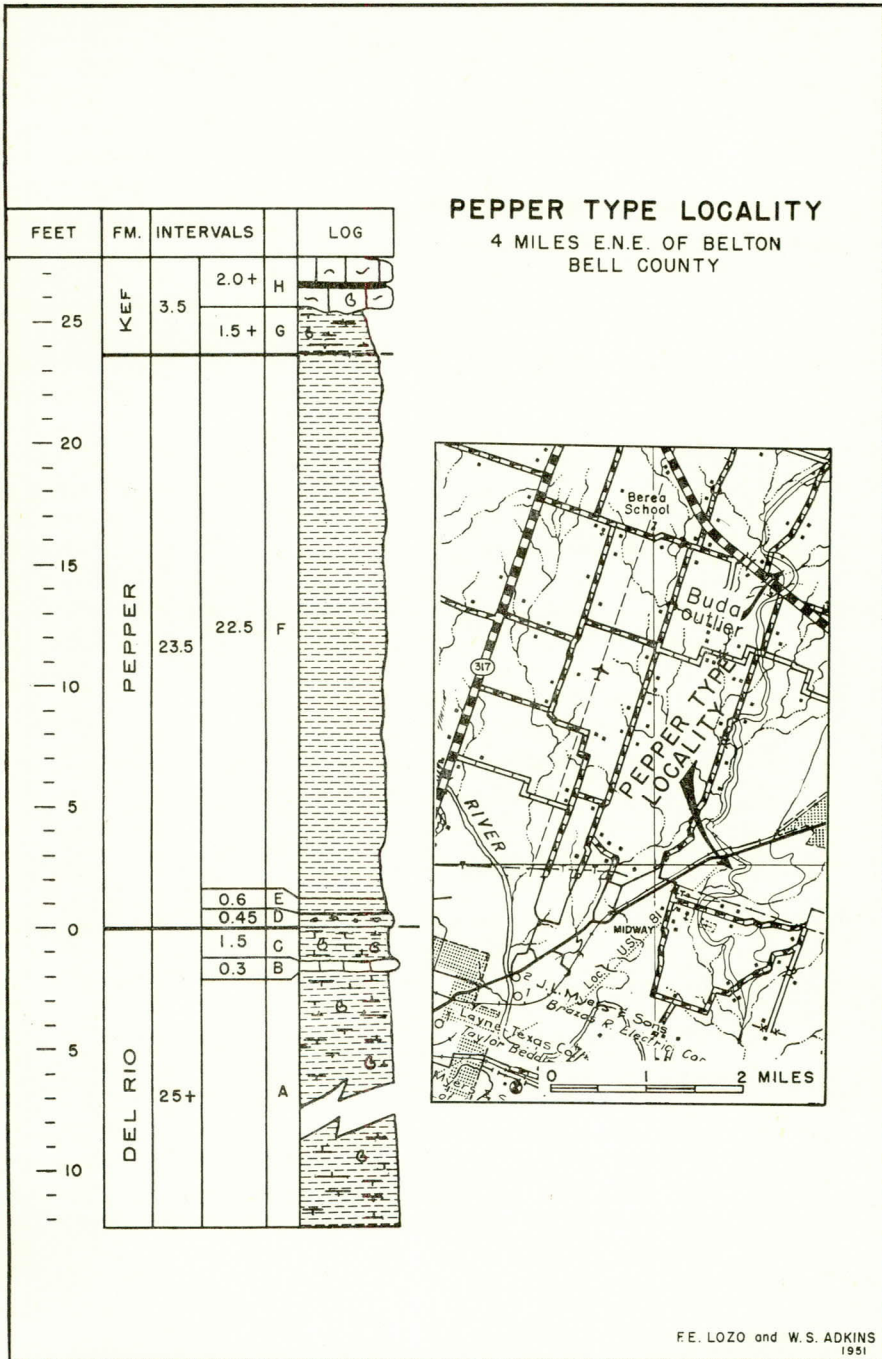


Fig. 13. Graphic section of Pepper shale type locality, Bell County.

This locality, so-called from the church a mile east, consists of exposures in the highway cut and in the adjacent fields. The main highway cut exposes the Eagle Ford-Pepper contact; several years ago the exposed cuts were clean and the contact was sharply visible. Located along State Highway 317, the Belton-McGregor road, the locality is 4 miles south of Moody, or 1.5 miles south of the McLennan County line in Bell County. As determined by use of the hand level and altimeter, the Pepper here is 36 feet thick and is similar in lithology and faunal content to the shale at the type locality 11 miles south. The Buda limestone in typical facies, fossiliferous, white and iron-stained, is but a few inches thick. Blocks of the Buda are visible in the stock tank excavation and in the fields adjacent to the road. A mile north is Adkins' "rolled Buda boulder" locality (1930, p. 52). This is the last known outcrop Buda, excepting the Bosqueville outlier, until the Parker outlier exposure near the Johnson-Hill County line, a distance of about 65 miles. The "rolled boulders" are considered to be pieces of the remnantal eroded "feather-edge" of the Buda, broken up by wave action and incorporated into the basal Pepper shale. From details in the Bell County bulletin cited above, the section at this locality is here inserted:

Willow Grove
Church
Locality
Figs. 8, 14

PEPPER

	Feet
e. Black lustrous, gypsiferous shale, rather purplish-gray when dry; basal feet contains fossils as at the type locality; exposed	5+
d. Reworked zone; irregular nodular stratum, which consists of yellowish and reddish, very gypsiferous, iron-stained clay, with gypsum crystals, iron hydroxides, pebbles (quartz, limestone, phosphate), and many Buda limestone boulders, water-worn and partly disintegrated. Maximum thickness seen.....	0.6

DEL RIO

c. Light gray sandy clay.....	1.0
b. Light yellowish-gray, platy, friable sandstone.....	0.4
a. Typical Del Rio clay, exposed.....	2+

The Eagle Ford flags overlying the Pepper at Willow Grove Church locality represent the Bluebonnet member of the Lake Waco. The locally developed coquinoid or shelly facies so rich in ammonites at Bird Creek and elsewhere is here poorly developed and large ammonites are relatively scarce. Common are inocerami and small ammonites (*Borissiakoceras*), with occasional fragments of *Acanthoceras*, *Eucalycoceras*, and thin, many-ribbed mantellicerids. The measured section is given below:

LAKE WACO (LOWER EAGLE FORD)

Cloice Member

	Feet
e. Shale, yellowish-weathered, calcareous, with thin limestone strata. Poorly exposed on grassy slope.....	30+

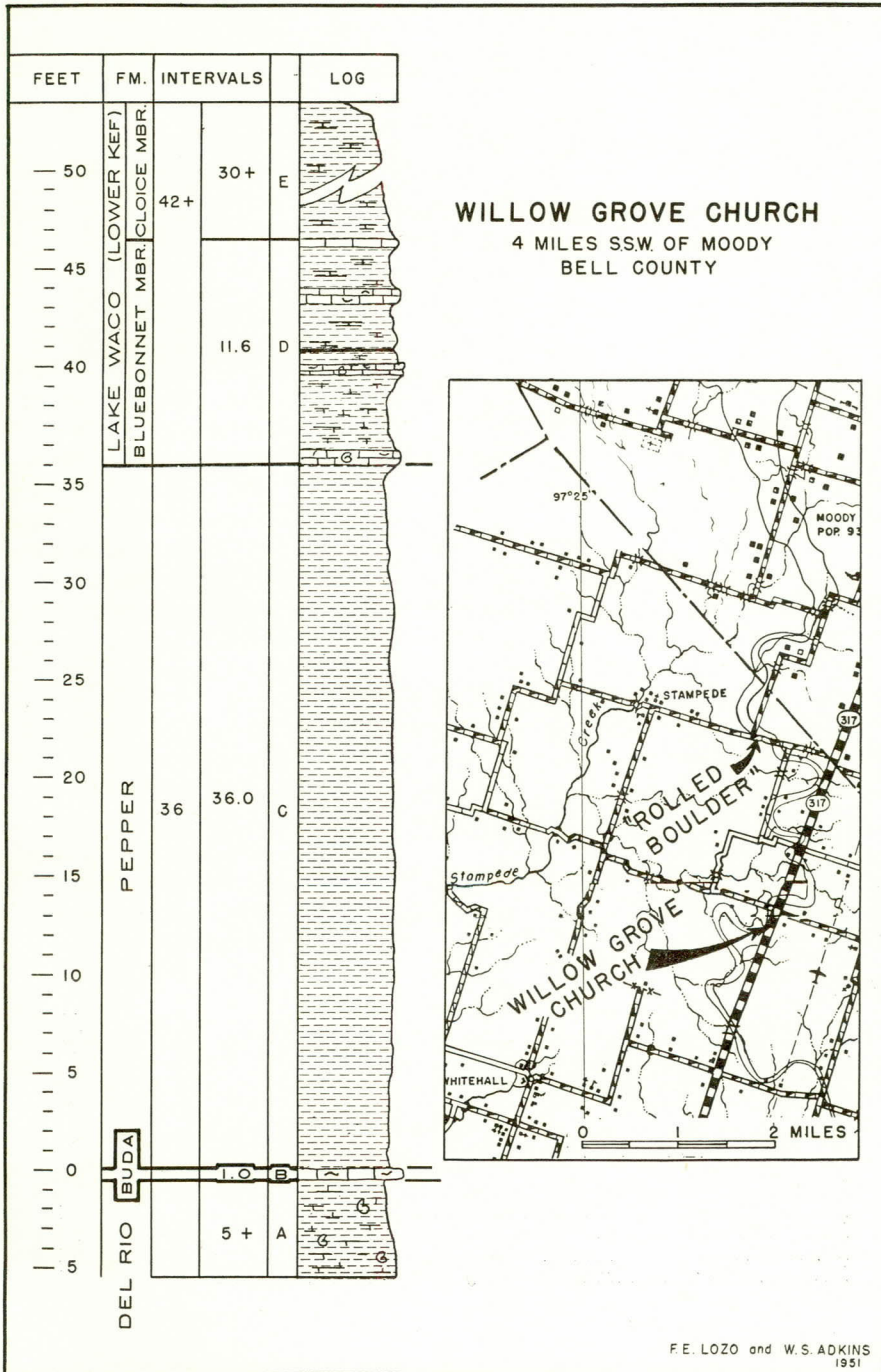


Fig. 14. Graphic section of Willow Grove church locality, Bell County.

Bluebonnet Member

- d. Limestones, ledge-forming, thin-bedded from 0.1 to 1.0 foot thick, with thin bentonite seams interbedded in yellow calcareous shale. Ammonites and inocerami common in the limestones 11.6

PEPPER

- g. Shale, purplish-black, weathered, partially exposed beneath the overlying flaggy limestone. Jarosite and selenite common 36.0

BUDA

- b. Limestone, fossiliferous, white, hard, massive, ferruginous stained. Exposed in the highway shoulder and as blocks in the nearby stock tank excavation..... 1.0

DEL RIO

- a. Clay, gray, fossiliferous, typical of Del Rio in Bell and McLennan counties..... 5+

Haunted Hill is a small ghostly mound at the south end of Moody Hills, about 3 miles northwest of Moody on the Paul Alexander farm. The locality is somewhat contaminated by Eagle Ford and Grayson float plus some boiler clinker or slag from a steam rig that put down a shallow hole many years ago. About 25 feet of Pepper shale is beautifully exposed. The Pepper-Del Rio contact is within 5 feet of the exposure base; an estimated 10 feet of Pepper has been removed since the protecting Eagle Ford limestone cap was destroyed. The locality is an excellent display of many features associated with the Pepper, e.g., abundant and large selenite crystals and jarosite masses in the weathered material, the poor soil-forming character of the shale and consequent sparse vegetation, thin iron-stone concretions of many shapes (flattened, oval, reniform and botryoidal), and here, the local development of shelly limestone lentils with pelecypods and gastropods of Upper Woodbine (Lewisville) aspect. The local variation of the individual thin beds of sandstone, limestone, and ferruginous layers is shown in figure 15. The section described below is the better exposure on the northeast side of the hill, section B of figure 15.

PEPPER

	Feet
Shale, blue-black, lustrous, jarositic and selenitic.....	10+
Siderite concretions, flat, small, oval, red-brown.....	0.1
Shale, blue-black, lustrous, jarositic and selenitic.....	4.0
Siderite concretions as above.....	0.2
Shale, blue-black, as above.....	3.5
Limestone shell breccia, bluish interiorly, weathered yellow-gray, very fossiliferous, discontinuous northwest.....	0.2
Shale, blue-black, as above.....	1.0
Siderite concretions, platy, dark reddish-brown.....	0.1
Shale, blue-black, as above.....	2.0
Sideritic layer	0.1
Shale, as above. Maximum exposed.....	3.1

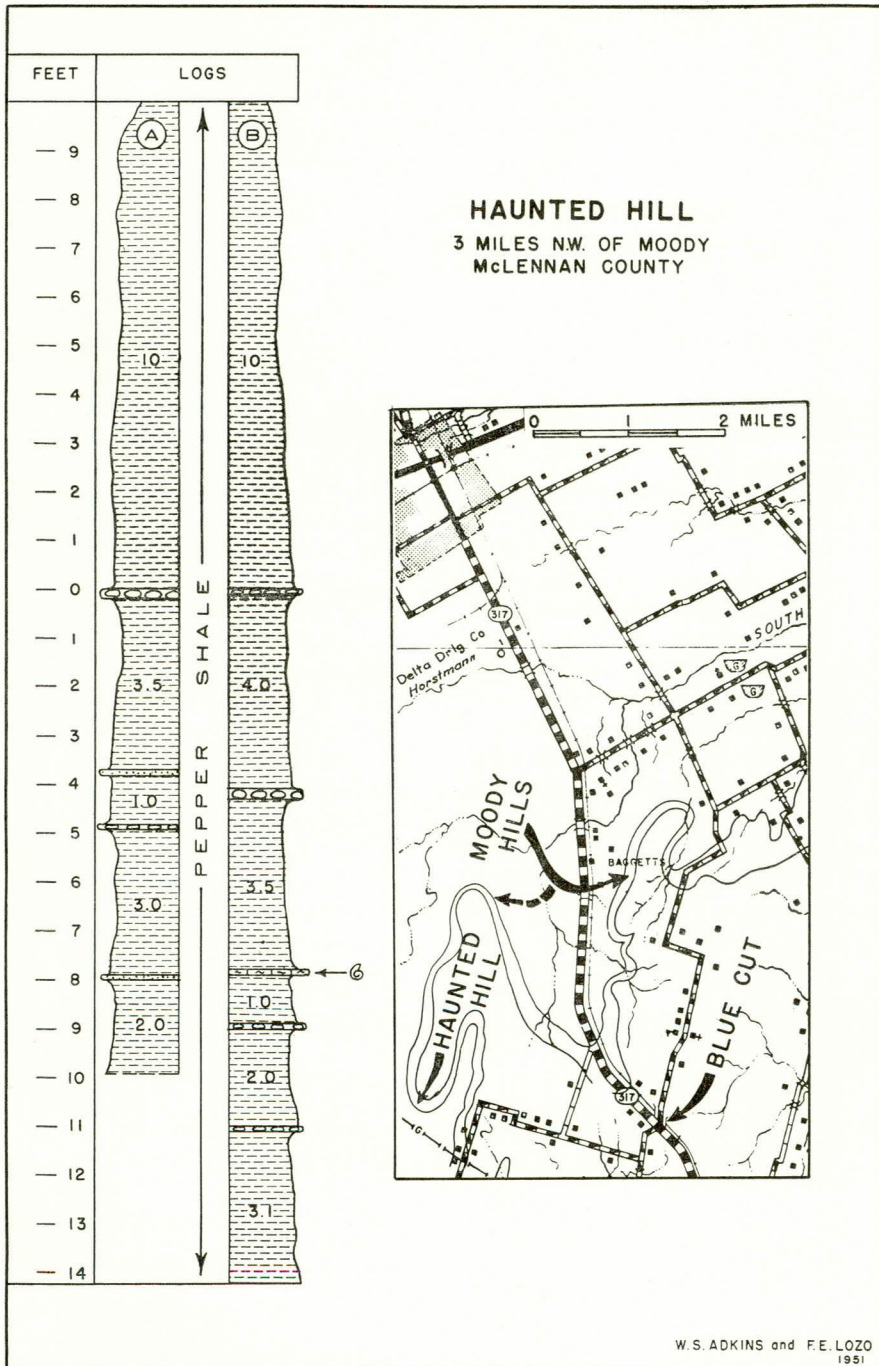


Fig. 15. Graphic section of Haunted Hill locality, McLennan County.

Blue Cut of the Santa Fe railroad, 2.5 miles north from Moody on the Belton-McGregor road (State Highway 317), is an excellent exposure of the section at the boundary between the Upper Eagle Ford South Bosque formation and the Lower Eagle Ford Lake Waco formation. At present, the exact position of the boundary here is indefinite but within an interval of 10 feet. The top-most flaggy limestones exposed contain Upper Turonian fossils ("*Prionotropis*"). The gray silty limestones near the base of the cut contain Upper Cenomanian fossils. On the basis of paleontology alone, the possibility exists that an unconformity representing a considerable amount of the Dallas County Eagle Ford may be present in the interval under question. This locality was detailed by Adkins (in 1924, p. 74) and described when additional section was visible in the lower part. In 1947 the tracks were relocated and elevated a few feet.

Although fossils are relatively difficult to collect, the following have been found: in the platy, sandy limestones of the South Bosque portion are common fish debris and ?*Watinoceras*; in the silty gray limestones of the Lake Waco portion occur

Proplacentoceras sp. *Eucalycoceras* sp.

Allocrioceras pariense *Mantelliceras* sp.

Pseudacompsoceras aff. *vectense*

Inoceramus and other pelecypods, fish remains.

Also reported (Adkins, 1928, p. 258) from this locality is *Scaphites* aff. *aequalis* var. *turonensis* collected by Prof. W. M. Winton.

The description of the Blue Cut section here given was detailed recently by Lozo and Hazzard and their assistants. Since more work needs to be done in this area, no divisions of the members of the Lake Waco formation are given.

SOUTH BOSQUE (UPPER EAGLE FORD)

	Feet
s. Shale, yellowish, weathered.....	1.5
r. Limestone, silty, yellowish-brown, platy and thinly bedded, fossiliferous (" <i>Prionotropis</i> "), with thin shale stratum in middle.....	1.0
q. Shale, yellowish when weathered, blue when fresh, bentonitic in part.....	3.0
p. Shale, blue-black (fresh), irregular lamination, somewhat silty, fish remains.....	1.6

LAKE WACO (LOWER EAGLE FORD)

o. Limestone, light gray, silty, thin-bedded, with abundant oyster and inocerami fragments.....	0.2
n. Shale, as in unit p.....	3.3
m. Very silty shale, gray, forms faint ledge.....	0.3
l. Shale, gray-black with brown-stained areas.....	2.4
k. Bentonite, creamy yellow.....	0.4
j. Shale, gray, with stained bentonitic streaks.....	0.4
i. Limestone, double ledge, silty, blocky, with gray silty shale break in middle.....	0.7
h. Shale, gray, silty, with thin limestone layer and interbedded bentonitic seams.....	1.25
g. Limestone, gray, silty, blocky, forms ledge.....	0.65
f. Shale, black, very silty, pelecypod casts. This unit was top of Lower Eagle Ford shale of Adkins (1924).....	1.5

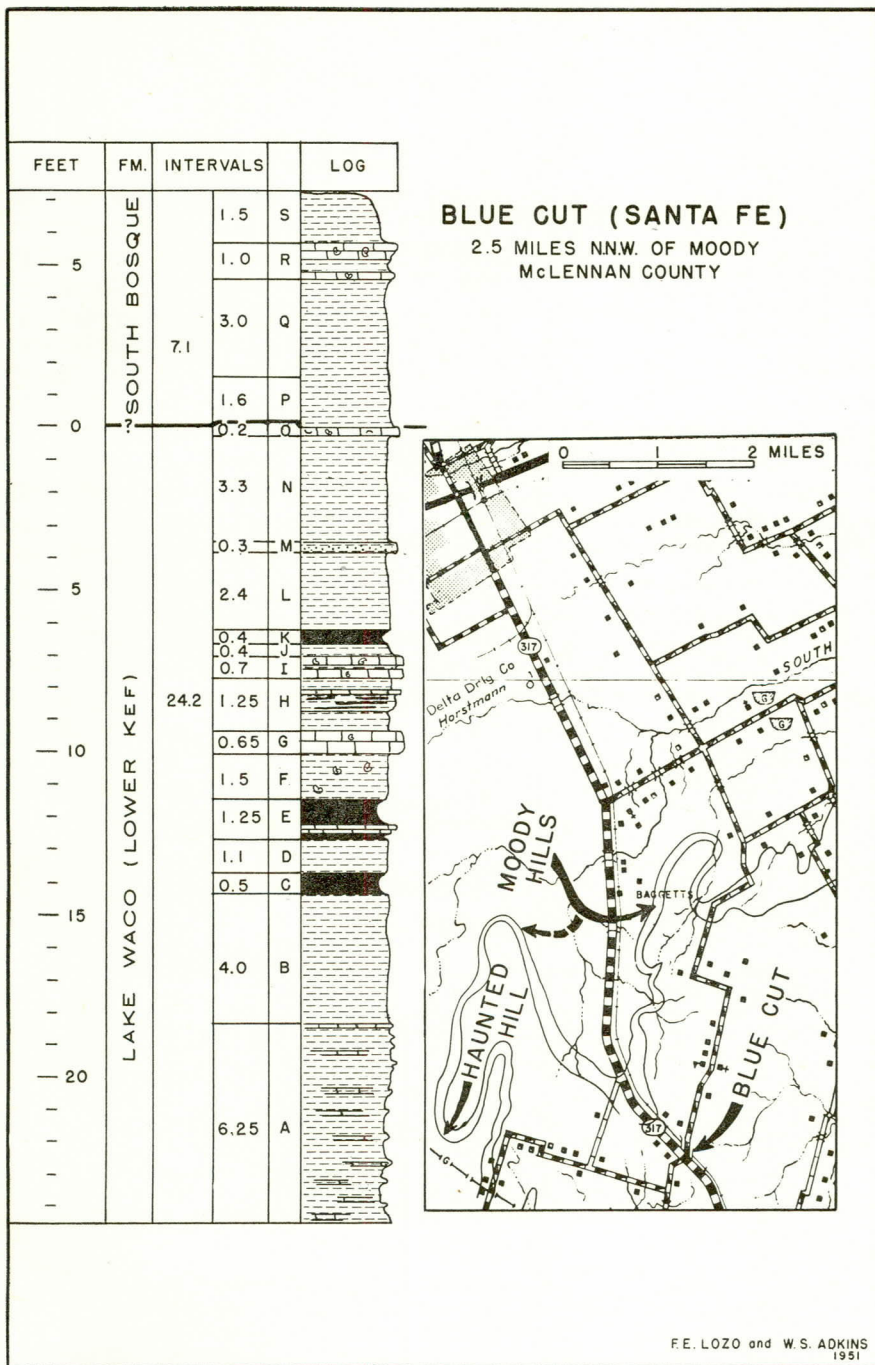


Fig. 16. Graphic section of Blue Cut of Santa Fe R.R., McLennan County.

e.	Bentonite, creamy-yellow, with a thin ledge-forming silty limestone layer near the middle.....	1.25
d.	Shale, blue. Upper part was base of exposure after 1947. Details of lower section were observed prior to track relocation....	1.1
c.	Bentonite	0.5
b.	Shale, blue	4.0
a.	Limestones, thin, flaggy, silty, and thin shale layers.....	6.2

The Del Rio-Pepper-Lake Waco (Eagle Ford) sections exposed west and east of the highway 4.5 miles south of McGregor provide close control between similar sections near South Bosque to the east and Bell County localities to the south. The basal Eagle Ford limestone flags are well exposed and the name Bluebonnet member is here applied to these limestones. The western Moody Hills, now part of the Bluebonnet Farm Agricultural Experiment Station, A & M College of Texas, were within the reservation of the vast Bluebonnet Ordnance Plant during the war. Somewhat cleaner exposures of the same section are exposed on the western slope of the eastern Moody Hills opposite Baggetts station on the railroad. The section presented in figure 17 was detailed here and may be considered the type section within the area. The locality includes the exposure given as Locality 966 in Adkins' McLennan County bulletin (1924, p. 57). Many pyritic replacement fossils have been collected here from the Del Rio clay. The two exposures which comprise the type locality are on the property of Ernest Weiss of McGregor; entrance from the highway is by way of a cattle underpass opposite the exposures.

The Moody Hills section, as detailed by the writers some years ago is as follows:

LAKE WACO (LOWER EAGLE FORD)

Cloice member

f.	Shale, yellow, grass-covered.....	6+
e.	Limestone, white, silty, blocky fracture (resembles ledges in lower section at Blue Cut).....	0.4
d.	Shale, yellow-weathered, with scattered thin (0.1 ft. ±) limestone flag layers, bentonite seams, and calcite veins from minor (slump?) faulting	35.0

Bluebonnet member

c.	Limestone, wavy bedded, with ledges varying in thickness from a foot or more at the base to 0.5 foot or less near the top. This section is essentially the same in lithology and faunal content from Cloice Branch to the east to beyond Willow Grove Church locality to the south in Bell County.....	11.5
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PEPPER

b.	Shale, purplish-black, lustrous, with selenite crystals, jarosite, and some ferruginous concretions. At the southern exposure, the basal 0.2 foot is composed of a red, iron-stained oyster breccia	45.0
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DEL RIO

a.	Clay, calcareous, light gray, with abundant pyrite fossils and larger Del Rio pelecypods.....	10+
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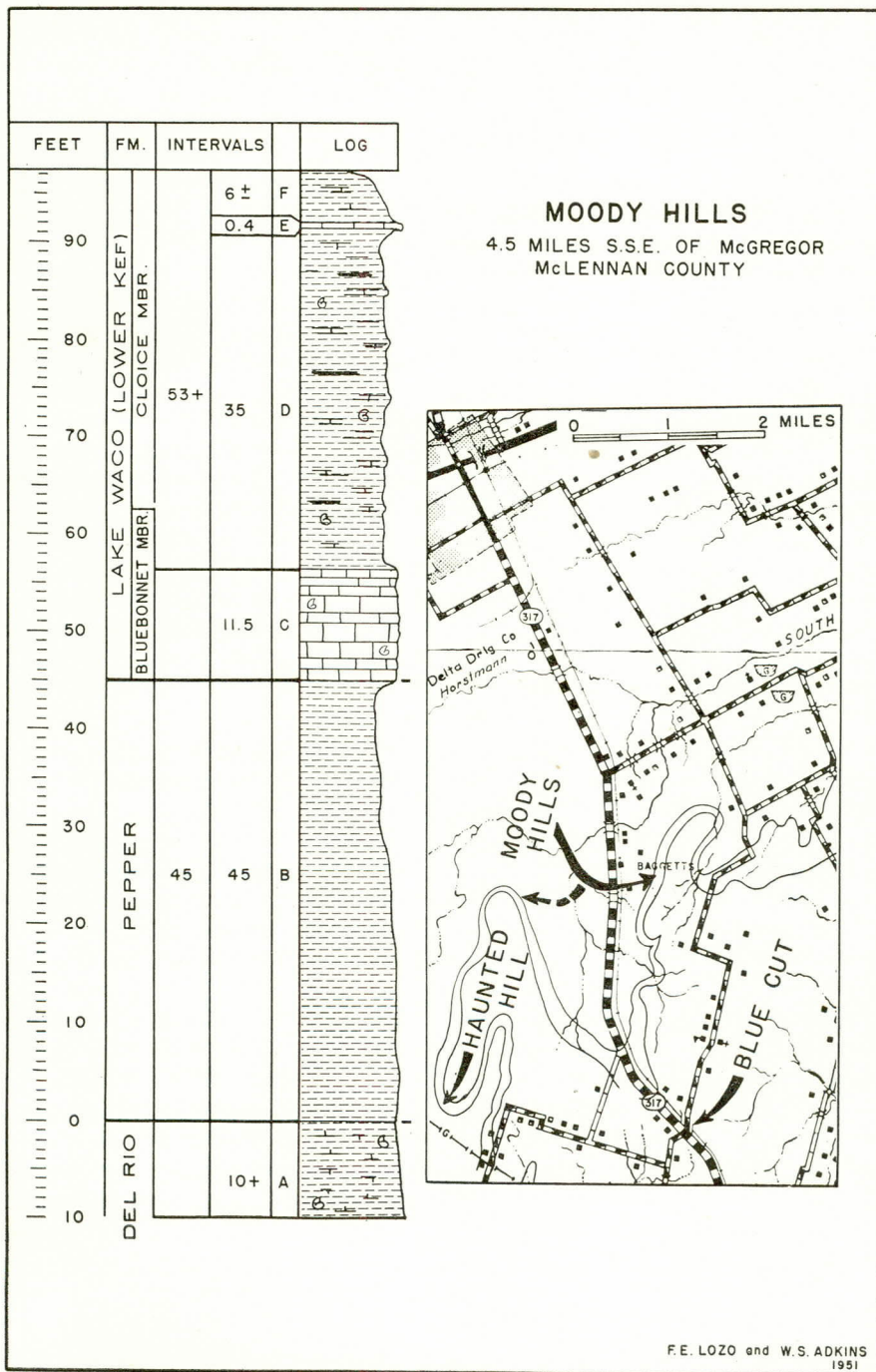


Fig. 17. Graphic section of Moody Hills locality, McLennan County.

Cloice Branch is a small northeastward flowing tributary of the South Bosque River, which heads in the vicinity of the cement plant east of South Bosque. The section here described is aggregated from the following exposures: Pepper and basal Eagle Ford limestones (Bluebonnet member of the Lake Waco) at the old South Bosque brickyard pit, adjacent to the Hanna property, 0.5 mile east of South Bosque (cf. Adkins, 1924, p. 73); upper Bluebonnet limestones and lower Cloice shale, along Cloice Branch on the "Mystery Acres" property; middle and upper Cloice, upper Lake Waco limestone (Bouldin member), and lower South Bosque shale on the J. E. Padgett property along Cloice Branch; and the upper 75 feet of the South Bosque shale in the shale of the Universal Atlas Cement Plant about one mile east of South Bosque station. With the exception of about 5 feet in the Cloice shale and 25 feet in the lower portion of the South Bosque, the total Eagle Ford section can be examined in detail. This is the type section of the Lake Waco formation (name derived from Lake Waco to the north) and the middle (Cloice) member of the Lake Waco. As J. K. Prather's South Bosque marl (1902) was named from nearby exposures, the total section may be taken as the type for the outcrop Eagle Ford in McLennan County. For subsurface purposes, the electric log of the J. L. Myers and Sons, Midway Independent School water well No. 1, 2 miles northeast of the cement plant, may be considered typical (see Fig. 27, section "A", well 6).

During the field investigations of the Lake Waco formation, three additional sections were detailed in the ravines below the Austin chalk scarp north of the McGregor-Waco highway (US 84) between the oil field road and the Fish Pond road. It was soon apparent that individual limestone and bentonite layers and the associated shale beds varied locally in thickness and somewhat in character. Since no purpose would be served by a minute and precise description of these individual strata, the Cloice Branch section, though accurately plotted, is recapitulated below in gross units. It is pertinent to add that the bentonites appear more common and generally thicker when associated with the silty gray limestones; the shale in the lower Eagle Ford is more silty than that of the upper Eagle Ford; the units are sufficiently persistent over McLennan County to form recognizable topographic features such as benches, slopes, and waterfalls; and the paleontologic data which assist in controlling the proper stratigraphic relations are the result of intensive and careful stratal collecting. Without the latter, the stratigraphy would certainly be less secure.

SOUTH BOSQUE (UPPER EAGLE FORD)

- g. Black glistening shale, locally with thin platy limestone layers. The upper 75 feet is completely exposed in the cement plant shale pit. *Inoceramus*, large *Prionotropis*, and *Proplacenticer* were collected at level of pit base. Lower 50 feet

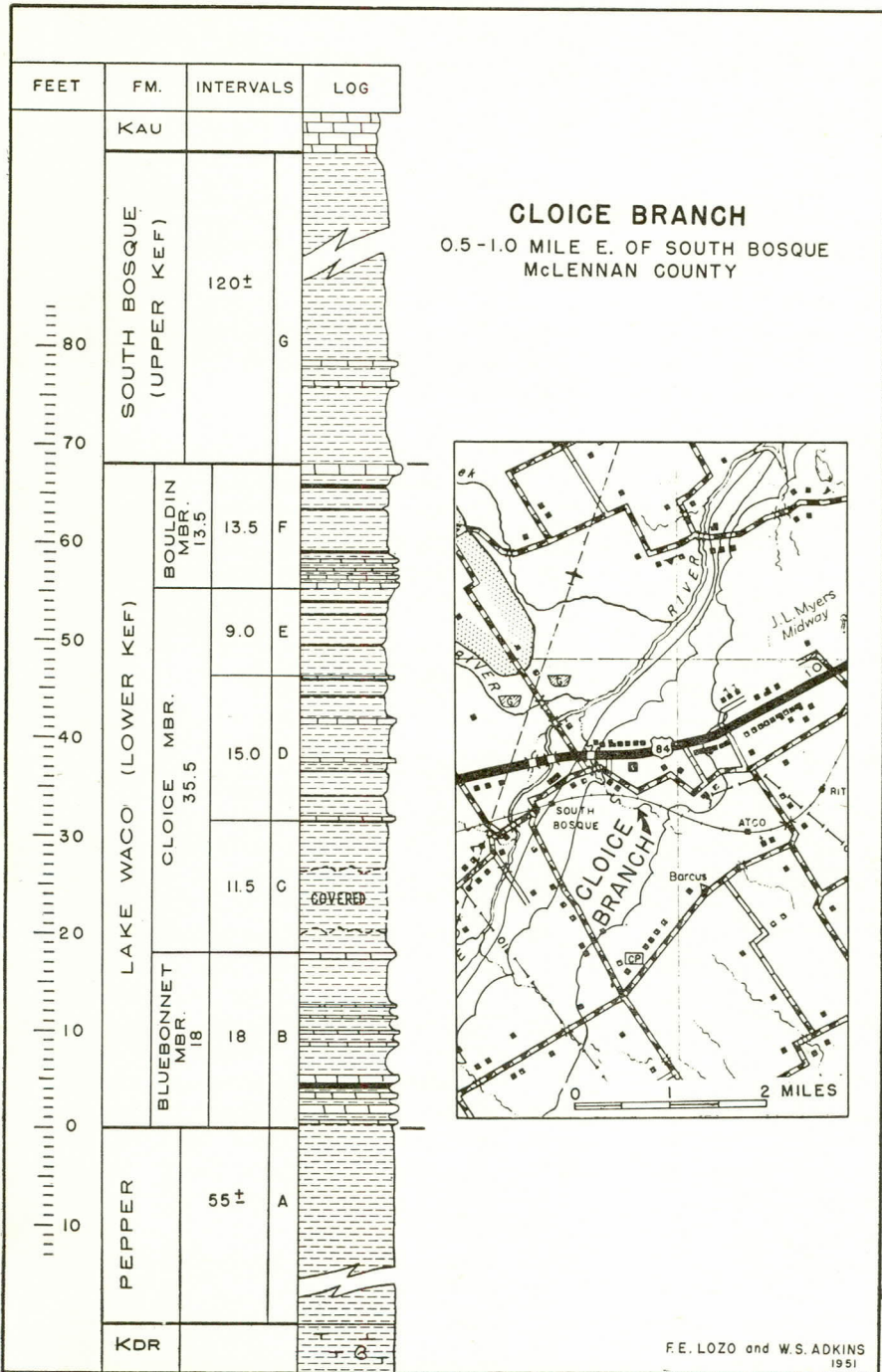


Fig. 18. Graphic section of Cloice Branch locality, near South Bosque, McLennan County.

	Feet
contains more platy limestones. From ant hills, small pyrite fossils (" <i>Prionotropis</i> ", non-ribbed discoid ammonites, and other molluscs) were obtained. Total interval by hand level.....	120±
LAKE WACO (LOWER EAGLE FORD)	
Bouldin member	
f. Black shale, silty, and interbedded limestones. The top 1 foot of gray silty limestone forms a waterfall. In the basal 4 feet are alternating thin limestones and shales. The shales are bentonitic. The limestones contain <i>Inoceramus</i> , <i>Eucalycoceras</i> , <i>Metoicoceras</i> , and mantelliceratidae.....	13.5
Cloice member	
e.-c. Principally black shale with thin bentonite layers throughout and a few thin gray silty limestone layers in the middle portion (unit d). Molluscs similar to those above and below present but generally scarce.....	35.5
Bluebonnet member	
b. Gray silty limestones interbedded with shale and creamy yellow bentonite beds. The basal limestones are characteristically wavy bedded and locally rich in oysters and ammonites. In the basal few inches above the Pepper shale, phosphate "pebbles" are often common. The thicker basal ledges form water-falls. Contact zone is often reddish-brown bed 0.5 to 1.0 inch thick with leached pelecypod shells, shark teeth, gypsum, and phosphatic pellets	18.0
PEPPER	
a. Shale, purplish-black, jarositic, flaky weathering, less firm and consolidated than the overlying grayer shales of the Eagle Ford. No observable fossils. Arenaceous Foraminifera common	55±

DEL RIO

Typical fossiliferous gray calcareous clay with thin sandy streaks. Exposed nearby.

The "Bosqueville rock," so referred to by Adkins (1924) and carefully mapped in the Bosqueville area, was noted by Pace (1921) and called Buda. Her map indicates that she considered the "Buda" continuous westward and consequently had it confused with basal Eagle Ford limestone in the Moody area. The section exposed at the Keas Branch at Bosqueville (Figs. 10, 19) small concrete bridge at Keas Branch was reexamined by the writers in 1945 and the data obtained are presented in figure 19 and in the description below. It may be noted that this outcrop is a portion of a demonstrable outlier west of the truncated subsurface edge of the Buda (Fig. 22). The Woodbine portion contains oysters common in the Lewisville Woodbine farther north.

PLEISTOCENE

WOODBINE

	Feet
j. Sand, yellowish-brown, fine-grained; shark teeth, fish remains, and reworked echinoid plates.....	1.0
i. Sandstone, calcareous and ferruginous; <i>Ostrea soleniscus</i> and <i>Ostrea ?carica</i>	0.5
h. Clay, gray, sandy and calcareous, discontinuous; <i>Flabellamina denisonensis</i> (?reworked?).....	0.3

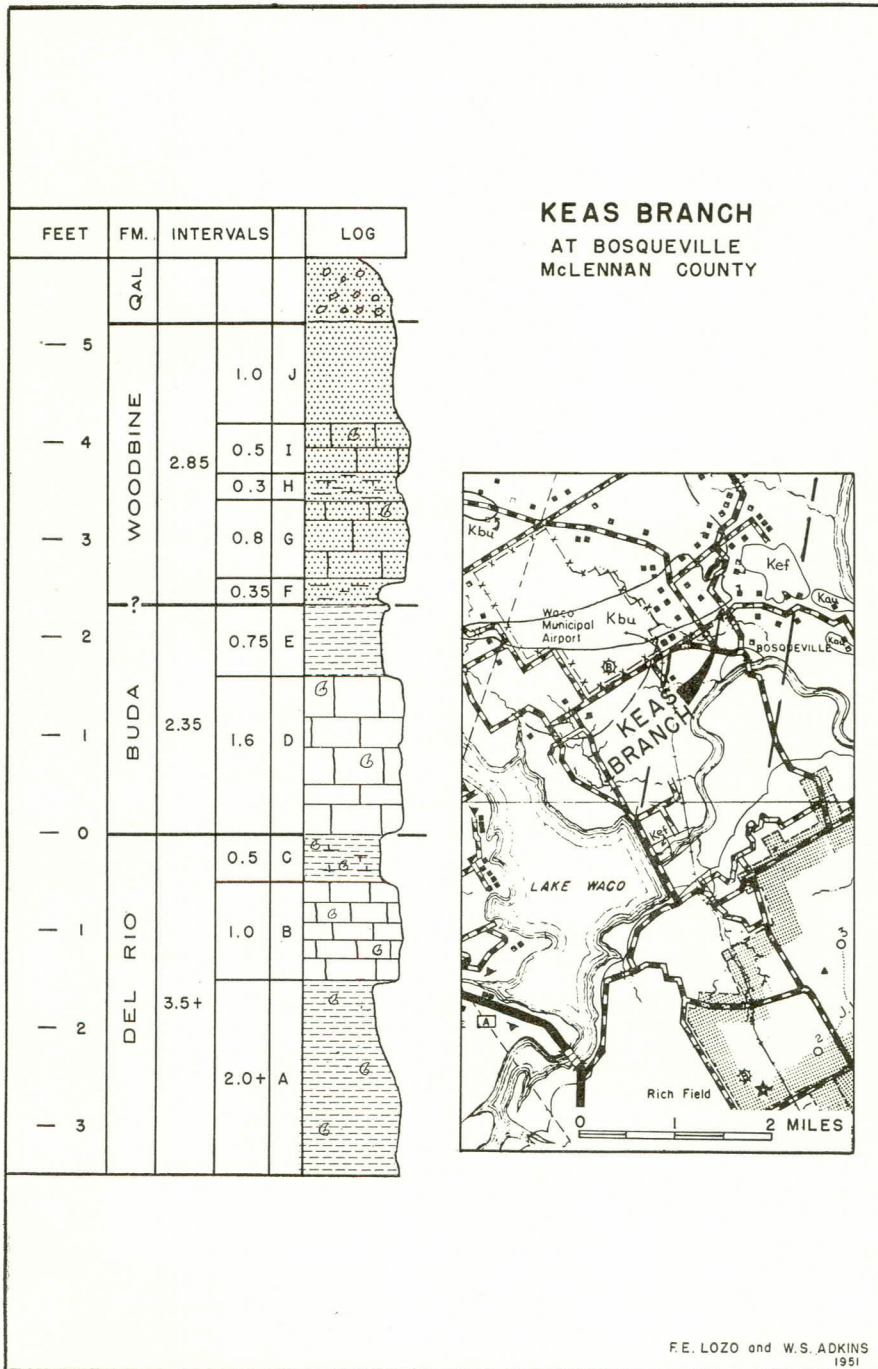


Fig. 19. Graphic section of "Bosqueville Rock," Keas Branch section, near Bosqueville, McLennan County.

- g. Sandstone, blue, very hard, fucoidal and ripple-marked: *Ostrea soleniscus* in upper part..... 0.8
- f. Reworked zone ?: greenish-gray sandy clay with abundant *Flabellamina denisonensis*, rare *Ammobaculites* sp..... 0.25

BUDA

- e. Detrital zone (Buda ?): gray clay with reworked fragments of red-stained Buda limestone; *Flabellamina denisonensis*, *Marginulina* n. sp., *Lenticulina washitensis*, and *Cythereis triplicata* 0.75
- d. Limestone, gray, massive, in part nodular, ferruginous blotches; pelecypod molds, *Exogyra whitneyi?*, *Pecten roemeri* 2.35

DEL RIO

- c. Marl, blue, fossiliferous. Contains gryphaeas, pectens, and echinoids common to the Del Rio..... 0.5
- b. Limestone, white, chalky. Fossils as above with pectens abundant 1.0
- a. Clay, gray, calcareous, Del Rio fossils..... 2+

A full section of Woodbine and portions of the adjacent formations are exposed in the Rogers Hill-Elm Creek area 2 to 3 miles southwest of Wiggins, McLennan County. This is within the area of sandstone dikes reported by Monroe elsewhere in this series of papers. Well shown is the development of thin fossiliferous sandstones of Lewisville Woodbine aspect within the main body of Pepper-type shale. The section displays in excellent fashion the transition between Lewisville-facies Woodbine to the north and Pepper-facies Woodbine south of the Brazos River. The sharp upper limit of the dikes (no dike debris or float has been found above the basal Eagle Ford) is interpreted as evidence that the sand source beds for the dikes were eroded prior to Eagle Ford deposition, and thus supports the statement that the Woodbine-Eagle Ford contact in this area is unconformable.

**Rogers Hill-
Elm Creek
Locality**

Figs. 11, 20

The section displays in excellent fashion the transition between Lewisville-facies Woodbine to the north and Pepper-facies Woodbine south of the Brazos River. The sharp upper limit of the dikes (no dike debris or float has been found above the basal Eagle Ford) is interpreted as evidence that the sand source beds for the dikes were eroded prior to Eagle Ford deposition, and thus supports the statement that the Woodbine-Eagle Ford contact in this area is unconformable.

EAGLE FORD (as exposed 2.3 miles southeast of Rogers Hill)

- i. Alternating flaggy limestones, weathered grayish brown, and yellow calcareous shale. The basal ledge of wavy bedded limestone contains oysters, inocerami, *Acanthoceras*, *Borissiakoceras*, and *Eucalycoceras*..... 20+

WOODBINE

- h. Shale, dark gray, slightly sandy..... 5.5
- g. Sandstone, light gray, friable, with a middle stratum of gray jarositic shale; pelecypod casts..... 1.6
- f. Shale, Pepper-type, partly concealed..... 22.8
Note: large sandstone dikes are present in the upper portion of this shale unit.
- e. Pepper-type shale with local thin ferruginous concretion layers and thin light gray friable sandstone beds with ammonites and other molluscs..... 16.0
- d. Shale, Pepper-type, partly concealed..... 27.5
- c. Thin sandstones, friable to quartzitic, with conglomeratic pebbles and phosphates at base..... 2.4
- b. Shale, Pepper-type..... 14.2

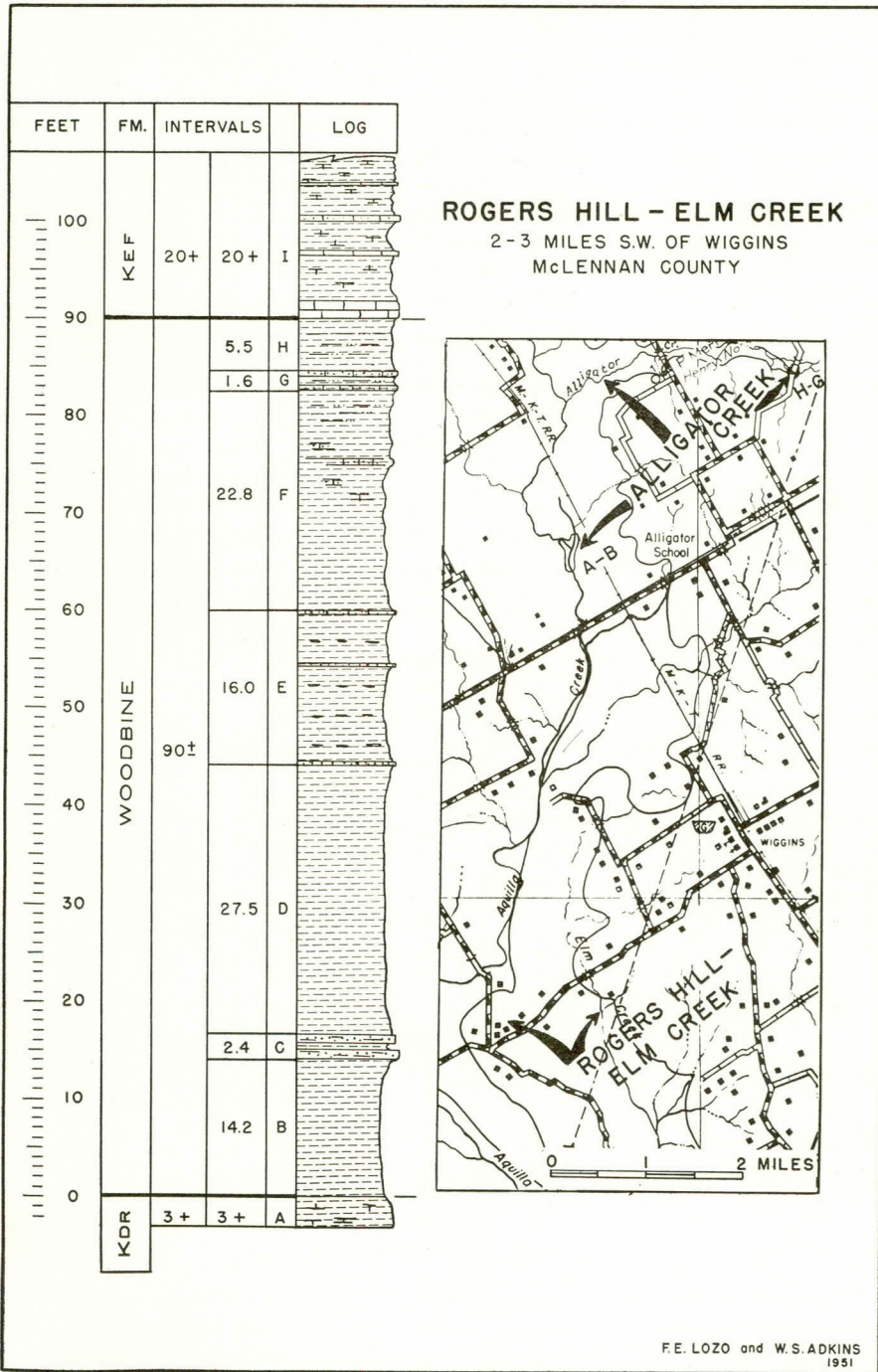


Fig. 20. Graphic section of Rogers Hill-Elm Creek locality, southwest of Wiggins, McLennan County.

DEL RIO

- a. Clay, gray, calcareous, with whitish-gray chalky nodular limestone 3+

The bluff and amphitheater-like exposure along Alligator Creek on the Nors property exposes the key section of the Woodbine in southwestern Hill County. With the exception of the basal 10 feet (below creek level) and the upper 10 feet (concealed by overwash), the total Woodbine section of 112 feet is magnificently displayed. The thin sandstones in the main body of Pepper-type shale have increased in number and thickness northward from the Wiggins area and additional sands in the uppermost part have entered the section. These latter sands presumably filled the fissures resulting in the dikes of the Rogers Hill-Elm Creek area. Details of the basal Eagle Ford limestones and the uppermost Woodbine are from the saturated oil sand exposure at the concrete dip over Alligator Creek about 2 miles upstream. The basal section in contact with the underlying Del Rio is no longer visible at the Del Rio inlier on Aquilla Creek, a mile upstream from the county line road; the section details are from Adkins' McLennan County bulletin (1924, pp. 53, 54).

Alligator
Creek
Locality
Figs. 11, 21

EAGLE FORD

- h. Limestone, grayish-brown, thin- and wavy-bedded with interbedded gray calcareous shale. Oyster fragments abundant..... Feet
2+

WOODBINE

- g. Sandstone, oil saturated, thin, friable, with abundant mollusc molds (cavities) interbedded with blue-gray sandy jarositic shale immediately below the contact; below this section are large concretionary sandstones several feet thick, fucoidal in part, imbedded in friable sandstone and sandy shale..... 10.0
- f. Interbedded friable and platy white to gray thin sandstones and gray sandy shale (partly concealed)..... 17.0
- e. Black Pepper-type shale with a few thin sandstone beds: small pyritic ammonites..... 28.5
- d. Black Pepper-type shale with ferruginous nodule layers and thin friable white sandstones at the top and bottom..... 13.5
- c. Black Pepper-type shale similar to unit e..... 16.0
- b. Black Pepper-type shale with common ferruginous nodules and thin fossiliferous sandstones at base..... 17.0

DEL RIO

- a. Gray, plastic, calcareous shale with chalky and argillaceous nodular limestone. Del Rio fossils..... 7+

NEAR-OUTCROP SUBSURFACE DATA

The subsurface data summarized on the isopach maps and stratigraphic sections are the result of many measured outcrop sections; data obtained verbally from numerous local water-well drillers and other individuals; drillers' logs; sample logs; and, more recently, electric logs of a few oil tests and many water well borings, from

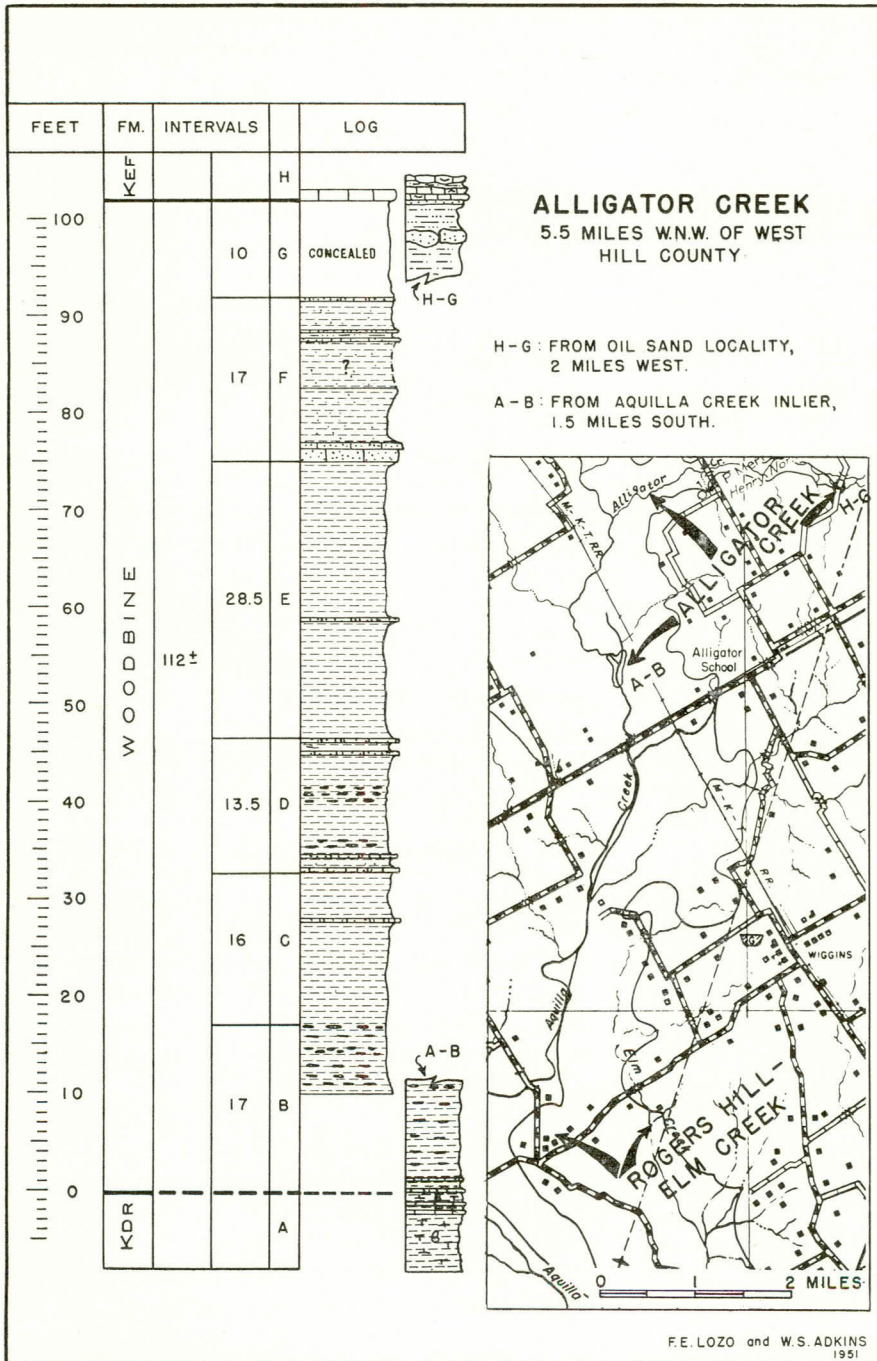


Fig. 21. Graphic section of Alligator Creek locality southeast of Aquilla, southern Hill County.

some of which cuttings were available. The isopach maps are generalized slightly in order to avoid contour irregularities caused by the choice of interval.

ISOPACH RELATIONS

Figure 22 shows the isopach contours of the Buda limestone and the truncated updip (westward) limit. The Buda-Del Rio contact is conformable and believed to be the same stratal datum. The upper contact of the Buda is an erosional surface. The downdip thickening thus is in part by addition of beds at the top plus some proportional thickening in the lower portion.

Figure 23 portrays the isopach relations of the Pepper shale, south of the Brazos, and the undifferentiated Woodbine sand and shale to the north. Both contacts are unconformable. The contour interval change from 25 feet to 5 feet southward from Temple should be noted. No statement is at present justified as to rate (feet per mile) of overstep in the basal portion or the rate of truncation at the top. It may be clearly inferred, however, that the McLennan-Falls-Bell County area was topographically elevated prior to, during (?), and after Woodbine deposition.

Figure 24 indicates some slight changes in isopach pattern of Eagle Ford deposition from that of the Woodbine. The contact of the Woodbine (or Pepper) and Eagle Ford is locally demonstrably unconformable and probably so some distance downdip. Southwestward thinning is in part proportional, principally near the top, and in part by overstep at the base.

STRATIGRAPHIC SECTIONS

Figure 25 presents two near-outcrop stratigraphic sections (for lines of sections see Fig. 22): section "A" (datum, top of the Georgetown limestone) is adjacent to the outcrop; section "B" (datum, base of the Austin chalk) is 20 to 30 miles downdip. The formations and contacts indicated have been tied-in to nearby outcrop sections and are considered secure and accurate for the area covered. Sample information was utilized when available.

Subdivisions of the Washita and Fredericksburg shown are the result of many similar stratigraphic sections over the East Texas Embayment prepared by Lozo. The lithic (formation) units indicated have been tied-in to the type localities (and subsidiary outcrop sections) and correlated by matching and near-tracing from one area to another. Divisions of the Fredericksburg were published in the Shreveport Geological Society's 1949 field trip guidebook on the Austin, Texas, Cretaceous area (pp. 85-91 and Figs. 1-5). Changes of identification within the subsurface Washita now in common practice were noted in the junior author's preceding paper (this publication) on the Maness shale.

THE WOODBINE AND ADJACENT STRATA

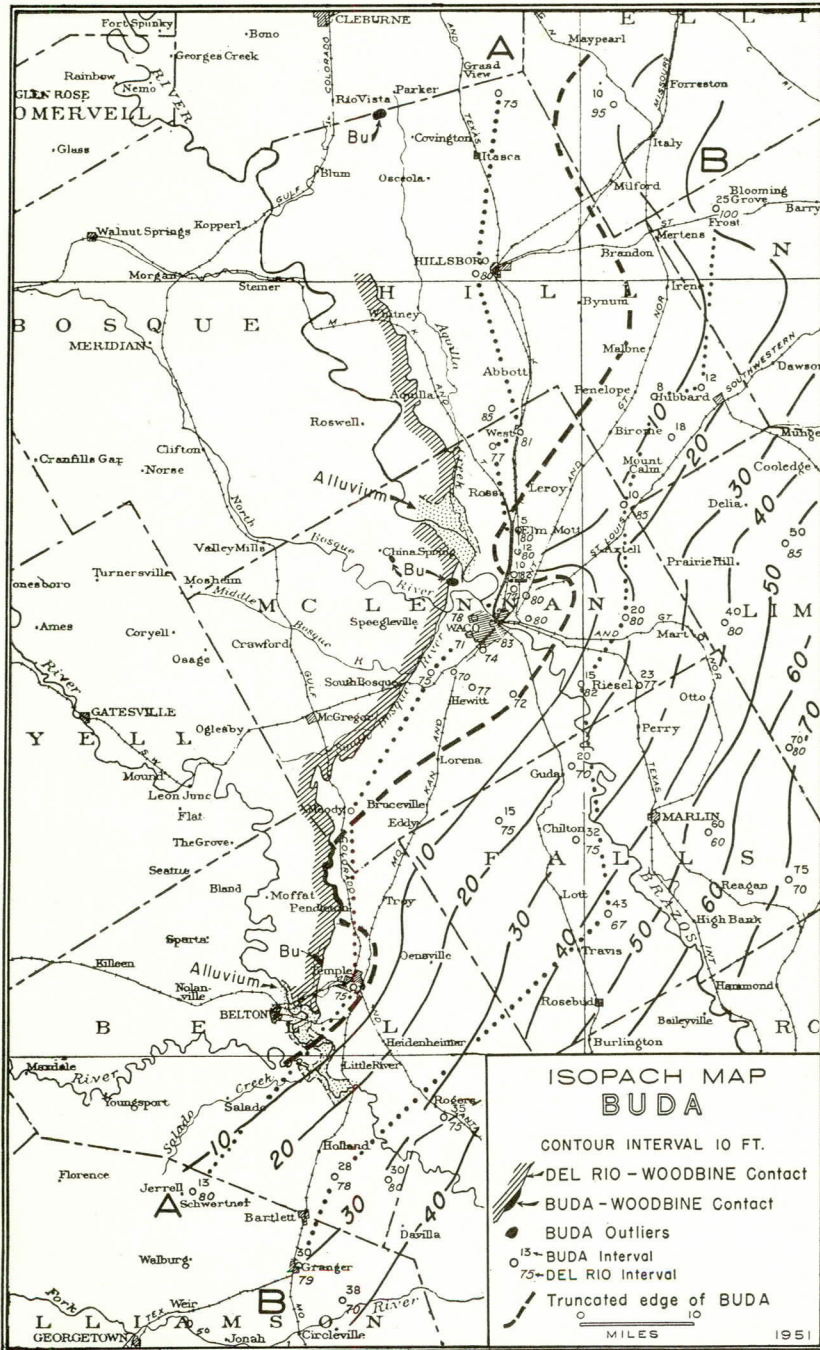


Fig. 22. Isopach map of Buda limestone, Waco area (with Del Rio intervals).

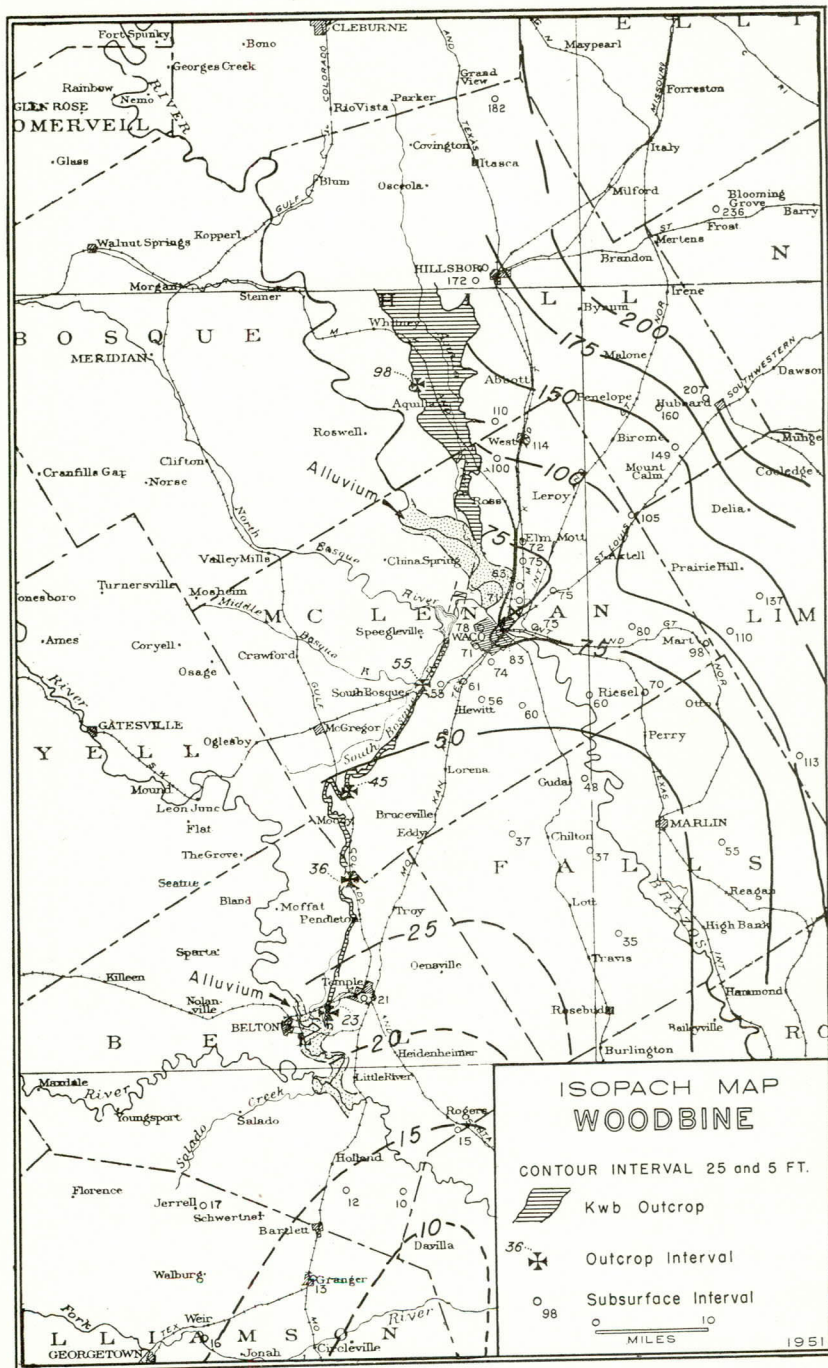


Fig. 23. Isopach map of Woodbine sand and Pepper shale.

PALEONTOLOGY

RELATION OF LITHIC AND ZONAL UNITS

Across the counties discussed, every outcrop known has been studied and carefully measured, elevations taken, and the tops (or bottoms) of the lithic units determined if possible. Such close outcrop matching produced a basic stratigraphic grid, which can be then used for further stratal or zonal studies. All zonation is superimposed upon this stratal grid. Thus in effect lithofacies work is done independently of zonal work.

A revised zonation of the Woodbine and Eagle Ford groups is here presented. Like all zonations, it is subject to improvement. The best zonation of the Woodbine is based on ammonites. Since the Woodbine covers only the equivalents of about two western European Cenomanian zones (*Pseudacompsoceras vectense* and *Mantelliceras costatum*), Woodbine zonation is obviously difficult. The best starting point for zoning the Eagle Ford is to separate its lower (Cenomanian) portion from its upper (Turonian) portion. We have accomplished this over the entire Texas outcrop; the part pertinent to this area is here presented. It is believed that along the outcrop strike, the stratal matching and the zonal matching are nearly parallel; hence it is hoped that more reliable stratal conclusions than were formerly possible may be reached concerning the boundaries of lithic units.

UPPER WASHITA ZONATION

Upper Georgetown. From North Texas to South Texas across the outcrop area here discussed, the Main Street limestone (uppermost member of the Georgetown formation) is stratally and zonally continuous, so far as is now known. This apparent continuity extends down-dip into the East Texas Embayment, but with thickening of the stratal units. The Main Street limestone contains divers invertebrate fossils; some common ones are *Kingena wacoensis*, *Pecten* (various species), *Ptychomya ragsdalei*, *Exogyra arietina*, *Gryphaea* spp., *Alectryonia quadriplicata* (highest), and the ammonites *Turrilites brazoensis*, *Stoliczkaia* spp., *Mantelliceras* spp., *Submantelliceras* spp., *Pervinquiera* spp. (highest); and nautili (*Cymatoceras* spp.)

Transition zone (Adkins, 1933, p. 387): About 5 feet of basal Del Rio consists of alternating whitish thin strata of soft, partly nodular limestones and very limy marls, with a distinctive fossil assemblage. It contains a new genus of the family Mantelliceratidae, *Stoliczkaia* spp., *Submantelliceras* spp., *Turrilites brazoensis*, *Kingena wacoensis*, *Gryphaea* spp., *Exogyra* spp., *Pecten*, nautili, etc. Aside from extensive lithic matching of localities, this fossil assemblage has been found widely in central Texas. We have nowhere (except at Cedar Mills, NW Grayson County) detected any unconformity at the top of the Main Street.

Del Rio: In the outcrop strike area under discussion, the Del Rio behaves evenly. In the area no unconformity is apparent at its base or at its top, and locally its down-dip thickening appears to be that of proportionality. An overall treatment of the equivalence of Grayson and Del Rio would take us far outside the present area. It may be convenient to retain the name "Grayson" for the formation north of Hill County characterized by high lime content and prominent white chalky nodular limestone members especially in its upper part; and in Hill County and farther south and west retain the name "Del Rio" for the formation characterized by less limy content, less limestone seams, and more sand and platy seams of fine sandstone or siltstone, which contain abundant *Haplostiche texana*, many of them oriented by current action.

Buda: In this area south of a point east of Salado, the outcrop Buda is a continuous body of indurated, locally porous, coquinoid or organic, ferruginous-stained limestone, about 5 feet thick, which forms a narrow hillside bench between the Del Rio and Pepper shales, and which slumps extensively. North of Salado, the Buda outcrops are intermittent, and have the same lithology. Buda here is marked by *Pecten roemeri*, *Gryphaea*, *Ptychomya ragsdalei*, *Exogyra* aff. *whitneyi*, *Exogyra* n. sp. aff. *texana*, *Protocardia*, *Isocardia*, and frequent *Trigonia*; *Budaiceras*, common both north and south of the area, has not yet been found. It is improbable that this small Buda thickness represents the entire Buda, but what unconformity relations exist in the area is still unknown; there is essentially no evidence for any ravining at the top of the Del Rio here; this fact, together with the Buda "rolled boulder" locality, may indicate post-Buda submarine erosion.

Maness: A subsurface formation which overlies the Buda, but which faunally seems very similar to the Buda.

South Tyler: a subsurface formation which may bridge the interval between Buda and Woodbine, according to how defined. These stratigraphic relations are still under study.

UPPER COMANCHEAN STRATIGRAPHY

(Brief Summary)

Lithic Unit (Formation)	Zonation
MANESS (subsurface only)	Only in cores, not enough ammonites known to assign zonal fossils. <i>Budaiceras</i> has been identified. Other megafossils suggest very close similarity to the Buda.
BUDA	(2) <i>Zone of Pecten roemeri</i> (1) <i>Zone of Budaiceras</i> , various species The above two zones are widespread. Other ammonites known are <i>Euhystriochoceras</i> , <i>Turrilites roemeri</i> , <i>Turrilites wysogorskii</i> , <i>Carthaganiites</i> sp., <i>Turrilites brazoensis?</i> , <i>Stoliczkaia texana</i> + spp., <i>Mantelliceras budaense</i> , <i>M. hoplitoides</i> ; and others.

GRAYSON
South and West
(Del Rio, in
Texas)

Local zones are known, but as extended they have proved rather reliable, as follows:

- (7) *Exogyra cartledgei*. Widespread; sparse in central Texas, abundant in Trans-Pecos Texas.
- (6) *Euhystriochoceras* n. sp. Known from north-central Texas, but probably widespread.
- (5) *Gryphea graysonana*. Widespread. Zone of abundance (= acme) in Upper Grayson, very sparse in Lower Grayson.
- (4) *Exogyra arietina*. Widespread. Acme in Middle to Lower Grayson, sparse above.
- (3) *Pyritic micromorph zone*. Partly overlaps No. 4, widespread, particularly in synclines. Contains: *Turrilites bosquensis*, *Scaphites subevolatus* + spp., *Adkinsia* (several spp.), *Submantelliceras* spp.
- (2) *Pseudananchys supernus* (echinoid). North-central Texas, west Texas, Coahuila, probably widespread.
- (1) *Graysonites-Mantelliceras zone*. Widespread. Zone of *Turrilites brazoensis*, *Kingenia*, *Pervinquieria* (highest), *Alectryonia quadruplicata* (highest), etc.

GEORGETOWN
(Main Street)

WOODBINE ZONATION

Going southward on the outcrop, the Woodbine thickness is reduced from 18 feet on the Johnson-Hill County line to zero on the San Marcos arch between Austin and San Antonio; south of Waco it loses all of its quartz, and consists only of Pepper shale. Just north of Waco the basal Woodbine zones are missing and only zones 4 and ?3 remain, with a shale lithofacies somewhat different from the equivalent Lewisville farther north. Likewise the heavy-shelled mollusca characteristic of the Lewisville have dropped out, leaving only shale fossils or else fossils in concretions or limy lentils, which however mostly resemble the type Lewisville fossils.

Zone 5 (Acanthoceras). Certain *Acanthoceras* have been found in the topmost Woodbine near Grandview and elsewhere north of Waco, but because of the extreme complexity of *Acanthoceras* taxonomy, which no one has yet found time to unravel, they have not been positively identified. Since regional data indicate that, at this point on the dip, the top of the Woodbine is relatively intact, i.e., the "Hillsboro top" is probably the same level as the "Arlington top" of the Woodbine, very probably zone 5 is present here.

Zone 4 (Aguileria cumminsi). A considerable thickness of this zone was reported by Taff from southern Johnson County; and traces of it exist in thin sandstone seams both there and in Hill County. By all results of the very careful measuring and matching of sections across these counties, it is supposed to cross Hill County, hence it would after losing its sandstones pass southward into Pepper shale, most of which is in this zone. Fossils known in this area are:

Aguileria cumminsi

Ostrea soleniscus

Brachydontes

Protarca tramitensis

Trigonarca

Cytherea

numerous other pelecypoda and gastropoda

Zone 3 (Middle Ammonite). Present in both sandstones and shales. Numerous ferruginous mollusca; ammonites too poor to determine, apparently schloenbachids or *Calycoceras*.

Zones 2 and 1. Apparently cut out at base of Woodbine in this area. In Bell County (Pepper Creek) the remaining Pepper is only 20-25 feet thick, in Williamson County, 15 feet, and at Austin 3.4 feet. South and west of here in Texas it is unknown at the outcrop.

EAGLE FORD ZONATION

Central Texas is an area of great lithologic and thickness change in the Eagle Ford. North of Waco in this area the Eagle Ford consists mainly of shale. Near Waco the Lower (Cenomanian) Eagle Ford takes on considerable amounts of limestone flags, which start shoreward at the transgressive overlap of the Eagle Ford onto the underlying beds and extend out into the basin as sheets of limestone. Farther out in the basin, these limestone sheets may be continued as zones of siderite nodules. The whole Eagle Ford markedly thins from Waco south to San Antonio. This thinning cuts out the basal Eagle Ford members toward the south until, between Austin and San Antonio (over the San Marcos arch) only a few feet are left. Over the same territory the shaly Upper (Turonian) Eagle Ford is also reduced in thickness, so that between Austin and San Antonio only a few feet are left. The disappearance or non-occurrence of the Lower Turonian (= Salmurian) in this territory has not yet been solved. From Bell County south to San Antonio on the outcrop and in the shallow subsurface, the very thinned upper Eagle Ford with its zonal sequence practically intact in about 2 feet of rock will be referred to as the "condensed zone" (cf. Adkins, 1949).

The zones appear in this area as follows:

Zone 9 (Alectryonia lugubris). Occurs at various places, rather sparse; at Austin, in the condensed zone.

Zone 8 (Coilopoceras austinense-Coilopoceras n. sp.). *C. austinense* and various other *Coilopoceras* species occur in numerous places; at Austin, they are the most numerous ammonite genus in the condensed zone. Ammonites in zone 8 in this territory are:

Coilopoceras ? n. sp. (small)

Coilopoceras austinense

Coilopoceras springeri

Coilopoceras spp.

"*Prionotropis*" spp.

Prionocyclus spp. (some with exaggerated ornamentation)

Zone 7 (Coilopoceras eaglefordense). Widespread in area; condensed zone at Austin.

Zone 6c (Metaptychoceras-Worthoceras). Excellently displayed in the Eagle Ford pit of the Universal Atlas cement plant. Includes Moreman's Loc. 5 (Ellis County).

Zone 6b (Romaniceras). Sparsely represented in area; known near Austin.

Zone 6a (*Salmurian*). Unknown in area.

Zone 5 (*Neocardioceras*). Various localities (sparse); condensed zone at Austin.

Zone 4 (*Ecalyoceras bentonianum*-*Mantelliceras* n. sp.) Wide-spread; at Austin, in limy flagstones. This is well developed in McLennan County and adjacent areas, where it contains:

Scaphites aequalis var. *turonensis*

Turrilites spp.

Proplacenticerias

Mantelliceras bosquense

Calycoceras (*Eucalycoceras*) *bentonianum*

Calycoceras (*Eucalycoceras*) spp.

Calycoceras sp. 3

Metoicoceras spp.

Allocrioceras pariense

Acanthoceras aff. *confusum* var. *tunetanum*. Probably a good marker.

Pseudacompsoceras aff. *vectense*. This occurs also in southwest Texas and is probably a good marker.

Fossil fish and reptiles (mosasaur; giant turtle *Desmatochelys lowi*, etc.) This zone covers most of the Lake Waco unit.

The same or an only slightly different level at Pepper Creek contains

Turrilites aff. *costatus* (common)

Turrilites aff. *desnoyersi*

Turrilites aff. *hugardianus*

Turrilites aff. *tuberculatus*

Caly. (*Eucalycoceras*) *bentonianum*

Caly. (*Eucalycoceras*) *leonense*

Caly. (*Eucalycoceras*) sp. 3

Mantelliceras aff. *rowei*

Cunningtoniceras lonsdalei

Acanthoceras aff. *hunteri*

Acanthoceras validum

Acanthoceras bellense

Acanthoceras stephensoni

Acanthoceras pepperense

Acanthoceras aff. *rotomagense*

Acanthoceras aff. *cornutum*

Acanthoceras aff. *turneri*

Acanthoceras aff. *discoidale*

Acanthoceras meridionale var. *africanum*

Acanthoceras confusum var. *tunetanum*

Acanthoceras aff. *sherborni*

Zones 3-2-1. These have not been recognized in the south, nor in the present area, and are probably absent in the upper condensed zone, and possibly are entirely absent at Austin by transgressive

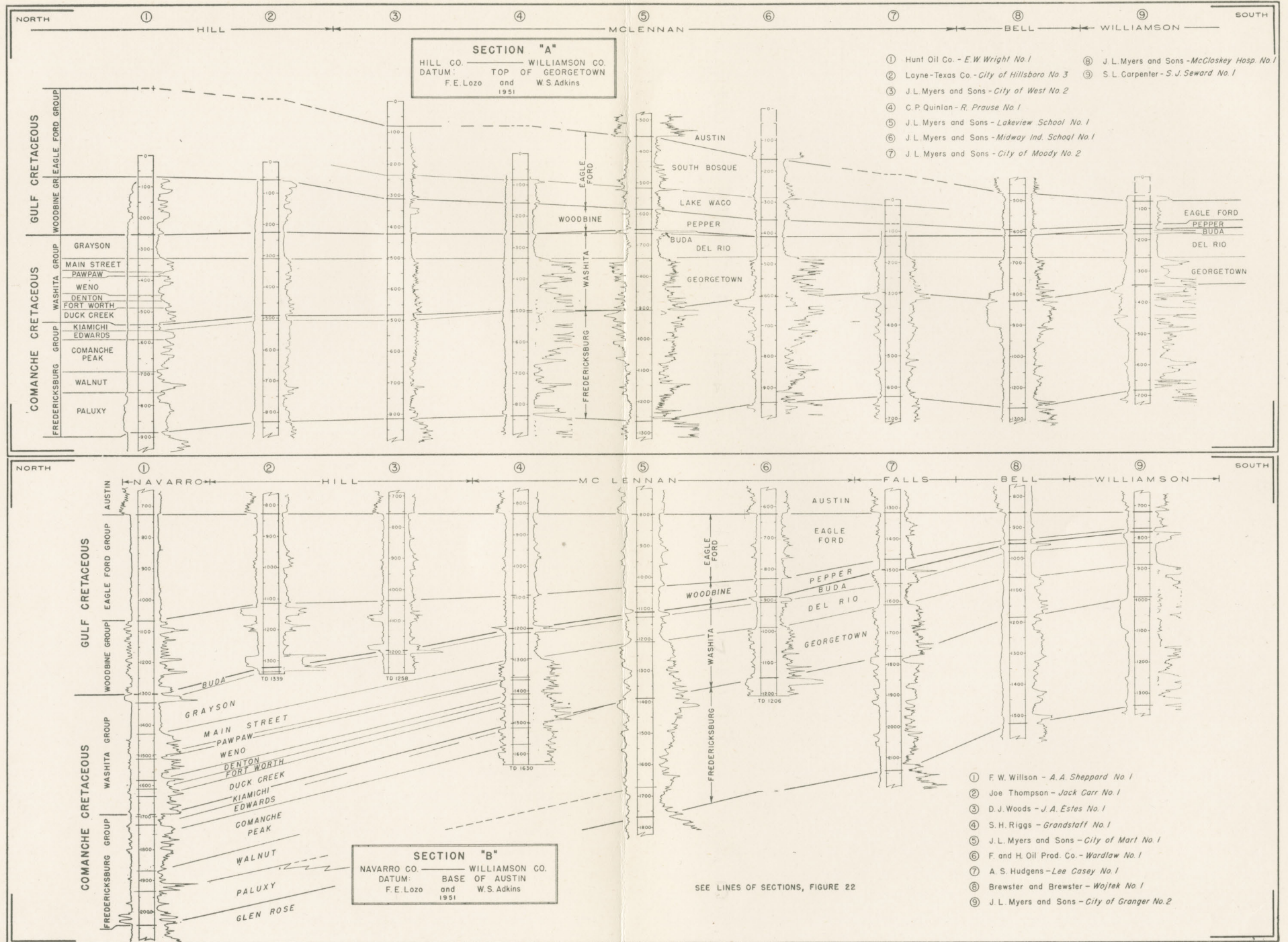


Fig. 25. Stratigraphic sections "A," Hill-Williamson County, and "B," Navarro-Williamson County.

overlap. The southernmost *Acanthoceras tarrantense* discovered were at and near the Webb inlier, southern Tarrant County.

At Austin, zone 5 (*Neocardioceras*) is the lowest known to be present in the condensed zone and zone 9 is the highest. The flagstone member (Cenomanian) of the Eagle Ford at Austin represents the upper Lake Waco member, probably near zone 4 above; it contains:

Eucalycoceras leonense
Eucalycoceras bentonianum
Eucalycoceras sp.
Mantelliceras sp. (compressed)
Acanthoceras aff. *cornutum* (as in McLennan and Bell counties)
Metoicoceras ?
Exogyra columbella
Turrilites n.sp, aff. *scheuchzerianus* Bosc.

AUSTIN ZONATION

At many outcrop localities and on some high structures in the Embayment there is stratal cut-out at the base of the chalk, some of it caused by erosion subsequent to top-Eagle Ford deposition. Accordingly at many places the Eagle Ford-chalk contact seems sharp, both stratally and zonally; at other localities especially in the subsurface it appears of alternating lithology, or at least less sharp.

The following are among the most reliable fossil markers for the Lower Austin (= Coniacian = Emscherian portion):

AMMONITES

Proplacentoceras sp.
Coilopoceras austinense
Parapuzosia aff. *stobaei*
Phlycticrioceras spp.
Neancyloceras spp.

PELECYPODA

Inoceramus subquadratus
Inoceramus spp.
Spondylus guadalupae
Exogyra laeviuscula
Gryphaea aucella

ECHINODERMATA

Hemiaster texanus
Codiopsis sp.
Austinaster (starfish)

SUMMARY

TECTONICS

1. The tectonic framework of the area includes a shelf region to the west, bordering the East Texas Embayment to the east.
2. Perpendicular to this border there is a series of faint anticlines and synclines. These are evidenced by published contour maps, by isopach maps and by the arrangement of the outcrop (lithofacies distribution, jump-ups in the basal transgressive overlap, outcrop reentrants, outliers, inliers, etc.).
3. Parallel to the border are the following features among others: the limit of Jurassic deposition or at least the limit of preserved Jurassic sediments; the Balcones fault system; the Mexia fault system; and the graben-like strip which they bound.
4. Within a given group of beds (Woodbine, Eagle Ford etc.) the

transgressive behavior of the basal beds of the group in related to the tectonic pattern.

5. Erosion of a group at its top is related to the tectonics, particularly on the high areas.

LITHOFACIES

1. In northern Hill County, there may be drawn at an angle to the outcrop a band of lithofacies change, north of which in the Eagle Ford there outcrop the Arcadia Park-Britton lithofacies, and south of which are the South Bosque-Lake Waco lithofacies; and north of which is the Grayson lithofacies grading to the south of the band into the Del Rio lithofacies. North of another band on the outcrop the Buda is intermittent, mainly absent; south of this band the Buda outcrop is continuous. North of a band in central McLennan County, the Woodbine contains sandstones and shales; south of the band, it is predominantly of the Pepper shale lithofacies.
2. These effects are intimately connected with the regional tectonic pattern.
3. Lake Waco, Bouldin, Cloice and Bluebonnet units are defined and described. The South Bosque unit is revived.

ZONATION

1. A provisional zonation of the Woodbine and Eagle Ford groups is here proposed.
2. The most satisfactory zonation of the Woodbine group is based on ammonites. Since the Woodbine covers only about the equivalent of two zones in the western European Cenomanian, its zonation is obviously difficult.
3. The best starting point for zoning the Eagle Ford group is to separate its lower (Cenomanian) portion from its upper (Turonian) portion. We have accomplished this over the entire Texas outcrop. Presented here is the part pertinent to the area under discussion.

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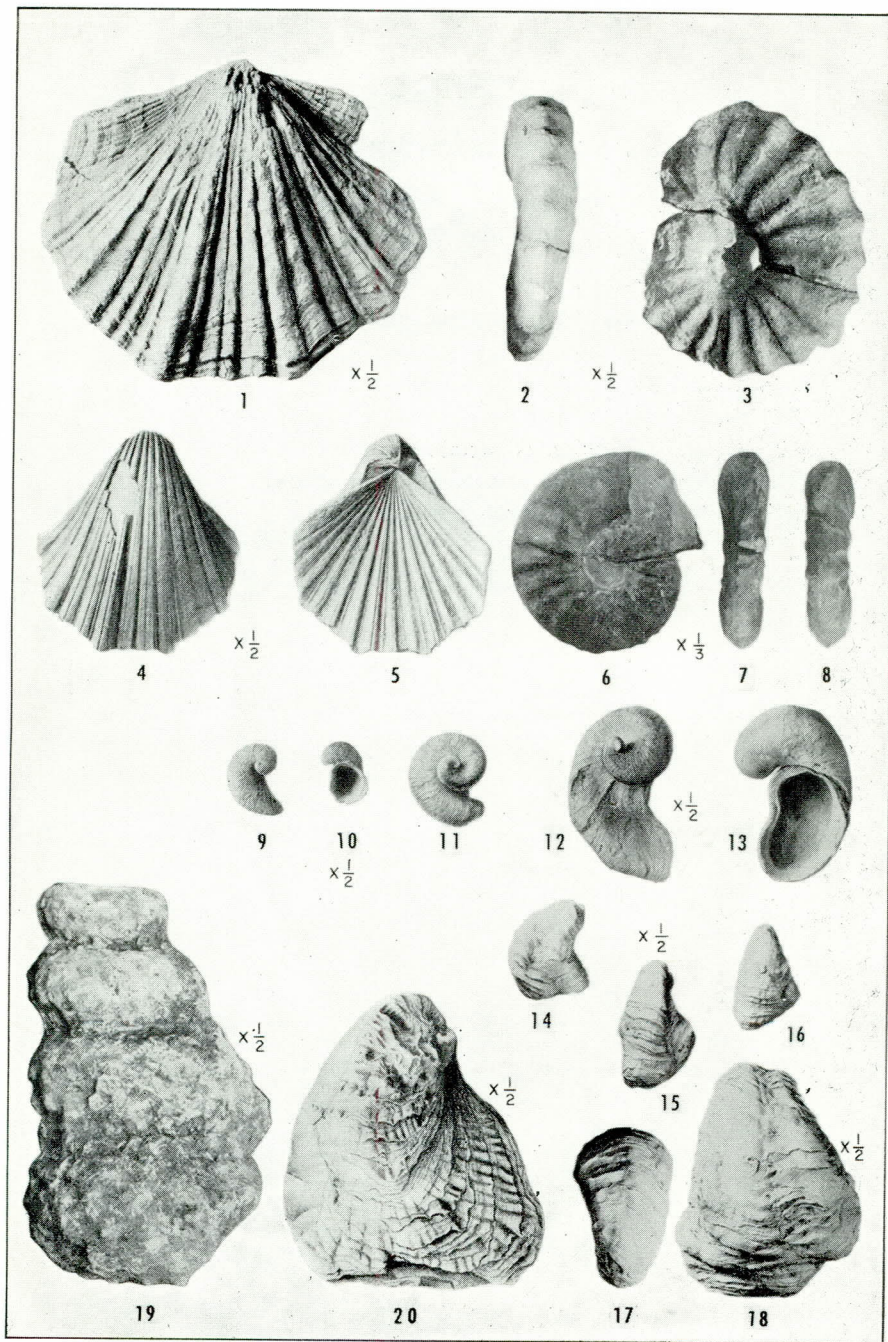
PLATES

PLATE 1

BUDA AND DEL RIO FOSSILS

Figure

1. *Pecten roemeri*. After Stanton, 1947
- 2, 3. *Stoliczkaia* aff. *dispar*. After Böse, 1927
- 4, 5. *Pecten georgetownensis*. After Stanton, 1947
- 6, 8. *Budaiceras mexicanum*. After Böse, 1927
- 9-13. *Exogyra arietina*. After Stanton, 1947
- 14-18. *Gryphaea graysonana*. After Stanton, 1947
19. *Turrilites brazoensis*. After Adkins and Winton, 1919
20. *Exogyra clarki*. After Stanton, 1947



BUDA AND DEL RIO FOSSILS

PLATE 2

WOODBINE FOSSILS

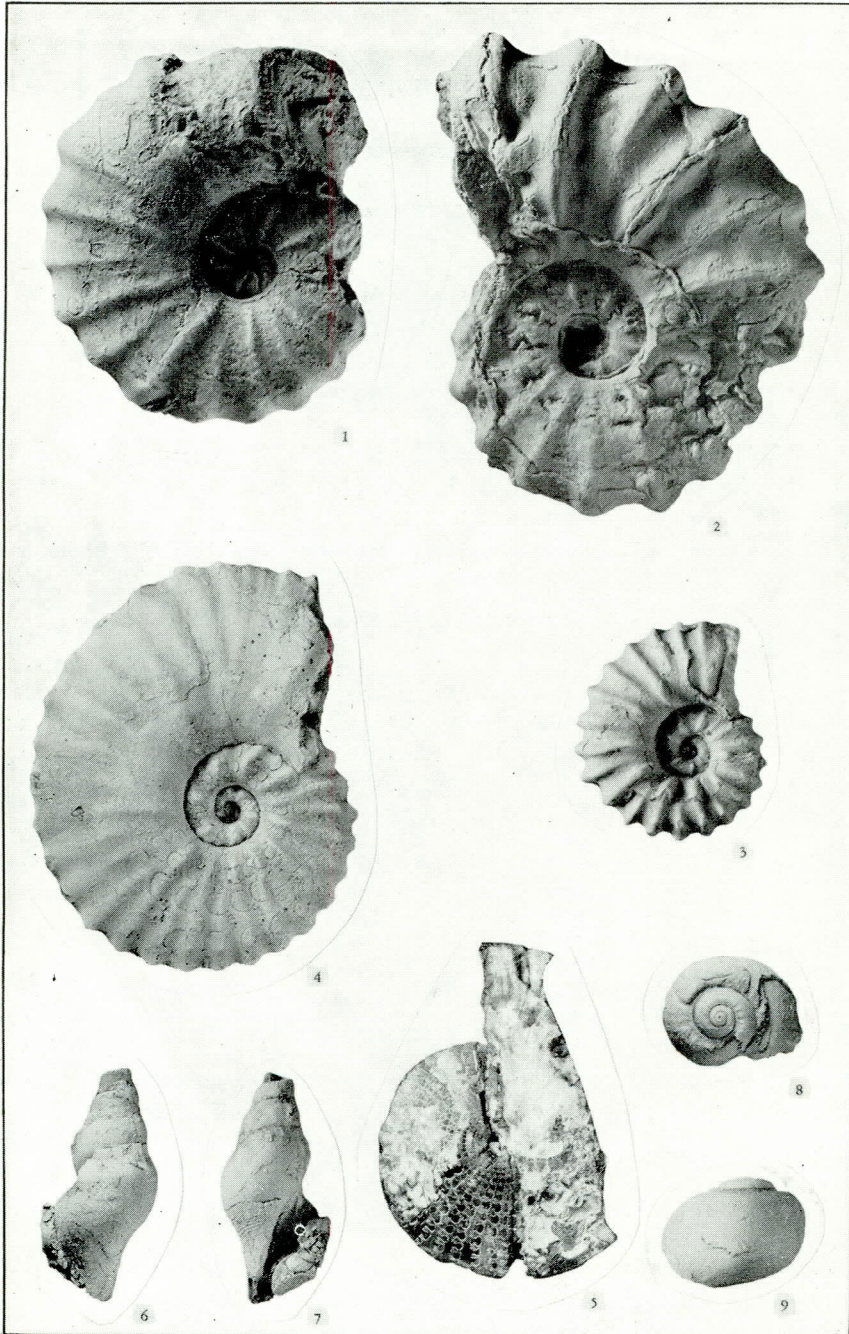
CEPHALOPODA AND GASTROPODA

(All figures x $\frac{1}{2}$)

Figure

1. *Acanthoceras wintoni* Adkins, type specimen.
2. *Acanthoceras tarrantense* (Adkins), holotype.
3. *Acanthoceras barwsi* Jones.
4. *Metoicoceras swallovi* (Shumard).
5. *Metengonoceras dumblei* (Cragin), cotype.
- 6, 7. "*Volutomorpha*" *graysonensis* (Cragin), a cotype.
- 8, 9. *Cyrodes tramitensis* (Cragin), type specimen.

Courtesy of L. W. Stephenson



WOODBINE FOSSILS

PLATE 3

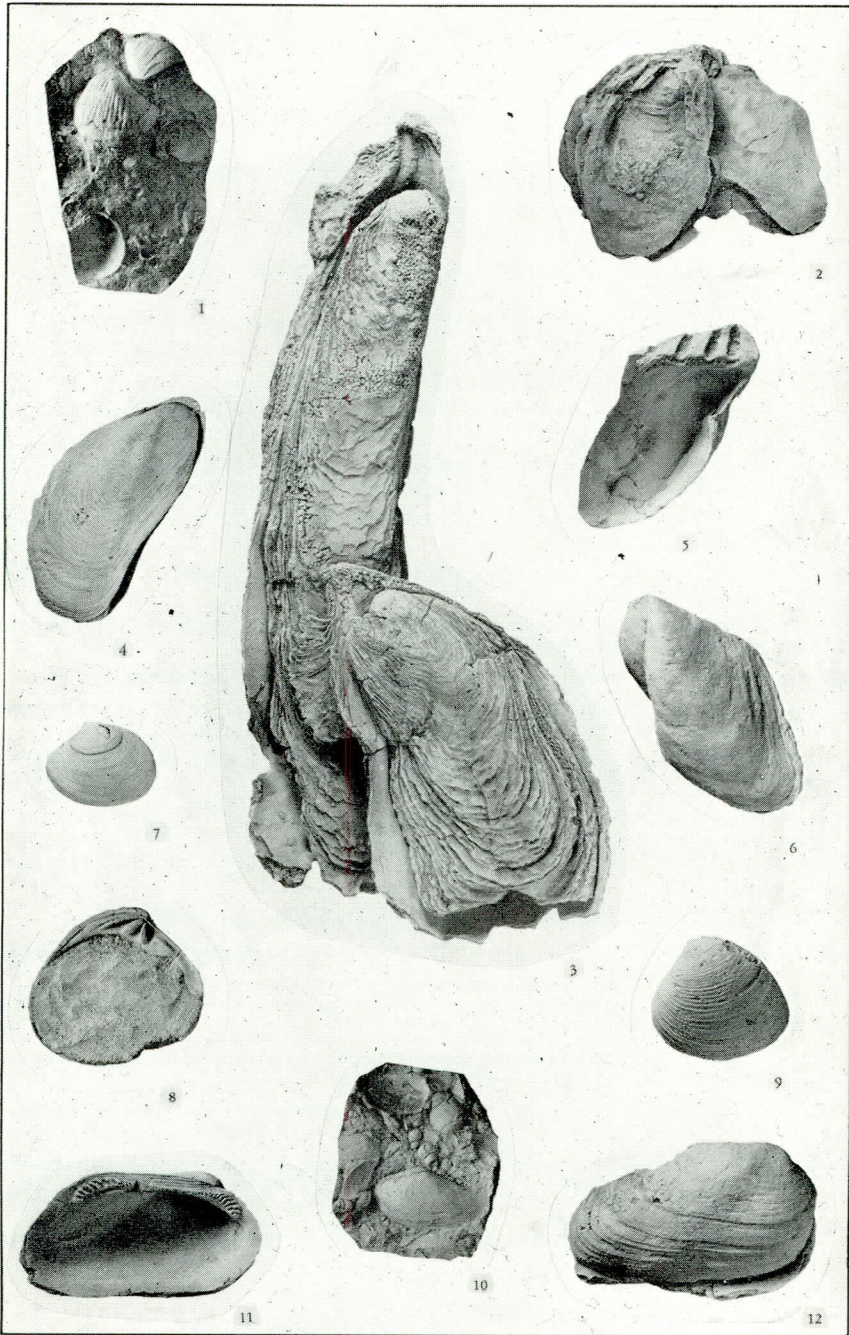
WOODBINE FOSSILS

PELECYPODA

Figure

1. *Exogyra columbella* Meek, cotype, x $\frac{1}{2}$.
2. *Ostrea carica* Cragin, cotypes, x $\frac{1}{2}$.
3. *Ostrea soleniscus* Meek, x $\frac{1}{2}$.
4. *Brachidontes flisculptus* (Cragin), cotype, x $\frac{1}{2}$.
- 5, 6. *Aguileria cumminsi* White, x $\frac{1}{2}$.
7. *Callistina lamarensis* (Shumard), x $\frac{3}{4}$.
- 8, 9. *Callistina taffi* (Cragin). Fig. 8, x $\frac{3}{4}$. Fig. 9, x 1.
10. *Yoldia septariana* Cragin, x 1.
- 11, 12. *Protarca ? tramitensis* (Cragin)=*Barbatia micronema* of authors, x $\frac{1}{2}$.

Courtesy of L. W. Stephenson



WOODBINE FOSSILS

PLATE 4

WOODBINE AND PEPPER FORAMINIFERA

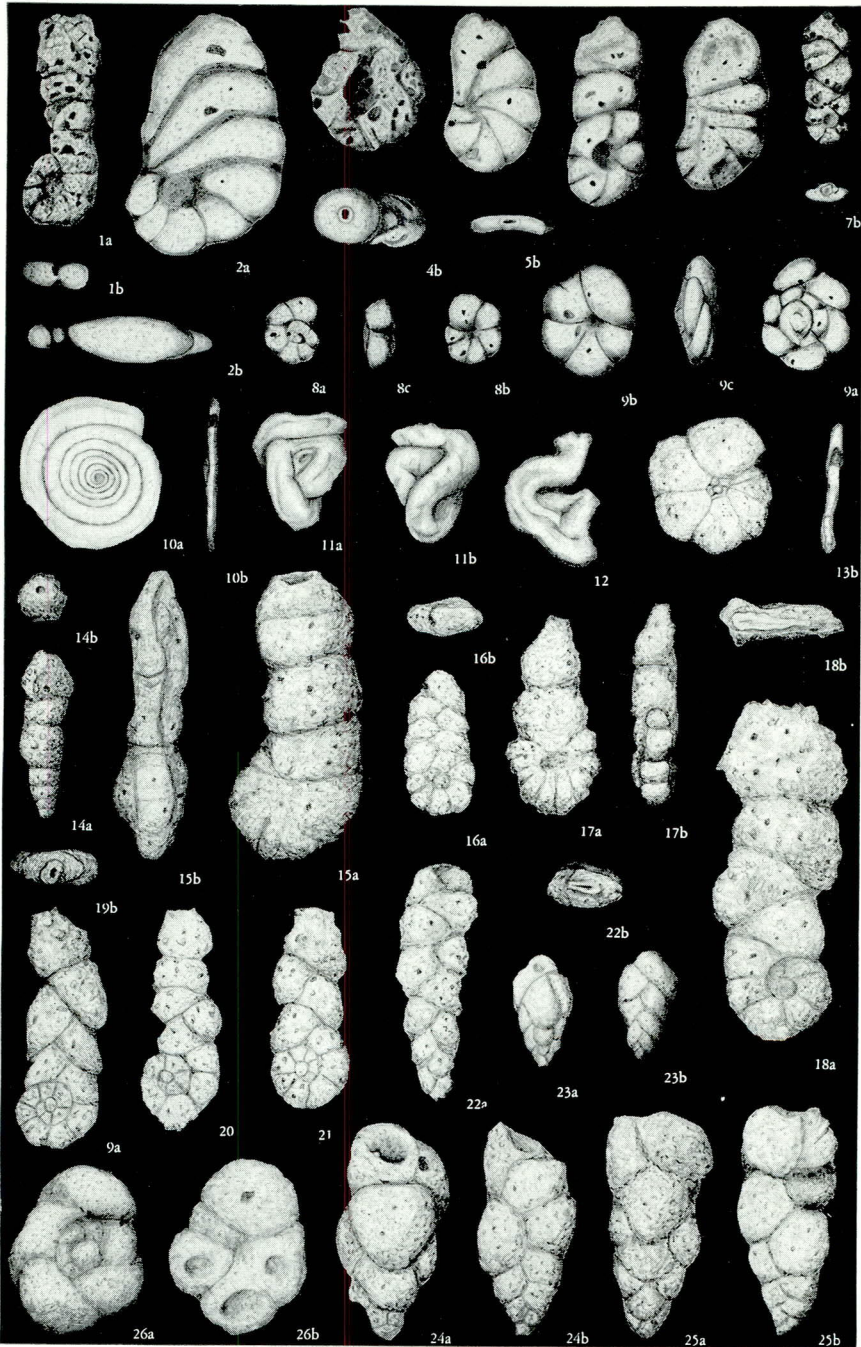
Figures 1-9, Woodbine Foraminifera (after Cushman and Applin).

Figures 10-26, Pepper Foraminifera (after Loeblich).

Figure

- 1a-b. *Ammobaculites junceus* Cushman and Applin. 1a, side view, 1b, apertural view, x 40.
- 2a-b. *Ammobaculites braunsteini* Cushman and Applin. 2a, side view, 2b, apertural view, x 40.
3. *Ammobaculites stephensoni* Cushman, x 40.
- 4a-b. *Ammobaculites comprimatus* Cushman and Applin. 4a, side view, 4b, apertural view, x 40.
- 5a-6. *Ammobaculites bergquisti* Cushman and Applin. 5a, side view of holotype. 5b, apertural view, 6, side view of paratype, x 40.
- 7a-b. *Ammobaculooides plummerae* Loeblich. 7a, side view, 7b, apertural view, x 40.
- 8a-c. *Trochammina exigua* Cushman and Applin. 8a, dorsal view, 8b, ventral view, 8c, peripheral view, x 40.
- 9a-c. *Trochammina rainwateri* Cushman and Applin. 9a, dorsal view. 9b, ventral view, 9c, peripheral view, x 40.
- 10a-b. *Ammodiscus planus* Loeblich. 10a, side view, 10b, edge view, x 76.
- 11a-12. *Glomospira watersi* Loeblich. 11a, dorsal view of holotype, 11b, ventral view, 12, paratype, showing tendency to uncoil, x 76.
- 13a-b. *Haplophragmoides platus* Loeblich. 13a, side view, 13b, edge view of holotype, x 76.
- 14a-b. *Reophax pepperensis* Loeblich. 14a, side view of holotype, 14b, top view, x 117.
- 15a-b. *Ammobaculites obscurus* Loeblich. 15a, side view of holotype, 15b, edge view, x 76.
- 16a-b. *Spiroplectamina* sp. 16a, side view, 16b, top view, x 76.
- 17a-b. *Ammobaculites polythalamus* Loeblich. 17a, side view, 17b, edge view of holotype, x 76.
- 18a-b. *Ammomarginulina bellensis* Loeblich. 18a, side view, 18b, apertural view of holotype, x 76.
- 19a-21. *Ammobaculites plummerae* Loeblich. 19a, side view of holotype, 19b, top view, 20, 21, side views of paratypes, x 76.
- 22a-b. *Textularia adkinsi* Loeblich. 22a, side view, 22b, top view of holotype, x 117.
- 23a-25b. *Verneuilinoides perplexa* (Loeblich). 23a, b, side views of paratype; 24a, apertural view of holotype, 24b, side view, 25a, b, side views of paratype, x 117.
- 26a-b. *Trochammina wickendeni* Loeblich. 26a, dorsal view, 26b, ventral view of holotype, x 76.

Courtesy of A. R. Loeblich and Helen Tappan



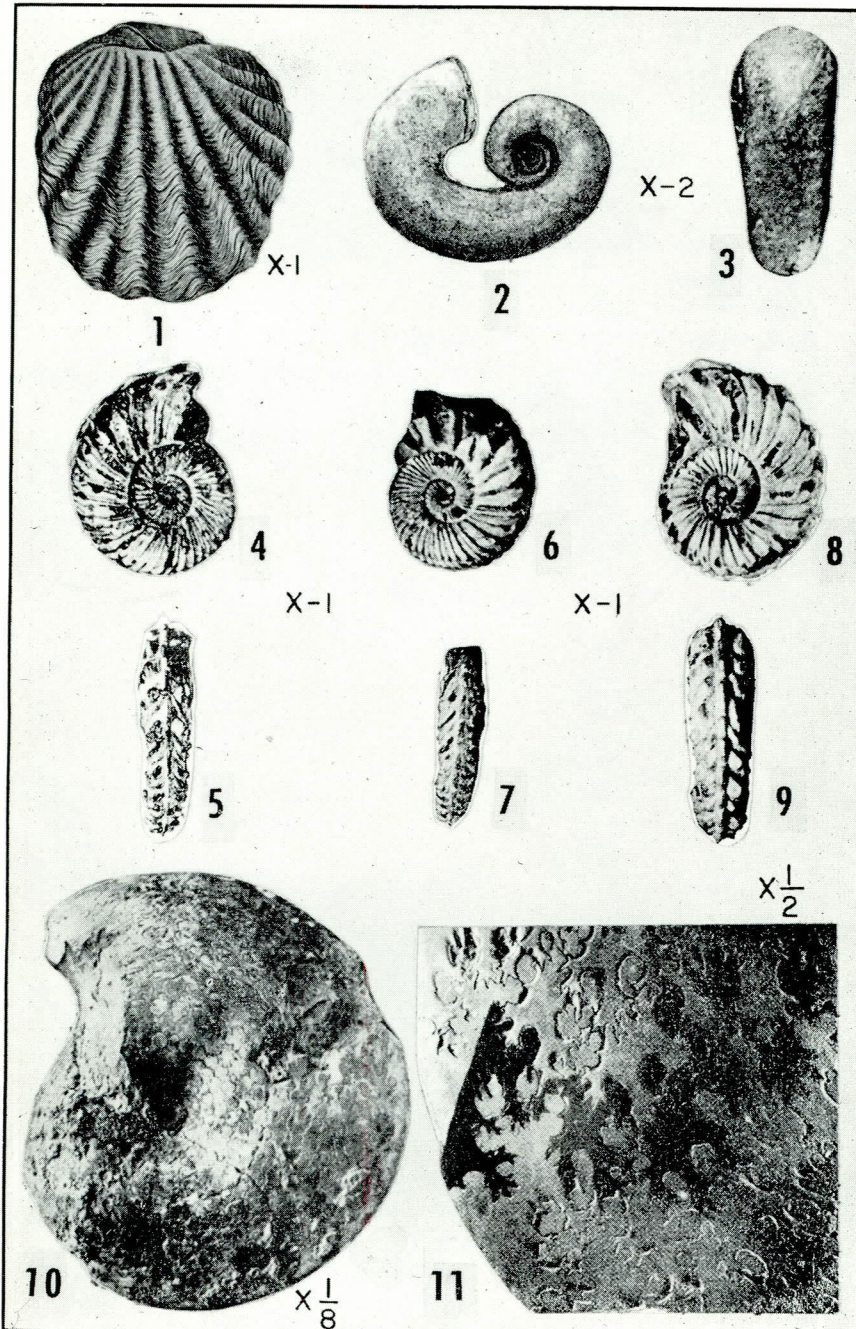
WOODBINE AND PEPPER FORAMINIFERA

PLATE 5

EAGLE FORD FOSSILS

Figure

1. *Alectryonia lugubris*. After Hill, 1901
- 2, 3. *Worthoceras*. After Moreman, 1942
- 4-9. *Prionotropis*. After Haas, 1946
- 10-11. *Coilopoceras*. After Adkins, 1931



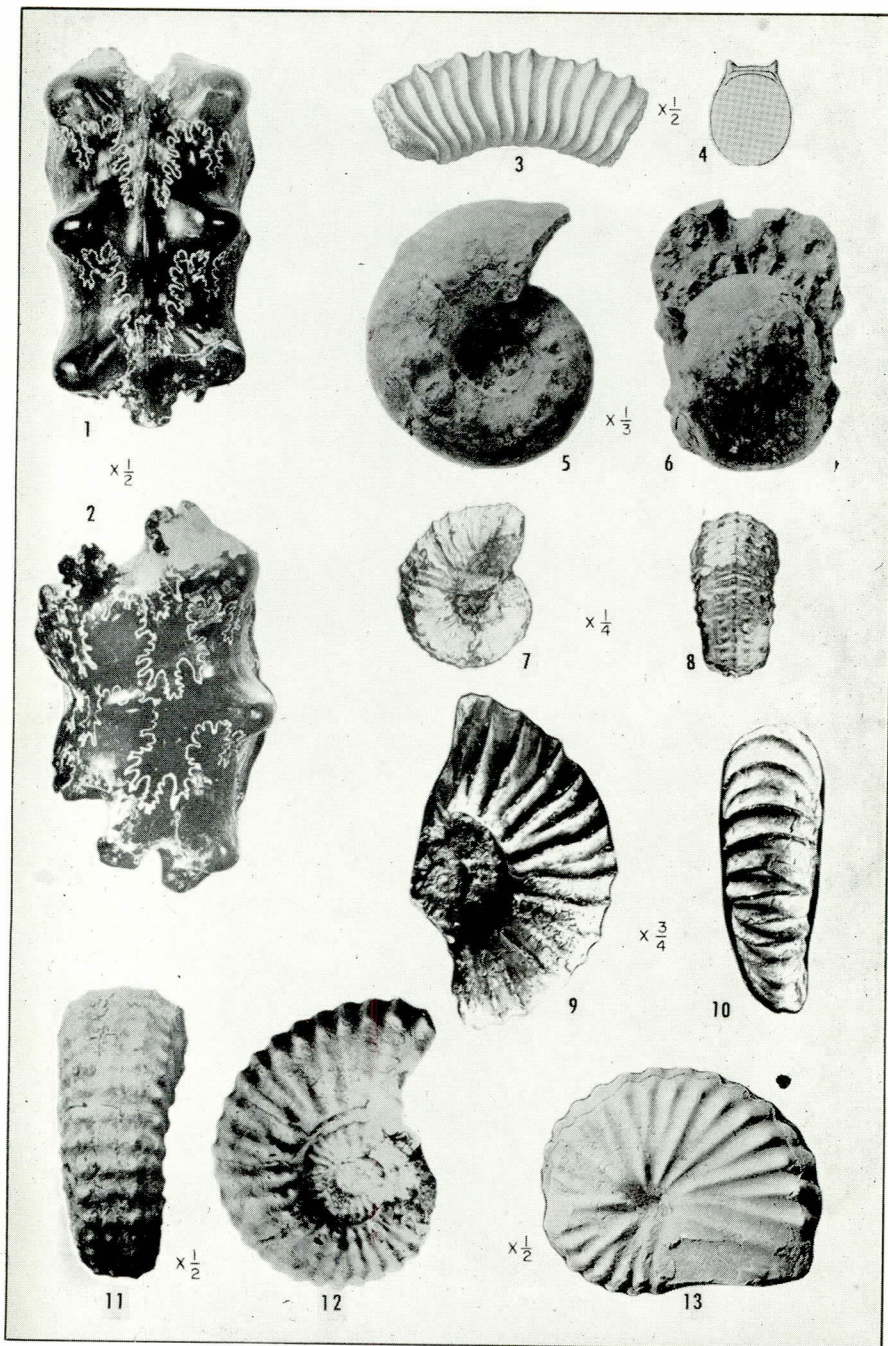
EAGLE FORD FOSSILS

PLATE 6

EAGLE FORD FOSSILS

Figure

- 1, 2. *Prionotropis*. After Haas, 1946
- 3, 4. *Allocrioceras*. After H. Woods
- 5, 6. *Fagesia*. After Anderson, 1931
- 7, 8. *Neocardioceras*. After Moreman, 1942
- 9, 10. *Eucalycoceras bentonianum* (Cragin). Holotype. Figure by W. S. Adkins
- 11, 12. *Romaniceras*. After Jones, 1938
13. *Metioceras*. After Moreman, 1927



EAGLE FORD FOSSILS