Missourian Facies in the Possum Kingdom Vicinity Palo Pinto County, Texas

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ABSTRACT

The uppermost Keechie Creek, the Palo Pinto, the Wolf Mountain, and the Winchell Formations of the Missourian Series were mapped in the Possum Kingdom vicinity, Palo Pinto County, Texas. The Keechie Creek and Wolf Mountain Formations are dominantly terrigenous facies. The Palo Pinto Formation is an off-bank facies which crops out immediately updip of an equivalent subsurface limestone bank. Both the bank and off-bank facies of the Winchell Limestone crop out in the study area.

Typical Missourian terrigenous facies includes mostly unfossiliferous silty clay shales intercalated with a small volume of fine-grained sandstones. Away from equivalent limestone banks the shales contain abundant clay-ironstone concretions. Near gradational contacts with limestone banks the silty clays become fossiliferous. Rarely, the terrigenous sandstones grade laterally into limestones.

Limestone banks grade laterally into terrigenous and calcareous facies that are different from the bank facies itself. Typical bank facies consist of 2/3 limestone with a micritic matrix and 1/3 limestone with sparry matrix; only thin shale partings are present. The primary bank builders are platy algae in micritic limestones, osagiid-like algae in sparry limestones, and fenestrate bryozoans in both micritic and sparry limestones. Normal to the sedimentary strike of the algal-bryozoan banks the typical bank limestones grade into limestone-types which usually have a micritic matrix and contain increasing amounts of clay. In the same direction the volume of terrigenous facies increases. As much as 75 feet of bank limestones grade laterally into entirely terrigenous facies in one-quarter mile.

The depositional environment of bank facies is inferred to have included: (1) slightly higher topography than surrounding terrigenous environments, (2) firm bottom sediments, (3) low turbidity in shallow marine water, and (4) abundant, loose faunal remains.

INTRODUCTION

Outcrops of upper Keechie Creek, Palo Pinto, Wolf Mountain and Winchell stratigraphic units were mapped in northern Palo Pinto County, Texas (Fig. 1). Lithologies are described in this paper as

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[1] Socony Mobil Oil Company, Inc., Field Research Laboratory, Dallas, Texas.

Cost of printing Plates 2 Jw through 6 Jw kindly donated by Socony Mobil Oil Company, Inc.

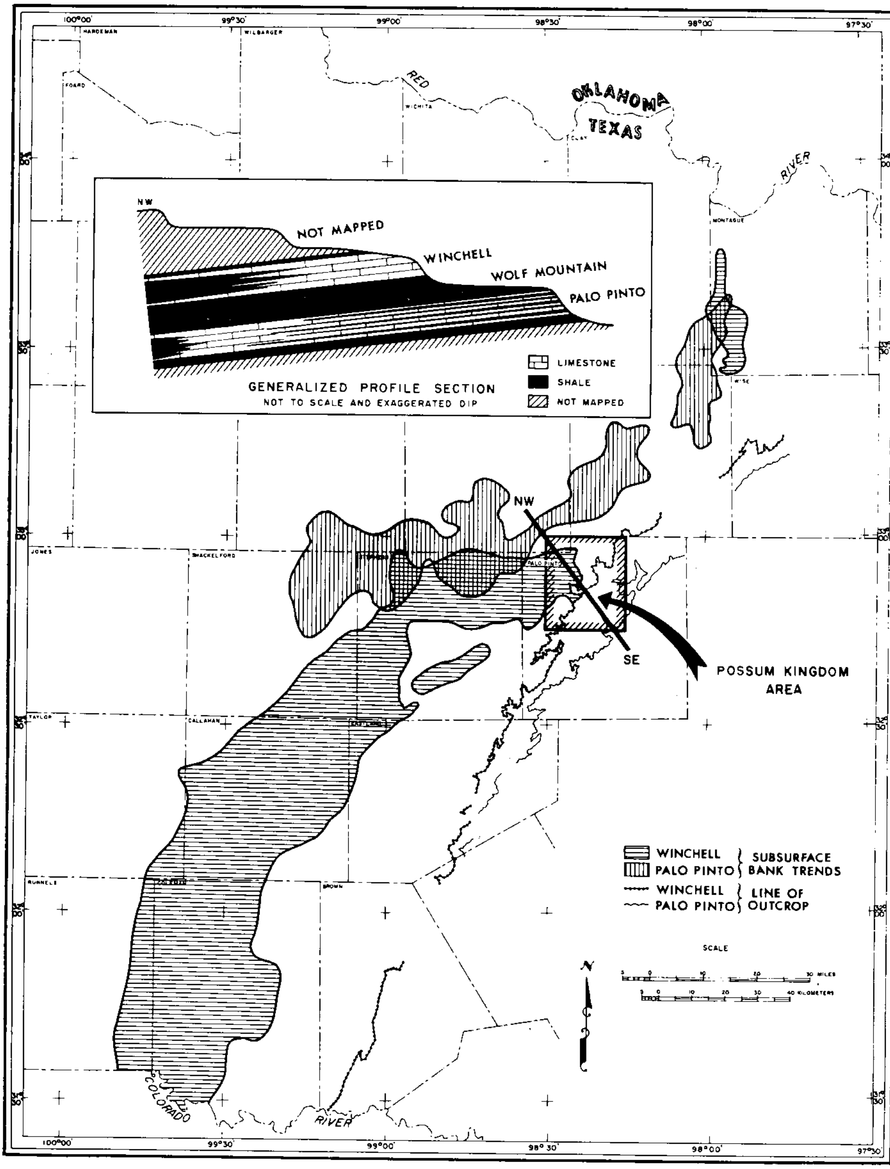


Figure 1. Location of mapped area and its relation to subsurface limestone banks in north-central Texas.

they were identified in the field with a hand lens. This identification was supplemented by binocular microscopic examination of about 200 polished sections of limestone. No thin sections were examined. Fossils were also identified in the field, and the nomenclature used is that of Shimer and Shrock (1944).

This mapping is part of a larger study of the upper Pennsylvanian history in north-central Texas. This region including the area of this paper probably was covered by a shallow epeiric sea throughout Missourian time. On an extensive shelf, the Eastern Shelf of previous authors, shallow marine sedimentation developed two predominant facies: (1) a terrigenous facies and (2) a calcareous or bank facies. The terrigenous facies constitutes the major volume of sediments. The calcareous facies was formed of material indigenous to the shelf. It resulted from the *in situ* growth of algae and bryozoans and their local redistribution by currents and waves.

The calcareous facies forms thick elongate trends in the Missourian outcrops and subcrops of the shelf. A limestone trend is herein called a bank—a ". . . skeletal limestone deposit formed by organisms which do not have the ecologic potential to erect a wave-resistant structure," after Nelson (1959, p. 24) and Nelson, Brown and Brineman (1961). The banks are described as algal-bryozoan banks as these organisms were primarily responsible for bank growth. The banks have either biostromal or biohermal shape.

The major purpose of this investigation is to describe the intergradational relationships at the contact between the terrigenous and bank facies. The intercalations of the major facies occur on both the scale of this study and a much larger scale as well. In addition, lithologic variations within each major facies are described as each facies differ from its normal aspect at their contacts.

Previous Work

Cummins (1891) first mapped the Strawn, Canyon and Cisco divisions as the fundamental rock-units in upper Pennsylvanian outcrops of north-central Texas. According to his descriptions and sections the base of the Canyon division was the base of the Palo Pinto limestone and the top was the top of the Home Creek limestone in the Brazos River Valley. Plummer and Moore (1921, p. 89) gave group status to the divisions based on regional surface mapping. Plummer and Hornberger (1935, p. 15) continued this usage in Palo

Pinto County. Cheney (1940, p. 87) redefined the groups as time-rock units to correspond with the Desmoinesian, Missourian and Virgilian Series of the mid-continent region. As recognized from faunal groupings he (op. cit., p. 89) redefined the base of the Missourian Series as the base of the Lake Pinto sandstone. His definitions were accepted by Moore (1944, p. 697) when the latter collated the Pennsylvanian rocks of north-central Texas with other continental regions. A recent review of the Strawn-Canyon boundary was given by Shelton (1958).

Following Cheney (1940) and Moore (1944) the stratigraphic units mapped in this investigation were included in the Missourian Series. It appears unnecessary to retain "Canyon" in preference to "Missourian" in spite of some excellent objections by Brown (1959).

The writer has also followed the recommendations of Cheney (1940) and Moore (1944) in considering the Keechie Creek Shale, the Palo Pinto Limestone, the Wolf Mountain Shale and the Winchell Limestone as formations. They are mappable surface units from the divide between the Colorado and Brazos Rivers northward into Wise County. Prior to 1940 the Keechie Creek unit was described as a member of the Mineral Wells Formation first by Plummer and Moore (1921, p. 78) and later by Plummer and Hornberger (1935, p. 30). The Palo Pinto Limestone was defined as a formation by Plummer and Moore (1921, p. 92) and slightly enlarged by Plummer and Hornberger (1935, p. 44). It was redescribed by Cheney (1940, p. 88) to include the Palo Pinto Limestone of previous workers, an overlying shale and the Wiles Limestone Member of Dobbin (1922). The Wolf Mountain strata were first defined as a member of the Graford Formation by Plummer and Hornberger (1935, p. 48). Prior to 1940 the unit called Winchell in this study was mapped as Adams Branch by Plummer and Moore (1921) and as Merriman by Plummer and Hornberger (1935). The Winchell unit was first named by Nickell (1938, p. 105) as a member of the Graford Formation in the Colorado River Valley. Winchell limestones were correlated into the Brazos River Valley by Cheney (1940) and Feray and Jenkins (1954). Jenkins (1952) recommended that the Winchell unit be given formational rank, and Eargle (1960, p. 65) formally gave the Winchell Limestone formational status.

Plummer and Moore (1921) and Plummer and Hornberger (1935) mapped only the gross lithologic relationships. Feray and Jenkins

(1954) first presented broader facies relationships of the Wolf Mountain and Winchell strata.

Present Study

Location.—The area is located in the north-central part of Palo Pinto County, Texas (Figure 1) and in the southeastern half of the U. S. Geological Survey 15-minute Palo Pinto quadrangle (1958). It is bounded on the north by an irregular line approximating latitude 32°54′N., on the east by longitude 98°15′W., on the south by latitude 32°45′N. and on the west by the left bank of the Brazos River, Ioni Creek and the east rim of Antelope Mountain overlooking Harris Creek.

Topographic maps available for the area are the U. S. Geological Survey 30-minute Palo Pinto sheet (1889), the 15-minute Palo Pinto quadrangle (1958) and the Abilene sheet, scale 1: 250,000 (NI 14-11).

Field work.—Intermittent reconnaissance of Missourian outcrops in the Brazos, Colorado and Trinity River Valleys was made in 1958 and 1959. Field work for this paper was conducted from April, 1958, until May, 1959. An outcrop map of individual beds was made on enlargements of the Palo Pinto quadrangle at the scale of 1:6000. Intermediate elevation control was determined with a Pauling Altimeter, and reference sections and key beds were hand-leveled. The geologic map (Plate 1) is a simplification of the detailed outcrop map.

CALCAREOUS FACIES

Principal Limestone Types

Variation of the principal limestone types observed in outcrops of Missourian limestones primarily depends upon the type, size and shape of the allochems (transportable debris) and the texture of the matrix. The most significant and abundant allochems are fossils. Intraclasts and pseudo-allochems in decreasing order of abundance are the only other allochems that were recognized. Principal limestone types are illustrated in Figure 2, but the total variability of the rocks is best seen in measured sections illustrated on cross-sections, Plates 2JW through 6JW.

The writer has generally followed the limestone classification of Folk (1959) within the limitations imposed by the field identification of rocks with a hand lens. There are two exceptions to Folk's terminology. First, the term rudite is not used. The grain size of the

Figure 2. Polished Slabs of the Principal Limestone Types, 10X

A. BIOSPARITE: numerous pellets of osagiid-like algae, few crinoid fragments, and rare brachiopods (*Composita*) in a coarse crystalline matrix. COARSE- to MEDIUM-GRAINED. Section 18, bed IVe.

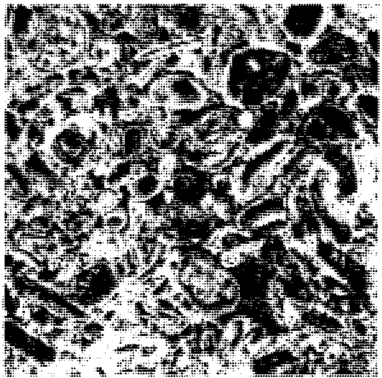
B. ALGMICRITE: numerous platy algae replaced by sparry calcite, slightly argillaceous and has a very fine crystalline matrix. COARSE- to FINE-GRAINED depending upon presence of algae. Section 1, bed IVh.

C. BIOSPARITE: bryozoans, echinoderm fragments and osagiid-like algae in a coarse crystalline matrix. COARSE- to MEDIUM-GRAINED. Section 6, bed IVm.

D. INTRAMICRITE: speckled, intraclasts and algal crusts in a very fine matrix. VERY FINE-GRAINED to SILT-SIZE AND FINER, sublithographic. Section 2, bed IVa.

E. BIOMICRITE: encrusted platy algae, small gastropods, fusulinids in a very fine matrix. MEDIUM- to FINE-GRAINED. Section 7, bed IV1.

F. MICRITE: finely comminuted fossil debris and intraclasts in a very fine matrix. SILT-SIZE AND FINER. Section 45, bed IIa.



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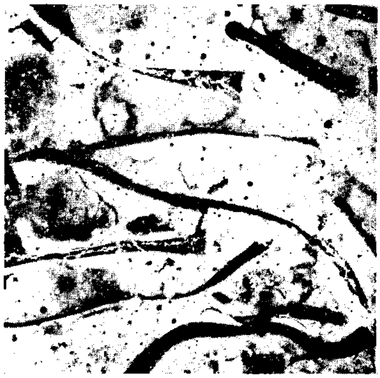

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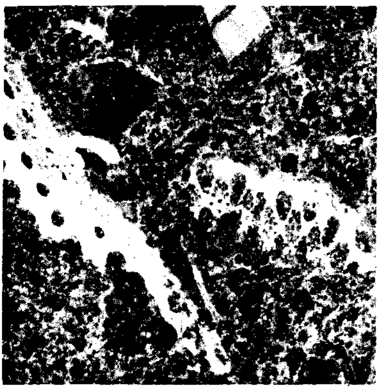

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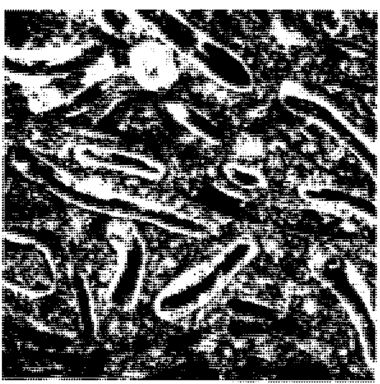

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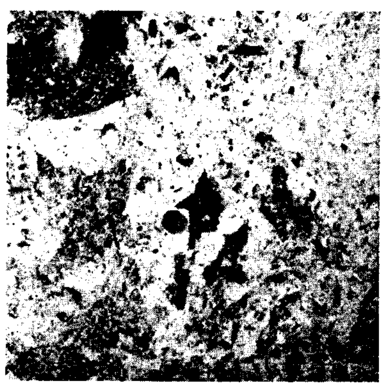

F

allochem in the rock was estimated and used as a modifier, e.g., micrite, very fine-grained. The grain sizes are equated to the Wentworth grade scale. A second modification is a change in the prefix in some instances. The prefix "bio" is modified where one fossil is dominant and part of the name of the fossil is substituted as a prefix. Examples are algmicrite (algal micrite of Folk) in which platy algae comprise most of the rock and fusmicrite (fusulinid biomicrite or fusulinid biomicrudite of Folk) in which fusulinids dominate the rock.

Limestones with a sparry matrix represent about one-third of the limestone volume in the mapped area and all are clastic biosparites (Fig. 2A and 2C). In order of decreasing abundance the common fossil allochems are echinoderm parts, pelletal algae, bryozoans, platy algae, brachiopods, fusulinids and gastropods. The pelletal algae have been tentatively identified as *Osagia* (?) or *Girvanella* (?). Although pelletal or osagiid-like algae form as much as 80 percent of some biosparites, the term pelsparite is not used, because the pellets probably do not originate like the pelsparites and grapestones described by Illings (1954) from the Bahama Bank.

There are three field characteristics of limestones with a sparry matrix making them more easily identifiable. The bedding is generally more massive than that of limestones with micritic matrix. The sparry matrix dissolves more rapidly than a micritic matrix so that limestones with a sparry matrix have more dripstone which frequently coats the rock. They are more porous and sound hollow when struck with a hammer. Third, stylolites are more common in limestones with a sparry matrix.

Limestones having a micritic matrix are the most abundant limestones in the area, and they too are predominantly clastic biomicrites, regardless of the fine texture (Fig. 2B and 2D-2F). By far the most abundant limestone type is a biomicrite—the algmicrite mentioned earlier (Fig. 2B and 2E). The platy algae, tentatively identified as *Eugonophyllum,* is the major building block of the clastic limestones. The algal plates are up to 2 inches in length as seen in cross-section and form an algal coquina that is equivalent in texture to a gravel where they are abundant and unbroken (section 1, bed IVi, Cross-Section A-B-C-D, Plate 2JW). Even in rocks in which algal plates are fragmented, the fragments are frequently the textural equivalent of a medium-grained sand (Fig. 2E).

Rocks identified as intramicrites in the field are relatively common in a part of the calcareous facies to be discussed later. On the outcrop this type of micrite appears speckled and the specks are identified as intraclasts. In polished slabs the specks are sparry calcite in irregular patches and may be pieces of algal matts displaced prior to induration (note the upper half of Fig 2D). Because these intraclasts, as identified on the outcrop, are not rock fragments torn from nearby lithified rock and redistributed (Folk, op. cit.) and Ginsburg (1957, p. 92), these rocks are probably dismicrites (Folk, p. 28).

From the weathering characteristics numerous limestones with micritic cement were identified as argillaceous (e.g., section 1, beds IVh and IVo). These argillaceous limestones frequently have nodular-bedding in which clay is wrapped about the nodules. There is clay in the weathered layer. When fresh they are generally darker in tone than non-argillaceous limestones.

Other than the algmicrites, fusmicrites are the most distinctive rock type in the area even though they make up a very small volume of the limestone. Frequently the fusulinids are the only allochem in the rock and micrite fills spaces between the fusulinids. Fusmicrite is diagnostic of one calcareous facies of the Winchell Limestone.

Palo Pinto Calcareous Facies

Stratigraphy

The Palo Pinto Formation crops out in the southeastern third of the mapped area (Geologic Map, Plate 1JW). The formation consists of about 165 feet of intercalated limestones and shales (section 48, Cross-Section E-E′, Plate 3JW). The base of this formation is the base of the thickest limestone (bed PP) in the formation; it conformably overlies the Keechie Creek Shale. Where the basal contact can be observed the limestone is generally underlain by a thin sandstone. The top of the unit is picked at the top of the highest continuous limestone and is readily identified in the field.

Several other intervals within the Palo Pinto Formation can be identified over much of the mapped area. Only the limestones were designated for control. The recognizable datums are bed PP, bed A which persists throughout the area, bed B which is a sequence of intercalated limestones and shales with no individual unit being persistent, bed C which is mappable from Kyle Mountain southward, and the uppermost persistent bed (Cross-Section E-E′, Plate 3JW).

Limestone lithology

Limestones with a micritic matrix are the dominant lithologic types and they are generally fine-grained. A single allochem in limestones with a micritic cement is uncommon. Although platy algae remain the dominant allochem, algmicrites are rare. In order of decreasing abundance the major allochems are platy algae, echinoderm fragments, bryozoans, productid brachiopods and bellerophontid gastropods. Rugose corals occur in the top bed in the vicinity of Schoolhouse Mountain (sections 44 and 45).

Syringopora are present in bed PP and a zone of these skeletal corals may be a mappable zone. Where these corals occur they form the only skeletal limestones or biolithites observed in the Palo Pinto Formation. During deposition they were more indurated than surrounding sediments as evidenced by thin fusmicrite draped over these colonies on Elm Creek (Geologic Map, Plate 1JW).

Argillaceous limestones are typical of Palo Pinto limestones and are more abundant south and east of Shutin Mountain. Thin plates of chert, as in section 43, bed IIA, are believed to be associated with increasing clay content.

Winchell Calcareous Facies

Stratigraphy

The Winchell Formation is predominantly limestone and ranges in thickness from 70 to 190 feet. The top is not shown on any of the measured sections (Plates 2JW-6JW). On State Highway 16 west of Loving Creek the top of the formation is the contact between the uppermost limestone of the Winchell unit and an overlying yellowish brown shale. The base is the contact between a basal sandstone and the highest shale strata of the underlying Wolf Mountain Formation (section 1, Cross-Section A-B-C-D, Plate 2JW). This sandstone is included in the Winchell Formation because it appears genetically related to the succeeding limestone deposition.

Although the base and top of the Winchell Formation are readily mapped, persistent horizons within this formation are rare. The most persistent bed is bed M (inset on Geologic Map, Plate 1JW) which is characterized by a *Myalina* fauna. Bed IVa in sections 1 through 5 can be traced in the northern part of the area. Fusulinid beds are mappable in the vicinity of Crawford Mountain (sections 9-12, Cross-Section A-B-C-D, Plate 2JW).

Facies

Depending upon the volume and type of limestones, the character and stratigraphic position of the sandstones, and the amount of shale, three lithologic facies of the Winchell Limestone can be recognized in the field. They are a bank facies, an off-bank facies, and a fusulinid-rich facies. The areal extent of the three Winchell facies are shown in Figure 3; vertical relationships are illustrated by schematic diagrams as insets on Cross-Sections A-B-C-D, A-A′, B′-B-B″, and C-C″ (Plates 2JW-6JW). A fourth facies, the *Aviculopinna* facies, is identified in section 7, Cross-Section A-B-C-D (Plate 2JW) and could possibly be extended southwestward by additional mapping.

Bank facies.—The bank facies is confined to the northwestern third of the Winchell outcrop (Fig. 3). This facies consists predominantly of clastic limestones with thin shale beds. This section is underlain by a massive sandstone (section 1, Cross-Section A-B-C-D, Plate 2JW). The sandstone is a thinly laminated, gently cross-bedded, fine-grained quartzose sandstone, and it is believed to underly the bank limestones throughout the area (Cross-Sections A-B-C-D and A-A′, Plates 2JW and 4JW). This sandstone crops out infrequently because of slumping.

It was previously noted that a Winchell limestone bank is present in the subsurface (Wermund and Jenkins, 1964) and that it first crops out near the dam (Fig. 1). In the typical bank facies near the dam, biosparites are abundant and commonly contain numerous osagiid-like algae. Limestones with a micritic matrix represent about two-thirds of the limestone of which half is algmicrite. Platy algae in this area are commonly fragmented and not as large as those in algmicrites to the east and north (Cross-Sections A-B-C-D, A-A′ and B′-B-B″, Plates 2JW, 4JW and 5JW). Brachiopod allochems are usually *Neospirifer* and *Composita.* Some rugose corals are present.

The only observed skeletal limestone or biolithite occurs in this same area of exposed bank facies. Two large cabbage heads of cryptozoan algae crop out in the south-flowering ravine immediately east of the dam. These algal structures form a skeletal mass up to six feet in diameter.

Less biosparite is present north of the dam (sections 20-22) and east of the dam (sections 2-5, 27-28 and 6) as one maps the upper

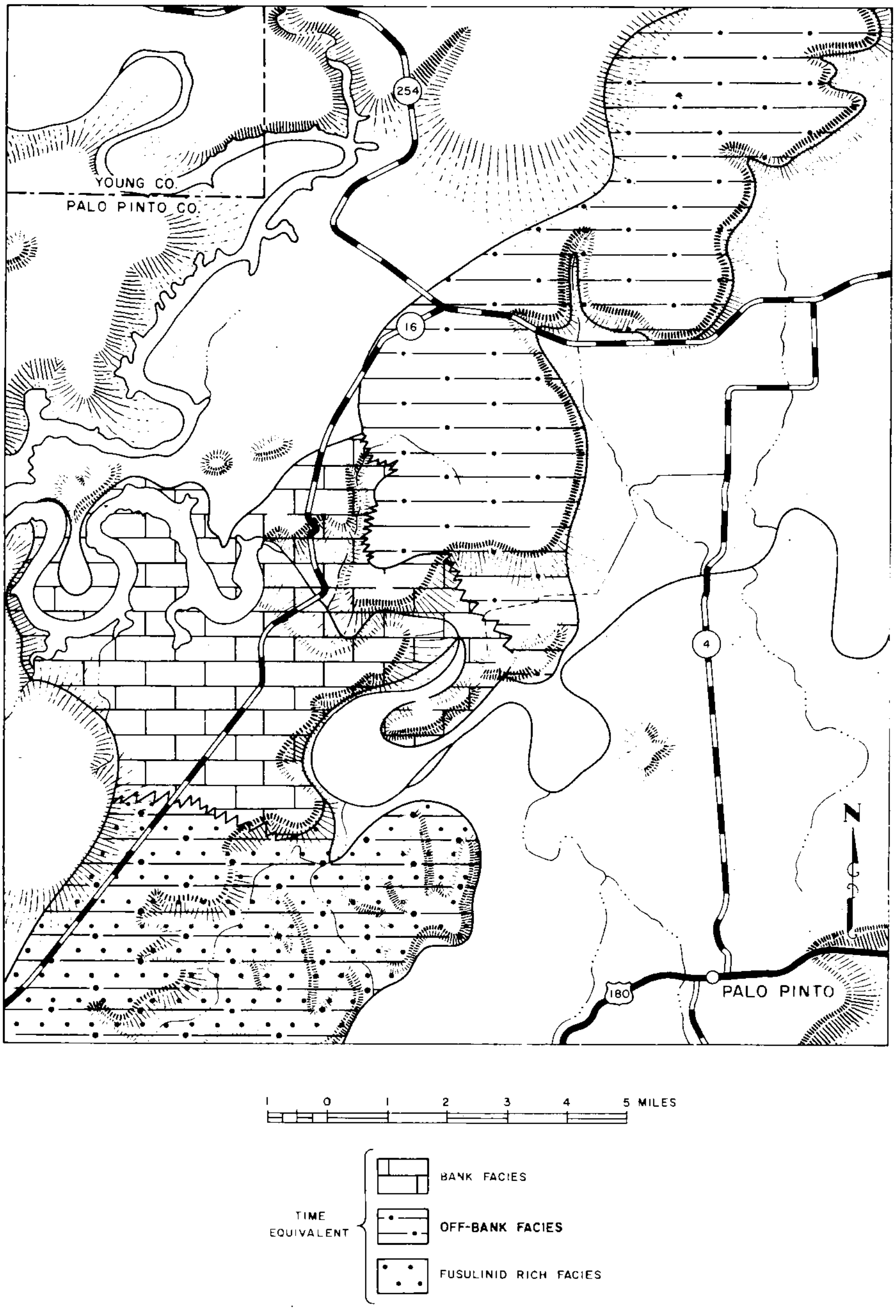

Figure 3. Distribution of major Winchell facies.

bank facies into the off-bank facies and the lower bank facies into a terrigenous facies. The algmicrites in the same localities become more abundant and contain large unbroken algal plates. Limestones with micritic matrix of all types become increasingly argillaceous. As the limestones increase in the clay content, fusulinids become more significant allochems and the most common productid brachiopod is *Echinoconchus*. Not far from the more typical bank facies (sections 2 and 22) the M- or *Myalina* bed becomes a useful marker horizon. Close to the bank it is a biosparite and away from the bank it has conspicuous amounts of quartz sand. Where this bed is composed only of calcite no *Myalina* are present and where the content of quartz sand is great *Myalina* does not occur. Only broken fragments of this fossil, usually the beaks, are present.

In the typical bank facies the bedding planes are generally parallel, and beds are consistent in thickness. The limestones with micritic matrix are thin-bedded for the most part and become increasingly nodular as the limestones become increasingly argillaceous. The nodules include concentrations of fossils and are surrounded by finer micrite and clay. The depositional dip of the limestones with micritic matrix is always horizontal. The limestones with sparry matrix appears massive and thick in typical bank facies but decrease in thickness to the north and east. In the north-south ravine just east of the dam, biosparites with dips up to 5 degrees are present in the upper bank facies.

Off-bank facies.—The off-bank facies grades into the upper part of the bank facies and its areal extent is shown in Figure 3. Reconnaissance mapping confirms that the Winchell Formation extending beyond the mapped area is the off-bank facies. Measured sections of exposed Winchell off-bank facies have been reported both north and south of the study area by Feray and Jenkins (1954, sections 60 and 68, p. 38). In the southeastern part of the mapped area, near Crawford and Antelope Mountains, the off-bank facies overlies the fusulinid-rich facies (Cross-Section A-B-C-D, Plate 2JW).

In typical sections of the off-bank facies north of the Brazos River, sections 25 (Cross-Section A-A′, Plate 4JW) and 33 (Cross-Section B′-B-B″, Plate 5JW), the facies contains a basal sand, a shale, the quartzose *Myalina* sparite and an overlying biosparite. The thickness of this facies approximates 40 feet; however, the top has not been observed.

The sandstone is generally thinly laminated and cross-bedded. The cross-laminae in some outcrops have dips up to 10 degrees; where cross-bedding is steeper, chert pebbles are common in coarser-grained sand. The sandstone grades transitionally into bank limestones at two localities—near sections 28 (Cross-Section B′-B-B″) and 38 (Cross-Section C-C′, Plate 6JW). At these localities the sandstone is increasingly calcareous with sparry calcite cement. As the quartz decreases the matrix and/or sand becomes micritic. Where the quartz is absent the micritic limestone becomes an algmicrite.

The shale adjacent to the bank-facies is slightly fossiliferous and calcareous. Farther from the bank-facies the fossils and marls, slightly indurated calcareous clays, wedge out (e.g., see sections 32, 33 and 34, Cross-Section B′-B-B″, Plate 5JW).

The overlying biosparite in the off-bank facies north of the Brazos river is generally underlain by the *Myalina* bed. At the northernmost locality on the geologic map, the equivalent bed does not contain *Myalina* and is a calcareous sandstone. The biosparite contains fewer osagiid-like algae than the equivalent limestone of the bank facies, but it does contain more echinoderm remains, bellerophontid gastropods and bryozoans. It is also more stylolitic.

South of the Brazos River where it overlies the fusulinid-rich facies, the off-bank facies is thicker and attains a thickness of 75 feet (section 10, Cross-Section A-B-C-D, Plate 2JW). This approximates the thickness of the Winchell Formation at Canyon type locality (Laury, 1962). Southward the off-bank facies is finer-grained than the same facies north of the river. Algmicrites and intramicrites are predominant.

Fusulinid-rich facies.—The fusulinid-rich facies is present only south of the Brazos River and is approximately equivalent to the lower half of the bank facies. It is characterized by several beds that are formed entirely of fusulinids bound in a micritic matrix. The fusmicrites are observed to grade laterally into sandstone at several locales (e.g., sections 11 and 12, Cross-Section A-B-C-D). The facies has not been accurately correlated with outcrops north of the river. It is possible that the fusulinid-rich facies would grade into the *Aviculopinna* facies.

TERRIGENOUS FACIES

Palo Pinto Formation

The Palo Pinto Formation is defined as a unit of intercalating shales and limestones. The formation has the least amount of shale in exposures near Shutin Mountain, and the amount of shale increases eastward and southward. The shales are generally light gray and nonfossiliferous with two exceptions. One is the shale between limestone beds PP and A (Cross-Section E-E′, Plate 3JW) as it is generally fossiliferous. Note the increase in thickness of this bed between sections 43 and 48. The other exception is the fossiliferous shale underlying the top bed. It is only fossiliferous in the northwesternmost exposures (sections 42 to 45, Cross-Section E-E′). Southwest of the river an equivalent shale contains a medium-grained sand. The sand is generally cross-bedded and frequently contains mud balls and wood fragments.

Wolf Mountain Formation

The formation ranges in thickness from 175 to 250 feet and is predominantly shale. The base lies conformably on the uppermost limestone of the Palo Pinto Limestone, and the top of the formation underlies the lowest limestone or sandstone bed of the Winchell Limestone.

The Wolf Mountain Shale is mostly brown, nonfossiliferous shale. It also contains laterally discontinuous beds of sandstone, limestone, marl and carbonaceous shale. Although the formation is mappable *in toto*, individual horizons cannot be traced within the formation for more than four miles. Certain fossiliferous zones are locally mappable such as the bryozoan zone near the top of the unit (section 34, Cross-Section B′-B-B″, Plate 5JW and section 4, Cross-Section C-C′, Plate 6JW) and the crinoidal conglomerate beneath the carbonaceous shale (sections 31-34). A bryozoan marl, about 30 feet above the base, is the most continuous bed in this part of the section (sections 6-12, Cross-Section A-B-C-D, Plate 2JW). The shale immediately overlying the bryozoan marl contains rugose corals and clayey or phosphatic nodules which weather white. Near Crawford and Antelope mountains, sand lenses (between 180 and 220 feet in section 8) are present.

Fossiliferous zones in the upper shale are usually equivalent to nearby limestones. In the lower 40 feet of the Wolf Mountain Formation the shale contains numerous fossils (section 7). These fossils include pelecypods (*Myalina, Nucula,* and *Astartella*), brachiopods (mainly *Chonetina* and some *Marginifera*), bryozoans (mostly fenestrate), gastropods (*Worthenia, Trepospira,* and *Glabrocingulum*), echinoid and crinoid fragments, rugose and minute colonial corals, and one trilobite species. The upper 50 feet of the Wolf Mountain Shale are also fossiliferous (sections 27 and 34) and upper fossiliferous zones are the lateral equivalents of the lowest limestones of the Winchell Limestone.

The Wolf Mountain Shale is less fossiliferous to the southwest near Crawford Mountain (section 9). Clay ironstone nodules are present through the formation and are abundant in the 60 to 80 feet of strata that includes a carbonaceous shale (sction 34). Weathering processes often emphasize the presence of these nodules and extensive exposures are present in which the slopes are literally covered by them. Many lower slopes of the Wolf Mountain Shale are also covered by fragments and crystals of gypsum. The gypsum is related to jointing and slump fractures and, therefore, may be a product of weathering.

CALCAREOUS-TERRIGENOUS TRANSITIONS

Distribution of Palo Pinto and Winchell Limestones

The major differences between the distribution of calcareous and terrigenous facies in the Palo Pinto and Winchell Formations results from the position of a limestone bank relative to the outcrop. Only the off-bank facies of the Palo Pinto Limestone is exposed, but the main part of the Winchell bank crops out in the mapped area. Other facies differences in the two units are related to the kind of contact between formations above and below the Palo Pinto and Winchell Limestones. The basal surface of Palo Pinto is nearly planar, but the basal surface of the Winchell is irregular as shown in Figure 4.

The calcareous facies always interfingers with a shale facies normal to the long direction (sedimentary strike) of the banks. In the Palo Pinto Limestone this facies change starts near the midpoint of the section, but in the Winchell Limestone it begins at the base of the section.

The highest as well as the lowest strata of the Palo Pinto bank persist for considerable distances, but only the uppermost beds of the Winchell bank are continuous. In outcrops the upper and lower contacts of the Palo Pinto are planar, but only the upper contact of the Winchell is planar. Therefore, the geometry of the Palo Pinto and Winchell banks differ in cross-section if their off-bank facies are included (Fig. 4). A cross-section of the Palo Pinto bank appears as

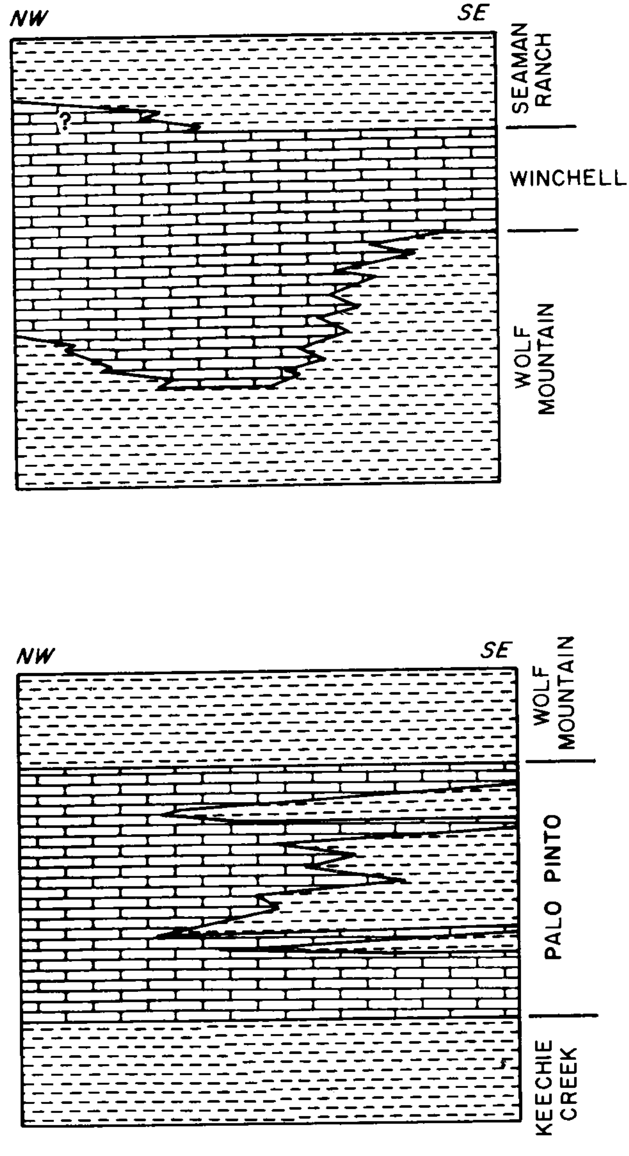

Figure 4. Calcareous-terrigenous transitions of the Palo Pinto and Winchell Limestones .

a fork in which the two outside tines are thicker and longer than those in the center. A cross-section of the Winchell bank approximates the serrated lower half of a circle.

Palo Pinto

The relatively consistent thickness of Palo Pinto exposures suggests that its planar base and top approximate time planes (Cross-Section E-E′). The lowest limestone (PP) represents a time of a widespread limestone deposition. Allowing for some downdip thickening, the bank core in the subsurface (Fig. 1) is only 30 to 40 feet thicker than surface exposures.

In addition to the thickness difference, a marked lithologic change occurs in the near off-bank (section 43, Cross-Section E-E′) and far off-bank equivalents (section 47). The entire Palo Pinto Formation represents an off-bank facies. In the interval from station 43 toward section 47 the unit becomes increasingly terrigenous in the middle of the sequence. Shales become less fossiliferous and contain increasing amounts of clay ironstone nodules. Sandier strata form an increasing volume of the facies. Limestones in the same interval change from gray to brown, become increasingly argillaceous, increase in micritic matrix, appear more ferruginous, and are less fossiliferous. The amount of limestone in the formation also decreases.

Winchell-Upper Wolf Mountain

The Wolf Mountain Formation is defined as a shale; the Winchell Formation is defined as a limestone. In the mapped area the contact between the two stratigraphic units is a facies boundary, an interfingering contact. This is illustrated by the contact as mapped in the headwaters of Loving Creek drainage (Geologic Map, near sections 20-26), on the south-facing escarpment of Rocky Prairie (Geologic Map, near sections 29-34), and on Shutin Mountain (sections 6-41). It is also evident at the contact on the cross-sections. Inasmuch as the lowermost limestones of the Winchell bank are not widespread, some exposures of the uppermost Wolf Mountain strata are commonly the time equivalents of lower Winchell bank facies.

The facies change from lower bank limestones into shale is best observed at two localities: at the head of Loving Creek near section 26 (Cross-Section A-A′) and in the south-facing escarpment of Rocky Prairie (Cross-Section B′-B-B″). The two localities are considered representative of the calcareous-terrigenous transition observed elsewhere.

In Cross-Section A-A′ (Plate 4JW) the following transitions were observed on the right bank of Loving Creek between sections 21 and 26. Thin regularly bedded limestones with a micrite matrix and algmicrites become dominantly nodular-bedded argillaceous algmicrites with locally abundant sponges. The sponges are tentatively identified as *Heliospongia*. In turn, the argillaceous algmicrites grade laterally into fossiliferous marls within a distance of 100 feet. The marls are replaced by shale within an additional 100 feet. The brachiopods *Composita* and *Echinoconchus* occur only in limestone; *Marginifera* and *Juresania* are present in the marls; and *Chonetina* occurs only in shale. Fenestrate bryozoans occur in limestone and marl, but only branching cylindrical bryozoans are present in the shale. Pinnate pelecypods are found in limestone but *Nucula, Nuculana,* and *Astartella* usually occur in the shale. No gastropods were observed in the limestone but pleurotemerid gastropods are common in equivalent shale. At the same locality the *Myalina* bed grades transitionally from a biosparite with platy algae into a calcareous sandstone containing *Myalina, Marginifera* and bellerophontid gastropods.

In Cross-Section B′-B-B″ (Plate 5JW) the following transitions are present between sections 28 and 34. Lower Winchell limestones with a micritic matrix become increasingly argillaceous with thicker clay partings between limestone beds. As the clay content increases platy algae and fusulinids become more abundant. *Composita,* which is relatively abundant in equivalent pure limestones, disappears with the increase of terrigenous particles. Where the limestones pinch out equivalent shales contain large branching cylindrical bryozoans, peanut-shaped sponges, and rare fusulinids. Higher in the Winchell, limestones grade transitionally into sandstone. Lateral transitions of limestone into sandstone or shale are present in relatively short distances. Twenty feet of limestone passes laterally into sand and 75 feet of limestone grade laterally into shale in less than one quarter mile.

DISCUSSION

Regional Framework

The sediments in the mapped area are only a local representation of sedimentation on a broad marine shelf. Subsurface structure and isopach maps indicate that the late Pennsylvanian shelf had regular topography of low relief, about 30 feet or less. (Wermund and Jenkins, 1964). Allowing for compaction, no evidence of relief or depositional topography is obvious in the surface stratigraphy. The predominance of algae and fenestrate bryozoans in the limestones, the abundance of crinoid and echinoid remains in limestones and shales, the presence of *Aviculopinna*, the *Myalina* in the sandy limestones, and the molluscan assemblage in the shales all suggest shallow marine deposition, probably never deeper than 100 feet. The algae were dependent on light, and in the Missourian sedimentary framework which contained so much mud the water was probably turbid.

In Palo Pinto County, the Keechie Creek Shale-Palo Pinto Limestone and the Wolf Mountain Shale-Winchell Limestone sequences are repeated higher in the section (Fig. 1). Above the Winchell Limestone vertical alternations of shale and limestone are repeated twice by the Seaman Ranch-Ranger units and Hog Creek-Home Creek strata. These alternating shale-limestone cycles can be traced approximately 180 miles along strike from the Colorado River to Wise County. On the Colorado River the Keechie Creek-Palo Pinto cycle is obscure, and a shale-limestone sequence (Brownwood-Adams Branch) is mappable between the Keechie Creek-Palo Pinto and Wolf Mountain-Winchell cycles. In the mapped area this intermediate cycle may be represented by the sequence of shale plus the bryozoan bed in the lower Wolf Mountain Shale that overlies the Palo Pinto Formation (Cross-Section C-C′, Plate 6JW).

Throughout the Missourian series the same shale fauna is generally present. The variations of facies for each major stratigraphic unit are similar throughout the series. The limestone facies appear to be related only to distance from bank (areal) and not to vertical changes (time). Because of like bio- and litho-relationships, any one stratigraphic unit may be confused with another similar facies if its vertical position is unknown.

Genesis of Limestone Banks

Numerous interdependent variables control the size, position, and character of limestone banks. They include: (1) the kind of organism or organisms primarily responsible for bank growth; (2) the bottom sediment-type which influences both the organic populations and the turbidity of the water; (3) the position of major currents affecting food supply and minor currents controlling the grain size of sediments; (4) the depth of water as influenced by fluctuations in sea level, bottom topography, or a combination of these factors; (5) depth to wave base; (6) the rate of terrigenous sedimentation; and (7) the maximum depth of light penetration as affected by depth and turbidity of the water. Few of these variables can be directly observed on the outcrop. Some could be determined from statistical analyses of sedimentary properties, but many must be inferred.

The primary bank builders in north-central Texas Pennsylvanian rocks are platy algae and fenestrate bryozoans. The abundant algae indicate that the banks were deposited above the maximum depth of light penetration. Both bryozoans and crinoids require a food supply of micro-organisms. The bottom sediments, over which the first bank sediments were deposited, are generally sandstones, silty shales, and very fossiliferous shales. These would form firm bottoms and make a sediment-water interface of low turbidity. Textures and structures are found in both limestones and sandstones indicating that current deposition was common. A study of the distribution of coarser limestones and diagnostic structures in sandstones was not conducted as a part of this work. Within exposures of the bank proper the terrigenous sediments are rare. This suggests that the rate of terrigenous sedimentation may have decreased during times of bank deposition.

No paleorelief is apparent at the base of the Winchell bank, as noted earlier. However, the writer believes that the bank stood slightly higher than its adjacent sediments during deposition. At the head of the ravine just east of the dam (Plate 1), granular limestones of the bank facies have steeper initial dips approaching 10 degrees. Polished specimens of bank limestones commonly have offset fractures which might have resulted from sliding on a slope, although desiccation can also explain them. Within any one bank the last type of calcareous deposition is generally granular—as evidenced by common biosparites composed almost entirely of osagiid-like algal pellets. The granular limestones appear to have been winnowed—perhaps on higher topography.

A regional control appeared to have been exerted over sedimentation in this area during Missourian time. It appears unlikely that the superposition of the Palo Pinto and Winchell banks at nearly the same locality is coincidental because two higher banks, Ranger and Home Creek, also superpose older banks at about the same place.

Several possibilities may explain the superposition of Missourian limestone banks. First, there may be a structural element having time continuity. From a continuous positive structural element having periodic movement one might infer a structurally controlled topographic high as a suitable environment for bank building organisms. No field evidence supports the assumption of structural control. Second, effects of compaction may explain the superposition of banks with the bank being topographically higher during bank building. The older and buried limestone banks being less compressible than surrounding shale may affect the depositional surface of younger sedimentation. Two observations from field mapping support this hypothesis. In both the Palo Pinto and Winchell Formations the off-bank facies are less thick than the bank facies. In the nodular-bedded argillaceous limestones it is observed that the fossiliferous limestones are thicker than laterally equivalent argillaceous limestones. At some locations it is observed that thin shale, up to 1 centimeter, drapes over and under calcareous nodules. This draping is believed a small scale representation of the larger situation of less compressible limestone and more compressible shale.

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APPENDIX I

LOCATIONS OF MEASURED SECTIONS

Section 1. Measured northward up the cliff opposite the Power House of Morris Shephard Dam. Starting elevation—900 feet. Modified after Jenkins and Feray (1954, figure 35).

Section 2. Measured northeastward up northern escarpment at the confluence of Loving Creek with the second westward flowing tributary from the mouth of the main stream. Top of *Myalina* bed—1148 feet.

Section 3. Measured up south-facing escarpment overlooking the Brazos River just east of the southward flowing drainage that flows into Loving Creek near its mouth. Top of *Myalina* bed—1186 feet.

Section 4. Measured down south-facing escarpment of the Brazos River opposite house in Garland Bend. Top of *Myalina* bed—1184 feet.

Section 5. Measured down the southeastward facing escarpment of Rocky Prairie on a ranch road and goat trail. Top of *Myalina* bed—1168 feet(?).

Section 6. Measured up the westernmost point of Shutin Mountain from the top bed of Palo Pinto Limestone where it crops in the drainage between Shutin and Schoolhouse Mountains. Top of the Palo Pinto Limestone—938 feet.

Section 7. Measured from first draw east of pecan grove and goat pen due north up the south face of Schoolhouse Mountain. Top of Palo Pinto Formation—928 feet.

Section 8. Measured on northernmost prong of Crawford (Wolf) Mountain. Elevation on the top of the Palo Pinto Formation—978 feet.

Section 9. Composited from measurements up south side of Crawford Mountain outlier out of Harris Creek and up westernmost scarp of Crawford Mountain. Top of Palo Pinto Formation—1006 feet.

Section 10. Measured from top of spillway on a stock tank up a jeep road on the south side of Crawford Mountain. Top of spillway—1187 feet.

Section 11. Measured up the southwestern tip of Crawford Mountain from the top of the Palo Pinto Formation where it crops out as a bench on the ranch road adjacent to the westward flowing drainage into Harris Creek. Top of the Palo Pinto—1061 feet.

Section 12. Measured westward up the escarpment of Antelope Mountain from U.S.G.S. Bench Mark LB 10. Top of Palo Pinto Formation—1073 feet.

Section 13. Measured up south-facing escarpment overlooking the Brazos River between Morris Shephard Dam and State Highway 16. Base of highest measured bed—1058 feet.

Section 14. Measured up (northward) on State Highway 16 from its intersection with road into powerhouse at Morris Shephard Dam. Intersection—915 feet.

Section 15. Measured down first eastward flowing stream east of Morris Shephard Dam. Base of measured section—984 feet.

Section 16. Measured down first southward flowing drainage east of State Highway 16. Starting elevation—1080 feet.

Section 17. Measured up westward flowing drainage in Winchell escarpment. Drainage part of system measured in sections 18 and 19. Base of section—1008 feet.

Section 18. Measured down the south-facing escarpment overlooking the Brazos River just east of State Highway 16. Top of section—1090 feet.

Section 19. Measured down center of south-facing escarpment overlooking the Brazos River between Highway 16 and Loving Creek. Top of section—1110 feet.

Section 20. Measured down western point on escarpment resulting from the intersection of Brazos River and Loving Creek. Top of section—1095 feet.

Section 21. Measured down east-facing escarpment overlooking Loving Creek opposite westward draining tributary, the fourth tributary north of the mouth of Loving Creek. Top of section—1092 feet.

Section 22. Measured down point occurring between fourth and fifth westward flowing tributaries above mouth of Loving Creek. Top of *Myalina* bed—1062(?) feet.

Section 23. Measured up small westward flowing branch of southward flowing tributary, fifth above mouth of Loving Creek. Top of *Myalina* bed—1068 feet.

Section 24. Measured westward up west escarpment of Loving Creek along fence line between Hinkson and Kimberlin properties. Base of section—965 feet.

Section 25. Measured south and east from the main branch of Loving Creek where it is forded by the north-south ranch road. Top of the *Myalina* bed—1046 feet.

Section 26. Measured up escarpment at intersection of northern branch of Loving Creek with an eastward flowing tributary that flows under State Highway 16. Top of *Myalina* bed—1026 feet.

Section 27. Measured up the eastward facing escarpment of the Winchell outcrop one-half mile northeast of where the top bed of the Palo Pinto Formation crosses the Brazos River. Top of the *Myalina* bed—1175 feet.

Section 28. Measured down the eastward facing Winchell escarpment from the southernmost intersection of the Dalton and Kimberlin properties. Top of *Myalina* bed—1146 feet.

Section 29. Measured up the Winchell bench at its southernmost point along the southward facing escarpment of Rocky Prairie.

Section 30. Measured up southward flowing drainage just east of the large bench of lower Winchell Limestone below Rocky Prairie.

Section 31. Measured up the south-facing scarp of Rocky Prairie from stock tank into primary drainage of the scarp. Top of the *Myalina* bed—1193 feet.

Section 32. Measured up the southward facing escarpment below Rocky Prairie in the eastern part of the major southward flowing drainage. Top of the *Myalina* bed—1208 feet.

Section 33. Measured down the southward facing point of the Winchell escarpment about Rocky Prairie. Top of the *Myalina* bed—1214 feet.

Section 34. Measured down the southeasternmost point of the escarpment that borders Rocky Prairie. Elevation on top of the *Myalina* bed—1226 feet.

Section 35. Measured up the south-facing escarpment of Shutin Mountain from the top bed of the Palo Pinto Limestones where it crops immediately below a stock tank and on an old ranch road which encircles both Shutin and Schoolhouse Mountains. Top of the Palo Pinto Formation—978 feet.

Section 36. Measured along jeep road from locked gate onto the McMurray property and northward up Shutin Mountain. Top of *Myalina* bed—1296 feet.

Section 37. Measured up the southward facing escarpment of Shutin Mountain from the top of the Palo Pinto Formation just east of intersection of ranch roads: one encircling Shutin and Schoolhouse Mountains and the other turning south toward the Brazos River. Top of Palo Pinto Formation—1019 feet.

Section 38. Measured down south-facing escarpment of Shutin Mountain from landslide area down to locked gate on the only ranch road on the south side of the mountain. Top of the Palo Pinto Formation—1022 feet.

Section 39. Measured down the north-facing scarp of Shutin Mountain to McMurray fence line as located on the Geologic Map. Top of *Myalina* bed—1295 feet.

Section 40. Measured down the south-facing escarpment of Shutin Mountain at location shown on the Geologic Map. Top of Palo Pinto Formation—996 feet.

Section 41. Measured northwestward up to the easternmost part of Shutin Mountain from the top of the Palo Pinto Limestone. Starting elevation—990 feet.

Section 42. Measured down first westward flowing tributary north of Shutin Mountain from intersection of the top of Palo Pinto Formation with major local ranch road. Top of Palo Pinto Formation—914 feet.

Section 43. Measured down south-facing escarpment on the Brazos River and down intermittent stream that drains the easternmost area of Shutin Mountain. Top of the Palo Pinto Formation—992 feet.

Section 44. Measured down the left bank (north) of the Brazos River on the McMurray Ranch, one-half mile west of State Highway 4. Top of the Palo Pinto Formation—1005 feet.

Section 45. Measured along Texas Highway 4, from the top of first hill north of Brazos River south to base of Bed A. Cross to south bank of river and measured down from base of bed A toward the Brazos River. Starting elevation—1002 feet.

Section 46. Measured along road in Worth Ranch Boy Scout Camp above and below the caretaker's home. Elevation on top of the Palo Pinto Formation—1075 feet.

Section 47. Measured from second gate on first ranch road that is south of Kyle Mountain on Texas Highway 4. Section above C bed measured up the fence line. Section below C bed measured down southward flowing drainage. Elevation on eroded top bed—1073 feet.

LEGEND FOR PLATES 2JW THROUGH 6JW

SPARITE

MICRITE

MICRITE WITH NODULAR BEDDING

MARL

SHALE

SANDSTONE

SANDSTONE, GENTLY CROSS-BEDDED

SANDSTONE, STEEPLY CROSS-BEDDED

SANDSTONE, CONTORTED BEDDING

COVERED

ARGILLACEOUS

CLAY IRONSTONE NODULES

CHERT

INTERCLASTS

FOSSILS

PLATY ALGAE

SYRINGOPORA CORALS

CORRELATION LINES: MAPPED; INFERRED

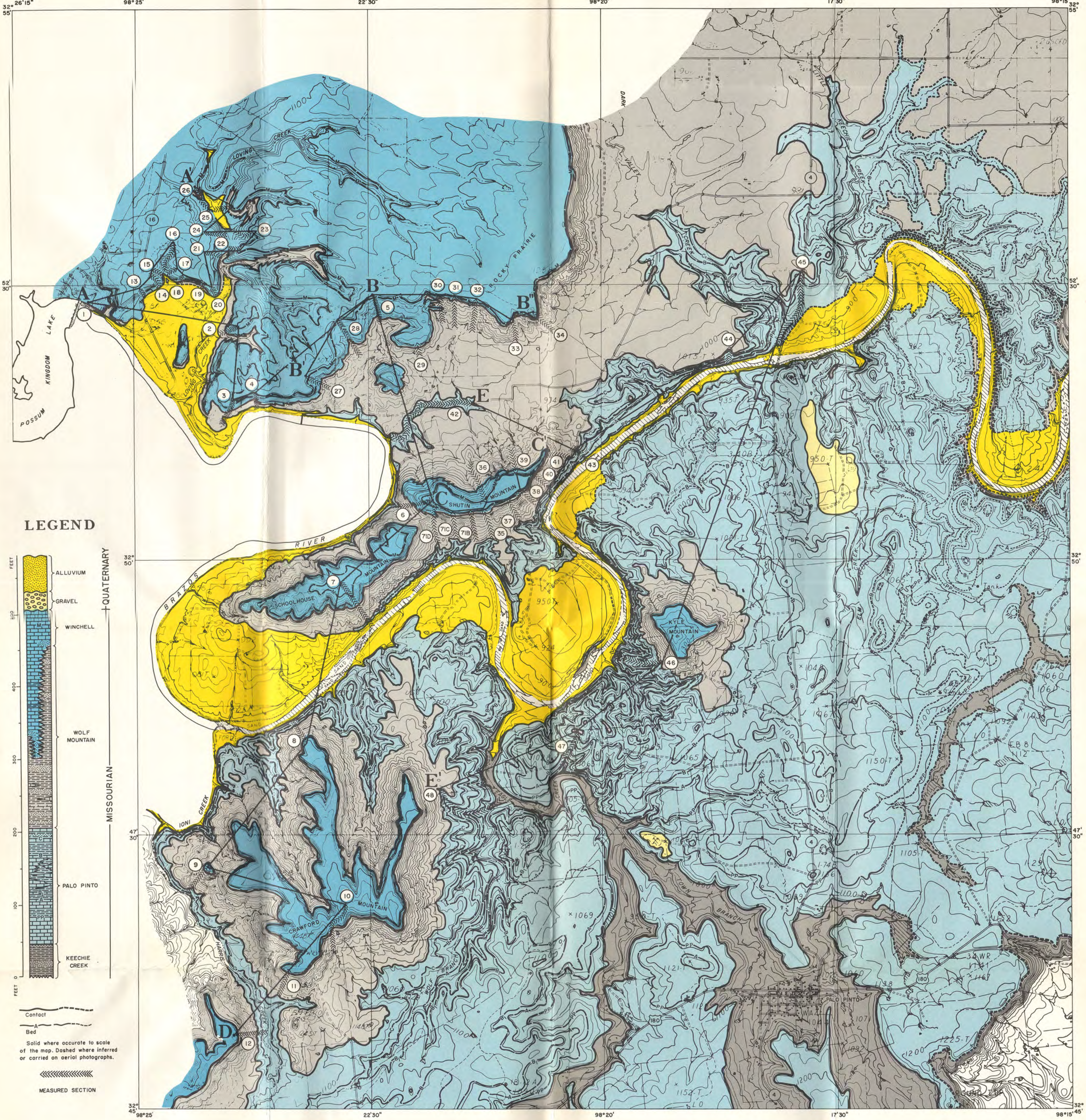
BASE OF WINCHELL

KEY TO LITHOLOGIC DESCRIPTIONS

ab = abundant
alg = algae
ar = arenaceous
arg = argillaceous
bed = bedding
bel = bellerophontid
br = brown
brach = brachiopod
bry = bryozoan(s)
cal = calcareous
carb = carbonized
cem = cement
ceph = cephalopods
cht = chert
cly = clay
col = column(s)
com = common
conc = concretion(s)
congl = conglomerate
cont = contorted
cor = coral
crin = crinoid
crm = cream
crsts = crusts
cse = coarse
csr = coarser
dcrs = decreasing
dk = dark
echin = echinoderm
fen = fenestrate
fer = ferruginous
fl = flag(gy)
flt = float
fn = fine
fol = foliae
fos = fossil(s)
frg = fragments
fus = fusulinid
fw = few
gas = gastropod(s)
grnd = grained
gr = green
gry = gray
honcmb = honeycombed
intra = intraclasts
intrb = interbedded
irg = irregular
lam = lamination
len = lens(es)
lg = large
lt = light
mass = massive
med = medium
mny = many
mks = marks
motl = mottled
mst = most(ly)
nod = nodule(ar)
num = numerous
or = orange
part = partings
pbl = pebble
pel = pelecypods
pit = pitted
pl = pleurotomerid
plty = platy
pnk = pink
por = porous
prb = probably
prod = productid
qtz = quartz
r = rare
res = resistant
rgh = rough
rip = ripple
rug = rugose
sh = shale
sid = siderite(ic)
sl = slightly
slty = silty
sm = small
sndy = sandy
sol. = sole
spks = specks(led)
ss = sandstone
sty = stylolitic
thn = thin
trans = transitional
v = very
vg = vug(gy)
vns = veins(lets)
w = with
wd = wood
weath = weathering
wht = white
y = yellow
z = zones

G = gravel
C = coarse sand
M = medium sand
F = fine sand
VF = very fine sand
S = silt-size and finer

PLATE 1JW



BASE TOPOGRAPHIC MAP COPIED FROM UNPUBLISHED MAP OF THE PICKWICK QUADRANGLE, U.S.G.S. PROOF, 1958.

GEOLOGIC MAP
OF THE
POSSUM KINGDOM VICINITY

SCALE 1:48,000

1 1/2 0 1 2 MILES

3000 0 3000 6000 9000 12000 FEET

1 .5 0 1 2 3 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
1960

GEOLOGY MAPPED IN 1959
GEOLOGY BY E. G. WERMUND, JR. DRAFTING BY A. S. PEARCE
FIELD RESEARCH LABORATORY
SOCONY MOBIL OIL CO., INC.

10°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION

CROSS-SECTION A-B-C-D

POSSUM KINGDOM VICINITY

PLATE 3JW

CROSS-SECTION E-E'
POSSUM KINGDOM VICINITY

CROSS SECTION A - A'
POSSUM KINGDOM VICINITY

PLATE 5JW

CROSS-SECTION B'-B-B''

POSSUM KINGDOM VICINITY


PLATE 6JW
CROSS-SECTION C-C'
POSSUM KINGDOM VICINITY
HORIZONTAL SCALE
C
C'
6
71D
71C
71B
35
36
37
71A
38
39
40
41
WINCHELL
WOLF MOUNTAIN
VERTICAL SCALE
MYALINA BED
LIMESTONE TO SANDSTONE GRADATION
FACIES CONTACT NOT EXPOSED
FACIES CONTACT NOT EXPOSED
FUSULINIDS
LIMESTONE FLOAT
LARGE BRYOZOA
LARGE BRYOZOA
BRYOZOAN MARL
DATUM
TOP OF PALO PINTO
BANK FACIES
OFF-BANK
FACIES
FUSULINID-RICH FACIES
TERRIGENOUS FACIES (WOLF MOUNTAIN SHALE)
OFF-BANK FACIES OF PALO PINTO FORMATION
NOTE: SECTIONS 71A THROUGH 71F MEASURED BY E. HEUER.
LIMESTONE LITHOLOGIES NOT DIFFERENTIATED.