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PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF PENNSYLVANIAN AND LOWER PERMIAN STRATA, TUCUMCARI BASIN

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INTRODUCTION

The Tucumcari basin of Guadalupe, Quay, Curry, De Baca and San Miguel Counties, northeastern and east-central New Mexico, is Middle Pennsylvanian to Early Permian in age. Little evidence of this basin can be garnered from surface geologic studies where gentle surface structures only vaguely mimic the large-scale, deeper, basinal structures. The Tucumcari basin (Fig. 1) is bounded on the north and west by the late Paleozoic Sierra Grande and Pedernal uplifts. Faults that bound the basin are chiefly Middle Pennsylvanian to Early Permian in age and some have vertical displacements of several thousand feet. Upper Pennsylvanian and Lower Permian strata thicken dramatically across these faults. Furthermore, the faults were a major controlling factor of basin geometry, and, because of this, they exhibit a strong control on sedimentary facies.

The Tucumcari basin has been the site of sporadic exploration and drilling for oil and gas during the last 50 years. Until now, commercial quantities of oil and gas have not been produced from the basin, but exploratory wells have encountered shows of oil and gas in Pennsylvanian, Permian and Triassic strata. Increased exploratory activity in the last five years has resulted in the discovery of oil and gas in Pennsylvanian rocks by Trans-Pecos Resources (now Gila Exploration) in Guadalupe County (Fig. 1, letter A) and by Yates Petroleum Corporation in western Quay County (Fig. 1, letter B). At the time this report was written, Trans-Pecos had initiated a gas-injection, enhanced, oil-recovery project to produce oil from their discovery.

This study was undertaken in order to investigate the late Paleozoic stratigraphy and structure of the Tucumcari basin. Comprehension of that stratigraphy and structure is crucial to understanding the distribution of petroleum source and reservoir facies within the basin. This report is preliminary and reflects only the initial stages of our study.

STRATIGRAPHY

Mississippian System

Arroyo Peñasco Formation

Strata assigned to the Arroyo Peñasco Formation unconformably overlie Precambrian basement and occur as scattered erosional outliers throughout the subsurface of the Tucumcari basin. Thickness varies from 0 to 300 ft (0–90 m) and is less than 150 ft (45 m) in most wells studied. In the subsurface of the Tucumcari basin, the Arroyo Peñasco Formation consists chiefly of two beds of limestone separated by a bed of siliciclastic mudstone. The limestones are generally dense and oolitic. Lithology and log signatures are uniform across the basin, although, in a few wells, either the upper or the lower limestone bed is absent. Assignment of this rock unit to the Arroyo Peñasco Formation is based on lithologic similarity to the Arroyo Peñasco of the Sangre de Cristo Mountains (Armstrong, 1967; Foster et al., 1972) and the presence of an unconformity between it and overlying Pennsylvanian rocks.

Pennsylvanian System

The Pennsylvanian System in the subsurface of west Texas and eastern New Mexico is generally subdivided into time-rock units (series) on the basis of fusulinid zonation. In the Tucumcari basin, preliminary investigations have revealed that boundaries of time-rock units approximately coincide with well-defined, electric-log markers. Therefore, for this report, the Pennsylvanian is subdivided stratigraphically into time-rock units that are coincident with lithostratigraphic units. Western Texas nomenclature was used to facilitate correlation with the Palo Duro basin of the Texas Panhandle. Mid-continent equivalents of the western Texas terms are given in Table 2.

Morrowan Series

The Morrowan Series has not been identified by us in any of the wells we have studied in the Tucumcari basin. Within the basin, it is represented by an unconformity. The Morrowan Series is also absent from that part of the northwest shelf of the Permian basin which is located immediately south of the Tucumcari basin (Meyer, 1966).

Atokan Series

We have identified the Atokan Series in only one well in the Tucumcari basin, the Abercrombie and Hawkins No. 1 Nappier (Figs. 2, 3,

TABLE 1. Wells used in cross sections A–A′ and B–B′. Numbers refer to locations in Figure 1 and well-identification numbers in Figures 2 and 3.

Well	Operator, well no., lease, location (section-township-range, county)	Completion date (mo/yr)	Total depth (ft)
1	Continental Oil Co. No. 1 Leatherwood-Read 15-16N-17E, San Miguel	9/54	3,911
2	Cities Service No. 1 Driggers 22-11N-21E, Guadalupe	5/58	4,581
3	General Crude Oil Co. No. 1 Simpson 21-10N-23E, Guadalupe	7/55	9,151
4	Trans-Pecos Resources No. 1 Latigo Ranch A 2-9N-23E, Guadalupe	7/82	7,202
5	General Crude Oil Co. No. 1-1 State 2-8N-23E, Guadalupe	2/58	7,103
6	Husky Oil Co. & General Crude Oil Co. No. 1 Hanchett State 16-8N-24E, Guadalupe	3/56	7,244
7	Abercrombie & Hawkins No. 1 Nappier 22-5N-26E, DeBaca	10/49	5,560
8	Pure Oil Co. No. 1 Pure 31-3N-28E, DeBaca	9/46	6,469
9	Cities Service No. 1 Widner 17-4N-31E, Curry	4/54	7,348
10	Shell Oil Co. No. 1 Stephenson 2-3N-32 E, Curry	2/64	7,012
11	Texas Gulf Prod. Co. No. 1 Garrett 34-5N-34E, Curry	12/62	7,538
12	Union Producing Co. No. 1 Jones 18-5N-37E, Curry	5/53	8,180

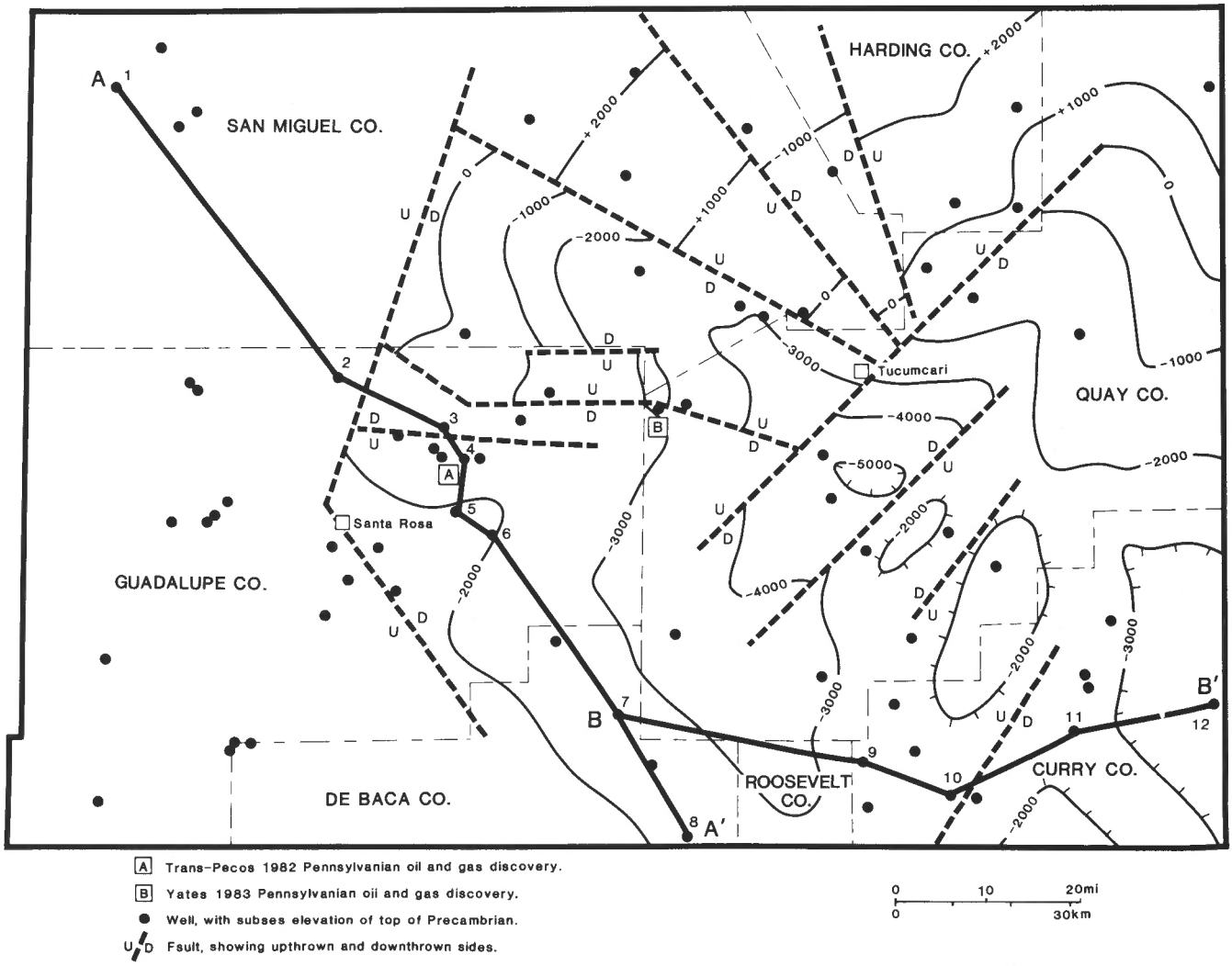

FIGURE 1. Study area, showing lines of cross sections A–A′ (Figure 2) and B–B′ (Figure 3), and structure contours on Precambrian surface. Map contoured from well data and the state gravity (Keller and Cordell, 1983) and magnetic (Cordell, 1983) maps. Numbers adjacent to wells refer to wells listed in Table 1.

well no. 7). In that well, the Atokan is 100 ft (30 m) thick and consists mostly of siliciclastic mudstone and minor amounts of light-gray, fine-grained sandstone. Its presence as a relatively thin layer in only one of the wells that we studied indicates that there is an unconformity on top of the Atokan and that the Atokan is present in the Tucumcari basin as scattered erosional remnants.

Strawn Series

The Strawn Series is present throughout most of the Tucumcari basin, but is absent over some buried uplifts, including parts of the Sierra Grande uplift (Figs. 2, 3). The Strawn is 0–1200 ft (0–370 m) thick in the basin and is more than 400 ft (120 m) thick in most wells studied. Generally, thicker areas of Strawn coincide with structurally low areas of Precambrian basement. The contact with the overlying Canyon Series is apparently conformable in most places, but is disconformable over Pennsylvanian-age positive structural elements.

The Strawn is composed of interbedded limestone, sandstone and siliciclastic mudstone. The sandstones are medium- to coarse-grained; both arkosic arenites and quartz arenites are present. Some Strawn sandstones contain as much as 20% fragments of marine fossils—crinoids, brachiopods, bryozoans and coralline algae. The presence of these fossils indicates that the sandstones were deposited in a marine environment either as shelf sands or on beaches.

Strawn mudstones are medium to dark gray. Red mudstone observed in drill cuttings is probably caved from the Lower Permian section. Some of the mudstones contain phylloid algae, crinoid debris, brachiopods and fusulinids, indicating that they are marine.

Strawn limestones are also marine and are bioclastic wackestones and packstones. They contain abundant fragments of crinoids, brachiopods, smaller foraminifera, bryozoans, fusulinids and phylloid algae.

TABLE 2. Time-rock subdivisions of the Pennsylvanian used in western Texas, and equivalent time-rock terminology used in New Mexico.

West Texas	New Mexico
Cisco Series	Virgil Series
Canyon Series	Missouri Series
Strawn Series	Des Moines Series
Atoka Series	Atoka Series
Morrow Series	Morrow Series

Canyon Series

The Canyon Series is present throughout most of the Tucumcari basin. It is absent from most of the Sierra Grande uplift and thins over intrabasinal uplifts (Figs. 2, 3). The Canyon is 0–1000 ft (0–300 m) thick in the basin, but is 300–500 ft (90–150 m) thick in most places. As with the Strawn Series, thicker areas of Canyon coincide with structural lows of the Precambrian basement. In the northern part of the basin,

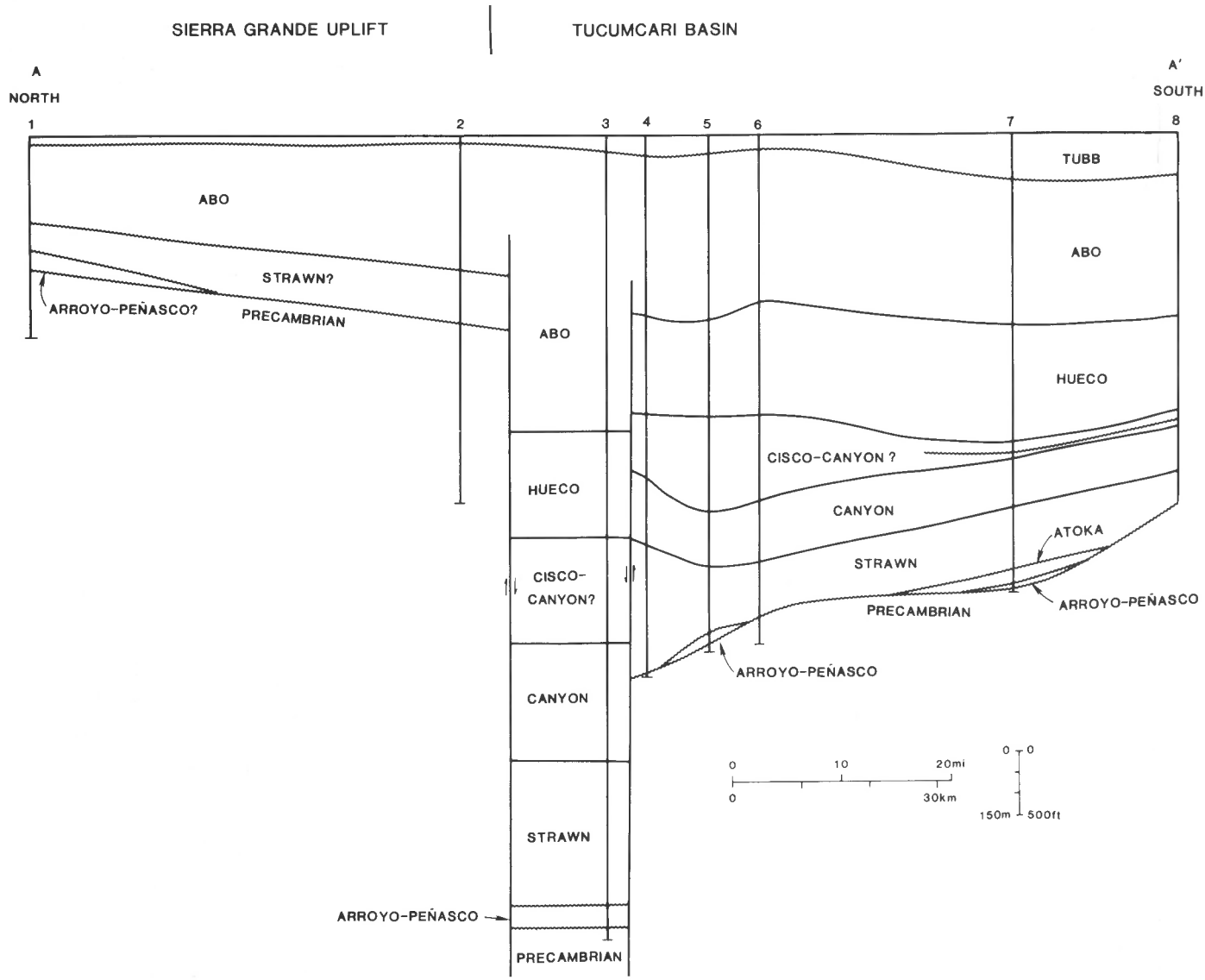

FIGURE 2. North–south stratigraphic cross section showing Mississippian, Pennsylvanian and Lower Permian stratigraphic units. Datum is top of Tubb sand zone. See Figure 1 for location and Table 1 for well data.

the Canyon thickens abruptly on the downthrown side of faults, indicating syndepositional faulting.

In the southern and central parts of the basin, the Canyon Series is composed mostly of interbedded limestone and siliciclastic mudstone. The limestones are marine; most are bioclastic wackestones and packstones that bear crinoid, bryozoan, smaller foraminiferan and fusulinid faunas. A few oolitic grainstones are also present. The mudstones are mostly gray, but some are red; many are calcareous and bear a marine fauna. Toward the northern and western boundaries of the basin, the limestones pinch out and the Canyon is composed of interbedded mudstones and sandstones. The sandstones are typical "granite wash" and are composed of sand- to gravel-size clasts of quartz and feldspar. At least some of the sandstones were deposited as channel sands in upward-coarsening deltaic sequences (Fig. 4). The coarse arkosic sandstones were derived from Precambrian basement. Their presence indicates major uplift of basement and major movement of bounding basinal faults during Canyon time.

Cisco–Canyon(?) Series

As mentioned below, the mudstones and limestones between 5960 and 6110 ft (1817–1862 m) in the Abercrombie and Hawkins No. 1 Nappier (Figs. 2, 3, well no. 7) may be of Cisco age. Detailed lithologic correlation of this interval with wells to the north and east indicates that there is as much as 500 ft (150 m) of section missing in this interval in the Nappier well; the missing section is represented by an unconformity developed over a basement-cored uplift. The Cisco–Canyon(?) unit is 300–800 ft (90–240 m) thick in the Tucumcari basin and is thickest in the basinal depressions (Figs. 2, 3). We will make further fusulinid identifications to determine the Cisco–Canyon boundary in wells where this unit is apparently complete and not represented mostly by an unconformity, as in the Nappier well.

The Cisco–Canyon(?) Series is composed of interbedded limestones and siliciclastic mudstones. The limestones are lime mudstones, bioclastic wackestones and packstones that bear a marine fauna of bryozoans, phylloid algae, gastropods, smaller foraminiferans and fusulinids. In the Trans-Pecos Resources No. 1 Latigo Ranch A (Fig. 2, well no. 4), the Cisco-Canyon(?) Series contains bedded dolostones as well as limestones and mudstones. The dolostones are fine-grained, compact crystalline and contain no visible porosity.

PERMIAN SYSTEM

Hueco Formation

The Hueco Formation is present throughout the Tucumcari basin, but is absent over higher parts of the Sierra Grande and Pedernal uplifts (Figs. 2, 3). The Hueco overlies Cisco–Canyon(?) strata with apparent

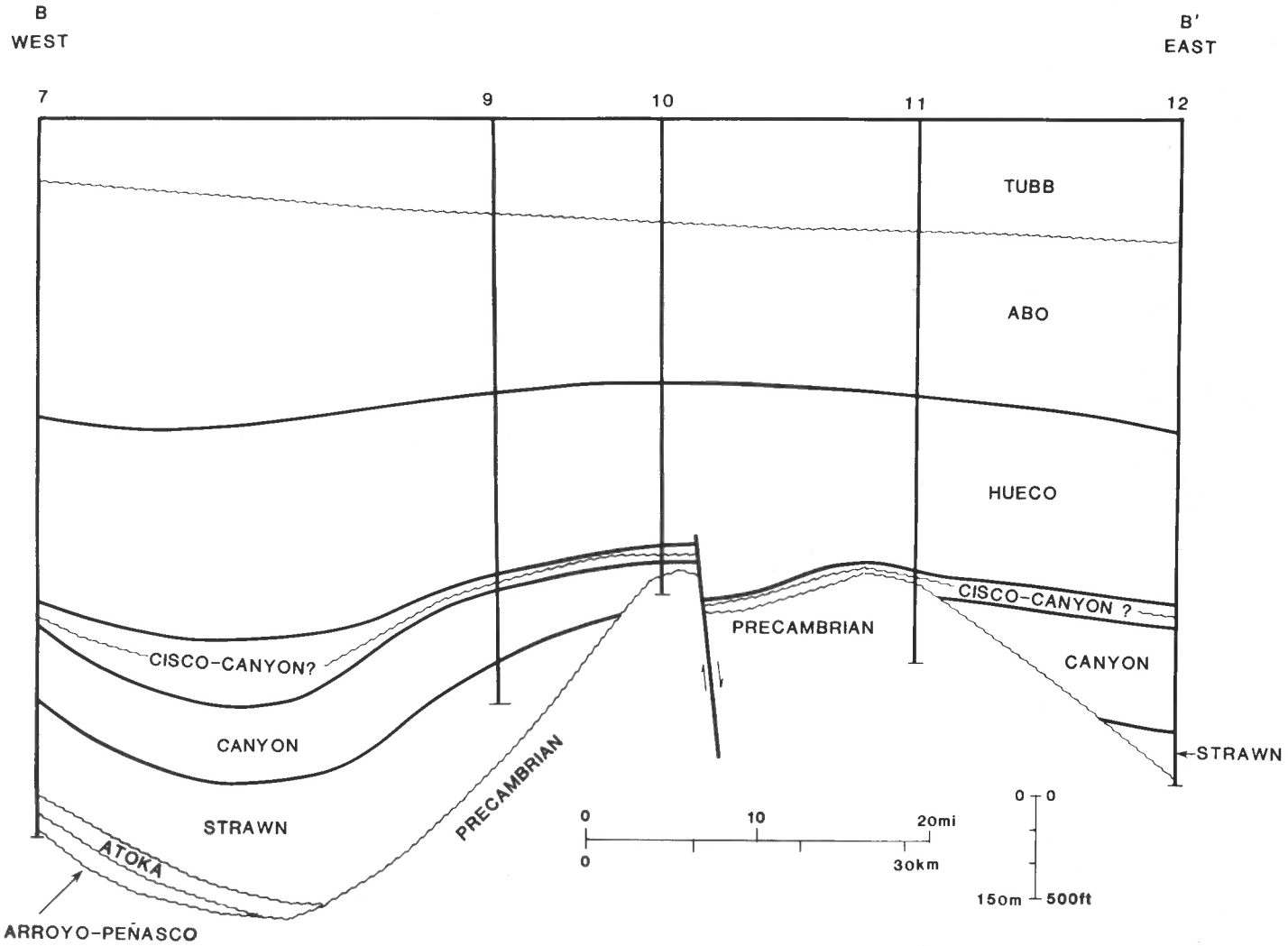

FIGURE 3. West–east stratigraphic cross section showing Mississippian, Pennsylvanian and Lower Permian stratigraphic units. Datum is top of Tubb sand zone. See Figure 1 for location and Table 1 for well data.

conformity. It has a fairly uniform thickness of 700–900 ft (210–270 m) throughout the basin. The base of the Hueco was picked biostratigraphically in the Abercrombie and Hawkins No. 1 Nappier, and corresponds to the base of the Wolfcampian Series; however, the base of the Hueco also has lithologic significance because it coincides with a regionally recognizable electric-log marker. The top of the Hueco is lithologic and coincides with an electric-log marker that is recognizable over most of eastern New Mexico. In De Baca and Chaves Counties that log marker corresponds with the highest marine limestone in the Abo–Hueco sequence.

The Hueco is composed of interbedded marine limestone, sandstone and siliciclastic mudstone. Limestones and mudstones are dominant in the southern part of the Tucumcari basin. The limestones are bioclastic wackestones and packstones that bear brachiopod, bryozoan, algal, gastropod, ostracode, smaller foraminiferan and fusulinid faunas. The mudstones are red to gray, burrowed and fossiliferous. In the Shell No. 1 Stephenson (fig. 3, well no. 10) the lower 150 ft (45 m) of Hueco contains bedded dolostones; some of the dolostones are sucrosic and have visual porosities in excess of 10%.

In the northern part of the basin, the Hueco is composed of interbedded sandstone and mudstone; only a few thin limestones are present. The sandstones are fine- to coarse-grained arkosic arenites; many are lithic arenites composed predominantly of sand- to gravel-size fragments of granite. The northward transition to sandstones and mudstones indicates proximity to exposed granitic rocks of the Sierra Grande uplift, which acted as a major sediment source during the Early Permian.

Abo Formation

The Abo Formation is present throughout the Tucumcari basin, where it conformably overlies the Hueco Formation. Over large parts of the Sierra Grande and Pedernal uplifts, the Abo unconformably overlies Precambrian basement or Pennsylvanian or older Permian rocks. The Abo is 400–2000 ft (120–600 m) thick in the Tucumcari basin. It is generally thicker on the downthrown sides of late Paleozoic faults than it is on the upthrown sides of those faults (Fig. 2). It thins over the Sierra Grande and Pedernal uplifts. The top of the Abo corresponds to a distinctive gamma-ray-log marker that is recognizable throughout east New Mexico. Investigations of the Abo to the south of the study area, in De Baca and Chaves Counties, indicate that the lower part is Wolfcampian and the upper part Leonardian in age (Broadhead, 1984).

The Abo is a red-bed unit composed of interbedded conglomerate, sandstone and mudstone. The sandstones are fine- to coarse-grained. Both the sandstones and conglomerates contain abundant feldspar and granitic-rock fragments; many of the sandstones and conglomerates are argillaceous. The source of much Abo sediment is thought to be the Precambrian core of the Sierra Grande uplift. In the northern part of the study area, the Abo was deposited as a complex of alluvial fans that bounded the southern margin of the Sierra Grande uplift. In the

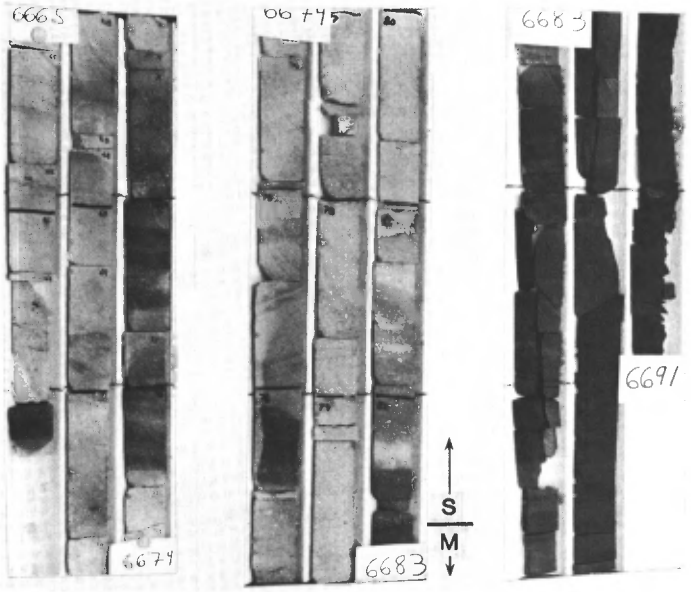

FIGURE 4. Upward-coarsening deltaic sequence, showing upward-coarsening prodeltaic and delta-front muds (M) erosionally overlain by distributary-channel sand (S). Trans-Pecos Resources No. 1 Latigo Ranch D, sec. 26, T10N, R23E, Guadalupe County, New Mexico; 6665–6691 ft (2031–2039 m), Canyon Series.

southern part of the study area, Abo sandstones are finer-grained and were deposited by meandering streams on an alluvial plain (Broadhead, 1984).

Tubb sand zone of Yeso Formation

The Tubb sand zone encompasses the lower part of the Yeso Formation. Its top is defined by a distinctive electric-log marker that can be mapped over a large part of eastern New Mexico and western Texas. In northeastern and east-central New Mexico, the Tubb rests on Abo red beds with mild disconformity. The Tubb zone is 20–600 ft (6–180 m) thick in the study area and thins northward and westward as it onlaps the Sierra Grande and Pedernal uplifts. Over the uplifts where it is thinnest, the Tubb is composed of nonmarine or marginal marine, orange-colored, fine-grained, silty sandstones that, in drill cuttings, are similar to fine-grained sands of the underlying Abo Formation. As it thickens to the south and east, the Tubb grades into an evaporitic marine sequence of interbedded, fine-grained sandstones, mudstones, dolostones and anhydrites.

PALEONTOLOGY

Fusulinids were identified from the Abercrombie and Hawkins No. 1 Nappier (Table 1, well no. 7; Figs. 1–3, well no. 7). The search for, and information from, fusulinids was hampered by very finely ground samples, abundant caving of shale and siltstone and several intervals of the well apparently devoid of fusulinids.

Several minute fragments of fusulinids with keriothecal wall structure were found in the 5430–5440-ft (1655–1658-m) interval. It was not possible to identify genera on the basis of the fragments, but we tentatively assigned the zone in which they were found to the Hueco Formation. We placed the top of the Hueco at 5120 ft (1561 m) by correlating electric logs and samples from Chaves and Eddy Counties, which are located to the south in the Permian basin.

From 5600 to 5960 ft (1707–1817 m), there are eight intervals with Wolfcampian *Triticites* and/or *Schwagerina*. We used the electric-log signature at 6000 ft (1829 m) as one that occurs near the top of the Pennsylvanian, and it is regionally distinctive in the wells of the basin.

No fusulinids were recovered from the 5960–6110-ft (1817–1862-m) zone. There could be rocks of the Cisco Series in this interval.

The first *Triticites* indicative of the Canyon Series were found at 6110–6120 ft (1862–1865 m), and we used the electric-log kick at 6120 ft (1865 m) as the tentative top of the Canyon. Other Canyon fusulinids were noted at 6160–6170 (1878–1881 m) and 6190–6200 ft (1887–1890 m).

From 6200 to 6530 ft (1890–1990 m), no fusulinids were recovered. However, lower Strawn Series *Beedina* and/or *Wedekindellina* are present in 12 zones from 6530 to 6940 ft (1990–2115 m). For preliminary cross-section preparation, we selected an electric-log signature at 6490 m (2115 m) near the top of the lower Strawn.

Palynology of a coal seam from the Trans-Pecos No. 1 Latigo Ranch C (located approximately two miles from the Trans-Pecos No. 1 Latigo Ranch A; Fig. 2, well no. 4) indicates that the Pennsylvanian section below 6200 ft is of lower Westphalian age (Atokan equivalent) and not Strawn, as our correlations indicate (Robert G. McKinney, written comm. 1985).

Atokan fusulinids of the genera *Fusulinella* and *Eoschubertella* were found from 6960 to 7030 ft (2121–2143 m). The electric-log marker at 6948 ft (2118 m) was chosen as the approximate top of the Atokan Series.

Using lithologic similarity, the top of the Arroyo Peñasco Formation (Mississippian) was placed at 7048 ft (2148 m).

ACKNOWLEDGMENTS

Robert G. McKinney and Frank E. Kottlowski reviewed the manuscript. Lynne McNeil typed the manuscript, and Irean Rae drafted the illustrations.

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The Morrison Formation at Punta de Gallegos (photo: S. G. Lucas).