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J. Wayland Roberts, J. J. Barnes, and H. J. Wacker
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SUBSURFACE PALEOZOIC STRATIGRAPHY OF THE NORTHEASTERN NEW MEXICO BASIN AND ARCH COMPLEX

J. WAYLAND ROBERTS, JOHN J. BARNES, HERBERT J. WACKER
Amoco Production Company
Houston, Texas 77001

INTRODUCTION

The basin and arch complex of northeastern New Mexico and extreme northwestern Texas contains the Raton-Las Vegas, Tucumcari, Palo Duro and Dalhart Basins, and the Sierra Grande and Bravo Dome arches (Fig. 1). During Pennsylvanian and Permian time detrital sediments were shed from the major positive feature, the Sierra Grande uplift, which trends northeast-southwest in the central part of the area. The Bravo Dome appears to be a southeast plunging salient of the Sierra Grande uplift and may represent the extreme northwestern extension of the buried Amarillo Mountain Range. Salients of the Sierra Grande uplift separate the basins from one another. The maximum sedimentary column penetrated in the area occurs in the Palo Duro (Plainview) Basin where thicknesses of 10,000 ft have been encountered. Subsurface sedimentary strata include rocks of Ordovician, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic and Cretaceous age (Fig. 2). This paper is restricted to discussions of Paleozoic rocks. The recognized major facies types in these rocks include continental-fluvial, marginal marine, marine-open shelf and deep water marine.

During the early Paleozoic (pre-Pennsylvanian), there was no strong positive structure to shed clastic sediments into the area. Lower Paleozoic (Ordovician and Mississippian) sedimentary environments were dominantly marine-open shelf. Regional unconformities left the Ordovician carbonates on Precambrian rocks and, Mississippian carbonates and shales on Ordovician strata in the Tucumcari, Dalhart, and Raton-Las Vegas Basins. An abrupt shift in sedimentary environment, caused by uplifting of the Sierra Grande Arch during Pennsylvanian time, resulted in preservation of a thick continental and marginal marine sedimentary sequence in upper Pennsylvanian and Permian strata. The Tucumcari, Palo Duro and Dalhart basins were strong negative features in the early stages of this cycle. Clastic deposition continued until Late Permian time when a widespread marine incursion advanced from the south covering most of the area with a veneer of marine carbonates. The regressive cycle which followed this transgression created many of the stratigraphic traps in the San Andres formation south of the study area in New Mexico and West Texas. Methane and carbon dioxide gas offer the greatest potential for economic development in northeast New Mexico; however, many shows of both oil and gas have been encountered throughout the Paleozoic sequence. To date there is no commercial hydrocarbon production, placing the area in a juvenile stage of oil and gas exploration.

MAPPING PROCEDURES

This study covers the Paleozoic subsurface geology of approximately 25,000 square miles of northeastern New Mexico and northwestern Texas. Figure 1 shows the location of the structural elements and New Mexico and Texas counties that are located within the area of investigation and the sub surface well control points used in the preparation of the maps and cross sections. Control points are sequentially numbered by county and a list of these control points are on file with the editors.

In subsurface investigations of large regions which have complicated lateral facies changes and where there is a paucity of paleontologic data, portraying these subsurface changes is a considerable challenge. The ti me-stratigraphic correlations, particularly in the Pennsylvanian sequence pose a particular problem. Foster and others (1972) in their extensive investigation of the subsurface geology of east central New Mexico discussed the correlation problems in this region, particularly within the Pennsylvanian sequence and chose to isopach the entire Pennsylvanian as a unit rather than sub-divide it into smaller units. Associated environmental assemblages are grouped so that the distribution of major facies patterns can be mapped. Paleontologic data have been used in the southeastern and eastern part of the area to establish major time-stratigraphic mapping units. Sample and mechanical logs were utilized to project these correlations in grouping four gross rock assemblages (Figs. 3, 4, 5 and 6). These four lithofacies and isopachous maps include time intervals spanning the Ordovician and Mississippian sequences (Fig. 3), the lower Pennsylvanian (lower Strawn, Atoka, Morrow) (Fig. 4), the upper Pennsylvanian (Cisco, Canyon, upper Strawn) (Fig. 5) and the Permian (Wolfcamp) (Fig. 6).

The composite facies depicted on these maps represent a progressive increase in distance from sediment source and an increase in water depth (Krumbein, Sloss and Dapples, 1949). The continental environment includes fluvial, lacustrine and eolian deposition with resulting lenticular or sheetlike sandstones and subordinate shales, coals and limestones. The near shore marine environment includes primarily deltaic deposits; but lagoonal, alluvial plain and barrier beach sediments are also present. This environment is represented by sandstones and shales with occasional marine limestones. The open shelf environment is composed of shallow marine deposits, mainly argillaceous to fragmental fossiliferous limestones, bedded shales and sheetlike or lenticular sandstone bodies. The high energy shelf margin deposits are isolated from the influence of terrigenous sediment and are dominated by carbonates. Many of these carbonates are biogenic. Clastic deposits are scattered and thin in this setting. Basinal environments consist of deeper water deposits of dark, fine-grained lithologies including shales, fine-grained sandstone and various types of marine carbonate.

STRATIGRAPHY

Pre-Pennsylvanian

The pre-Pennsylvanian rocks preserved in the study area consist of at most a few hundred feet of Ordovician and Mississippian carbonates (Fig. 3). In general, the limits of these two rock units represent erosional remnants of what was a

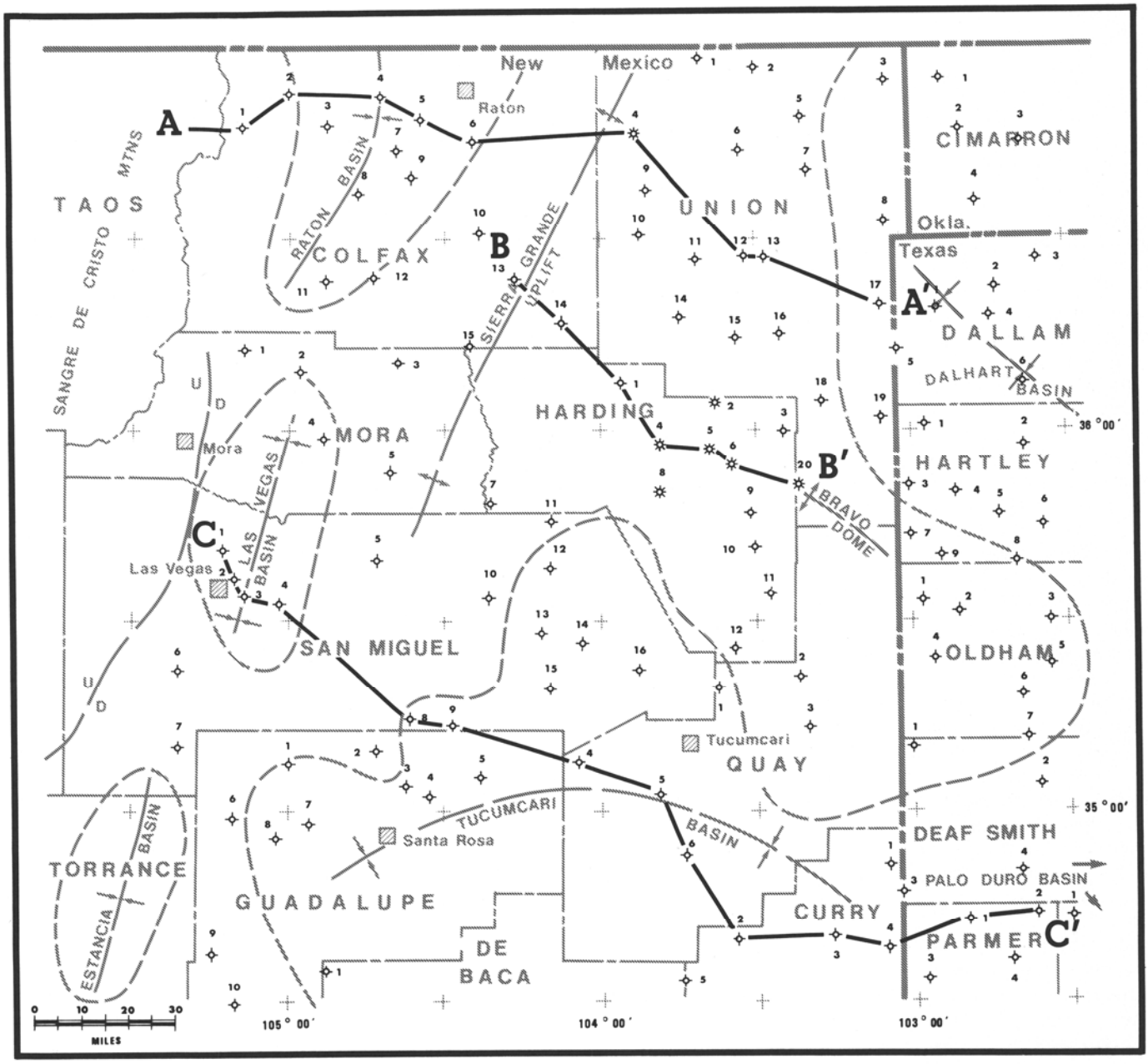


Figure 1. Regional reference map.

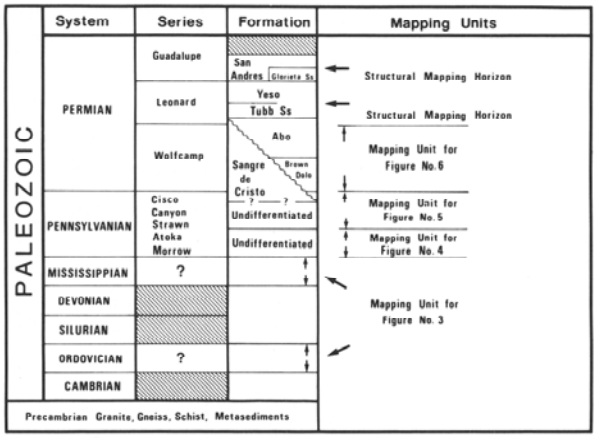


Figure 2. Correlation chart.

regionally widespread, open shelf carbonate. Although some scattered porosity has been observed in a few wells that have penetrated this part of the section, the potential for oil and gas production appears limited. Perhaps the most favorable area for production occurs in the western portion of the Dalhart Basin where the thickest pre-Pennsylvanian sequence is preserved (Fig. 3).

Lower Pennsylvanian

Early Pennsylvanian time marked the initiation of basinal sedimentation in all the basins of the study area. The distribution of continental facies indicates that major source areas were located to the west in the Uncompahgre Highland and that the sediments thinned onto the Sierra Grande Arch which was slightly emergent.

Several sedimentary facies are recognized in the subsurface in the Raton-Las Vegas Basin including delta, delta front and nearshore clastics. The Continental #1 Mares-Duran (Mora County #1) penetrated a thick sequence of deltaic facies including interbedded black and gray shales, sandy limestones and scattered coals (Miller and others, 1963). Porous quartz sandstones of delta front and nearshore environments were encountered in an 1,800 ft section of the Shell #1 Mora Ranch in Mora County. These sandstones contain little conglomeratic material on the eastern side of the Raton-Las Vegas basin and thin by non-deposition or slight erosional truncation onto the Sierra Grande Arch.

Lower Pennsylvanian sediments in the Tucumcari Basin show a similar reduction of maximum grain size to the southeast. Interbedded gray shales, quartz sandstone and coals also represent a deltaic depositional environment. On the south side of the basin, clastic influence was lost and sedimentation was dominated by shelf carbonates. Sedimentation during early Pennsylvanian time within the western margin of the Palo Duro Basin was very similar to that described for the Tucumcari Basin, but differs substantially from the much larger lower Pennsylvanian basin that existed in southeastern New Mexico and West Texas. In this region, source areas for terrigenous detritus were to the north from the buried Amarillo Mountains, to the northwest from the Sierra Grande Arch and to the west from the Pedernal land mass. This influx of detritus decreased through early Pennsylvanian time and the carbonate regimen became increasingly important in the Palo Duro Basin. Within the basin, alternating sandstone and shale sequences provide a close association between potential source and reservoir rocks that could trap oil and gas.

On the western rim of the Dalhart Basin, lower Pennsylvanian strata consist of black shales with thin sandstone interbeds. Part of the nearshore marine and all of the continental deposits were removed during the upper Pennsylvanian erosional period.

Upper Pennsylvanian

In late Pennsylvanian time, the sedimentary pattern was drastically altered with the Sierra Grande Uplift serving as the major source area (Figs. 5, 9). This change is interpreted from the widespread continental deposits encircling the arch and the change to non-terrigenous deposits away from this source. The Uncompahgre Highland and Pedernal Uplift were still active to the west and southwest but were subordinate clastic sources.

In the Raton-Las Vegas Basin, quartz sandstones along the eastern margin are a near-source facies of more distal interbedded shales, siltstones and limy arkoses. Limestones predominate further to the west. Clastic sedimentation dominated in the northern portion of the Tucumcari Basin with a transition to carbonate deposition in the southern part (Fig. 5). Sediment colors change from predominantly gray to red, which indicates more rapid filling in shallow, oxidizing environments nearer the Sierra Grande Arch source area.

Open shelf and basin margin carbonates were the principal sediment types during the late Pennsylvanian within the Palo Duro basin. Basin margin high energy carbonates are located slightly east of the study area and interfinger with the more common shelf carbonates. This arrangement could provide potential reservoir and trap conditions.

The facies patterns observed and mapped in the Palo Duro basin probably were connected to those portrayed for the Dalhart basin and would represent a continuation of the same sedimentary processes (Fig. 5); however, in the Dalhart Basin, upper Pennsylvanian red arkoses, granite washes, and continental red shales are the predominant rock types that grade laterally downdip into nearshore marine (Fig. 7).

Permian-Wolfcamp

Wolfcamp sedimentation, like the upper Pennsylvanian, was dominated by ferruginous continental deposits. This red bed sequence surrounded the Sierra Grande Arch as uplift of that feature continued. The entire period from late Pennsylvanian through early Permian time was one of intense erosion in a semi-arid climate. A thick clastic wedge of Permo-Pennsylvanian arkoses and red shales blanketed all but the highest points of the arch (Fig. 6). Basinward, in all directions, the sandstones and siltstones grade to red shales with brown dolomite interbeds. Further basinward within the Dalhart, Palo Duro, and Tucumcari Basins this brown dolomite facies becomes cleaner and slightly porous, offering potential for hydrocarbon entrapment.

The Tubb San dstone (Leonard) and the Cimarron Anhydrite were deposited during a period of structural quiescence. These two units onlap the Sierra Grande Uplift creating an effective reservoir and seal for the carbon dioxide in Bueyeros Field, Harding County, New Mexico (Figs. 8, 10). The Yeso Formation, consisting of sandstones and shales, indicates a minor rejuvenation of the source area, but by the

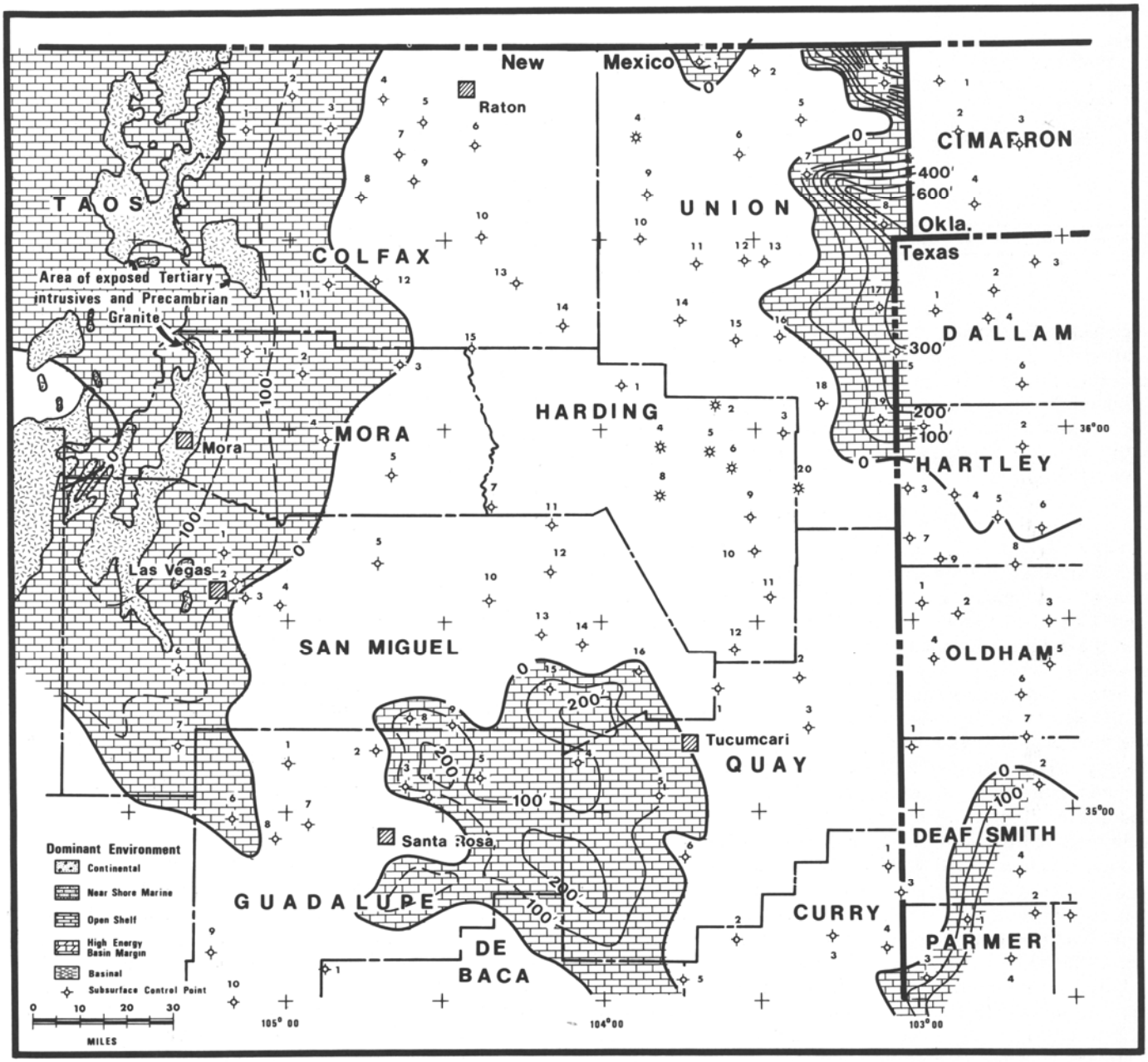


Figure 3. Lithofacies and isopachous map of pre-Pennsylvanian.

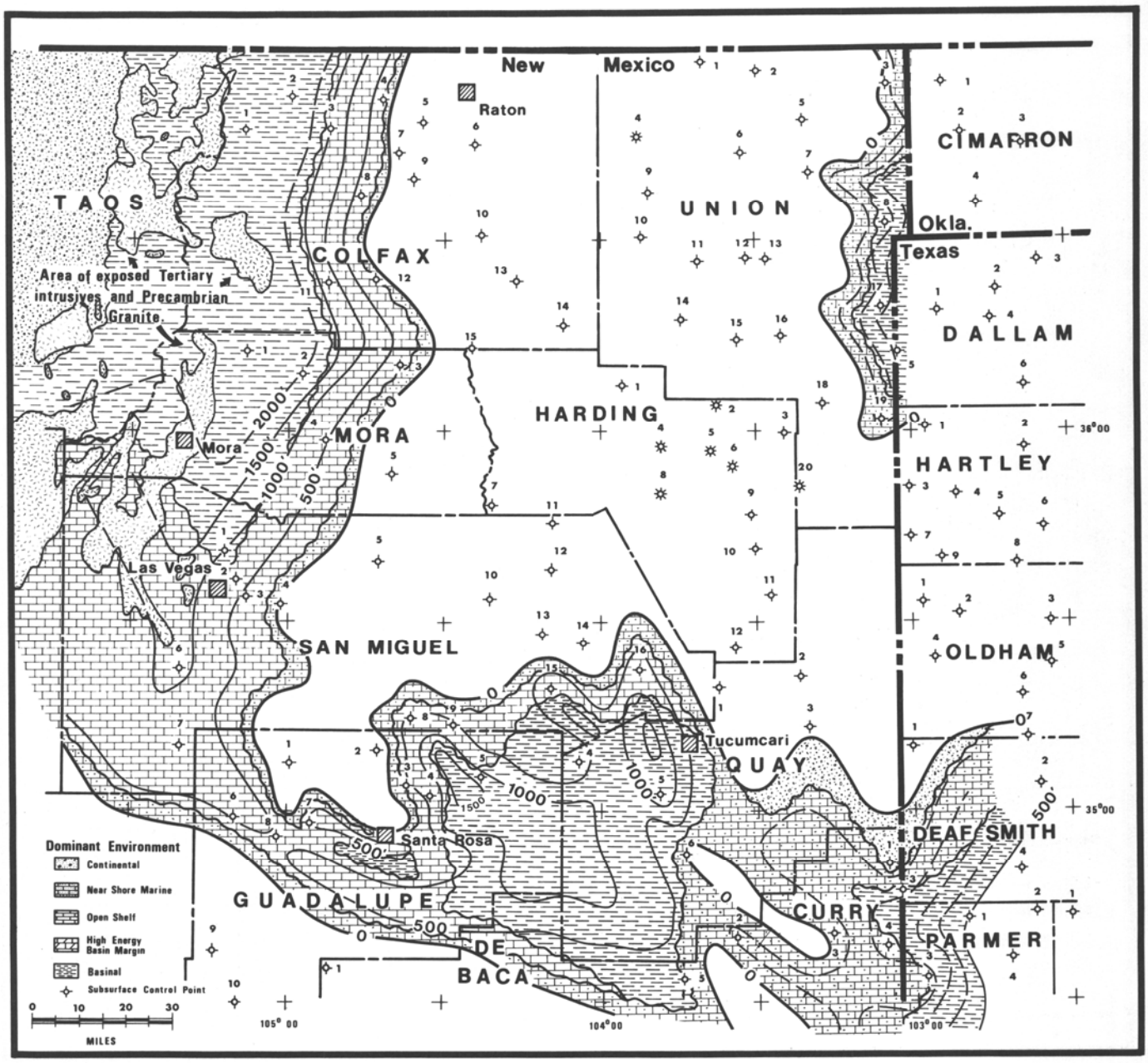


Figure 4. Lithofacies and isopachous map of lower Pennsylvanian.

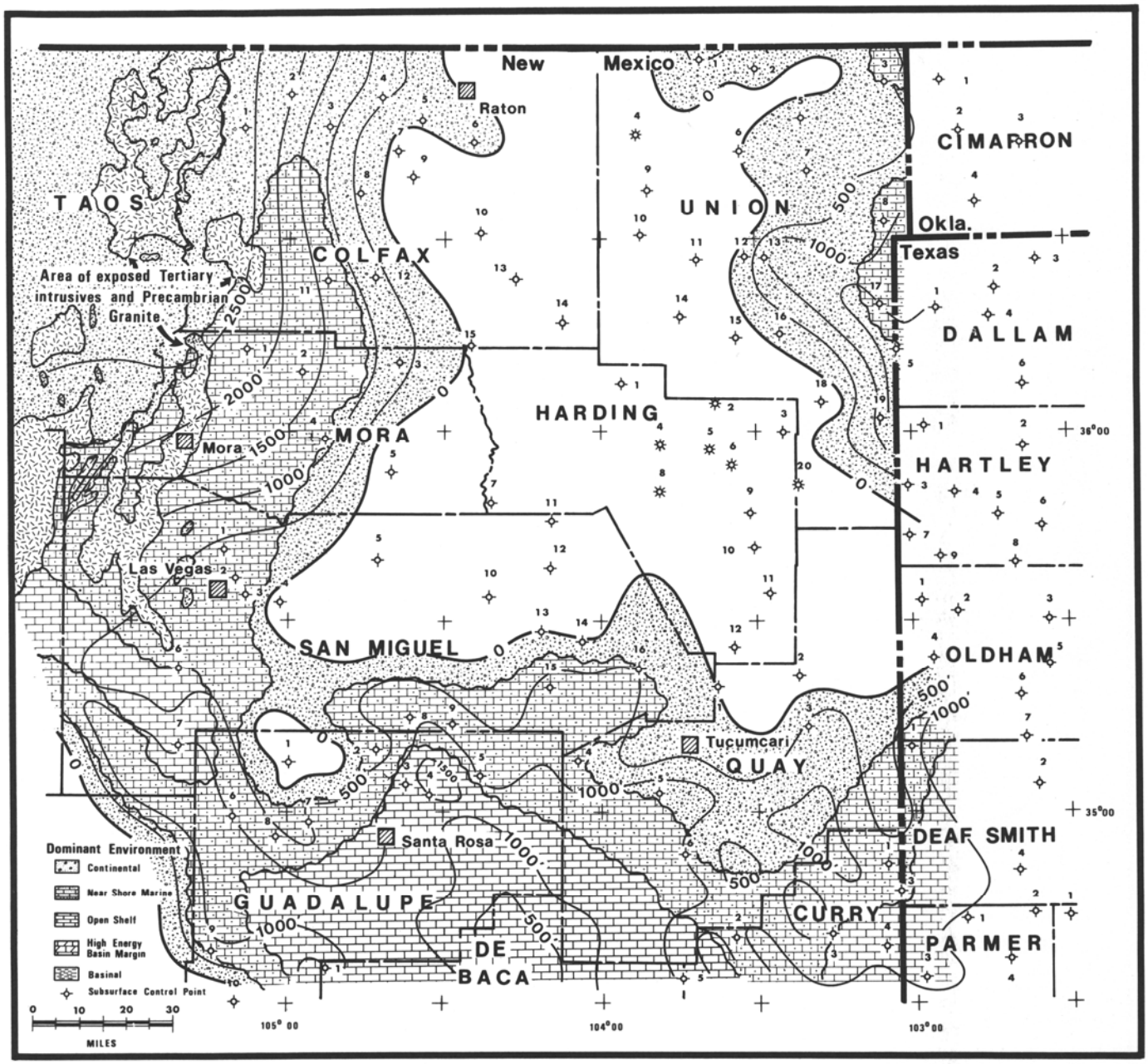


Figure 5. Lithofacies and isopachous map of upper Pennsylvanian.

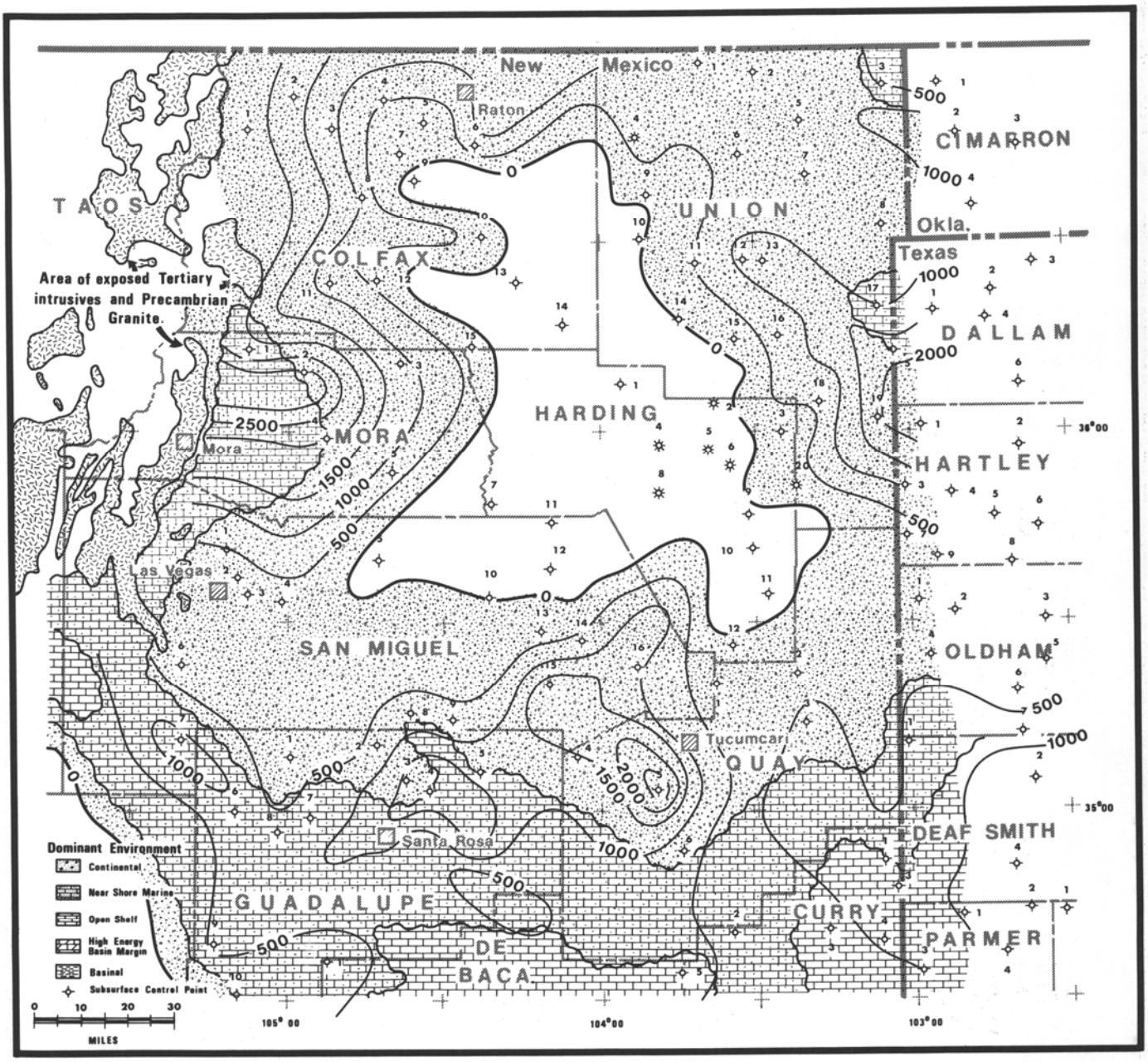


Figure 6. Lithofacies and isopachous map of Permian-Wolfcamp.

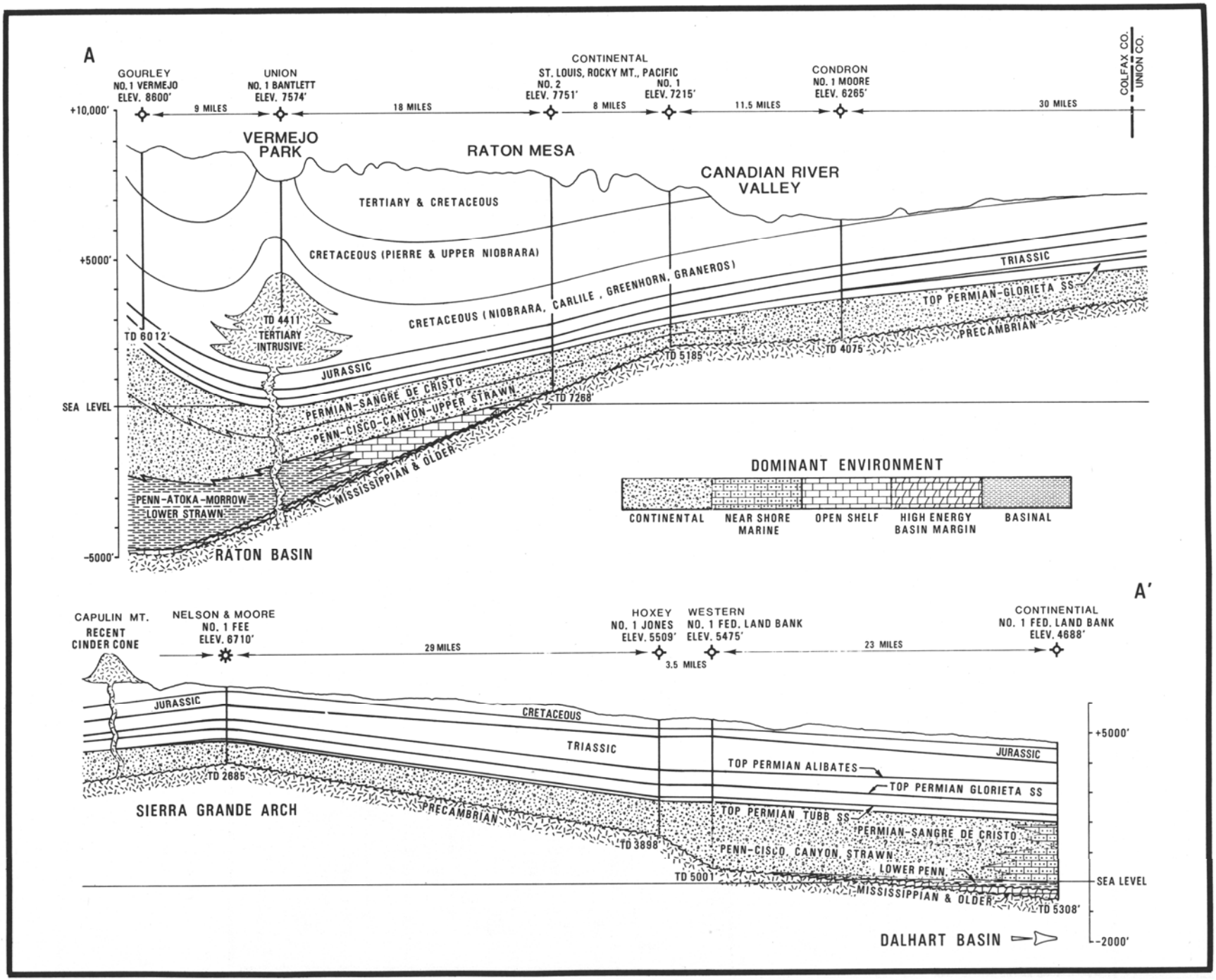


Figure 7. Regional structural cross section A-A'.

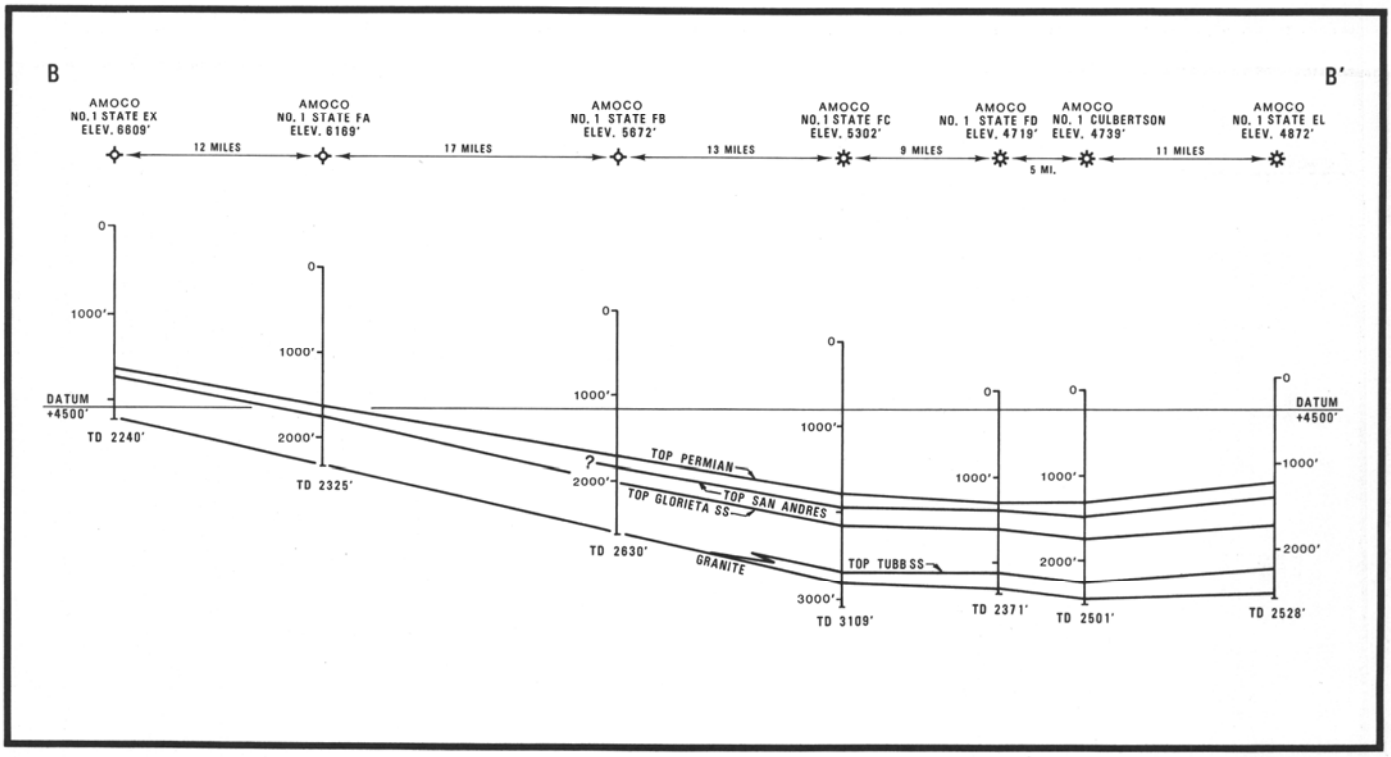


Figure 8. Regional structural cross section B-B′.

time of Glorieta deposition the Sierra Grande was not a significant sediment source.

Upper Permian

By Late Permian time (mainly post-Leonard) the sediment collecting basins and sediment generating arches were in equilibrium. This is recorded as a widespread marine transgression at the beginning of San Andres deposition which spread a thin sequence of marine carbonates over most of the study area. This was followed by southeastward regression with periodic interruptions. Evaporites were deposited behind the retreating, moderately high energy carbonates. Slight interruptions in the overall regressive pattern permitted minor transgressions forming stratigraphic traps. These typical San Andres traps consist of a porous carbonate sealed above, below and up-dip by anhydrite but open down-dip for oil migration.

The upper Guadalupian rock sequence consists of thin to thick bedded quartz sandstones, some evaporites, variegated shales, and thin beds of carbonates. This assemblage of facies represents an overall regressive depositional pattern. To the south this part of the upper Guadalupian sequence has produced large volumes of oil and gas from combination and structural traps. A substantial erosional unconformity separates the Upper Permian from overlying Triassic sandstones and shales.

CONCLUSIONS

The basin and arch complex of northeastern New Mexico contains up to 10,000 ft of sediments including rocks of Ordovician, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic and Cretaceous age. In late Pennsylvanian time, the Sierra Grande Arch became a major source area for terrigenous detritus that was deposited on the margins and in the interiors of adjoining basins. Around the Sierra Grande Arch, continental, marginal marine and marine clastics were deposited up-dip from marine carbonates and shales. The volume and areal distribution of detritus continued to increase through middle Permian time, culminating in a thick clastic wedge completely encircling the Sierra Grande Arch and practically burying the arch under its own erosional material. Beginning during San Andres deposition, seas invaded the area from the south depositing thin carbonates over most of the area. Regression followed immediately and continued with minor transgressions through Upper Permian time.

The complete tectonic and depositional history of Pennsylvanian and Permian sediments in this region should offer many opportunities for the formation or creation of stratigraphic traps in close association with potential source beds. Given these favorable conditions, the petroleum geologist must address the question of why there is no commercial production of oil or gas in this region aside from CO_2 gas in Harding County. One explanation might be that there is insufficient deep well control to properly evaluate all of the stratigraphic section within such a large area. Another explanation may be that source beds are inadequate, in terms of volume, organic content, or stage of hydrocarbon maturation. The lack of production may be some combination of these factors but we think exploration opportunities still exist. Foster and others (1972) in discussing the complex tectonic and depositional history of the Pennsylvanian stated, "In any event the rapid facies changes, variety of trap possibilities, and potential source and reservoir rocks obtained from this cursory examination makes the area one of considerable interest for petroleum exploration." We further suggest that opportunities exist for the entire Paleozoic rock sequence within the basin and arch complex of northeastern New Mexico.

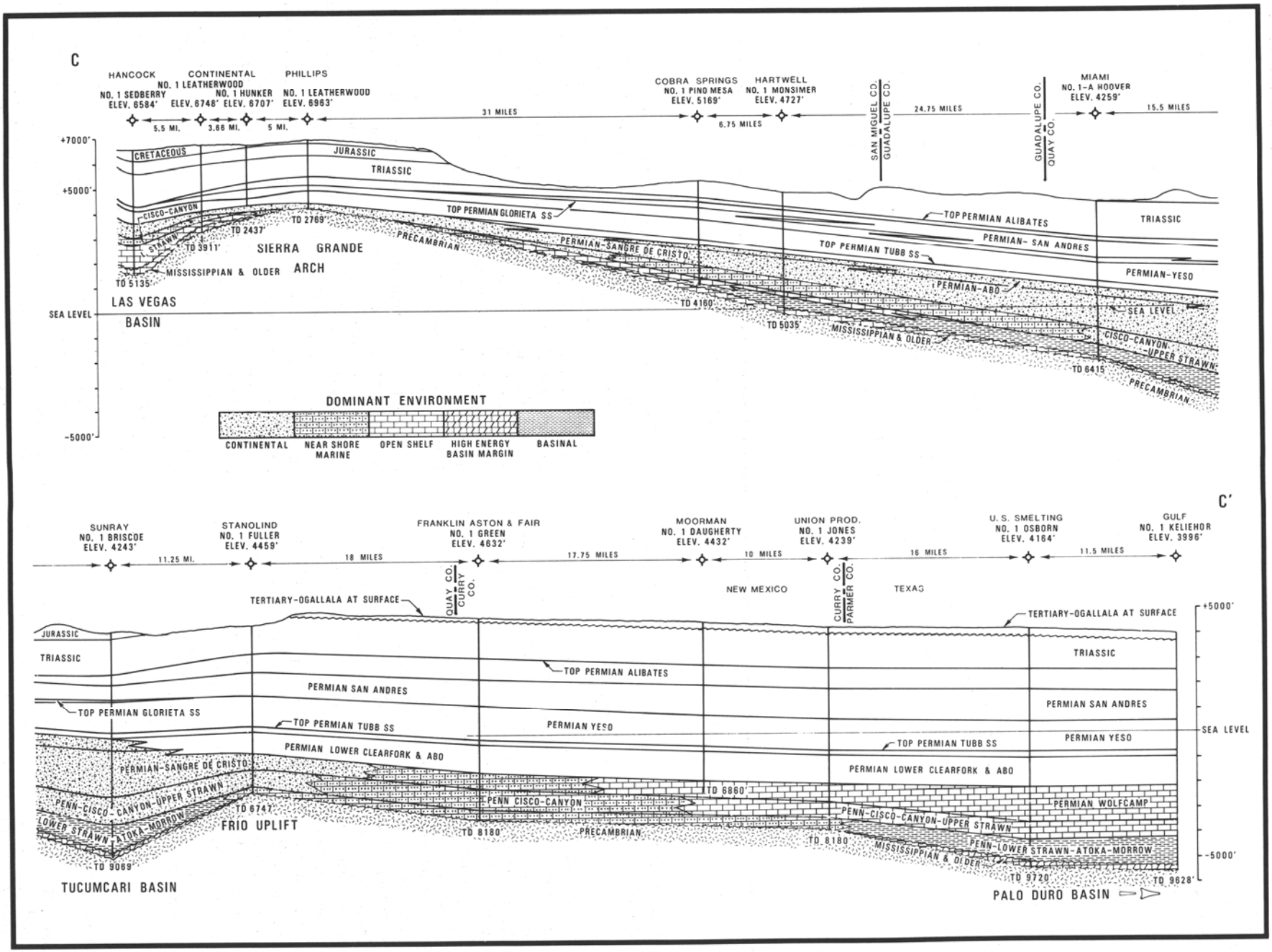


Figure 9. Regional structural cross section C-C'.

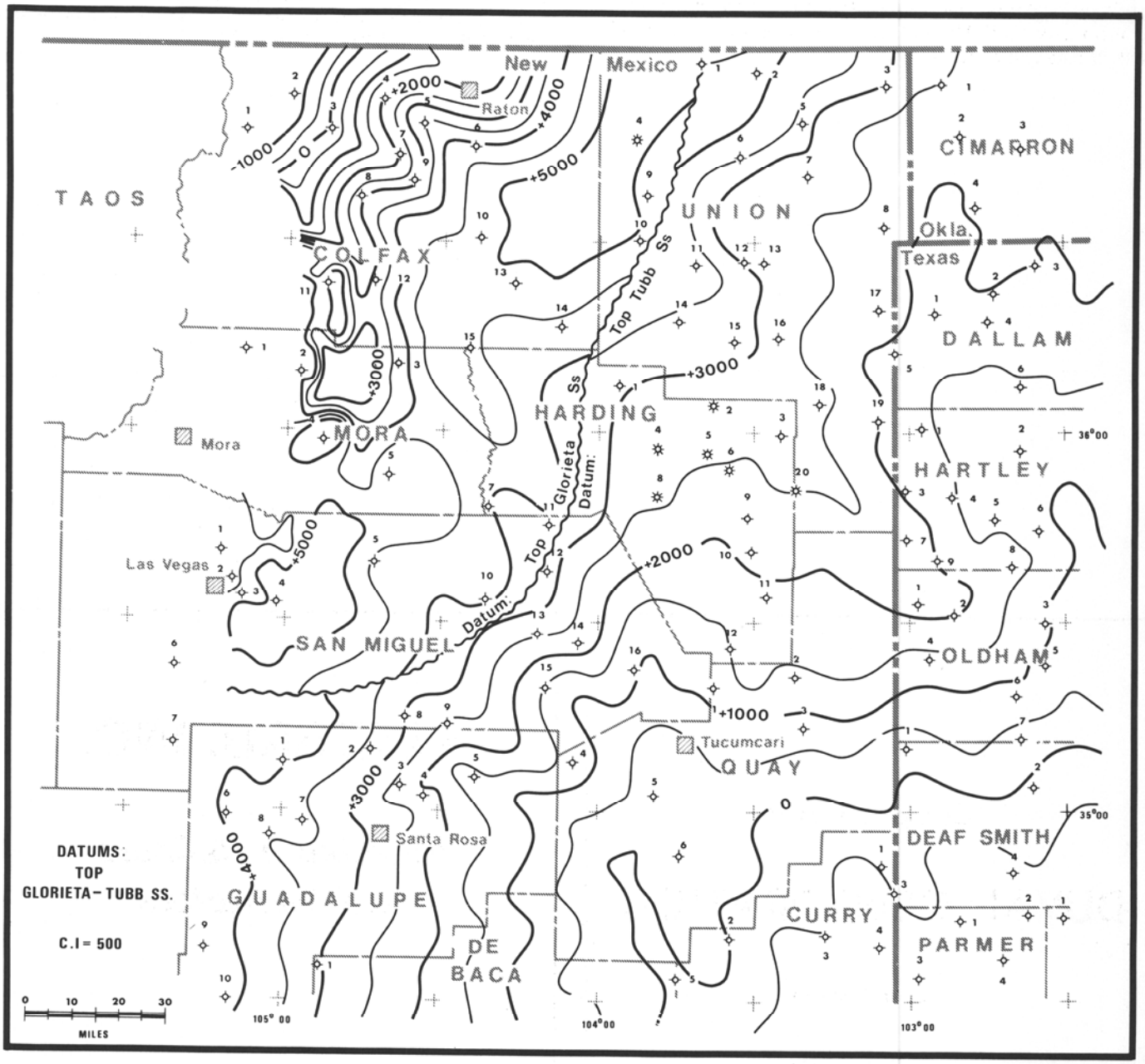


Figure 10. Structure map—datum; T. Glorieta—Tubb; contour interval: 500'.

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