GEOLOGY AND PRODUCING FORMATIONS CHARACTERISTIC OF SOUTHEAST NEW MEXICO

J. L. Tweed
ARCO Oil and Gas Company

INTRODUCTION

The Permian Basin is one of the major hydrocarbon producing provinces in the United States. It produces approximately 22% of the nation's oil and substantial amounts of gas. Geographically, it covers southeastern New Mexico and much of West Texas. This paper will concentrate on the New Mexico portion of the Basin in an effort to provide the engineer with a basic review of the geological features and reservoir characteristics of the area. There are many subprovinces in this large basin which affected the formation of reservoir rock and the accumulation of hydrocarbons. An understanding of the origin of these subprovinces should greatly aid the engineer's efforts to develop new reserves and improve recovery from existing reservoirs.

Shown in Figure 1 are the major geological features (or subprovinces) of the area. These are the Central Basin Platform, the Delaware Basin, Eddy Shelf, Northwest Shelf and Pedernal Land Mass. All but the Pedernal Land Mass are major producing areas. Each has its own structural and depositional characteristics which resulted in distinct reservoir properties and hydrocarbon accumulation. Each of the features will be discussed in some detail.

GEOLOGICAL HISTORY

From Cambrian to Missippian times the area shown in Figure 1 was characterized by shallow-sea deposition with only minor interruptions due to transgressing and regressing seas. Early Pennsylvanian time saw the rise of the Ancestral Rocky Mountains (general area of Pedernal Land Mass) and the Central Basin Platform. These were a result of uplifted basement fault blocks. Subsequently, erosion occurred in these areas resulting in the deposition of Pennsylvanian age clastics in the lower basin areas. Subsidence continued through Pennsylvanian time.

In late Pennsylvanian or early Permian time the Central Basin Platform was again uplifted and exposed to erosion. This erosion stripped away the overlying sediments exposing the granite core in some areas. Subsidence then resumed and thick Permian sediments were deposited over the entire area (see Figure 2). This was also a time of major reef buildups in the shallow water along the basin fringes. The final stages of development consisted of land emergence from shrinking Permian seas, resulting in the deposition of red beds and evaporites. This phase culminated in the complete emergence of the present land mass. Stratigraphic sections are presented for the Delaware Basin and Central Basin Platform in Figure 3 for reference to age and depositional position of the formations mentioned.

The structural configuration and structural traps in the area are predominately a result of uplifted basement fault blocks with later sediments draped over them. The Permian beds draping over the Central Basin Platform are the largest example. In addition, reefing amd mounding along the basin edges created localized highs. Some differential compaction also occurred, but its effect is not too significant.

Almost all of the hydrocarbon accumulations within the study area are stratigraphically controlled to some degree. They run the spectrum from almost totally stratigraphic, such as the Morrow gas play, to predominatly structural with local areas of porosity and permeability pinchouts as typified by most Devonian reservoirs.

CENTRAL BASIN PLATFORM

The Central Basin Platform is located in the extreme southeastern corner of New Mexico as shown in Figure 1.

The Platform was uplifted in two stages. The first stage occurred in early Pennsylvanian time and the second in late Pennsylvanian or early Permian time. This latter uplift resulted in the Platform rising above sea level. The resulting erosion stripped off overlying sediments down to basement rock on the high structural features. Subsidence then occurred and a thick Permian section was deposited. Finally, the retreating seas resulted in evaporite deposits prior to the emergence of the current land mass.

Figure 2 is a cross section from the Guadalupe Mountains through the Central Basin Platform. This shows the uplifted platform with the truncation of the older beds against the Permian sediments as a result of erosion.

This sequence created two types of traps in the Ordovician and Siluro-Devonian age sediments. The first was a result of the truncation of these beds against the granite high associated with the unconformity. These traps are truncated anticlines with hydrocarbons trapped in formations below the unconformity. The Brunson Ellenburger field is probably the best example of this type of trap. Here the Ellenburger has been eroded off the granite high but is present on the north and west sides of the anticline. Other examples are the Justis Fusselman, Justis Montoya, and Teague Ellenburger fields.

The second type of trap is a structural high associated with uplifted basement fault blocks. Examples are the Crosby Devonian, Fowler Ellenburger, Fusselman, Devonian, Custer Ellenburger, Devonian, Langley Deep Ellenburger, and Devonian fields. These traps are generally located on the fringe of the Central Basin Platform and often have some faulting associated with the anticlinal structures. Porosity is both vugular and fractured type and is typically best on top of the structure. Development of these types of reservoir should be active for the next several years.

The Permian beds are draped across the Central Basin Platform and form a large anticlinal structure (see Figure 2). The middle Permian beds (Blinebry, Tubb, Drinkard, and Abo) were deposited in a shallow sea environment and are predominatly carbonates though some sands appear in the Tubb. Production from these formations is both structurally and stratigraphically controlled. Productive limits are controlled in some areas by the presence of water along the flanks of the structure. However, production over the entire Platform is generally determined by porosity and permeability development. Such development tends to improve in the higher structural positions. Dolomitization was widespread across the Platform; however, where this does not occur, the formations tend to be unproductive due to an absence of permeability in the limestone.

The San Andres formation is a massive dolomite section overlain by a thick sequence of sand and dolomite stringers through the Grayburg, Queen, Seven-Rivers and Yates formations (see Figure 3). The Central Basin Platform forms one massive regional structure for this entire sequence of formations. There is apparently enough vertical permeability among these formations so that over geological time vertical migration occurred between them. As a result, they all have a common gas-oil and oil-water contact from the top of the Yates through the San

Andres. The gas-oil contact is found at an elevation of approximately -150 ft and the oil-water contact at approximately - 300 ft. Depths vary only slightly across the Platform. Therefore, whether these formations yield gas, oil or water is structurally controlled. The vertical permeability throughout the section is low enough that over historic times no significant migration of fluids is occurring. Currently, gas is being produced in formations encountered above -150 ft elevation, while oil is produced from the interval -150 to -300 ft and in a number of instances is being waterflooded.

Current activity in the Yates through San Andres formations includes improving recovery on existing properties, drilling undeveloped interior locations, and some extension development. None of the formations above the Yates have been found to contain significant amounts of hydrocarbons.

DELAWARE BASIN

The Delaware Basin contains the thickest sedimentary section in southeastern New Mexico. It has been typified by continual subsidence throughout its depositional history. There is very little evidence of basement tectonics. A stratigraphic section for the Basin is shown in Figure 3.

Very little production exists in the deeper Devonian to Ordovician age sediments. This is primarily due to the lack of structural closure at these depths. The most promising locale for production from these beds is the east edge of the Basin near the edge of the Platform. There has been some production found in this area in the Devonian such as at the Bell Lake Field. Here, as in other areas, the Devonian fields are primarily structural traps.

Early Pennsylvanian times saw the rise of the ancestral Rocky Mountains in the area of the Pedernal Land Mass. Subsequent erosion provided the source material for the Pennsylvanian age sandstones in the Delaware Basin and Eddy Shelf.

The Morrow and Atoka sands are the most widely productive formations of Pennsylvanian age. Shown in Figure 4 is a log of this section. Here the Morrow is divided into four depositional sequences marked by transgressing and regressing seas. Typically, Cycle 2 and Cycle 3 are the best developed of the sequences. Both channel and deltaic type sand deposits are found in the Morrow. In Figure 4, the Cycle 2 sand is a channel deposit and the Cycle 3 sand is deltaic. The sand lenses trend northwest-southeast, but examples can be found of lenses oriented to all directions of the compass. Morrow activity has been greater on the Eddy Shelf than in the Delaware Basin. This is due to the generally better sand development there and its shallower depth on the Shelf with resultant lower drilling costs. As the price of gas has increased, however, development has moved basinward. Morrow drilling in the Delaware Basin is expected to remain active. The Atoka also produces in areas where well developed sands are found. However, generally the reservoirs are smaller and more scattered than those found in the Morrow.

The sand members of the Delaware Mountain Group of Permian age are also productive in the Basin. Most of the production is from the upper Bell Canyon sands (Yates through Queen equivalent) and both stratigraphic and structural traps exist. The Black River, El Mar, N. Mason and Malaga fields are examples.

EDDY SHELF

With the formation of the ancestral Rocky Mountains in early Pennsylvanian times, the Eddy Shelf was established as a shallow shelf bordering the Delaware Basin. The shelf has an easterly dip. In middle Pennsylvanian times reefs began to form

along the south edge of the shelf. As the seas transgressed through time, the reef building extended north and continued through middle Permian times.

Reef trends are first noted in the Strawn. Production from the Strawn reef occurs at the Lusk Field, which is located on the south edge of the shelf. Cisco-Canyon reefing is found along the west flank of the shelf, with the major field here being Indian Basin.

The reef building activity reached its height in Permian times. Shown in Figure 5 is the Abo reef trend. The Abo is a large transgressive barrier reef. Production is found in the structurally high areas with an underlying water table. The oil-water contact is found at lower elevations going from west to east. Empire, Lovington and Vacuum Abo are examples of fields in this formation. The maximum oil column thickness was encountered in the Empire Abo field and was about 700 feet. Some exploration along this trend is continuing in Texas.

The San Andres is productive all along the Shelf. A large concentration of fields extends along a trend from Artesia east to the Texas border. Both reef and shelf deposits are productive in this area. The Vacuum and Hobbs fields are examples of San Andres reef production. Large-scale waterflood operations are being conducted in this formation and enhanced recovery projects are under study for large fields.

Production is also found in the middle Permian age sands above the San Andres. The per-well recovery tends to be less in these formations than in the deeper horizons. These zones are also being waterflooded in the larger fields. Loco Hills, Shugart and E-K Queen are examples of this type of production.

NORTHWEST SHELF

The Northwest Shelf has a regional east and south dip. It is bordered on the west by the Pedernal Land Mass and on the south by the Eddy Shelf. It continues on to the east into Texas. The north boundary is deliniated by the Roosevelt uplift and the Tucumcari Basin.

The deepest productive formation of any consequence in the subprovince is the Siluro-Devonian. The traps here are typically anticlines and faulted anticlines. These are undoubtedly associated with uplifted basement fault blocks. The uplifts probably occurred at the same time as those that formed the Central Basin Platform. These structures lie in the eastern half of the shelf and tend to line up in a north-south direction. In a number of cases the Wolfcamp produces on the same structural feature as the Siluro-Devonian. Examples of this type of field are Denton, Dean, Bronco, Gladiola, Bagley and East Caprock. With the improvement of seismic techniques, increased drilling activity for the small Devonian features can be expected.

The San Andres is widely productive throughout this subprovince. Most San Andres fields here are stratigraphic traps. Such fields as Cato and Chaveroo are found on south dipping monoclines with porosity and permeability pinching out to the north. Usually this porosity pinchout is due to secondary deposition of anhydrite in the pore spaces. San Andres production extends west as far as Roswell. However, it is less prolific to the west because of the lower pressures associated with the shallower depth.

The Queen sands are also productive in this area. Like the San Andres the traps are primarily stratigraphic in nature. Production depends on sand development and the lack of anhydrite fill in the pore spaces. The Caprock Queen field is the most significant of these reservoirs.

In the past few years, a significant play has developed in the Abo sand trend along the west edge of the Northwest Shelf. The Abo here is an admixture of continental and marine sediments with some deltaic deposits within. The source material came from the Pedernal Land Mass. The Abo section is over 1,000 ft thick along the trend and has numerous sand lenses within the section. The trend runs north-south along the east edge of the Pedernal Land Mass. These prospects are in the early stages of development and the productive limits are not well defined. Future activity along the trend will undoubtedly be quite senstivite to gas price.

SUMMARY AND CONCLUSIONS

Shown in black in Figure 6 are the producing fields within the New Mexico portion of the Permian Basin. The degree of development shown clearly indicates a mature producing province. Despite this fact, there are substantial new oil and gas reserves being developed in this area every year. Also, some local developments are still considered to be in their earlier stages. The Abo gas sand play and the deep Devonian and Ellenburger play along the west edge of the Central Basin Platform are obvious examples. All of this adds up to the fact that drilling in southeastern New Mexico should remain active into the foreseeable future. It is safe to predict that more new reserves remain to be found here than in any other province in the state. Certainly a better understanding of basin geology should contribute to this development.

REFERENCES

1. Stipp, T. F.: "Major Structural Features and Geologic History of Southeastern New Mexico", Roswell Geological Society Symposium (1956) 17-20.

2. LeMay, William J.: "Abo Reefing in Southeastern New Mexico", World Oil, October, 1960.

3. Pope, Capt. John W.: "Reports of Exploration and Surveys 1853-54", Senate Executive Document 78, 33rd Congress, 2nd session, Washington, D.C., 1855.

4. Palk, A. E.: "The Permian Basin: Geology and Hydrocarbon Accumulation", Southwestern Petroleum Short Course, 1982, Lubbock, Texas.

5. Thornton, Dewey E. and Gaston, H. H. Jr.: "Lusk Strawn Field," Oil and Gas Journal, 1966.

6. Dunlap, William H.: "San Andres Oil Exploration in the Cato-Slaughter Trend of Southeastern New Mexico", Roswell Geological Society Symposium (1967) 21-24.

7. Kumar, Naresh and Foster, Jack D.: "Trap and Reservoir Created by Drape and High Depositional Energy over Bioherm in Texas", Oil and Gas Journal, January 18, 1982.

8. Meyer, Richard F.: "Geology of Pennsylvaian and Wolfcamp Rocks in Southeast New Mexico", United States Geological Survey, 1966, Memoir 17.

ACKNOWLEDGEMENTS

I would like to thank ARCO Oil and Gas Company for their kind permission to publish this paper.

I would also like to express my appreciation to Mr. E. R. Douglas, Area Geologist, ARCO Oil and Gas Company, for his technical advice and counsel in preparing this paper, and to Mr. S. W. Barton of ARCO Oil and Gas Company for his review of the draft.

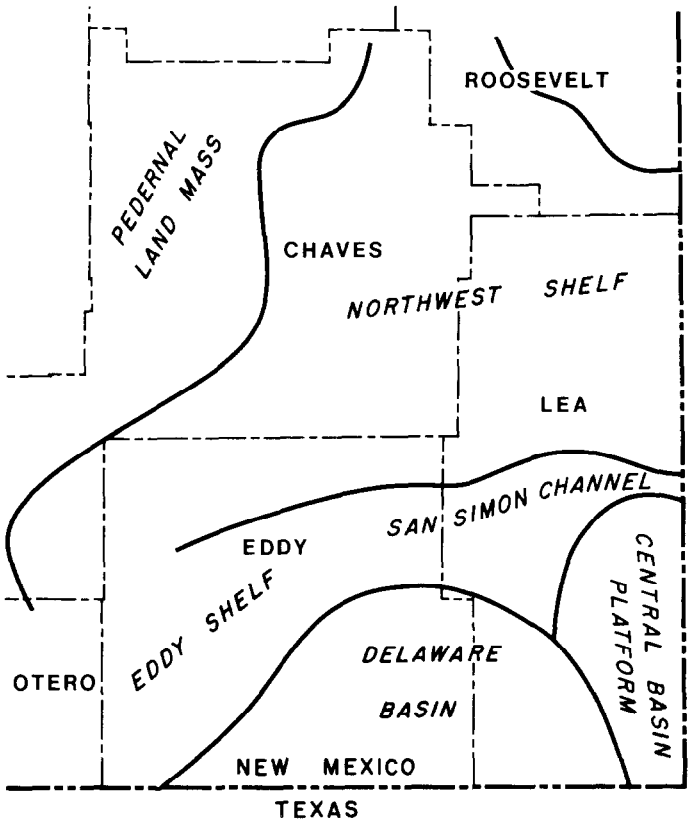

FIGURE 1 — MAJOR GEOLOGICAL FEATURES

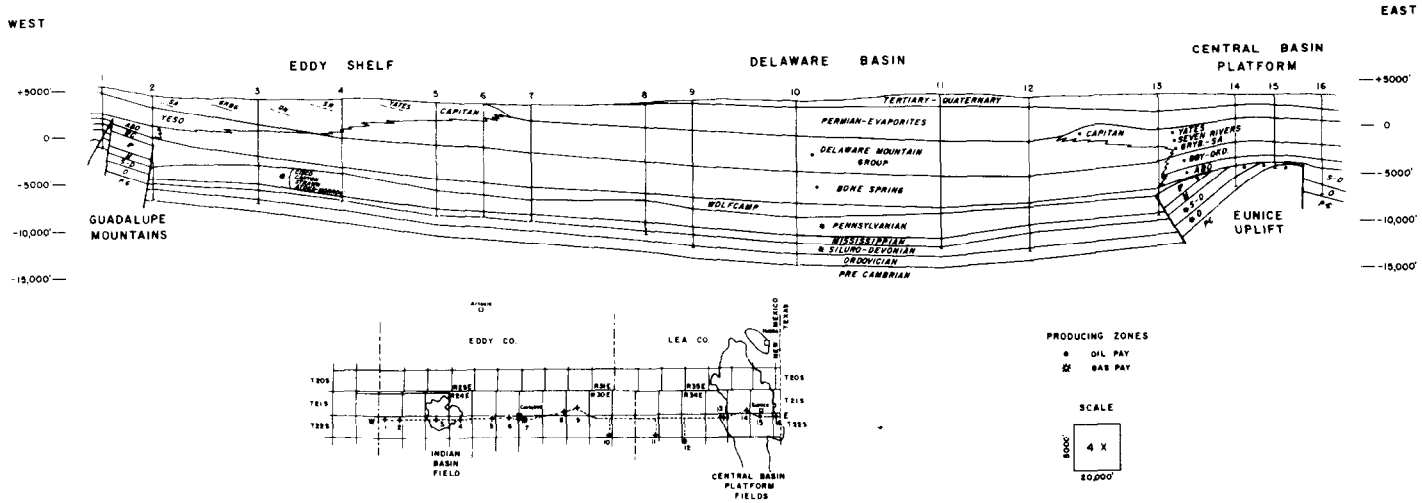

FIGURE 2 — W-E CROSS SECTION
GUADALUPE MTNS. — EUNICE UPLIFT
EDDY & LEA COS., N.M.

GEOLOGIC SECTIONS

PLATFORM EDGE - LEA CO., N.M.

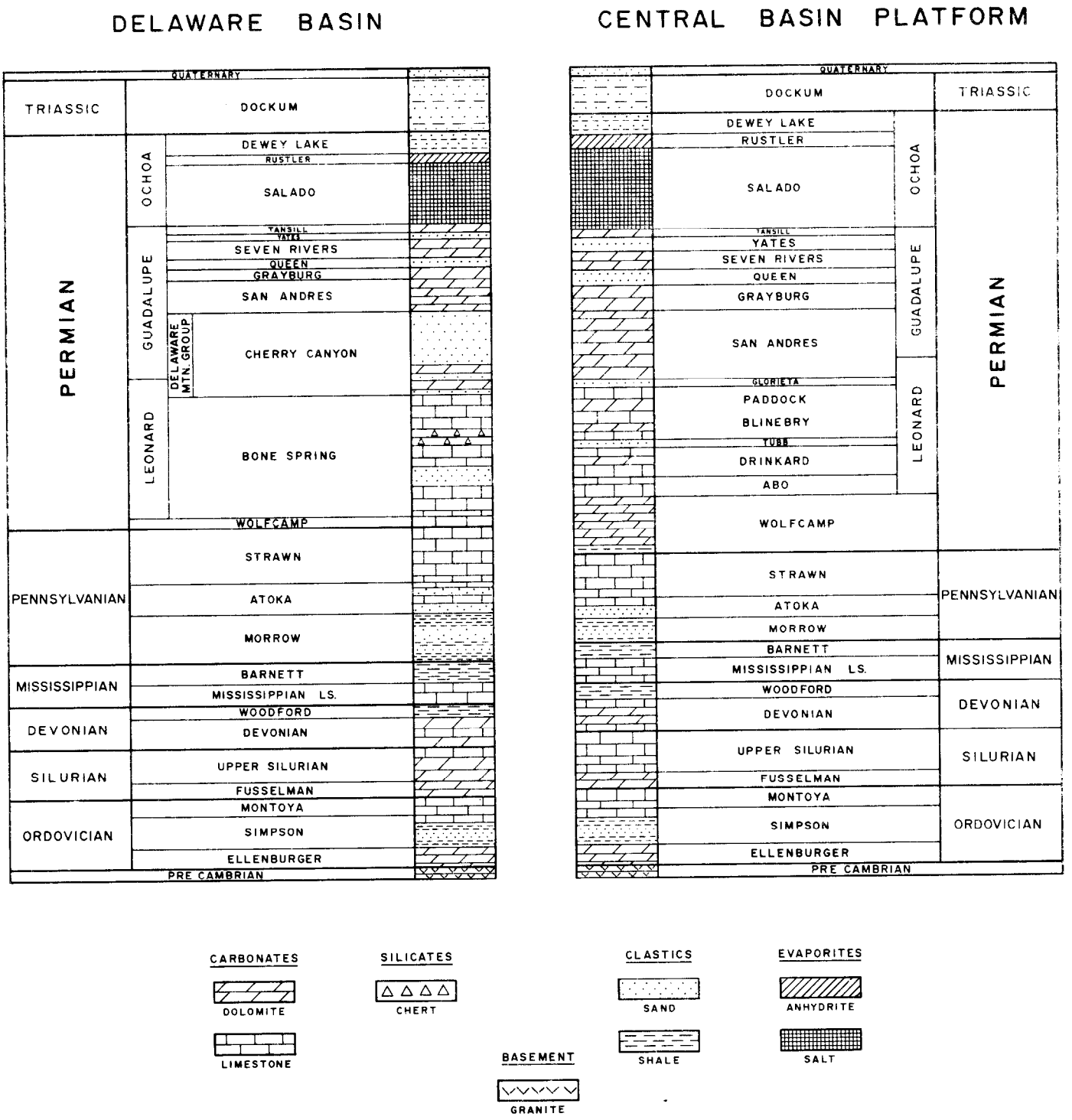

FIGURE 3

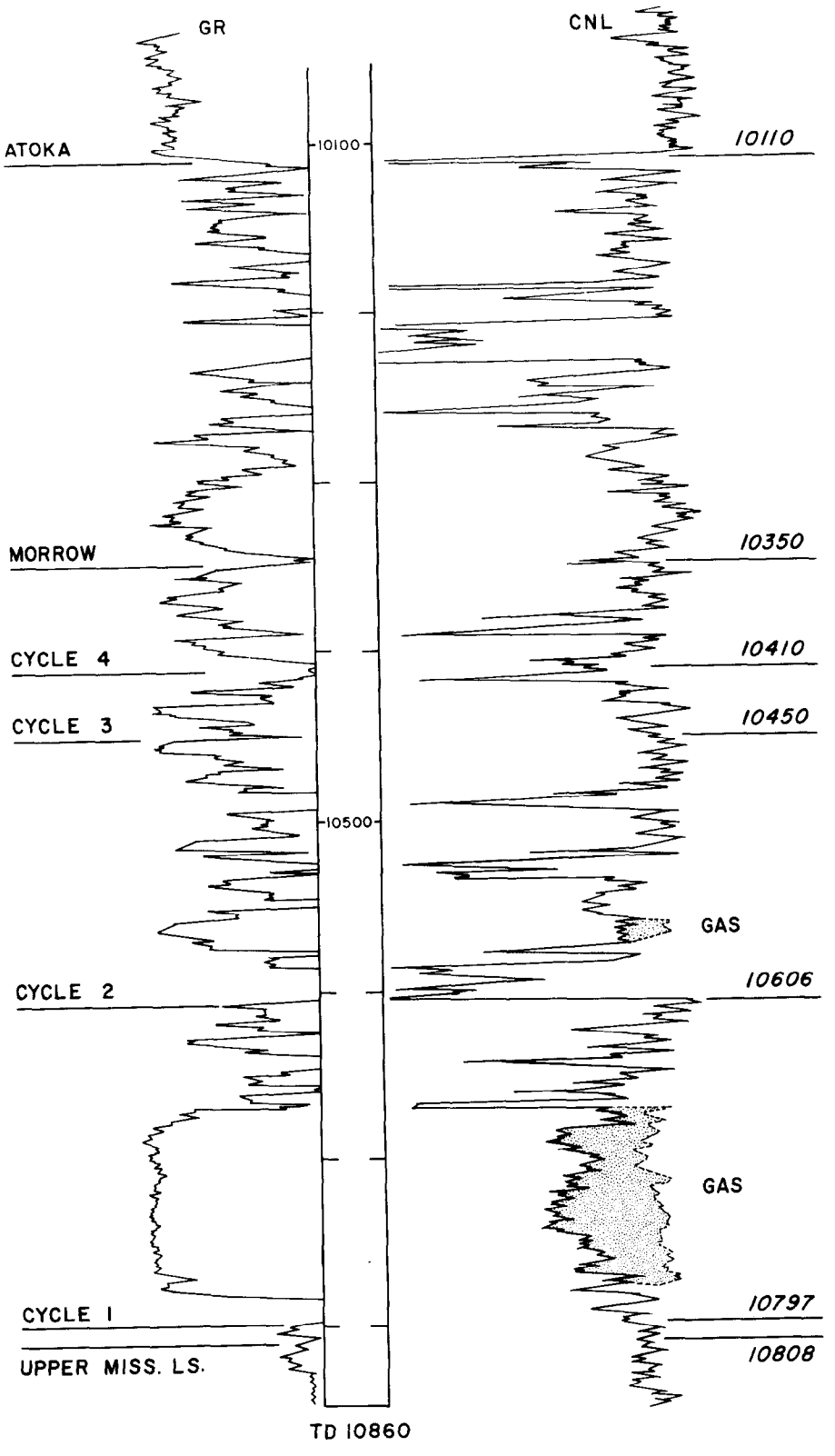

FIGURE 4

MORROW SAND CYCLES - EDDY CO. NM
ARCO STATE BV No. 1 - S. EMPIRE FIELD
NW SE SEC. 25 - TWP. 17S - RGE 28E

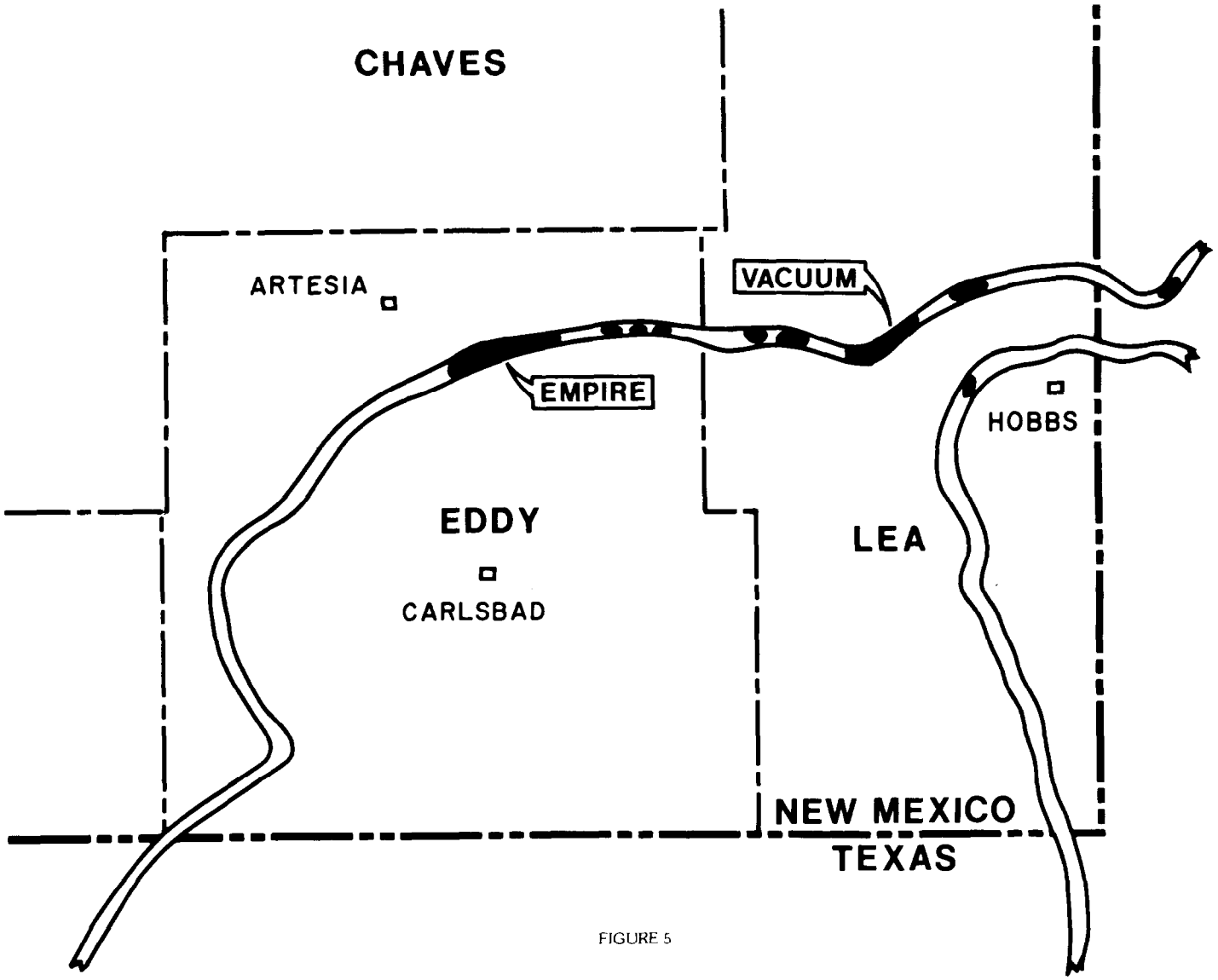

FIGURE 5

ABO REEF TREND

S/E NEW MEXICO

SCALE

12 MILES

OIL FIELD

ABO REEF TREND

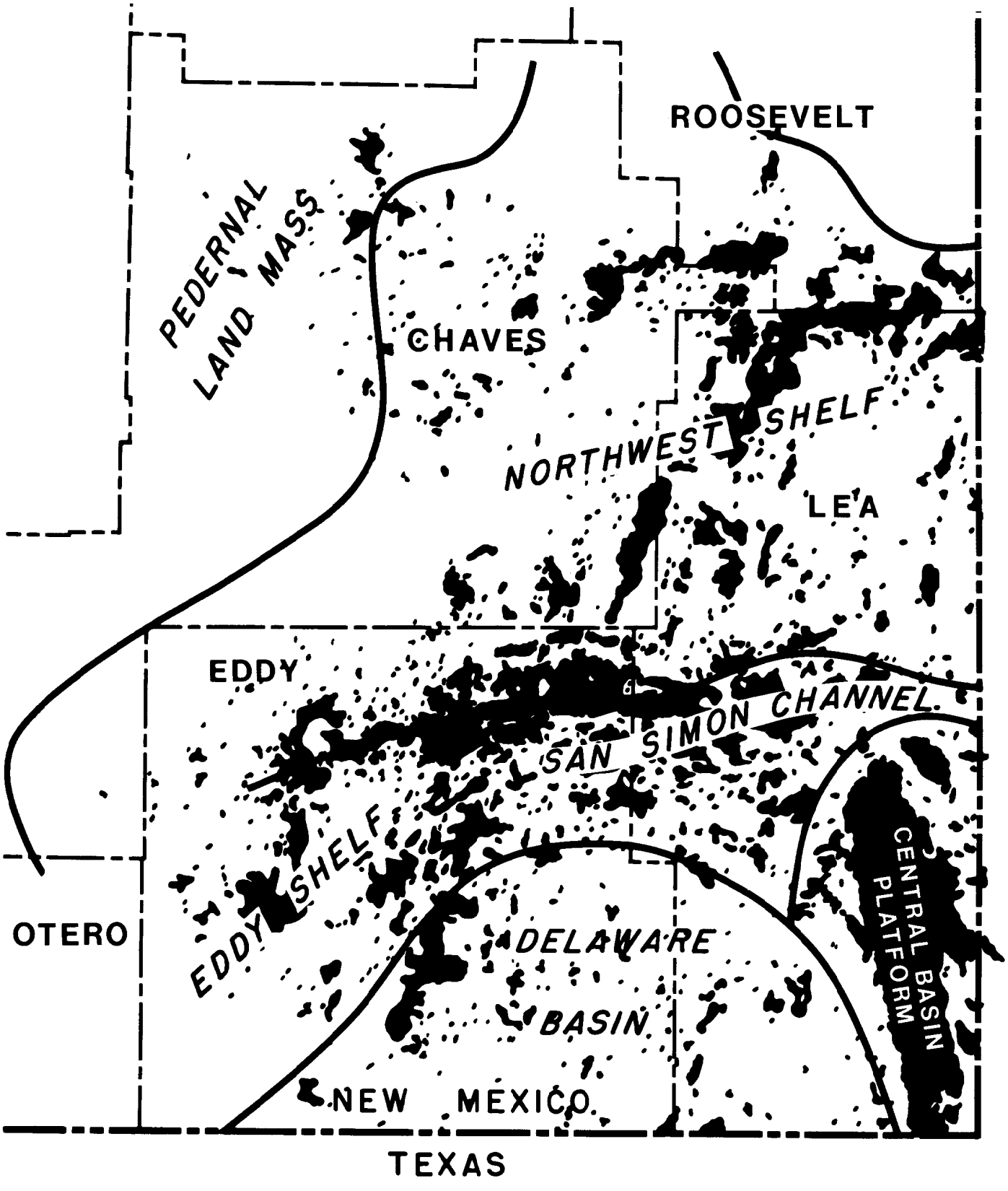

FIGURE 6

PRODUCING FIELDS