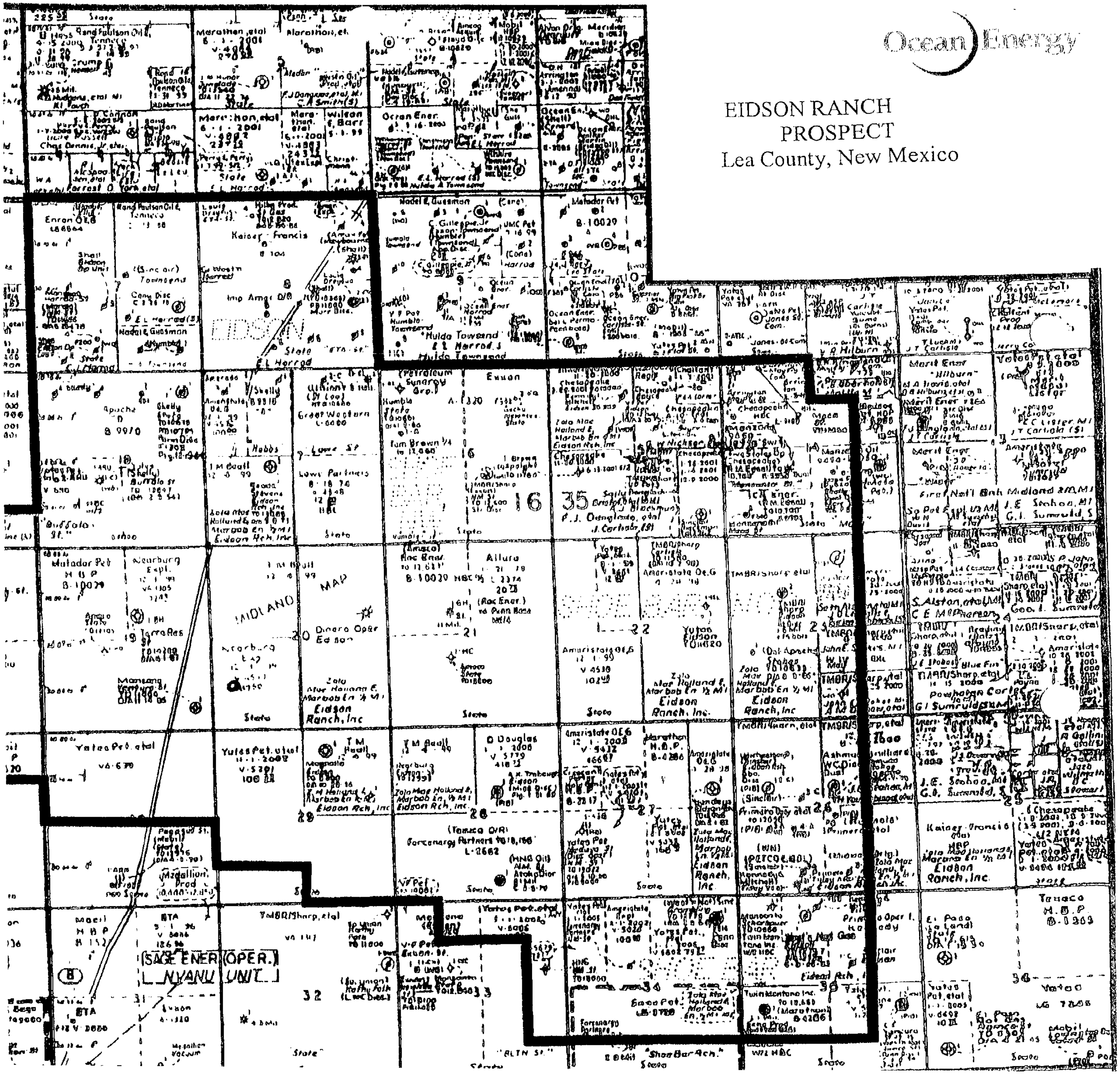
Ocean Energy

EIDSON RANCH
PROSPECT
Lea County, New Mexico



OIL CONSERVATION [redacted] COMMISSION

CASE NUMBER ____________

Ocean EXHIBIT 1

03/27/01 Called Andy Grooms with Primero Operating (Brannex) and began negotiations to acquire farmin/term assignment.

04/25/01 Sent first proposal letter.

05/18/01 Sent second proposal letter.

06/12/01 Received counter proposal letter from Primero.

07/23/01 Final agreement sent to all parties.

08/14/01 1st amendment changes date agreement must be accepted.

11/30/01 2nd amendment changes language so well did not have to be on farmout lands and contract depth from 12,500' to 13,200'

OIL CONSERVATION [redacted] COMMISSION

CASE NUMBER ______

EXHIBIT 2

# GEOLOGIC HISTORY AND RESERVOIR DEVELOPMENT IN THE SHOEBAR FIELD AREA, LEA COUNTY, NEW MEXICO

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## ABSTRACT

**Production in the Shoebar Field area comes from many different types of reservoirs in rocks ranging in age from the Silurian up through and including the Permian Abo Formation. A complex structural setting in this area created a Paleozoic stratigraphy that is difficult to interpret with seismic data alone. The section from the upper Mississippian Chester through the upper Atoka Formations is further complicated by inter- and intra-formational unconformities, and differential movement along major faults. Faults and unconformities were important to the development of reservoirs throughout the section because tectonic movement and exposure events associated with those surfaces affected reservoir distribution, quality, and locally, erosion.**

**Several formations in the area, including the Wristen, Chester, Atoka, Strawn and lower Wolfcamp, are key targets because of recent exploratory successes or because they offer new reserve development potential. Reservoirs in each of these formations were developed under unique depositional conditions, and prediction of ideal reservoir conditions in these rocks may be facilitated through coordinated lithologic correlations and seismic interpretation. Lithologic data are critical to understanding the abrupt changes that affect the stratigraphy in the area, and to preventing mis-correlations that could inhibit optimum evaluation of prospective targets in a well.**

## INTRODUCTION

The Shoebar Field area is located west-southwest of Lovington in Lea County, New Mexico, and is situated on the east side of the Northwest Shelf at the junction of several other major structural elements of the Permian Basin: the Tatum Basin to the north, North Platform to the northeast, and Central Basin Platform to the southeast (Figure 1). In this setting, the Paleozoic section had undergone numerous episodes of tectonic activity, reactivation of older structures, and periodic exposure and erosion of parts of the section. This episodic tectonic activity had varying affects upon development of carbonate and siliciclastic reservoirs that occur in formations from the Wristen (Silurian) through the Abo (Permian). The purpose of this geologic note is to summarize the tectonic setting of the Shoebar area, the types of reservoirs that have developed as a result of the complicated history of the area, and characteristics of major oil and gas reservoirs in the area. The aim of this study was to apply an understanding of reservoir development mechanisms to broadening old plays and developing new ones in formations that have been producing in the area for years. Study in this area is a work in progress, as new drilling activity will no doubt continue to reveal useful details of the stratigraphy that will add to our exploration tools.



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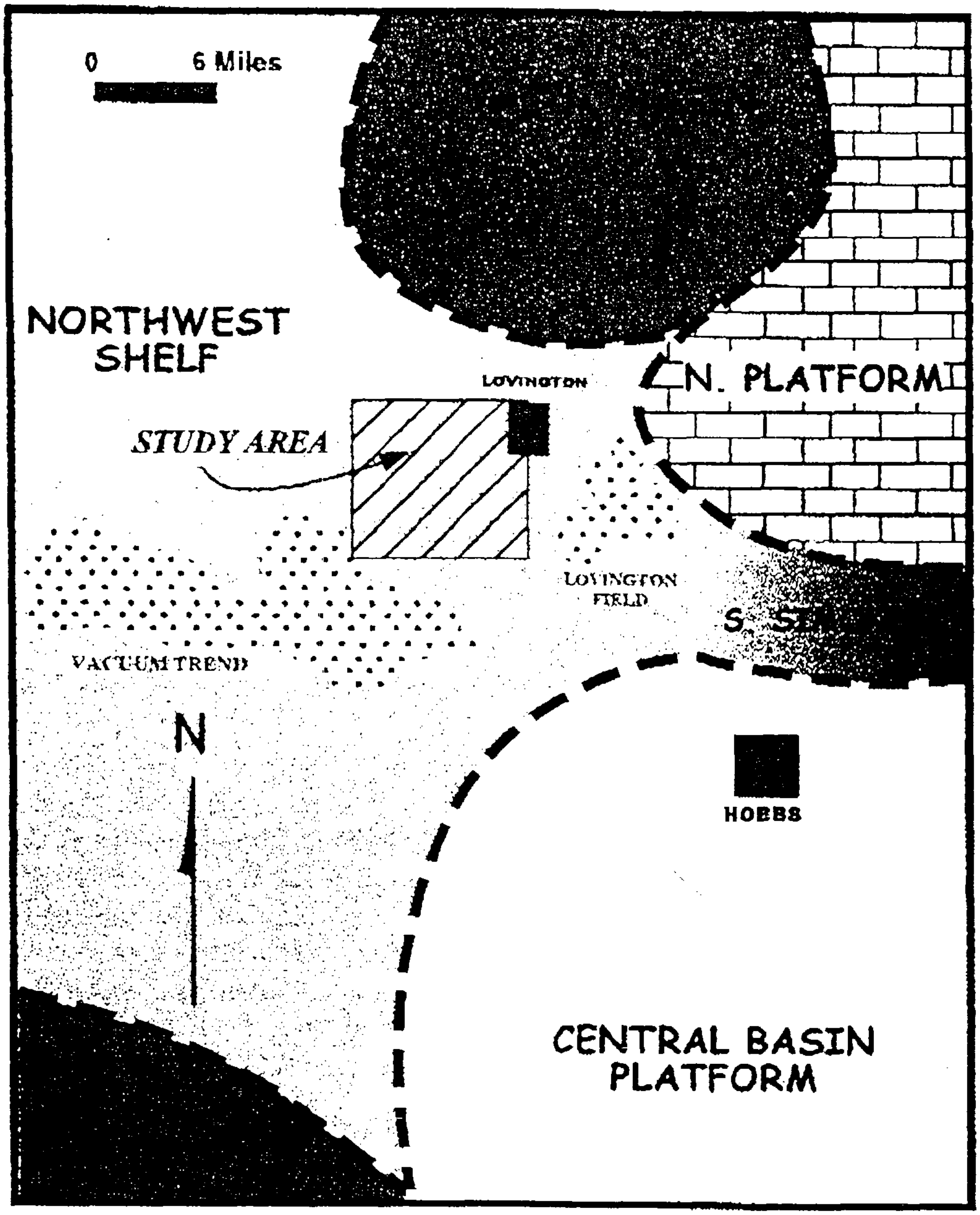


**Figure 1. Location and tectonic setting of Shoebar Field study area in eastern Lea County, New Mexico.**

## GEOLOGIC SETTING

### General

Detailed lithologic study of well cuttings from 19 wells in the area were used to evaluate the stratigraphy of the major producing horizons, identify and correlate formation contacts, and provide depositional models for each of the major target zones. Several high-resolution 2-D seismic lines were also used to identify fault locations and penetrations, and in some cases, to confirm the presence of reservoir facies. Figure 2 shows the stratigraphy of the area and the formations that produce there. Some of the formational contacts (e.g., between the lower Atoka shale and lower Atoka limestone) differ from colloquial use in the area, but are based on detailed lithologic correlation and faunal assemblages.

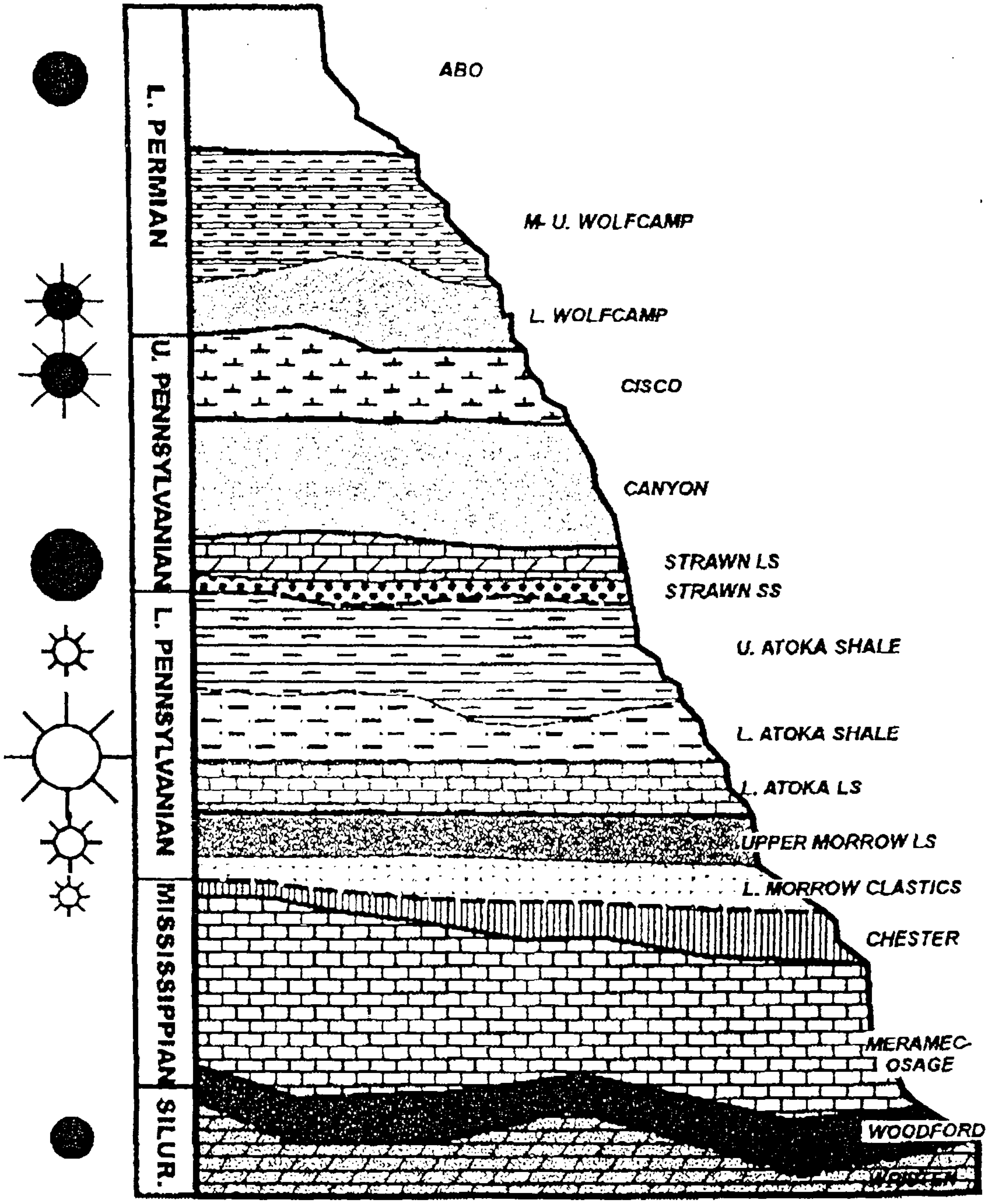


**Figure 2. Silurian through Lower Permian stratigraphic section of the Shoebar area. Well symbols at left are sized in relative proportion to production from formations in the area. Dashed contacts represent major unconformities.**

## Pay Zones and Production

The greater Shoebar area is in one of the oldest producing areas of the Permian Basin, yet new and significant discoveries continue to be made there. The most prolific production to date has been from sandstones near the base of the Lower Pennsylvanian Atoka Formation (up to 30 billion cubic feet of gas per well), and from algal mound carbonates in the Middle Pennsylvanian Strawn Formation (up to 600,000 to 1,000,0000 barrels of oil equivalent (BOE) per well). Other significant production has been from (1) algal mounds of the Lower Permian Wolfcamp Formation (variously referred to as Permo-Penn or Wolfcamp), which produces dual-phase hydrocarbons (up to 775,000 BOE per well); (2) carbonates of the Silurian Wristen Formation (up to 650,000 barrels of oil per well); (3) Upper Pennsylvanian Cisco algal mounds (similar in reserves to the Wolfcamp); (4) foreshelf carbonates of the Permian Abo Formation (up to

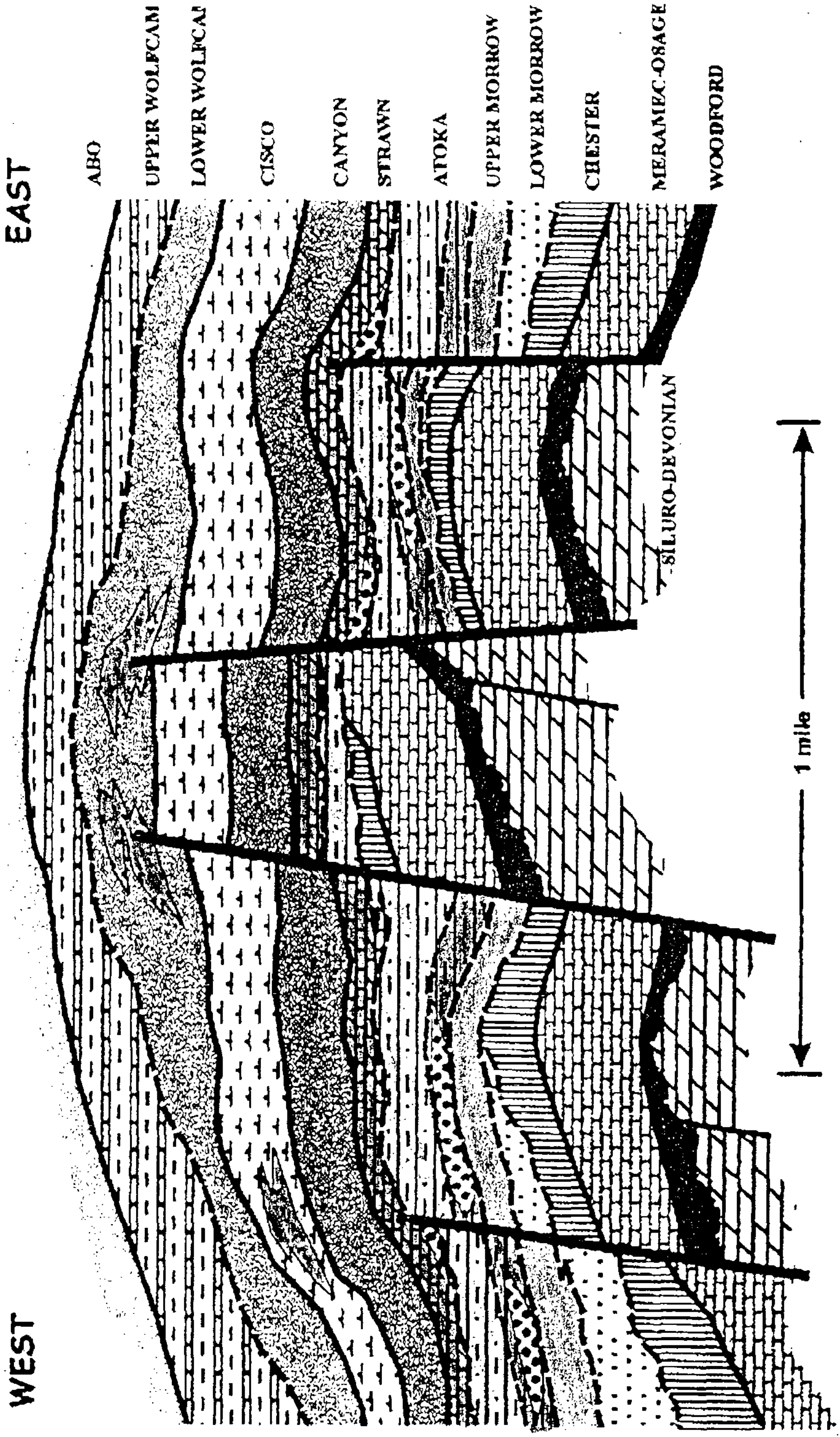


**Figure 3. Schematic structural cross-section through the Shoebar area, showing various age faults and major unconformities (dashed contacts).**

100,000 barrels of oil per well); and (5) various sands in the Lower Pennsylvanian Morrow and upper Atoka shale sections (up to 2.5 billion cubic feet of gas per well). Depths to the various pay formations range from approximately 8,500 feet (Abo) to 13,000 feet (Silurian or Atoka-Morrow).

## Tectonic Setting

Figures 2 and 3 show a number of inter- and intra-formational unconformities that have been recognized in the area. Figure 3 also shows that over relatively short distances, the Paleozoic section is cut by several faults of different ages.

The terminal tectonic event occurred in the Early Wolfcamp, but only affected a small part of the study area. Faults that penetrate only to the upper Atoka are more numerous, and in some areas, faulting terminates in the Silurian and does not extend any farther up section. The major unconformities are found at the top of the Silurian, Mississippian, Atoka, and lower Wolfcamp formations. Important intraformational unconformities are found within the Wristen, Morrow, Atoka, and lower Wolfcamp Formations. Faults and unconformities were important to hydrocarbon production in the area because tectonic movement and exposure events associated with those surfaces affected reservoir distribution and quality, hydrocarbon migration, and locally, reservoir erosion.

## EXPLORATION PROBLEMS

Because of the structural complexity and resultant variable stratigraphy of the area, conventional 2-D seismic data has its limitations in exploring for and developing hydrocarbon reservoirs in the Shoebar area. 3-D seismic, which has been used a lot in the area over the last several years, has had mixed success because of the way the section and structure can change very abruptly over short lateral distances. For example, Figure 3 shows that on the highest fault blocks, part or all of the upper Mississippian, Morrow, and lower Atoka Formations can be stripped off, depending upon the timing of movement along each fault. It is not surprising, then, that seismic interpretations sometimes miss their mark because these abrupt changes in structure and stratigraphy are not always recognized or anticipated.

Another problem that arises from misunderstanding the stratigraphy is drilling short of potential pay zones. For example, the lower Atoka and upper Morrow limestones have been often mistaken for the Mississippian Chester or Meramec-Osage limestones, causing some operators to drill short of targets in the Morrow. The lithologies of the Atoka-Morrow and the Mississippian are distinguishable in samples, but log responses in these formations are often similar. Well logs are not a reliable means by which to correlate sections, especially when it comes to deciding on the final depth of a well.

## MAJOR RESERVOIRS

Table 1 lists the types of reservoirs found in the Shoebar study area. The more important reservoirs in terms of recent exploratory successes or potential new development are summarized below.

### Silurian

The oldest rocks that produce in this immediate area are dolomitic carbonates that have been referred to as Devonian, but which are lithologically similar to the Upper Silurian Wristen Formation (e.g., Mazzullo, 1998). The Wristen Formation subcrops beneath a relatively thick section of dark Woodford Shale in this area. Production is from moderately-bedded porous dolomites that are interbedded with non-porous limestones. Although most of the production is on higher structural blocks, productive features are small and reserves not always commensurate with the amount of structural closure.

Figure 4 suggests the reason for lackluster production out of the Wristen. Unit *A* is a limestone reference horizon, identified with samples, that is used to show the relationship between pre-Woodford and post-Woodford structure. The changing structural attitude of unit *A* relative to the base of the Woodford reflects pre-Woodford folding and removal of the upper part of the section, which is a common occurrence in this part of the Lower Paleozoic (Mazzullo, 1990). The base of the Woodford Shale is an exposure surface. The section below this surface was folded prior to exposure and erosion and further modified by subsequent tectonic events in the Mississippian, Atoka, and early Wolfcamp. Consequently, porous reservoir facies (dolomites) could be eroded off or are not always ideally juxtaposed on the later structures, and are often reverse-structured from what is mapped on the base of the Woodford shale. With adequate

TABLE 1

**RESERVOIRS IN THE SHOEBAR AREA AND VICINITY**

| | |
|---|---|
| **SILURIAN:** | **Restructured karsted carbonates; dolomites interbedded with limestones** |
| **MISSISSIPPIAN:** | **Weathered tripolitic limestones near top of the Chester** |
| **MORROW:** | **Primarily alluvial sandstones, absent on higher structures** |
| **ATOKA:** | **Fluvial/Transitional marine sandstones in lower part; Fluvial and marine sands in upper part** |
| **STRAWN:** | **Sandstones on top of upper Atoka unconformity; Algal mound carbonates on flanks of deeper structures** |
| **CISCO:** | **Algal mound carbonates; foreslope detrital carbonates** |
| **L. WOLFCAMP:** | **Tubiphytes/algal mounds along flanks of deeper highs** |
| **ABO:** | **Foreslope to shelf-edge carbonates** |

sample control, the Wristen can be zoned, and reservoir dolomites traced to areas where they might trap more favorably, even if these areas do not coincide directly with highest structures.

## Mississippian

The Upper Mississippian Chester Limestone pays in a few wells in the area, although it is often mis-correlated as a Morrow pay zone. It is noted here because it may offer additional reserve opportunity that has generally gone unrecognized. Based on correlations of Mississippian lithologies from several wells, the pay zone is a reworked, tripolitic, carbonate sand that appears to form very close to major fault scarps that cut the Upper Mississippian section.

Figure 4 suggests how these carbonate sands may have formed. The top of the Mississippian is one of the major unconformities in the area. During the latest Mississippian, low-relief uplift occurred along the faults and exposed cherty Chester limestones to erosion. Unit *B* was formed from erosion of the fault scarp, and deposition of debris in alluvial fans close to the base of the scarps. The carbonate debris was exposed and tripolitized, which created the outstanding porosity seen in these reservoirs. Since they were deposited so close to the source, they are limited in width and probably discontinuous along trend, which makes them hard to predict. To date, these reservoirs have been found to be up to 20 to 25 feet thick, and capable of delivering in excess of 1.0 billion cubic feet of gas per well.

## Atoka

Sandstones near the base of the lower Atoka shale (Figure 2) are the most sought after reservoirs in the area because of their potentially large gas reserves. These sandstones were

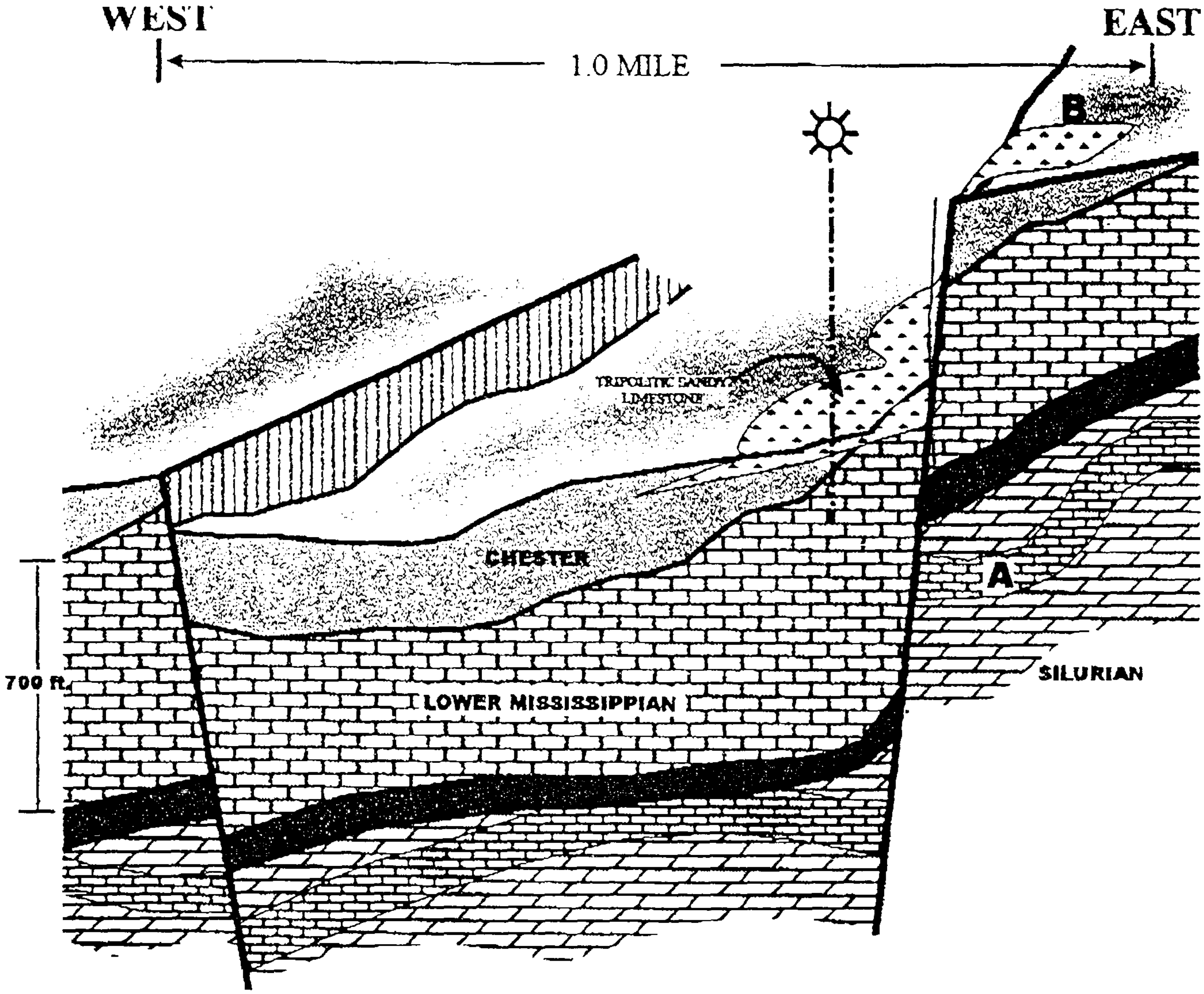


**Figure 4. Structural cross-section through the Silurian and Chester sections in the Shoebar area. Unit A represents a limestone marker bed in the Wristen; Unit B is a tripolitic lime grainstone in the Chester.**

deposited in fluvial environments over most of the area, but the net pay section is actually a composite of several individual channel units that locally stack into appreciable thicknesses of sand (Figure 5). These sandstones were deposited on a relatively gently-sloping alluvial plain. Because these sands are found on both high and low structural blocks, they appear to have been deposited in relatively low areas that were differentially uplifted after deposition, either in the late Early Atoka or Late Atoka.

Some basal Atoka sands terminate abruptly on parts of the higher fault blocks in the area (Figure 6). Because their grain size and lithology do not change closer to these highs, it is suspected that the lower Atoka section was uplifted shortly after deposition of the sands, and the sands were eroded off the highs. This event is marked by an intraformational unconformity that separates the lower Atoka shale and limestone from the upper Atoka section (Figures 2 and 3). On the highs, the Atoka thins by erosion of the basal part of the lower Atoka shale and the Atoka limestone sections. Lower permeability is also associated with these sands in close proximity to the highs, presumably due to early post-depositional occlusion of primary porosity in the meteoric environment.

## Strawn

The Shoebar area is south of (i.e., basinward of) the main Lovington Strawn trend. The Lovington trend is characterized by a few

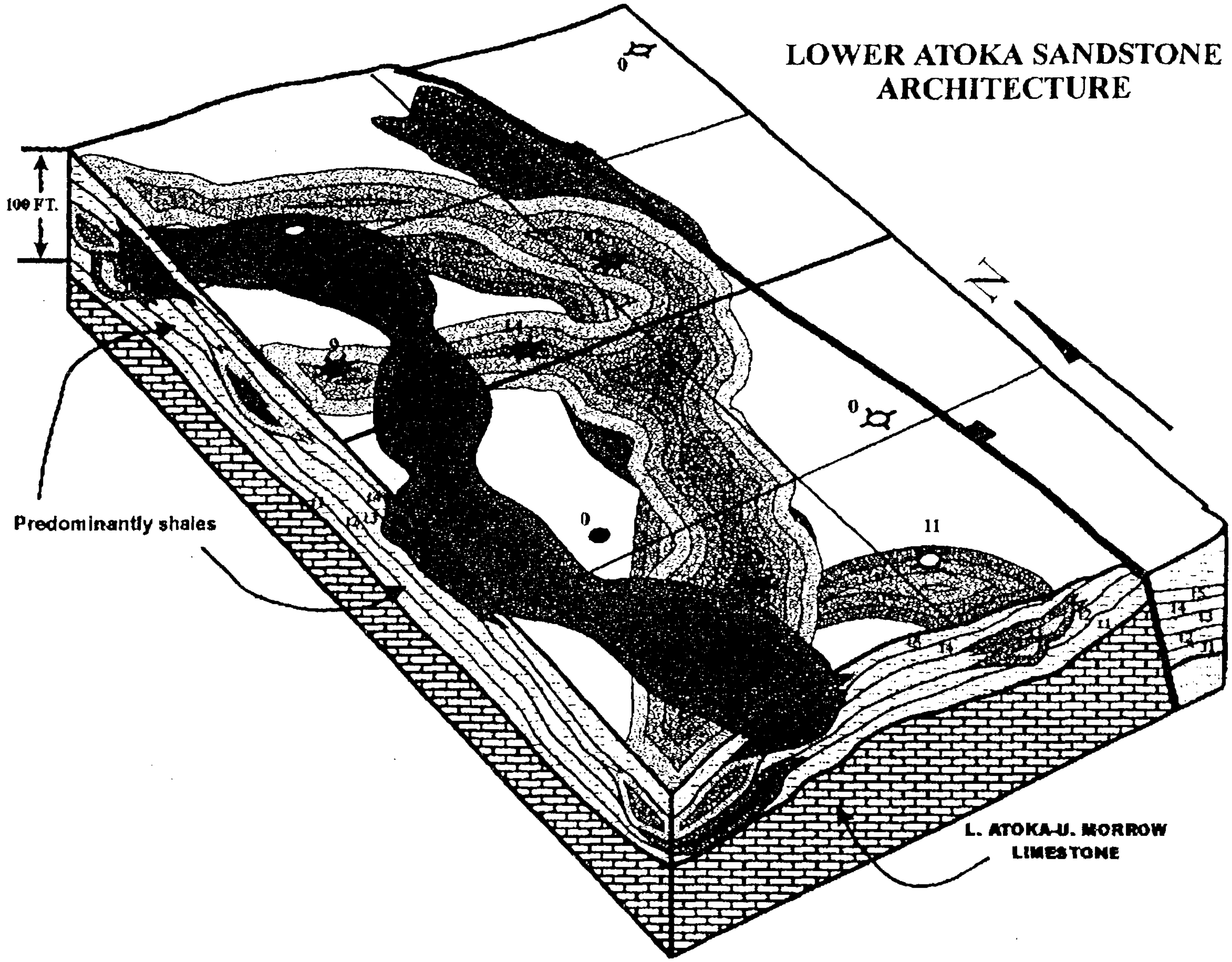


Figure 5. Block diagram showing development of fluvial sandstones (t1 through t5) in the lower Atoka shale section. Each square represents a one mile-square section.

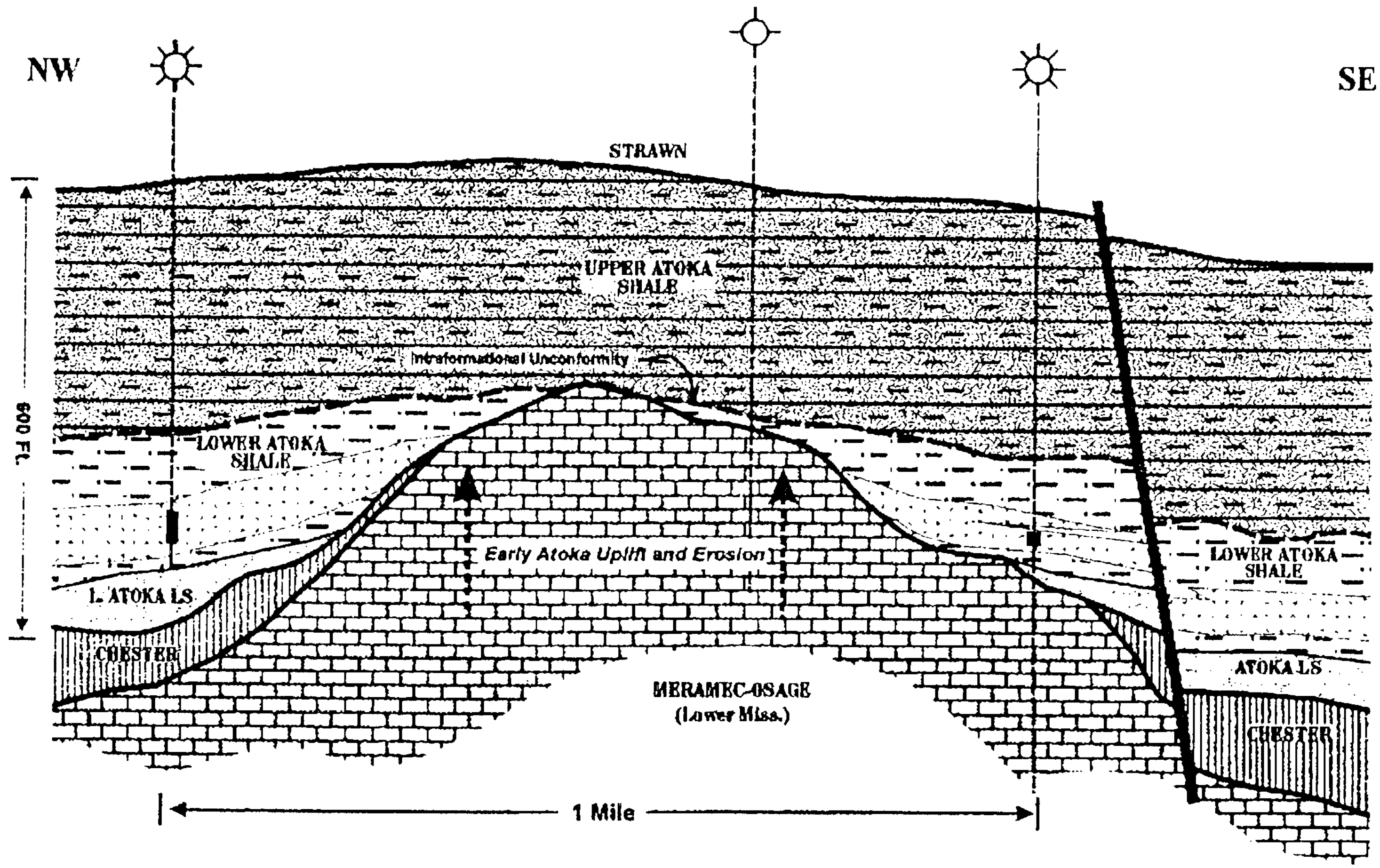


Figure 6. Structural cross-section across the crest of a major Early Wolfcamp fault block in the Shoebar area, showing erosion of the lower Atoka section beneath the early Atoka intraformational unconformity.

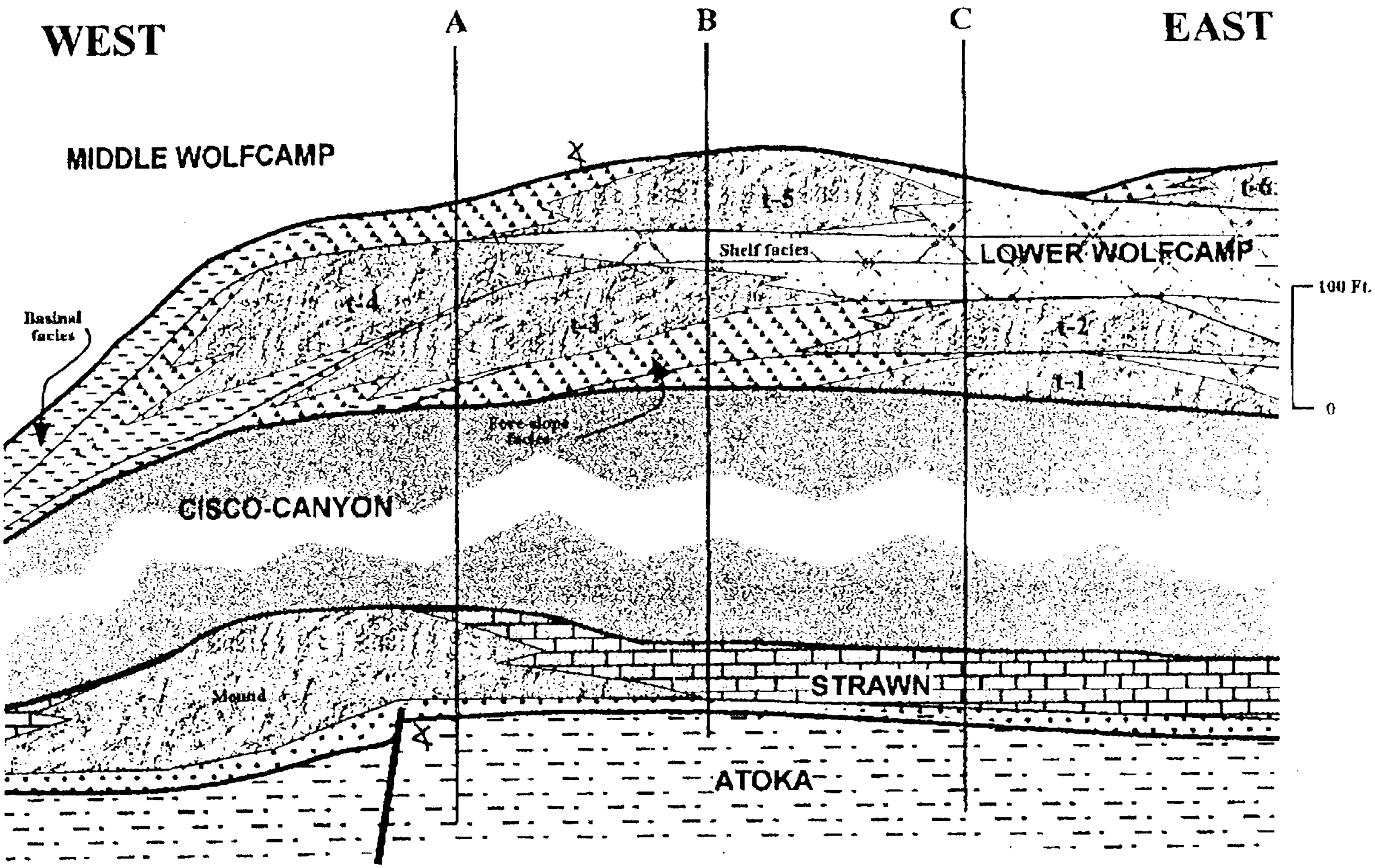


Figure 7. Structure section depicting development of Strawn algal mounds and lower Wolfcamp *Tubiphytes*-algal mound sequences (t1 through t6). Part of the Cisco-Canyon section is omitted for clarity.

hundred feet of Strawn carbonate that is comprised of multiple, stacked carbonate algal mound sequences. In the Shoebar area, the Strawn is only 50 to 150 feet thick. It locally contains isolated algal mound sequences (Figure 7) in the northern part of the study area, but grades to basinal, muddy limestones in the southern part. The mounds are commonly found on the flanks of underlying structural highs rather than on the crests. These highs provided paleo-topographic substrates on the sea floor on which mounds grew. However, the wave-intolerant phylloid algae that are common to these mounds favored the slightly lower-energy environments around the flanks of the highs.

## Lower Wolfcamp

The lower Wolfcamp produces from algal mounds similar to those in the Strawn (Figure 7), but are dominated by *Tubiphytes* algae, red algae, and bryozoans. These species were more resistant to wave energy than those in the Strawn, and grew both on the flanks and near the crests of substrate highs. The lower Wolfcamp is often mis-correlated as the upper Cisco because it has been generally thought that the southernmost extent of *Tubiphytes* mound development in the Wolfcamp was to the north along the Eidson-Townsend trend. A high-relief Early Wolfcamp reverse fault block, however, provided the substrate for more basinward development of these mounds in the Shoebar area.

The lower Wolfcamp mounds developed in carbonate facies tracts that shifted depositional sites laterally through time in response to changes in relative sea level. As a result, mounds were able to grow on the higher structural blocks in the area several miles seaward of the main Eidson-Townsend shelf-edge trend to the north. At Shoebar, lower Wolfcamp reservoirs occur as discrete mound sequences of less than 30 feet thickness, or locally develop over 300 feet of stacked, composite sequences.

## CONCLUSIONS

The Shoebar area is an exploration and development play in a mature hydrocarbon producing region because of the number of potential reservoir zones in the section, many of which have not been developed to their full potential. Part of the reason why reservoirs are underdeveloped or overlooked is the stratigraphic complexity that arises from the unique tectonic setting of the area. It is understandable that mis-correlations have limited development in some areas because it is difficult to sort out the section without detailed lithologic correlations.

Seismic evaluation of the area should not be conducted without coordinated lithologic study. The examples cited in this report have shown how critical lithologic and faunal correlation can be to correctly placing reservoirs in the section, and how abrupt changes in section may not be easily recognized. Log correlations are not reliable for gross stratigraphic correlation here because logs cannot characterize facies and faunal assemblages, and different formations often show similar log signatures. In areas where well control is adequate, it should possible to enhance chances for a successful well and finding new reserves from old producers by applying reservoir models based on lithologic study to the location of new well sites and interpretation of 3-D seismic.

## REFERENCES CITED


Mazzullo, L. J., 1990, Implications of sub-Woodford geologic variations in the exploration for Silurian-Devonian reservoirs in the Permian Basin; West Texas Geological Society, Publ. 90-86, p.29-42.

Mazzullo, L. J., 1998, Exploration model of non-conventional Siluro-Devonian reservoirs in the Permian Basin (abstract); Frontier and Underdeveloped Basins of New Mexico, Albuquerque: Petroleum Technology Transfer Council Symposium.