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Producing Characteristics and Depositional Environments of Lower Pennsylvanian Reservoirs, Parkway-Empire South Area, Eddy County, New Mexico[1]

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ABSTRACT

The Parkway-Empire area, on the Northwest shelf of the Permian basin about 15 mi (24 km) northeast of Carlsbad, New Mexico, produces gas from stratigraphic traps within four Lower Pennsylvanian zones: lower and middle Morrow sandstones, Atoka sandstones, and Strawn limestones.

The lower Morrow sandstones, which occur at about 11,400 ft (3,470 m), are interpreted to be a prograding fluvial-deltaic sequence of channels and point bars with a northwest source. They trend toward the southeast, generally normal to the Morrowan paleoslope. The lower Morrow sands are separated from the middle Morrow sandstones by a widespread, dark-gray, organic lagoonal shale. In southeastern New Mexico, middle Morrow sandstones are a transgressive series of marine beaches and bars deposited along the northeast-trending ancient shoreline. Stratigraphic traps are created in the lower and middle Morrow sandstones by variations in cementation and depositional patterns. Productive Atoka sandstones occur at approximately 10,700 ft (3,260 m) and appear to be a series of prograding barrier bars deposited along the northeast-trending shoreline. Strawn limestones produce from a series of small, low-relief algal banks developed along northeast depositional strike. The Strawn limestones occur between 10,250 and 10,500 ft (3,120 and 3,200 m).

The area is economically attractive. Payout of a typical well occurs in 1.2 years with a rate of return of 78.1%. Pennsylvanian completions in this area have typical ultimate recoveries of approximately 1.5 bcf (42×10^6 m^3) of gas and 22,000 bbl (3.5×10^6 L) of condensate. The stacked nature of the reservoirs causes a success rate of 85.2% for this area. The high success rate, good production, and attractive economics make this area of the Morrow trend an important exploration target.

INTRODUCTION

The Parkway-Empire area is located on the Northwest shelf of the Permian basin in central Eddy County, New Mexico, about 15 mi (24 km) northeast of Carlsbad (Figure 1). It consists of eleven or more designated pools (fields).[3] Two discovery wells have led to aggressive development. The first of these, Southland Royalty Company 1 Parkway State located in Sec. 15, T19S, R29E, was completed from middle Morrow sandstones on August 24, 1978, for a flowing potential of 2,714 MCFGD (77×10^6 m^3/day). As of December 31, 1982, cumulative production was 1.3 bcf (37×10^6 m^3) of gas and 20,000 bbl (3.5×10^6 L) of condensate. The second well, Southland Royalty Company 1 Empire Federal State Commission located in the SW¼ of Sec. 27, T18S, R29E, was completed from an Atoka sandstone in June 1980, for a calculated absolute open flow (CAOF) of 1,800 MCFGD (51×10^3 m^3/day). It had produced 1.3 bcf (37×10^6 m^3/day) of gas by December 31, 1982, when it was flowing 1,200 MCFGD (34×10^3 m^3/day). This well was originally completed in the lower Morrow in May 1980, where it produced a small amount of gas before being plugged back to the Atoka. Since these two wells were drilled, about 30 additional wells have been drilled, extending the various Parkway and Parkway West pools north to the Empire South pools to form one large producing area. Besides Southland Royalty Company, major operators in the area are Petroleum Corporation of Texas, Threshold, Amoco, Conoco, and Hondo (ARCO).

The Parkway-Empire South area produces gas from four Pennsylvanian zones and oil from several Permian zones. The Pennsylvanian production occurs from four distinct sequences: lower Morrow sandstones, middle Morrow sandstones, Atoka sandstones, and Strawn limestones.

Permian productive zones include Wolfcamp carbonates, Bone Spring carbonates, San Andres carbonates, Grayburg carbonates, and Queen and Seven Rivers sandstones. The Wolfcamp and Bone Spring carbonates have not yielded commercial quantities of oil. The Queen, Seven Rivers, Grayburg, and San Andres sediments produce oil from 1,800 to 2,500 ft (550-760 m) in large portions of the study area. These zones are economic objectives and are being developed in portions of the study area. Economically, the significant production in this area is gas occurring between 10,200 and 11,500 ft (3,100 and 3,500 m) in the Strawn, Atoka, and Morrow. As of December 31, 1982, cumulative production from these zones in 99 wells in the Parkway-Empire South area was 109 bcf (3.09×10^9 m^3) of gas and 1,600,000 bbl (260×10^6 L) of condensate. The

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Jack W. Becher and Michael G. Metcalf helped develop the regional concepts used in this paper. They prepared the regional environmental maps, and Metcalf prepared the Atoka net sand isopach map. Statistical production data were compiled by E. R. Andrews. Gilbert R. Barragan drafted the figures, and Nelta G. Baccus and Janet C. George typed the drafts and final manuscript. All these people are employees of Southland Royalty Company. Special thanks is given to these individuals for their help and efforts and to Southland Royalty Company, who permitted publication of this study.

[3]The state of New Mexico designates pools rather than fields. In productive areas, each producing zone is assigned a separate pool name, such as Parkway Atoka West and Empire Morrow South.

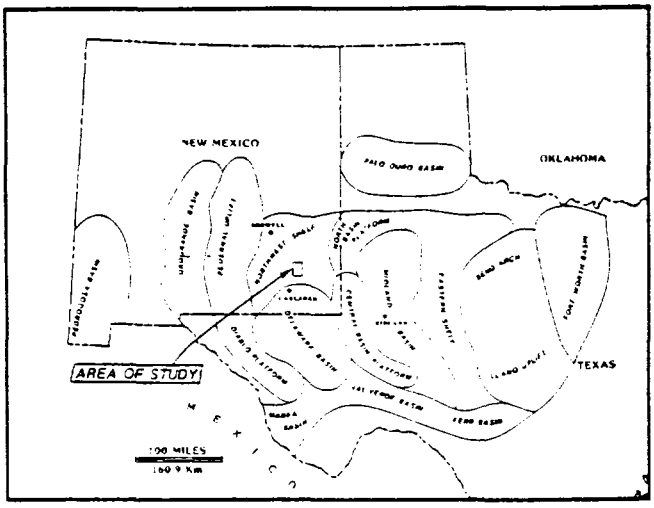

Figure 1—Permian basin geologic provinces. Study area is outlined.

producing reservoirs from these sediments have been mapped and will be discussed in this paper. Figure 2 shows the generalized stratigraphic sequence of sediments in the area.

Discrete field or pool outlines are not readily apparent in the study area because small stratigraphically trapped productive reservoirs are present from several zones. The productive areas overlap, making field or pool outlines vague and arbitrary. Pools for the study area as shown in New Mexico Oil and Gas Engineering Committee report (1982) include Parkway Atoka West, Parkway Morrow West, Parkway Strawn West, Empire Morrow South, Loco Hills Morrow, Loco Hills Morrow South, Turkey Track Morrow North, Millman Morrow, Millman Morrow South, Winchester Morrow North, and Winchester Strawn.

Figure 3 shows typical compensated density neutron log responses through the Pennsylvanian section in this area. A dual laterlog with a microlateral curve is usually run with this log to calculate water saturations and evaluate formation permeability. Wells are drilled with a salt-base mud because the Pennsylvanian sandstones are especially susceptible to formation damage when drilled with freshwater mud systems.

MORROW STRATIGRAPHY

The Morrowan sediments consist of limestones, sandstones, shales, and siltstones. These sediments can be divided into three correlative units. The lower Morrow consists of a fluvial-deltaic sequence of sandstones and shales that rest unconformably on the Mississippian. The middle Morrow consists primarily of marine sandstones and shales with minor interbedded limestone. The middle Morrow unit is defined in this paper as occurring from the base of a distinct shale, called the Morrow shale, to the top of the Morrow clastics. The upper Morrow unit consists of light-

SYSTEM	SERIES	NORTHWEST SHELF
QUATERNARY	RECENT	ALLUVIUM
	PLEISTOCENE	
TERTIARY	PLIOCENE-EOCENE	OGALALLA
CRETACEOUS	GULF	
	COMANCHEAN	
TRIASSIC	UPPER	DOCKUM: CHINLE; SANTA ROSA; TECOVAS
PERMIAN	OCHOAN	DEWEY LAKE; RUSTLER; SALADO
	GUADALUPIAN	WHITEHORSE: TANSILL; YATES; SEVEN RIVERS ●; QUEEN ●; GRAYBURG ●; CAPITAN; WORD: SAN ANDRES ●; GLORIETA; GOAT SEEP
	LEONARDIAN	YESO; ABO-BONE SPRING ●
	WOLFCAMPIAN	WOLFCAMP ●
PENNSYLVANIAN	VIRGILIAN	CISCO
	MISSOURIAN	CANYON
	DESMOINESIAN	STRAWN ✲
	ATOKAN	ATOKA ✲
	MORROWAN	MORROW ✲
MISSISSIPPIAN	CHESTERIAN	BARNETT SH
	MERAMECIAN-OSAGEAN	MISSISSIPPIAN LM
	KINDERHOOKIAN	KINDERHOOK; WOODFORD
DEVONIAN	UPPER	
	MIDDLE	
	LOWER	DEVONIAN
SILURIAN	U/NIAGARAN	U SILURIAN
	L/NIAGARAN	FUSSELMAN
	ALEXANDRIAN	
ORDOVICIAN	CINCINNATIAN	MONTOYA
	MOHAWKIAN	SIMPSON GR: BROMIDE; McKEE; WADDELL; CONNELL; JOINS
	CHAZYAN	
	CANADIAN	ELLENBURGER
	OZARKIAN	
CAMBRIAN	UPPER	
PRECAMBRIAN		

PRODUCING ZONES WITHIN STUDY AREA
OIL ●
GAS ✲

Figure 2—Stratigraphic column for west Texas and southeast New Mexico. Modified from Geomap, 1981 (reproduced with permission of Geomap, Inc.).

gray limestone with interbedded marine shales and local marine sandstones. The upper portion of this carbonate unit is probably Atokan in age. No easily defined wireline log correlation marker separates the Morrow from the Atoka in this area. For simplicity, the entire carbonate unit is generally designated as upper Morrow.

Figure 4 is a depositional environment map for southeast New Mexico during early Morrowan time. Sands and shales from the Pedernal highlands were being deposited in the Parkway–Empire South area in fluvial-deltaic systems of channels, point bars, and stream-mouth bars. A secondary source was probably also present to the east on the Central Basin platform. The sea level was static, and these sediments prograded from northwest to southeast into the basin. On top of the lower Morrow sediments is the Morrow shale, which occurs over a large part of the Northwest shelf. It is dark gray and contains coal. This shale represents the transition from fluvial-deltaic to marine conditions.

The middle Morrow sediments contain marine sandstones probably deposited in a transgressive system of beaches and nearshore bars. These sands trend northeast, and were deposited near and parallel to the ancient shoreline.

During early Morrowan time, as shown in Figure 4, marine sands stratigraphically equivalent to the middle Morrow sands were being deposited south of the study area. The Morrow lagoonal shale was being deposited across a wide front immediately north of the beaches. South of the beaches, upper Morrow carbonates and interbedded shales were deposited on a shallow shelf in front of the middle Morrow sands. The middle and upper Morrow sediments are diachronous and transgress the lower Morrow fluvial sediments depositing in succession: (1) the Morrow lagoonal shale, (2) middle Morrow beach sands, and (3) upper Morrow shelf carbonates and shales.

Figure 5 is a structure map of the base of the Morrow shale. The Morrow shale occurs between 11,336 and 11,374 ft (3,455 and 3,467 m) on the type log (Figure 3). The Morrow shale structure map shows 150 ft/mi (29 m/km) of regional dip with a northeast strike. This present-day dip and strike are probably similar to the dip and strike of the depositional slope during Morrowan deposition. Figure 5 shows an alternating pattern of northwest-trending ridges and lows. This pattern was probably caused by differential compaction of the sands and shales and, in a very generalized fashion, tends to reflect the underlying main depositional channels for the lower Morrow. Arrows on the map show the channel patterns. Compaction in the middle Morrow sediments tends to obscure the lower Morrow drainage pattern, making it difficult to observe and predict from the Morrow shale structure map.

LOWER MORROW RESERVOIRS

Stratigraphic traps in the lower Morrow sandstones are formed by variations in depositional patterns and cementation of the sands. These traps are small, with reservoirs only 200 to 400 ac (81 to 162 ha.) in areal extent. These reservoirs can be defined by using closely spaced subsurface control, production data, and test data. The method used to define the traps was to prepare a lower Morrow net sand thickness map (Figure 6), which was then used as a contouring guide to prepare a net effective porosity thickness map (Figure 7).

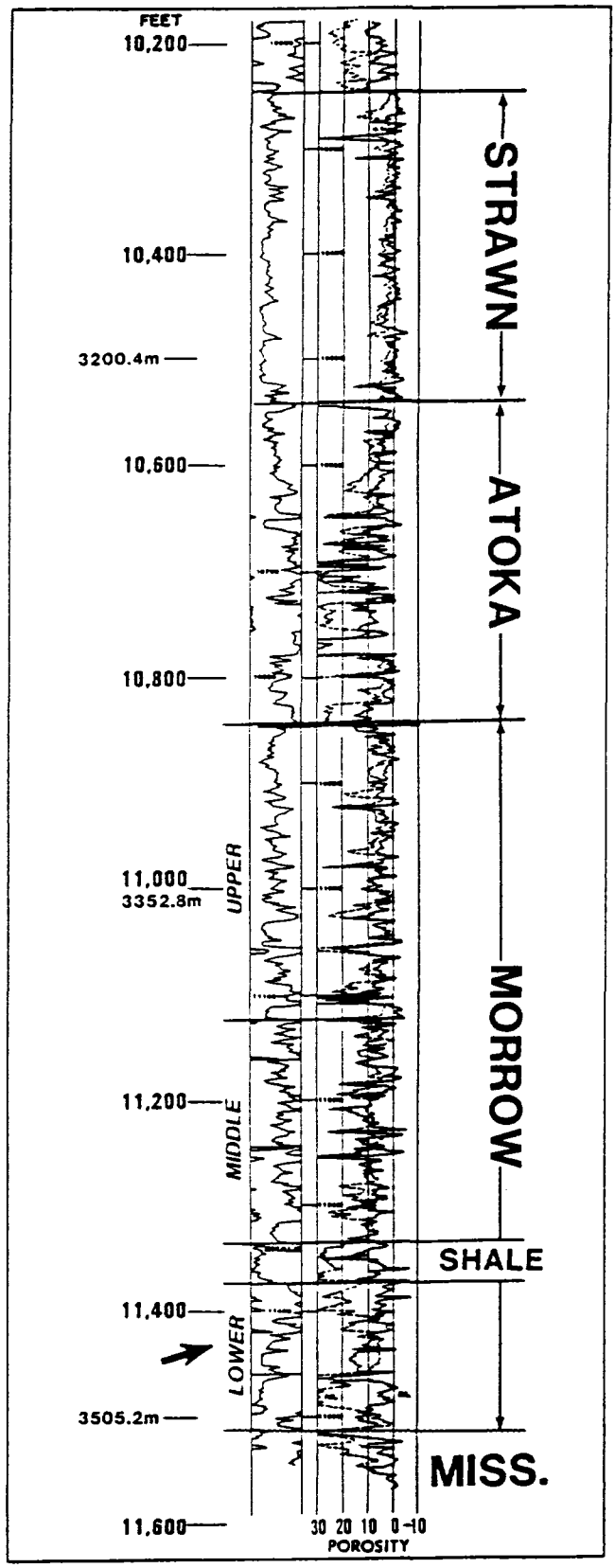

Figure 3—Compensated density-neutron log from Southland Royalty Company 1 Parkway State well.

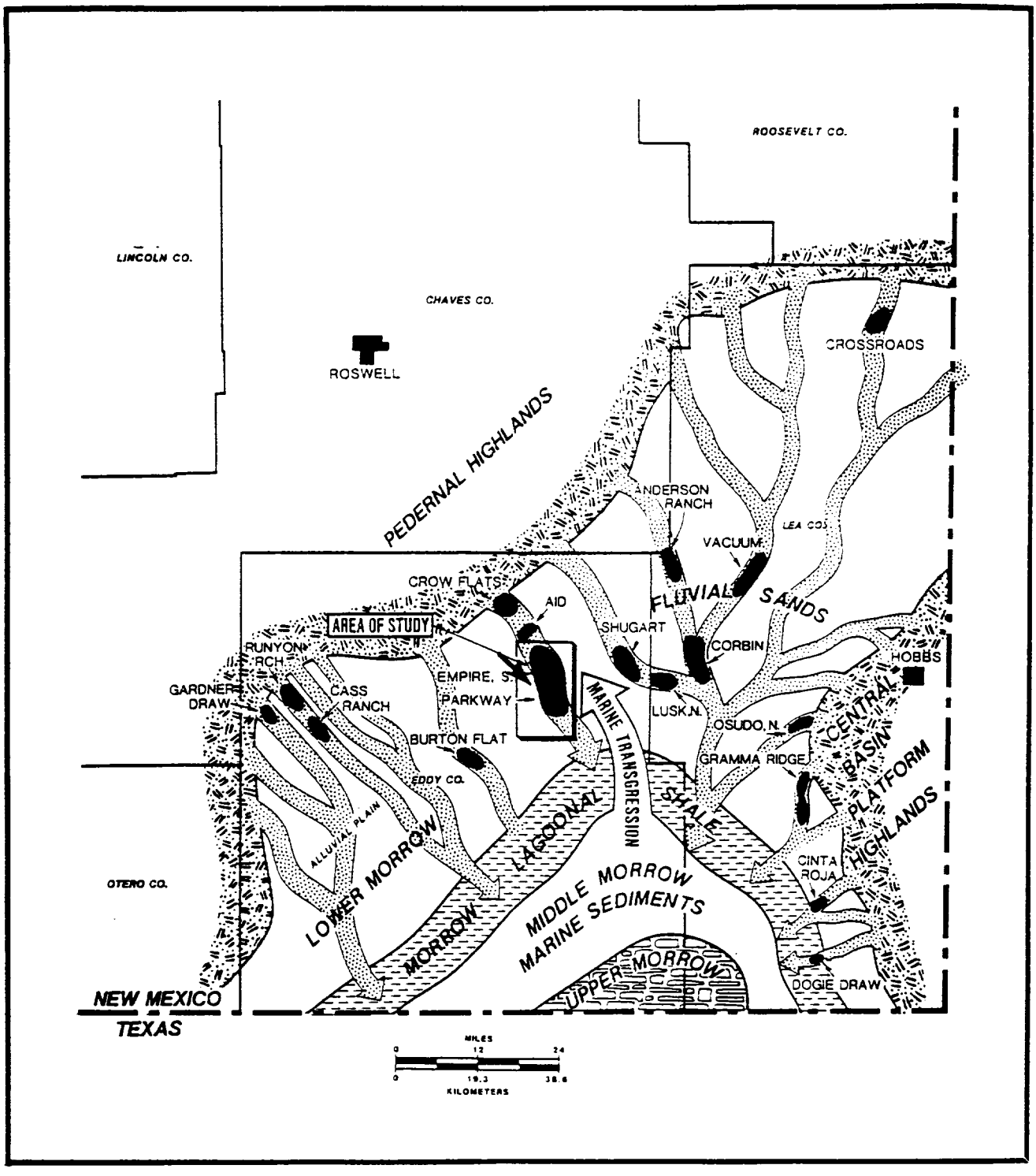

Figure 4—Interpreted depositional environments and oil pools in southeast New Mexico during early Morrowan time. Study area is outlined.

The porosity isopach was overlaid with the Morrow shale structure map (Figure 5). Mapping was fitted to account for test data, water-saturation calculations, and production data to define discrete reservoirs and productive areas. The shaded areas on Figure 7 show the proven and probable gas-producing areas, and the clear areas show the water legs of the reservoirs. Saltwater production commonly occurs from the lower Morrow sands throughout the Northwest shelf.

Similar irregularly shaped reservoirs are shown in Figure 8, a three-dimensional diagram of a complex meander belt. The channels can become filled with clay, forming irregular and complex reservoirs. Generation and migration of hydrocarbons in conjunction with gravity segregation set

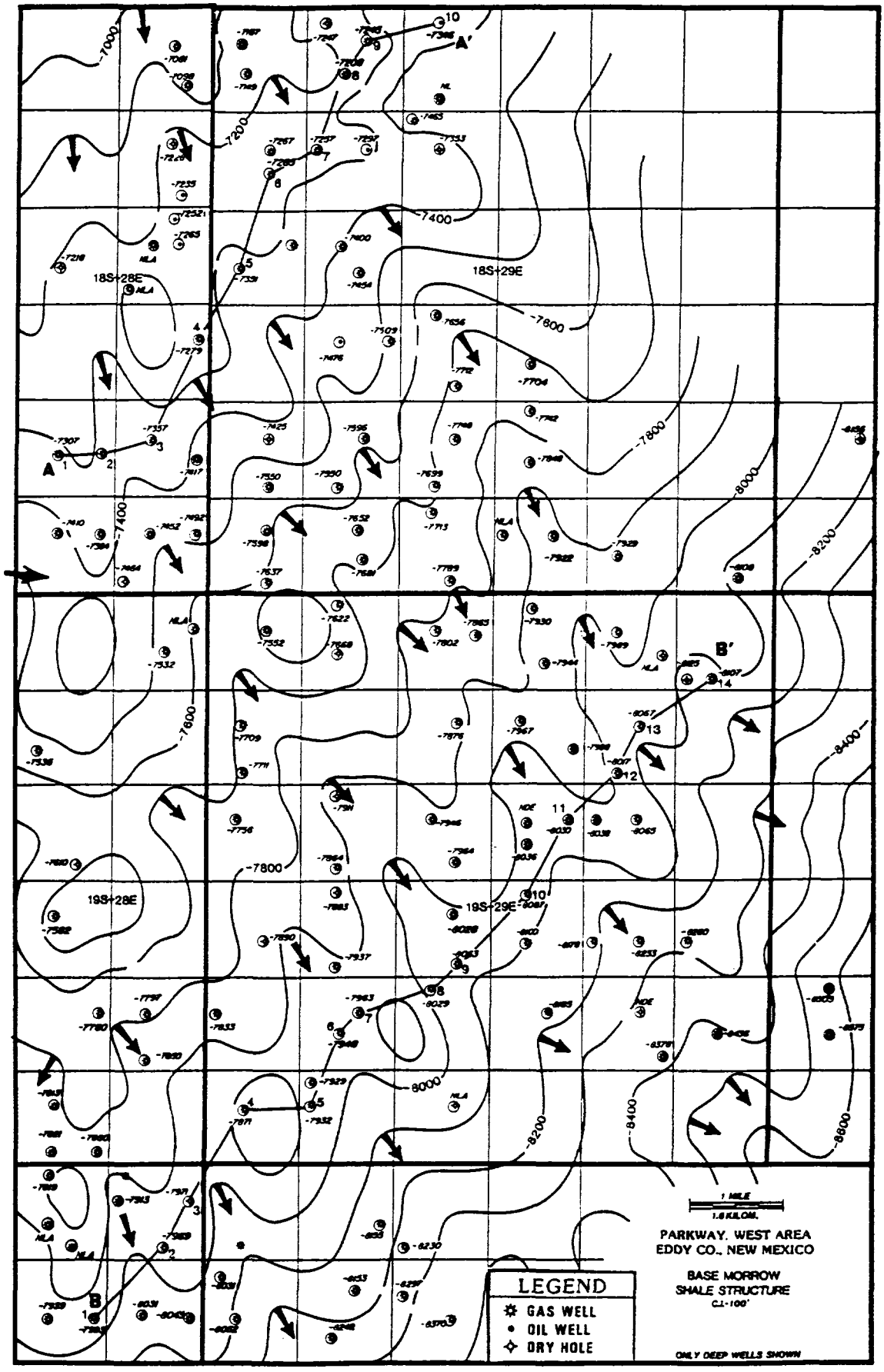

Figure 5—Structure map of Parkway West area, contoured on base of Morrow shale. Contour interval: 100 ft (30 m). See Figure 14 for cross section AA′, and Figure 15 for cross section BB′. NLA = no log available.