Wells in this area have typical ultimate recoveries of between 1.0 and 3.0 bcf of gas. The combination of stacked reservoirs and good production makes this area of the Morrow trend especially attractive.

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Marfa Basin of West Texas: Foreland Basin Subsidence and Depocenter Migration

The Marfa basin, encompassing approximately 6,000 mi^2 (15,539 km^2) of Presidio and Brewster Counties in west Texas, is a foreland basin that formed in the late Paleozoic in response to the encroaching Ouachita-Marathon thrust belt. The basin is one of several, including the Arkoma, Fort Worth, and Val Verde basins, that developed along the southern margin of the North American craton during convergence of North America and Africa-South America in Pennsylvanian to Permian time. We present a model of the formation of the Marfa basin in which basin subsidence is effected by compression from plate convergence and by loading owing to the emplacement of the Marathon fold-thrust complex.

A model of foreland basin evolution by thrust loading as applied to the Idaho-Wyoming thrust belt can be applied with some modification to the Marfa foreland basin. Preexisting northwest-trending faults in the Marfa region were reactivated by the Marathon thrust belt as the latter advanced onto the continental margin toward the craton. Subsidence owing to compression and thrust loading first formed the Tesnus basin, a Pennsylvanian basin now buried beneath the Marathon overthrust. In the later stage of thrust-sheet emplacement, the depocenter split into two prongs, and the Marfa and Val Verde basins collected thick sections of Wolfcamp sediments.

Preexisting northwest trends, which result from a Precambrian rifting event and the late Precambrian to Cambrian development of the Delaware aulacogen, controlled the location of subsidence in front of the thrust sheet. The fragmented craton was composed of northwest-trending high and low areas including the Diablo platform and the Delaware basin. These fragments behaved much like piano keys, subsiding first in a central region to form the Tesnus basin and later in adjacent regions forming the Marfa and Val Verde basins.

The model is supported with data from 63 well logs that indicate the position of the depocenters through time and that suggest the differential elevation of crustal slices controlling the formation and location of the three Pennsylvanian-Permian foreland basins.

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Detrital and Authigenic Clay Minerals in Lower Morrow Sandstones of Eastern New Mexico

Sandstone reservoirs of the Morrow Formation of southeastern New Mexico are important natural gas reservoirs. Production from this unit is affected by the types and distributions of detrital and authigenic clay minerals present in the rocks. Thus, X-ray diffraction and scanning electron microscopic analyses of samples from the lower Morrow reservoirs were conducted to understand the types, morphologies, petrographic positions, and regional trends of clays in the unit.

By far, authigenic kaolinite and chlorite are the major clays present in the lower Morrow sandstone reservoirs. The kaolinite content of the clay fraction of the formation can reach a maximum of 100%, whereas that of chlorite can be as high as 59%. When both are present, authigenic kaolinite and chlorite can effectively reduce much of the permeability of the sandstone reservoirs. Smectite, illite, and mixed-layer smectite-illite are relatively insignificant clays in the lower Morrow, except in certain small areas of the study area, and are largely detrital in origin.

The distribution of smectite, illite, and mixed-layer smectite-illite reflects the depositional processes acting in each of the facies of the lower Morrow. These clays are most abundant in immature fluvial-deltaic and basinal sandstones and relatively deficient in reworked marine sandstones. Distribution of authigenic kaolinite and chlorite also mimics the facies pattern, but is not controlled by it. In the lower Morrow, kaolinite increases landward while chlorite increases toward the basinal facies.

Successful treatment procedures for reservoir sandstones must differ with the different clay mineral types present.

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Queen Formation of Millard Field, Pecos County, Texas: Its Lithologic Characteristics, Environment of Deposition, and Reservoir Petrophysics

The Queen Formation is a sequence of interbedded siliciclastics, carbonate mudstones, and evaporites, that extend across a large area of the subsurface Permian basin in west Texas and southeastern New Mexico. We present a description of the lithologic and diagenetic characteristics of the formation in Millard field, Pecos County, Texas, and propose a model for its depositional environment and reservoir formation.

The Queen Formation in Millard field consists of four major lithologic characteristics: (1) cross-stratified or ripple-laminated sandstones of eolian origin, and a sabkha mudflat facies complex composed of (2) unfossiliferous and anhydritic mudstones, either massive or ripple-laminated; (3) thin dolomicrite crusts with birdseye structures and desiccation cracks; and (4) anhydrite in the form of discrete nodules, beds of nodular-mosaic texture and massive beds in the mudstones and sandstones, and as palisade anhydrite in the mudstones and dolomicrites.

Production from the Queen Formation in the field is consistently from two eolian sandstone units, designated the Queen A and C, which can be correlated across the field area. SEM examination of these sandstones indicates a positive correlation between the amount of grain-lining, authigenic smectite and porosity, and concomitantly an inverse relationship between anhydrite cement content and porosity. The porosity of the sandstone reservoirs in the Queen is of secondary origin.

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Pre-Leonardian Geology of Midland Farms Field Area, Andrews County, Texas

The Midland Farms (Ellenburger) oil field was discovered on September 16, 1952, with the completion of Anderson-Pritchard's 1 Fasken-24 well, drilled on an indicated single-fold seismic structure. The field produces from vuggy, fractured

Ellenburger dolomite with up to 310 ft (94 m) of gross and net pay. The Midland Farms (Ellenburger) field is part of a larger structure which incorporates not only Midland Farms field, but Midland Farms, West (Devonian), Inez (Ellenburger), and parts of the Fasken (Penn) and Block 41 (Wolfcamp) fields. The structure is a complex, uplifted block composed of two doubly plunging, asymmetric anticlines bisected by at least one wrench-type fault and several normal faults. This block has undergone at least three periods of structural compression and uplift. Middle Ordovician folding and faulting of Ellenburger dolomite created initial fracture porosity and permeability. Fractures and vugs were enlarged by meteoric water circulating through the emergent Ellenburger carbonates prior to the deposition of the overlying Simpson rocks. A post-Fusselman period of exposure developed vuggy and cavernous porosity in the Fusselman limestones, and beveled existing fault scarps. Late Mississippian to Early Pennsylvanian compression, related to the uplift of the Central Basin platform, folded the Paleozoic rocks and reactivated conjugate shears trending N10° to 30°E. Ellenburger fracture porosity was enhanced during this period of structural movement. No significant fracture-controlled reservoirs developed in any of the younger rocks, probably due to ductile deformation of the interbedded limestones and shales. Oolite limestone banks developed on a shallow platform over the Midland Farms area during the early Wolfcampian. Penecontemporaneous leaching produced oomoldic porosity in the limestones.

Ellenburger oil production was established in the Midland Farms area in September 1952, and has amounted to 61.6 million bbl oil and 28.5 bcf of gas from 91 wells to January 1983. Major Fusselman and Wolfcamp oil accumulations were discovered during development of the Ellenburger field. Fusselman oil was first produced in June 1953, and has totaled 10.1 million bbl of oil and 5 bcf of gas from 33 wells to January 1983. Wolfcamp production was established in January 1954 and totals 10.7 million bbl of oil and 1 bcf of gas from 39 wells. Less significant deep production has been established in several other pre-Leonard reservoirs in the Midland Farms area, including the Thirtyone Formation (Devonian) (751,624 bbl of oil and 1.8 mmcf gas from 31 wells); Atoka (368,000 bbl of oil and 0.2 mmcf gas from 8 wells); and Strawn (420,000 bbl of oil and 1.1 mmcf of gas from 9 wells). Total production from all zones including post-Leonard beds in the Midland Farms field area to date has been 210 million bbl of oil and 84 bcf of gas.

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Advanced Mud-Logging Analysis Techniques in Delaware Mountain Group of Delaware Basin

Ineffective electric-log interpretations and complex completion problems have discouraged much of the possible development of the Delaware Mountain Group of the Delaware basin of west Texas and New Mexico for over 40 years. During the early days of exploration and development, many producible horizons in the Bell Canyon, Cherry Canyon, and Brushy Canyon Formations were eliminated from future consideration because of faulty oil/water ratio and permeability estimates based primarily on resistivity logs, and the subsequent difficulties in completing wells using this information. Along with inefficient water shutoffs, and complicated cementing techniques, wells drilled during this period were further handicapped by a $2 per bbl or less market price.

In the 1980s, with the price of oil at or near the $30 per bbl level, many DMG prospects that originally were marginal, or even submarginal, are now being considered for prime exploitation programs because of the tremendous amount of acreage in the Delaware basin that has been either passed over as "non-producible" or has not been investigated or drilled at all. New electric-log presentations, although markedly improved by computer-enhanced parameters, are still less than decisive in too many situations, leading to continued completion problems.

This paper describes a possible solution to many of the problems presently restraining more economical development within the Delaware basin and other areas with similar complex formations. An example of a typical oil/water inversion commonly found in the DMG is given along with references explaining the creative mechanism. This reservoir type is matched with a "textbook" type reservoir of the same formation and the methods used to analyze and identify each. The instruments and techniques required to accomplish an accurate determination of reservoir oil/water ratios are given along with documentation.

The benefits of this system of reservoir analysis during the drilling process are (1) elimination of testing and/or completing salt water or other non-producible zones; (2) augmentation or elimination of coring programs; (3) as an aid to a selective frac and/or acidizing program; and (4) a maximum production potential indicator when used with only neutron or sonic porosity logs.

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Permian (Guadalupian) Shelf Deposition and Diagenesis: Tansill Formation of Cheyenne Field, Winkler County, Texas

Cheyenne field, Winkler County, Texas, produces oil from shelf-margin lithofacies of the Tansill Formation of late Guadalupian age. The Tansill Formation encountered in the Cheyenne field compares favorably with basin-margin outcrops found in the Guadalupe Mountains of New Mexico and Texas. The Delaware basin margin consisted of (1) outer shelf ooid shoals and back-shoal green-algal flats, (2) a shelf-crest pisoid-tepee complex, and (3) inner shelf evaporitic, stromatolitic, and peloidal sediments during the late Guadalupian.

The Cheyenne field reservoir exhibits varied lithologies and porosities in the Tansill Formation. Fresh-water phreatic diagenesis created moldic porosity in the outer shelf, green-algal lithofacies. Fresh-water vadose conditions existed during low sea level stands preserving intergranular porosity in the pisolitic lithofacies of the shelf-crest tepee complex. Fresh-water vadose diagenesis also helped form burrow-moldic porosity and fenestral porosity in the inner shelf peloidal lithofacies. Periodic hypersaline vadose conditions occluded some porosity with evaporites and aragonitic cements. Dolomitization of the Tansill Formation occurred in the mixing zone between a seasonal fresh-water lens in the shelf-crest sediments and the saline waters of the Permian sea and inner shelf lagoon. As sea level fluctuated the mixing zone migrated laterally. In this way, much of the Tansill Formation was dolomitized, forming finely crystalline dolomite that preserved textural details well but did little to enhance porosity.

Porosity is best developed in the thin beds of the outer shelf, green-algal lithofacies. More importantly, the 194 ft (59 m) of pay in the Cheyenne field results from favorable diagenesis of lithofacies on the shelf margin that were interbedded with the shelf-crest lithofacies by fluctuations of sea level. The arid climate at the time of deposition was essential in maintaining porosity created by early diagenesis and for the absence of abundant vadose cements in the Tansill Formation. The trap in Cheyenne field is depositionally controlled by updip, nonporous, and impermeable sediments of the inner shelf lagoon. Anhydrites of the overlying Salado Formation provide an excellent seal. Interbedded