Individual depositional systems have been identified and mapped using data from 4,100 well logs and 75 measured sections. For the upper Strawn (above the Brannon Bridge Limestone), subsurface isolith maps indicate the presence of four deltaic depocenters, one fan delta system, two carbonate banks, one carbonate platform, and an embayment-strand-plain complex during various stages of Desmoinesian and early Missourian deposition. Higher, within the Canyon Group, there are two deltaic depocenters, one fan delta complex, a clastic slope system, carbonate shelf-edge and shelf-interior banks, and a carbonate platform. On the basis of outcrop facies characteristics and net sandstone geometry, river-dominated and lobate deltas, as well as coarse-grained fan deltas, are the dominant clastic systems deposited on the Bend arch.

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Trace Fossils in Middle and Upper Austin Chalk near Dallas, Texas—Paleoecologic and Economic Significance

In outcrops throughout northeast Texas, the Austin Group consists of interbedded thin to very thick-bedded (0.3-1.5 m) chalk with thin intervening calcareous claystone ("marl") layers. Both chalk and claystone are moderately to intensely bioturbated, and multiple generations of cross-cutting burrows are common. Austin trace fossils occur as endogenic full-relief individuals filled with chalk, clay, or iron oxides. The abundance and diversity of ichnofossils within the Austin are in distinct contrast to the paucity of other megafossils, except large, locally conspicuous inoceramids with oyster epiliths.

Variations in ichnofossil content, quality of burrow preservation, and petrographic character allow definition of three Austin substrate types. (1) Softground—vaguely mottled, argillaceous, foraminiferal biocalcilutite containing poorly preserved *Planolites, Thalassinoides,* and *Chondrites.* Burrowing is intense. *Chondrites* typically infests fillings of other ichnofossils. Inoceramids occur as widely scattered epifauna. (2) Bioclastic lenses—coarse-grained inoceramid biocalcirudite with interstitial chalk matrix. This lithology forms broad, low-relief channels; dense networks of *Thalassinoides* occur on lower surfaces. (3) Firmground—phosphatic, glauconitic, foraminiferal biocalcilutite containing well-preserved *Rhizocorallium jenense* and *Pseudobilobites.* South of Dallas, the disconformable Austin-Taylor contact is a *Rhizocorallium*-dominated firmground omission surface.

The Austin contains a shallow marine (middle to inner shelf) ichnoassemblage. A vertical increase in the ratio of suspension to deposit-feeding burrows suggests that the Austin is a shallowing-upward sequence.

Trace fossils impart textural heterogeneities to chalk which can either enhance or degrade reservoir quality and can also complicate wireline log interpretations and well completion procedures.

DE KEYSER, THOMAS, Marathon Oil Co., Houston, TX, W. F. MULLICAN, III, Texas Bur. Econ. Geology, Austin, TX, and J. E. BARRICK and C. J. GROSSNICKLAUS, Texas Tech Univ., Lubbock, TX

Ecofacies Transect of Lake Valley Shelf, San Andres Mountains, New Mexico, and Its Relation to Early Mississippian Orogrande Basin

South-central New Mexico has been well known for its excellent exposures of Mississippian strata. The Sacramento Mountains have become famous for their fortuitous exposures of the Lake Valley shelf margin. A transect of measured sections there exposes the transition from shallow carbonate shelf with beautifully developed reefs to a starved basin with isolated pinnacle reefs to the south. A new transect, to the west in the San Andres Mountains, reveals a complete shelf-to-basin transect, from shoreline to shelf-margin to starved basin. There, however, no reefs are present in time-equivalent strata. Studies there, integrating physical stratigraphy, depositional systems, microfacies analysis, and conodont biostratigraphy and biofacies, allow formulation of a leeward shelf ecofacies depositional model for the Lake Valley formation. This is combined with the Sacramento Mountains transect to delineate a model of an Early Mississippian Orogrande basin in the same position as the Pennsylvanian-Permian Orogrande basin and the present Tularosa basin. A series of such basins may have existed along the southern flank of the ancient Transcontinental arch in the southwestern United States.

DIXON, SELENA A., Geological Consultant, and DOUGLAS W. KIRKLAND, Mobil Research and Development Corp., Dallas, TX

Method of Predicting Reservoir Quality for Feldspathic Sandstones of Southern California

The diagenetic alteration of a sandstone results from the combined effects of many factors. In order to ascertain the role played by a particular diagenetic factor, the remaining diagenetic factors must be held constant. For the sandstones of the basins of southern California, we have found that the effects of almost all of the principal diagenetic factors are essentially uniform, the notable exception being thermal history. Because of this, we have been able to evaluate the diagenetic imprint of temperature upon the sandstones. Measured reservoir property data taken on core samples of reservoir sandstones from 16 fields in the Los Angeles, Ventura, and San Joaquin basins were used to determine the average rate of porosity and permeability loss with depth for each field. A straight line appears to be the proper representation for the porosity vs. depth profiles for the interval of interest. The slope of this line is defined here as the porosity gradient. Porosity gradients for the fields investigated range from 1.1% to 5.8%/1,000 ft. A direct relationship exists between the porosity gradient and the present geothermal gradient for the 16 fields which have been examined. As geothermal gradient increases, porosity gradient increases. The correlation coefficient between these variables is +0.916 for geothermal gradients between 1.6°F and 2.2°F/100 ft. A similar relationship also exists between the rate of permeability loss with depth and the geothermal gradient, but the average deviation from the mean permeability value is so great the relationship has little practical significance.

EHLMANN, ARTHUR J., Texas Christian Univ., Fort Worth, TX, and RITA J. EHLMANN (deceased), Murjo Oil & Royalty Co., Fort Worth, TX

Aledo Southeast 1,200-Ft Strawn Gas Field and Associated Deeper Production, Southeast Parker and Southwest Tarrant Counties, Texas

Most of the gas production in this region comes from earlier shallow zones (< 2,000 ft) in the lower Strawn or from deep zones (4,000-6,000 ft) in the Atoka to Marble Falls. The reservoirs, except for minor production from carbonates, are in clastic strata ranging from conglomerate to fine sandstone that are sporadic, lensing bodies of limited areal extent. The production is from clastics that occur in an eastward-thickening sequence lying just west of the Ouachita foldbelt.

The Aledo Southeast 1,200-ft Strawn field is one of the most profitable gas fields in the area. The marked linearity of this field demonstrates that the productive sand body is of fluvial origin. Its general east-west orientation indicates a fluvial system that flowed westward from the Ouachita highlands, and its flared shape on the western end suggests shoreline redistribution of the sands. Study of core and cuttings clearly reveals fluvial features, such as mud clasts, ripple laminations, wood fragments, and slump structures.

Detailed mineralogic analyses by x-ray diffraction and scanning electron microscopy indicate the shallow and deep reservoirs are feldspathic sandstones that are variously limy or dolomitic and contain major amounts of kaolinite and lesser amounts of illite, chlorite, and mixed layer clays.

Isopach maps combined with structure contour maps show the field is a trap formed where an east-west channel sand is tilted downward on the north side intercepting a gas-water contact. The south (updip) margin is a sand pinch-out. A marked sag, caused by differential subsidence, intercepts the gas-water contact and interrupts continuous production along the channel beneath the Parker-Tarrant county line.

GARRETT, CHRISTOPHER H., and RICHARD H. SNYDER, Core Laboratories, Inc., Dallas, TX

Use of Core-Measured Fracture Patterns in Exploration and Exploitation Strategy

Optimum results are obtained from core fracture studies when the core can be oriented. There are two approaches to core orientation: downhole orientation and surface orientation. Downhole core orientation is most

suitable for cores cut in formations where bedding is not visible. Drawbacks are encountered in highly fractured formations. Highly fractured cores are most effectively oriented at the surface provided that the bedding is visible or that other directional core parameters, such as paleomagnetic properties, can be measured.

The fold fracture classification presented differentiates between fracture systems associated with folds that result from horizontal compressive stress systems and those that result from vertical diapiric uplift. Each type of fold is characterized by two dominant fracture patterns. Fracture patterns 1 and 2 occur in association with compressive folds, and fracture patterns P and R are associated with diapiric structures. Potentially, each fracture pattern consists of an extension and two conjugate shear fractures. All four fracture patterns result from stresses generated during the folding process. Fracture patterns 2, P, and R result from extension parallel to the bedding, and are best developed where bed curvature is greatest.

Analysis of core-measured fracture patterns is best effected by plotting the poles to the fractures, with bedding plane orientation, on a stereographic projection. The fracture patterns distinguished can then be projected to other parts of the structure or to adjacent structures. Areas of maximum fracture potential can be distinguished by calculation of both cross-sectional and planar bed curvature.

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San Andres and Grayburg Oil Plays in Permian Basin—Past Performance and Prediction for the Future

Crude oil production in Texas totals more than 47 billion bbl; however, the rate of production has been declining since 1972. The most rapid decline was 6% in 1979, but subsequent decline rates have diminished to 2.5% in 1983. Production of second-crop oil (attributable to infill drilling and enhanced recovery methods) from Permian basin reservoirs has been responsible for a large part of this improvement. Second-crop oil will likely be instrumental in arresting the rate of production decline for the state.

Production from San Andres and Grayburg reservoirs played a major role in establishing the Permian basin as a premier oil province in Texas and the United States. Since the first commercial production at Westbrook field, Mitchell County, in 1921, these reservoirs have accounted for more than 40% of the oil produced from the Permian basin and more than 15% of the oil produced in Texas. Researchers at the Bureau of Economic Geology have subdivided these reservoirs into several plays on the basis of geographic association and similarities in depositional controls, trapping styles, and drive mechanisms. The reservoirs consist of dolomitized carbonates interpreted as restricted-shelf deposits on the northern and eastern shelves of the Midland basin and restricted-platform carbonates on the Ozona platform, Yates area, and the Central Basin platform. The San Andres and Grayburg exhibits widespread reservoir heterogeneity owing to complex depositional and diagenetic facies relationships. This internal complexity, along with a less efficient solution-gas drive, accounts for the large volume of unrecovered movable oil. Innovative infill-drilling programs based on geologic concepts of facies-controlled reservoir development provide an opportunity for further reserve growth as well as increased production.

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Integration of Seismic and Well Log Data Using Vertical Seismic Profile

Use of the vertical seismic profile (VSP) as the link between surface seismic data and advanced log evaluations makes it possible to calibrate seismic sections in terms of subsurface petrophysical parameters.

A step-by-step procedure of (1) tying a surface seismic section to the borehole measurements via the VSP, (2) reprocessing the seismic section, and (3) propagating log information outward from the well using the calibrated seismic section is practical. In fact, if a VSP is run in the discovery well in a field, this procedure can be followed to obtain information about where to drill the first development well. If vertical seismic profiles are run in each subsequent development well, a continually updated reservoir description can be used to guide the development of the field.

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Stratigraphic Dipmeter Interpretation—Fort Worth Basin Submarine Slope Systems

Submarine slope systems pose several exploitation problems. Previous dipmeter interpretation techniques using the standard dipmeter with CLUSTER processing are highly successful in fluvial to deltaic sequences, but lack of accuracy in the anastomosing depositional environment associated with submarine slope systems. Both the delineation of individual depositional units and the precise trend determination of each are essential for optimum exploitation. A new interpretation technique has been devised to provide accurate and consistent answers to these problems. The technique involves the use of multiple logging passes and detailed stratigraphic correlation to provide a paleocurrent and depositional analysis.

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Middle Atokan to Early Missourian (Pennsylvanian) Conodonts, Fort Worth Basin and Concho Platform, Central Texas

Middle and Upper Pennsylvanian strata in the Colorado River Valley and Llano area south of Brownwood, Texas, have not been extensively studied, and little is known regarding their precise correlation. Conodont faunas have been recovered from many units, particularly Smithwick Shale (Atokan), lower Strawn Group (Atokan-Desmoinesian), upper Strawn Group (Desmoinesian-Missourian), and lower Canyon Group (Missourian). Conodonts permit more refined correlation of this important sequence with Mid-Continent and Appalachian series than has previously been possible. In addition, age relationships of stratigraphic units places constraints on developmental models for the Fort Worth basin and adjacent Concho platform.

The Smithwick conodont fauna is indicative of a middle to late Atokan age. Diagnostic species are *Neognathodus atokaensis, N. bothrops, Neogondolella clarki, N.* n. sp. A, and *Idiognathoides* spp. Approximately the lower one-half of the lower Strawn Group is latest Atokan based on occurrences of *Idiognathoides* spp. The appearance of *Gondolella laevis* and advanced neognathodids distinguish the early Desmoinesian portion of the lower Strawn Group. *Neognathodus roundyi, N. dilatus,* terminal neognathodids, *Gondolella bella,* and *G. magna* are typical conodonts of middle to late Desmoinesian strata of upper Strawn Group. Missourian conodont faunas are relatively depauperate, and seemingly have less value for precise correlation than older Desmoinesian and Atokan faunas.

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Truncated Devonian and Fusselman Fields and Their Relationship to Permian Basin Reserves

The Permian System accounts for a majority of oil produced in the Permian Basin. However, the Devonian rocks and Silurian Fusselman rocks are excellent producing zones. These produce on both structure and truncation, but this paper deals with truncated aspects only.

It appears that production in these fields is the result of an updip pinch-out of the formation along with lateral closure to trap the hydrocarbons. Lateral closure must be by faulting and/or reentrants along either or both sides of the pinch-out. When a prospect exhibits all these features, production should be assured.

The truncated Fusselman along the Eastern shelf produces both from dolomite and limestone ranging in depth from 8,000 to 11,000 ft. It is believed that both the overlying Woodford Shale and underlying Sylvan Shale act as source rock and seal.

When exploring for the truncated Devonian in southern Crane and northern Pecos Counties, Texas, a third requisite is required: tripolitic chert. This unique rock appears to be the result of subaerial erosion. The tripolitic chert is usually found in downthrown fault blocks or grabens which are present along the flank of the "Old Fort Stockton high." These faults appear to be adjustment features which formed as a result of movement along and around this positive area.