can sometimes explain log and seismic discrepancies.

When the forward modeling can be visually and statistically resolved, seismic data become a vehicle for typing the well logs. Statistical measures of lateral change in the seismic response verifies changes from borehole conditions. Such measures are difficult when data quality is variable—just as are visual evaluations. Recognition of lateral changes is an area of potential development.

Controversy exists as to the most appropriate model for the entropy of seismic data. Deconvolution may be based on minimum, maximum, or variable entropy assumptions. If the entropy can be statistically determined, deconvolution can be more effective.

More interchange of information between borehole and surface measurements would seem to be a rewarding endeavor. Indeed, current exploration and exploitation economics demand better use of all available data.

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Goddard Sand Study, East Ardmore and Caddo Fields

Chevron and three partners began developing the East Ardmore structure near Ardmore, Oklahoma, in 1974-75. The discovery well and first offset both produced gas from the Mississippian Goddard sands. The drilling program was abruptly halted when a zero sand well was drilled less than 1 mi (1.6 km) from the producing wells, thus a structural prospect became a stratigraphic problem. A study of the Goddard sand on nearby Caddo anticline was conducted to determine the sedimentary environment of the Goddard. These data were then used by analogy to help determine the Goddard sand distribution on the East Ardmore structure.

The sand study was used to help interpret the 3-D seismic survey that was shot in an attempt to seismically map the Goddard sand distribution at Ardmore. The results of the 3-D survey will be briefly discussed and data will be shown to explain the selection of the Chevron City of Ardmore 3-No. 1 drill site. The results of the study are summarized below.

(a) The Goddard sands are marine and relatively discontinuous. (b) The Goddard sand interval at Caddo probably represents a submarine or barrier bar. The sands were carried by currents and collected as a sand shadow on the lee side of growing structures. The sands were subsequently winnowed of clay and silt. (c) Truncation of the upper part of the Caney shale on local structures indicates early structural growth. (d) The 3-D seismic survey at East Ardmore supports the idea that the Goddard sands are discontinuous and erratic.

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Subunconformity Seismic Stratigraphic Exploration

Seismic stratigraphic exploration is particularly applicable to exploration for unconformity traps. Typical upstructure truncation and angularity can often be detected with conventional seismic displays. More subtle traps created by lateral truncation of secondary porosity in either limestone or chert are more difficult to explore for using the seismic tool. Often sophisticated data processing techniques like Seislog^{R} aid in identification of the reservoir-seal relation. Comparison of the Seislog expression of a structural unconformity with a low relief erosion surface provides insight into seismic stratigraphic exploration for subunconformity fields.

South Laredo field, Webb County, Texas, serves as a classic upstructure unconformity. Eocene Wilcox sandstones are either progressively truncated at the flanks of the Salado uplift or preserved in rotated fault blocks. On Seislog, unique high velocity sandstone beds progressively lose thickness updip beneath a low-velocity shale. This truncation provides clear evidence for the trap.

In contrast, erosional plays that search for shale overlying porous carbonate rocks or chert often need to recognize units with similar velocity. At Star Lacey field in Kingfisher County, Oklahoma, porous Hunton is not a distinct unit but, on Seislog, exhibits velocity comparable with the overlying Woodford Shale. The seismic trap expression is created by anomalous Woodford thicks which represent the superposition of shale over Hunton porosity. The chert trap at Nicols field, Kiowa County, Kansas, similarly is based on a subtle slope change on the Seislog at the shale reservoir interface. Seislog colors separate the gentle character formed when shale overlies porous chert to the steep slope generated by shale over nonporous carbonate rock.

The expression of the fields on Seislog provides encouragement that seismic data can successfully locate unconformity-type reservoirs. The subtle nature of the features, however, suggests that careful integration with subsurface data is required to maximize exploration efforts.

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Exploration for Petroleum in Cyclic Sediments of Upper Pennsylvanian and Lower Permian in Kansas—A Closer Look in a Mature Province

Refined sedimentologic concepts and favorable economics accord further exploration for subtle hydrocarbon traps in mature areas such as Kansas. Upper Pennsylvanian sediments of the Lansing and Kansas City Groups in central and western Kansas represent a succession of cyclic reservoir carbonates and sealing shales deposited on a shallow cratonic shelf. A subsurface study conducted by the senior author demonstrates using cores that subaerial exposure occurred in many cycles during late regression across much of the shelf. This resulted in the flushing of the regressive carbonates by fresh or undersaturated water and the formation or redistribution of porosity in these rocks.

Primary and diagenetic porosity that are observed in cores and keyed to well logs commonly are associated with paleohighs or breaks in slope across the shelf. Selected maps of structure, thickness, and porosity from logs integrated with diagenetic and depositional facies from cores together provide necessary criteria to define subtle reservoir trends with the regressive carbonate.

A study of a shallow gas reservoir in the Nolans Limestone in central Kansas found that porosity is best developed in a transgressive dolomitic mudstone to moldic bivalve packstone. During later regressive sedimentation of the Nolans cycle hypersaline waters apparently percolated through the sediment and precipitated anhydrite and dolomitized the carbonate mud particularly in the upper Nolans.

The gas reservoir is structurally high with flanking water production and exhibits improved porosity development over the structural crest. Gamma ray—neutron crossplots and facies-ratio mapping aid in recognition of this subtle carbonate facies of the lower Nolans.

Characterizing carbonate facies and early diagenesis of these reservoirs in the framework of cyclic sedimentation is critical to minimizing risks in locating drill sites. Similar concepts as described here can be applied to other Middle and Upper Pennsylvanian and Lower Permian cyclic sequences in Kansas.