LeFlore Counties, Oklahoma, contain 1.1 to 1.5 Tcf of methane; these coal beds are expected to contain a similarly high methane content in deep parts of the basin farther west in Pittsburg, Coal, and Hughes Counties.

Various geophysical logs from gas wells were used to analyze thickness and sedimentary facies of the Hartshorne formation in the Arkoma basin. Bulk density and sonic logs indicate the presence of lower and upper Hartshorne coal beds with an apparent thickness of up to 8 ft (2.4 m), flanking a linear body of Hartshorne Sandstone in Pittsburg and Coal Counties. The natural gas produced from wells along this and other linear trends of thick Hartshorne Sandstone probably originated in the associated coal beds.

The depth of the coal (up to 4,000 ft or 1,219 m) and its proximity to several gas fields producing from the Hartshorne Sandstone suggest a high methane content (200 to 600 cu ft/ton) for the Hartshorne coal beds in the western parts of the Arkoma basin. However, methane content is not as high as in coal beds farther east at similar depths because of the lower rank (less thermal maturation and therefore lower gas generation) of coal beds in Pittsburg, Coal, and Hughes Counties. Effective placement of gas drainage wells should take into consideration the thickness and depth of coal, possible communication with the natural gas-bearing Hartshorne Sandstone, and rank of associated coal beds.

JACOBSEN, MARK I., Chevron U.S.A., Denver, CO

Harrisburg Trough, Stephens County, Oklahoma—An Update

On the northeast edge of the Wichita Mountain uplift, northwest of Loco, Oklahoma, is a depositional syncline with Pennsylvanian sediments from Atokan through Virgilian. This depositional syncline was named the Harrisburg trough by Harlton. Sedimentary onlap relations within the Harrisburg trough suggest that it formed as a topographic valley that was at times partly above and below sea level. Seismic evidence indicates that this buried valley (canyon?) has paleotopographic relief of more than 10,000 ft (3,048 m). Atokan drainage in the Harrisburg trough was from the southeast to the northwest. Continued erosion of the highlands of Mississippian through Ordovician rocks, and located mainly to the south but also present to the north, provided the clastics deposited in the trough.

The compression that probably caused the uplifted source areas continued through Virgilian time and folded the northeast flank of the Harrisburg trough into the Northwest Velma and West Velma anticlinal hydrocarbon traps. Future hydrocarbon discoveries will probably find production in stratigraphic traps of Atokan sands that pinch out or onlap the flanks of the trough.

MORRISON, L. S., Lamima Corp., Ardmore, OK

Ouachita Facies, an Overview

Since the discovery of oil in the Arkansas Novaculite in Marshall County, Oklahoma, in February 1977, several significant wells have been drilled in southeastern Oklahoma and in Grayson County, Texas. Sands in the Stanley formation and parts of the Bigfork formation have proven to be productive. An unnamed sand zone in the Womble that occurs about 200 ft (60 m) below the Bigfork has had significant shows and indicates that it too will be productive.

Structural problems and stratigraphic surprises will probably be exposed as wildcat drilling continues.

STEEPLES, DON W., Kansas Geol. Survey, Univ. Kansas, Lawrence, KS

Geothermal Energy Resources in Mid-Continent

Awareness of the energy availability problems in the United States has led to increasing curiosity about and interest in geothermal energy. The U.S. Department of Energy has contracted with state agencies in several Mid-Continent states to evaluate geothermal prospects in the Mid-Continent region. The data being gathered will augment and update the data published by the AAPG from their geothermal survey conducted about 10 years ago. The DOE program not only includes support for accurate geothermal gradient and heat flow measurements, but also includes programs in gravity, aeromagnetics, and geochemistry.

This program will not discover any new "Old Faithful" type of geothermal resource. However, preliminary indications are that heat pump applications for space heating may be economically viable in this decade, especially in southeastern Kansas and northeastern Oklahoma. Geothermal gradients in that region are in the 50°C/km (2.8°F/hundred ft) range in the upper 300 m of the sedimentary section. The gradients decrease drastically below this relatively shallow depth to about 15 to 20°C/km (0.8 to 1.1°F/hundred ft). It is not yet clear whether this change in gradient is due to changes in thermal conductivity in the sediments or to hydrothermal convection.

Low-grade geothermal energy could be produced from brine that comes to the surface as a by-product of oil production. Such energy could be used for space heating or even to eventually drive oil well pumps as low-temperature-differential engines are developed. The energy that could be extracted from such brine is six times the energy required to pump it if initial temperature is 150°F/km (66°C) and final temperature is 100°F (38°C) and a lift of 3,000 ft (915 m) with 50% pump efficiency is assumed.

STONE, DALE G., Seismograph Service Corp., Tulsa, OK

Statistical Relations Between Borehole and Surface Data

Reconciliation of measurements made on the surface and in the borehole is often difficult. The most prevalent practice is visual alignment and evaluation of forward synthetics. Recently inverse seismograms have generated more direct involvement and vertical seismic profiles provide more positive information on correlation.

For relations between the forward log synthetic and the well-site seismic trace, normalized cross-correlation is the most obvious statistic. Time alignment, polarity, and the coefficient of correlation can often (but not necessarily) be determined. Log editing may be required as well as multiple studies. General scaling curves for seismic data can be derived from the log instead of simple exponentials. Time variant coherency measure quantifies the degree of similarity between the seismic well-site trace and the synthetic. The coherency points out problem areas to be corrected or edited to improve the match. Used as a weighting function on both signals, editing can be automated to make wavelet extraction practical. Extracted wavelets provide a good quality control for statistical wavelet processing of seismic data.

Similar procedures may be used between the VSP and log or VSP and seismic data. Time-depth relations are often clarified as the VSP provides a reliable time-depth curve. While poorly sampled relative to the sonic log, it may be used to correct problem zones in the log. The VSP also shows which multiples interfere constructively and which interfere destructively. This 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.

VIETTI, J. S., and S. D. ADAMS, Chevron USA, Inc., Denver, CO

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.

WARD, J. A., Teknica Inc., Houston, TX

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.

WATNEY, W. LYNN, and JEFFREY M. GLOSSA, Kansas Geol. Survey, Lawrence, KS

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.