pervasive secondary porosity as well as remobilization of materia: for localized late-stage cements.

TYLER, NOEL, and WILLIAM A. AMBROSE, Bur. Econ. Geology, Austin, TX

Facies Architecture and Production Characteristics of Wave-Dominated Deltaic Reservoir, Big Wells Field, Southern Texas

The Big Wells (San Miguel) oil field in Dimmit and Zavala Counties, southern Texas, produces from a broadly lenticular, wave-dominated deltaic sandstone encased in prodelta and shelf mudstones. An updip porosity pinch-out coincides with a gentle undulation on an otherwise smooth, gulfward-dipping monocline, resulting in a combination stratigraphic and structural trap. The reservoir is relatively tight with average porosity of 10% and permeability of 7 md; wells require fracing to stimulate production. Ultimate recovery is projected to be 30% of the 180 million bbl field.

The reservoir is subdivided into a nonproductive, transgressive upper sandstone and a productive but intensely bioturbated, predominantly deltaic lower sandstone. The tight upper sandstone provides the reservoir seal. Internal architecture of the reservoir is complex, consisting of strike-elongate beach-ridge deposits that merge north into a dip-elongate, digitate channel-sandstone system representing the deltaic entrant into the basin. SP-log facies display mostly strike-parallel orientations; however, resistivity-log facies are more complex and varied, reflecting a high degree of reservoir heterogeneity.

Early production is uninfluenced by the sedimentary fabric of the reservoir. Initial isoproductivity maps display peaks that correspond with faults, proximity to the gas cap, and to a lesser extent, local sandstone thicks. However, during subsequent production, internal architecture strongly influences reservoir yields as the depositionally complex northern half of the field displays lower recoveries than the beach-ridge deposits to the south.

ULRICH, MARK R., Mobil Oil Corp., Dallas, TX, J. RICHARD KYLE, Univ. Texas at Austin, Austin, TX, and PETER E. PRICE, Marathon Oil Co., Littleton, CO

Textural Evidence for Origin of Salt Dome Anhydrite Cap Rocks, Winnfield Dome, Louisiana

Textures within anhydrite cap rock are products of repeated cycles of halite dissolution and residual anhydrite accretion at tops of salt stocks. Quarrying operations at Winnfield dome have exposed extensive portions of the anhydrite cap rock zone. This zone is composed primarily of unoriented, xenoblastic anhydrite crystals in laminae less than 1 mm to several centimeters thick. Laminations are defined by thin, dark sulfide accumulations and pressure solution of anhydrite. Deformed, banded anhydrite clasts are contained locally within laminae. Multiple-laminated, concave downward anhydrite mounds occur along some horizons. They may contain anhydrite breccia fragments or sulfides. Coarsely crystalline salt mounds, containing disseminated idioblastic anhydrite also occur along horizons. Mound morphologies vary from tall and thin to broad and squat; maximum dimensions range from less than 0.5 m to about 2.0 m. These moundlike structures are related spatially and genetically.

Moundlike structures are believed to form from salt spines along the salt-anhydrite contact. As the spine dissolves through several cycles of dissolution and accretion, a laminated anhydrite mound is preserved; if the spine becomes isolated from dissolution, then a salt inclusion is preserved. Anhydrite beds within the Louann Salt, deformed during diapirism, are preserved as deformed anhydrite clasts. Steeply dipping, bedded anhydrite zones within the salt stock may produce brecciated anhydrite mounds when incorporated into the cap rock. Sulfides record the movement of metalliferous fluids through the salt-anhydrite contact. Cores from other Gulf Coast domes indicate that these textures and interpreted processes are common.

UNDERWOOD, MICHAEL B., Univ. Missouri, Columbia, MO

Reexamination of Bengal Fan Model for Turbidites of Frontal Ouachitas

The lower member of the Pennsylvanian Atoka Formation outcrops within the frontal Ouachitas of Arkansas. Strata are comprised of turbidites and related deep-marine deposits, which locally exceed 5.5 km (18,000 ft) in structural thickness. Several previous workers have drawn analogies between Ouachita turbidites (or flysch) and the present-day Bengal Fan, located in the eastern Indian Ocean. As a first-order approximation, this model is basically correct, especially in terms of overall tectonic setting. Yet, when examined in detail, there are striking dissimilarities between the frontal Ouachitas and the Bengal Fan.

The dimensions of the Bengal Fan are staggering, it measures roughly 1,000 km (620 mi) by 3,000 km (1,860 mi). The main feeder channel is 13 km (8 mi) across and 850 m (2,790 ft) deep. Channels within the mid-fan region are up to 2-3 km (1.2-1.9 mi) in width and 100 m (330 ft) in depth, and some channels maintain continuity for well over 2,000 km (1,240 mi). Rates of vertical sediment accumulation are no more than 75 m/m.y., with isopach data showing only 3.5 km (11,500 ft) of post-Eocene accumulation. Limited sampling also shows rather low sand-mud ratios over much of the fan.

Lithofacies data and depositional cycles within the lower Atoka Formation are suggestive of middle-fan, outer-fan, and basin-plain environments. If Atoka channels were as large as those of the Bengal Fan, they certainly remain unrecognized in the rock record. Instead, the entire length of the outcrop belt in Arkansas is less than 250 km (155 mi), and facies changes define a clear east-to-west transition from middle fan to basin plain. Significantly, Atoka sedimentation rates were approximately 10 times higher than Bengal rates. It is evident that the Atoka fan system was much more confined than the Bengal Fan; it probably formed within a narrow, rapidly filling, remnant ocean basin rather than on an unrestricted abyssal floor.

VAIDEN, ROBERT C., Illinois State Geol. Survey, Champaign, IL, and RALPH L. LANGENHEIM, JR., Univ. Illinois, Urbana, IL

Biostratigraphy and Paleoenvironment of Morrowan (Zone 2) Brachiopoda, Bird Spring Group, Arrow Canyon, Clark County, Nevada

Comprehensive study of the Morrowan brachiopod faunas of the Bird Spring Group at Arrow Canyon, Clark County, Nevada, is important because the section has been suggested as a stratotype for the base and top of the Pennsylvanian Subsystem and for the Atoka Series. Twenty-three species of brachiopods belonging to 17 genera occur in zone 20 at Arrow Canyon. Many of these also occur in described Morrowan faunas in Wyoming, Colorado, Utah, and New Mexico; but similarities with the Mid-Continent and Appalachian assemblages are less. However, no striking regional differences are evident, and it appears that the North American Morrowan fauna is more or less homogeneous. In contrast to the exotic South American and Arctic elements known from Atokan, Missourian, and Virgilian rocks at Arrow Canyon, no foreign taxa have been noted in zone 20. Microfacies and faunal associations indicate four distinct brachiopod-bearing environments: (1) relatively deep water below turbulence with few brachiopods on a soft substrate; (2) somewhat shallower, more turbulent water with many species, of which only a few are represented by large populations, living on a more firm substrate; (3) environments just below the zone of turbulence in which many species of brachiopods are represented by substantial populations on a calcarenitic substrate; and (4) crinoidal bars in the zone of turbulence with a few species represented by relatively few individuals.

VAN GIJZEL, PIETER, Getty Oil Co., Houston, TX

New Developments in Microphotometry of Kerogen and Bitumen at Various Stages of Thermal Maturity and Applications to Hydrocarbon Exploration

Microphotometry is the computerized microscopic measurement of reflectance, fluorescence, and transmittance of organic matter in sedimentary rocks. Microphotometric data are an indispensable tool in exploration of hydrocarbons.

The chromaticity of kerogen particles in fluorescence and transmitted light is derived from spectral analysis and provides new scales for thermal maturity: the Fluorescence Color Index and Transmittance Color Index. The TCI could substitute for the inaccurate TAI. Generation of crude oil within thermally mature kerogen particles shows characteristic fluorescence phenomena when microscopically observed and measured.

Spectral data and chromaticity values provide an improved method for determining the thermal maturity of petroleum source rocks, in particular when vitrinite reflectance data are unreliable or unavailable. The "oil floor" in a basin is marked by the disappearance of the fluorescence of fossil alginite, exinite, amorphous organic matter, and most bitumen. This method provides a better mapping of thermally mature petroleum source rocks.

Other applications of microphotometry are: (1) calculation of the effective organic carbon content from the amount of fluorescent oil-prone kerogen and its fluorescence characteristics, a technique providing a better estimation of the volume of hydrocarbons that may have been generated by a source rock, and (2)"fingerprinting" of various types of kerogen, bitumen, drilling contaminants, and caved rock material, and identification of kerogen and bitumen in the mineral matrix of rock samples.

VAN GIJZEL, PIETER, Getty Oil Co., Houston, TX

Organic Indicators of Thermal Maturity, a Review

Organic geochemical parameters include: (1) Rock-Eval data, including T_{max}, S_1, S_2, S_3, and plots of some indices, (2) extract and chromatographic data (i. e., several ratios and the shape of chromatograms), and (3) fluorescence colorimetry and 3-dimensional spectra of extracts.

Organic petrologic indicators are indispensable for assessing thermal maturity. Microscopic analysis provides a quality control of geochemical data and enables identification of kerogen mixtures and contaminants from caved rocks and drilling mud additives. Organic petrologic indicators are: (1) ranges of mean vitrinite reflectance (R_0) for the "oil window" (0.60-1.35%), for the onset of wet gas formation (0.90%), and for the occurrence of dry gas only (2.0%), (2) fluorescence observations and spectral measurements, such as double-peaked spectra for mature kerogen and a shift in its fluorescence at increasing maturity, extinguished when the oil floor is reached (parameters include spectral peaks, spectral ratio, F.C.I., and photochemical effect, and crude oil is microscopically identified by spectral data and kerogen liquefaction under UV-exposure), and (3) visual estimation of the TAI of spore colors in transmitted light.

Conclusions are routinely drawn only from those parameters that show reliable data from both geochemical and petrologic determinations. Lopatin calculations from maturity profiles in wells are used to determine both the thermal history of a basin and mature source rocks.

VREDENBURG, S. ERIC, Old Dominion Univ., Norfolk, VA

Foraminiferal Paleoenvironments and Biostratigraphy of Eocene Nanjemoy Formation, Virginia and Maryland

Foraminiferal and sedimentologic data from 80 spot samples collected in Virginia and Maryland were used to investigate the paleoenvironments and biostratigraphy of the lower Eocene Nanjemoy Formation. The predominant lithology of the Nanjemoy Formation is variably glauconitic fossiliferous muddy sands, with foraminiferal abundance decreasing up section. The sediments of the lower Potapaco member are typically fine to medium-grained muddy sands containing abundant lignite and sparse glauconite. The upper Woodstock member is characterized by fine to coarse-grained sands with a decreased mud content and increased glauconite abundance.

Distributions of individual foraminiferal taxa, planktonic-benthic ratios, foraminiferal suborder ratios, and species diversity patterns were used to determine variations in the Nanjemoy paleoenvironment throughout the lower Eocene Salisbury embayment. Planktonic foraminifera place the samples sections within established biostratigraphic schemes. Supplemental evidence of paleoenvironmental variations was obtained from grain size and composition data of all samples collected.

Cluster and canonical variate analyses were used to investigate further similarities and differences in the foraminiferal content between samples, locations, and members.

WADLEIGH, RICHARD F., JR., and JOHN A. WARD, Teknica Inc., Houston, TX

Carbonate-Anhydrite Facies Determination by Quantitative Seismic Stratigraphy in Paradox Basin

Recent advances in seismic acquisition and processing techniques have greatly improved the usable bandwidth and signal-to-noise ratio of seismic data collected in the Paradox basin. Historically, the irregular terrain coupled with shallow velocity gradients limited the usable stratigraphic thin-bed resolution to near 60 Hz. Analysis of filtered sonic logs of the upper Ismay formation suggests that even with 100-Hz seismic data, carbonate porosity will not be represented seismically as an individual low-velocity trough on wavelet-processed data. Conventional seismic stratigraphy attempted to interpret these zones based on a qualitative study of synthetic seismograms.

The purpose of this paper is to evaluate an inverse method of calibrating seismic data by the integration of quantitative analysis of filtered sonic logs from bore-hole data with seismically derived sonic logs (Seislogs). The Seislog display has a horizontal scale in transit time and a vertical scale in depth. In this format it is possible to compare quantitative variations observed on the Seislogs with changes derived in model studies that relate filtered velocity on sonics to lithologic variation.

This paper discusses the application of this method in an upper Ismay field (Patterson Canyon), located in San Juan County, Utah. The field is currently producing oil from a porous carbonate algal-mound facies, which in filtered-sonic logs is typified by a decrease in both velocity and thickness when compared to the anhydrite facies. When the carbonate facies becomes tight, there is a transit-time decrease and an apparent increase in thickness. The anhydrite facies sonically has the lowest transit time and also is the thickest facies. It is important to note that a limestone with intercalated clastics may have exactly the same sonic response as the porous carbonate facies. The distribution of these facies in map view provides the key to differentiation of the two types of low velocity response in this trend. The porous carbonate facies is typically narrow and lenticular in contrast to the more sheetlike clastic carbonate facies.

WAGNER, KARMA, M. M. Mace, Wichita, KS

Hydrocarbon Production Potential of Mississippian Rocks in Cowley County, Kansas

Petroleum geologists are continually searching for new and better techniques of exploring for hydrocarbons. This study uses one such technique, discriminant function analysis, to predict trends of potential hydrocarbon production of Mississippian rocks in Cowley County, Kansas, Discriminant function analysis is a method of studying differences between two or more groups, using a set of discriminating variables. The two groups used for this study were (1) wells producing from the Mississippian and (2) wells not producing from the Mississippian.

Variables used were thought to be potentially significant to hydrocarbon accumulation in Mississippian rocks within the study area. These variables included structural tops and thicknesses, surface elevation, presence of tripolitic Mississippian chert, trend surface residuals, and four types of satellite lineation data. A total of 564 wells, each with 21 distinct parameters, was used in performing the two-phased analysis.

The two phases, consisting of a principal components analysis and the discriminant function analysis, were accomplished through use of computer programs and resulted in a single discriminant score value for each well. These values were used to generate a discriminant score surface map. Statistical analysis of the map resulted in 80.6% of the producing wells being correctly classified within producing areas. Alternately, 75.9% of the nonproducing wells were correctly classified. These favorable results suggest that this technique could be successful in establishing trends of production and potential production while simultaneously delineating areas of nonproduction.

WALKER, DAN, and GREG H. MACK, New Mexico State Univ., Las Cruces, NM

Tectonics and Dispersal of Miocene Rift-Fill Sediments, Southern New Mexico

Late Tertiary rifting in southern New Mexico took place in two stages: early to late Miocene and Pliocene-Pleistocene. Sedimentary rocks of the earlier stage are represented by the Hayner Ranch and Rincon Valley Formations, which were examined at San Diego Mountain, Dona Ana County, New Mexico. The Hayner Ranch Formation consists of 950 m of red fanglomerate derived from volcanic rocks. The Rincon Valley Formation consists of 325 m of limestone- and volcanic-cobble fanglomerate overlain by 25 m of red playa shale.

Measurements of maximum clast size at 50 m intervals ($n = 1,820$) and cobble imbrications at 50 m intervals ($n = 650$) indicate that the initial stage of rifting took place in two distinct phases and involved two separate source areas. The lower 600 m of the Hayner Ranch Formation were derived from volcanic rocks north of San Diego Mountain. Following a period of tectonic quiescence, represented by a 150 m thick fining-upward sequence, uplift occurred to the south of the study area, depositing the upper 350 m of the Hayner Ranch Formation and the lower 300 m of the Rincon Valley Formation. Limestone cobbles recovered from the Rincon Valley Formation are identical to lithologies in the Permian Hueco formation exposed in the Robledo and Dona Ana Mountains, 15 km south and southeast of San Diego Mountain, respectively.