WALTERS, ROBERT D., and RICHARD T. BUFFLER, Univ. Texas at Austin, Austin, TX

Seismic Stratigraphy of Pliocene-Pleistocene Deposits, Continental Slope-Upper Mississippi Fan, Northern Gulf of Mexico

Regional multichannel seismic data are used to develop a seismic stratigraphic framework for the continental slope-upper Mississippi fan region in the northern Gulf of Mexico. In the Mississippi canyon area, upper Pliocene and Pleistocene paleontologic zones from wells provide age control for major seismic sequence boundaries. A major unconformity and high-amplitude reflector identified as the base of Pleistocene represents a break in sedimentation and probably marks onset of fan deposition. This unconformity and others within the Pleistocene define sequences showing cyclic patterns of deposition, which are related to Pleistocene sea level changes and salt mobilization.

Interpretation of seismic facies and their relationships to sea level changes, glaciations, and salt movement results in a model for the depositional history of the Mississippi fan from the canyon area to the deep-water part of the fan. Low-amplitude, chaotic, onlapping facies are interpreted as slump or debris-flow deposits associated with canyon cutting by retrogressive failure and initiation of large-scale mass movement due to a relative lowering of sea level. High-amplitude, parallel, continuous reflectors at sequence boundaries represent pelagic and hemipelagic sediments associated with a succeeding rise in relative sea level.

In the shelf-upper slope area, isolated salt diapirs influence sedimentation on a localized scale. In the lower slope to upper fan, most Pleistocene section is extensively disrupted by parallel sets of salt ridges that result from differential loading of fan sediments. Shifting depocenters and migratory channel systems funnel sediment through this area onto the lower fan. Salt wedges in the eastern study area appear to represent detached salt masses isolated within the Pleistocene section.

WARD, W. BRUCE, and WILLIAM J. MEYERS, State Univ. New York, Stony Brook, NY, and ROBERT GOLDSTEIN, Univ. Wisconsin, Madison, WI

Early Diagenesis of a Phylloid Algal-Mound Complex, Laborcita Formation, Southeastern New Mexico

Marine carbonate cementation was the initial stage in the paragenesis of phylloid algal mounds in the Laborcita Formation (Wolfcampian), Sacramento Mountains, New Mexico, and the cements are almost identical to those in Holocene coral reefs of Belize. These cements include relicts of botryoids and crusts of needle crystals, in part defined by inclusion patterns and luminescent "ghosts" in mosaic calcite. Individual needle crystals are pseudohexagonal in cross section and range from less than 1 to 30 μm wide. These nonluminescent early cements line cavity walls, coat phylloid-algal blades and stromatolites, and are interlayered with marine sediment. Early cements also include bladed, fibrous, and rare radiaxial fibrous calcites, which are microdolomite-rich. They have a proximal nonluminescent zone, a central bright-luminescent zone, and a distal blotchy, moderate-luminescent zone. The bright zone may be time equivalent to bright-luminescent micritic coatings on botryoids and grains. Botryoids are encrusted by isopachous bladed cement, some of which has prismatic overgrowths containing an early inclusion-rich zone. This initial cementation was followed closely by: (1) dissolution of algal blades and mollusks, (2) in-situ brecciation, and (3) cementation by blocky calcite.

Botryoidal and acicular cements are interpreted as originally marine aragonite precipitates, based on morphology, occurrence, susceptibility to diagenesis, and similarity to Holocene reef cements. The same criteria, plus the microdolomite inclusions, indicate that the bladed, fibrous, and radiaxial cements had a marine Mg-calcite precursor. This assemblage followed by prismatic overgrowths, dissolution, and blocky-calcite cementation indicates an evolution from marine to freshwater diagenesis.

This early diagenesis was followed by, in order: (1) cementation by multiple stages of blocky calcite (interrupted by episodic fracturing), (2) local dolomitization, (3) stylolitization, (4) dedolomitization and blocky-calcite cementation, and (5) minor chertification.

WATTERS, D. G., M. C. T. PAGAN, and D. M. J. PROVAN, Shell U.K. Exploration, London, United Kingdom

Cormorant Field, United Kingdom North Sea—Synergistic Approach to Optimum Development of a Complex Reservoir

The Cormorant oil field containing 1.5 billion bbl of oil in place, is situated in the United Kingdom sector of the northern North Sea. The reservoir comprises Middle Jurassic Brent Group sandstone in a westward tilted fault block. The top seal is provided by Upper Jurassic shales. The Brent Group consists of several units, which represent a single large-scale regressive and transgressive sequence of a northerly prograding delta complex.

The structure style is a product of two tectonic phases, one dominated by wrench tectonics and a subsequent one which created the westward-dipping faults blocks. This has resulted in a complex field consisting of four separate fault-bounded blocks. Each has distinctive characteristics and problems associated with varying internal geometry and sedimentology.

Block IV, resulting from crestal collapse, is internally faulted and displays a number of elongate subblocks, which are bounded by a complex interactive suite of faults. Three-dimensional seismic coverage has not allowed adequate resolution of this complex faulting. Delineation of subblocks is critical as development has shown that many faults are sealing.

Block II, southwest of the main culmination, presents problems of a sedimentological and structural nature. Production history shows the existence of barriers within the reservoir, probably associated with small-scale faulting, the sealing caused by juxtaposition, and/or clay smearing.

There is also evidence of permeability reduction with increasing depth. Kaolinite is the predominant clay mineral within the reservoir, whereas illite may be present in small quantities in the water-bearing zone; this differential impairment has an effect on development strategy.

WEIBEL, C. PIUS, Univ. Illinois, Urbana, IL

Lithostratigraphic Revision Within Upper Pennsylvanian Mattoon Formation, Illinois

Pennsylvanian strata in the Illinois basin comprise a stratigraphic bridge between the well-studied dominantly terrestrial Appalachian succession and the marine Western Interior basin sequences. Within the Virgilian Series, understanding of this transition has been hampered by uncertainty as to stratigraphic order and a generally poor data base in Illinois. Previous studies in Illinois attempted local correlation by means of limestones and coals, both of which are largely thin and discontinuous. This study shows that black "sheety" shales are the most widespread lithologic units within the Virgilian. As many as six different black shales—associated with the Shumway, Bogota, Effingham, Reisner, Woodbury(?), and "Steel Bridge" limestones, respectively—have been recognized in the upper half of the Mattoon Formation in east-central Illinois. Detailed outcrop examination indicates that the black shales associated with the Shumway, Effingham, and "Steel Bridge" limestones are stratigraphically equivalent. Subsurface data confirm this conclusion. In addition to reducing the number of black shale beds to only four, this correlation shows that the lithology directly below the black shales is more diverse than previously thought. Rocks below the black shale associated with the Shumway-Effingham-"Steel Bridge" limestones include coal, gray shale, fossiliferous limestone, and unfossiliferous limestone.

WESTPHALL, MICHAEL, J., and ROBERT N. GINSBURG, Univ. Miami, Miami Beach, FL

Taphonomy of Coral Reefs from Southern Lagoon of Belize

The Southern Lagoon of the Belize barrier complex, an area of some 600 km^2, contains a tremendous number of lagoon reefs, which range in size from patches several meters across to rhomboidal-shaped structures several kilometers in their long dimension. These lagoon reefs are remarkable because they have Holocene sediment accumulations in excess of 13 m consisting almost entirely of coral debris and lime mud and sand, and rise up to 30 m above the surrounding lagoon floor with steeply sloping sides (50-80°), yet are totally uncemented.

The reef-building biota and their corresponding deposits were studied at a representative reef, the rhomboidal complex of Channel Cay. As with many of the reefs in this area, the steeply sloping flanks of Channel Cay are covered mainly by the branched staghorn coral *Acropora cervicornis* and ribbonlike and platy growth of *Agaricia* spp. The living corals are not cemented to the substrate, but are merely intergrown. Fragmented pieces of corals accumulate with an open framework below the living community; this open framework is subsequently infilled by lime muds and sands produced mainly from bioerosion. Results from probing and coring suggest that the bafflestone fabric of coral debris and sediment extends at least 13 m into the subsurface.

Radiocarbon-age estimates indicate these impressive piles of coral rubble and sediment have accumulated in the past 9,000 yr (giving a minimum accumulation rate of 1.4 m/1,000 yr) and illustrate the potential for significant carbonate buildups without the need for early lithification.

WHITE, BRIAN, Smith College, Northampton, MA, KAREN A. KURKJY, Univ. Miami, Miami, FL, and H. ALLEN CURRAN, Smith College, Northampton, MA

Diagenesis and Sea Level Change in a Pleistocene Coral Reef, San Salvador, Bahamas

Near the Cockburn Town reef (dated 125,000 yr B.P.), precisely surveyed bench marks are related to accurately measured mean sea level, and they provide a convenient datum plane. This coral reef developed during a sea level highstand of no more than 10,000 yr, which was insufficient time for significant subsidence; however, subsidence of approximately 3 m may have occurred since the formation of the reef. Sea level changes were caused by fluctuations in glacial-ice volume. The upper beach to dune transition, which is in the calcarenites overlying the reef, is at +4 m. A minimum highstand of +7 m is indicated when corrected for subsidence.

Below +2.5 m, marine aragonite cement occurs within the intragranular pore space of the following: *Halimeda* plates, benthic foraminifera, *Favreina* (Callianassid fecal pellets), gastropods, and corals. Marine aragonite cement also occurs as intergranular isopachous rims on matrix grains of coral rubblestone. Remaining pore space was partly to completely occluded by freshwater vadose calcite cements, which occur without marine cements in the overlying shallow subtidal, beach, and dune calcarenites. No unequivocal freshwater phreatic cements have been found, although syntaxial overgrowths and irregular calcite rims about grains do occur in finer grained sediments where local patches of freshwater saturation occurred within the vadose zone. Later calichification, which affected all facies, is characterized by alveolar texture, whisker calcite, microsparite, rare bladed calcite spar, *Microcodium*, and rhizocretions.

WHITICAR, M. J., E. FABER, and M. SCHOELL, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Federal Republic of Germany

Hydrogen and Carbon Isotopes of C_1 to C_5 Alkanes in Natural Gases

A technique has been developed to determine C^{12}/C^{13} and D/H isotopic ratios on small quantities of methane through pentane hydrocarbons and has been applied to natural gases from various genetic sources (i.e., early-diagenetic, oil-associated, late-catagenic and mixed-gas sources).

Carbon isotopes measured from 27 natural gases have $\delta^{13}C$ range of 23, 15, and 20‰ for the C_1 to C_3 alkanes and maximum $\delta^{13}C$ values of −35.1, −26.8, and −20.8 ‰ respectively. With a smaller sample base, butane and pentane vary within 16 and 4 ‰, respectively, for those samples with the most positive $\delta^{13}C = -26.5$ and −26.9 ‰.

Deuterium isotopes exhibit greater isotopic variation than the corresponding carbon values. D/H variations clearly decrease toward the higher homologues with δD ranges of 182, 110, 75, 43, and 29 ‰ for C_1 through C_5. Most negative D/H measurements also decrease with carbon number from δD = −311 ‰ for methane to −128 ‰ for pentane.

These relative changes in carbon and hydrogen isotopic contents for the higher homologues are useful in the classification of natural gases, particularly those of mixed origin.

WHITICAR, MICHAEL J., ECKHARD FABER, and WOLFGANG STAHL, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Federal Republic of Germany

Sorbed vs. Free Sediment Gases—Differentiation of Thermogenic and Biogenic Gas Sources

The unique phenomenon of hydrocarbon gas sorption on mineral and organic matter surfaces provides the basis of a novel aid for geochemical petroleum exploration. A refined vacuum sediment degassing procedure permits separate analysis of sorbed and free gas fractions. Hydrocarbon gases from both individual fractions can be genetically classified (e.g., diagenetic, thermogenic, catagenic) by their molecular and ^{13}C and ^{2}H isotopic compositions.

In contrast to the normal bulk or free gas fractions, where the composition is frequently influenced by alteration effects such as bacterial gas generation or oxidation, comparative analyses indicate the the sorbed gas fraction can retain its unaltered genetic signature. Exchange between the sorbed and free gas fractions is severely restricted by surface sorption energies and perhaps by structure water, which may assist in the partitioning of gas fractions with different genetic characters. Gas transport within the sorbed fraction is probably a surface-controlled "handshake" diffusion process that minimizes contact with the free gases.

Examples of this phenomenon are provided by Gulf Coast and California surface sediment cores, which display strong biogenic methane formation and oxidation effects in the free gas fraction. In contrast, the corresponding character of the sorbed gas fractions is clearly distinguished as thermogenic and originating in subsurface. Evidence of thermogenic hydrocarbons is obscured during routine bulk analysis by the biogenic free gas component.

This sorption phenomenon has good potential for the identification of subtle geochemical hydrocarbon anomalies previously masked through bulk analysis.

WIGGINS, WILLIAM D., and PAUL M. HARRIS, Gulf Research and Development, Houston, TX

Burial Diagenesis of Allochthonous Carbonates from a Permian Slope Setting, Southeastern New Mexico

The Bone Spring formation (Permian-Leonardian) from 3-km (9,850-ft) deep conventional cores in the northern Delaware basin is a laminated, black, mixed terrigenous-carbonate mudstone with thin intervals of gray, coarse carbonate-debris flows. All carbonates have been pervasively dolomitized, and porosity and permeability were reduced to 3-8% and 1 md, respectively, during several diagenetic events related to burial history.

Three dolomite generations are defined by fluorescence and cathodoluminescence microscopy and electron microprobe, and are further characterized by means of microsampling for carbon and oxygen isotopes. Over a range of 2 ‰ (PDB), $\delta^{13}C$ decreases steadily from the first to last dolomite generation, reflecting constant mixing of rock carbon and organic carbon as hydrocarbons were evolving in the Bone Spring muds. The first dolomite generation was introduced during the time interval between early postdeposition and burial to approximately 1 km (3,280 ft). Dewatering and compaction of the Bone Spring muds accompanied matrix dolomitization, leaching of metastable grains, fracturing, and silicification of carbonate components. The mean $\delta^{18}O$ of the high-strontium, matrix dolomite is -2.1 ± 0.4 ‰ (PDB). A second dolomite generation may have been late Ochoan; by this time an additional 1.2 km (3,925 ft) of Guadalupian-Ochoan carbonates and evaporites had been deposited. This fluorescent, nearly stoichiometric dolomite cement has a mean $\delta^{18}O$ of -3.0 ± 0.3‰ (PDB), and was coeval with hydrocarbon generation in the Bone Spring. It precipitated from fluids that interacted with the overlying evaporites. Hydrocarbon inclusions are contained in this dolomite, which is succeeded by a generation of anhydrite cement. Sulfur isotopes strongly suggest that remobilized Guadalupian anhydrite-sulfur formed this cement.

The last two diagenetic phases, including the third dolomite generation, crystallized at about present burial depth. Coarsely crystalline, luminescent, pore-filling calcian dolomite, containing hydrocarbon inclusions, has a mean $\delta^{18}O$ of -5.4 ± 0.6‰ (PDB). Depleted poikilotopic calcite cement ($\delta^{18}O = -10.3$ ‰, PDB) records the input of Tertiary water.

WILBER, R. JUDE, Sea Education Assoc., Woods Hole, MA, ALBERT C. HINE, Univ. South Florida, St. Petersburg, FL, and A. CONRAD NEUMANN, Univ. North Carolina, Chapel Hill, NC

Multiple Submarine-Cemented Grainstone Sequences Along Leeward Carbonate Margins: Examples from Late Quaternary of Little and Great Bahama Banks

Coarse-grained, leeward-margin sand shoals, developed during the late Quaternary along the western edges of Little and Great Bahama Bank, have been deposited and preserved in response to regional sediment-transport processes and local physicochemical conditions. These sand bodies are fundamental depositional sequences, chronostratigraphically bounded by subaerial exposure crusts, and thus are of major importance in determining rates of bank-margin growth and in understanding the dynamics of carbonate margin buildup. In the Holocene sediments, these sand bodies are 1-2 km wide, up to 35 m thick, and are present along 400