

and strike, were quantified and compared. Relative permeabilities of gas over the spectrum of oil saturation and porosities were also determined.

Permeability across the laminae ranged from 0.5 to 4 md, whereas permeability parallel to lamination ranged from 3 to 97 md. Permeability parallel to lamination was not significantly different when strike and dip directions were compared. Quantitative analyses of textures and fabrics of individual laminae explain the observed diversity of permeabilities. Relative permeabilities were highest at a given oil saturation measured downdip and along the laminae and lowest when measured perpendicular to lamination.

SHINN, EUGENE A., U.S. Geol. Survey, Miami, FL, RANDOLPH P. STEINEN, Univ. Connecticut, Storrs, CT, BARBARA H. LIDZ, U.S. Geol. Survey, Miami, FL, and ROBERT B. HALLEY, U.S. Geol. Survey, Denver, CO

Bahamian Whittings—No Fish Story

Bahamian whittings, controversial patches of drifting mud-laden water, have been thought to be produced by fish. Observations over several 7-day periods show that whittings are long-lived phenomena (days and possibly weeks) and that the dozens which exist at any time on the Great Bahama Bank continually "rain" aragonitic sediment. Although chemical changes consistent with precipitation have not been detected in seawater near or within whittings, new data indirectly suggest that precipitation from seawater causes whittings.

Lime mud settled in approximately 6 hr in large (30 gal) containers of water taken from whittings, whereas in the sea, the "parent" whittings persisted for days. Sediment traps verified continual transport of sediment. Divers noted no fish stirring up the bottom nor any evidence of bottom feeding. Side-scan sonar failed to detect unusually large schools of fish, and a shrimp's net dragged in the whittings failed to catch any fish known to be bottom feeders. Dragging the net in clear water near active whittings created "artificial" whittings that settled back to the bottom in a few hours. Current measurements within and outside of whittings ruled out current eddies. Near the edge of the Bahama platform, whittings occur over bottom sediments too coarse-grained to be stirred into suspension, yet the muddy bottom of the banks was miles away. These data suggest that natural whittings must be continually replenished with sediment.

Filtration of known volumes of water from 15 whittings and from clear seawater indicates that active-whiting water contains only a very small (10-12 mg/L) amount of suspended carbonate sediment, yet whittings are considered a potential major source of lime mud on the Great Bahama Bank. Inasmuch as nearly one-half the world's oil is pumped from limestone, knowledge of the origin and deposition of lime mud has implications for hydrocarbon exploration.

SHOWERS, WILLIAM J., D. G. ANGLE, C. A. NITTRouer, and D. J. DEMASTER, North Carolina State Univ., Raleigh, NC

Carbon Isotopic Composition of Amazon Shelf Sediments

The distribution of carbon isotopes in Amazon shelf sediment is controlled by the same processes that are forming the modern subaqueous delta. The terrestrial (-27 to -25‰) isotopic carbon signal observed in surficial sediments near the river mouth extends over 400 km northwest along the shelf. Terrestrial carbon is associated with areas of rapid sediment accumulation (topset and foreset regions). A sharp boundary between terrestrial (-27 to -25‰) and marine (-23 to -22‰) isotopic carbon values in surficial sediments is associated with a change in depositional conditions (foreset to bottomset regions) and a decrease in sediment accumulation rate. POC water-column isotopic values (-27‰) near the river mouth are similar to the underlying surficial-sediment TOC isotopic values, but POC water-column samples collected 20 km off the river mouth have marine carbon isotopic values (-22 to -19‰) and differ from the underlying surficial-sediment TOC isotopic values. These water column observations are related to variations in turbidity and productivity. Down-core isotopic variation is only observed in cores taken in areas of lower sediment accumulation rates. These observations indicate that the organic carbon in Amazon shelf sediment is dominantly terrestrial in composition, and the location of deposition of this carbon is controlled by modern processes of sediment accumulation. The modern Amazon shelf is similar to large clinoform shale deposits of the Cretaceous in North America. Thus, the stratigraphic setting may help predict the isotopic variations of carbon in ancient deposits.

SHURR, GEORGE W., St. Cloud State Univ., St. Cloud, MN, JOHN T. JENKINS JR., Southland Royalty Co., Denver, CO, and DANIEL M. LIKARISH, Geo-Search Corp., Englewood, CO

Seismic Expression of Structural Features on Landsat Lineaments: an Example from Denver Basin

Lineaments interpreted from Landsat images mark the location and trend of basement faults observed on seismic lines in the eastern Denver basin.

Linear features mapped as tone and texture patterns on multispectral scanner images in northeastern Colorado and southwestern Nebraska are used to interpret regional lineaments. Individual linear features up to 25 mi (40 km) long and visible on both bands 5 and 7 define a grid of regional lineaments trending northeast and northwest. Comparisons of lineaments with aeromagnetic and gravity maps and with interpretations of basement geology suggest that lineaments are the boundaries of basement blocks with areas of about 1,000 mi² (2,590 km²). Constituent linear features within the lineament zone probably mark boundaries of smaller blocks of about 50 mi² (130 km²).

Seismic lines in northeastern Sedgwick County in extreme northeastern Colorado cross linear features that are components of a broad regional lineament that trends northeast and parallels the South Platte River. Seismic data consist of a grid of about 100 mi (160 km) of multifold Vibroseis lines. Basement faults, generally with offsets of less than 100 ft (30 m), are observed in seismic lines that cross some individual linear features. Monoclines and faults are present in Pennsylvanian to Tertiary strata that overlie basement. A time-structure map on the Precambrian and an isochron map of Wolfcamp (Lower Permian) to Precambrian show that the lineament is a 7-mi (11-km) wide zone of small, downdropped basement blocks. Thickening of Permian-Pennsylvanian strata on the downthrown side of faults suggests tectonic activity. Further tectonic activity is indicated by listric faulting in the Cretaceous Niobrara Formation.

SIESSER, WILLIAM G., Vanderbilt Univ., Nashville, TN

Chronostratigraphy and Biostratigraphy of Paleogene Formations in Eastern Gulf Coastal Province

Paleogene formations extending from eastern Alabama to Arkansas have been assigned to internationally recognized biostratigraphic zones based on calcareous nannoplankton fossils. All zones from NP 1 to NP 24 are present in the study area, with the exception of NP 11 (within the early Eocene) and NP 23 (within the early Oligocene).

Gulf Coast formations correlate to international standard chronostratigraphic stages as follows. The Clayton and Porters Creek formations correlate to the Danian Stage. The Naheola Formation, Salt Mountain Limestone, Nanafalia Formation, Tusahoma Sand, and lower Hatchetigbee Formation (in part) correlate to the Selandian Stage. The Hatchetigbee (in part) and lower Tallahatta correlate to the Ypresian Stage; the upper Tallahatta and most of the Lisbon and Cook Mountain Formations correlate to the Lutetian Stage. The upper Lisbon and Cook Mountain formations, the Gosport Sand, Moodys Branch, and lowermost Yazoo formations correlate to the Bartonian Stage. The Crystal River and most of the Yazoo Formation correlate to the Priabonian Stage. The uppermost Yazoo Formation, the Bumpnose Limestone, Red Bluff, Forest Hill, and Mint Spring Formations, Marianna and Glendon Limestones, and Byram and Bucatunna Formations correlate to the Rupelian Stage. The Chickasawhay Limestone and Paynes Hammock Formation span the Rupelian-Chattian boundary.

The Paleocene-Eocene boundary (approximately the NP 9-NP 10 boundary) is therefore within the lower Hatchetigbee Formation (Bashi Marl Member). The Eocene-Oligocene boundary (within lowermost NP 21) is within the uppermost Yazoo Formation (Shubuta Clay Member) in places, and within the lowermost Bumpnose, Red Bluff, and Forest Hill Formations and Marianna Limestone elsewhere in the region.

SLATT, ROGER M., Cities Service Co., Tulsa, OK (present address: ARCO Oil & Gas Co., Dallas, TX), KATHE LIGHTY, Cities Service Co., Tulsa, OK (present address: College Station, TX), and JOHN ROBINSON, Cities Service Co., Tulsa, OK

Recognition of a Thin Stratigraphic Trap by Seismic Reflection Character Analysis

The Cretaceous Cardium Formation, Alberta, Canada, which produces oil and gas from thin stratigraphic traps comprising coastal and

offshore shelf sand-ridge deposits, appears as "railroad tracks" on seismic sections. Ninety-seven seismic lines were examined over a 10,000 km² area. Here, the Cardium is divided into the Cardium Sand and the overlying Cardium Zone, both of which are 15-50 m thick. The Cardium Sand systematically grades eastward from (a) shoreface-strandplain massive sandstones to (b) inner-shelf sandstones encased in shale. The Cardium Zone grades eastward from (a) marginal marine/inner-shelf sandstones (< 10 m thick) encased in shale to (b) shelf shales.

Two major reflection patterns characterize the Cardium Formation. One consists of two high-amplitude reflections spaced 20-30 m apart, and the other consists of a single reflection; further subdivision is possible on the basis of reflection amplitude. Areally, these patterns correlate with the regional distribution of sedimentary facies described above.

Reflection patterns of 26 1-D seismic models generated from sonic logs correlate with those of the field seismic data thus allowing interpretation of the field data in terms of sedimentary facies. Thickness of the Cardium Zone and number and thickness of sandstone beds in the Zone were found to control seismic reflection patterns. The double reflection pattern occurs where the Cardium Zone is more than 24 m thick and contains shelf sandstone beds encased in shale. A single reflection, generated from the Cardium Sand, occurs where the zone is less than 24 m thick and lacks sandstones. These relationships can be used to detect and map potential sandstone reservoirs on seismic records.

SLOW, EVAN S., and ROBERT ANDERHALT*, Bowling Green State Univ., Bowling Green, OH

Carbonate Cements in Sandstones—Mineralogy and Chemical Composition

The chemical compositions of carbonate cements in sandstones were analyzed with an energy dispersive analyzer (KEVEX) and a scanning electron microscope in order to provide a baseline data base for one of the most common authigenic phases in sandstones. A total of 205 spectra was analyzed with respect to mineral standards using ZAF corrections. These spectra were acquired from 35 Cambrian to Cretaceous carbonate-cemented sandstones from our sedimentary rock collections.

Only 19% of the analyses were pure calcite (i.e., no Mg, Mn, or Fe were detected). Impure calcites accounted for 54% of the analyses, and dolomites and ankerites accounted for 27%. When the calcites were treated as a single group, the distribution of the components was as follows: calcite 91.6-100%; magnesite, 0-8.4%; rhodochrosite, 0-2.3%; and siderite, 0-4%. The dolomites and ankerites showed a larger range: calcite, 47.8-60.6%; magnesite, 20-52.2%; rhodochrosite, 0-12%; and siderite, 0-28.6%. The values of the calcite component in the dolomites that were significantly higher than 50% probably resulted from the beam (spot mode) encountering dolomite plus some calcite. In most cases, the calcite component was nearly 50%.

Many of these compositions displayed a large variation within a sample, even at the micron-level scale. A series of closely spaced analyses—all within an area 200 × 100 μm—from a sample rich in dolomite and/or ankerite ranged between 20 and 43% magnesite and 6 and 29% siderite. The calcites normally only ranged a few percent for each component in analyses that were spaced at a similar scale.

SMITH, GUY W., Chevron U.S.A. Inc., New Orleans, LA

Decade of Exploration in Deep Lower Tuscaloosa Gas Trend in Southern Louisiana

The deep lower Tuscaloosa gas trend, now in a mature stage of exploration, was discovered in 1975. Production is from lower Tuscaloosa sandstones of Late Cretaceous age. During the past decade, the petroleum industry has drilled approximately 217 new-field wildcats and 232 development wells in the trend. This exploration effort has discovered 24 fields. Most of these fields produce from depths between 15,000 and 20,000 ft. In February 1984, the average daily production was 426.6 mmcf of gas and 18,350 bbl of liquid hydrocarbons from approximately 115 wells. Five fields, False River, Irene, Judge Digby, Moore-Sams, and Port Hudson, all discovered prior to 1980 and concentrated northwest of Baton Rouge, Louisiana, have produced about 72% of the cumulative gas and 80% of the cumulative liquids.

Reservoirs in deep lower Tuscaloosa occur in a terrigenous clastic sequence, which thickens rapidly downdip from a carbonate shelf of Early Cretaceous age. Occurrences of commercial hydrocarbons in the trend are primarily dependent on depositional environment, syndepositional

tectonics, source rock, original sand mineralogy, and burial diagenesis. Salt diapirism is locally important.

SMITH, THOMAS N., State of Alaska, Anchorage, AK, JAMES G. CLOUGH, State of Alaska, Fairbanks, AK, JOHN F. MEYER, State of Alaska, Anchorage, AK, and ROBERT B. BLODGETT, Oregon State Univ., Corvallis, OR

Petroleum Potential and Stratigraphy of Holitna Basin, Alaska

The Holitna basin, an interior Alaskan basin, is flanked by Cambrian to Cretaceous sedimentary rocks that have been highly folded and faulted. Gravity mapping and modeling indicate up to 15,000 ft of sedimentary section is present within the basin.

Cambrian rocks consist of trilobite-hash lime mudstone, red siltstone, and basinal chert. Ordovician through Devonian basinal facies rocks consist of platy limestone to graptolitic shale with minor interbeds of limestone turbidites and turbidite-channel debris flows. Ordovician through Middle Devonian shallow-water platform carbonate rocks prograde over the basinal rocks and are composed of algal boundstone buildups with associated inboard lagoonal, oolitic shoal, and tidal-channel deposits. Toward the interior of the platform, restricted subtidal and intertidal to supratidal carbonate rocks were deposited. Upper Devonian to Permian platform carbonate deposition occurred to the east of the older platform rocks and conformably(?) over basinal rocks. Minor mixed carbonate-clastic deposition occurred into Triassic time.

The Cretaceous Kuskokwim Group is in fault contact with and/or unconformably overlies the Paleozoic carbonates. This unit varies from lithic-rich conglomerates to marine turbidite deposits. Maturation values for Cretaceous and Paleozoic rocks are within the oil window, with most of the shales showing a thermal alteration index (TAI) from 2 to 3. Organic carbon content exceeds 3% in some samples, however, deep surface weathering has resulted in low hydrocarbon values. The lithic-rich Cretaceous sandstones are well indurated, poorly sorted, and are considered to have low reservoir potential. Partly dolomitized, shallow-water Ordovician to Devonian carbonate rocks are the best potential reservoir rocks exhibiting vuggy porosities greater than 10% and good intergranular porosity.

SNEDDEN, JOHN W., Louisiana State Univ., Baton Rouge, LA, ANTHONY F. AMOS, Univ. Texas Marine Science Inst., Port Aransas, TX, and DAG NUMMEDAL, Louisiana State Univ., Baton Rouge, LA

Bottom Currents During Early Winter on South Texas Continental Shelf: Implications for Shelf Sediment Transport

During a 42-day period in the early winter of 1981, bottom currents and temperature were measured by a current meter moored 2 m off bottom in 130 m of water on the south Texas continental shelf. During this time, nine cold fronts passed over the area, bringing about substantial changes in the overlying wind field. Particularly significant were the strong southeasterly winds that preceded several of the frontal passages. These wind events appear to have indirectly affected the bottom current velocity structure.

During the early part of the record, bottom currents averaged 10 cm/sec, with bursts up to 32 cm/sec. Flow was generally along the shelf to the southwest until late in the time series when net water motion changed abruptly to become southeasterly (toward deeper water). Current speeds then averaged 13 cm/sec with peaks of up to 26 cm/sec.

The cause of this unusual offshore bottom water motion is believed to be best understood by study of the bottom water temperature record. It is hypothesized that during the latter part of the record, when southeasterly winds were strongest, surface water was driven toward the coast. However, bottom water was advected in the opposite direction, resulting in coriolis-deflected offshore flow. A noticeable rise in the bottom water temperature accompanying this motion suggests advection of warmer coastal waters into deep water. Hydrographic surveys show a slight deepening of the thermocline at this time.

This time series is significant for several reasons. First, data on the current velocity field of the south Texas continental shelf is sparse. Second, the current speeds measured are for some periods in excess of that which, theoretically, is necessary for the transport of fine (3 φ) sand. Third, the record shows an apparent interaction between bottom currents and the overlying wind field.