infilled by matrix-supported gravel overlain by mass-flow deposits of planar-interstratified sand and mud. Channel infills are overlain by stratified matrix-supported gravels and sands and structureless clast-supported gravels deposited by debris flows which deformed underlying sands. Inasmuch as submarine outwash-fan sequences characteristically contain matrix-supported gravels, planar-interstratified sand and mud infill of channels and lack large-scale trough cross-bedding, they can be distinguished from deltaic sequences.

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Relationships Among Carbon Dioxide, Pore-Fluid Chemistry, and Secondary Porosity, Texas Gulf Coast

Sequences of diagenetic minerals associated with secondary porosity show striking similarities. The formation of quartz overgrowths on detrital quartz grains is followed generally by carbonate cementation. The dissolution of this carbonate is the main secondary porosity-forming event, which commonly precedes kaolinite precipitation and iron-rich carbonate cementation. In the Texas Gulf Coast, oxygen isotopic analyses provide temperature estimates of authigenic phases that predate and postdate secondary porosity development: quartz, ≥ 80°C (176°F); kaolinite, ≥ 70°C (158°F); albite, 100°-150°C (212°-302°F); late carbonate, > 100°C (212°F). These data suggest that secondary porosity in the Tertiary Gulf Coast forms at temperatures of about 100° ± 25°C (212° ± 45°F).

Correlations among calcite saturation indices in pore fluids, abnormally high permeabilities, and mole % CO_2 in natural gases of the Eocene Wilcox Group imply a strong interrelationship between CO_2 and secondary porosity development in clastic reservoirs. The CO_2 content of gases varies systematically with both the reservoir age and temperature, which suggests a kinetic control on generation. The amount of CO_2 in natural gases increases rapidly at approximately 100°C (212°F); this coincides with a rapid increase in the ratio of secondary to primary porosity in associated sandstones. Stable isotopic analyses of carbonate cements indicate a strong component of organically derived carbon and therefore cycling of carbon between inorganic and organic systems. The type, amount and distribution of organic matter, and early carbonate in both shales and sandstones control the quantity of CO_2 available for generating secondary porosity.

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Complete Dehydration of Illite/Smectite in Gulf Coast Overpressured Shales

Twelve samples of Frio and Vicksburg (Tertiary) overpressured shales from Brazoria and Hidalgo Counties, Texas, were examined by both x-ray and transmission electron microscopy (TEM) techniques. TEM lattice fringes from shallower samples show mixed-phase illite/smectite (I/S) layers in random orientations relative to each other. Electron diffraction patterns of these shallower I/S layers show very diffuse basal reflections together with very pronounced turbostratic structure and streaking along z*. Electron diffraction patterns of I/S layers from intermediate depths still show z* streaking and turbostratic structure, but the basal reflections are more distinct. TEM lattice fringe images of intermediate depth samples show I/S layers arranged in a subparallel orientation. Electron diffraction patterns of I/S layers from deeper samples generally show well-defined basal reflections, and both turbostratic structure and z* streaking are less pronounced. An electron diffraction pattern of I/S layers from one deep sample (12,490 ft, 3,800 m, calculated equilibrium temperature of 168°C, 334°F, and pore-pressure gradient > 0.7 psi/ft, 15.8 kPa/m) shows an illite $2M_1$ pattern, indicating complete dehydration of original I/S layers. The presence of pronounced z* streaking is thought to be due to disordered stacking of layers, which in turn is caused by diagenesis of original mixed-phase I/S layers. TEM lattice fringe images for this sample show parallel illite layers with basal spacing of approximately 20 A.

FREZON, SHERWOOD F., and KATHARINE L. VARNES, U. S. Geol. Survey, Denver, CO

U. S. Geological Survey Oil and Gas Atlas of the United States

The U. S. Geological Survey is compiling a series of oil and gas maps that the Survey will publish as an oil and gas atlas of the United States. The maps in the series will synthesize information both on the national scale and for individual basins, and will include geologic, geochemical, geophysical, and exploratory data.

The maps displayed are the preliminary publications (open-file reports) of this new series. The national-scale maps for the conterminous United States show (1) location and names of basins, (2) total thickness of sedimentary rocks, (3) location of oil and gas wells drilled deeper than 15,000 ft (4,500 m), and (4) location of oil and gas wells drilled deeper than 20,000 ft (6,000 m). Basin maps of the north slope of Alaska show (1) well locations, (2) isopachs, and (3) structure contours.

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Reservoir Facies Architecture in a Micro-Tidal Barrier System, Frio Formation, Texas Gulf Coast

Barrier-bar sand bodies are a complex mosaic of barrier-core, shoreface, inlet-fill, tidal-delta, and back-barrier facies. In addition, sandbody stratigraphy and internal depositional architecture are determined by the progradational, aggradational, or transgressive origin of the barrier complex.

The Frio barrier/strandplain system of the middle Texas Gulf Coast has produced more than 3 billion bbl of oil. Examination of the Greta, Glasscock, and 41-A sands in West Ranch field illustrates the variability of barrier reservoirs. Each reservoir is a mosaic of variably interconnected compartments having sheet, tab, pod, or channel geometries. Conventional facies analysis (isolith and log-pattern mapping and limited core examination) combined with semiquantitative delineation of hydrocarbon-saturation distribution using resistivity logs defined the facies components of each reservoir. The 41-A sand consists of juxtaposed progradational barrier-core, inlet-fill, and flood tidal-delta units. The Glasscock sand is largely a transgressive barrier-flat and washover-fan deposit. The Greta sand is a complex of aggradational barrier-core and inlet-fill facies.

Productive attributes of each reservoir are influenced by its facies architecture and attendant relative permeabilities. Natural water drive is ineffective in the volumetrically restricted transgressive Glasscock reservoir. Permeability distribution in the 41-A reservoir is facies defined. Erratic injection response, irregular oil-water contact advance, and variable water/oil ratios observed during the productive history of individual reservoirs document localized facies effects on fluid flow. Spatial variation of the gas/oil ratio may also reflect facies distribution.

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Potassium-40/Argon-40 Age Determinations on Low-Potassium Glauconites Near Missing Cretaceous-Tertiary Transition at Littig Pit, Travis County, Texas

Potassium-40/Argon-40 dating on glauconites from Littig Pit, Travis Co., Texas, indicates that 4 to 6 Ma of lowermost Tertiary section are missing. The glauconite-containing samples were examined biostratigraphically. At least 1 calcareous nannofossil zone and at least 2 planktonic foraminiferal zones missing from the lowermost Tertiary limit the missing section to 2.5 to 5 Ma. These paleontologic data are fully consistent with the radiometric dates obtained on low potassium glauconites and refute the view of Odin that all low potassium glauconites are suspect. A missing nannofossil zone in the uppermost Cretaceous represents an undetermined amount of time.

A strong probability exists that the Midway Group at Littig Pit and elsewhere was deposited rapidly during one of the earliest Paleocene transgressions described by Vail and others, and our data support the conclusion of Berggren and Aubert that the Midway fauna are correlatable worldwide. The iridium layer of Alvarez and others is missing at the Littig

Pit, confirming missing section and illustrating how this iridium layer is proving useful as a worldwide time marker.

GARY, ANTHONY C., Old Dominion Univ., Norfolk, VA, and NANCY HEALY-WILLIAMS, Univ. South Carolina, Columbia, SC

Relationship of Morphologic Variation and Environment in Recent *Bolivina* (Foraminiferida) from Northwestern Gulf of Mexico

This study investigates intraspecific morphological variation trends of recent benthic foraminifera in relation to depth and environmental factors (temperature and salinity). Twelve samples were obtained from traverses trending south-southeast from offshore Galveston, Texas, to the Sigsbee Deep. Samples are cuts of short cores (30-40 cm, 12-16 in.) from 33-3,431 m (108-11,257 ft) in depth. Fifty specimens from the total population (all growth stages) and 30 specimens of a specific growth stage were randomly selected for each of 4 foraminifera species, *Bolivina albatrossi, B. lowmani, B. subspinescens,* and *B. ordinaria,* from each sample site. Test outline, as an indicator of overall shape, was quantified by an automated video digitizer using closed-form Fourier series analyses. Significant variations in shape outline components were tested for their relationships to bathymetry and environmental factors using analysis of variance and multiple discriminant analysis for both total populations and the specific growth stage.

Morphologic trends relatable to both depth and environmental variables are recognizable in the 2 data sets. Such trends may be observable in the fossil record, thus indicating relative depths and suggesting possible absolute depth and values of environmental variables. This morphologic approach may be utilized even though different species are incorporated in analyses and different absolute depths involved.

GASSAWAY, GARY S., Terra Linda Group, Inc., San Rafael, CA, and H. J. RICHGELS, Marjac Geo Inc., Franktown, CO

SAMPLE—Seismic Amplitude Measurement for Primary Lithology Estimation

SAMPLE is a method of seismic interpretation that extracts shear wave velocities or Poisson's ratios from the seldom used amplitude variations within a common-depth-point (CDP) gather. From a crossplot of pressure wave velocity and Poisson's ratio, lithologies and pore fluids are then estimated.

The SAMPLE method works because reflection and transmission of elastic waves (seismic waves) at the boundary between two media are a function of 6 parameters. Three elastic parameters in each media are P-wave velocity, Poisson's ratio or *S*-wave velocity, and density. Given these 6 parameters and the angle of incidence of a plane elastic wave, the reflection and transmission amplitudes (coefficients) can be calculated using Zoeppritz's equations. SAMPLE is an inversion of this calculation. *P*-wave velocity is determined in a conventional manner (i.e., Dix interval velocities). Density is assumed to be a function of *P*-wave velocity. The unknown Poisson's ratios can be determined from the reflection amplitude variation with angle of incidence (offset versus amplitude variations within a CDP gather.)

Having solved for *P*-wave velocities and Poisson's ratios, lithologies and fluids are estimated.

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Landsat Maps of Iraq: Tools for Non-Invasive Exploration

Optical analysis of Landsat imagery is a valuable preliminary step for exploration in areas where a detailed geologic base is lacking, logistics are difficult, or the political situation is insecure. Two maps of Iraq produced by such analysis elucidate structural and lithologic relations across a broad oil-producing region. The Landsat map of Iraq is divided into units based on drainage patterns, surface textures, relative resistance to erosion, and color. These units tentatively correlate to the broadly generalized geologic map of Iraq. The Landsat map clearly delineates Iraq's 3 major geotectonic zones: (1) desert and alluvial plains, (2) simply folded, and (3) overthrust. The lineament and anomaly map, derived from optically enhanced imagery, shows noncultural lineaments and 5 types of anomalies: (1) linear, (2) circular, (3) structural, (4) textural, and (5) shade. Conjugate shear sets form lineaments oblique to the regional and local compression directions. Lineaments also reflect normal faults, tear faults, thrust fronts, structural control of wadis, and wind-direction features. The intersection of 3 or more lineaments defines a linear anomaly. Circular anomalies can be attributed to structural domes or basins, diapirs, calderas, or astroblemes. Appreciable deviations from local deformational style are considered structural anomalies. Textural anomalies are abrupt changes in texture unrelated to lithologic changes. Shade anomalies, mapped from band 5 enhancements, reflect a shade change from light to dark, usually across a lineament. Comparison of oil field locations to Landsat-mapped units, lineaments, and anomalies can indicate exploration targets for more detailed ground-based geologic and seismic investigation.

GHOSH, SANTOSH KUMAR, Univ. Central de Venezuela, Caracas, Venezuela

A Shallow Water Eocene Turbidite Sequence From Venezuelan Andes

Part of the Eocene sequence in Trujillo State, overlying the sublittoral marine Valle Hondo Formation, reveals a turbiditic mode of origin in a prodeltaic setting. The exposed basal fining- and coarsening-upward cycle implies a gradual abandonment phase and a subsequent progradational pulse of a suprafan channel respectively. The upper unit, in a separate exposure, is a thick coarsening-upward sequence of deltaic progradation origin.

The fining-upward (and thinning-upward) sequence, resting on a prodeltaic shale, consists of: (a) basal stacked conglomeratic arenites (suprafan channel) with graded beds, imbricate clasts and transported shells; (b) a sandy/shale unit (channel margin/inter-channel) with flame structure, lenticular bedding, infrequent $T_{b\text{-}d}$ sequence, rippled flats, and rare *Planolites*; and (c) a dark shale (prodelta-platform) with scarce *Chondrite* and *Sclarituba* (?) traces. The overlying coarsening-upward sequence consists of thickening-upward sandy/shaly facies and lenticular stacked pebbly arenites.

The upper unit is a typical deltaic progradational sequence with a basal prodelta shale with $T_{b\text{-}d}$ and $T_{b\text{-}e}$ sequences in thin intercalated sandstones; a delta-front heterolithic facies with flute and groove casts, *Planolites/Thalassinoides*; and a thick cross-stratified coastal marine sandstone.

Considerations such as maturity of the turbiditic arenite, its inferred proximity to the paleoshoreline, and facies relationship with the Valle Hondo deposits suggest deposition at the toe of delta-front slopes and seaward. It is likely that this flyschoid sequence may be part of a mixed-type fan as it merges northward and basinward into the deep-sea fan sequence of the coeval Trujillo Formation.

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Pteridinium: An Element of Late Precambrian Ediacaran Fauna from Carolina Slate Belt, Southern Appalachian Orogen

Discovery of oil and gas in the western overthrust belt has spurred renewed efforts in the southwestern and eastern overthrust belts. Reinterpretations of existing data and acquisition of new data, both geologic and geophysical, have led to several interpretations of the sedimentary history and overthrust geometry of these belts.

Although the Carolina Slate belt (CSB) is not a prime petroleum exploration target, the documentation of metazoan elements belonging to the late Precambrian Ediacaran fauna in the CSB is new data pertinent to interpretations of sedimentary history and accretion geometry of an exotic terrane that by some interpretations may be involved in overthrusting and is thus concealing potentially petroleum-bearing strata. The presence of *Pteridinium* in the CSB provides correlation with late Precambrian strata of the Russian platform, South West Africa, and South Australia, and is thus very significant in paleogeographic reconstructions.

Pteridinium in the CSB is represented by 4 specimens that are impressions of "petal-like" metazoans. These metazoans are approximately bilaterally symmetrical, crudely ovoid-shaped, and composed of curved segments that join across a medial zig-zag groove created by the proximal