

km of the western Bahamas. Surficial sediment is composed of coarse sand and granules dominated by composite-oid grains. Submarine cementation is active and has led to the development of coarser grain sizes during the depositional interval. Fine to medium-sized grains are cemented with fibrous aragonite and surficially coated at the tidally active margin. The resultant composite-oid sediment is more hydrodynamically stable and is rapidly cemented into hardgrounds characterized by a smooth (tidally abraded) upper surface. Lithification is gradational through a thickness of 50-100 mm to an irregular lower boundary transitional with uncemented material. These hardgrounds are submarine discontinuity surfaces developed during inter-storm conditions of winnowing and bypass sedimentation along a depositional profile of equilibrium. Rock cores into the Pleistocene section have recovered sediments and submarine discontinuity surfaces identical to those in the Holocene. These are present in the two latest Pleistocene sequences representing the last major interglacial intervals. Both the Holocene and Pleistocene sequences have one or two cemented zones per meter in the upper section. The presence of these deposits throughout the preserved stratigraphic package indicates the persistence of characteristic leeward depositional processes during the late Quaternary and their importance in bank-margin growth. A combination of characteristics including typical microfacies, cements, and discontinuity surfaces (if seen in the ancient) should be good indicators of leeward-margin settings.

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Point-Bar Deposits and Analysis of Subsurface Reservoir Dimensions, Toolachee Formation, Southern Cooper Basin, South Australia

Point-bar deposits occur ubiquitously within the lowest facies association of the Upper Permian Toolachee Formation (+500 ft thick). The association represents deposition in a moderate to high-sinuosity, mixed-load, fluvial channel system in which lateral bar deposits constitute major hydrocarbon sandstone reservoirs. Bars may be simple or punctuated in their upward-fining, vertical facies transitions, but heterolithic lateral accretion surfaces of upper point bars may occasionally be preserved in cores.

Detailed facies studies of Association 1 in 17 cored wells reveal that pebbly thalweg lags locally include chaotic bank-collapse conglomerates. These basal point-bar deposits fine upward into cross-bedded sandstones. Ripple bedding is common in upper bar sequences. The bars are associated with a variety of abandonment fills, levees, and crevasse splays, backswamp deposits, and autochthonous coals.

Paleohydraulic studies of point bars in the Moomba field demonstrate an average bankfull depth of the Toolachee channels of 14 ft and bankfull width of 320 ft. Empirical relationships indicate a maximum meander loop diameter of 1,650 ft with meander belt width at 3,650 ft. These parameters allow an evaluation of reservoir geometry, storage potential, and permeability barriers. The latter, generated by clay-plug abandonment fills, can restrict fluid migration within the field and produce overestimation of hydrocarbon reserves. Conversely, avulsive channel events may locally increase point-bar reservoir dimensions by partially, or totally, removing preexisting abandonment fills.

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New Deeper Exploration Frontiers in Bass Basin

The Bass basin is the sister basin to the Gippsland. Both are extensional basins in southeast Australia between Tasmania and the mainland, and both occupy areas in excess of 60,000 km². The Bass and Gippsland basins were resurveyed seismically by the Bureau of Mineral Resources to provide regional correlation and to penetrate seismic energy barriers caused by Eocene coals.

Analyses of these recent good quality deep seismic data, existing seismic data, and well information including thermal maturity, source rock richness, porosity, and permeability suggest that the Bass basin is not fully analogous to the Gippsland basin. Though stratigraphy is similar, there is a paucity of significant secondary faulting in Bass basin to act as paths for migration of hydrocarbons to thermally immature levels, as is the case in the Gippsland basin. Consequently, in spite of minor oil and gas in the thermally immature section, the hydrocarbon potential of Bass basin could be substantially limited to thermally mature levels.

Reservoir, seal, and source appear to be present in the Bass at thermally mature but rarely drilled levels within the deeper lower Tertiary and Upper Cretaceous lower Eastern View coal measures and in the rifted Lower Cretaceous Otway Group. Hydrocarbon leads at these levels are predicted from structural analysis, with synsedimentary transverse faults that developed during the extensional phase of the basin providing an important trapping component. Such leads are defined at drillable depths by seismic mapping. The Bass basin could thus ultimately emerge as a deeper hydrocarbon province.

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Red Mountain Unit, Piceance Basin, Colorado: Field Laboratory for Research and Development in Coal Bed Methane Production

The coal bed methane resource of the Piceance basin has been estimated to exceed 60 tcf. Two wells have been drilled in Red Mountain unit, Mesa County, Colorado, to develop and improve the technology required to produce gas from deeply buried coal seams via vertical wells. The objective at Red Mountain is the Cameo coal member, Williams Fork Formation, Upper Cretaceous Mesaverde Group, at depths of about 5,500 ft. The 1 Deep Seam was drilled with the objective of coring and evaluating reservoir properties of both the coal and bounding sandstones. A continuous section of more than 200 ft of 3-in. core was recovered. Pressure transient tests were conducted in the 20-ft thick coal seam and in the overlying sandstone unit. The 2 Deep Seam was drilled underbalanced with an air/foam mixture, resulting in minimal formation damage and excellent recovery of coal cuttings. Extensive reservoir and production testing has been performed for the purpose of designing artificial stimulation procedures. Subsequent drilling and production testing at Red Mountain may require five additional years and may include as many as 20 additional wells.

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Lewis Shale Reservoirs, Southern Wyoming: Turbidite Sandstones Deposited in Delta-Toe Settings

Depositional history of the Lewis Shale, Maestrichtian, south-central Wyoming, consists of a transgressive period followed by an interval of delta infill. Clastics are up to 760 m thick. The Lewis sea transgressed westward to areas of the Rock Springs and Wind River uplifts and opened eastward into the main part of the Interior Seaway. Transgressive shales are black, high in organic material, relatively silt-poor, and totally bioturbated. Depositional setting was a shallow, well-oxygenated shelf. Lewis clastics above the transgressive shale are coarser and are related mostly to deltas that entered the basin first from the northeast and later from the south. Sediments were deposited in delta-front, prodelta, deep-basin, and interdistributary areas. Lewis sandstones produce at Wamsutter and Hay Reservoir fields in addition to other areas. Wamsutter and Hay Reservoir sandstones were deposited beneath storm wave base by sediment gravity flows at the toe of the northern delta system. Sandstones may be thickly bedded and are commonly massive. Presence of fluid escape structures indicates that many thick beds underwent liquefaction during the final stages of deposition. Thinner sandstones are graded and many show Bouma sequences. Interbedded shales are unburrowed or are slightly burrowed by restricted faunas, indicating anaerobic to dysaerobic conditions and water depths of 150-200 m or more at times.

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Potential Hydrocarbon Traps Along Growth Faults of Rio Grande Rift, New Mexico

Major tectonic boundaries along the Rio Grande rift are mostly listric normal faults that controlled late Cenozoic sedimentation in the rift. Potential hydrocarbon source and reservoir rocks occur in Cretaceous, Jurassic, and Pennsylvanian units beneath presumably barren upper Cenozoic continental sediments. Largest of the grabens and half-grabens comprising the rift is the Albuquerque basin, which was explored during the last decade with several deep tests. Upper Cenozoic strata generally dip gently toward the basin center except near bounding faults where "reverse drag" has beds on the downthrown block dipping toward the growth faults marking the basin margins. Most bounding faults are covered with surficial sediments, but at a few localities with good, deep expo-

tures, stratigraphically deeper beds have undergone more "reverse drag" than higher strata. Thus, these reversals of dip adjacent to bounding faults may provide structural traps along the margins of the Albuquerque basin.

Recent deep wells were drilled in the central part of the Albuquerque basin on structural highs, probably intragaben horsts. Most of these recent tests were tight holes, but encouraging hydrocarbon shows were encountered. The margins of the Albuquerque basin have not been tested yet, but there may be numerous traps where "reverse drag" is present. These structures could have trapped hydrocarbons where potential reservoir rocks (mainly sandstones) and source beds (mainly organic-rich marine shales of the Cretaceous and Pennsylvanian, and organic-rich laminated limestone of the Jurassic Todilto Formation) occur.

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Effects of Mississippian Tectonic Movement on Sedimentation and Diagenesis of Greenbrier Group in Eastern Appalachian Plateau

The Greenbrier Group of eastern West Virginia consists of marine carbonates interbedded and mixed with siliciclastics that were deposited on a shallow shelf in the Late Mississippian. The Denmark Formation is the lowest unit of the Greenbrier Group present in east-central West Virginia, and it represents a shallow tidal-flat and platform sequence deposited by a transgressing sea during the Meramecian. This transgression was followed by a regression with progradation of Taggard Formation terrigenous clastics onto restricted tidal flats during the earliest Chesterian.

The Denmark tidal-flat deposits are characterized by pelleted mudstones, limited and depauperate fauna, calcite-filled and dolomite-filled geodes, caliche crusts, fenestral structures, dolomite, burrows, and channel deposits. The platform deposits include more diverse fauna, less micrite, cross-bedded and massive oolitic grainstones, and cross-bedded quartzarenites. Most of the siliciclastics were derived from the north and east of the Appalachian basin. Additional quartz silt, sand, and pebbles were eroded from an uplifted area within the basin and were incorporated into the tidal-flat and platform sediments. This Meramecian tectonic uplift, considered to be part of the 38th parallel lineament, created a sub-aerial and submarine topographic high that affected sedimentation patterns during the remainder of Greenbrier deposition.

Early phreatic cementation occurred along the flank of the uplift in at least two stages. There is evidence of both penecontemporaneous and later replacement dolomite. In certain strata in the western outcrops, hydrocarbons migrated through permeable layers and filled remaining pores.

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Dolomites and Early Mississippian Bioherms, Leadville Formation, Molas Lake, Colorado

Two dolomite facies that exhibit little petrographic evidence of their original textures are interpreted to be integral parts of two bioherms. A core facies of rugose corals (*Vesiculophylum*), pelmatozoans, cephalopods, and brachiopods in a peloid wackestone-packstone matrix forms two mounds 50×40 m and 110×75 m in diameter and 7 and 20 m high, resting on a basal unit of foraminiferal (endothyrid) ooid, coated-grain grainstone. These mounds are surrounded and overlapped by a bedded flank facies with relic cross-bedding that forms a halo 15-40 m wide around each mound. The facies consists of very coarsely to coarsely crystalline dolomite, but field evidence shows that it was originally detrital and is coeval with the core facies. It grades laterally away from the core into a distal flank-intermound facies of dolomudstone interbedded with millimeter-thick laminae of dolomite peloid packstone. This facies occurs up to 100 m from the mounds.

Corals in the core facies have been replaced and cemented by nonferroan, nonluminescent sparry calcite at temperatures of at least 200°C. The matrix of micrite and skeletal grains is composed of nonferroan, red-orange luminescent calcite. Diagenetic changes have been modest. In contrast, the two flank facies show obliteration of original textures and replacement by inclusion-rich, nonferroan, red-luminescent, anhedral to subhedral dolomite at temperatures of a least 165°C. Other than appealing to differences in original porosity and susceptibility to subsurface fluids, it is difficult to explain why these closely associated facies have followed such divergent diagenetic paths.

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Piauí Basin, a Jambalaya of Geologic Structures

Although the Piauí basin was the last of the Brazilian equatorial marginal basins to be studied in detail, it is the one that presents the most fascinating structural geology of them all. The superposition of two major tectonic events, quite distinct in nature (rifting and wrenching), produced an abundance and diversity of geologic structures unparalleled by any other Brazilian basin.

The first tectonic event, the rift-stage (early Aptian), created the basin through a series of normal faults predominantly oriented N40°-45°E in the western part, and N75°-85°E in the eastern part. Clastic continental sediments constitute the rift depositional sequence. Continental drifting followed (late Aptian-early Cenomanian), and a thick clastic sequence of transitional to marine sediments was deposited. Wrenching was already taking place, but on a small scale.

During the middle Cenomanian (\approx 95-93 m.y.B.P.) the separation between South America and Africa in this area changed from north-south to east-west along the oceanic Romanche fracture zone. Shear stresses developed. The right-lateral motion, the large bend in the Paranaíba platform, and the different average trends of rift faults from west to east resulted in convergent wrenching. Transpression was greatly enhanced. Rift faults were reactivated as dextral strike-slip faults. Synthetic (N65°-70°W) and antithetic (N20°W and NS) strike-slip faults were formed. Flower structures occurred along the fault trends. Abundant en echelon folds and shale ridges (N20°E) were created. By the time wrenching ceased, a transpressive belt of significant dimensions had emerged in the Piauí basin. Sedimentation resumed in the area during the Oligocene-Miocene.

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Partitioning of Sediments Among Shoreface Transport Paths: Analysis of Sediment Dispersal Patterns Using Empirical Orthogonal Functions

Recent geomorphic evidence from the inner shelf and shoreface to the east of Long Island's barrier island system indicates that reworking of glacial outwash deposits at the inner shelf-shoreface transition, as sea level rises, may be supplying much of the sediment needed to maintain barrier islands to the west. A conceptual model describing sediment dispersal from outwash source areas was developed from this hypothesis. It was reasoned that outwash sediments ranging from silts to coarse gravels would be subject to differential transport paths across and along the shoreface upon reworking. Coarser grain sizes would move onshore toward the intertidal beach, whereas finer sediments would move offshore. Sand of intermediate grain size would be concentrated in the surf zone and move alongshore in wave-generated longshore currents.

To test this model, 400 samples from the beach and shoreface of Long Island were analyzed for grain-size frequency distribution and each grain-size class was examined for frequency of occurrence in the cross-shore and alongshore directions. On a spatially averaged basis, grain-size classes displayed peak abundance in specific zones across the shoreface as predicted by the model, but alongshore trends could not be recognized among the "noisy" data. Therefore, empirical orthogonal functions (EOF) were used to examine uncorrelated (orthogonal) modes of variability in the occurrence of each grain-size class in the alongshore direction. The first function, representing more than 60% of the variability among the data, showed that grain sizes subject to longshore transport in the surf zone increase in frequency in the alongshore direction relative to coarser grain sizes. Results also show that peak concentrations of coarse sediments correspond to zones subject to frequent overwashing. It is concluded that EOF analysis of individual grain-size classes holds promise for extracting trends from noisy data sets.

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Devonian Novaculites as Source of Oil in Marathon-Ouachita Thrust System

The Arkansas Novaculite of southern Oklahoma and the Caballos Novaculite of west Texas (both Devonian) form fractured reservoirs in the Marathon-Ouachita thrust system. These formations were examined to ascertain their petroleum potential.