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#### Thermal Maturation and Burial History Processes in Lower Mesozoic Sediments of North Atlantic Georges Bank Basin

The time-temperature burial relationships that influence organic maturation processes in the Upper Triassic-Lower Jurassic rift basin sediments and the Middle Jurassic shelf-edge carbonates and sand-shale facies of the North Atlantic Georges Bank basin are believed to be regionally influenced by sediment loading and residual subsidence associated with the contractions and cooling of a thinned lithosphere and crust. Localized zones of high heat flow may have occurred during the rifting process. Relict heat flow from such sources may have influenced the principal zone of oil formation (PZOF) in the Georges Bank basin. Plots of specific temperature-sensitive, intercompound ratios of isomeric groups for light hydrocarbons that separate chromatographically in the cyclohexane through methylcyclohexane range and plots of the molecular ratio of n-hexane to methylcyclohexane were found to be consistent with the temperature-sensitive, saturated hydrocarbon to organic carbon ratios. These ratios suggest that the threshold of intense oil generation in the depocenter of the basin begins at a depth of about 3.2 km with the PZOF occurring between 3.9 and 4.9 km. Correlation of these temperature-sensitive maturation parameters with the time-temperature burial history models indicates that Middle to Lower Jurassic and probable Liassic to Upper Triassic units may be the most favorable exploration targets within the main Georges Bank basin.

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#### Miocene Calvert and Choptank Formations in Inner Coastal Plain of Virginia: A Record of Marine Onlap and Late Cenozoic Deformation

The 200-ft thick section of lower and middle Miocene beds in the Maryland-Virginia coastal plain includes two diatomaceous sand-silt-clay sequences, the Calvert Formation (below) and the Choptank Formation. The Calvert has been mapped over much of eastern Maryland and Virginia and is commonly believed to represent the maximum marine transgression during the early and middle Miocene. In contrast, a much more restricted distribution for the Choptank was suggested because it was known only in southern Maryland and northeasternmost Virginia. Thus, until recently, a general picture of offlapping relationships of the Calvert and Choptank beds has prevailed.

Our field studies show that both the Calvert and the Choptank are widely distributed in the central and inner Virginia coastal plain. The sandy and silty Calvert beds contain diatom assemblages typical of diatom zones 3 and 4 of Andrews; the Choptank is lithologically similar, but its diatom assemblage correlates with diatom zones 6 and 7. In updip areas in Virginia, the formations are separated by an erosional unconformity that is equivalent, in part, to the time interval represented by diatom zone 5.

The Calvert is truncated by the Choptank beds well east of the Fall Line. The Choptank laps over the Calvert and successively overlies, from east to west, Eocene, Paleocene, and Cretaceous strata and crystalline rocks of the Piedmont. These relations indicate extensive marine onlap during Choptank deposition and record a major transgression of the Miocene sea. Choptank beds thicken and thin across coastal plain structures, a result of erosion over structural highs following deformation of the Choptank and preceding deposition of higher rock units.

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#### Comparison of *Cubitostrea* (Mollusca, Bivalvia) Assemblages from Atlantic and Gulf Coastal Plains

Specimens of the oyster genus *Cubitostrea* from lower and middle Eocene beds in Maryland and Virginia were compared with collections of that taxon from correlative units in North Carolina, South Carolina, Alabama, and Mississippi. Material from these collections indicates some differences with Stenzel's model of successional speciation. Stenzel pro-

posed a single lineage of *Cubitostrea* including (from oldest to youngest) *C. perplicata* (Dall)—l.m. Eocene, *C. lisbonensis* (Harris)—m.m. Eocene, *C. smithvillensis* (Harris)—m.m. Eocene, and *C. sellaeformis* (Conrad)—m.m. Eocene. Stenzel's model suggested a change from a primitive trigonal form to one with well-developed auricles and finally to one with a profound fold in the valves. The development of auricles and folds in the genus *Cubitostrea* appears to depend on the maturity of the individuals, however, and is not an evolutionary progression, because the oldest known representative, *Cubitostrea* sp. from the lower Eocene Nanjemoy Formation, exhibits both of these tendencies.

We believe that there are two distinct oyster lineages, both belonging to the genus *Cubitostrea*. The first lineage consists of *C. perplicata* and *C. lisbonensis*; the second consists of *C. sp.* and *C. sellaeformis*. *C. smithvillensis* appears to be an ecophenotypic variant of *C. sellaeformis* as are *C. divaricata* (Lea) and *C. vermilla* (de Gregorio). Specimens of *Cubitostrea* that have been identified as *C. lisbonensis* from South Carolina (Santee Limestone) and North Carolina (Castle Hayne formation) are immature and resemble the young of *C. sellaeformis* from Virginia and Alabama.

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#### Detailed Depositional Analysis of Reservoir Sandstones of Catskill Delta, North-Central West Virginia

Upper Devonian Hampshire and Lower Mississippian Pocono sandstones were correlated over a 370-mi<sup>2</sup> area in north-central West Virginia using 400 gamma-ray logs. Isolith maps show the geometry, position, trend, and distribution pattern of the sandstones. Sandstone belts occur in north-south (strike) trends particularly in the western part (Lewis County), whereas east-west (dip) trending sandstone belts and dendroids generally occur in the eastern part (Upshur County) of the study area. The north-south-trending sandstone belts are interpreted as barrier islands, and their adjacent eastward facies consisting of some plant-rich black shales and thin sandstones are interpreted as lagoonal. Tidal inlets are associated with barrier islands along the strike trend. Sands probably were supplied to the ancient barrier islands by east-trending distributary channels that were affected by both tidal and fluvial processes. East-west cyclic shifting of the barrier islands and the north-south shifting of the feeder systems were strongly influenced by the paleotopography of the next lower sandstone unit. The nearly 5-mi (8-km) shoreline shift east-west within sand intervals (Fourth, Thirty-foot, Fifty-foot) of these shoreline sandstones probably resulted from combinations of changes in sea level, sediment supply, and differential compaction. The interpreted "feeder systems" of tidal and fluvial channels trending east-west indicate a history of distributaries shifting with time also. The Hampshire Formation and Pocono Group of north-central West Virginia are interpreted facies of coastal plain-nearshore environments in which marine-dominant deltas characterize the shoreline.

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#### Eastover (Upper Miocene) and Yorktown (Lower Pliocene) Formations in Virginia—Tracking a Shifting Depocenter

Detailed mapping and regional studies indicate that fossiliferous marine formations and nonfossiliferous upland deposits of the Tertiary Chesapeake Group can be integrated into two major sequences that reflect a systematic change in depositional patterns. The lower sequence (Calvert, Choptank, and St. Marys Formations of Miocene age) largely consists of marine-shelf deposits that collectively thicken toward the center of the Salisbury embayment. The upper sequence (Eastover and Yorktown Formations of late Miocene and early to middle Pliocene age) includes complex assemblages of marine-shelf, marginal marine, and nonmarine deposits. A major erosional unconformity and overlying basal deposits of the Eastover Formation are the first evidence of depositional shift southward into the Albemarle embayment.

The Eastover and Yorktown Formations have been recognized and mapped as fossiliferous shelf sediments. Recent fieldwork has shown the two formations to be much more extensive and lithologically variable from the Fall Line to the Chesapeake Bay. Each formation comprises a typical transgressive-regressive sequence. Landward, the base of the

Yorktown is a mappable unconformity truncating the Eastover; seaward, in the lower James River area, marine-shelf deposits of both units converge and are distinguishable only on the basis of their faunas. These units thicken southward toward the Albemarle embayment. Across the same region, the distribution of upper Pliocene and lower Pleistocene transgressive and regressive deposits records a continued trend of tilting toward the southeast.

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#### Significance of Great Lateral Extent of Thin Units in Newark Supergroup (Lower Mesozoic, Eastern North America)

The lacustrine sediments of the Newark Supergroup accumulated in rift valleys developed during the early phases of the fragmentation of Pangea. Analogy with modern rift valleys has led us to expect abrupt facies transitions and syndepositional structural complexity. However, in contrast to their supposed modern analogs, many thin (<6 m) organic-rich lacustrine units within the Newark can be traced over large areas (+2,000 km<sup>2</sup>) with only gradual lateral changes in thickness and lithology.

Lateral correlation is afforded by: (1) detailed ecostratigraphic correlation of fossils in lacustrine cycles, (2) key marker beds such as earthquake-induced fluidized beds, (3) detailed paleomagnetic reversal stratigraphy (by others), and (4) matching of microlaminae and turbidites. These observations suggest that the lakes which produced the organic-rich units were very large (+2,000 km<sup>2</sup>) and deep (+100 m) while at their maximum extent.

The continuity of thin beds across the major intrabasin faults and the gradual lateral change in thickness over the basins show that these faults were not active during the deposition of the units and that the size of the subsiding blocks of these Mesozoic basins was much larger than is currently the case in the east African rifts. Simple analogy between Newark and African rift systems in structure and facies is not justified and obscures their real and important differences.

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#### New Method for Interpreting Coal-Forming Environments of Deposition

Coal petrographic methods used to characterize coals for industrial purposes have further application in the interpretation of environments of deposition through the plotting of maceral data that have been grouped on the basis of mutual abundance using correlation coefficients. Huminite (or vitrinite), exinite, inertinite ternary diagrams do not readily distinguish environmental conditions during peat deposition because the three categories of macerals are based on broad ranges of reflectance. Macerals within each group are not genetically related. Lignite cores from Neshoba County, Mississippi, having an undetermined depositional environment, have been analyzed petrographically. Petrographic data from other Gulf Coast lignites of known environments of deposition (determined by nonpetrographic means) were grouped using the genetically discrete maceral associations formed by combining macerals that correlate with each other. These genetically discrete maceral groups are termed "lithogroups." When maceral data are plotted on ternary diagrams by lithogroups, the plot reveals fields that are characteristic of particular environments of deposition. The Neshoba lignites overlap in the fluvial/deltaic region of the ternary plot. An important factor controlling peat composition is thought to be pH, thereby affecting the petrography of the resulting coal.

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#### Kirkwood Formation and Cohansey Sand of New Jersey: Age and Spatial Relation to Chesapeake Group of Virginia and Maryland

Time and space equivalency between the well-studied Neogene beds of Virginia and Maryland and those to the northeast in New Jersey are only generally understood. Diatom and foraminifer assemblages from a recently cored hole through the Cohansey Sand and underlying Kirkwood Formation indicate that Kirkwood is the same age as the

Calvert Formation of Maryland (early to early middle Miocene). The Cohansey yielded no mega-invertebrates; however, pollen studies showed that the Kirkwood and overlying Cohansey have similar microfloras. The Cohansey is probably also middle Miocene in age and equivalent to the Choptank Formation of Maryland.

In New Jersey, the Cohansey is as high as 300 ft above sea level, with no Miocene or Pliocene deposits above it. In Virginia and Maryland, the Choptank is generally below 200 ft and is overlain by higher Miocene and Pliocene marine deposits in a series of small basins. The Cohansey and Kirkwood represent deposition in an older Miocene basin that was a highland when younger Miocene and Pliocene sediments were deposited in basins to the south.

The altitudes and areal distribution of the Miocene and Pliocene formations from New Jersey to Virginia suggest that tectonic movements along the continental margin have controlled sediment supply and sites of deposition. Eustatic changes in sea level only slightly modified this pattern.

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#### Folds Along Junction of Central and Southern Appalachian Trends in Southeastern West Virginia and Adjacent Virginia

Field mapping of crest and trough lines of the larger folds clarifies the junction between central Appalachian structural trends (striking about N25°E) and southern Appalachian trends (striking about N65°E) in southeastern West Virginia and adjacent Virginia. Previous interpretations have argued whether the change in orientation is gradual or abrupt, whether the two trends formed simultaneously, whether the more obviously overthrust southern Appalachians overrode the central trend, whether the central Appalachians were overprinted across the southern trend, whether the junction of the two trends is caused by rotational movement, or whether the differences result from a major basement fracture zone separating the two blocks.

Our mapping shows that the folds are continuous across the junction of the trends, with a gradual bending of the fold traces. For tens of miles north of the junction of the two trends, gentle folding striking about N35°E can be mapped within the relatively flat major synclines of the central Appalachian area, but cannot be readily traced into the steeper flanks and more sharply folded crests of the major anticlines. We believe that these gentle anticline folds trending N35°E are related to the initial folding of the southern segment that trends N65°E. Subsequent to the development of the southern Appalachian folds, the central area was simultaneously folded and rotated, reorienting the northern extension of the southern fold generation to their present position of N35°E. This suggests that the southern fold and fault trend was overprinted by the central trend, a conclusion consistent with studies of stylolites by Dean and Kulander. Near the junction of the central and southern trend, structural domes and depressions formed as a result of fold interference.

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#### Sedimentary Basin Analysis of Middle Ordovician Limestones in Central Appalachians

Seven of 28 wells penetrating the Trenton Limestone in West Virginia have reported shows of natural gas, enough to continue industry's interest in this potential reservoir. The formation consists of thin limestones interbedded with shales and bentonites. Sediments were deposited on a ramp that sloped eastward from a shallow platform in northwest Ohio into the foreland basin of Virginia, and the unit forms a wedge-shaped mass that thickens into the basin. Limestones of the upper ramp were deposited on sand shoals (skeletal grainstones) and restricted flats (lime mudstones), which passed downslope into skeletal patches of a deep, muddy environment (packstones and wackestones). Rapid downwarping of the carbonate ramp produced a major transgression, and deeper limestone facies migrated westward during time. Bentonites spread across the region from distant volcanic islands. In West Virginia, a lower bentonite package is present in the Black River Limestone to the southwest, whereas an upper package occurs in the Trenton to the east and north. This distribution