ment of the individual coccoliths. Most cylinders are open at both ends, but one specimen illustrated by electron micrographs with one end nearly closed reveals significantly smaller coccoliths at the ends. These smaller, simpler coccoliths probably did not articulate as tightly as those on the rest of the cell and were easily detached. Because of the difference in size and morphology, these terminal coccoliths may have previously been assigned to other taxa. A coccosphere of *Braarudosphaera bigelowi*, not previously illustrated from the fossil record, is also documented in this study.

The stagnant, anoxic benthic environment prevalent during these intervals of Niobrara deposition also fostered the preservation of monospecific coccolith clusters that represent coccospheres formed of nonarticulated coccoliths. These clusters, representing 35 different species, including *Lithraphidites carniolensis, Bolevetelum* sp., *Microrhabdulus belgicus,* and *Rhagodiscus angustus,* provide information on the minimum number of coccoliths originally present on the living cell. Such may prove valuable for determining the total biomass of the living populations based on the abundance of individual coccoliths in the fossil record.

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Arctic Reconstruction from Alaskan Viewpoint

Field, seismic, structural, and stratigraphic data were used to reconstruct the geologic history of the Arctic in 10 m.y. time slices from the present to mid-Jurassic—the time of initial opening of the Arctic Ocean. A basic assumption used for the reconstruction is that Lomonosov Ridge, Alpha Ridge, Mendeleyev Ridge, and Chukchi Plateau are all foundered continental plates.

Opening of the Arctic occurred in 2 stages: Late Jurassic–Cretaceous for the Canada basin, and Neogene for the Eurasian basin. Opening was facilitated by 2 subparallel transform shears: the Arctic (Kaltag-Porcupine) on the east and the Chukchi on the west. Deformation was essentially tensional on the Barents side of the Arctic, and shear-compressional on the Alaska side.

The development of Chukotsk, the North Slope, Brooks, Range, northwestern Canada, Seward Peninsula, and central Alaska can be sequentially related to Arctic opening, modified by impingement of allochthonous terranes (the Pacific plates of Tintina, Denali, Orca, Anadyr, Khatyrka, Kolyma) arriving from the south.

The North Slope of Alaska—a passive, rifted, subsided margin—was aligned with a similar margin on Alpha Ridge. Northeastern Alaska (the Romanzoff Mountain area) lined up opposite the north end of the Sverdrup Rim, near Prince Patrick and Borden Islands.

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Reaction of Organic Material to Progressive Geologic Heating

The generation of oil is a process that begins to occur at some point during the burial history of a source rock. This "onset of maturation" is dictated largely by temperature and residence time. However, the nature of the source rock itself also influences the hydrocarbon product being expelled from the source rock. The vast majority of the world's oil can be ascribed to source rocks of the following types. (1) Marine mudrocks deposited in anoxic conditions and dominated by phytoplankton organisms; this type of source rock can have a carbonate or clay inorganic matrix and total organic carbon values from 1 to 30% (commonly 4 to 10% when immature). Examples of this classical oil source rock would be the source rocks of western Canada, the Middle East, and the North Sea. (2) Specific coal facies such as torbanites and cannel coals, which contain a mixture of hydrogen-rich plant detritus (e.g., spores, pollen, cuticle, resin, and algae); deposition was probably in open-water areas of an overall coal-swamp environment. Examples of hydrocarbons from this type of source include the Gippsland basin, Canadian Beaufort Sea, and Southeast Asia. (3) Lacustrine organic-rich deposits, rich in freshwater algae, which ultimately result in high-wax crude oils. Examples are relatively rare, but include major source rocks in the Uinta basin and China.

The effect of increasing maturity on marine mudrocks of the Devonian Duvernay Formation of Alberta illustrates oil generation from this type of source rock. The data base in this unit consists of 40 conventional cores, ranging from immature to completely overmature, and 80 oils from separate accumulations sourced from the Duvernay. An illustration of oil generation in a coaly source rock is provided by a single core from the Lower Cretaceous of the Beaufort-Mackenzie basin plus many of the oils and condensates reservoired in that area.

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Benthic Foraminiferal Morphology: New Approach to Paleodepth Interpretations in Northern Gulf of Mexico

Variation in benthic foraminiferal morphology is a potentially powerful tool in paleoenvironmental and paleobathymetric interpretations. Recognition of distribution patterns of particular morphologic characters in modern Gulf of Mexico taxa will enable these distributions to be applied to bathymetric interpretations of Tertiary core samples.

The morphology of the 295 most commonly recorded benthic foraminiferal species in the northern Gulf of Mexico was scored into 68 categories describing test shape, chamber shape, chamber arrangement, apertural characteristics, and surface sculpture. Cluster analyses of these data at 300 localities resulted in maps showing the distribution of particular sets of morphologic features. Many of these "morphologic biofacies" are depth relatable. Canonical variate analysis was used to determine which morphologic variables were most important in distinguishing the various biofacies.

This approach to paleobathymetric interpretations should be applicable throughout the Cenozoic and perhaps into the Mesozoic, as morphology can be considered as an adaptive response to environmental factors. Even though different taxa are involved throughout the Cenozoic, similar morphologic characters can indicate adaptations to similar environments. Hence, this modern data set can be applied to determine paleobathymetry in older samples.

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Molecular Thermal Maturity Indicators in Oil and Gas Source Rocks

Detailed chemical parameters have been proposed as indicators of thermal maturity in oil and gas source rocks. Certain classical maturity parameters involving carbon preference indices and compound class ratios such as HC/EOM and EOM/TOC are infrequently used today, having been largely replaced by detailed molecular parameters. Among these parameters, the molecular distributions of metalloporphyrins, cyclic hydrocarbons, low molecular weight hydrocarbons, and gases are most commonly used. Recent instrumental advances have allowed the measurement of detailed molecular ratios in geochemical organic matter, stimulating the development of biologic markers, such as steranes, hopanes, and metallated tetrapyrroles, as thermal maturity indicators. Increased chromatographic resolution of source rock hydrocarbons has also promoted the use of low molecular weight hydrocarbons, methylphenanthrenes, and aromatized steranes as maturity indicators.

The future use of molecular thermal maturity indicators in source rocks is expected to increase significantly. In addition to further advances in understanding the significance of biologic marker hydrocarbons, metalloporphyrins, and thermally generated light hydrocarbons, the use of other nonhydrocarbons as maturity determinants will probably develop.

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Paleoecology of Foraminifera of Lower Castle Hayne in Southeastern North Carolina

Foraminiferal fauna present in the lower Castle Hayne biomicrudite exposure northeast of Wilmington, North Carolina, suggests a depositional environment in a transitional zone between the open-marine outer continental shelf and the upper continental slope. Evidence that supports

this assumption is the assemblage of abundant *Lenticulina* and *Globigerina* genera, and common occurrence of *Uvigerina, Nonion,* and *Cibicides* genera. This typical assemblage indicates a paleodepth of 90-300 m, which is analogous to depth ranges of extant foraminifera of the Gulf of Mexico. Further evidence of an outer-shelf to upper-slope depositional environment is the benthic to planktonic ratio of 4:1, a common ratio found in modern foraminiferal assemblages of the Gulf of Mexico at these depths.

Rare specimens of *Textularia* and *Globulina* genera present in the assemblage may have been displaced downslope of their natural habitat via ocean currents or influx of fluvial discharge from the Eocene age Cape Fear River.

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Depositional and Diagenetic Aspects of Siliciclastic and Carbonate Reservoirs in Glorieta Formation (Permian), Northern Midland Basin, Texas

The Glorieta formation is oil productive in the northern Midland basin. Production through 1982 totaled over 25 million bbl of oil. Carbonate as well as siliciclastic facies are productive in different locations on the shelf. This production is largely diagenetically controlled, with secondary porosity enhancement prevalent in both clastic and carbonate reservoir types.

The Glorieta formation is composed of cyclicly deposited siliciclastics, carbonate, and carbonate-evaporite units. Environments of deposition range from supratidal sabkha through shallow subtidal to open-marine conditions. The siliciclastics are eolian-derived sediments that prograded onto the shelf of the northern Midland basin. The overall coarsening-upward sequence, the gently seaward dip of the clastics, and the open-marine characteristic of adjacent carbonate sediments suggest a subaqueous deposition similar to that described by Shinn along the leeward, southeast coast of Qatar Peninsula in the Persian Gulf.

Diagenetic features affecting porosity development in the siliciclastic intervals include etching of quartz grains and penecontemporaneous precipitation of pore-filling, poikilotopic anhydrite cement. Subsequent partial dissolution of anhydrite cements increased porosity in clastic reservoir facies. The carbonate units have undergone pervasive dolomitization of mud matrix, leaching of allochems, and extensive anhydrite void filling. Replacement of dolomicrite by anhydrite and later solutioning of replacement fabric anhydrite contributed to secondary porosity in carbonate reservoirs. A better understanding of these diagenetic relationships could aid in predicting porosity trends in these distinctly different reservoir types within the Glorieta formation.

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Wrenching and Oil Migration, Mervine Field, Kay County, Oklahoma

Since 1913, Mervine field (T27N, R3E) has produced oil from 11 Mississippian and Pennsylvanian zones, and gas from 2 Permian zones. The field exhibits an impressive asymmetric surface anticline, with the steeper flank dipping 30°E maximum. A nearly vertical, basement-involved fault develops immediately beneath the steeper flank of the surface anticline. Three periods of left-lateral wrench faulting account for 93% of all structural growth: 24% in post-Mississippian–pre-Desmoinesian time, 21% in Virgilian time, and 48% in post-Wolfcampian time.

In Mesozoic through early Cenozoic times, the Devonian Woodford Shale (and possibly the Desmoinesian Cherokee shales) locally generated oil, which should have been structurally trapped in the Ordovician Bromide sandstone. This oil may have joined oil already trapped in the Bromide, which had migrated to the Mervine area in the Early Pennsylvanian from a distant source. Intense post-Wolfcampian movement(s) fractured the competent pre-Pennsylvanian rocks, allowing Bromide brine and entrained oil to migrate vertically up the master fault, finally accumulating in younger reservoirs.

Pressure, temperature, and salinity anomalies attest to vertical fluid migration continuing at the present time at Mervine field. Consequently, pressure, temperature, and salinity mapping should be considered as valuable supplements to structural and lithologic mapping when prospecting for structural hydrocarbon accumulations in epicratonic provinces.

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Geophysical Model of Gravity-Magnetic High, Virginia Coastal Plain

The Coastal Plain province of Virginia is characterized by a coincidental gravity and magnetic high parallel with the northeast-southwest Appalachian trend in the north changing to a north-south trend in the south. Both ends of the anomaly steeply grade into the regional field in Maryland and North Carolina.

Interpretation of 2 cross-strike geophysical profiles indicates that the anomaly is due to a high-density mafic unit flanked by low-density granitic(?) units. Geophysical signatures to the east of the anomaly are not parallel with Appalachian regional trends that characterize areas to the west.

Gravity models extending to 3 km depths on the southern profile (parallel with I-64 USGS line) and 4 km on the northern profile were chosen experimentally for optimal estimation of density contrasts. First approximations of the profile using vertical blocks to obtain density contrasts showed that east-dipping ($\approx 60°$) crustal blocks better represent the data. Well logs show that the anomaly is characterized by metagabbro, metabasalt, and amphibolite flanked by coherent lower-density granitic crustal blocks. Triassic-Jurassic clastic basins on the flanks of the anomaly to the west are fault-bound, but occur as vast basin infills to the east.

A conceptual model suggests that the anomaly may represent a suture zone between the North American crustal block to the west and possibly a remnant Avalonian(?) microplate to the east. Marked lineaments observable on computer-enhanced Landsat images closely parallel the subsurface trend of the anomaly.

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Experimental Fabric-Selective Porosity in Phylloid-Algal Limestones

Secondary fabric-selective porosity was experimentally produced in Pennsylvanian phylloid algal limestones from the outcrop in southeastern Kansas and from the subsurface in southeastern Utah (Ismay field, Paradox basin). Plastic-jacketed cylindrical specimens of well-cemented limestones were subjected to pressures simulating burial at 12,000 and 15,000 ft in a specially designed triaxial apparatus that permitted circulation of weakly acidic (pH 6) pore fluid (CO_2-enriched distilled water) under constant pressure and temperature. Thin sections revealed that the experiment produced algal moldic pores by selective dissolution of coarse low-magnesian calcite cement and pseudosparite. Dissolution was initiated along intercrystalline and intracrystalline pores (crystal boundaries and cleavage planes). Experimental pore systems were identical to natural porosity in Ismay reservoirs. Moldic porosity formed in the early stages of tests when flow rates were slowest; prolonged experimentation and more rapid rates of fluid circulation promoted the formation of vugs and channels.

These experiments document, for the first time, a potential for moldic-porosity formation during late diagenesis in deeply buried, mineralogically homogeneous phylloid algal limestones; thereby, extending the known depth range for porosity in late Paleozoic algal carbonates. Reservoir-quality algal moldic porosity may, therefore, exist within deep, as yet undrilled, parts of basins where mesogenetic decarbonatization has been operative.

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Sedimentary and Reservoir Geology of Upper Cretaceous Doe Creek Sandstone, Alberta, Canada

Northwest of Edmonton, Alberta, in the Valhalla area, recent drilling has proven the Upper Cretaceous Doe Creek Member of the Kaskapau Formation to be an oil-bearing sandstone. Based on core examination, the oil-bearing sandstone is interpreted to have been deposited on the transition from lower shoreface to inner shelf adjacent to a progradational wave-dominated coastline. Mapping indicates a northeast-southwest-trending reservoir sandstone body. The reservoir sandstone is a well-sorted fine-grained sublitharenite. The principle framework min-