gradient, fluvial-paludal setting. Organic-rich black shales accumulated in lakes (oxbows?) and overbank deposits. An influx of cross-bedded fluvial sands, possibly triggered by renewed border faulting on the west, characterizes the final stage of basin fill. These sediments represent fan-delta systems that prograded northeastward across the lacustrine-paludal lowlands.

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Sedimentary Silica in Newark Basins of Eastern United States

One way in which low-temperature, near-surface excess silica was introduced into the Newark sedimentary system was by extensive chemical weathering in the source area, when tectonic quiescence allowed it. Further concentration of silica within the basins was accomplished in the following ways: (1) eogenesis, by fluctuating pH, with values greater than 9.5 causing silica to be extracted from silicates within playa lakes or within soil zones; (2) eogenesis, by stands of silica-concentrating plants such as *Equisetites*, within ponds, playas, or fringes of larger lakes; and (3) mesogenesis, by pressure solution among quartz grains and possibly other silicates, possibly associated with high pH, causing release of silica.

In all situations, the silica, either from solution or gel, probably initially formed as opal-A and proceeded to the opal-CT stage, and then to the stable quartz phases of chalcedony, microquartz, and the megaquartz that we find today. The stable quartz phases are associated with primary silica precipitation in playa lakes, replacement of carbonate in playa lakes, possible replacement of carbonate oolite in playa lakes, vadoids in silcrete paleosols, possible replacement of vadoids in caliche paleosols, replacement of wood cell walls, syntaxial overgrowths on quartz grains, and nonaffiliated pore filling.

The various processes of quartz formation, coupled with associated microfacies and paleoenvironments of deposition, may be used for finer delineation of fluctuating paleoclimates during Newark deposition.

THAYER, PAUL A., Amoco Prod. Co., New Orleans, LA

Petrology, Diagenesis, and Reservoir Potential of Upper Triassic Dan River Group Sandstones, North Carolina and Virginia

The Dan River Group, a thick sequence of conglomerate, sandstone, and mud rock, is preserved in the northeast-trending Dan River–Danville basin of central North Carolina and Virginia. Thick lenses of organic-rich lacustrine strata (Cow Branch Formation) are surrounded by potential reservoir sandstones of fluvial, deltaic, and fan-delta origin.

Dan River sandstones consist of fine to very coarse-grained, moderately to poorly sorted, immature plagioclase arkose and lithic arkose. Source terrane was nearby and consisted of gneiss and schist with small amounts of granite and metavolcanic rock.

Diagenesis has significantly reduced initial porosity and permeability. Measured porosity of 125 representative sandstones averages 5.7% (ranging: 0.3-18.1%), and geometric mean permeability is 0.14 md (ranging: <0.01-14.1 md). Variation in porosity and permeability results mainly from allogenic clay matrix, packing density, and cementation.

Porosity-reducing diagenetic processes include mechanical compaction (ductile grain deformation and pressure solution) and cementation. Calcite, siderite, quartz, albite, hematite, and authigenic clay (illite and chlorite) cements are widespread and are the main porosity occluding agents.

Rock-Eval pyrolysis T-max values, vitrinite reflectance data, and black coloration of spores and pollen from associated mud rocks indicate an advanced stage of burial diagenesis. These data and the low porosity and permeability values indicate that Dan River Group sandstones have poor reservoir potential.

THOMAS, ROGER E., and KENNETH J. ENGLUND, U.S. Geol. Survey, Reston, VA

Environmental Controls on Accumulation of Thick, Low-Sulfur Coal (Peat) in Lower Pennsylvanian Pocahontas Formation, Virginia and West Virginia

Thick, low-sulfur coal beds are intercalated with a sequence of stacked delta-lobe deposits in the Pocahontas Formation of southwestern Virginia and southern West Virginia. Coal thickness and coal quality are related to the distribution and thickness of the underlying deltaic sandstone beds.

During the Early Pennsylvanian, the northwestward progradation of deltaic lobes on the southeastern shoreline of a regressive Carboniferous seaway was interrupted by periodic stillstands. Sand at the delta front was reworked and segregated by coastal currents and waves to form a system of fringing barrier bars. Vegetation flourished in swamps behind these protective barriers, mostly on platforms created by the abandoned delta lobes. The growth and accumulation of plants on the inactive, sand-dominated delta lobes formed domed deposits of ombrogenous peat that were low in ash and sulfur. In contrast, interlobe areas accumulated high-ash mucks consisting of organically rich clay and silt. In modern analogous peat-forming environments in tropical southeastern Asia, accumulations of low-ash and low-sulfur domed peat are dependent on high rainfall, which contributed little if any mineral matter to the peat. The ombrogenous origin of the Pocahontas coal beds is similarly indicated by the distribution of thick, low-sulfur and low-ash coal over the thick central area of the sandstone lobes, whereas thin, impure, and discontinuous coal beds occur in the shale-dominated interlobe areas. This analysis demonstrates that knowledge of the geometry, thickness, and orientation of delta lobes can be useful in the exploration for thick, high-quality coal.

TRAVERSE, ALFRED, Pennsylvania State Univ., University Park, PA

Paleopalynological Insights on Dating of Newark Supergroup Rocks and Their Correlation with European Sections

Once thought to be prevailingly barren of palynomorphs, sediments from all of the known Newark basins have now yielded correlatable palynofloras. However, for various reasons, only poorly preserved florules (Danville–Dan River basin) or scarce productive zones (Fundy basin) have been found in some of the basins. Sedimentation in the Newark rift zone apparently began in late Ladinian to late Carnian time along most of the front. New analytical data from a buried basin in southern Georgia now extend this observation about 400 km (two stages) farther south. From south Georgia to the Richmond basin in Virginia, the youngest sediments are Carnian or Carnian/Norian. In the Culpeper basin, Virginia, new information indicates sedimentation beginning during the Carnian, in keeping with the other southern basins. However, in the Culpeper basin and all of the northern basins, sedimentation persisted much longer. Latest Triassic to late Liassic floras are found in all of them. Palynoflorules as young as Toarcian have been studied in the Hartford-Deerfield basin of Connecticut-Massachusetts. Ultimately, these dates depend on correlation with palynofloras from classic marine fossil zones in south-central Europe, work which is in flux and progressing rapidly in European laboratories, boding probable changes in the Newark basin palynostratigraphic framework.

VENKATAKRISHNAN, RAMESH, and T. BRITT MCMILLAN, Old Dominion Univ., Norfolk, VA

Basement Controls on Lineament-Block Tectonics of Coastal Plain Province in Virginia

Linear features in the coastal plain of Virginia were interpreted from Landsat images and analyzed to define the geologic framework of the underlying basement. The lineaments were digitized, and length-weighted frequency distributions were calculated at 5° intervals on a 10-km^2 grid. Statistically significant peaks ($>95\%$) and troughs ($<5\%$) within each cell were identified. These significant trends identify 13 major lineament zones, which in turn were compared with structural domains recognized from a combined interpretation of geophysical, subsurface form-surfaces, and basement well-log data. Correlation between lineament frequency, aeromagnetic, and gravity data was tested on a regionwide and smaller domain basis.

The major lineament zones divide the western part of the area into north-south and northeast-southwest bound rhomboidal blocks. The eastern part is characterized by north-south and northwest-southeast bound rectangular blocks, quite different from the regional Appalachian grain. The lineament zones are documented to parallel basement domain boundaries because subsurface structure, lithologic and stratigraphic changes, and steep geophysical gradients occur along their extent. Some lineament zones clearly cut across several stratigraphic levels, indicating Mesozoic and Cenozoic reactivation of favorably oriented preexisting basement faults. The depositional control of sedimentary units, fracture propagation due to basement-block tectonics, and apparent reversals of fault movement observed at the surface are also suggested in a conceptual model.

WARD, L. W., U.S. Geol. Survey, Reston, VA

Late Tertiary Evolution of Salisbury Embayment

Upper Tertiary beds of the Chesapeake Group deposited in the Salisbury embayment preserve a detailed record of periodic sedimentation that is punctuated by unconformities and diastems. Correlation of these Miocene and Pliocene units is possible by the use of various microfossil and macrofossil groups. The unconformities that separate the beds are easily recognized and regionally traceable. Detailed analysis of the beds indicates that most formations are the product of one or more marine transgressions.

One transgression is represented by the Old Church Formation (upper Oligocene/lower Miocene), six by the Calvert Formation (lower and lower middle Miocene), two by the Choptank Formation (middle middle Miocene), three by the St. Marys Formation (upper middle Miocene), two by the Eastover Formation (upper Miocene), three by the Yorktown Formation (middle and upper Pliocene), and one by the Chowan River Formation (upper Pliocene).

In this sequence, on the basis of mollusk data, a temperature chart can be constructed that reflects oscillation within the cool-temperate to subtropical range. The relative stability of the temperatures and the continuing submergence of the Salisbury embayment allowed a richly fossiliferous, diverse, essentially temperate molluscan assemblage to form. This nearly endemic, perched fauna was decimated during the period of low sea level after the Yorktown transgression and before the Chowan River transgression. The result was a large-scale extinction at the generic as well as specific level because of low temperatures and the loss of habitat due to the low sea level stand.

Thus, the beds of the Chesapeake Group record a detailed history of regional and local tectonism, and global and local sea level fluctuations.

WICKSTROM, LAWRENCE H., and JOHN D. GRAY, Ohio Geol. Survey, Columbus, OH

Development and Geology of Harlem Gas Field, Delaware County, Ohio: An Ordovician Carbonate Exploration Model

Gas in commercial quantities was first discovered in 1964 in Harlem Township, Delaware County, by Federal Oil and Gas Company in their 1 Fronk well. This well had an initial production of 4,435 MCFGD after treatment, from the Black River Limestone (Ordovician). Following this discovery, several unsuccessful attempts were made through the 1970s to locate additional reserves in this area.

After an extensive geophysical investigation of the area, Industrial Natural Gas Corporation drilled the 1 Jackson well in 1982. This well had an initial production rate of 225 MCFGD and proved there were additional reserves in the field. Since then, numerous wells have been drilled defining this field, and more than 300 mmcf of gas has been produced.

The geology of the field is more complex than that associated with most oil and gas deposits within the state. The reservoir is located along a northwest-trending fault and fracture system. This fracture zone cuts a northeast-trending anticlinal nose. The reservoir rock is dolomitized Trenton and Black River Limestone. Trapping is accomplished by porous dolomite sections being surrounded by relatively impermeable limestone and dolomite.

This field provides a modern model to which future exploration for hydrocarbons in the Ordovician carbonates of Ohio may be keyed.

WILSON, THOMAS H., and ROBERT C. SHUMAKER, West Virginia Univ., Morgantown, WV

Three-Dimensional Structural Interrelationships Within Cambrian-Ordovician Lithotectonic Unit of Central Appalachians

A block diagram of the Cambrian-Ordovician lithotectonic unit illustrates three-dimensional structural interrelationships within that sequence along the length of the central Appalachian Valley and Ridge and Plateau provinces. Examination of the block diagram and the sections used to construct it illustrates that the Valley and Ridge portion of the central Appalachians can be divided into three sections based on shortening differences within the Cambrian-Ordovician lithotectonic unit. These differences are measured between the Allegheny structural front and the northwestern edge of the Great Valley. In the southern part of the central Appalachians, the shortening across this segment is approximately 23% of a 61-km undeformed length. To the north, shortening increases to 43% of a 119-km undeformed length across Shenandoah County, Virginia, and Hardy and Grant Counties, West Virginia. In this central section, shortening increases from that in the southern section and ranges from 39% of a 120-km undeformed length across the Broadtop coal basin to 44% of a 195-km length across the Nittany arch. This central section can be further subdivided on the basis of internal shortening differences. To the north of the Nittany arch, the Lackawanna syncline and the structures bounding it assume a more northerly trend, and the shortening across this northernmost section is only 8% of an 88-km undeformed length. Our discussion is focused on Cambrian-Ordovician fault systems within the the southern part of the middle section, and on their relationship to higher level structure, northwest in the plateau.

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Seismic Detection of Fractured Reservoirs: A Case Study of a Devonian Shale Gas Field in West Virginia

Interpretation of seismic data over the Cottageville gas field in West Virginia reveals the presence of numerous changes in the amplitude and shape of reflections within the lower and middle Huron Shale. Production from the lower Huron is fracture controlled, and some of the more pronounced changes in amplitude and shape occur in the more productive areas of the field. These changes are related to the development of low-impedance intervals that extend into the middle Huron Shale. Gamma-ray logs and a velocity log from the field indicate that the basal part of the middle Huron is homogeneous in character. Changes in reflection character from this interval arise from changes in the bulk properties of the rock over an area the size of a Fresnel zone. The Fresnel zone radius at the lower Huron depth is approximately 400 ft, so changes in bulk properties of the rock over this scale may not be observable in the well bore. Reduction of the shear and bulk moduli caused by increased fracture intensity and the dependance of P-wave velocity on these properties could produce the observed changes in impedance. The organic portions of the lower Huron have been intensely fractured; however, these fractures are often closed or are partially mineral filled, so fracture related changes in P-wave velocity are less likely.

Our research indicates that the fractured Devonian shale reservoir is detectable on conventional seismic data.

WINDOLPH, JOHN F., JR., U.S. Geol. Survey, Reston, VA

Lower and Middle Cambrian Shady Dolomite Above the St. Clair Thrust Fault, Tazewell County, Virginia

Previous studies in southwestern Virginia indicate a major decollement at or near the base of the Rome Formation. Recent geologic mapping in the structurally complex southeastern corner of the Amonate quadrangle, southwestern Virginia, identified as much as 800 ft of Shady Dolomite and 600 ft of Rome Formation above the St. Clair thrust fault. The Shady Dolomite, which contains several chert and shale beds up to 1 ft thick, is light gray to white, finely to coarsely crystalline, and thick bedded to massive. The upper part of the unit contains interbeds of grayish-red and reddish-brown shale and siltstone and is in normal stratigraphic sequence with the overlying Rome Formation. "Sunbursts" of barite crystals and pyritized fractures occur approximately 300 ft below the top contact. Above the St. Clair thrust fault, the Shady Dolomite is highly deformed and brecciated, and it contains nappe structures. The dolomite is thrust over Devonian shale, which is overturned and dips 35° to the southeast. The shale is in sequence with strata as young as Late Mississippian. The dolomite dips 55° to the southeast and is truncated by the thrust approximately 1 mi southwest and 0.5 mi northeast of "The Jumps" on State Route 637 at Rourkes Gap, Virginia. This occurrence of Lower and Middle Cambrian strata indicates that the decollement extends locally