reveal a separation of samples into two groups: a geographically restricted "northern" group and a more extensive "southern" group. This discrimination is consistent with paleocurrent and facies distribution data, which delineate two sources of sediment to the Dunkard basin: a dominant southeastern source and a subordinate northern source.

Northern sandstones are rich in nonundulatory, monocrystalline quartz, "stable" polycrystalline quartz, and sedimentary lithic fragments. These sandstones largely reflect a stable cratonic source wherein rocks were formed from multicycle sediments, some of which were ultimately derived from a low-lying craton of granite and/or high-rank metamorphic Precambrian rocks. Southern sandstones are enriched in mud rock and foliated, quartz-mica rock fragments, "unstable" polycrystalline quartz, and polycyclic, monocrystalline quartz reflecting a southeastern source terrane of mixed low-rank metamorphic and sedimentary lithology.

Comparison of the Dunkard detrital mode with modern sands from tectonic settings capable of producing uplifted terranes of supracrustal source rocks reveals that the Dunkard basin was a foreland basin that received sediment from both the adjacent foreland fold-thrust upland and from positive areas on the craton. Low to medium-grade metamorphic and recycled sedimentary detritus, shed from an orogenic highland, diluted contributions of supermature sedimentary and magmatic detritus from the continental lowlands.

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Fluvial Model for Deposition of Basal Pennsylvanian Quartzarenite in Eastern Kentucky and Southwestern Virginia

Sedimentary structures, textures, plant fossils, and the continental character of associated Pennsylvanian strata suggest that basal Pennsylvanian quartzarenite in eastern Kentucky and southwestern Virginia was deposited in a fluvial environment. Along the Kentucky-Virginia border, a southwest-trending paleovalley as much as 400 ft deep and 7 mi wide is cut into Mississippian rocks; it contains the basal quartzarenite of the Middlesboro Member (Pennsylvanian) of the Lee Formation. The arenite is mineralogically and texturally mature, and previous studies have interpreted it as a beach, barrier bar, or barrier island deposit. Those studies resulted in an interpretation of the geologic history of the area that included uplift and erosion of the northwestern part of the basal Pennsylvanian Pocahontas Formation followed by deposition of the Middlesboro arenite by a southeastward-transgressing sea.

Another interpretation of the same subsurface data used to support the coastal marine depositional model is that the Pocahontas was deposited in an interior valley southeast of and subparallel to the Middlesboro paleovalley. In this interpretation, the two paleovalleys are part of the same southwest-trending drainage system, and the Mississippian-Pennsylvanian unconformity, contrary to most presently accepted ideas, probably extends completely across the Appalachian basin. Furthermore, filling of the Middlesboro paleovalley by coarse sand and gravel may have caused damming of the Pocahontas paleovalley at a confluence southeast of the present eastern limit of the Pennsylvanian in southwestern Virginia. If Pocahontas sediments were deposited in a subsiding interior valley blocked by the basal beds of the Middlesboro, then the Pocahontas and Lee Formations are in part lateral equivalents.

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Modern Continental Rifts: Characteristics and Applications to Recognition of Ancient Rifts

Characteristics of modern continental rifts can provide a checklist of expected features in ancient rift systems: (1) distinctive morphology and dimensions as long, linear, sinuous structures up to thousands of kilometers in length and tens of kilometers in width; (2) high heat flow, resulting in extrusive and intrusive igneous bodies and hot-spring deposits; (3) small volcanoes within and large volcanoes outside only certain parts of rift systems; (4) complex stress fields that combine elements of extension, compression, shear, and torsion; (5) complex internal faulting; (6) gravity highs over intrusive mafic rocks and gravity lows over sedimentary rocks; (7) high seismicity, which leaves a record of earthquake-induced sedimentary structures; (8) progressive basin abandonment because of "rift-jumping"; (9) reactivation through time; (10) individual basins within rift systems formed by complexes of tilted-fault blocks, grabens, and horsts; (11) interfingering sedimentary deposits from slope, riverine, valley-floor, and lacustrine environments; (12) large and small rift-valley lakes, only some of which exhibit high biological productivity and anoxic bottom waters depositing organic-rich muds; and (13) deposits of the precursors of coal, petroleum, gas, and minerals that bear such elements as copper, lead, zinc, phosphorus, barium, or uranium.

The combination of these critical features helps to identify ancient rift systems. However, crust weakened by rift-forming processes may be overprinted by later tectonic events that tend to obscure important details in ancient rifts such as the Newark rift system of eastern North America.

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Petroleum as an Ore-Bearing Fluid: A Hypothesis

Each of the many organisms from which petroleum is generated concentrates a large number of elements. Of 75 elements recognized in organisms, Co, Cu, Mo, Pb, and Zn are among the 41 identified as participating in metabolic reactions and tissue formation. Many of the important "ore-forming elements" are fixed into metalloproteins such as cobalamine (Co), cytochrome oxidase (Fe, Cu), alcohol dehydrogenase (Zn), and xanthine oxidase (Mo, Fe). Most proteins including metalloproteins degrade between 60° and 70°C. Until that critical temperature is reached, such metals are bound in the tissues; after that, the metals are free to move from the tissues. It is also within this temperature range that petroleum begins to be generated.

Besides forming parts of metalloproteins, metals also attach to organisms and organic matter by other processes, including attachment to metabolic wastes, to decay products such as humic acids, to surface-active compounds of bacteria, and to organic remains in sediments. The attached metals may be locked in and on the organic matter until it is converted into liquids.

Metabolically used elements such as Co, Cu, Mo, Pb, and Zn are among the 50 recognized in petroleum. It is possible that metals such as these begin as part of the organic remains, catalyze the generation of petroleum, and then are carried by petroleum to reservoir rocks that can also serve as host rocks for metallic concentrations.

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Mapping of Fracture Zones by Helium Emanometry and Possible Relationship of Helium Anomalies to Hydrocarbon Reservoirs in Western Pennsylvania

Helium is ubiquitous within the earth's crust. Local helium concentrations in the subsurface are observed in association with ores containing uranium and thorium, oil and gas reservoirs, and thermal fluids. In addition, permeable fracture zones tend to intensify local concentrations of helium because of its relative ease of migration along these conduits. A survey of helium in soil-gas samples was conducted across a previously mapped fault zone and a drilling-defined hydrocarbon reservoir in Greene and Fayette Counties, southwestern Pennsylvania, to demonstrate the utility of such surveys for mapping fracture zones and for locating hydrocarbon reservoirs. In the study area, a northwest-trending fracture zone cuts across both an area of hydrocarbon accumulation and an area thought to be relatively barren of hydrocarbons. The survey indicated that the helium content of the soil was anomalously high in a 30-m wide zone above the mapped fault and fracture system. Similar results were obtained from traverses made across both the accurately mapped fault zone and the hypothesized extensions of that zone. These data support the concept that helium can be used to locate fault and fracture zones where location is precluded by more conventional mapping procedures. Although helium surveys have delineated known hydrocarbon reservoirs in other areas, this preliminary survey, which consisted of a few traverses rather than an extensive grid pattern, failed to produce a significant anomaly above a known reservoir in southwestern Pennsylvania. This may be due to the low density of sample distribution and the high average background helium value for these traverses.

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Faulting in Triassic Gettysburg Basin, Pennsylvania and Maryland

The structural framework of the Gettysburg basin is defined by three parallel, northeast-southwest-trending, southeast-dipping, postdepositional (Sinemurian?) normal faults into which originally horizontal Triassic strata now dip 20°-30° northwest. The faults are controlled by the earlier Alleghanian structural grain. The main portion of the Gettysburg basin extends 120 km from its termination near Frederick, Maryland, to an arbitrary cutoff near Palmyra, Pennsylvania. The basin is bounded on the northwest by a normal fault with a probable maximum displacement of several thousand meters. Inliers of basement, surrounded by Triassic strata, occur adjacent to the border fault, indicating that the deepest part of the basin is not necessarily at the border fault as in a simple half-graben model. At York Springs, Pennsylvania, basement and Triassic strata occur in a fault sliver on the major east-west, older Transylvania fault, which was reactivated with 3.5 km of right-lateral wrenching. Extensive normal faults in the Blue Ridge and Great Valley are associated with development of the Gettysburg basin.

Southeast, near Keymar, Maryland, two normal faults with an aggregate displacement of 1,350 m partially separate a subbasin 20 × 5 km from the main basin. These faults extend 40 km south along the Martic Line into the Triassic Culpeper basin.

Farther southeast, near Tyrone, Maryland, a normal fault with 800 m of displacement totally separates a small (4 × 0.6 km) Triassic basin from the main basin on the northwest.

Dip reversals are rare and develop on a minor scale only adjacent to faults. Therefore, petroleum plays based on surface structural closure are not viable.

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Thermal Maturity of Newark Supergroup Basins from Vitrinite Reflectance and Clay Mineralogy

Thermal maturity estimates from vitrinite reflectance and clay mineralogy point to significant differences between the Newark Supergroup basins in their thermal structure and/or their original depth of burial. The Richmond and Taylorsville basins are relatively immature, with mean vitrinite reflectance values in the range of 0.6 to 1.1%. The clay mineral assemblages are dominated by early diagenetic smectite and mixed-layer clays. Likewise, organics in the Hartford basin have mean vitrinite reflectances between 0.7 and 1.1%. In contrast, the Culpeper, Gettysburg, and Newark basins are thermally more mature. Although a wide range of vitrinite reflectance values is observed in each of the basins, the majority of the mean reflectances are 1.5-3.0%. Well-crystallized illite and chlorite constitute the fine-grained clay fractions.

In general, the lowest degrees of thermal maturity are associated with rocks that either are stratigraphically and structurally highest in the basins or form the updip taper of the half grabens. However, systematic correlations are not observed between stratigraphic/structural position within a basin and the degree of thermal maturity. This may be attributed to a thermal "homogenization" of the basins by circulating hydrothermal fluids. The basins with the highest thermal maturities are those with large volumes of diabase intrusions and that had presumed higher geothermal gradients.

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Schurflingsfensters in Pulaski Thrust Sheet and Their Implications for Hydrocarbon Potential

Highly deformed Cambrian through Devonian rocks are exposed in fensters in the Pulaski thrust sheet of the Virginia Valley and Ridge province. Detailed mapping of these exposures shows a consistency of structural style—namely, faulted, stacked antiforms with duplex geometry and folded roof thrusts. Strain intensity and the style of regional folds and faults suggest that the fensters are schurflingsfensters that expose rootless tectonic slices, or horses, possibly derived from a thrust ramp in the trailing part of the subjacent Saltville thrust sheet. Recent interpretations of the U.S. Geological Survey's central Virginia seismic line place this ramp east of and below the crystalline rocks of the Blue Ridge structural front. Geometric modeling of rocks in the schurflingsfensters suggest the existence of possible Cambrian through Mississippian hydrocarbon-bearing rocks below the Pulaski, Max Meadows, and Blue Ridge thrust sheets. Rock samples from horses are presently being collected to determine thermal maturity and source rock potential. If these rocks were derived from the Saltville thrust sheet, sampling should prove important in evaluating hydrocarbon potential below eastern thrust sheets of the Appalachian Valley and Ridge, and Blue Ridge provinces.

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Stratigraphy and Depositional Environments of Part of Pennsylvanian Pottsville Formation in Black Warrior Basin, Alabama and Mississippi

The upper part of the Pennsylvanian Pottsville Formation of the Black Warrior basin of Alabama and Mississippi is composed of cyclic sequences of conglomerates, sandstones, siltstones, mudstones, and coals, deposited in response to alternate phases of constructive and destructive deltaic sedimentation. The coal-bearing interval has been divided into seven coal groups (Black Creek, Mary Lee, Pratt, Cobb, Gwin, Utley, and Brookwood), each of which contains several coal beds. A detailed study of the three oldest coal groups, the Black Creek, Mary Lee, and Pratt, identified a variety of deltaic facies. These include distributary channel, interdistributary bay, crevasse splay, distributary mouth bar, lagoon/prodelta, and barrier island.

The small, elongate deltas of the Black Creek, Mary Lee, and Pratt coal groups prograded northeastward from an orogenic source southwest of the Black Warrior foreland basin. A possible southeastern source terrain is suggested during deposition of Pratt strata. Distributary channels of the upper Black Creek and Mary Lee coal groups shifted extensively across the lower delta plain. Two general centers of deposition, one in Mississippi and one in Alabama, were maintained. Associated coals, trending northeast, accumulated in bays adjacent to the channels. In contrast, the northwest-trending coals of the lower Black Creek and Pratt coal groups were deposited in back-barrier settings during destructive phases of deltaic sedimentation. A single Pratt depocenter, located in Mississippi, is coincident with the upper Black Creek and Mary Lee depocenter.

Determination of depositional environments is based on the interpretation of geophysical log signatures and the distribution of sandstones and coals. Most of these data have been obtained from dual induction and density logs of wells drilled to underlying Mississippian reservoirs. The Pottsville sediments have not been a major petroleum objective; however, the numerous coal beds are a potential source of methane.

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Structural Geology of Delsignore 1: A Central Eastern Overthrust Well

Located along the Appalachian structural frontal zone of the central Eastern Overthrust, the Robert Delsignore 1 was drilled in early 1984 to a total depth of 9,965 ft after 77 days. The well was spudded within the lower Upper Devonian Chemung Group, and at total depth, the well was in the Lower Devonian Helderberg Group. The well is located less than 1 mi from the nearest Lower Devonian outcrop and approximately 1 mi across strike from the Mastellar discovery wells by Columbia Gas in Mineral County, West Virginia.

The well penetrated only Upper Devonian through Upper Silurian strata and showed the existence of the following: repeated and overturned strata, numerous southeast-dipping thrust faults, a northwest-dipping backthrust, nearly recumbent folds, and a folded, overturned thrust fault. From this "geologic discombobulation," a nearly true stratigraphic penetration of 3,150 ft was made within a 9,965-ft well. Several good hydrocarbon shows were found in the lower portion of the well while drilling.

Data obtained from this well, coupled with local and regional studies, have several implications relevant to development of size, geometry, timing, and emplacement of frontal-zone structures involving Silurian-Devonian rocks. Structural development involving Silurian-Devonian strata near a major decollement step-up can be shown to have generally progressed from east to west, resulting in a frontal-zone "pile-up." The well data also provide insight into the stratigraphy, potential reservoirs, and relative timing of migration and entrapment of hydrocarbons along structurally complex frontal zones.