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