Structural Interpretation of Buried Silurian Reefs in Southwestern Indiana

Two or more generations of buried Silurian reefs are present in southwestern Indiana. Possibly all the larger reefs grew until Devonian time. Some may have attained thicknesses greater than those of any other group of Silurian reefs. Strata topping the reefs range from Middle or Late Silurian to Middle Devonian in age. Deep drilling is sparse in southwestern Indiana, and limited geophysical surveys are mostly confidential. Interpretation of the reef province then relies heavily on evaluation of structural deformation (broad sense) of the rocks both encasing and overlying these and other Silurian reefs and of the reefs-proper and their flanks.

The amounts of suprareef drape in strata as young as Pennsylvanian are related to reef thickness, kind of reef, erosion of reef and postreef rocks, height above reef, and counterproductive subreef sagging. Both suprareef draping and subreef sagging are expectable for any given reef. Long-continued diagenesis, even to the present time, was the most significant cause of such structural deformation; subreef soft-sediment deformation penecontemporaneous with reef growth also was a factor. Differential compaction between reef and contemporaneously deposited interreef rocks was the most important diagenetic process. Differential compaction in rocks far above the reefs, acting in concert with lithologic and thickness differences brought about by continued growth of drape structure, had a minor role. Differential solution and recrystallization could have contributed especially to subreef sagging. These interpretations temper some ideas that localized tectonic uplifts influenced both reef siting and suprareef draping and that early cementation resulted in structural stabilization of substrate, reef, and reef flank penecontemporaneous with growth.

The ranges in geologic circumstances that apply—in setting, reef genesis and abortion, erosion or nonerosion and burial of reefs, and postreef attainment of structural clues to reef recognition—suggest that southwestern Indiana has a reef-related reservoir potential that applies differentially within the reef province. The differential extends to the reefs themselves and to individual formations draped over the reefs. This province, surely, is inadequately explored for hydrocarbon potential in sub-Mississippian rocks.

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Coal in Pennsylvania: Geology, Current Production, and Reserves

Pennsylvania is at the northern end of the Appalachian coal basin. Approximately 15,000 sq mi (39,000 sq km) or one third of the state, is underlain by coal measures. The coal is Pennsylvanian to Permian in age, and includes bituminous and anthracite coal found in several separate fields.

The bituminous coals have dips of less than 2°, with some beds dipping up to 8° and rarely exceeding 8°. These steeper dips are found along the flanks of the major Plateau fold structures and in proximity to the Allegheny Front. Bituminous coal in the Broad Top field and in the anthracite basins have dips commonly exceeding 60°.

The earliest record of coal being mined in Pennsylvania was at Fort Pitt (now Pittsburgh) in 1761. To date, more than 22 billion tons of coal have been mined out or lost due to mining. Coal production in 1978 was 80,342,913 net tons of bituminous coal and 5,037,960 net tons of anthracite coal.

Recoverable reserves are estimated at 22 billion tons of bituminous coal more than 28 in. (71 cm) thick, and 8 billion tons of anthracite coal more than 24 in. (61 cm) thick. These estimates assume that all the major coals are continuous throughout their projected area of occurrence, as with the Pittsburgh seam.

However, recent detailed studies on the sedimentology of the Upper Freeport coal in southwestern Pennsylvania indicate that the stratigraphy of the coal-bearing measures may be more complex than previously believed. These units consist of a highly variable sequence of coals, clays, sandstone, shales, limestones, and other rock types occurring in lenses, pods, channel-fills, etc. Because of the presence of these coal-seam discontinuities in some of the coals, the current coal reserve estimates may be significantly inaccurate.

The Pennsylvania Geological Survey is currently cooperating with the U.S. Geological Survey in the National Coal Resources Data System. We are currently in the third year of the program to enter all point-specific data, including coal thickness and quality, into the computer. In addition, coal crop maps for each principal coal seam showing areas of deep and strip mining are being compiled. This program will result in much more accurate estimates of the remaining coal reserves in Pennsylvania.

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Coal Resources of Indiana and Potential Geologic Problems in Their Exploration

Indiana has about 33 billion tons of coal resources, and about 17 billion tons are estimated to be recoverable by present-day mining technology. Coal mining, beginning in the early 1800s and continuing until the late 1930s, was principally underground, but since 1940 mining has been mainly surface. At present only five of the more than 120 active operations are underground, and they produce about 2% of the annual tonnage.

Underground mining of coal in Indiana is expected to increase, since about 15 billion of the 17 billion tons of recoverable coal appear to be recoverable only by deep mining methods. Studies of past and present underground operations in the Springfield Coal Member (V), taking into consideration partings, roof conditions, faults, water problems, and gas concentrations in the coal and roof strata, should prove useful in planning for future operations.

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Coal Resource Studies in Virginia

There are three coal-bearing areas of Virginia: the Richmond and Farmville Triassic basins in the Piedmont province, the Valley coalfields in the Valley and Ridge province, and the Southwest Virginia coalfield in the Appalachian Plateau province. All present production and most coal resources are within the Southwest field. Coal production in 1978 was 32,004,341 short tons of which 31% was by surface mining methods.

The Division of Mineral Resources is currently studying the geology of all of Virginia's coalfields, especially the Southwest field. For the past several years the Division has collected coal samples from the Southwest field to be analyzed by the U.S. Geological Survey and U.S. Bureau of Mines, with the results being entered into the National Coal Resources Data System. Mapping at a 1:24,000 scale is continuing on several quadrangles in the Southwest Virginia field and in parts of the Valley coalfields. The Division is compiling geologic data related to the methane potential of unminable coal beds, in cooperation with the Department of Mining and Minerals Engineering at Virginia Tech.

A mine inventory for all active coal mines in Virginia has been completed. This information will be used, along with other information gathered by the Division, to revise the coal resource estimates for Wise, Lee, Dickenson, and Scott Counties. The U.S. Geological Survey will concurrently revise the resource estimates for Buchanan, Tazewell, and Russell Counties.

Future work by the Division will include studies of mine-roof stability, hydrology, and geochemistry in the Southwest Virginia coalfield. In addition, we anticipate new mapping at 1:50,000 and 1:24,000 scales. Work is also planned in continuing existing sampling and mine inventory programs.

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Elemental Abundances in Devonian Shales of Kentucky and West Virginia: Statistical Comparison and Depositional Environments

Stratigraphic and geographic controls on the distribution of major elements, minor elements, and minerals define depositional environments and provide a base line with which to compare local geochemical distributions in the detection of anomalies or trends related to gas production. Data consist of (1) cuttings from more than 30 wells in western and southern West Virginia, (2) similar analyses on samples collected from outcropping rocks of the Greenland Gap Group and Hampshire Formation in eastern West Virginia, and (3) outcropping black shales in eastern Kentucky.

Factor analyses revealed several groups of elements: a detrital association of aluminum, potassium, titanium, iron, and sodium; a carbonate association of magnesium and calcium; an association of sulfur, iron, and zinc; and an association of phosphorus and calcium. The carbonate association is observed in black shales of Kentucky; the association of calcium with phosphorus is observed in carbonate-poor clastics of West Virginia.

Within most West Virginia wells, such elements as potassium, silicon, and aluminum show gradual trends through the section, contrasting with abrupt changes in abundance exhibited by sulfur and titanium. Sulfur occurs in high percentages with black shales. In some wells, silicon has a higher abundance in black shales than in gray shales.

Trend surface analyses of data from western and southern West Virginia show that titanium peaks in easternmost wells, sulfur peaks in westernmost wells, and silicon peaks in easternmost and some westernmost wells. Observed trends agree with the accepted view of a prograding delta complex in Late Devonian time, but geographically local, time-restricted depositional processes influenced elemental percentages in subsets of wells and stratigraphic intervals. One example of such a process is possible deposition of clastics from a source west of the study area in West Virginia.

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Coal Rank in Part of Western Kentucky Coalfield

Coal rank (vitrinite maximum reflectance) has been determined for coals in the Henderson basin, Rough Creek fault complex, and Webster Syncline of the western Kentucky part of the Eastern Interior basin (Henderson, Union, and Webster Counties). The samples represent major coals (Western Kentucky No. 6, No. 9, No. 11) as well as minor coals from several bore holes.

The rank increases from high volatile C in the Henderson basin to high volatile B and A in the Webster Syncline to the south of the Rough Creek fault complex. The rank decreases to high volatile C to the south across the central faults in the Moorman Syncline. Coals in a bore hole in a graben of the Rough Creek complex (Bordley quadrangle, Union County) display a variable rank gradient. Rank increases from the hvC (0.56%R) of the top coal (youngest known Paleozoic coal in Kentucky) to hvA (0.88%R) of coals 400 m below (still several hundred meters above the WK No. 9 coal). The coal 15 m below the top coal, however, has a reflectance of 0.86%R. Hydrothermal metamorphism is suspected as the cause of the rank anomaly. The relatively high rank of coals in the Webster Syncline may have been influenced by the above event but in general the rank can be attributed to a higher paleogeothermal gradient in the syncline. The heat flow regime may have been influenced by the activity which produced the mineralization in the Fluorspar complex to the west. The fault zones to the north and south may have delineated the boundaries of the block subjected to higher heat flow.

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Devonian Oil Shale of Eastern United States

The Devonian oil shales of the eastern United States constitute one of the nation's major energy resources. The eastern Devonian oil shale resource is estimated to exceed 400 billion bbl of synthetic oil, if all surface and near-surface shales of ore quality were strip or deep mined for above-ground hydroretorting.

Work done at the Institute of Gas Technology since 1972 under the sponsorship of the American Gas Association, The Gas Research Institute, and the U.S. Department of Energy has shown that if retorted in hydrogen gas at temperatures of 500 to 730°C and pressures