

mont 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 hydrotreating.

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

of 20 to 50 atm, the eastern Devonian shales are a viable source of synthetic liquid or gaseous fuels. Experimental work, in equipment capable of processing up to 1 ton/hour of shale, has confirmed the technical and economic feasibility of above-ground hydroretorting of oil shales. Work done to date on nearly 500 samples from 12 states indicates that the HYTORT process can give organic carbon recoveries from 2 to 2.5 times those of conventional retorting of the Devonian shales, so that the HYTORT process yields 25 to 30 gal/ton on syn-crude at many localities, compared with 10 to 15 gal/ton using Fischer Assay retort methods.

Criteria for inclusion of shale in estimates of recoverable resources for the HYTORT process are (1) organic carbon of at least 10% by weight, (2) overburden of less than 200 ft (59 m), (3) volumetric stripping ratios of less than 2.5 to 1, and (4) stratigraphic thickness of 10 ft (3 m) or more.

Resource estimates include: Kentucky (Ohio, New Albany, and Sunbury Shale), 190 billion bbl; Ohio (Ohio and Sunbury Shale), 140 billion bbl; Tennessee (Chattanooga Shale), 44 billion bbl; Indiana (New Albany Shale), 40 billion bbl; Michigan (Antrim Shale), 5 billion bbl; and Alabama (Chattanooga Shale), 4 billion bbl. Recoverable resources have not been identified in West Virginia, Georgia, Oklahoma, Illinois, Arkansas, or Missouri outcrops. Co-production of uranium and metals is a possibility in the areas favorable for syn-crude production.

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#### Absence of Connate Water in Michigan Reefs Attributed to Anhydrite

Dehydrated gas stored in depleted reef reservoirs behaves uniquely in that the gas comes out essentially as dry as when injected. This observation leads to the conclusion that the major part of the reservoir does not contain connate water. However, the base of the reservoir, usually of low porosity, is filled with brine.

Reef rocks contain anhydrite. A study of anhydrite occurrence leads to the relation of gypsum to anhydrite. A review is made of the controversial views held as to this relation in the earth. One concludes anhydrite in the earth must react with liquid water to form gypsum. Further, it is believed the anhydrite conversion to gypsum forms the seal to project salt layers.

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#### St. Louis and Salem Stratigraphy and Oil Production, Owensville North Consolidated and Mt. Carmel Consolidated Fields, Gibson County, Indiana

Recent oil discoveries in the St. Louis and Salem Limestones of Middle Mississippian age, on the eastern flank of the Illinois basin in Indiana, have been significant enough to stimulate exploration. Most previous oil exploration in the area was confined to depths shallower than the St. Louis and the Salem.

Along with the oil discoveries came problems of stratigraphic identity in Gibson County and adjoining counties. The problems were resolved by a study in

which the Salem Limestone and associated rocks were traced from the outcrop area into the subsurface, where geophysical logs and drill cuttings were used for correlation. Within the St. Louis a geophysical log marker—the X marker—and the Sisson Member were introduced as new names.

Two adjoining fields in Gibson County, Owensville North Consolidated and Mt. Carmel Consolidated, were studied in detail in an attempt to determine the conditions for oil entrapment in the St. Louis and Salem reservoirs. Production in both fields abut one another, and therefore the reservoirs are treated as one unit. Production is from the St. Louis (Sisson Member) and the Salem. The Salem reservoir is about 180 ft (55 m) below the St. Louis reservoir, and both produce from porous zones in a calcarenite facies composed of microfossils, fossil fragments, and oolites. Porosity studies of the reservoirs show that the lower limit of producible porosity is 6%, and most oil wells have at least 5 ft (1.5 m) of net porosity greater than 6%. Maximum porosity recorded in the St. Louis was 15%, and in the Salem 21%. Density logs were used for porosity determinations. Salem wells had higher initial production than St. Louis wells. Entrapment is influenced by both stratigraphic and structural conditions.

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#### Geology and Mining of Tennessee Coal

The coal deposits of Tennessee occur in Pennsylvanian strata on the Cumberland Plateau. The southern half of the plateau contains Lower Pennsylvanian strata which are thick, massive sandstones and thin shales. The northern half consists of Lower and Middle Pennsylvanian strata. Relatively thick shales and thin sandstones comprise the Middle Pennsylvanian section. Most of Tennessee's present coal production comes from the northern Cumberland Plateau.

The first recorded production of coal in Tennessee was in 1814. Significant production did not begin until the expansion of the railroads which occurred around 1850. Except for a lapse in production because of the War Between the States, production increased steadily until 1900. Although production has fluctuated, Tennessee has produced approximately 9 million tons per year since that time.

Today there are over 300 operating mines in Tennessee. Of these, about 60% are surface mines. The average production of surface mines in Tennessee is about 6,500 tons per month. Underground mines average about 4,500 tons per month. All of the coal produced in Tennessee is bituminous and is used largely in steam-powered electric plants.

There are several experimental uses of coal being studied in Tennessee. These include synthetic fuel plants, magneto-hydro-dynamics plants, atmospheric fluidized-bed combustion plants, and coal gasification plants. The development of any of these processes could significantly affect coal production in Tennessee.

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