CLAYPOOL, GEORGE E., U.S. Geol. Survey, Denver, CO

Appalachian Basin Devonian Shales—Regional Organic Geochemistry and Hydrocarbon Genesis

Small amounts of methane were formed in the Devonian black shales of the Appalachian basin during early, low-temperature stages of diagenesis, but most of the natural gas was generated by thermochemical conversion of solid and liquid organic matter during later, higher temperature stages. At any given locality, the amount of methane generated in the Devonian shales was determined by the amount of organic matter originally present and the extent of the transformation process; transformation was determined by the maximum depth of burial and subsurface temperature to which the rock was subjected. The transformation process was halted in its early stages in rocks of the western part of the basin, but approached completion in the east. The degree of transformation is indicated by systematic, west-to-east changes in the geochemistry of gas ($\delta^{13}C$ of methane changes from -55 to $-25‰$), in the extractable organic matter (saturated hydrocarbons evolve from an immature to an incipiently metamorphosed assemblage), and in the solid organic matter (atomic H/C changes from 1.1 to 0.4).

The hydrocarbon geochemistry of oils derived from Devonian shales also changes systematically. On the basis of correlations with Devonian source rocks, oils on the western margin of the basin in the Mississippian Berea Sandstone must have been generated in and migrated from shales located about 100 km to the east. In contrast, the easternmost oil occurrences in lenticular sandstones were products of very local migration from adjacent shales. In the eastern part of the basin, the advanced stage of thermal maturity of both oils and extractable hydrocarbons in adjacent source rocks suggests that hydrocarbons, both in the reservoir and source rock, underwent parallel thermal maturation after migration and emplacement of the oil.

CLAYPOOL, GEORGE E., JOEL S. LEVENTHAL, and MARTIN B. GOLDHABER, U.S. Geol. Survey, Denver, CO

Geochemical Effects of Early Diagenesis of Organic Matter, Sulfur, and Trace Elements in Devonian Black Shales, Appalachian Basin

The relation between organic carbon and sulfides in Devonian black shales can be used to identify these units as having been deposited in ancient marine euxinic environments. Based on the modern Black Sea analogy, the euxinic environment is indicated by a positive intercept for sulfur at zero organic carbon on a carbon-sulfur plot. Furthermore, the slope of the plot can be related to position in the basin and to deposition rate. Sulfur-isotope ratios of fine-grained, early diagenetic iron sulfides are typically light, indicating that a majority of the sulfide formed in the water column and near the sediment-water interface. Isolated heavier values are observed, however, which demonstrate that sulfide formation persisted into later diagenesis at least locally. Carbon and oxygen isotopes of carbonate minerals show the effects of both early diagenesis of organic matter by micro-biological processes and later redistribution of carbonate into veins and nodules. A range of δ-values suggests that anaerobic oxidation of organic matter is more important than methane generation for carbonate diagenesis. Trace-element abundances (U, Mo, V, Ni, Hg) are related to organic-carbon and sulfide content. These relations can be explained by invoking an organic-concentration mechanism and aqueous-sulfide protection and redistribution processes. Trace-element/organic and trace-element/sulfide ratios do not change greatly in the basin, although deposition rates vary by more than one order of magnitude.

CLIFTON, H. EDWARD, and R. LAWRENCE PHILLIPS, U.S. Geol. Survey, Menlo Park, CA

Stratification Types in Intertidal Sediment, Willapa Bay, Washington

Intertidal areas contain a number of subenvironments, many of which generate distinctive types of internal structures. Experimental studies conducted over a 5-year period in intertidal areas in Willapa Bay, Washington, indicate the origin of different types of structures. The experiments consisted of establishing a datum by scattering fine particles of lead over the surface in six subenvironments and repetitively coring the experimental plots at daily, seasonal, or yearly intervals. The subenvironments studied include the upper and middle accretionary bank of a tidal runoff channel, the uppermost bank of a tidal river, muddy tidal flats covered by (1) *Zostera* and (2) low mounds of blue-green algae, and sandy tidal flat.

The internal structure in each subenvironment depends on the dominant processes and on the rate of sedimentation. The middle accretionary bank of the runoff channel accreted at a rate of more than 5 cm per month during the summer of 1976; the stratification reflects the semidiurnal ebb and flood of the tides. On the upper accretionary banks of the runoff channel and on the tidal river, the sediment responds more to seasonal variations, accreting during the summer and eroding during the winter. On the uppermost bank of the tidal river, these processes were recorded over a 5-year period in 8 cm of alternating mud (summer) and fine sand (winter) laminae.

Very little net accumulation of sediment occurred on the tidal flats. The *Zostera*-covered muddy flat and the sandy flat are dominated by bioturbational processes and no lamination is preserved. On the algal mounds, the binding of the sediment by algal filaments and the inhibition of faunal activity by oxygen depletion combine to produce well-defined thin laminations. Repeated sedimentation and algal growth produce stratification similar to the upper accretionary bank of the tidal river.

CLUFF, R. M., M. H. BARROWS, and M. L. REINBOLD, Illinois State Geol. Survey, Urbana, IL

Relation of Depositional Facies and History to Hydrocarbon Generation in New Albany Shale Group (Devonian-Mississippian) of Illinois

The distribution of potential hydrocarbon source beds within the New Albany Shale group of Illinois was determined by studies of the stratigraphy, lithology, and organic matter of the shales. Shelf-to-basin correlations (across western Illinois to southern Illinois and western Kentucky) reveal a complete and continuous transition from high-energy, aerobic, shallow-water (<50 m ?) environments (fossiliferous limestones) to low-energy, dysaerobic, moderately deep-water (~50 to 150 m ?) environments (bioturbated greenish-gray shales and thickly laminated olive-black shales) to very quiet, anaerobic, deep-water (>150 m ?) environments (finely laminated black shales).

The types and abundance of the organic matter preserved within the shales were predominantly controlled by the depositional environment. Appreciable amounts (3 to 15%) of mixed humic-sapropelic kerogen were preserved in the anaerobic black shale environments. The kerogen assemblage is interpreted to be well-preserved, locally derived organic material. Only small quantities (typically <1%) of humic (degraded ?) kerogen were preserved in the dysaerobic greenish-gray shale environments. This kerogen assemblage is interpreted to result from selective preservation of only the organic constituents most resistant to destruction by benthic invertebrates (detritus feeders) and aerobic bacteria.

Petroleum generation in the New Albany shales is likely to have occurred only in the anaerobic black shales where the sapropelic and liptinite fractions have been preserved and where sufficient organic maturation has taken place. Gas generation may have occurred in the greenish-gray shales where humic kerogen has been preserved selectively, but in very small quantities due to the low maturity and paucity of organic matter in these shales.

CONROY, B. W., and J. D. EISEL, Power Resources Corp., Englewood, CO

Uranium Solution Mining—Integration of Exploration and Production Development

The observations and conclusions are based on a study of uranium deposits in Weld County, Colorado. The deposits occur along geochemical interfaces (roll fronts) in the sandstones of the Fox Hills and Laramie formations of Late Cretaceous age.

The uranium deposits are epigenetic and were formed by solutions moving down through a pre-Oligocene unconformity developed on the gently dipping Cretaceous strata in the southern part of the Cheyenne basin.

Uranium solution mining has become important as a means of exploiting roll-front deposits with geologic and hydrologic characteristics amenable to controlled solution flow.

The interaction between exploration and mine development in evaluating the technical, economic, and environmental feasibility is of paramount importance for a successful solution mining project. Exploration provides data such as total reserves, minable reserves, lithology, thorough interpretation of geophysical logs, and geohydrologic observations to assist mine development in establishing well field patterns, mine economics, well completion methods, and solution control and containment methods. Mine development aids exploration by providing information generated during metallurgical testing, groundwater evaluation, mining, and aquifer restoration. In particular, radon and gross alpha activity measurements which are made in the groundwater prior to mining are significantly valuable in developing the ore body, and in regional exploration in similar lithologies.

COOK, FREDERICK A., DENNIS S. ALBAUGH, JACK E. OLIVER, et al, Cornell Univ., Ithaca, NY

Crystalline Overthrusting of Paleozoic Shelf in Southern Appalachians Mapped by COCORP Reflection Data

COCORP seismic reflection data have shown that the early Paleozoic shelf in the southern Appalachians has been overthrust by a thin sheet of crystalline rocks. The profiles extend from southeastern Tennessee to the Carolina slate belt in Georgia and show that the thrust sheet attains a maximum thickness of 15 km along this traverse. Sedimentary rocks which are interpreted as shelf sediments extend beneath the Blue Ridge and Inner Piedmont. Their discovery suggests an expansion of hydrocarbon exploration of the eastern thrust belt and perhaps other similar thrust belts. Near the Inner Piedmont-Charlotte belt boundary a transition in reflection character of the sediment layers and deep crust suggests that a major crustal transition was present in this area during the early Paleozoic. Preliminary field data and palinspastic reconstructions imply this transition marks the boundary between continental and oceanic crust of the early Paleozoic. Further profiling to be conducted in the winter of 1979-80 may provide important new information on the nature and extent of the overthrusting.

COOPER, ALAN K., MICHAEL S. MARLOW, an DAVID W. SCHOLL, U.S. Geol. Survey, Menlo Park, CA

Prospective and Future Hydrocarbon Provinces of Bering Sea, South of St. Lawrence Island

The Bering Sea can be divided into three hydrocarbon provinces that coincide approximately with three major geomorphic areas, namely the continental shelf, the slope rise, and the abyssal basin. The significant findings of several recent USGS studies on the regional tectonic framework and hydrocarbon potential of these provinces are summarized.

The shelf province is underlain by a continental platform that is extensionally rifted along its outer edge. Mesozoic rocks form the basement complex and thick Mesozoic(?) and Cenozoic sedimentary sections fill the rift basins. Recent evidence documents (1) several deep sedimentary basins within the shelf province, (2) shallow-water Mesozoic and Cenozoic sedimentary rocks from the continental slope, and (3) confirmation of postulated subsidence along the shelf edge.

The slope-rise province, which includes the marginal Umnak plateau, delineates the deep-water transition from oceanic to continental crustal rocks. In Mesozoic time, oceanic crust may have collided with continental crust beneath this province. At present, thick (6 to 10 km) accumulations of Cenozoic and Mesozoic(?) sedi-