Petroleum Geochemistry and Geology of Southeast Georgia Embayment and Florida-Hatteras Slope

Petroleum geochemical and geologic studies were carried out on the COST GE-1 well (Southeast Georgia Embayment), and on the Atlantic Margin Coring Project (AMCOR) core 6004 on the Florida-Hatteras slope. Mud additives contaminated some of the COST GE-1 samples, but by analyzing several duplicate handpicked sample suites the effect, although not totally removed, was minimized.

In the COST well, the Tertiary shale-chalk-limestone section to a depth of approximately 1,088 m contains very small quantities of indigenous, biogenic hydrocarbons that are not believed to have had a thermal-chemical history. Upper Cretaceous rocks (Maestrichtian, Campanian, Santonian, Coniacian, and Turonian) from 1,088 to 1,814 m consist of gray, calcareous deep-water shales that contain the most organic-rich intervals in the well which are composed of thermally immature, amorphous, hydrogen-rich algal marine kerogens. If these Upper Cretaceous rocks were buried more deeply or found in a region of higher thermal gradient, they could be significant potential oil and gas source rocks. The Lower Cretaceous sedimentary rocks from 1,814 to 2,700 m are dominantly of continental origin with intercalated marine carbonate and sand units that contain very small amounts of terrestrial organic matter (less than 0.1% organic carbon). Although the kerogen in these rocks is of marginal thermal maturity, it promises little as a potential petroleum or natural-gas source.

Sediments in the AMCOR hole 6004 range from Holocene to Upper Cretaceous and are of a predominantly outer shelf–upper slope depositional character. The hydrocarbon and fatty-acid distributions and molecular compositions are typical of marine biogenic sources that are thermally immature with regard to petroleum generation. The organic geochemistry of Paleocene sediments taken from the AMCOR core 6004 may reflect the influence of erosion by the ancestral Gulf Stream.

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Devonian Shale Characterization—Evaluation of Some Significant Exploitation Properties

Hundreds of trillions of cubic feet of natural gas are contained in the Upper Devonian black shales of the Eastern Interior basins. These organically rich (up to 15 wt. %) shales have porosities and permeabilities substantially lower than conventional clastic reservoirs. To exploit this "unconventional" resource, the results of a detailed physiochemical characterization of this shale are being used to obtain the following project goals: assess basin natural gas potential, select basin regions with relatively high potential, and design and/or improve exploration and production techniques. To date, over 500 core and drill cuttings samples are being evaluated. Appalachian, Illinois, and Michigan basin Devonian shales were obtained from eight, six, and one well, respectively, in each basin.

Evaluations of the shale by physical properties, biostratigraphy, and chemical characteristics have shown that the most significant amounts of natural gas have been associated with sediments rich in thermally mature organic matter. This organic matter is characterized as having been deposited in a restricted marine environment where restricted is used in a faunal context—precisely, an unusual environment in which a very restricted faunal assemblage was formed, deposited, and preserved within the sediment. The analyses lead to a determination of whether the organic matter is of the type suitable for optimum gas production.

The lateral and vertical continuity of the hydrocarbon resource is being investigated. The results of this investigation will have a significant impact on assessing the true potential of the Eastern Interior basin as well as aiding basin exploration.

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Lithology Studies of Upper Devonian Well Cuttings in Eastern Kentucky Gas Field

Well cuttings from 14 wells in the Eastern Kentucky gas field, studied under reflected light, permit comparison of lithology changes across the field and between stratigraphic units. Comparison is made with formation density logs, gas production studies, and geochemistry. Such field-study approach, in more detail, is valuable for future exploration and evaluation in production of gas from Upper Devonian shales in this area.

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Inorganic Geochemical Studies of Eastern Kentucky Gas Field and Comparison with Gas Production

The Upper Devonian Ohio Shale sequence, including the Cleveland, Three Lock, and upper, middle, and lower Huron, and the Mississippian Berea-Bedford sequence were studied by using XRF and XRD on 14 well samples from the Eastern Kentucky gas field. Elements studied were Mg, Al, Si, P, K, Ca, Ti, Mn, Fe, S, Cu, Zn, Sr, and Na. Minerals studied were chlorite, illite, gypsum, kaolinite, anhydrite, szomolnokite ($FeSO_4 \times H_2O$), quartz, orthoclase, plagioclase, calcite, dolomite, siderite, pyrite, coquimbite ($Fe_2(SO_4) \times 9H_2O$), and secondary quartz.

The data were studied in terms of average values for the total producing sequence, for the Ohio Shale sequence, and for each stratigraphic unit. Computer-drawn maps, using six contour levels, were compared with final open-flow data patterns from a hand-contour map using 4,750 data points and with maps showing density contours of highly productive wells.

A striking pattern match is shown by comparison of several element and mineral maps with the highly productive well density maps. The predictive value of such an investigation is obvious.

Changes of given elements and minerals, within and between wells, were compared across Eastern Kentucky gas field. The pattern relations are not obvious from graphs, nor from the formation density logs of the wells.

Further refinements of this work are in process. To

date, 72 maps on the elemental analysis have been run and a similar number will be performed on the mineral data.

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How Good are Regional Coal Reserve Figures? Case Study of Winifrede Coal, Boone County, West Virginia

With the increased interest in coal in recent years has come a demand for accurate reserve figures on a regional basis. The tonnage of coal in the area in question is usually all that is considered. This presents a grossly simplified picture, because accuracy is usually implied which may not exist, and much information is not available. With a better understanding of the nature of the raw data and the interpretation process, better use can be made of reserve figures.

To illustrate the process of producing regional coal-reserve figures, recent work of the West Virginia Geological Survey on the Winifrede coal in Boone County was chosen. First, the types of data were considered both from the viewpoint of method of collection and from the viewpoint of value and accuracy. Next, the geologic interpretations, structure, outcrop, cross section, and isopach, were considered. Then the engineering and mining interpretations, percent parting, cover thickness, proximate analysis, sulfur values, mining height, mined area, and reserves, were determined. Finally, economic considerations were overlaid on the geologic and engineering considerations.

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Computer-Aided Graphics for Analysis of Cottageville Field, Jackson County, West Virginia

It has been said that the purpose of computing is insight, not numbers. In the Cottageville field, Jackson County, West Virginia, computer-aided graphics relate structure and stratigraphy to observed gas production. The Akima bivariate interpolation scheme for irregularly distributed data points provides structure and isopach contour maps or perspective three-dimensional surface displays. NCAR (National Center for Atmospheric Research) graphics software is helpful.

Further insight into the Cottageville field is obtained by use of open-flow and production data from the lower Huron Member of the Ohio Shale. These data are converted to graphics quickly displayed on a cathode-ray tube terminal followed by output on a 36-in. (91.4 cm) matrix plotter or a color-microfilm recorder. This method makes it possible to reject or recheck spurious data points or modify previous computations. Correlation using three-dimensional isometric histograms, gray intensity shading, and color blending is useful.

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Fabric-Element-Based Classification for Low-Porosity-Shale Gas Reservoirs

Several hundred shale samples have been characterized by us with respect to mineralogic composition, chemical composition, and petrophysical properties. However, no study based on composition reveals the fabric or manner in which the components are put together to form the resultant rock. Classification by fabric elements, based on X-radiography and direct prints from thin sections, is practical and appears useful for interpretation of both depositional environments and reservoir properties of shale.

Six lithotypes based on fabric elements are defined in Devonian shales of West Virginia: (1) sharply banded shale, (2) thinly laminated shale, (3) lenticularly laminated shale, (4) nonbanded shale, (5) siltstones, and (6) concretions. A gradational series exists from thinly laminated through lenticularly laminated to nonbedded. Thinly laminated and organic-rich lenticularly laminated shales appear the most favorable types for gas productivity because the laminated fabric permits the best lateral continuity of the low porosity (about 2%) present. The higher organic content of these lithotypes also probably acts as sites for significant sorption of gas, which is slowly released during production.

No microfracture system appears to exist, and macroscopic fractures do not necessarily coincide with productive zones. Wells without natural fractures prove productive after stimulation, which suggests that outgassing of a favorable rock type is responsible for the bulk of productive gas in Devonian shale wells. Natural fracture porosity, while important in extending effective volume tapped by a given well, represents only a minor portion of reservoir storage volume.

Thinly laminated shales are interpreted as being generally representative of shallow-marine deposits (dominantly shelf deposits) accumulating under anoxic conditions. Nonbanded and lenticularly laminated shales are deeper water accumulations deposited farther from shore. Sharply banded shales and some siltstones generally represent pulses of more rapid sedimentation in the prodelta environment. A single sample in itself is not diagnostic of depositional environment, but relative abundance of specific lithotypes in a given vertical section is useful for general environmental reconstruction. Better definition of the diagnostic worth of shale fabric-element lithotypes awaits results of more detailed fabric-element studies of modern fine-grained clastics and marine muds.

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Patch Reefs and Interreef Deposits of Silurian McKenzie Formation, West Virginia

Coral-stromatoporoid patch reefs are present in the lower part of the McKenzie Formation of the western West Virginia subsurface. Between these organic buildups is a bedded, argillaceous dolomite with very sparse fauna, and underlying the McKenzie is the Keefer Sandstone which served as the firm substrate on which McKenzie benthic communities became established.