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Diagenesis of Coeymans (Lower Devonian) Patch Reefs, Northern Appalachian Basin

Fourteen Coeymans-age patch reefs and bioherms have been identified along the Silurian-Devonian outcrop belt in northeastern Pennsylvania, northwestern New Jersey, and central New York. Detailed petrographic analysis of samples from five reefs has led to development of a regional diagenetic model.

Diagenetic fabrics show evidence of near-surface conditions that developed in five successive stages. The reconstruction of the diagenetic history of the reefs is as follows: (1) lithologic development of the reef facies, (2) syndepositional infilling by detrital micrite in pores, fractures, and cavities to form geopetal structures, (3) early subaerial emergence in which minor amounts of calcite cement were precipitated in a freshwater vadose environment, (4) a regional transgression that briefly resubmerged the reefs, followed by subaerial exposure, which led to a mixing of fresh and marine pore waters resulting in localized development of silica cements and dolomite precipitation, and (5) continued subaerial exposure of the reefs where large-scale freshwater phreatic conditions resulted in total porosity occlusion by stable low-Mg calcite.

Stage 4 shows the most regional variation in fabrics and conditions. An abundance of various forms of silica has been described in the Coeymans reefs of central New York. These varied forms resulted from fluctuations in pH and salinity. Stage 5 is the most pervasive within the reefs studied. Common phreatic fabrics are syntaxial overgrowths on crinoidal grainstones, drusy calcite rims, and neomorphic spar with crystals coarsening and completely filling the central parts of all remaining pores.

The model developed in this study leads us to infer that Coeymans reefs found in the shallow subsurface would not be favorable hydrocarbon reservoirs. The possibility does exist that localized porosity development occurs in untested reefs within the deeper subsurface portions of the basin.

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Trenton Exploration and Wrenching Tectonics—Michigan Basin and Environs

Hydrocarbon production in the Michigan basin occurs primarily from Silurian pinnacle reefs or Middle Ordovician and Middle Devonian linear, faulted, and dolomitized structures. The writer has previously proposed a wrenching model for the basin based on lineament (fault) patterns from Landsat imagery and outcrop fracture analyses ("ground truth"). The azimuths of existing linear producing fields, whether from Trenton–Black River or younger rocks, closely fit the shear model.

Analyses (x-ray diffraction) of numerous well samples from several producing fields show dolomite/calcite ratios of epigenetically formed dolomite (porous reservoir rock) channelways along vertical shear faults, shear folds, cross faults, cross folds, and stratigraphic permeable offshoots from the fault channelways of the wrenching model. The dolomitizing fluids probably entered the fault channelways from artesian waters from below. If so, basin form would be important to reservoir rock development in this system.

Geophysical exploration for the strike-slip shear faults in nearly horizontal rocks generally has proved elusive, even for accompanying shear folds where they have small amplitudes. The Trenton–Black River Albion-Scipio giant field is shear faulted but not shear folded. Geophysical search for other similar structures has been far from successful.

Thus, "model fitting" in many instances may be the most effective tool. It should be recognized that faults sensed by the reflected infrared of Landsat are open systems, at least near the surface. It is the "unseen" closed system components of the model for which one searches.

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Geologic Framework and Hydrocarbon Evaluation of Devonian and Mississippian Black Shales in Appalachian Basin

The Paleozoic wedge of sedimentary rocks in the Appalachian basin is a repetitive cyclic rock sequence consisting mainly of three alternating rock types—siliciclastics, carbonates, and black shales rich in organic matter. Of the two black-shale sequences in the basin, the upper is the Devonian and Mississippian shales, which have attracted interest as a source of uranium, oil and gas, and pyrolytic oil. Recent geologic studies have defined their regional stratigraphy, distribution, and thickness. These studies have provided the necessary framework for resource evaluations and for geochemical characterizations, including analysis of the chemical structure of the kerogen by ^{13}C nuclear magnetic resonance (NMR). An eastward-thickening sequence of predominantly very fine to fine-grained rocks contains an aggregate thickness of dark shale (rich in organic matter) that ranges from about 15 ft (4.6 m) or less in the south-central part of the basin to about 500 ft (150 m) in the northeastern part of the basin. The average organic-carbon content for the black shales ranges from about 3% in the eastern part of the basin to about 10% in the western part. Regionally, the maturation of the shales increases eastward. Various studies suggest that the Devonian and Mississippian shales west of the Allegheny front have not exceeded the catagenic stage. The ^{13}C NMR determinations of aromaticity of kerogen from selected stratigraphic intervals suggest that a significant amount of the parent organic material was of terrestrial origin. This NMR work corroborates visual evidence such as the presence of coalified plant material and the known initial flourishing of vascular plants in Devonian time. Maturation of shale containing aromatic kerogen derived primarily from vascular plants generated mostly nonassociated "dry" natural gas. Therefore, the composition of the gas in the black shales, whether "wet" or "dry," appears to be more closely related to the kerogen type or degree of aromaticity than to the degree of thermal maturation. The Devonian and Mississippian black shales in the basin are estimated to contain 200-300 mmcf of gas. Recoverable-reserve estimates are highly variable because the source and reservoir rock are one and the same and because the exploitation conditions and techniques vary across the basin.

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Model for Tectonic Deformation of Eastern Stable Interior Crustal Rocks as Interpreted from Overlying Sediments

The Eastern stable interior is characterized by arches, domes, and synclinal basins usually covered by sedimentary layers dating back to the Cambrian. On the basis of data from outcrops and deep tests drilled into or through the sedimentary cover, activity in the underlying crustal (basement) rocks can be interpreted from many of the sedimentary tectonic features created by this movement. Geophysical studies of crustal rocks indicate that as much as 12 km (7.5 mi) of relief exists at their base and that there is layering within the crust. Since Precambrian time, new crust, probably supplied by a stationary hot spot in the asthenosphere as continental drift shifted the overlying plate, created uplift of features such as the La Salle anticlinal belt, while dense crustal layers subsided to create riftlike grabens. During periods of plate collision or very rapid drift, the mantle and crust were decoupled; this action produced an upward vector of thrust against downward crustal bulges, and arches and domes responded by uplift. Platewide unconformities developed during the decoupled movement of crust and mantle. The sedimentary rocks record the time and nature of the activity.

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Environments of Deposition in Medina Group in Western New York

The basal Silurian Medina Group including the Whirlpool Sandstone, Power Glen Shale, Grimsby Sandstone, and Thorold Sandstone was studied in the outcrop belt along the Niagara escarpment from St. Catharines, Ontario, east to Rochester, New York. These formations represent facies changes in a wave-dominated environment.

The Whirlpool Sandstone and Power Glen Shale are a transgression succession of shoreface to delta-front sediments. Regression followed with deposition of the Grimsby Sandstone in lower to upper delta-plain environments.

The Whirlpool Sandstone contains lower shoreface, upper shoreface, and foreshore deposits. These deposits are clean, well-sorted white orthoquartzites. The overlying Power Glen Shale, deposited in a delta-front environment, contains numerous lenses of storm-deposited, hummocky, cross-stratified, fine-grained sandstone; scattered colonies of crinoids and starfish; and thin lenses of limestone. The Grimsby Sandstone overlies the Power Glen Shale. It is composed primarily of red sand and siltstone deposited in foreshore to upper delta-plain environments. The foreshore sediments in the Grimsby are generally clean, white, and well-sorted because clay and silt-size particles were winnowed by wave processes.

The foreshore deposits of the Whirlpool and Grimsby Sandstones contain the cleanest, best sorted sands in the Medina Group, and possess the greatest primary intergranular porosity. Although primary porosity in the Medina has been largely obliterated by quartz overgrowths, these foreshore deposits offer good potential for porosity development and provide gas reservoirs in the Medina Group.

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Rocky Gap Sandstone and Huntersville Formation—Potential Hydrocarbon Reservoirs of Southwestern Virginia

In southwestern Virginia, west of New River and east of East Stone Gap, the Lower Devonian Rocky Gap Sandstone and Huntersville Formation have the best potential as hydrocarbon reservoirs. Both units have a large areal extent and a combined thickness locally exceeding 150 ft (45 m).

In outcrops formed by the present erosional cycle, the Rocky Gap Sandstone is a poorly indurated and friable sandstone. Secondary porosity could have formed also by leaching during erosional cycles both before and after deposition of the Oriskany Sandstone. Combined with primary and fracture porosity, the Rocky Gap Sandstone appears to have good reservoir potential.

All of the exposures of the Huntersville Chert are fractured. The thrust faulting of southwestern Virginia could have led to the development of significant fracture permeability and porosity in the subsurface. Like the Huntersville Chert in West Virginia, the unit could become an important gas producer in southwestern Virginia.

Both the Tonoloway Limestone and the Millboro Shale are excellent source beds for hydrocarbons. In western counties, the Onondaga Limestone also smells highly petroliferous after fracturing. Conodont color alteration index (CAI) maps of Silurian through Middle Devonian rocks in the Appalachian basin indicate that the rocks are above the upper limit of thermal maturity for gas.

Unconformities throughout the area have the potential for stratigraphic traps. More detailed seismic surveys of the area can help to define structural and stratigraphic traps that are capped by the Millboro-Chattanooga Shale.

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Silica Cement Source and Porosity Preservation for Ohio's Lower Silurian Sandstones

The Lower Silurian sandstone sequence of Ohio is comprised of sandstone, siltstone, and shale, commonly recognized as three more-or-less distinct informal subunits. The lowermost is called white Clinton, the intermediate is red Clinton, and the uppermost is stray Clinton. These subunits have been correlated by others, respectively, as the Cabot Head Shale, the Grimsby Sandstone, and the Thorold Sandstone of western New York. The sandstones and siltstones are generally tight and highly cemented by pervasive secondary silica. Original depositional clay was probably mixed-layer illite-smectite which, as indicated by x-ray diffraction, was transformed to the present discrete illite and very minor iron-chlorite. Remnant expandable illite-smectite is present as less than 5% total clay. The released silica of this transformation probably provided much, if not most, of the silica cement. The remnant mixed-layer illite-smectite occurs within the sandstones where apparently it was preserved by the protective framework of detrital sand grains. Other probable minor sources of silica cement were pressure solution of original quartz grains and dissolution of allogenic feldspar, as exhibited in this section and by scanning electron microscopy. Porosity increase toward the middle of some sandstone intervals suggests migration of silica from transformed overlying and underlying shales. Porosity was preserved, in part, by collophane grain coatings inhibiting authigenic silica growth, as exhibited by petrography and scanning electron microscopy, and by clay overgrowths, as demonstrated in earlier study.

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Computer Mapping of Coal-Quality Data in West Virginia—an Aid in Finding the Right Coal for an Application

In 1907, the first studies of the state's coal reserves were initiated as part of the West Virginia Geological and Economic Survey's statewide geological mapping program. Since then, extensive work has been conducted to map and characterize the state's minable seams. This effort has shown that the coals exhibit a wide diversity of quality, and this diversity provides the coal user a choice of grades to meet specifications for varied applications.

Approximately 6,000 coal samples have been analyzed, and a computer data base of coal-quality information is now maintained and continues to grow. An extensive mapping project makes this information convenient to use.

The objective of coal-quality mapping is to produce a series of contour maps showing the variations in quality for West Virginia coal. Parameters being mapped include sulfur, ash, Btu, fuel ratio, Hardgrove grindability, volatile matter, fixed carbon, and kilocalories per kilogram. This type of information is extremely valuable for someone interested in buying, selling, evaluating, or developing West Virginia coal.

The maps are computer-generated at a scale of 1:500,000 and show the trends of quality in the state's coal measures. From these maps, a "target area" map can be prepared. (A target area is a particular geographic area where coals meeting a user's specifications are likely to be found. Target areas change in size, shape, and location as the coal specifications change.)

These maps are supplemented further by two computer-generated products. One is a "target point" map. (A target point is a specific point-location where coal meeting the required specifications has been sampled.) The other computer product is a list of seams and geographic areas within the state in which coal that meets the desired specifications has been sampled.

These computer techniques provide a statewide overview and quickly show areas in West Virginia that match the right coal to the desired end-use.

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Gas Reserves in Medina Group of Northwestern Pennsylvania as Related to Fracture-Porosity and Stratigraphic Control

Gas reserves in the Medina Group of northwestern Pennsylvania were investigated for fracture-porosity and stratigraphic control with remote sensing and geophysical tools. Lineaments were mapped on Landsat MSS band 7 (scale 1:250,000), and RBV (scales 1:125,000 and 1:500,000) images, and low-altitude photographs (scale 1:20,000). Zones of high estimated-net gas reserves were noted along French Creek, between Meadville and Franklin, Pennsylvania. A lineament, which bisects the French Creek lineament and is oriented N55°E, also parallels and overlaps gas-pool trends. The largest gas pool underlies an area devoid of lineaments mapped on Landsat imagery.

The dominant lineament orientations measured from the high- and low-altitude imagery coincide when compiled for the entire study area. This relationship is not evident for individual 7.5′ quadrangles. Coal cleat orientations, available in the New Lebanon, Sandy Lake, and Kennerdell quadrangles, are not parallel with the dominant lineament orientations. Joint orientations, available in the Meadville quadrangle, coincide with dominant lineament orientations in the area.

The gamma-ray log was used to establish stratigraphic parameters and to approximate lithologies. Sandstones were subdivided into "qualities" representing degrees of shaliness. Other variables derived from this log with respect to the Medina Group include: depth below sea level, formation thickness, net-sandstone thickness, and Cabot Head Shale thickness. The Whirlpool Sandstone Member was not included in this analysis. No statistical correlation was found between the above variables and estimated-net gas reserves. Visual inspection reveals trends common to the isopach maps and estimated-net gas reserves. Thus, stratigraphic control probably is important to hydrocarbon-pool location and geometry, with the proper combination of variables yet to be identified.