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Trenton Group of New York State

The carbonate bank deposits of New York state's Trenton Group have been studied for nearly 150 yr. Curiously, it has been only recently that the facies patterns of the unit have been recognized. These facies patterns reveal that Trentonian epeirogeny was closely related to the regional inversions of topography that occurred at the beginnings of the Vermontian and Hudson Valley phases of the Taconic orogeny that was occurring in nearby New England. Each inversion resulted in a subsidence of the Trenton platform and an abrupt westward migration of the black shale facies derived from uplifting source lands.

Trentonian deposition began with the Vermontian phase. Carbonate-producing seas flooded onto a subsiding New York. The Napanee, Kings Falls, Sugar River, and lower Denley Limestones represent that transgression. At the same time, the shale facies migrated westward as far as Utica.

During the middle Trentonian, downwarping slowed markedly. Deposition was rapid enough to produce a shallowing facies pattern in the upper Denley and lower Steuben Limestones. During this time, the shale facies made no further westward advance.

The Hudson Valley phase began with a second, more intense, topographic inversion that would end Trentonian deposition. The upper Steuben and Hillier Limestones record a rapid subsidence. A brief, but puzzling, unconformity overlies the Trenton Group. Then, a final westward migration of the clastic facies buried the Trenton platform.

Thus, the upper and lower Trentonian strata were deposited in remarkably similar tectonic settings. The Vermontian phase initiated Trentonian deposition; the Hudson Valley phase brought that carbonate deposition to a close.

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Petrographic Characterization of Coals in Kozlu and Kilic Formations (Westphalian A), Zonguldak, Turkey

The Zonguldak coal region is about 130 km (80 mi) long and 30-50 km (18-31 mi) wide and is situated on the southwest coast of the Black Sea. The basin is the main bituminous coal-producing region of Turkey. It has a complicated faulted structure.

The Carboniferous of the Zonguldak region consists of three natural divisions: Alacaagzi (Namurian), Kozlu and Kilic (Westphalian A), and Karadon (Westphalian B, C, and D). The main concern of this study is the Kozlu and Kilic Formations, which have about 31 coal seams with a total thickness of 45 m (150 ft) of coal.

Estimated bituminous coal reserves in Turkey are 1.3 billion MT; about 5 million MT are produced each year and are used mainly for steel making. The coals have a high volatile and ash content. They are high volatile bituminous coals by the ASTM (American Society for Testing Materials) classification.

The coals show semi-bright luster and very fine banding. Clarain, fusain, and durain are common lithotypes; the predominant lithotype is vitrinous clarain. Few thick vitrain bands are present. Some Turkish bituminous coals contain a very high percentage of mineral matter. Clay minerals, pyrite, and calcite are the most common.

Ninety polished samples were taken from three different locations—Karadon, Uzulmez, and Kozlu—and analyzed under a reflected light microscope with oil immersion objectives.

The Turkish bituminous coals exhibit a complex combination of macerals and microlithotypes. Vitrinite is the most abundant maceral type, and exinite is the least abundant. The presence of a high amount of inertinite macerals and duroclarite as well as virtinertite microlithotypes suggests a lacustrine depositional environment for the coals. Successive coal seams, or even a single coal seam, indicate transgressions and regressions. Turkish bituminous coals match the properties of the Pictou coalfield coals in Canada and the Gondwana coals of South Africa, India, and Australia.

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Hydrocarbon Entrapment in Trenton of Southern Ontario

Middle Ordovician Trenton strata in southern Ontario are represented by a generally transgressive sequence that reflects a wide spectrum of carbonate environments from tidal flat, through lagoon and shoal, into deeper shelf carbonates. The Trenton conformably overlies the shallow water carbonates of the Black River and is unconformably overlain by the gray-black noncalcareous shales of the Blue Mountain Formation.

Virtually all Ordovician production in Ontario is associated with structural deformation related to rejuvenation of a Precambrian fracture framework triggered by orogenic events in the nearby Appalachian orogene. The reservoirs are characterized by the replacement of original bioclastic limestone beds by more or less discontinuous lenses of fine to medium-grained, light to medium-brown crystalline dolostone. Pools generally are linear, following the trend of the associated fracture.

Six of the 18 known Ordovician pools in Ontario are located in Essex County. A detailed study of the geology and reservoirs confirmed the close association of fracturing, dolomitization, and hydrocarbon entrapment. Representative samples of well cuttings from 20 wells were analyzed by XRD (x-ray defraction) to determine calcite-dolomite ratios. As expected, low ratios were present in the producing reservoirs. Partially dolomitized zones were revealed in wells in close proximity to fractures. Formation water originating in the underlying Cambrian sandstones was probably the main dolomitizing agent as it migrated up through the fracture. Dolomitization enhanced already existing porosity within the bioclastic zones.

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Nature of Petrographic Variation in Taylor-Copland Coal of Middle Pennsylvanian Breathitt Formation of Eastern Kentucky

The Taylor-Copland Coal is petrographically distinctive in that it has lowest average vitrinite content (63%) and concomitant highest inertinite (25%) and exinite (12%) of all eastern Kentucky coals. Additionally, average total sulfur is 3.4%, or nearly twice the 1.8% figure determined for all eastern Kentucky samples. Deviations from the maceral averages are equally distinctive. Particularly interesting is an areally extensive, though discontinuous, sample sequence showing significantly lower vitrinites (commonly 40%), very high inertinites (40%), and high exinite content (15-20%). This "high inertinite" trend is traceable over an east-west linear distance of at least 20 mi (32 km), is occasionally interrupted along trend by samples having higher than average vitrinite, and probably disappears completely southward where coals with high vitrinite–lower inertinite contents prevail.

The high-inertinite and high total-sulfur trends and variations for each were presumed to be related to proximity to the coal of marine lithologic units of the overlying Magoffin Member. However, it was found that maceral and possible sulfur trends are probably unrelated to roof rock variation, but are related to existence or absence of a thick durain coal lithotype toward the middle of some coal beds. When present, the durain is commonly interspersed with fusain and/or pyrite bands or lenses, and is microscopically observed to be enriched in inertinite-exinite.

Palynology reveals that spores in the durain-rich samples are poorly preserved (micrinitized), but assemblages and relative percentages of genera forming the assemblages remained unchanged from those found in high-vitrinite (durain-free) samples. Unchanged spore assemblages possibly indicate that unchanging plant communities existed through the durain-forming episode of the Taylor-Copland swamp. Rather, the effect of the durain phase on the Taylor-Copland swamp was to accelerate degradation (oxidation) of peat deposits associated with the surrounding plant community. The durain deposit is thought to have accumulated within an encroaching brackish-marine water system. This influx may have represented an early, short-lived pulse of the same advancing marine system that ultimately produced the extensive overlying Magoffin deposits.

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Application of Vitrinite Reflectance to Interpret Gas Content, Maximum Depth of Burial, and Paleogeothermal Gradient of Coal Beds in Dunkard Basin

A thorough understanding of the interrelationship of the geologic history, thermal maturation, and petrographic characteristics of a coal bed is necessary to interpret its present methane content. Coalification of organic matter occurs contemporaneously with burial through the interaction of temperature and pressure during geologic time. In initial stages of coalification, pressure is an important factor in volume, pore, and moisture reduction. In later stages of coalification, temperature and duration of heating are more significant. During this period, methane and other gases are generated as coalification by-products. The degree of coalification, referred to as rank or thermal maturity, is commonly measured by vitrinite reflectance. This value has been used by the Bureau of Mines to determine the rank of Permian and Pennsylvanian coal beds from several boreholes in southwestern Pennsylvania. From these values, estimates of former depths of burial and coalification temperatures may be made. Owing to the discontinuous nature of the Permian coal beds, detailed lithologic correlation of noncoal marker units was necessary to ensure that the coal bed reflectance values were placed in proper stratigraphic sequence. The thermal maturity, as indicated by vitrinite reflectance, was found to relate directly to by-product gas content.

The average vitrinite reflectance gradient of all the bore holes is 0.10%/100 m (320 ft), which corresponds to gradients measured for the Rocky Mountain Foothills of Canada. An estimate of the paleogeothermal gradient for the study area, using the Karweil nomogram to appraise the paleotemperatures of the coal beds, indicates a significantly higher gradient than that proposed earlier. The former maximum depth of burial for these coal beds, based on the estimated paleogeothermal gradient, would be 1.2-1.5 km (0.7-0.9 mi).

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Stratigraphy and Structure of Clinton Section in Wayne County, Ohio

The Clinton section in Wayne County represents a clastic wedge of the Lower Silurian Albian Group. It was deposited on the distal flank of the Appalachian basin as a result of the Taconic orogeny. The section extends vertically from the Queenston unconformity to the base of the Packer shell (Brassfield Limestone). It is primarily composed of sandstone, shale, limestone, and dolostone. Within this stratigraphic section, the sandstone facies is an important hydrocarbon reservoir rock. The sandstone facies pinches out laterally along a north-south depositional limit that is roughly located along the western boundary of Wayne County.

The study relied primarily on geophysical log data. However, drill cuttings were used to correlate lithologies to specific curve assemblages on the geophysical logs. This helped define lithologies to logs in areas where drill cuttings were lacking. Eight cross sections—four north-south and four east-west—show the complexity of the intertonguing clastic and carbonate deposits resulting from the progradation and shifting of deltaic and nearshore marine environments. The cross sections also show that the driller's terms of stray, red (1st), and white (2nd) Clinton sandstone are arbitrary units and are not temporally equivalent or correlative from well to well over great distances.

Stratigraphic interpretations indicate that the deposition of the Clinton section began with a marine transgression from the northwest across a subaerially exposed coastal plain that was deposited as the distal end of the Ordovician Queenston delta. This transgression reworked the upper Queenston sediments and redeposited them as calcareous silts and sands. Renewed uplift of the Taconic highlands caused a clastic influx into the areas and a relative regression of the sea. These sediments were deposited in prodeltaic and lower delta-plain environments. Some of the sediments were reworked offshore by ocean currents and wave action and redeposited as offshore bars. As the influx of Taconic sediment ended, muds were deposited, which were eventually transgressed by a carbonate-rich sea. A limestone unit, the Packer Shell, was then deposited ending the Alexandrian Epoch.

The structural setting is one of homoclinal dip to the southeast, with localized basement-controlled, minor folds normal to the basinal axis. Small-scale faulting can also be seen on structure maps of the base of the Packer Shell and the top of the Queenston. Local structural highs and faults affect oil and gas production in this mainly stratigraphic trap. Local structure commonly segregates the oil and gas in the same reservoir body.

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High Fluid-Inclusion Homogenization Temperatures in Carbonates of Lower Ordovician Beekmantown Group in Northern Appalachian Basin

Data from analysis of fluid inclusions in carbonates of the northern Appalachian basin indicate higher paleotemperatures and greater depths of burial than have been inferred for the rocks of this region.

Preliminary research has revealed fluid homogenization temperatures averaging 96°C (205°F) for the formation of saddle dolomite, 114°C-170°C (237°F-338°F) for calcite vein fillings, and 290°C (554°F) for calcite cements in samples from the Mohawk and Champlain valleys of New York state.

The calcite-filled veins sampled in the Champlain valley of eastern New York display higher average homogenization temperatures than similar veins from the Mohawk valley of central New York. This difference may reflect a higher post-Early Ordovician paleogeothermal gradient operative in eastern New York.

Drusy calcite cements in samples from central New York are interpreted as precipitates from saline brines having temperatures between 267°C (512°F) and 302°C (576°F). These temperatures support conodont alteration data obtained by others for the rocks of this area.

Using a geothermal gradient of 25°C/km (72°F/mi), a former depth of burial in excess of 9 km (5.6 mi) is implied. Seismic and gravity data do not show evidence of the presence of post-Early Ordovician shallow plutons. Therefore, it appears unlikely that precipitation at the high temperatures measured resulted from magma-derived hot meteoric fluids.

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Oriskany Sandstone Lithofacies, Paleoenvironment, and Fracture Porosity in Somerset County, Pennsylvania

The Lower Devonian Oriskany (Ridgeley) Sandstone is an important deep exploration target in the Appalachian basin. In outcrop, the Oriskany is typically a calcareous quartzarenite with few discernible lithologic variations. Petrographic examination of two drill cores of the Oriskany–Needmore Shale interval from south-central Somerset County indicates that identifiable lithofacies of the upper Oriskany Sandstone exist in the subsurface. Oriskany lithofacies are defined as silica-cemented quartzarenite, sandy biosparite, calcareous-cemented quartz wacke, and coquinoid calcareous-cemented quartzarenite. These lithofacies are interpreted as depositional features of a shallow marine sand-bar complex, corresponding to central-bar, bar-margin, interbar, and storm-generated sheet-sand (tempestite) depositional units. Paleoenvironmental interpretations are supported by diagnostic trace-fossil assemblages and coarsening-upward grain size trends indicative of vertically stacked marine bars. Correlation of gamma-ray logs from Oriskany wells across Somerset County suggests that these marine bars are laterally discontinuous and may change abruptly in thickness over relatively short distances. The basinal Needmore Shale overlies the Oriskany in this area, indicating a deepening of the depositional setting after Oriskany deposition.

Although vertically oriented fractures were observed in all the Oriskany lithofacies and Needmore Shale, most of the fractures are healed by secondary calcite. Fracture porosity occurs primarily in the silica-cemented quartzarenite lithofacies, or central-bar paleoenvironmental unit. The quartzarenite lithofacies is recognizable on gamma-ray logs by its blocky, low API unit signature at the top of sequences that exhibit a downward increase in shale content. As the presence of fracture porosity is important in Oriskany natural gas production in this region, central-bar units are primary targets for exploration.

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Geology of Trenton Limestone (Middle Ordovician) of Northwestern Ohio

The Middle Ordovician Trenton Limestone has produced over 350 million bbl of oil and an unestimable amount of gas from reservoirs in north-