ville clastics, fracture porosity and thick delta front sandstone development combine in the more eastern outcrop belts to increase the potential for a hydrocarbon reservoir in the Clearville siltstone.

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Paleomagnetism of Late Ordovician Neda Iron Ore from Wisconsin and Late Ordovician Queenston Shale from New York

The Neda iron formation is a hematite and goethite-rich oolitic ore which occurs in lens-shaped deposits on top of the Maquoketa Shale at only a few locations in the Wisconsin area. Its origin has been a puzzle for over a hundred years, but there have been suggestions that it is the westernmost extension of the Queenston Shale. Paleomagnetic studies were undertaken to see if paleopole directions from the two formations could aid in determining the origin of the Neda.

Thermal demagnetization of the Neda samples indicates the remanence is carried by hematite. Chemical demagnetization suggests the remanence is produced by the interstitial material rather than the oolites. The paleopole from 25 samples is at S 45.4°, W 48° (α 95 = 16°). This pole position is similar to Late Mississippian to Early Permian of North America rather than Late Ordovician. This suggests that the hematite in the ore was produced from dehydration of goethite during Late Mississippian time.

Queenston Shale samples from western New York were similarly measured. Thermal demagnetization indicates the remanence is carried by hematite and the pole position from 8 samples is at S 45°, W 38° (α 95 = 10°). This pole position is very similar to that of the Neda. This indicates that both formations were presumably subjected to the same post-depositional chemical changes in the late Paleozoic, but it does not conclusively show that the Neda is in fact the western extension of the Queenston. This late Paleozoic pole position has been found in almost all red sediments of Ordovician age in North America, both folded and nonfolded, which suggests that the remanence is not simply due to deformation produced by the Appalachian orogeny.

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A Local Deep Water Basin and Shoreline Model for Middle Devonian Ludlowville Formation of New York

In the Seneca Lake region, both the Ledyard and Wanakah members of the Middle Devonian Ludlowville formation have a black shale facies. This grades westward to a gray shale facies and eastward to a gray shale and siltstone facies. The black shale facies represents an anoxic basin of deeper water than the shallower water gray shale facies to the east and west. The axis of this basin trends northeast-southwest.

The Ludlowville formation from Lake Erie to the Genesee Valley has many thin argillaceous limestone beds, 1 to 4 in. (3 to 10 cm), that are useful for detailed correlation. Because these thin beds can be traced as far as 43 mi (70 km), this part of the outcrop belt probably parallels an ancient east-west shoreline. Between Genesee Valley and Seneca Lake, the inferred shoreline turns to a northeast direction parallel to the axis of the basin, and bedrock exposures display a barren, black shale facies. In these exposures the thin beds disappear. From Seneca Lake to Owasco Lake, the deeper water, black shale facies gives way to shallower water, gray shale facies with thin traceable beds. Because the thin beds disappear in the basin exposures, it becomes difficult to correlate the detailed stratigraphy of the western beds across the basin with the eastern beds. Some correlations have been made using ammonoids. The inferred northeast-trending shoreline may have circumscribed the northern end of this basin, and then turned southward to become part of the southwest-trending shoreline in eastern New York.

This basin first appeared during the deposition of the Early Devonian Helderberg Group and persisted during the deposition of the Middle Devonian Onondaga Limestone and Hamilton Group. Throughout this period, the basin axis shifted from eastern to western New York. This basin has already proven to be of economic importance as a gas producer from the Onondaga reefs that occur on its margin, and may provide other areas of economic importance.

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Brachiopod Community Paleoecology, Paleobiogeography, and Depositional Topography of Devonian Onondaga Limestone in Eastern North America

The lower Middle Devonian Onondaga Limestone was deposited in a northwest-southeast elongated topographic basin and on the surrounding carbonate platform. Two sedimentary cycles are present in the Onondaga. The Edgecliff represents a transgression which spread epeiric seas over much of eastern North America. During the Nedrow-Lucas regression, the interior of the platform became restricted resulting in the deposition of evaporites. The Moorehouse transgression continued through the deposition of the Tioga Bentonite, followed by pre-Speeds-Dundee regression from the craton.

Onondaga brachiopod communities, arranged from nearshore to offshore, include the Atrypid-*Megakozlowskiella*, Atrypid-*Levenea*, Chonetid, *Atlanticocoelia*, Ambocoeliid, and *Truncalosia* communities. The Onondaga-age Eastern Americas Realm is divided into the Appohimchi province in the Appalachian basin and the Michigan basin-Hudson Bay Lowland province in the midwest. The provincial assignment of the James Bay region of Ontario is uncertain; the eastern townships of Quebec are near the boundaries both of the two provinces of the Eastern Americas Realm, and of the Eastern Americas Realm and the Old World Realm.

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Stratigraphic Correlation of Planktonic and Larger Foraminiferal Zones

A very few areas of the sedimentary basins of the world are characterized by marine facies of clastic and non-clastic origin, which are rich in planktonic and larger foraminiferal assemblages. Pakistan is one of the countries where the Tertiary marine deposits (Paleocene to Miocene) are represented by both clastic and non-clastic facies characterized by stratigraphically restricted planktonic and larger foraminiferal species, which provide the basis for the interregional biostratigraphic correlation.

The marine clastic deposits of Paleocene to Miocene age in the Lower Indus and Baluchistan basins of Pakistan are rich in the planktonic assemblages. On the basis of the stratigraphically restricted species, 22 planktonic foraminiferal zones were delineated to mark the stratigraphic boundary of the various European stages (Kureshy, 1977). The non-clastic marine deposits of Paleocene to early Miocene age in the Lower Indus and Upper Indus basins of Pakistan, which are interbedded with clastic deposits, are rich in larger foraminifera. On the basis of the stratigraphically restricted species, ten biostratigraphic zones of the larger foraminifera are designated (Kureshy, 1978).

These assemblages are cosmopolitan in occurrence of identical geological ages. The planktonic foraminiferal zones are more widespread and have close resemblance to the Caribbean region, as compared to larger foraminiferal zones. The larger foraminifera of Pakistan have no resemblance to the Caribbean region; however, they closely resemble Middle East and Indo-Pacific regions. The planktonic and larger foraminiferal zones are correlated, and datum planes are designated. These zones are correlated to Blow (1969) and van der Vlerk (1927) Letter Stage Classification for interregional correlation.

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Could Middle Ordovician Carbonate Shelf Depositional Patterns in Appalachian Orogene Indicate Collision Along an Irregular Continental Margin?

Analysis of Lower to Middle Ordovician carbonate successions and the conodonts they contain from Tennessee to New York show that (1) in the northern Great Valley, strike-parallel disconformable contacts occur between Lower and Middle Ordovician and within Middle Ordovician carbonate units, (2) apparent maximum extent of unconformities along tectonic promontories, and (3) relatively rapid subsidence and transgression at promontories. Diachronous early Paleozoic collisional events at an irregular continental margin might explain these observations. Initial Taconic collisions may have occurred at the Virginia promontory resulting in uplift and erosion of the Knox/Beekmantown shelf in Whiterockian time followed by rapid subsidence and transgression. Uplift and erosion, possibly related to continued convergence migrated southwest and at least as far northeast as Lexington, Virginia; beyond Lexington, shelf deposition continued relatively uninterrupted on the east side of the Great Valley. Collision at the New York Promontory could have produced the two pre-Blackriverian and pre-Rocklandian Middle Ordovician intervals of uplift and erosion on the Beekmantown shelf. These unconformities are greatest near Newburgh, New York, and decrease in magnitude northeastward and southwestward. West of Reading, Pennsylvania, in the Great Valley, carbonate shelf deposition remained virtually continuous. Thus between Reading and Lexington, in the Pennsylvania reentrant, continuous deposition during early Paleozoic collisions suggests that an irregular outline of the continental margin may have controlled patterns of sedimentation during collision tectonics.

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Sedimentation on a Passive Continental Margin (Late Cambrian-Early Ordovician), Central Appalachians

Environmental reconstruction of rocks of the Richmond slice, the tectonically highest slice at the eastern end of the Hamburg klippe in Pennsylvania, indicates that these rocks were deposited on a northwest-facing passive continental margin in Late Cambrian to Early Ordovician time. Detailed sedimentologic studies suggest that they can be divided into four main lithologic types, each bearing the imprint of one or more processes involved in its deposition. These include: (1) thin to thick-bedded, massive to graded, parallel and cross-laminated grainstone or calcarenite (high density turbidity currents; fluidized flows); (2) thin to medium-bedded, massive to structureless, graded and cross-laminated black lime mudstone and wackestone rhythmically interbedded with very thin to thin-bedded black limy mudstone and shale (low density turbidity currents and suspension); (3) thinly laminated graphitic black shale interlayered with irregular (lag) concentrations of fine sand and silt (redistribution of sediment by bottom currents); and (4) very thick-bedded, sand-matrix carbonate-clast conglomerate (gravelly high density turbidity currents and cohesive debris flows). The proposed depositional processes form a continuum of mechanisms that were in operation in the slope environment.

Regional stratigraphic studies suggest that the carbonate rocks of the Richmond slice were deposited on a depositional margin or ramp characterized by a gentle slope (1 to 2°) that decreased in gradient basinward. Only the lower slope portion of the continental margin has been preserved.

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Diagenesis and Secondary Porosity in Medina Reservoir Sandstones, Athens and Geneva Fields, Crawford County, Pennsylvania

Lower Silurian Medina Group reservoir rocks at Athens and Geneva fields in Crawford County, Pennsylvania, consist of very fine-, fine-, and medium-grained red and gray sandstones. The sandstones were deposited as bars and tidal deltas in a transitional marine setting. The sandstones produce gas from depths of 4,650 to 5,000 ft (1,395 to 1,500 m). The productive intervals are characterized by low average porosity and permeability (4.0% and <0.1 md) and low reserves.

Petrographic analyses show that primary porosity was extensively reduced during burial diagenesis by the precipitation of quartz and feldspar overgrowths. This stage of chemical compaction resulted in the reduction of intergranular porosity to irreducible lamellar porosity in the very fine to fine-grained intervals. These intervals also functioned as an extra stratal source of dissolved silica which precipitated as pore-filling cement in adjacent medium-grained intervals. Silica cementation was followed by the formation of authigenic clays, which diminished any remaining effective intergranular porosity.

Secondary porosity developed after deep burial. A variety of secondary sandstone pore textures are present in the Medina reservoirs at Athens and Geneva fields. Fracturing and grain shrinkage, coupled with remaining lamellar porosity, provided adequate passage for leaching brines formed during the generation of hydrocarbons in the adjacent shales. Additional secondary porosity formed through dissolution of sedimentary material and authigenic cement. Dissolution is evidenced by oversized and elongate pores, corroded grain margins, inhomogeneous packing, and microporosity within individual grains and cement. Some secondary porosity was subsequently reduced by the precipitation of carbonate and anhydrite cements concomitant with the entrapment of hydrocarbons. Secondary porosity was further reduced by grain alteration in the feldspathic intervals, as evidenced by a well-developed replacement fabric in these zones.

Adequate porosity for commercial production is found where the sandstones have the highest secondary porosities as determined by petrographic examination. Optimum reservoir development occurs where late-stage cementation by carbonate, anhydrite, and alteration product clays has not been extensive.

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Minnehaha Member of Upper Devonian Brallier and Scherr Formations of Central Appalachians

The Minnehaha member of the Upper Devonian Brallier and Scherr formations has been informally named, and its use as a time band within the marine strata of the Devonian Catskill delta complex of the central Appalachians is suggested. The coarse clastic bundle of the Minnehaha member can be identified in both outcrop and subsurface for approximately 150 mi (235 km) along the Allegheney Front from Bedford County, Pennsylvania, to Greenbrier County, West Virginia. The Minnehaha member is 20.9 to 98.4 ft (6.37 to 30.0 m) thick, consisting of interbedded very thinly to thickly bedded medium-gray siltstones and olive gray shales, with some grayish-red siltstones and shales.

The Minnehaha member was deposited by turbidity currents in generally unchanneled suprafan environments during the earliest Cohocton Stage. Three major, time persistent, depositional systems are recognized as having contributed to the Minnehaha member.