regional geometry of this rock sequence, vertical and lateral changes in lithology, and the presence and nature of several unconformities.

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Depositional Systems of Clinton Sandstone and Petroleum Exploration, Guernsey County, Ohio

The Lower Silurian Clinton Sandstone is the most commonly drilled formation in eastern Ohio. Successful exploration for subtle stratigraphic traps requires detailed knowledge of Clinton depositional systems. Two highly constructive cratonic delta systems (Claysville and Salt Fork deltas) are present in Guernsey County, Ohio. These deltas are typical of the small deltaic complexes present along the eastern margin of the Clinton-Medina production trend. Production from these deltaic deposits occurs in multistory and laterally discontinuous sandstone bodies deposited as distributary mouth bars, distributary channel fill, and delta-plain point bars. Criteria used to define depositional environments and patterns include: (1) sandstone isopach maps, (2) gamma-ray log cross sections, (3) log signature, and (4) slice isopach maps. Environmental interpretations are augmented by examination of two cores and thin sections. The three types of sandstone deposits are interrelated in a predictable manner and each has a unique isopach pattern, log signature, and production characteristics. Distributary mouth bar deposits are the most common reservoirs, and are characterized by coarsening-upward log signatures and elongate isopach patterns. Distributary channel-fill deposits are the most prolific reservoirs, and have eroded into underlying mouth-bar deposits. They are characterized by blocky log signatures and linear, narrow isopach patterns. Meander point-bar deposits have fining-upward log signatures and an ovoid to kidney-shaped isopach pattern. These methods and results provide a visualization of paleogeography and sedimentologic processes that should be used as a guide for development of and exploration for the Clinton Sandstone.

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Influence of Depositional Environment on Type and Probability of Encountering Coal-Bed Discontinuities

Predictive models that characterize coal bed discontinuities enable mine operators to be better judges of the size, geometry, and influence of these features in unmined portions of the coal bed. An analysis of depositional environments in initial geologic studies of prospective mine properties will indicate the specific types of coal bed discontinuities that can be anticipated.

The type of coal bed discontinuity and the frequency of occurrence are functions of the depositional environment. Peat, the precursor of coal, accumulated in swamps that may form on fluvial plains, on delta plains, and in littoral areas. Using generalized depositional models for these environments, the types of coal bed discontinuities that can be expected and an estimate of the likelihood of their occurrence can be determined. Coal beds deposited on fluvial plains generally are thin, erratic, and discontinuous because of the highly oxidizing character of this environment. Discontinuities due to irregular topography and fluvial channel activity are common, as displayed by Upper Pennsylvanian and Permian coal beds of the Dunkard basin. Coal beds formed in deltaic settings are generally thick and laterally extensive, as they commonly infill broad interdistributary areas. These coal beds are typically plagued by discontinuities associated with distributary channels (e.g., avulsion, splays). The Freeport and Kittanning coal beds in west-central Pennsylvania demonstrate features characteristic of delta-plain coals and the discontinuities that beset them. Coal beds deposited landward of barrier bar sequences generally are irregular and are interrupted by tidal channels and washover deposits. The Pocahontas 3 coal bed of southern West Virginia exhibits many of the characteristics of this paralic setting. Although some clastic dikes may be depositionally related, such discontinuities, as well as faulting, may be overprinted by tectonic activity on coal beds from any depositional environment.

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Middle Ordovician (Chazyan-Trentonian) Tectonic Activation of Lower Paleozoic Carbonate Platform, Central Appalachian Orogene

Trentonian and Chazyan carbonates of eastern Pennsylvania provide important information regarding tectonic activation of the North American carbonate platform during the Middle Ordovician. In particular, the well-studied Lehigh Valley sequence records Chazyan-Blackriverian uplift and erosion of the Beekmantown carbonate platform (Black River hiatus) followed by rapid subsidence and sedimentation of the transgressive Jacksonburg Limestone in Trentonian time. A more detailed reconstruction of these events is gained from analysis of allochthonous Chazyan carbonates that tectonically overlie the Lehigh Valley sequence. These rocks, the Moselem Member of the Hamburg klippe sequence, include 230 m (755 ft) of ribbon limestone, black shale, slump deposits, and minor flint-bearing carbonate-clast conglomerates. Abundant gravity-flow deposits (ribbon limestones, conglomerates), widespread black-shale sedimentation, and slump and sediment-creep folding are indicative of deposition on a subsiding, low-angle depositional slope. Carbonate mud and flint pebbles were derived from the eroding Beekmantown platform, which palinspastic reconstructions place northwest of the Moselem depocenter. Synthesis of Chazyan-Trentonian stratigraphic relations of eastern Pennsylvania suggests the following scenario for this part of the orogene. During the Chazyan-Blackriverian, uplift and erosion of the Beekmantown platform were concomitant with sedimentation of the Moselem Member in a subsiding southeasterly foredeep. In the Trentonian, rapid collapse of the exposed platform was followed by deposition of the transgressive Jacksonburg Limestone. This scenario is similar to Middle Ordovician events in other parts of the orogene (e.g., Trenton Group, central New York) and accords well with sedimentation patterns associated with downbending of the Australian plate in the Timor Trough.

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Paleozoic Carbonate Deep-Sea Fan Sedimentation—Evidence for Late Cambrian Regression

Most studies of early Paleozoic eustatic variations have focused on carbonate platform sequences. Platform-margin deposits have received little attention. The Onyx Cave member of the allochthonous Hamburg klippe sequence of eastern Pennsylvania was deposited at the base of the North American carbonate platform in Late Cambrian time and emplaced on the platform during Middle Ordovician crustal convergence. It consists of (1) thick to very thick quartzose limestone beds, (2) very thick carbonate clast conglomerate beds, and (3) thin to thick laminated calcilutite beds. These deposits are arranged in thinning- and fining-upward cycles identical to channel abandonment sequences documented from clastic submarine mid-fan areas. A particularly interesting feature of the Onyx Cave is the abundance of rounded and well-sorted quartz and minor but conspicuous K-feldspar grains. The applicability of deep-sea fan models to the Onyx Cave member and the lack of mud and slump deposits are consistent with sedimentation on a canyon-fed (point source) carbonate submarine fan rather than the more typical Bahamian carbonate-slope turbidite system (line source). The abundance of well-sorted and rounded quartz sand within the Onyx Cave records a basinward migration of nearshore sediments across the platform toward the head of a submarine canyon where it was funneled into the deep sea. This scenario accords well with investigations of platform sequences that have proposed a Late Cambrian regression, and reinforces the important dependence of deep-sea clastic sedimentation on eustatic variations in sea level.

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Provenance of Upper Ordovician (Richmondian) Bald Eagle and Juniata Formations, Central Pennsylvania: Implications for Nature of Taconian Orogeny in Central Appalachians

Medium to coarse-grained lithic sandstones and lithic-pebble conglomerates of the Bald Eagle and Juniata Formations contain recycled sedimentary, low-grade metamorphic, and volcaniclastic detritus that was shed northwestward in an alluvial and/or fluvial system from an uplift produced during the Taconian orogeny.

Intermediate to felsic volcaniclastic rock fragments comprise approximately 3% of the framework grains. They consist of devitrified shards, partially kaolinized plagioclase laths, and biotite in a cryptocrystalline groundmass. Siltstone, mudstone, chert, radiolarian chert, and recycled grains are indicative of a sedimentary source. Chlorite-quartz, epidote-quartz, and muscovite-chlorite phyllite clasts indicate a low-grade metamorphic provenance. Quartz varieties plotted on a diagram are consistent with a low-grade metamorphic provenance. Metaquartzite, slate, and cataclastic lithic fragments indicate tectonic deformation in the source area.

Provenance criteria support a plate tectonic model involving an eastward-dipping subduction zone in the central Appalachians during the Middle to Late Ordovician. The climax of the Taconian orogeny has been described as a collision of an island arc with the North American continental margin. Petrologic data from the Bald Eagle and Juniata Formations suggest that this collision was accompanied by uplift of accretionary prism and continental margin or forearc basin sediments prior to the Richmondian. The presence of sedimentary, low-grade metamorphic, cataclastic, and volcaniclastic lithic fragments, and the notable absence of higher grade metamorphic and plutonic grain-types, indicate unroofing at relatively shallow levels of the orogene.

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Foreland Fold and Thrust Belt Deformation Chronology, Trenton Group Limestones and Overlying Shales, Northwestern Vermont

Outcrops of Trenton and younger limestones and shales between Plattsburgh, New York, and Malletts Bay, Vermont, show eastwardly increasing progressive deformation fabric in the foreland fold and thrust belt of northwestern Vermont.

The deformation sequence within the calcareous Stony Point and Iberville shales is: (1) bed-parallel slip, marked by grooved calcite-covered surfaces; (2) folding accompanied by pressure solution cleavage; (3) overturned folds with frequent faulting along overturned limbs; fault surfaces, marked by calcite slickensides, at high angles to calcite-filled extension fractures; cleavage frequency increases and is rotated into a lower angle with bedding; (4) late-stage features 2-3 km (1.2-1.9 mi) from the Champlain thrust include high-angle faults and pervasive shearing of early fabric. Less than 1 km (0.6 mi) from the Champlain thrust (Malletts Bay area), fold hinges are sheared out and closely spaced cleavage is folded.

The Cumberland Head Argillite (transitional between the Trenton Glens Falls Limestones and the younger Stony Point Shale) contains medium to thick micrite beams in a calcareous shale matrix. Deformation in the beams occurs by brittle failure and minor thrusting up ramps in the beams. The surrounding shale deforms by bed-plane slip and pressure-solution cleavage.

Glens Falls Limestone in the study area consists of medium to thick beds of fossiliferous micrite. A widely spaced pressure solution cleavage is intensified and rotated in ramp-and-fold zones. The cleavage is cross-cut by late high-angle faults.

A progressive increase in deformation fabric from west to east across the Ordovician limestones and shales of the northern Champlain Valley allows the fold and thrust chronology to be determined for the different lithologies.

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Stratigraphy and Depositional Environments of Catskill Deltaic Sequence, Northern West Virginia

The Catskill deltaic sequence (Upper Devonian–Lower Mississippian) is inadequately mapped and subdivided in the subsurface of northern West Virginia (central Appalachian basin). Stratigraphic interpretations are often hindered by the liberal use of drillers' names for noncontemporaneous gas-bearing sandstones.

Base-line analysis of 275 gamma-ray logs permits the resolution of lithostratigraphic units in this sequence. Five regionally mappable units are recognized, within which the position, geometry, trend, and distribution of reservoir sandstones are interpreted. Three units are within the Upper Devonian Chemung Formation, and two are considered equivalents of the Hampshire (Upper Devonian) and Pocono (Lower Mississippian) Formations. Stratigraphic cross sections graphically display relative thickness variations of reservoir sandstones and document the intertonguing facies of the Catskill deltaic sequence that are attributable to "cyclic" marine transgression and regression, and/or to changing sedimentation or subsidence rates in the basin.

Five lithofacies (A-E) are identified by the study of equivalent strata on outcrop. Facies A consists of gray shales and thin-bedded siltstones, interpreted as interbedded hemipelagic shales and turbidites. Facies B is comprised of thick-bedded and amalgamated siltstones and sandstones containing hummocky cross-stratification, representing composite storm deposits of the shelf and slope. Facies C consists of thick-bedded to massive clean sandstones and interbedded red and gray shales, interpreted as barrier-beach and back-barrier deposits. Facies D is dominated by red beds (silty mudstones and siltstones) with some interbedded sandstones, representing vertical accretion and channel deposits of an alluvial plain. Facies E consists of gray sandstones containing marine fossils and greenish-gray shales (Pocono Formation), interpreted as marine and marginal marine deposits developed during net transgression of the subaerial "Catskill delta."

Contrary to some previous studies, this study indicates these strata are best interpreted within the context of deltaic sedimentation. More specifically, stratigraphic and sedimentologic evidence suggests deposition in a wave- and storm-dominated deltaic complex.

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Upper Cretaceous and Cenozoic Sedimentary Sequence, Baltimore Canyon Trough, United States Atlantic Margin

The extent and character of Upper Cretaceous and Cenozoic rock units in the Baltimore Canyon Trough are revealed by geologic data from 29 exploratory wells. These data, released to the public in 1982, have been used previously in the description of regional rock-stratigraphic units in the trough. Now, a more detailed interpretation and correlation of electric logs and mud logs from these wells and a petrographic examination of thin sections have revealed the composition and lateral distribution of these units. Four detailed stratigraphic cross sections were constructed to show rock-unit correlations among 19 exploratory wells based on lithology and electric logs. Thin-section photomicrographs of drill cuttings and conventional cores document the mineralogic composition of these units.

The Upper Cretaceous section is composed principally of gray to brown, calcareous mudstone and is 1,555-3,220 ft (475-980 m) thick. One major shaly, glauconitic quartzarenite within the mudstone is present at most of the well sites. An Eocene carbonate unit, 100-1,100 ft (30-335 m) thick, overlies the mudstone. This unit grades from fossiliferous wackestones to calcareous shale. Oligocene to Miocene calcareous mudstone overlies the Eocene carbonate. White to gray, calcareous clay, shale, and siltstone are common constituents, and limestone, dolomite, and sand are minor constituents. Miocene to Pliocene unconsolidated fine to very coarse-grained sand overlies the mudstone. An uppermost unit of predominantly gray clay is present in the eastern part of the basin.

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Upper Jurassic and Lower Cretaceous Sedimentary Sequence, Baltimore Canyon Trough, United States Atlantic Margin

The extent and character of Upper Jurassic and Lower Cretaceous rock units in the Baltimore Canyon Trough are revealed by geologic data from 29 exploratory wells. These data, released to the public in 1982, have been used previously to define regional rock-stratigraphic units. In this study, four detailed stratigraphic cross sections were constructed to show rock-unit correlations based on lithology and electric logs. Thin-section photomicrographs document the mineralogic composition of these units. The stratigraphic terminology used herein is informally adopted from the nomenclature used on the Scotian Shelf.

Most of the Upper Jurassic section consists primarily of "Mic Mac" gray shale and siltstone with minor amounts of very fine to medium-grained quartzarenite, red-brown shale, and lignite. This interval also