highs are parallel with portions of major tectonic features such as the Eastern Kentucky syncline. Overall, though, the association of north-south–trending rank highs with tectonic expression is not as marked as that with the anomaly associated with the Kentucky River faults. It is possible that the rank trends are related to basement features with subdued surface expression. Rank generally increases with depth, and regional trends observed in one coal are also seen in overlying and underlying coals.

The cause of the regional southeastward increase in rank is likely to be the combined influence of greater depth of burial and proximity to late Paleozoic orogenic activity. The anomalous trends could be due to increased depth of burial, but are more likely to have resulted from tectonic activity along faults and basement discontinuities. The thermal disturbances necessary to increase the coal rank need not have been great, perhaps on the order of 10-20°C (18-36°F) above the metamorphic temperatures of the lower rank coals.

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Reactivation of Landslides by Surface Subsidence from Longwall Mining

Subsidence research by the U.S. Bureau of Mines has identified and documented the occurrence of landslides over a longwall mining area in the Dunkard basin. Most of these landslides occurred in masses of slumped hummocky soil generally associated with limestone and claystone beds of the Washington and Greene Formations. Identification and characterization of this phenomenon are needed to model accurately the future effect of subsidence-related surface damage to postmining land use.

Mining by longwall methods has been observed to produce a gradual surface subsidence profile of up to 60% of the thickness of the mined coal bed. The gradual subsidence of panels averaging 600 × 5,000 ft (180 × 1,525 m) can cause reactivation of older landslide deposits by decreasing the support to the landslide toe area. Examination of surficial features over a longwall mining area comprised of nine panels has led to the identification of several reactivated landslides. The two largest landslides occurred above a thin sandstone member with several associated springs. The largest landslides ranged from 100 to 300 ft (30 to 90 m) in length and from 100 to 200 ft (30 to 60 m) in width. Maximum scarp-slope displacements were approximately 7 ft (2 m). Less significant mass wasting was also observed over the longwall panels. Identification of landslides was accomplished through examination of premining aerial photographs and geologic field investigation. Characterization of reactivated zones was achieved through evaluation of current aerial 2-ft (0.6-m) surface contour map and field surveys. Recognition of problem areas will make civic and mining personnel aware of the landslide potential so that damage in such areas can be minimized.

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Depositional Environment and Reservoir Characteristics of Upper Devonian Kane Sandstone in Central Western Pennsylvania

Interpretative mapping techniques provide the basis for an environmental analysis of the Upper Devonian Kane sandstone in part of central western Pennsylvania.

Stratigraphically, the Kane sandstone is defined as the basal marine sandstone unit of the Upper Devonian Bradford Group. It represents the initial stages of clastic influx accommodated by the prograding Catskill delta complex. In eastern parts of the Appalachian Plateau, it most commonly exhibits an elongate lenticular geometry with long axes oriented normal to subnormal to regional strike.

The study area spans the three-county junction of Cambria, Clearfield, and Indiana Counties, where the Kane sandstone has been the target of intense drilling activity. Kane completions in this area are characterized by high initial potentials (up to 20 MMCFGD) and correspondingly high recoverable gas reserves.

Gross interval isopachs (G.S.S. and G.I.S.), net sand isopachs, sand percentage, and structure contour maps show that Kane sediments were emplaced as part of a small-scale submarine-fan environment, with a long axis trending west-northwest.

A complex suite of subenvironments ranges from submarine channel (proximal) to a radiating complex of small channels at the fan apex, which become broad flat channels and sheetlike sands in a downfan direction. These environments ultimately give way to distal mud facies away from the fan area.

Gross interval isopachs of the lower third of the Bradford Group interval show that increased thicknesses of sediment were emplaced along an inferred structural boundary trending west-northwest. This boundary very nearly coincides with a zone of cross strike structural discontinuity observed in the Valley and Ridge province.

The interpretations used in this analysis provide useful methods for evaluating future Devonian reservoirs.

KEARNEY, MATTHEW W., Sun Exploration and Production Co., Dallas, TX

Subsurface Geology of Medina Group (Lower Silurian) and Clinton Group (Lower to Upper Silurian) of New York

The depositional environments and geologic history of the Medina Group (Lower Silurian) and the Clinton Group (Lower to Upper Silurian) of New York have been interpreted from a regional subsurface study using approximately 250 gamma-ray logs and 125 sample logs. A sequence of paleogeographic maps illustrate the geologic history and depositional environments associated with this predominately clastic, rock sequence.

Seven principal depositional environments are recognized on the basis of subsurface sedimentary facies. These environments are: (1) transgressive clastic shoreline, (2) stationary clastic shoreline, (3) progradational clastic shoreline, (4) shallow marine nearshore to deltaic, (5) transgressive shallow marine clastic shelf, (6) transgressive shallow marine carbonate shelf, (7) progradational shallow marine clastic-carbonate shelf. Subenvironments recognized within the stationary clastic shoreline include beach, bay, barrier, and open-marine.

The Silurian clastic rocks were deposited during an overall marine transgression that was interrupted by three major progradational phases. The orogenic episodes represented by these progradational phases steadily decreased in intensity. The sediment influx during the first progradational phase was large enough to produce a deltaic system that extended throughout New York. During the second progradational phase, the sediment influx was small relative to the first event, and subsidence probably increased from loading of the Grimsby sediments. The deltaic system that developed during this time was restricted to east-central New York. The final progradational phase represents an even smaller influx of terrigenous material; only a linear clastic shoreline developed in eastern New York. This phase marks the last major influx of terrigenous clastic sediments until Devonian time.

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Subsurface Stratigraphy of Medina Group (Lower Silurian), Clinton Group (Lower to Upper Silurian), and Lockport Group (Upper Silurian) of New York

A network of ten regional cross sections across New York reveals the detailed subsurface stratigraphy of the Medina Group (Lower Silurian), Clinton Group (Lower to Upper Silurian), and Lockport Group (Upper Silurian). Both gamma-ray logs and sample logs were used to correlate from outcrop to subcrop and well to well throughout the subsurface of New York. Approximately 250 well logs and 125 sample logs were incorporated into this study.

The study indicates that the Medina Group can be subdivided into the Whirlpool, Power Glen, and Grimsby Formations. The Clinton Group is subdivided into 16 formations. In the west, the Clinton Group includes the Thorold, Reynales, Irondequoit, and Rochester Formations. In central and eastern New York, this group is subdivided into the Oneida, Bear Creek, Kodak, Sodus, Wolcott, Otsquaqo, Willowvale, Sauquoit, Williamson, Irondequoit, Dawes, and Heidimer Formations. Two formations are recognized in the Lockport Group: the Sconondoa and Ilion Formations.

In addition to the stratigraphy, the cross sections also display the 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 sedi-