silty shales, siltstones, and sandstones laid down by turbidites on the basin floor (Snake Hill Shale). Transport direction was to the east on the slope, and axial (north-northeast–south-southwest) on the basin floor. Clay particles were derived from the volcanic source terrane. The facies gradually shifted west laterally; the length of time span investigated is about 6 m.y.

From the distribution of organic carbon and the concentration of benthic epifauna and infauna, it can be inferred that conditions were aerobic on the shelf (> 1 ml/L O_2), anaerobic on the slope (< 0.4 ml/L O_2), and dysaerobic on the basin floor (< 1 ml/L O_2). Through time, four long-term anaerobic and dysaerobic cycles are revealed, lasting between 500,000 and 1,000,000 yr. Anaerobic cycles are characterized by over 50% higher organic carbon values, lack of infaunal burrowing traces, and a highly impoverished benthic epifauna. Dysaerobic cycles are marked by lower organic carbon contents, sporadic burrowing traces, and a slightly more diverse and abundant benthic epifauna. This cyclicity was most likely caused by changes in the density stratification within the water column, possibly related to climatic changes. The longest anaerobic cycle occurred during the transgressive phase that led to widespread deposition of black shale over the carbonate platform.

Anoxic conditions in the Taconic foreland basin may have been influenced by the prevailing global oceanographic conditions during the Middle Ordovician.

HAYWARD, WILLIAM C., CNG Development Co., Pittsburgh, PA

Subsurface Stratigraphy of Upper Cambrian Through Carboniferous Rocks in Western and Central Pennsylvania

The analysis of geophysical well log data from 20 deep wells in western and central Pennsylvania, southern New York, and northern West Virginia confirms the presence of anomalies in the distribution and thickness of the Lower Ordovician Beekmantown, Middle Ordovician Trenton, Lower Devonian Oriskany, and Middle Devonian Onondaga and Tully rock units. The nonuniformity of these rock units occurs in an area of western Pennsylvania referred to by W. R. Wagner in 1976 as the Olin basin. The margins of this feature are delineated by Upper Cambrian and Lower Ordovician growth faults. Wagner considered these faults to be extensions of Precambrian basement faults.

A structural depression in southwestern Pennsylvania and northwestern West Virginia hosted the depocenters of many of the Ordovician, Silurian, and Devonian sediments. This feature coincides geographically with the southern boundaries of the Late Cambrian Olin basin. Displacement along Precambrian basement faults coincident with this structure could have accounted for the distribution and thickness of the Beekmantown sediments in this region. The correlation of bentonite layers of the Trenton Group in western Pennsylvania indicates that faulting coincident with this depression appears to have affected the distribution and thickening of sediments across this basin.

Limited, renewed displacement of Wagner's Upper Cambrian growth fault as a positive flexure, resulting in an uplift of basement highs in Devonian time, might have accounted for the minimum deposition of the Oriskany, Onondaga, and Tully units in western and north-central Pennsylvania.

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Effects of Clastic Dikes on Roof-Rock Stability in Central Pennsylvania Coal Mine

Clastic dikes are common in coal beds of the Appalachian basin. Their presence often causes delays in mine production and poses safety hazards to mine personnel. The U.S. Bureau of Mines is conducting research on the occurrence and origin of clastic dikes and associated roof-rock instability, to gain a better understanding of the effect clastic dikes have on ground pressure around mine openings. Geologic mapping and pressure monitoring of clastic dikes at the Greenwich Collieries North Mine, Indiana County, Pennsylvania, has provided insights to this problem.

The North Mine (producing from the lower Freeport coal bed) is experiencing an increase in the number of clastic dikes and associated roof failure as mining advances toward the axis of the Brush Valley syncline. Over 200 individual clastic dikes of claystone matrix with fragments of shale and coal have been mapped at the mine. The dikes range in thickness from a maximum of 2 ft (60 cm) to as small as 0.25 in. (6 mm) and commonly extend vertically from the roof rock 20 ft (6 m) above the coal bed into the coal bed, but rarely through the coal bed to the underclay. Observations of the dikes indicate that they were formed by tensional and compressional forces and may be related to paleostress fields. Characteristically the dikes penetrate the coal bed at high angles to bedding with as much as 8 in. (20 cm^3) of normal-fault type displacement at the contact of coal bed and roof rock. The measured strike of the clastic dikes shows a strong bimodal distribution of N40°W and N50°E, which is offset 30° to the east of the bimodal distribution of the coal cleat (face N70°W and butt N20°E). Joints in the shale roof rock show a dominant peak of N 40° W, which is coincident with one of the major peaks of the dike distribution.

The depositional environment may have been an important factor in clastic dike formation, as the abundance of preserved casts of tree stumps in the shale roof is inversely proportional to the number of clastic dikes.

Hydraulic pressure-monitoring devices were installed near the clastic dikes to monitor the development of associated roof failure. The results of this monitoring show that the roof behaved as two cantilever beams where a clastic dike was present and that the roof must be supported immediately after mining. Analysis of the anisotropic qualities of the roof strata and rock-pressure conditions suggests that changes in the in-situ stress field near clastic dikes have aided in the propagation of roof failure.

HILLEBRAND, LAURIE B., and ALAN H. COOGAN, Kent State Univ., Kent, OH

Berea Sandstone Reservoirs in Ashland and Medina Counties, Ohio

The Berea Sandstone is one of the better known rock formations in Ohio. It occurs at shallow depths throughout a broad belt in central Ohio and crops out to the north and west of these counties. Stratigraphically, the Berea Sandstone is part of the Waverly Group and is underlain by the red and gray Bedford Shale and overlain by the black Sunbury Shale, all of which are of Early Mississippian age.

In Ashland and Medina Counties, the Berea may be divided into two separately identifiable units. The upper unit, called the "blanket" Berea in outcrop, is approximately equivalent to the "cap" Berea in the subsurface. The second unit, which lies below the "cap" Berea varies considerably in its thickness. The thickness of the Berea Sandstone (excluding the "cap") ranges from zero to over 125 ft (38 m) in the study area. The thickness changes occur within very short distances (i.e., 100-200 ft or 30-60 m) owing to the original depositional conditions responsible for the formation of the sand body.

The traditional, long-standing, and generally accepted view is that the Berea Sandstone was deposited in Ashland and Medina Counties in southward-flowing river channels. More recent drilling in these counties has demonstrated that these sand channels are not continuous, but are isolated sandstone bodies in which petroleum has accumulated.

The reservoir capacity of the Berea is between 8 and 22% with an average porosity of 15%. The sandstone consists of loosely cemented, medium to fine-grained quartz with only rare shale breaks below the "cap" Berea. In Ashland and Medina Counties, Berea wells generally produce oil. Initial production in this area ranges between 1 or 2 bbl and to 40 BOPD after treatment. Reservoirs in the Berea Sandstone generally are productive where the sandstones are thick. They are also productive where the sandstone is thinner, but high on structure. Although a high structural position is preferred, the critical consideration is the thickness of the sandstone body and the reservoir geometry.

HOWER, JAMES C., and ERIC J. TRINKLE, Univ. Kentucky, Lexington, KY

Coal Rank Trends in Eastern Kentucky

Examination of coal rank (by vitrinite maximum reflectance) for eastern Kentucky coals has revealed several regional trends. Coal rank varies from high volatile C (0.5% R_{max}) to medium volatile bituminous (1.1% R_{max}), and generally increases to the southeast. One east-west–trending rank high and at least four north-south–trending rank highs interrupt the regional increase. The east-west–trending rank high is associated with the Kentucky River faults in northeastern Kentucky. It is the only rank high clearly associated with a fault zone. The four north-south–trending rank 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.

IANNACCHIONE, ANTHONY T., and TERRY E. ACKMAN, U.S. Bur. Mines, Pittsburgh, PA

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.

JOHNSON, SHANNON S., Mark Resources Corp. and Univ. Pittsburgh, Pittsburgh, PA

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.

KEARNEY, MATTHEW W., Sun Exploration and Production Co., Dallas, TX, and LAWRENCE V. RICKARD, State Univ. New York, Albany, NY

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