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Prediction of Geologic Anomalies in Advance of Mining: Three Case Studies

Studies at three underground mines in Illinois show great differences in the predictability of geologic anomalies that interfere with mining. Exploratory drilling can be used to detect major features of the depositional environment such as areas of thin or no coal, ancient channels, and unstable roof lithologies. Local features such as faults, jointing, clay dikes, and rolls can best be delineated and predicted by in-mine mapping. Some anomalies, however, such as unexpected stresses, some clay dikes and rolls, and faults encountered for the first time, defy successful prediction by either method.

Mine A, a small drift mine in the Herrin (No. 6) Coal, was opened with very little test drilling. It soon became apparent that the single set of main entries was confined to an 800-ft wide (240 m) trough of minable coal bounded by areas of nondeposition and erosion. When the roof rock became so unstable that further advance was impossible, the mine was abandoned. With an additional investment in exploratory drilling, the company could have been forewarned about the confining nature of the trough and the presence of unstable roof, and perhaps could have relocated to a more minable body of coal.

At Mine B, also in the Herrin Coal, the density of drill holes was well above average for Illinois. Nevertheless, abnormally hard, thin coal was encountered at several faces. While exploratory drilling failed to detect these thin coal areas, in-mine mapping delineated them as narrow, sinuous, branching features, and offered a means of short-range projection.

A thorough exploration program preceded shaft sinking at Mine C. This program and subsequent in-mine mapping failed to predict severe roof stability problems in the north-south headings. The in-mine mapping did indicate that the north-south weakness was not due to lithologic or structural changes, but to high horizontal stresses. Ultimately, the mine headings were turned 45°, with an overall improvement in roof stability.

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Upper Devonian Black Shales Across Appalachian Basin

The relatively high positive gamma-ray response and corresponding low-compensated density of black shales facilitated extension of outcropping Upper Devonian black shales (the Rhinestreet Shale Member of the West Falls Formation, the Pipe Creek Shale Member of the Java Formation, and the Dunkirk Shale Member of the Perrysburg Formation) southward in the subsurface beneath the Appalachian Plateau about 500 mi (800 km) to wells in the Greendale syncline in southwestern Virginia.

Subsurface mapping clearly outlines an arcuate area from western New York through northwestern Pennsylvania, eastern Ohio, and western West Virginia to southwestern Virginia, in which the black shales are laterally continuous. Presumably, depositional environments were also uniform throughout this area at any given time during the accumulation of these dark rocks.

Regionally, the black shales delineate an offshore part of the extensive Upper Devonian delta complex, although their distribution is somewhat restricted by a westward-expanding Middle Devonian unconformity against which the Rhinestreet and Pipe Creek Shale Members feather out. However, the Dunkirk Shale Member equivalent is present in outcrop as the lower part of the Huron Member of the Ohio Shale in Ohio and northern Kentucky, and in the corresponding part of the Gassaway Member of the Chattanooga Shale in central Tennessee and contiguous southern Kentucky.

To the east, in the Appalachian basin, the black shales grade laterally into an eastward-thickening sequence of gray shale and siltstone turbidite beds. In the absence of extensive key beds, the thick sequence of coarser grained clastic rocks cannot be divided stratigraphically.

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Stratigraphic Control of Oriskany Production

The Oriskany (Ridgeley) Sandstone, Lower Devonian (Deerpark Stage), is one of the major deep gas producers in the central Appalachian basin. It is most productive in the southern tier of New York, western Pennsylvania, West Virginia, eastern Ohio, and to a lesser extent, in westernmost Maryland and northwestern Virginia.

Typically, the Oriskany is a calcareous quartzarenite with a distinctive megascopic fauna. Locally the Oriskany is orthoquartzitic, and in places conglomeratic. In outcrop, leaching of the calcareous components of the Oriskany produces a more friable, biomoldic quartzarenite. In the subsurface, the formation is usually tightly cemented by carbonate.

The Oriskany is a sheet sand that reaches a maximum thickness of over 300 ft (100 m) in western Maryland, and thins to zero toward the north, west, and south. This pinch-out is due to pre- and/or post-Oriskany unconformities which become more pronounced along the edges of the basin and locally in northwestern Pennsylvania and western New York.

Most of the major Oriskany fields are stratigraphic traps associated with the Oriskany pinch-out. In these fields, porosity is usually intergranular and was probably developed soon after deposition on pre-Middle Devonian topographic highs. Entrapment is due to updip loss of permeability at the pinch-out or to structural highs near the pinch-out.

Oriskany fields that are not associated with the pinch-out are structural traps characterized by fracture porosity and entrapment along anticlinal highs or against faults. Fields of this type are more common in the high plateau province and in the Eastern Overthrust belt.

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Stratigraphy and Sedimentology of Upper Helderberg Group (Lower Devonian), New York

Field and petrologic study of the upper Helderberg Group has elucidated facies relationships. A "tongue" of the Kalkberg formation, recognized locally by Rickard (1962), at the top of the lower Helderberg cycle, extends southeastward to Catskill Creek where it thickens slightly, changes lithologic character, and passes laterally into the basal Becraft formation of the upper cycle. The Becraft represents a progradational phase within the general Lower Devonian transgression, and is seen as correlative with parts of both cycles. Thus, sedimentation was continuous between the two transgressive cycles. These revisions only slightly alter lower-cycle stratigraphy and preserve the integrity of Rickard's time lines.

The Becraft formation is divisible into three units. (1) (Base) High-angle, cross-stratified, crinoidal grainstones interbedded with shale, cross-laminated, silty, peloidal grainstones, and packstones. (2) Trough cross-stratified, gypidulid-bearing, crinoidal grainstones with rare channels. (3) (Top) Finer grained, bioturbated to vaguely laminated grainstones containing gypidulids, and in-situ, rootlike crinoid holdfasts, but less crinoidal debris. Units 1 and 2 represent progradation of a tidally influenced, skeletal-sand shoal over shoal-margin and deeper subtidal environments. Unit 3 is transitional to the superjacent Alsen formation.

The Alsen formation consists of irregularly bedded, bioturbated, skeletal, and peloidal grainstones. Bryozoans, brachiopods, and