

show the trends of coal-quality parameters for individual seams. The maps are supplemented by a computer program that searches the data base and generates a printout of geographical areas within the state where coal has been sampled that meets the desired specifications. These computer techniques go a long way in helping the user to find target areas within the state to match the right coal to the desired end use.

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Depositional Patterns of a Silurian Shelf Sand in Central Appalachians

The Keefer Sandstone in the subsurface of West Virginia and Kentucky, where it produces small volumes of natural gas, was deposited on the western shelf of the Appalachian basin. The formation is a dolomitic quartzarenite and quartzwacke and ranges from 13 to 50 ft (4 to 15 m) thick. As interpreted from four cores and isopach and lithofacies maps, the sand was transported by longshore currents from a southeastern source area and laid down in a variety of environments. In Kentucky, Keefer deposition was on a wave-dominated coast. The rocks are characterized by physical sedimentary structures and textures which developed under high-energy conditions, and the formation is divided into shoreface and foreshore facies. In adjacent West Virginia, however, Keefer deposition occurred offshore in water near the depth of wave base, swept out onto the shelf by storm-generated currents. Sedimentary structures and textures indicate a lower energy environment, bioturbation is more common, and the formation contains a greater amount of shale. The isopach map shows two linear tracts of thick sand in this offshore facies that may represent a coalescence of subtidal bars on the shelf. Between major sand bodies, the Keefer becomes appreciably thinner and is interbedded with fossiliferous dolomite. In the basin center of West Virginia, sandstone is replaced by shale. Thus, the geographical distribution of lithofacies shows a transition of shelf environments within a blanket sandstone. In all cores, regardless of depositional facies, the sandstone displays evidence of aggrading sedimentation; sedimentation exceeded subsidence, and the sand body built upward into shallower water.

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A Potential Method for Predicting Coal-Mine Floor Heave

Floor heave or deformation of the mine floor into the mine opening is a problem which has plagued coal mines in this country and others. This paper describes the problem as it was manifested in two coal mines located in eastern Illinois, and reports the results of a U. S. Bureau of Mines-sponsored study conducted by the University of Missouri-Rolla. The ultimate objective of the study was to develop a procedure that could be used to define a potential floor heave problem during the exploration phase of mine design—before initiation of production mining.

Floor heave within the mines did not occur with uniform intensity throughout each mine or even within mine panels. Floor deformation was often deep-seated and involved two subfloor lithologies. A wide variation in measured strength for each of the subcoal lithologies was recorded during laboratory testing; underclay triaxial compressive strength best correlated with underclay natural water content. The severely heaved areas were not located in the deepest or shallowest portions of the mines. Severe floor heave occurred in areas of thicker (greater than 6 ft, 2 m) underclay. Severe floor heave occurred at those sites where the natural water contents of the underclay and claystone were highest. The presence of swelling montmorillonite clay did not seem to be a major cause of floor heave. Triaxial compressive strengths measured from under-

clay samples from severely heaved sites were not the lowest values measured. A bearing capacity model developed by Vesic was modified so that a "heave factor" could be calculated using only that information obtainable from exploration core borings; use of the "heave factor" would have predicted floor heave at the study sites where severe heave occurred.

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Porosity Pods in Whirlpool Sandstone (Lower Silurian), Chautauqua County, New York

The Lower Silurian Whirlpool Sandstone is an important natural gas producing formation in western New York State. The Whirlpool outcrops in Niagara County, and is present in the subsurface in portions of Erie and Chautauqua Counties as well as adjacent areas in Pennsylvania.

In gas-productive areas of Chautauqua County, the Whirlpool usually ranges in thickness from 5 to 20 ft (2 to 6 m). Porosity as measured by the compensated formation density logging tool is typically 4 to 8%. Gas saturation is normally in the 20 to 65% range. The permeability of the rock is limited. Occasional localized areas of sharply greater porosity, permeability, and hydrocarbon saturation ("porosity pods") occur within the larger volume of tight, low permeability Whirlpool. The producing characteristics of the porosity pods are such that gas recovery may increase by a factor of 3 to 5 as compared with an average well. The economic benefits of drilling into these features are therefore substantial.

The presence of a porosity pod is sometimes indicated by an unusually large natural flow of gas from a well prior to stimulation. It can also be detected by certain characteristic indications on the density, resistivity, and neutron logs. Whirlpool porosity pods appear to be mappable and may be sufficiently large to provide 4 or 5 well locations. Recognition of their characteristics can be a significant aid to natural gas exploration in Chautauqua County, New York, and possibly elsewhere in western New York and northwestern Pennsylvania.

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Fracture Analysis of Eastern Ohio

Selected shale characterization exploration parameters defined from Eastern Gas Shales Project investigations to identify highly potential Devonian shale exploration areas were used by Tetra Tech, Inc., to select drilling sites in the Appalachian, Michigan, and Illinois basins. The characterization parameters used for site selection were: (1) thickness of the shales, (2) type of organic matter, (3) percent of organic carbon, (4) thermal maturation, and (5) the presence of secondary natural-fracture porosity. The fracture analysis investigation over eastern Ohio using remote sensing techniques describes a method which should prove useful for locating secondary natural-fracture porosity reservoirs in regions of horizontal or slightly dipping strata.

Detailed field checks over a pilot area in Hocking County, Ohio, indicated that approximately 50% of mapped photo linears were not fracture related. A hypothetical interpretive technique developed to identify only the fracture-related photo linears was used in interpreting and mapping fractures over the entire area of eastern Ohio.

Statistical analysis of this data was necessary due to the large volume of data. A computer program was developed that analytically distinguished the regional and local components of the data. Computer-generated first and second-degree and corresponding residual maps showed areas of eastern Ohio where fracture density exceeded or was less than the regional norm.