sequence usually including thin, marine sandstones which form a transition into the overlying limestones. Many of these limestones display remarkable lateral continuity. In the outcrop area of southeastern Missouri and southwestern Illinois, the Aux Vases, Renault, and Yankeetown Formations are primarily clastic units which interfinger with one another and probably make up a single depositional package. The massive sandstones, called the Aux Vases, occur at different horizons within the sequence and interfinger with shales which have been variously assigned to either the Renault or the Aux Vases. Furthermore, the Aux Vases differs from other Chesterian sandstone units in that it does not contain coal beds anywhere, and it displays prominent herringbone-type cross-beds. In some places, the sandstone contains marine fossils. However, the Renault, which is usually considered to be a limestone unit, in many places does not contain limestone, and when marine limestone lenses are present they are highly discontinuous. The Yankeetown is a thin, highly continuous unit that typically contains characteristic cherty sandstones along with sandstones like those found in other Chesterian sandstone units, as well as shales and limestones. Some of these strata also contain marine fossils. Thus, the Aux Vases differs from other major Chesterian sandstone units in showing strong tidal influence and in lacking both coals and rooted zones, but is similar to other Chesterian sands in showing widespread marine influence.

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Geologic Structures and Horizontal Stresses—Their Impact on Petroleum and Coal Production in Illinois Basin

Knowledge of subsurface structures and stress is important to the petroleum and mining industries. These factors have a direct impact on reservoir performance and mine roof stability. Local structures and stresses typically cannot be defined by normal exploration drill spacing. Underground mine mapping, however, provides a unique opportunity to measure these local features and to determine how they affect petroleum and coal production.

A geologic mapping program was conducted at Old Ben Coal Company's Mine 27, which operates in the Illinois No. 6 Coal in Franklin County, Illinois. The mine is in an area of "pod-type transitional roof," in which isolated Energy Shale pods are overlain by Anna Shale and Brereton Limestone. Each facies has a distinctive structural and deformational assemblage. Mapping shows that an excessive east-west horizontal stress also exists in the area. The stress and the structural and lithologic discontinuities are the primary cause of roof failure in the mine.

The detailed structure and stress data acquired in the Mine 27 investigation can also be used to model oil and gas reservoirs. The measurements of joint density, fracture orientation, etc, can be integrated with petrophysical and mechanical data to evaluate fracture permeability. Because underground stresses control hydraulic fracture propagation, knowledge of the subsurface stress field can be used to evaluate stimulation techniques. The orientation of hydraulically induced fractures can be approximated if the magnitude and direction of the stresses are known.

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Structural Geology of Shawneetown Fault Zone, Southeastern Illinois

Vertical movements of crustal blocks along the narrow east-west-trending Shawneetown fault zone in southeastern Illinois occurred between Early Permian and Late Cretaceous. The main blocks moved vertically and returned to roughly their original positions so that strata now show little relative offset across the fault zone. However, individual faults with displacements up to 3,500 ft (1,070 m) bound narrow slices of steeply tilted or overturned strata resulting in a juxtaposition of Kinderhookian (Lower Mississippian) and Upper Devonian strata with Lower Pennsylvanian strata. The bedrock is intensely fractured, commonly brecciated, and cemented with either silica or calcite. Slickensides and mullion display various orientations within the zone and on individual outcrops. The dominant movement, however, appears to be vertical with no evidence for significant strike-slip movements. Pleistocene deposits do not exhibit offsets across the fault zone, indicating that no tectonic activity has occurred since the beginning of that epoch.

The trend of the fault zone changes abruptly from east-west in southern Gallatin and easternmost Saline Counties to south-southwest in southern Saline and northeastern Pope Counties, where it joins the Fluorspar area fault complex. Here the zone widens and develops a braided pattern as the amount of displacement along individual faults decreases. The Shawneetown fault zone and Fluorspar area fault complex in part are younger than the Cottage Grove fault system to the northwest and the Wabash Valley fault system to the north. The hope of finding structural traps near the junctions of the fault systems has spurred recent oil exploration in the area.

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Geology and Petrology of Tertiary Lignites Adjacent to Beartooth Mountain Front, Montana-Wyoming

Along the eastern margin of the Beartooth front a sequence of Laramide conglomerates, sandstones, siltstones, shales, and minor coals are exposed. These minor Paleocene-Eocene coals, ranging from lignite to subbituminous in rank, are the focus of this study.

Four coal exposures were sampled along a north-south strip (17 mi, 27 km), proximal to the Beartooth front. These coals range in thickness from less than a 1-in. (2.5 cm) lens to about 10 ft (3 m) and contain partings of carbonaceous shale, shale, siltstone and sandstone. Two of the seams, designated as Meeteetse Trail and Burgess Lignite occur in typical Fort Union sediments. The Meeteetse Trail locality is less than 0.25 mi (0.4 m) from vertical Madison Limestone with a westerly dip "under" the Madison. The other, the Burgess Lignite locality, is composed of alternating papery fusinitic lignite, siltstones, thin lenses of channel sandstones, carbonaceous shales, and carbonaceous mudstones. The coals here are high in organic matter, fossil stems, leaves, megascopic resins, randomly oriented petrified tree stumps, and gypsiferous deposits.

Two other localities, Gold Creek and Clarks Fork Canyon, are in Paleocene alluvial fan deposits. The Clarks Fork coals are found at the distal end of an alluvial fan system and dip rather gently basinward. The Gold Creek coals are found at the base of a fan interbedded with massive sandstones and conglomerates containing andesitic porphyry clasts up to 1.5 ft (0.4 m) in maximum dimension.

The Fort Union Formation in this area includes lacustrine, paludal, fluvial, and conglomeratic members. There is a wide diversity of megaflora in different sedimentary facies. Petrographic examination reveals well preserved cell structure, especially in the fusinoid macerals. Although the coals have undergone severe alteration and weathering, they still exhibit excellent fluorescence properties.

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Petroleum Geology of Macoupin County, Illinois

The Carlinville oil field is located along the upper flexure of a monocline and is not associated with an anticline or domes as previously described. West of the monocline, minor accumulations of petroleum occur in stratigraphic traps in Pennsylvanian sandstones that are organic matter-enriched. The oil is "heavy," may be relatively immature, and may have formed in the sediments in which it occurs. Significant oil shows also occur in oolites of the Ste. Genevieve Formation.

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Analysis of Effects of Foam Stimulation Treatment on Upper Freeport Coal Seam in Indiana County, Pennsylvania

A detailed underground mapping survey to determine the impact of foam stimulation treatments on the mining environment was conducted at an underground mine in Indiana County, Pennsylvania. Three vertical boreholes intercepted unmined coal south of active workings. The boreholes were geophysically logged, and cased to the top of the Upper Freeport Seam. Nitrogen-generated foam was injected to fracture the seam, and 20/40 mesh sand was used to prop open the fractures. The

foam was tagged with fluorescing, ultraviolet paint pigment to enable its pathway to be mapped with a short wave ultraviolet light.

As mining advanced toward the holes, the lithologic characteristics of the coal seam, roof, and floor were mapped, along with the location of roof falls and deformational features. The roof strata consisted of thin, irregular pods of gray shale and siltstone and of an overlying sandstone, which had an erosional contact with the seam in many areas. Roof falls and "slips" occur where the roof's lithologic character is transitional from shale to sandstone. The falls occur with time as the roof weakens along slip planes and bedding planes where individual lithologic characteristics are not thick enough to support themselves.

Paint pigment from the treatment fluid was distributed in horizontal planes at the coal-roof interface and along the top of an in-seam rock binder up to 225 ft (70 m) from an individual borehole. Propping sand was found only on the top of the rock binder and in vertical fractures in the lower bench of the seam, near the boreholes. Fluorescing vertical fractures occurred predominantly in the friable lower bench and extended outward for a distance of up to 160 ft (50 m) from the boreholes. No fractures penetrated the roof or floor strata. No roof falls occurred near the well bores.

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New Madrid Seismic Zone: A Test Case for Naturally Induced Seismicity

Induced seismicity caused by man-made events, such as the filling of reservoirs has been well documented. In contrast, naturally induced seismicity has received little attention. It has been shown that a fluctuation of as little as several bars can trigger reservoir induced earthquakes. Naturally occurring phemonena generate similar fluctuations and could trigger earthquakes where the faults in ambient stress field are suitably oriented and close to failure.

The New Madrid Seismic Zone (NMSZ) presents an ideal test case for the study of naturally induced seismicity. The ideal data set for a study of triggering effects must contain a statistically significant number of events, a constant accumulated strain, and a limited focal region. New Madrid earthquakes are well documented from 1974 to the present, down to a magnitude ~1.8. They lie in a distinct fault pattern and occur as a reaction to the regional stress regime.

A statistical correlation was made between the earthquakes and a variety of different types of loads, to see if New Madrid seismicity could be triggered by natural fluctuations. The types of "triggers" investigated ranged from solid earth tides to variations in barometric pressure, rainfall, and stages of the Mississippi River. This analysis becomes complex because each factor investigated creates individual stresses, as well as having imbedded in it a reaction to other factors. For example, changes in barometric pressure influence the observed solid earth tides, as well as leading to rainfall, which in turn cause changes in the river stages. Most likely it is a combination of effects, reinforcing each other, that act as possible trigger sources.

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Tectonic History of Southeastern Illinois

Recurrent movements on the northeast-trending Reelfoot rift and west-trending Rough Creek fault zone dominated southeastern Illinois tectonic history. Early Cambrian rifting along both zones created deep trenches that began to fill with sediments. Intermittent movements continued, but faults were quiescent by the Mississippian. Then renewed extension on the Reelfoot rift in the Early Permian produced high-angle normal faults in the Wabash Valley fault system and Fluorspar area fault complex, and the right-lateral Cottage Grove fault system. Igneous intrusions accompanied this action: upwelling magma formed Omaha dome; Hicks dome and associated concentric and radial faults appear to have been formed by explosive igneous activity.

After the Early Permian, recurrent up-and-down movements of several thousand feet reactivated the fluorspar area fault complex and created the present day Rough Creek and Shawneetown fault zones. Blocks bordering faults returned roughly to their original positions by the Late Cretaceous, leaving narrow slices of rock upthrown and downthrown along faults.

Faults in Illinois probably have been inactive since the Cretaceous Period, although the Reelfoot rift south of Cairo has been reactivated. Earthquakes in Illinois today apparently are caused by local east-west horizontal compressional stresses not related to known bedrock faults.

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Coal Mine Ground Control—The Effect of Geology

The stability of an underground coal mine is highly influenced by the regional and local geologic conditions. Certain geologic features have an effect on roof and floor stability. A method of engineering geological data collection involves engineering geological mapping, diamond-core drilling, geotechnical logging, borescope observations, integral sampling of floor strata, and in-situ stress measurements. Individual aspects of the method were developed and tested during the course of field investigations at three Pennsylvania and West Virginia coal mines. The field investigations were supplemented with laboratory testing of rock and coal specimens and regional geologic studies involving lineament and hazard analyses. The method of engineering geological data collection was found to be effective for quantifying geologic conditions in parameters directly applicable to engineering design.

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Biofacies and Habitats of Brereton Limestone Member (Carbondale Formation, Middle Pennsylvanian), Southwestern Illinois

The Brereton Limestone is a shallow-water, open-marine carbonate deposited over peat or delta-plain muds after delta abandonment and a marine transgression. Six distinct biofacies are recognized, utilizing quantitative analysis of abundance data on 32 fossil types obtained from detailed petrographic examination of 141 samples. The biofacies partly overlap and probably represent coexisting paleocommunities. Data on autecology, lithology, insoluble residue content, and thickness were used to interpret the habitats of each biofacies.

Biofacies V, a low-diversity biofacies dominated by brachiopods and ostracods, occupied turbid-water, mud- or shelly mud-bottom areas during influxes of detrital clays late in the abandonment of the Herrin delta and, also, early in the construction of the Jamestown delta.

Low-relief carbonate mud mounds accumulated within and around baffles provided by thickets of phylloid algae, crinoids, fenestrate bryozoans, or productid brachiopods, and are separated by narrow to broad intermound areas. Shallow-water mud mounds, containing Biofacies I, which is dominated by calcareous phylloid algae and foraminifers, are capped locally by Biofacies VI, a low-diversity biofacies dominated by ostracods. Biofacies VI, occupied the high subtidal to supratidal crests of algal mud mounds which had a stressed (possibly hypersaline) environment. Deeper water mud mounds were occupied by either Biofacies III, a crinoid-mixed fossil biofacies, or by Biofacies IV, which is dominated by fusulinids, strophomenids, and trilobites.

Biofacies II, dominated by sponges, mollusks, and impunctate brachiopods, generally occurred on the flanks of the shallow-water mounds. Biofacies I, III, and IV also occurred in broad, muddy intermound areas and Biofacies III in narrow, winnowed intermound areas.

Spatial distribution of biofacies and inferred habitats is characterized by irregular and local changes, and does not conform to regular, predictable changes perpendicular to a paleoshoreline.

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Morphotectonic Features Interpreted from Remote Sensing, Erie County, Northwest Pennsylvania

Linear features (lineaments) have been discerned in Erie County from multi-temporal Landsat MSS images and return-beam vidicon scenes. This 2,107 km^2 (814 mi^2) portion of the Appalachian Plateau is crisscrossed by at least 24 Landsat linear features, some of which may be of