upper biofacies, the *Composita* and *Composita-Fenestella* biofacies, contain more distinct and well-preserved grains. Brachiopods, such as *Composita,* and bryozoans, such as *Fenestella* and *Archimedes,* are present as whole specimens, some in life position. The thicker, upper biofacies probably accumulated as a result of the baffling action of fenestrate bryozoans.

Some of these biofacies display distinct zoning or concentration of shelly material interpreted to be the result of intermittent storm waves and suggesting that the depth of deposition was below normal wave base not yet below storm wave base. The skeletal-lime mud buildup indicates deposition on a shallow sloping shelf of the Chester sea. The quiet water marine conditions were favorable for a localized concentration of fauna, some of which had been abraded by bioturbation, and which were intermittently affected or concentrated by storm waves not yet largely fragmented or abraded.

HOUSEKNECHT, DAVID W., and PAUL H. WEAVERLING, Univ. Missouri, Columbia, MO

Early Paleozoic Sedimentation in Reelfoot Rift

Analysis of subsurface data from deep tests drilled in the northern Mississippi embayment and southern Mid-Continent suggests that earliest Paleozoic sedimentation was dominated by the tectonic evolution of the Reelfoot rift.

Throughout most of the Mid-Continent, the Upper Cambrian Lamotte (Mt. Simon) Sandstone rests nonconformably on Precambrian basement and is overlain by the Bonneterre (Eau Claire) Formation. However, in the area of the Reelfoot rift, both the Lamotte and Bonneterre grade into thick, basinal shales that locally display evidence of episodic deposition of coarse clastics, perhaps on submarine fans.

Moreover, two major sedimentary units are present beneath the Lamotte-Bonneterre basinal facies within the Reelfoot rift. Immediately underlying the Lamotte-Bonneterre shale is a carbonate stratum (probably dolomite) that thickens to more than 1,000 ft (300 m) along the axis of the basin in eastern Arkansas. Underlying this carbonate is a detrital unit that grades from arkosic sandstone near the northern terminus of the basin to a basinal shale southward. This basinal shale is at least several hundred feet thick near the axis of the basin. These two strata occupy the stratigraphic position of the Conasauga (Middle Cambrian) and Rome (Lower Cambrian) Formations of the southern Appalachians.

The axial and transverse distribution of these strata suggests that the Reelfoot evolved as paired grabens or half grabens during the Early and Middle Cambrian. Subsequently, the Reelfoot remained the axis for more widespread subsidence and sedimentation throughout much of the Paleozoic.

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

Association of Coal Metamorphism and Hydrothermal Mineralization in Rough Creek Fault Zone and Fluorspar District, Western Kentucky

The ambient coal rank (metamorphism) of the Carboniferous coals in the Western Kentucky coalfield ranges from high volatile A bituminous (vitrinite maximum reflectance up to 0.75% $R_{max}$) in the Webster syncline (Webster and southern Union Counties) to high volatile C bituminous (0.45 to 0.60% $R_{max}$) over most of the remainder of the area. Anomalous patterns of metamorphism, however, have been noted in coals recovered from cores and mines in fault blocks of the Rough Creek fault zone and Fluorspar District.

Coals in Gil-30 borehole (Rough Creek faults, Bordley Quadrangle, Union County) vary with no regard for vertical position, from high volatile C (0.55% $R_{max}$) to high volatile A (0.89% $R_{max}$) bituminous. Examination of the upper Sturgis Formation (Missourian/Virgilian) coals revealed that the higher rank (generally above 0.75% $R_{max}$) coals had vein mineral assemblages of sphalerite, twinned calcite, and ferroan dolomite. Lower rank coals had only untwinned calcite. Several sites in Webster County contain various coals (Well [No. 8] to Coiltown [No. 14]) with vitrinite reflectances up to 0.83% $R_{max}$ and associated sphalerite mineralization. Mississippian and Lower Pennsylvanian (Caseyville Formation Gentry coal) coals in the mineralized Fluorspar District have ranks to nearly medium volatile bituminous (1.03% $R_{max}$). Rank varies between fault blocks and, in places, shows unexpected vertical trends. The regional rank trend exhibited by the fault zones is generally higher rank than the surrounding areas. Sphalerite mineralization in itself is not unique within Illinois basin coals, but if it was partly responsible for the metamorphism of these coals, then the fluid temperature must have been higher within the above mentioned fault complexes.

JACOBSON, RUSSELL J., Illinois State Geol. Survey, Champaign, IL

Stratigraphic Correlations of Seelyville, De Koven, and Davis Coals (Desmoinesian) of Illinois Basin Coalfield

The Seelyville, De Koven, and Davis Coal Members (Spoon and Staunton Formations, Illinois and Indiana) or beds (Carbondale Formation, western Kentucky) presently are considered stratigraphically separate seams of restricted regional extent in the basin. Recent subsurface investigation reveals that the De Koven and Davis Coals are splits of the Seelyville Coal. A 170-mi-long (275-km) cross section, with an average of one well per mile, links the type Seelyville of west-central Indiana with the type Davis (Western Kentucky No. 6) and De Koven (Western Kentucky No. 7) Coals of western Kentucky. Geophysical logs formed the basis of the correlations. In its type area, the Seelyville Coal contains several partings of shale, one of which is fairly continuous but variable in thickness, ranging from less than 1 in. (2.5 cm) to more than 20 ft (6 m). Southward, this parting continues as a clastic wedge (more than 100 ft, 30 m, thick in some places) that separates the De Koven Coal (above) from the Davis Coal (below) in their area of outcrop in southeastern Illinois.

Knowledge that these coals are equivalent rather than separate seams should increase understanding of previously mapped resources, and facilitate mapping of additional resources in the future.

JACOBSON, RUSSELL J., and C. BRIAN TRASK, Illinois State Geol. Survey, Champaign, IL

New Burnside "Anticline"—Part of Fluorspar Area Fault Complex?

Field mapping in the Abbott Formation and examination of topographic lineaments in the Creal Springs, Stonefort, Eddyville, and Harrisburg Quadrangles (southeastern Illinois) reveal the New Burnside "anticline" and its northeastern extension, the Stonefort "anticline" to be a single, extensively faulted structure. Interpretation of this evidence also leads to the conclusion that this is a fault-block structure rather than an anticline. Trending northeast-southwest, the structure seems to be the northwesternmost extent of the Fluorspar Area fault complex. We found evidence for two episodes of faulting. The first involved northeast-trending, high-angle faults similar to those in the known Fluorspar complex to the southeast. Faults on the northeast (Stonefort "anticline") step down toward the center of the structure, forming a graben. Vertical movement also occurred to the southwest (New Burnside "anticline"), but the structure in this vicinity is a horst with some blocks tilted. As with other faults in the Fluorspar complex, horizontal slickensides are present locally. The second episode of movement occurred along northwest-southeast-trending strike-slip faults that offset the northeast-trending high-angle faults. This second phase of faulting may correspond with previously reported reactivation of northwest-trending faults elsewhere in the Fluorspar Area fault complex.

JENNINGS, JAMES R., and GEORGE H. FRAUNFELTER, Southern Illinois Univ., Carbondale, IL

Aux Vases–Renault–Yankeetown Depositional Sequence in Comparison to Other Chesterian Depositional Sequences

The major Chesterian sandstone units from the Bethel to the Degonia have a thick, lower progradational part. This is typically overlain by a sequence of thin-bedded sandstone, siltstone, and shale-bearing thin, in-situ coals and rooted zones wherever the underlying sandstone is thick. Overlying these coals and rooted zones is a much thinner transgressive

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.

LIZAK, JOHN B., SOHIO/Royal Land Co., Evansville, IN

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.

LUMM, DONALD K., and W. JOHN NELSON, Illinois State Geol. Survey, Champaign, IL

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.

MARKOWSKI, ANTONETTE K., and RUSSELL R. DUTCHER, Southern Illinois Univ., Carbondale, IL

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.

MILLER, HALSEY W., Southern Illinois Univ. at Edwardsville, Edwardsville, IL

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.

MURRIE, GARY W., and JOHN T. POPP, Dames & Moore, Cincinnati, OH, DAVE OYLER, U.S. Bur. Mines, Pittsburgh, PA, and DENNIS J. SHAY, Indiana, PA

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