

ONE-DAY FIELD TRIP D
MAY 20, 1979

UNDERGROUND COAL MINE— Herrin (No. 6) Coal Member: Stratigraphy, deformational structures, and roof stability

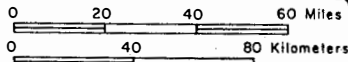
HANS-FRIEDRICH KRAUSSE
W. JOHN NELSON
JOHN T. POPP
ROGER B. NANCE

ILLINOIS STATE GEOLOGICAL SURVEY
URBANA, ILLINOIS

PREPARED FOR

NINTH INTERNATIONAL CONGRESS OF CARBONIFEROUS STRATIGRAPHY AND GEOLOGY (IX-ICC)

GEOLOGIC MAP



- Pleistocene and Pliocene not shown
- TERTIARY
 - CRETACEOUS
 - PENNSYLVANIAN
Bond and Mattoon Formations
Includes narrow belts of older formations along La Salle Anticline
 - PENNSYLVANIAN
Carbondale and Modesto Formations
 - PENNSYLVANIAN
Caseyville, Abbott, and Spoon Formations
 - MISSISSIPPIAN
Includes Devonian in Hardin County
 - DEVONIAN
Includes Silurian in Douglas, Champaign, and western Rock Island Counties
 - SILURIAN
Includes Ordovician and Devonian in Calhoun, Greene, and Jersey Counties
 - ORDOVICIAN
 - CAMBRIAN
 - Des Plaines Disturbance - Ordovician to Pennsylvanian
 - Fault

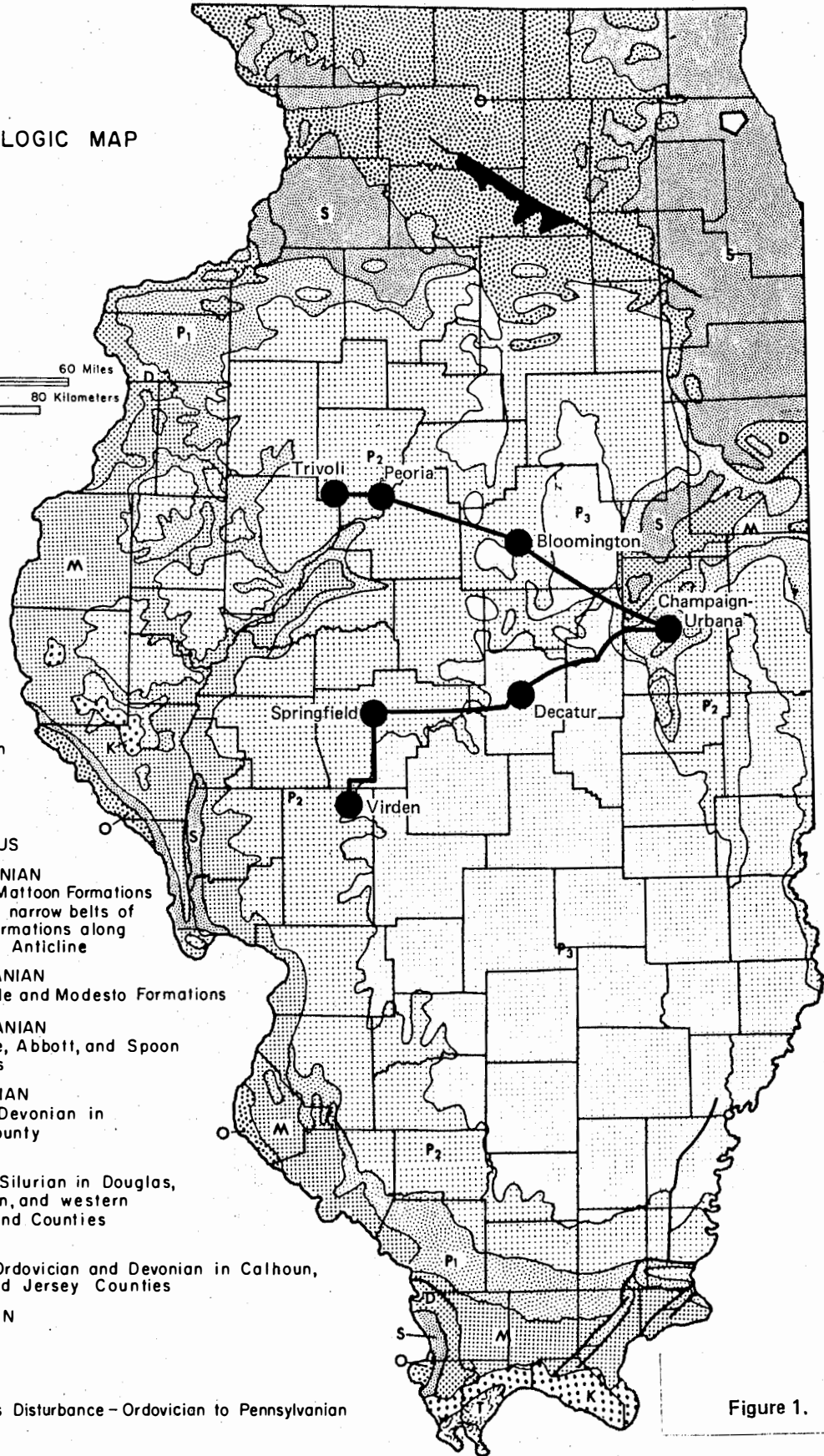


Figure 1.

UNDERGROUND COAL MINE - HERRIN (NO. 6) COAL MEMBER:
STRATIGRAPHY, DEFORMATIONAL STRUCTURES,
AND ROOF STABILITY

General Overview

Crown II Mine of the Freeman United Coal Mining Company will be visited on this field trip. At Crown II the Herrin (No. 6) Coal Member of the Carbon-dale Formation averages 2.0 meters (80 inches) thick and is being mined at a depth of about 100 meters (330 feet). The main purpose of the trip is to show stratigraphic and structural features of the Herrin (No. 6) Coal and overlying rocks, and relate these to problems of roof stability. The roof consists of strata deposited in a variety of marine, brackish-water and fluvial environments. In ascending order the roof sequence includes the Energy Shale, the Anna Shale, the Brereton Limestone, the Anvil Rock Sandstone, and the Bankston Fork Limestone Members of the Carbondale Formation. Structural features to be seen include a normal fault and a zone of left-lateral strike-slip faulting. Other abundant deformational structures that will be examined include clay-dike faults, clay dikes, "white top," and limestone "bosses."

Crown II Mine lies on the Western Shelf, an area of essentially flat-lying strata west of the axis of the Illinois Basin. On most of the Western Shelf the Herrin (No. 6) Coal is the only seam of minable thickness, but north of Crown II the Herrin (No. 6) Coal becomes thin while the older Springfield (No. 5) Coal reaches commercial thickness. Both seams have been extensively exploited in shallow shaft and slope mines. The Pennsylvanian strata are mantled by glacial drift of Illinoisan age, as shown on the accompanying map of glacial deposits.











Typical of the large, modern underground mines of Illinois, Crown II is a room-and-pillar operation utilizing ripper-type continuous miners. Coal is hauled through the mine by conveyor belt, while trackless electric haulage is used for men and materials. Because the drainage system of the very flat, highly productive farmland above the mine is very sensitive to subsidence, the pillars in the mine are not extracted, and longwall mining methods are not employed at Crown II. In southern Illinois, where the surface is less valuable for agriculture, longwall mining methods are applied in a somewhat experimental stage.

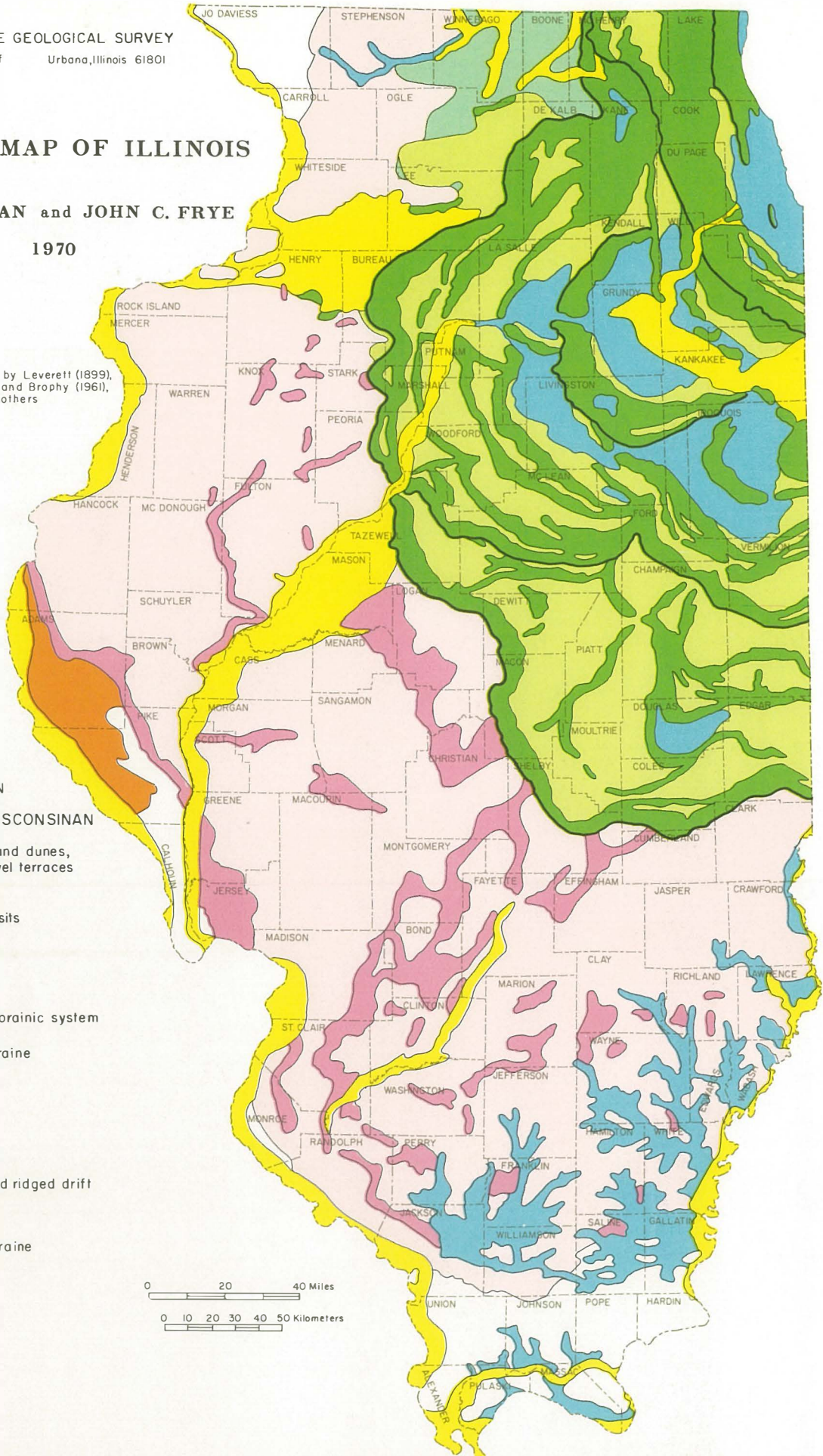
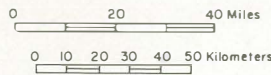
GLACIAL MAP OF ILLINOIS

H.B. WILLMAN and JOHN C. FRYE

1970

Modified from maps by Leverett (1899),
 Ekblow (1959), Leighton and Brophy (1961),
 Willman et al. (1967), and others

- EXPLANATION
- HOLOCENE AND WISCONSINAN**
 -  Alluvium, sand dunes, and gravel terraces
 - WISCONSINAN**
 -  Lake deposits
 - WOODFORDIAN**
 -  Moraine
 -  Front of morainic system
 -  Groundmoraine
 - ALTONIAN**
 -  Till plain
 - ILLINOIAN**
 -  Moraine and ridged drift
 -  Groundmoraine
 - KANSAN**
 -  Till plain
 - DRIFTLESS**
 - 



STRATIGRAPHIC MEMBERS EXPOSED IN CROWN NO. II MINE

(Sequence described from oldest to youngest member)

The Herrin (No. 6) Coal is the most important coal in Illinois. It correlates with the No. 11 Coal of western Kentucky, the Lexington Coal of Missouri, and possibly the Middle Kittanning Coal of Pennsylvania. It is a bright-banded coal, like nearly all the minable seams in Illinois. The coal rank is high volatile C bituminous in this area. The seam averages two meters (80 inches) thick at Crown II and has several clay partings 0.5 to 7.5 centimeters ($\frac{1}{4}$ to 3 inches) thick. The thickest and most persistent parting is called the "blue band" and is recognized in the Herrin (No. 6) Coal throughout the Illinois Basin Coal Field. At Crown II, the "blue band" occurs about 45 centimeters (18 inches) above the base of the seam. Other less continuous clay partings or bands are common in the middle and upper part of the coal. Pyrite is abundant, finely dispersed in the coal, in small nodules, as fracture-fillings, and as coating of cleats. It is largely responsible for the high (3-5%) sulfur content of the coal. Occasional flat calcareous coal balls are found in the upper part of the seam at Crown II.

The coal lies upon a rooted underclay that varies from a few decimeters to about one meter thick. Below the underclay is a zone of limestone, or of calcareous nodules in a matrix of shale, that probably correlates with the Higginville Limestone of Missouri. Exposures of the floor are few in the mine; part of the sequence can be observed along the fault at Stops 4, 11, and 13.

The sequence of strata overlying the coal seam is shown diagrammatically in Figure 6.

The Energy Shale is the lowest stratigraphic unit overlying the Herrin (No. 6) Coal. It consists of medium to dark gray, generally weak, poorly laminated shale. The shale contains abundant carbonaceous particles and plant debris, and occasional shells of Pecten and other brackish-water fauna. The Energy Shale occurs in the mine as small pods or lenses, ranging from several decimeters to more than a meter (few inches to some feet) thick and from about 10 to 100 meters (a few tens of feet to a few hundred feet) in diameter. It probably was deposited in small depressions on the surface of the peat. Most of the Energy Shale lenses are intensively penetrated and deformed by numerous small slips and minor faults.

The Anna Shale is the most widespread member forming the immediate roof at Crown II; it covers about $\frac{3}{4}$ of the area we have mapped. Although patchy and discontinuous locally, it is a very persistent unit regionally and is known in Kansas, Missouri, and throughout the Illinois Basin Coal Field. At Crown II it varies in thickness and is locally absent. It averages 0.15 to 0.9 meters ($\frac{1}{2}$ to 3 feet), but it also has been found as thick as 2.1 meters (7 feet). The Anna Shale particularly tends to become thin and pinch out above thick Energy Shale. The Anna Shale is a distinctive member of black, hard, fissile shale, typically well jointed and contains abundant phosphatic lenses and large calcareous concretions. The upper part is usually less fissile, weaker, less jointed, and in places mottled. Most geologists interpret it as a lagoonal deposit. Its sparse fauna

consists mainly of Lingula, Orbiculoidea, and Dunbarella. Anna Shale can be seen at Stop 1 and numerous other points along our tour.

The Brereton Limestone, which normally overlies the Anna Shale, is recognized throughout most of the Illinois Basin Coal Field. It is regionally just as persistent as the Anna Shale, but may locally pinch out. In Kentucky, the Brereton Limestone is equivalent to the lower part of the Providence Limestone Member. It is correlated with the Myrick Station Limestone in Missouri. Although locally the thickness of the Brereton Limestone exceeds 3 meters (10 feet), it averages 0.6 to 1.5 meters (two to five feet). It contains open-marine fauna, comprised mostly of brachiopods, fusulinids, and cephalopods. The Brereton Limestone consists of gray impure limestone that may grade laterally and vertically into a calcareous shale.

The Brereton Limestone is probably the most important unit with regard to stability of the roof at Crown II. Where the limestone is thicker than 0.6 meters (two feet), the roof is stable and provides good anchorage for roof bolts, especially where the underlying shales are thin or absent. But in some areas of the mine, particularly above the pods of Energy Shale, the Brereton becomes thin and nodular and may pinch out entirely. Roof falls are common in these areas, which also tend to be wet from water dripping from the overlying sandstone. Other troublesome areas occur along faults, where the Brereton Limestone is intensely fractured, as at Stop 4.

The Lawson Shale and Anvil Rock Sandstone are facies-equivalents that occupy the interval between the Brereton Limestone and the Bankston Fork Limestone at Crown II. The Lawson Shale generally consists of mottled greenish or gray, poorly bedded shale which may contain lenses of siltstone and sandstone. Animal fossils are scarce, but well-preserved plant fossils are abundant in some exposures. These indicate a non-marine environment of deposition, with occasional brackish influence. Lawson Shale occurs sporadically in Crown II and is not well exposed on the route of our tour. It grades vertically and laterally into the Anvil Rock Sandstone.

The Anvil Rock Sandstone includes a "sheet" phase and a "channel" phase. The sheet phase, which we will see on our visit and which covers most of Crown II, normally is about 1 to 3 meters (3 to 10 feet) thick and consists of thinly bedded, argillaceous siltstone or fine-grained sandstone. The bedding planes are coated with mica and fine carbonaceous debris, which promote separation of the layers in roof falls. The sandstone is slightly permeable, and is believed to be the main source of water that seeps from the roof into mine workings.

The channel phase of the sandstone occurs in one major channel and several minor channels in central and southern Illinois. The major channel, which passes southeast of Crown II, has been traced for over 160 km (100 miles) and is up to 3.2 km (2 miles) wide. In this channel, the Herrin (No. 6) Coal and lower members have been eroded, and the Anvil Rock Sandstone may exceed 30 meters (100 feet) thick. The smaller channels are quite numerous and, like the main channel, follow winding courses. One such channel, in which the Anna Shale and Brereton Limestone but not the coal have been eroded, has been mapped in the northern part of Crown II. The sandstone filling the channels tends to be medium grained (rarely coarse grained), slightly argillaceous, gray to brown, porous, and often cross-bedded. A

basal conglomerate with fragments of coal, shale, and other lithologies may be present. In some areas the channel fillings include shale and siltstone as well as sandstone.

The Bankston Fork Limestone normally overlies the Lawson Shale or the Anvil Rock Sandstone and is overlain by medium-gray or greenish-gray shales. It can be traced through most of the Illinois Basin, but it has not been definitely identified west or north of the Illinois River. In the east and southeast of the basin, it correlates to the Universal Limestone Member of Indiana, and it is present in western Kentucky. The Bankston Fork Limestone consists of one or more benches of limestone, occasionally slightly dolomitic. The limestone benches are separated by calcareous shales. One to three impure limestone benches are most common. Where the Anvil Rock Sandstone is thick, the limestones are frequently absent. The Bankston Fork Limestone commonly is 0.9 to 2.45 meters (3 to 8 feet) and generally less than 1.8 meters (6 feet) thick. Although persistent throughout the Illinois Basin, rapid changes in thickness and purity, and local pinch-outs have been found. Its fauna, composed mainly of brachiopods and fusulinids, implies an open marine environment.

The Bankston Fork Limestone is the highest rock unit visible along the tour route. It is generally a competent layer that caps the highest roof falls. The base of it can be seen in the large roof fall just east of Stop 14.

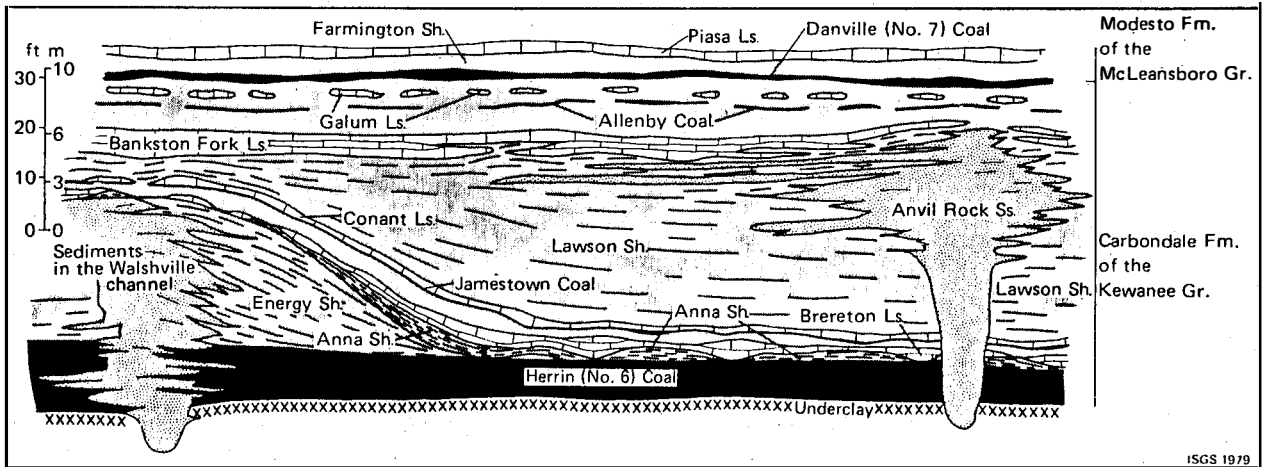
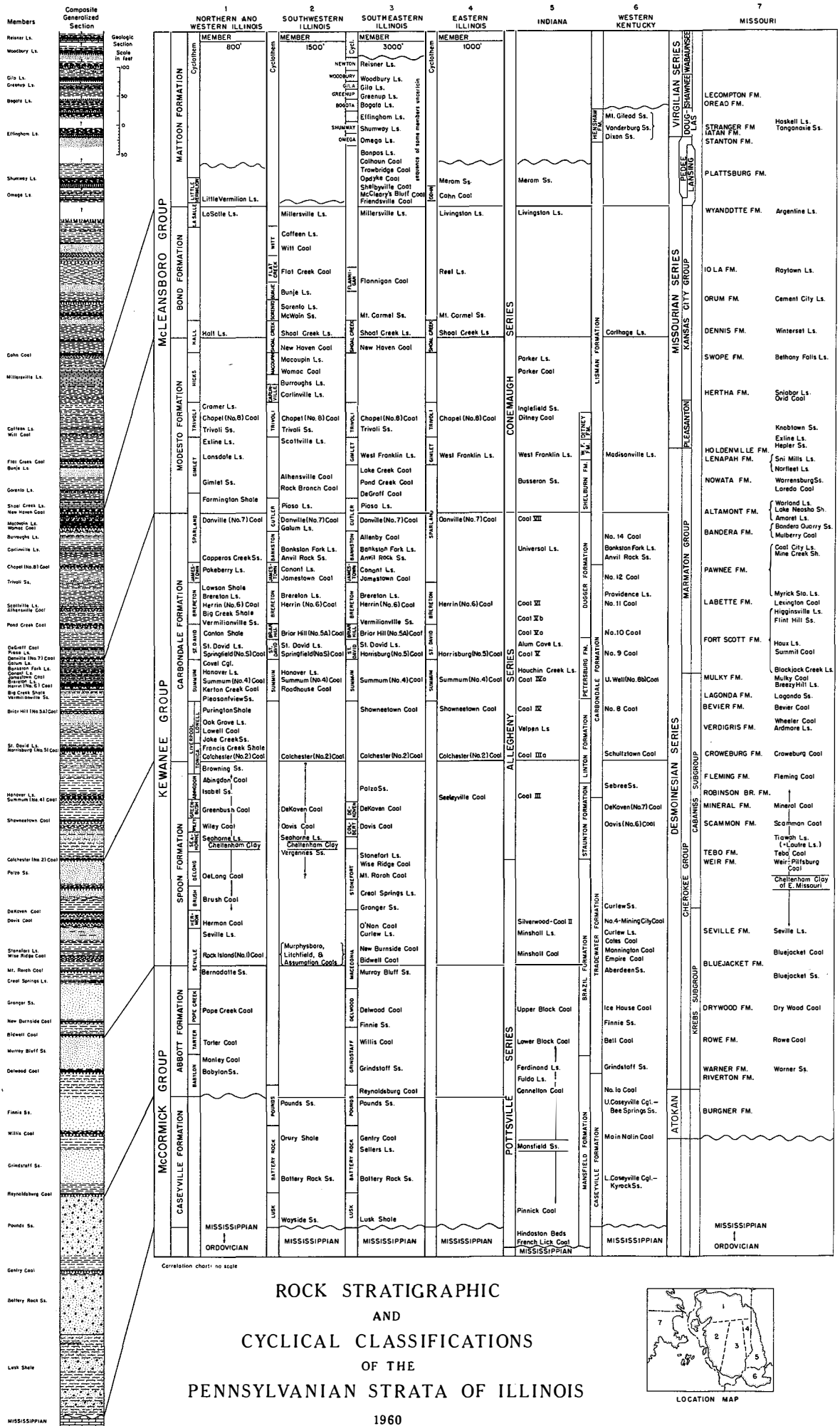
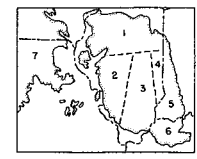


Figure 3. Schematic section of the interval between the Herrin (No. 6) Coal Member and the Piasa Limestone Member. (After G. J. Allgaier, June 1974.)



Correlation chart - no scale

ROCK STRATIGRAPHIC
AND
CYCLICAL CLASSIFICATIONS
OF THE
PENNSYLVANIAN STRATA OF ILLINOIS



LOCATION MAP

Kewanee Group

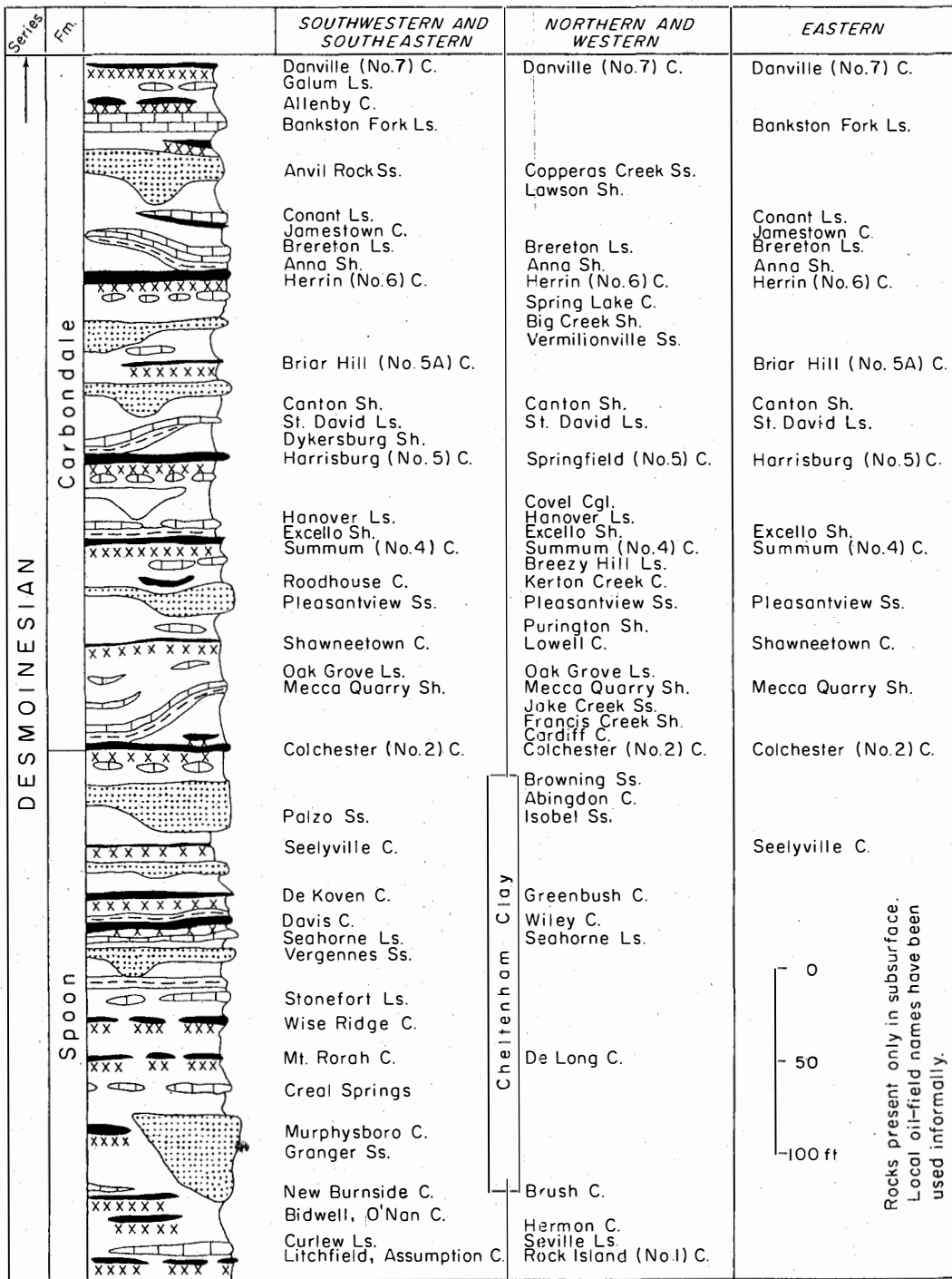
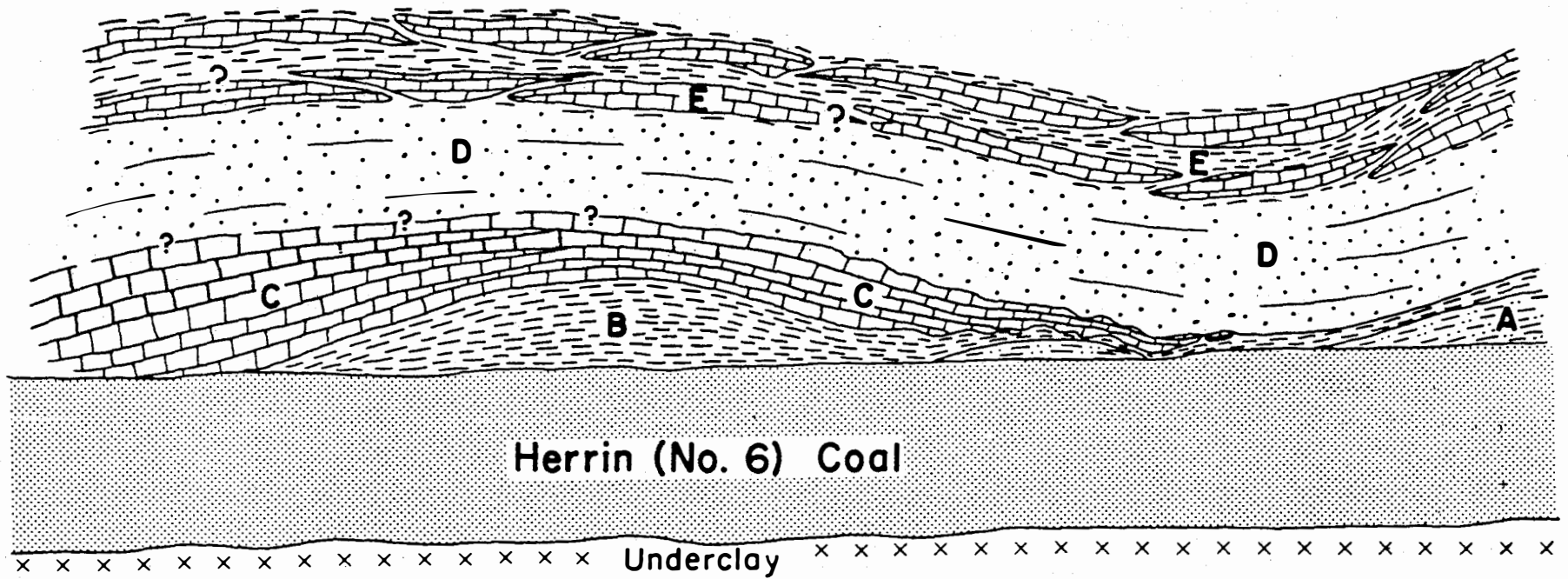


Figure 5

Diagrammatic column of lithologic members of the Spoon and Carbondale Formations (Pennsylvanian System) in Illinois. Blank space indicates gray shales; named members are listed to the right of the stratigraphic column (from Hopkins and Simon, 1975)

Generally dry

Generally wet








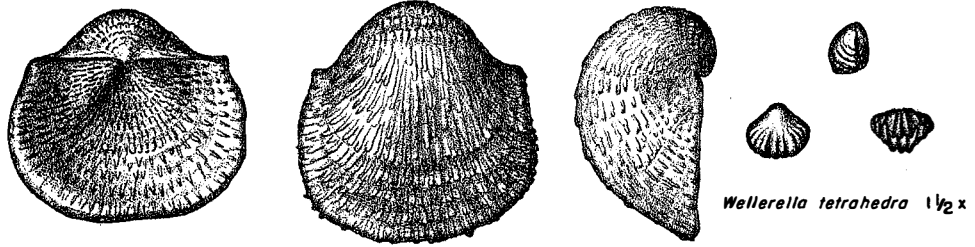
-  E: Bankston Fork Limestone (limestone and limey shale)
-  D: Anvil Rock Sandstone
-  C: Brereton Limestone
-  B: Anna Shale (black shale)
-  A: Energy Shale (dark and medium gray shales)

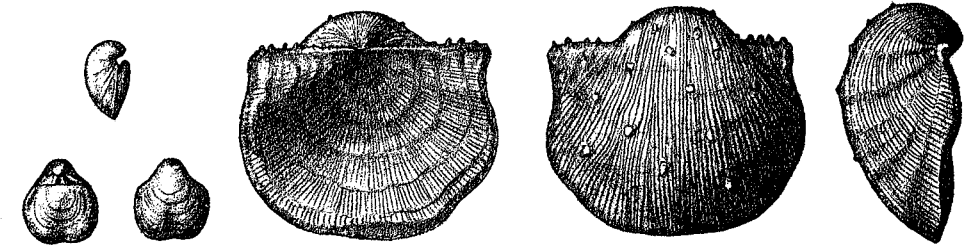
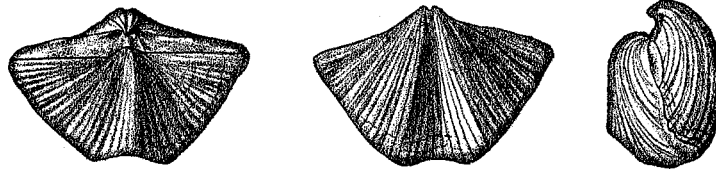
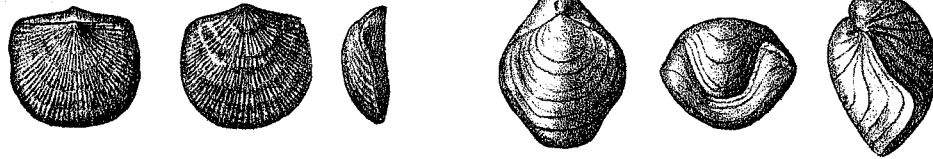
Figure 6.

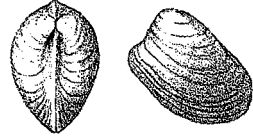
Schematic of sequence and interrelationships of roof strata above the Herrin (No. 6) Coal Member in the Main Entries of the Crown II Mine.

BRACHIOPODS



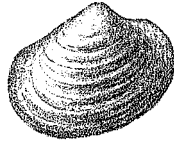
Juresania nebrascensis 2/3 x





Nucula (Nuculopsis) girtyi 1x

PELECYPODS



Edmonia ovata 2x



Astartella concentrica 1x



Dunbarella knighti 1/2 x



Cardiomorpha missouriensis
"Type A" 1x



Cardiomorpha missouriensis
"Type B" 1/2 x

GASTROPODS



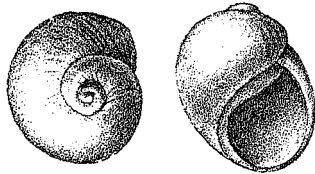
Euphemites carbonarius 1/2 x



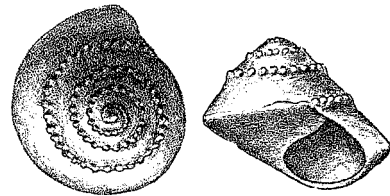
Trepospiro illinoisensis 1/2 x



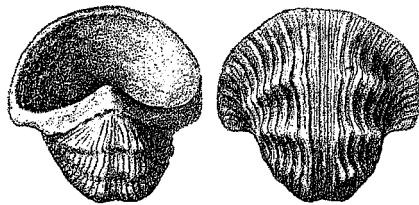
Donaldina robusta 8x



Naticopsis (Jedria) ventricosa 1/2 x



Trepospira sphaerulata 1x

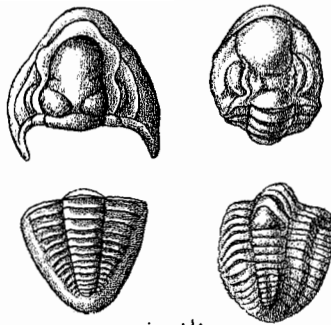


Knihtites mantfortianus 2x



Glabrocingulum (Glabrocingulum) grayvillense 3x

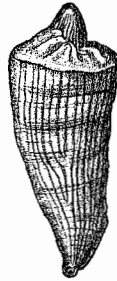
TRILOBITES



Ameura sangamonensis 1 1/3 x

Ditomopyge parvulus 1 1/2 x

CORALS



Lophophliidium proliferum 1x

FUSULINIDS



Fusulina acme 5x

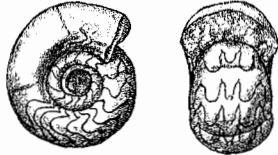


Fusulina girtyi 5x

CEPHALOPODS

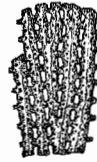


Pseudorthoceras knoxense 1x

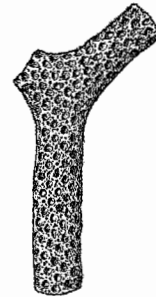


Glaphrites welleri 2/3 x

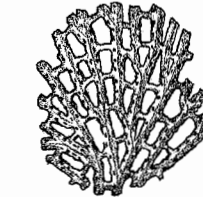
BRYOZOANS



Fenestrellina mimica 9x

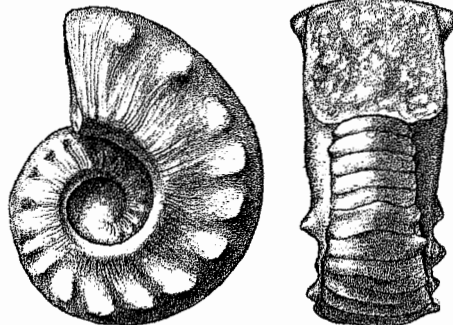


Rhombopora lepidodendroides

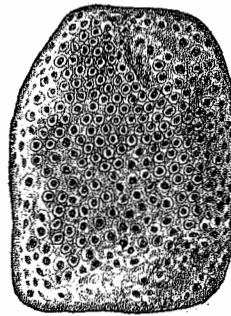


Fenestrellina modesta 10x

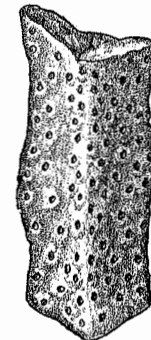
6x



Metacoceras cornutum 1 1/2 x



Fistulipora carbonaria 3 1/3 x



Prismopora triangulata 12x

DEFORMATIONAL STRUCTURES

Besides cleat in coal and common joints in the roof rock three major types of deformational structures will be seen during the field trip: (a) Old-est are numerous clay-dike faults, clay dikes and "white top" disturbances. (b) A normal fault is younger and displaces the clay-dike faults. (c) A strike-slip fault zone penetrates the normal fault.

Clay-dike faults, clay dikes and "white top" have been encountered in many mines of the Illinois Basin Coal Field. They are genetically related and result from the same deformational process. Clay-dike faults, clay dikes and "white top" make mining difficult because they increase the impurity of the coal, decrease the roof stability in underground mines and hinder the movements of equipment upon the coal seam in surface mines. The abundance of clay dikes in some mines has been a factor in their abandonment.

Clay-Dike Faults are common in the Desmoinesian Series of the Illinois Basin Coal Field. They are particularly abundant in the Springfield (No. 5) and the Herrin (No. 6) Coal Members and associated strata of the Carbondale Formation.

Clay-dike faults are tension and shear fractures. They are named for their close genetic relationship to clay dikes. They are a different portrayal of the same process that forms clay dikes.

Clay-dike faults are normal faults that tend to curve along their strike. Commonly they strike sub-parallel to the boundaries of lithologic bodies in the immediate roof of the coal seam. Along their strike, they may branch and rejoin, and often form an "en echelon" pattern, intersect other faults, or dissipate into minor fractures and die out. Their inclination varies from near vertical, which has been observed more often in the Springfield (No. 5) Coal, to low angle or sub-horizontal as is common in the Herrin (No. 6) Coal.

Many faults appear as sub-horizontal shears in the roof rock. They increase in dip downward and steepen to vertical in the coal. The major fault may be accompanied by or grade into sets of antithetic and synthetic subsidiary faults. Downwards the faults generally branch and terminate in a dendritic bundle of vertical tension fractures without vertical displacement. The bundles of tension fractures are commonly mineralized with pyrite, calcite, sphalerite, or rarely barite.

Clay-dike faults and associated fractures result from lateral extension and horizontal displacement. The amount of vertical throw depends on the inclination of the fault. Vertical faults are pure tension fractures, whereas horizontal faults are pure extensional shear faults. Both show little or no vertical displacement. Maximum vertical throw occurs at a dip of about 45 degrees is generally greatest near the top of the coal, and is commonly less than one meter (3 feet). Clay-dike faults displacing the strata more than three meters (9 feet) have been mapped in some areas. They usually extend in strike over long

distances (several thousand feet, more than a kilometer) and seem to trend independently of the lithologic boundaries in the immediate roof rock.

Other structural features associated with clay-dike faults also indicate extension. They include false drag (reverse drag) at normal faults, tilted blocks between faults, thinning of roof strata and coal towards the faults, flow structures, convergence of bedding at the tips of low-angle shear surfaces and of lateral fissure fillings, and intrusion of detrital material.

Clay Dikes are intrusions of extraneous, dominantly detrital sediments (clay, silt, sand, limestone) into clay-dike faults.

Clay dikes are abundant in coals of the Illinois Basin, where they are also called clay veins, clay seams, mud seams, clay sills, dirt slips, and horsebacks. Their widths range from millimeters to meters. From their irregular walls, numerous short lateral intrusions extend into the adjacent bedding of the coal (comp. "white top"). The dikes extend downward from the roof rock of the seams. They are generally thicker where nearly vertical and thinner where they dip at only a low angle to the bedding. Their filling consists dominantly of angular fragments of shale, limestone, and coal in a matrix of clay, silt, or sometimes sand. The size of the fragments varies from less than a millimeter to several centimeters (fraction of an inch to few inches). Coals truncated by clay dikes display the same deformational structures as clay-dike faults, such as false drag (reverse drag) and convergence of bedding at the very ends of lateral fissure fillings. The dikes may dissipate downward within the coal in the form of minor slips and/or as numerous near-vertical, generally en echelon extension fractures. Clay dikes normally do not intrude into the underclay. The underclay is generally bulged upward where the clay dikes or associated clay-dike faults penetrate the entire coal seam.

"White Top" is a miners' term which is frequently used in northwestern Illinois for intense disturbances of the coal seam, especially its upper parts. "White Top" is another mode of the same process that formed clay-dike faults and clay dikes.

"White top" in coal gives the superficial impression of an intensely disturbed, almost brecciated, rock body consisting of light gray, bleached clay intermixed with numerous, irregular coal fragments. Many geological reports describe "white top" in this manner (Udden 1912, Cady 1915, Damberger 1971). A close look at a "white top" body, however, reveals an interior structure that combines the original structural elements of the coal seam (e.g. bedding) and younger, superimposed structural elements of clay dikes and clay sill, as described above.

Tracing from the undisturbed coal seam toward "white top", either laterally or from the base of the seam upwards, an increasing abundance of minute, mostly vertical fractures can be seen. Gradually the fractures are found filled with thin films of white clay. Along with the thickening of such fracture-filling clay, a separation of coal laminae and bedding planes can be observed. Those generally horizontal or subhorizontal bedding plane fractures are also filled with tiny streaks of clay. Nearer

to the core of the "white top" body, fractures increase in density and the clay fillings increase in thickness. There the coal seam contains abundant irregular fractures and short, thin clay dikes which are filled with the same light gray, bleached clay. In many places, silty material is also observed in "white top."

The core of the "white top" body usually consists of clay, silty clay, or occasionally sandy silt, in which coal fragments of all sizes (chips less than a millimeter across to pieces of several decimeters long) are embedded. Most of the coal fragments display an almost orderly, not chaotic, fabric within the "white top" body. They are normal, well-laminated, unaltered coal. Usually they are flat and elongate parallel to their lamination, angular at their ruptured edge. Their bedding is oriented horizontally or nearly so, usually parallel or almost parallel to the bedding of the seam.

The clay-filled fractures grading into the core of the "white top" body vary widely in dimension. They may be as wide as one meter (3 feet) in the center of the "white top" and less than one millimeter (fraction of an inch) in and around the "white top." Along their strike they may extend for less than one centimeter to several meters (less than half an inch to several yards). The vertical thickness of a "white top" body may vary from a few millimeters (fraction of an inch) to the entire thickness of the seam.

Usually "white top" and clay dikes are closely associated. In heavily disturbed areas, "white top" and clay dikes may be difficult to distinguish because both modes of deformation grade into each other.

We have mapped "white top" as forming elongate bodies over long distances (several hundred meters). Many of the elongate "white top" bodies in the upper portion of the coal seam grade downward into one or more clay dikes. Like clay-dike faults and clay dikes, "white top" disturbances also involve the roof strata of the Herrin (No. 6) Coal. Predominantly the Energy Shale and the Anna Shale, but also the lower portion of the Brereton Limestone, may be affected.

This involvement of roof strata indicates that the deformation, which resulted in the formation of "white top," must have happened after accumulation and burial of the seam, after the major compaction and after a high degree of lithification of the coal seam. It is not an erosional feature as indicated by Udden (1912) and Wanless (1952).

Damberger (1973) concludes that clay dikes and "white top" formed as earthquake-induced disturbances when the Herrin (No. 6) Coal was not yet buried. In accordance with many of his conclusions, we also infer that clay-dike faults, clay dikes, "white top," and associated structural features are the result of seismic activity. However, the "white top" as well as clay dikes of the Herrin (No. 6) Coal have been formed after burial of the affected strata.

Normal Fault. A major point of interest on this visit is the normal fault that crosses the Main South Entries in a southeasterly direction (Stops 4, 6, 11, and 13). The fault has the greatest vertical displacement of any fault in Crown II; 1.2 to 2.1 meters (4 to 7 feet) with the northeast side downthrown. It displaces all exposed strata from the underclay through the Bankston Fork Limestone. It crosses all twelve entries of the Main South and continues through the 1st Panel South into the 2nd Panel South off the Main East. Thus it has been traced about 910 meters (3000 feet) along strike. It follows practically a straight course for the entire distance.

The angle of dip averages about 45 degrees. The fault exhibits little drag in the roof rock and locally false drag in the coal. In places the fault splits into two or more narrowly-spaced subparallel branches. Coal and rock in the fault zone commonly are fractured, and locally are pulverized. The main accompanying fractures trend parallel with or at right angles to the fault zone. The fault displaces and is younger than the clay-dike faults and "white top." It is, however, older than the strike-slip fault which offsets the normal fault (as seen at Stop 13). Elsewhere in the mine a few similar faults of much smaller displacement have been mapped in the same southeasterly direction of strike.

The genetic origin of these faults is still being discussed. The low angle of dip is more typical of growth faults than of tectonic normal faults, which generally have an inclination of more than 55 degrees. Normal faults of this type are not known to correspond with any known system of tectonic faults in the area of central Illinois.

Strike-Slip Fault Zone. An unusual structural feature at Crown II Mine is a zone of strike-slip faulting that extends across the Main South Entries (Stops 5, 6, and 12) and intersects the normal fault at Stop 13. To date the zone has been mapped continuously for about 1800 meters (6000 feet), and there are no indications that it dies out at either end. The overall trend of the zone is slightly north of east. Similar structures were noted years ago by Survey geologists in Freeman's Crown I Mine, about five miles (8 km) due east of Crown II.

The fault zone consists of three main elements: (1) left-lateral faults trending east-west or slightly north of east, with maximum vertical offset of about 1.2 meters (4 feet) and lateral displacement of 3-5 meters (10-15 feet) at the most, (2) oblique-slip reverse faults and small, tight folds striking south of east, and (3) extensional faults and fractures striking northeast. In some of the latter (outside the area visited) the walls of the fractures actually have been pulled away from each other, and pulverized or brecciated rock has fallen into the voids. In less extreme cases (as at Stops 6 and 7) extensional forces have resulted in closely-spaced northeast-trending vertical fractures in the coal and roof. These three elements fit the pattern of left-lateral shear, as illustrated in Fig. 13.

At Stop 13 the strike-slip fault offsets the normal fault and is younger than the normal fault. The strike-slip fault also appears to jog slightly

along the normal fault. It probably followed the pre-existing zone of weakness created by the normal fault. Some of the high-angle fractures observed elsewhere along the normal fault may be the result of re-activation by wrenching. The normal fault cannot be a direct result of wrenching. In a left-lateral shear zone, northwest-trending fractures are compressional.

The normal fault and the strike-slip fault both severely weaken the roof and provide pathways for water to enter the mine. Along the lateral fault in particular, many major roof falls have occurred. The fault has been observed to penetrate through the Bankston Fork Limestone and its overlying strata of shale. The northeast-trending tensional fractures also decrease the stability of the roof, and frequently yield water.

The origin of the strike-slip fault is still unknown. The fault is much smaller in magnitude than most known strike-slip faults, and occupies an area where tectonic activity is virtually unknown. Perhaps it was formed in response to local settling during the subsidence of the Illinois Basin.

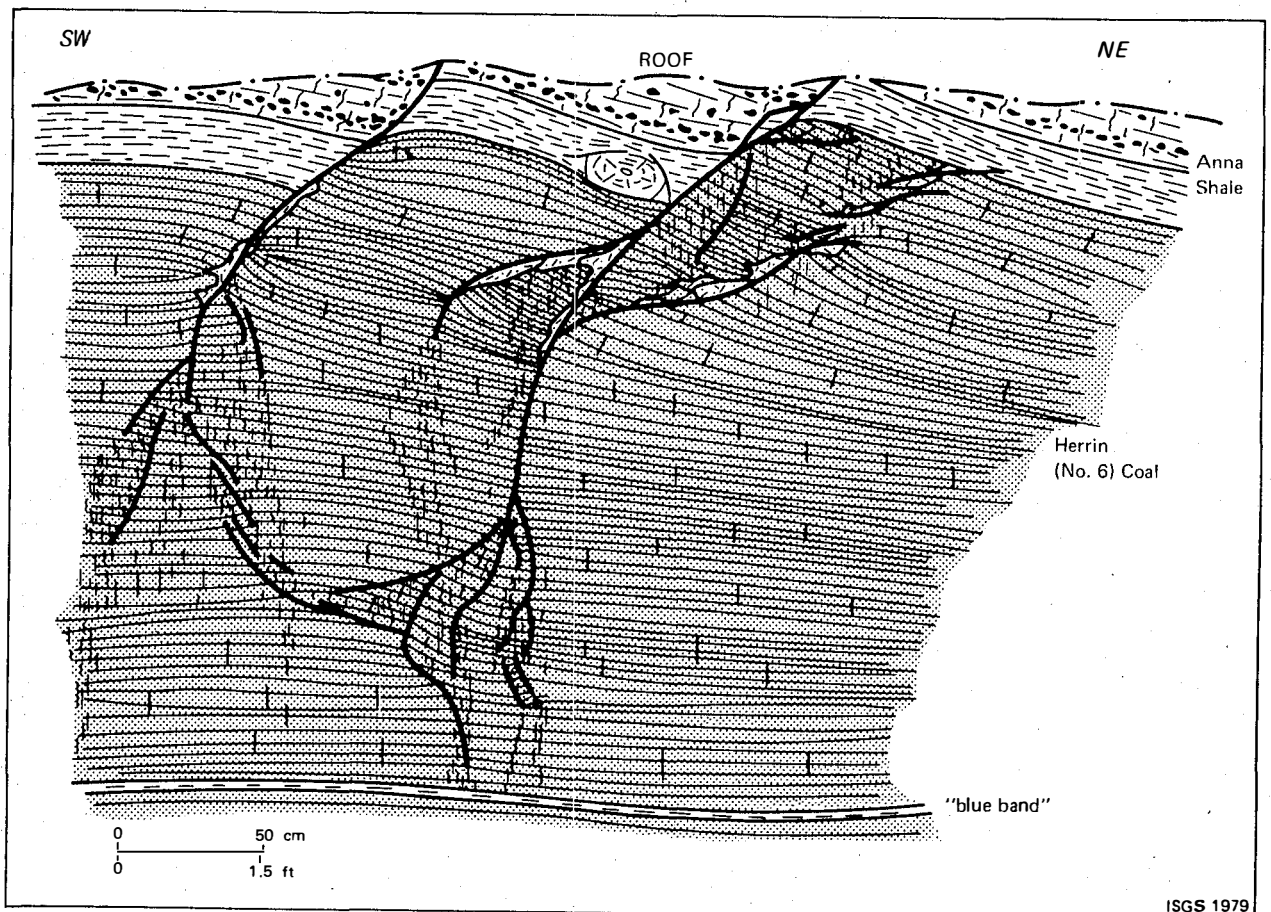


Figure 10. Clay-dike faults with clastic dikes in the Herrin (No. 6) Coal and Anna Shale. Displacement at top of coal is more than one foot; however, the "blue band" has not been cut. Horizontal extension in the coal above the "blue band" results from dip-slip shearing along the low-angle faults and from rupturing and opening of numerous en echelon extension fractures ("goat beards"), which are filled with abundant pyrite and in some places with barite and calcite. Note false drag and tilting of blocks between the faults, and convergence of coal beds at some ends of clastic dikes and sills. Location: mine A, west-central Illinois.

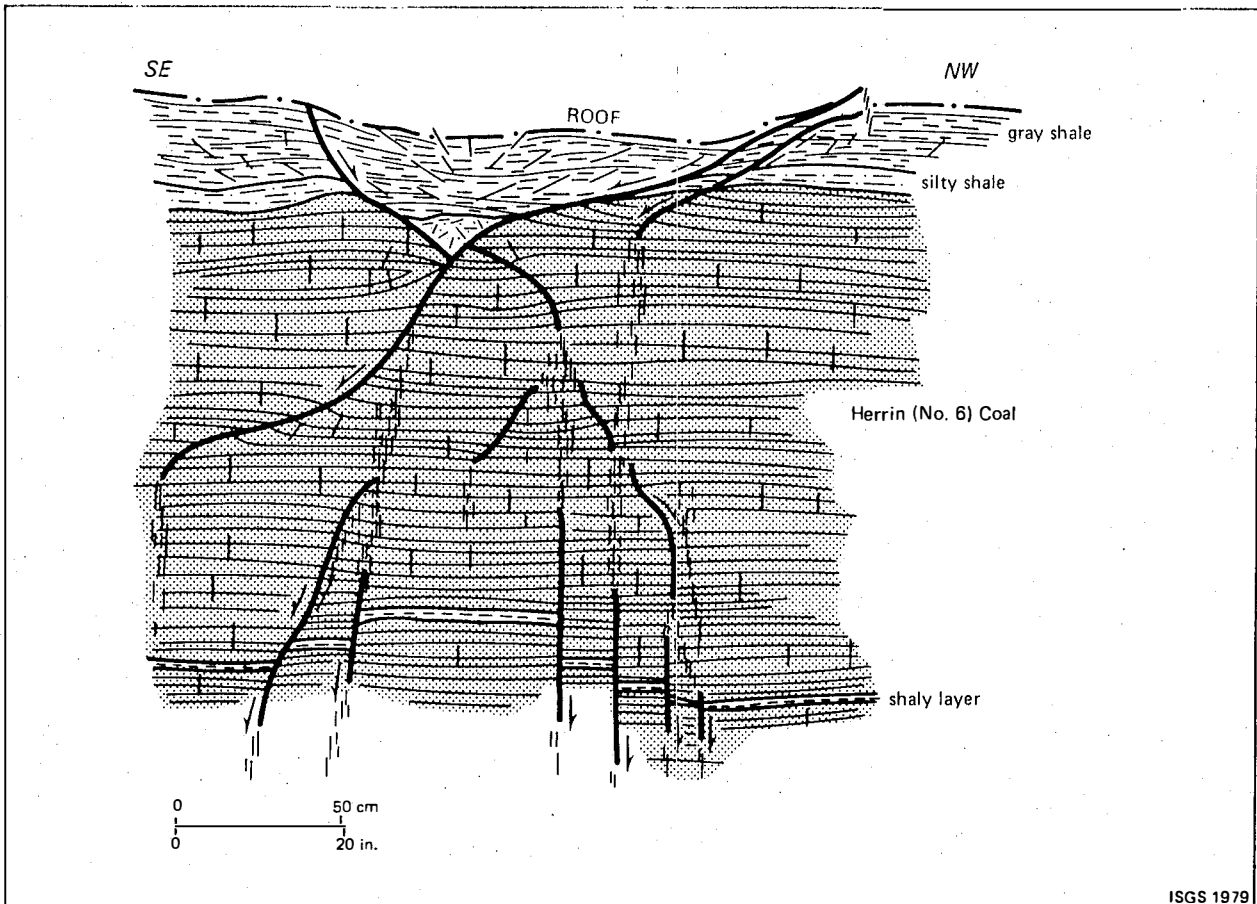


Figure 11. Clay-dike faults forming a graben at the top (note the intensely sheared gray shale) and a horst at the bottom of the Herrin (No. 6) Coal. Low-angle normal faults in shales above the coal steepen downward into the coal and dissipate in the form of an echelon extension fractures ("goat beards"). Farther down in the coal seam faults also form an echelon pattern and produce a step-faulted horst. Note convergence features of coal beds (upper left area) and false drag. Total deformation is due mainly to horizontal extension with little or no vertical throw of strata. Location: west-central Illinois, mine N.

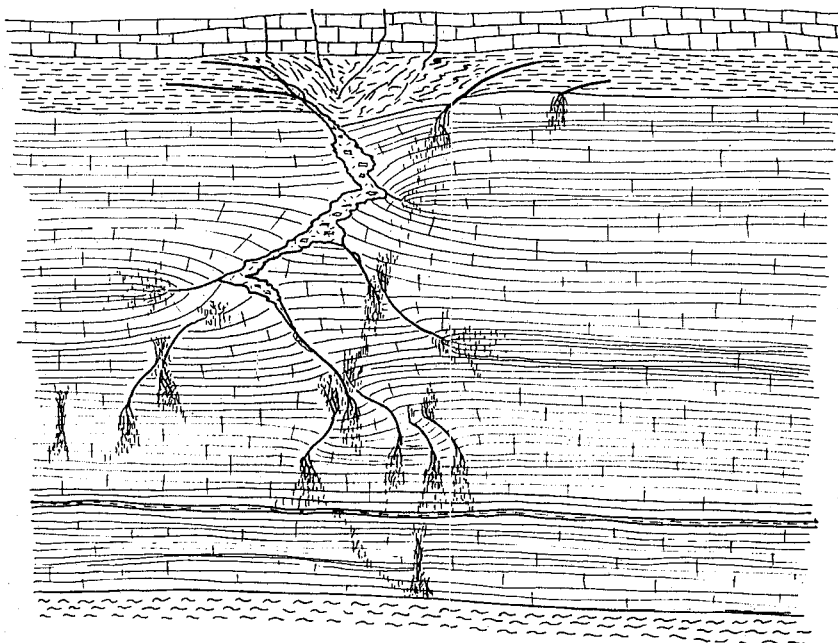


Figure 12. Composite of clay-dike fault and associated features. (clay dike, tension shears, tension fractures, "goat beards," false drag, convergence and fanning of coal bedding.)

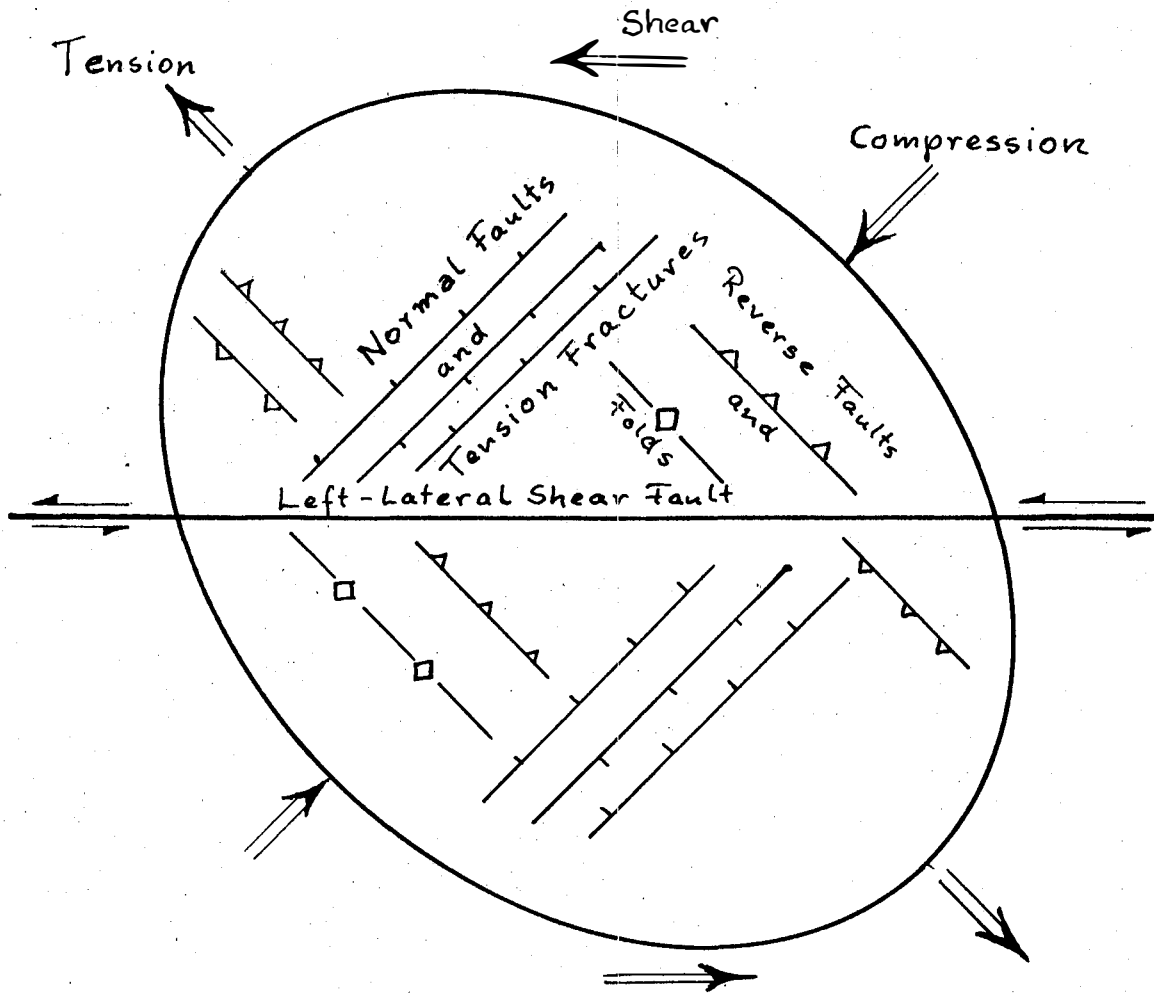


Figure 13. Stress ellipsoid for east-west trending left-lateral shear. Maximum extension is northwest-southeast, producing northeast-trending normal faults and extension fractures. Maximum compression is at right angles, producing northwest-trending anticlinal folds and reverse faults. In the real world, drag along the fault tends to orient the folds and reverse faults more nearly east-west. The through-going left-lateral fault, where developed, trends east-west. All of these elements can be observed in Crown II at Stops 5, 6, 12, and 13.

- Smith, W.H., R. B. Nance, M. E. Hopkins, R. G. Folinson, and C. W. Shabica, 1970, Depositional environments in parts of the Carbondale Formation - western and northern Illinois: Illinois State Geological Survey Guidebook Series No. 8, 119 p.
- Smith, W. H. and J. B. Stall, 1975, Coal and water resources for coal conversion in Illinois: Illinois State Water Survey and Illinois State Geological Survey, Cooperative Resources Report 4, 79p.
- Udden, J. A., 1912, Geology and mineral resources of the Peoria Quadrangle, Illinois: United States Geological Survey Bulletin 506, 103 p.
- Wanless, H. R., 1952, Studies of field relations of coal beds: 2nd conference on the origin and constitution of coal, Crystal Cliffs, Nova Scotia, p. 155-159.
- Wanles, H. R., 1957, Geology and mineral resources of the Beardstown, Glasford, Havana, and Vermont Quadrangles: Illinois State Geological Survey Bulletin 82, 233p.