ONE-DAY FIELD TRIP J
MAY 27, 1979

SURFACE COAL MINE-

Major coals of the Carbondale Formation

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URBANA, ILLINOIS

PREPARED FOR

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

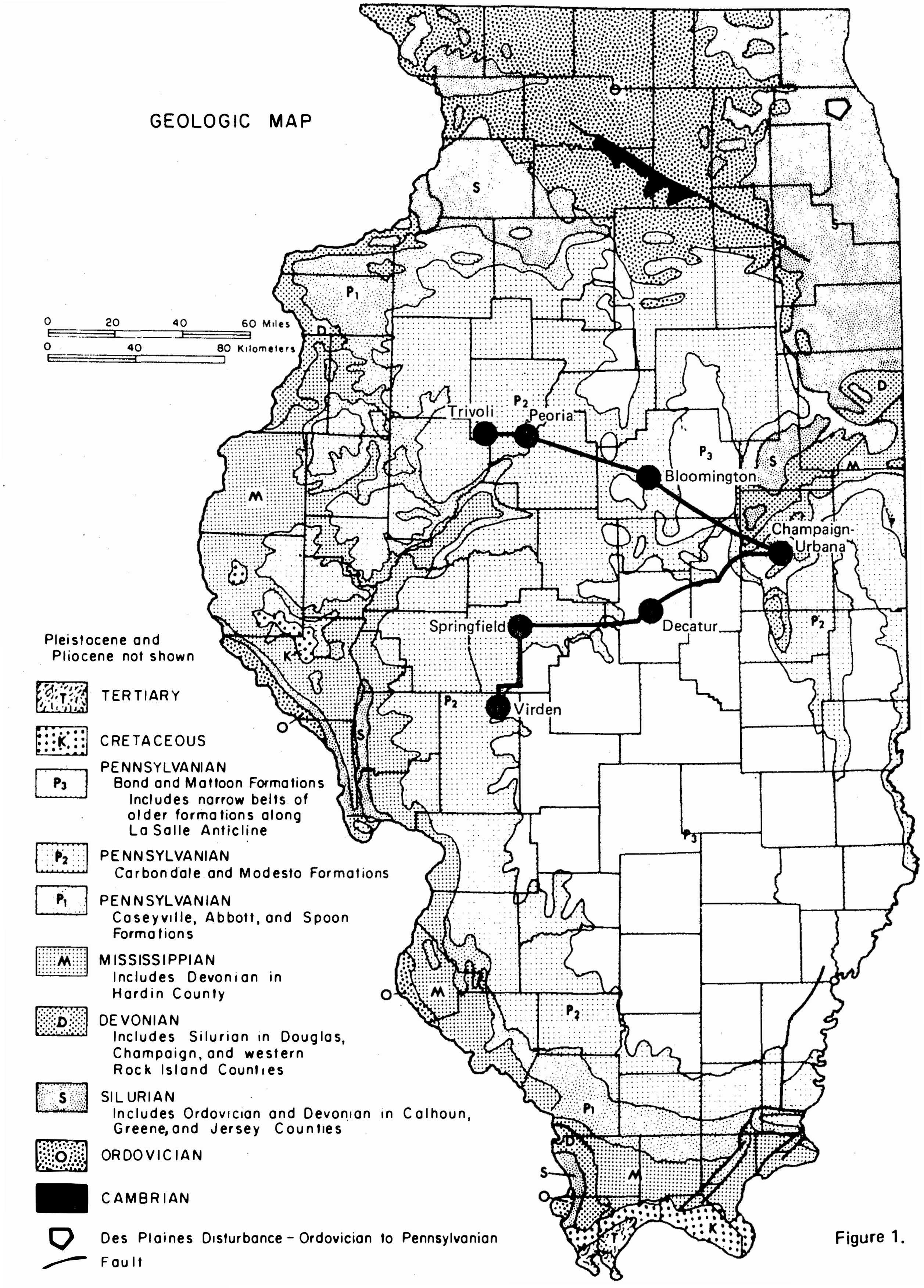
GEOLOGIC MAP
0 20 40 60 Miles
0 40 80 Kilometers
Pleistocene and Pliocene not shown
T TERTIARY
K CRETACEOUS
P3 PENNSYLVANIAN Bond and Mattoon Formations Includes narrow belts of older formations along La Salle Anticline
P2 PENNSYLVANIAN Carbondale and Modesto Formations
P1 PENNSYLVANIAN Caseyville, Abbott, and Spoon Formations
M MISSISSIPPIAN Includes Devonian in Hardin County
D DEVONIAN Includes Silurian in Douglas, Champaign, and western Rock Island Counties
S SILURIAN Includes Ordovician and Devonian in Calhoun, Greene, and Jersey Counties
O ORDOVICIAN
CAMBRIAN
Des Plaines Disturbance - Ordovician to Pennsylvanian
Fault
Trivoli
Peoria
Bloomington
Champaign-Urbana
Decatur
Springfield
Virden
S
P1
P2
P3
M
D
K
T
O

Figure 1.

SURFACE COAL MINE - MAJOR COALS OF THE CARBONDALE FORMATION

General Overview

Two active surface coal mines (strip mines) of the Midland Coal Company in western Illinois will be visited during this field trip. The exposed strata are of the Carbondale and Modesto Formations of the Pennsylvanian Period and of the Glasford Formation of the Pleistocene Epoch. Three coals, all of the Carbondale Formation, may be seen (from the top): the Danville (No. 7), Herrin (No. 6), and Springfield (No. 5) Coal Members. Together these coals make up 79 percent of the mapped coal resources of Illinois. The features of particular interest on this trip are: (1) the stratigraphy of rock units associated with the coals, (2) clay-dike faults, clay dikes, and "white top" disturbances of the coals, and (3) sphalerite mineralization in the coals and associated strata. The strata from the Herrin (No. 6) Coal to just above the Danville (No. 7) Coal are exposed in the highwall of the Elm Mine. Strata from the Springfield (No. 5) Coal to the Herrin (No. 6) Coal are exposed in the Rapatee Mine.

The surface mines visited are located on the western margin of the Illinois Basin called the Western Shelf, where Pennsylvanian strata dip gently (regionally less than 4 meters per kilometer or 20 feet per mile) easterly into the basin. In much of this area, upper Pennsylvanian rocks have been removed by pre-Pleistocene erosion and weathering and Pleistocene glacial erosion. About 150 meters (500 feet) of Pennsylvanian strata are present in the immediate vicinity of the Elm Mine. The Pennsylvanian strata thin rapidly to the west.

Surface coal mines have been active in western Illinois since 1924. At one time, strip mines in this area yielded the highest coal production of surface mining in the state of Illinois. However, the number of surface mines has been declining since 1970. Although large resources of surface minable coal remain, there are currently only 6 active mines in this area. The decline in production reflects the lack of demand for coals with high sulfur content as well as the increasing costs of surface mine reclamation. The abundance of clay dikes and "white top" may also contribute to a decrease in mining, because clay dikes and "white top" increase the impurity of the raw coal and make mining more difficult.

ILLINOIS STATE GEOLOGICAL SURVEY
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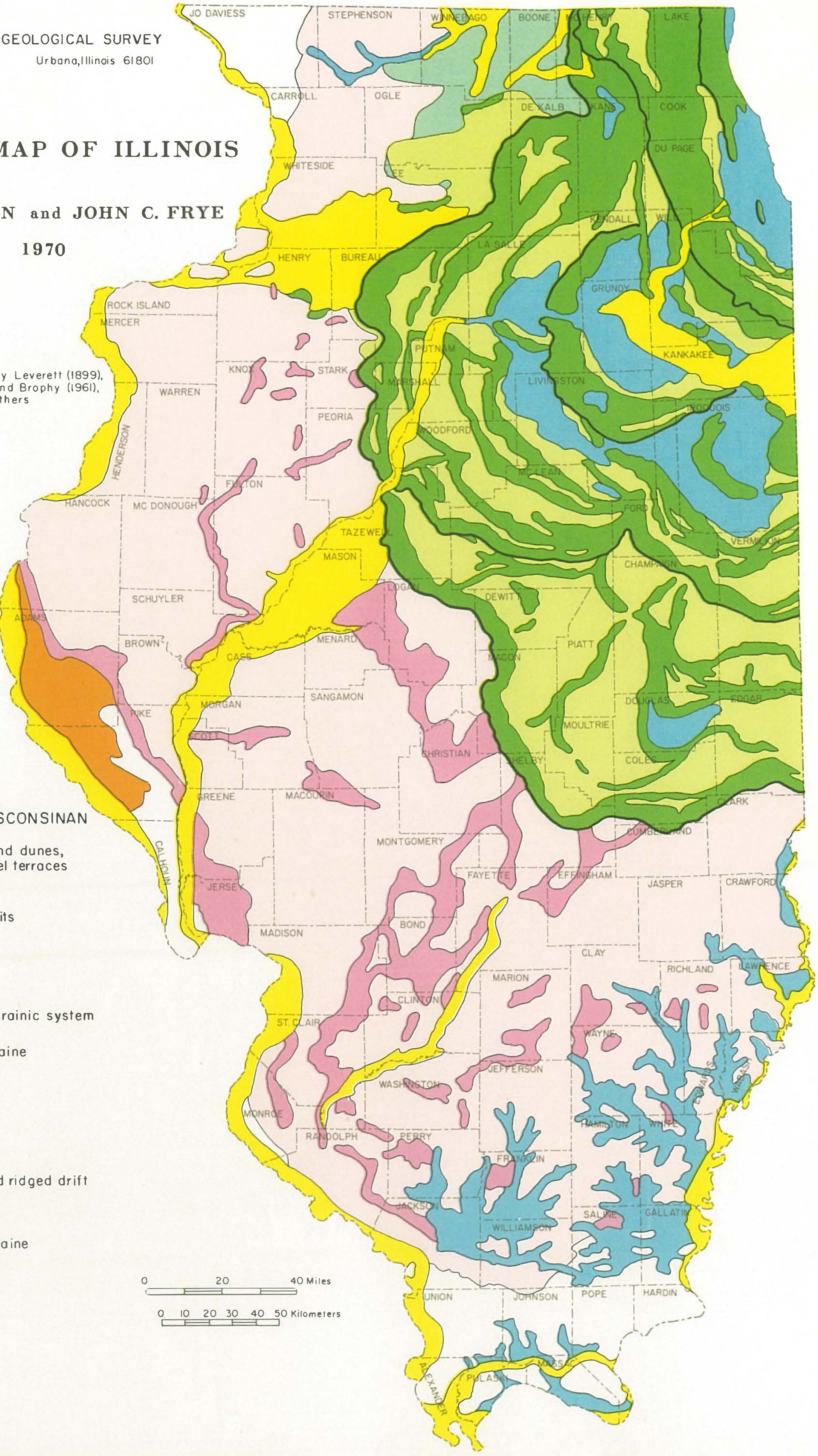
GLACIAL MAP OF ILLINOIS

H.B. WILLMAN and JOHN C. FRYE

1970

Modified from maps by Leverett (1899), Ekblaw (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

⬜

MAJOR STRATIGRAPHIC UNITS

(Sequence described from oldest to youngest member)

Springfield (No. 5) Coal: Commercially and resource wise second most important coal in Illinois. Averages 1.2 meters (4 feet) in thickness at Elm and Rapatee Mines; thins and pinches out to the north; thickens to an average of 1.5 meters (5 feet) to the south. No persistent clay partings in the seam. Contains numerous clay dikes and mineralized veinlets. The coal is correlative with the Springfield V Coal in Indiana, the Summit Coal of Missouri, and the Kentucky No. 9 Coal. In southern Illinois, it is called the Harrisburg (No. 5) Coal.

Black Shale over Springfield (No. 5) Coal: Unnamed member overlying the Springfield (No. 5) Coal throughout much of Illinois; ranges up to 0.8 meters (2½ feet) thick. The lower portion is hard and fissile. The upper portion is softer and flaky. Contains large black limestone concretions; thin and small light colored phosphatic bands and nodules, many with sphalerite mineralization; abundant pyritized fossils in some areas - brachiopods, pelecypods, gastropods, and fish remains (Dunbarella rectilaterius, Lingula carbociaria, Orbiculoidea missouriensis).

St. David Limestone: 0 to 2.1 meters (0 to 7 feet) thick, but generally 0.3 meters (1 foot) or less in this area. Light gray, weathers buff. Lower surface is knobby; fossiliferous (Mesolobus mesolobus, Marginifera splendens, Chonetina verneviliana (?) and Dictyoclostus americanus). Correlates with the Alum Cave Limestone of Indiana and the Houx Limestone of Missouri.

Canton Shale: In places, more than fifteen meters (50 feet) thick, often eroded and replaced by Vermilionville Sandstone. Light to medium gray shale becomes silty and sandy in upper portion. The lower few decimeters consist of dark gray shale with marine fauna. A discontinuous band of gray limestone concretions is sometimes present in the lower 4.5 meters (15 feet).

Vermilionville Sandstone: 0.8 to 24 meters (3 to 80 feet) thick. It occurs in a sheet facies and a channel facies. Often found replacing lower units including the No. 5 Coal. The argillaceous to silty sand is fine- to very fine-grained contains many shaly zones.

Big Creek Shale: Three to nine meters (10 to 30 feet) thick, gray, soft, locally slightly sandy shale, grading into often hard shaly zones of underlying Vermilionville Sandstone.

Herrin (No. 6) Coal: Most important coal seam in Illinois. 1.0 to 1.4 meters (3½ to 4½ feet) thick in western part of state. Has several clay partings 0.005 to 0.075 meters (¼ to 3 inches) thick. The thickest and most persistent is called the "blue band." It is generally found throughout the state about 0.3 to 0.8 meters (12 to 30 inches) above the base of the coal. Throughout western Illinois, the coal is penetrated by clastic dikes and disturbed by "white top" (see p. 4). The coal is correlated with the Herrin Coal in Indiana, the No. 11 Coal in Kentucky, the Lexington Coal in Missouri, and the Mystic Coal in Iowa.

Anna Shale: Averages 0.3 to 0.9 meters (1 to 3 feet), but reaches 2.3 meters (7½ feet) thick; patchy in occurrence, although persistent throughout the Illinois Basin. Lower portion is black, hard, fissile. Contains Orbiculoidea, Dunbarella, Lingula, and conodonts. Upper portion is very dark gray to dark greenish gray, soft, and nonfossiliferous.

Brereton Limestone: Commonly 0.6 to 1.5 meters (2 to 5 feet) thick, but may be thicker locally; lenticular and discontinuous, although recognized throughout the Illinois Basin. Light to medium gray, weathers buff, slightly crystalline. Contains abundant fusulinds, brachiopods and cephalopods. Correlated with portions of the Providence Limestone of Kentucky and the Myrick Station Limestone of Missouri.

Lawson Shale: Averages three meters (10 feet) thick in western Illinois, maximum 7.5 meters (25 feet). Widespread, light gray, silty and sandy, usually nonfossiliferous. Lies directly on Anna Shale or Herrin (No. 6) Coal in many areas. Grades laterally and vertically into sheet facies of Copperas Creek Sandstone; is truncated by channels filled with same sandstone.

Copperas Creek Sandstone: 0.9 to 8.2 meters (3 to 27 feet) thick, averages 3 meters (10 feet). Thickest where it replaces lower units. In places, rests directly on coal. Occurs in sheet and channel facies. Light green to brownish gray sandstone; micaceous massive to shaly; calcareous; in some places almost a sandy limestone. Correlative with Anvil Rock Sandstone of southern Illinois and Kentucky.

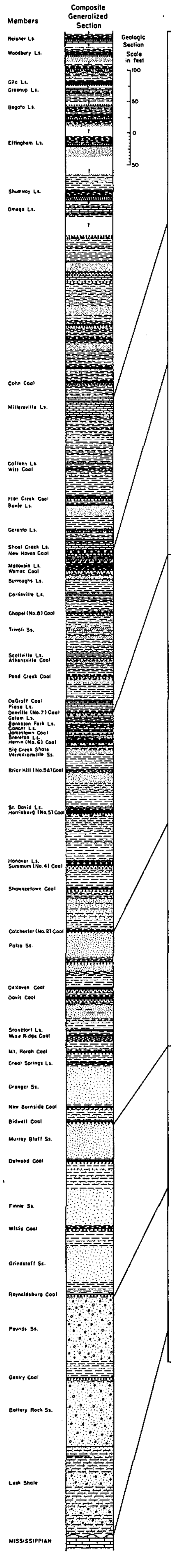
Unnamed discontinuous bench or band of limestone nodules and concretions: Zero to one meter (0 to 3 feet) thick. This bench occurs approximately in the position of the Bankston Fork Limestone, which has not formally been recognized west of the Illinois River. Wanless (1957) did not describe it nor did Hopkins and Simon (1975) recognize it.

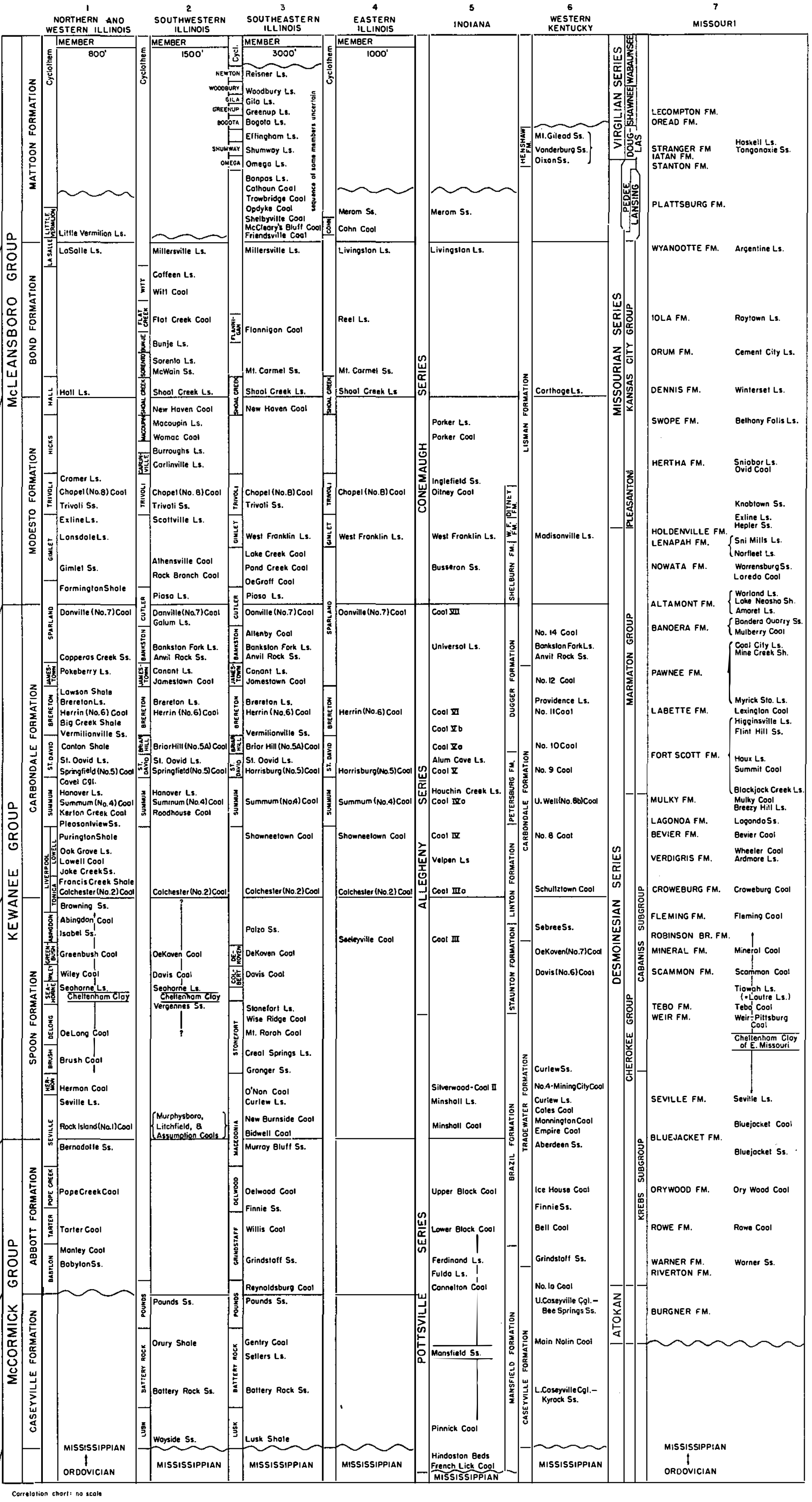
Unnamed varigated shale: Red, mottled gray, blue green; not always present, grades into underclay of Danville (No. 7) Coal.

Danville (No. 7) Coal: Averages 0.4 to 0.5 meters (1½ feet) thick in Elm Mine area. Averages 0.6 to 0.8 meters (2 to 2½ feet) thick in areas to the north and 1.0 to 1.2 meters (3 to 4 feet) thick to the northeast. Generally has no partings. Locally a black, carbonaceous shale may be in its position. Correlative with the Danville Coal (VII) in Indiana, and is present as a thin unnamed coal in Kentucky.

Unnamed black shale overlying Danville Coal: 0.4 to 0.6 meters (1½ to 2 feet) thick; dark gray to black shale; calcareous, fossiliferous.

Farmington Shale: Maximum thickness 15 meters (50 feet), locally cut out by channels filled with overlying Gimlet Sandstone. Gray to olive green; contains ironstone concretions; a few marine fossils found in lower portion. Lowest named member of the Modesto Formation.

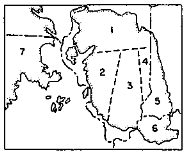




Correlation chart: no scale

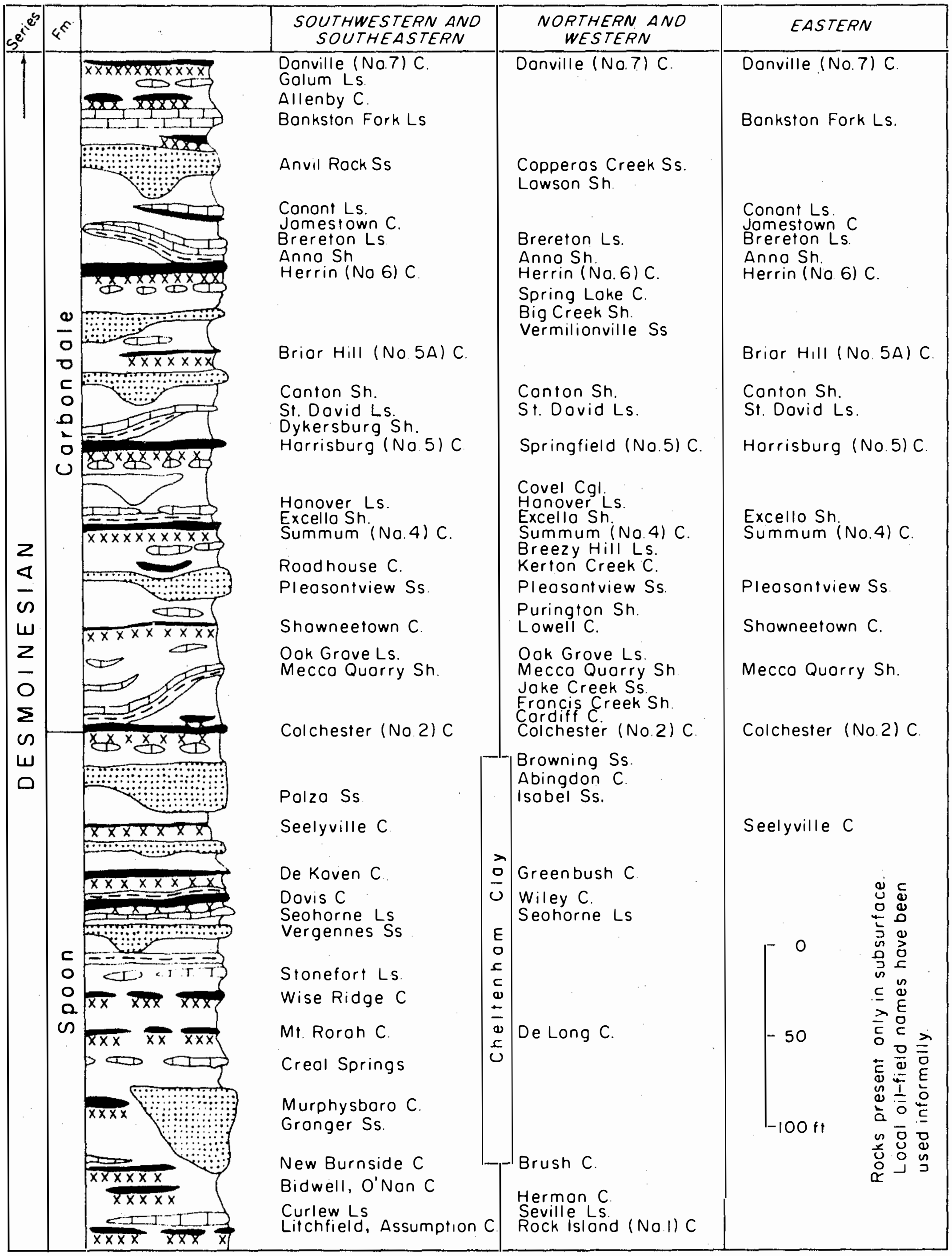
ROCK STRATIGRAPHIC
AND
CYCLICAL CLASSIFICATIONS
OF THE
PENNSYLVANIAN STRATA OF ILLINOIS

1960



LOCATION MAP

Kewanee Group



Series	Fm.	SOUTHWESTERN AND SOUTHEASTERN	NORTHERN AND WESTERN	EASTERN
DESMOINESIAN	Carbondale	Danville (No.7) C.	Danville (No.7) C.	Danville (No.7) C.
		Galum Ls.		
		Allenby C.		
		Bankston Fork Ls		Bankston Fork Ls.
		Anvil Rock Ss	Copperas Creek Ss.	
			Lawson Sh.	
		Conant Ls.		Conant Ls.
		Jamestown C.		Jamestown C
		Brereton Ls	Brereton Ls.	Brereton Ls.
		Anna Sh	Anna Sh.	Anna Sh.
		Herrin (No 6) C	Herrin (No. 6) C.	Herrin (No 6) C.
			Spring Lake C.	
			Big Creek Sh.	
			Vermilionville Ss	
		Briar Hill (No 5A) C.		Briar Hill (No. 5A) C.
		Canton Sh.	Canton Sh.	Canton Sh.
		St. David Ls.	St. David Ls.	St. David Ls.
		Dykersburg Sh.		
		Harrisburg (No 5) C	Springfield (No.5) C.	Harrisburg (No.5) C.
			Covel Cgl.	
		Hanover Ls.	Hanover Ls.	
		Excello Sh.	Excello Sh.	Excello Sh.
		Summum (No.4) C.	Summum (No.4) C.	Summum (No.4) C.
			Breezy Hill Ls.	
		Roadhouse C.	Kerton Creek C.	
		Pleasantview Ss.	Pleasantview Ss.	Pleasantview Ss.
			Purington Sh.	
		Shawneetown C.	Lowell C.	Shawneetown C.
		Oak Grove Ls.	Oak Grove Ls.	
		Mecca Quarry Sh.	Mecca Quarry Sh	Mecca Quarry Sh.
			Jake Creek Ss.	
			Francis Creek Sh.	
			Cardiff C.	
		Colchester (No 2) C	Colchester (No.2) C.	Colchester (No.2) C.
	Spoon		Browning Ss.	
			Abingdon C.	
		Palzo Ss	Isabel Ss.	
		Seelyville C		Seelyville C
		De Koven C.	Greenbush C.	
		Davis C	Wiley C.	
		Seahorne Ls	Seahorne Ls	
		Vergennes Ss		
		Stonefort Ls.		
		Wise Ridge C		
		Mt. Rorah C.	De Long C.	
		Creal Springs		
		Murphysboro C.		
		Granger Ss.		
		New Burnside C	Brush C.	
		Bidwell, O'Non C		
			Herman C.	
		Curlew Ls	Seville Ls.	
		Litchfield, Assumption C	Rock Island (No 1) C	

Figure 4.

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)

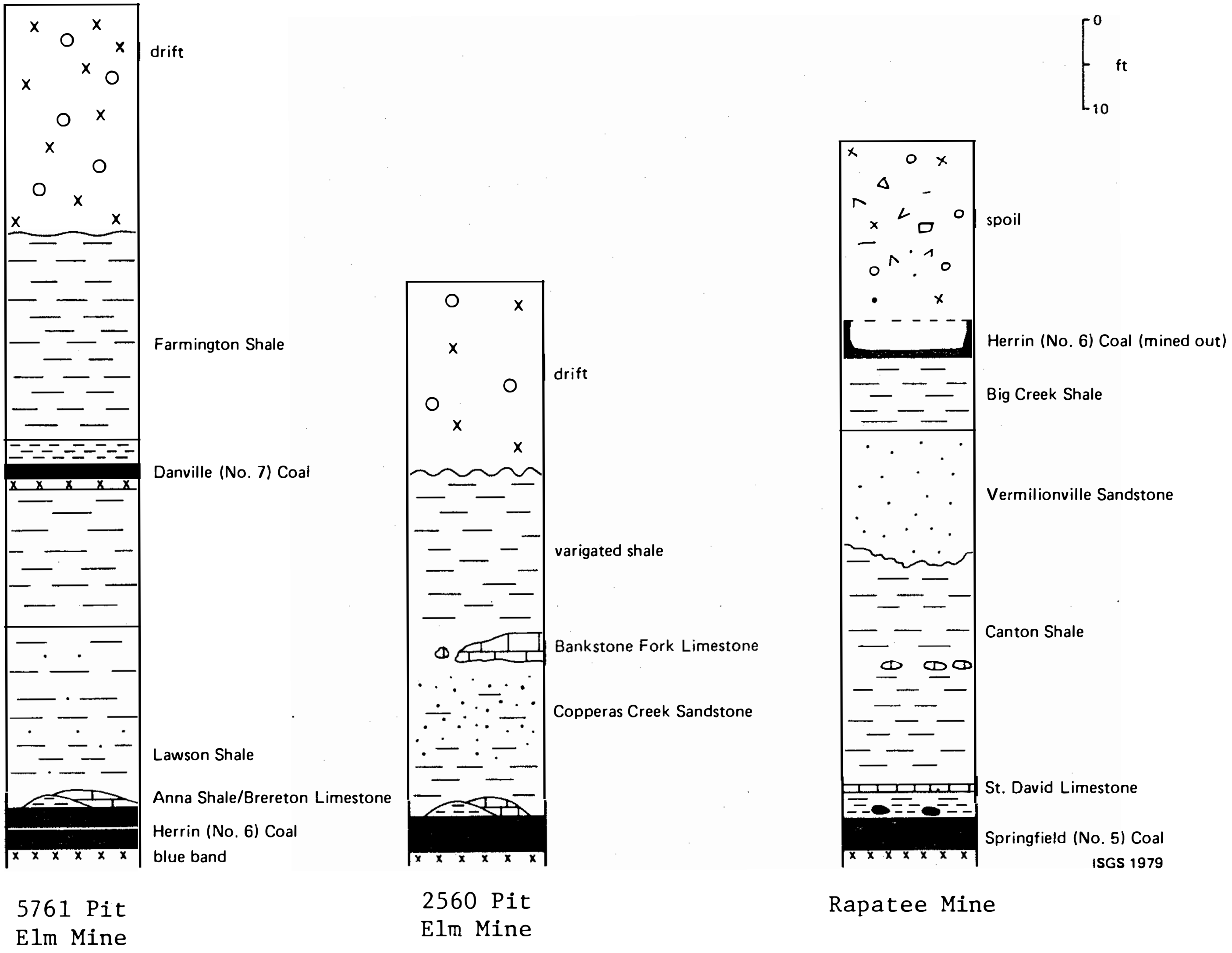


Figure 5. Stratigraphic Columns of Midland Coal Company Elm and Rapatee Mines

CLAY-DIKE FAULTS, CLAY DIKES AND WHITE TOP

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.

1) 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, often form an "en echelon" pattern, or intersect with 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 or grade into sets of antithetic and synthetic subsidiary faults. Downwards the faults generally branch and terminate in a dentritic 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 and 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 detridal material.

2) Clay Dikes are intrusions of extraneous, dominantly detridal 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 (less than an inch to several feet). 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 feet). 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.

3) "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 which combines the original structural elements of the coal seam (e.g. bedding) and younger, superimposed structural elements of clay dikes and clay sills, as described above.

As "white top" is examined from the undisturbed coal seam, 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 (a fraction of an inch) across to pieces of several decimeters (several feet) 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 (yards)). 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 burried. 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.

SPHALERITE IN COAL

Some coals in the central region of the United States are enriched in zinc and cadmium. The zinc and cadmium is attributed to the presence of sphalerite which is an epigenetic mineral in these coals. Sphalerite-bearing coals have been observed in Illinois, Iowa, Missouri, and Kansas.

Sphalerite in coal is an open-space filling and is mainly found in vertical veins. The veins are usually about 0.5 millimeters (fraction of an inch) wide and extend for several decimeters (feet) in all directions (Figures a and b). Veins commonly terminate in the vertical direction at fusain bands into an array of small veinlets which die out. Minerals commonly associated with sphalerite include pyrite, kaolinite, and calcite (Cobb and Krausse, 1979). Sphalerite also occurs as subhedral to euhedral, crystalline aggregates in the matrix of clastic dikes which intrude coal seams (Figures c and d). Sphalerite in veins, as well as in crystalline aggregates, is multibanded and has color bands of orange, yellow, and colorless with purple lamellae.

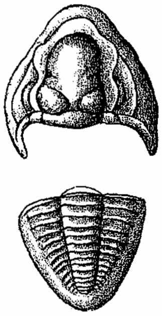
The area we are visiting has five sphalerite-bearing coals: the Rock Island (No. 1), Colchester (No. 2), Springfield (No. 5), Herrin (No. 6), and Danville (No. 7) Coals. In these coals, a strong positive correlation exists between high zinc and cadmium concentrations and the degree of disturbance in the seams. Disturbances of the coal seams include clastic dikes, clay-dike faults, and numerous extension fractures, all of which may or may not contain sphalerite.

The arithmetic mean concentrations on a whole coal basis for the No. 2, No. 5, and No. 6 Coals are 750 ppm for zinc and 7.4 ppm for cadmium. The confidence intervals for these means at the 90 percent significance level are 490 to 1010 ppm for zinc and 4.6 to 10.2 ppm for cadmium.

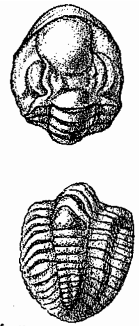
The coal in this area is considered to be "high-sulfur" coal. All of the coal mined is cleaned using crushers, cyclones, and flotation cells. The refuse material contains clastic material and sulfide minerals.

Certain of the refuse deposits have been evaluated for their zinc content. One such deposit contains 2000-3500 ppm zinc in its proximal portion (closest to the discharge pipe) and less than 100 ppm in its distal portion. This deposit which covers approximately 45 acres contains an estimated 900-1100 tons of zinc metal and 1-2 million tons of coal (Cobb et al., 1979).

TRILOBITES

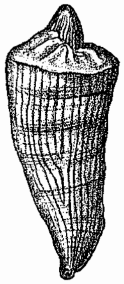


Ameura sangamonensis 1 1/3 x



Ditomopyge parvulus 1 1/2 x

CORALS



Lophophllidium proliferum 1 x

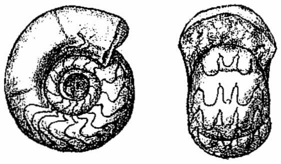
FUSULINIDS

Fusulina acme 5 x

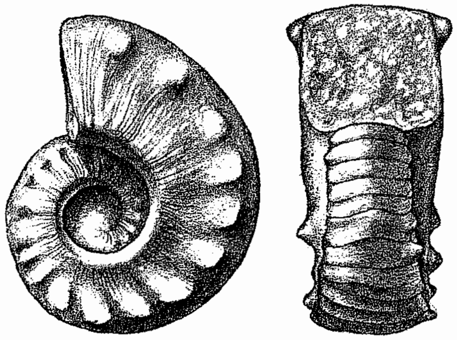
Fusulina girtyi 5 x

CEPHALOPODS

Pseudorthoceras knoxense 1 x

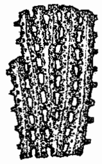


Glaphrites welleri 2/3 x

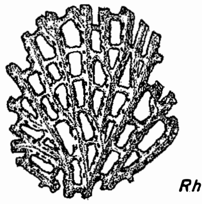


Metacoceras cornutum 1 1/2 x

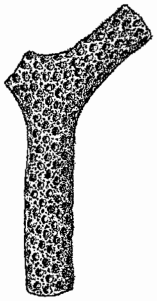
BRYOZOANS



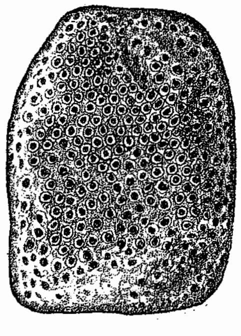
Fenestrellina mimica 9 x



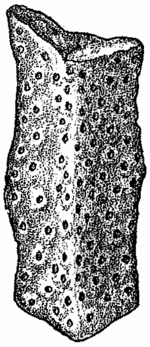
Fenestrellina modesta 10 x



Rhombopora lepidodendroides 6x

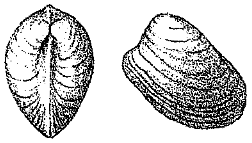


Fistulipora carbonaria 3 1/3 x

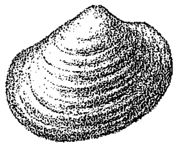


Prismopora triangulata 12 x

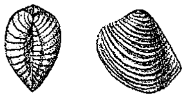
PELECYPODS



Nucula (Nuculopsis) girtyi 1x



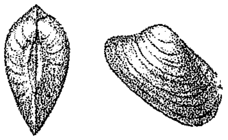
Edmonia ovata 2x



Astartella concentrica 1x

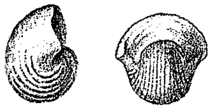
Dunbarella knighti 1½x

Cardiomorpha missouriensis
"Type A" 1x



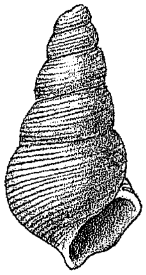
Cardiomorpha missouriensis
"Type B" 1½x

GASTROPODS

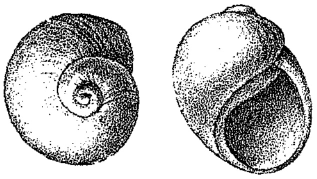


Euphemites carbonarius 1½x

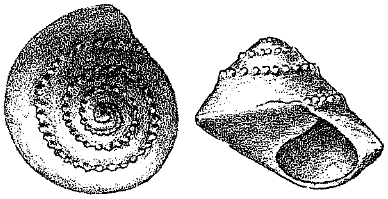
Trepospira illinoisensis 1½x



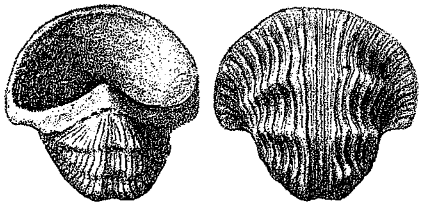
Donaldina robusta 8x



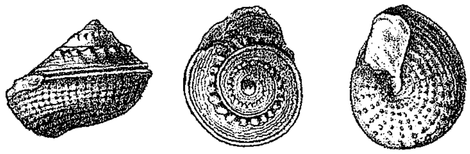
Naticopsis (Jedria) ventricosa 1½x



Trepospira sphaerulata 1x

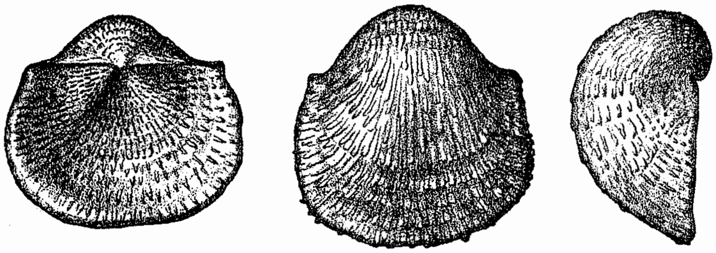


Knightites montfortianus 2x



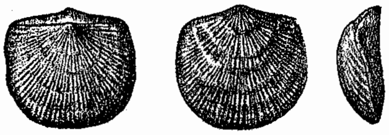
Glabrocingulum (Glabrocingulum) grayvillense 3x

BRACHIOPODS

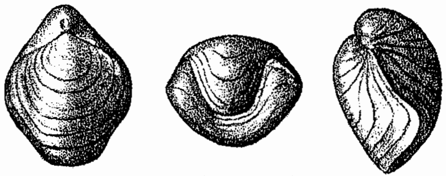


Juresania nebrascensis 2/3 x

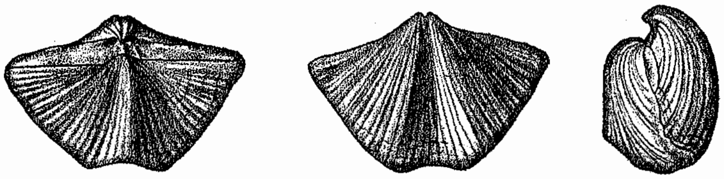
Wellerella tetrahedra 1 1/2 x



Derbya crassa 1x



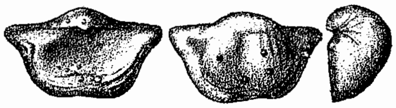
Composita argentia 1x



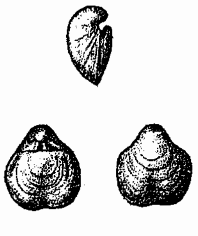
Neospirifer cameratus 1x

Chonetes granulifer 1 1/2 x

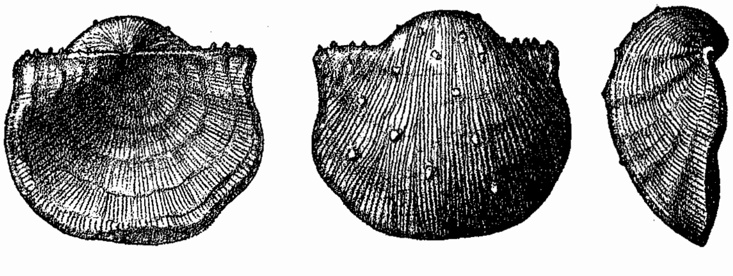
Mesolobus mesolobus var. *evampygus* 2x



Marginifera splendens 1x



Crurithyris planoconvexa 2x



Linoproductus "cora" 1x

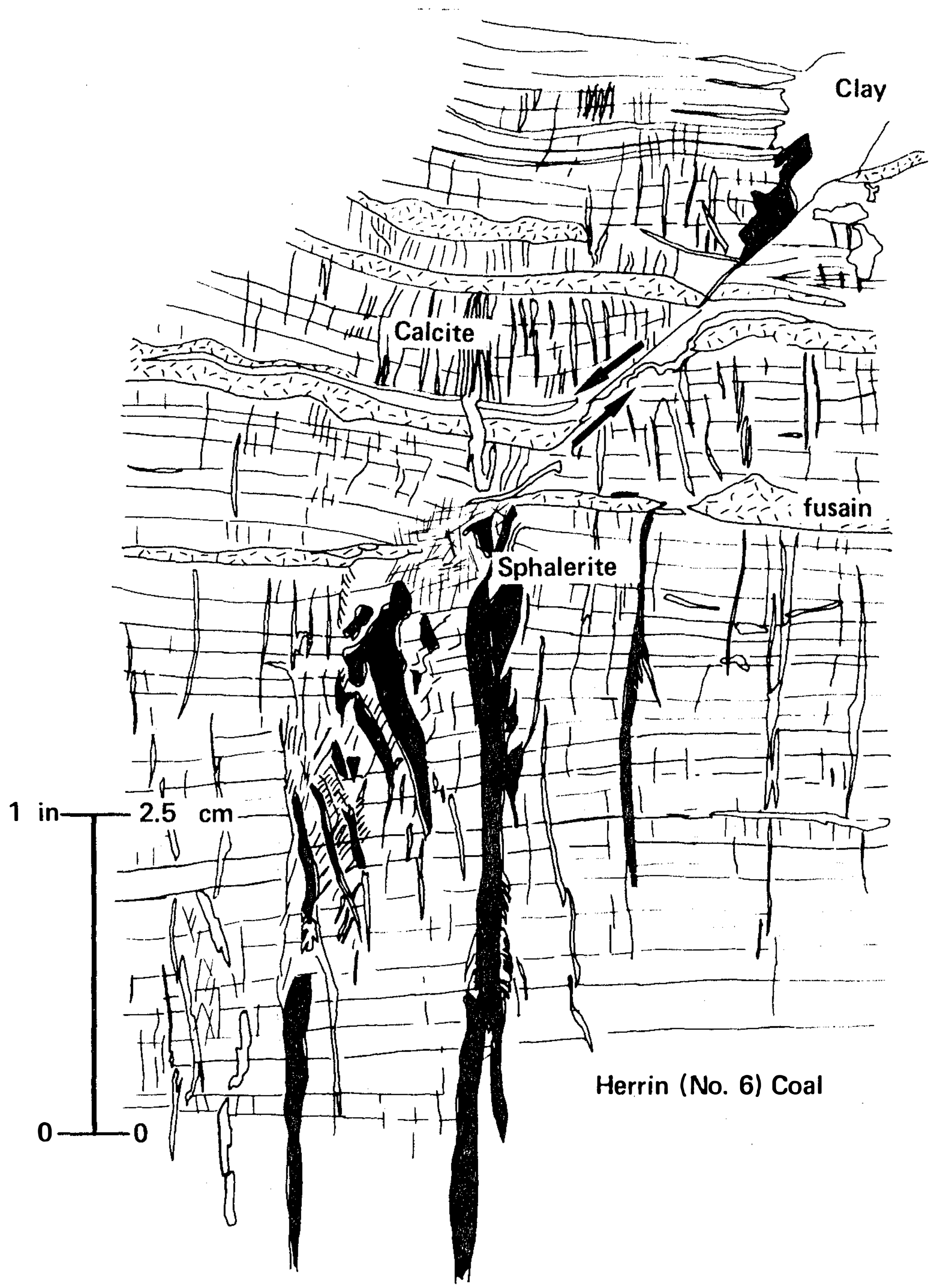


Figure 9. Clay-dike fault and associated extension fractures in coal. Vertical throw along shear plane decreases downward. Note mineralization (black) in gash veins.

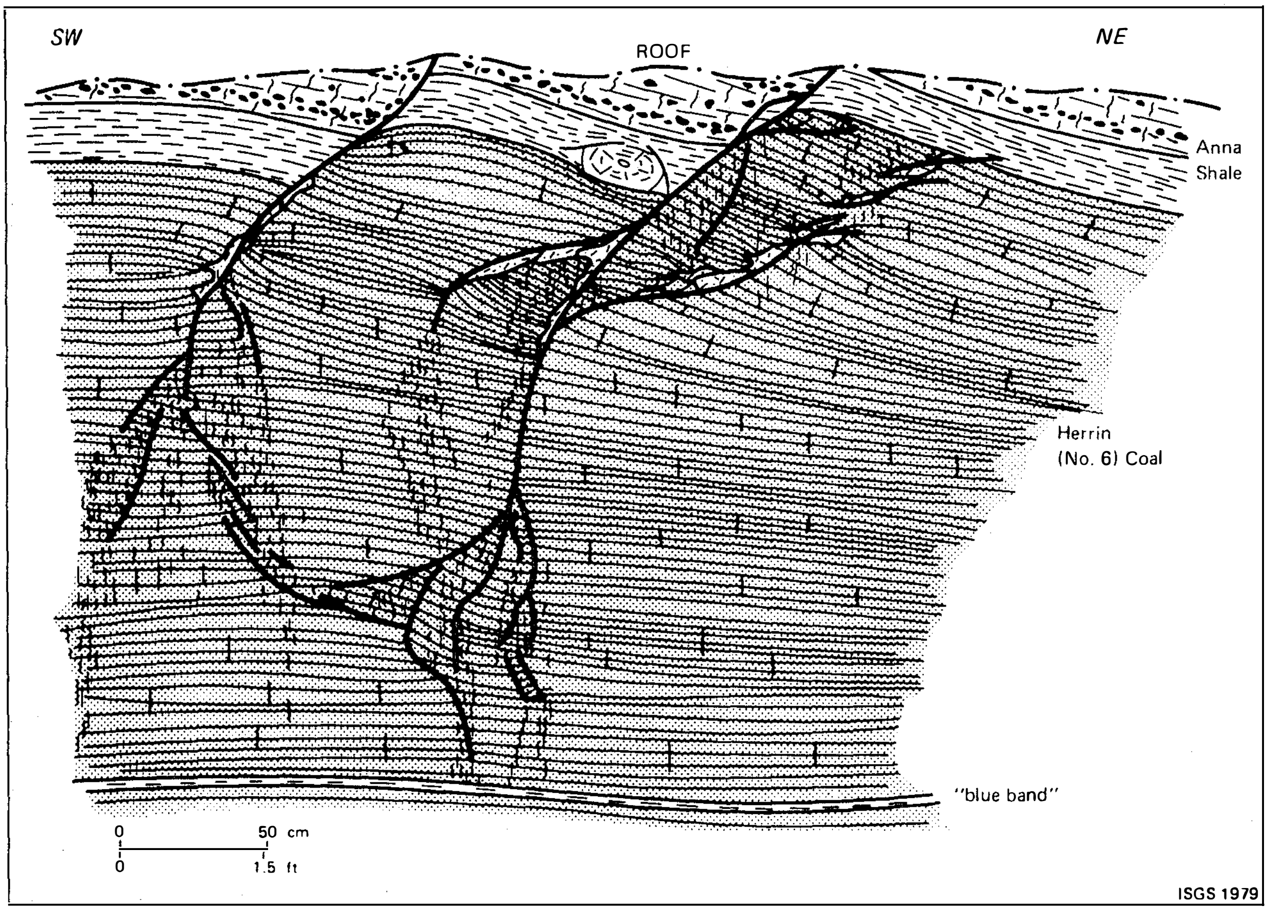


Figure 10. Clay-dike faults with clastic dikes in the Herrin (No. 6) Coal and Anna Shale. Displacement at top of coal is more than one foot; however, the "blue band" has not been cut. Horizontal extension in the coal above the "blue band" results from dip-slip shearing along the low-angle faults and 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.

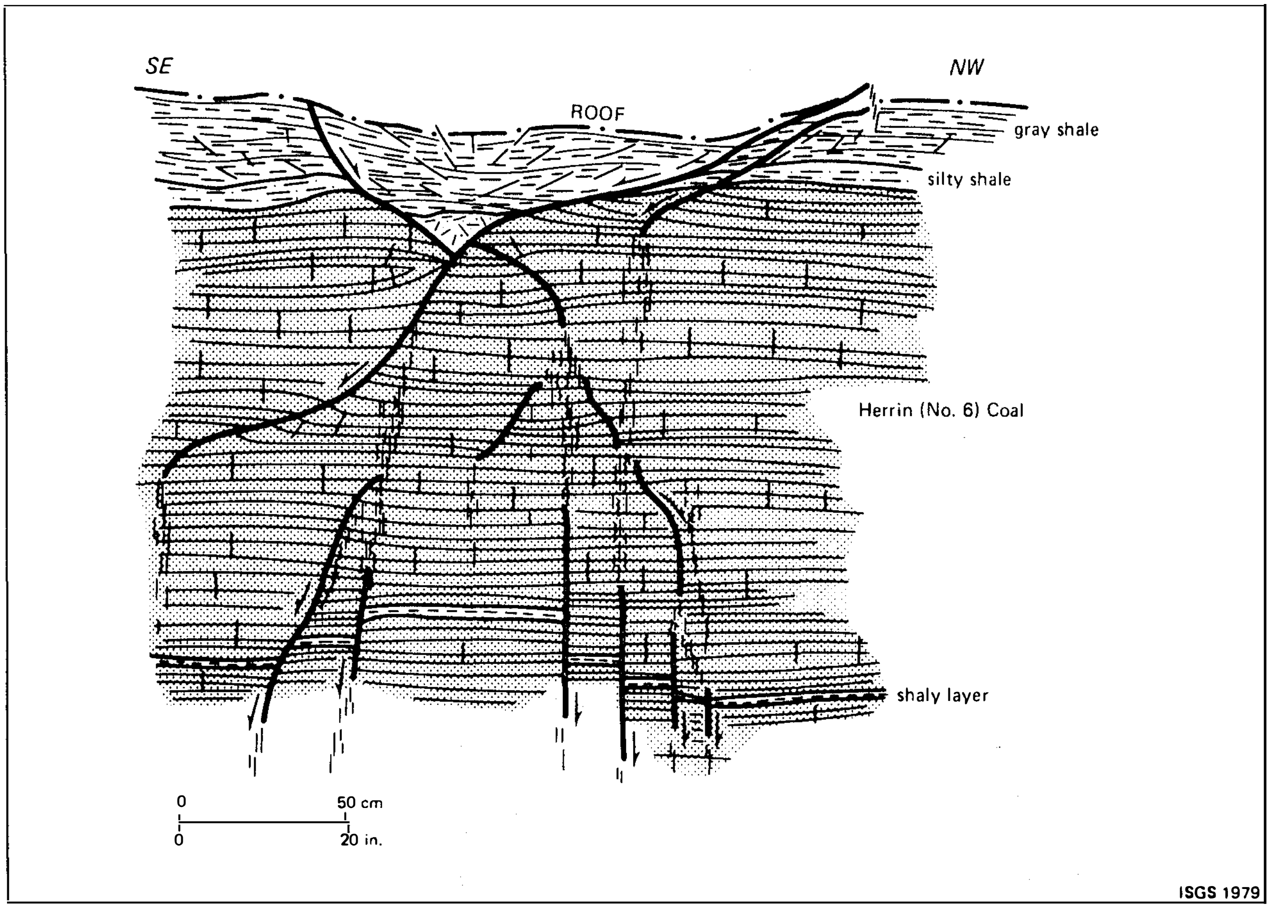


Figure 11. Clay-dike faults forming a graben at the top (note the intensely sheared gray shale) and a horst at the bottom of the Herrin (No. 6) Coal. Low-angle normal faults in shales above the coal steepen downward into the coal and dissipate in the form of en echelon extension fractures ("goat beards"). Farther down in the coal seam faults also form an en 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.

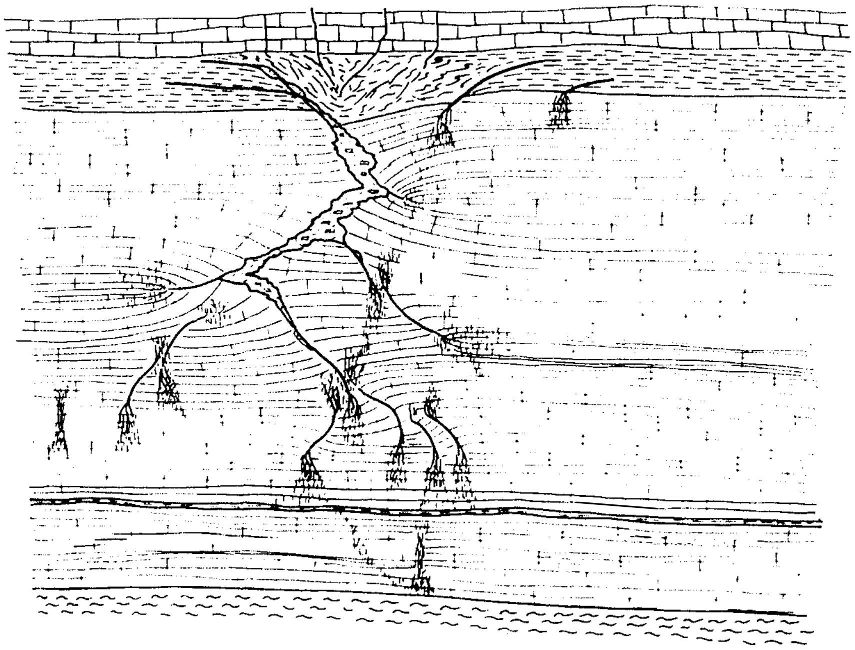


Figure 12. Composite of clay-dike fault and associated features. (clay dike, tension shears, tension fractures, "goat beards," false drag, convergence and fanning of coal bedding.

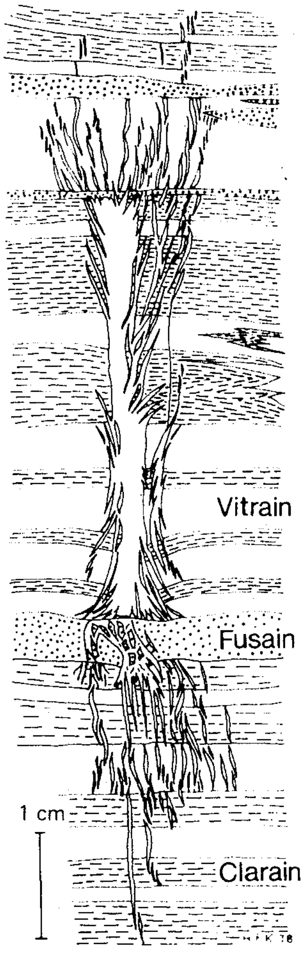
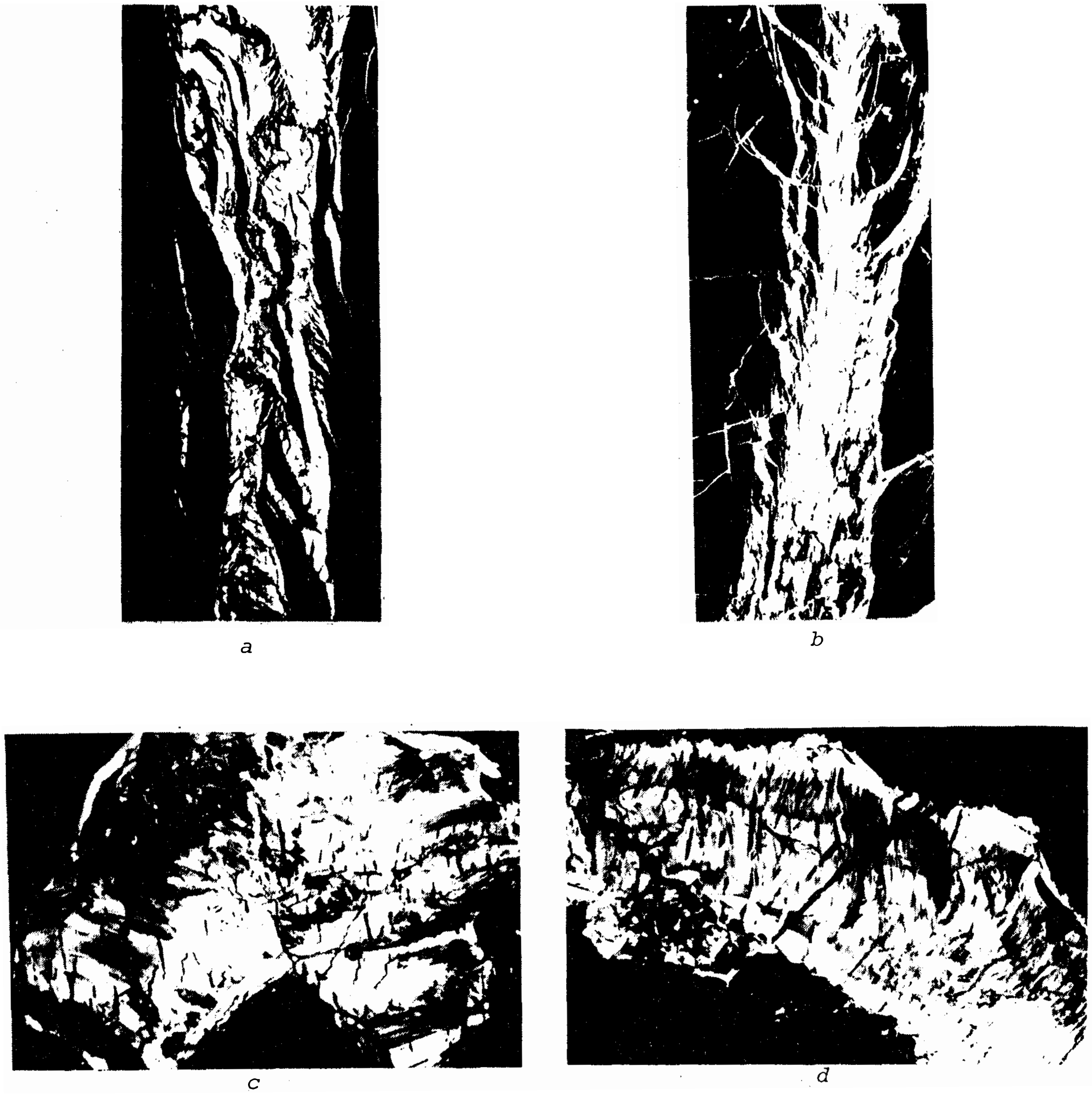


Figure 13.

Gash vein in coal; commonly mineralized with pyrite, sphalerite, calcite, kaolinite and seldom barite.



a

b

c

d

Figure 14. *a* and *b*—Vertical and horizontal thin sections of sphalerite filling in gash veins of the Springfield (No. 5) Coal. Areas of view are 1.8 x .6 inches *c* and *d*—Thin sections of sphalerite crystal aggregates from clay dikes in the Herrin (No. 6) Coal (*c*) and the Colchester (No. 2) Coal (*d*). Areas of view are 1.6 x 1.0 inches.

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