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Mining Geology of Coals in Western Kentucky

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Introduction

Each of the most heavily mined coal seams in the Western Kentucky Coal Field, as indicated by analyses, mine visits, and discussions with mine inspectors and engineers, has its own roof and floor characteristics. Also, because roof rocks above several of the seams are laterally continuous (especially in the Carbondale Formation), roof characteristics related to rock type are often widespread and continuous between mines. This chart discusses the mining geology of three western Kentucky coal beds, highlighted on the stratigraphic column shown in Figure 1.

Additional mining obstacles that can affect all coal beds and roof strata are (1) tectonic faulting, which is prevalent in western Kentucky, (2) fractures related to low cover and past mining, and (3) fractures related to the regional tectonic stress field.

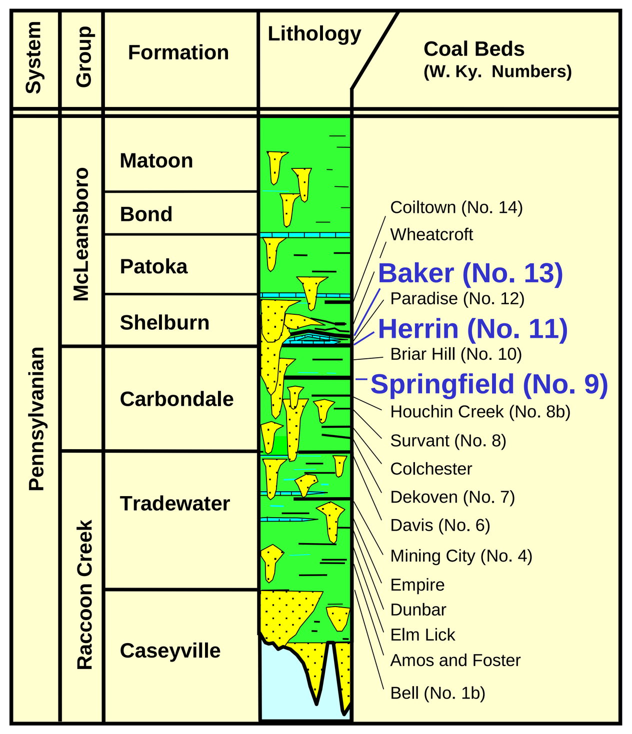

Figure 1. Major coal beds and stratigraphy of the Western Kentucky Coal Field. From Greb and others (1992).

Faulting

The term "fault" as used in this chart means a tectonic fault, which is a sharp displacement of strata along a plane of offset that is continuous into the subsurface beneath the coal (Figs. 2–4). This type of feature should not be confused with sandstone paleochannel cutouts and paleoslump margins, which can look similar to cutouts and are sometimes called "faults" in underground coal mines (Nelson, 1983).

The Western Kentucky Coal Field is bisected by several large fault zones. The Pennyrile Fault Zone occurs on the southern edge of the coal field, south of the limit of the Carbondale Formation. The Rough Creek Fault Zone occurs in the northern part of the coal field, and consists of a complex of bifurcating, mostly east–west-oriented faults. Normal, reverse, and thrust faults have been encountered during mining within and adjacent to this zone. The area north of the Rough Creek Fault Zone is considered a stable shelf area with relatively flat-lying beds and few faults. The area between the Rough Creek and Pennyrile Fault Zones is part of a broad regional downwarping called the Moorman Syncline. Beds dip from the north and south toward the axis of the syncline. Several northeast–southwest-oriented faults and fault-bound grabens cut across the syncline and the northern shelf region. These faults cut across near-surface coal resources in the Carbondale and Shelburn Formations, and have been encountered during mining.

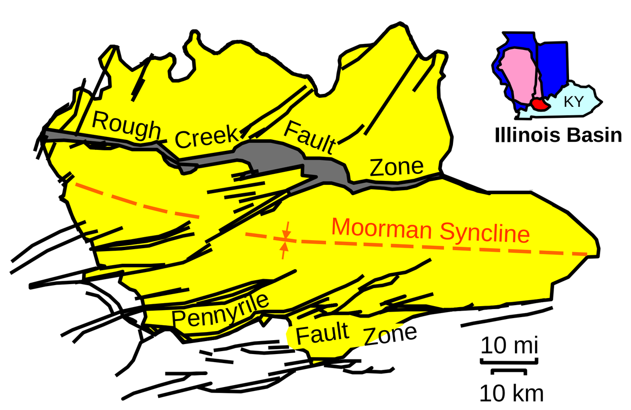

Figure 2. Major tectonic structures of the Western Kentucky Coal Field, in the southern Illinois Basin.

Because there are numerous faults in western Kentucky, many blocks of coal reserves are defined by faults. Faults are not generally as much of a roof-fall problem as they are a barrier problem. We are fortunate in Kentucky to have maps at a scale of 1:24,000 available that show most of the larger faults, and sometimes fault position at depth. Unmapped faults are still sometimes encountered during mining, however (Fig. 3).

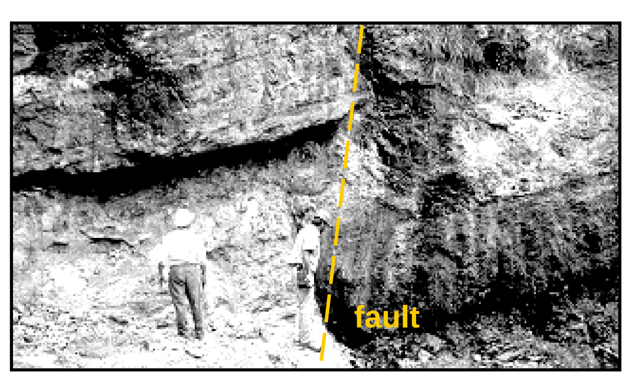

Figure 3. Offset of the Springfield coal along a fault encountered when a slope was made to begin an underground mine.

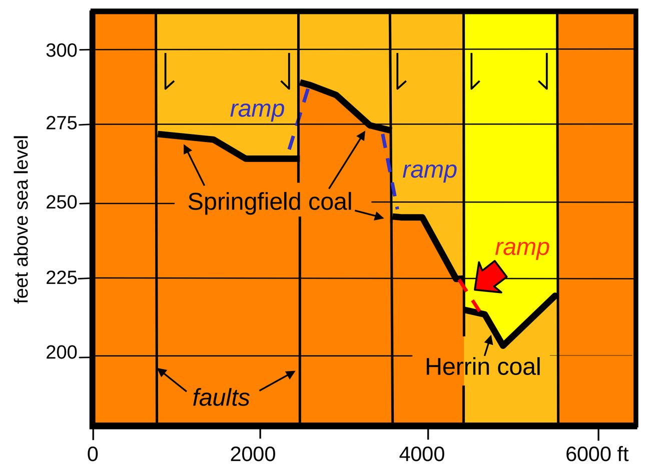

Figure 4. Section through a fault-bound coal mine that crossed a fault into another coal bed.

In some cases mines can ramp through a fault to the position of the coal bed across the fault plane. In rare cases, mines have actually crossed faults into different coal beds (Fig. 4). This has happened by plan and by accident in the Western Kentucky Coal Field.

Faults can also act as pathways for fluids (water and oil) and natural gas. Some may be associated with increased mineralization and sulfur content in adjacent coals.

Lateral-Stress Field

In the Illinois Basin, stress within the earth's crust, called the lateral-stress field, can cause jointing and fracturing (Krausse and others, 1979; Nelson, 1983; Nelson and Bauer, 1991). Regional studies of the stress field in the basin indicate a dominantly horizontal, N80°E to east–west orientation of the regional compressive stress field (Zoback and Zoback, 1980; Nelson and Bauer, 1987, 1991). Joints may develop parallel to the stress field, but a survey of large mines in western Kentucky shows that the largest falls have historically occurred along north–south orientations, which would be perpendicular to the lateral-stress field. In many cases, falls are preceded by cutters along rib lines (Figs. 5A, C), or kinks along the center axis of the roof (Fig. 5B).

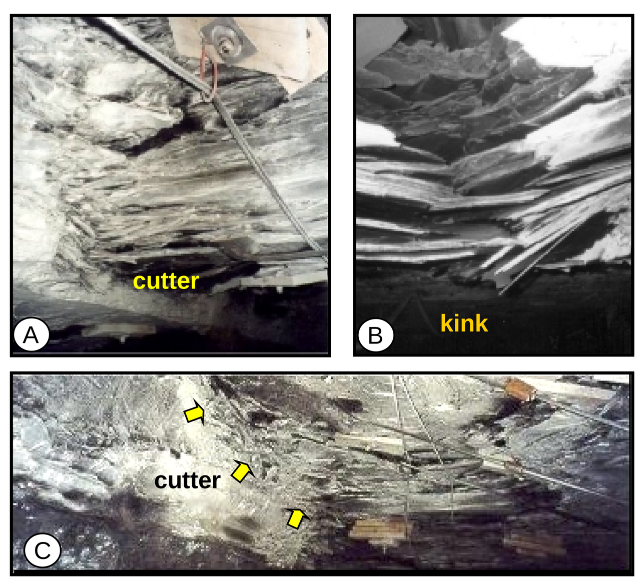

Figure 5A–C. Cutters and kinks in shaly strata oriented along north–south headings in Springfield coal mines.

For this reason, deep mines (greater than 600 ft) in the Western Kentucky Coal Field are generally required to orient entries in northeast–southwest directions (within 10° of a 45° azimuth), oblique to the trend of possible falls and cleat fractures in the coal (Fig. 6). At depths of 400 to 600 ft, an orientation within 15° of a 45° azimuth may be required. Fractures formed by regional stress should be intersected obliquely so that planes of weakness in the roof are not oriented parallel to entries, where they would be unsupported by the pillars. Numerous methods are available to test lateral stress in mines, including studying old mine maps and using hydrofracturing (Haimson, 1974) and borehole breakouts (Dart, 1985).

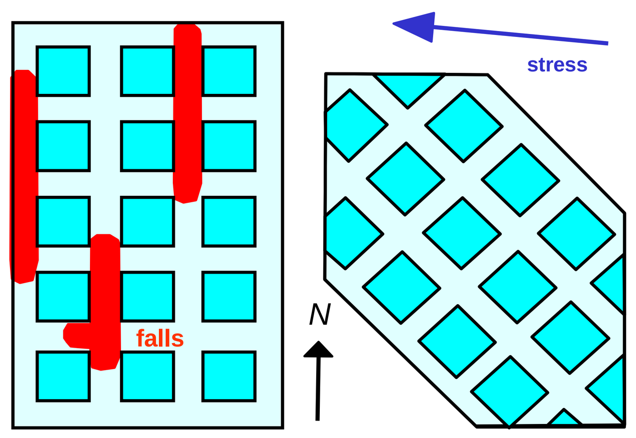

Figure 6. Roof falls related to the lateral-stress field are affected by heading orientations.

Low-Cover Areas

When coal is mined within 100 to 150 ft of the surface, it is considered beneath low cover. Low-cover areas often occur beneath alluvial valleys, where bedrock thickness has diminished. These areas are commonly associated with fracturing and roof instability. Trends of roof falls or fractures observed underground should always be compared with a topographic map to see if they are related to low cover. Likewise, studying old mine maps of low-cover areas can aid in determining susceptibility of the roof to falling beneath low cover in adjacent or similar areas.

Low-cover areas are perhaps more prone to roof instability when they parallel known faults or the lateral-stress field, because in these cases, fractures are more likely to occur in swarms, and to be connected deeper into the subsurface. Water infiltration beneath low cover, especially beneath alluvial valleys, also increases roof instability.

Baker (W. Ky. No. 13) Coal

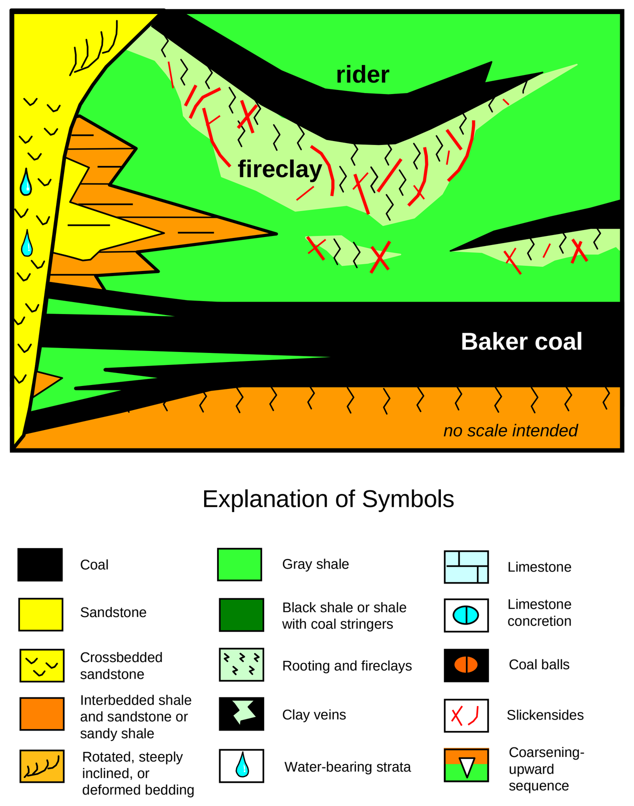

Figure 7. Generalized Baker coal bed geology.

The Baker coal is often overlain by coal riders, which is unusual for mined seams in western Kentucky. Riders may be more than 2 ft thick, and range from 30 ft to less than a foot in height above the main seam. Where mined by surface methods, the riders are sometimes mined with the main coal. In underground mines they can cause significant roof problems, however (Figs. 7–10). Roof falls related to coal riders result from slickensided underclays, called fireclays, beneath the riders (Figs. 8–10). These fireclays can be very thick (several feet), and commonly contain crosscutting slickensides at random orientations (Figs. 9–10). Also, water can accumulate at the coal-fireclay contact in the roof. Clay deterioration is accelerated by increased moisture along the contact and by exposure to mine air when the clay is undercut. Supplemental support is usually needed in rider areas.

Roof problems related to coal riders can be monitored by keeping accurate records on the height of the rider above the main coal bed, obtained from boreholes, geophysical well logs, and in-mine monitoring. Also, the height of the rider above the main bed may increase next to lateral paleochannels in the roof (Fig. 7). Decreasing sandstone content in the roof may parallel a decrease in height of the rider above the seam where the rider overlies broad wedges of sandy strata. For information about riders in other coals see Horne and others (1978), Nelson (1983), Moebs and Ellenberger (1982), and Greb (1991).

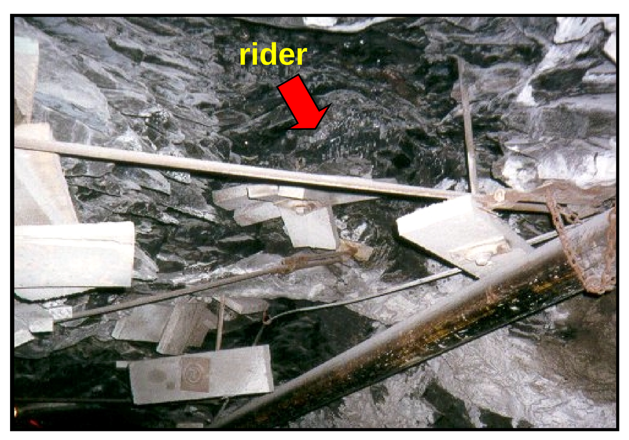

Figure 8. Roof fall beneath coal rider above the Baker coal bed. Wooden headers, steel straps, and bars were needed to support the roof.

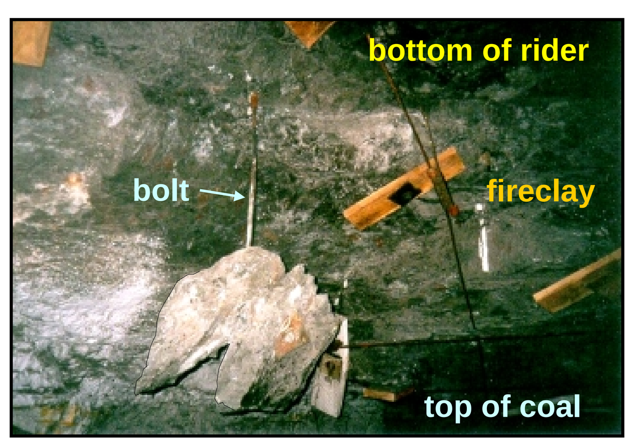

Figure 9. Fall of thick fireclay beneath a thin coal rider above the Baker coal.

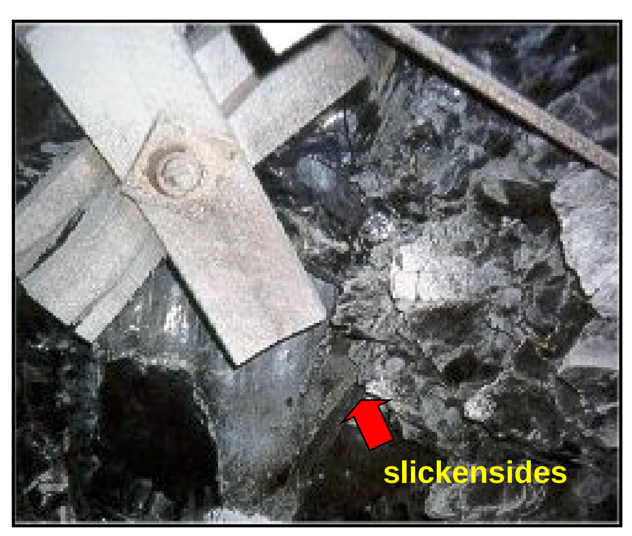

Figure 10. Slickensides at different orientations in fireclay exposed in the roof above the Baker coal bed after a fall.

Herrin (W. Ky. No. 11) Coal

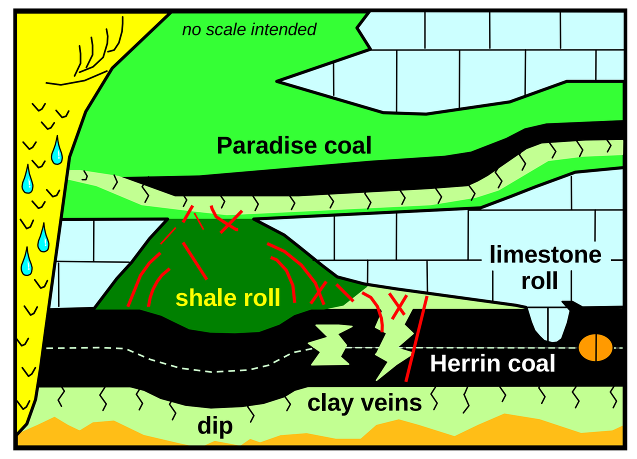

Figure 11. Generalized Herrin coal bed geology.

The Herrin coal has different geological characteristics than the Baker coal (Figs. 11–15). The Herrin is overlain by the Providence Limestone, which may rest directly on the coal and form a good roof; locally thicken, causing rolls and cutouts; or be separated from the coal by a thin calcareous claystone (called "gob" in the mines), which deteriorates on contact with mine air and must be taken as draw rock. In some mines, the limestone appears to pinch out against a black shale. Pockets of the black shale are often localized and irregular in distribution, which makes them difficult to predict and support. Similar conditions have been noted in the Herrin in Illinois (Krausse and others, 1979; Nelson, 1983). In one mine, the Paradise (W. Ky. No. 12) coal descended in elevation past the pinchout of the limestone, leading to falls to the base of the coal, a condition similar to what happens where riders occur above the Baker coal (Fig. 7).

Clay veins have been documented in the Herrin coal in Kentucky (Figs. 12–15). They are claystone-filled discontinuities in the coal seam. They may be wedge-shaped, thicken up or down within the seam, or be irregular in shape (Moebs and Ellenberger, 1982; Nelson, 1983). Clay veins tend to occur in swarms, may be randomly oriented, may parallel fracture trends in the roof (Fig. 14), or may roughly parallel the trends of black shale in the roof. Clay veins have been noted in several seams in Illinois (Krausse and others, 1979; Nelson, 1983), but are most associated with the Herrin coal in western Kentucky.

Figure 12. Near-vertical clay vein in Herrin coal bed with downward-thickening wedge shape.

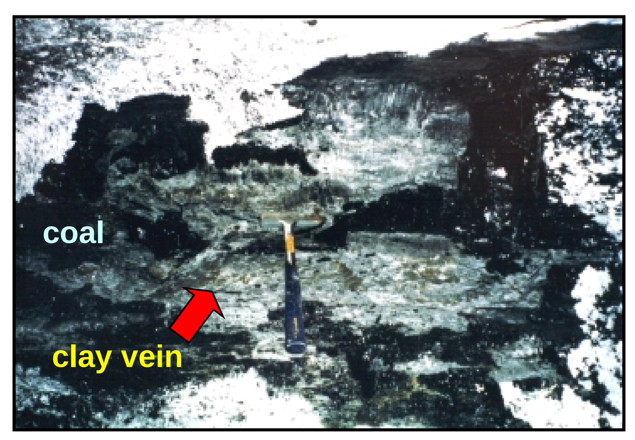

Figure 13. Irregular clay vein in Herrin coal bed.

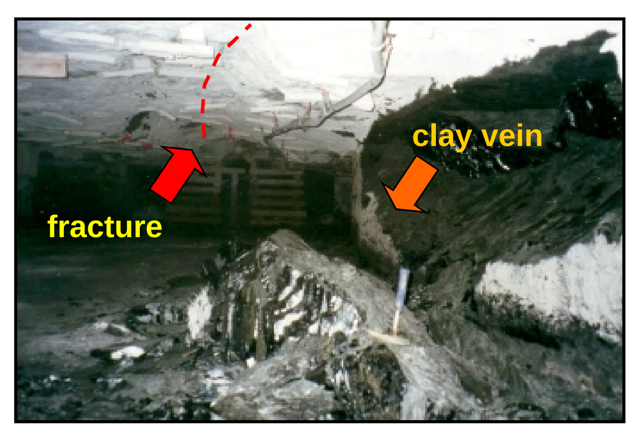

Figure 14. Pillar collapse where clay vein and roof fracture parallel the orientation of the mine heading.

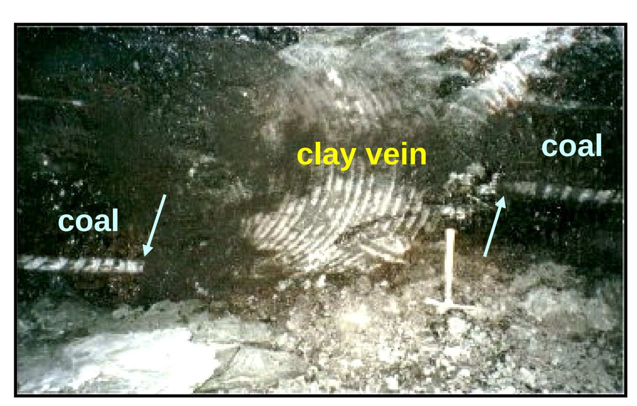

Figure 15. Clay vein along small-offset fault in the Herrin coal bed. Arrows show direction of parting offset. Hammer for scale.

Springfield (W. Ky. No. 9) Coal

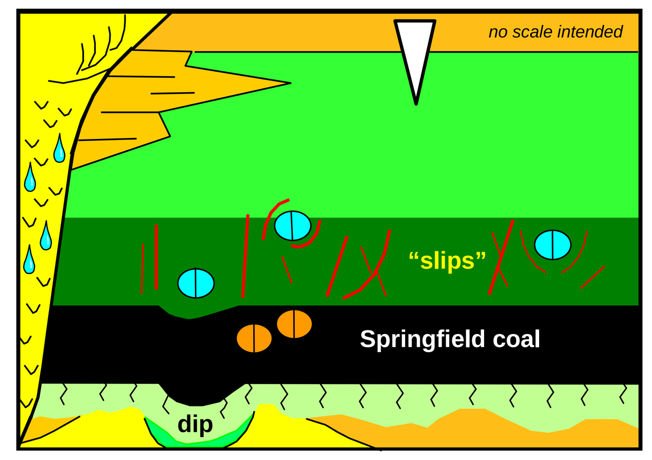

Figure 16. Generalized Springfield coal bed geology.

The Springfield is the most heavily mined seam in the coal field. Like the Herrin, the Springfield commonly rests on a well-developed underclay (Fig. 16). Floor heave has been documented where the underclay is thick (3 to 5 ft) or adjacent to areas in which water has entered the mine through the coal or roof (Figs. 16–17). Underclays with greater than 8 percent moisture have been reported to be most susceptible to heaving. Floor heave has also been documented where pillars did not collapse and entries had been driven too wide. Similar conditions have been noted in the Herrin coal.

The Springfield coal is usually overlain by an immediate roof of hard, black shale (miners' "slate"), which commonly contains "slips," a miners' term for slickensides (Figs. 16, 18). Slickensides occur in shales above other coals as well, but the slips are much more prevalent above the Springfield than other western Kentucky coals, and are probably the single most common geologic obstacle encountered during mining of the Springfield coal. Where slips have developed after mining, and appear to increase in extent following mining, they have been called "kink zones" (Krausse and others, 1979; Nelson, 1983). Also, overlying silty, gray shales may deteriorate on exposure to air, which can present problems in keeping main headings open for long periods of time in large, long-lived, underground mines in the Springfield.

In many areas, elliptical carbonate and pyrite concretions occur in the dark shale or near the contact with the overlying gray shale (Figs. 16, 19). These concretions are commonly bounded by slickensided shale, and will fall if not supported, or promote excessive spalling in the surrounding shales. In some areas, the coal itself may contain very hard, brown carbonate masses called "coal balls." Coal balls may be elliptical like concretions, but are more commonly irregular in shape (Figs. 16, 20). They can be a significant nuisance to mining, since they can stop a continuous miner and cause excessive wear on bits. Generally, individual occurrences are not widespread and can be circumvented. Although a nuisance, they are of great scientific interest.

Locally, sandstone paleochannels truncate the common gray shale roof (Figs. 16, 21). These sandstones may be water-bearing. The Henderson Paleochannel is laterally continous and has been mapped across part of the coal field (Beard and Williamson, 1979; Andrews and others, 2000). Cutouts are common along the margins of these paleochannels. Rotated and deformed bedding formed by ancient failures of channel margins, called "paleoslumps," is also common. Figure 22 shows the rotated bedding typical of paleoslumps. Because of the deformed and high angle of bedding, such features are very difficult to support underground (Nelson and others, 1985; Greb and Weisenfluh, 1996).

The coal may dip or roll beneath sandstone roof channels and paleoslumps, causing steep grades. Locally, pre-coal channels draped by the coal may also cause depressions or dips with steep grades and sometimes increased tensional stresses in the roof along the hinges of the dip (Fig. 16).

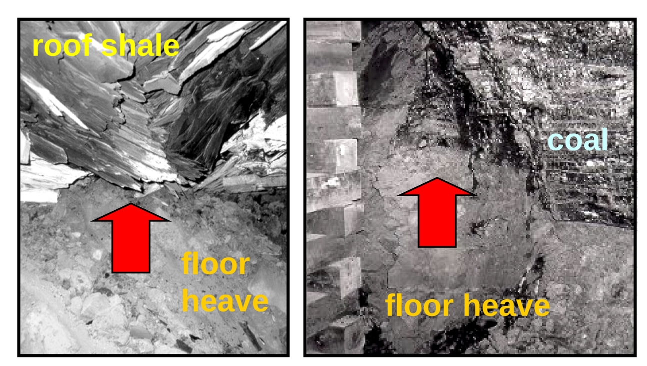

Figure 17. Floor heave in a Springfield coal mine.

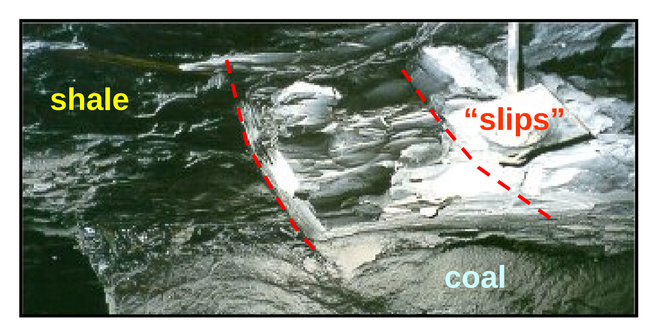

Figure 18. Slips in dark shale roof of a Springfield coal mine.

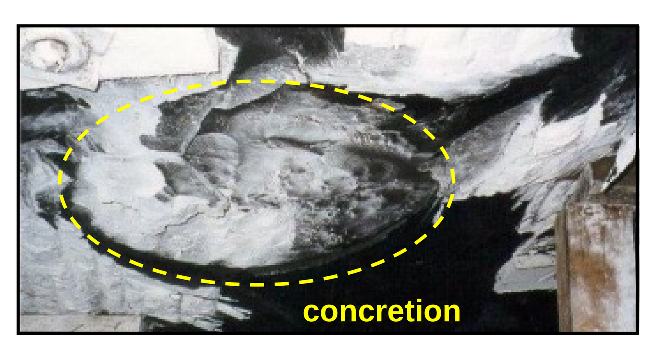

Figure 19. Spherical carbonate concretions are common in the dark shale roof of the Springfield coal. Supplemental support may be needed.

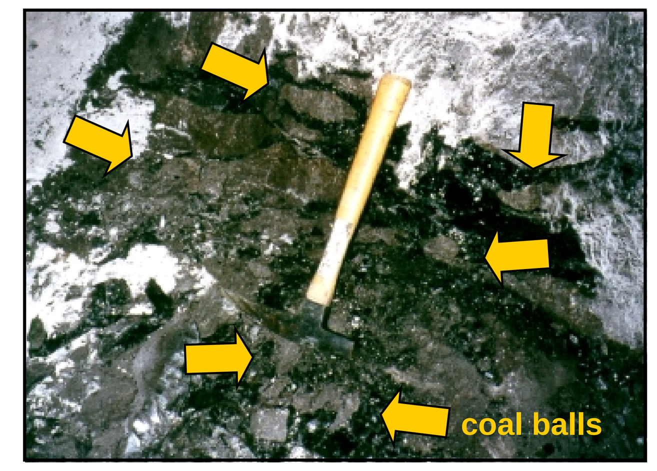

Figure 20. Hard, dark-brown, irregularly shaped, carbonate coal balls in the Springfield coal bed. Hammer for scale.

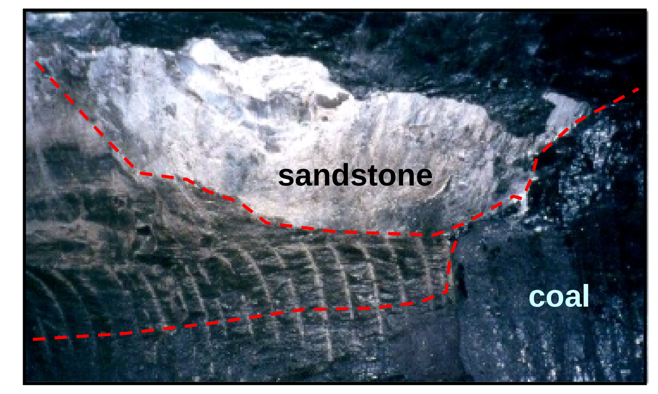

Figure 21. Sandstone cutout in a Springfield coal mine.

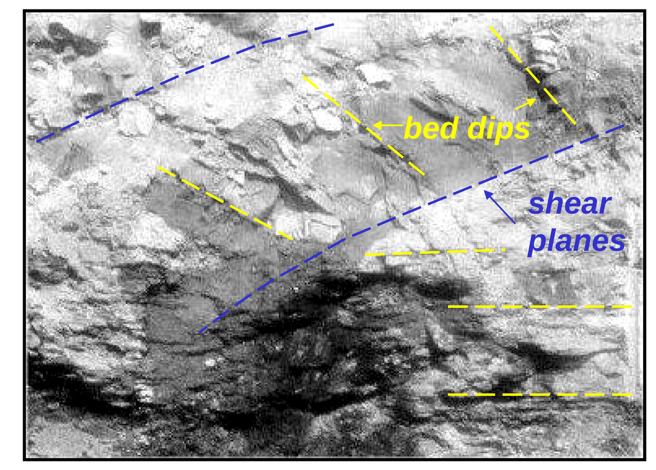

Figure 22. Rotated, high-angle beds separated from flat-lying beds by shear planes (red) are typical of paleoslumps. This example was exposed in a highwall of a Springfield coal surface mine.

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