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Mining Geology of the Lower Elkhorn Coal

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Introduction

The Lower Elkhorn (and its equivalents) is one of the leading producers of coal in the Eastern Kentucky Coal Field with 12 to 18 million short tons of annual production between 1974 and 1996, according to the Kentucky Department of Mines and Minerals. Stratigraphically, the coal occurs in the lower part of the Pikeville Formation of the Breathitt Group (Fig. 1), which was previously part of the Breathitt Formation (Chesnut, 1992). The coal occurs from 150 to 300 ft above the base of a thick coarsening-upward sequence containing the Betsie Shale and from 250 to 450 ft beneath the base of the Kendrick Shale.

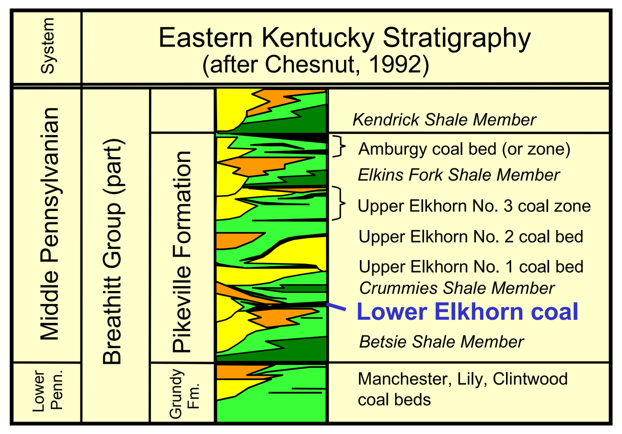


Figure 1. Stratigraphic position of the Lower Elkhorn coal bed.

The Lower Elkhorn coal is overlain by laterally variable roof rocks, which control roof conditions during underground mining. Figure 2 summarizes the mining geology of the Lower Elkhorn coal. Features shown in the figure are discussed elsewhere in this chart. Splitting and thickness variation are discussed in Thacker and others (1998).

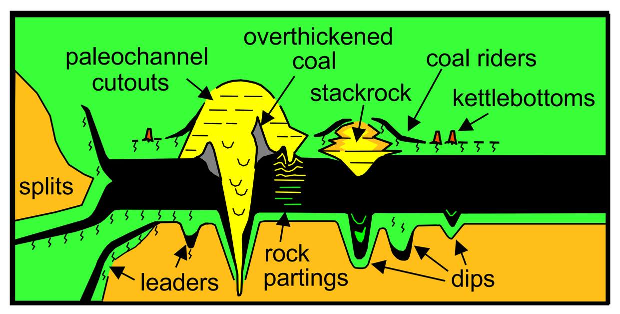


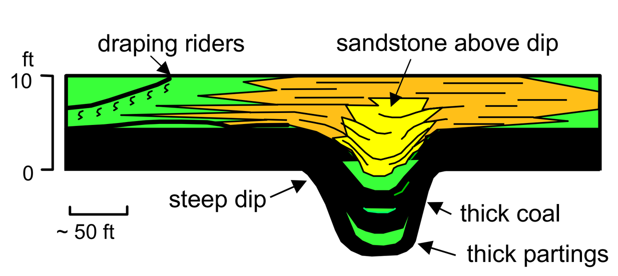
Figure 2. Generalized Lower Elkhorn geology (after Greb and Popp, 1999, Fig. 15).

Coal Dips and Swags

The Lower Elkhorn coal dips locally (Fig. 2): the coal drops and then rises in elevation along narrow elongate depressions in the floor (Nelson and others, 1991; Greb and Popp, 1999). Most dips are discontinuous, less than 150 ft across, and vary in depth from inches to as much as 15 ft. Some may be seen to branch in map view (Nelson and others, 1991). In many dips, the coal thickens toward the axis of the dip (Fig. 3), but in dips overlain by sandstone, cutouts may cause thinning toward the dip axis. Increased coal thickness in dips is mostly a function of additional coal in the bottom of the seam (Fig. 3); the upper part of the seam is relatively consistent onto the margins of the dip. This bottom coal may contain partings and higher ash yields (Vogler, 1994; Greb and Popp, 1999).

The dips probably represent abandoned channels and depressions on the paleotopographic surface on which the Lower Elkhorn coal developed. Dips are often detrimental to mining because slopes into the dip are too steep for continuous mining equipment and belts, so that floor and roof must also be taken to mine the coal. Where the coal is mined with longwall methods, dips can cause delays in advance of the face, especially where the longwall face crosses the dip at an oblique angle. Subsequent rotation and misalignment of the longwall shields in dip areas are accentuated by the steeply dipping floor on dip margins (Nelson and others, 1991). Roof falls may occur along dip margins because of tensional stresses in the roof along the dip limbs, and because of roof rocks changing from finer grained away from the dip, to coarser grained above the dip.

Dips may also be associated with paleochannels in the roof (narrow, linear belts of sandstone). These roof sandstones may have been deposited above the paleo-topographic depression in which the coal was deposited, or differential compaction beneath the sandstone may cause the coal to be pushed downward to form the dip.



Explanation of Symbols

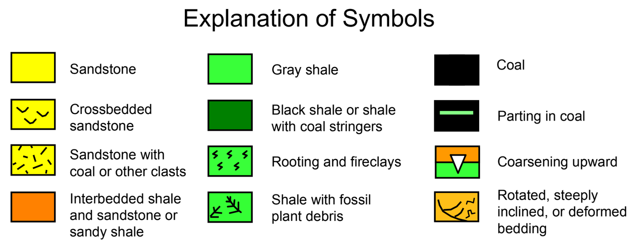


Figure 3. Section across a dip in the Lower Elkhorn coal seam. Note increased partings and thickness in dip.

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Hard Parting Concentrations

An unusual feature of some Lower Elkhorn mines is narrow belts of densely concentrated rock partings in the coal (Fig. 2). The partings occur in elongate belts 650 to 4,600 ft wide, paralleling dips or cutout trends. The partings consist of sandstone and very hard siltstone and shale laminae vertically interbedded with the coal (Fig. 4). More than 50 partings may occur within the coal, with each parting varying in thickness from less than an inch to 4 in. Generally, the thickness of partings increases upward, and laterally the extent of the partings increases upward. Close examination of individual partings shows that they tend to be coarser grained toward the center of parting concentrations and then become finer grained laterally into carbonaceous shale and bone coal.

Concentrations of dense partings may be associated with decreased coal recovery, and increased dust.

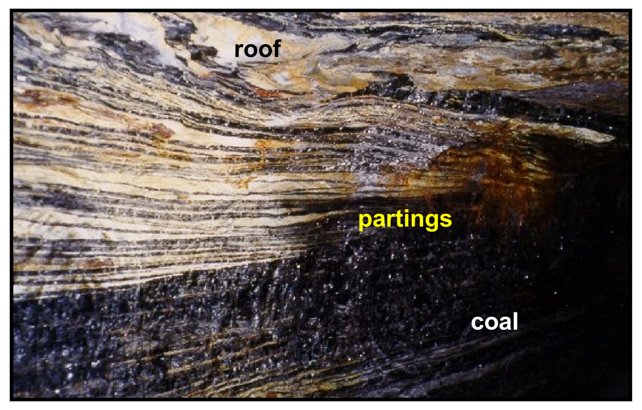

Figure 4. Concentration of rock partings in the coal seam.

Sandstone Roof and Sulfur Content

The Lower Elkhorn coal and its equivalents are high-volatile A bituminous, generally have low sulfur contents (0.4–1.7 percent, mean 0.8 percent), and low ash yields (5.1–16.7 percent, mean 9.6 percent). Higher-sulfur Blue Gem coal has been noted where sandstones cut through shales into the immediate roof (Rimmer and others, 1985; Hower and others, 1991b, 1994). Similar associations have been noted in Pike and Martin Counties where the coal is called the Pond Creek. Apparently, sulfate-bearing waters percolate through the permeable sandstones into the coal (Fig. 5). Where shales occur between the sandstones and coal, the finer-grained rocks create a permeability barrier and the sulfates remain in the roof (Fig. 5). The model suggests that mapping roof sandstones can aid in quality prediction.

Geologic structures also locally affect the quality and mineability of the Lower Elkhorn and equivalent coals; variable thickness and quality trends have been reported along the northeast-plunging Belfry Anticline (Hower and others, 1991a).

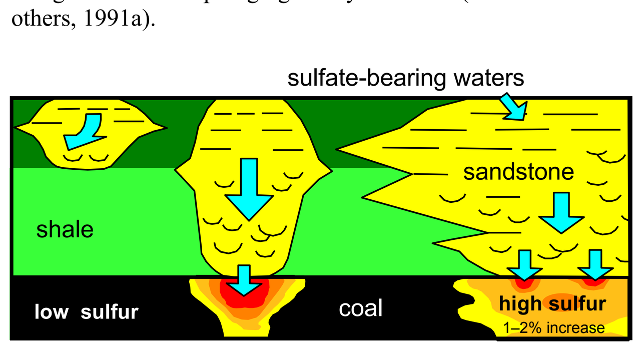

Figure 5. Migration of sulfur-bearing waters through different rock types in the roof into coal seam.

Hill Seams, Regional Stress, and Low Cover

Some of the largest falls in Lower Elkhorn mines are independent of the type of roof rock along fractures. Fractures within 200 ft of the outside of ridges, which generally parallel the trend of the surface topography, are common and called "hill seams" (Fig. 6). Often these hill seams are connected to the surface and become pathways for ground water and sediment, causing weaknesses in the roof rock above the coal. Similar fractures may also occur beneath drainages and other depressions in the topography, and are termed low-cover areas (Fig. 6). In Figure 7, several large roof falls in an underground mine can be seen to align with a creek at the surface. Such falls may be caused by the process of unloading beneath modern valleys (Overbey and others, 1973; Moebs, 1977; Hylbert, 1984; Kipp and Dinger, 1991; Sames and Moebs, 1991). In general, unloading fractures affects underlying strata to depths of 600 ft (Moebs, 1977). Topographic overlay maps should always be compared with maps of fall locations to see if falls are following trends of drainages or other low-cover areas. If they are, headings can be adjusted to avoid similar areas. In eastern Kentucky, the drainages themselves are often fracture-controlled.

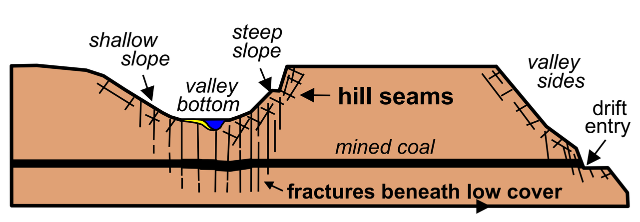

Figure 6. Relationship of hill seams and topography.

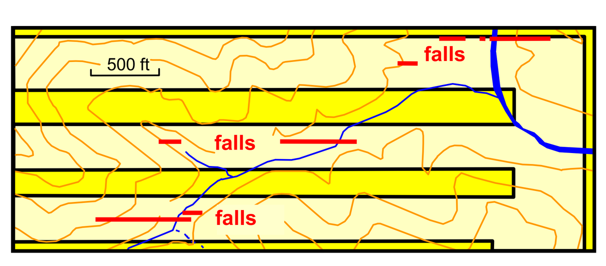

Figure 7. Roof falls (red) beneath low cover in an underground mine (light yellow). Blue lines are streams and orange lines are surface contours (after Greb and Popp, 1999, Fig. 13A).

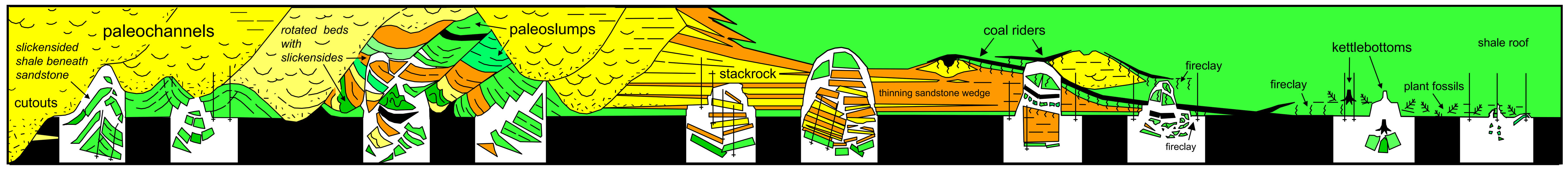

Figure 8. Schematic diagram showing the types of lateral variation seen in roof rocks, and inherent mining obstacles associated with each, above the Lower Elkhorn coal bed. Rates of variation are variable, which is why no scale is inferred.

Roof-Rock Variation

The immediate roof (0–3 ft) of Lower Elkhorn mines is commonly gray shale but the overlying main roof may exhibit lateral variability. Figure 8 illustrates common roof-rock associations above the Lower Elkhorn coal. Some mines may only have one type of roof strata, while others will exhibit rapid lateral variation between different roof-rock associations.

Sandstone Cutouts and Rolls

Cutouts and roof rolls (bowing down of coal beneath sandstone) are relatively common in Lower Elkhorn mines (Fig. 8–11). Most are discontinuous along trend, and rise and fall in the roof. Often the coal will dip in elevation toward cutouts and rolls (Fig. 9). Coal dips of as much as 15 ft within a horizontal distance of 100 ft have been recorded. Also common along cutout trends are (1) slickensided shale or rotated bedding beneath pockets in the sandstone or where sandstones cut underlying shales, (2) compactional slips and offsets in the direction of the roll or cutout, and (3) splits or sand injections into the coal along the cutout margin (Fig. 12).

Along some cutouts the coal may thicken to as much as 9 ft, before being cut out (Fig. 9). Increases in thickness are caused by coal riders dropping from above the sandstone and merging with the coal, or by rotated blocks of coal emplaced above the main coal (Figs. 8–9).

Sandstone cutouts and rolls in Lower Elkhorn mines were mostly deposited as ancient stream and tidal channels and are similar to paleochannels noted in the literature for other coals (Horne and others, 1978; Moebs, 1977; Greb, 1991; Greb and Popp, 1999). Because they were deposited in channels, these types of sandstones tend to follow linear to slightly sinuous trends and can be projected in advance of mining.

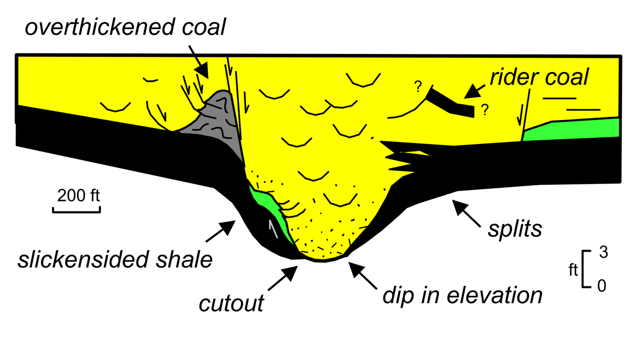

Figure 9. Diagram through a cutout in a Lower Elkhorn coal mine (after Greb and Popp, 1999, Fig. 7A).

Figure 10. Cutout of Lower Elkhorn coal by roof sandstone.

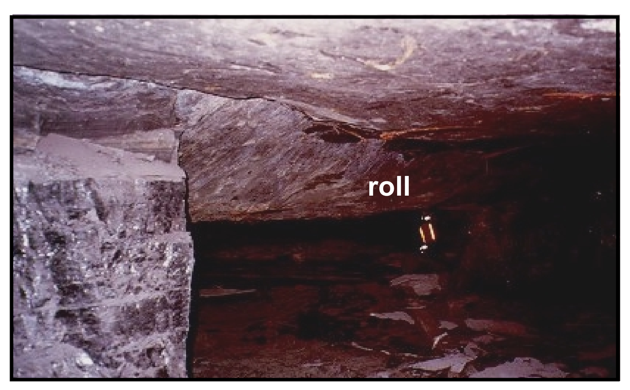

Figure 11. Narrow, linear roll in roof above the Lower Elkhorn coal.

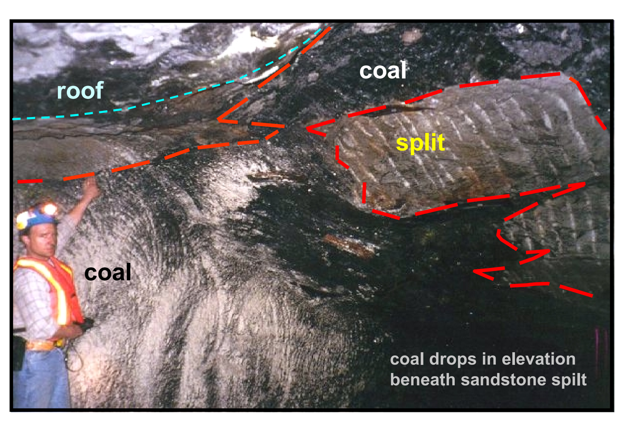

Figure 12. Split and over-thickened coal along cutout margin.

Rotated-Bedding Roof Falls

Large falls along the margins of paleochannels, or beneath down-cutting paleochannel sandstones, are often caused by slickensides and rotated bedding (Fig. 8). Slickensides develop in shales when they are compacted beneath irregularities in overlying rock units, or bedding has slid or been rotated. Rotated bedding refers to bedding that has been rotated from its original horizontal position. Rotated bedding in some Lower Elkhorn mines appears to be caused by paleoslumps, which were formed from the slumping or failure of ancient channel margins into the channel (Fig. 13). Sudden increases in dip angle of beds (Figs. 13–15), slickensided rotation surfaces, and sudden roof irregularity may indicate the presence of paleo-slumps, especially in the vicinity of cutouts and rolls. Another key to recognizing paleoslumps may be the sudden appearance of over-thickened coal (Fig. 9, 12), which can occur because of riders merging from above paleochannel sandstones, or slump-generated thrusting of the coal on top of itself (Greb and Weisenfluh, 1996).

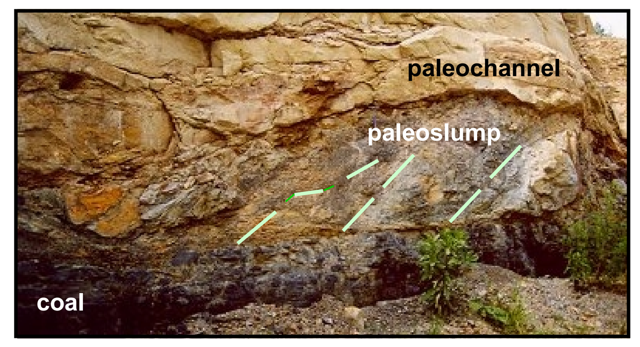

Figure 13. Slickensides and rotated bedding.

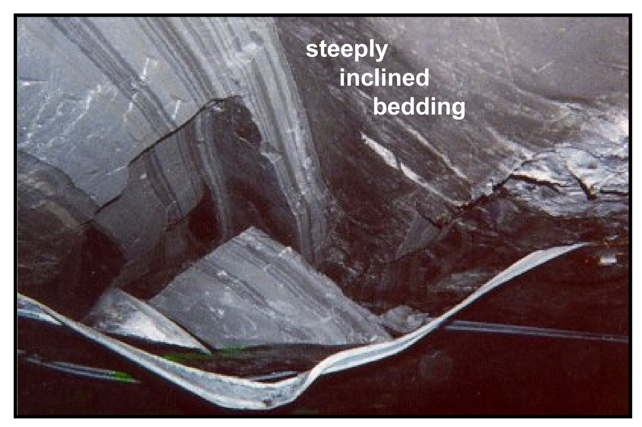

Figure 14. Roof fall exposes steeply dipping beds.

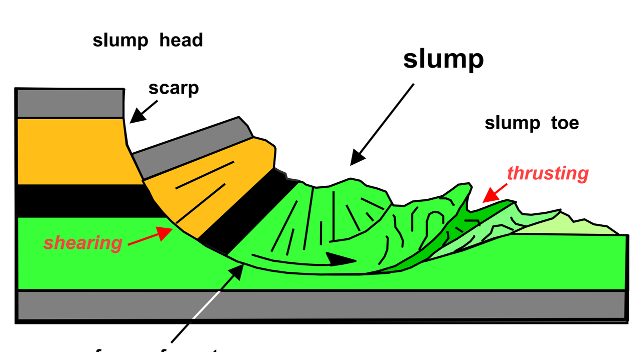

Figure 15. Schematic section through a slump.

Stackrock Roof Falls

"Stackrock" roofs are common in Lower Elkhorn mines and are often cited as major geological obstacles in deep mines. Falls are most common where sandstone beds are thin (< 3 ft) and interbedded with abundant, closely spaced shale or coaly laminae. In some mines, thin-bedded stackrock tends to fall like pages in a book (called catalogue top) even after bolting (Fig. 16). Roof falls are most common along the thinning margin of stackrock units where they are overlain by gray shales, coals, or truncated by overlying sandstones. Local falls as much as 100 ft in length and 20 ft in height have been recorded under thick stackrock conditions (Fig. 17) in some mines, however. Falls are generally flat-topped with near-vertical sides along entry margins.

Figure 16. Thin beds of sandstone and shale in small fall.

Thin-bedded, sheet-form sandstones called stackrock in Lower Elkhorn mines were mostly formed as levees and crevasse splays along ancient paleochannels (Fig. 18). Stackrock units tend to thicken toward crossbedded sandstones and major cutouts and rolls, and thin toward gray shale roofs. They have lobate to linear geometries in plane view (Horne and others, 1978; Moebs and Ellenberger, 1982; Hylbert, 1984; Weisenfluh and Ferm, 1991).

Figure 17. Stackrock strata in roof fall above Lower Elkhorn coal.

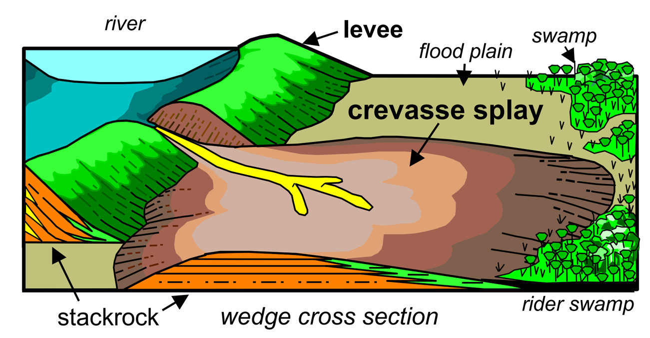

Figure 18. Stackrock strata is commonly deposited in crevasse splays and levees.

Coal-Rider Roof Falls

Multiple, thin (< 6 in.) coal riders are common above the Lower Elkhorn coal bed, especially in the eastern parts of the coal field. Riders often cap laterally thinning stackrock intervals (Figs. 8, 18, 19, 20) and then drop in elevation along the thinning stackrock wedge to the top of the coal, where they either merge with the coal, or thin above a rooted fireclay (Figs. 8, 19, 21). Roof falls are common where riders are within 10 ft of the top of the coal, especially where riders are underlain by fireclays (slickensided and disrupted claystones).

Coal riders represent the accumulation of additional peat mires after burial of the main peat swamp. Coal-rider roofs are particularly susceptible to roof falls because of poor bonding between thin coals and shales, ancient rooting structures disrupting bedding beneath riders, slickensides in underlying fireclays, and shale-coal contacts concentrating moisture, which promotes shale swelling and continued falls (Horne and others, 1978; Moebs and Ellenberger, 1982; Hylbert, 1984; Greb, 1991; Weisenfluh and Ferm, 1991).

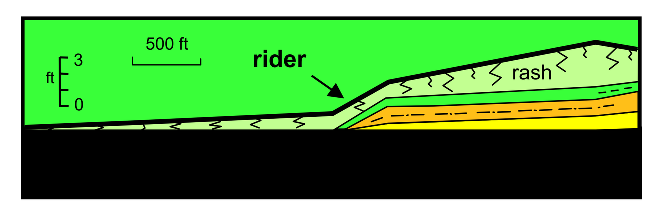

Figure 19. In-mine example of thinning wedge of stackrock strata draped by a thin coal rider, which merges with the top of the Lower Elkhorn coal laterally (after Greb and Popp, 1999, Fig. 11C).

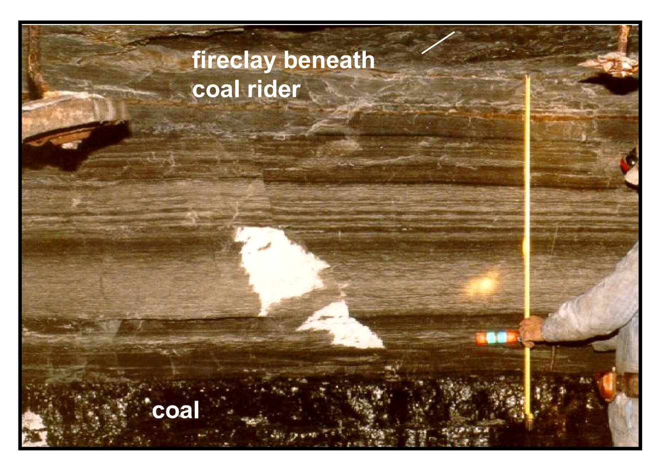

Figure 20. Rider and fireclay above thin-bedded stackrock.

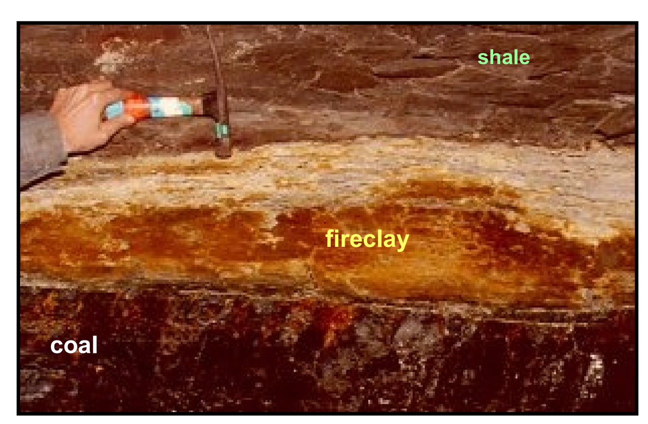

Figure 21. Fireclay in the immediate roof where rider pinches out.

Shale Roofs and Kettlebottoms

The most common roof rock in Lower Elkhorn mines is laminated gray, silty shale with sideritic laminations. In some mines, gray shales contain well-preserved plant fossils. In the immediate roof, the plant fossils occur as carbonaceous streaks, often associated with thin, discontinuous coal streaks and stringers, which weaken the competency of the roof. Where carbonaceous streaks occur in the immediate shale roof, the roof usually must be taken as draw rock. Out-of-seam dilution caused by the draw rock is an important economic factor in mining. Overlying shales in the main roof generally make for good top, although spalling is common in intake passages, and may continue after bolting. Local falls may be related to kettle-bottoms (Fig. 22), which are fossil tree stumps in the roof, and are common in many Lower Elkhorn mines, especially in areas where riders merge with, or come near to merging with, the main coal bed (Fig. 8).

Although the falls associated with shale roofs are generally small, they are common and have been responsible for several fatalities. Between 1988 and 1994, at least six fatalities in Lower Elkhorn–equivalent mines were attributed to small drawrock falls in which the fall material consisted of shale and thin coal or carbonaceous streaks. Three more fatalities occurred in thicker shale roofs.

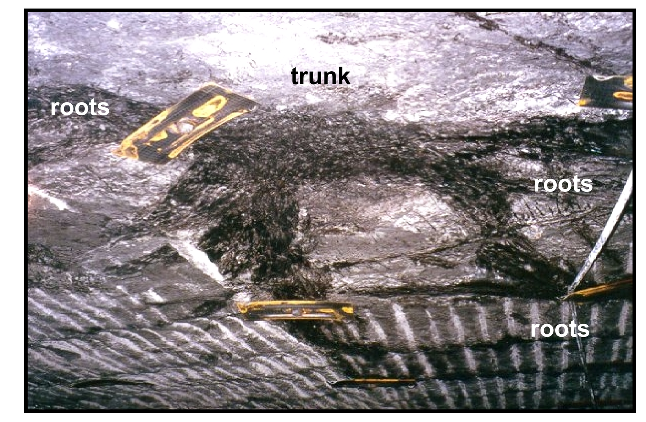

Figure 22. Kettlebottom in shale roof above Lower Elkhorn coal.

Acknowledgments

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