Kentucky Section

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Spring Field Trip & Awards Banquet

May 20, 2006
Breaks Interstate Park
Breaks, Virginia

Geology and Geomorphology of the Breaks Interstate Park Area

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Spring Field Trip

May 20, 2006

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Geology and Geomorphology of the Breaks Interstate Park Area

Stephen F. Greb, William M. Andrews Jr., and Richard A. Smath

Introduction

Breaks Interstate Park straddles the state lines of Kentucky and Virginia along Pine Mountain. It is one of only two interstate parks in America. The park is named for a "break" in Pine Mountain, where the Russell Fork River has carved a 1,600-foot-deep, 5-mile-long gorge, sometimes referred to as the "Grand Canyon of the South" or "Grand Canyon of the East." Whichever direction, the beautiful scenery that attracts people to this end of Pine Mountain was shaped long ago. This field guide summarizes the geology and geomorphology behind the scenery in and around the park.

Location

Breaks Interstate Park is located in the Elkhorn City quadrangle in Pike County, Ky., and Buchanan County, Va. Most of the park, and the scenic overlooks that the park is famous for, are located in Virginia. This field trip will examine rock exposures on Highway 80 along Russell Fork in front of Pine Mountain in Kentucky, on Pine Mountain in the park, and exposures along Highway 690 in Virginia (Fig. 1). The geology of the Kentucky portion of the field area is mapped on the Elkhorn City 7.5-minute geologic quadrangle map (Alvord and Miller, 1972), and the Virginia portion of the area is mapped on the Harman 7.5-minute geologic quadrangle map (Henrika, 1989).

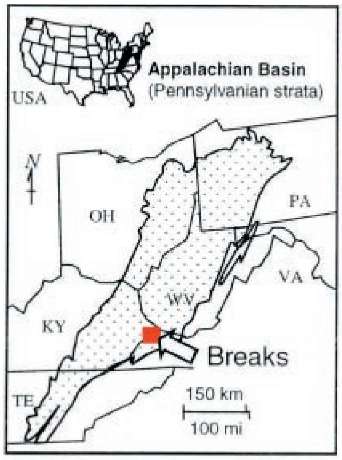
Structure of Pine Mountain

Breaks Interstate Park is located at the northeastern end of Pine Mountain, a northeast–southwest-trending, linear mountain extending for more than 120 miles through southeastern Kentucky and adjacent parts of Virginia and Tennessee (Fig. 2). This mountain resulted from the differential Cenozoic erosion of strata pushed to the surface along the Pine Mountain Thrust Fault during the Pennsylvanian. Pine Mountain is the westernmost expression of the Appalachian Valley and Ridge physiographic province, a belt of long, linear ridges and intervening valleys extending from eastern Tennessee into eastern Pennsylvania. The rocks in the Valley and Ridge are deformed into numerous thin, west-directed, stacked thrust sheets of Paleozoic strata. Thrust fault development and movement in the Valley and Ridge Province occurred in the Pennsylvanian (Mitra, 1988).

The Pine Mountain Thrust Sheet (as exposed at the surface) is 125 miles wide and 25 miles long (Mitra, 1988) (Fig. 2). The thrust sheet can be as much as 2 miles thick and extends under the next overriding thrust sheet to the east. The thrust sheet is not a perfectly flat plane, but rather has a series of ramps and flats. The fault surface moved horizontally along weaker layers, but broke more steeply upward through stronger layers. Lateral offset is greater than 13 miles at the southwest end of the thrust sheet, but decreases systematically to less than 5 miles at the northeast end near Elkhorn City. The Russell Fork Fault is the northeastern boundary fault of the Pine Mountain Thrust Block (Figs. 2–3). The Russell Fork is a passive right-lateral transform fault accommodating the slip of the thrust block past the relatively undisturbed sedimentary rocks to the northeast. The bedrock stratigraphy exposed at the thrust front ranges from Late Devonian black shale through Middle Pennsylvanian coal-bearing strata.

The surface trace of the Pine Mountain Thrust Fault trends approximately N55°E to N60°E along most of its outcrop. To the southwest, the rocks exposed in the hanging wall along Pine Mountain are tilted approximately 25 to 35° to the southeast, because the fault surface is ramping upward everywhere along this surface trace, and the beds are parallel to the fault-ramp surface (Fig. 3). To the northeast, bed dips and at the surface decrease toward the fault terminus.

The Pine Mountain Thrust Sheet moved over flat-lying Pennsylvanian coal-bearing strata, which experienced significant drag as a result. The footwall strata were locally overturned, with a series of small normal and reverse faults (Fig. 3), because fault motion exerted drag on the rocks underlying the thrust sheet. Numerous features clearly illustrate the overturned nature of the bedding in the footwall. Coal beds are below their associated underclays. Sandstone-channel scour surfaces are inverted, and overturned crossbeds and inverted graded beds are common in some outcrops, especially at the Pound Gap exposure in Letcher County to the southwest (Chesnut and others, 1998; location shown on



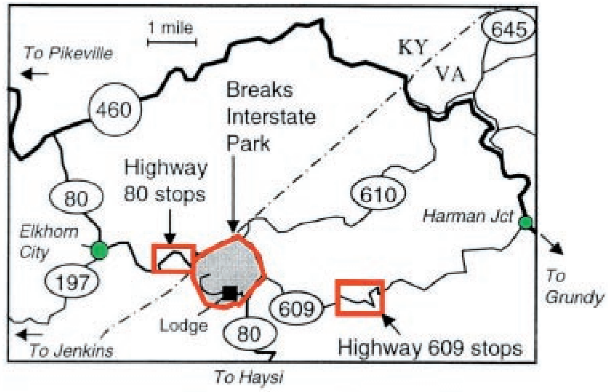


Figure 1. Location of Breaks Interstate Park and field trip stops in Kentucky and Virginia. See Figure 9 for more details.

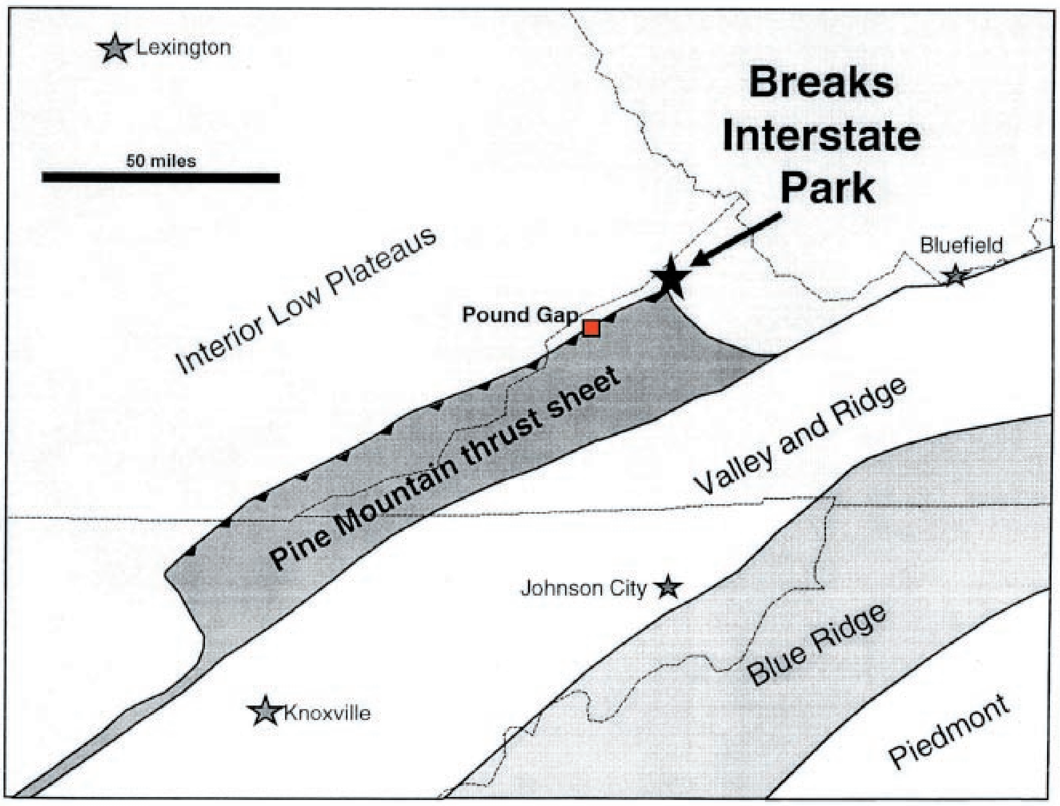


Figure 2. Map of the central Appalachian region, showing the location of Pine Mountain and Breaks Interstate Park in relation to other geologic provinces.

Fig. 2). The area of overturned footwall beds exposed at the surface is typically less than half a mile wide. At the distal edge of this zone, the bed orientations are tightly folded from subhorizontal on the northwest to overturned on the southeast. The fold hinge is tight, and is only a few tens of feet wide.

Geomorphology

In the area of Breaks Interstate Park, Pine Mountain has been dissected into three distinct and separate topographic highs (Fig. 4). The southwesternmost high is the sharp, linear ridge of Pine Mountain developed on the bedrock of the Pine Mountain Thrust Sheet (Fig. 5). The bedrock in this part of the mountain was transported 2 to 4 miles to the northwest during emplacement of the thrust sheet. The beds dip 25 to 35° to the southeast, and the ridge is capped by resistant Lower Pennsylvanian sandstones. The Pound Gap field guide (Chesnut and others, 1998) describes a good exposure of this part of Pine Mountain several miles to the southwest (a downloadable version of this field guide is available at www.uky.edu/KGS).

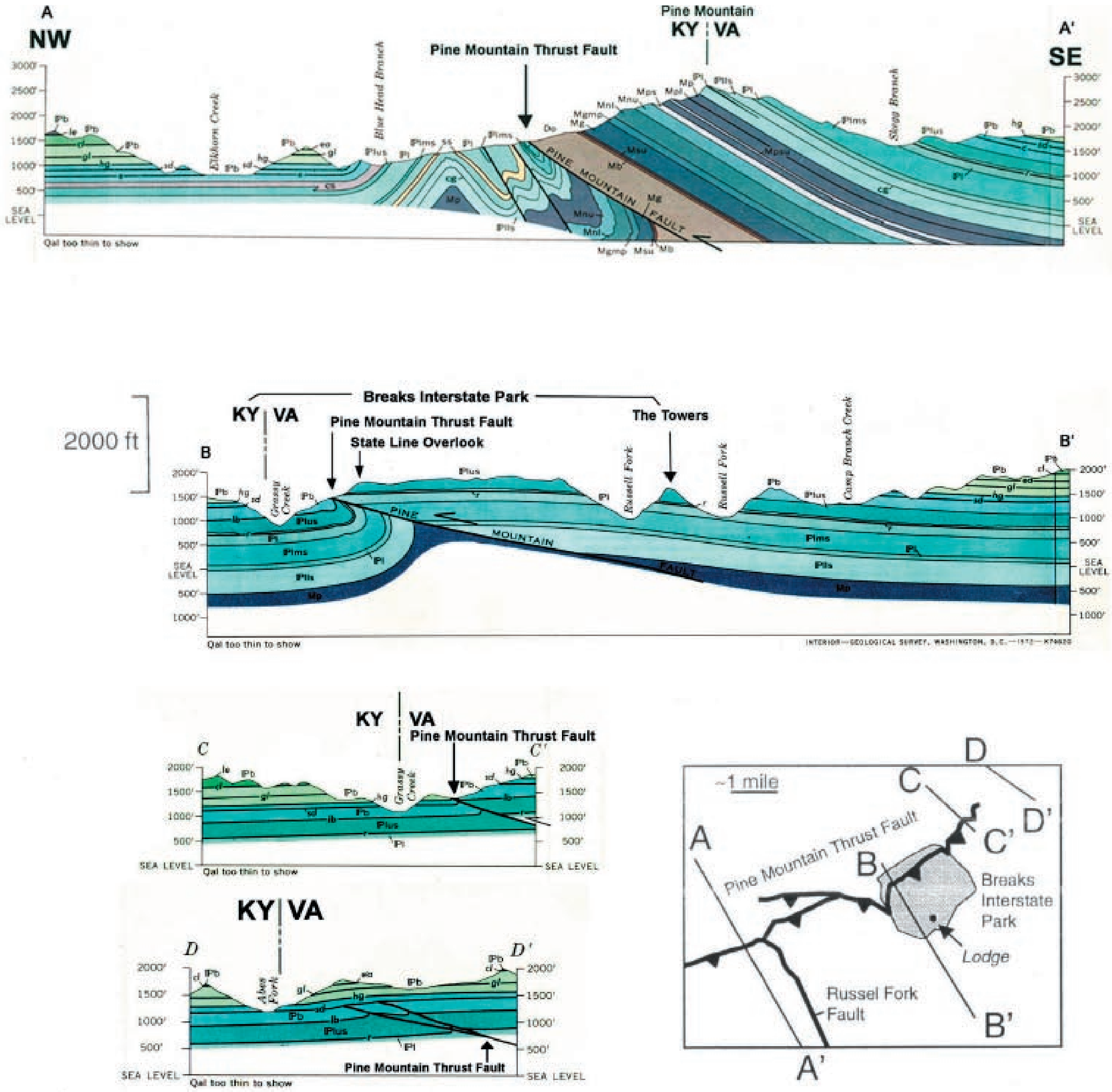


Figure 3. Series of cross sections showing the changes in the Pine Mountain Thrust Fault from its northeastern terminus (D-D′) to the southwest (A-A′) on the southern half of the Elkhorn City quadrangle (Alvord and Miller, 1972). Breaks Interstate Park is located along section B-B′. In section A-A′ (3.5 miles southwest of the lodge) there is more than 2,500 ft of vertical displacement across the fault; B-B′ is approximately 750 ft, C-C′ is approximately 350 ft (1.75 miles northeast of the lodge), and at D-D′ (2.75 miles northeast of the lodge) there is little or no displacement and the fault is buried. To the southwest, beds in the hanging wall (right) are parallel to the fault plane; beds in the footwall (center) are overturned by drag from the overlying thrust to the southwesst, but drag diminishes to the northeast as the fault terminates.

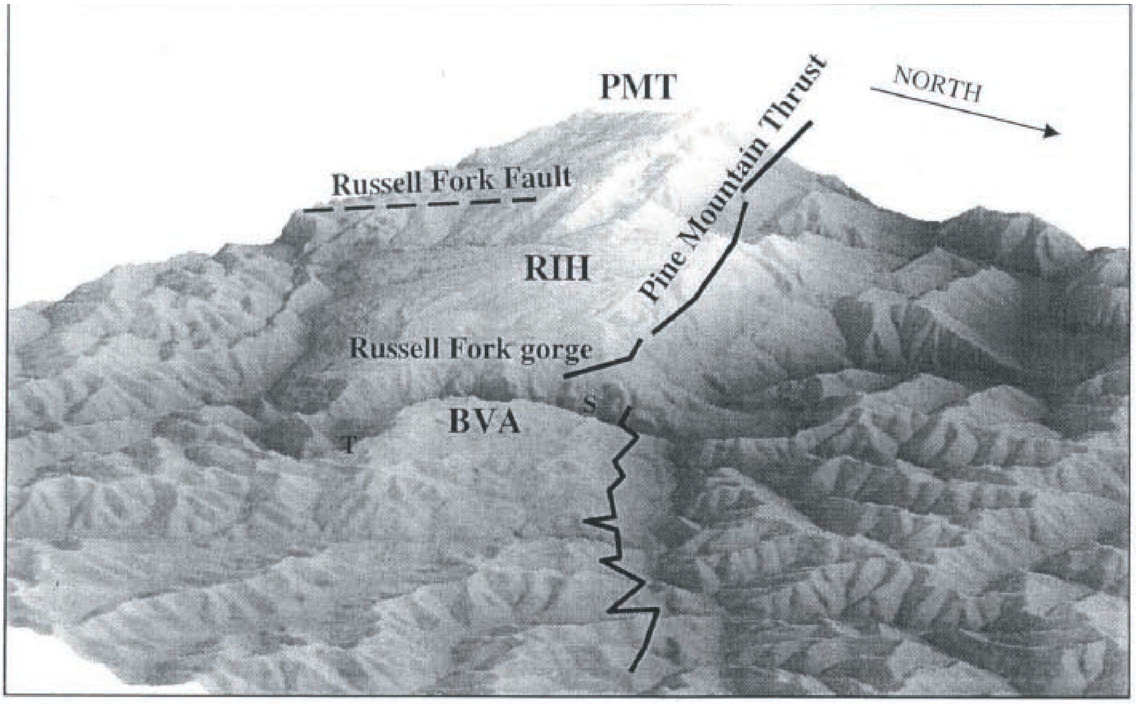


Figure 4. Oblique digital view of field trip area, showing three distinct topographic highs discussed in the text and the trace of faults discussed in the text. PMT: sharp linear ridge of Pine Mountain Thrust Sheet to the southwest; RIH: rotated beds of the intermediate high; BVA: anticline in the Breaks Interstate Park visitors area; S: Stateline Overlook; T: Towers Overlook.

Figure 5. View looking southwest from Stateline Overlook, showing the thrust fault developed in the valley walls, and the topographic expression of the Pine Mountain Front in the distance. Inferred trace of fault shown by dashed line.

The central topographic high represents rocks outside the thrust sheet that were disturbed and rotated by lateral drag from the thrust sheet to the southwest. Bedrock dips are more variable and typically more horizontal, ranging from 30 to less than 10° to the southeast or east. This high is separated from the thrust sheet by the Russell Fork Fault (shown in Figure 3); Upper Skegg Fork (Va.) and Blue Head Branch have dissected the mountain along/near the fault to produce the topographic distinction.

The northeastern topographic high represents the fading effects of the disturbance with increasing distance from the thrust sheet. At the main visitor area of Breaks Interstate Park, the sandstones are bent into a large anticline, with a northeast–southwest axis. This anticline, with minimal fault slip below it, is separated from the tilted rocks to the southwest by the deep gorge of the Russell Fork River, which has created the "Grand Canyon of the East" (or "South," depending on preference). The steep valley walls are held up by the Lower Pennsylvanian sandstones in the bedrock walls.

Stratigraphy

The stratigraphy of rocks in and around Breaks Interstate Park are shown in Figure 6. The cliff-forming, quartzose, conglomeratic sandstones in the park were previously termed the middle and upper members of the Lee Formation, but were separated into individual formations by Chesnut

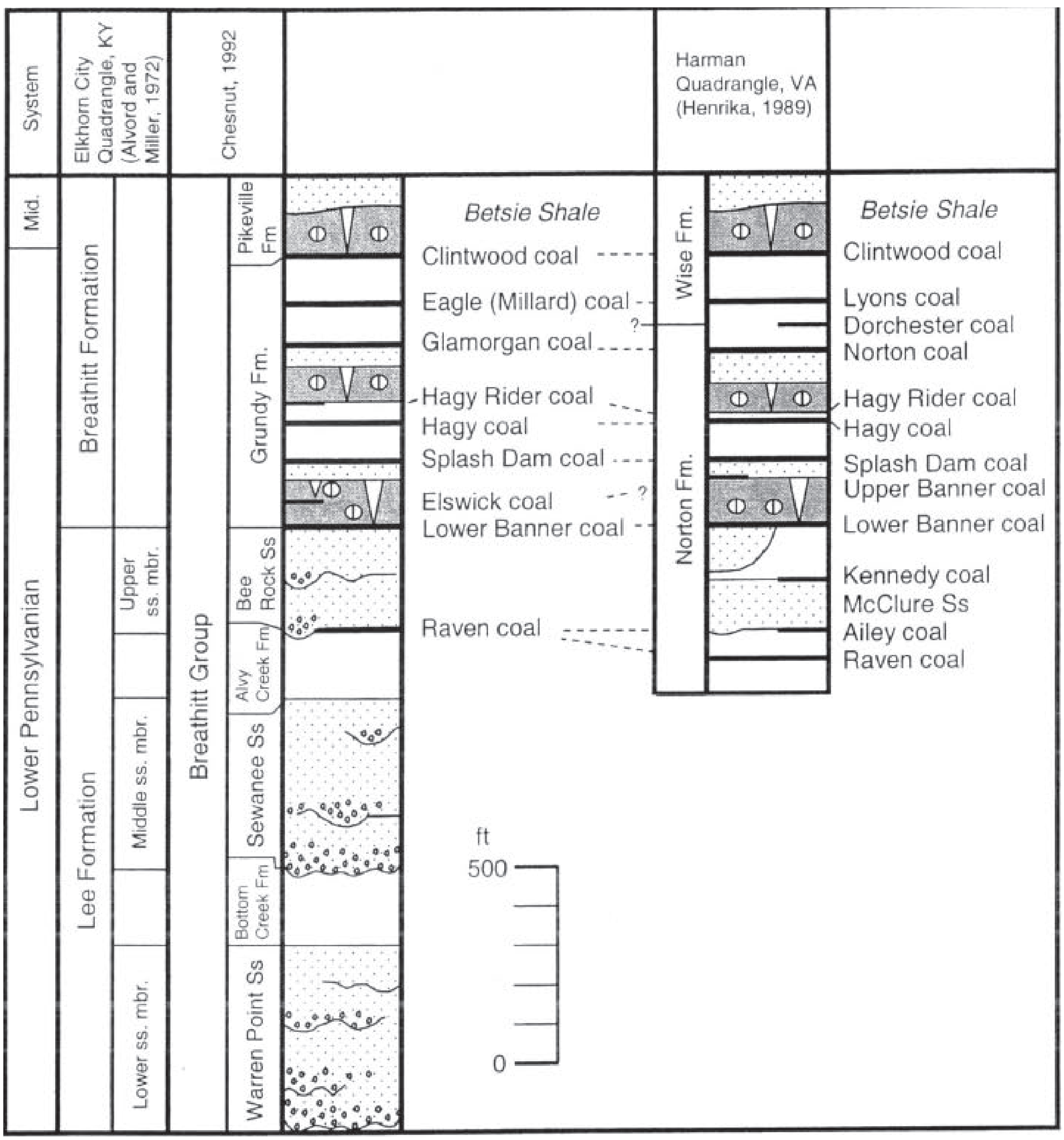


Figure 6. Stratigraphy of rocks exposed at the surface in Breaks Interstate Park and surrounding area.

(1992). There are actually three cliff-forming, conglomeratic sandstones. The lower sandstone (460 to 500 feet), which comes to the surface at the base of Pine Mountain, but is largely covered in the park area, is the Warren Point Sandstone (previously, lower sandstone member of the Lee Formation). The middle sandstone (450 to 500 feet), which forms the gorge walls east of the Pine Mountain Thrust Fault in the park, is the Sewanee Sandstone (previously, middle sandstone member of the Lee Formation). The upper sandstone on the ridgeline at Breaks Park, and forming the lower gorge at river level northwest of the Pine Mountain Thrust Fault, is the Bee Rock Sandstone (formerly, the upper sandstone member of the Lee Formation). These sandstones are separated by, and laterally juxtaposed to the southeast by, coal-bearing strata (Figs. 6–7). Successive quartzarenite belts are truncated updip by the next youngest belt. To the northwest, each sandstone formation truncates underlying strata, and stratigraphically lower (older) sandstones merge with or pinch out beneath stratigraphically higher (younger) sandstones or the sub-Pennsylvanian unconformity. Neither the Warren Point or Sewanee sandstones extend far into Kentucky (Fig. 7). The Bee Rock, however, is very extensive, and is exposed again on the western margin of the basin, where it is mapped as the Rockcastle Sandstone.

Coal-bearing units separate each of the major quartzose sandstones. In the park, southeast of the Pine Mountain Thrust Fault, the Sewanee and Bee Rock Sandstones are separated by 180 to 220 feet of shale, siltstone, sandstone, and coal assigned to the Alvy Creek Formation in Kentucky (Chesnut, 1992) and Lee Formation in Virginia (Henrika, 1989). The Raven coal (mostly covered) occurs toward the top of this interval in the park, just beneath the Bee Rock Sandstone. The coal occurs at the level of the Prospector's Trail in the park, 350 feet beneath the ridgeline. Another coal, the Lower Banner coal, occurs on top of the Bee Rock Sandstone near the park entrance (gateway) on the Virginia side of the park and, again, just below road level on Highway 80 in front of the Pine Mountain Thrust Fault on the Kentucky side of the park. The Lower Banner coal is the base of Chesnut's (1992) Grundy Formation. The Grundy Formation includes the Lower Banner, Elswick (limited extent), Splash Dam, Hagy, Hagy rider, Glamorgan, Eagle, and Clintwood coal beds. Several of these coals occur in zones of multiple beds (Fig. 6).

In Virginia, the same coal-bearing interval is part of the Norton and Wise Formations. To the south, the top of the Norton Formation is placed at the top of the Gladeville Sandstone, but this unit does not extend into the Harman quadrangle, so the top of the formation is placed at the base of the Dorchester coal (Henrika, 1989). Coals in the Norton Formation include the Raven, Kennedy, Lower Banner, Upper Banner, Splash Dam, Hagy, Hagy rider, Norton (Glamorgan), and Dorchester beds. The Lyons (Eagle) and

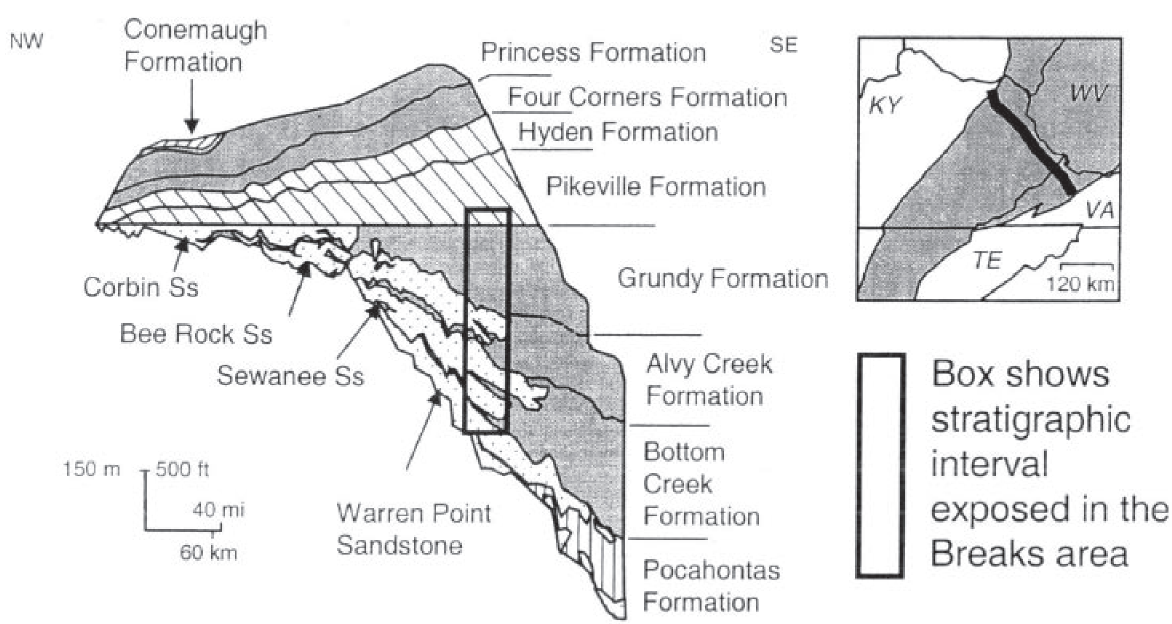


Figure 7. Cross section of Pennsylvanian strata in eastern Kentucky showing the formation nomenclature of Chesnut (1992).

Clintwood coal beds are assigned to the Wise Formation in Virginia (Fig. 6).

Several regionally persistent, coarsening-upward marine units are useful marker horizons in the area, including a unit above the Lower Banner coal (Hensley Member of Chesnut [1992]), a unit above the Hagy rider coal, and the Betsie Shale Member (Rice and others, 1987) above the Clintwood coal. The base of the Betsie Shale is the contact between the Lower and Middle Pennsylvanian. The Betsie Shale is a member of the Pikeville Formation in Kentucky and a member of the Wise Formation in Virginia (Fig. 6).

Lower Pennsylvanian Sandstone Composition

The cliff-forming sandstones of the Warren Point, Sewanee, and Bee Rock (previously Lee Formation) are quartzarenites with common quartz pebbles (Bement, 1976; Rice, 1984; Barnhill, 1994; Churnet, 1996; Greb and Chesnut, 1996). On the western margin of the basin they exhibit south to southwest paleocurrents (Rice, 1984; Barnhill, 1994; Greb and Chesnut, 1996). Along Pine Mountain and southward into eastern Tennessee, paleocurrents in the quartzarenites are west to southwest (Bement, 1976; Churnet, 1996). Sandstones in lateral and overlying coal measures contain micaceous litharenites, sublitharenites, and quartzarenites (Davis and Ehrlich, 1974; Englund, 1974). Micaceous litharenites and sublitharenites in lateral (and intervening) Lower Pennsylvanian coal-bearing strata, as well as micaceous litharenites in Middle Pennsylvanian sandstones, exhibit mostly west or northwest paleocurrent modes and intrabasinal clasts (Donaldson, 1974; Ferm, 1974; Englund, 1979; Rice and others, 1979; Houseknecht, 1980; Rice and Schwietering, 1988).

Lower Pennsylvanian Depositional History

The cliff-forming, conglomeratic, "Lee"-type quartzarenites have been interpreted as beach barriers (Ferm and others, 1971; Ferm, 1974; Horne and others, 1974; Englund, 1974, 1979), fluvial bedload (braided) systems (Rice, 1984; Rice and Schwietering, 1988; Churnet, 1996), and tidal straits (Cecil and Englund, 1989; Englund and Thomas, 1990). Recognition of tidal facies in the tops of otherwise fluvially dominated sandstones at some locations in the basin has more recently been interpreted as indicating that "Lee"-type sandstones were deposited in fluvial trunk systems that were locally converted to tidal estuaries during transgressions (Greb and Chesnut, 1996; Greb and Martino, 2005). In the park, signs and brochures indicate marine origins for the quartzose sandstones (based on marine interpretations of earlier workers), but as you will see on the field trip, the sandstones have sharp scour bases and unimodal paleocurrents more consistent with fluvial origins.

During the Lower Pennsylvanian, two different styles of depositional sequences developed (Fig. 8). The first style consisted of transverse depositional systems prograding west and northwest from the Appalachians, represented by the coal-bearing strata. Coals of the central Appalachian Basin were deposited in peat mires on broad coastal and alluvial plains. Micaceous sandstones in the Alvy Creek and Grundy Formations (Figs. 6–7) represent fluvial and tidal depositional systems along these coastal and alluvial plains (Greb and others, 2004). Rivers flowed westward and then south-southwest into a broad, longitudinal drainage system. This longitudinal drainage is the second major Lower Pennsylvanian depositional style, which is recorded in the cliff-forming quartzarenites (Chesnut, 1992; Greb and Chesnut, 1996; Greb and others, 2004). These sandstones occupy depositional belts that are 60 to 80 km wide (Chesnut, 1992). Each represents broad, long-lived, braided fluvial systems. Lower Pennsylvanian quartz-pebble-bearing sandstones can be traced northward into Pennsylvania, suggesting huge drainage areas (Archer and Greb, 1995). The quartz pebbles are from an extrabasinal source to the northeast (either reworked from eroded older Paleozoic sandstones, northern Appalachians, or Canadian Shield). By the Middle Pennsylvanian, changing climate and tectonic influences led to the demise of the longitudinal drainage system (Greb and Chesnut, 1996; Greb and others, 2004). The absence of these broad, thick quartzarenites in the Middle Pennsylvanian resulted in much more widespread coals in eastern Kentucky and West Virginia.

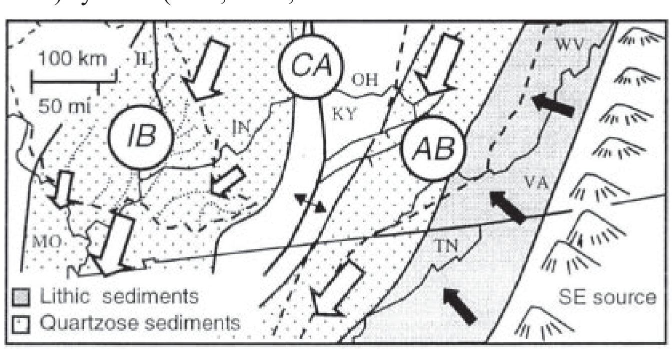


Figure 8. Lower Pennsylvanian depositional trends (from Greb and Martino, 2005). AB=Appalachian Basin, CA=Cincinnati Arch, IB=Illinois Basin.

Each of the thick quartzose sandstones is overlain by a marine (at least marginal marine shale) (Chesnut, 1981, 1991, 1992). These shales indicate marine transgression into the basin. Three of these shales will be observed on the field trip. The bases of the shales are marine flooding surfaces and so are useful for defining third-order genetic sequences (Greb and others, 2004). Each coal-bearing interval represents a shorter, fourth-order cycle of transgression and regression. Within each third-order sequence, the greatest accommodation (most basinward thickening) appears to occur in the brackish to marine shales that bound each sequence, like the Betsie Shale. Foreland basin subsidence influenced the stacking of successive Lower Pennsylvanian quartzarenites, the westward overlap of successive quartzarenite belts, third- and fourth-order sequence thickening across apparent structural hingelines, basinward increases in the number of coal beds, development of coal zones in third-order sequences, and basinward increases in the thickness of coal beds (Greb and others, 2004).

Highway 609 Outcrops East of the Park

From the park entrance-gateway, turn left onto Highway 80W toward Elkhorn City (Fig. 9). Within 0.75 mile, turn right (first right) onto Highway 768 toward Harman and Route 460. Head down the mountain to the intersection with Highway 609 (approximately 0.25 mile). Turn right (east) on Highway 609 (Willard Owens Memorial Highway) toward Harman, Va. Continue on Highway 609 past the Willowbrook Country Club for approximately 2.75 miles to a tight, hairpin turn in the road as the road climbs in elevation. From this point eastward there are several roadcuts that expose the stratigraphic interval between the Hagy rider coal, Norton Formation, to the Betsie Shale Member of the Wise Formation (Figs. 6, 9). The geology along this section of road is shown on the Virginia portion of the Harman and Jamboree geologic quadrangle maps (Henrika, 1989) and is discussed here to illustrate the stratigraphy and geology of the strata on the eastern side of the park. Three sections of the road are described (sections A, B, and C in Fig. 9). Continue on Highway 460 east, past sections A and B, to a crest in the road at Bull Gap. Just past Bull Gap there is a scenic pulloff on the right side of the road (about 1 mile from where the road begins to climb from the hairpin turn in the road). Park here to examine outcrops east of the pulloff in the Betsie Shale Member (section A in Fig. 9), and then return to examine sections B and C (Fig. 9).

Stop A: Betsie Shale Member

The Betsie Shale and an overlying unnamed sandstone are exposed on the north side of the road from the pulloff

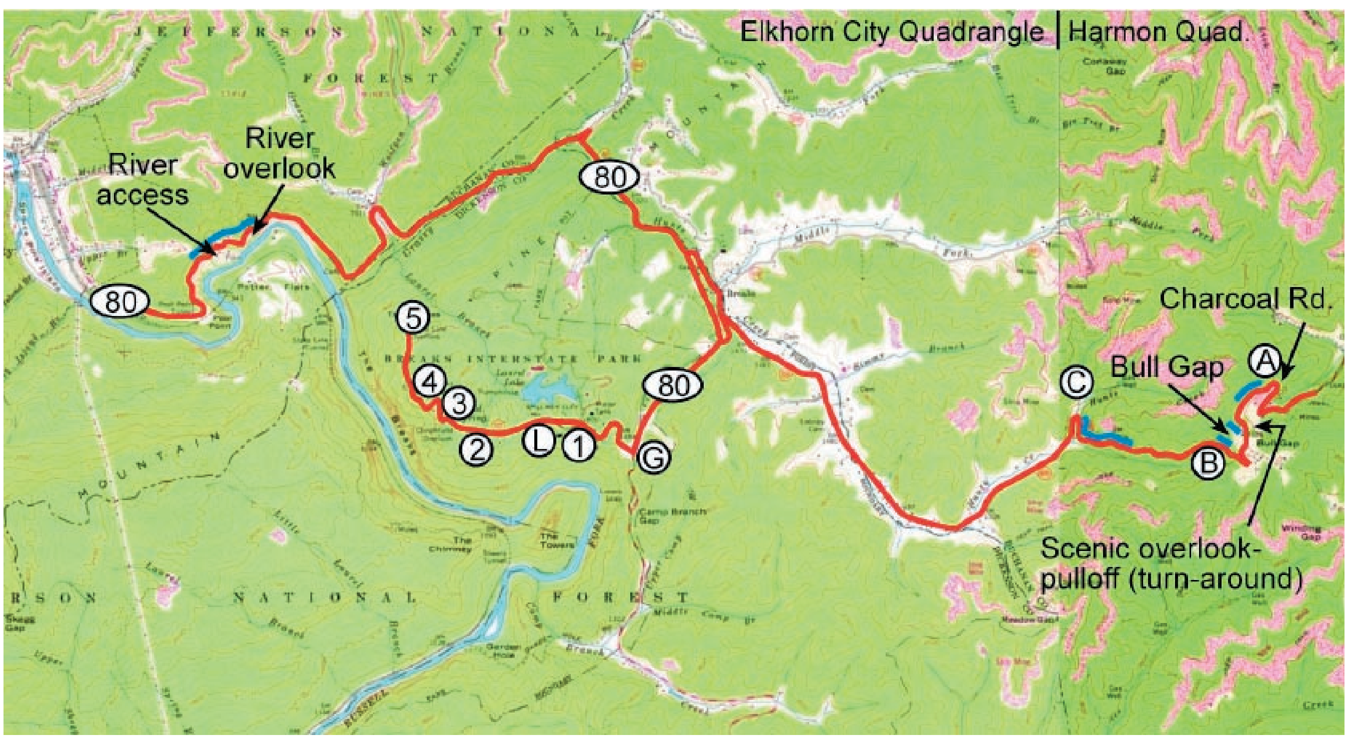


Figure 9. Topographic map of Breaks Interstate Park and surrounding area. Stops mentioned in this field guide include three sets of outcrops (A, B, C) on Highway 609 in Virginia. Stops in the park: G=Gateway-Virginia entrance, 1=Towers Overlook, L=Lodge, 2=Towers Tunnel Overlook, 3=Clinchfield Overlook, 4=Pinnacle Rock, 5=Stateline Overlook, including the Geologic Trail. Stops on Highway 80 in Kentucky: at the River Overlook and River Access.

down the ridge (section A in Fig. 9). At the base of the long exposure, Charcoal Road crosses Highway 609, before a sharp, hairpin turn in the highway back toward the south (Fig. 9). This road marks an old surface contour bench on the Clintwood coal (Henrika, 1989). The thick, gray shale above road level at Charcoal Road is the Betsie Shale Member.

The Betsie Shale Member (Wise Formation in Virginia and Pikeville Formation in Kentucky) is 80 to 150 feet thick in the Harman quadrangle, and is overlain by 35 to 100 feet of sandstone. Both are exposed in the roadcut. Brachiopods have been found in the lower part of the shale in parts of the quadrangle (Henrika, 1989) and throughout eastern Kentucky (Rice and others, 1987; Chesnut, 1991). At this location, the base of the shale is covered, but the lower part of the shale contains several large discordances. Some are scour-based and filled with rotational slumps; others are scour-based but overlain by concordant bedding. Discordances are most easily seen where coarse siltstone to very fine-grained sandstone beds overlie beds with finer grain sizes. Overall, the shale coarsens upward. Higher in the section, bedding looks distinctly more graded, with rhythmic sets of gray siltstone to fine sandstone and a series of low-angle cross-beds. Toesets of each foreset continue laterally as one of the horizontally bedded, rhythmic beds (Fig. 10). Although beds appear graded, internal lamination indicates millimeter-scale laminae with coarser-grained laminae separated by finer-grained laminae (Fig. 10). Thicker laminae occur toward the middle of each bed. Some laminae appear to exhibit thick-thin alternations (Fig. 11). Foresets are oriented to the west and define broad limbs of troughs or scours.

A medium- to coarse-grained, micaceous sandstone overlies the Betsie Shale above the rhymically bedded interval. The sandstone is sharp-based with an irregular, siderite and shale-clast lag (Fig. 12). There are actually several scours in the lower part of the sandstone. The sandstone continues upward to the exposures at the scenic overlook.

Interpretation. The Betsie Shale has been interpreted as a marine, prodelta shale (Rice and others, 1987; Chesnut, 1992). The large paleoslumps exposed in roadcuts toward the base of section A (and again in section B) represent prodelta slumps, possibly as a result of growth faulting during progradation of the Middle Pennsylvanian coastline into the Betsie seaway. Continued progradation led to a coarsening-upward sequence. The rhythmic bedding at the top of the shale may indicate tidal influences, as thick-thin laminations are typical of tidal sedimentation (e.g., Greb and Martino, 2005), although more work is needed to discern tidal influences here. Many of the marine units in the Central Appalachian during the late Early and Middle Pennsylvanian were tidally influenced (Greb and Martino, 2005). Tidal rhythmites are preserved in prodelta reaches of the Amazon delta, and similar features are noted in the Kendrick Shale (Middle Mississippian) in Kentucky, which have been interpreted as tidal deposits (Adkins and Eriksson, 1998).

Using sequence-stratigraphic principles, the juxtaposition of coarse-grained sandstone above a thick, marine gray shale and siltstone could be interpreted as continued progradation of distributary channels above prodelta shales during

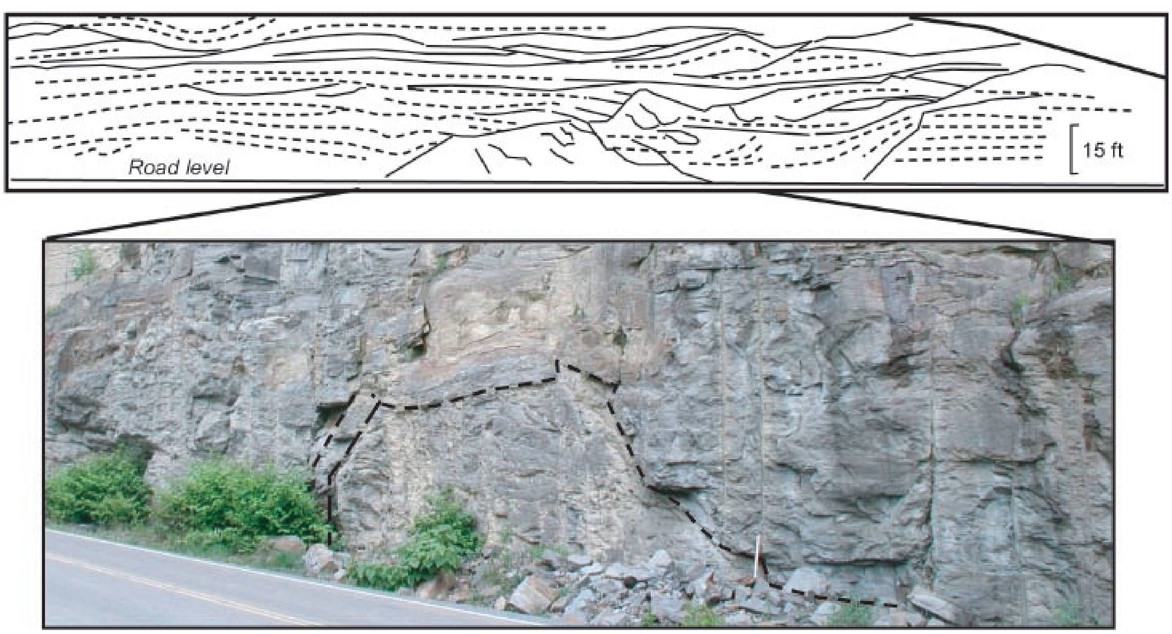


Figure 10. Trace of photomosaic from the Betsie Shale exposure along Highway 609 near Charcoal Road. The lower part of the shale contains numerous discontinuities, scours, and rotational slumps. Photograph is oblique view of disturbed beds near road level. Yardsick scale in lower image.

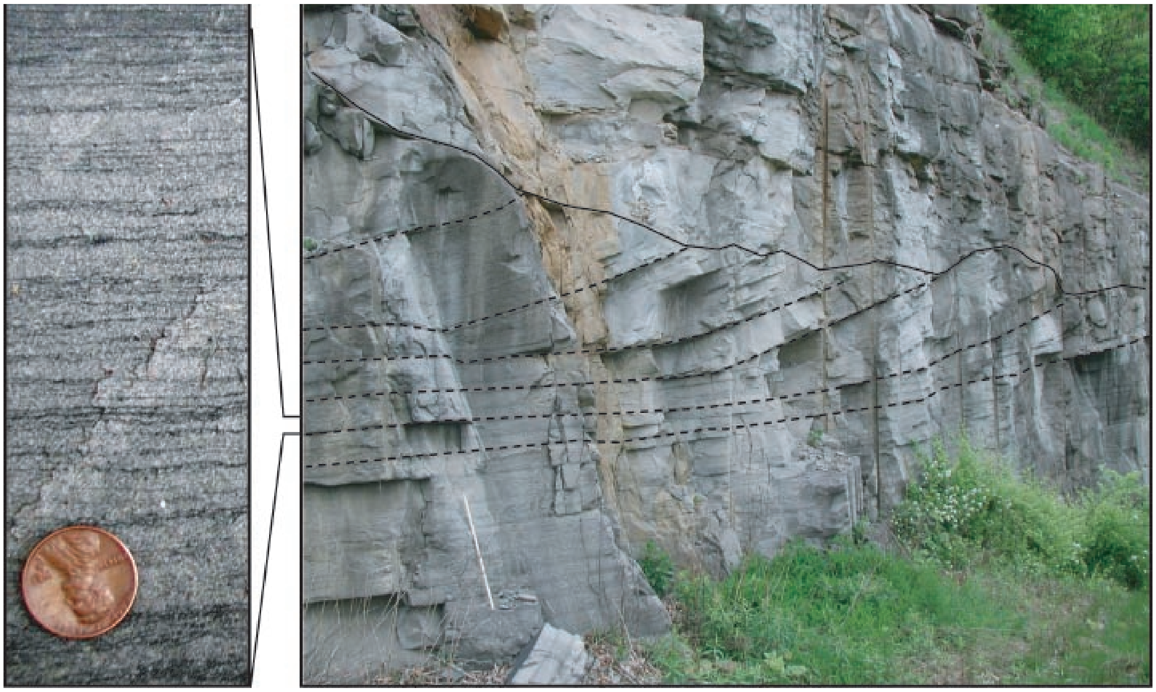


Figure 11. Low-angle inclined crossbeds with rhythmically laminated toesets in the upper part of the Betsie Shale along Highway 609. Yardstick scale. Detail shows internal lamination of laminae with possible thick-thin alternations. Penny scale. The rhythmic beds are truncated by a scour-based, coarse-grained sandstone.

Figure 12. Scour-based sandstones cutting Betsie Shale.

highstand conditions, or lowstand paleovalley incision into the underlying highstand deposits. The sharp basal contact and coarse grain size of the overlying strata suggest lowstand incision rather than transition at this location. Aitken and Flint (1995) used the scour contacts at the base of sandstones above the Betsie Shale in a sequence-stratigraphic analysis of the Middle Pennsylvanian strata in eastern Kentucky. Greb and others (2004) defined similar-scale sequences on the basis of marine-flooding surfaces at the base of the widespread marine units.

Stop B: Betsie Shale Paleoslump

Westward (and down the hill) from the crest of the road at Bull Gap, roadcuts drop below the level of the capping sandstone, back into the Betsie Shale (Fig. 9). A large paleoslump is exposed in the Betsie Shale along this section of road (Fig. 13; section B in Fig. 9). This is a similar stratigraphic interval to the slumped interval in section A.

As in the paleoslumps in the Betsie Shale at the previous stop, there are many internal discordances. Some blocks are rotated and appear to thicken (or show growth). There are also numerous scour-based lenses of coarser grain size, indicating small channelized flows on the original slope before rotation. Some scours appear to have occupied lows on the irregular slump surface after rotation. The western end of the slump complex is very sharp and needs further investigation to interpret the movement and history of this slumping event. Slumping at both outcrops may have been initiated along growth faults in the prodelta shales, or from rapid sediment loading on the fine-grained prograding delta front.

Stop C: Coal-Bearing Interval (Grundy/Norton Formations)

Westward from the paleoslump, the lower part of the Wise Formation and upper part of the Norton Formation (Figs. 6, 9) are exposed. There are no pulloffs or parking areas along this section of road. The Clintwood coal was mapped above the thick sandstone at the curve in the road downhill from the paleoslump. The coal was surface-mined on several ridges in the area and is no longer exposed. The Clintwood coal averages 4.6 feet in thickness in the quadrangle (Henrika, 1989).

The sandstone beneath the Clintwood coal is very thick, and is exposed in two outcrops along the road. A sharp scour base with a well-developed lag is overlain by coarse-grained, crossbedded, micaceous sandstone. Paleocurrents are to the west and northwest (265 to 358º). No correlations of coals were attempted for this field guide, so assignment of coal nomenclature to the beds exposed along the road is based on stratigraphic position as mapped by Henrika

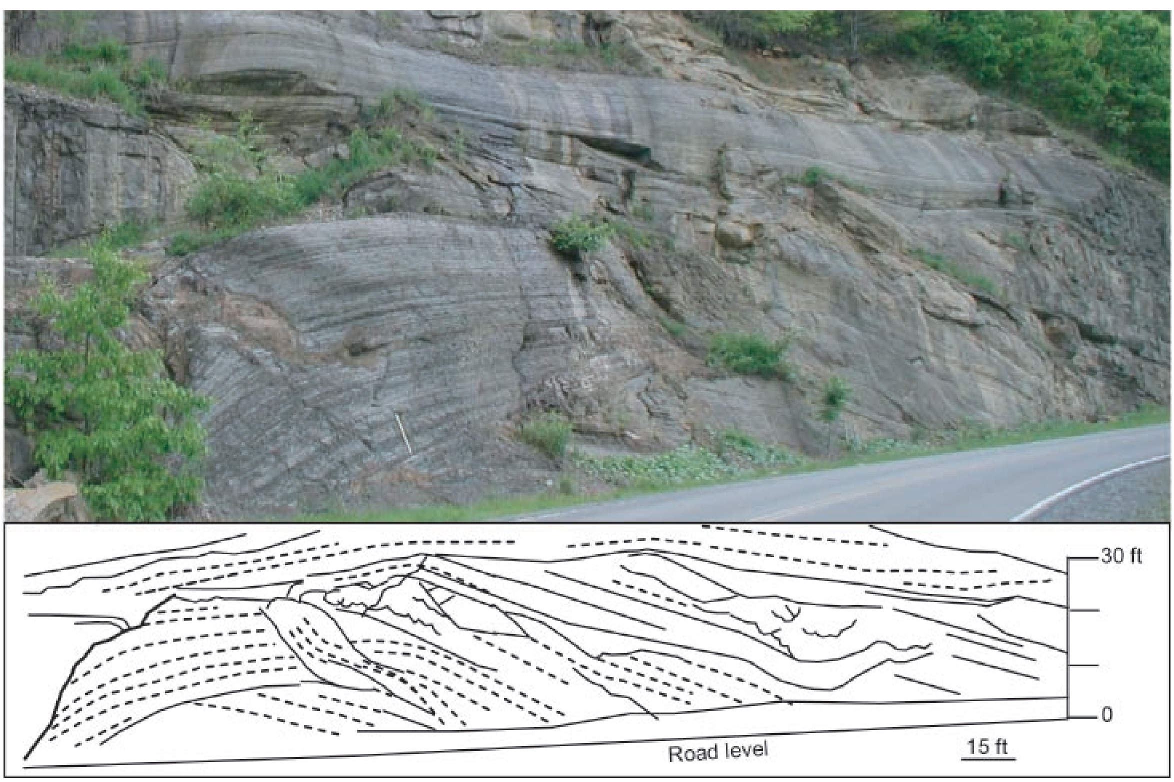


Figure 13. Large paleoslump (oblique view) in the Betsie Shale on Highway 609. Yardstick scale in photograph. The line drawing is a preliminary trace of a photomosaic (at right angles to the road) of the paleoslump, showing the numerous discontinuities within the slump block.

(1989). The geologic quadrangle map indicates that there are four coal-based intervals along this section of road. In descending order, these are the Lyons, Dorchester, Norton, and Hagy rider coals. In the quadrangle, each of these coals occurs in zones of multiple beds, so that assignment of a name to any single bed in a single outcrop without correlation is problematic, especially since some of the covered intervals above sandstones may be covered coal beds.

The Hagy rider at the base of the roadcut is only 3 to 4 inches thick, and is overlain by a thick (30 to 50 feet), coarsening-upward interval (Fig. 14). The gray shale contains an interval of carbonate concretions and is capped by a scour-based, medium- to coarse-grained sandstone, similar to the Betsie Shale at stop A, but thinner. This shale was interpreted as equivalent to the old Eagle Limestone (for the carbonate concretions it contains) by Henrika (1989), but in the adjacent Elkhorn City quadrangle and eastern Kentucky, Chesnut (1991) suggested that the shale above the Hagy rider was not the same as the old Eagle Shale (Limestone) and renamed the unit the Mollus Shale. Regardless of name, this shale is widespread above the Hagy rider and a useful subsurface marker for this stratigraphic interval. Linguloid brachiopods, gastropods, ostracodes, and cephalopods have been found in the lower part of the shale in other areas (Chesnut, 1991).

The coarsening-upward Mollus Shale is capped by a thick, scour-based, micaceous, crossbedded sandstone overlain by a thick coal. This coal is likely the Norton coal. The Norton (Glamorgan, Blair) coal normally occurs in a zone of two beds separated by 1.5 to 8 m of shale and sandstone. Near Harman Junction (east on Highway 609; see Fig. 1) the two beds come together to form a coal 8 feet thick (Henrika, 1989). The coal at this location consists of two benches separated by thin shale, and may represent a similar merging of the coals into a single bed. The coal at this roadcut is 5 feet thick, but contains numerous shale partings (Fig. 14).

The Norton coal is overlain by another thick, scour-based sandstone, which fines upward and is capped by a thin coal (2.5 cm) and carbonaceous (coaly) shale (1 m). The carbonaceous zone is overlain by a thin, sharp-based sandstone and interval of interbedded sandstone and shale, which generally fines upward and is capped by another coal, which is overlain by another, thick, scour-based sandstone (Figs. 15–16). One or both of these coals is in the Dorchester coal zone. The Dorchester coal marks the contact between the Norton and Wise Formations (Fig. 6), but the lack of a persistent marker horizon makes differentiation of the formations problematic in this area. This is one of the reasons Chesnut (1992) chose to redefine Pennsylvanian stratigraphic units eastward in Kentucky on the basis of regionally persistent marine zones (coarsening-upward intervals), which tend to be more recognizable than individual coals or sandstones.

Breaks Interstate Park

There are several scenic overlooks along the ridgeline in Breaks Interstate Park. All of the ridgeline is formed in the Lower Pennsylvanian Bee Rock Sandstone (previously, the upper member of the Lee Sandstone). As described in the introduction, this unit is a thick, cliff-forming, conglomer-

Figure 14. Thin Hagy rider coal overlain by Mollus Shale of Chesnut (1991) along Highway 609. Yardstick scale.

Figure 15. Thick, multiple-bench coal overlain by sandstone along Highway 609. Yardstick scale.

Figure 16. Coal overlain by scour-based sandstone along Highway 609. Yardstick scale.

atic, quartzose sandstone. Several of the signs and brochures for the park describe the sandstone as resulting from deposition in inland seas. As discussed earlier in this field guide, the sandstone was more likely deposited in braided fluvial systems. Herein, short descriptions of bedding and other features that illustrate various aspects of the sedimentology and scenic geology of the park are presented for each overlook. Many of the features seen at the different overlooks are similar.

Towers Overlook

The Towers is a cliff-lined “island” in a broad meander of the Russell Fork River (Figs. 9, 17, and cover photo). The Towers are visible from this overlook and the nearby park lodge. The elevation at the top of The Towers is approximately 1,650 feet (similar to the elevation at the overlook). River level on the northeast side of The Towers is 1,000 feet. The cliffs at the top of The Towers are also part of the Bee Rock Sandstone. At the overlook, several broad trough crossbeds crosscut each other and can be observed in cross section and along bedding planes. Foreset and trough dips are to the west and southwest, with troughs oriented to the southwest. Washed-out ripples occur on several foresets.

Tower Tunnel Overlook

Tower Tunnel Overlook (Fig. 18) is located west of the lodge on the road toward the Stateline Overlook (Fig. 9). From the overlook there is a good view down to the Old Clinchfield Railway tunnel at river level. The tunnel was built to allow transportation of coal from the Southwest Virginia Coal Field westward. The overlook is on crossbedded sandstone in the top of the Bee Rock Sandstone.

Clinchfield Overlook

The Clinchfield Overlook (Fig. 9) provides a good view back toward Pinnacle Rock and down to the railroad tunnel. The overlook itself is on crossbedded sandstone in the top of the Bee Rock Sandstone. A quartz-pebble lag is exposed on the overlook.

Pinnacle Rock

Pinnacle Rock is named for an exposure of sandstone only 30 yards from the road between the Clinchfield Overlook and Stateline Overlook (Fig. 9). There is a fence at the rock itself, but there is no fence along the ridge trail to the left, so be careful. Overturned crossbeds are visible in side

Figure 17. View of the Towers from the Towers Overlook.

Figure 18. View from the Tower Tunnel Overlook.

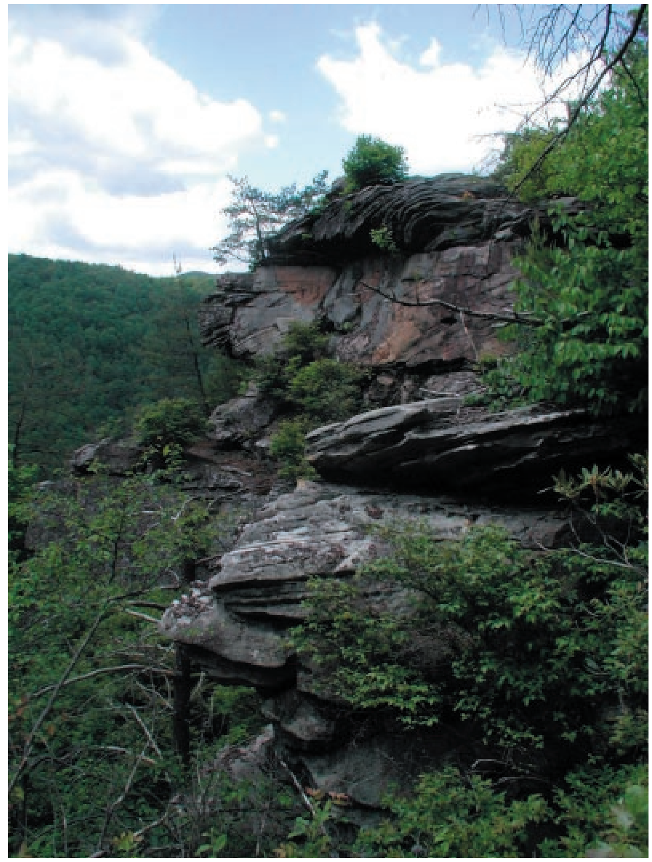


Figure 19. Pinnacle Rock.

of Pinnacle Rock visible from the trail, as are several large, southwest-oriented crossbeds (Fig. 19).

Stateline Overlook—Chestnut Ridge Nature Trail

The Chestnut Ridge Trail is a combination of a part of the Ridge Trail and Geological Trail. A park trail guide has been set up for the trail, and is referenced as part of this field guide. Red wooden posts, numbered from 1 to 30, correspond to points of botanical, historical, and geological interest on the trail. Herein, outcrops near the numbered posts are described to illustrate various aspects of the sedimentology of the Bee Rock Sandstone and scenic geology. From the Stateline Overlook, start at the Ridge Trail (on the left to the northeast) and return on the Geological Trail (on the right) (Fig. 20). The loop is approximately 1 mile in length, and generally takes a little over an hour to walk.

Posts 1 to 8. This part of the trail (Fig. 20) follows the ridgeline atop the Bee Rock Sandstone and is relatively flat. The soil here is thin and sandy. The park trail guide notes several types of plants typical of climax oak-hickory hardwood forests along Pine Mountain. This plant community thrives on dry, sunny ridges. Posts 1 and 2—oak *(Quercus)* and hickory *(Carya)* trees, post 3—earleaf magnolia *(Magnolia fraseri),* post 4—mountain laurel *(Kalmia latifolia),* post 5—rosebay rhododendron *(Rhododendron maximum),* post 6—sassafras tree. There is a good earleaf magnolia at post 8 as well. At post 8 the trail begins to descend down the ridge.

Posts 9 to 10. Between posts 9 and 10 the trail descends steeply down the ridgeline (Fig. 20). Watch your step. The park trail guide notes that the vegetation changes from the ridgetop to the wetter, shadier habitats along this face of the ridge. The shady side of the ridge is dominated by rhododendrons, eastern hemlock, basswood, yellow birch, and sugar maple. Some of the tallest trees at post 9 are yellow poplars *(Liriodendron tulipfera),* also called tulip poplars. American chestnuts *(Castanea dentata)* once grew along this slope but were wiped out 50 years ago during a fungal blight that decimated these trees across the United States.

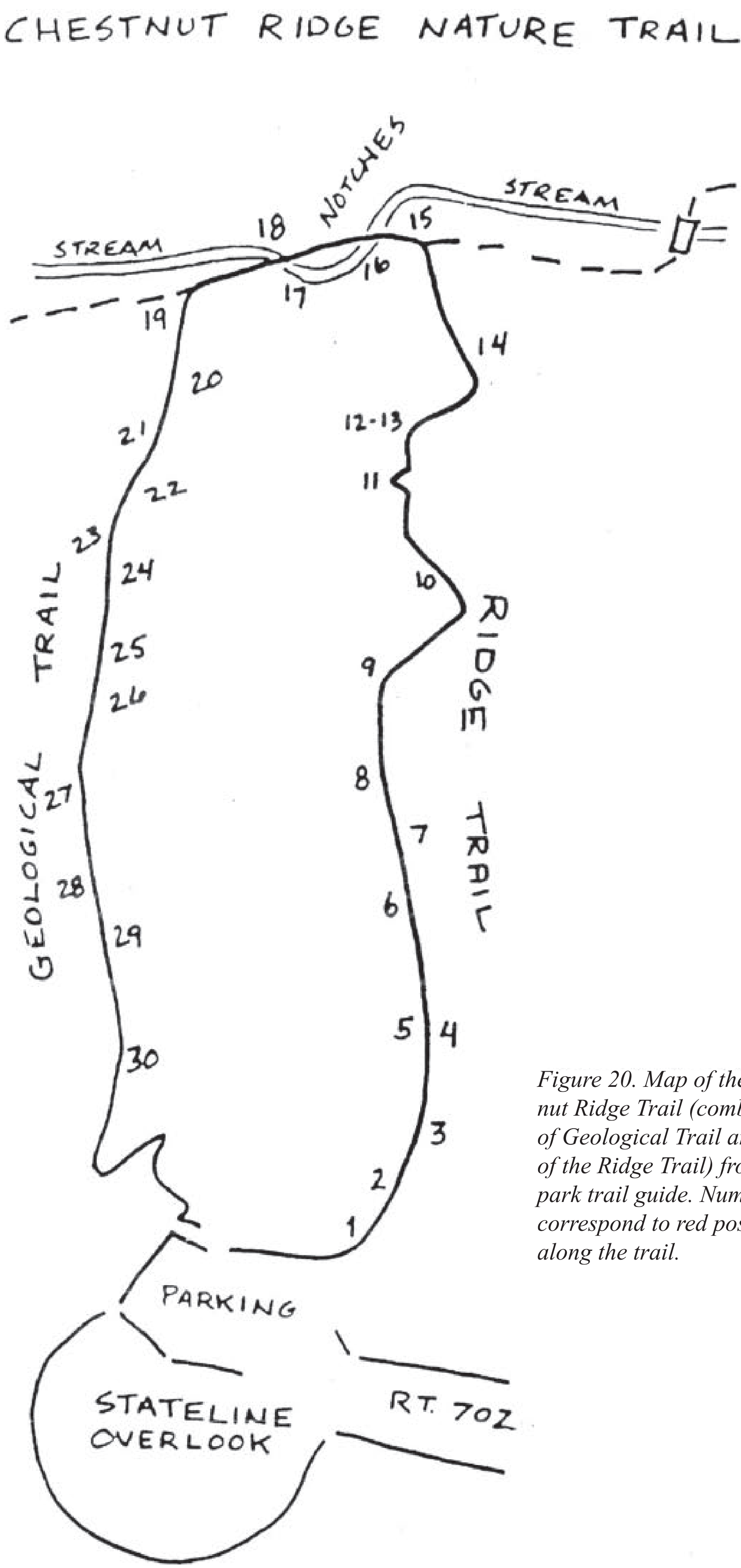


Figure 20. Map of the Chestnut Ridge Trail (combination of Geological Trail and part of the Ridge Trail) from the park trail guide. Numbers correspond to red posts along the trail.

Posts 11 to 13. Just past post 10 the trail levels off for a short distance to post 13. This bench is formed on a ledge of resistant sandstone. To the left of the trail there is a steep cliff formed along a fracture in the bedrock. Be careful; there is no railing. If you look over the edge at Post 13, the base of the ledge you are standing on is between posts 16 and 17 (Fig. 20).

Posts 14 to 15. From post 13, the trail descends to Laurel Branch, a small stream that descends to Grassy Creek at the base of the ridge. The creek cuts a steep path through the sandstone forming the top of the ridge. Its northwest-southeast path is parallel to Russell Fork to the west, suggesting a set of parallel fractures (oriented sub-perpendicular to the Pine Mountain Front) controlling these drainages.

Post 15 is a trail junction with the Laurel Branch Trail. Follow the Geological Trail to the left. The trail follows the base of the exposed sandstone cliff (Fig. 20).

Posts 15 to 16. The sandstone exposed along the trail is the Bee Rock Sandstone (formerly the upper member of the Lee Formation; see the Stratigraphy section of this field guide). Exceptional outcrops of this quartzose sandstone and its bedding are exposed along the trail. Because the trail loops around the ridge, and the ridge is cut by numerous fractures, there is a good opportunity to observe vertical sections of the sandstone and to observe the way the orientation of the exposure influences the appearance of bedding.

The outcrops along the trail between posts 15 and 16 contain numerous trough crossbeds. These crossbeds have curved (smiles) lower surfaces and truncate each other. The axis of the troughs marks the flow path of the current that formed the bedding. The dip angle of bedding into the trough defines the direction of flow to the southwest.

Post 16 to 17. At post 16, you can see the stream to the right, but listen to the right. A spring exits the base of the sandstone at this spot and you can hear the water on your left. Walk a little farther and you can see water from the spring in a small channel join the stream to the right. During the summer, the water table drops and the spring flows underground at this spot. The amount of undercutting in the cliff face shows the power of the stream in past seasonal floods (Fig. 21). Crossbeds are 2 to 4 feet thick. Beds generally thin upward. Foresets of crossbeds are unimodally oriented to the west and southwest (Fig. 21), similarly to post 15.

The rock faces between posts 16 and 17 are separated by a fracture, which continues into the cliff wall as a small opening (cave). The orientation of the fracture is 215 to 206º. If you walk along the fracture from post 17 you can observe the planar crossbeds exposed in the cliff wall in two directions to get a better feel for the three-dimensional shape of a larger bedform, essentially a downstream-migrating river bar. Each of the crossbeds in the lower part of the sandstone is situated on low-angle-dipping surfaces, which define a larger bedform. Both the crossbeds and larger composite bedform are oriented west-southwest (Fig. 21).

Post 17. Just above post 17, the sandstone in the overhang is stained orange and black. There are a series of resistant U-shaped red to black features along and across bedding. These features are iron- (orange) and manganese (black)-rich deposits called "liesegang." Liesegang is only weakly developed here, but is common in Lower Pennsylvanian sandstone cliffs in many of Kentucky's state parks. The minerals are deposited as groundwater in the cliff seeps out of pore spaces in the sandstone at the cliff and fracture surfaces.

Post 18. If you look across the stream at post 18, there is a cave-like opening in the cliff. This is another fracture oriented at 226º.

Figure 21. The stream undercuts the sandstone cliff between posts 16 and 17. Crossbeds in the sandstone are well exposed and are oriented to the west and southwest.

Post 19. At post 19, there is a trail junction. The Laurel Fork Trail continues straight ahead and the Geological Trail continues to the left (0.35 mile to the Stateline Overlook from this spot) (Fig. 20). The post is located in a series of fall blocks. The ridgeline here forms slowly through the weathering and erosion of fall blocks from the ridgeline upslope. If you look at the sandstone wall just uphill from post 19, and retrace your steps uphill a few feet, you can see that the sandstone cliff is only a few feet thick. The narrowness of the ridge is likely caused by closely spaced fractures. It is easy to see that someday this block of rock will tumble to the slope below, as the rocks did around post 19.

From post 19 the trail rises and falls along fall material at the base of the cliff. There is a thick crossbed near trail level, oriented west-southwest. Shade and moisture keep this side of the cliff wet so that the rocks are covered by moss and wildflowers. Dense thickets of rhododendrons are also common along the base of these faces.

Post 20. The cliff exposure at post 20 is a good location to look at the vertical stacking of bedding in the sandstone (Fig. 22). Thick (19- to 29-inch) planar crossbeds are well exposed in the rock at this post. These crossbeds may be part of a larger compound crossbed, defining a larger bedform such as a subaqueous river bar. Paleoflow is to the southwest and west (Fig. 22). Midway up the exposure there is a break, which represents an erosional surface. This scour is overlain by a very thick crossbed (49 inches), which is overlain by thinner crossbeds. The overlying stacking of crossbeds represents a second "story." In general, each story in a sandstone is formed as part of a similar channel fill or bar migration in the channel. From post 20 to 21, large-scale compound bedding is well developed.

Post 21. There are several well-developed fractures running parallel to the cliff face at post 21. Many of the trees here are hemlocks *(Tsuga canadensis),* also called hemlock spruce or spruce pine. These evergreen trees like acidic soils

Figure 22. Crossbeds in the sandstone at trail level near post 20 are oriented to the west and southwest.

Figure 23. Towering cliffs of Bee Rock Sandstone at post 23.

and shade. The park trail guide indicates that hemlocks thrive on shady sides of cliff lines and beneath taller overstory trees in the Breaks region.

Post 22. In the rock adjacent to the post, there are several impressions of fossil *Calamites,* a common Pennsylvanian reed-like plant. The plant debris is from a scour surface in the overlying sandstone. Plant debris and coal clasts are common along internal scour contacts within the sandstone.

Post 23. At post 23 the trail passes between two tall cliffs of sandstone (Figs. 20, 23). The park trail guide indicates that this may be a collapsed natural arch. Natural arches are common in the quartzose sandstones in eastern Kentucky, but not along Pine Mountain. Although a possibility here, there are no large overhangs or curved faces in the cliff faces, which would be typical of the type of slow, updip weathering and undercutting that are typical of natural arch development. The vertical faces of the two cliffs here likely represent fracture traces along which the two cliffs separated.

Near the base of the separated downslope block, a weak bed is weathering faster than the surrounding rock, which makes the overlying sandstone appear as if it is balancing on the edge of the cliff. This less-resistant interval represents a scour surface. It is overlain by very conglomeratic sandstone (Fig. 24). Pebbles consist of quartz grains, typical of the Bee Rock Sandstone. The conglomeratic interval is overlain by thick (4 to 8 feet) crossbeds, which are in turn overlain by thinning-upward crossbeds. Crossbed orientations are to the southwest, as in all other exposures along the cliff wall. Quartz pebbles decrease in abundance upward. If you look at the cliff, at least three stories are visible in the Bee Rock Sandstone at this location.

In the ridgeline cliff there are two thick crossbeds just above trail level. Both crossbeds are oriented to the southwest, but the upper crossbed is oriented a little bit more westerly than the lower crossbed. These beds represent the downstream migration of sand bars in a large braided channel. Although the overall bed dip is to the southwest, there

Figure 24. Quartz-pebble conglomerate above scour in cliffs at post 23.

are slight differences in the dips of any individual crossbeds because the bedforms defined by the crossbedding have three-dimensional geometry. In this case, the upper crossbed had to migrate over and probably slightly around the lower crossbed, so that it has a slightly different orientation. Both are still oriented in a down-paleoslope direction, which is typical of fluvial sandstones.

Post 24. At post 24, a thick (15 to 20 feet) composite crossbed is well exposed. This crossbed is a continuation of the bedding exposed at post 23, and is still oriented to the southwest.

Posts 25 to 26. These two posts are next to each other (Fig. 20). A smaller block of rock is separated from the cliff line along a fracture that runs parallel to the cliff face near post 25. The rock in the cliff face above post 26 is a good place to see conglomerates. Note that the bedding is less well defined than at the previous stop, or higher in this rock wall. There are also large coal clasts. This is a lag deposit.

Posts 26 to 27. There is a slight rise in the trail from post 26, followed by a descent between two sandstone cliffs separated from each other by a narrow fracture (Fig. 25). As you walk through the fracture, look up and see a rock that is wedged between the two rock faces. The fracture is oriented at 230º. It narrows to 34 inches at the far end of the fracture at post 27.

Posts 28 to 29. These two posts are close to each other. Post 29 is tucked up against the cliff wall, so is easy to miss. There are several fractures exposed in the cliff along this part of the trail, and the trail is once again at the level of the large composite crossbed. Post 29 is a good location to see large crossbeds (Fig. 26). Planar crossbedding dominates (still oriented to the west-southwest), but some of these crossbeds may be part of larger bedforms.

Posts 29 to 30 to Stateline Overlook. This is the last part of the trail, as it begins to climb the ridgeline (Fig. 20). The large crossbed is overlain by thinner-bedded, planar tabular crossbeds (Fig. 27). At post 30, stairs ascend the sandstone to the trail to the parking lot above. Straight ahead and up you can see the Stateline Overlook. Crossbeds in the Bee Rock Sandstone at the overlook are exposed in bedding planes. The dominant bedding features are foresets dipping to the northwest, but these curve around into troughs with

Figure 25. Trail goes between a fracture "squeeze" between posts 26 and 27.

Figure 26. Large crossbeds near post 28.

axes to the southwest to define asymmetric, three-dimensional bedforms. This surface is an excellent example of the need to take many paleocurrent measurements, to take measurements of trough axes where possible, and to understand the three-dimensional shape of the bedding feature being measured when collecting data for interpreting the depositional origin of sandstones.

Stateline Overlook

This overlook provides a sweeping vista that illustrates many of the topics discussed on this field trip. The view to the northwest shows the multiple sandstones that characterize the bedrock stratigraphy of the field trip area. The shale-dominated marine zones and coal-bearing intervals form the intervening slopes. The sharp, linear ridge of the Pine Mountain Thrust Sheet can be seen in the distance to the southwest. The shallower bedrock dips of the disturbed rocks outside the main thrust block are clearly expressed in the topography of the intervening ridge. The steep bedrock gorge of the Russell Fork has exhumed the minor thrust fault that extends beneath the park area, and the disturbed and repeated sandstone section is well exposed in the valley wall southwest of the overlook (Figs. 5, 28).

Mining operations in the distance show the economic importance of coal in the surrounding mountains, and of the limestone exposed along Pine Mountain. Both mountaintop and contour surface mines are visible. You can also see several large outcrops on Ky. 80 near the river. The top of the Bee Rock Sandstone (approximately the same level as you are standing on at the overlook) is exposed in the river below, in front of the Pine Mountain Thrust Fault (covered). Along the road you can see several large outcrops, in the Hensley Member, which will be the final stops on the trip.

Highway 80 Outcrops West of the Park

From the park entrance in Virginia, turn left on Ky. 80 toward Elkhorn City and down the mountain until the road levels off near the river (Fig. 9). Just past the Unknown Soldier's Grave, there is a parking lot for the River Overlook. Watch out for oncoming traffic. We will continue west after this stop.

Figure 27. Large crossbeds at base of cliff near post 30 in typical multiple-story outcrop of the Bee Rock Sandstone. The Stateline Overlook is on top of this cliff. Note the fracture at this outcrop.

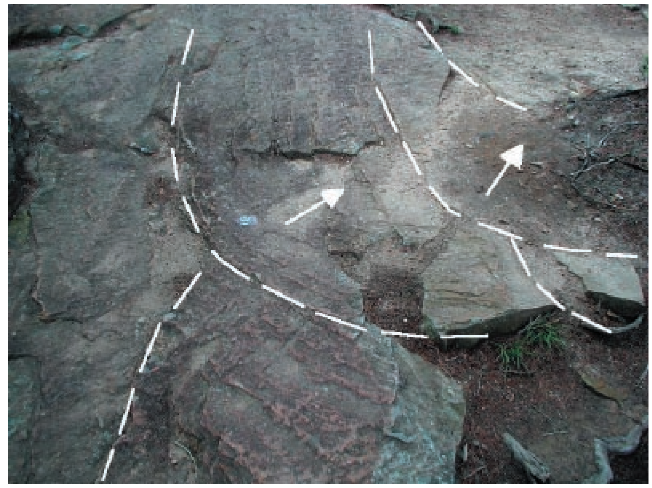


Figure 28. Asymmetric trough crossbeds exposed in bedding-plane surfaces at the Stateline Overlook. Foresets dip to the northwest, but trough axes (arrows) are oriented to the west-southwest, similarly to the rest of the sandstone.

River Overlook

A thick, silty gray shale is exposed in outcrops along Highway 80 at the overlook access in Kentucky (Fig. 29). The shale can be viewed from the picnic area at the overlook parking area. At road level, the shale is a dark carbonaceous shale with siderite nodules and thin interlaminae of fine-grained sandstone (2 to 15 mm) capped by thin siderite layers. Two meters above road level the carbonaceous shale is sharply overlain by thick, gray, silty shale to siltstone. The silty shale is at least 10 m thick. Toward the top of the outcrop, a thick, sandstone caps the shale. Several conjugate fracture planes cut the shale along road level (Fig. 30). The dominant set is 240 to 250º and the conjugate set is 345 to 360º.

The Elkhorn City 7.5-minute geologic quadrangle map indicates that the Lower Banner coal (covered) is at a level 40 to 50 feet below road level (Alvord and Miller, 1972). Less than a kilometer to the west, a thin coal called the Elswick coal occurs 40 to 90 feet above road level (80 to 100 feet above the Lower Banner coal), but that coal was not mapped at the River Overlook. It is uncertain how the gray shale at the River Overlook relates to the Elswick coal to the west, whether it truncates the coal and underlying strata, or whether the dark shale at the base of the road is the Elswick equivalent. More work is needed to determine the correlation in this area.

The thick coarsening-upward sequence above the Lower Banner coal (and therefore above the Bee Rock Sandstone) is a widespread marine zone in southeastern Kentucky, equivalent to the Hensley Member of Chesnut (1992). Marine fossils have been found at the base of the unit in other areas (Chesnut, 1981). As noted earlier with the Betsie and Mollus Shale members, these coarsening-up marine zones are helpful for correlating Lower Pennsylvanian strata in the subsurface, especially where coals between the marine zones are thin or discontinuous. Also, because the Pennsylvanian strata is generally cased off in drilling, there is a lack of density logs in many areas. Without density logs, correlating coals is difficult to impossible. The coarsening-upward shales, however, can sometimes be differentiated on other types of logs and can be used to determine the approximate stratigraphic interval and therefore where coals might be above and below the shales.

The overlook itself is on a ledge of the Bee Rock Sandstone. From the overlook, there is a beautiful view of the lower gorge (Fig. 31).

River Access and Recreation Area

The Hensley Member continues to be exposed westward to the access road to the river. Carbonate concretions are exposed just above road level along Highway 80. These concretions are common in the shales and are one of the reasons these units were sometimes called "limestones" in the old literature. The carbonate concretions tend to occur at the same laminae or bed level in a shale. Sometimes they will be nucleated around a fossil. Other times, marine fossils (generally brachiopods and gastropods) are found in the shales around the concretions.

The access road drops down to river level, where there are a shelter, picnic facilities, and bathrooms. At the river, the Bee Rock Sandstone is exposed in the lower part of the Breaks gorge. A scour-based channel form is exposed midway up the cliff wall. The scour truncates 6 to 10 feet of underlying sandstone. Thirty-foot exposures of the sandstone are also exposed behind the picnic shelter and bathrooms on this side of the river. Paleocurrents in both outcrops are unimodally to the west-southwest, similarly to the Bee Rock Sandstone atop Pine Mountain. Coarse-grained to conglomeratic sandstones with scour bases and unimodal paleocurrents are consistent with deposition in a fluvial, braided stream.

This stop marks the end of the field trip (Fig. 32).

Kick back and enjoy the view along the river.

Figure 29. View of conjugate fractures in gray shale above Lower Banner coal along Highway 80 at the River Overlook.

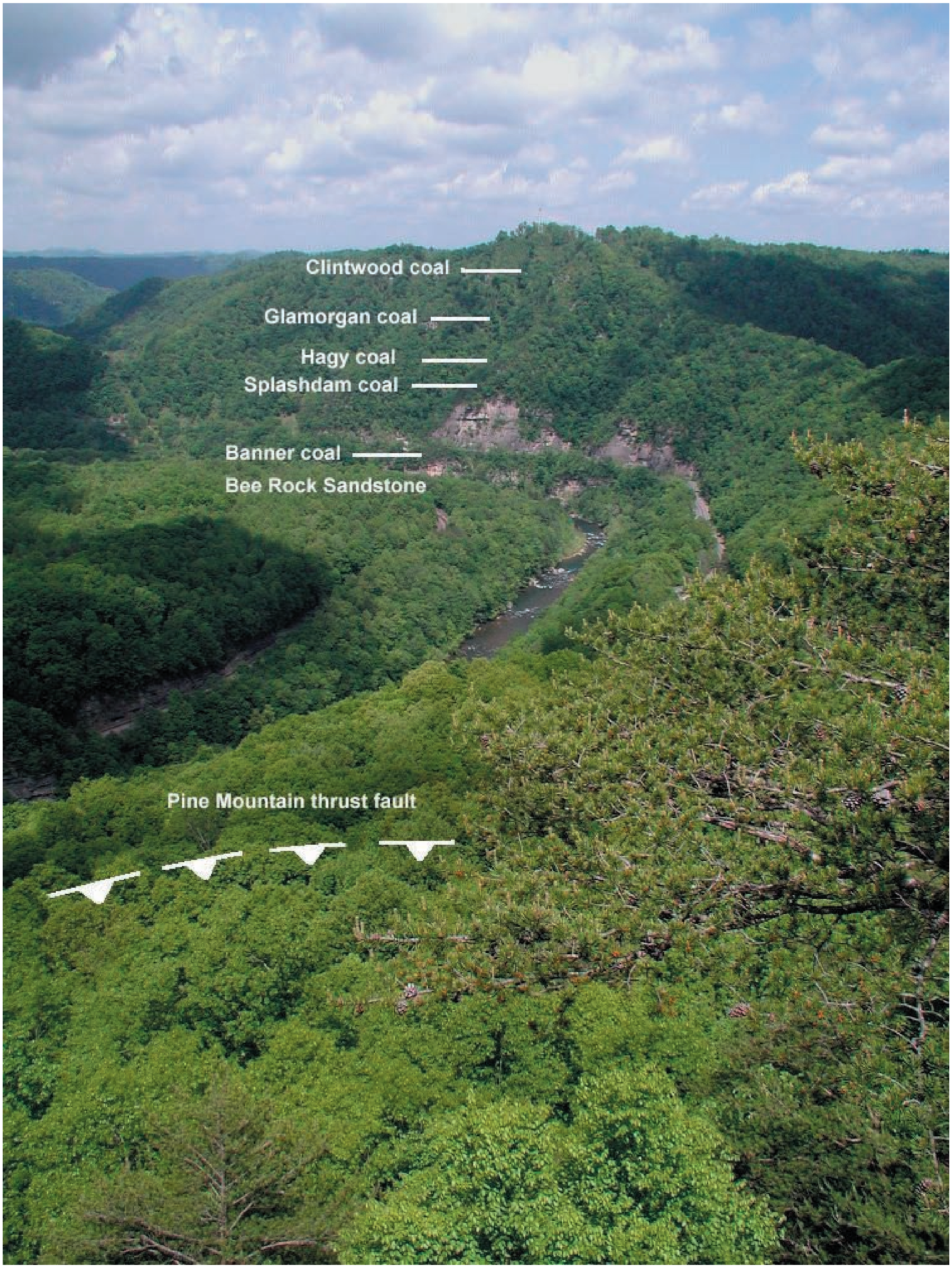


Figure 30. View toward Kentucky from the Stateline Overlook showing the relative position of stratigraphic units as indicated on the Elkhorn City geologic quadrangle map. The exposures above the Lower Banner coal are the stops along Highway 80.

Figure 31. View of the river (lower gorge) from the overlook.

Figure 32. View downriver from the river access road. Hope you had a fun trip!

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