Geologic Setting of Landslides Along South Slope of Pine Mountain, Kentucky

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Landslides along the south slope of Pine Mountain in southeastern Kentucky are integrally related to bedrock geology. Most of the slides are planar block glides of sandstone and interbedded shale and siltstone that have slid down dip slopes on floors of shale, coal, or underclay. The central portion of a ½-mile wide slide that had been stable for many years recently slid when the toe was cut into during highway construction. The old slide probably originated as a planar block glide, but it developed rotational aspects at the toe and flanks. Strata underlying the south slope of Pine Mountain are of Pennsylvanian age and include massive sandstone, interbedded siltstone and shale, and thin beds of coal and underclay. Beds dip generally southeastward but flatten abruptly at the foot of the mountain and are nearly horizontal south of it. The Cumberland River follows this flexure along much of Pine Mountain and in many places cuts laterally against the dipping beds. Landslides have repeatedly occurred and others may occur where dipping strata of Pine Mountain are undercut by rivers or by construction work. Old but presently stable slides may be reactivated when cut into by highway or other excavations.

•PINE MOUNTAIN, with about 1,500 ft of relief, trends northeasterly for 100 miles across southeastern Kentucky (Fig. 1). Roads are under construction and others are being planned around, across, or through Pine Mountain as a part of the Appalachian Highway Development Project. Recent geologic mapping under a cooperative program of the Kentucky Geological Survey and the U.S. Geological Survey has demonstrated that landslides along the south slope are related to geologic structure and stratigraphy. The following discussion is based mainly on field examinations and observations of aerial photographs in the Wallins Creek quadrangle, where the geologic setting is representative of most of Pine Mountain. The purpose of this paper is limited to setting forth the geologic framework of landslides along the south slope of Pine Mountain.

Bedrock along the south slope of Pine Mountain includes part of the Breathitt Group and Lee Formation, both of Carboniferous age (Fig. 2). The upper part of the Lee Formation and the basal sandstone of the Breathitt Group (Fig. 3) consist largely of resistance hogback-forming sandstone beds that are not disrupted by landslides. The overlying strata are largely an incompetent sequence of interbedded siltstone, impure sandstone, carbonaceous clay shale, and coal with underclay. Several hundred feet of these beds underlie the foothills south of Pine Mountain. Ancient and all recent landslides north of the Cumberland River have occurred in these strata.

Figure 1. Index map.

The structural setting is shown by a simplified geologic map of the northern part of the Wallins Creek

Paper sponsored by Committee on Engineering Geology and presented at the 49th Annual Meeting.

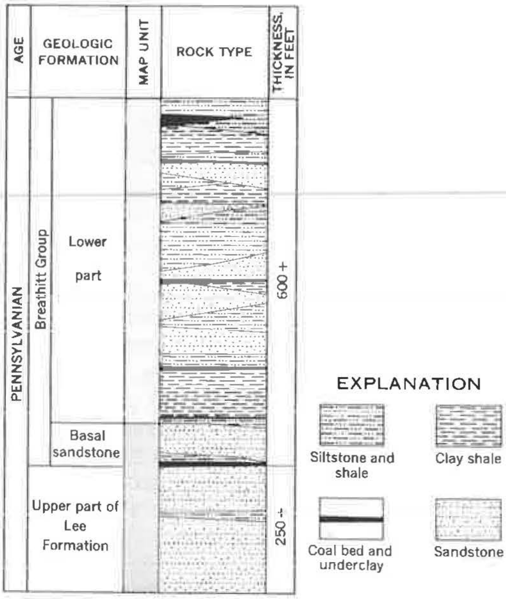

Figure 2. Generalized lithology of strata exposed along south slope of Pine Mountain in Wallins Creek quadrangle.

Figure 3. Resistant sandstone typical of upper part of Lee Formation in foreground, overlain by interbedded siltstone, shale, coal, and impure sandstone of the Breathitt Group. Strata dip southeastward. View is northeastward; Pine Mountain is to left and Cumberland River is on right.

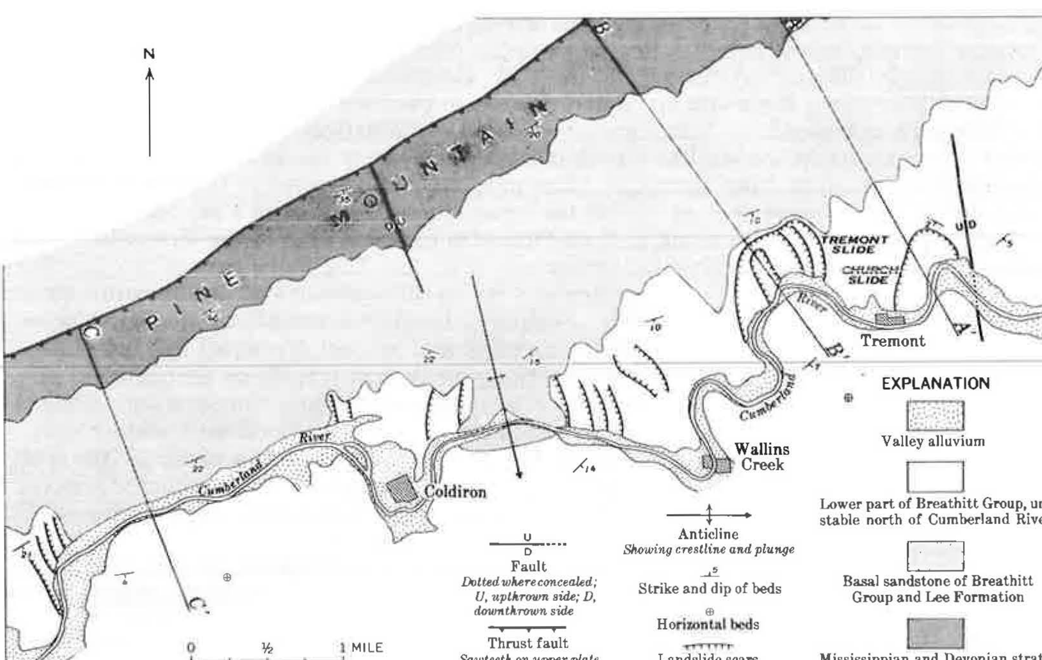

Figure 4. Generalized geologic map of northern part of Wallins Creek quadrangle, Kentucky.

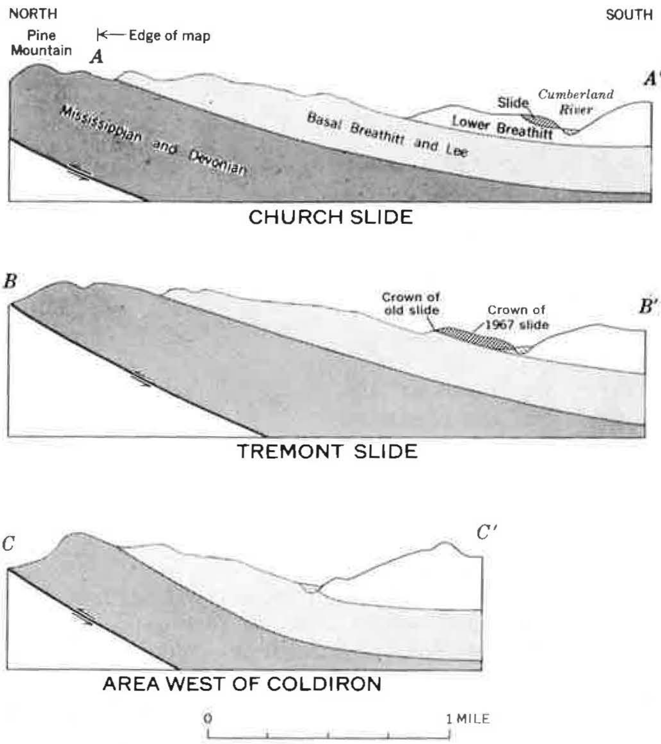

Figure 5. Cross sections showing relation of landslides to geology and position of Cumberland River.

quadrangle (Fig. 4). The regional strike of the Lee Formation is northeasterly, and beds dip generally southeastward from 10 to 40 degrees. The Breathitt strata dip generally southward from 5 to 20 degrees but are gently warped by minor transverse folds and cut by several faults and numerous joints perpendicular to the regional trend. The beds flatten abruptly near the foot of Pine Mountain and are nearly horizontal south of it. The narrow valley of the Cumberland River follows this flexure along much of the mountain, and in many places the river cuts laterally into the dipping beds.

Figure 6. Strata in lower, unstable part of Breathitt Group at Church slide. Roadbed taken out by 1969 slide, rebuilt on strata that continue intermittent down-dip movement toward observer.

Relations among geology, topography, and landslides are shown by three cross sections. The Church slide, northeast of Tremont, is shown in cross section A-A' (Fig. 5); it is wholly within bedrock of the lower part of the Breathitt. The Church slide is on the west flank of a local transverse flexure that is cut by a small fault. Although the strata dip less than 10 degrees toward the Cumberland River, they are unstable even at that low angle. During road construction in 1968, a 50-ft thick plate of sandstone and siltstone about 800 ft wide by 500 ft long failed and slid

Figure 7. West scarp of the 1967 Tremont slide showing scar on old landslide debris. Bedrock visible in middle background along old landslide scar, dips about 10 degrees to left. View is northwestward (Deen and Havens, 2).

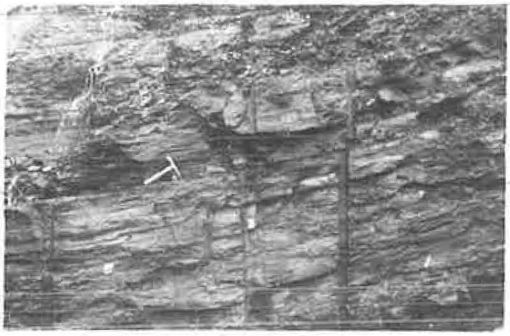

Figure 8. Offset boreholes in shale and siltstone intersected by road cut. Sliding of plates along bedding planes is toward observer in direction of dip of strata with lower plate having moved relatively more than upper.

along a floor of coal and underclay. The unstable bedrock upslope from the slide was removed by the contractors. Nevertheless, several hundred feet of highway reconstructed across the slide slipped into the river in 1969 (Fig. 6).

The slide west of Tremont is an old planar block glide of the type described by Varnes (1). The debris of the ancient slide, as much as 80 ft thick, consists of a jumble of blocks, mostly sandstone, enclosed in a gummy matrix of clay, shale, and siltstone. The old slide is 3,000 ft wide, 2,000 ft long, and drops 400 ft from crown to toe. The crown and flanks are marked by prominent scarps and the main body of the slide is characterized by irregular, hummocky topography. Large slumped and rotated sandstone blocks, most with up-slope dip, mark the toe and flanks. Cross section B-B′ (Fig. 5) shows that the Tremont slide is within, but near the base of, the lower part of the Breathitt. The river here is closer to Pine Mountain and is cutting into beds with steeper dip than at the Church slide. In July 1967, after heavy rains, the central part of the old slide gave way. It slid across the road then being constructed across the toe of the slide and into the river. That slide was 600 ft wide, 1,400 ft long, and had a 200-ft drop from crown to toe, as described by Deen and Havens (2). New scarps clearly show that the recent slide resulted from reactivation of the old (Fig. 7).

The third example, cross section C-C′ (Fig. 5), is west of Coldiron where for 2 miles no lower Breathitt is present north of the river. The lower Breathitt rocks long

Figure 9. Southwestward view of deep roadcut west of Wallins Creek quadrangle where sandstone, shale, and siltstone in lower part of Breathitt Group slid down a dip slope into the excavation.

Figure 10. Joint face, above front end of truck, at edge of landslide scarp. Joints exert control over slides by dividing dipping bedrock into segments.

ago slid into the river, leaving resistant beds of sandstone at the surface. Areas such as this are characterized by relatively straight courses of the river, which contrast with the meander pattern in the nearly flat-lying Breathitt. Dip slopes on sandstone are smooth, moderately steep (15 to 25 degrees), and are bounded by remnants of unstable lower Breathitt rocks flanked by prominent landslide scars.

Where the lower part of the Breathitt remains north of the river, much of it is slowly moving down dip, even in areas not mapped as landslides. Drill holes made just prior to recent road cut excavation are offset (Fig. 8), indicating movement along slippage or glide planes that are parallel or subparallel to bedding planes. Thick beds of sandstone have slid down dip slopes on coal beds or shale (Fig. 9) into recent road cuts. Slides are aided by joints (Fig. 10) that have broken the bedrock into discrete units, which may move coherently.

The foregoing has described the general geologic framework of the landslides along the south slope of Pine Mountain. Variations in the dip of the strata, presence of joints, small folds and faults, and the action of groundwater, all of which may play critical roles in localizing landslides, are beyond the scope of this report. In summary, landslides have taken place where the Cumberland River is cutting beds of shale, siltstone, coal, clay, and sandstone in the lower part of the Breathitt Group that are dipping toward the river, and old landslides have been reactivated where disturbed by construction work. If local geologic conditions are known in advance, potentially unstable areas may be predicted, slide-prone localities bypassed, and construction planned to avoid disturbing natural equilibrium.

REFERENCES

1. Varnes, D. J. Landslides and Engineering Practice. HRB Spec. Rept. 29, 1958, pp. 20-47.
2. Deen, R. C., and Havens, J. H. Landslides in Kentucky. Kentucky Department of Highways Research Report, 1968.