STATE OF ARKANSAS

Arkansas Geological Commission

Norman F. Williams, State Geologist

INFORMATION CIRCULAR 31

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Little Rock, Arkansas
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ABSTRACT

Recent study has provided a first-order approximation of the landslide features, processes, and potential of Crowley's Ridge in Arkansas. Landslides are a relatively common phenomena on the Ridge, occurring every year to a greater or lesser degree. In dry cycles the events are typically few, small, and little noticed. In wet cycles the landslides are more common and somewhat of a public nuisance. Currently, most landslides are related to man's activities. The majority occur along roads, in old quarries, and in areas recently logged; stream cuts, valley walls, and loess "canyons" account for most of the rest.

The seismic events of 1811-1812, as well as those of 1843 and 1895, may have caused significant landslides on the Ridge. However, due to the erodibility of the soils as well as the cultural domination of the current topography, few if any relicts of these possible past displacements survive in a clearly recognizable form. Degradation and revegetation of new landslides are rapid, removing most primary indications of the features within a few months to a few years. Traditional recognition criteria of old landslide scars such as hummocky ground, stepped slopes, sag ponds, concave scarps, tilted trees, etc. are equivocal. Other less naturally catastrophic processes can be called upon to explain similar features.

Four broad landslide types or combinations thereof are indicated by the features of the currently observable landslide set. They are falls, flows, slides, and creep. The falls tend to be small in volume and are most common along the near-vertical walls of roadcuts and old quarries but are seen associated with the cut banks of streams and the walls of loess "canyons" and amphitheaters. Flows are a frequent component of many of the other landslide types and dominate the displacement process at a few sites. The slide category exhibits rotational and translational slump, block glide, and carpet slide forms. Creep is a likely component of most steep slopes but is specifically identified as the transportive process only for certain localized strata. Some landslide sites on the Ridge reactivate from time to time by episodic displacement of the same slide blocks over a period of years or by development of new landslides in the same general area. All currently observable landslides are on slopes steeper than 20°.

Large earthquakes occurring in the New Madrid Seismic Zone will likely cause numerous small-scale landslides along the Ridge. The potential for larger earth displacements seems to increase to the south where the loesses are thickest. It is suggested that most of these seismically induced landslides will be minor, causing, for the most part, only temporary inconvenience to civil authorities and the general population. However, some county roads are likely to be closed by failed soils under special conditions of soil saturation and seismic load.

INTRODUCTION

Landslides in all their various forms, sizes, and causes are the most ubiquitous geologic hazard modern man faces. In the United States landslide damage costs about a billion dollars and twenty-five lives each year (Nilsen and Turner, 1975; USGS, 1982; Brabb, 1984; NRC Task Group, 1984). Reduction of these losses can only be accomplished by becoming more systematically familiar with this hazard in the local regions. If we can observe the patterns of occurrence, develop a deeper understanding of the processes involved, learn to recognize the factors that promote landslide development, design new facilities that circumvent the dynamics of the features, avoid susceptible sites, and enact policies that promote warning and mitigation, we can significantly reduce their impact on the citizens of our land.

Earthquakes are a frequent cause of landslides. With a high probability of a magnitude 6 or greater event occurring on the New Madrid Seismic Zone (NMSZ) in the near future (Johnston and Nava, 1984), a very real threat of seismically induced landslides exists in Arkansas (Keaton, 1987). Whereever the potential for landslides is present under aseismic conditions, the prospect of catastrophic failure is enhanced by seismic shaking. Also, slopes that are stable under normal conditions may fail with seismic loads. When the next major New Madrid earthquake occurs landslides are likely to take place on many of the sloped areas of Arkansas, not only on Crowley's Ridge but in the western highlands as well (USGS, 1982). Even a moderate seismic shock would likely cause displacements (Keefer, 1984) along the steeper slopes of Crowley's Ridge and along the river and stream banks of eastern Arkansas.

By starting investigations into the type, distribution, earth material components, age, and physical parameters of the current set of observable landslides on Crowley's Ridge, this initial study has attempted to develop insights into the potential for landsliding due to seismic activity on the NMSZ as well as information concerning modern slope vulnerability and its causes. This project had several initial goals: 1) to see if any evidence existed of landslide features that may have been caused by the New Madrid earthquakes of 1811-12 or any other major seismic events in the region (paleoseismicity indicators); 2) to establish a better understanding of the current landslide activity on the Ridge; 3) to learn more about the landslide processes; and, 4) to establish an electronic database of landslide features to allow ease of monitoring their activity, building long-term observations, and tracking feature degradation. Although this initial investigation did not reveal any ancient landslides a clearer understanding of the catastrophically displacive geomorphic processes at work on Crowley's Ridge has been gained.

CROWLEY'S RIDGE

Crowley's Ridge in Arkansas is a 145 mile long (235 km), 1/2 to 11 mile wide (1 to 18 km) gently arcuate, disharmonious highland extending from the northeast corner of Arkansas north of Piggott to the town of Helena along the Mississippi River in east-central Arkansas (Figure 1). It commonly stands one hundred to two hundred and fifty feet above the surrounding topographically unremarkable lowlands and is the only significant relief in eastern Arkansas. The Ridge is traditionally considered an erosional remnant formed during the Pleistocene when the ancestral Mississippi and Ohio rivers eroded the Mississippi Alluvial Plain (Embayment) sediments to either side (Call, 1891; West, Rutledge, and Barber, 1980; Guccione, Prior, and Rutledge, 1990). However, recent studies by VanArsdale (1991) suggest that the Ridge may have a tectonic origin in part.

The Ridge is composed primarily of weakly consolidated to unconsolidated clay, silt, sand, and lignite of Eocene age overlain by sand and gravel of Pliocene age and capped by Pleistocene loess (Saucier, 1974; Haley, 1976; Guccione, Prior, and Rutledge, 1990). However, outcrops of well lithified Eocene sand can be found in a few small areas along the west side of the northern portion of the Ridge. The margins and slopes of the ridge are commonly draped with colluvium made up of silt, sandy silt, and gravelly silt to various thicknesses.

Crowley's Ridge falls into three natural divisions in Arkansas based on its topographic expression and to a lesser degree it stratigraphic representation. The northern portion runs from the Missouri border south to Ridge, AR, just south of Jonesboro. This portion of Crowley's Ridge is generally twice as wide as the southern two segments. It is asymmetrical in cross-section with the crest

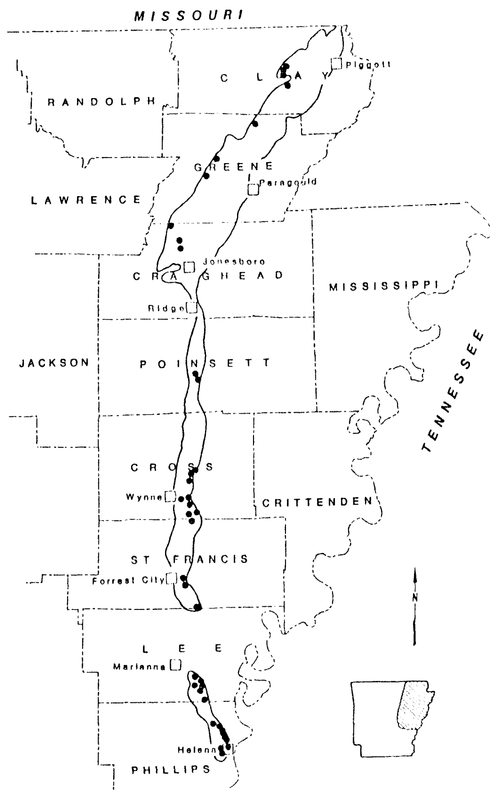


Figure 1. Crowley's Ridge, Arkansas. The open squares represent towns. The filled circles show the locations of landslides studied during the course of this investigation.

of the Ridge being located in the western third. The loess cap that is so widespread all along the Ridge is quite thin across this northern segment and often missing from the hilltops.

The middle segment of the Ridge is only half as wide as the northern segment. It too is asymmetrical in cross-section but skewed to the east rather than the west. This middle section of Crowley's Ridge extends from Ridge, AR (south of Jonesboro, AR) to the vicinity of the south boundary of the St. Francis County line. The lithologies are no different from the other portions of the Ridge except that the loess cap thickens significantly to the south. Along the north end of this middle segment the loess cap is patchy and thin; toward the south end of the segment the loess is several tens of feet thick. Where the loess is thickest, deep (10 to 40 foot), sheer-walled loess "canyons" are not an uncommon feature.

The southern most segment of the Ridge seems to be an erosionally isolated extension of the middle portion (Saucier, 1974). It runs from Marianna, AR to Helena. More of this segment is in steep slope than the other segments. This appears to be the result of the thick loess cap, often 50 feet or more, and the formation of a dense dendritic network of deeply incised, irregular gullies. The Eocene sediments are not seen in this southern segment.

All the modern landslides investigated in this study were associated with slopes steeper than 20 degrees. Local areas where the slopes are this steep or greater are found on both sides of the ridge crown in all segments of the ridge but are more common to the west of the ridge crown of the northern segment and to the east side of the southern two segments.

Many of the topographic details of Crowley's Ridge have been generally altered by man's activity. Currently, the Ridge is dominated by private land with only a few state parks and the St Francis National Forest (which occupies most of the southern segment) residing in public ownership. Most of the land is fenced and much of it is cleared, especially the Ridge top and the gentler slopes. All original stands of timber have been harvested and certainly none remain that stood in the early nineteenth century.

The softness of the soils encourages topographic modification upon clearing or logging, thereby destroying the details of any evidence of past catastrophic geomorphic alteration. Bulldozers are used to smooth land cleared for pasture or crop. Loggers force new trails and unwittingly change local drainage patterns via the gouges made by their log skids. Disruption or destruction of the vegetation mat allows unchecked erosion of the colluvium, many loesses, and some of the sands and gravels. Even the natural erosional processes work to the disadvantage of the preservation of landslide features. The plant cover seems to be the major retardant to erosional destruction. Where it has been disturbed soils losses are rapid and land forms ephemeral.

PROCEDURES

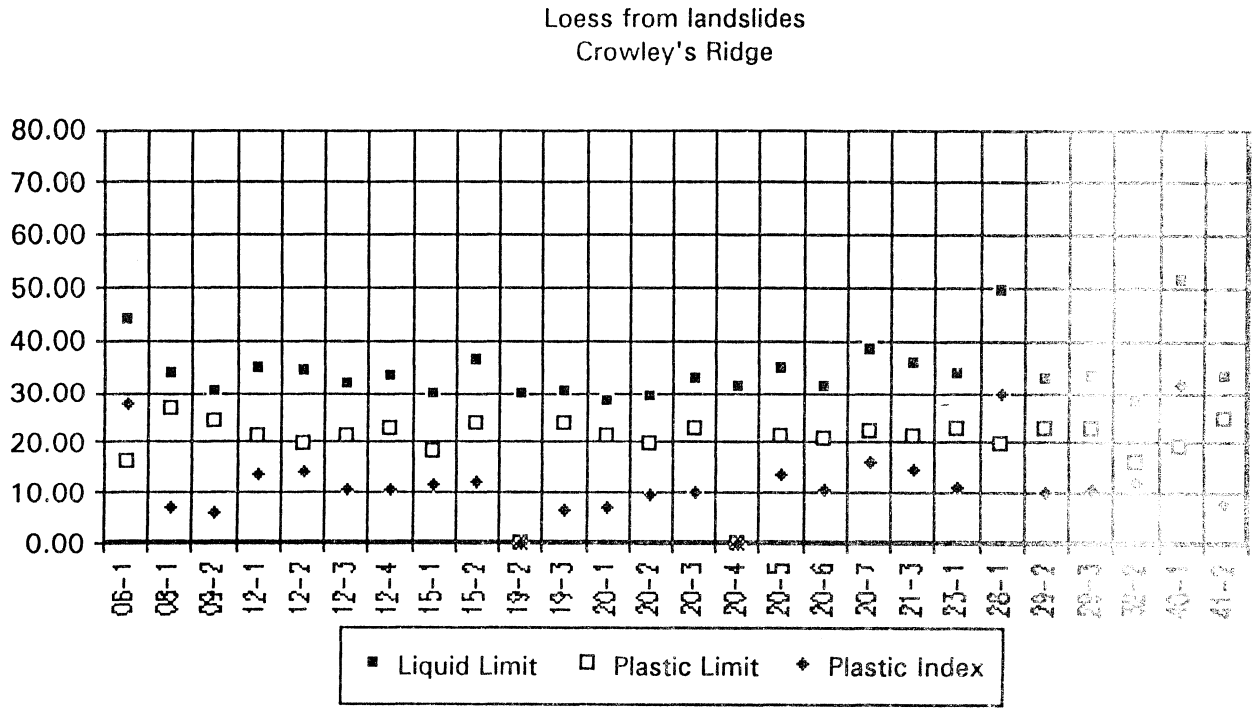
Low altitude aerial photographs (1:20,000-scale, winter stereo coverage, taken in 1985-90) from the Arkansas Highway and Transportation Department were used in the initial survey of the Ridge. First the photos were examined for classic landslide indications: arcuate scarps, truncated slopes, disrupted or hummocky topography, and ponded drainage. Later the photos were reexamined for any anomalous features. All discerned anomalies were noted and compiled on 1:24,000-scale topographic base maps for field checking.

As observed by Jibson and Keefer (1984) it was found that features smaller than about 200 feet in minimum dimensions, especially in forested areas, could not be successfully mapped by this technique. Somewhat smaller features could be resolved on cleared acreage. Only one unequivocal landslide was found via the aerial photography. Subsequent field surveys showed that most modern landslides are too small and too ephemeral to be explicitly captured by routine air photo reconnaissance.

With the failure of photo reconnaissance to provide guidance a program of "Ridge running" was undertaken. Initially all roads were selected, however as experience was gained, limits were placed on the territory covered. Most of the roads of the southern segment were driven, but only the roads on the eastern one third of the middle segment and western one third of the northern segment were traveled, along with a fair sampling of other routes beyond the marginal limits. These other routes were selected to investigate areas of steep slopes and photo-identified anomalies. Most of these roads were driven in the winter and early Spring prior to the Spring "leaf-out". This allowed visual observation of the landscape to either side of the road usually limited only by the topography. All significant landslide features (i.e. more than a few clods of dirt) were indicated on field sheets for later detailing. Some selected areas were retraced after "leaf-out" because the heavy rains during April, 1991 induced so many new landslides. The located features were all later revisited, most briefly described, and some sampled. Selected features were revisited several times during the course of this study to observe the rate and style of feature degradation.

A few small valleys and streams were randomly selected for foot reconnaissance. These were chosen to compare streamside, gully, and valley-wall features and processes "back in the woods" with features visible from the roads. Several of the larger lakes on the Ridge were sampled from multiple points of view. Binocular examination of the shorelines of these lakes and interviews with local fishermen provided data on lakeshore caving. Railroad right-of-ways were not investigated because of the manner in which service equipment cleared ditches adjacent to the tracks by piling excavated debris atop the right-of-way cuts thereby modifying beyond recognition any potential landslide features.

Among the laboratory tests the Arkansas Highway and Transportation Department normally uses to determine the stability of a roadbase are the Atterberg limits (Dave Lumbert, personal communication). Recognizing that the amount of water in a fine-grained soil has dramatic effects on its properties, we performed Atterberg limit tests on selected samples of loesses from various failed and unfailed sites. In order to assure that our test results would produce the same types and kind of numbers that the highway department would get themselves, we used their laboratory, tools, methods (AHTD Test Method 353 & 354), and report forms. Liquid limit, plastic limit, and plastic index were determined for samples of displaced material from 15 sites and samples of undisturbed material from 23 sites. Ignoring those samples that were indeterminate for the values tested, we found no significant differences between the failed and unfailed silts (figure 2). Samples of the collapsed material did appear to have a more limited range of test values than the unfailed materials, however.



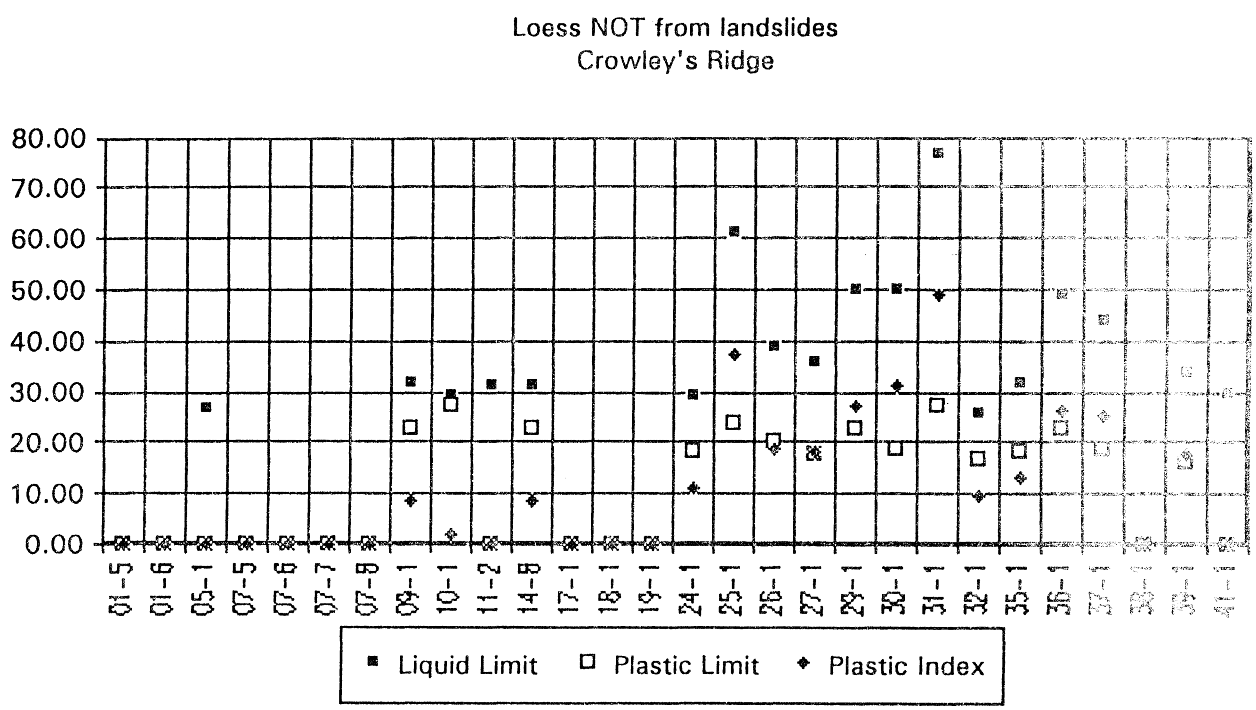


Figure 2. Atterberg limits for loess samples collected from Crowley's Ridge. The first numbers of the labels across the base of the graph are the site numbers. A) Samples of failed material. B) Samples from unfailed sites. Some samples of unfailed material were collected adjacent to landslides.

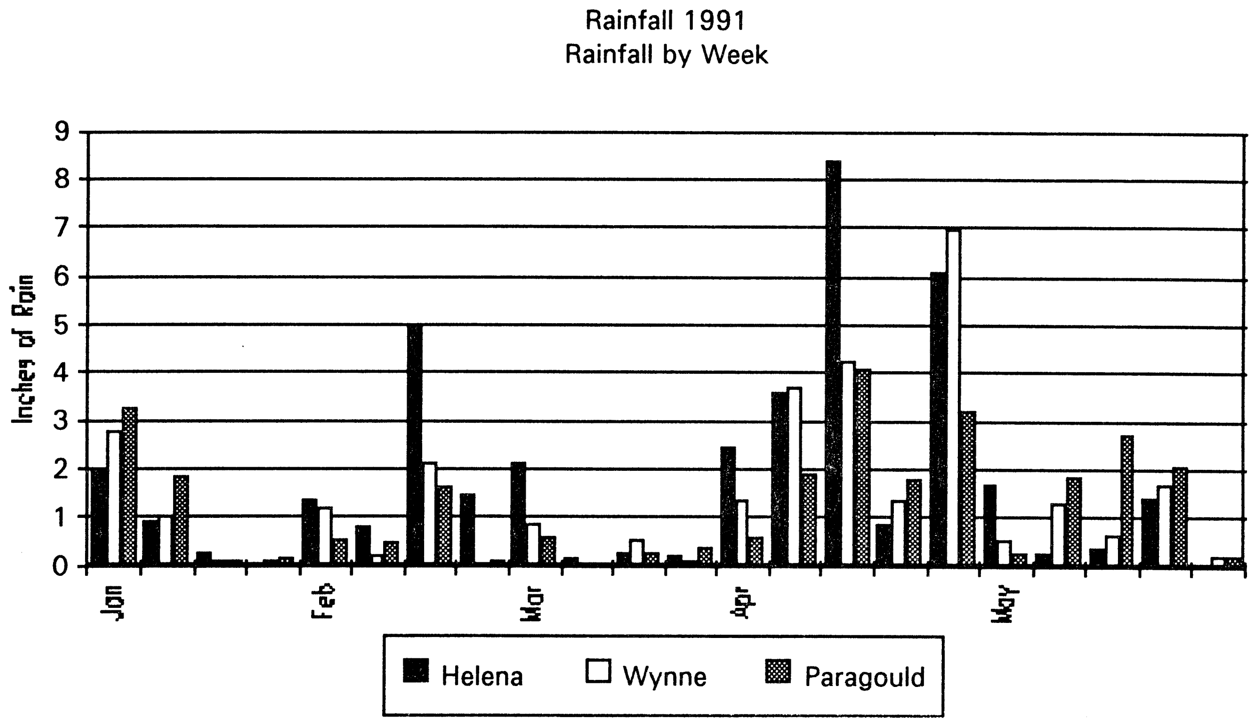


Figure 3. Weekly precipitation for Helena, Wynne, and Paragould for the first five months of 1991 (NOAA, 1991). Most of the landslides that developed this year occured during or shortly after the period of increased rainfall in April.

LANDSLIDES

Aseismic, non man-induced landslides are the result of several interrelated factors. Degree of slope, nature of the soils, vegetation cover, but most especially excessive water play a role in their development (Nilsen and Turner, 1975; Killey and others, 1985; Keefer et al, 1987, Baskerville, 1991). Almost all of the displacements we observed occurred on slopes steeper than 20 degrees. Most of the landslides occurred in fine-grained materials, usually loess, although some sand and gravel were the major displaced components in a few cases. Landslides on undisturbed wooded hillsides were rare; most displacements were found associated with slopes that recently had been naturally or culturally modified. Few fresh landslides were observed on Crowley's Ridge until the rainy period that began in early April (figure 3) suggesting that water is the proximal causative agent of landslides under normal conditions.

Large ancient landslides were not identified by this initial investigation. This is not to say that they don't exist (Fuller, 1912; Jibson and Keefer, 1984)), but rather the criteria for their recognition is uncertain on Crowley's Ridge. Quite a few sites displayed features that might be interpreted as being the result of eroded landslides. However, other geomorphic processes, both natural and cultural, may be called on to explain these same features. I prefer to await a more complete understanding of the broad range of geomorphic activities on Crowley's Ridge before attempting to assign these atypical sites to landslides causes.

Judging from what we observed during this study, the most common landslide type to occur is the carpet slide, a shallow displacement usually involving only a few inches to a few feet of the hillside soils (Table 1). Most carpet slides occurred on the walls of gullies where thin vegetation mats of

TABLE 1
1991 Landslide Site Locations on Crowley's Ridge

Site #	County	Quad	UTM Location	Type
1	Phillips	Helena	720830e/3827370n	slide
2	Phillips	Helena	720795e/3827670n	flow
3	Phillips	Helena	720220e/3829290n	flow
4	Phillips	Helena	720060e/3829745n	slide
5*	Phillips	Helena	719640e/3824065n	fall/flow
6	Phillips	Helena	720040e/3823230n	fall/flow
7*	Phillips	Helena	720470e/3828630n	flow/slide
8	Lee	LaGrange	712120e/3841780n	fall
9*	Lee	LaGrange	712910e/3843650n	slide
10*	Lee	LaGrange	712450e/3844820n	slide/flow
11a	Lee	LaGrange	712340e/3845180n	slide
11b	Lee	LaGrange	711970e/3846060n	slide
11c	Lee	LaGrange	711910e/3846070n	slide
11d*	Lee	LaGrange	711000e/3846860n	fall
12	Lee	Dansby	709940e/3864270n	fall
13	Cross	Wittsburg	708120e/3902100n	flow?
14	Green	Walcott	711040e/3989770n	slide
15*	Cross	Wittsburg	706080e/3900670n	flow
16	Cross	Wittsburg	708760e/3900380n	slide
18	Phillips	LaGrange	716715e/3834880n	slide
19*	Lee	LaGrange	714735e/3835910n	slide/flow/fall
20*	Cross	Wittsburg	710530e/3896300n	fall
21	Cross	Princedale	708490e/3907170n	slide/flow
22*	Cross	Princedale	708540e/3910860n	slide/flow
23	Poinsett	Harrisburg	712040e/3933300n	slide
28	Craighead	Lorado	705240e/3977600n	slide
29*	Craighead	Lorado	704860e/3978930n	flow/slide
32	Green	Delaplaine	713100e/4003650n	slide
38	Green	Lafe	724480e/4013560n	slide
40	Clay	Boydsville	734740e/4024290n	slide
41	Clay	Boydsville	734110e/4027600n	slide
42	Clay	McDougal	734165e/4028520n	slide
43	Clay	McDougal	734800e/4029070n	slide
45	Craighead	Bono	701690e/3980920n	flow
46a	Cross	Wittsburg	707900e/3892150n	slide
46b	Cross	Wittsburg	707880e/3893040n	slide/flow
46c	Cross	Wittsburg	707980e/3893340n	slide/flow?
46d	Cross	Wittsburg	708090e/3893870n	slide/fall
47	Cross	Princedale	708680e/3812450n	slide
48	Phillips	Helena	721220e/3824950n	flow
49*	St Francis	Madison	706530e/3875370n	flow/slide/fall
50*	St Francis	Dansby	706400e/3875000n	slide/flow
51*	Greene	Walcott	712030e/3999670n	creep
52Lsc	Phillips	Helena	719000e/3830500n	flow/slide/fall
52Lbc	Lee	LaGrange	711000e/3843000n	flow/slide/fall
52La	Cross	Wittsburg	707500e/3892200n	flow/slide/fall
52Ld	Cross	Wittsburg	709000e/3894000n	flow/slide/fall
52Lp	Poinsett	Harrisburg	711000e/3934000n	flow/slide/fall
52Lf	Greene	Lorado	706000e/3984000n	flow/slide/fall

Table 1. These selected sites are the locations of most of the more significant of the many landslide features identified by this study. Many small roadside, stream cut, and gully-wall landslides were noted but due to their omnipresentence and insignificant nature they were not given a site number. Other sites that were used to obtain stratigraphic enlightenment, grab soil samples, or some other non-landslide background observation were given site numbers in the course of this investigation but are not listed here. The sequence of numbers tends to skip around geographically due to the time of the slide, time of discovery, order of investigation, and/or caprice. The UTM locations presented here are from the 1000-meter Universal Transverse Mercator grid, zone 15, 1927 North American Datum. (The changes in UTM locations brought about by the 1983 North American Datum grid will alter the locations listed here by less than 10 meters.) For an extended site (indicated by *) the location given is usually some central point and may include more than one landslide feature. An "L" followed by initials after a site number indicates a lake.

mosses, ferns, and other small plants would slide into the floor of the gully to be washed away with the next rain. Individually these slides typically carried small volumes, but in aggregate a great deal of soil was displaced. Some carpet slides did occur on wooded hillsides, but in almost every case some recent modification of the local geoenvironment could be demonstrated.

Generally following organizational guidelines proposed by Simonett (1968), Varnes (1978), Keefer (1984), and Killey et al (1985), the landslides observed on Crowley's Ridge were broadly classified principally on their character of movement and degree of internal disruption. These categories are: fall, flow, slide, and creep. Although these are clear divisions, in the real world one type often evolves into another as the landslide progresses. The materials involved in most of the displacements are similar, usually a silt soil, sometimes with sand or gravel. The term "soil" is used in this report to mean any aggregate of particles that is relatively loose and unconsolidated (or nearly so); organic content is not considered. The phrase "vegetation mat" is used to mean the upper several inches of soil bound by plant roots, the dense root network itself, and the associated aerial floral infrastructure. "Root mat" is used to describe just the root-bound portion of the vegetation mat.

FALLS. A fall is when a block of coherent sediments falls freely from a steep or undercut bank. This type of landslide was most commonly seen in active and inactive quarries, vertical roadcuts, and along the cut banks of streams. Its most common expression was as a fall of loess.

The larger of these loess falls involved "sheets" or "strips" of silt that collapsed from a cliff onto the talus slope below (normally the talus is previously fallen loess). Most of the fallen material disaggregates and becomes indiscernible from the previously fallen silt, but some holds together in blocks that may persist for a short while. Weathering soon diminishes these blocks. Where the collapse falls into a road ditch or stream, the loess is swiftly washed away. Where the loess falls onto preexisting talus the silt may cover some colonizing plants, thereby leaving a buried horizon marker.

Most of the dirt roads on Crowley's Ridge are not dressed with gravel: the roadbed is whatever the underlying material is. The repair of these roads is usually accomplished by just scraping the roadbed smooth. (In some cases, however, if the roadbed becomes very soft and if it is a well used road, a load of gravel may be applied.) Where the roadbed is fine soils, these roads may become incised over the years anywhere from a few inches to over 20 feet. If deeply entrenched, they become mini-canyons with sheer walls. Soil falls are a common feature of these vertical cuts, but usually involve only a small amount of silt. The greatest hazard from this roadcut silt-fall process seems to be a temporary fill of the road edge. The roads are normally crowned in the center to force water runoff down the road edges. With this blockage the runoff is directed out into the road and into the traffic stream. Not infrequently the runoff entrenches the road bed, sometimes to impassable depths.

FLOWS. Flow is the downslope displacement of incoherent soils in the manner of a viscous fluid. Flows are a common minor component of slides and falls, but in a few cases seem to be the dominate displacive process. Flows tend to extend well beyond the boundaries of the site of failure.

Many of the flows observed were extensions of slides or falls. Frequently the internal disruption of the toe of a slide would increase to a state of near complete disaggregation into individual soil grains resulting in continued downslope movement as flow. Once flow is established continued and reactivated transport was observed to usually continue by the same manner. In some cases the viscosity of the flow was sufficiently great to form bulging lobes toeward. These lobes sometimes oversteepened and developed secondary slumps and flows. Dry falls of loess usually disaggregated upon collapse and became nearly pure dry flows.

In a few cases the failure of the slope material seemed to be dominated by flow failure. In these cases the conversion from stable slope to flow seemed to be quite sudden. Intermediate landslide types may have been involved in these processes but were short-lived and not preserved. The runout of these flows indicated that the muds were generally quite fluid and in at least one case capable of erosive action (Site 3). In each of these cases the flowing muds extended well beyond the failure site. An abundant water supply seems to be one of the most important factors leading to flowage.

Some flow-type soil failures were observed whose resultant expressions suggests other geomorphic processes. Features that mimic streamcut benches and abandoned channels were observed to be formed by the failure of the soils below the root mat and above some lower, stable horizon. In each observed case the soils in the failed interval had apparently flowed out into a creek or ditch to be washed away. As the soils were lost the vegetation mat sank more or less uniformly downward, thus protecting the disturbed surface from outside erosion. This tended to obscure the timing of the event. There was no observed displacement of the underlying materials and usually little disruption of the vegetation mat. Even small trees settled in so well that they showed little indication that they had been disturbed and they continued to grow in a normal manner. Marginal scarps were clearly delineated, arcuate, and provided the only suggestion of a fresh surface. The revegetation of the scarp quickly masks this distinguishing landslide detail. Proper identification of these founder features is apparently dependant on observation at a critical time period during or shortly after their formation. Water seems to be the main agent causing this type of failure. In all cases observed to date the failed material has been a loess or very silt-rich deposit with little clay. The underlying strata seem to act as an aquatard.

This process as observed on the floor of a valley (Site 50) caused, in one case, a roughly semicircular area (10'x10') adjacent to a small creek to subside. The displacement was only about 2 feet, lowering the vegetation mat down to near the water level. The forest litter and root mat at the margins of the failure area was stretched and pulled apart clearly indicating the nature of the process. Undercutting by the stream was clearly not the causative process. If it were the streamside edge of the vegetation mat would have collapsed first blocking the erosive action of the stream from the back of the feature. Other similar but less fresh features are seen in many valley floors in the southern portions of the Ridge. Some, possibly most, of these features are abandoned stream channels, but it is suggested that at least a few are formed by surface foundering via the process herein described.

Along Copperas Creek (Site 15) a streamside bench was created by this foundering process early in the year (Figure 4). A 5-foot silt interval from beneath the vegetation mat failed and flowed over the underlying clayey, gravelly, silts into the creek some 20 feet below. The small trees, bushes, and other plants were lowered down as a single unit with its root mat intact. By summer this 10x25 foot bench looked as if it had been there for at least as long as the trees. The failed silt in the creek bed had long since washed away leaving no local trace. The resulting bench looked quite similar to other "stream-cut" benches near at hand. A slightly larger bench is developed a few yards upstream and at the same horizon. Is this other bench stream cut or a flow-failure/surface-foundering result?

At another site on the eastern margin of Crowley's Ridge (Site 13), a narrow bench was noted about 90 feet above the current stream level and a few feet below the slope crest. The face of the slope is near vertical and did not display any conventional landslide features or relics; however the site has been observed to display blocks of failed sediments in the past. The slope face has little vegetation colonizing it, is gullied in the lower part, and as a cut bank of the stream it would appear that the scarp is in active retreat. The bench is level, developed on the first clayey sands below the loess cap, and sports a few small pine trees. There is no indication of strata displacement below the bench. The rear wall of the bench is vertical. It seems unlikely that a stream-cut bench at that level would survive in such sharp detail

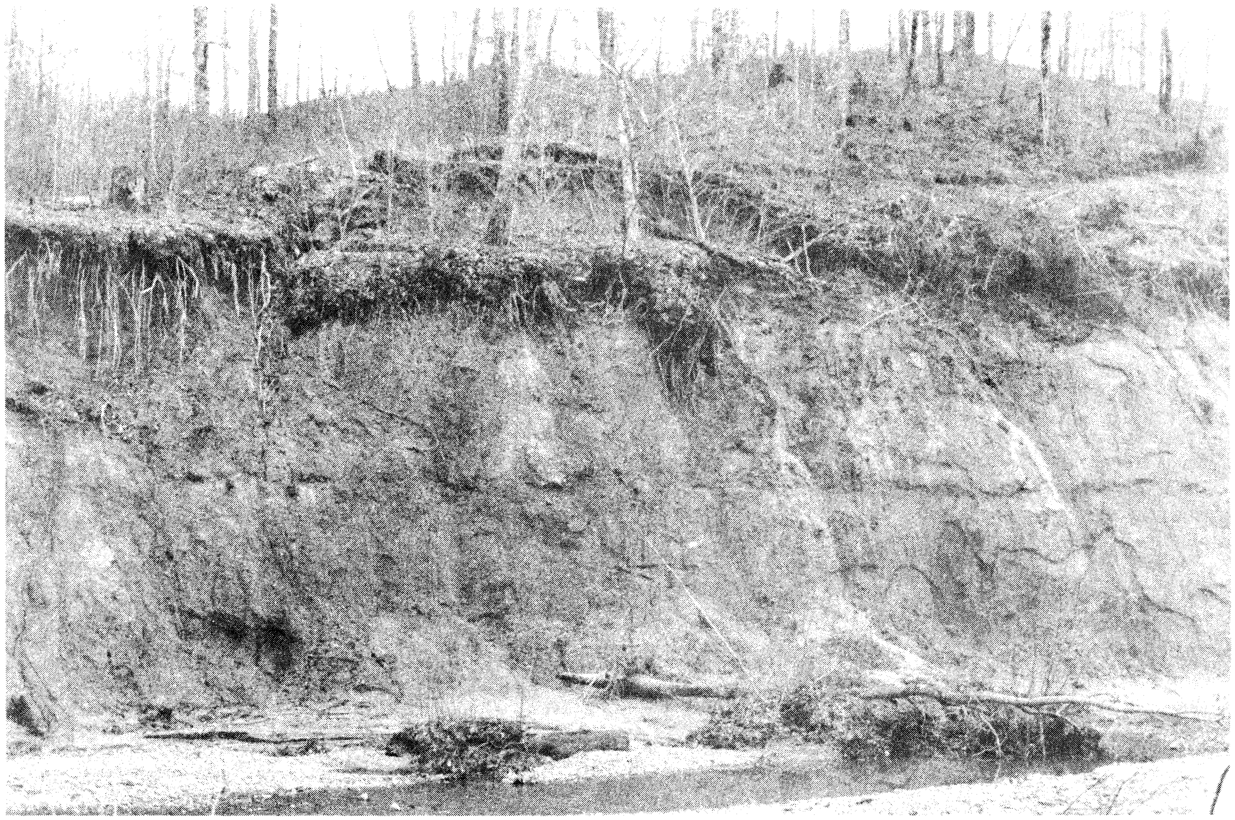


Figure 4. One of the Site 15 flow landslides. The vegetation mat atop the displacement site settled up to five feet as the underlying silts flowed over the underlying bank and into the creek below. Note that there is no displacement of the underlying sediments. Traces of the failed material can still be seen at the surface and base of the stream bank.

in the time it took to erode the valley to its present configuration.

Small loess amphitheaters (Sites 2 & 19) were observed that appear to be the result of this foundering process. Their appearance connotes flowage of mud from a narrow outlet of a larger, foundered area upslope. As with the streamside developments, the vegetation mat subsided more or less uniformly downward with little signs of disruption. Initial drainage tended to be ponded and a few marginal trees later collapsed into the resultant depression. Large loess amphitheaters are frequently found along the southern segments of the Ridge. These observations may indicate the initial processes leading to their development are related to this foundering. Long-term observation should provide some understanding of the development of this geomorphic feature.

SLIDES. A slide is the downslope displacement of coherent masses along one or more well-developed failure planes. The slide category involves several forms of expression on Crowley's Ridge: slump, either rotational (where the units are few and commonly display backward rotation) or translational (where there are several coherent units displaced in step-like fashion); carpet slide, where the displaced material is restricted to the upper layers of soil; and, block glide, where the mass is dislocated along a very shallow plane with little internal disruption of the main block. Commonly the toes of slides became internally disrupted to the point of flowage. The most common types of landslides observed on Crowley's

Figure 5. A typical and commonly seen road side rotational slump landslide. Most of the failed debris has been removed by local road crews.

Ridge were carpet slide and rotational slump forms.

Most roadside failures observed were rotational slumps (figure 5). These usually involved just the banks of the road cut. The most general outline of these slumps was a near equidimensional one although long, relatively low displacements occurred in several places. The near equidimensional slumps came in various sizes but all tended to be slightly higher than the feature was wide at the base. Usually the main scarp was highly arched and generally formed a continuous surface. The long, low, roadside rotation blocks extended laterally several times their height. All these roadcut rotational slumps were generally shallow and usually observed to displace only the material between the road bed and the lip of the roadcut, a distance of 5 to 25 feet. Shortly after failure the local road crews would remove that part of the slump that intruded onto the road leaving a small fresh scarp at the top of the bank as the only indication of displacement. Displacements were usually only a few inches to a few feet and were observed to become reactivated after significant rainfall. Trees up to 18 inches in diameter were seen displaced by a few of these slumps suggesting long-term stability. In general the tilt of tree trunks was not an obvious indication of recent movement. Trees often grow at odd angles or shift their orientation along these steep banks and slopes due to incipient wind loads, light direction (breaks in the forest canopy), disease, human activity, and loss of supportive soils around their root systems during the life of the tree.

The carpet slide form of landslide was the most common hillside, valley wall, and gully wall expression although rotational slumps were noted in some places. The failures called carpet slides are shallow-based slumps that quickly degenerate basally or toeward to incoherent flows carrying the vegetation mat. This slide type is similar to Keefer's "disrupted soil slides" (1984) but seem to differ in the material displaced and the coherence of the vegetation mat. On Crowley's Ridge the vegetation mat of a carpet slide is sometimes kept nearly entire, just wrinkled a bit. At other times it is broken into rafts of various sizes.

Block glide displacements (Simonett, 1968) seem to be a rare form of landslide on Crowley's Ridge. Only one example of this form was observed and there is little doubt that it is the result of artificial conditions. The initial displacement of the Lake Austell landslide (site 46a, figure 6) occurred in the spring of 1980 and was first ascribed to a shallow seismic event (Lowman, 1980; Zollweg, 1980) but later investigations dismissed this suggestion in favor of the failure of a confined strata due to increase pore pressure (McFarland and Stone, 1982; Dow and Schweig, 1990). This feature is developed on a northeast facing slope that forms the south abutment of Lake Austell Dam. Lake Austell is an 1100 acre-foot lake in Village Creek State Park near the southern boundary of Cross County. It was constructed in the late seventies and first filled in 1979. The slide developed in two phases: one in 1980 and the other at least a year and a half but not more than 48 months later. (Note: Dow and Schweig [1990] indicated a failure of the second block within a few days of the first block. This is in error.) In the first phase a large coherent block slid on a near horizontal plane out into the valley floor pushing up a series of pressure ridges. A graben developed behind this laterally translated block that vertically displaced the crest of the ridge spur some 40 feet in places. The second phase of the feature may have been initiated during this time but displayed no discernable offset for at least the next 20 months. However, by 48 months after the initial failure, another equally large block was observed to have moved in essentially the same fashion, extending the main scarp to within a few 10s of feet from the foot of the dam.

CREEP. The process of creep is a very slow displacement where downslope movement is detected only over a period of years. Practically all of the colluvium blanketing the Ridge's steeper slopes is undoubtedly undergoing some measure of incipient creep (intermixed with occasional, small to large scale, more catastrophic earth movements). Nevertheless, the orthoquartzite boulders at Site 51 and in that vicinity are the only specifically identified examples of creep in this investigation. There the large blocks of sandstone are becoming detached from the outcrop and slowly migrating downslope. The outcrops of sandstone from which these boulders are derived are quite limited due to the lack of persistence of the well lithified sands: these Tertiary sand strata may be hard orthoquartzites on one hill and only loose sand on the next. As there is no other local source of dimension stone in Green County some of the creeping rocks have been "harvested" and the outcrops quarried.

BANK CAVING

Several small lakes and numerous ponds have been built on Crowley's Ridge. To a greater or lesser degree all of these impoundments show some signs of bank caving. Bank caving is the incremental collapse of the shoreline of a water reservoir typically by fall, flow, or slide. All individual incidents of bank caving observed were small scale, but the cumulative effect has produced some problems. Where the forest comes to a lake's edge the trees are being undermined. Each year more trees fall into the water as the lake margin advances landward. Although these trees provide cover for the fish and therefore are not entirely unliked by the people who use these lakes for recreation, they are indicative of a problematic erosional process. Lakeside or pondside cleared regions erode at an alarming rate in numerous spots. All of this places a significant quantity of clay and silt into the lake. There it causes turbidity and a shallow, muddy bottom. This causes loss of lakeside recreational space, water quality, and/or usefulness as a stock pond. Also, some private ponds regularly show severe erosion of their dams necessitating frequent repairs. Riprap, hauled at significant expense, is frequently used with limited

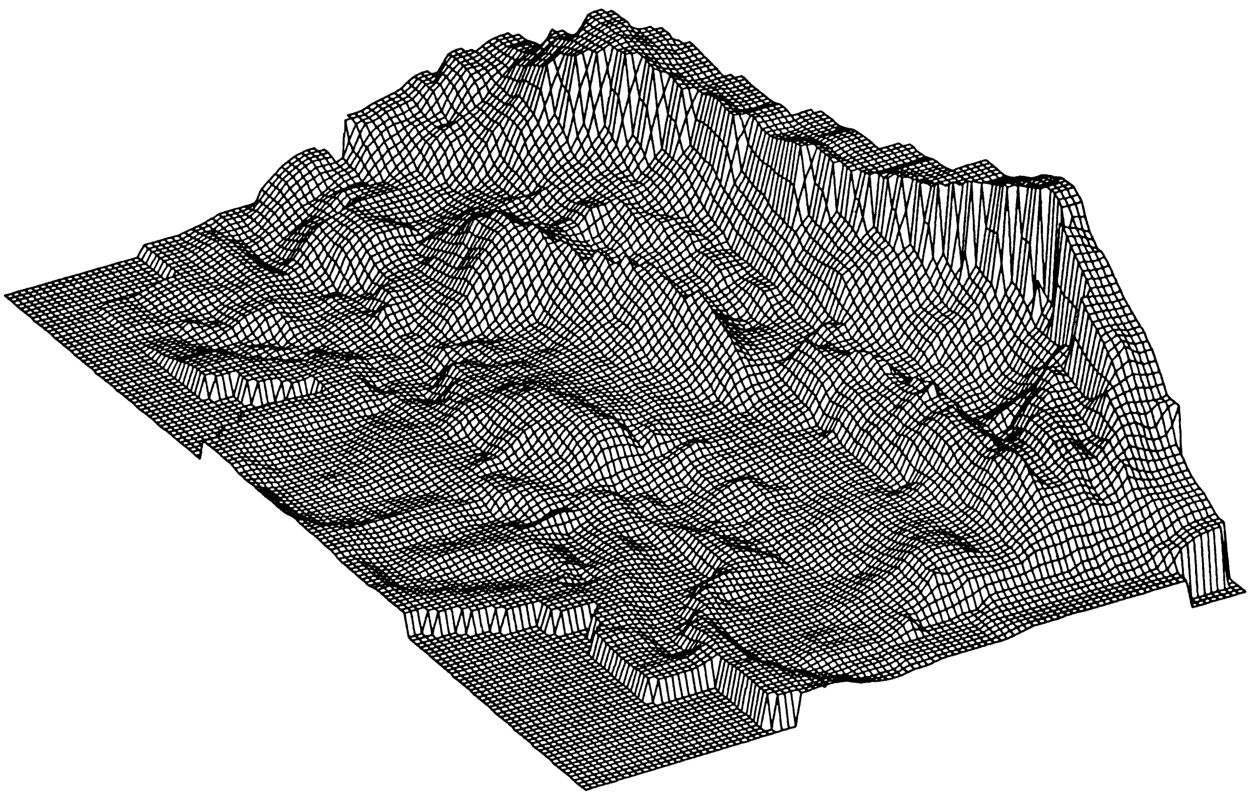
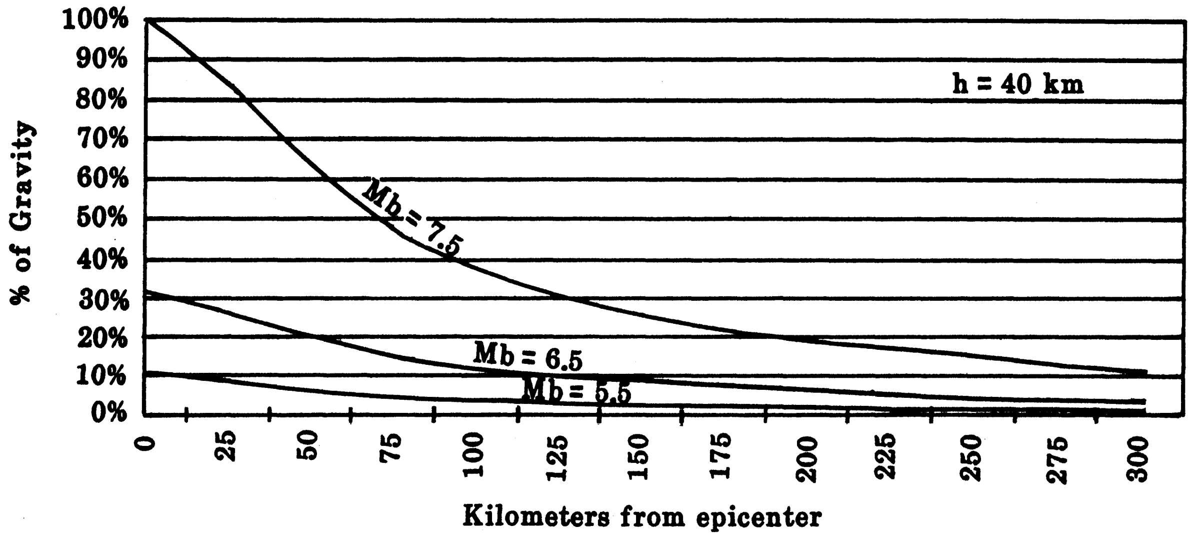


Figure 6. A) Digitized image of the Lake Austell landslide at Village Creek State Park. This 3D surface plot was created by digitizing the detailed contour map of Dow and Schweig (1990) and using the program SURFER from Golden Software. The view is from the north. B) The graben of the Lake Austell landslide. The picture was taken from the top of the crown scarp looking southeast.

Peak Horizontal Ground Acceleration



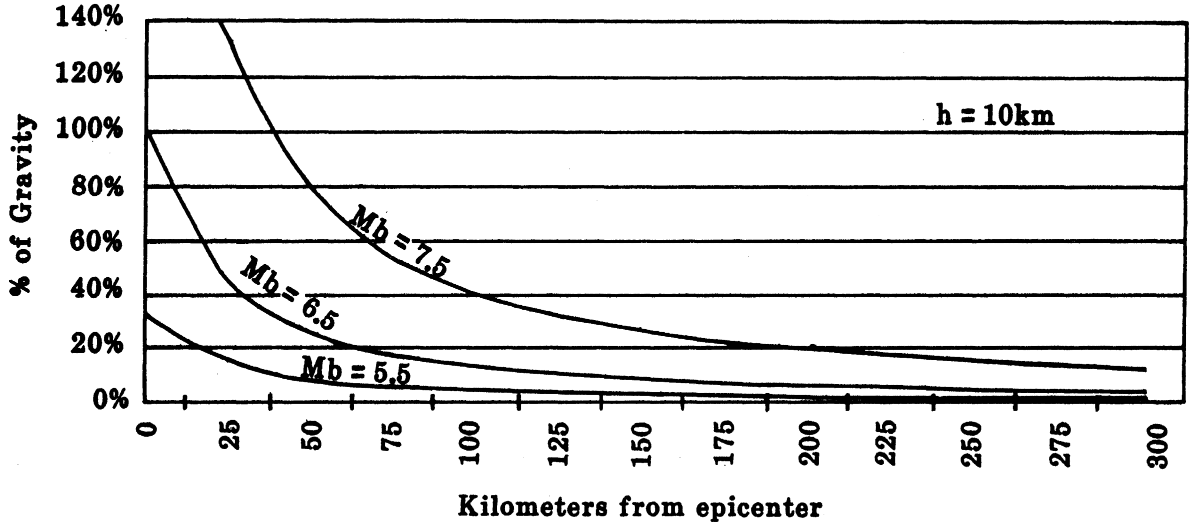


Figure 7. Peak horizontal ground acceleration to be expected at various distances from the epicenter of large New Madrid earthquakes. Graph based on the equation: $\log ah = 0.57 + 0.50*M_b - 0.83*\log((R^2+h^2)\hat{}.5) - 0.00069 * R$ published by Nuttli and Herrmann (1984) where ah=peak horizontal ground acceleration (cm/sec), M_b=body wave magnitude, R=epicentral distance (km), and h=depth (km).

success to attempt bank stabilization on both ponds and lakes.

THE HAZARDS

Prediction systems can be based on empirical and analytical relations between seismic loads and landslides. If we know the soil, geometric, hydrologic, and seismic parameters along with the landslide history of an area we can evaluate the slope's stability (Keefer, 1987) under seismic loads. However, we can never know all these parameters in a complex system. Through observation we can establish empirical relationships that allow us to approximate the relative slope stabilities and make reasonable assumptions.

Keefer (1984) recommends $M_L = 4.0$ as the smallest earthquake capable of causing a landslide. Applying this value to the equation for peak horizontal ground acceleration suggested by Nuttli and Herrmann (1984) indicates that a minimum acceleration of about 5% of gravity is needed for slope failure. Plotting the peak horizontal ground acceleration for a range of large seismic events and depths against distance implies that most large seismic events will produce sufficient forces to induce landsliding along significant portions, if not all, of Crowley's Ridge (Figure 7).

As Bak and Chen (1991) point out "interactive systems naturally evolve toward a critical state in which a minor event can lead to a catastrophe." The steeper slopes of Crowley's Ridge seem to be in a critical state and even failure of a portion of a slope by landslide does not significantly change that state or the potential for other landslides. Thus it seems possible to make valid inferences relating to the effects an earthquake might have at some future time based on the currently observable landslide features. Extrapolating from the present understanding of the landslide potential of Crowley's Ridge, however, is highly speculative. Our observations of this year coupled with discussions with local residents suggest that protracted periods of rainfall will continue to provoke landslides similar in character to those reported herein. Seismic loads would undoubtedly encourage additional slope displacements, especially if the earthquake occurred during the wet season. The lack of demonstrated seismically induced landslide features makes it difficult to suggest just what the results of various levels of seismic shaking may be. However, I think a few generalizations can be made.

Roads. Luckily, most of the state highway system roads run north/south just off the ridge margins with only occasional east/west traverses across the Ridge. Only one highway was observed to have been partially inundated by a landslide during this investigation (Site 16). The banks of the highways that run along the foot of the Ridge on the east side of the middle portion of the Ridge also showed numerous small-scale displacement features. For the most part the road cuts for state highways are wide enough to accept these minor landslides without effecting the roadway and the failure potential of the roadbed by landslides seems low. Although the danger of landslide damage to the state highways seems low the same cannot be said for many county roads. Typically county roads are narrow and commonly have high, close banks. Some of the roads on the east side of the southern segment of the Ridge were blocked this year for a few hours to a few weeks by landslides. Clearly, these roads could be closed by seismically induced landslides isolating various areas and possibly hampering rescue and recovery operations after a significant earthquake.

Communities. Most of the population concentrations are in areas of reduced slope thereby reducing the hazard potential. Vertical cuts for roads and buildings around these communities, however, do present a commonplace hazard, albeit one of very local scale. Normally there is sufficient room between the highwall and the cultural feature to absorb simple collapse or flow. No housing or commercial developments were observed on steep slopes or near any of these steeper slopes except in Helena. Broad-scale earth flows and lateral spreads were not encountered in this study but do offer a conceivable problem. Keefer (1984) notes that these types of landslides can occur on slopes of less than 1 degree. That possibility will have to await further study.

Gravel Mines. Gravel has been mined on Crowley's Ridge for as long as modern development has taken place. Increasingly the abandoned gravel mines are being used as landfill sites. White and Kyriazis (1968) suggest that the effluent from these landfills as well as septic systems and other concentrated sources of chemicals can cause certain sediments, notably clays, to become unstable increasing the risk of failure by landslide. We did not observe any suspected relationships between the two but this is a concern. Also, active gravel mines pump large amounts of water from working pits to inactive areas promoting localized anomalous hydrostatic heads. By their removal of the forest cover these mines allow localized increased rates of infiltration. Both these factors cannot help but lower the additional conditions necessary to bring about slope failure in nearby down-slope regions. One of the largest slumps we observed in this study was on a wooded slope directly below an active gravel mine (site 16).

Lakes. The growth in population along Crowley's Ridge has placed a great demand on the current water supply sources. Currently most of the water supply is from wells, but surface impoundments are being increasingly discussed by many public leaders. The Lake Austell experience clearly suggests caution in this kind of development. Additionally, the ubiquitous bank caving problem on all existing lakes causes one to wonder if seismic loads under certain other preconditions might be dramatically catastrophic to a lake.

THE FUTURE

Our study of the landslides of Crowley's Ridge has just begun. Our understanding of the landslide dangers and potentials is very rudimentary at this time. To bolster our systemic comprehension an electronic database is being established to keep track of the landslides identified in this study and other landslides to be investigated in the future. Continued visits to the Ridge are envisioned to document the rate of formation of new landslides and degree of degradation of old features. Over time this database will broaden our insight into the landslide hazard of Crowley's Ridge. An earthquake large enough to cause landslides is in our future: of this there can be no doubt. Through long term observation and data collection we will be better prepared to understand the effects of seismic loads on the hillsides, carry out post-earthquake investigations, and project those lessons to future seismic shocks.

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Appendix

Representive Landslide Site Locations and Descriptions

These selected sites are the locations of most of the more significant of the many landslide features identified by this study. Many small roadside, stream cut, and gully-wall landslides were noted but due to their omnipresentence and insignificant nature they were not given a site number. Other sites that were used to obtain stratigraphic enlightenment, grab soil samples, or some other non-landslide background observation were given site numbers in the course of this investigation but are not listed here. The sequence of numbers tends to skip around geographically due to the time of the slide, time of discovery, order of investigation, and/or caprice. All observations relate to the features as they appeared at various times during the winter, spring, and early summer of 1991.

The UTM locations presented here are from the 1000-meter Universal Transverse Mercator grid, zone 15, 1927 North American Datum. (The changes in UTM locations brought about by the 1983 North American Datum grid will alter the locations listed here by less than 10 meters.) The values were extropolated from the quadrangle maps indicated and are considered accurate to within 10 meters. For an extended site the location given is usually some central point.

<u>**Site 1 - Big Spring:**</u>
County: Phillips **Quad:** Helena **Sec:** e,ne,se,ne, 32 **Ts:** 1s **Rn:** 5e
UTM Easting: 720830e **UTM Northing:** 3827370n
This large slide (~225 feet wide) developed in April and early May, 1991, during times of unusually heavy rains. The toe of the first failure had not reached the road which runs near its base by late April. However, later rains further lubricated the sediments causing additional movement in May and caused the slide to extend into and across the road. The county highway crews removed the road-borne failed material before the latter observations. This is a rotational slump landslide with a prominent flow component. The crown scarp is up to 27 feet high. The unfailed Ridge margin slopes at about 36 degrees in this area.

The largest slump block is cracked, 20-30 feet wide, about 100 feet long, and shows little rotation. Several smaller slump units, apparently bound by the forest root-mat, were observed below the crown scarp adjacent to the main slump block. Several small plant rafts have slid on down the slope leaving striations on the slide surface. The trees often seem little disturbed, are generally upright, and have continued to leaf out just like the other trees of the same kind in adjacent non-disturbed areas (as far as I can tell). One or two trees that seem to be on portions of the main slump block have rotated slightly tilting the trees toward the crown scarp. Other trees have had enough of their root-clod dissolve to allow downslope tilting.

Re-vegetation is proceeding rapidly. Erosion is gullying the new surface as of June and adding fines (mud) to the road below. Compound toe lobes have developed with the multiple episodes of failure. Minor secondary slumping was observed on the faces of these collateral features. Root-rafts continue to slide down the slope in places leaving faint to deep (6") striations in the surface which are later channelling the runoff and being destroyed by gullying.

Adjacent to and in the large gullies in the woods behind the slope this slide is developed on there are several other smaller slumps, mud flows, tree falls, etc. The natural slopes on which these other slides have developed is steep and in all cases better than 35 degrees.

Conversations with local residents reveal that this site was adjacent to gravel washing site long ago (30± years?). One man reported a previous slide (date not given) that occurred in association with a 10" rain. He stated that a section of the ridge top "trees and all" slid down the slope, across the road, and came to a stop with the trees still upright and against the power lines. This same man reported feeling the 1976 Marked Tree earthquake (magnitude 5 event) but indicated that no slope collapse was associated with the tremor.

Site 2 - Amphitheater:

County: Phillips **Quad:** Helena **Sec:** ne,ne,ne, 32 **Ts:** 1s **Rn:** 5e
UTM Easting: 720795e **UTM Northing:** 3827670n

This compound landslide is a flow/collapse feature. The slide occurred during April on a 32 degree wooded slope. The interesting thing about this slide is the small amphitheater that formed as a result. The earth material flowed out through a constriction (about 12 feet wide) and down onto the road below (where the highway crews removed most of it up to the road edge) lowering the vegetation-mat (trees and all) more or less straight down. A few trees at the margin of the feature have subsequently collapsed into the depression. The floor of the amphitheater is relatively level however a small sag- puddle has developed near the crown scarp. The crown scarp is 10 to 15 feet high. The feature is approximately 45 feet by 35 feet. The toe of the slide is a mudflow and has remained quite soft several weeks after the slide. It would appear that water is still issuing from the slide area through the sediments. The main scarp displays an undisturbed stratigraphic sequence of orange sands and gravels overlain by tan loess. It is unclear how much of the failed material is secondary deposits, however, some orange sand was found in the debris flow at the toe.

On the bank south of and adjacent to the mudflow toe of the principal Site 2 flow (where the mudflow enters the roadway) a small roadside carpet slide about 10 feet wide and about 20 feet tall occurs on a 70 degree slope. The south slide does not appear to involve much more than a the root mat (about down to the depth of the roots of the grasses and weeds), less than a foot. The displaced material is co-mingled with the larger mudflow.

Just north of the principal Site 2 flow another area shows indications of minor displacements over an area similar in size to the principal Site 2 slide. A minor scarp is incipiently developed there and down hill the slope displays a group of conspicuous bulges. The forest floor litter and recent rainfalls preclude identification of other, potentially more definitive features

Site 3 - Sluice:

County: Phillips **Quad:** Helena **Sec:** ne cor,nw,nw,ne, 29 **Ts:** 1s **Rn:** 5e
UTM Easting: 720220e **UTM Northing:** 3829290n

The most noteworthy part of this feature is the long, narrow, debris flow channel. A small carpet slide occurred at the head of the slope where a slight drainage has developed a near vertical cut bank into the loess near the top of the ridge. Enough water was apparently caught by this drainage to produce a mud slurry of this collapsed material. The mudflow channelled down the slope to where some entrained sticks lodged forcing the flow to jump channel (avulsion?) and establish a new swath to the road below. The channel is about 3 feet wide, 100 feet long (or so), and 2 to 4 feet deep. It has natural levees on both sides a few inches high, is bowl-shaped in cross-section, and sports smooth sides and floor. The mud lobe at the toe of the flow is built out onto the road margin. Two single-plant fern rafts were found in the sluice at the time of observation.

Site 4 - Tree Fall:

County: Phillips **Quad:** Helena **Sec:** sw,sw,nw,se, 20 **Ts:** 1s **Rn:** 5e
UTM Easting: 720060e **UTM Northing:** 3829745n

This site is along a typical, steep (~34^{O}), wooded slope. The displaced area is moderate in size and suggests rotational slumping of the earth materials with debris flow indications at the toe. Several large trees rooted in the loess on this slope have fallen downslope. The loess has been fluffed at the top of the slide by the pull-up of the tree roots obscuring some evidence. It is suggested that the slide developed just below the larger trees destabilizing them. They later fell, fluffing the soils as mentioned above, and in two cases slid down the slide slope a bit garbling the evidence. No skid scars were observed but rain and minor soil adjustments could have covered the skid scars of these trees. The trees had been trimmed of many of their branches prior to our observation.

The 8- to 12-foot roadcuts for 100' or so south of the slide have failed as a near continuous rotational slump. This type of feature along with small debris flows is incipiently developed along many of the roadcuts in this region.

Site 5 - Helena/Hywy 49:
County: Phillips **Quad:** Helena **Sec:** sw,se,nw,nw, 8 **Ts:** 2s **Rn:** 5e
UTM Easting: 719640e **UTM Northing:** 3824065n
This site is a near vertical loess road-cut along Highway 49 as you enter Helena. About 20-25 feet of loess is exposed in this cut. These vertical loess cuts are common in and around the town, both along the roads and associated with housing tracts and other man-made developments. This site (and several other nearby sites) experienced block falls and debris flows during the rains of April/early May. Little material involved in the displacements remained as coherent blocks of loess. It either collapsed to a pile of silt or "dissolved" into mud flows. This particular block fall failure was sheet-like; about 15 feet wide, 1 to 1.5 feet thick, and involved at least the upper 15 feet of the vertical bank face. The lip of the bank was not engaged in the displacement, being held together by a root mat of the plants growing atop the bank.

Site 6 - Porter Street:
County: Phillips **Quad:** Helena **Sec:** sw,se,ne,sw, 8 **Ts:** 2s **Rn:** 5e
UTM Easting: 720040e **UTM Northing:** 3823230n
This site is behind a small duplex at the west end of Porter Street in Helena, AR. A 30-foot, near vertical, loess bank is exposed 20 feet behind the structure. Several episodes of collapse have marked this site this Spring, generally associated with heavy rainfall. Most of the landslides seem to be the block (sheet?) falls with some blocks up to 2 feet thick. The entire bank has been involved but it is impossible to say how much fell at any one time. Conversations with the local residents indicate that this is an ongoing problem but individual collapses are poorly noted. As commonly observed, discreet mud flows have developed and have extended well away from the bank into the yard, about half way to the house. Later rains have washed additional mud from the pile of collapsed material all the way to the backdoor of the building.

Call (1891) noted a slide at the west end of Porter Street (p. 40) however, I do not think this is his site. Modern construction and Kudzu vine seems to have removed all traces of what Call described 100 years ago.

Site 7:
County: Phillips **Quad:** Helena **Sec:** nw cor,nw,sw,se, 29 **Ts:** 1s **Rn:** 5e
UTM Easting: 720470e **UTM Northing:** 3828630n
This 40-foot, near-vertical bank rises above a 50- to 200-foot wide bench that runs for about a quarter mile along the eastern margin of the Ridge. The bench top, in turn, is about 20 feet above the general level of the local Mississippi River flood plain. The bench area topography may have been created by some gravel washing operation sometime in the past. No local history has been developed to confirm this suggestion. However, the general topography of the immediate region is strongly suggestive. The only other suggestion to account for the local topography is to interpret an old stream-cut bench developed by a resistant stratigraphic unit or a well developed pseudo stream-cut bench *a la* Site 15. This site offers a good exposure of the undisturbed stratigraphic units generally observed to be involved in the landslides along this portion of Crowley's Ridge.

There has been some recent failure of this slope as evidenced by the plant rafts at the base of the slope and the relatively fresh, low, mudflow lobes and outwash sediments blanketing the woods floor between the high bank and the roadway (both atop the bench). The larger plant rafts were between 5 and 6 feet wide and usually longer than wide. The bank showed some root-mat overhang at the top of the bank usually 6" to 2 feet. The failed slope material has generally "melted" away and has been spread out as outwash leaving little behind except the plant rafts. Some small trees upon the rafts have toppled (usually the marginal ones -- or do toppling trees tear the raft into?) but many are upright or only slightly tilted (no preferred direction) and have continued to leaf-out and grow. I could not tell if past similar processes contributed some of the dense plant growth at the base of the slope but that seems likely.

<u>Site 8</u>:
County: Lee **Quad:** LaGrange **Sec:** se cor,ne,nw,ne, 16 **Ts:** 1n **Rn:** 4e
UTM Easting: 712120e **UTM Northing:** 3841780n
A 20-foot roadcut developed on the point of a Ridge spur near the confluence of two creeks. A ditch separates the cut from the roadbed. All failed material and talus slides into the ditch where it is removed by runoff. All materials seem to be loess. Loess "puppies" are common. Failure is typical of the fairly common loess "sheet" or block fall landslides. Failed area involves surface of entire upper vertical (about 8 to 10 feet) bank and is about 25 feet wide. Old talus slope (lower 10-12 feet) covered by fresh material to unknown depth. Digging did not reveal buried vegetation suggesting a fairly active slope disintegration process. (Buried vegetation would indicate a temporarily stable talus slope surface) The removal of dirt via the ditch seems to provide a mechanism for continued oversteeping of the talus.

<u>Site 9 - Jeffersonville South</u>:
County: Lee **Quad:** LaGrange **Sec:** cw cor,sw,se,sw, 10 **Ts:** 1n **Rn:** 4e
UTM Easting: 712910e **UTM Northing:** 3843650n
Ten to twenty percent of the roadcuts about a half mile south of Jeffersonville have developed rather typical, rotational slumps and carpet slides with debris flow toes. One small feature appeared to be just a flow without indications of slump. The highway crews had already removed the toes of the most of these slumps precluding full determination of volume of material involved. However, the slides seem to be a shallow, carpet-like landslides commonly seen in many other road-cut slides. The larger features are about 10 to 12 feet high and about 15 feet wide.

<u>Site 10 - Jeffersonville North</u>:
County: Lee **Quad:** LaGrange **Sec:** se,se,ne,ne, 4 **Ts:** 1n **Rn:** 4e
UTM Easting: 712450e **UTM Northing:** 3844820n
A road-cut just north of Jeffersonville. Various slump and flow features on both sides of road for several hundred feet. The landslides tend to be long, rotational slump complexes, 8 to 20 feet high and up to 100 feet long. The debris flows occur at the toe of the slumps and in localized places along the banks. Several trees up to 18" in diameter show some displacement suggesting longterm stability. The road crews clean these landslides by scooping the failed material off the road bed and dumping it back on the road bank.

<u>Site 11 A</u>:
County: Lee **Quad:** LaGrange **Sec:** nw,ne,ne,ne, 4 **Ts:** 1n **Rn:** 4e
UTM Easting: 712340e **UTM Northing:** 3845180n
A roadside landslide near the northeast end of the southern segment of the Ridge less than a mile north of Jeffersonville. The landslide is a shallow rotational slump about 70 feet wide, 25-30 feet high and has displaced surficial material 2-6 feet thick. This slide was somewhat unique in that near the

crown scarp several square yards of a hard, smooth, and "polished" slide surface was exposed. This hard slide surface could be traced into the undisplaced material adjacent to the feature. The stratigraphic transition from the looser soil to the firm silt appeared stepped and took place in a 3 to 4 inch interval. The color of the hard ground was gray and orange zoned parallel to the slide surface suggesting potential incipient iron oxide cementation. The overlying soils were a light brown color. Both slide base and failed material is silt. The dip of the slide surface was 30-34 degrees.

Site 11 B:

County: Lee **Quad:** LaGrange **Sec:** se,sw,ne, 33 **Ts:** 2n **Rn:** 4e
UTM Easting: 711970e **UTM Northing:** 3846060n

A small slump on a loess bank adjacent to the road on the south side of Robinson Hill. A few small trees have been displaced by this slide.

Site 11 C:

County: Lee **Quad:** LaGrange **Sec:** se,sw,ne, 33 **Ts:** 2n **Rn:** 4e
UTM Easting: 711910e **UTM Northing:** 3846070n

A small slump (10' by 10') in the roadcut where the road ascends up the west side of Robinson Hill. Along this portion of the road several clods have fallen from the bank.

Site 11 D:

County: Lee **Quad:** LaGrange **Sec:** n,nw,nw, 33 **Ts:** 2n **Rn:** 4e
UTM Easting: 711000e **UTM Northing:** 3846860n

A number of block falls have occurred from the banks of this canyon-like roadcut. None of the falls have been of major consequence but they have served to divert rain water runoff into the center of the road.

Site 12 - Lee County Dump:

County: Lee **Quad:** Dansby **Sec:** ne,se,nw, 5 **Ts:** 3n **Rn:** 4e
UTM Easting: 709940e **UTM Northing:** 3864270n

The Lee County Dump is an old gravel mine at the south end of the middle section of the Ridge. Currently the county is using the area as a landfill. 40 to 50 feet of loess is exposed above the gravels in several places. Most of the high-walls around the dump/mine have developed silt talus slopes covering most of the gravel strata. Small ponds occupy several corners of the dump/mine.

The loess silts stand as vertical walls of various heights around the quarry and exhibit common fall features, generally of small volume. The loess seems to develop joint sets that trend sub-parallel and sub-normal to the slope face. The loess collapses as relative thin blocks separating from the bank along these joints. Although this is not consolidated rock the term "joint block separation" seems to express the same idea. The failed blocks are "sheet-like" meaning that the general shape of the collapsed material is tall, wide, but not very thick. The "sheets" tend to be thicker the higher the wall section, usually less than 12 inches, but some may be 2 feet thick or more. In general, the "sheets" are taller than they are wide by better than a 2:1 ratio; however, wide, short blocks were noted. The thickness of an individual block seems to be fairly consistent, apparently varying from a somewhat limited range only at the top and bottom. The lateral block edges are generally sharp and marked by fractures. The top and bottom edges tend to be beveled. Where fractures are few some falls separate from the highwall leaving a shallow blind arch behind. Upon collapse the "sheets" usually disaggregate into loose silt and loess blocks. However, a few hang together for a while and end up looking like a tall obelisk leaning against the highwall or protruding from the talus slope. This same type of failure is common along the all loess cuts on the Ridge.

Site 13 - Levesque:
County: Cross **Quad:** Wittsburg **Sec:** Land Grant Survey 498 **Ts:** n/a **Rn:** n/a
UTM Easting: 708120e **UTM Northing:** 3902100n
The location is a stream cut east of Wynne on the eastern margin of the Ridge. Copperas Creek truncates a spur of the Ridge here where it passes from the ridge. 100+ feet of section is exposed in this cut and is the thickest exposed sequence of strata in this portion of the Ridge.

The lower 80 feet of the sequence is composed of sands, clays, and sandy clays (with some ironstone (limonite) and lignite) of the Tertiary age Claiborne Group. A few feet of Pliocene-Pleistocene sands and gravels lie above. The section is capped-off by several feet of Quaternary loess.

This site has been under intermittent observation for over a decade and has never been known to produce any substantial slumps, only small blocks a few cubic feet is size at the most have fallen. One feature at the top of the west end of the outcrop suggests a process similar to that observed midway up Copperas Creek at Site 15. This narrow bench occurs a few feet below the top of the ridge on the face of the cut. Small trees are growing on this bench. It seems to be developed in the loess section.

Site 14 - Fox Den on Poplar Creek:
County: Green **Quad:** Walcott **Sec:** ne,nw,ne,se, 9 **Ts:** 16n **Rn:** 4e
UTM Easting: 711040e **UTM Northing:** 3989770n
This site is a stream cut on Poplar Creek about 1/4 mile upstream from the section 9 crossing. The exposure is developed along the outside of a near 180 degree bend in the creek. The upstream end of the exposure sports a "mini-canyon" cut back by the down-cutting and back-wasting of the sediments via a side drainage. The majority of the exposure is developed as a simple cut bank on the creek. Large units occasionally slump from the highwall of the cutbank to be degraded by the stream. Several coherent blocks up to cubic yard in size were evident. One large block 12 feet tall, 15 feet long and 6 feet thick topped with 4 small pine trees had apparently collapsed by rotational slump this Spring. Another block of slightly smaller size is defined by fractures a short distance along the outcrop but has yet to be displaced. The fractures defining this latter block developed between April and June of this year.

The cut is about 30 feet high. The much of the lower 20$\pm$ feet is a 38 to 45 degree talus slope of sands, clays, and coherent sand/clay blocks with a mixture of gravel derived from the Pleistocene gravel beds above. The bedrock is often only thinly buried to occasionally poking through. The upper third of the cut is a near vertical section of gravel and sand capped by a 2 foot layer of silt. The uppermost foot contains most of the roots of the plant cover and is darker brown than the underlying layers probably due to the organic components. The binding of the soils by the plant roots in the upper foot produces an overhanging lip . The overhanging lip extends as much as 3 to 4 feet in places. Some roots dangle down from this lip as much as 6 feet. This suggests a fairly rapid retreatment of this cut. The bank top is wooded and several trees are currently being undermined. A few trees have fallen onto the slope below or into the creek. Those in the creek will most likely be washed away during next Spring's high water.

The sequence as dug out and measured at the downstream end of the outcrop and seems to be: 19 feet of fine to medium sands with variable amounts of clay as beds (sandy/silty clay) and rip-ups (Tertiary age Wilcox Group); 8 feet of Pleistocene sands and gravels; and, 2 feet silt (loess).

The strata has an apparent dip to the northwest that is less toward the top and center of the outcrop. Along the base of the section at the downstream-most exposure the beds seem to dip about 16 degrees NW. Near the top of the same portion of the outcrop the apparent dip is only 9 degrees NW. Near the center of the exposure the apparent dip is about 6 degrees NW.

Most of the coherent blocks are from units in the upper part of the section. A 10 foot fine to medium sand unit at the base of the sequence seem to allow easy undermining of the bank and subsequent collapse of the clays and gravel blocks.

<u>Site 15 - Copperas Creek Slides</u>:

County: Cross **Quad:** Wittsburg **Sec:** ne,nw,sw, 13 **Ts:** 7n **Rn:** 3e
UTM Easting: 706080e **UTM Northing:** 3900670n

Two landslides are evident here along a straight reach of Copperas Creek east of Wynne. At this site the creek is against the south wall of the valley. The site is especially open due to a powerline swath crossing the creek here and an old abandoned gravel mine higher up the slope.

The lower 12' of the creek banks are firm Tertiary clayey sands with ironstone concretions and a trace of lignite. They do not seem to be involved in any of the slope failures observed at this site. All along the outcrop small incipient seeps are developed at the top of this unit suggesting that this unit is more resistant to water infiltration than the overlying beds.

The beds above the firm sand unit exhibit an incipient gravel base with some channeling into the underlying beds. The gravel entrenchments show sand and clay drapes. The basal gravel is 0 to 4 feet thick (thickest in the entrenchments). This middle 12 foot section is unsorted sand becoming silty and clayey toward the top. It is gray and tan mottled in the lower part and brown and tan mottled in the upper part. A clay rich zone was found about 8 feet above the base of this unit and seems to be the horizon that marks the base of at least one of the slides developed here. A trace of gravel is mixed throughout the unit. The top of the unit is mostly silt.

The upper 3 feet of this exposure shows no significant lithologic break with the underlying section except for an absence of gravel. The unit is brown fine sand or silt.

The displacements that occurred here are good examples of the debris flow/collapse process. The most recent and smaller displacement (10'x30') exhibits failure by flow of the soils below the root mat and above the clay-rich layer at 20'. Examination of the lower bank showed no signs of displacement. The flow ran out over the bank and into the creek where it later washed away leaving little trace. The root mat (and all its associated aerial infrastructure) collapsed straight down with little noticeable effect on the plants. A 3 to 5 foot crown scarp partly covered with overextended roots and forest floor litter remains as testimony to the action. (Later in the year one of the mat trees half-way fell over and seemed to die.)

The other older and larger (20'x60') feature several 10's of feet upstream in the same cut suggests a similar process occurred some time before. This other displacement looks as if slippage has carried some portions of the root-mat into the creek where it, too, was washed away. Between the two landslides the bank is covered with dense vegetation but appears to reflect minor slope collapse.

<u>Site 16 - Wittsburg Slide:</u>

County: Cross **Quad:** Wittsburg **Sec:** ne cor,sw,ne,se, 18 **Ts:** 7n **Rn:** 4e
UTM Easting: 708760e **UTM Northing:** 3900380n

This large east-facing slide is located on the west side of highway 163 about one half mile north of Wittsburg in Cross County. The slide is a shallow rotational slump complex about 100' x 100' with a debris flow toe. The slide was first noted in late May 1991 and had yet to reach the highway. Sometime in June 1991 the feature was reactivated and slid onto the road. A few large trees had fallen toward the base of the slope. One large, old stump rafted down to the highway. The natural slope is 26 to 38 degrees.

Two large coherent blocks were evident in the upper half of the slide area. Below them the coherent blocks were much smaller: split and pulled apart into root rafts by the debris flow at the base of the slide.

One 30" tree that had been growing near the head of the slide had been cut down. Although it was not directly involved in the slide it appeared to be a potential problem. The smooth arch outline of the upper margin typical of most of these types of slides was significantly deflected by the root structure of this tree on the north west corner. With the loss of the supporting soils on two sides it seemed likely that the tree would cause further difficulties.

Adjacent to this active slide was the scar of an older failure about half the size of the current slide. From the size of the trees growing there it would appear to be a decade or so old. An active quarry is located on the ridge top 500 feet west of this site. All material involved in this slide is a generally homogeneous mixture of unsorted gravely, silty, clayey, fine sand (colluvium) apparently stratified parallel to the slope.

Site 18 - Roadside:
County: Phillips **Quad:** LaGrange **Sec:** sw,sw,sw,ne, 1 **Ts:** 1s **Rn:** 4e
UTM Easting: 716715e **UTM Northing:** 3834880n
This location is 12 foot loess roadcut. It is mostly stable. Small rotational slumps noted about .2 miles east of this intersection.

Site 19 - Phillips Bayou Road:
County: Lee **Quad:** LaGrange **Sec:** nw,nw,se,sw, 35 **Ts:** 1n **Rn:** 4e
Sec: Land Grant Survey 2411 **Ts:** n/a **Rn:** n/a
UTM Easting: 714735e **UTM Northing:** 3835910n
UTM Easting: 715560e **UTM Northing:** 3836195n
UTM Easting: 716040e **UTM Northing:** 3836320n
This site is the Phillips Bayou road just north of the Lee/Phillips County line on the east side of the southern portion of the Ridge. This road was closed for several weeks in the spring 1991 due to washout and roadcut collapse. (The mud was very deep in places.) All along the road are small-scale landslides of various types (falls, slumps, flows) associated with the loess banks. Older collapse feature similar to that seen at Site 2. was noted toward east end of road.

Site 20 - Wittsburg Quarry:
County: Cross **Quad:** Wittsburg **Sec:** n,sw,ne,ne, 32 **Ts:** 7n **Rn:** 4e
UTM Easting: 710530e **UTM Northing:** 3896300n
Incipient small loess collapse blocks similar to those seem at Lee County Dump occur associated with this old gravel quarry. Evidence of some very minor gravel falls was also observed. Much of the erosion seen in this pit seems to be by particulate displacement as well as by small scale mass wasting. The road across the middle of the quarry makes a cut through a thick section of loess. This quarry has been the site of study and several professional field trips.

A moderate flat was created by the quarry operators along the east edge of the operation south of the trans-quarry road. Since the close of operations a "canyon" has cut a third of the way across the flat. A pond north of the flat exhibits a classic delta fan from a small gully on its north side.

Site 21 - Old Roadside Slide:
County: Cross **Quad:** Princedale **Sec:** nw,se,nw,se, 30 **Ts:** 8n **Rn:** 4e
UTM Easting: 708490e **UTM Northing:** 3907170n
This site is located on the east side of the central portion of the Ridge along a dirt road running west of Highway 163, 2.8 miles north of Highway 64. It is the site of several small landslides, both new and old. The earth materials involved are clayey fine sand and silt. Most of this material appears to be secondary deposition: a mantle of Ridge-capping materials redeposited on the flanks of the Ridge. This redeposition process mixes loess with sands and some gravels and homogenizes the resultant mixture.

The old landslide is a rotational slump with a central debris flow component. The hillside is generally pine forest with a slope of 24 to 40 degrees. The feature is about 75 feet wide and about 50 feet from back to front. Three displaced coherent blocks are still evident (in 1991), all with pine trees growing atop them. The interblock areas sport weeds. The central debris flow channel is smooth topped, treeless, and slightly depressed.

A small amphitheater gully is developed by surface water on the same slope a little way up the road.

A few other examples of rotational slump and debris flow are evident in the road cuts of this road toward the top of the Ridge. Small plant rafts are associated with many of these features. The coherent blocks of the rotational slumps were undergoing destruction apparently by rain and runoff.

Site 22 - Roadside:
County: Cross **Quad:** Princedale **Sec:** se,ne,sw,ne, 18 **Ts:** 8n **Rn:** 4e
UTM Easting: 708540e **UTM Northing:** 3910860n
On the west side of Highway 163 about 5 miles north of Highway 64 a number of small landslides were observed in late Spring. The largest was 30 feet long and 20 feet front to back with a 2 to 3 foot crown scarp. Most of these slides occurred in April. The failing portion of this slope is artificial, shaped by the highway department. The brush and small trees along here had been cut not more than a year ago. The landslides were mostly debris flows with some coherent blocks displaced downslope as rotational slumps or carpet slides. Much of the displaced material ended up in the ditch and was being sporadically washed away. Other topographic variations of the roadcut along here suggest similar processes have occurred in recent years.

Site 23 - Roadside:
County: Poinsett **Quad:** Harrisburg **Sec:** s,sw,sw,sw, 15 **Ts:** 10n **Rn:** 4e
UTM Easting: 712040e **UTM Northing:** 3933300n
Small slump block and 60 foot stratigraphic section exposure in roadcut east of Lake Poinsett.

Site 28:
County: Craighead **Quad:** Lorado **Sec:** ctr ln,se,sw,sw, 13 **Ts:** 15n **Rn:** 3e
UTM Easting: 705240e **UTM Northing:** 3977600n
Small slumps.

Site 29:
County: Craighead **Quad:** Lorado **Sec:** ne,se,ne,ne, 14 **Ts:** 15n **Rn:** 3e
UTM Easting: 704860e **UTM Northing:** 3978930n
Small debris flows in roadcuts. Tree raft at base of largest feature. 1.5' to 3' scarp at crown of largest feature. Slope of roadcut 40 to 75 degrees. Topographic features in area suggest older landslides.

Site 32:
County: Green **Quad:** Delaplaine **Sec:** ne,sw,se,ne, 34 **Ts:** 18n **Rn:** 4e
UTM Easting: 713100e **UTM Northing:** 4003650n
A coherent collapse block with small elm tree was observed.

Site 38:
County: Green **Quad:** Lafe **Sec:** se,nw,se,ne, 35 **Ts:** 19n **Rn:** 5e
UTM Easting: 724480e **UTM Northing:** 4013560n
Small slumps in road cut. Topographic features suggestive of similar processes in past.

Site 40:
County: Clay **Quad:** Boydsville **Sec:** ctr s,sw,ne,sw, 25 **Ts:** 20n **Rn:** 6e
UTM Easting: 734740e **UTM Northing:** 4024290n
Small slump features in eroded road cut.

Site 41:
County: Clay **Quad:** Boydsville **Sec:** ne,se,ne,se, 14 **Ts:** 20n **Rn:** 6e
UTM Easting: 734110e **UTM Northing:** 4027600n
Small, tall slump feature.

Site 42:
County: Clay **Quad:** McDougal **Sec:** nw,nw,nw,nw, 12 **Ts:** 20n **Rn:** 6e
UTM Easting: 734165e **UTM Northing:** 4028520n
Most of roadcut has failed, rotational slump, producing 2 to 3 foot scarp at crown, bulge at base.

Site 43:
County: Clay **Quad:** McDougal **Sec:** sw,se,ne,sw, 13 **Ts:** 20n **Rn:** 6e
UTM Easting: 734800e **UTM Northing:** 4029070n
150 foot long and 25 feet high (max) landslide in roadcut. Another typical roadcut rotational slump. A small tree raft has slid to the base to the cut near one end. Older and smaller landslide scars were observed on the face displaced block.

Site 45:
County: Craighead **Quad:** Bono **Sec:** nw cor, sw,nw, 3 **Ts:** 15n **Rn:** 3e
UTM Easting: 701690e **UTM Northing:** 3980920n
Small narrow debris flow. This feature is about 6 feet wide and about 20 feet long. The slope is 28 to 45 degrees. The failed material flowed into the roadside ditch were it is being washed away (spring 1991). Honey Suckle is rapidly recovering the site.

Site 46A - Village Creek State Park - Lake Austell:
County: Cross **Quad:** Wittsburg **Sec:** e,nw,sw, 7 **Ts:** 6n **Rn:** 4e
UTM Easting: 707900e **UTM Northing:** 3892150n
Very large block glide landslide on the northeast facing slope of the ridge spur that forms the south abutment of Lake Austell. This landslide developed in 1980 and has been under intermittent observation ever since then. The displaced area is over 700 feet long and 250 feet wide. The current feature experienced most of its displacement during at least two different times. The southeast

segment had its major movement in the Spring of 1980, while the northern segment shifted between 20 months and 48 months later.

<u>Site 46B - Village Creek State Park - Visitor Center:</u>
County: Cross **Quad:** Wittsburg **Sec:** ne,nw,nw, 7 **Ts:** 6n **Rn:** 4e
UTM Easting: 707880e **UTM Northing:** 3893040n
A compound landslide scar is located at the bend in the creek adjacent to the road near the small bridge just south of the Visitor Center. The native slope is 30 to 35 degrees but parts of the failed slope are now near verticle. The site displays features suggesting recent rotational slump and debris flow. Both new and older slides are evident here with most features appearing to be composed of many smaller failures. A little ridge splits the feature and runs offcenter from a scarp at the rear to the creek's edge. Trees grow atop this small ridge. Upstream of the ridge an older slide scar with small fresh slumps was observed. Trees have fallen from the edge of the scarp. Water seeps were observed from the gravels at the base of the scarp.

<u>Site 46C - Village Creek State Park - Nature Walk:</u>
County: Cross **Quad:** Wittsburg **Sec:** w,se,sw, 6 **Ts:** 6n **Rn:** 4e
UTM Easting: 707980e **UTM Northing:** 3893340n
On the east-facing slope above the bank of Village Creek along the lower portion of the Nature Walk trail that starts across from the Visitor Center is a feature that seems to be an old slope failure. The suspected landslide is a lobe-shaped positive topographic feature on the floor of the flood plain just below a concavity in the bank. Both features are subdued. The general area is a fully wooded stream side. The flood plain seems to be developed on a clay/sand of Tertiary age whereas the slope is gravels and loess. The natural slope is 30 to 44 degrees.

<u>Site 46D - Village Creek State Park - Streamcut:</u>
County: Cross **Quad:** Wittsburg **Sec:** w,ne,sw, 6 **Ts:** 6n **Rn:** 4e
UTM Easting: 708090e **UTM Northing:** 3893870n
Small rotational slumps and block falls occur in a tight bend in Village Creek. Small coherent blocks of clayey silt have partly blocked the creek. Part of the cut bank is near vertical at this site. Some of the collapse seems to be the result of toppling columns of polygonally jointed soils. Small trees have fallen onto the site.

<u>Site 47 - Sharpe's Chapel:</u>
County: Cross **Quad:** Princedale **Sec:** w,se,ne, 7 **Ts:** 8n **Rn:** 4e
UTM Easting: 708680e **UTM Northing:** 3812450n
Small rotational slump landslide in ditch beside church, just south of dirt road leading to active quarry.

<u>Site 48 - Helena Cemetery:</u>
County: Phillips **Quad:** Helena **Sec:** Land Grant Survey 158 **Ts:** n/a **Rn:** n/a
UTM Easting: 721220e **UTM Northing:** 3824950n
A small debris flow was observed here. It initiated on a terrace midway across the graveyard. The flow ran out across the yard for several yards. The maintenance crew scraped the flow up and repaired the terrace.

Site 49 - Little Crow Creek:

County: St Francis **Quad:** Madison **Sec:** nw, 36 **Ts:** 5n **Rn:** 3e
UTM Easting: 706530e **UTM Northing:** 3875370n

A series of stream cuts developed along this creek exhibit small scale debris flows, slumps, and block falls. Where the creek impinges on the valley's walls high cut-banks develop that experience landslide failure from time to time. Simple particulate displacement seems to account for most erosion at these sites, however. Many other creeks on the Ridge present the same landslide modes and features.

Near the confluence of this creek with the Site 50 creek a tree covered, stream-side bench is found that is suggestive of the debris flow/collapse process observed at Site 15. (It also may be just an old stream-cut bench.) The maturity of the site's topographic features limit analysis.

Site 50 - Example valley:

County: St Francis **Quad:** Dansby **Sec:** sw, 36 **Ts:** 5n **Rn:** 3e
UTM Easting: 706400e **UTM Northing:** 3875000n

This small valley is typical of the ubiquitous small valleys developed throughout the southern portion of the Ridge and along the eastern side of the middle portion of the Ridge. The surficial materials of the valley slopes tend to be silt soils. The silts seem to be primary deposits at the upper levels but redeposited as a veneer over the lower slopes burying silts, sands, gravels, and clays of older units. The flood plains materials are usually silt with mixtures of sand, clay, and gravel. The creekbeds are sometimes entrenched into the bedrock.

The valleys are highly dendritic. The gullies running off the walls tend to be serpentine and very steep-walled (commonly 45 to 70 degrees). The valley wall spurs between the gullies are often stepped suggestive of stratigraphic control in some cases; in other cases the frequent lack of alignment implies the contrary. Outside the fairly level valley floors and bench tops limited observations imply two dominate ranges of slope angles: a 10 to 20 degree range and a 30 to 45 degree range. Other slope angles exist but these ranges seem to command the greatest surface area.

Non-continuous narrow benches are occasionally found along the valley walls that do not seem the be stratigraphically controlled. Lack of exposure and/or common materials precludes displacement determination. Many of these benches seem too high on the slope to be stream cut. These features may represent small slumps.

Small landslides are fairly common along the gully walls. These are of all types but dominated by carpet slides. Subsurface flow/collapse features were occasionally found adjacent to the streams in the flood plains. These latter features tended to be small in area. These streamside collapse features would be difficult to tell from abandoned meanders or streamcut benches after an interval of weathering. In most cases displaced material has been removed by flowing water.

Site 51 - Tertiary Sandstone:

County: Greene **Quad:** Walcott **Sec:** w, sw, ne, 10 **Ts:** 17n **Rn:** 4e
UTM Easting: 712030e **UTM Northing:** 3999670n

Hard, coarse grained orthoquartzite boulders creeping downslope from ridgetop outcrop. Sandstone unit not persistant. Other indurated sandstone exposures in area exhibit similar displacive processes. Due to the ledge-like nature of the outcrop, the joint fractures, and the steepness of the upper slopes (>30 degrees) it would appear a danger exists for rock falls under strong seismic loads.

Site 52 - Lakes:

Lake: Storm Creek Lake
County: Phillips **Quad:** Helena **Sec:** 19 **Ts:** 1s **Rn:** 5e
UTM Easting: 719000e **UTM Northing:** 3830500n
Lake: Bear Creek Lake
County: Lee **Quad:** LaGrange **Sec:** 5 **Ts:** 1n **Rn:** 4e
UTM Easting: 711000e **UTM Northing:** 3843000n
Lake: Lake Austell
County: Cross **Quad:** Wittsburg **Sec:** 7 **Ts:** 6n **Rn:** 4e
UTM Easting: 707500e **UTM Northing:** 3892200n
Lake: Lake Dunn
County: Cross **Quad:** Wittsburg **Sec:** 5 **Ts:** 6n **Rn:** 4e
UTM Easting: 709000e **UTM Northing:** 3894000n
Lake: Lake Poinsett
County: Poinsett **Quad:** Harrisburg **Sec:** 4 **Ts:** 10n **Rn:** 4e
UTM Easting: 711000e **UTM Northing:** 3934000n
Lake: Lake Frierson
County: Greene **Quad:** Lorado **Sec:** 36 **Ts:** 16n **Rn:** 3e
UTM Easting: 706000e **UTM Northing:** 3984000n

All of these lakes show bank stabilization problems. Bank caving is a common problem. Landslides in the form of flows, falls, and slides are common along many but not all banks. Trees at the lake's margin frequently fall into the lake due to failure of the supporting soils. Some campgrounds have been reduced by lake encroachment. Some lakeside clearings show gully development.

All these lakes were turbid when examined. Discussions with locals indicated that that is a normal condition. The turbidity seem to be a result of the erosion of the marginal silts and clays. Riprap does not seem to provide a final solution to the problem.