A CASE HISTORY OF A MAJOR LANDSLIDE ON CROWLEY'S RIDGE, VILLAGE CREEK STATE PARK, ARKANSAS

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ABSTRACT

Crowley's Ridge in the vicinity of Village Creek State Park in eastern Arkansas is an erosional remnant of unconsolidated Pleistocene age sands and gravels underlain by Tertiary age clays, capped by loess, and characterized by numerous landslides. Most landslides noted in recent times have been small slumps or slides displacing a few tens of yards of material. The Village Creek State Park landslide is rather unique in that it is much larger than the "normal" slide. The slide developed on the east side of a wooded hill forming the south abutment of Lake Austell Dam. The slide appears to be the result of near horizontal movement of a large, essentially single block producing pressure ridges in the direction of movement and developing a graben behind. The area disturbed is about 600 feet long by 250 feet wide. Model constructs using topographic profiles and graben block dimensions and displacements indicate a 15 to 20 foot near horizontal displacement of the main block and depth-to-slide-surface of less than 10 feet beneath the original valley floor. The main part of the graben is 50 to 90 feet wide with a maximum vertical displacement of 35 feet on the uphill side and 15 feet on the downhill side. Pressure ridges developed at the toe of the hill temporarily impounded a small stream. The slide did not occur as a single event but rather as a series of movements, most of which occurred during the first 45 days but extended over a period of months. Each significant movement occurred a few days after a heavy rain. The instability of this slope is apparently self generated. The impounded stream, forced to seek a new course, cut its new channel into the toe of the hill. A series of abandoned stream channels indicates each slide previously developed on this hillside has diverted the stream into the toe of the hill.

INTRODUCTION

R. Ellsworth Call in the Geology of Crowley's Ridge (1891) makes note of "numerous landslides which have characterized the region" (1891, p. 40) and warns of the difficulties the stratigrapher has because of this process. Most landslides noted in more recent times have been small slumps or slides displacing a few tens of yards of unconsolidated Pleistocene and Tertiary age sediments. The landslide described in this report is rather unique in that it is much larger than the normal slide. This slide is classified as a multiple pulse block glide (Simonett, 1968, p. 640) with pressure ridges developed along the advancing front and a graben (with associated slump blocks) developed between the retreating front and the crown of the slide. The area of the slide is in Village Creek State Park, Cross County, Arkansas, on the east side of a wooded hill forming the south abutment of Lake Austell Dam (SW¼, Sec. 7, T. 6 N., R. 4 E)(Fig. 1). The statements set forth in this report are the result of repeated geological reconnaissance of the area by the authors augmented by conversations and reports from Arkansas State Parks personnel and personnel of the Tennessee Earthquake Information Center. Base maps and cross-sections were developed from tape and compass surveys of the area by the authors and from existing topographic information.

DESCRIPTION

The area disturbed by the landslide is about 550 feet long by 250-300 feet wide. The slide can be divided into three general

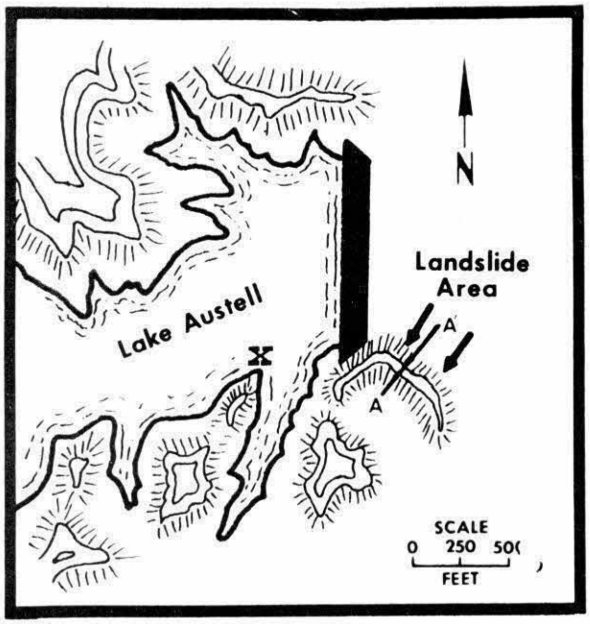

FIGURE 1 – Location map for Village Creek State Park landslide. A–A' is line of Figure 4 topographic profile. X marks the location of the borrow pit from which clay was taken for the dam core and bank blanket.

areas: a pressure ridge zone, a glide block, and a graben (Fig. 2). The area of pressure ridges is presently at the toe of the hill and extends for a short distance out onto the valley floor. In this area many indications of uplifted ridges of various lengths subparallel to the long axis of the block glide are evident. Where the surface was compressed, shallow roots of the trees were folded and forced out of the ground and in some cases broken. Numerous holes and short cracks initially seen throughout this area seemed to be the result of these buckling roots. Cracks in the ground surface seemingly unrelated to tree roots were seen only at places where the forest floor litter was thin or nonexistent. Most of these cracks trended subparallel to the long axis of the slide. Plants on the crests and troughs of the pressure ridges showed little indication of the dramatic activity they had undergone; whereas trees on the flanks of these ridges were tilted and in a few cases had fallen.

A small creek passed close to the toe of the hill before the landslide took place. The pressure ridges changed the local topography enough to partially impound the stream, flooding patchy areas. The stream bed itself is the site of the most obvious pressure ridges. The creek bed in some places had been uplifted so that it was the same level as the bank tops. (Subsequent erosion has partially retrenched the stream). Semipolygonal cracks were present where mud covered the surface of the crests of the pressure ridges. Continued observations of the site revealed the development of fresh tension cracks for several weeks indicating continued movement (uplift). Repetitive surveys by the Arkansas State Parks survey crew over a period of 10 months showed a fairly uniform decreasing rate of growth (see Fig. 3). Buried logs were partially raised and left protruding from the ground with strings of roots and vines seemingly trying to tie them down. During our initial investigations incipient low scarps (18" - 30") were observed in the creek bed. Although most of the material we examined along the scarps was sand and gravel in flat-lying beds of Pleistocene age, near the center of the uplifted portion of the creek bed we found two varieties of clay, apparently extruded; a dark gray clay with fragments of lignite, and a mottled light tan to orange silty clay considered to be in the upper Claiborne Group of Eocene (early Tertiary) age. At the time of our initial examination both clays were soft and plastic.

One hundred and fifty feet or so up the slope from the zone of pressure ridges a graben feature is developed. The graben is about 400 feet long and 50 to 90 feet wide. It shows a maximum vertical displacement of 12 to 18 feet on the downhill side and about 25 to 35 feet on the uphill side. Tension cracks with minor displacement extend from each end of the graben resulting in a total main scarp length of 500 - 550 feet. One major block, partially split by a transverse crack has collapsed into the graben along with numerous secondary blocks (Figs. 2 and 4). The main block formerly was the crest and part of the slope of the hill. Trees that were

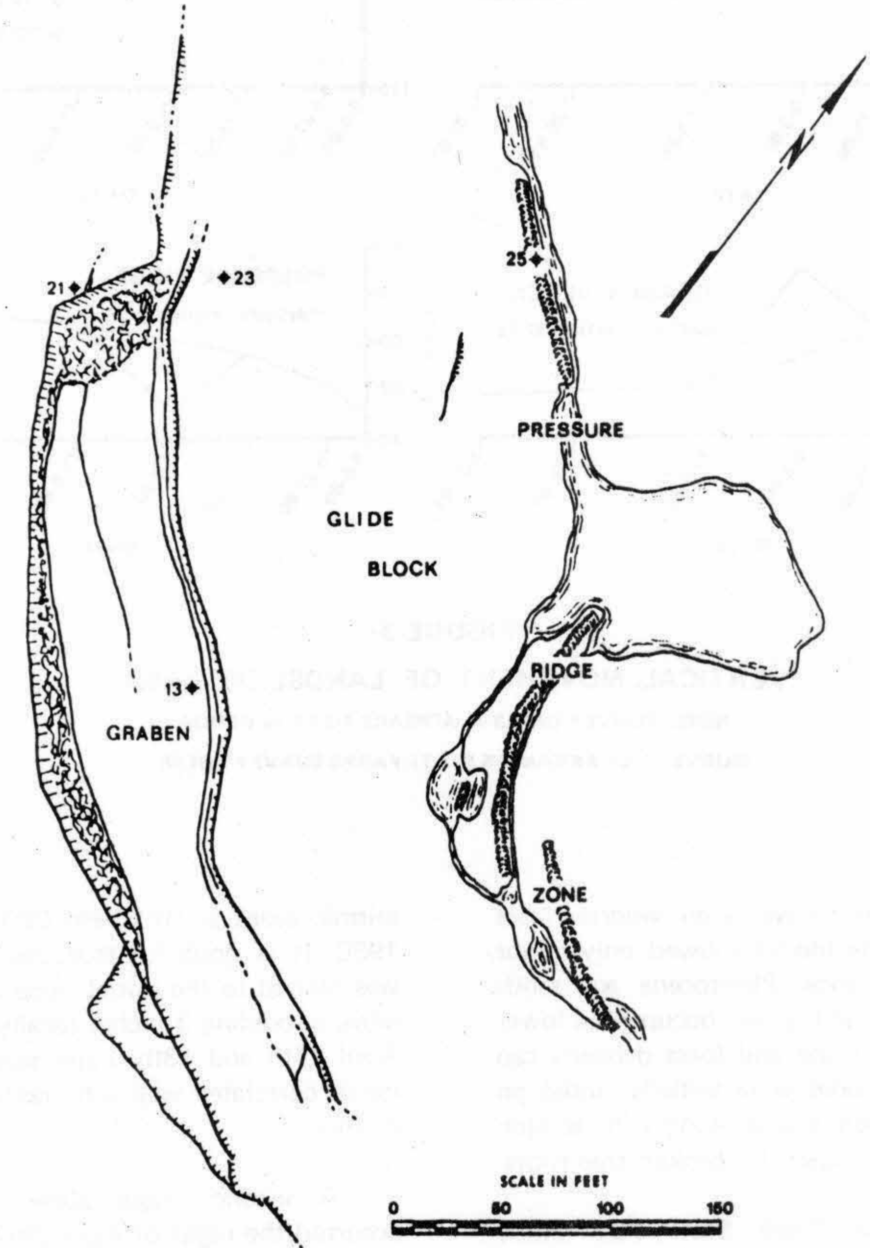

FIGURE 2

VILLAGE CREEK STATE PARK LANDSLIDE AREA

LEGEND

PRESSURE RIDGE — CREEK POOL — CRACK SCARP

◆23 SURVEY CONTROL POINTS

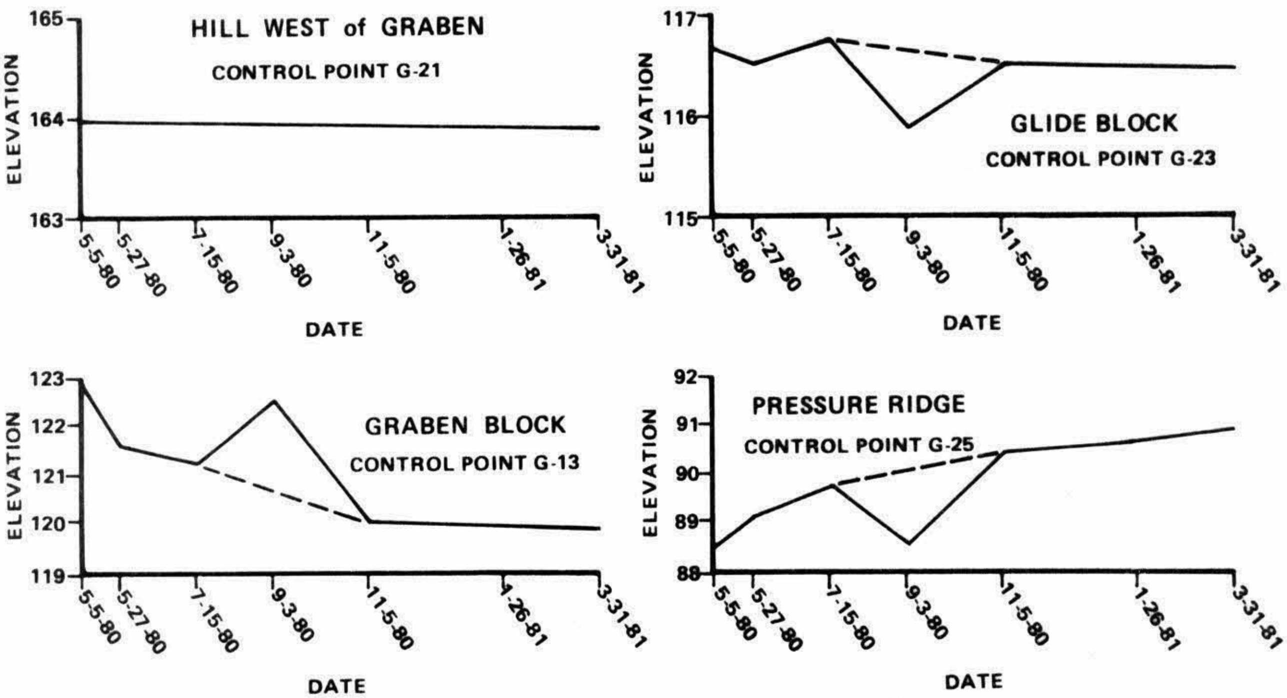

FIGURE 3

VERTICAL MOVEMENT OF LANDSLIDE AREA

NOTE: SURVEY ON 9-3-80 APPEARS TO BE IN ERROR

(SURVEYS BY ARKANSAS STATE PARKS SURVEY CREW)

astraddle the faults have fallen; whereas trees that were on the blocks showed only minor signs of disturbance. Pleistocene age sands with some clay and gravel occupy the lower portions of the slope and loess deposits cap the hill. Slickensides were initially noted on some of the fault scarps along with scratch and drag marks caused by broken tree roots.

The Village Creek State Park block glide landslide developed over a period of several months with most of the movement occurring during the first few weeks. Conversations with Park personnel indicate the first movement took place between April 5th and 18th, 1980. The graben and pressure ridges were first discovered on April 19, 1980 by Park Naturalist Larry Lowman. The Tennessee Earthquake Information Center's (TEIC) Wittsburg Lake Station (WLA), located about 2 miles north of the slide area, recorded a local (recorded only at this one station) seismic event at 10:10 PM CDT on April 11, 1980. It is doubtful that this seismic event was related to the initial slope failure. Heavy rains, exceeding 3 inches locally, fell between April 11th and 13th. Later significant movements correlated well with moderate to heavy rainfall.

A second major pulse of movement occurred the night of April 28-29, 1980. Part of this event was observed first hand by personnel of Village Creek State Park. The first suggestion of movement was indicated by two coincidental seismic events detected by TEIC's WLA station around 9:00 PM local time. Park personnel living nearby, within the Park, felt nothing of these seismic events, but were called by TEIC and notified of their occurrence. Park Naturalist Larry Lowman entered the site about 9:45 PM and reported the following (Lowman, 1980, p. 12-13):

"To my astonishment, there was no water flowing in the channel where water had flowed the day before; a few small fish flopped helplessly on the gravel. The bed of the creek was rising again, and a portion of an adjacent bank was tilting upward as well. As the trees which grew on the bank were tilted ever more precariously, their branches tangled or interlocked and thrashed or snapped overhead. Roots beneath the surface groaned or occasionally parted with a muffled pop. But surpassing everything else, was the eerie sound that emanated from beneath the upwelling mud, sand, and gravel of the creek: a bubbling, boiling sound. This was initially (around 10:00 PM) rather sporadic; as time passed, it reached a very vigorous peak (around 11:30 PM) and quickly subsided thereafter.

"Along with the bubbling, boiling sound, there was a gritty, grinding sound as the sand and gravel moved. Together, the bubbling and the grinding action produced slightly perceptible vibrations, but there were no shakes or tremors. The uplifting motion was not detectable at any given moment, but could be measured at intervals as the soil rose near adjacent trees on the opposite bank which was not rising. At one point, the gravel material in the creekbed apparently rose about 4 to 5 inches in roughly a half hour.

"Over at the graben, cracks had widened, indicating lateral displacement. Some additional sinking was occurring in all parts, as indicated by additional movement of trees already toppled or dislocated. At the northern end of the graben, considerable additional sinking took place (6 to 8 feet) and the graben extended northward an additional 50 feet or so, toppling several trees previously undisturbed . . . . large hunks of loess were caving off the face of the escarpment with ponderous thuds. The various evidences of sinking near the north end of the graben, and the rising and bubbling in the creekbed seemed to very gradually increase over the next hour (reaching a peak about 11:45 PM). An entirely new area of uplift occurred near the creek, extending northward from the original uplift more than 50 feet. It followed the creekbed very closely . . ."

Although Mr. Lowman interpreted the bubbling sound as the result of escaping gases, he heard "no whistling or rushing of large amounts of gas," nor did he report any distinctive odor. Our investigations did not reveal any indications of significant gas expulsion.

TEIC staff members arrived on the site around midnight, set up two portable seismometers, and explored the area, but activity had subsided and nothing significant was recorded.

The two earlier events recorded at TEIC WLA Station were preliminarily interpreted as shallow (less than 3280 feet deep), earthquake-like, and involving a source area several hundred yards across (Zollweg, 1980) (Bob, 1981), but it does not seem likely that strain energy could be stored in unconsolidated sediments to the point of catastrophic release. Later analysis resulted in the events being interpreted as possibly caused by air blasts questionably related to the block glide (Arch Johnson, TEIC, personal communication). Attempts by the TEIC staff to monitor subsequent events by portable seismometers located on the hill above the slide were somewhat thwarted by equipment malfunction.

Creep and settling occurred over the next several weeks, temporarily increasing after significant rainfall. For example, three months after the April glide a 6-inch plus rainfall resulted in a 12-15 inch subsidence in the graben and minor uplift along the pressure ridge zone (Lowman, 1980, p. 49).

On the valley side of the pressure ridge zone and extending out into the valley some 150 feet a series of abandoned stream channels were observed. From the degree of channel degradation and estimated ages of trees and other plants growing in the abandoned channels a rough chronology of the stream's adjustments could be made. The older appearing channels were in general most distant from the toe of the hill. The effect of the pressure ridges was to impound the present stream, forcing it to seek new channels. Although the stream reestablished its original channel in part, overflow is now diverted into the toe of the hill. The consequences of this action would reasonably seem to result in the erosion of the toe of the hill thereby reducing the static stability of the slope. The evidence of the abandoned channel chronology indicates this process has been active for some time: erosion of the slope toe, landslide, reestablishment of the stream channel into the toe of the slope, and subsequent erosion of new slope toe, slope destabilization and landslide. A low linear ridge trending subparallel to the hillside and pressure ridges was found on the essentially flat valley floor beyond the pressure ridge zone and abandoned stream channels. This linear ridge has the external appearance of an old pressure ridge further supporting the above process. None of the recent developments described herein affected this ridge.

The proximity of Lake Austell to the Slide area (Fig. 1) may be cause for concern. No evidence of stress has been observed behind the slide, where the dam abuts the hillside, or in the emergency spillway located just behind the hill. Six piezometer and standpipe test wells were drilled on the Dam by Arkansas State Parks to monitor the Dam's integrity. Lake Austell is a new lake filled for the first time in 1979. Clay mined from a pit in the center of the Lake was used as a dam core and to blanket the banks of the lake around the south end of the dam and spillway area. Much of this clay appears to have been eroded away at present lake levels (full). Undoubtedly some water from the lake is migrating into these sediments. The water levels in the lake being higher than "normal" groundwater produces an anomalous hydrostatic head thereby increasing the pore pressure in the local sediments. Such a situation can contribute to a lowering of the shear strength and sliding friction of various strata. Add to this the additional weight and lubrication of rain soaked sediments and one can expect a pronounced loss of strength. Without core drilling or some sensitive geophysical device the exact stratum or zone of failure is a matter of speculation. But, model constructs (Fig. 4) using topographic profiles and graben block dimensions and displacements indicate that the observed features are likely caused by a 15 to 20 foot horizontal displacement of the glide block and a depth-to-slide surface of less than 10 feet beneath the original valley floor. (The model constructs were developed for the slide as it appeared shortly after the late April, 1980 movement). The failure mechanism could be in part liquefaction of a sand layer(s) but field investigations indicate mostly the shear of a sensitive silty clay.

It is impossible to say with certainty whether the lake is in danger of dam failure due to continued slumping and sliding, but it is our opinion that this landslide did not affect the integrity of the dam. Future slides are equally difficult to predict, but observations seem to indicate that the glide block may be displaced a few more feet horizontally, and that the portion of the hill behind the slide may continue to slump into the graben. Eventually the limb of the hill on which the slide occurred should become subdued, losing some 20 feet or so from its crest but forming a new and more stable slope. Whether or not this will progress to the extent of endangering the stability of the dam only time will tell; but as things look now, no danger is foreseen in the immediate future. Other landslide scars were observed on the hill in the same

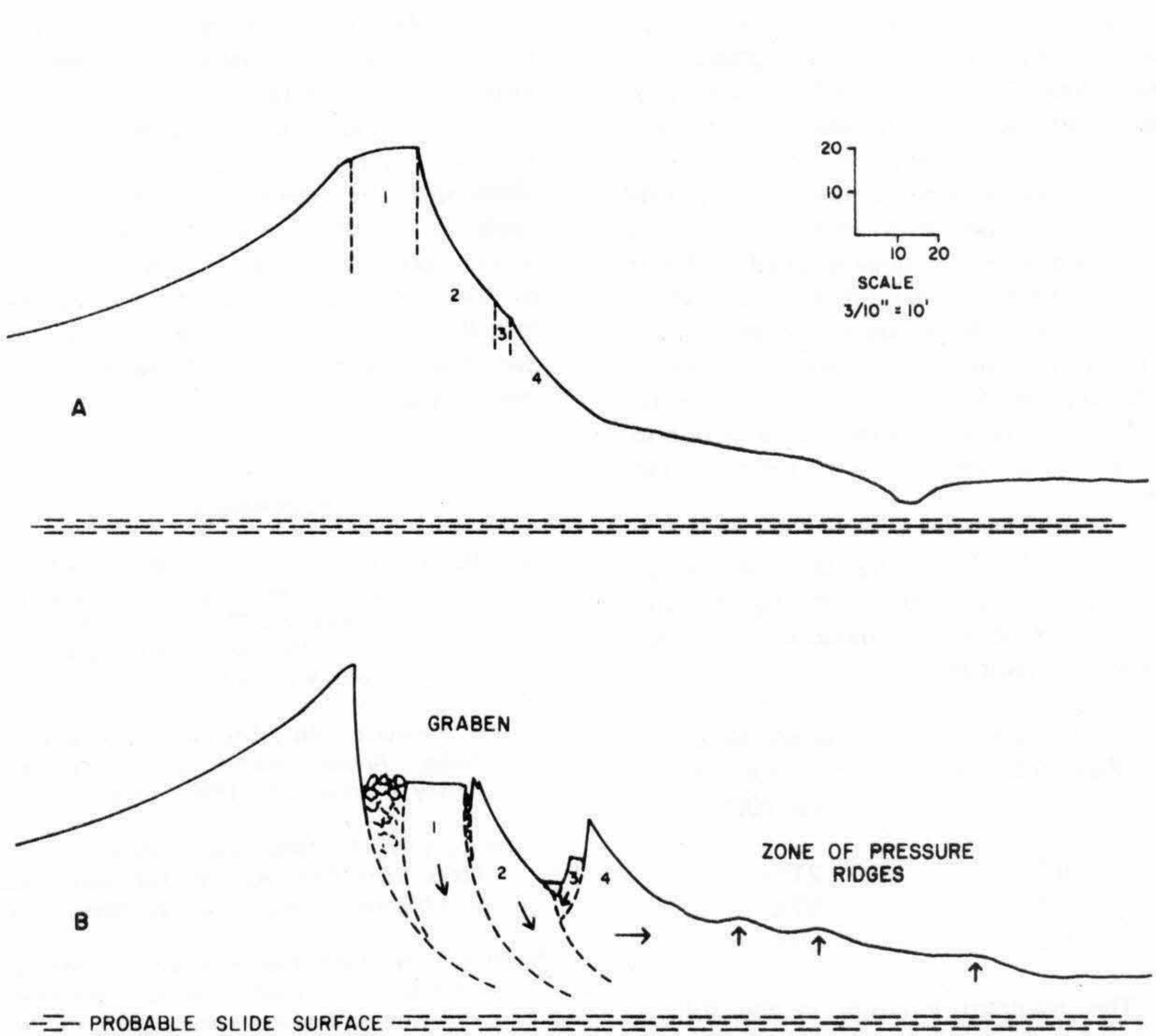

FIGURE 4

A. This topographic profile of the landslide area is taken from Figure 1 (A–A') and indicates what the hill looked like before the landslide. The dashed lines show the boundaries of the major blocks involved in the slide.

B. This idealized cross-section is a construction from the same profile as "A" modified per the authors' field observations. The horizontal displacement of block 4 as shown here is about 17 feet. The depth to slide surface was based on the cross-sectional areas of these two models. Arrows indicate direction of movement for each block.

general area as this slide, but were much smaller. Judging from the trees growing on these older slides, slides occur naturally at least decades apart. If the lake is a contributing factor to the present landslide (the factor that must be considered) then the landslide rate can be expected to increase until such time as a more stable slope is established. But if the landslide is incidental to the lake which some of the evidence suggests, then there is no reason to expect an increase in the rate of landsliding. In fact, if this is an incidental occurrence, one might expect a reduction in the rate of landsliding due to the reduction of the hill.

A recent report by Otto W. Nuttli (1981, p. 1-2) gives the following probabilities for damaging earthquakes in the nearby New Madrid fault zone.

Surface-wave Magnitude (Ms)	Probability of Occurrence before year 2000
8.5	21%
7.5	51%
6.5	63%

The resultant intensity in the Village Creek State Park area from any of the above listed earthquakes might result in massive failure of the hillside and breechment of the lake, especially if the event were preceeded by heavy rains. When full, Lake Austell holds about 1100 acre feet of water. The Willow Creek valley downsteeam from Lake Austell covers about 300 acres. Hill failure could flood major portions of the valley and represents a danger to the few homesites located within it.

The borrow pit for the clay used for the dam core and bank blanket was developed into the toe of the ridge marked by an X on Fig. 1. Although the pit was bermed on the ridge side, the removal of the natural slope along with the demonstrated propensity for landslides in the immediate area indicates another potential danger. If a sizable portion of the ridge were to catastrophically glide into the lake, water could be swept over the dam resulting in erosion of the dam, abutments, or both.

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