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Description, Origin, and Implications of a Newly Identified Slumgullion Landslide Deposit, San Juan Mountains, Southwestern Colorado

by

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ABSTRACT

A truncated landslide deposit covering an area of approximately 140,000 m^2 immediately adjacent to the well-known Slumgullion landslide, southwestern Colorado, is here identified and described. The deposit was investigated to determine its extent, general surface characteristics, and relationship to the Slumgullion landslide. The location, orientation, and composition of the deposit indicate that the deposit originated in the same source area as the Slumgullion landslide. Results of this study and comparison of the location of the deposit with a published reconstruction of the pre-Slumgullion topography suggest that the landslide debris 'spilled-over' an east-west trending ridge (divide) and then moved down a preexisting ravine in a southwesterly direction into the drainage basin of Slumgullion Creek. Subsequent movement of landslide debris within the bounds of the currently recognized Slumgullion landslide truncated the deposit leaving a steep scarp and exposing a basal contact with underlying colluvium. The headwall origin, relative age, and implied large volume of landslide debris suggest that the newly identified landslide deposit was emplaced as part of an early, 'valley-filling' episode of Slumgullion landsliding.

INTRODUCTION

A newly identified landslide in the San Juan Mountains of southwestern Colorado, about 7.2 km (4.5 mi) southeast of Lake City, was investigated to determine its extent, general surface characteristics, and relationship to the well-known Slumgullion landslide. It is situated immediately adjacent to, and south of, an upper part of the presently recognized boundary of the Slumgullion landslide (fig. 1). The landslide deposit described herein was identified and mapped during field studies in June 1993. The field studies were part of a multifaceted investigation of the Slumgullion landslide initiated by the U.S. Geological Survey in 1990 (Savage and others, 1992).

The Slumgullion landslide was noted or briefly described in several early studies (Endlich, 1876; Cross, 1909; Howe, 1909, Atwood and Mather, 1932). In a subsequent investigation, Crandell and Varnes (1960, 1961), described the landslide, reported ages of sliding, and measured rates of movement of the active portion. More recently, preliminary reports have been published on the volume and shape of the active and inactive parts of the landslide and on its surface features and kinematics (Parise and Guzzi, 1992; Guzzi and Parise, 1992). The Slumgullion landslide is a complex landslide that extends nearly 7 km (4 mi) from a 230 m (700 ft)-high scarp at the top of Mesa Seco to the valley bottom of the Lake Fork of the Gunnison River. It heads in a large basin approximately 1 km (0.6 mi) across at elevation 3,400 m (11,400 ft) and descends to an elevation of 2,700 m (8,860 ft) just north of Lake San Cristobal. About 700 years ago the landslide blocked the flow of the Lake Fork (Crandell and Varnes, 1960, 1961) and formed Lake San Cristobal, one of the largest natural lakes in Colorado. Source materials consist mostly of hydrothermally altered Tertiary volcanic rocks (latite flows, breccias, and tuffs); abundant montmorillonite in the landslide is derived from the altered rock (Crandell and Varnes, 1961; Lipman 1976; Guzzi and Parise, 1992).

This report briefly describes the newly identified landslide deposit and presents field data and observations concerning its origin, relative age, and relationship to the Slumgullion landslide.

ACKNOWLEDGMENTS

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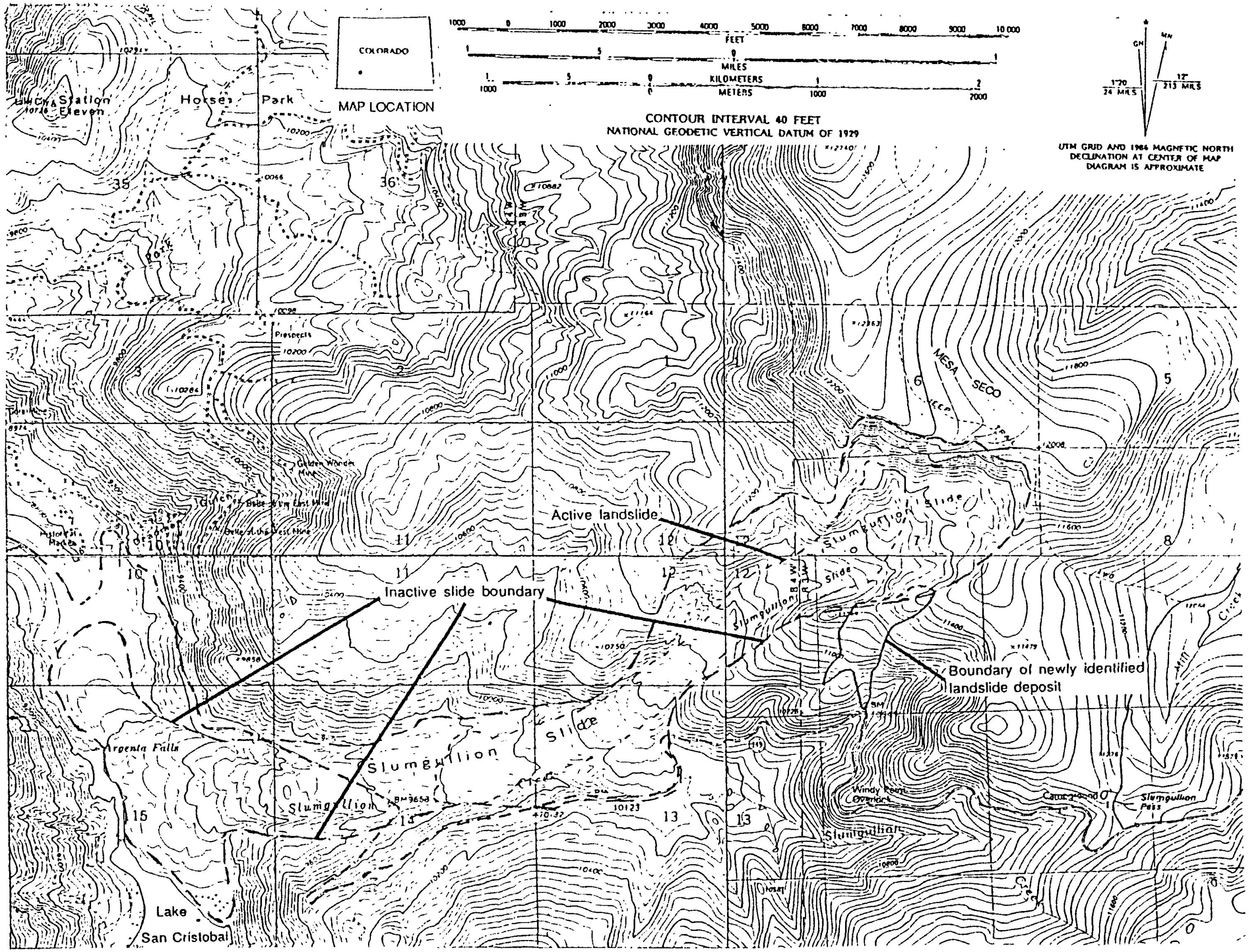

Figure 1.--Topographic map showing the location of the newly identified landslide deposit in relation to the currently recognized boundary of the Slumgullion landslide (adapted from Parise and Guzzi, 1992) (base from U.S. Geological Survey 1:24,000 Cannibal Plateau, 1963 (photorevised 1982); 1:24,000 Lake City, 1963 (photorevised 1982); 1:24,000 Lake San Cristobal, 1964; 1:24,000 Slumgullion Pass, 1986).

DESCRIPTION OF THE NEWLY IDENTIFIED LANDSLIDE DEPOSIT

The boundary of the newly identified landslide deposit was mapped in the field using 1967 black-and-white airphotos that have a scale of approximately 1:17,000. The mapped boundary was then transferred to a 1:24,000 scale topographic map (fig. 2). The deposit extends approximately 0.85 km (0.53 mi) from north to south, and has a maximum width of about 0.5 km (0.3 mi). In plan view it is somewhat doglegged and is forked at its lower end (figs. 1 and 2). It covers an area of approximately 140,000 m^2 (167,000 yd^2) and ranges in elevation from 3,490 m (11,450 ft) at it's northern extreme to 3,246 m (10,650 ft) at its southern limit.

Mapping and field observations indicate that the deposit has been truncated at the north end by a subsequent movement of landslide debris downvalley to the west or northwest as part of the main body of the Slumgullion landslide (figs. 1 and 2). The subsequent movement that truncated the newly identified landslide deposit resulted in a 50-m-high scarp that exposed the basal contact between the landslide deposit and underlying (buried) surface (fig. 2).

The preliminary estimate of the volume of the newly identified landslide deposit (fig. 2), based on an estimated average depth of 15 m (50 ft), is 2.2 million m^3 (2.9 million yd^3). The truncated (now missing) upper part of the landslide is discussed in a later section. Factors that indicate that the deposit is now stable include (1) the presence of mature aspen and conifers, apparently undisturbed by previous landslide movement, on the deposit's surface; and (2) an absence of recent scarps, faults, or other fractures that would indicate fresh movement. Deep gully erosion has removed some of the deposit.

Much of the upper surface of the deposit is covered by vegetation that obscures the underlying landslide material (fig. 3). However, patches of mostly pale yellow (2.5Y 8/6) to yellow (10YR 7/8), stoney, clay-rich landslide debris are visible at a few upper surface locations. In addition, exposures of concentrated rock debris that are somewhat elongate in the downslope direction and are composed of boulders or blocks of volcanic rock having a maximum dimension of about 2 m (6 ft) are present at two locations on the upper part of the deposit (figs. 2 and 4). The concentrations of rock debris are generally similar in shape, composition, and orientation with respect to direction of landslide movement as groupings of rock debris on the main body of the Slumgullion landslide reported by previous investigators (Parise and Guzzi, 1992).

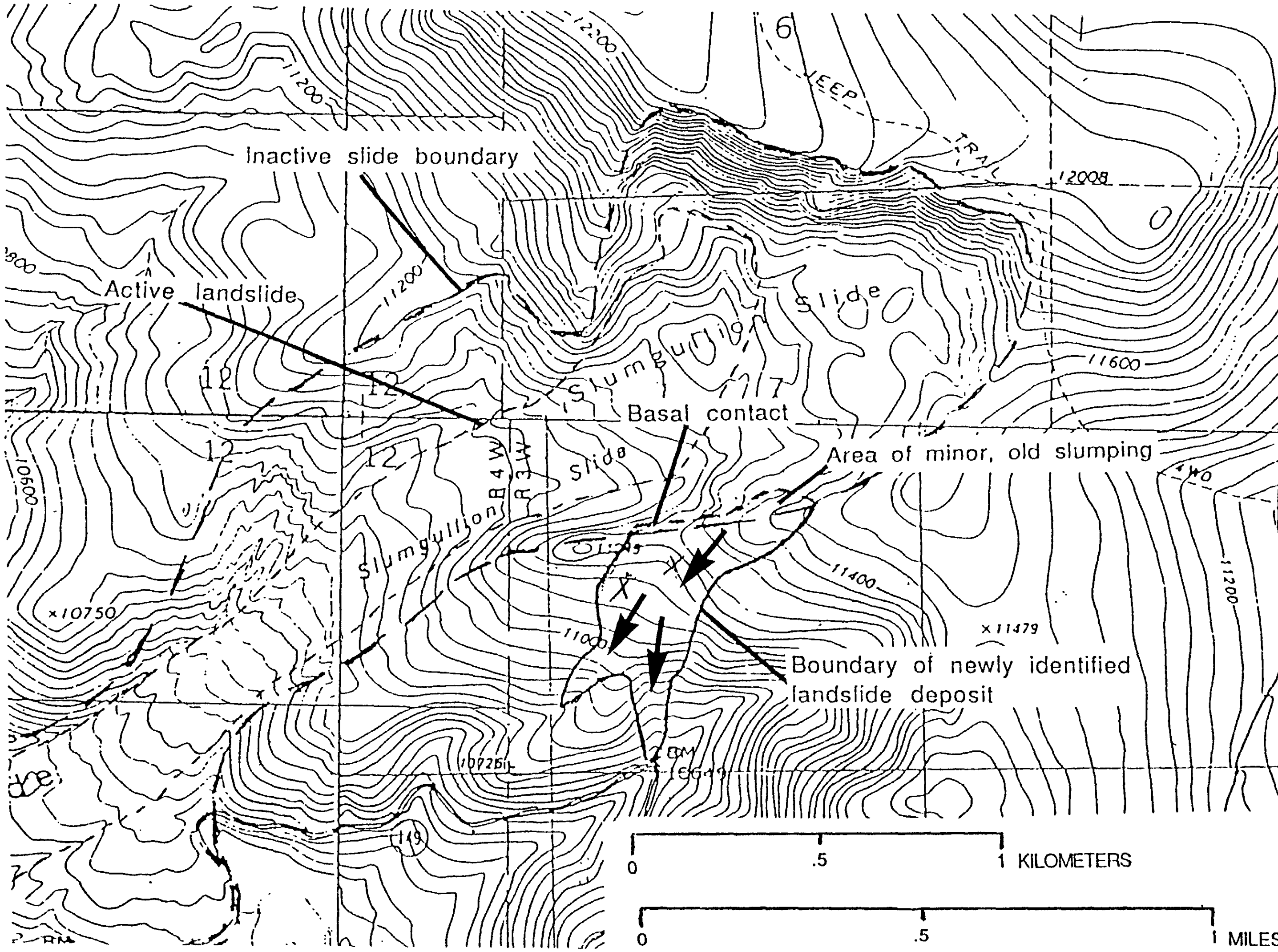

Figure 2.--Topographic map of the upper area of the Slumgullion landslide showing the mapped boundary of the newly identified landslide deposit and the location of features discussed in the text. Arrows show the direction of movement of the landslide debris at the time of emplacement. The X's on the upper part of the deposit show the location of areas of concentrated rock debris. Contour interval is 40 feet. Base from U.S. Geological Survey 1:24,000 Cannibal Plateau, 1963 (photorevised 1982); 1:24,000 Lake San Cristobal, 1964; 1:24,000 Lake City, 1963 (photorevised 1982); 1:24,000 Slumgullion Pass, 1986.

Figure 3.--Panoramic view (looking north) of the area of the newly identified landslide deposit (middle forground). Arrows point to the exposed lower part of the deposit and the tree covered, hummocky upper part. The 250-m-(820-ft)-high headwall of the Slumgullion landslide is in the background. Photograph was taken from Windy Point Overlook located approximately 0.8 km (0.5 mi) south of the deposit (fig. 1).

Figure 4.--Area of concentrated rock debris located on the upper part of the newly identified landslide deposit. View is to the southwest.

The southern fork or branch of the lower end of the landslide deposit, below elevation 3,340 m (10,960 ft), is steep and nearly barren of vegetation (fig. 3). The material in that part of the deposit is mostly white (2.5Y 8/2) to pale yellow (2.5Y 8/4) and yellow (10YR 7/8), clay-rich debris with scattered stones or blocks of volcanic rock of various sizes and shapes and some buried tree parts and wood fragments. A partly buried log (fig. 5) at an elevation of approximately 3,290 m (10,800 ft) was sampled for radiocarbon dating.

Results of this investigation indicate that the landslide debris of the newly identified landslide deposit moved in a southwesterly direction down a pre-existing ravine to elevation 3,353 m (11,000 ft) where it divided. One part then moved down a southwesterly trending ravine forming a lobe approximately 0.2 km (0.12 mi) long, while the other fork moved approximately 0.25 km (0.15 mi) down a steeper, southerly trending channel to that channel's confluence with a tributary ravine of Slumgullion Creek (fig. 2).

Sometime after the newly identified landslide mass was deposited and then truncated by the movement of landslide debris downvalley, minor slumping occurred along the steep scarp, which displaced a small part of the northeast corner of the landslide mass to the north (fig. 2). The slumping formed a closed depression about 150 m (500 ft) long, 60m (200 ft) wide, and as much as several meters deep (not apparent on figure 2 due to the small scale). Numerous large, mature conifers are present in the depression and on the sloping surfaces created by the rotating slump block. None of the trees display tilting or bending that would indicate movement after tree growth began, which suggests that the slumping is at least as old as the trees.

DESCRIPTION OF BASAL CONTACT AT THE TRUNCATED END OF THE DEPOSIT

A basal contact was exposed at the truncated northwest corner of the deposit by removing a thin layer of landslide-debris-derived colluvium from the scarp face (fig. 6). The exposure, 15 m (50 ft) long from east to west, revealed a sharp, gently undulating contact between a brown (10YR 5/3) to dark-brown (10YR 3/3) stoney colluvium and overlying, mostly white (2.5Y 8/2) to pale yellow (2.5Y 8/4), clay-rich, landslide debris (fig. 7). The buried surface of dark, stoney colluvium is continuous with the present surface located at the top of the scarp west of the northwest corner of the landslide. Because of the contrast between the light-colored landslide debris and dark colluvium, it is readily apparent that little or no

Figure 5.--Photograph of partly buried log at an elevation of about 3,290 m (10,800 ft) on the nearly barren lower part of the newly identified landslide deposit. The log was sampled for radiocarbon dating.

Figure 6.--View (looking south) of the truncated northwest corner of the newly identified landslide deposit. Arrows mark the basal contact.

Figure 7.--Photograph showing sharp contact between landslide debris and underlying colluvium. Abundant wood fragments are present in the clay-rich landslide debris in a 0.3 m (1 ft) zone above the contact.

Figure 6.--View (looking south) of the truncated northwest corner of the newly identified landslide deposit. Arrows mark the basal contact.

Figure 7.--Photograph showing sharp contact between landslide debris and underlying colluvium. Abundant wood fragments are present in the clay-rich landslide debris in a 0.3 m (1 ft) zone above the contact.

mixing or churning of the two materials resulted from emplacement of landslide debris. In addition, there is a notable absence of slickensides or other structure that would indicate basal shearing in the zone of contact. Wood fragments, in various states of decomposition, are abundant in the landslide debris in a 0.3-m-(1-ft)-wide zone above the contact. Nearly all of the wood fragments in the landslide debris are oriented parallel or subparallel to the contact. Wood from the debris was sampled for future radiocarbon dating. A thin layer of dark-brown, decomposed organic material is present at the top of the buried surface that, in most places, is less than 2 cm (1 in) thick. A few wood fragments, interepreted as decomposing roots, were visible in the buried colluvium a few centimenters below the contact. Further excavation of the contact to the east was prevented by deeper, unstable colluvium on the steep scarp face.

ORIGIN AND IMPLICATIONS OF THE NEWLY IDENTIFIED LANDSLIDE DEPOSIT

The data presented in this report leave unanswered questions regarding the deposit's mode of emplacement, age, and original extent and volume prior to truncation. However, some general conclusions can be drawn from the available data.

A Slumgullion-landslide-source-area origin for the deposit is indicated by (1) the location and orientation of the deposit; (2) truncation of the north end of the deposit, which indicates that, prior to truncation, the deposit extended to the north and northwest in the direction of the headwall; and (3) the types of rock and engineering soil exposed at the surface of the deposit that, overall, appear very similiar to Slumgullion landslide surface and source materials described by Crandell and Varnes (1961), Parise and Guzzi (1992), and Guzzi and Parise (1992).

Regarding the mode of emplacement, mapping suggests that, unlike high velocity failures, such as the prehistoric Blackhawk landslide in California (Shreve, 1968), which tend to spread over the surface with relatively little sensitivity to topography, this movement was highly sensitive to the existing topography. That is, it closely followed the topographic lows (ravines) as it moved downslope. On the basis of the present data and for the purpose of the remaining discussion, I postulate that the newly identified landslide deposit was not emplaced at high velocity.

Comparison of the location and orientation of the newly identified landslide deposit with a reconstruction of the topography that existed prior to Slumgullion landsliding (Parise and Guzzi, 1992) indicates that the pre-Slumgullion headwall was the only possible source of the newly identified deposit (figs. 2 and 8). Further, the pre-Slumgullion topography suggests that the debris composing the newly identified landslide deposit must have first 'spilled over' an east-west trending divide or ridge that existed on the south side of a valley separating the ridge and the original 800-ft-high headwall (fig. 8). The top of the ridge along the 'spillover' interval was as high as 60 m (200 ft) above the valley bottom (fig. 8). Comparison of the pre-Slumgullion topography (fig. 8) and the location of the newly identified landslide deposit in the present topography (fig. 2) indicates that the ridge location was at or near what is now the truncated north end of the deposit. Also, the reconstructed topography implies that, in order to spill over the high ridge opposite the headwall, landslide debris had to fill part of the upper valley (hachured area in Figure 8), which was as much as 0.5 km (0.3 mi) wide and 90 m (300 ft) deep between the base of the headwall and the ridgetop (fig. 9). The minimum volume of landslide debris needed to fill the upper valley (hachured area in Figure 8) to a 'spillover' level is estimated at 6 x 10^6 m^3 (8 x 10^6 yd^3). Therefore, the total mimimum volume of landslide debris (valley fill and 'spillover' combined) was approximately 8 x 10^6 m^3 (11 x 10^6 yd^3). A more realistic geometry for the valley fill would include an additional volume of landslide debris downvalley below the line of cross section A-A' (fig. 9). However, that volume cannot be estimated. Also, an additional, unknown volume of landslide debris may have existed at the headwall source above the filled valley. It follows from the foregoing discussion that the volume of landslide debris needed to achieve a 'spillover' was probably greater than 8 x 10^6 m^3 (11 x 10^6 yd^3). Parise and Guzzi (1992) estimated the volume of material missing from the headwall area as a result of Slumgullion landsliding by comparing the present topography with the pre-Slumgullion topography. That calculation shows that about 102 x 10^6 m (133 x 10^6 yd^3) is missing from the pre-Slumgullion headwall. Therefore, the total volume of Slumgullion landslide debris that existed after emplacement of the newly identified landslide deposit was a minimum 7.8 percent of the estimated missing headwall volume and was probably larger. The implied large volume of

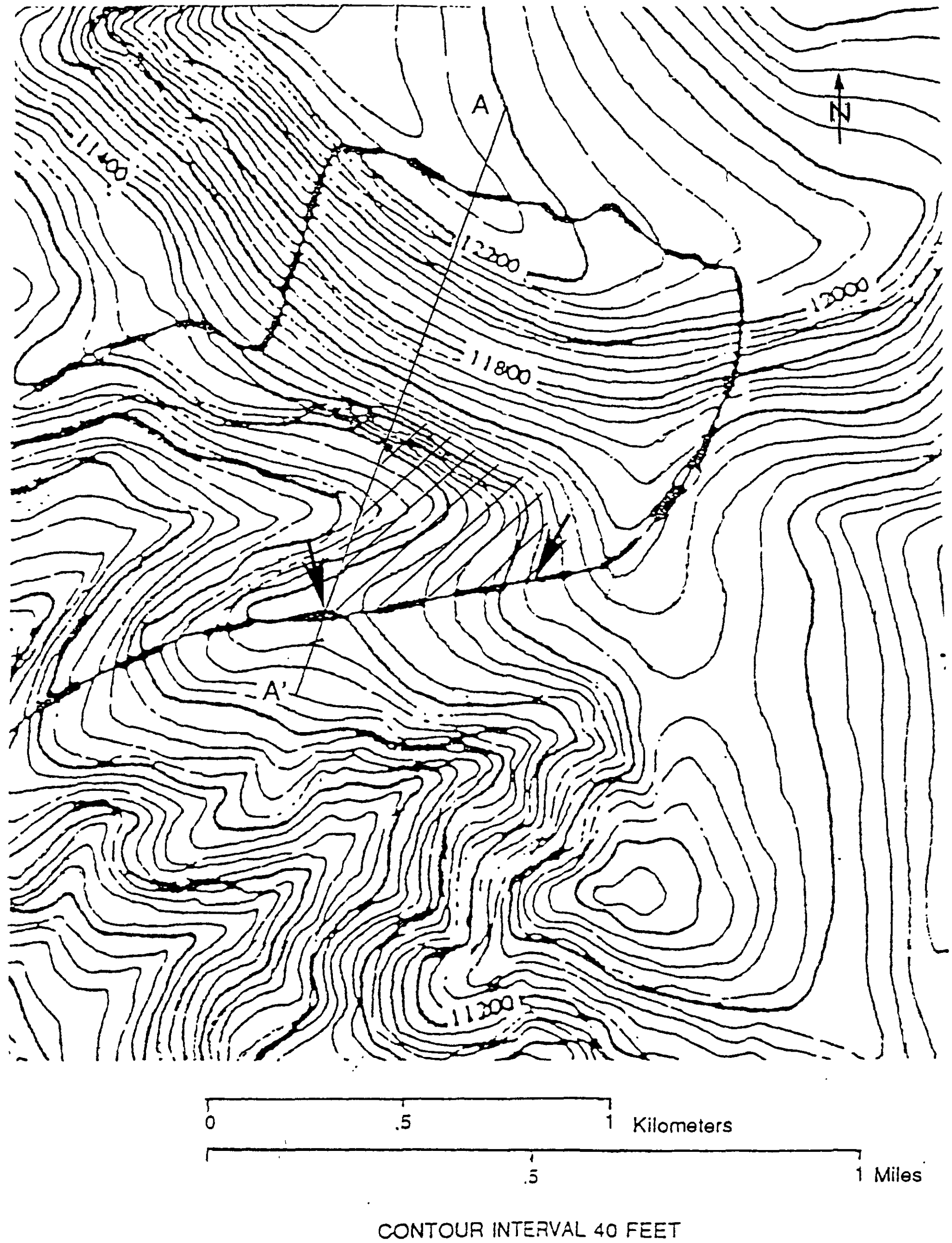

Figure 8.--Pre-Slumgullion topography in relation to the currently recognized boundary of the Slumgullion landslide (heavy dashed line), the location of cross section A-A' (fig. 9), and the northeast and northwest corners of the newly identified landslide deposit (arrows) (adapted from Parise and Guzzi, 1992). Note that the headwall is the only possible source of the truncated landslide deposit and that a large volume of landslide debris that traversed, and probably filled, the intervening valley between the ridge top and the headwall (hachured area) would be required to explain the existence of the newly identified landslide deposit.

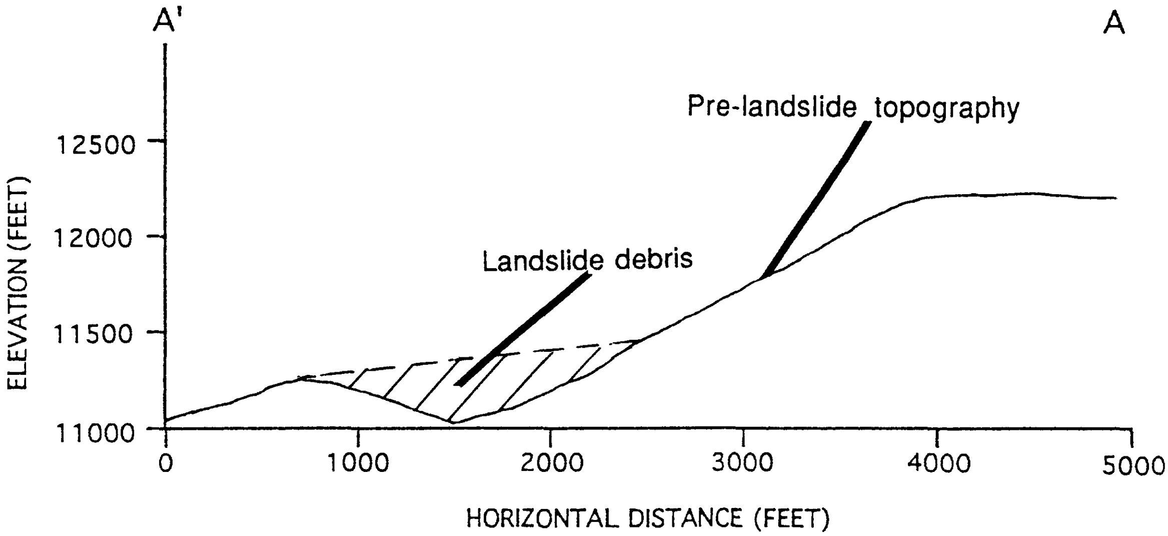

Figure 9.--Cross section A-A' showing profile of the pre-Slumgullion topography extending from the top of the headwall to beyond the point at the top of the ridge now occupied by the northwest corner of the truncated landslide deposit (see fig. 8 for location). The dashed line is the assumed minimum level of landslide debris needed for a spillover at the ridgetop on the left side of the profile (adapted from Parise and Guzzi, 1992).

landslide debris needed to fill the upper-valley and achieve a 'spillover' suggests that a significant part of the headwall was involved in one or more 'valley-filling' episodes of Slumgullion landsliding. Based on the available data the following sequence of landslide events appear likely: (1) the occurrence of one or more 'valley-filling' episodes of Slumgullion landsliding that culminated in the spillover, and (2) the subsequent occurrence of one or more depleting episodes that resulted in truncation of the deposit and movement of valley fill (landslide debris) downvalley. The 'valley-filling' and depleting episodes may have been separated by a significant interval of time or they may have been continuous.

As previously mentioned, samples of buried wood were collected from the landslide debris for radiocarbon dating. At this writing, the results are not yet available, however, the dates probably will provide an estimate of the age of the deposit and may establish important age relationships relating to the history of movement of the Slumgullion landslide. Additional work is currently underway to better determine the characteristics of the deposit and to establish a chronology of landslide events relating to the currently recognized Slumgullion landslide.

CONCLUSIONS

This report has presented the results of field mapping, the collection of stratigraphic data, and general observations that identify and describe a newly identified, truncated landslide deposit immediately adjacent to the presently recognized boundary of the Slumgullion landslide. The following major conclusions are based on the results of this investigation and the assumed validity of the reconstructed pre-Slumgullion topography:

1. The newly identified landslide deposit is part of a landslide that originated at the Slumgullion landslide source area headwall.
2. Truncation of the deposit by a subsequent movement of landslide debris within the bounds of the presently recognized Slumgullion landslide indicates that the newly identified landslide deposit is older than that movement.
3. The headwall origin, relative age, and implied large volume of landslide debris suggest that the newly identified landslide deposit ('spillover') was emplaced as part of an early, 'valley-filling' episode of Slumgullion landsliding.

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