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THE APRIL 30, 1987 TELLURIDE AIRPORT LANDSLIDES AND RESULTANT DEBRIS FLOWS

by

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THE APRIL 30, 1987 TELLURIDE AIRPORT LANDSLIDES AND RESULTANT DEBRIS FLOWS

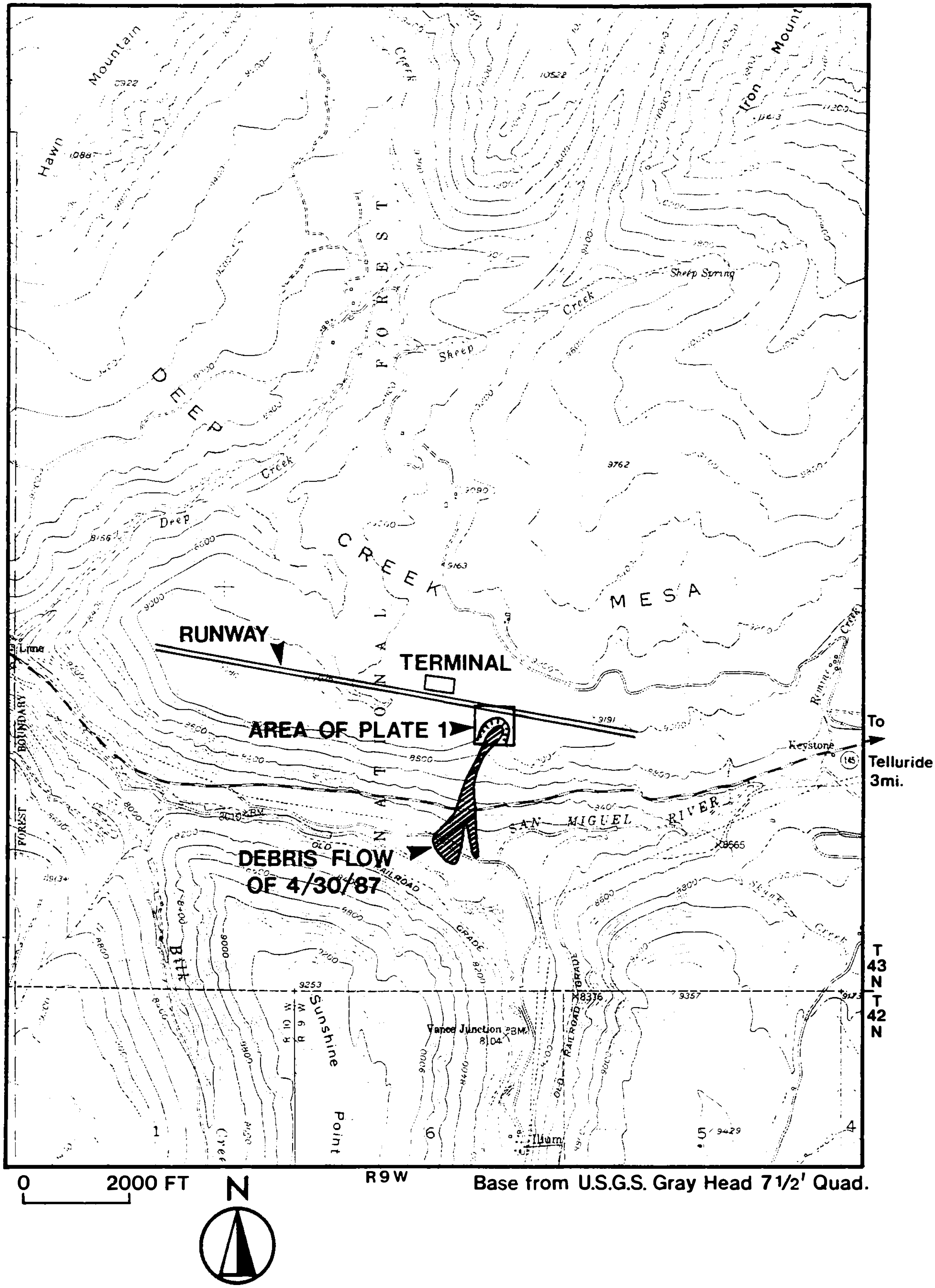
INTRODUCTION

Starting at approximately 8:30 p.m. on April 30, 1987, a series of landslides occurred on the upper edge of Deep Creek Mesa, 4.5 miles west of Telluride, Colorado (Figure 1). The landslides initiated in a bowl-shaped depression that had been partially filled with engineered materials in order to build the runway for the Telluride Airport (Figure 2). As the landslides moved over the edge of the mesa and through a narrow notch in the sandstone rim, they mobilized into debris flows. The debris flows then traveled down-slope, crossed State Highway 145, and stopped in the San Miguel River Valley. Up to 12 ft of material was left on the highway and the Animas Aggregate buildings and equipment on the valley floor sustained extensive damage.

In the following report, we describe our observations from a 4-day (5/4/87 to 5/7/87) field investigation of the landslide and the subsequent debris-flow events. The report includes a description of the geologic and geomorphic settings, a compilation of eye-witness accounts of the events, and our description of the landslide scar, debris-flow path, and runout zone. The emergency advice and assistance provided by Rahe Junge to local authorities immediately following the event is described, as well as our assessment of any remaining immediate hazard. We also suggest a possible sequence of failure in the scar area.

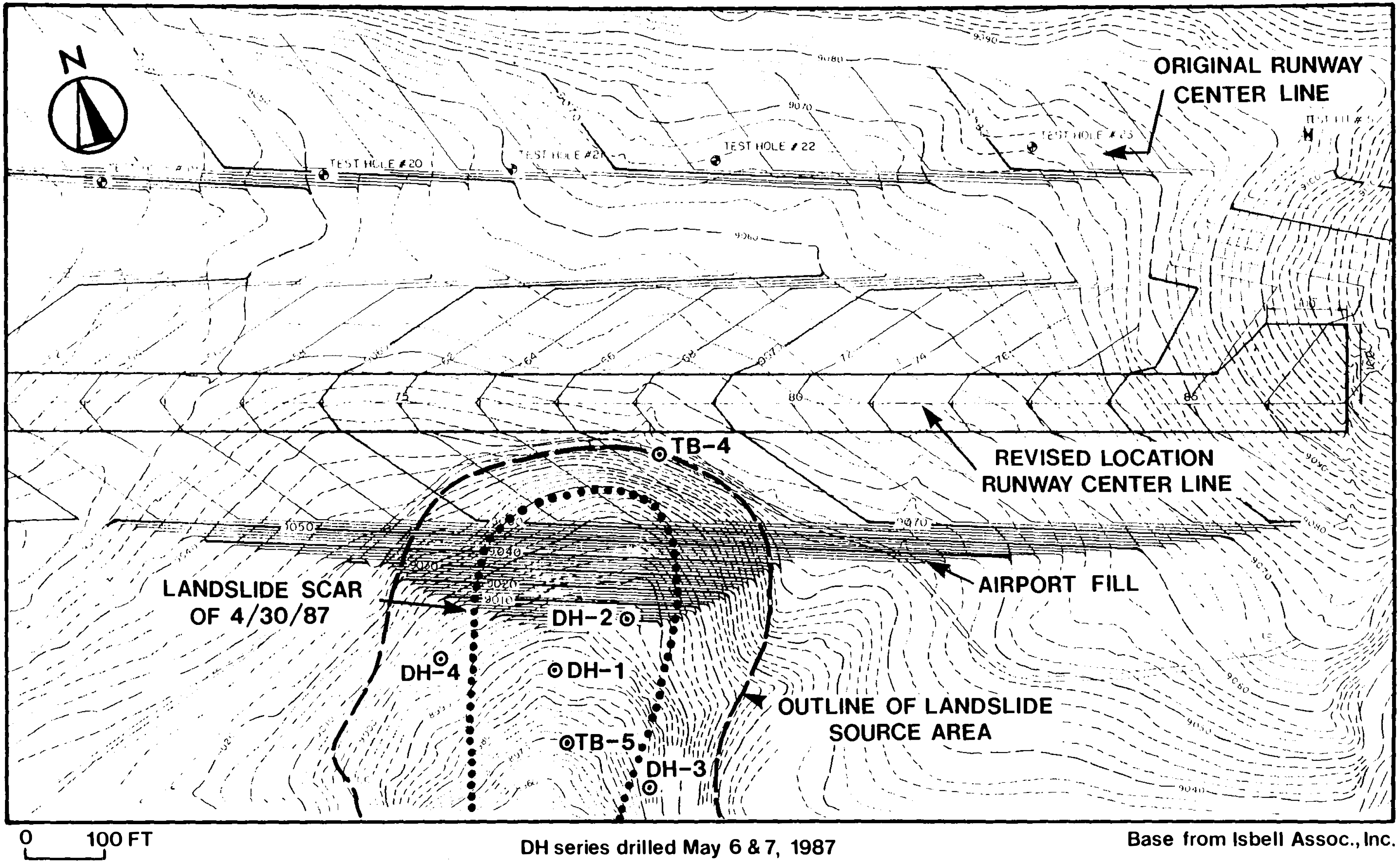
ACKNOWLEDGMENTS

A number of eye-witnesses were interviewed in the days following the debris flow to construct this account. Speed Miller, an employee of Animas Aggregate and John Micetic, the emergency coordinator for Telluride, were in particularly opportune positions to view the event and we rely heavily on their accounts. We would also like to thank Gary Bennett of Animas Aggregate for allowing us access to the deposits in the runout zone, and Conrad Rauh and Joe Cline at the airport for their assistance. Walter Vanderpool of Lincoln DeVore also supplied drill-hole information.



Base from U.S.G.S. Gray Head 7 1/2' Quad.

Figure 1. Location map of Telluride Airport landslide and debris flow.



DH series drilled May 6 & 7, 1987
TB series drilled Aug. 24, 1984
by Lincoln DeVore

Base from Isbell Assoc., Inc.

Figure 2. Map of landslide source area showing locations of test borings, fill configuration, and runway location.

GEOLOGIC SETTING

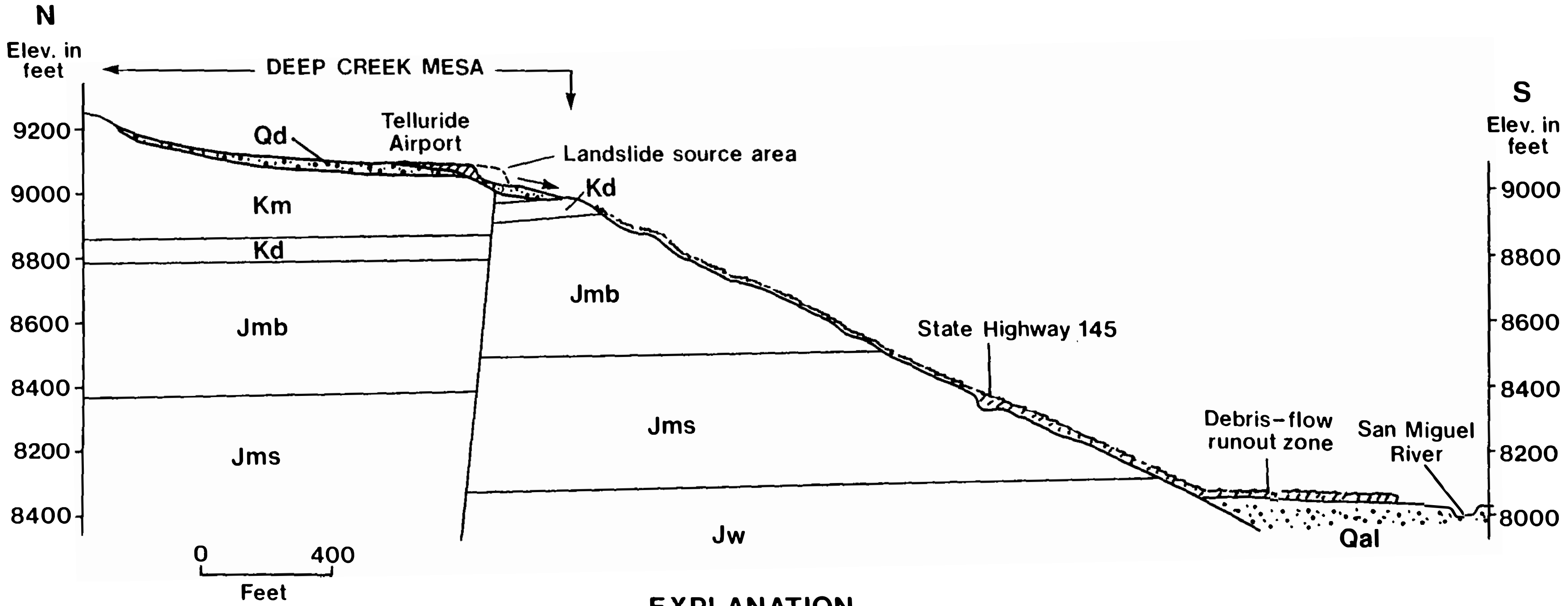
Deep Creek Mesa is underlain by interbedded sandstones and shales of the Cretaceous-age Dakota Group and the Mancos Shale (Figure 3). The Dakota Sandstone forms the resistant rim of the mesa, the remainder of which is underlain by Mancos Shale. These units dip approximately 3° towards the northeast. Scattered patches of glacial drift overlie the Mancos and Dakota in swales and form small isolated hills on top of the mesa. The glacial deposits consist of brownish to brownish-orange silty clays, clayey sands, granitic and volcanic gravels, cobbles, and boulders.

Test borings by Lincoln DeVore, a geotechnical engineering firm, along the original proposed runway centerline (Figure 2) indicate that what had been previously mapped as Mancos shale outcrop was actually 5 to 15 ft of weathered colluvial clay overlying glacial clayey sands and gravels that extend to a depth of at least 20 ft. Water was present at the contact between the glacial deposits and the underlying Mancos shale.

In the area of concern, the east-west trending Vanadium fault (Bush, et al., 1961) displaces the Dakota Sandstone up against the Mancos Shale approximately 350 ft from the edge of the mesa (Figures 1 and 3).

GEOMORPHIC SETTING

Inspection of large-scale aerial photographs taken prior to airport construction (provided by Lincoln DeVore) indicates that the present landslide scar occupies a pre-existing landslide source area (Figure 2). The area consists of a bowl-shaped depression that outlets downslope over the edge of Deep Creek mesa. The slope of the head of the bowl is approximately 60%, and the base is approximately 17% and steepens to 30% in a narrow throat near the edge of the mesa. Test holes drilled by Lincoln DeVore during airport-siting studies, and on May 6 and 7 of this year, indicate that at least 20 ft, and at most, 32 ft, of colluvial silty clay, sand, and gravel derived from nearby Mancos Shale and glacial deposits have been deposited in the source area (Figure 4). The drill log for TB-5 describes saturated, silty clay to a depth of 13 ft, then gravel to refusal at 20 ft. Drill-hole 1 encountered water-bearing gravels and cobbles to 32 ft. A map of the airport site by Lincoln DeVore also shows five springs and a wet, marshy area on the floor of



EXPLANATION

Qal	Alluvium of San Miguel River
Qd	Glacial drift and colluvium on Deep Creek Mesa
Km	Mancos Shale
Kd	Dakota Sandstone
Jmb	Morrison Fm., Brushy Basin Member
Jms	Morrison Fm., Saltwash Member
Jw	Wanakah Fm.

Figure 3. Schematic-geologic cross section of Telluride Airport landslide and debris flow.

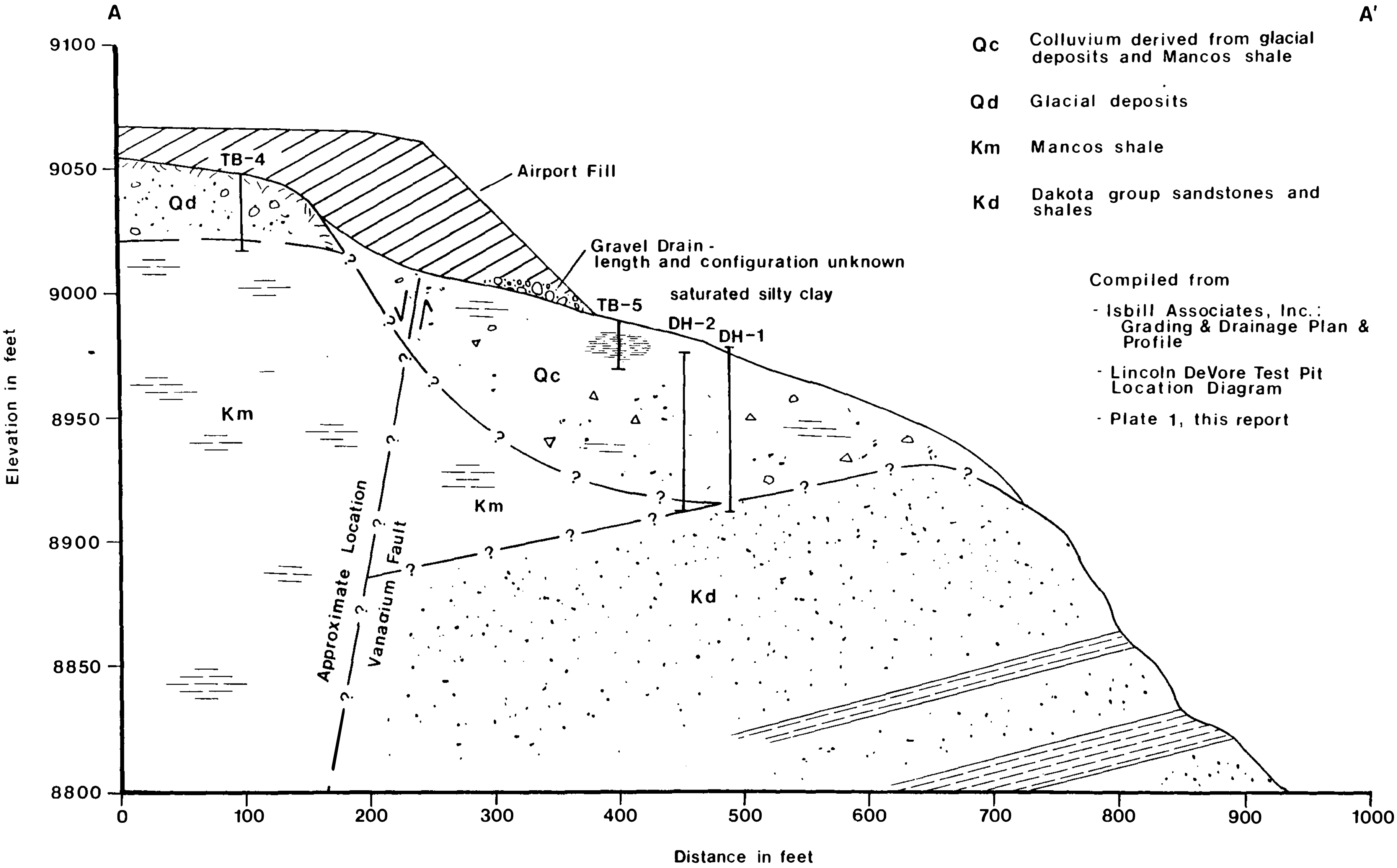


Figure 4A. Geologic cross section through landslide source area prior to movement.

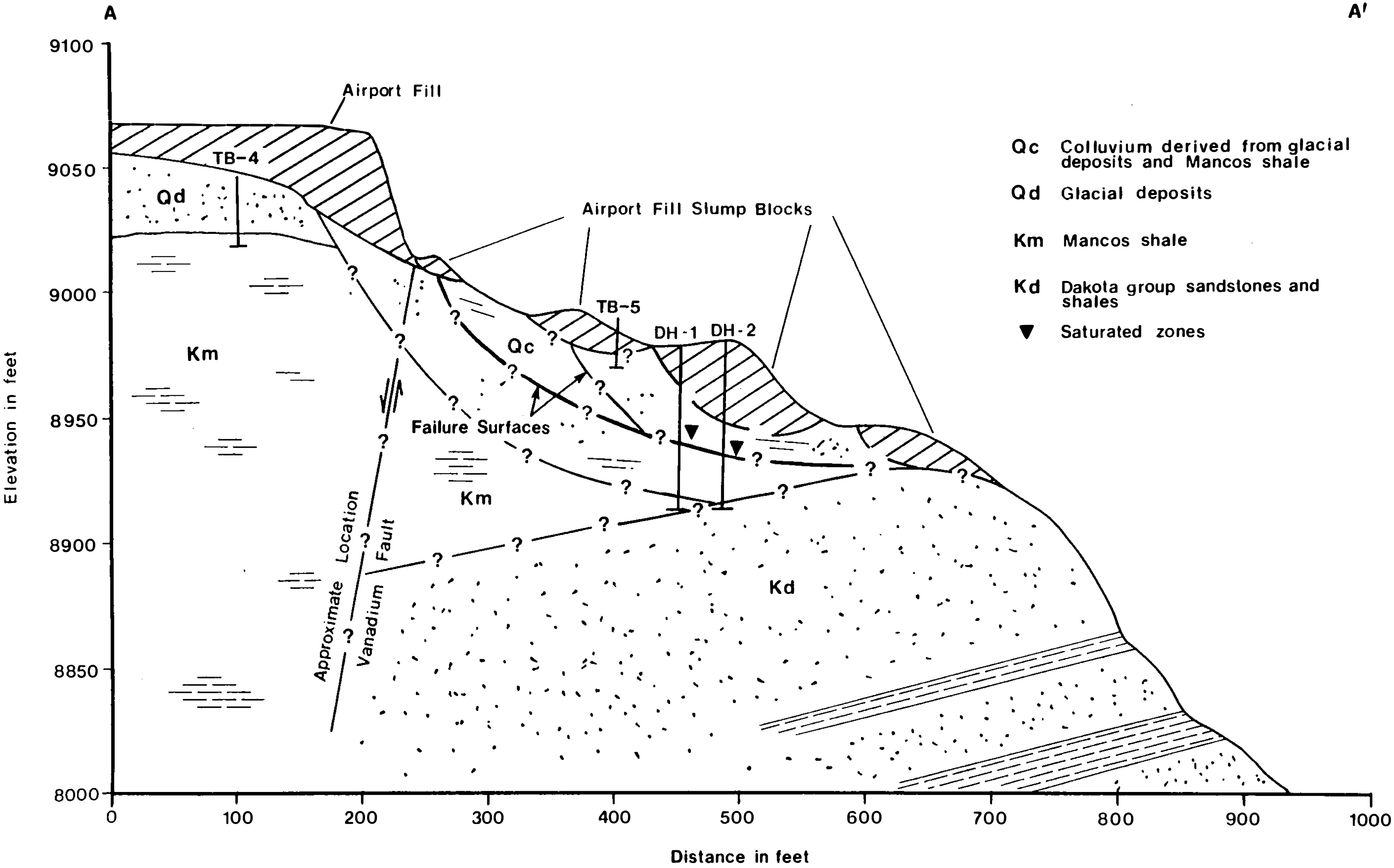


Figure 4B. Geologic cross section through landslide source area following movement.

the source area. Humic soils and cattails were observed along the sides of the present scar.

We observed older slope-movement deposits in the cut for Highway 145, but did not observe any at the foot of the slope in the San Miguel River Valley. This suggests that earlier debris flows did not have sufficient quantity of material or the rheologic properties needed to reach the base of the slope, or that any older deposits have been removed by erosion from the lower slopes and valley bottom.

A broad, east-west-trending swale drains into the western edge of the debris-flow source area. A pond was reported to have formed in the swale and periodically drained into the source area in the days preceding the landslides of April 30.

In order to build the Telluride Airport runway a fill prism of Mancos Shale derived from nearby "Windy Knoll" was placed across the upper part of the landslide source area (Figure 2). The fill was up to 70 ft thick with a 2:1 slope and extended 270 ft southward into the source area.

An additional fill prism (not shown on the available grading plan [Figure 2]) was constructed parallel to, and on the eastern edge of, the source area (Plate 1). This fill covered a small surface drainage channel.

DESCRIPTION OF THE EVENT

Starting at approximately 8:30 p.m. on April 30, 1987, a series of landslides occurred in a pre-existing landslide source area located along the upper edge of Deep Creek Mesa. As the landslides moved over the edge of the mesa and through a narrow notch in the sandstone rim, they mobilized into debris flows. The debris flows then traveled 2200 ft over slopes of approximately 50% (a vertical drop of 960 ft) into the valley of the San Miguel River. The debris flows crossed State Highway 145 at a point 700 ft upslope from the valley floor.

Speed Miller, an employee of the Animas Aggregate plant located at the base of the slope, witnessed the first debris flow as it traveled through the plant. He reported that a sound "like thunder that didn't stop" preceded the appearance of the debris for about 30 seconds. The first wave of debris moved at "a jog or slow run" through the plant site, rafting trees and boulders. The debris broke down a power line, moved several pick-up trucks and dump trucks, and pushed up against the edge of the maintenance shop and office.

Mr. Miller reported that two or three smaller surges of debris followed over a 5-minute period. After moving his personal vehicle from the path of the debris, he drove down the valley to Sawpit and alerted authorities. (See the May 7, 1987, Telluride Times for a detailed description of the local emergency response.)

Approximately 45 minutes to one hour later, a second major landslide apparently occurred in the source area. The resultant debris flow traveled down the path that was smoothed and cleared of vegetation by the previous event. John Micetic, by then on the scene at Highway 145, reported that a three-to-six-ft high wave of material moved "at least 30 miles per hour" across the highway, which at that time was covered by up to 8 ft of debris from the earlier flow. Mr. Micetic described the sound as "the passage of six jet planes overhead" and observed approximately three more surges of material following this event.

This second series of debris flows partially destroyed the facilities of Animas Aggregate. Two 9 cu. yd. concrete mixer trucks were partially buried, and "tossed around like toys". Four 10 cu. yd. dump trucks were completely buried in a gravel pit near where they were parked. The office and maintenance shop (with another truck inside it) were ripped off their slab foundations, and totally destroyed. A trash compaction facility and garbage truck were also destroyed, and several other vehicles were severely damaged. A large propane tank and diesel storage tanks were narrowly missed.

Various estimates of damages were made. Damage estimates for Animas Aggregate are on the order of $1.5 million, and airport design consultant Greg Isbill gave the Telluride Airport Authority an estimate of $250,000 to $500,000 to repair the landslide scar area.

DESCRIPTION OF DEPOSITS

The final configuration of debris in the runout zone was 3.5 to 4 ft thick on level ground, and deeper where it had filled pits and low areas. Approximately five acres were covered with an estimated total volume of 32,300 cu. yds. of debris. The highway was buried by 8 to 12 ft of debris over a 300-ft length, and required 12 hours to clear with front-end loaders.

The debris-flow deposits consisted of dark brown, sandy, silty clay and some gravel with gray and black shale fragments admixed. At the time of our investigation the deposits resembled wet, lumpy concrete, and were covered by a thin, dry crust. The underlying material was still quite wet.

Pieces of a geo-textile believed to be from the toe-drain system installed at the base of the fill, as well as several fragments of aqua-colored heavy-wall PVC pipe and couplings, were observed in the deposits.

During our investigation, we could not distinguish the deposits left by each of the individual events. There were no discernible differences in color, grain-size distribution, or consistency of material on the surface, or in excavations made in the deposits during salvage work at Animas Aggregate.

LANDSLIDE SCAR

Description

The landslide scar is located in a pre-existing landslide source area that had been partially filled by engineered materials (Figures 2 and 4, Plate 1). Portions of the runway and safety zone of the Telluride Airport are constructed on the fill, and the headscarp of the failure is in the fill (Figure 4B). The day following the event, the fill exposed in the headscarp was essentially dry.

The sides of the landslide scar extend from the toe of the fill 380 ft to the edge of the mesa. The u-shaped scar is 300 ft wide and 52 ft deep at its head, and narrows and thins to 130 ft wide and 2 to 3 ft deep at its lip (Plate 1).

The fill material presently occupying the scar consists of at least three main blocks which slumped into the scar following the landslide events, and which now remain on the base of the scar. It appears that these blocks mobilized at least partially along basal shear zones. The first block traveled at least 250 ft from the base of the fill prism. The second block traveled approximately 200 ft from within the fill prism and the third block traveled 150 ft from the head of the scar. On the day following the landslide, the slump blocks were not saturated and a nearly continuous surface of blocks of intact vegetation similar to that which exists on the outslope of the fill embankment was observed in the scar. In fact, it appears that most of the fill material from the runway embankment now remains in the landslide scar.

The slump blocks have obscured the failure surface(s) of the landslides and consequently it is difficult to reconstruct the sequence of events in the scar prior to the movement of the slump blocks.

A number of springs and surface drainages were observed contributing water to the landslide scar during our investigation. Springs and seeps were issuing water at the base of both sides of the scar at several points, as well as from numerous areas within the base of the scar. A spring in the northwest portion of the scar near the base of the fill was observed running muddy water on May 6 and 7, 1987. A spring only 2 ft to the east, and all others, were clear during this time.

Observable surface and subsurface flow was apparent at the time of our investigation coming from the broad east-west-trending swale and traveling into the west side of the scar. In this area, small blocks of material have slumped off the edges of the scar and formed a small debris flow that has traveled approximately 10 ft into the scar. Drill-hole 4 was drilled on May 7, 1987 and artesian flow, at a rate of approximately 0.5 gpm, issued from drill-hole 4. Artesian flow continued for at least several days afterward (Walter Vanderpool, personal commun., May 14, 1987).

It appears that the concentration of ground water associated with the springs in the source area is due more to the stratigraphic configuration of colluvial silty clay, sand, and gravel overlying relatively impermeable shale, than to the presence of the Vanadium fault. The fault is exposed in a topographically lower position in cliffs 1000 ft east of the source area, and was not observed to be associated with springs there.

Draining the Scar

On the morning of May 1, 1987, airport and emergency officials noticed that water was ponding behind the blocks of fill material that had slumped into the scar. Concern arose that should the bases of the blocks became saturated, they might mobilize into debris flows and thus cause further damage downslope. Rahe Junge of the Colorado Geological Survey was in Telluride on another matter at the time, and assisted in devising an emergency drainage plan to stabilize the material remaining in the scar. A series of connecting trenches were cut across the base of the scar to allow surface drainage for each of the ponds. Progressing upslope, each pond was then drained. John Micetic informed us that at least one small debris flow generated by the draining process crossed the highway 1,500 ft downslope.

A trench was also cut along the axis of the east-west-trending swale that drains into the landslide source area in order to channel water westward into the airport fire protection reservoir and away from the source area. An additional trench was excavated across the swale about 175 ft west of the source area to collect water that would otherwise drain into the scar. This drainage was then directed over the edge of the mesa.

STATUS

At the time of our inspection, it appeared that the drainage system was successfully dewatering the areas of concern within the source area. The potential for the remaining blocks of material to mobilize, and thus cause further damage, was dramatically decreased.

The remaining immediate hazard is the inevitable backwasting of the 52 ft high vertical scarp in the airport runway fill. The headscarp of the landslide scar cut into 13 ft of the airport safety zone, and a 50 ft-long tension crack has formed 35 ft back from the headscarp. Any additional slumping of the fill into the scar will affect the remaining safety area, and could possibly damage the runway. All parties involved in airport operations are aware that the fill embankment must be repaired as soon as possible to prevent further damage.

SUMMARY AND CONCLUSIONS

The Telluride Airport debris flows originated in a pre-existing landslide source area on the edge of Deep Creek Mesa. Deposits from previous slope movement are exposed 1,500 downslope from the scar in the road cut of Highway 145. Engineered fills were installed parallel to, and across, the head of the source area during airport construction. The fill was composed of Mancos Shale placed in thin lifts to a maximum thickness of approximately 70 ft. A gravel and pipe sub-drain system was constructed at the base of the fill on top of water-bearing colluvium. With available information we are not able to determine the depth or effectiveness of the drainage system.

The landslide source area was the site of numerous springs and seeps and had a marshy base. Ground water from Deep Creek Mesa and above travels through glacial and colluvial deposits that overlie the relatively impermeable Mancos Shale, and surfaces as springs in the source area.

Surface water also drained into the source area. In the days preceding the occurrence of the landslides a pond formed from snowmelt water in the east-west trending swale adjacent to the source area. Periodically, some of the water from the pond backed up through the swale and flowed into the west side of the source area. Surface drainage also entered the source area from the fill prism on its east side.

Our observations suggest that the failure event probably initiated well downslope from the toe of the fill within the saturated colluvial materials that occupy the source area. Water contributed by snowmelt and rainfall resulted in the generation of high pore-water pressures in the materials within the landslide source area. This increase in pore pressure was sufficient in the neck of the source area to initiate sliding movement there. Iverson and Major (1986) also suggest that debris-flows may initiate either by Coulomb failure or liquefaction, both generated by strong upward and convergent seepage forces. Such seepage forces may have been generated by movement of groundwater downslope through the colluvium and up over the sandstone ridge at the edge of the mesa (Figures 3 and 4). Such failure would have sent the first large wave of debris downslope, and removed support for the colluvium remaining in the source area.

The second landslide event, which occurred about one hour later, appears to have involved the colluvium remaining in the source area downslope from the toe of the fill prism, and the lower portion of the airport fill prism itself.

The final stages of failure involved slumping of the airport fill into the newly formed scar. Relatively dry blocks of fill slumped and at least partially mobilized along basal shear zones to allow for movement in the scar. Being essentially dry, these fill materials were not able to fully mobilize into debris flows.

The sequence outlined above is most consistent with field observations, the accounts of eyewitnesses, and the geometry and geology of the source area. The field evidence does not suggest that movement initiated in the saturated substrate directly beneath the fill prism. The fact that most of the fill material from the runway embankment remains in the landslide scar indicates that the main portion of the fill slumped into the scar subsequent to the second landsliding event.

The immediate hazard of potential movement of the blocks of fill material remaining in the landslide scar has been alleviated by a temporary surface drainage system. The remaining hazard is the inevitable backwasting of the 52 ft high headscarp into the safety zone of the runway, and possibly the runway itself. Surface and subsurface drainage of the area should be carefully evaluated and integrated with any proposed reconstruction.

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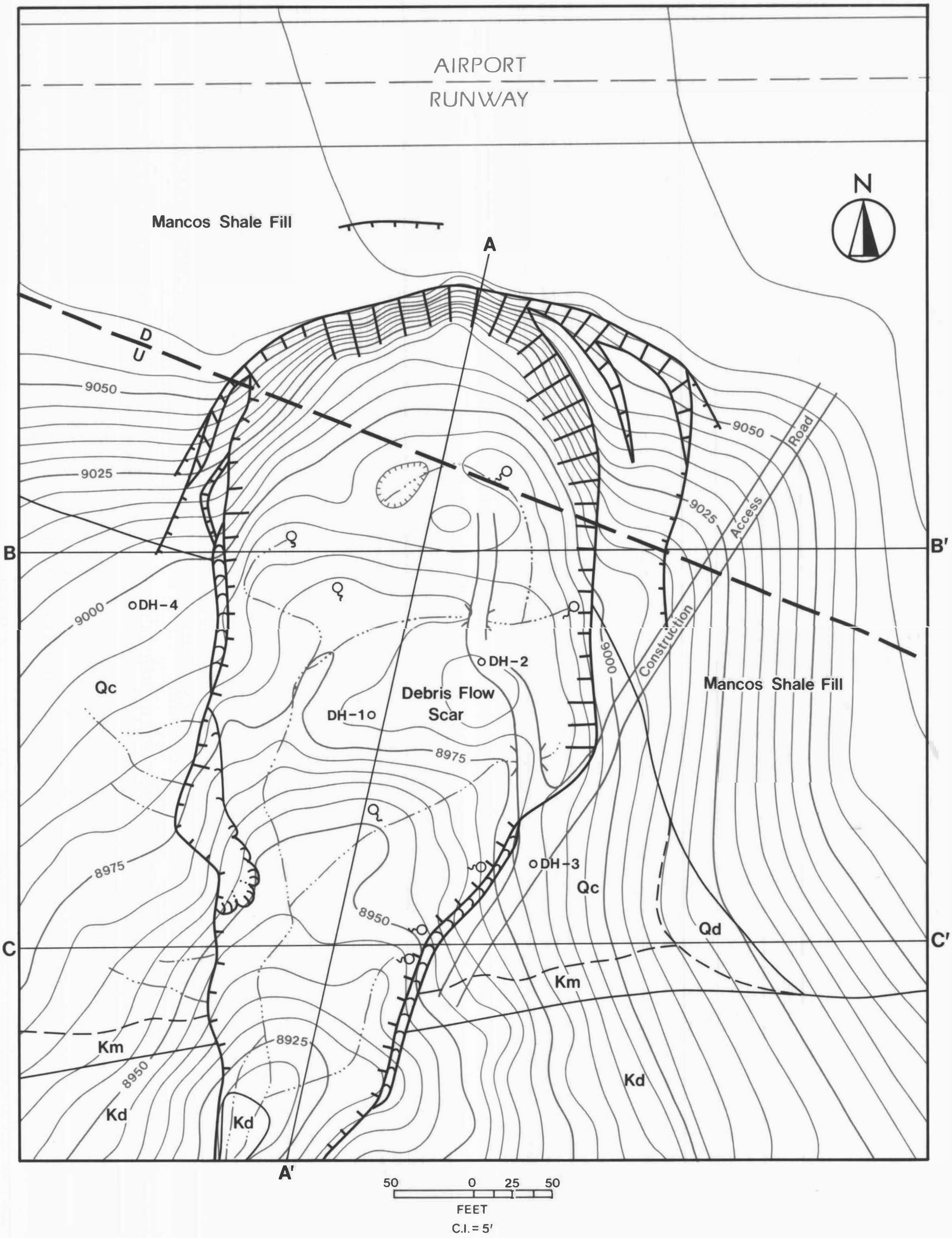
COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
JOHN W. ROLD, DIRECTOR

OPEN-FILE REPORT 87-2
PLATE 1
1987

Topographic and Geologic Map of the Telluride Airport Landslide

by Bruce K. Stover and Susan H. Cannon



EXPLANATION

Qc	Colluvium derived from glacial materials and Mancos Shale	○DH-2	Lincoln DeVore drill hole [May 6 & 7, 1987]
Qd	Glacial drift	⊤⊤⊤	Landslide scar-length of hatchures represent vertical depth
Km	Mancos Shale	┬┬┬	Crack
Kd	Dakota Group sandstones and shales	⌣⌣⌣	Secondary debris flow
—— – –	Contact, dashed where approx.	⊐⊐⊐	Berm
▬▬ ▬	Vanadium Fault, approx. location	○~	Area of spring or seep
A——A'	Line of cross-section	—···—	Surface drainage