UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Landslides and debris flows east of Mount Pleasant, Utah, 1983 and 1984

by

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Open-File Report 85-382

Prepared in cooperation with the Utah Geological and Mineral Survey
Contract Number 85-5016

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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Menlo Park, California

1985

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Introduction

In the mountainous terrain of central Utah, several hundred landslides, including debris flows[1], resulted from melting of above-normal snowpacks during the springs of 1983 and 1984. One area of abundunt landslide activity was along the western flank of the Wasatch Plateau, east of the town of Mount Pleasant (fig. 1). This study provides an inventory and discussion of the landslides that occurred during this period within this area.

Mount Pleasant is located in Sanpete Valley at an elevation of 5,924 feet (1,805 m). Two miles (3.2 km) east of town, the Wasatch Plateau rises abruptly from the valley floor to elevations over 11,000 feet (3,352 m). The transition between the Wasatch Plateau and Sanpete Valley is the Wasatch Monocline, a large flexure fold in which relatively flat-lying beds of the Wasatch Plateau bend down abruptly westward to pass beneath the floor of Sanpete Valley. This monocline trends approximately north-south and extends 10 miles (16 km) to the north and 45 miles (72 km) to the south of Mount Pleasant. Sedimentary rocks of late Cretaceous to Eocene age constitute the bedrock of this area.

Landslides were mapped in a 45 square mile (116 square kilometers) study area along the western flank of the plateau. The principal drainages in the study area are Twin Creek, Pleasant Creek, North Creek, Birch Creek, and Cottonwood Creek.

Acknowledgments

John Christensen, Chief of Police and Emergency Preparedness Director of Mount Pleasant, assisted in the logistics necessary for this study. He provided detailed accounts of the landslide events before my mapping began, provided the aircraft for aerial observations and photographs, and provided a county emergency-services radio so I could respond to flooding and landslide events as they took place.

[1]The term landslide is used in this report as a general term that includes debris flow and other types of slope movement, even where sliding is not the dominant process.

Study Methods

Most landslides were mapped in the field between May 21 and June 6, 1984. Location, size, and classification of landslides were recorded on U.S. Geological Survey 7.5-minute topographic maps. Snow and high stream runoff prevented access to some areas during this period. On May 30, 1984, observations were made and oblique photographs were taken from a small fixed-wing aircraft. From enlargements of these photographs, including those in figures 2-5, landslides were identified and mapped for areas in which ground observations were not possible. These photographs also provided a means of checking landslides that were mapped previously as well as identifying areas that needed further investigation. Between August 2 and August 7, 1984, field mapping took place for areas that had been inaccessible in the spring, and several of the drainages previously mapped from the aerial photographs were field checked.

For sites that were inspected in the field, a high level of confidence exists concerning the type of slope movement; these sites are designated by upper-case letters on plate 1. For sites that were not reached in the field but rather were either viewed from a distance, or mapped from oblique aerial photographs, the type of slope movement was determined by comparing morphologic features to those at field inspected sites. For example, narrow deposits extending long distances downslope were identified as debris flows, whereas deposits that appeared more or less intact and did not travel long distances were identified as slides. For these sites, designated by lower-case letters on the map, a moderate level of confidence exists concerning type of slope movement.

All landslides identified in this study occurred in 1983 and 1984, although features and deposits from older landslides are also present within the study area. For some of the mapped landslides, eyewitness accounts permit determination of the year or date of occurrence. For others the date can be determined by inspecting the deposits. For example, debris-flow deposits observed during the field reconnaissance that were still wet and would not support weight applied to the surface are assumed to have occurred during the spring of 1984. Similarly, deposits that were dry and showed signs of new vegetation were assumed to have occurred prior to 1984. However none of the mapped features showed sufficient revegetation or modification to imply occurrence prior to 1983. Furthermore, reports from residents of Sanpete County indicate that landslide activity began in the spring of 1983. Based on such evidence, a high level of confidence exists that the landslides included in this study occurred in 1983 and 1984. It is possible that some sites experienced movement during both years; these sites would be shown on plate 1 as having occured in 1984. If the year of occurrence was not determined no date is assigned.

Landslide Description

Most landslides in this inventory occurred within the soil mantle overlying weathered bedrock. The landslide deposits therefore consist of a mixture of soil, water, and organic debris (where hillsides are vegetated). The proportions of these constituents were not evaluated, and there was no systematic sampling of the deposits to determine grain-size distribution. For these reasons the materials, which are largely granular soils are simply referred to as debris, and the landslides are classified solely on the basis of type of movement. The processes include slides, both translational and rotational, and flows (Varnes, 1978). Most of the debris flows developed from debris slides, and where this complex process occurred the feature is mapped as a debris flow. Landslides were mapped as debris slumps only if rotation was distinct; where rotation was questionable they were mapped as translational slides. Block slides were mapped only where the slip surface appeared to be within bedrock and the material moved for the most part as a single unit (fig. 2).

The landslides range in size from debris flows up to 3.8 miles (6 km) long, to debris slides having displacement less than 15 feet (5 m). Most landslides are mapped to scale on the 1:24,000 base map. For this reason landslides smaller than approximately 30 feet (10 m) (largest dimension) were not mapped. Therefore, the width of some particularly narrow debris flows may not be accurately represented.

Potential for Future Activity

Based on theoretical considerations and on observations of the 1983 and 1984 events, it is possible to evaluate the potential for future activity. This evaluation assumes that future climatological conditions like those of 1983 and 1984 will result in similar landslides. In addition, this evaluation considers the potential for future activity resulting from the landslides that have occurred during 1983 and 1984. The potential for future activity is evaluated by discussing the types of landslides and the conditions under which they should occur in the future.

Debris slides

The debris slides that occurred in 1983 and 1984 resulted from rapid influx of moisture to the soils. This moisture resulted in high pore-water pressures and/or perched ground-water levels that produced sufficient loss of shear strength to permit movement. The conditions critical to the initiation of landslides of this type are an above-normal snowpack and a rapid melting rate. Of these, the rate at which the snow melts appears to be the dominant factor; if the snow melts over a long period, pore-water pressures may not build up enough to cause landsliding.

Based on these considerations, debris slides would be most likely to occur during the spring months in response to snowmelt. Most importantly, if there is a long, cool, and wet spring extending into late May or June, there is an increased likelihood that the snow will melt quickly, resulting in high potential for debris slides. These landslides will probably occur in similar habitats to those of 1983 and 1984 and will be of approximately the same size.

Block slides

The potential for future movement of block slides depends more on the total amount of precipitation than on the rate at which this precipitation enters the ground. A long period of time may be necessary for water to reach the deep slip surface. The time required is greater than debris flows because of both the greater distance the water must travel and the decreased hydraulic conductivity of bedrock compared to soils. Whereas debris slides require only a few days or weeks for influx of water to result in hillside instability, large block slides may require a few weeks to several months. This in part explains why the block slide in the lower reaches of Birch Creek (fig. 2), which was first observed to be moving in May 1984, showed signs of movement through August 1984, long after the snow had melted. High pore pressures must have existed at the slip surface during this time period due to the slow influx of water from snowmelt higher up the slope. It is also possible that heavy snowfall during the two previous years elevated the regional ground-water level resulting in the continued instability of the hillside. In either case the movement will probably continue to be dependent on the total amount of water at this site.

Based on these considerations, it is likely that the block slides in this study area will continue to move in the future in response to the total amount of precipitation. The movement will probably not be confined to times of snowmelt. If regional-ground water levels are elevated future movement is likely until ground-water levels drop, which may require one or more years of normal to sub-normal precipitation.

Debris flows

Because debris flows in the springs of 1983 and 1984 resulted from mobilization of debris slides, it follows that the time of greatest potential for such debris flows coincides with the times of greatest potential for debris slides. It is likely that future debris flows of this kind will be of similar size to those that occurred in 1983 and 1984.

In addition to the debris flows that resulted from debris slides one large debris flow resulted on July 24, 1984, from mobilization of channel material during an intense thunderstorm

(Blue Slide Fork, Pleasant Creek). The source material for this debris flow was the loose, unconsolidated deposit of a debris flow that had occurred earlier in the spring. In evaluating the potential for events similar to this, two factors must be considered: a sudden increase in discharge in a stream, and accumulations of material available for mobilization. With regard to suddenly increasing discharge, one possibility is an intense local summer thunderstorm, similar to that of July 24, 1984. Such thunderstorms are not rare during the summer months in this area. Another manner in which discharge might suddenly increase is if a landslide were to temporarily dam the stream, creating an accumulation of water, which can surge down the channel when the dam is breached. Because both thunderstorm and landslide dams are difficult to predict the potential for debris flows of this type is best evaluated by considering the amount of unconsolidated material in the channel bottom. Such material commonly results from landslide activity, especially stream-bank slumps and slides in channels recently scoured by debris-flow activity. One drainage which has a large amount of loose material in the channel bottom, and hence a high potential for a debris flow of this type, is the PC Fork of North Fork of Birch Creek. Other drainages can be evaluated similarly.

Size limitation

Although the events of 1983 and 1984 provide an indication of the types of events that may occur in the future, they should not be taken as the limiting cases, especially when considering size. For example, the longest debris flow mapped in this study traveled approximately 3.8 miles (6 km) from it's source in the channel until coming to rest in the Mount Pleasant Upper Debris Basin. The amount of material deposited in the basin suggests that this debris flow would have traveled further if the basin had not been present; in 1946, before the basin was built, a debris flow traveled to at least the town of Mount Plesant, 3.5 miles (5.6 km) below the basin. Hence these canyons have the potential to produce debris flows that can extend farther beyond the canyon mouths than those that occurred in 1983 and 1984. Similarly, even though the block slide on the lower reaches of Birch Creek is relatively large it does not represent the largest landslide that can occur in this region; during reconnaissance some large old landslide deposits were recognized. These deposits may represent truly exceptional events, but it must be recognized that such events are possible.

Summary

The landslides and debris flows described in this study resulted from a distinct sequence of climatological events. If these events are repeated in the future, landsliding and debris flow activity should be expected.

Some hillsides are less stable as a result of slope movement during 1983 and 1984, these in particular have potential for future movement. Some stream channels have a higher potential for debris flows now than they did prior to the events of 1983 and 1984. It is therefore likely that landslide and debris-flow activity will recur in this area when climatological conditions permit.

Further investigations are necessary to delineate potentially hazardous parts of this study area. It is recommended that local governmental agencies monitor conditions on the hillsides, especially during the spring and early summer. Careful observations by trained individuals may detect slope movements that pose a threat to life or property. Furthermore, instrumentation of some hillsides should be considered as a means of monitoring movement of the large block slides.

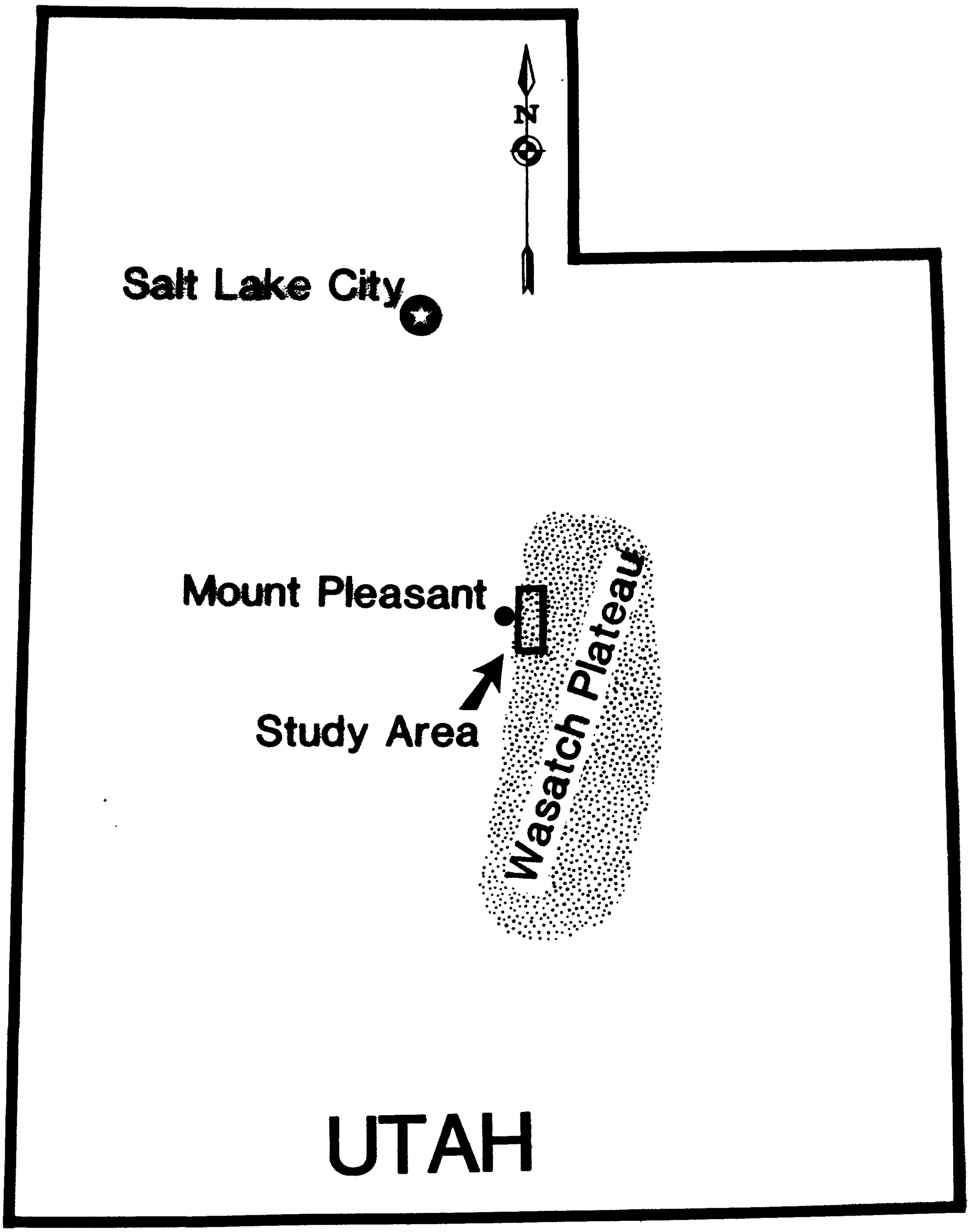

Figure 1. Approximate Location of Study Area

Figure 2. Birch Creek.

Oblique aerial photograph showing the north-facing slope in lower reaches of Birch Creek. The beds of the Wasatch Monocline are seen dipping westward toward Sanpete Valley, which appears at upper right. The large landslide in the center is believed to have a slip surface within bedrock, and is therefore identified as a block slide. The movement of the block slide has generated some debris slides, left center and right center, and also a debris flow, far left. Small stream-bank debris slides can be seen at foot of slope in right and left center.

Figure 3. South Fork of Birch Creek

Oblique aerial view showing drainage basin of the South Fork of Birch Creek. Scars on the hillsides are debris slides that have mobilized into debris flows. Some flows traveled short distances down hillsides, whereas other flows reached the channel bottom. In the lower reach of the channel, fresh sediment is accumulating from recent debris flows. Most debris slides occurred in either topographic planar parts of hillsides or in gentle swales. The debris flows farthest up the canyon, on the right, occurred near the snow line, demonstrating the rapid response of soils to influx of melt water.

Figure 4. South Fork of North Creek and North Fork of Pleasant Creek

Oblique aerial photograph looking northeast over the Wasatch Plateau. South Fork of North Creek is shown in the center and North Fork of Pleasant Creek in the lower right. The debris flows in the North Fork of Pleasant Creek occurred in gentle swales and first order drainages near the ridge crest. The large debris flow at left center, which occurred in 1983, traveled 2.9 miles (4.6 km). Debris flows in upper reaches of South Fork of North Creek occurred as the snow line receded up the hill. The debris flows at lower elevations in the basin occurred earlier in the spring as the snow line receded.

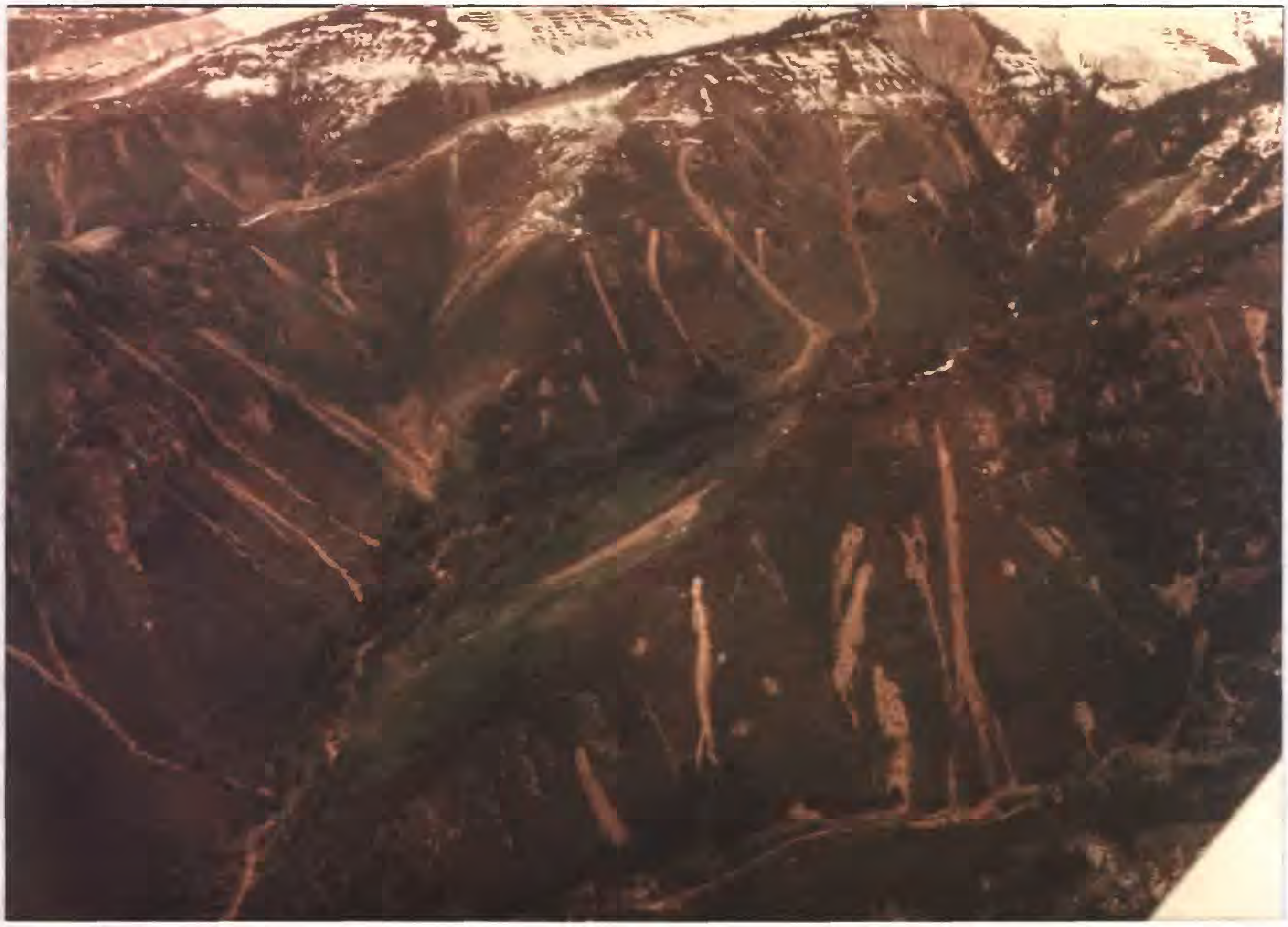

Figure 5. Blue Slide Fork of Pleasant Creek and Straight Fork of Pleasant Creek

Oblique aerial view showing the drainages of Blue Slide Fork of Pleasant Creek (center) and Straight Fork of Pleasant Creek (lower right). Some debris flows and debris slides in Straight Fork of Pleasant Creek have deposited material in the channel bottom and this material has the potential to mobilize into debris flows in the future. A similar situation in Blue Slide Fork of Pleasant Creek resulted in the large debris flow on July 24, 1984.

REFERENCES

Varnes, D. J., 1978, Slope movement types and processes, _in_ Schuster, R. L., and Krizek, R. J., eds., Landslides--analysis and control: Transportation Research Board Special Report 176, National Academy of Sciences, p. 12-33.

Wieczorek, G. F., 1982, Map showing recently active and dormant landslides near La Honda, central Santa Cruz Mountains, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1422, scale 1:4,800.