LANDSLIDES OF UTAH
by

John F. Shroder, Jr.

THE GREAT SEAL OF THE STATE OF UTAH
1847
1896

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
affiliated with
THE COLLEGE OF MINES AND MINERAL INDUSTRIES
University of Utah, Salt Lake City, Utah

SEPTEMBER 1971 PRICE $2.50 BULLETIN 90

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LANDSLIDES IN UTAH

by

John F. Shroder, Jr.[1]

ABSTRACT

Approximately 600 landslides have been identified in Utah. These geologic hazards have been studied to provide information about their causes and distribution and their relation to slope exposure, climate, rock type and age. Descriptive and landform nomenclature, a simplified classification and criteria for assessing geomorphic age have been developed to facilitate work with them. Twenty-eight individual landslides and four landslide zones in which individual landslides cannot be distinguished are described in the appendix.

The primary cause of landsliding is the lithology, argillaceous sedimentary rocks which either commonly contain bentonite or which underlie massive sandstones, conglomerates or basalts. Most of the landslips have occurred in the Canyonlands section of the Colorado Plateau province because of the common occurrence there of these rock types. Cretaceous and Tertiary formations have produced the majority of movements. The largest number of landslips occurs between 6,000 and 8,000 feet. This elevation range is widespread and has steep slopes, high relief and moderate precipitation.

Approximately 83 landslips occur on each slope exposure except on the drier south- and southwest-facing slopes which have an average of 50. One-fourth of the landslides occur in areas with 12 to 16 inches of annual precipitation. The majority occur in midlatitude semiarid and humid microthermal climate zones. During the colder and wetter parts of the Pleistocene, when many of the landslips occurred, the dry climates were much reduced and landslides occurred primarily in the more humid climates.

INTRODUCTION

A landslide is a dramatic event precipitated by extremes—freeze-and-thaw, a cloudburst, an earthquake—and then the law of gravity takes over.

The stage is set, quietly, however, for this event by a series of circumstances—a combination of lithologies, accumulation of groundwater, angle and compass direction of a slope, mechanical disturbance—the raw material, so to speak for the drama to come.

The drama may ensue as a result of a series of natural events or of intervention by man. A highway cut which removes the toe of a slide may cause the mass to move again. If a highway undercut destroys the equilibrium of an earth mass, a landslide will follow. Dam construction rearranges land and water and may start movement. Disturbing a hillside for subdivision development may create an economically disastrous situation.

Those concerned with the physical and economic development of Utah are interested in the role of landslides, past and future, in this development. Classification, description and nomenclature of slides, their sculpting of landforms, the influence of slope exposure, elevation, formation, lithology and geomorphic province, precipitation amounts and distribution, and past and present climates, are the subject of this study.

A large concentration of landslides occurs along the Wasatch Line. This zone is seismically active, and the great relief and relatively high precipitation facilitate sliding.

Landslides in Utah fall into two groups: individual landslides and landslide zones in which individual landslides cannot be distinguished. Twenty-eight individual landslides and four landslide zones throughout Utah were studied in the field. Individual landslides provided information on the processes of mass movement; the landslide zones gave an overall view of the role of mass movement in the production and modification of landforms.

The most common type of landslide studied in the field is the complex blockslide and debris-flow. Landslides known as Boars Tusk, Goslin Mountain, Thistle, York, Elbow, Green Hollow, Square Mountain, North Roundy, Dry Hollow, South Roundy and Dry Canyon, and the four landslide zones, Fish Lake Plateau, Thousand Lake Mountain, Boulder Mountain and Mount Peale, are largely of this type. The widest individual slides, South Roundy, Elbow and Goslin Mountain, average 10,000 feet in width. Montezuma Canyon landslide zone has the greatest width of all the reported landslide zones in the state (about 82 miles). Thompson Creek is at least four miles long, the longest in the state. The thickest known slide is Graveyard Flat, about 300 feet. This slide piled up in a steep-sided narrow valley. The largest volume of an individual landslide in the state

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is Thompson Creek, at least 1 billion cubic yards. The largest volume of a landslide zone is probably the Boulder Mountain landslide zone, about 18 billion cubic yards.

The main scarp of Thompson Creek is about 2,000 feet high, the largest main scarp of the individual landslides.

The formations most commonly involved in landsliding are the Chinle, Morrison, Tropic and North Horn formations, and an unnamed limestone and tuffaceous sandstone which may be equivalent to the Flagstaff Formation. Contractors would be advised to use utmost caution in construction in areas where these formations crop out.

Most of the landslides described in the appendix have been stable for a long time. Exceptions are Currant Creek, unstable and creeping slowly; Little Creek Peak, which slid within historic time because of a combination of faulting, tuffaceous sedimentary rock and heavy rains; Mount Terrel, which probably moved within historic time; Thistle, which moved at various times in the Pleistocene and Holocene; Washington Terrace, active until recently, with some minor slump and flow now in the spring. Fish Lake Plateau zone, Thousand Lake Mountain zone, and Boulder Mountain zone all have had some minor recent landsliding. These three areas are all high and remote from population concentrations.

Many old landslides could become active again if precipitation increased or if man altered ground-water or shear-strength characteristics. In general, however, the sites of old slides are stable and likely to remain so.

CLASSIFICATION OF LANDSLIDING

The terms *landslide* (American usage) and *landslip* (British usage) are usually considered synonymous and are generally applied only to the larger perceptible downslope movements of rock and earth materials. The term *landslide* should be restricted and used as little as possible because it implies a sliding movement to the exclusion of falling and flowing. Nevertheless, although *landslip* is preferable, *landslide* is so firmly entrenched in the literature and in common usage as to be virtually immutable. Both terms will therefore be used throughout this paper.

The terms *mass wasting* and *mass movement* are often used interchangeably for downslope movement of rock materials due to gravity. Savage (1968, p. 696), however, restricts the term *mass movement* to the movement of large masses as a unit (landslips) and thereby excludes mass-wasting phenomena such as creep, solifluction, talus accumulation and other imperceptible or small-scale movements of colluvial material.

Many classifications of mass wasting and mass movement have been proposed over the years (Sharpe, 1938; Varnes, 1958; Hutchinson, 1968; Savage, 1968). In general, the classifications have tended to use type of movement and type of material as their basis. The classification used herein (figure 1) is a modification of that of Varnes (1958), and all terms used herein are as defined by him with the exception of the following changes. The primary alteration is the substitution of the geological terms *debris* and *earth* for the engineering term *soil*. *Earth*, as used herein, connotes material with about 80 percent or more of fragments smaller than 2 mm in size, *debris*, about 20-80 percent of the fragments greater than 2 mm in size and the remainder less than 2 mm, and *rock* connotes 80 percent or more of the fragments more than 2 mm in size. In addition, *blockslide*, a new term, means slides involving rotational slump-block and tilt-block movements as well as planar glide-block and ridge-block movements (figure 1).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
KIND	RATE	ROCK	DEBRIS	EARTH
Falls	Very rapid	Rockfall	Debris-fall	Earthfall
Few units *Slides*	Slow to very rapid	Blockslide		
Many units		Rockslide ✓	✓ Debris-slide	Failure by lateral spreading
Dry	Slow to very rapid	Rock fragment-flow or avalanche		Sand-run Loess-flow
Flows			Debris-avalanche	Slow and rapid earth-flow
Wet			✓ Debris-flow	Sand- or silt-flow Mud-flow
COMPLEX		Combinations of materials or types of movement		
UNKNOWN		Rockslip	Debris-slip	Earthslip

Figure 1. Classification of mass movement (adapted from Varnes, 1958, figure 5). The term *blockslide* means slides involving rotational movement of slump and tilt blocks and nonrotational planar movement of ridge and glide blocks. Subsidence and subaqueous movements are not included in this classification.

Application of the classification is easy as long as the type of material and type of movement are known. Difficulties arise, however, in classifying old landslips in which surficial erosion and interior weathering and cementation have subsequently obscured the original characteristics of the mass. It is commonly difficult to classify a landslip in which the original bedrock has been extensively pulverized during transport. Thus an initial rockslide could ultimately be classified as a debris-slide if much of the rock material were finely ground. In all such cases, the mass is classified according to its existing characteristics regardless of possible pre-slip characteristics.

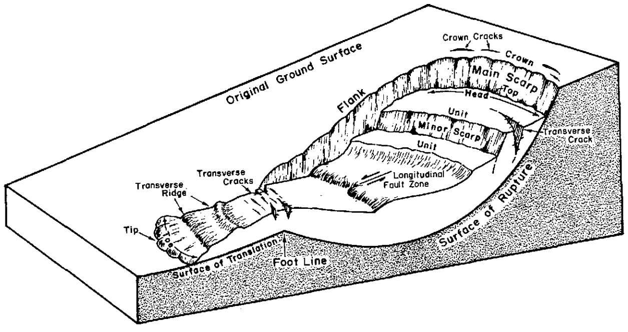


Figure 2. Anatomy of a landslide (adapted in part from Varnes. 1958, plate 1-t).

DESCRIPTIVE NOMENCLATURE FOR LANDSLIDES

The nomenclature of landslides has long been informal and vague. Varnes (1958, plate 1-t) was the first to formally name and describe the parts of a landslide. His definitions follow:

Main scarp–a steep surface on the undisturbed ground around the periphery of the slide, caused by movement of slide material away from the undisturbed ground. The projection of the scarp surface under the disturbed material becomes the surface of rupture (slip surface).

Minor scarp–a steep surface on the disturbed material produced by differential movements within the sliding mass.

Head–the upper parts of the slide material along the contact between the disturbed material and the main scarp.

Top–the highest point of contact between the disturbed material and the main scarp.

Toe–the margin of disturbed material most distant from the main scarp.

Tip–the point on the toe most distant from the top of the slide.

Flank–the side of the landslide.

Crown–the material that is still in place, practically undisturbed, and adjacent to the highest parts of the main scarp.

Original ground surface–the slope that existed before the movement which is being considered took place. If this is the surface of an older landslide, that fact should be stated.

Left and right–compass directions are preferable in describing a slide, but if right and left are used they refer to the slide as viewed from the crown.

Varnes (1958, plate 1-t) originally defined the foot as the "line of intersection (sometimes buried) between the lower part of the surface of rupture and the original ground surface." H. D. Goode (personal communication) pointed out that the definition of the foot as a line is poor because the common connotation of the term would require it to apply to a definite part of the slide and not to a boundary between two parts. Consequently, I have herein changed Varnes's term *foot* to *foot line* in order to fit his definition, thus:

Foot line–The line of intersection (generally buried) between the lower part of the surface of rupture and the original ground surface.

The term *foot* should be used as an alternate for the *area of translation.*

Davis and Karzulovic (1963, p. 1404) assigned the term *crown cracks* to the fractures often found in the relatively undisturbed crown area of the slide. They also applied the term *unit* to a given portion of a landslide having a similar structure. A *block* is an individual mass which may have fractured but not separated during movement.

In addition to these terms, I herein apply the term *surface of translation* to the original ground surface

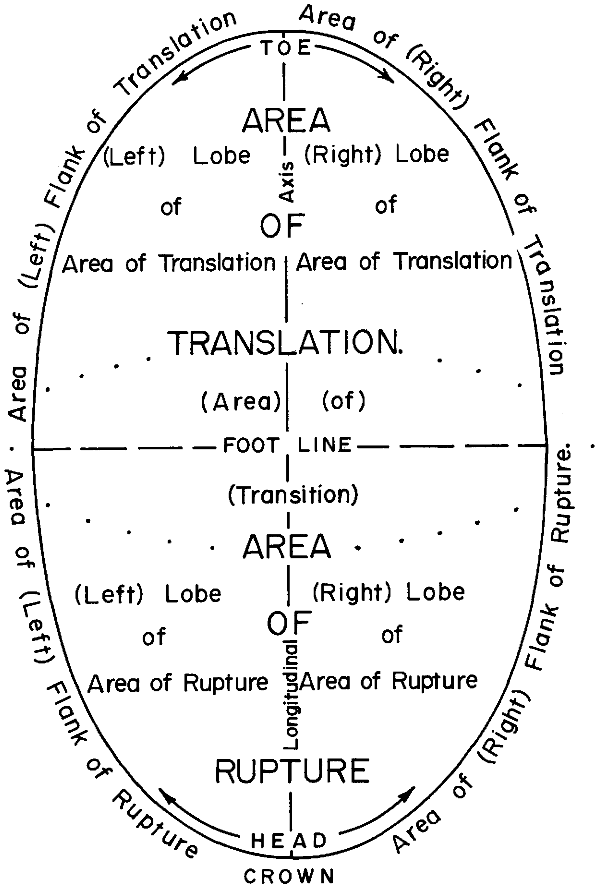


Figure 3. Diagram of landslide showing nomenclature developed to facilitate discussion of areal portions of a slide. See text for definition of terms.

Table 1. Lithologies involved in landslides in Utah.

Lithology	Individual Landslides[1]		Landslide Zones[2]		Total	Percent
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field		
Sandstone and/or conglomerate over mudstone[3] (bentonitic in part)	11		214	56	281	47
Mudstone[3] (may be bentonitic)	78	8		12	98	17
Basalt over limestone and tuffaceous sandstone	5	1		87	93	16
Carbonates	22	6		3	31	5
Conglomerate	9	1		12	22	4
Undivided volcanics (largely flow rocks)	21	2			23	4
Quartzite	18	1			19	3
Sandstone	14	6			20	2
Granite	1				1	
Tuffs, agglomerates, quartz latite, latite, quartz diorite porphyry, quartz monzonite, tillite, volcanic ash	5	2			7	2
Unknown	4				4	
Total	188	27	214	170	599	

[1] Number of landslides which involve given lithology.
[2] Miles of landslide (width of head) involving given lithology.
[3] Refers also to siltstone, claystone and shale.

below the foot line over which the slide has moved. The surface of translation and the surface of rupture together make up the slip surface. Most of the above terms are applied to the idealized landslide in figure 2.

Some designation is needed for the areas on the surface and environs of a landslide. Accordingly the following terms are herein introduced and illustrated in figure 3:

Area of rupture—The surface area of a slide which lies vertically above the surface of rupture and is bounded by the flanks, crown and projection of the foot line to the surface. If no landslide material remains above the foot line there is no area of rupture.

Area of transition—The surface of a slide which may lie partially above the surface of rupture or partially above the surface of translation or both. This term designates the vertical surface above the foot line where the nature of movement from rupture to slide, flow, fall or glide.

Area of translation (foot)—The surface area of a slide which is above the surface of translation and which is bounded by the flanks, toe and projection of the foot line upon the surface.

Areas (right and left) of flanks of rupture—The areas of original ground surface which border the slide between the foot line and the crown. Compass directions should be substituted for right and left.

Areas (right and left) of flanks of translation—The areas of original ground surface which border the slide between the foot line and the toe.

Longitudinal axis—The imaginary surficial line extending from the middle of the crown, through the center of the projection of the foot line upon the surface, to the middle of the toe.

Right and left lobes of the area of rupture—The areas bounded by the flanks of the area of rupture, the projection of the foot line upon the surface, and the crown.

Right and left lobes of the area of translation—The areas bounded by the flanks of the area of translation, the projection of the foot line upon the surface, and the toe.

In an occasional landslide it might be necessary to divide the area of transition into right and left lobes of transition above the foot and right and left lobes of transition below the foot.

NOMENCLATURE FOR LANDFORMS PRODUCED BY LANDSLIDES

Numerous landforms produced by landslips have been given formal names in the literature and will not be described further. New and useful terms, however, are listed herein (Shroder, 1968).

Landslide (landslip) block—any large mass which moves as a unit without breaking up. Landslip blocks include the *slump block* (Toreva-block of Reiche, 1937), with backward rotation in the direction of movement, the *tilt block*, with forward rotation, the *ridge block* (Watson and Wright, 1963, p. 532), with nonrotational downward and possible outward movement due to removal of underlying material, and the *glide block*, with nonrotational movement along a bedding plane or other planar surface.

Landslide (landslip) outlier—a disconnected erosional remnant of a formerly larger landslip mass.

Landslide (landslip) erratic—a boulder located apart from a landslip because of erosion of the mass from around it.

Landslide (landslip) levee—the linear ridge piled up along the flanks of a rapidly moving, commonly wet and fluid flow of debris or earth.

Landslide (landslip) col—a low pass through a ridge produced by the near junction of two back-to-back landslips.

Landslide (landslip) plateau—a plateau surrounded by and owing much of its topography to landslips which are commonly of the complex blockslide and debris-flow type. This landform commonly has a cuspate scarp and a lower *landslide (landslip) bench* (Yeend, 1966B, p. 60) surrounding it.

Landslide (landslip) blade or ridge—a residual linear ridge produced by back-to-back landsliding.

Table 2. Cenozoic formations involved in landslides in Utah.

Formation Q–Quaternary T–Tertiary TK–Cretaceous-Tertiary	Individual Landslides[1]		Landslide Zones[2]		Total
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field	
Q Gravel deposits				12.0	12.0
Q Provo Fm.	2.0				2.0
Q Bonneville Fm.	0.3				0.3
Q Alpine Fm.	0.3	1.0			1.3
T Salt Lake Group	1.3				1.3
T Sevier River Fm.	2.0				2.0
T Brian Head Fm.		1.0			1.0
T Bishop Conglomerate	4.1				4.1
T Duchesne River Fm.	1.0				1.0
T Uinta Fm.	1.0	0.5			1.5
T Green River Fm.	3.0	0.3		2.3	5.6
T Colton Fm.		0.7			0.7
T Flagstaff Fm.	5.3	1.2		3.2	9.7
TK North Horn Fm.	20.3	0.8		9.0	30.1
T Knight Fm.	1.5				1.5
T Currant Creek Fm.		0.5			0.5
T Bald Knoll Fm.	1.0				1.0
T Bullion Canyon volcanics	12.5	0.8			13.3
T Dry Hollow Fm.	4.5	0.8			5.3
T Laguna Springs latite		1.0			1.0
T Packard Quartz latite	1.0				1.0
T Quartz monzonite of Little Cottonwood stock	0.5				0.5
T Undivided volcanics	3.8	0.3			4.1
T Basalt over limestone and/or tuffaceous sandstone	5.0	1.0		87.5	93.5
Total	72.9	9.9	00.	114.0	194.3

[1] Number of landslides which involve given formation; decimals refer to division of one landslide when it involves several formations.

[2] Miles of landslide (width of head) involving given formation.

Landslide (landslip) peak–an isolated residual peak produced by landsliding all around it.

GEOMORPHIC AGE AND LANDSLIDES

In general, youthful landslips are characterized by freshness of appearance and lack of weathering, mature landslips by the blunting of features due to erosion and vegetative encroachment, and old landslips by a general removal of typical landslip landforms.

Features indicative of age are modified by variables–amount and type of precipitation, temperature changes, presence of groundwater, compass direction of slopes, degree of slope and lithology of the moving mass and of its substrate.

LITHOLOGIES INVOLVED IN LANDSLIDING IN UTAH

A compilation of the rock types involved in large-scale mass movements in Utah shows that argillaceous sedimentary rocks overlain by compact, well-indurated rocks are the chief lithologies associated with landslips (Shroder, 1970).

The greatest frequency of movement is related to a compound lithology of sandstone or conglomerate or both which overlie mudstone that is commonly bentonitic. This lithologic grouping occurs in 281 landslips; the Kayenta and Wingate over the Chinle Formation and the Dakota Sandstone and Burro Canyon Formation over the Brushy Basin Member of the Morrison Formation (table 1) are frequent combinations.

Mudstone, which may be bentonitic in places, and basalt, which overlies limestone and tuffaceous sandstone, are associated with the next two greatest frequencies, 98 and 93 landslips, respectively.

Carbonates, conglomerates, volcanic flow rocks, quartzite and sandstone follow in frequency with an average of 23 landslips apiece.

All other lithologies are associated with fewer than three landslips apiece.

FORMATIONS INVOLVED IN LANDSLIDING IN UTAH

Compilation of the formations involved in landsliding in Utah (tables 2–5) demonstrates a correlation between specific formations and landsliding.

Landslides occurring in Tertiary formations are approximately equal in number to those of the Cretaceous. The exact number depends on how the 30 landslides in the Cretaceous-Tertiary North Horn Formation are counted. If these 30 are divided equally between Cretaceous and Tertiary, then Tertiary landslides total 169 and Cretaceous 163.

The large outcrop area of Cenozoic rock in Utah (61 percent of total area) compared to the outcrop areas of all the other eras combined, greater lithologic unconsolidation than in older formations and the high stratigraphic and topographic positions in regions with greater precipitation and relief, all help to account for the high incidence of landslides in the Tertiary.

The large number of landslides in the Cretaceous may be explained by the high proportion of argillaceous

Table 3. Mesozoic formations involved in landslides in Utah.

Formation K–Cretaceous J–Jurassic TR–Triassic	Individual Landslides[1] Reported in Literature	Individual Landslides[1] Investigated in Field	Landslide Zones[2] Reported in Literature	Landslide Zones[2] Investigated in Field	Total
TK Quartz diorite porphyry	2.5				2.5
K Echo Canyon Cgl.	0.5				0.5
K Henefer Fm.	1.0				1.0
K Frontier Fm.	5.2	0.2			5.4
K Aspen Fm.	0.2				0.2
K Kelvin Fm.	0.2				0.2
K Blackhawk Fm.	1.0				1.0
K Wahweap Ss. and volcanic ash	1.0				1.0
K Straight Cliff Ss.	0.5	2.0			2.5
K Tropic Fm.	18.5	4.0			22.5
K Mancos Sh.	4.5				4.5
K Mowry Sh.		0.2			0.2
K Undivided Dakota-Tropic	0.5				0.5
K Dakota Ss.	2.0	0.2	31.2	18.7	52.1
K Burro Canyon Fm.	4.5		31.2	18.7	54.4
J Brushy Basin Mbr. of Morrison Fm.	4.5		31.2	18.7	54.4
J Morrison Fm.	1.7	0.2			1.9
J Carmel Fm.	0.5				0.5
J Twin Creek Ls.	2.2				2.2
J Navajo Ss.	2.0	0.5			2.5
TR Kayenta Fm.		0.5	40.0		40.5
TR Wingate Ss.			40.0		40.0
TR Moenave Fm.		0.5			0.5
TR Chinle Fm.	6.1	0.5	40.0		46.6
TR Shinarump Cgl.	0.3				0.3
TR Ankareh Fm.	1.3	1.0			2.3
TR Thaynes Fm.	1.0				1.0
TR Moenkopi Fm.	0.2				0.2
Total	61.9	9.8	213.6	56.1	341.4

[1] Number of landslides which involve given formation; decimals refer to division of one landslide when it involves several formations.
[2] Miles of landslide (width of head) involving given formation.

sediments contained within its sections. The Mowry, Mancos and Aspen shales and the Tropic Formation all contribute to sliding within the Cretaceous, as also does the Jurassic Morrison Formation which immediately underlies the Cretaceous.

The Triassic has a large number of landslips (132), largely because of the unstable bentonitic shales and mudstones of the Chinle Formation.

The Mississippian has the highest proportion of landslips (22) among the Paleozoic rocks, largely due to the massive carbonate beds that overlie such incompetent units as the Manning Canyon Shale, undivided shale units and interbedded shales.

The Precambrian has the smallest number of landslips (28) of any era, due in part to the denseness and greater strength of the commonly metamorphosed rocks and in part to their limited outcrop area. The Red Pine Shale accounts for the largest number of landslips; the remainder of the slips are associated with faults and river undercutting.

ELEVATIONS OF LANDSLIDES IN UTAH

The relief of Utah may be divided into four zones according to altitude: 2,000-6,000 feet, 6,000-8,000 feet, 8,000-10,000 feet and 10,000 to 14,000 feet. Figure 4 and table 6 show distribution of landslides in Utah.

EXPLANATION

Figures 4, 6, 7, 8 and 9

Individual landslides

∘ Size not reported[1]

○ Less than 1 million cubic yards[2]

8 ⊖ 1 million to 1 billion cubic yards[2]
Numbers correspond to landslides below

Landslide zones

⊕ More than 1 billion cubic yards[2]

⬭ More than 1 billion cubic yards[2]
Long axis of ellipse indicates general orientation of zone

Arrows indicate generalized direction of movement

[1] Reported in literature

[2] Investigated in field

Individual landslides

1. Ingham Peak landslide
2. Washington Terrace landslide complex
3. Boars Tusk landslide
4. Goslin Mountain landslide
5. South Fork landslide
6. Iron Canyon landslide
7. Albion Basin
8. Graveyard Flat landslide
9. Silver Creek landslide
10. Currant Creek landslide
11. Thistle landslide
12. York landslide
13. Pole Canyon landslide
14. Couch Creek landslide
15. Silver Pass landslide
16. Rattlesnake Hill landslide
17. Mount Terrel landslide
18. Thompson Creek landslide
19. Elbow landslide
20. Little Creek Peak landslide
21. Green Hollow landslide
22. Square Mountain landslide
23. Johnson Mountain landslide
24. Eagle Crags landslide
25. North Roundy landslide
26. Dry Hollow landslide
27. South Roundy landslide
28. Dry Canyon landslide

Landslide zones

Fish Lake Plateau landslide zone
Thousand Lake Mountain landslide zone
Boulder Mountain landslide zone
Mount Peale landslide zone

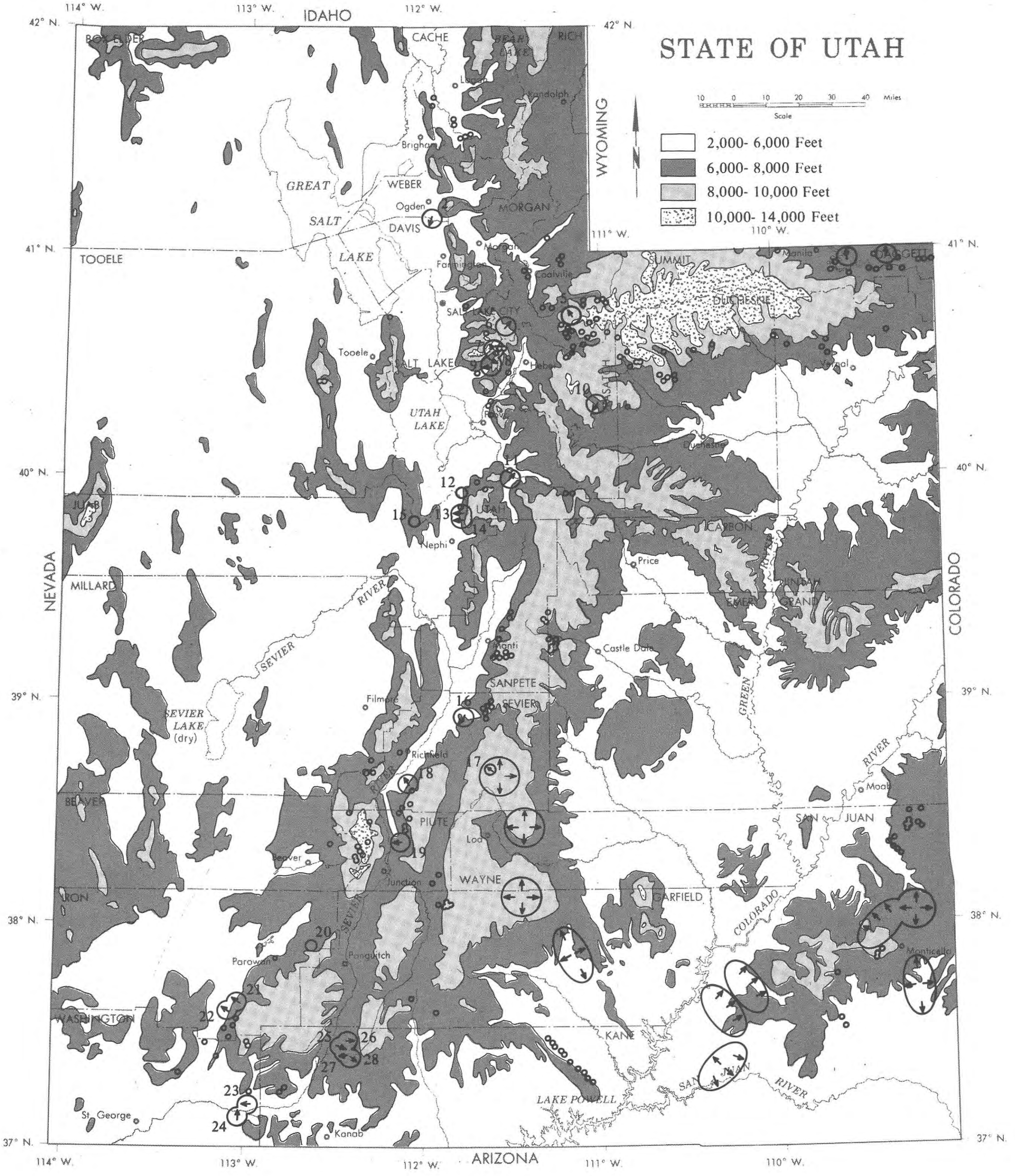


Figure 4. Relief and landslides of Utah (explanation on page 6).

Table 4. Paleozoic formations involved in landslides in Utah.

Formation ℙ–Permian P–Pennsylvanian M–Mississippian C–Cambrian	Individual Landslides[1]		Landslide Zones		Total
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field	
ℙ Park City Fm.	0.7				0.7
ℙ P Oquirrh Fm.	2.3	.03			2.6
P Weber Fm	0.3				0.3
P Morgan Fm.					
P Round Valley Ls.	0.3				0.3
M Brazer Ls.	2.3	0.5			2.8
PM Manning Canyon Sh.	2.3	0.3			2.6
M Doughnut Fm.	0.8	1.0			1.8
M Great Blue Ls.	1.8	0.3			2.1
M Humbug Fm.	2.2				2.2
M Deseret Ls.		0.5			0.5
M Madison Ls.	1.5	0.5			2.0
M Gardison Ls.	1.5	1.5			3.0
M Undivided black shale	5.2				5.2
C Maxfield Ls.		1.0			1.0
C Ophir Fm.	3.0				3.0
C Tintic Quartzite	1.5				1.5
Total	25.7	5.9	00.0	00.0	31.6

[1] Number of landslides which involve given formation; decimals refer to division of one landslide when it involves several formations.

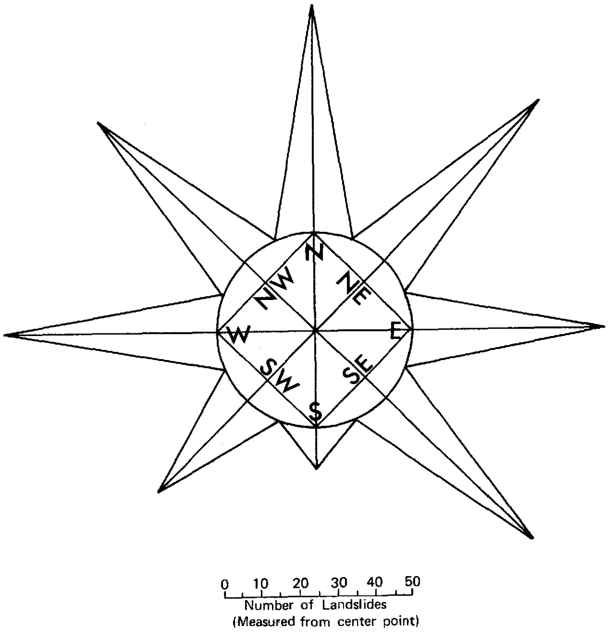


Figure 5. Rose diagram illustrating relative numbers of slope exposures of landslides in Utah. This shows graphically the paucity of landslides with a slope exposure facing to the south or southwest.

The zone at 6,000-8,000 feet contains the largest number of landslips. This is largely because the zones between 4,000 and 8,000 feet represent the largest area in the state, and because the area below 6,000 feet is largely a zone of gentle slopes and moderate relief. The zone at 6,000-8,000 feet not only covers a large area but it is mountainous, with the steep slopes of landslide-prone terrain.

SLOPE EXPOSURE OF LANDSLIDES IN UTAH

Maps and field measurements of both reported and investigated landslips and landslip zones reveal a distinct pattern in slope exposures of known large-scale mass movements in Utah (Shroder, 1969, 1970). Compass bearings of the landslips were grouped in eight zones, each one 45° wide and distributed symmetrically on either side (22° 30' per side) of the four cardinal points and four lesser points of the compass.

The slopes facing west, northwest, north, northeast, east and southeast share a similar frequency of landslips, approximately 83 each (figure 5, table 7). The slopes facing to the south and southwest have 38 and 61 landslips respectively.

Frequency of landsliding is partly controlled by slope wetness. The paucity of slips on the south and southwest is therefore probably the result of partial drying of those slopes which face the sun.

PRECIPITATION AND LANDSLIDE AREAS IN UTAH

One-fourth of the landslips in Utah occur in areas with annual precipitation between 12 and 16 inches (figure 6, table 8). This widespread occurrence of landslips in relatively dry situations contradicts the high correlation to be expected between sliding and precipitation. This contradiction can be explained by the fact that many of the landslides must have occurred in intervals in the late Pleistocene when temperatures averaged 10° to 15° F lower and the annual precipitation averaged 10 inches higher than those which now prevail (Schumm, 1965, p. 786).

Large amounts of precipitation favor landsliding for the following reasons (in part after Terzaghi, 1950, p. 91, and Varnes, 1958, p. 43-45):

(1) Water which enters voids in earth increases the unit weight of the material. The component of this weight in the slope direction may exceed the shear strength of the material, producing failure.

(2) Water may dissolve a soluble cement and reduce cohesion, reducing shear strength.

(3) Water entering ground may cause an increase of pore-water pressure with a resulting decrease in shear resistance.

(4) Water may freeze and thaw repeatedly, fracturing and weathering material to reduce shear strength.

(5) Water may cause hydration of clay minerals in which swelling and loss of cohesion results from absorption of water by the minerals.

(6) Water may cause saturation which will destroy intergranular pressure which results from capillary tension.

(7) Percolating groundwater may cause seepage pressures resulting from viscous drag between water and solid grains.

CLIMATE AND LANDSLIDES IN UTAH

Most landslips in Utah are of Late Pleistocene and Holocene age. This age distribution implies wide temporal climatic variability, ranging from cold and wet to warm and dry. Figure 7 is a climate map on which landslips are plotted to show relationships between Pleistocene climate and mass movements.

Figure 8 and table 9 show landslips relative to the present climates of Utah. The climate base map was made by Burnham (1950), who used the Koeppen scheme of climate classification as modified by Trewartha (1954).

Schumm (1965, p. 786) estimated that during times of glaciation the nonglaciated regions of the southwest were 10° to 15° F cooler and the annual precipitation was about 10 inches more than at present. I took the temperature and precipitation figures for the 27 Utah stations that Burnham (1950) used and applied a 10° F temperature reduction and a 10-inch precipitation increase to them to obtain hypothetical figures for the glacial part of the Pleistocene (figure 7). I then applied these figures to formulae or to nomographs to obtain the new desert-steppe and steppe-humid boundaries. The maximum distribution of glaciers and of Lake Bonneville was also plotted. This map is, of course, based on many unprovable assumptions and is only a generalization because the maximum extent of glaciers, pluvial lakes and cool, wet climate zones may not have occurred simultaneously.

Landslips in Utah occur today primarily in humid cool summer and cool short summer and middle latitude steppe climate zones (figure 8). The cool summer climate zone has the highest proportion (224). During the glacial portions of the Pleistocene, the dry climates were greatly reduced in areal extent and landsliding occurred primarily within the humid climates (352 landslips) (table 10).

Table 5. Precambrian and unknown formations involved in landslides in Utah.

Formation	Individual Landslides[1]		Landslide Zones		Total
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field	
Red Pine shale	8.0				8.0
Mutual quartzite	2.5				2.5
"Buff" quartzite	2.5				2.5
Mineral Fork tillite	0.5				0.5
Red Creek quartzite	3.0				3.0
Uinta Mountain grp.	7.0	1.0			8.0
Harrison Fm.		1.0			1.0
Undivided Precambrian	2.0				2.0
Unknown	1.0				1.0
Total	26.5	2.0	00.0	00.0	28.5

[1] Number of landslides which involve given formation; decimals refer to division of a landslide when it involves several formations.

Table 6. Generalized elevations of landslides in Utah.

Elevation in feet	Individual Landslides[1]		Landslide Zones[2]		Total	Percent
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field		
12,000-14,000						
10,000-12,000	10			61	71	10
8,000-10,000	60	9		53	122	21
6,000-8,000	95	15	63	56	229	39
4,000-6,000	22	4	150		176	30
2,000-4,000						
Total	187	28	213	170	598	

[1] Number of landslides given elevation.
[2] Miles of landslide (width of head) within given elevation.

Occurrence of a large proportion of landslides in past or present D climate zones is probably a reflection of the influence of moderate to high precipitation and freeze and thaw in this zone. D climates here are largely a function of altitude and are therefore mountain climates.

PRIMARY CAUSES OF LANDSLIDING IN UTAH

Sharpe (1938, p. 84) proposed two primary groups of causes of landslides. *Basic* or *passive* conditions favor-

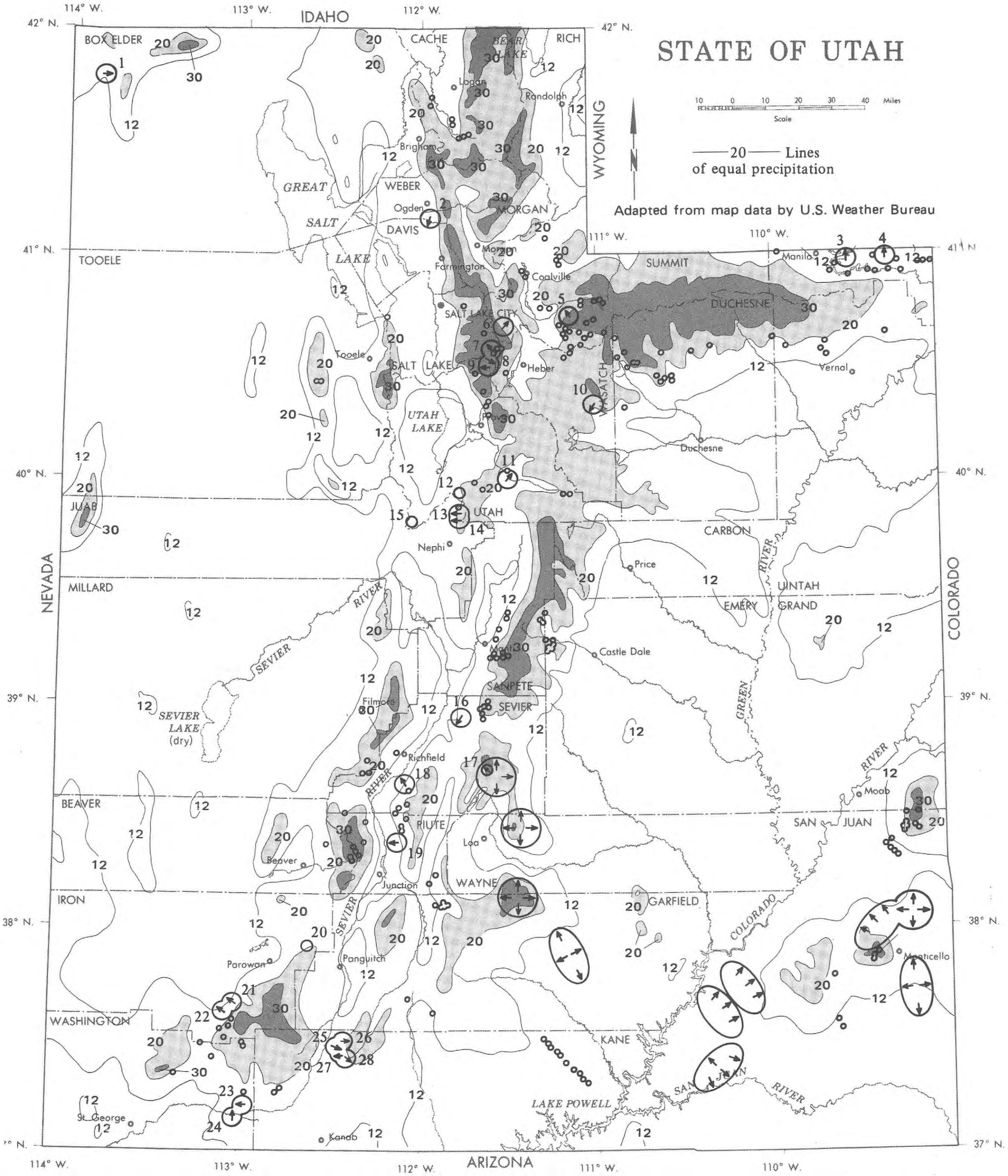


Figure 6. Average annual precipitation (1931-1960) and landslides of Utah (explanation on page 6).

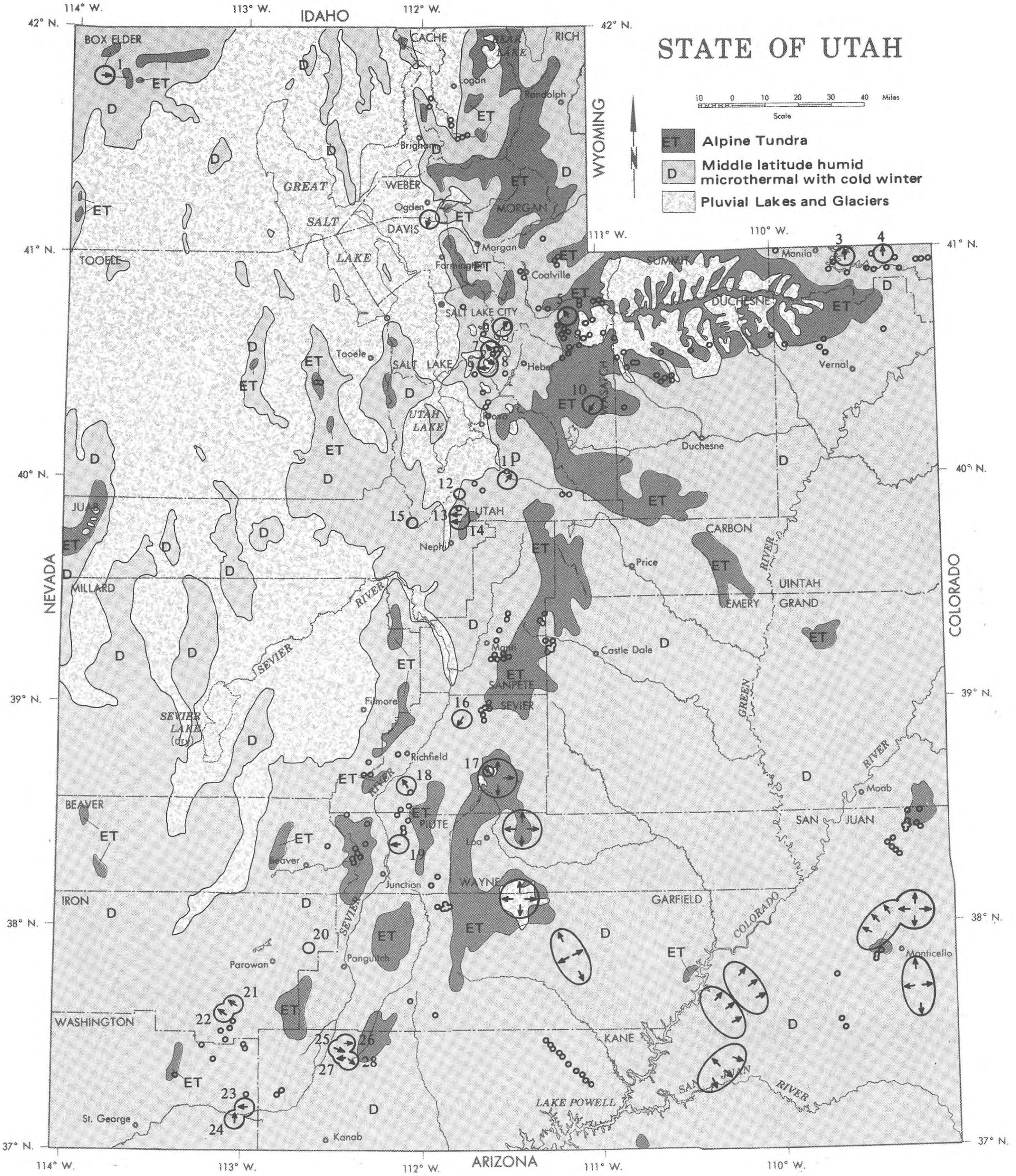


Figure 7. Pleistocene glacial climates and landslides of Utah (explanation on page 6).

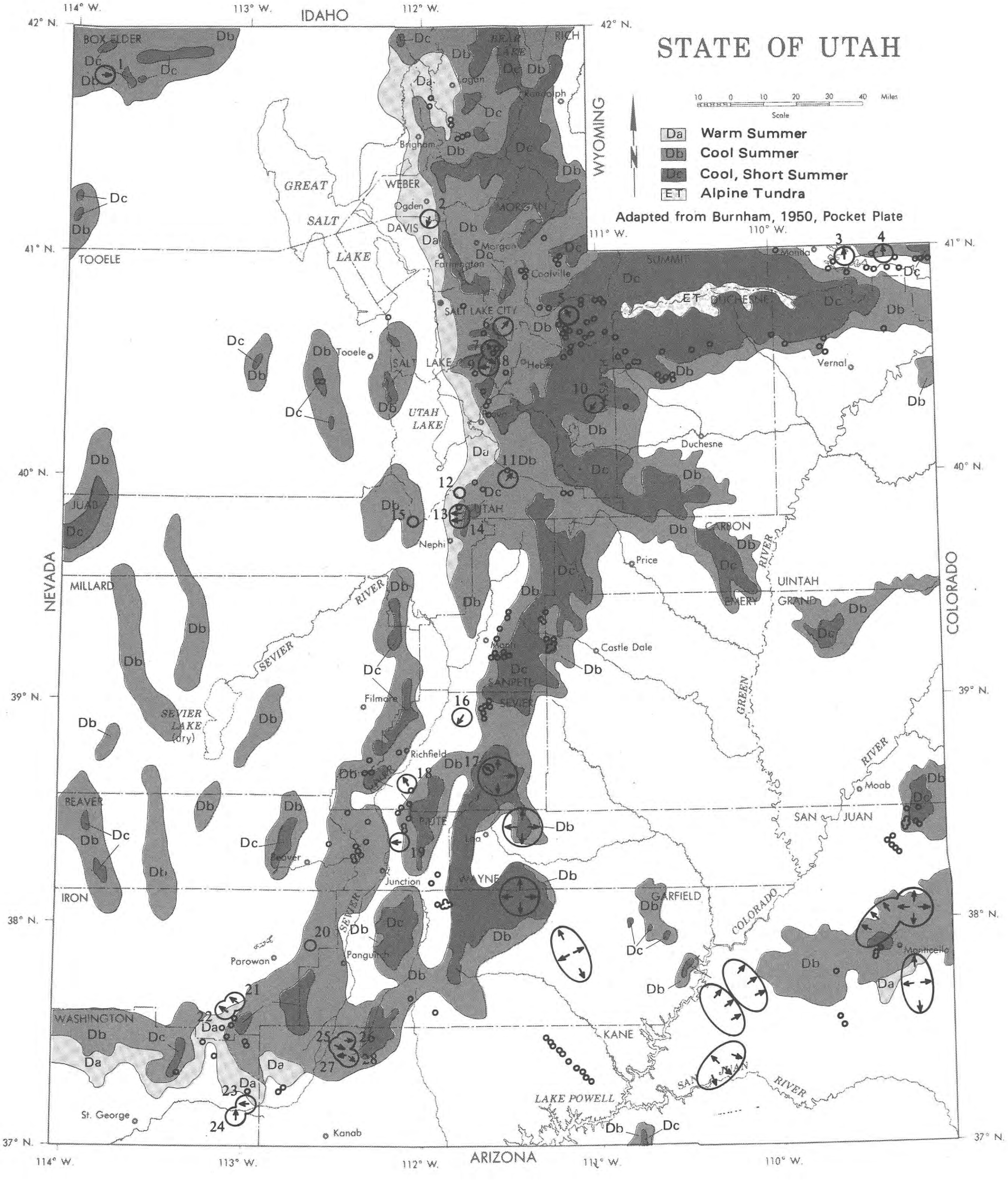


Figure 8. Present climate regions and landslides of Utah (explanation on page 6).

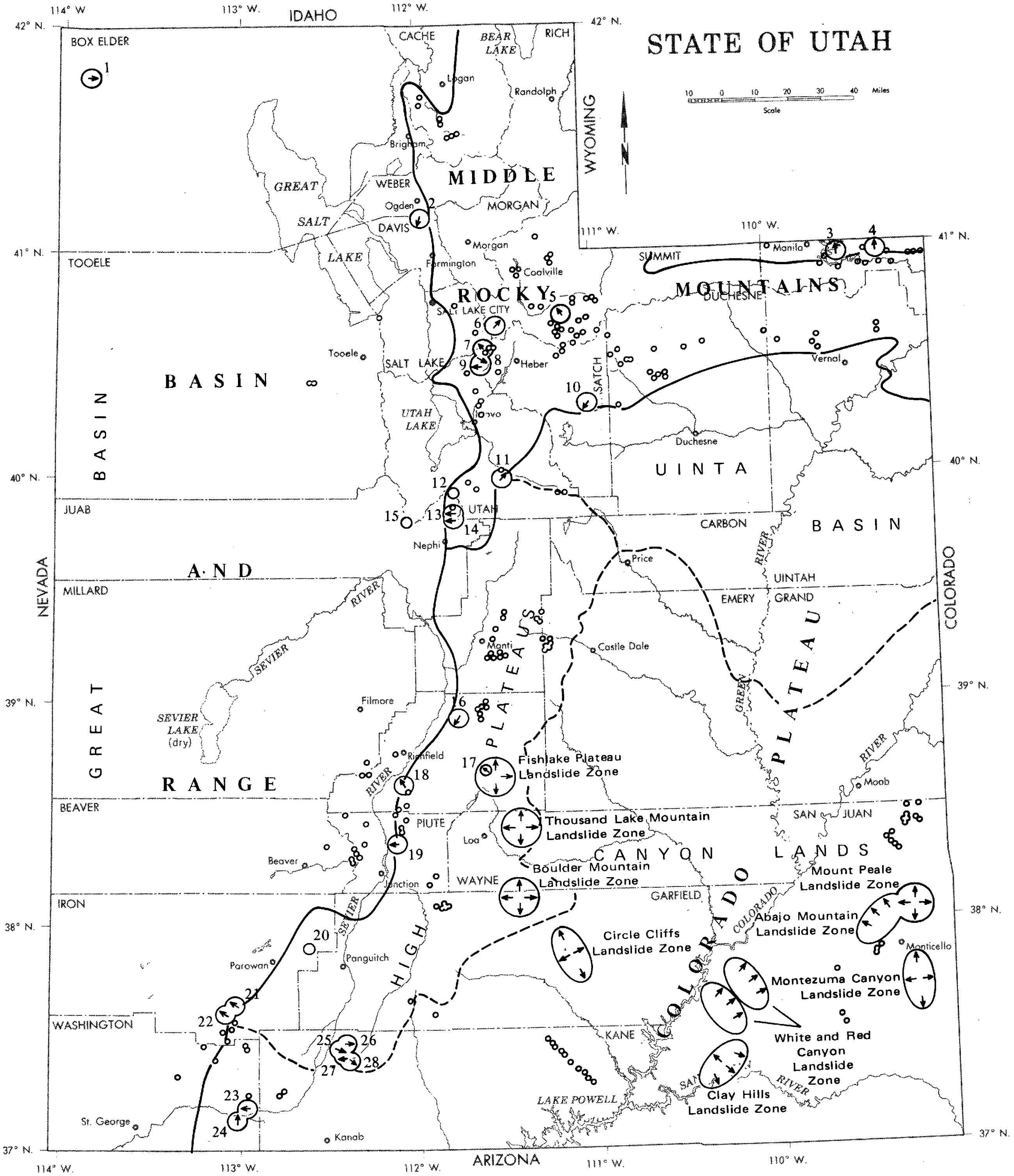


Figure 9. Geomorphic provinces and landslides of Utah (explanation on page 6).

Table 7. Slope exposure of landslides in Utah.

Slope Exposure	Individual Landslides[1]		Landslide Zones[2]		Total	Percent
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field		
North	41	4	15	28	88	14.6
Northeast	22	2	35	27	86	14.4
East	18	2	20	38	78	13.0
Southeast	15	4	58	5	82	13.7
South	19	1	9	8	37	6.4
Southwest	21	3	19	17	60	10.1
West	30	10	18	25	83	14.1
Northwest	20	1	40	21	82	13.7
Total	186	27	214	169	596	

[1] Number of landslides with given slope exposure; decimals refer to division of one landslide when it involves more than one slope exposure.

[2] Miles of slope exposure measured at head of landslide zone.

ing landslips are lithologic (presence of weak formations), stratigraphic, structural, topographic (steep slopes), and organic (lack of vegetation). *Active* or *initiating* causes are removal of support, overloading, reduction of friction, reduction of cohesion, earth tremors, prying or wedging action, production of oversteep constructional slopes, and earth strains produced by natural agencies such as tidal pull.

The most common passive cause is stratigraphic. Two hundred and eighty-one landslips resulted from sandstone or conglomerate or both overlying mudstone which may be bentonitic, and 93 landslips result from basalt which overlies limestone or tuffaceous sandstone or both.

The next most common basic cause is lithologic, with 109 landslips in an argillaceous lithology and 14 in bentonitic mudstone or sandstone.

Structural causes are fault zones (22 landslips) and dip in slope direction (10 landslips).

Active or initiating causes known or assumed to have had influence are river undercutting or spring sapping (11 landslips), glacially oversteepened cliff (1 landslip) and known heavy rain (1 landslip).

On a regional basis, if the distribution of landslides is compared to precipitation, climate, elevation and lithology, some generalizations emerge. It is obvious that landslips are more common in areas of high precipitation (figure 6), but it is impossible to determine whether high precipitation initiated any individual landslip.

GEOMORPHIC PROVINCES OF LANDSLIDES IN UTAH

The greatest proportion of landslides in Utah occurs in the Canyonlands section of the Colorado Plateau province (figure 9, table 12). This is largely a result of the occurrence of massive cliff-forming sandstones which overlie incompetent mudstones in this area. The most common form of landslip here is rockfall from the numerous cliffs.

The second highest proportion of landslides occurs in the High Plateaus section of the Colorado Plateau province. Landsliding here is largely in massive basalt, limestone and sandstone overlying incompetent units, commonly the North Horn or Flagstaff (?) Formation. Landslips in this zone are largely complex landslide blocks and debris-flows.

The Middle Rocky Mountains province contains the third highest proportion of landslips which, in this region, are largely rockslides, rockfalls, and some complex blockslides and debris-flows.

The Great Basin, with its low precipitation and generally competent rocks, has had few landslides. Mudflows and debris-flows are the most common types of mass movement here.

No landslides have been reported from the Uinta Basin. Several have been reported, however, in the Green River Formation there, and many have occurred in the Book Cliffs just across the Utah-Colorado border, suggesting that there may be some in Utah.

Table 8. Present annual precipitation rates on landslide of Utah.

Precipitation	Individual Landslides[1]		Landslide Zones[2]		Total	Percent
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field		
50–60		1			1	.2
40–50	6	2			8	1.3
35–40	7				7	1.2
30–35	18	2			20	3.2
25–30	28	1		57	86	14.2
20–25	40	2		57	99	16.5
16–20	42	15			57	9.5
12–16	30	5	53	56	144	24.5
10–12	6		61		67	11.2
8–10	10		81		91	15.2
6–8			18		18	3.0
0–6						
Total	187	28	213	170	598	

[1] Number of landslides within given precipitation zone.

[2] Miles of landslide (width of head) in given precipitation zone.

Table 9. Location of landslides of Utah relative to present climatic zones.

Climatic Zone	Individual Landslides[1]		Landslide Zones[2]		Total	Percent
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field		
Dry						
Middle Latitude Steppe	29	2	105		136	22.7
Low Latitude Steppe		2			2	.3
Middle Latitude Desert	1		44		45	7.5
Low Latitude Desert			12		12	2
Humid Microthermal						
Warm Summer	6	2	41		49	8.2
Cool Summer	83	16	12	113	224	37.4
Cool, Short Summer	68	6		57	131	21.9
Alpine Tundra						
Total	187	28	214	170	599	

[1] Number of landslides with given climate.

[2] Miles of landslide (width of head) involving given climate.

Table 10. Location of landslides of Utah relative to proposed climatic zones of Pleistocene glacial time.

Climatic Zone	Individual Landslides[1]		Landslide Zones[2]		Total
	Reported in Literature	Investigated in Field	Reported in Literature	Investigated in Field	
Dry	1		45		46
Humid Microthermal	110	21	165	56	352
Alpine Tundra (ET)	56	3		115	174
Unknown (landslides within glacial or pluvial lake zones)	21	5			26
Total	188	29	210	171	598

[1] Number of landslides within given climate.

[2] Miles of landslide (width of head) involving given climate.

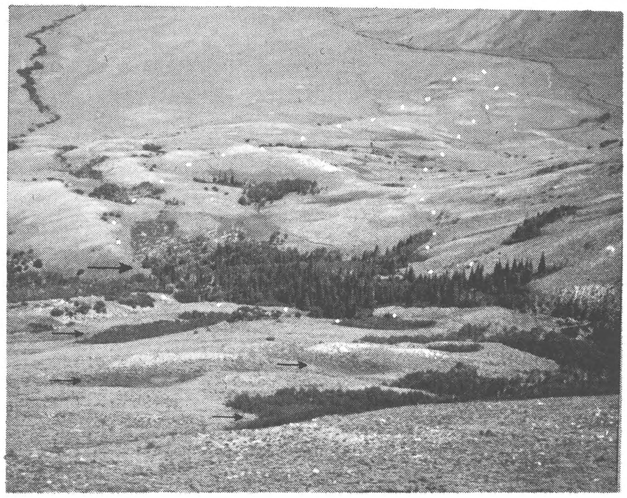


Figure 10. View of the Ingham Peak landslide from the summit of Ingham Peak. The rather vague lateral extent of the slide is indicated by white dots. Several small slumps (small arrows) are located in the foreground of the picture. The large arrow points to a landslide levee which occurs along the north flank of the slide.

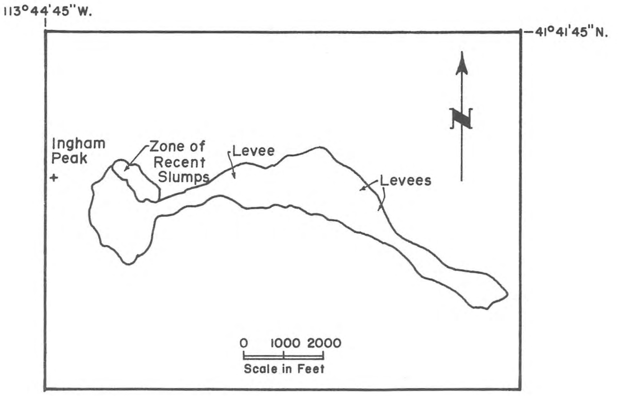


Figure 11. Outline map of Ingham Peak landslide. Scale and direction indicated by north arrow were derived from measurements of aerial photographs and are therefore approximate.

Figure 12. View of typical landslide topography of Washington Terrace landslide complex. Photograph courtesy H. D. Goode.

APPENDIX

INGHAM PEAK LANDSLIDE
(figures 10, 11)

Previous work: map, Stringham, unpublished.

Type: probably debris-flow or debris-avalanche.

Dimensions: width, 2,200 ft at crown, 350 ft at head, 900 ft at foot; length, 10,000 ft; thickness, 25 ft; volume, 5.5 million cubic yards.

Elevation: crown, 9,000 ft; head, 8,000 ft; toe, 6,200 ft.

Rate of movement: probably rapid.

Slope exposure: east.

Vegetation: conifers, aspens, mountain mahogany and sagebrush.

Geologic setting: strongly foliated, micaceous schist and granite of the Harrison Formation of Middle Precambrian age (Stringham, 1961) underlies this area. The slide had its source primarily in the overlying regolith.

Causes: possible saturation of the regolith.

Correlation: possibly late Pleistocene or early Holocene.

Geomorphic age: early to middle maturity, based on filled ponds and general erosion.

Discontinuous landslide levees, up to 10 ft high and 20 ft wide, occur on the north flank. They probably were formed by debris which piled up on the outside of the curve of the arcuate flow of the landslide.

WASHINGTON TERRACE LANDSLIDE COMPLEX
(figures 12-14)

Previous work: brief mention, Feth, 1955, p. 58.

Type: complex slump, earth-flow and mudflow.

Dimensions: width, 8,000 ft; length, 1,900 ft; thickness, 50 ft; volume, 28 million cubic yards.

Elevation: crown, 4,680 ft; head, 4,640 ft; toe, 4,400 ft.

Rate of movement: probably slow to rapid depending on type of movement and amount of water.

Slope exposure: south to southwest.

Vegetation: grass.

Geologic setting: cyclicly bedded clays and sands of Alpine Formation (Feth, 1955, p. 52).

Causes: undercutting of slope by Weber River combined with clays and sands prone to slide when saturated.

Correlation: downcutting through Lake Bonneville delta (Alpine Formation) by Weber River indicates a Holocene age, probably within last few hundred or thousand years.

Geomorphic age: early youth to middle maturity, based on complete range of youthful landslide landforms and a few mature types.

BOARS TUSK LANDSLIDE
(figures 15-17)

Previous work: description and map, Hansen, 1965, p. 135-136, plate 1.

Type: slump, probable debris-flow, and several small slump blocks and one small debris-flow to the west.

Dimensions: width, 1,600 ft at head, 2,500 ft at toe; length, 3,400 ft; thickness, 75 ft; volume, 19 million cubic yards.

Elevation: crown, 7,200 ft; head, 6,720 ft; toe, 6,200 ft.

Rate of movement: probably rapid.

Slope exposure: north.

Vegetation: sagebrush and juniper.

Geologic setting: Hansen (1965, p. 135) cites failure of overturned and steeply inclined beds of Morrison and Carmel formations which caused sliding in these units and in parts of Navajo, Entrada, Curtis, Dakota, Mowry and Frontier formations.

Causes: probable saturation of incompetent argillaceous beds in Morrison and Carmel formations.

Correlation: dissection and rounding of slump blocks indicate a probable late Pleistocene age.

Geomorphic age: middle to late maturity, based on integrated drainage system, dissection of slump blocks at head, and lack of hummocky topography.

Immediately west of the main slide mass are a debris-flow and several slump blocks of sandstone from the Frontier Formation. These are genetically related to the main mass but may not have moved at the time Hansen thought.

GOSLIN MOUNTAIN LANDSLIDE
(figures 18-20)

Previous work: map, Hansen, 1961; map and description, Hansen, 1965, plate 1 and p. 134-135.

Type: slump and debris-flow.

Dimensions: width, 2 miles; length, 0.5 miles; thickness, 100 ft; volume, 100 million cubic yards.

Elevation: crown, 8,185 ft; head, 7,300 ft; toe, 7,080 ft.

Rate of movement: probably slow in places, rapid in others.

Slope exposure: north.

Vegetation: conifers, aspens and sagebrush.

Geologic setting: Precambrian Uinta Mountain Group thrust over Cretaceous Hilliard shale along Uinta fault zone.

Causes: Hansen (1965, p. 134-135) cites incompetent and unstable shale in fault zone on steep, wet north-facing slope.

Correlation: probably middle or late Pleistocene.

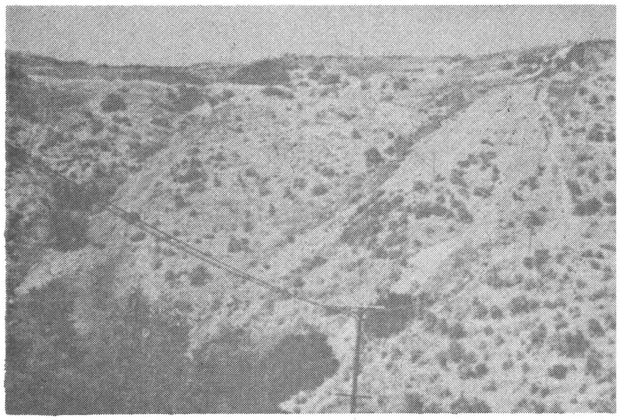


Figure 13. These two mudflows on Washington Terrace occurred in the wet spring of 1965. The right-hand flow had a small spring at the base of its main scarp when visited a few months after movement. The location of these mudflows is marked by X in figure 14.

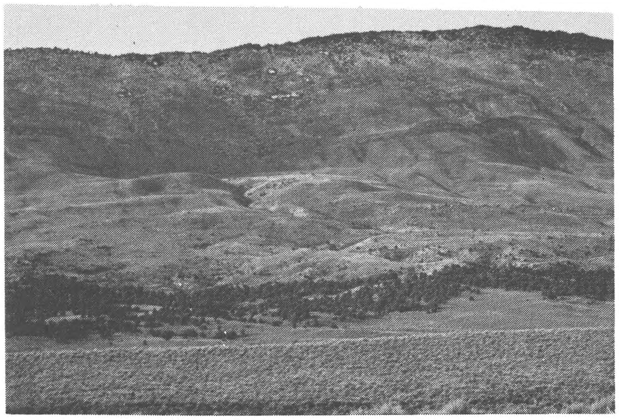


Figure 15. View to the southwest showing Boars Tusk landslide. The toe of the slide is just above the row of trees in the middle distance. The flanks of the slide are indistinct but lie somewhere between the small gully to the extreme left and the end of the row of trees to the right. The main scarp is the large shadowed area in the upper left center of the picture. Several slump blocks can be seen at the base of the shadowed main scarp.

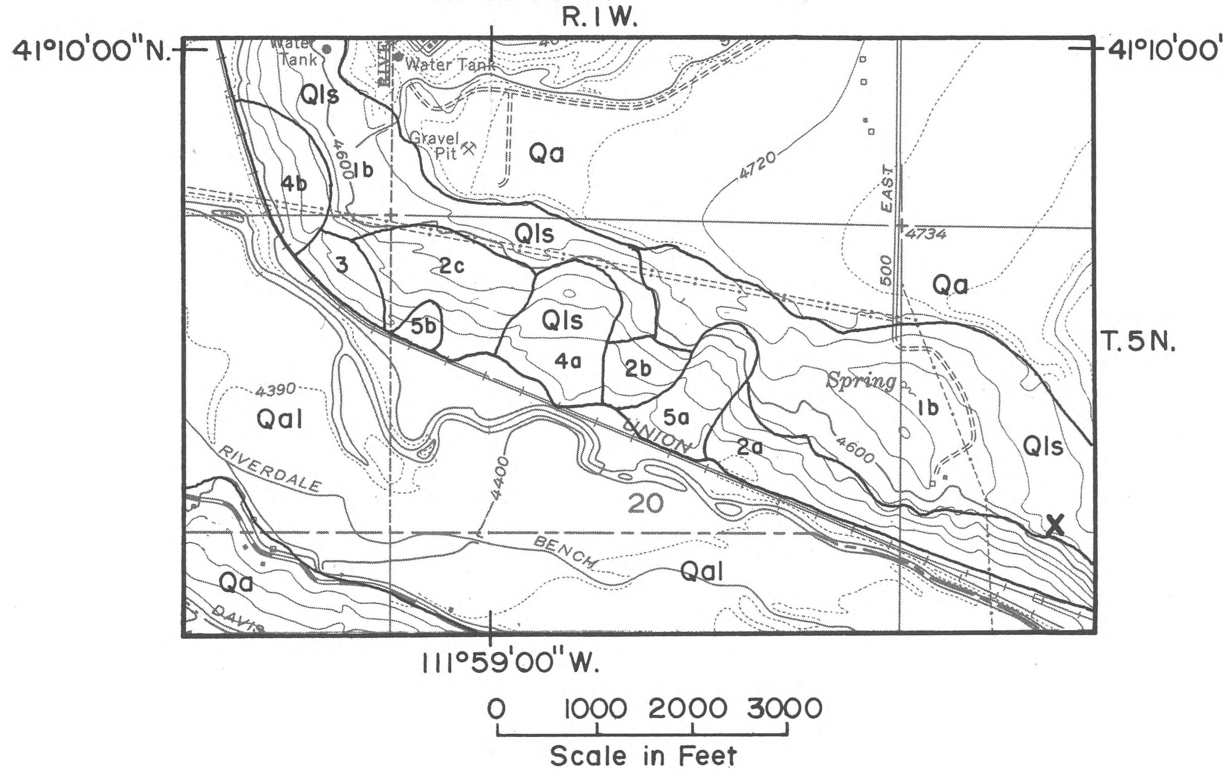


Figure 14. Geologic map of Washington Terrace landslide complex. The numbers and letters represent several generations of landsliding. No. 5 is the youngest and No. 1 is the oldest. X marks the site of several recent mudflows.

Qal – Quaternary alluvium
Qls – Quaternary landslide
Qa – Quaternary Alpine Formation

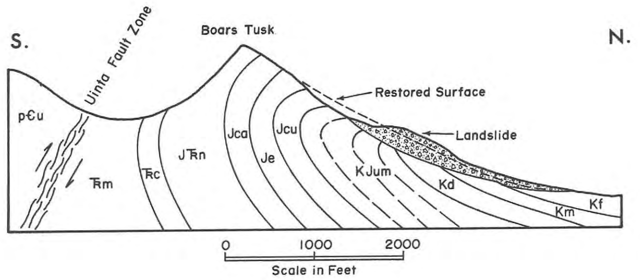


Figure 16. Cross section showing general relationships of Boars Tusk landslide. Initial failure was probably in Morrison Formation. Vertical exaggeration about 1:3 (after Hansen, 1965, p. 136).

p€u	–Uinta Mountain Group	Jcu	–Curtis Formation
₮m	–Moenkopi Formation	KJum	–Unnamed Lower Cretaceous rock and Morrison
₮c	–Chinle Formation		
J ₮n	–Navajo Sandstone	Kd	–Dakota Sandstone
Jca	–Carmel Formation	Km	–Mowry Shale
Je	–Entrada Formation	Kf	–Frontier Formation

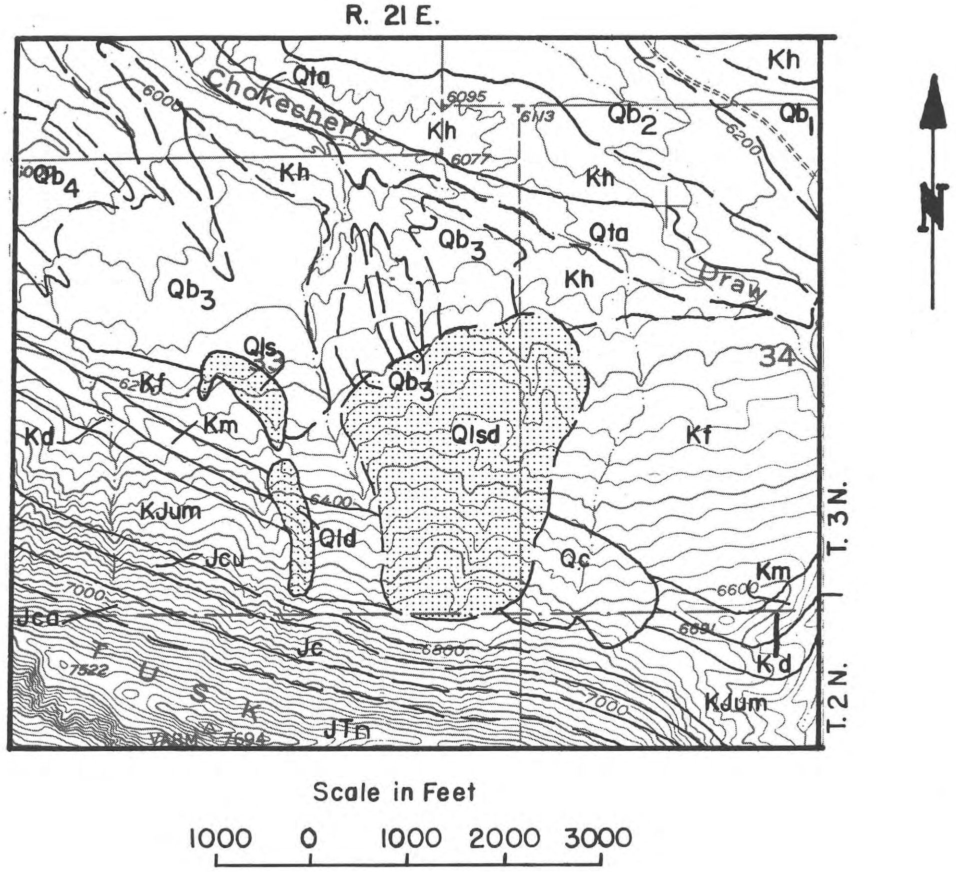


Figure 17. Geologic map of Boars Tusk landslide (geology adapted from Hansen, 1964).

Qta – Quaternary tributary valley alluvium
Qc – Quaternary alluvium
Qlsd, Qls, Qld – Quaternary landslide: slump and debris-flow (Qlsd); slump (Qls); debris-flow (Qld)
Qb$_4$, Qb$_3$, Qb$_2$, Qb$_1$ – Quaternary bench deposit (alluvial deposits described by Hansen)
Kh – Cretaceous Hilliard Shale

Kf – Cretaceous Frontier Formation
Km – Cretaceous Mowry Shale
Kd – Cretaceous Dakota Sandstone
KJum – Cretaceous undivided and Jurassic Morrison Formation
Jcu – Jurassic Curtis Formation
Jc – Jurassic Entrada Sandstone
Jca – Jurassic Carmel Formation
JTn – Jurassic and Triassic Navajo Sandstone

Geomorphic age: middle to late maturity, based on integrated drainage system, dissected appearance and lack of undrained depressions.

SOUTH FORK LANDSLIDE
(figures 21-23)

Previous work: description, Atwood, 1909, p. 14; description and map, Hooper, 1951.

Type: rockslide.

Dimensions: width, 1,300 ft at head, 700 ft at foot line, 1,950 ft at toe; length, 2,800 ft; thickness, 50 ft; volume, 2.2 million cubic yards.

Elevation: crown, 8,200 ft; head, 7,900 ft; toe, 7,600 ft.

Rate of movement: very rapid.

Slope exposure: west.

Vegetation: aspen and conifers.

Geologic setting: strongly jointed Madison and Brazer Formation limestone of Mississippian age dip into canyon of south fork of Weber River.

Causes: glacial oversteepening, strong joints, smooth bedding planes and canyonward dip of rocks.

Correlation: post-Pinedale, slide overlies Pinedale till.

Geomorphic age: late youth, based on weathered landslide blocks, large talus cones and beginning of soil development.

The rockslide caused damming of the river and consequent deposition of lacustrine sediments. Subsequent solution or modification of previously existing joints or caves now allows subterranean flow of the river under the slide mass.

IRON CANYON LANDSLIDE
(figure 24)

Previous work: map of surrounding geology, Crittenden, Calkins and Sharp, 1966.

Type: multiple mudflows and debris-flows.

Dimensions: width, 400 ft at head, 600 ft at toe of upper debris-flows, 2,500 ft at toe of lower mudflows; length, 4,000 ft from head to toe of debris-flows, 5,300 ft from toe of debris-flows to toe of mudflows; thickness, 10-50 ft; volume, 5 million cubic yards.

Elevation: head, 8,320 ft; toe of debris-flows, 7,480 ft; toe of mudflows, 6,680 ft.

Rate of movement: probably rapid.

Slope exposure: northeast.

Vegetation: scrub oak, aspen, willow and conifers.

Geologic setting: shale, mudstone and sandstone of upper member of Ankara Formation which overlies the Gartra Grit Member and underlies the Nugget Sandstone.

Causes: argillaceous upper member of Ankara Formation, downslope dip, and possible ground-water movement from nearby White Pine Lake.

Correlation: late Pleistocene to Holocene.

Geomorphic age: early maturity, based on recent appearance but lack of any truly youthful features.

A boulder field of Nugget Sandstone blocks occurring on the southeast flank of the debris-flows may be the result of periglacial congelifraction or landsliding.

ALBION BASIN
(figure 25)

Previous work: description, Calkins and Butler, 1943, p. 50; description and map, Richmond, 1964, p. D28 and plate 1.

Type: rockfall avalanche.

Dimensions: width, 700 ft at crown, 900 ft at head, 550 ft at narrowest point, 1,000 ft at toe; length, 5,300 ft from crown to toe; upper 2,150 ft covered by till, rock glaciers, protalus and active talus; thickness, 20 ft; volume, 3 million cubic yards.

Elevation: crown, 10,800 ft; head, 9,800 ft; toe, 9,260 ft.

Rate of movement: very rapid.

Slope exposure: north.

Vegetation: conifers and highland grasses.

Geologic setting: Deseret and Gardison limestones of Mississippian age.

Causes: glacial oversteepening, downslope dip and frost wedging.

Correlation: occurred during late interstade of Pinedale glaciation (Richmond, 1964, p. D28).

Geomorphic age: middle maturity, based on overlying till, integrated drainage, strong development of soil profile, deeply weathered landslide blocks and lack of undrained depressions.

GRAVEYARD FLAT LANDSLIDE
(figures 26, 27)

Previous work: description, Calkins and Butler, 1943; map, Crittenden, 1965a; map, Baker, Calkins, Crittenden and Broomfield, 1966.

Type: rockslide.

Dimensions: width, 5,600 ft; length, 6,000 ft from crown to toe, 1,800 ft from head to toe; thickness, 300 ft; volume, 44 million cubic yards.

Elevation: crown, 9,200 ft; head, 7,600 ft; toe, 7,450 ft.

Rate of movement: probably very rapid.

Slope exposure: southeast.

Vegetation: conifers, aspen and scrub oak.

Geologic setting: Maxfield Limestone which overlies the Ophir Formation.

Causes: glacial oversteepening, faults, shale beds in the upper shaley sandstone member of the Ophir Formation, and 20°-30° dip into American Fork Canyon caused the failure of the Maxfield Limestone.

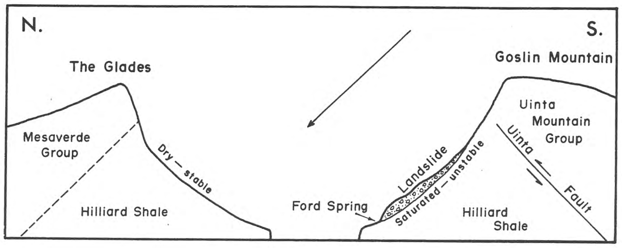


Figure 18. Schematic cross section showing relationships in a north-south profile of Goslin Mountain landslide. Arrow indicates prevailing angle of insolation (diagram in part after Hansen, 1965, figure 43, p. 135).

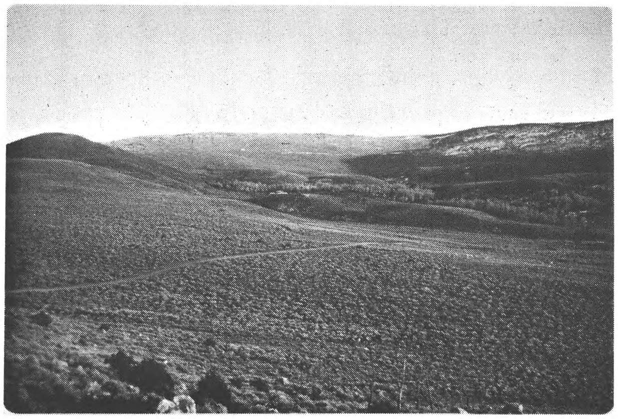


Figure 19. View to the southeast of the center and east flank of the Goslin Mountain landslide. The snow in the shadow at the right shows an area where the sun's rays rarely, if ever, reach.

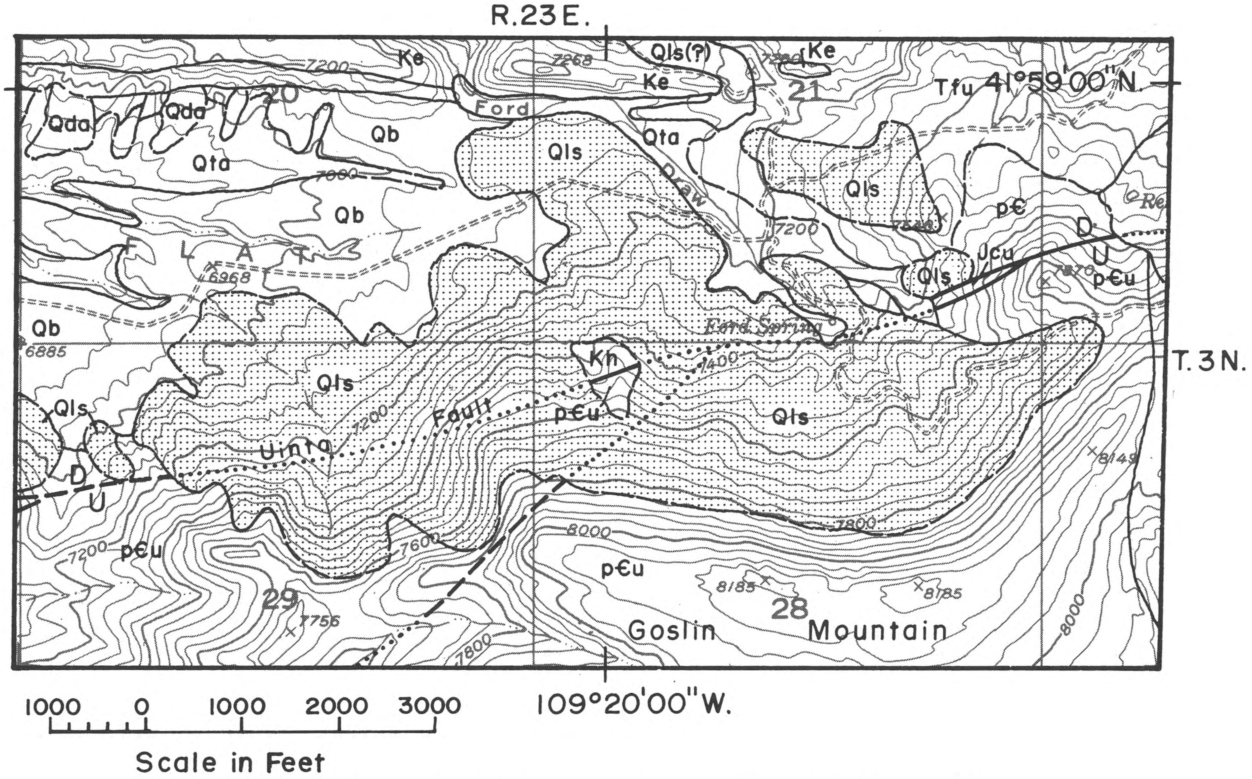


Figure 20. Geologic map of Goslin Mountain landslide (geology from Hansen, 1961).

Ke – Cretaceous Ericson Formation
Krs – Cretaceous Rock Springs Formation
Kh – Cretaceous Hilliard Shale
Jcu – Jurassic Curtis Formation
p€u – Precambrian Uinta Group

Qda – Quaternary dunes, inactive
Qls – Quaternary landslides
Qta – Quaternary tributary valley alluvium
Qb – Quaternary bench gravels
Tcu – Tertiary Fort Union Formation

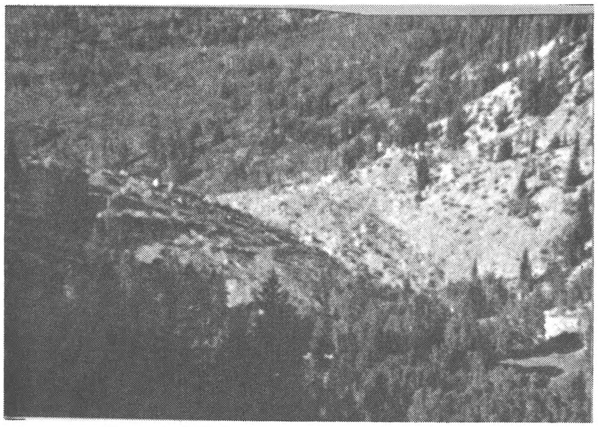


Figure 21. This part of the toe of the South Fork rockslide was deflected by a rock buttress and moved from a northwest path to a west path and thence part way up the west wall of the canyon. The remainder of the slide continued to move northwest and out of sight down the canyon.

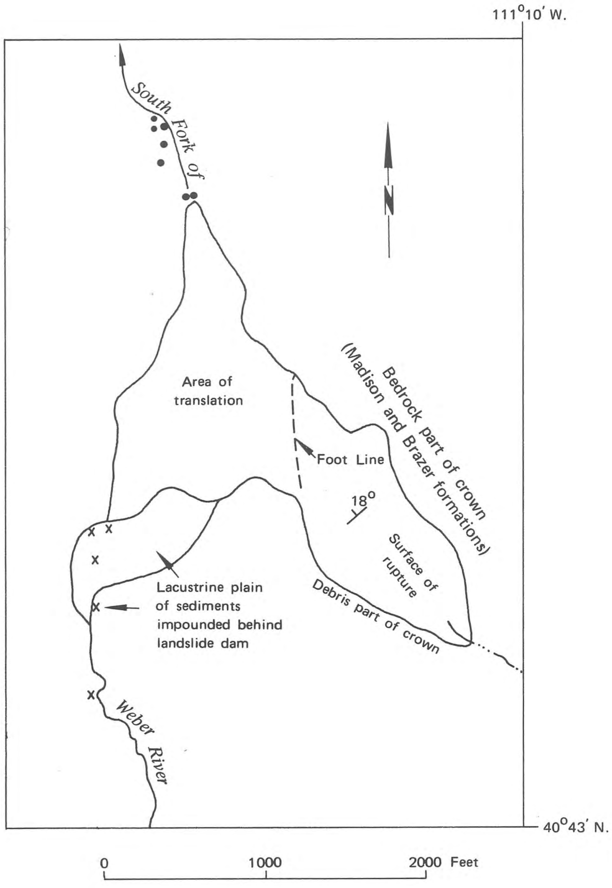


Figure 22. Outline map of South Fork rockslide. The black dots along the margin of the South Fork of the Weber River are intermittent springs which receive their water from swallow holes above the landslide. Swallow holes are marked by X's. The small arrow points to a cave several feet in diameter which receives water when the water level is very high (above 10 feet) in the pond behind the landslide. Map taken from aerial photographs.

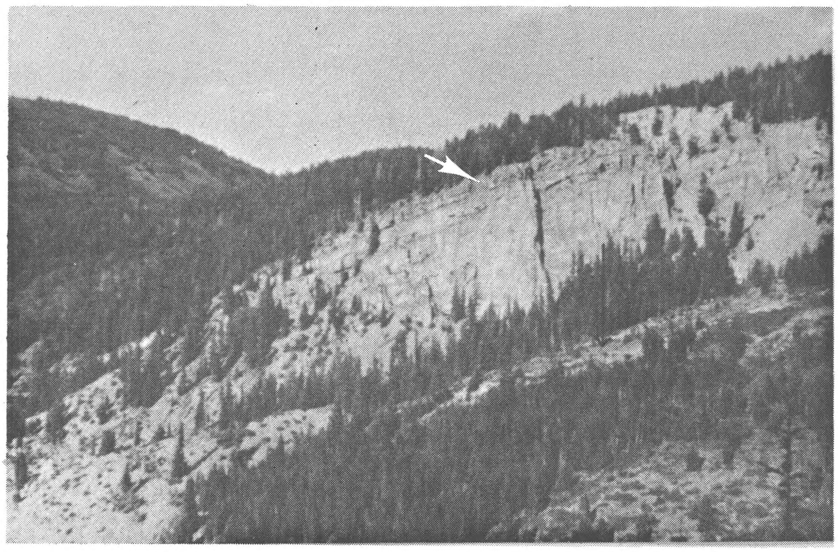


Figure 23. The cliff portion of the main scarp of the South Fork rockslide. The main mass of the landslide is to the left and out of the picture. The arrow points to the slip surface of the landslide.

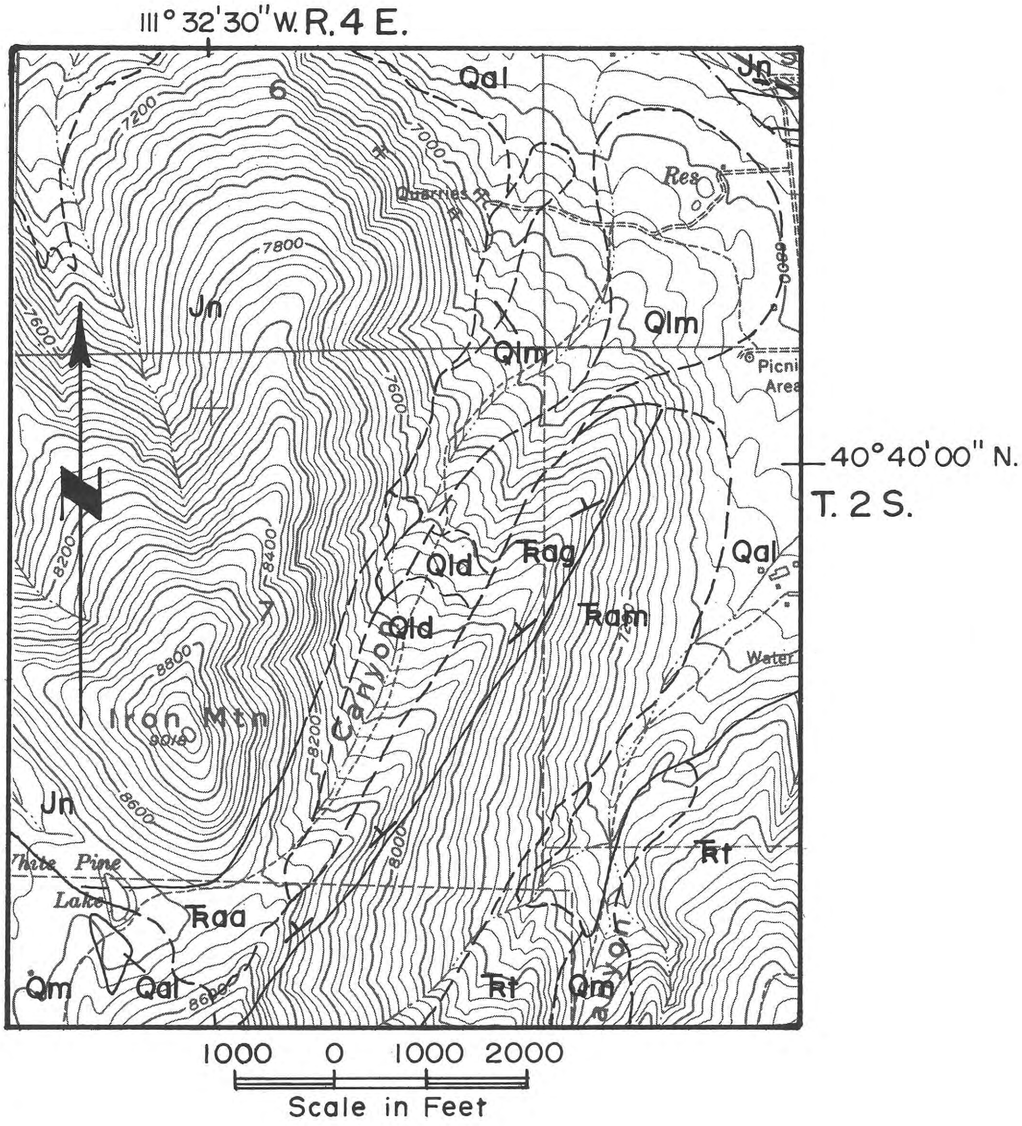


Figure 24. Geologic map of Iron Canyon landslide and mudflows near Park City, Utah (bedrock geology adapted from Crittenden, Calkins and Sharp, 1966).

Qal – Quaternary alluvium
Qld – Quaternary landslide, debris-flow
Qlm – Quaternary mudflow
Qm – Quaternary glacial moraine
Jn – Jurassic Nugget Sandstone

TRa – Triassic Ankareh Formation
  TRau – Upper Member
  TRag – Gartra Grit Member
  TRam – Mahogany Member
TRt – Triassic Thaynes Formation

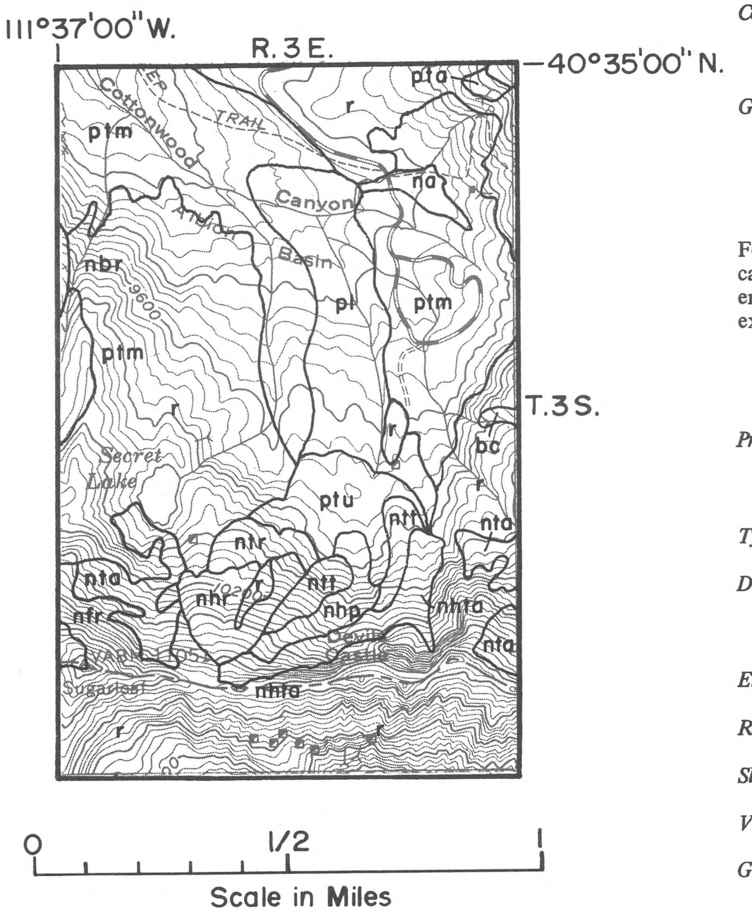


Figure 25. Geologic map of the Quaternary glacial deposits in the vicinity of Albion Basin landslide (Richmond, 1964, plate 1).

nhr	– Neoglaciation, historic stade rock glacier
ntr	– Neoglaciation, Temple Lake stade rock glacier
ntt	– Neoglaciation, Temple Lake stade till
ptu	– Pinedale glaciation, late stade
ptm	– Pinedale glaciation, middle stade
r	– bedrock
pl	– landslide

Alluvial and colluvial deposits

na	– Neoglaciation allvium
nta nhta nhp	} – Neoglaciation talus and protalus

Correlation: overlying Pinedale till and strong cementation indicate middle to late Pleistocene age, probably a pre-Bull Lake (pre-Wisconsin) age.

Geomorphic age: late maturity to early old age, based on strong cementation, overlying till, downcutting through slide by American Fork, and lack of landslide hummocky topography.

The rockslide originally completely filled American Fork Canyon to a depth of several hundred feet. This caused upstream alluviation followed by subsequent entrenching by American Fork. Prominent terraces now exist in the valley upstream from the landslide.

SILVER CREEK LANDSLIDE
(figures 27-29)

Previous work: maps, Baker and Crittenden, 1961; Baker, Calkins, Crittenden and Broomfield, 1966; Crittenden, 1965a; Baker, 1964a.

Type: complex slump and rockslide.

Dimensions: width, 3,000 ft at head; 3,000 ft at toe; length, 5,200 ft from head to toe; thickness, 100 ft; volume, 58 million cubic yards.

Elevation: crown, 8,800 ft; head, 8,480 ft; toe, 6,600 ft.

Rate of movement: probably rapid.

Slope exposure: west.

Vegetation: confiers, scrub oak and aspens.

Geologic setting: shaly limestone of Doughnut Formation thrust over Humbug Formation.

Causes: glacial oversteepening, shale beds in Doughnut Formation and thrust fault.

Correlation: overlying till and deep dissection by American Fork indicate probable late Pleistocene age.

Geomorphic age: late maturity, based on overlying till, degree of dissection, lack of hummocky topography and eroded slump blocks.

CURRANT CREEK LANDSLIDE
(figures 30-34)

Previous work: map and brief description, Bissell, 1952, figure 2 and p. 618-619; map, Garvin, 1967.

Type: complex slump and debris-flow.

Dimensions: width, 1,900 ft at head, 700 ft at narrowest point below foot line, 4,000 ft at toe; length, 12,000 ft; thickness, 100 ft; volume, 68 million cubic yards.

Elevation: crown, 9,200 ft; head, 8,800 ft; toe, 7,700 ft.

Rate of movement: rapid to very rapid.

Slope exposure: southwest.

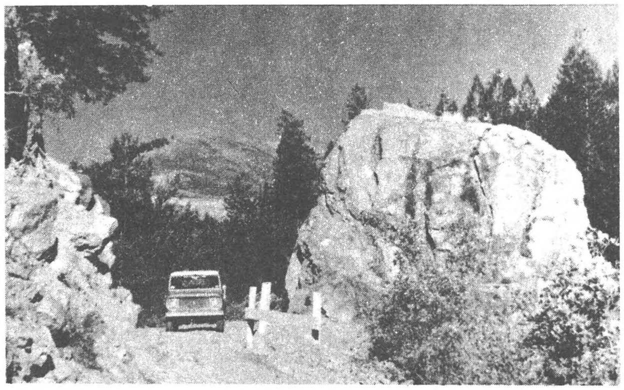


Figure 26. Road cut through well-cemented breccia of Graveyard Flat landslide. The large boulder is more than 20 feet in diameter.

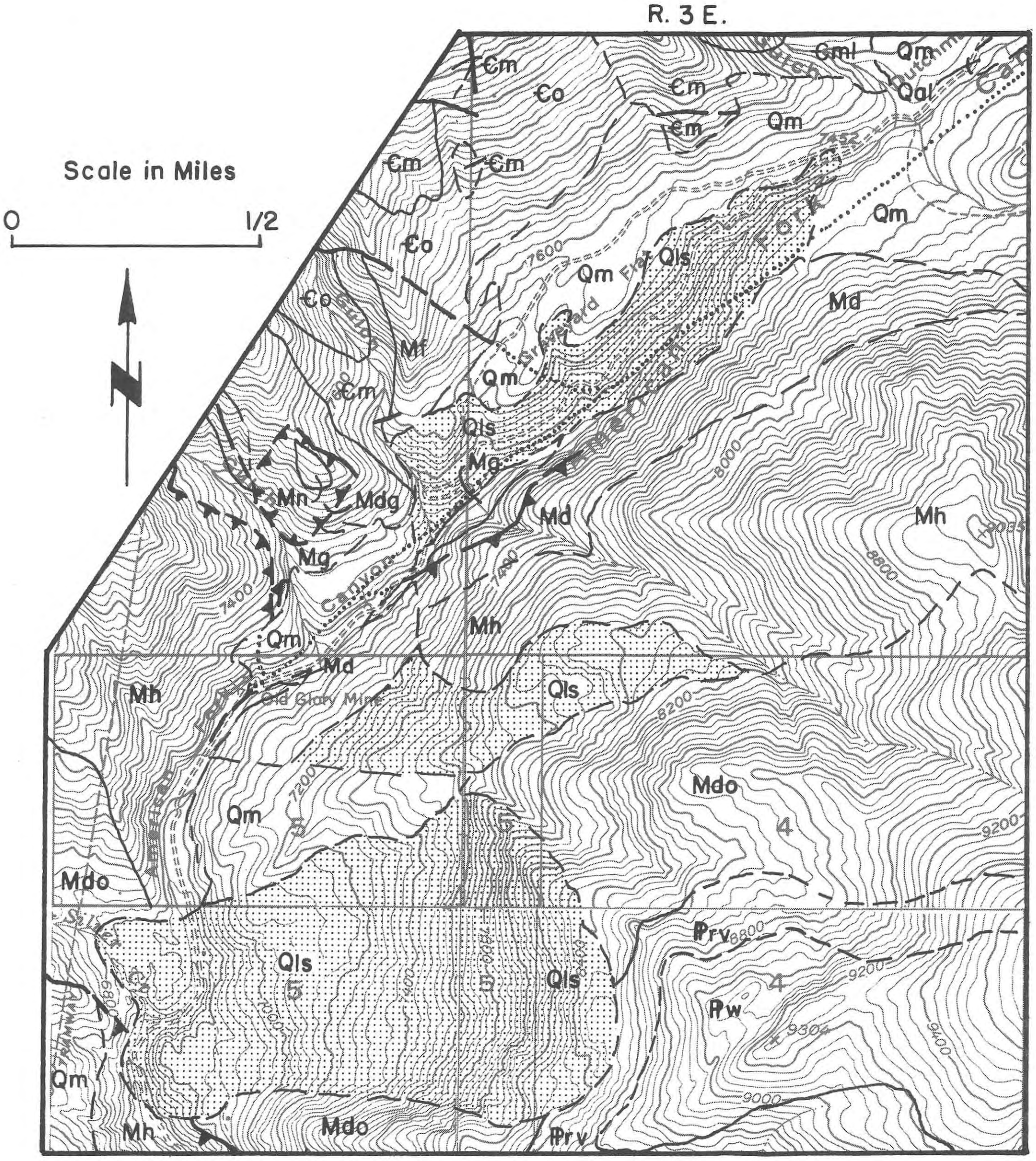


Figure 27. Geologic map of Graveyard Flat and Silver Creek landslides (geology adapted from Crittenden, 1965a; Baker and Crittenden, 1961; Baker and others, 1966; Baker, 1964a).

Qal – Quaternary alluvium
Qm – Quaternary glacial deposits
Qls – Quaternary landslide
IPw – Pennsylvanian Weber Quartzite
IPrv – Pennsylvanian Round Valley Limestone
Mdo – Mississippian Doughnut Formation
Mh – Mississippian Humbug Formation
Md – Mississippian Deseret Limestone
Mdg – Mississippian Deseret and Gardison Limestone
Mg – Mississippian Gardison Limestone
Mf – Mississippian Fitchville Formation
€m – Cambrian Maxfield Limestone
€o – Cambrian Ophir Formation

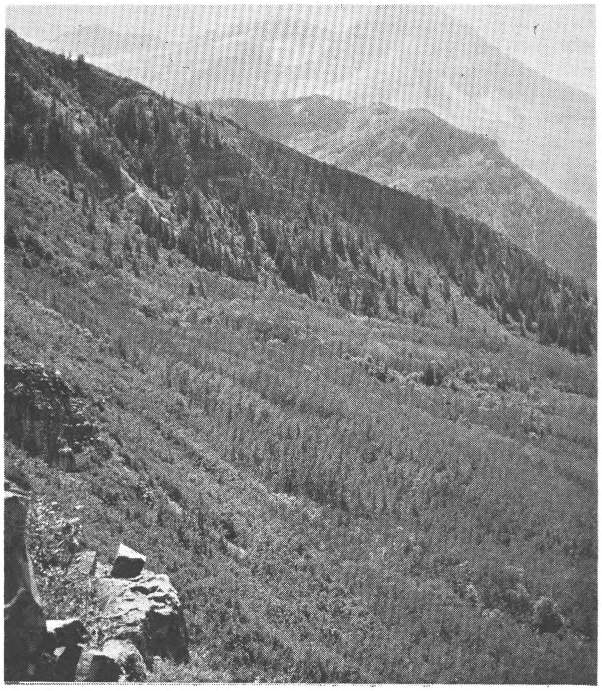


Figure 28. Part of the south flank and minor scarp of Silver Creek landslide. Post-slide talus and alluvial fan deposits now covered with aspens may be seen throughout the area below the scarp.

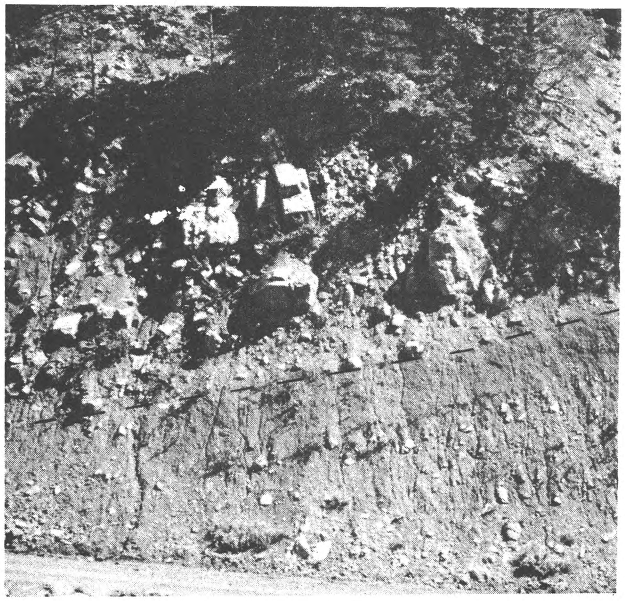


Figure 29. Road cut in Silver Creek landslide showing landslide material above dashed line and pre-landslide soil developed on Doughnut Formation. The landslide came down from the left of this picture and slid up the paleoslope on the Doughnut Formation. The pre-slide channel of American Fork was to the left of this picture; the present channel is to the right.

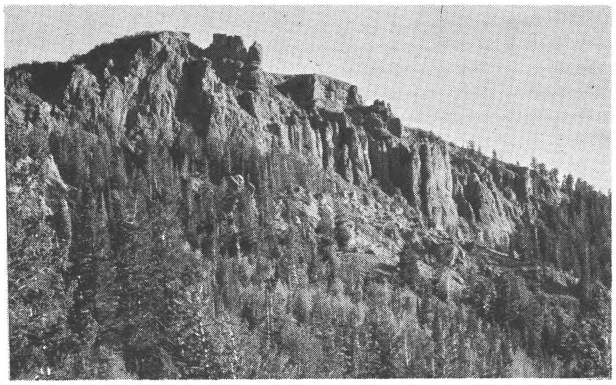


Figure 30. Red Ledge, the main scarp of the Currant Creek landslide. The rock is a conglomerate of the Uinta (?) Formation. It is underlain by bentonitic sandstones and conglomerates of the Currant Creek Formation.

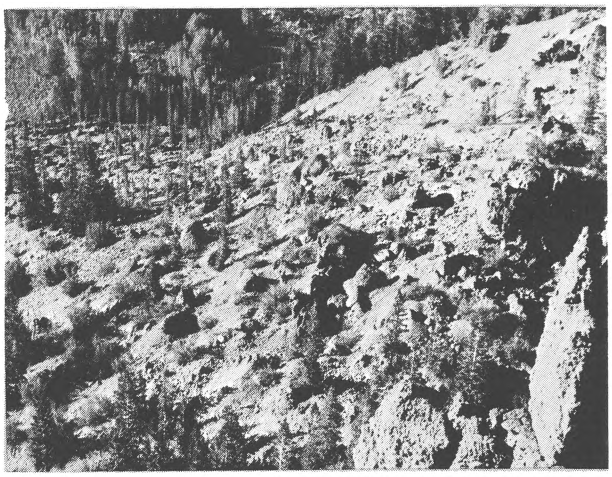


Figure 31. Subsidiary debris-slide below Red Ledge on the Currant Creek landslide. This debris-slide is much younger than the Currant Creek landslide.

Figure 32. The main mass of the Currant Creek landslide is moving slowly past the levee on the right. Distortion of the aspens indicates recent movement.

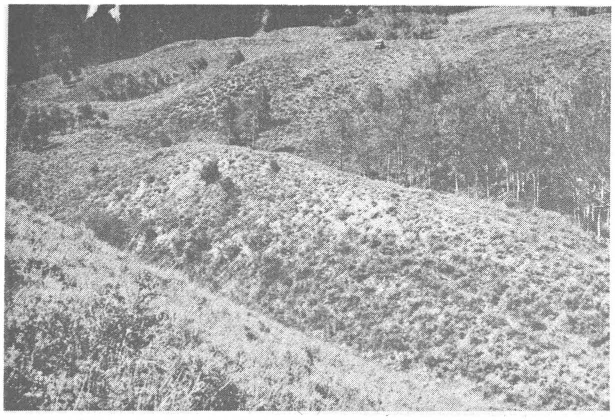


Figure 33. Large landslide levee on the south flank of the Currant Creek landslide. The view is northwest from the slopes west of Red Ledge towards the toe of the landslide.

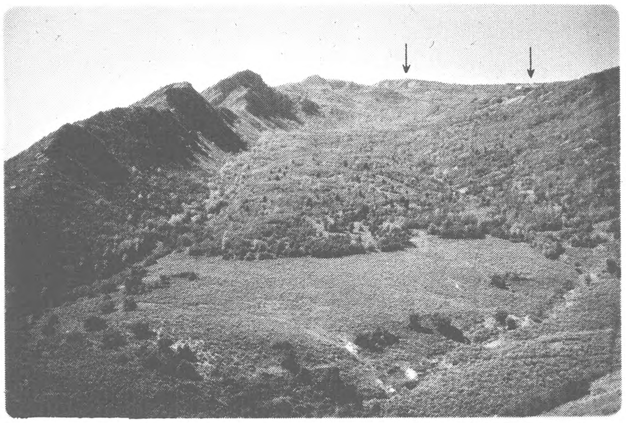


Figure 35. Middle and upper portions of the Thistle landslide. The largest and oldest of the several slides (1 on figure 36) here passes out of the picture to the left. The toe of the next larger and older slide (2) is marked by the prominent vegetation change from sagebrush to scrub oak in the middle distance. Slump block related to the first or second debris-flow, or both, is seen in the right foreground (3). The arrow points to historic slumps and flows in the head region (4).

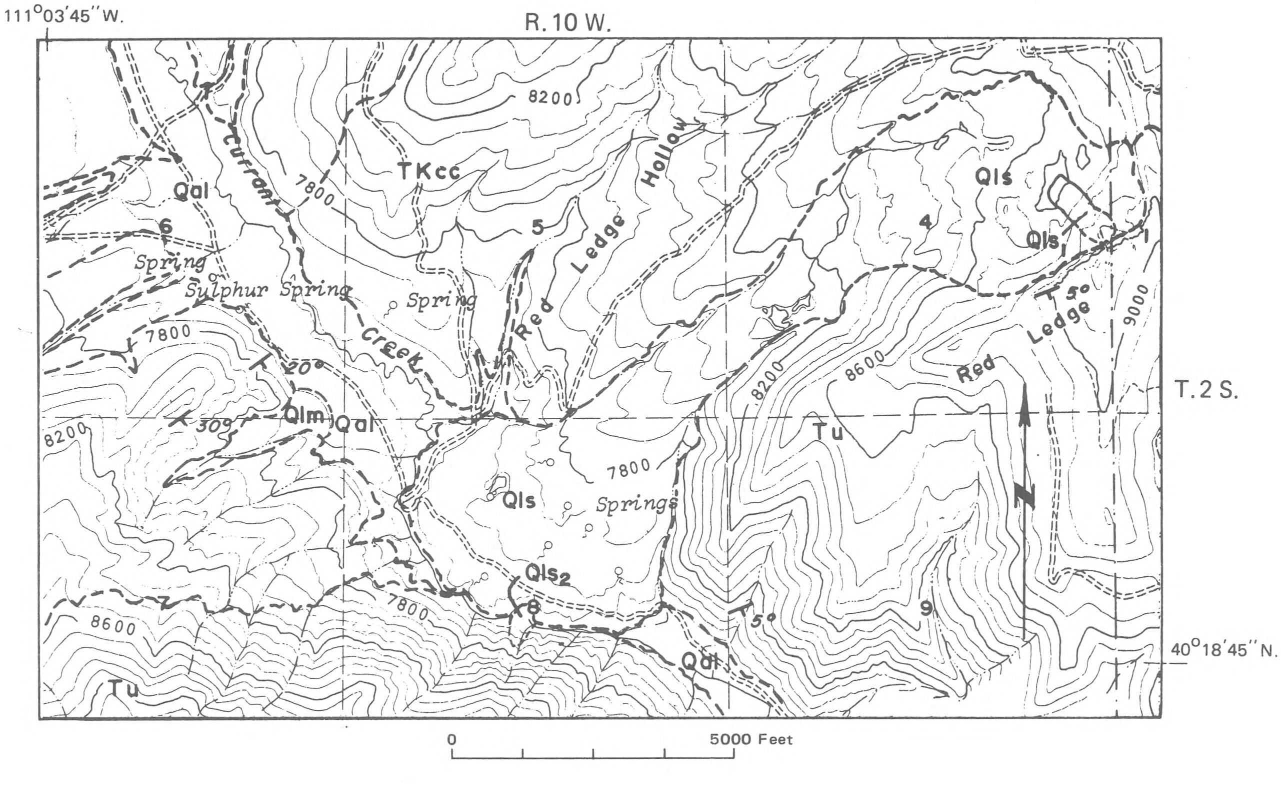


Figure 34. Geologic map of Currant Creek landslide (geology mostly from Garvin, 1967).

Qal – Quaternary alluvium
Qls$_1$ – Quaternary debris-slide No. 1
Qls$_2$ – Quaternary debris-slide No. 2
Qls – Quaternary landslide (slump and debris-flow)
Qlm – Quaternary mudflow
Tu – Tertiary Uinta (?) Formation
TKcc – Tertiary and/or Cretaceous Currant Creek Formation

Vegetation: sagebrush and aspen on lower flowed portion; scrub oak, willows and conifers on upper slumped portion.

Geologic setting: conglomerate and bentonitic sandstone of the Currant Creek Formation of Cretaceous and Paleocene age, and conglomerate, sandstone and shale of the Uinta (?) Formation of Eocene age, all of which dip gently to the south.

Causes: bentonitic sandstone in the Currant Creek Formation became saturated and very unstable.

Correlation: fresh uneroded aspect indicates a definite post-Wisconsin age; tree rings indicate the slide is more than 311 years old.

Geomorphic age: late youth, based on hummocky topography, partially filled surface ponds, fairly recent draining of landslide-dammed lake and development of meanders in subsequent lacustrine plain; rejuvenation in some areas is indicated by creep phenomena such as fresh cracks and recently tilted trees.

This landslide has a number of distinctive features which set it apart from many other landslides in Utah. Its relative recency and large size have allowed preservation of many landforms which usually are swiftly eroded away. For example, striking landslide levees occur all along the flanks of the slide; their presence attests to the fluidity of the moving mass and their large size to its high speed. Two subsidiary debris-slides occurred, one from the crown caused by oversteepening by the original slide, and one at the toe caused by undercutting of the opposite side of the valley by Currant Creek.

THISTLE LANDSLIDE
(figures 35-37)

Previous work: map, Metter, 1955; description, Rigby, 1962; map, Hintze, 1962.

Type: complex slump and debris-flow.

Dimensions: width, 4,000 ft at head, 1,000 ft in middle, 900 ft at toe; length, 8,000 ft; thickness, 50 ft; volume, 25 million cubic yards.

Elevation: crown, 6,800 ft; head, 6,500 ft; toe, 5,100 ft.

Rate of movement: very rapid to slow.

Slope exposure: northeast.

Vegetation: sagebrush and scrub oak.

Geologic setting: conglomerate, sandstone and red shale of the North Horn Formation of Cretaceous-Tertiary age, which is overlain by Tertiary limestone, shale and sandstone of the Flagstaff Formation and conglomerate and red beds of the Colton Formation, also of Tertiary age.

Causes: poorly consolidated, argillaceous nature of the North Horn Formation.

Correlation: numerous slides have occurred, dating from late Pleistocene until very recently.

Geomorphic age: early youth to maturity, as shown by successively younger slides headward.

This slide well illustrates repetitive or retrogressive movement. Continued instability in the head region is maintained by the formation of the main scarp after each episode of movement. Subsequent triggering effects produce successive landslides, each shorter and smaller than the preceding because of the reduction in slope and available unstable material.

YORK LANDSLIDE
(figures 38, 39)

Previous work: map, Eardley, 1934; map and description, Foutz, 1960.

Type: debris-flow.

Dimensions: width, 1,980 ft at head, 300 ft at narrowest point below foot line, 2,600 ft at toe; length, 6,280 ft from toe to head; thickness, 60 ft; volume, 200,000 cubic yards.

Elevation: crown, 6,200 ft; head, 5,900 ft; toe, 5,000 ft.

Rate of movement: rapid.

Slope exposure: west.

Vegetation: sagebrush, juniper and scrub oak.

Geologic setting: conglomerate and sandstone of Price River-North Horn Formation of Cretaceous-Tertiary age and Flagstaff Limestone of Tertiary age, which unconformably overlie Paleozoic carbonate and detrital rocks.

Causes: poorly consolidated and argillaceous nature of Price River-North Horn Formation and presence of possible earthquake-prone fault along mountain front.

Correlation: late Pleistocene or Holocene.

Geomorphic age: middle maturity, based on eroded remnant of landslide levees, dissection, lack of undrained depressions, and integrated drainage.

POLE CANYON LANDSLIDE
(figures 40, 41)

Previous work: map, Hintze, 1962.

Type: probably complex rockslide and debris-slide but best called debris-slip because type of original material and movement are obscure.

Dimensions: width, 3,700 ft; length, 3,000 ft; thickness, 100 ft; volume, 43 million cubic yards.

Elevation: crown, 7,400 ft; head, 6,600 ft; toe, 5,800 ft.

Rate of movement: probably rapid.

Slope exposure: west.

Vegetation: sagebrush, scrub oak and juniper.

Geologic setting: Gardison Limestone of Mississippian age outcrop in the prominent Wasatch fault scarp.

Causes: steep slopes and possible earthquakes, both produced by the Wasatch fault.

Correlation: middle or late Pleistocene, based on thick caliche horizon.

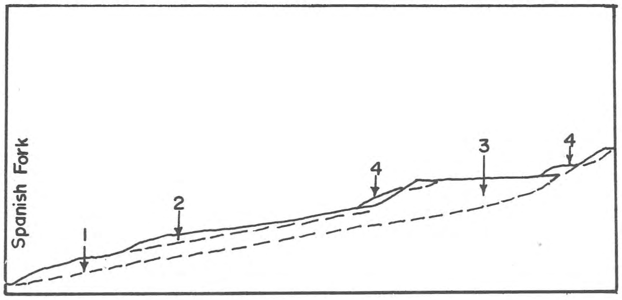


Figure 36. Schematic cross section of Thistle landslide drawn nearly to scale. 1–first debris-flow, 2–second debris-flow, 3–slump block related to either first or second debris-flow, or both, 4–mudflows and debris-flows of historic age. Refer to figure 35 for locations of these features.

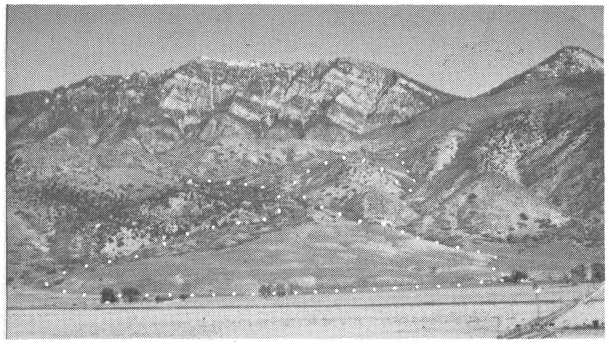


Figure 38. York landslide from the opposite side of Juab Valley. White dots indicate lower limits of slide.

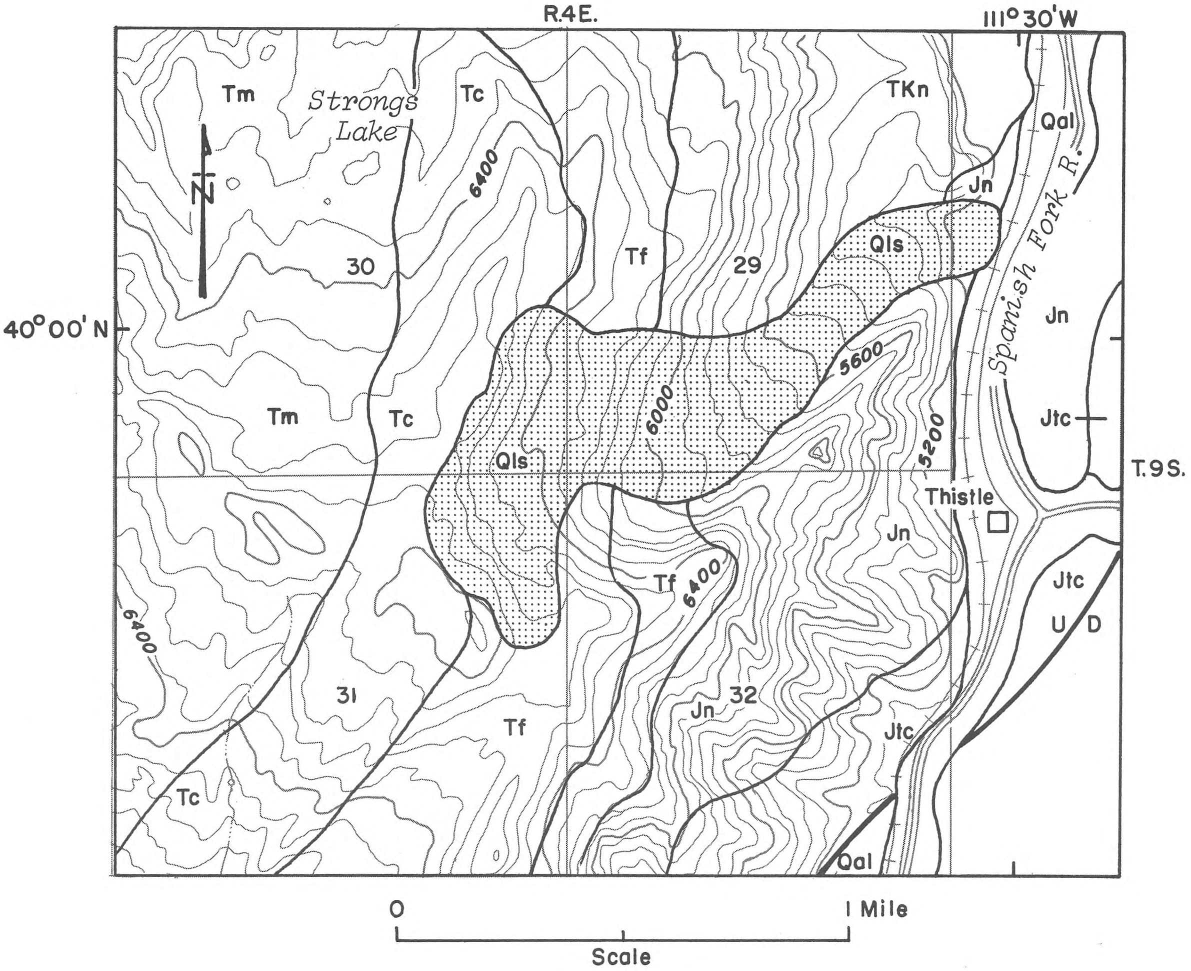


Figure 37. Geologic map of Thistle landslide (adapted from Hintze, 1962).

Qal	Quaternary alluvium	Tf	Tertiary Flagstaff Formation
Qls	Quaternary landslide	Tkn	Cretaceous and Tertiary North Horn Formation
Tm	Tertiary Moroni Formation	Jn	Jurassic Nugget Sandstone
Tc	Tertiary Colton Formation	Jtc	Jurassic Twin Creek Limestone

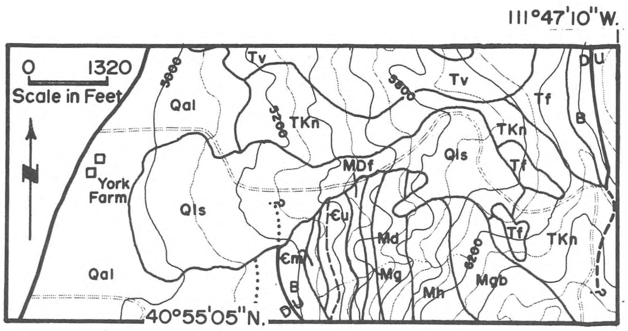


Figure 39. Geologic map of York landslide (adapted in part from Foutz, 1960, and Hintze, 1962).

Qal – Quaternary alluvium
Qls – Quaternary landslide
Tv – Tertiary volcanics undifferentiated
Tf – Tertiary Flagstaff Formation
TKn – Cretaceous and Tertiary Price River–North Horn Formation
Mgb – Mississippian Great Blue Limestone
Mh – Mississippian Humbug Formation
Md – Mississippian Deseret Limestone
Mg – Mississippian Gardison Limestone
MDf – Mississippian and Devonian Fitchville Formation
Cu – Upper Cambrian, undivided
Cm – Middle Cambrian, undivided
B – fault breccia
. . . . – Lake Bonneville shoreline

Geomorphic age: middle to late maturity, based on strongly eroded main scarp, lack of hummocky topography and extensive post-slide faulting.

Post-slide movement on the Wasatch fault produced a prominent scarp and partial graben on the toe of the slide.

COUCH CREEK LANDSLIDE
(figures 41-43)

Previous work: map, Eardley, 1934; map and description, Johnson, 1959; map, Hintze, 1962; description, Rigby, 1962, p. 81.

Type: debris-slide (?); impossible to classify because original type of material and movement is unknown.

Dimensions: width, 1,400 ft at head, 3,100 ft at toe; length, 6,100 ft; thickness, 100 ft; volume, 25 million cubic yards.

Elevation: head, 7,000 ft; toe, 5,400 ft.

Rate of movement: slow to moderately fast.

Slope exposure: west.

Vegetation: sagebrush and scrub oak.

Geologic setting: Manning Canyon Shale, Great Blue Limestone and Oquirrh Formation outcropping in the eroded scarp of the Wasatch fault.

Causes: argillaceous nature of Manning Canyon Shale, and steep slopes and possible earthquakes produced by Wasatch fault.

Correlation: middle to late Pleistocene, based on thick caliche zone.

Figure 40. Overall view of the Pole Canyon landslide at the base of Mount Nebo. The landslide is in the center of the picture at the base of the scarp between the large canyon to the left and the equally large canyon immediately to the right. The arrows indicate a fairly recent post-landslide fault scarp.

Geomorphic age: early to middle maturity; based on lack of closed depressions, possible eroded remnant of landslide levee, and deep dissection by Couch Creek.

Post-slide faulting produced a zone of scarplets at the toe and has caused offset of caliche beds. Couch Creek subsequently cut down into its bed several tens of feet and caused an increase in slope of its banks from 30° to 40°. The eroded material was deposited as an alluvial fan which buried the fault scarp on the flank of the slide.

SILVER PASS LANDSLIDE
(figure 44)

Previous work: map, Lovering and others, 1960; description, Goode, 1961, p. 133.

Type: blockslide or slump.

Dimensions: width, 800 ft; length, 700 ft head to toe, 1,000 ft crown to toe; thickness, 25 ft; volume, 440,000 cubic yards.

Elevation: crown, 7,000 ft; head, 6,800 ft; toe, 6,600 ft.

Rate of movement: possibly moderate to rapid.

Slope exposure: east.

Vegetation: sagebrush.

Geological setting: tuffs and agglomerates of the Laguna Springs latite of Tertiary age. The rocks were subjected to intense argillic alteration, producing a variety of clay minerals. A fault probably passes under the landslide.

Causes: probably the presence of the clay minerals and the fault.

Correlation: late pre-Lake Bonneville or early Lake Bonneville in age (Goode, 1961, p. 133), or middle to late Pleistocene.

Geomorphic age: middle to late maturity, based on strongly eroded slump blocks, strong soil profile development, alluvial fan at base of main scarp; and general erosive blunting of typical landslide features.

At least five and perhaps eight slump blocks occur on the north lobe of the slide. No recognizable debris-flow exists below the slump blocks; this is either due to original absence or to subsequent removal by erosion. The probable original absence of

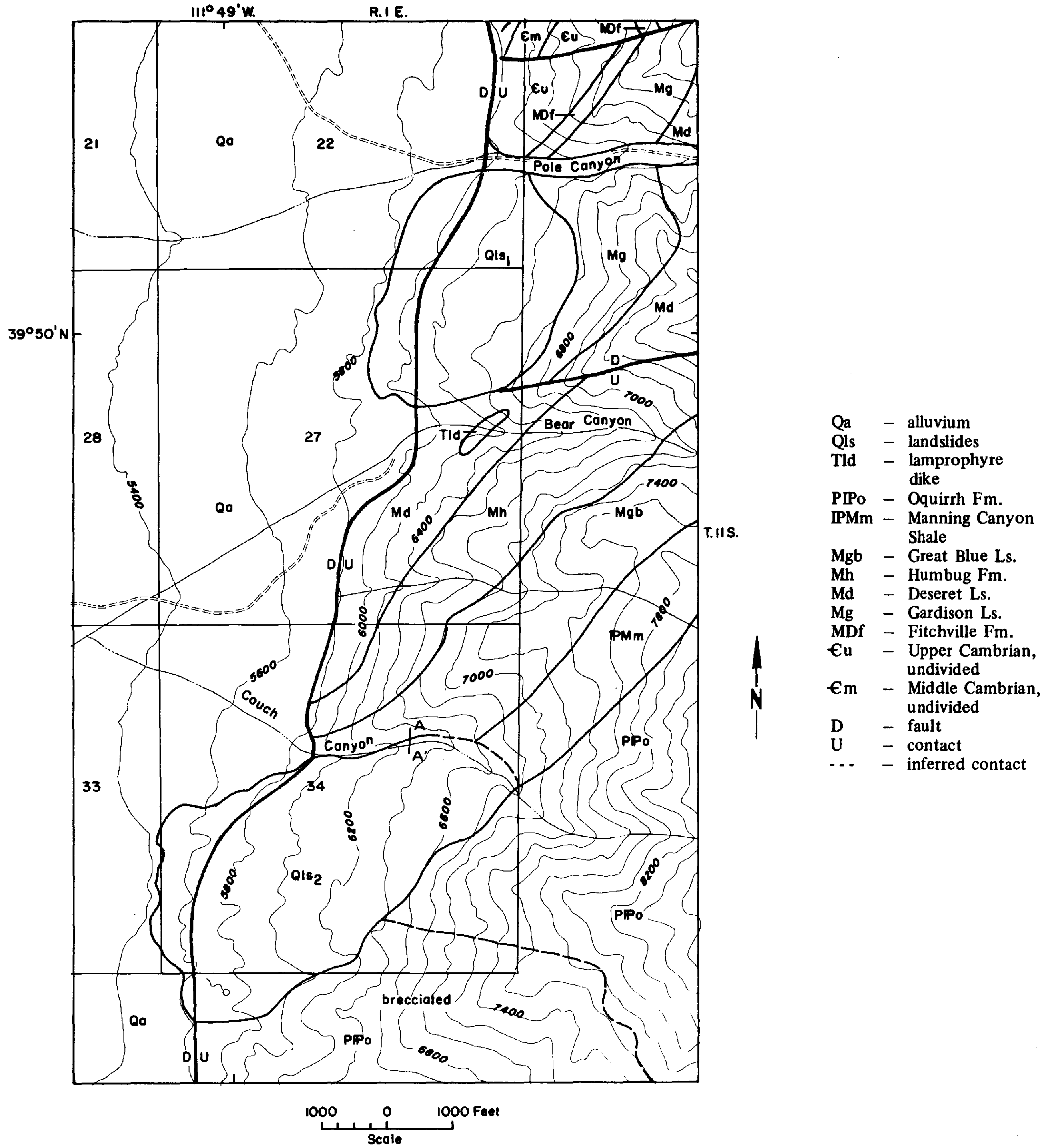


Figure 41. Geologic map of Pole Canyon (Qls_1) and Couch Creek (Qls_2) landslides (adapted from Hintze, 1962).

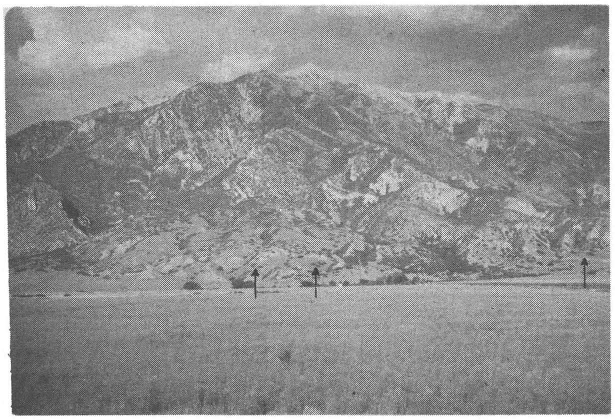


Figure 42. View to the east showing Couch Creek landslide at the base of Mount Nebo. The dark zone at the left on the lower central slopes of the mountain is the slope-forming Manning Canyon Shale. This zone passes downslope into the light-colored hummocky topography of the landslide. The right-hand vertical arrow points out a fault scarp formed by recent movement on the Wasatch fault. This scarp passes laterally into a zone of scarps in the landslide. The scarp zone is shown by the two central arrows.

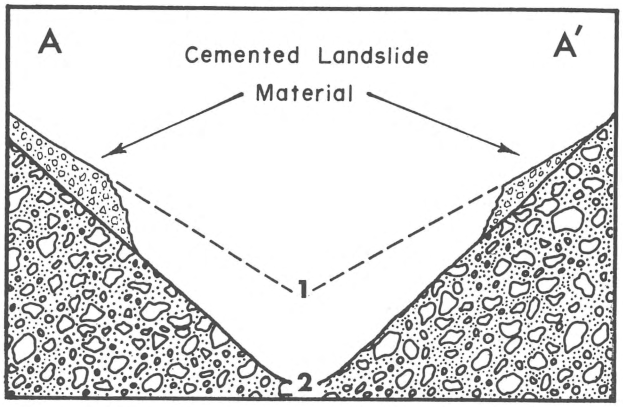


Figure 43. Schematic cross section of Couch Creek Canyon showing profile of canyon (1) prior to most recent faulting, and present profile (2). Location of this cross section shown by line connecting A–A' on figure 41.

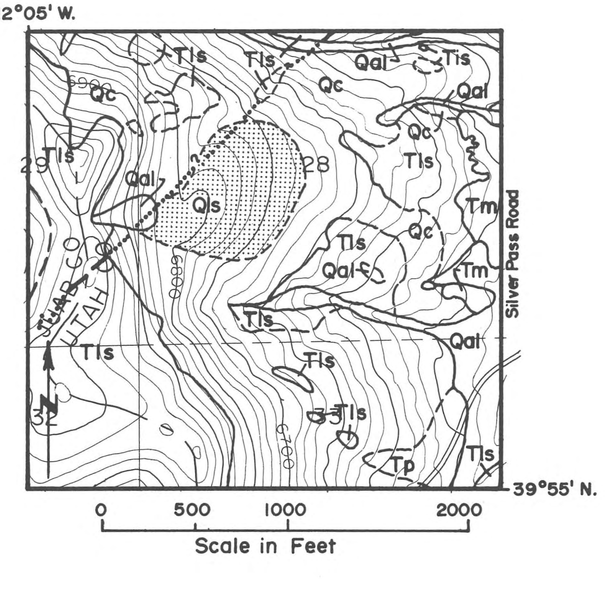


Figure 44. Geologic map of Silver Pass landslide SW¼ sec. 28, T. 10 S., R. 2 W., Salt Lake Meridian, Utah County, Utah (geology from Lovering and others, 1960).

Qal – Quaternary alluvium
Qc – Quaternary colluvium
Qls – Quaternary landslide
Tls – Tertiary Laguna Springs latite
Tp – Tertiary Packard quartz latite
Tm – Tertiary monzonite

flow indicates dry conditions at the time of sliding, a characteristic of the Great Basin and a reason for the paucity of landslides there.

RATTLESNAKE HILL LANDSLIDE
(figures 45, 46)

Previous work: description, stratigraphy and maps, McGookey, 1958, 1960.

Type: rock- or debris-slide; difficult to classify because the speed and size of the initial movement and subsequent weathering reduced much of the original bedrock to fine clastics.

Dimensions: width, 3,500 ft at toe, 2,000 ft at narrowest point at foot line, 3,500 ft at head; length, 4,400 ft head to toe, 5,400 ft crown to toe; thickness, 100 ft; volume, 34 million cubic yards.

Elevation: crown, 6,800 ft; head, 6,300 ft; toe, 5,500 ft.

Rate of movement: very rapid.

Slope exposure: south.

Geologic setting: siltstone, sandstone and limestone of Flagstaff Formation, bentonite bed, shale and siltstone of Colton Formation, and shale and limestone of Green River Formation, all are of Tertiary age.

Causes: argillaceous and bentonitic components of the rock units and downcutting of Salina Creek, combined with possible earthquakes produced by the nearby Sevier fault.

Correlation: middle to late Pleistocene, based on large amount of erosion of surface features.

Geomorphic age: late maturity to early old age, based on degree of erosion of slide surface and main scarp.

MOUNT TERREL LANDSLIDE
(figure 47, 48)

Previous work: map, McGookey, 1958.

Type: debris-flow.

Dimensions: width, 800-1,000 ft at head, 140 ft at narrowest point below foot line, 800 ft at toe; length, 4,300 ft; thickness, 15 ft; volume, 280,000 cubic yards.

Rate of movement: rapid.

Slope exposure: southwest.

Vegetation: sagebrush, willows, aspen and conifers.

Geologic setting: unnamed bentonitic sandstone and conglomerate unit which overlies and may interbed with the Flagstaff Formation of Paleocene age.

Causes: unstable bentonitic rock unit.

Correlation: Holocene, based on obvious recency of movement.

Geomorphic age: middle youth, based on early climax vegetation in places and general uneroded aspect.

This slide has at least two sets of landslide levees, the largest measuring 27 ft in height, indicating two or more surges or times of movement.

THOMPSON CREEK LANDSLIDE
(figure 49)

Previous work: map and description, Callaghan and Parker, 1961.

Type: debris-flow or debris-avalanche; criteria for assessing original mositure conditions and velocity are lacking.

Dimensions: width, 8,000 ft; length, 4 miles; thickness, 150 ft; volume 1,000 million cubic yards.

Elevation: crown, 10,500 ft; head, 8,750 ft; toe, 5,300 ft.

Rate of movement: very rapid.

Slope exposure: northwest.

Vegetation: sagebrush and conifers.

Geologic setting: basaltic andesite flows of the Dry Hollow Formation and latite flows, tuffs and breccias of the Bullion Canyon volcanics.

Causes: strongly jointed volcanic rocks, great relief along upthrown side of Sevier fault, and possible earthquakes resulting from movement on the fault.

Correlation: middle to late Pleistocene; three separate and distinct episodes of movement, separated by long intervals of erosion, might be correlated with increased precipitation during glacial stages but this is highly speculative.

Geomorphic age: first slide, early to middle old age, based on dissection; second slide, late maturity, based on extensive alluvial fan development and integrated drainage; third slide, early to middle maturity, based on possible landslide-levee or distal ridge remnant, and small amount of alluviation.

The large size and great length, coupled with possible distal ridges and debris cones, indicate that this slide may have been lubricated by a layer of compressed air in the manner Shreve (1959) envisioned for several large, very rapid mass movements.

ELBOW LANDSLIDE
(figures 50, 51)

Previous work: map and description, Willard and Callaghan, 1962.

Type: complex slump, and rock- and debris-flow and avalanche.

Dimensions: width, 2.6 miles at toe, 1.1 miles at foot line, and 1.8 miles at head; length, 3 miles; thickness, average 100 ft; volume, 825 million cubic yards.

Elevation: crown, 10,000 ft; head, 8,600 ft; toe, 6,250 ft.

Rate of movement: probably very rapid.

Slope exposure: west.

Vegetation: juniper, sagebrush and scrub oak.

Geologic setting: gently dipping Bullion Canyon volcanics, Dry Hollow Formation (volcanics) and basalt; with Sevier fault passing under middle of slide.

Causes: probably due primarily to steep slopes and possible earthquakes produced by the Sevier fault.

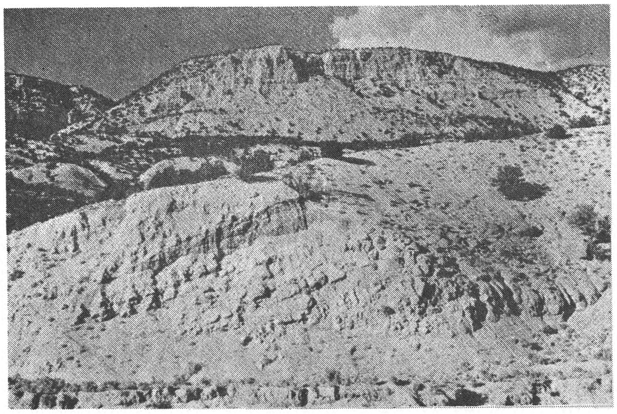


Figure 45. View from the toe of the Rattlesnake Hill landslide to the main scarp of Green River Formation limestone in the background. The large bedded block in the foreground is a mass of the Flagstaff Formation which is about 190 feet long and at least 75 feet thick. It was moved from its original position many hundreds of feet upslope.

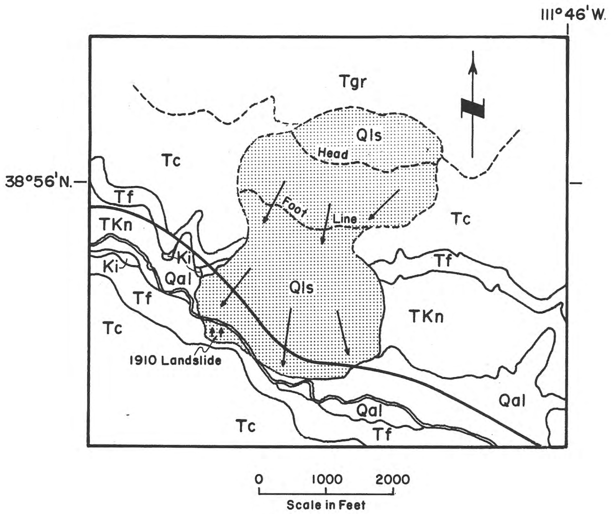


Figure 46. Geologic map of Rattlesnake Hill landslide. Map taken from aerial photographs.

Qal	–	Quaternary alluvium
Qls	–	Quaternary landslide
Tgr	–	Tertiary Green River Formation
Tc	–	Tertiary Colton Formation
Tf	–	Tertiary Flagstaff Formation
TKn	–	Cretaceous and Tertiary North Horn Formation
Ki	–	Cretaceous Indianola Group

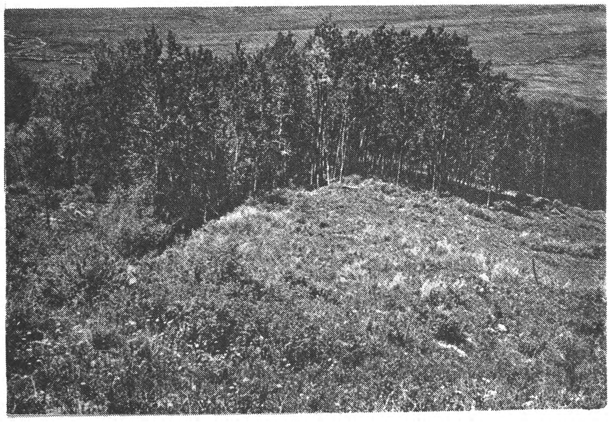


Figure 47. Landslide levee on the north flank of the Mount Terrel debris-flow. The flow passed by on the left. The levee is asymmetrical with the side toward the flow the steeper.

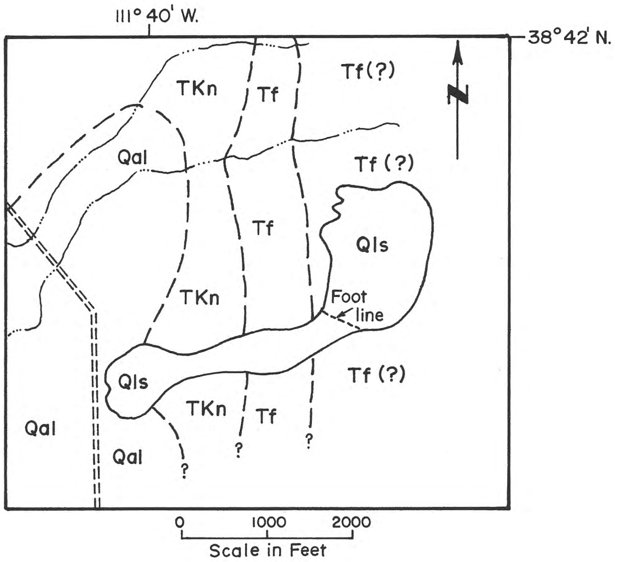


Figure 48. Geologic sketch map of Mount Terrel landslide. The geologic boundaries are uncertain because of extensive colluvial cover. Adapted from aerial photographs.

Qa	–	Quaternary alluvium
Qls	–	Quaternary landslide
Tf(?)	–	Tertiary Flagstaff (?) Formation, sandstones, tuffs and conglomerates
Tf	–	Tertiary Flagstaff Formation limestone
TKn	–	Cretaceous and Tertiary North Horn Formation

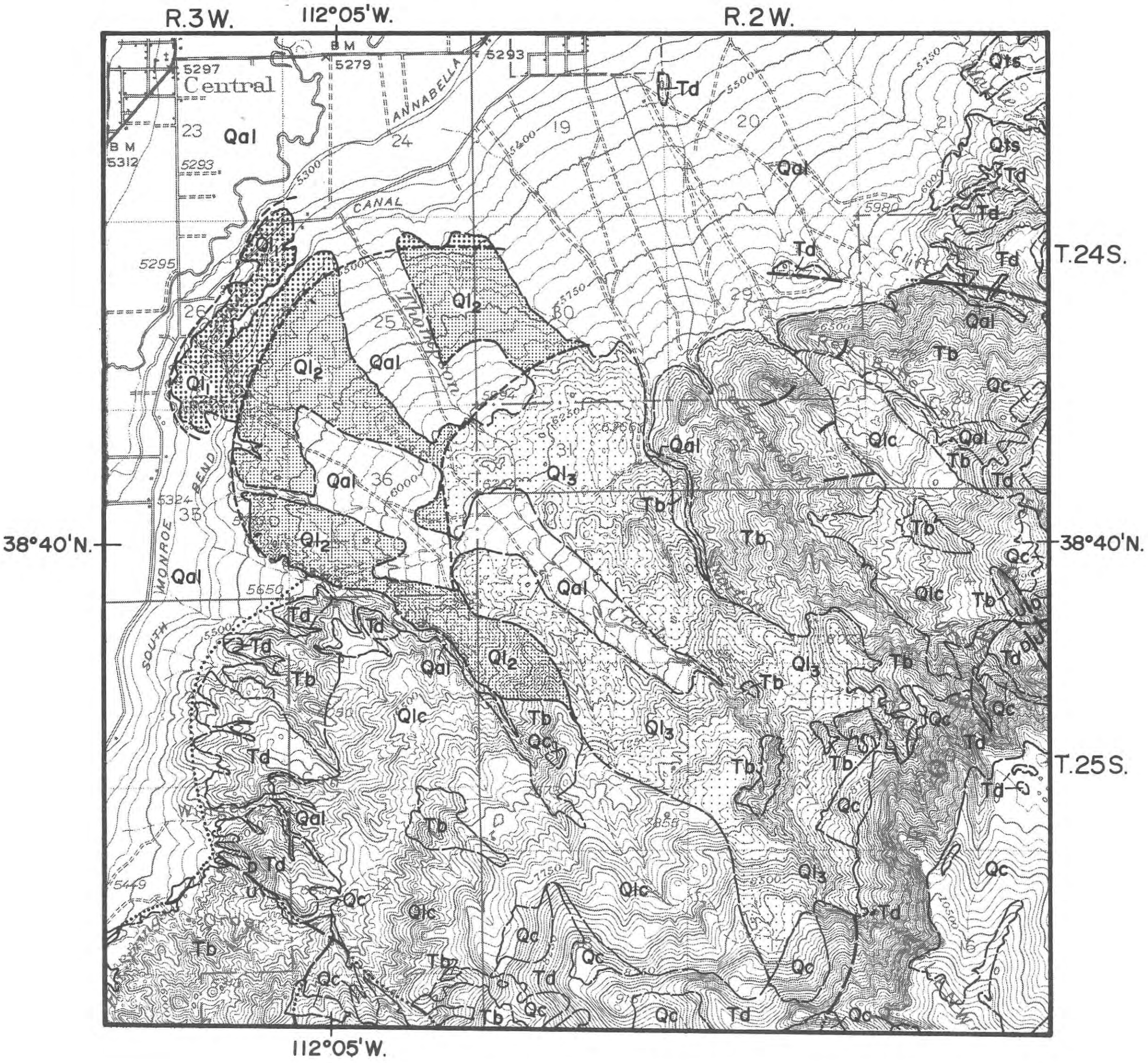


Figure 49. Geologic map of Thompson Creek landslide (geology adapted from Callaghan and Parker, 1961).

Qal	– Quaternary alluvium
Qc	– Quaternary colluvium and talus
Qlc	– Quaternary colluvium, talus and landslide
Ql_3 Ql_2 Ql_1	– Quaternary Thompson Creek landslide; three generations of sliding
QTs	– Quaternary and/or Tertiary Sevier River Formation
Td	– Tertiary Dry Hollow Formation
Tb	– Tertiary Bullion Canyon volcanics
---	– Marks toes of three generations of sliding of Thompson Creek landslide

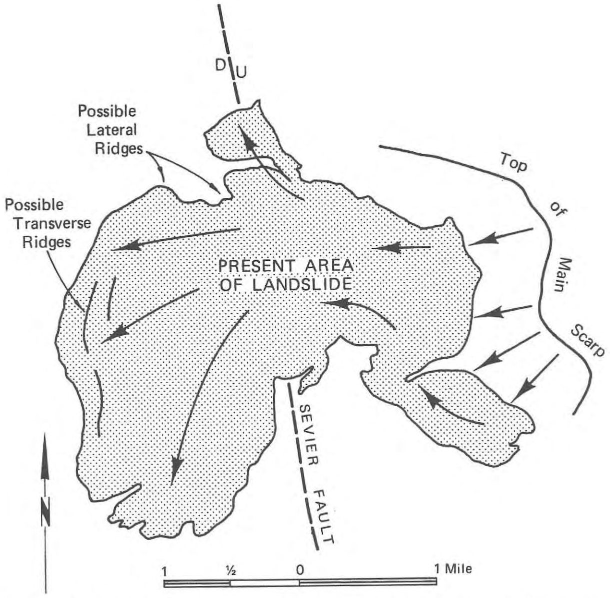


Figure 50. Diagram of Elbow landslide showing inferred multi-directional movement.

Correlation: middle to late Pleistocene, based on depth of dissection of slide.

Geomorphic age: middle maturity, based on filled depressions, moderately integrated drainage, eroded slump blocks and strongly developed soil profile.

This landslide has prominent transverse ridges in its lower part and possible eroded lateral ridges on the north flank. These features, together with the 3-mile length, lend support to a possible air-lubrication hypothesis of movement for this slide.

LITTLE CREEK PEAK LANDSLIDE
(figures 52-54)

Previous work: brief mention, Gregory, 1950a, p. 144.

Type: rockslide.

Dimensions: width, 550 ft at head; 900 ft at foot line; 500 ft at toe; length, 1,700 ft head to toe; thickness, 50 ft; volume, 300,000 cubic yards.

Elevation: between 8,000 and 9,000 ft.

Slope exposure: west.

Vegetation: aspen, scrub oak and sagebrush.

Geologic setting: volcanic agglomerates, tuffs and volcanic conglomerates of Brian Head Formation.

Causes: Gregory (1950a, p. 144) said that heavy rains in August (?) 1908 were probably the primary cause of the slide. A small normal fault passes through the south flank of the slide and under the foot. The fault dropped a friable tuff down to an unstable position as the bulwark against which the main mass of the slide rested. Saturation of the agglomerates and tuffs above the fault could then have caused the weak bulwark to burst (figure 53).

Correlation: historic Holocene.

Geomorphic age: middle youth, based on incomplete aspen succession, fresh rock, extremely hummocky topography and complete lack of dissection.

GREEN HOLLOW LANDSLIDE
(figures 55, 56)

Previous work: map and description, Thomas and Taylor, 1946; map and description, Gregory, 1950a.

Type: complex slump and debris-flow.

Dimensions: width, 1 mile at crown, ½ mile at head, ¾ mile at toe; length, 2½ miles head to toe; thickness, 50 ft; volume, 290 million cubic yards.

Elevation: crown, 9,000 ft; head, 8,500 ft; toe, 6,120 ft.

Rate of movement: rapid.

Slope exposure: west.

Vegetation: sagebrush, ponderosa pine, juniper and mountain mahogany.

Geologic setting: interbedded shale, sandstone and coal of the Tropic Formation, Straight Cliffs and Wahweap sandstones and Quaternary basalt form the main mass of the slide. The landslide passed over the upturned edges of the Winsor, Curtis, Entrada, Carmel, Navajo, Chinle, Shinarump and Moenkopi formations.

Causes: failure of the Tropic Formation, probably because of bentonitic shales or friable coal beds. An abundance of moisture or movement on the Hurricane fault could have been the trigger.

Correlation: late Pleistocene or early Holocene.

Geomorphic age: early maturity, based on fairly recent appearance but absence of youthful features. Integrated drainage is partially established across the slide, and Green Lake, formed on the backslope of a slump block at the head (figure 55) is largely filled with sediment and vegetation.

Several small earth- and debris-flows occurred on the main scarp in historic times.

SQUARE MOUNTAIN LANDSLIDE
(figures 56, 57)

Previous work: map and description, Thomas and Taylor, 1946; map and description, Gregory, 1950a; map and description, Averitt, 1962.

Type: complex slump and debris-flow.

Dimensions: width, 3,000 ft at head, 400 ft at narrowest point, 4,000 ft at toe; length, 2.5 miles; thickness, 50 ft; volume, 47 million cubic yards.

Elevation: crown, 8,600 ft; head, 7,700 ft; toe, 5,880 ft.

Rate of movement: rapid.

Slope exposure: west.

Vegetation: juniper.

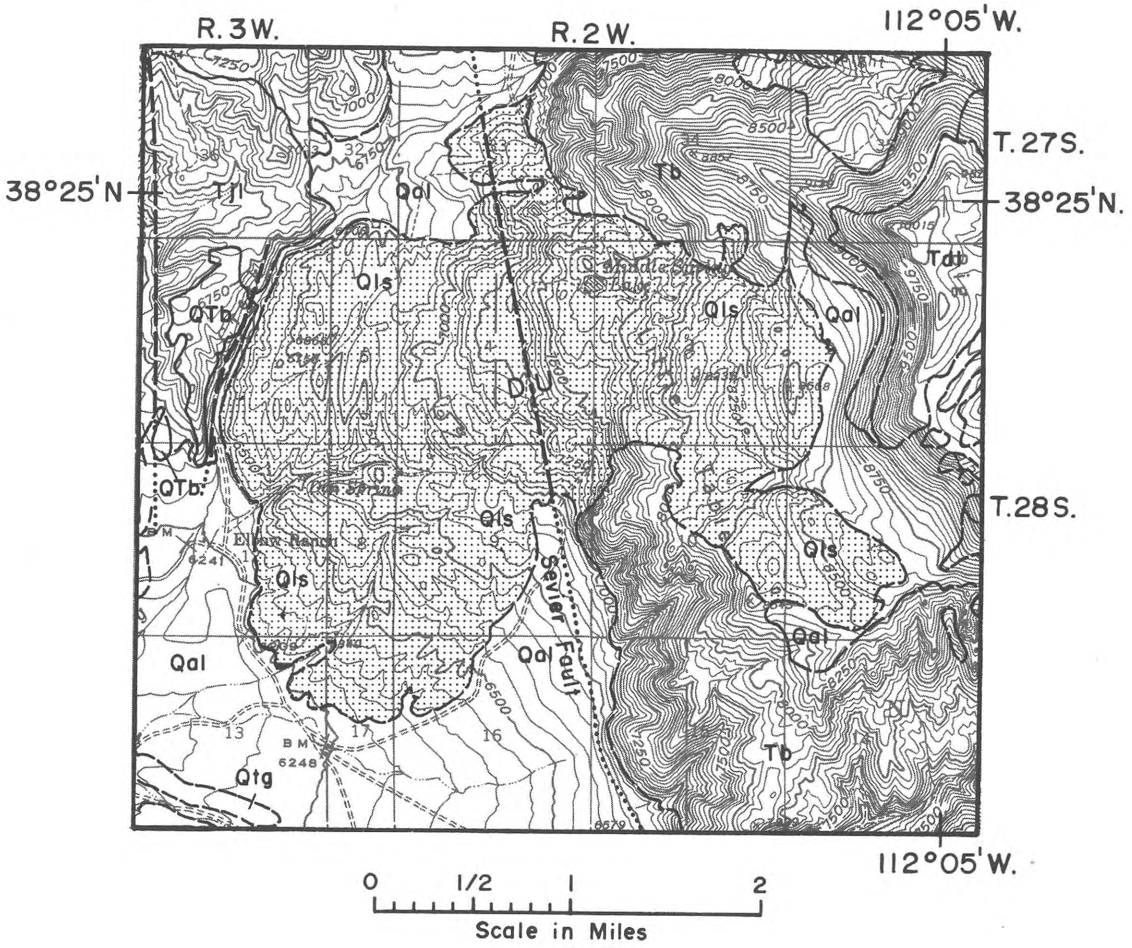


Figure 51. Geologic map of Elbow landslide (geology from Willard and Callaghan, 1962).

Qal – Quaternary alluvium, colluvium and talus
Qls – Quaternary landslide
Qtg – Quaternary terrace gravel
QTb – Quaternary or Tertiary basalt
Tjl – Tertiary Joe Lott tuff
Tdl – Tertiary Dry Hollow Formation
Tb – Tertiary Bullion Canyon volcanics

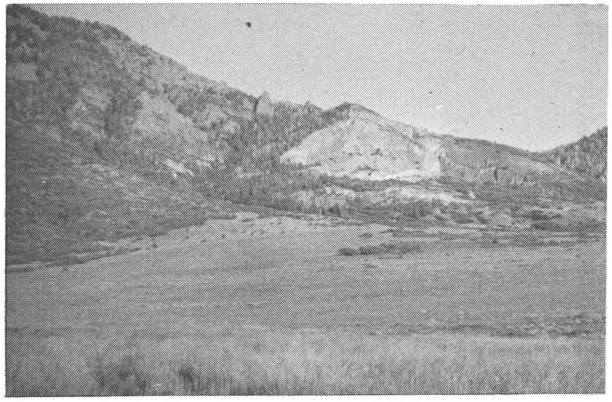
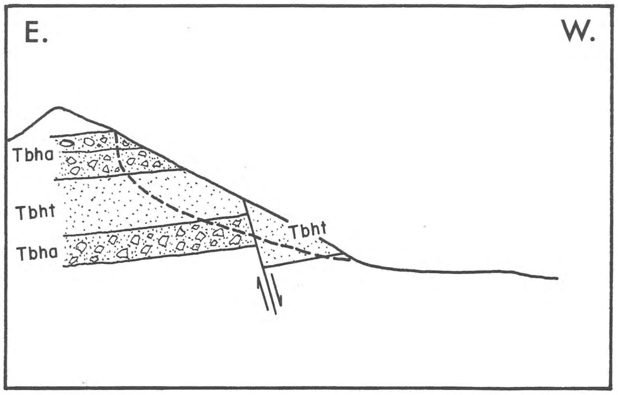


Figure 52. Little Creek Peak landslide as seen from the northwest. The light-colored, triangular main scarp shows prominently. The lower portions of the slide are moderately vegetated.

Figure 53. Schematic cross section showing very generalized structural relations of Little Creek Peak landslide. Dashed line indicates approximate slip surface.

Tbht – friable tuff of the Brian Head Formation
Tbha – agglomerates of the Brian Head Formation



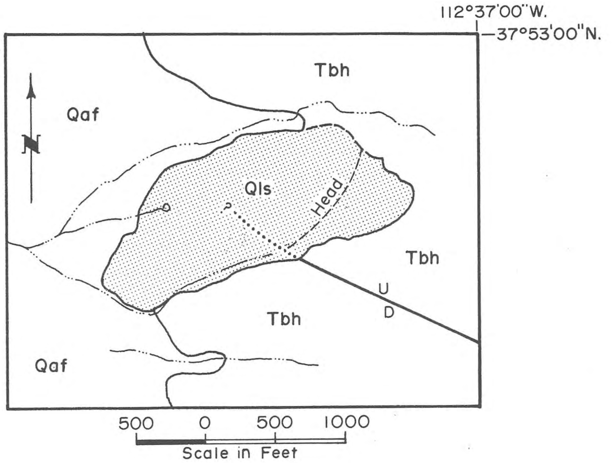
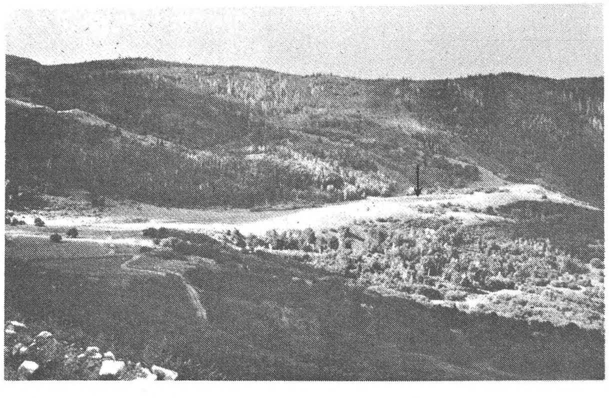


Figure 54. Geologic map of Little Creek Peak landslide. Adapted from aerial photographs.

Qaf – Quaternary alluvial fan
Qls – Quaternary landslide
Tbh – Tertiary Brian Head Formation

Figure 55. South-facing view of Green Lake (indicated by arrow) which owes its origin to the back tilt of a large slump block which is about a mile long and just under 1,000 ft wide. Part of the main scarp of the landslide shows at the extreme left of the picture.



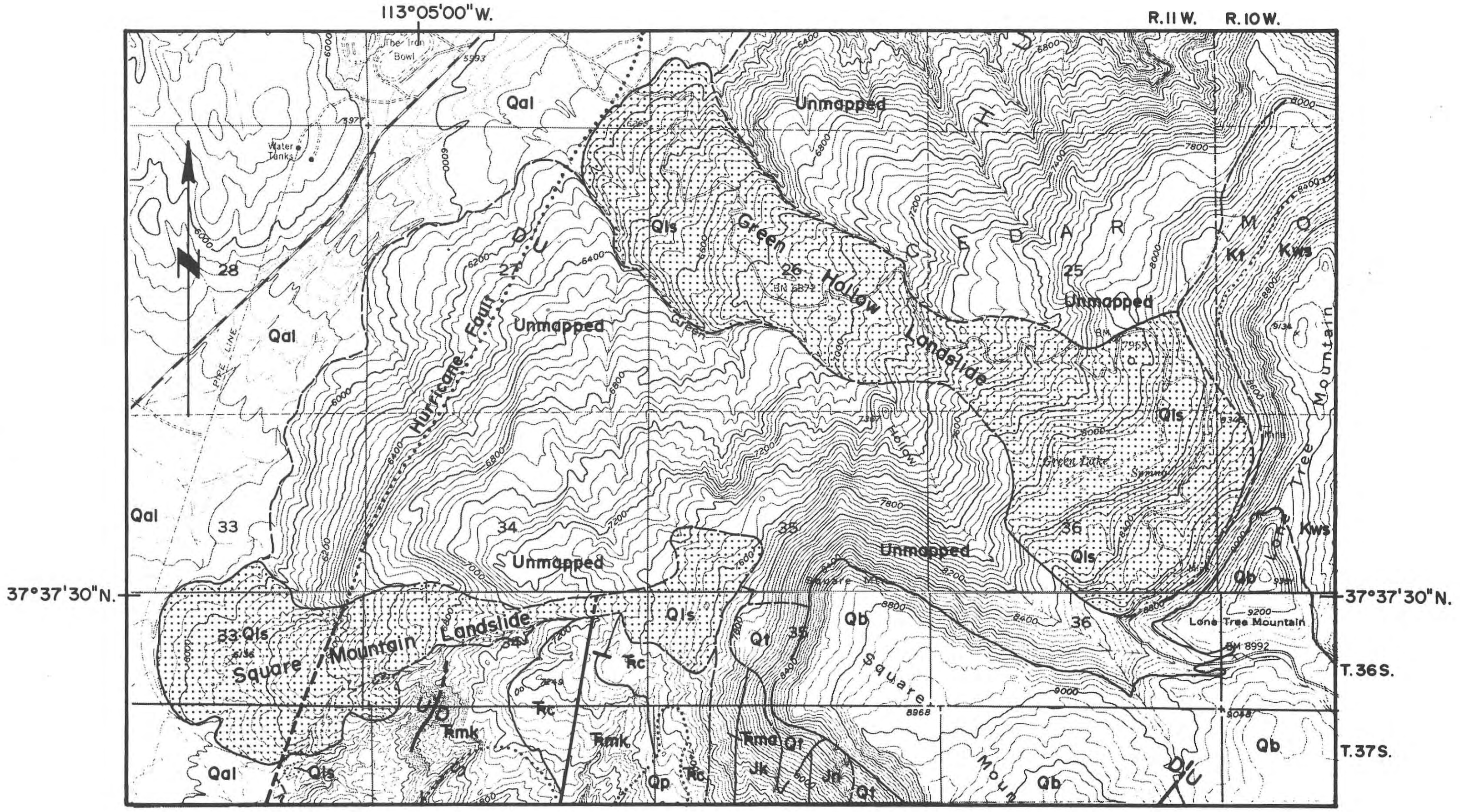


Figure 56. Geologic map of Green Hollow and Square Mountain landslides (geology in south part of map from Averitt, 1962).

Qal – Quaternary alluvium
Qls – Quaternary landslide
Qp – Quaternary pediment deposits
Qb – Quaternary basalt
Qt – Quaternary talus
Kws – Cretaceous Wahweap and Straight Cliffs Sandstone

Kt – Cretaceous Tropic Shale
Jn – Jurassic Navajo Sandstone
Jk – Jurassic Kayenta Sandstone
Ŧma – Triassic Moenave Formation
Ŧc – Triassic Chinle Formation
Ŧmk – Triassic Moenkopi Formation

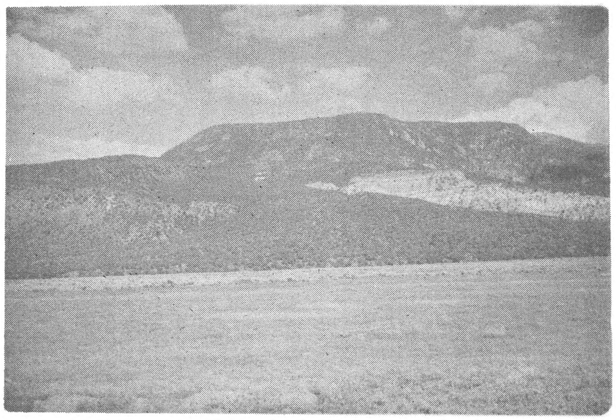


Figure 57. Overall view of the Square Mountain landslide, the large lobate heavily wooded zone. The main scarp is the imposing face of Square Mountain in the background.

Geologic setting: the flow is largely composed of Navajo and Kayenta Sandstone and Quaternary basalt which passed over the upturned edges of the Moenave, Chinle and Moenkopi formations (figure 56).

Causes: failure of Chinle Formation underlying the massive Navajo and Kayenta sandstones and Quaternary basalt; may have been started by abnormal precipitation or earth tremors on the nearby Hurricane fault.

Correlation: late Pleistocene or early Holocene.

Geomorphic age: early maturity, based on appearance of recency but absence of youthful features.

JOHNSON MOUNTAIN LANDSLIDE
(figure 58)

Previous work: mention and photograph, Gregory, 1950b, p. 183 and figure 30.

Type: complex blockslide and rockslide in upper elevations with possible flow in lower elevations.

Dimensions: width, 7,000 ft; length, 5,000 ft; thickness, 50 ft; volume, 65 million cubic yards.

Elevation: crown, 6,150 ft; head, 4,750 ft; toe, 3,850 ft.

Rate of movement: probably variable slow to rapid, with movement occurring over a long period.

Slope exposure: west and southwest.

Vegetation: sagebrush and juniper.

Geologic setting: the Petrified Forest Member of Chinle Formation has an upper unit composed of sandstone, conglomerates, shale, gypsum and limestone, and a lower unit of shales, soft sandstones, weathered volcanic ashes and many kinds of calcareous rocks (Gregory, 1950b, p. 67). The overlying Moenave Formation consists of a lower Dinosaur Canyon Sandstone Member, predominantly siltstone here, and an upper Springdale Sandstone Member. The overlying Kayenta Formation is here a sandstone with subordinate limestone and conglomerate (Gregory, 1950b, p. 80) which usually forms slopes. The uppermost unit is the Navajo Formation which is a strongly jointed, thick, cliff-forming mass of sandstone.

Causes: argillaceous and bentonitic nature of Chinle, coupled with downcutting and probable influent ground-water flow by North and East forks of Virgin River.

Correlation: late Pleistocene; possibly in early Wisconsin time, according to Eardley's (1965a) working hypothesis.

Geomorphic age: middle to late maturity, based on presence of minor hummocky topography together with extensive dissection of the surface.

Three large slump blocks have dips of 30°, 35° and 48° which indicate their rotation from the original nearly flat-lying position.

EAGLE CRAGS LANDSLIDE
(figures 58, 59)

Previous work: description, Gregory, 1950b, p. 183; map, Marshall, 1956.

Type: probably blockslide, flow, and subsidence resulting from lateral migration of plastic Chinle Formation.

Dimensions: width, 8,000 ft; length, 12,000 ft; thickness, 50 ft; volume, 180 million cubic yards.

Elevation: crown, 6,400 ft; head, 5,200 ft; toe, 3,850 ft.

Rate of movement: probably slow.

Slope exposure: north.

Vegetation: sagebrush and juniper.

Geologic setting: Petrified Forest Member of Chinle Formation, Dinosaur Canyon Sandstone Member and Springdale Sandstone Member of the Moenave Formation, the Kayenta Formation, and Navajo Sandstone.

Causes: failure of the Chinle Formation due to downcutting of East Fork of Virgin River and introduction of water into the formation.

Correlation: probably middle Pleistocene through Holocene.

Geomorphic age: late maturity to early old age, based on erosion through mass in several places and general obscure lateral relations between landslide and non-landslide topography.

This landslide is unique among those studied for this report in that it is so large an area of such low relief. Movement may have involved either retrogressive block sliding from the Virgin River to Eagle Crags, or individual unrelated failures of the Chinle as the formation was differentially saturated during downcutting and terracing above it.

NORTH ROUNDY LANDSLIDE
(figures 60-62)

Previous work: stratigraphy and map, Gregory, 1951; stratigraphy and map, Cashion, 1961; ground-water geology, Goode, 1964; stratigraphy, Lawrence, 1965; landslides mapped by writer with R. Sayre and J. Schmoker during 1966 University of Utah geology summer field camp.

Type: blockslide and debris-flow.

Dimensions: width, 8,000 ft; length, 3,500 ft; thickness, 100 ft; volume, 100 million cubic yards.

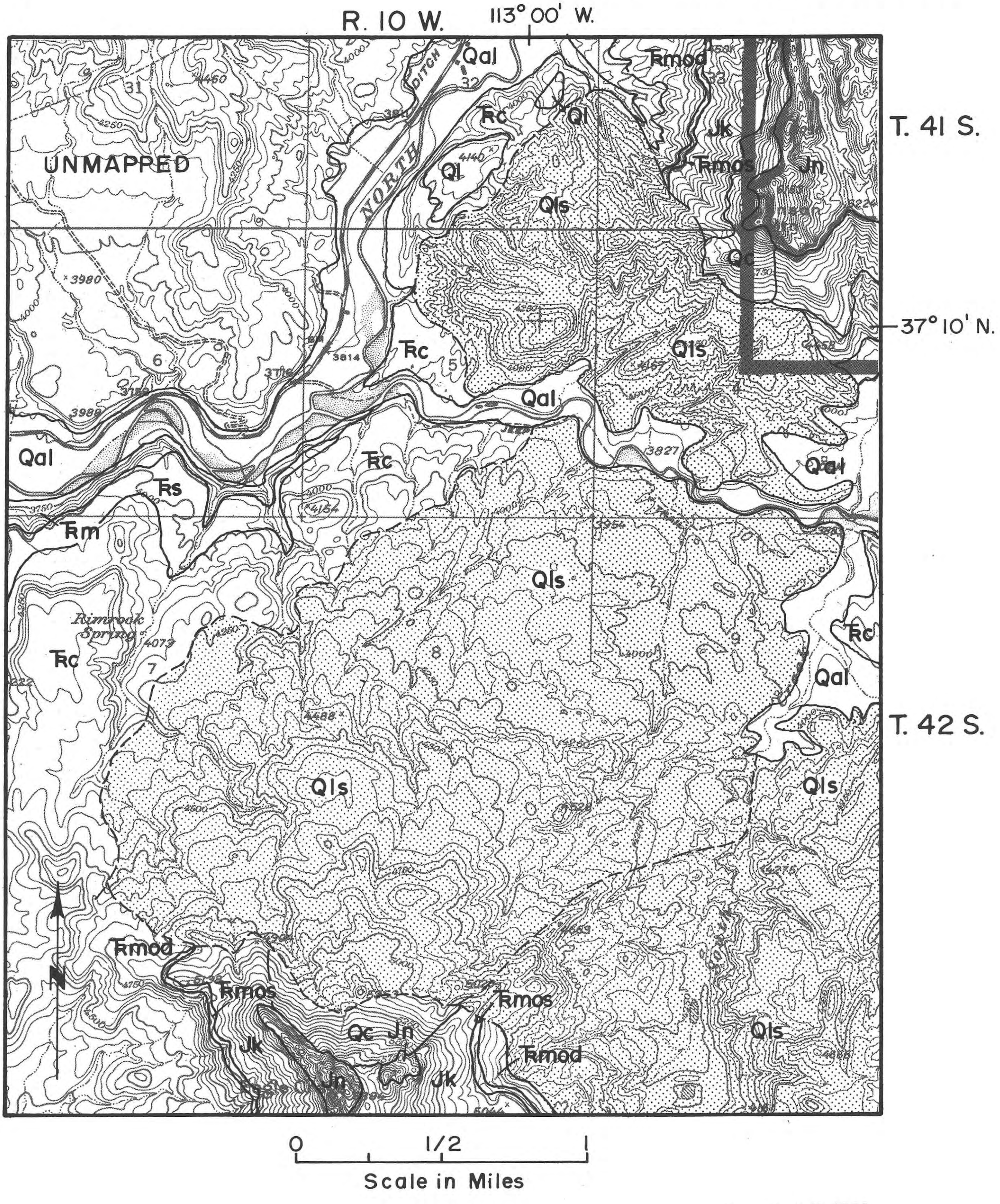


Figure 58. Geologic map of Johnson Mountain and Eagle Crags landslides (geology in part from Marshall, 1956).

Qal – Quaternary alluvium
Qc – Quaternary talus and colluvium
Qt – Quaternary terrace gravel
Qls – Quaternary landslide

Jn – Jurassic Navajo Sandstone
Jk – Jurassic Kayenta Formation
TRmos – Triassic Moenave Formation, Springdale Sandstone Member

TRmod – Triassic Moenave Formation, Dinosaur Canyon Sandstone Member
TRc – Triassic Chinle Formation
TRs – Triassic Shinarump Formation
TRm – Triassic Moenkopi Formation

Figure 59. View of Eagle Crags landslide from near the summit of Johnson Mountain. The entire area between Eagle Crags and the river in the foreground is landslide material. The arrow points to an arroyo in which the Chinle Formation is thrust up and squeezed about.

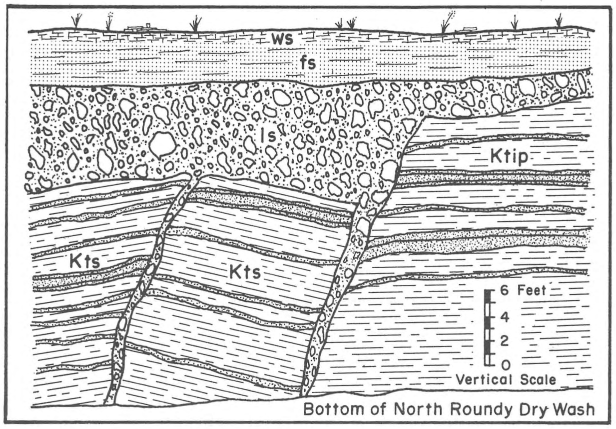


Figure 60. Diagram of stratigraphic relations between North Roundy landslide, overlying fluvial sands and underlying Tropic Shale in place and slumped. Profile exposed on west edge of North Roundy dry wash.

ws – weak soil
fs – fluvial sand
ls – landslide
Kts – slumped Tropic Shale
Ktip – Tropic Shale in place

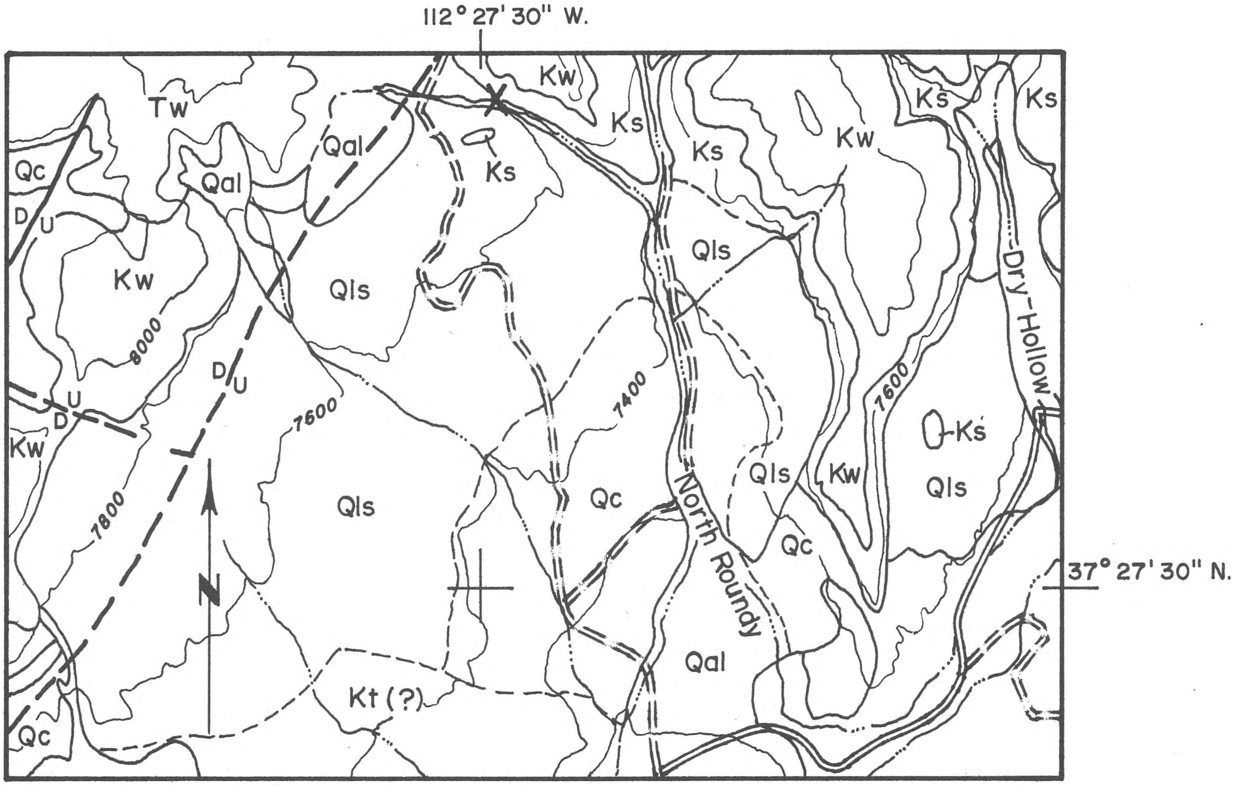


Figure 61. Geological map of North Roundy and Dry Hollow landslides. X marks the site of North Roundy landslide.

Qal – Quaternary alluvium and alluvial fan
Qc – Quaternary colluvium
Qls – Quaternary landslide
Kw – Cretaceous Wahweap Sandstone
Ks – Cretaceous Straight Cliffs Sandstone
Kt – Cretaceous Tropic Shale
Tw – Tertiary Wasatch Formation

Figure 62. View to the south showing part of the North Roundy landslide. The highland to the right is the main scarp of the slide and is also an obsequent fault-line scarp. The prominent lineation running north-south just to the right of center is a fault scarp representing recent movement along part of the Sevier fault. The North Roundy landslide is the gently sloping surface outlined by dots in the middle distance.

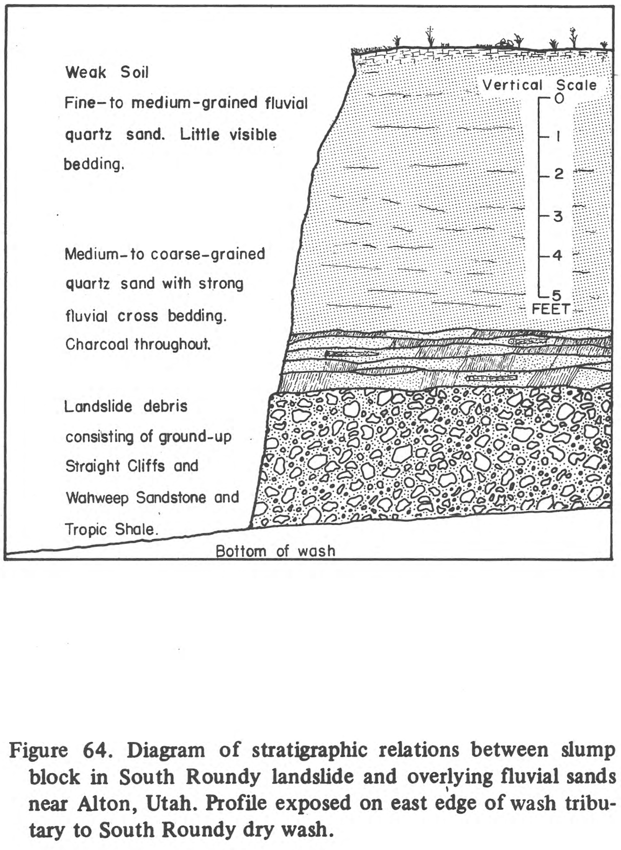


Figure 63. Diagram of stratigraphic relations between South Roundy landslide and overlying fluvial sands. Profile exposed on east edge of wash tributary to South Roundy dry wash. Location also shown by X on figure 65.

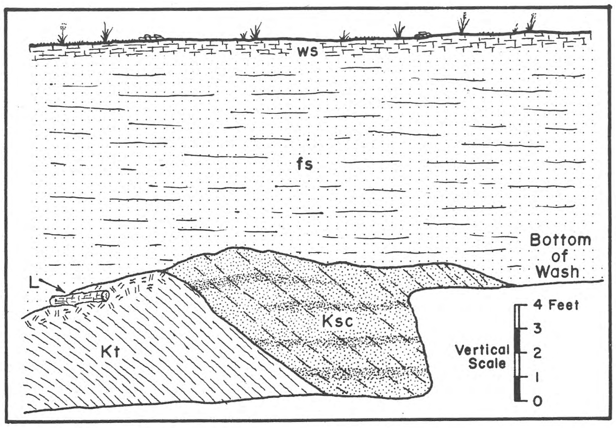


Figure 64. Diagram of stratigraphic relations between slump block in South Roundy landslide and overlying fluvial sands near Alton, Utah. Profile exposed on east edge of wash tributary to South Roundy dry wash.

Kt – Tropic Shale
Ksc – Straight Cliffs Sandstone
fs – fluvial sand
ws – weak soil
L – log buried in disturbed Tropic Shale landslide surface (radiocarbon date 750 ± 200 years).

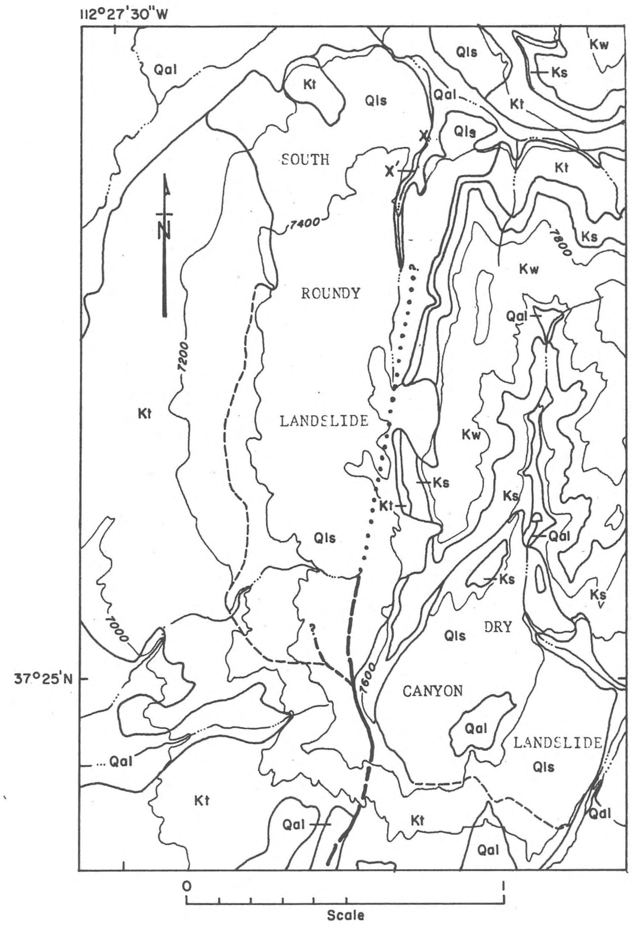


Figure 65. Geologic map of South Roundy and Dry Canyon landslides. Heavy solid, dashed and dotted lines indicate faults.

Qal – Quaternary alluvium
Qls – Quaternary landslide
Kw – Cretaceous Wahweap Sandstone
Ks – Cretaceous Straight Cliffs Sandstone
Kt – Cretaceous Tropic Shale

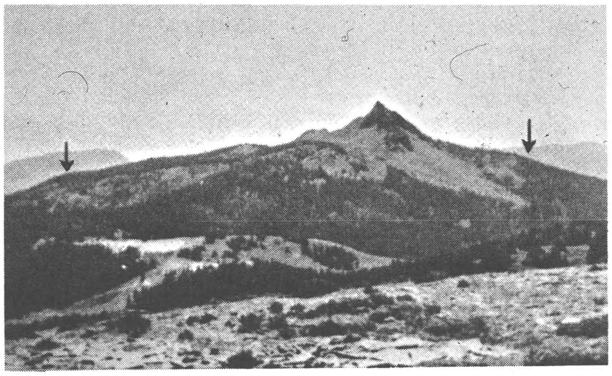


Figure 66. Mount Marvine in the Fish Lake Plateau landslide zone as seen from the north from the summit of Mount Terrel. The arrows indicate the approximate lateral extent of the landslide bench.

Figure 67. A very large landslide block on the east side of Mount Marvine. This block is unusual in that it has tilted forward toward its direction of motion instead of the usual backward tilt of the slump block or the lack of tilt of the ridge block and glide block. Such forward-tilted blocks are herein termed "tilt blocks."

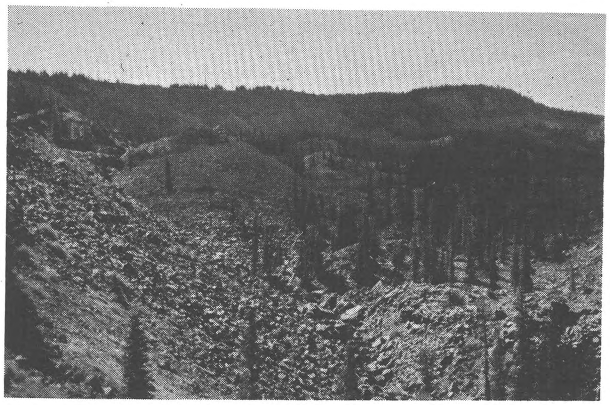


Figure 68. Detail of the head and main scarp of the prominent northwest-facing alcove on Thousand Lake Mountain. The entire area in view is an extremely rough area of landslide blocks and boulder fields.

Elevation: crown, 8,200 ft; head, 7,800 ft; toe, 7,400 ft.

Rate of movement: unknown; movement probably at different intervals and at variable rates.

Slope exposure: southeast.

Vegetation: scrub oak, sagebrush and ponderosa pine.

Geologic setting: shaly mudstones with bentonite beds of Tropic Shale (Lawrence, 1965, p. 86) and Straight Cliffs Sandstone. The Sevier fault passes under head of slide and the main scarp is an obsequent fault-line scarp.

Causes: unstable bentonitic mudstones of Tropic Shale coupled with shattering of rock, possible inflow of water and earthquake tremors along the Sevier fault.

Correlation: late Pleistocene or Holocene.

Geomorphic age: early to middle maturity, based on beginnings of coherent drainage system, eroded slump blocks, strongly eroded main scarp, many filled depressions and beginning of cementation at depth.

An isolated block of seemingly undisturbed Straight Cliffs Sandstone occurs near the head of the slide (figure 61). It was apparently undisturbed while mass movement went on around it. If it moved at all, it was as a ridge block in a nearly horizontal direction.

DRY HOLLOW LANDSLIDE

(figure 61)

Previous work: see discussion of North Roundy landslide.

Type: blockslide and debris-flow.

Dimensions: width, 3,000 ft; length, 2,000 ft; thickness, 100 ft; volume, 17 million cubic yards.

Elevation: crown, 7,720 ft; head, 7,560 ft; toe, 7,360 ft.

Rate of movement: unknown; movement possibly at different intervals and variable rates.

Slope exposure: southeast.

Vegetation: scrub oak, sagebrush and juniper.

Geologic setting: Tropic Shale and Straight Cliffs Sandstone.

Causes: Failure of Tropic Shale; probably coupled genetically and temporally with North Roundy landslide.

Correlation: late Pleistocene or Holocene.

Geomorphic age: early to middle maturity, based on beginning of coherent drainage system, eroded slump blocks and some partially filled depressions.

A large isolated block of Straight Cliffs Sandstone near the head of the slide does not appear to have moved, or if it has moved it has done so only in a horizontal direction.

This slide and the northeast flank of North Roundy slide have formed a 3,000-foot long landslide col between them by back-to-back retrogressive landsliding.

SOUTH ROUNDY LANDSLIDE

(figures 63-65)

Previous work: see discussion of North Roundy landslide.

Type: blockslide and debris-flow.

Dimensions: width, 10,000 ft measured north to south; length, 3,000 ft measured east to west; thickness, 100 ft; volume, 100 million cubic yards.

Elevation: crown, 8,000 ft; head, 7,600 ft; toe, 7,200 ft.

Rate of movement: unknown, probably at different intervals and variable rates.

Slope exposure: west.

Vegetation: scrub oak, sagebrush and juniper.

Geologic setting: Tropic Shale, Straight Cliffs Sandstone and Wahweap Sandstone; see discussion of North Roundy landslide. Field mapping has confirmed Goode's tentative hypothesis (Goode, 1964, p. 35) for a north-south fault in Sink Valley south of the landslide.

Causes: failure of Tropic Shale; the presence of charcoal overlying slide material in many places indicates a possible genetic link between landsliding and changes in runoff following a forest fire.

Correlation: late Pleistocene to Holocene; a radiocarbon date on a log of ponderosa pine in the landslide gave a figure of 750±200 years, indicating the relative recency of the movement of this area, and possibly of the entire mass.

Geomorphic age: early to middle maturity, based on beginning of integrated drainage, eroded landslide blocks and main scarp, numerous filled depressions and beginning of cementation at depth.

DRY CANYON LANDSLIDE

(figure 65)

Previous work: see discussion of North Roundy landslide. Landslides mapped by writer with H. Suekawa and G. Montgomery during 1966 University of Utah geology summer field camp.

Type: blockslide and debris-flow.

Dimensions: width, 4,000 ft; length, 3,500 ft; thickness, 100 ft; volume, 52 million cubic yards.

Elevation: crown, 7,725 ft; head, 7,600 ft; toe, 7,200 ft.

Rate of movement: unknown, possibly at different intervals and at variable rates.

Slope exposure: southeast.

Vegetation: scrub oak, juniper and sagebrush.

Geologic setting: shaly mudstone with bentonitic beds of Tropic Shale and Straight Cliffs Sandstone.

Causes: failure of Tropic Shale; probably coupled genetically and temporally with South Roundy landslide.

Correlation: late Pleistocene to Holocene.

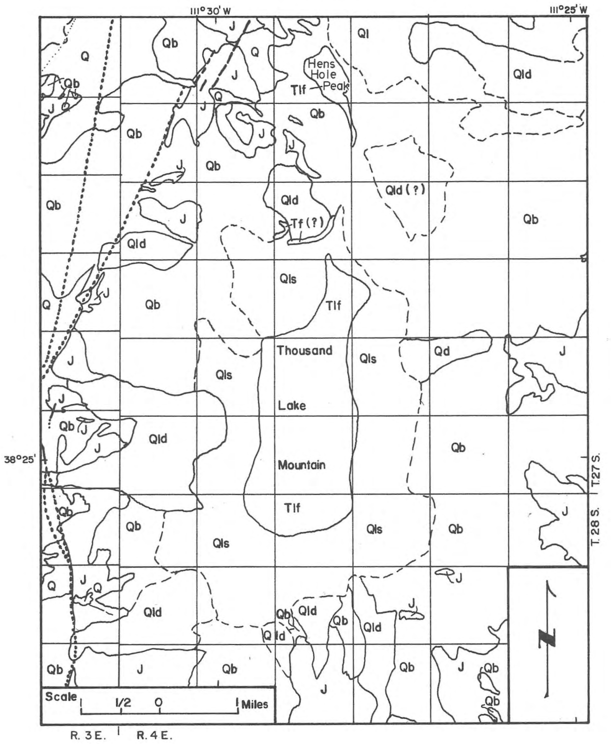


Figure 69. Geologic map of Thousand Lake Mountain landslide zone. Dotted and dashed lines represent faults (geology in part from Smith and others, 1963).

Q	– Quaternary alluvium, colluvium pediment, and alluvial fan
Qld	– Quaternary landslide, debris-flow
Qls	– Quaternary landslide slump
Qb	– Quaternary boulder deposits
Tlf	– Tertiary lava flows
Tf (?)	– Tertiary Flagstaff (?) Formation
J	– Jurassic rocks, undivided

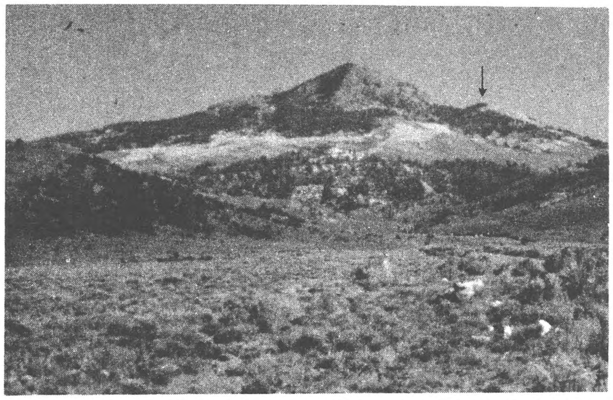


Figure 70. Hens Hole Peak from the west. This peak owes its origin primarily to landsliding and is herein termed a "landslide peak." Thousand Lake Mountain is just out of the picture to the right. An eroded remnant of a probable landslide block is indicated by the arrow.

Geomorphic age: early to middle maturity, based on beginning of integrated drainage, eroded slump blocks and nearly filled depressions.

Dry Canyon slide has a large isolated block of Straight Cliffs Sandstone near the head which does not appear to have moved, or if it has moved it has done so only in a horizontal direction.

A small playa-like surface near the south flank is a consequence of alluviation in a closed depression on the slide.

An interesting feature of Dry Canyon slide is the landslide col formed by the back-to-back headward sliding of this landslide and the South Roundy slide. The knife-edge of the col is about 3,000 feet long.

FISH LAKE PLATEAU LANDSLIDE ZONE
(figures 66, 67)

Previous work: map and description, McGookey, 1958, 1960.

Type: complex blockslide, debris-flow, mudflow, rockslide, rockfall, and other varieties of mass wasting.

Dimensions: area, 54 square miles; thickness, 100 ft; volume, 5.5 billion cubic yards.

Rate of movement: highly variable, slow to rapid.

Slope exposure: 5.30 miles to north; 14.35 to northeast; 17.05 to east; 1.70 to southeast; 0.30 to south; 3.20 to southwest; 11.40 to west; 10.10 to northwest.

Vegetation: conifers, aspen, willow and sagebrush.

Geologic setting: shale, siltstone and sandstone of North Horn Formation, interbedded limestone and shale of Flagstaff Formation, an unnamed tuffaceous and bentonitic sandstone with conglomerate beds, and Bullion Canyon volcanics (lava flows) are the units primarily involved in mass movement. The Colton, Green River, Crazy Hollow, Bald Knoll, and Dipping Vat formations and Bullion Canyon volcanics (clastics) may occur between the Flagstaff and the lava flows except where eroded.

Causes: thick argillaceous sections, particularly the unnamed unit, steep slopes, well-jointed basalt cap rock, and greater precipitation during the Pleistocene.

Correlation: Pleistocene and Holocene; mass movement occurred over a long span of time.

Geomorphic age: early youth to late old age, based on nearly complete range of geomorphic age criteria.

Mount Marvine (figure 66), in the Fish Lake Plateau landslide zone, is a remnant knife-edged ridge of a once large plateau which was reduced to its present form by retrogressive landsliding. I suggested elsewhere (Shroder, 1968) that such landforms be termed "landslide blades" after Dutton's (1880, p. 269) original name, "The Blade", for Mount Marvine. Subsequent criticism, however, indicates that "landslide ridge" is more descriptive and hence a better term.

No geologic map of sufficiently large scale is available.

THOUSAND LAKE MOUNTAIN LANDSLIDE ZONE
(figures 68-70)

Previous work: map and description, Smith, Huff, Hinrichs and Luedke, 1963.

Type: complex blockslide and debris-flow.

Dimensions: area, 17 square miles; thickness, 100 ft; volume, 1.7 billion cubic yards, 5 billion cubic yds. if 32 square miles of surrounding boulder deposits of probable landslide origin are added.

Elevation: crown, 11,100 ft; head, 10,800 ft; toe of blockslides (edge of landslide bench) 10,200 ft; toe of debris-flows, 8,600 ft.

Rate of movement: slow to fast.

Slope exposure: north, 1 mile; east, 3 miles; south, 1¼ miles; and west, 3¼ miles.

Vegetation: grass, conifers, aspen and scrub oak.

Geologic setting: basalt which overlies limestone, tuff, sandstone, mudstones and conglomerates of Flagstaff (?) Formation which in turn unconformably overlies various Jurassic sedimentary rocks. A fault along the base of the west side of the area caused Thousand Lake Mountain to be upthrown about 2,500 to 3,000 ft.

Causes: well-jointed basalt overlying tuffaceous and argillaceous sedimentary rocks coupled with higher precipitation during various portions of the Pleistocene and probably also during part of the Holocene.

Correlation: early and late Wisconsin for two observed generations of landsliding, and pre-Wisconsin for boulder deposits (Smith and others, 1963, plate 1 and p. 50), based on correlation with landslide-glacial deposits on nearby Boulder Mountain.

Geomorphic age: late youth to late old age, based on absence of very youthful features but a wide range of others.

Thousand Lake Mountain is an ideal example of one of the numerous landslide plateaus in the western United States. It is completely surrounded by a landslide bench upon which occur scores of blockslides, mostly slump blocks. The lower slopes are mantled with extensive, relatively young debris-flows and older boulder deposits.

Hens Hole Peak, located two miles to the north, is a landslide peak which also owes its origin to peripheral blockslides and debris-flows.

BOULDER MOUNTAIN LANDSLIDE ZONE
(figures 71-73)

Previous work: map and description, Flint and Denny, 1958; Smith, Huff, Hinrichs and Luedke, 1963.

Type: complex blockslide and debris-flow.

Dimensions: area, 41 square miles; thickness, 100 ft; volume, 4.2 billion cubic yards; 18 billion cubic yards if 175 square miles of boulder deposits of probable landslide origin are included.

Elevation: crown, 10,880 ft; head, 10,400 ft; toe of blockslides, 9,700 ft; toe of flows, 8,600 ft.

Rate of movement: slow to rapid.

Slope exposure: north, 11¾ miles; east, 12¼ miles; south, 6¾ miles; southwest, 6 miles; west, 5 miles.

Vegetation: grass, conifers, aspen and scrub oak.

Geologic setting: basalt which overlies the varied clastics and limestones of the Flagstaff (?) Formation. This unit unconformably overlies the Salt Wash Sandstone Member, and possibly the argillaceous Brushy Basin Member of the Morrison Formation. Several faults occur on the west side of the mountain.

Causes, correlation, and geomorphic age: same as Thousand Lake Mountain landslide zone.

Boulder Mountain is a good example of a landslide plateau. It probably owes most of its topographic characteristics to landslide phenomena although it has also been extensively modified by glacial and fluvial action. Of particular topographic prominence here are the 10 or more landslide cusp-points.

MOUNT PEALE LANDSLIDE ZONE
(figures 74, 75)

Previous work: maps, Weir, Puffet, and Dodson, 1961; Weir and Dodson, 1958a, 1958b, 1958c, 1958d; Weir and Puffet, 1960.

Type: complex blockslide and debris-flow.

Dimensions: width, 56 miles; length, range 1,000-8,000 ft, average 3,000 ft; thickness, 50 ft; volume 1.5 billion cubic yards.

Elevation: crown, 7,100 ft; head, 6,900 ft; toe of block-slides, 6,600 ft; toe of debris-flows, 6,000 ft.

Rate of movement: slow to rapid.

Slope exposure: north, 10 miles; northeast, 13 miles; east, 5.5 miles; southeast, 3.5 miles; southwest, 8 miles; west, 5 miles; northwest, 11 miles.

Geologic setting: flat-lying sedimentary rocks in order from oldest to youngest; Entrada Sandstone, Summerville Formation, Salt Wash and Brushy Basin members of the Morrison Formation, Burro Canyon Formation and Dakota Sandstone.

Causes: unstable bentonitic mudstones of the Brushy Basin Member of the Morrison Formation, combined with higher precipitation in the Pleistocene.

Correlation: movement occurred throughout the Pleistocene and possibly in the early Holocene.

Geomorphic age: early maturity to middle old age, based on wide range of indicative features.

Much of this area may be considered a landslide plateau. Several locations have landslide cusp-points and a landslide bench occurs throughout the area. Numerous landslide outliers and erratics occur.

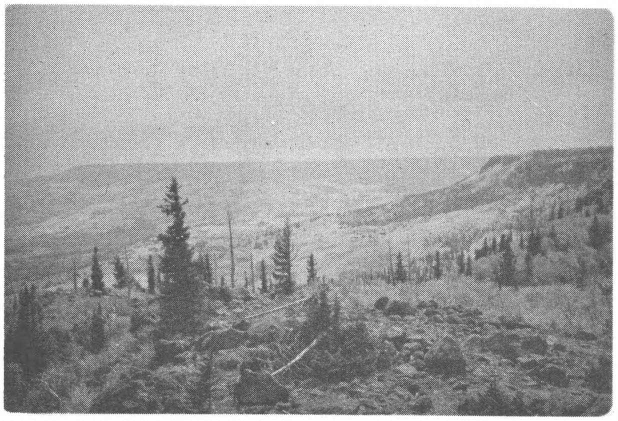


Figure 71. South view from Chokecherry Point towards Bowns Point, which is in the far left of the picture. The entire area below the escarpment of Boulder Mountain is a vast landslide bench.

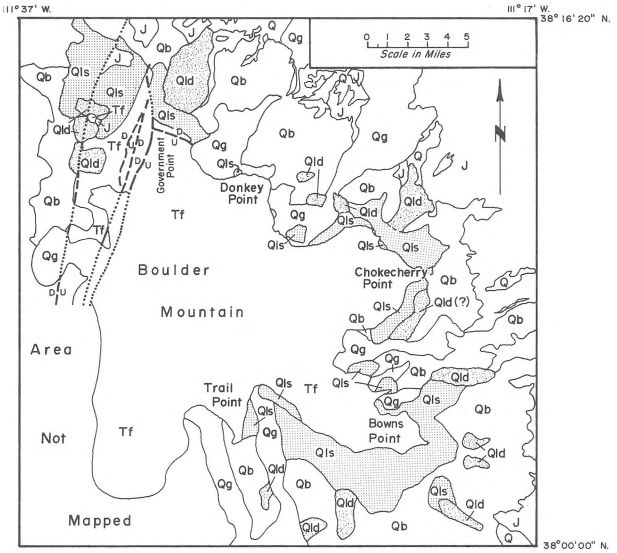


Figure 73. Geologic map of Boulder Mountain landslide zone (geology in part from Smith and others, 1963).

Q – Quaternary alluvium, pediment, and alluvial fan
Qld – Quaternary landslide, debris-flow
Qls – Quaternary landslide, slump
Qg – Quaternary glacial deposits
Qb – Quaternary boulder deposits
Tf – Tertiary lava flows
J – Jurassic rocks, undivided

Figure 75. Outline geologic map of Mount Peale landslide zone (adapted in part from Williams, 1964).

Qls – Quaternary landslide slump and debris-flow
Q – Quaternary alluvium
Kbd – Cretaceous Burro Canyon Formation and Dakota Sandstone
J – Jurassic Morrison Formation and other rocks

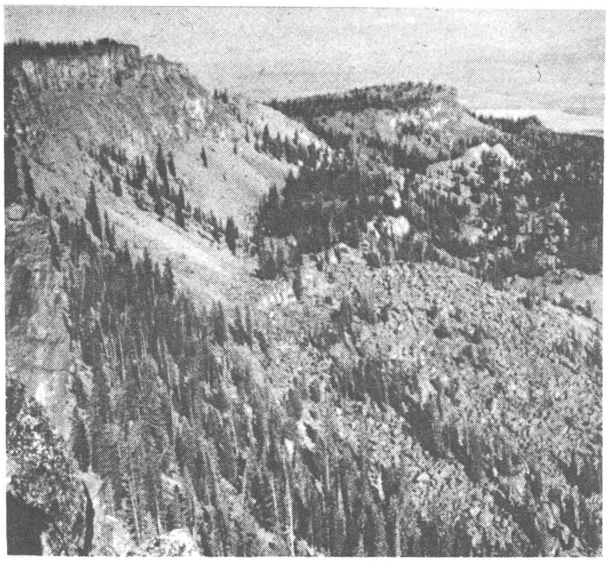
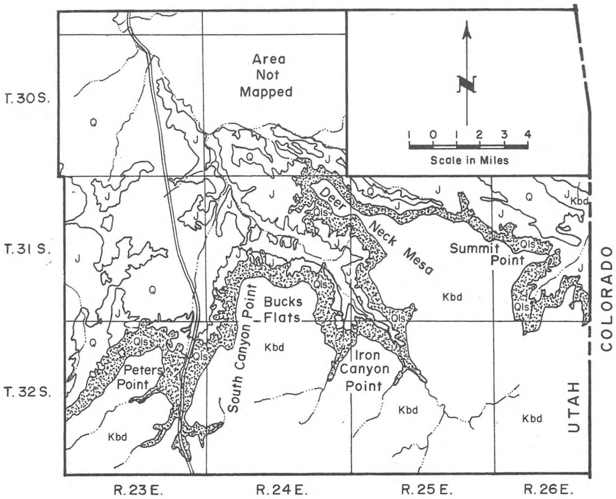


Figure 72. Government Point on Boulder Mountain is the high cliff to the left. Below it and in the foreground are landslide blocks and boulder fields. This is the head of the 3 mile-long Coleman landslide, studied by Flint and Denny (1958).

Figure 74. Southwest side of Deer Neck Mesa showing prominent landslide bench and five debris-flows.



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UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

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THE UTAH GEOLOGICAL AND MINERALOGICAL SURVEY since 1949 has been affiliated with the College of Mines and Mineral Industries at the University of Utah. It operates under a director with the advice and counsel of an Advisory Board appointed by the Board of Regents of the University of Utah from organizations and categories specified by law.

The survey is enjoined to cooperate with all existing agencies to the end that the geological and mineralogical resources of the state may be most advantageously investigated and publicized for the good of the state. The *Utah Code, Annotated, 1953 Replacement Volume 5, Chapter 36, 53-36-2,* describes the Survey's functions.

Official maps, bulletins, and circulars about Utah's resources are published. (Write to the Utah Geological and Mineralogical Survey for the latest list of publications available).

THE LIBRARY OF SAMPLES FOR GEOLOGIC RESEARCH. A modern library for stratigraphic sections, drill cores, well cuttings, and miscellaneous samples of geologic significance has been established by the Survey at the University of Utah. It was initiated by the Utah Geological and Mineralogical Survey in cooperation with the Departments of Geology of the universities in the state, the Utah Geological Society, and the Intermountain Association of Petroleum Geologists. This library was made possible in 1951 by a grant from the University of Utah Research Fund and by the donation of collections from various oil companies operating in Utah.

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THE SURVEY'S BASIC PHILOSOPHY is that of the U. S. Geological Survey, i.e., our employees shall have no interest in Utah lands. For permanent employees this restriction is lifted after a 2-year absence; for consultants employed on special problems, there is a similar time period which can be modified only after publication of the data or after the data have been acted upon. For consultants, there are no restrictions beyond the field of the problem, except where they are working on a broad area of the state and, here, as for all employees, we rely on their inherent integrity.

DIRECTORS:

William P. Hewitt, 1961-
Arthur L. Crawford, 1949-1961