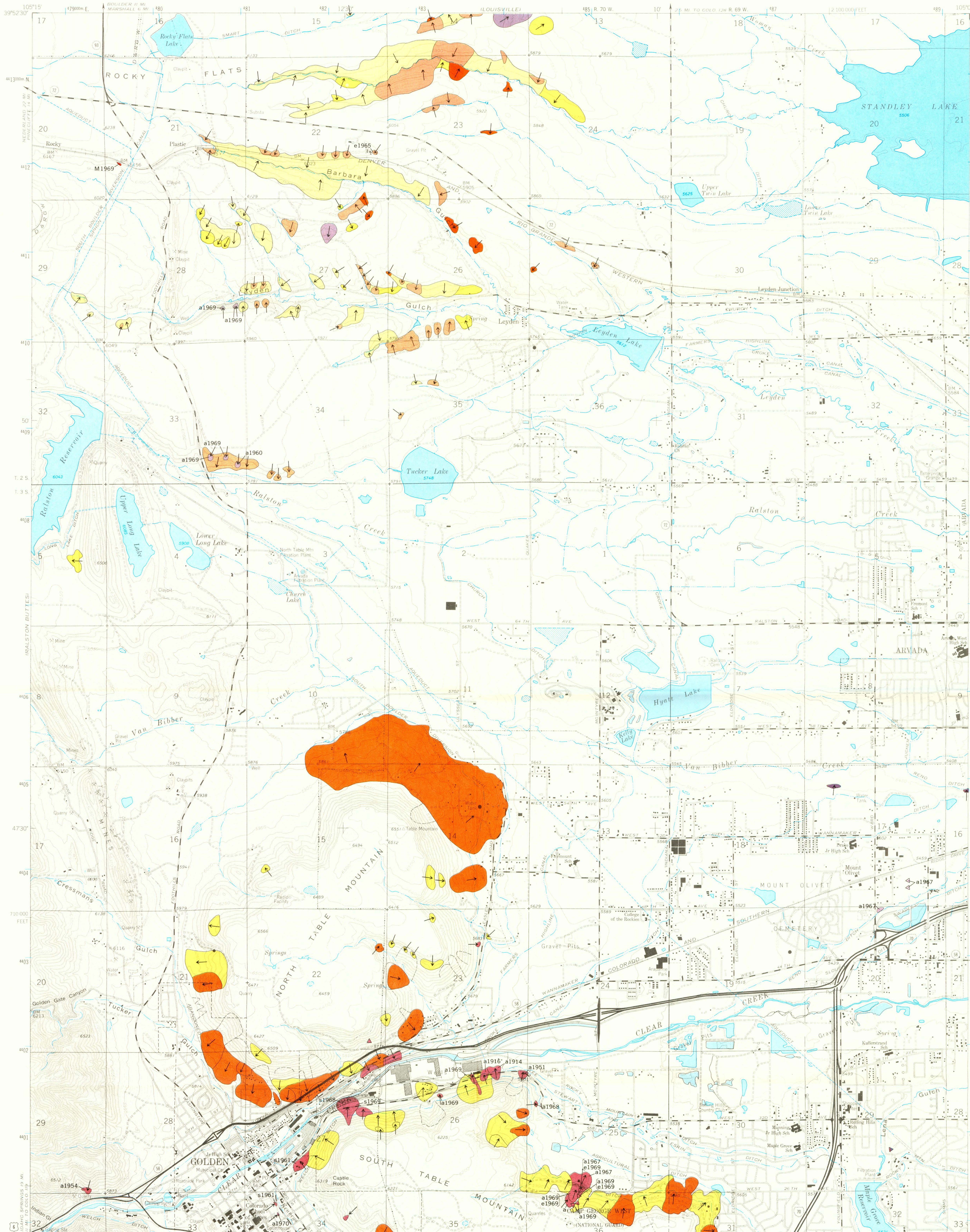
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

FOLIO OF THE
GOLDEN QUADRANGLE, COLORADO
MAP I-761-B



Base from U.S. Geological Survey, 1965
Photorevision as of 1971
10,000-foot grid based on Colorado coordinate system central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

APPROXIMATE MEAN DECLINATION, 1973

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1973—G73015

Modified from Van Horn (1965) and Gardner, Simpson, and Hart (1971); additions by H. E. Simpson, 1972

MAP SHOWING LANDSLIDES IN THE GOLDEN QUADRANGLE, JEFFERSON COUNTY, COLORADO

By
Howard E. Simpson

1973

EXPLANATION

KNOWN LANDSLIDE — Area where slope materials are known to have failed. Reported, or indicated by good topographic and geologic evidence, and by good cultural evidence locally. Boundaries accurately located

- Derived predominantly or wholly from alluvial materials
- Derived predominantly or wholly from underlying bedrock and loose bedrock material
- Derived mainly from underlying bedrock and loose bedrock material, but may contain significant quantities of overlying alluvial materials
- Derived from manmade deposit
- Too small to outline on map; generally less than 200 feet across. Color as in boxes above

a1960 — Landslide known or believed to be active in 1972; first reported active in year indicated, but may be older. (Year may not be known.)

s1969 — Landslide on which effort was made toward stabilization during year indicated; effort not necessarily successful. (Year may not be known.)

e1969 — Landslide wholly or partly excavated in an effort toward stabilization during year indicated; effort not necessarily successful

PROBABLE LANDSLIDE — Area where slope materials are believed to have failed. Indicated by good to fair topographic evidence, and by good to fair cultural evidence locally, but geologic evidence insufficient or inconclusive. Boundaries accurately to approximately located

- Derived predominantly or wholly from underlying bedrock and loose bedrock material
- Derived mainly from underlying bedrock and loose bedrock material, but may contain significant quantities of overlying alluvial material

POSSIBLE LANDSLIDE — Area where slope materials may have failed. Indicated by fair to poor topographic evidence, and by fair to poor cultural evidence locally, but geologic evidence inconclusive or not available. Boundaries approximately to indefinitely located

- Derived predominantly or wholly from underlying bedrock and loose bedrock material
- Derived mainly from underlying bedrock and loose bedrock material, but may contain significant quantities of overlying alluvial material

← APPROXIMATE DIRECTION OF MOVEMENT OF LANDSLIDE

LANDSLIDE SCAR

INTRODUCTION

Landslides in the Golden quadrangle may be recognized by distinctive accumulations of earth and rock, or by characteristic scars. Landslides have caused damage to buildings and other construction in or near Golden, but none is known to have been a serious hazard to human life. Some of the landslides have occurred naturally; others have been caused by the activities of man. When landsliding will occur, or which area will eventually be affected, is difficult to predict. Stabilization of a landslide may be possible, but it may be difficult and expensive.

The map shows those areas in the quadrangle that geologic investigations indicate are landslides, or were landslides before they were excavated, and classifies the landslides in terms of the certainty of their existence. It also shows which of the landslides are considered active and which of them are known to have been the object of stabilization effort, together with appropriate dates insofar as such information is available. The subsequent discussion defines terms where appropriate, explains the causes and process of landsliding, and characterizes the significance of landslides to land-use planners, landowners, and others who may be interested.

The map and explanation are a practical presentation of the distribution and character of the chosen map units at the scale of the base map. Use of the map does not necessarily eliminate the need for detailed geologic and engineering study of a proposed site prior to acquisition, design, and construction.

LANDSLIDING AND STABILITY

A landslide is the downward and outward movement of rock and earth materials that form a slope; by general usage the term refers also to the materials that move or have moved in this manner. A landslide occurs when the natural forces that tend to hold a mass of earth and rock in place are exceeded by other forces, mainly gravity, that tend to move the mass downslope. For the purposes of land-use planning an active landslide may be defined as one characterized by evidence of present or recent movement, such as bare scarps and open cracks; in an inactive landslide such features may be present but they are modified, subdued, or even obliterated by weathering, erosion, and the growth of vegetation. The presence of a landslide, whether active or inactive serves as a warning of the potential instability of slopes in the vicinity; additional landslides may occur, or now-inactive landslides may move again. Rockfalls, a particular kind of landslide, are not included here but are treated in another map in this folio (I-761-C).

The stability of a slope, or of an inactive landslide, is influenced by many factors. Among these are the shape and angularity of the mineral particles; the tendency of particles to remain together because of their mutual attraction and friction; the kinds of clay minerals present; the direction and amount of tilt (attitude) of layering in the material; the slope of the bedrock surface beneath any overlying loose surficial material; the external load placed on the slope; the water content of the slope-forming material; and the natural loss or artificial removal of downslope support. The potential stability of a slope commonly can be determined with considerable accuracy through the combined efforts of the geologist and soils engineer.

CHARACTER OF LANDSLIDES

Some landslides in the Golden quadrangle consist of slumped blocks of the original material in the upper part, and grade downslope into loose soillike material. Such a mass is illustrated in figure 1. The thickness of a landslide mass may range from about 1 foot to perhaps as much as 50 feet. Other landslides, especially the smaller ones, consist of a layer of loose weathered rock from 1 foot to 10 feet thick that slid downward on a surface of underlying bedrock. On the flanks of both Table Mountains, landslides of this type have left prominent scars, some of which are now overgrown with vegetation.

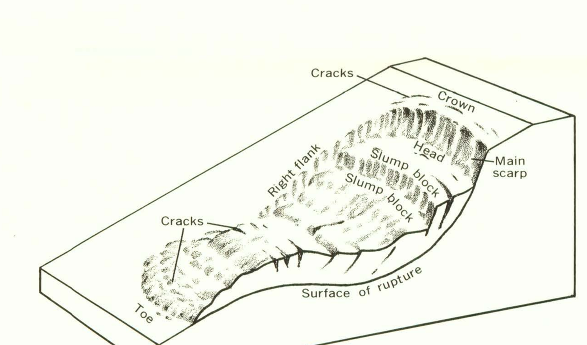


Figure 1. — Diagram and cross section of a type of landslide common in the Golden quadrangle. The same landslide, after modification by erosion, is represented in figure 2. Modified from Varnes, (1958).

Movement of landslides in the Golden quadrangle is generally imperceptible. Consequently, movement is recognized only by minor changes in characteristic details such as the widening of a small crack in the ground surface, the development of a shallow break in a natural slope, or the appearance of a scarp, perhaps only a few inches high. In buildings it is most likely to be recognized by the damage it causes.

The surface of rupture on which the mass slides is commonly a curved concave-upward surface that, if exposed, may be seen as an arcuate inclined scarp at the upslope edge of the landslide mass. Where landsliding has recently occurred it may be possible to see distinctive irregular but subparallel grooving or fluting on the surface of rupture. These grooves may range from a fraction of an inch to several inches across. Landslide scars on the flanks of the Table Mountains are marked by similar but very large scale flutings.

A rockslide is a particular kind of landslide wherein a mass of rock slides on an essentially planar surface. The surface is marked by a fracture that may lie parallel to or across layering in the rock, or parallel to the orientation of flat or elongate mineral grains. Rockslides may occur in the mountainous southwestern part of the quadrangle and on the eastern slope of the hogback ridge that lies just north-northwest of Golden.

RECOGNITION OF LANDSLIDES

Recognition of landslides is based on three kinds of evidence: topographic, geologic, and cultural. Topographic features that may be observable include a ridge of earth, perhaps a few feet high, pushed out or up along the lower edge of the landslide mass; curved scarps at the upper end of the mass, and perhaps within it; nearly vertical curved cracks in the ground; undrained depressions; hummocky ground surface; and terracelike or steplike surfaces that may be tilted downward and backward into the hillslope. (See fig. 1.)

Geologic evidence includes displaced rock or earth layers; abnormally tilted layers of rock and earth; disturbed, broken, and intermixed rock and earth; seeps and springs; and exposed surfaces of sliding, particularly including polished, grooved, or fluted surfaces.

Cultural evidence includes curved or displaced fence, road railroad and irrigation-canal alinements; tilted, displaced, or ruptured utility lines; structural damage to buildings and other construction; and tilted or curved tree trunks.

Landslides commonly are identified by a combination of nongeologic evidence chiefly because the internal characteristics of landslides rarely can be observed. In time a landslide mass becomes so modified by weathering, erosion, and vegetation, that visual identification is uncertain; subsequently the mass may become obliterated and unrecognizable. The typical topographic expression of many of the landslides shown on the map is so subtle that they are readily apparent only when crosslighted by a low sun as in figure 2. If only a subdued terracelike form is the basis of identification, the features may express geologic conditions other than landsliding.

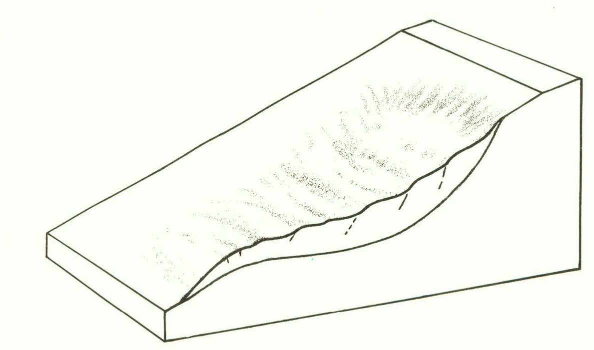


Figure 2. — Diagram and cross section of the typical landslide in figure 1, shown as it might look subdued by erosion and crosslighted by a low sun.

CAUSES OF LANDSLIDING

Forces that tend to hold a mass of earth materials in place on a slope may be overcome as a result of changes in the physical environment of the mass. These changes may be either natural or manmade in origin. There are three principal kinds of changes: (1) an increase in the weight of the mass, (2) a decrease in the internal strength of the mass, and (3) the removal of downslope support of the mass.

The weight of the mass is increased by the addition of a load, perhaps fill or buildings placed upon it, or by an increase in the water content of the mass itself, or both. The source of the water may be natural as from springs and seeps, or from heavy or prolonged rain or snowmelt; or it may be manmade, as from septic systems, lawn irrigation, broken water pipes, cracked swimming pools, or leaking irrigation canals.

The water content is important not only because of the load it imposes on the mass, but also because it tends to weaken any natural cement in the material, and because it tends to reduce friction within the mass. Clay that swells when wetted is commonly present in the slope materials, and the addition of water significantly reduces the internal strength of these clay particles, further weakening the material.

Downslope support of a mass may be removed by stream erosion, by excavation for roads, quarries, or buildings, or even by a landslide below. Actual removal of material may not be required, for although the lower part of a slope appears to be less hazardous, an increase in the groundwater content there could result in loss of support. Rockslides are most likely to occur if a surface, or potential surface, of sliding slopes downward into an excavation or other open space.

Another cause of landsliding may be ground shaking of moderate to strong intensity. Earthquakes of low intensity have been felt in the quadrangle, but none of these is reported to have caused a landslide. Shaking caused by blasting may have been a factor in the development of the landslide in a quarry wall near the southwest corner of the quadrangle. Ground vibration caused by the passage of heavy equipment adjacent to an active landslide may cause minute displacement, but it is not known to have caused significant movement.

TIME OF LANDSLIDING

It is rarely possible to predict exactly when landsliding will begin, when landsliding will stop, or precisely what area will be affected. Movement may seem to follow construction on hillside sites. It may be caused by the associated manmade sources of additional ground water, the increase in load, or perhaps the cutting of roads. A delay in landsliding may be an expression of the time required for the necessary change in the physical properties of an earth mass underlying a slope. In general, landsliding is most likely to occur, or to reoccur, during the wettest times of the year, and during the wettest years.

Landsliding of recent geologic age probably began in the Golden quadrangle many thousands of years ago as Clear Creek was cutting its valley downward through the rocks that now form the Table Mountains. Undoubtedly the landsliding has been a continuing process, caused mainly by the streams removing support from the base of steeper slopes. Since the late 1800's man's activities have been an added cause.

DAMAGE FROM LANDSLIDING

Movement of a landslide mass commonly causes settlement of, and thus damage to, buildings or other construction situated upon it. Because the amount, rate, and direction of movement may differ from one part of a landslide to another, settlement is generally uneven. It causes twisting or wrenching, commonly expressed by sticking windows, jammed doors, and cracked ceilings, walls, floors, and foundations. A structure built partly on a stable area and partly on a landslide is especially subject to damage. In addition, damage may be caused by horizontal stresses, and, in the lower part of the landslide mass, wrenching may result from heaving caused by differential uplift. In any situation the degree of damage may range from minor to severe. Structural problems like those caused by landsliding may be caused also by compaction of fills, swelling and drying of expansive clays, and subsidence over overground mining excavations.

RELATION TO PLANNING

Construction sites on and immediately adjacent to landslides are subject to potential failure and should be considered hazardous without appropriate slope-stability investigations and acceptable engineered safeguards. Moreover, other slopes of similar angles and underlain by similar rock and earth materials also may be subject to potential failure. This potential should be considered in the planning and design of construction.

Detailed engineering geologic and soils engineering studies of a landslide area are advisable if one is to accurately delineate the unstable mass and determine how future changes in the vicinity of the landslide, such as lawn irrigation and additional construction, may affect stability of the mass or slope. Locally, removal or stabilization of a landslide may be necessary, but elsewhere it may be possible to design foundations that will transmit the load imposed on them to competent material beneath a very thin landslide mass.

CORRECTION OF LANDSLIDES

Methods used for correction of landslides commonly involve an attempt to remove the causes of landsliding. These methods include the elimination or reduction of water entering the landslide mass; drainage by means of pumped wells or horizontal drains; removal of unnecessary load, perhaps including some of the upper part of the landslide itself; excavation of all or part of the landslide mass; and adding load to, or buttressing, the lower part of the mass. Sometimes these methods are not successful, and the cost may be considerable. If correction by excavation is attempted, care must be taken not to aggravate the situation by causing instability upslope

HISTORICAL LANDSLIDES

Newspaper reports of landslides in the vicinity of Golden extend as far back as the early 1880's, and undoubtedly cover only those events that damaged property close to Golden. None appear to have endangered human life. Richard Van Horn (written commun., Feb. 1972) examined issues of the "Golden Globe" filed in the Pioneer Museum, Golden City Hall, and found news items about landsliding on the following dates:

March 12 and 19, 1881	South side, North Table Mountain
July 21 and 28, and August 4, 1883.	Same area
May 16, 1896	Same area
June 5, 1897	North side, South Table Mountain
May 5, 1900	South side, North Table Mountain
November 8, 1902	Same area
May 4, 1907	West side, North Table Mountain
May 2, 1914	Same area
July 18, 1914	North side, South Table Mountain

Other news items during this period mention "landslides," but these are not included here because the event may not have been a landslide, or because the location is not given.

The effects of landsliding along Clear Creek during and since 1914 on the maintenance of roads, the railroad, and irrigation canals have been summarized by Van Horn (1954) and by recent news articles in "The Sentinel" (Lakewood, Colo., May 16, 1968), "Metro West" (Denver, Colo., Dec. 26, 1968), and "The Golden Transcript" (Golden, Colo., Apr. 27, 1971).

A landslide on the north side of Ralston Creek near the southeast corner of sec. 33, T. 2 S., R. 70 W., was apparently reactivated in April 1956 by highway improvement. A result was relocation of a segment of Colorado Route 93. A detailed study of this landslide has been prepared by Irvine (1963).

REFERENCES

Much of the data on the map was taken from geologic maps of the bedrock and surficial materials by Van Horn (1957, 1968), and from an engineering geologic map by Gardner, Simpson, and Hart (1971). Modifications and additions were made by H. E. Simpson in March 1972, based on field observations in 1972 and study of aerial photographs dated August 8, 1971. Publications used in the compilation are listed below, and the list includes an additional reference by Van Horn (1972), which combines information shown on his two earlier maps.

Gardner, M. E., Simpson, H. E., and Hart, S. S., 1971, Preliminary engineering geologic map of the Golden quadrangle, Jefferson County, Colorado: U.S. Geol. Survey Misc. Field Studies Map MF-308 [1972].

Irvine, B. M., 1963, Ralston Creek landslide, Jefferson County, Colorado: Colorado Univ. Studies Ser. Geology, no. 2, 20 p.

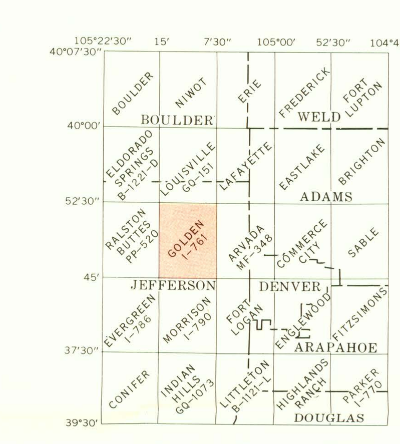
Van Horn, Richard, 1954, Landslides near Golden, Colorado: Engineers' Bull., v. 38, no. 12, p. 6, 15.

_____ 1957, Bedrock geology of the Golden quadrangle, Colorado: U.S. Geol. Survey Geol. Quad. Map GQ-103.

_____ 1968, Preliminary surficial geologic map and materials test data of the Golden quadrangle, Jefferson County, Colorado: U.S. Geol. Survey open-file map.

_____ 1972, Surficial and bedrock geologic map of the Golden quadrangle, Jefferson County, Colorado: U.S. Geol. Survey Misc. Geol. Inv. Map I-761-A.

Varnes, D. J., 1958, Landslide types and processes, Chap. 3 of Eckel, E. B., ed., Landslides and engineering practice: Highway Research Board Spec. Rept. 29 (Natl. Acad. Sci. — Natl. Research Council Pub. 544), p. 20-47.



INDEX SHOWING LOCATION OF GOLDEN QUADRANGLE