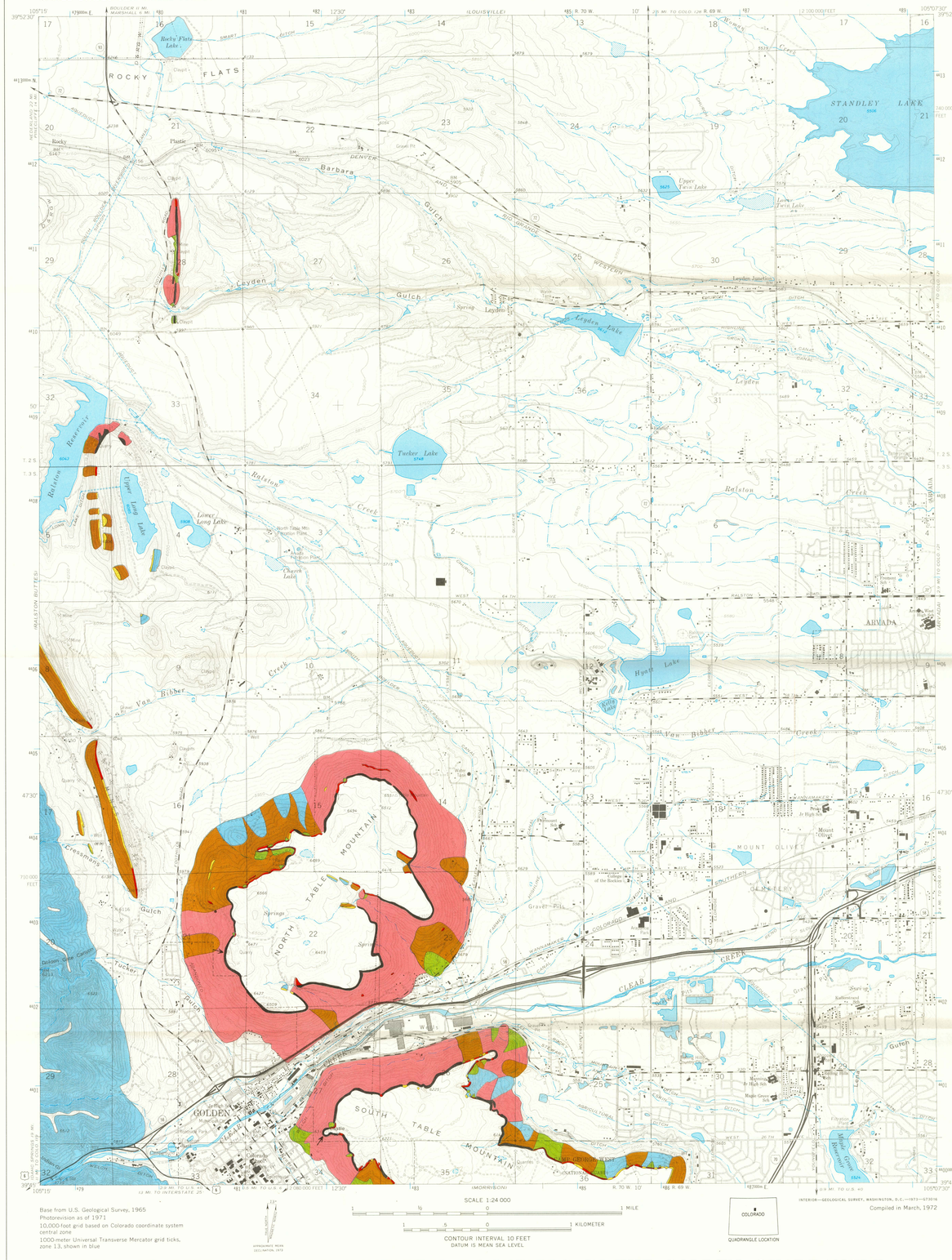
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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



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

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

COLORADO
QUADRANGLE LOCATION

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1973—G73016

Compiled in March, 1972

MAP SHOWING AREAS OF POTENTIAL ROCKFALLS IN THE GOLDEN QUADRANGLE, JEFFERSON COUNTY, COLORADO

By
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1973

EXPLANATION

ESTIMATED RELATIVE LIKELIHOOD OF ROCKFALLS – Source areas of potential rockfalls, showing estimated relative likelihood of occurrence. In the mountainous southwest part of the quadrangle the scattered exposures of rock that constitute potential sources of rockfalls are too numerous and varied in significance to map individually

- Generally moderate to low; may be high to moderate in event of strong ground shaking
- Generally low to very low; may be moderate to low in event of strong ground shaking
- Generally very low to negligible; may be low to very low in event of strong ground shaking
- Generally negligible to absent; may be very low to negligible in event of strong ground shaking

LIKELIHOOD OF BOUNDING, ROLLING, OR SLIDING ROCK – Inferred approximate areas subject to bounding, rolling, or sliding rock of rockfalls; relative degree of likelihood estimated. Boundaries are only approximately located because they are not clearly defined in nature

- Generally great to moderate
- Generally moderate to low
- Generally low to very low
- Generally very low to negligible

ROCKFALLS – Known locations of two recent rockfalls in Golden from the west face of Castle Rock on South Table Mountain, and the inferred location of one or more rockfalls from the cliff immediately west of the quarry on North Table Mountain. Numerous inferred rockfall localities marked by broken rock are not individually indicated

INTRODUCTION

Rockfalls are expectable locally in the Golden quadrangle because cliffs and ledges of rock overlie steep slopes. Rockfalls account for many of the boulders scattered on the flanks of the Table Mountains and the prominent ridges north of Golden. A few of these rockfalls are reported to have caused damage to property, and one is reported to have caused human injury. Rockfalls also have occurred in Clear Creek Canyon, but their location is not certain; they are reported to have caused human injury and two deaths. Most of the rockfalls have been caused by natural processes, but some may have been caused by the activities of man. It is possible to prevent rockfalls, but in some areas it may be easier to deflect or block them.

The map shows those areas in the quadrangle where geologic investigations have identified both the source areas of potential rockfalls and the downslope areas that may be subject to rolling rock of rockfalls. The areas are classified into four categories of estimated relative likelihood of occurrence. The following discussion defines terms where appropriate, explains the causes and process of rockfalls, and characterizes their significance to land-use planners, landowners, and others who may be interested. The material is 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.

ROCKFALLS AND STABILITY

Movement of a mass of rock by falling and rolling downward and outward from a cliff or ledge is called a rockfall; geologically it is one kind of landslide. Rockfalls occur when the natural forces that tend to hold a mass of rock in place are exceeded by the forces, mainly gravity, that tend to pull the mass downward. Thus they are an expression of slope failure because of loss of stability. The rock separates along natural cracks and falls free to the slope below, down which it may roll. Some falls occur because the supporting rock or earth material is removed, either by natural processes or by man; others occur because of the widening of cracks.

The stability of a rock mass is influenced by two main factors: the support provided by the underlying rock or earth materials, and the trends, spacing, attitude, and extent of joints or cracks in the rock. Once a piece of rock has fallen, the distance it rolls is determined by the form, length, and angle of the slope, and the absence of obstructions on the slope, together with the initial height of fall and the size, shape, and other characteristics of the rock fragments.

The cracks in the source rock originated in different ways. In the Table Mountain rocks, most cracks originated as a result of cooling of once-hot lava. With the passage of time a crack is enlarged by weathering of the rock, the accumulation of soil, the growth of vegetation, and the expansive force of freezing moisture. Eventually the rock has insufficient support, or attachment, and falls. Boulders as large as 12 by 10 by 6 feet and weighing several tons have fallen, and one such block lies in the Golden quadrangle on the slope below Castle Rock on South Table Mountain. The total size of individual rockfalls has ranged from a few cubic yards, and weighing several tons, to a fall reportedly weighing "one thousand tons" ("Golden Globe," June 22, 1871).

Rockfalls in the mountainous southwest corner of the Golden quadrangle differ somewhat from those in the other parts of the quadrangle, owing mainly to the different kind of rock and soil. There the steep slopes are mantled by a thin vencer of soil through which the rock projects at many places. The rock is closely fractured but in a somewhat irregular manner; some of the fractures are roughly parallel to a viable layering in the rock. Rockfalls in this area are likely to consist of one to several boulders rolling downslope, but, if the rock is undercut by an excavation for a road, quarry, or other purpose, a considerable quantity of broken rock may fall into the excavation with little or no warning. Because of the great number of exposures of the rock, it is impractical to map each possible source of rockfalls, so all slopes are considered potential sources, and the entire area is shown as subject to the hazard of rockfalls.

ROCKFALLS AND TIME

Most rockfalls occur suddenly and usually without obvious warning. Historically, rockfalls in this quadrangle have occurred about equally during the spring and summer, and at various times of day or night. A delay may occur between loss of support provided by underlying rock or earth material and an actual rockfall if the loss of support is not complete or if the rock is capable of temporarily supporting its own weight.

The probability of rockfalls would increase greatly if moderate to strong ground-shaking were to occur in the Golden quadrangle because of an earthquake. Earthquakes of low intensity have been felt in the quadrangle, but none of these is reported to have caused a rockfall. The probability of rockfalls can also be increased by blasting. Rockfall debris that mantles the west flank of North Table Mountain adjacent to the quarry may have been dislodged because of blasting at the time the quarry was in operation. The location of this area is shown on the map by an arrow.

ROCKFALLS AND PLANNING

Construction sites planned downslope from source areas of potential rockfalls may be hazardous, but the degree of hazard may differ from one locality to another. Particular attention should be given to slopes characterized by scattered boulders. The hazard from rolling rock is reduced by natural features such as sheltering hillocks, flattened slopes, drainage courses, and even previously fallen rock, and by manmade obstructions such as roads, irrigation canals, buildings, and clay pits. Construction on the tops of the Table Mountains should be placed well back from the edge of any cliff, especially where the cliff face is high and shows vertical cracks. In the mountain area, construction on the level or gently sloping crests of ridges is the safest location to avoid rockfalls.

PREVENTION OF ROCKFALLS

Visual examination of source areas of potential rockfalls should be made periodically, both at the top and base of cliffs or ledges. Then, depending on the degree of hazard presented downslope, loose rock may be removed by use of a pry bar or perhaps a mobile crane, or the stability of the rock may be increased by the use of steel pins, cables, and concrete. However, the result may prove to be only temporary. The potential loss of support by landsliding, slope wash, stream cutting, or the activities of man should be prevented as much as possible.

Deflection or blocking of rolling rock may be accomplished with embankments, gullies, or strong walls; roads or other graded surfaces are less effective. One boulder in a rockfall from Castle Rock is reported to have bounded a ground distance of 75 feet, thus the possibility exists that stones may jump such obstructions. The nearer the site is to a source area, and the steeper the terrain upslope, the greater the likelihood that this may occur.

In the mountains, exposures of rock upslope from construction should be examined periodically for potential failure. Excavations for roads and buildings preferably should be oriented or placed so that the principal cracks in the rock tilt downward and away from the excavation, rather than downward and into it. By so doing unsupported rock is less likely to fall or slide into the excavation.

HISTORICAL ROCKFALLS

Newspaper reports of rockfalls in the vicinity of Golden extend as far back as the early 1870's. They probably mention only those events close to the community or its transportation routes. Some of the early events damaged property, and one is reported to have caused human injury; none appears to have taken human life. Richard Van Horn (written commun., 1972) examined issues of the "Golden Globe" filed in the Pioneer Museum, Golden City Hall, and found news items about rockfalls on the following dates:

June 21, 1871	South side, North Table Mountain
August 15, 1896	Clear Creek Canyon
August 22, 1896	Same area
April 8, 1899	Same area
August 12, 1899	Mouth, Golden Gate Canyon
May 26, 1900	Castle Rock
May 4, 1907	West side, North Table Mountain
September 16, 1907	South side, North Table Mountain
May 17, 1913	Same area
April 4, 1914	Rock quarry, North Table Mountain

Other news items during this period mention events not included here because they may not have been rockfalls; one rockfall not included above took place on April 4, 1914, when rock fell "at the rock quarry on North Table Mountain," perhaps within the quarry.

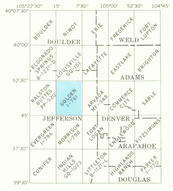
Two rockfalls in the Golden quadrangle have been investigated and described in detail by Van Horn (written commun., 1972). Both fell from the west face of Castle Rock, the first on March 23, 1958, the second in February 1962. The first fall consisted of an estimated 400 cubic yards of rock that formed a columnar mass of rock several feet across and about 100 feet high. The column collapsed with a roar at 5:20 a. m.; the temperature was close to freezing. The fall produced a pile as much as 6 feet deep of freshly broken rock including numerous boulders, and it formed a fan-shaped deposit that extended about 100 feet downslope from the former base of the column. Beyond the pile was a zone of debris approximately 100 feet wide that contained fragments as much as 6 inches across. Several boulders a foot in diameter rolled and bounded beyond this debris a distance of some 300 feet to the base of the steep slope; their manner of travel was indicated by gouges and furrows in the earth. One block of rock about 4 by 3 by 2 feet traveled some 900 feet downslope and came to rest in a driveway. The second fall was much smaller. It consisted of about 32 cubic yards of rock that fell from the recess formed by the earlier rockfall; one block about 3 by 2 by 2 feet rolled and bounded about 500 feet downslope from the base of the lava cliff. The locality of these falls is now marked by a whitish scar on the cliff face, and it is indicated by an arrow on the map.

REFERENCES

The map of potential source areas of rockfalls in the Golden quadrangle was prepared in March 1972 and is based on geologic investigations in the field and aerial photographs dated August 8, 1971, together with references to a geologic map of the quadrangle by Van Horn (1957) and an engineering geologic map by Gardner, Simpson, and Hart (1971). Publications are listed below:

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].

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



INDEX SHOWING LOCATION OF GOLDEN QUADRANGLE

For sale by U.S. Geological Survey, price 75 cents