INFORMATION SERIES 5

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA GUNNISON COUNTY, COLORADO

BY
JAMES M. SOULE

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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO

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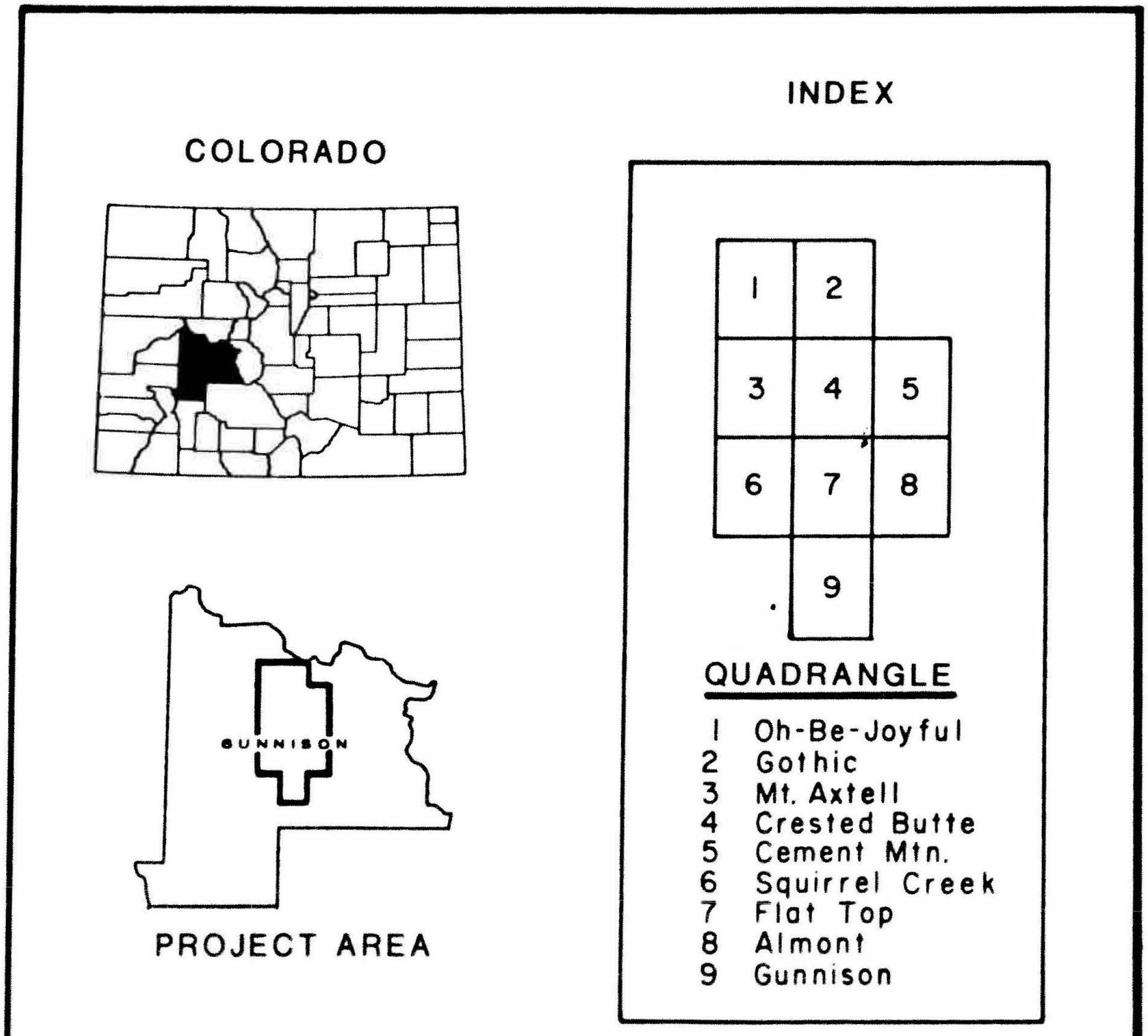
Introduction

A study of geologic hazards in the Crested Butte-Gunnison Area was undertaken by the Colorado Geological Survey as a direct response to Colorado House Bill 1041 (H.B. 1041), passed by the Colorado Legislature in 1974. In addition, the Survey's originating act provided that the Survey "determine areas of geologic hazard that could affect the safety of or cause economic loss to the citizens of Colorado." Work on this project began in Autumn, 1974, and has involved about 7 months of field and office research and compilation effort by the author. Studies and mapping have been done in all or parts of the following 7½-minute quadrangles that constitute the Crested Butte-Gunnison area: Gothic, Oh-Be-Joyful, Crested Butte, Cement Mtn., Flat Top, Almont, Gunnison, Squirrel Creek, Mount Axtell.

This text, which was prepared to accompany the hazards maps, includes an explanation of the study, description of mapping techniques and problems, and discussion of the hazards themselves. In addition, the design and presentation scheme of the maps is discussed. The quadrangle hazards maps are each published as open-file maps by the Colorado Geological Survey separately, and are designed to stand individually, exclusive of this report and of each other. Reduced-scale (1:50,000) versions of these maps and the explanation for the maps are included with this report (plates 1-10, in pocket).

Basic Data Sources and Allocation of Work Time

Up-to-date, detailed geologic data and maps are not available for most of the Crested Butte-Gunnison area. Detailed quadrangle-scale geologic mapping exists only for the Oh-Be-Joyful Quadrangle (Gaskill and others, 1967). However, this map emphasizes bedrock geology and was not of much use in assessing and mapping active geologic processes that are responsible for most of the hazards. The Anthracite-Crested Butte Folio (Emmons and others, 1894) provides some general information, but it also is concerned principally with the bedrock geology and was not very helpful to this study. Bedrock geologic mapping also exists for the area east of the East River from Cement Creek to Gothic (Prather, 1964). Down valley, in the vicinity of Almont and Gunnison, the only detailed mapping available is some work done by faculty



Location Map
Crested Butte - Gunnison Area

Figure 1

and students at Western State College of Colorado, Gunnison, and field exercises done by students of the University of Kentucky Geology Field Camp that is based every summer at lower Cement Creek.

At the outset of the work, we decided that due to lack of any significant amount of past geologic study directly applicable to hazards mapping in the area, and the time and budget constraints on the author and the Survey, the most practical approach would be photogeologic mapping supplemented by fieldwork to establish "ground-truth" parameters for final photogeologic mapping. Consequently, we secured three sets of aerial photographs of different types and scales, which were taken at different times. These were the most essential and most used basic-data source for the study. These three sets of photographs are: Army Map Service aerial photographs (VV OA M 31), scale approximately 1:60,000, monochrome, flown October 13, 1955; U.S. Forest Service aerial photographs (DKK), scale approximately 1:20,000, monochrome, flown during the autumn of 1950; NASA-Colorado School of Mines Bonanza Project aerial photographs, scale approximately 1:60,000; color-infrared transparencies, flown August 1973. (NASA aircraft mission 248; roll 24). After a preliminary field reconnaissance at the beginning of the project, the procedure used for the balance of the investigation consisted of photo-interpretation followed by field checking of critical or problematical areas. In addition to the aerial photographs approximately 150 35-mm ground photographs were made to document important sites or record critical data. Some of these are reproduced in this paper as examples of particular features or hazards. All of the originals are on file in the field records of the Colorado Geological Survey as 35-mm color transparencies and are available for inspection. Of the total time spent on this project, approximately one month was spent in the field, approximately three months were spent studying photographs and preparing basic data maps, and three months were spent compiling and analyzing the data and preparing the final maps and reports.

Acknowledgements

Several people contributed substantially in various ways to this project. W. P. Rogers, and others, of the Colorado Geological Survey staff offered criticism, advice, and assistance throughout this work. Roger B. Colton, David L. Gaskill, Helen E. Hodgson, and David J. Varnes of the U.S. Geological Survey were of considerable assistance during various phases of the project. Professor Bruce Bartleson of Western State College and Edward M. Morris of Lincoln-DeVore Laboratories, Gunnison, both of whom have considerable field experience in the Crested Butte-Gunnison area, were invaluable in relating their experience and firsthand field observations. R. A. Santarelli and Faith A. Stukey of the Gunnison County government were very helpful in indicating the kind of study and presentation of data that would be most useful to the County and the general public. Robert H. Gast of the Colorado Geological Survey and Raymond Lokken of Gunnison County drafted the maps and tables. Judith A. Primon of the Colorado Geological Survey typed the manuscript.

General Geology and Geography: Relationships to Geologic Hazards

The Crested Butte-Gunnison area physiography consists of mountainous terrain cut by several major river valleys. The East and Slate Rivers join at Crested Butte, and the confluence of the East and Taylor Rivers at Almont forms the Gunnison River. Ohio Creek flows into the Gunnison River a few miles north of the City of Gunnison. The lesser streams of Coal Creek and Cement Creek flow in steeper-gradient, relatively narrow valleys and join the East River at Crested Butte and the East River a few miles north of Almont, respectively. Higher mountains are formed by laccoliths or stock-like intrusives (Gothic Mountain, Carbon Peak, Crested Butte Mountain, Mount Axtell, and Round Mountain), by basalt caprock (Flat Top Mountain, Red Mountain), or other resistant sedimentary, crystalline or volcanic rocks. Most of the mountainsides are underlain by or composed of softer, less resistant sedimentary rocks such as Mancos Shale, Mesaverde Formation, and Morrison Formation, or colluvium derived from these units. Most of the mountain slopes are degrading rapidly. This rapid degradation of slopes during and since the late Pleistocene glaciation(s) has resulted in the distinctive landforms present today, and is cause for the most extensive of the area's geologic hazards--massive landslide and earthflow complexes. Upper reaches of most of the major stream valleys were

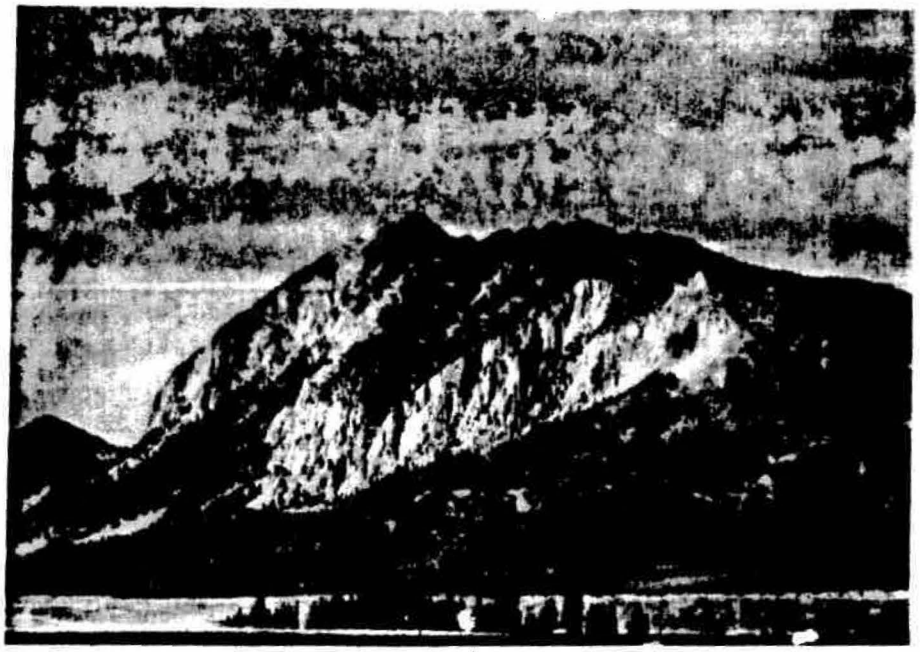


FIGURE 2. Crested Butte Mountain from Cement Creek-East River confluence. View to northwest. Note that lower slopes have subdued topography that is composed of Mancos Shale or rockstreams from higher slopes. Mountain is held up by a laccolith-like body of quartz-monzonite porphyry. (200-mm lens)[1/]

greatly modified by Pleistocene glacial erosion, whereas most of the valley bottom areas are underlain by sand and gravels deposited by ice or by voluminous glacial meltwater during these same glaciations. These valley materials have undergone further modification by fluvial (stream) processes since the Pleistocene.

The climate and climatic changes since the ice age have had considerable influence on rate, extent, and location of surficial geologic processes in the Crested Butte-Gunnison area. Generally there are three modern climate zones present. The semiarid zone characterizes the valleys and lower sideslope areas between Almont and Gunnison. This zone is commonly evidenced by sagebrush and grasslands, and except along stream courses, is nearly devoid of tree cover. Of the three, this zone is coldest in winter and warmest in summer. Most of its precipitation occurs as snow. The second zone is one of somewhat higher year-round precipitation and lesser temperature extremes. This

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[1/] *Focal length of lens on normal film format (24 x 36 mm) 35-mm camera.*

includes lower sideslope and valley areas between Almont and Crested Butte. In the higher mountain areas is a zone of greater year-round precipitation and considerably warmer winter temperatures. Slope angle and aspect affect the microclimates of this zone considerably. Predominantly north-facing slopes receive more snow and hold snow longer, and consequently have greater amounts of ground moisture and retain it longer. Predominantly south-facing slopes are typically drier and have a microclimate that, in many lower areas, approximates that in the vicinity of Gunnison. For geologic hazards, the significance of these different climate zones and microclimates is great. Active landslides and earthflows are much more common in the northern part of the Crested Butte-Gunnison area owing to increased ground moisture. However, there is strong evidence that the southern part of the study area experienced extensive slope failure in the recent geologic past. North-facing slopes tend to be more heavily vegetated, especially with coniferous forest, and *tend* to be more stable, although this is not a firm rule. Spring snowmelt runoff is greater in places that receive more snow, and orographic influences of high mountains can greatly affect the summer precipitation that occurs in a specific locality.

In addition to the general influences of climate, the added factors of slope angle, vegetation (that is, in itself, influenced greatly by aspect of slope, elevation, slope stability, and microclimate), and composition of underlying surficial and bedrock geologic materials, have a great influence on the type and degree of hazards that exist in a given area. Slope stability, for example, tends to be a minimal to nonexistent problem in places with very gentle slope.[2/]

[2/] As used in this paper, slope modifiers mean:

<u>Very gentle slope</u>: less than 1 percent slope
<u>Very gentle to gentle slope</u>: 1 percent to 5 percent slope
<u>Gentle to moderate slope</u>: 5 percent to 15 percent slope
<u>Moderate to steep slope</u>: 15 percent to 30 percent slope
<u>Steep slope</u>: greater than 30 percent slope
<u>Very steep slope</u>: much greater than 30 percent slope

Percent slope equals vertical rise of land surface divided by horizontal distance times 100; e.g., a 15 percent slope has an inclination from the horizontal of 15 ft vertical rise per 100 ft of horizontal distance (8.53°); and a slope of 100 percent has an inclination of 45°.

However, there are some notable exceptions. Some very steep slopes composed of crystalline intrusive rocks tend to be stable, whereas some gently sloping areas of debris and mudflow deposits can be very unstable.

Geologic Hazards

Geologic hazards in the Crested Butte-Gunnison area are natural geologic conditions and processes that, if unrecognized or inadequately planned for can result in loss of life, damage to structures, and costly maintenance, especially for homes, other buildings, roads, and utilities. There are six classes of geologic hazards mapped in this study and shown on the hazards maps: 1) Landslide-earthflow areas, 2) Unstable slopes, 3) Potentially unstable slopes, 4) Rockfall areas, 5) Mudflow-debris fan areas, and 6) High water-table areas. This selection of hazards mapping units was made for several reasons. The mapping units combine features, processes and/or conditions that are either related genetically or could cause similar problems for man's activities. Moreover, these mapping units and their definitions conform to the language and definitions given in H.B. 1041, and the Colorado Geological Survey's "Guidelines" (Rogers and others, 1974). Thus, the map unit scheme is simple and to the point in indicating hazards of the area. Except the class of high water table, all of the mapped hazards indicate places where slow to rapid movement of earth materials downslope is occurring, has occurred in the past or can be expected under certain man-caused or natural conditions. The nature of these "slope-failure" hazards is such that they interfere with man's activities or structures on the land surface. High water-table areas are places where either perenially or seasonally the ground-water level is at, or near, the land surface. These areas are roughly coincident with maximum probable flood plain (physiographic flood plain of some authors). However, the principal basis for delineation of this hazard is different in this study (riparian-streambank moisture-seeking vegetation). The hundred-year flood plain will usually fall well within these boundaries, except in some places where a stream course or valley has been extensively modified by man.

Landslide-earthflow areas:

Landslide-earthflow areas are places with demonstrably active natural movement of landslides and/or earthflows. Evidence for activity includes distinctive, undissected, hummocky topography with low ridges and swales transverse to downslope direction of movement of earth materials (pressure ridges), sag ponds or other drainage anomalies, springs near or at the toes of landslides, moisture-seeking plants, fresh main scarps or sharp, distinctive topographic breaks near crowns of landslides, disrupted vegetation, and in some cases, diverted drainages, fences, or roads.

For most moderate- to high-intensity land uses prevalent in the Crested Butte-Gunnison area, landslides and/or earthflows are serious hazards. In most cases, safe use of such areas will necessitate the modification of an active, ongoing natural process. Commonly this is difficult or impossible to do economically. Consequently, these areas are usually high-cost, difficult areas for most developments. Additionally, some development practices that result in undercutting,

FIGURE 3. The slope to the left of the road is failing rapidly as evidenced by the curved trunks of the aspens. Note water on road that results from leakage of excess soil moisture from slope at left. (105-mm lens)

wetting, overloading or oversteepening of slopes can cause accelerated slope movements and result in even greater problems that may be impossible to rectify satisfactorily. Lower intensity uses, such as utility lines and recreational facilities (including ski trails) are generally possible, but more intensive uses such as buildings, heavy weight structures, and roads commonly are feasible only with careful preplanning and engineering. However, maintenance costs for these installations will likely be unusually high. Very low-intensity land uses like grazing and light agriculture typically experience little difficulty in these areas, except for particular types of agricultural development, notable irrigation ditches.

Landslide-earthflow areas are most common on gentle to very steeply sloping ground underlain by predominantly shaly bedrock (Mancos, Morrison, Mesaverde, and Maroon Formations) that has high ground moisture much of the year. These hazards are much more common from the vicinity of Almont to the northern limit of the area than they are in the vicinity of Gunnison where the climate is considerably drier.

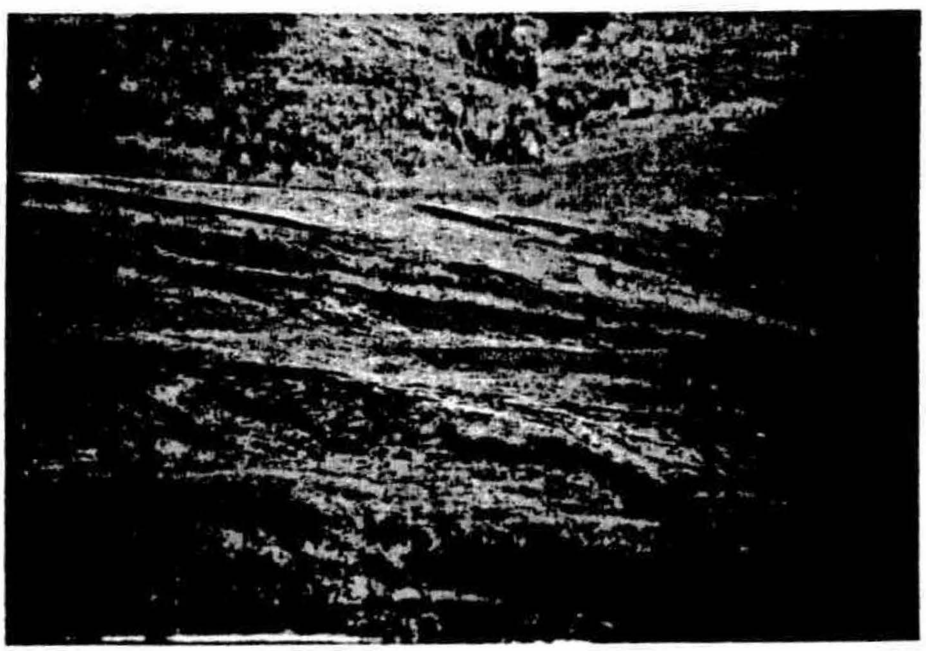

FIGURE 4. Earthflows caused by increased ground moisture resulting from irrigation ditch leakage. Upper Ohio Creek area. (200-mm lens)

FIGURE 5: Earthflow complex at Mt. Crested Butte. (105-mm lens)

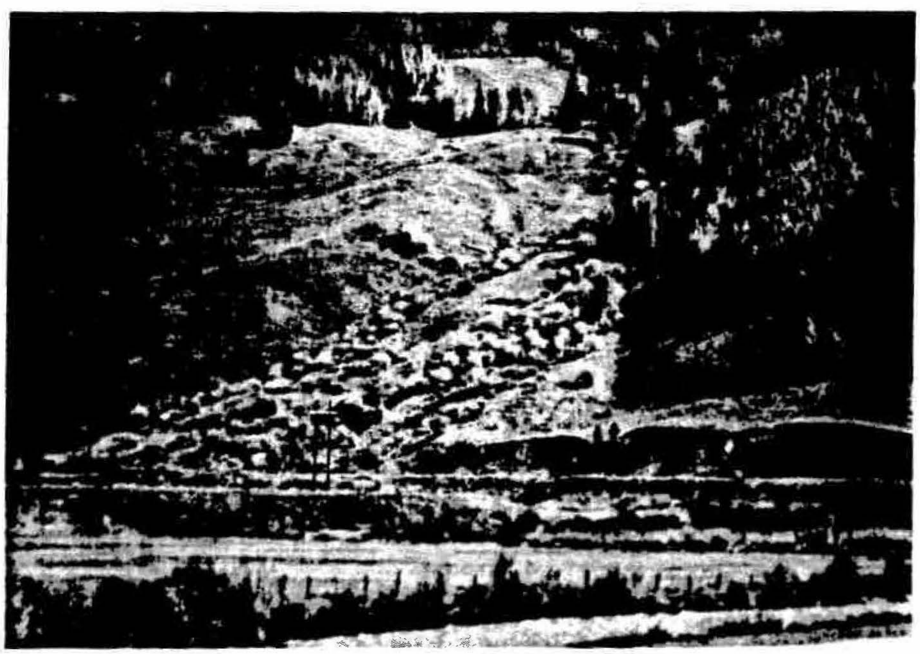

FIGURE 6. Small earthflow that has moved out over a stream terrace. On lower slopes of Mt. Axtell adjacent to the Slate River. (105-mm lens)

FIGURE 7. Active landslide area: Obvious evidence for landsliding indicated on photograph. Upper East River area south of Gothic. (105-mm lens)

FIGURE 8. Recent landslide on southeast slope of Snodgrass Mountain. The entire side slope here is a complex of landslides. (105-mm lens)

Additionally, rates of movement vary considerably from one mapped area to another, as well as within individual features. Overall fresh appearance (unmodified or undissected by subsequent erosion) of a feature is not an absolute criterion for active slope failure. Because of this, other factors in addition to freshness usually must be considered.

In addition to the landslide-earthflows involving shaly rocks, the West Elk Breccia composed of volcanic rock and accumulations of scree and rockfall-derived talus in the higher mountain areas commonly are undergoing active movement. These mountain rockstreams and rock glaciers are indicated by notes on the maps in most places, or they are combined with landslide-earthflow or rockfall classes depending on the process that appears to predominate. An example of this is the rockstream-rock glacier areas on Mt. Axtell. The large landslide immediately northwest of Gunnison involves West Elk Breccia that is underlain by the Mancos, Dakota, and Morrison Formations.

FIGURE 9. Landslide area north-northwest of Gunnison. This is a relatively recent case of large-scale landsliding that involves the West Elk Breccia. (105-mm lens)

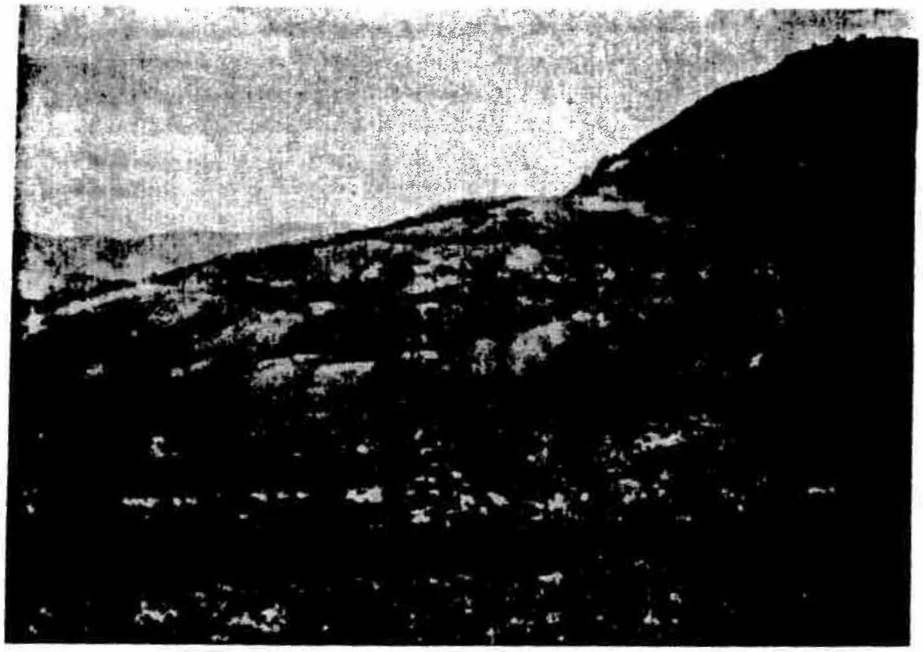

FIGURE 10. Older stabilized landslides north-northwest of Gunnison involving West Elk Breccia. (105-mm lens)

Unstable Slope

Unstable slope areas are places with physiography (landforms) characteristic of landslides and earthflows, but where current or very recent activity of these slope failure processes in nonexistent or uncertain. However, all of the areas mapped as unstable slope have undergone slope movement in the recent geologic past. Due to climate changes and other factors, some of these areas have become completely stabilized in the natural state, whereas other places included in this category are metastable or possibly even failing slowly at the present time. Most of the diagnostic characteristics applicable to landslide-earthflow areas apply to unstable slopes, except that features in many of these areas have been modified by subsequent erosion. The distinguishing characteristic is that active landslide-earthflow areas show obvious evidence for current movement, whereas unstable slopes do not.

Hazards in unstable slope areas differ from landslide-earthflow areas in that in the case of the latter, an active process is taking place, and in the case of the former, a slope failure process can be initiated by the activities of man. Also included in the former is the implication that the hazard is less certain, and if land-use

FIGURE 11. Soil ripples indicative of unstable slope conditions. (105-mm lens)

FIGURE 12. Unstable slope-forming materials composed of admixed Mancos Shale colluvium and glacial drift. Such materials as this tend to be unstable on moderate to very steeply sloping ground as they are permeable and have little cohesion. Arrow points to "2 x 4" lumber. (35-mm lens)

change is contemplated in these areas, then a precise determination of the degree of slope failure hazard as it relates to *that particular land use* probably will be necessary.

Many of the unstable slopes in the Crested Butte-Gunnison area are suitable for low- to moderate-, and in some cases high-intensity land uses, *if the nature of the hazard is well understood and considered seriously in development plans and in subsequent construction.* Installation of roads, and benching and deep cuts for building foundations can be especially problematical in these areas. In places where natural slope movements can be demonstrated, such land uses may be difficult, if not impossible. In other places high-density housing developments may be feasible, especially if site drainage and building and landscaping designs are appropriately engineered and constructed.

Unstable slope areas are found contiguous to and associated with landslide-earthflow areas throughout the Crested Butte-Gunnison area. This association is understandable as these hazard classes are fundamentally the same, with the exception of conditions necessary to initiate modern movement. Most of the slope failure areas south of Almont are of this type. As mentioned earlier, a close correlation apparently exists between occurrence and activity of landslides and earthflows and moisture conditions. In the drier area south of Almont and extending to the Gunnison area, most of the extensive slope-failure areas appear to be stabilized. This stability seems to be the result of considerably less annual precipitation, especially on lower slopes immediately above the valley floors. The large unstable slope areas southeast of Almont appear to be stabilized although they appear conspicuously fresh on aerial photographs. These involve extensive areas of bedrock (Dakota Formation on Morrison Formation) and occur on moderate to steep slopes. The bluffs west of Ohio Creek and immediately north of its confluence with the Gunnison River are composed predominantly of West Elk Breccia that has undergone extensive landsliding in the recent geologic past. With the exception of this one area northwest of Gunnison mentioned earlier, all of this area appears stabilized at the present time. However, it appears that major disturbance of such unstable slopes by man or exceptional natural conditions could initiate slope failures.

Potentially Unstable Slope

Potentially unstable slopes are ones with all attributes of unstable slopes, but where evidence of past or present slope failure is not apparent. The most significant of these attributes are composition of surficial and bedrock materials, proximity to and geological similarity to areas that have failed in the past or are failing now, slope angle, aspect, and microclimate.

Potentially unstable slope hazards differ from the previous two classes primarily because there is essentially no obvious evidence that large-scale slope failure has taken place naturally. This implies that landslides and earthflows are less likely to occur and this is probably true in most areas so mapped. However, also implied is less certainty about the presence or absence of significant hazard for a given land use. Therefore, as in the case of unstable slopes, determination of actual hazard must be made in the context of the land use being contemplated. For some areas, potentially unstable slopes can, in fact, be more hazardous than either of the two previous classes. Man-caused slope failures in areas where natural slope movements are unknown can be much more difficult to plan for than in places where slope movement is very predictable in advance and is routinely avoided or mitigated.

Most of the moderate to steeply sloping ground in the Crested Butte-Gunnison area is potentially unstable. Potentially unstable slopes are found in nearly all mountain and sideslope areas where weak nonresistant bedrock is covered by its derived colluvium; and where it is weathered, or on slopes that are oversteepened by erosional downcutting or for other reasons are excessively steep. At higher elevations, rain and snowfall are considerably greater than at lower elevations. Colluvial deposits tend to be thicker on gentler slopes as the rate of mass wasting resulting from gravitational stress and snowmelt and rainfall runoff is usually considerably less. Consequently, lower slopes are usually composed of less consolidated, less cohesive materials, whereas higher and typically much steeper slopes commonly fail by shear failure of bedrock.

FIGURE 13. Small slope failure in roadcut. These are common in many places where steep cuts have been made into potentially unstable or unstable slopes. Arrow points to fencepost approximately 4 ft (1.3 m) high. (35-mm lens)

Rockfall Areas

Rockfall areas are localities subject to rapid, intermittent, somewhat unpredictable, rolling, sliding, bounding, or free-falling of large masses of rocks and debris or individual rock blocks. Areas subject to rockfall are most commonly adjacent to barren, very steep and/or fractured and jointed cliffs of bedrock. Consequently, rockfall hazards are usually found in and near places where bedrock exposures occur on very steep slopes. Although many subtle aspects of rockfall processes are poorly understood, the general manifestations of rockfall are quite evident, and consequently identification of rockfall hazard areas is straightforward. Most rockfall areas have three distinct hazard zones: (1) a source, usually a cliff or very steep slope; (2) an acceleration zone, usually immediately downslope from the primary source of rock fragments and having a slope of 50 to 100 percent, where moving rock fragments can accelerate in their movement downslope, (3) an area, usually of lesser slope where moving rock fragments decelerate and eventually come to rest. The boundaries between individual zones vary according to specific details of rock materials, size, and slope geometry. In some cases zones (1) and (2) (source and acceleration zones) are essentially coincident. Although the frequency and number of events involving larger rocks is usually considerably less, larger rock fragments tend to move farther before they come to rest. In some cases, they have sufficient momentum to roll and bound out onto very gently sloping areas below and adjacent to the slopes down which they moved initially. In the acceleration zones near the primary rock sources, slopes tend to be steeper, moving rocks have large momentum, and most sizes and shapes of rock fragments can move the same distance within that zone. Most smaller rock fragments come to rest at or near the lowest part of this intermediate zone. In the lower "runout" zone (3), which is less steep, moving rocks lose momentum, and the actual distance traversed in this zone is more dependent on the magnitude of momentum, size and shape of rock particles, and slope and frictional effects of the ground itself.

FIGURE 14. Rockfall area in Taylor Canyon. Note large rock fragments in foreground that rest on nearly level ground (35-mm lens)

The most important of these ground effects appear to be vegetation type and cover, soil type and moisture, texture of the surface, and presence or absence of frozen ground and/or snow. Additionally some rock fragments that have come to rest within the acceleration zone of the rockfall area can experience renewed movement. Likelihood of this secondary movement apparently depends on composition of underlying surficial materials on which the rocks rest, size and shape of the rock fragments, and exceptional but recurrent weather conditions. This secondary movement can be of either individual rock fragments or *en masse* mobilization of accumulated rocks and/or surficial debris. The term ***debris avalanche*** is usually applied to this process.

Most rockfalls and associated processes occur rapidly without much, if any, warning. This lack of predictability and periodicity of rockfall events results from the variation in the natural processes that precipitate most rockfalls. Torrential rainstorms that undercut and loosen rock, frequent freeze-thaw cycles that loosen and dislodge rocks, and ground motion from earthquakes and man-caused earth vibrations probably initiate most rockfalls.

With the exception of the higher mountain areas, most of the Crested Butte-Gunnison vicinity rockfall hazards are found adjacent to drainage courses where the stream is incised into resistant bedrock. Most of these places are tempting for development sites as they offer an overview of the surrounding countryside and are in themselves scenic. Rockfall hazard is nearly ubiquitous in the higher mountains wherever resistant bedrock occurs on steep to very steep slopes. The rockfall hazard areas mapped should not be used as development sites without some effective mitigation of the hazard. Defensive structures and related corrective engineering work in rockfall areas are apt to be prohibitively expensive for many kinds of development.

Mudflow-Debris Fan Areas

Mudflow-debris fan areas are typically made up of three elements: (1) a source of mud and debris, usually in the upper reaches of a drainage basin or its contiguous sideslopes, (2) a drainage way or other channels down which this mud and debris can move, (3) a debris or "alluvial" fan formed by successive episodes of deposition of mud and debris. Mud and debris flowage is usually initiated by high-intensity summer rainstorms or rapid snowmelt runoff that mobilizes accumulated sediment and debris. This moving material is channeled down into a drainage way (element 2), and eventually this material is discharged onto the debris fan (element 3) where it is deposited, completing the process. Although these events can be anticipated and identified, their periodicity is very difficult to determine. They are closely related to weather conditions, but temporal details of the weather itself, except for regular seasonal variations, are nearly impossible to predict.

Mudflow-debris fan areas mapped during this study include all three elements described. Evidence for mudflow-debris fan hazards includes: rapid erosion and degradation (including degradation by slope failure) in the upper reaches of a drainage; damage to vegetation from impact by moving mud and debris in drainage ways; fresh recent mud and debris deposits in drainage ways and on debris fan(s)

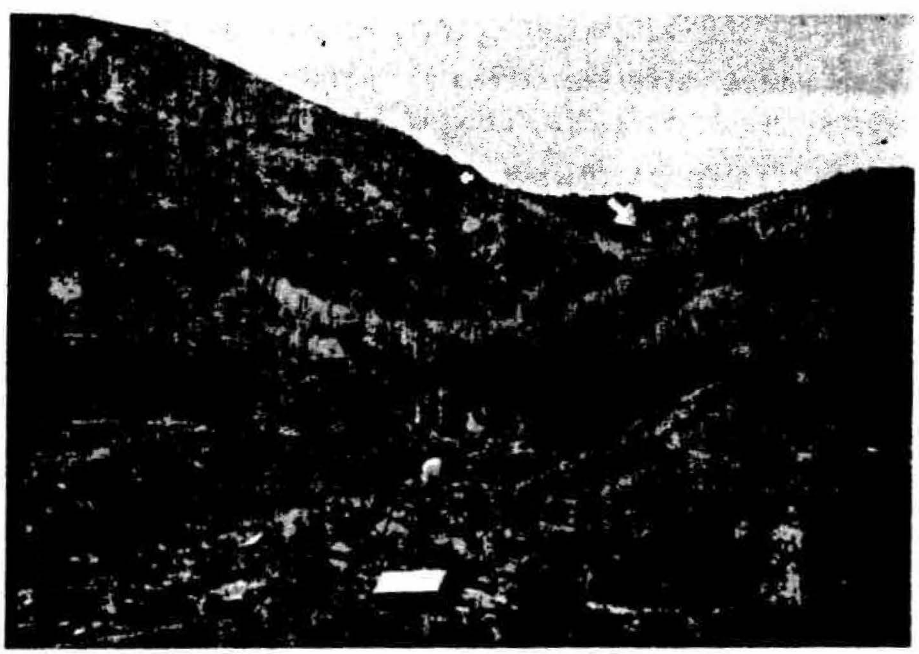

FIGURE 15. Mudflow-debris fan area on the northeast side of the East River South of Gothic. Note apparent freshness of deposits and debris on side slopes. Arrow points to rapidly receding cliff at the head of the drainage that is the principal source for mudflow material. (200-mm lens)

FIGURE 16. Mudflow material. Note sizes of rock fragments and debris caught by trees, probably during the initial flood surge of the mudflow. (35-mm lens)

FIGURE 17. Typical small mudflow. Upper Ohio Creek area. (35-mm lens)

(usually evidenced by little, if any, soil development on the deposits). Hazards in debris fan-mudflow areas result from impact and inundation by mud and debris. Commonly this impact and inundation is of sufficient severity to destroy all but the strongest and most rigid structures. Additionally, lower intensity land uses such as roads and utilities can be seriously jeopardized resulting in loss of service and high maintenance costs.

Debris fan-mudflow areas of the Crested Butte-Gunnison area are found in several larger drainages, as well as in numerous small drainages in higher mountain areas. They are more common in places where snowfall and/or accumulation and rainfall are most abundant. Consequently, debris fan-mudflow areas are more common in the northern part of the Crested Butte-Gunnison area than in the southern part. In contrast to other geologic hazards, debris fan-mudflow hazard areas are not especially dependent upon slope. The dominant criterion for this type of process to occur seems to be an abnormally high sediment supply and debris in the upper part of a drainage basin that occasionally experiences extremely high runoff rates. Consequently, some of man's activities can induce development of the hazard. Removal of vegetation is the most important factor in artificially accelerating erosion of the land surface. Poorly designed road cuts, drainage diversions, and other construction practices commonly associated with land development can cause or increase the likelihood that an area will be subject to this hazard

High Water Table Areas

High water table areas are places where ground water occurs at or within a few feet of the ground surface during much of the year. This condition can result either from natural seasonal fluctuations in ground-water level or from man-caused variations, especially those that result from irrigation of valley bottomlands. There are two general types of high water table areas in the Crested Butte-Gunnison area -- those adjacent to the main streams and those found on valley sideslopes. Those areas adjacent to all of the major stream courses, and evidenced by riparian (streambank) vegetation and/or lush grass growth are indicated on the hazards maps. Higher sideslopes have

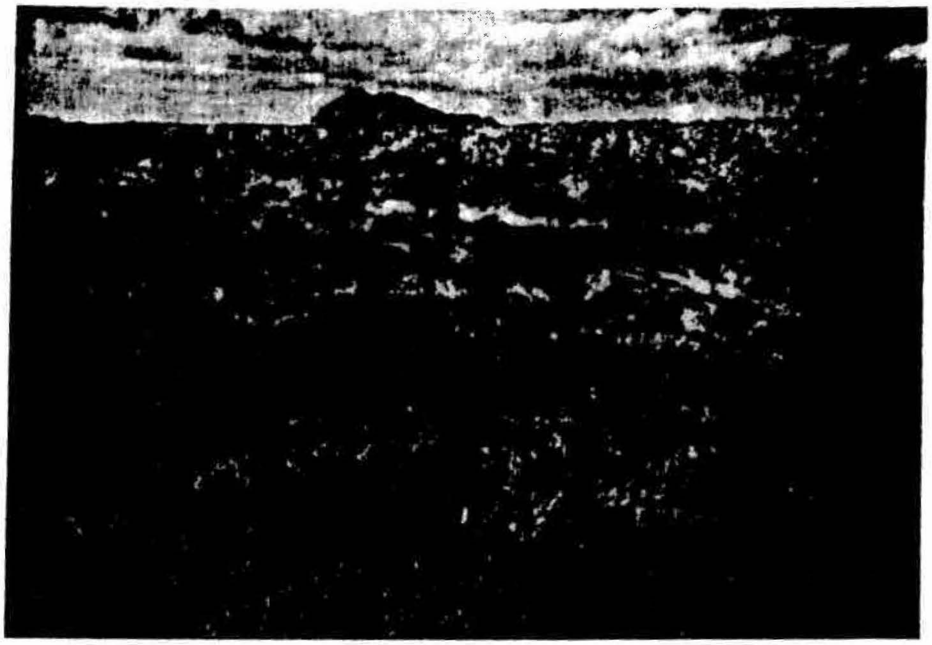

FIGURE 18. High water table area near the confluence of Cement Creek and the Gunnison River. Arrow points to gravel stream terrace. (35-mm lens)

numerous swamps and small bogs in many areas. Commonly these features are associated with landslides and earthflows, as they are ancient sag ponds that result(ed) from collection of surface and ground water in local small depressions in slopes that are moving or have moved in the recent geologic past. Most examples of this second class of high water table hazard area are too small to be shown at the scale of the hazards maps, and none is mapped. Low-bearing-strength soils also commonly occur in association with landslide-earthflow areas and unstable slopes. These result from infilling of ancient swamps with organic-rich muck. Additionally, high water tables are prevalent on many sideslopes during the spring and early summer months owing to accumulation of snow meltwater in small sags and other depressions and infiltration of meltwater into colluvial deposits.

High water table areas occur along stream courses throughout the Crested Butte-Gunnison area. In association with landslides and earthflows, localized high water table areas on sideslopes are more common in the northern part of the area. However, in addition, there are occasional bogs or swamps located on nearly level ground that is stable. There are a few of these in the vicinity of upper Coal Creek near the Irwin townsite, as well as in some other high mountain areas.

The principal hazard in high water table areas that occurs along major drainages is related to buildings with basements. Moreover, septic tank-type sewage disposal for residences rarely can be used without difficulties, and excessive infiltration of effluent may result where sewage interceptor lines are located in saturated ground. Usually the high water table areas along streams are roughly coincident with the physiographic flood plain, i.e. that part of the stream valley that has undergone flooding during the most recent period of geomorphic development of the stream valley. However, no statistical recurrence interval of floods of a specified magnitude is implied. Actual flooding during a flood event and flood potential of a stream can be considerably altered by man-made modifications of the flood plain and the drainage basin of the stream involved.

The principal kinds of hazards associated with high water table areas on sideslopes are increases in susceptibility to landslides and earthflows, site-specific drainage problems, and construction difficulties with associated low-bearing-strength and/or compressible soils.

<u>Snow Avalanches, Seismicity, Expansive Soil and Rock, Subsidence, Radioactivity</u>

These geologic hazards are found in the Crested Butte-Gunnison area but are not delineated on the geologic hazards maps for several reasons. These geologic hazards are not mapped because they have been or are being studied by others or their nature is not amenable to mapping, there is insufficient data to map them, or they are found in so few places, or so many, that including them in the simplified map unit scheme used would be cumbersome.

Snow avalanche hazards have been studied in detail in the Coal Creek Area, Gothic Area, and Round Mountain Area, by Arthur I. Mears, consultant to the Colorado Geological Survey (Mears, 1976a). Most of the remaining higher mountainous parts of the Crested Butte-Gunnison area have places that are subject to rapid snow movement downslope, especially small snowslides that can be very hazardous to recreational users of the back country. As Mears (1976b) points out, avalanche hazards are dependent on a number of interrelated factors including variation in the weather and resultant variation in the statistical recurrence interval of avalanche events, velocity of snow in various parts of avalanche paths and runout zones, and most importantly, man's activities in avalanche-prone areas. It is suggested that precise avalanche hazard determination be made for any of the higher mountain areas where moderate- to high-intensity land uses are contemplated. Such determination should include extent of runout zones in lower valley areas as well if applicable to a particular development.

Natural seismicity (earthquake) hazards in Colorado have not been precisely evaluated to date but are currently under study by the Colorado Geological Survey. The only official designation of seismic potential for Colorado is the generalized and probably understated Seismic Risk Map given in the Uniform Building Code. This map shows all of Coborado in its "Zone 1" described as, "minor damage from distant earthquakes." Our preliminary findings indicate that all of Colorado west of the 104th meridian should be considered to be in Modified Mercalli Class VII that indicates:

> "...Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken...",

and that this be used as a preliminary working standard for the Crested Butte-Gunnison area. Consideration of seismic hazards is especially important in view of some of the other hazards present in the area. Slope failures and rockfalls can be initiated or accelerated by ground shaking; thus, a combination of hazardous processes could result that could be far more serious than any one individually.

Expansive Soil and Rock[3/]

Much of the Crested Butte-Gunnison area is underlain by Mancos Shale, a bedrock formation that generally contains clays that expand when wetted. The pressures exerted by these expanding clays have, in other parts of western Colorado, caused significant heaving and cracking of highways, sidewalks, basement floors, and even building foundations. These montmorillonitic clays are not, however, equally abundant

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[3/] by Stephen S. Hart, formerly with the Colorado Geological Survey in all of the shale and claystone beds of the Mancos. Instead, "swelling" clays are concentrated in thin, white to yellowish-brown beds locally called "bentonite" beds. In a very limited sampling of weathered, brown to black shale and claystone form the Mancos in the Crested Butte-Gunnison area, no expansive clays were found. This result may, however, be due more to the limited sampling, the abundance of vegetation, and the rapid erosion rates of the bentonite than to the lack of expansive clays in the area. Therefore, testing programs for expansive soil should be included in the design phase of every building or highway project located in the Mancos Shale or soils derived directly from the Mancos. In addition, *all foundations* in these areas should be carefully designed and inspected by a professional engineer who (1) is registered in Colorado, (2) specializes in soil engineering and foundation design, and (3) is familiar with foundation problems in expansive soils.

Ground subsidence hazards of the study area are known only in places where underground mining has occurred in the past. These include land over shafts and tunnels that were dug during the era of coal mining in the Crested Butte district and similar areas in the vicinity of the precious-metal mining camps of Irwin, Ruby, Pittsburgh and Elkton. Additionally there are numerous small prospects in various places in the mountains as well as the abandoned uranium workings near Gunnison. Although essentially all of these workings are inactive at the present time, many are on patented mining claims that in most cases are the only enclaves of private ground in the surrounding national forest lands. Consequently they are under some pressure for recreational and part-year residential use. Unstable mine tailings and the possibility of persons, especially children, falling into mine shafts are additional hazards common on many of these claims.

Known danger from radioactivity exists in the vicinity of some abandoned uranium mine workings and tailings in numerous localities over an extensive area south of Gunnison. Several prospects, mine spoils, and abandoned mine(s) are located in SW¼ sec. 14, T. 49 N., R. 1 W. A tailings pile and inactive mill are located near the Gunnison Airport in NW¼ sec. 11 and SW¼ sec. 2, T. 49 N., R. 1 W. U. S. Environmental Protection Agency data (Douglas and Haus, 1975) indicate that these tailings present a low-level radioactivity hazard. Radioactive minerals are known to occur in both the Dakota and Morrison Formations, as well as other rock units in this part of western Colorado. Consequently, it is suggested that water wells completed in sedimentary bedrock aquifers, and especially those wells completed in the indicated formations, be tested for radioactivity if the water is to be used domestically or for stock watering. Ranger Warm Spring and Cement Creek Warm Springs are being analyzed for radioactivity, among other properties, currently by the Colorado Geological Survey and the U. S. Geological Survey.

Design of the Hazards Maps

A geologic hazard is a situation that results from interaction of man and his natural environment. Conventional geologic mapping shows the distribution of one or more natural features such as landforms and drainage, or materials such as rocks and surficial deposits on the surface or subsurface of the earth. A geologic hazard typically is contingent on natural conditions, geologic materials, and man-made environmental changes. These man-made changes may include either one-time events or cyclic changes. Included are agricultrual activities such as vegetation disturbance, irrigation, or grazing, and permanent, higher intensity land-use activities such as the installation of roads and buildings.

A geologic hazards map must necessarily be different from a conventional geologic map. In the case of the Crested Butte-Gunnison area maps, the hazards map units are inclusive units that indicate areas where man's activities may interact with existing geologic conditions (unstable slopes, potentially unstable slopes, high water tables), natural features (landslide and earthflow deposits, debris fans), and geologic processes (rockfalls, mudflows). The Colorado Land Use Commission (Guidelines for identification and designation [of natural hazard areas], 2-1-204, September 19, 1975) suggests that a "hazard area should be one that is large enough to provide assurance to a prudent layman that the hazard lies totally within the area described." Mapping units of this report conform to this approach by showing geologic hazards that can vary greatly in degree depending on the natural variation within the mapped hazard area and on various man-caused changes that may occur in the land surface or subsurface. Because most of the Crested Butte-Gunnison area currently is either in the natural state or in low-intensity use such as agriculture and grazing, most of the mapped hazards cause no severe difficulties for present human activities. No detailed quantification of geologic hazards is made in this study other than the matrix-type table below which is also an integral part of the map explanations. In short, the actual degree of hazard depends as much, if not more, on human decisions affecting land use as it does on geologic factors.

Boundaries between mapping units on the Crested Butte-Gunnison area hazard maps are located as precisely as permitted by the methods and data used. Because the definitions of the mapping units reflect the language in H.B. 1041, the unit boundaries of such physical features as debris fans conform more closely to ground- and aerial photograph-observable features than do such hazards as potentially unstable slopes. Mapping a physical feature such as a debris fan requires different evidence than mapping a potentially unstable slope where the definitive evidence might be the condition of particular vegetation types or the general geologic environment. Although the presentation and format used is quite different from that of conventional geologic or geomorphic maps, it is our opinion that the hazards maps produced for the Crested Butte-Gunnison area provide the practical type of identification that H.B. 1041 calls for (106-7-103 (14), C.R.S., 1973). In all cases, the mapped areas contain definitive observable evidence for the hazards shown.

In higher mountainous areas where there are overlapping multiple hazards that make cartographic presentation difficult or impossible, the map unit pattern is that of landslide-earthflow areas. The dominant hazards in these areas are typically similar to landslides, i.e. rockstreams and rock glaciers. Notes on the individual maps indicate other hazards present—snow avalanches, rockfalls, and commonly unstable accumulations of talus, scree, and debris.

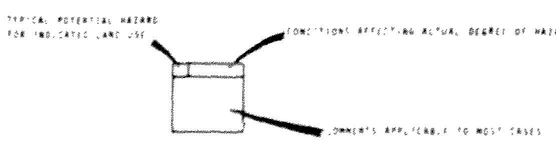
In the context of H.B. 1041 with regard to administration of geologic hazard areas (106-7-202 (III), C.R.S., 1973), these geologic hazards maps are recommended as guides to the problems that may be ski runs, ski trails but not

GEOLOGIC HAZARDS FOR COMMON LAND USES

HAZARDS MAP UNIT	Residential Development: High density	Residential Development: Low density	Roads	Utilities	Open-space recreational complexes including ski areas but not associated structures	Commercial and industrial development, including larger residential buildings such as condominiums and apt buildings	Low-value light-weight agricultural buildings	Agriculture uses grazing and similar
Landslide-earthflow area	3+ A B C D E F H REMEDIAL ENGINEERING TYPICALLY IS PROHIBITIVELY EXPENSIVE	3 A B C D F H MAY BE POSSIBLE WITH CAREFUL ENGINEERING.	3+ A B C D E F H TYPICALLY NOT FEASIBLE WITHOUT CAREFUL ENGINEERING.	2 A B C E F H COMPATIBLE WITH OPEN-SPACE LAND USE	1+ A B COMMONLY FEASIBLE. MAINTENANCE COSTS MAY BE HIGH.	3+ A B C F H MAINTENANCE COSTS PROBABLY WILL BE HIGH.	2+ A F H MAINTENANCE COSTS MAY BE HIGH.	1+ A B E USUALLY MINOR PROBLEMS EXCEPT FOR IRRIGATION DITCHES AND FENCES.
Unstable slope	3 A C D E F H REMEDIAL ENGINEERING USUALLY NECESSARY.	2+ A C D E F H REMEDIAL ENGINEERING MAY BE NECESSARY.	3 A C D E F H REMEDIAL ENGINEERING USUALLY NECESSARY.	1+ A C F H REMEDIAL ENGINEERING MAY BE NECESSARY.	1 A F COMMONLY FEASIBLE.	3 A C D E F H REMEDIAL ENGINEERING NECESSARY.	2 A F H REMEDIAL ENGINEERING NECESSARY.	1 A D E USUALLY MINOR PROBLEMS EXCEPT WHERE DITCH LEAKAGE CAUSES EARTHFLOWS.
Potentially unstable slope	3 C D E F REMEDIAL ENGINEERING MAY BE NECESSARY.	2 C D E F REMEDIAL ENGINEERING MAY BE NECESSARY	2+ A C D E F H MAY EXPERIENCE DIFFICULTIES WITHOUT CAREFUL PLANNING/ ENGINEERING.	1 C D E CAREFUL PLANNING CAN MINIMIZE HAZARD.	0 F TYPICALLY NO DIFFICULTIES.	2 A C F H REMEDIAL ENGINEERING NECESSARY.	2 A C F H REMEDIAL ENGINEERING NECESSARY.	0 E USUALLY MINOR PROBLEMS EXCEPT IN AREAS OF INTENSE CULTIVATION OF HILLSLOPES
Rockfall area	3+ A B C F H RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	3 A B C F H CAREFUL SITING TYPICALLY NECESSARY TO MINIMIZE HAZARD	3 A B C F H REMEDIAL ENGINEERING CAN MINIMIZE HAZARD.	2 A B C H CAREFUL PLANNING CAN MINIMIZE HAZARD.	1+ B CAREFUL SITING CAN MINIMIZE HAZARD.	2 A B C H MAINTENANCE COSTS PROBABLY WILL BE HIGH.	2+ A B C F H CAREFUL SITING CAN MINIMIZE HAZARD.	1 B USUALLY FEW OR MINOR PROBLEMS
Mudflow-debris fan area	3+ B C D F H RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	3 B C D F H RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION	3 B D H COMPATIBLE ONLY WITH ELABORATE AND EXPENSIVE MITIGATION	2 B F H POSSIBLY EXCESSIVE MAINTENANCE NECESSARY.	2 B COMMONLY FEASIBLE IF RISK IS ACCEPTABLE	2 B C D F H OCCASIONAL VERY HIGH MAINTENANCE COSTS CAN BE EXPECTED	2 B D F H OCCASIONAL VERY HIGH MAINTENANCE COSTS CAN BE EXPECTED.	0 B USUALLY FEW OR MINOR PROBLEMS
High water table area	3 G H BASEMENTS AND SEPTIC TANK SEWAGE DISPOSAL USUALLY NOT FEASIBLE	2+ G H BASEMENTS AND SEPTIC TANK SEWAGE DISPOSAL USUALLY NOT FEASIBLE	3 G H USUALLY DIFFICULT - DEPENDS ON TYPE OF DEVELOPMENT FLOOD PLAIN DETERMINATION MAY BE NECESSARY	0 G SOME REMEDIAL ENGINEERING MAY BE NECESSARY IN UNUSUAL CASES	1 G USUALLY LITTLE DIFFICULTY POSSIBILITY OF FLOOD DAMAGE	2+ G H MAY REQUIRE SPECIAL CONSTRUCTION TECHNIQUES OR REMEDIAL ENGINEERING	2 G H MAY REQUIRE SPECIAL CONSTRUCTION TECHNIQUES OR REMEDIAL ENGINEERING	0 G DESIRABLE FOR MANY KINDS OF AGRICULTURE

EXPLANATION OF CHART SYMBOLS

- 3 HIGH HAZARD
- 2 MODERATE HAZARD
- 1 LOW HAZARD
- 0 VERY LOW IF ANY HAZARD



MEANING OF LETTER SYMBOLS

- A ESPECIALLY SEVERE ON SLOPES GREATER THAN 30 PERCENT
- B SLOPE MOVEMENT INTERMITTENT DEPENDENT ON VARIATION IN WEATHER OR OTHER FACTORS
- C OVERSTEEPENING OR CUTTING OF SLOPES CAN INCREASE HAZARD GREATLY
- D ARTIFICIAL OR NATURAL INCREASE IN GROUND MOISTURE CAN INCREASE HAZARD GREATLY
- E REMOVAL OF NATURAL VEGETATION CAN INCREASE HAZARD GREATLY
- F HAZARD MAY DECREASE CONSIDERABLY AS SLOPE DECREASES
- G VARIES SEASONALLY
- H DETAILED ENGINEERING GEOLOGY STUDIES NECESSARY DURING PRE-PLANNING STAGES OF DEVELOPMENT

Figure 19

encountered in or caused by certain kinds of land uses if they should occur in these hazard areas. These maps should be used only as a reference indicating need for more detailed site-specific studies to be carried out in advance of proposed land-use changes or they may be used for general planning of land use. Because of the scale of 1 inch equals 2000 feet (1:24,000) these maps have limited suitability for precise determination of specific site planning and engineering problems. However, they should provide information to both governmental groups and prospective developers of certain geologic factors that should be considered in advance of any serious commitment to more intensive land uses.

Photogeologic Mapping of Hazards

As mentioned earlier, interpretation of aerial and ground photographs was the principal method used to identify hazards in the Crested Butte-Gunnison area. Most of the hazards of the area are so extensive that the synoptic view afforded by aerial photographs makes identification of the hazardous conditions easier on aerial photographs than it is on the ground. Study of aerial photographs was enhanced considerably by documenting subtle ground surface features and conditions with 35-mm ground photographs. Then we compared the ground photographs of such features as soil ripples, vegetation anomolies, and changes in ground-observable textures of surficial deposits with the less obvious indications of the same features on the aerial photographs. Once established, such photomorphic units could be used for basic photogeologic mapping. This technique was especially useful with the color-infrared aerial photographs, as vegetation color changes show up well on this type of color rendition. Additionally, identification of ground conditions not ordinarily obvious in aerial photograph study were enhanced by comparison of ground photographs of the feature with aerial photographs. For example, high ground moisture conditions evidenced by preponderance of grasses over sagebrush could be demonstrated by ground photography and then used as an indicator (signal) for identification of that condition over wide areas on aerial photographs. Common coincidence of this condition with physiography of landslides and earthflows usually indicated that these areas

FIGURE 20. Evidence in vegetation that this area has increased soil moisture. Note sagebrush in distance. Also note the hummocky ground indicative of probable small-scale earth flowage. Arrow points to stake approximately 1 ft (.3 m) high. (35-mm lens)

were undergoing active slope movement. Rockfall areas, especially the zone where rocks roll out onto adjacent gently sloping ground, were mapped by noting the maximum extent of runout of larger rock blocks on the ground, and then extrapolating this to wider areas. Riparian vegetation, readily apparent on color-infrared photographs, was the basis in addition to streambank physiography for delineation of the high water table areas. Fresh mudflow deposits are readily detected on photographs, as vegetation in these areas usually has been modified or damaged by recent mud movement.

Another aspect of photograph interpretation that is especially useful for mapping geologic hazards is study of repetitive photographs of the same area over a considerable period of time. This can be done with either aerial or ground photographs. The principal advantage of this technique is that a careful observer can demonstrate that a geologic process is active by noting changes that have occurred in the land surface and vegetation during elapsed time between photographs. Moreover, due to possibly different lighting conditions and other technical factors, two or more sets of photographs of the same scene offer much more information than a single set. By using three sets of aerial photographs in the Crested Butte-Gunnison area, we were able to prove that many of the obviously fresh landslide-earthflow areas are currently moving. Some of these movements are surprisingly large. Parts of the large landslide-earthflow area east of and adjacent to Red Mountain and Flat Top have moved as much as 100 ft (30 m) during the 23 years between the oldest and most recent aerial photographs. Subtle changes in the gross morphology of similar areas adjacent to Mt. Axtell and near the town of Mt. Crested Butte led me to conclude that these areas are moving actively also. Although older, high-quality, well-documented ground photographs of parts of the Crested Butte-Gunnsion area were not available, a number of ground photographs made during this study were made especially for the purpose of duplication at a future date. These include views near Crested Butte Mountain, avalanche features near Gothic, selected sites near Meridian Lake, and several views of valley sideslopes between Crested Butte and Almont. All of these photos were precisely made with Nikon 35-mm cameras and accessories. Notes and technical data regarding these photographs are available from the Colorado Geological Survey and/or the author.

Although most, if not all, geologic study of the land surface should involve some field "ground-truth" investigation, most of the mapping and interpretation presented in this Crested Butte-Gunnison area geologic hazards study would not have been possible without photograph interpretation. Because most of the hazards are, in some way, photograph-detectable, it is suggested to future workers who may make site-specific investigations that they consider the use of large-scale, precision aerial photography as a source of basic data. This is emphasized both for practical reasons and because it is the experience of the author that conventional ground fieldwork alone can cause one to "not see the forest for the trees" when determining hazards in this area. For example, a typical proposed development site that is located on a moderately steep sideslope may be seriously affected by geologic processes and conditions from mountain top to valley floor.

Recommendations

Additional, detailed geologic study of the Crested Butte-Gunnison area would benefit understanding and mitigation of geologic hazards and land-use planning problems. Engineering geologic maps for the areas being rapidly developed around the towns of Crested Butte, Mt. Crested Butte, and Gunnison would be most useful for both planners and developers. Such maps should show chemical, physical, and engineering properties of surficial materials, thickness and excavatability of these materials, their distribution, and their susceptibility to erosion and percolation of surface and ground water. The combination of the hazards maps and the engineering geology maps would form an adequate data base for most geology-related land-use decisions. The maps prepared during this study address only those geologic hazards specified in House Bill 1041. Additional engineering geologic investigations described above would require considerably more fieldwork and laboratory testing, and consequently would be costly. However, the Colorado Geological Survey feels that Gunnison County and the municipalities most directly affected by rapidly expanding development could benefit far in excess of the cost of the proposed additional geologic study. This is especially true owing to the existence of the basic reconnaissance data developed by this study.

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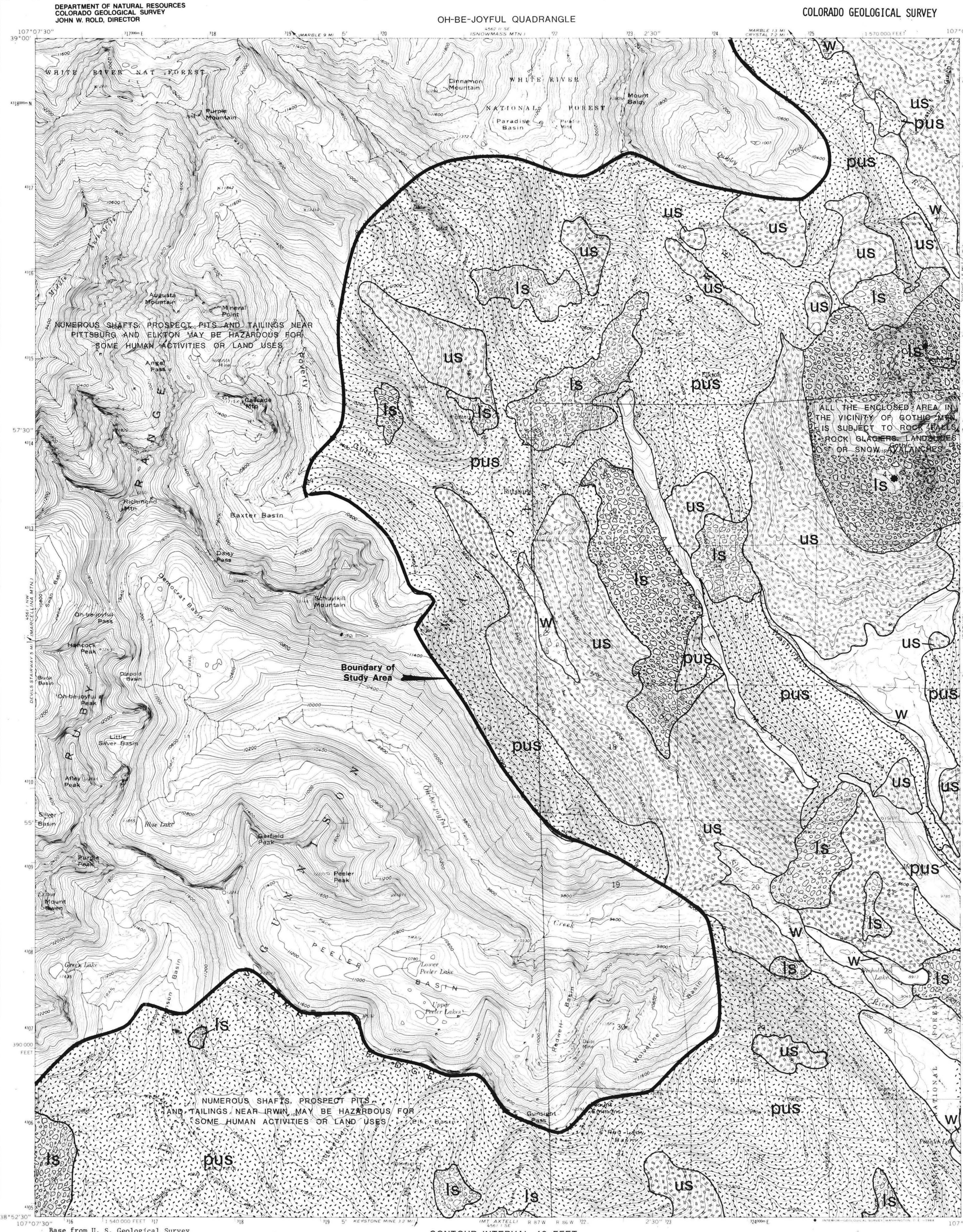

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA
GUNNISON COUNTY, COLORADO

by
James M. Soule
1976

GENERAL

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HAZARDS MAP UNIT	Residential Development: High density	Residential Development: Low density	Roads	Utilities	Open-space recreational complexes including ski areas, but not associated structures	Commercial and industrial development, including larger residential buildings such as condominiums and apt buildings	Low-value light-weight agricultural buildings	Agriculture uses grazing and similar
Landslide-earthflow area **ls**	3+ A B C D E F H — REMEDIAL ENGINEERING TYPICALLY IS PROHIBITIVELY EXPENSIVE	3 A B C D F H — MAY BE POSSIBLE WITH CAREFUL ENGINEERING.	3+ A B C D E F H — TYPICALLY NOT FEASIBLE WITHOUT CAREFUL ENGINEERING.	2 A B C E F H — COMPATIBLE WITH OPEN-SPACE LAND USE	1+ A B — COMMONLY FEASIBLE. MAINTENANCE COSTS MAY BE HIGH.	3+ A B C F H — MAINTENANCE COSTS PROBABLY WILL BE HIGH.	2+ A F H — MAINTENANCE COSTS MAY BE HIGH.	1+ A B E — USUALLY MINOR PROBLEMS EXCEPT FOR IRRIGATION DITCHES AND FENCES.
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EXPLANATION OF CHART SYMBOLS

- 3 HIGH HAZARD
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EXAMPLE: TYPICAL POTENTIAL HAZARD FOR INDICATED LAND USE; CONDITIONS AFFECTING ACTUAL DEGREE OF HAZARD; COMMENTS APPLICABLE TO MOST CASES

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- A ESPECIALLY SEVERE ON SLOPES GREATER THAN 30 PERCENT.
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REFERENCES

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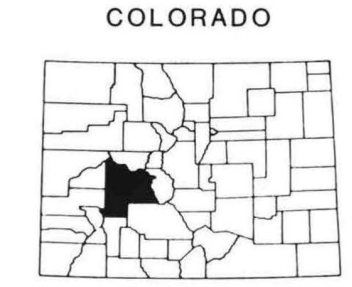
COLORADO



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1 Oh-Be-Joyful
2 Gothic
3 Mt. Axtell
4 Crested Butte
5 Cement Mtn.
6 Squirrel Creek
7 Flat Top
8 Almont
9 Gunnison

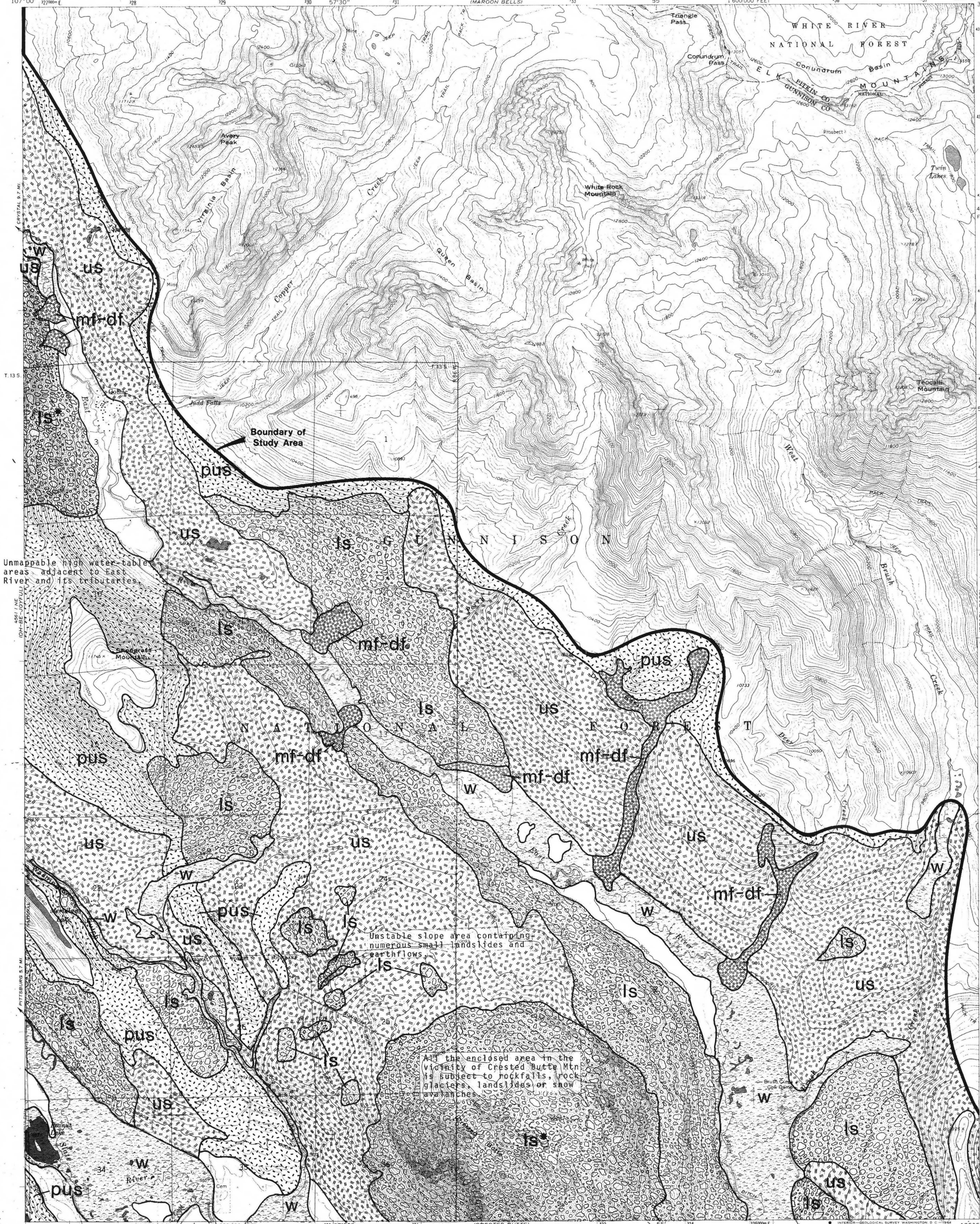
drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
1876

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

GOTHIC QUADRANGLE

COLORADO GEOLOGICAL SURVEY



CONTOUR INTERVAL 40 FEET

Base from U. S. Geological Survey 7-1/2-minute quadrangle

SCALE 1:24 000

OPEN-FILE REPORT
PLATE 2 OF 9

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA GUNNISON COUNTY, COLORADO

by

James M. Soule

1976

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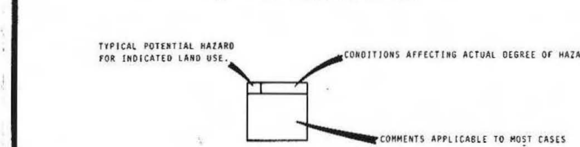

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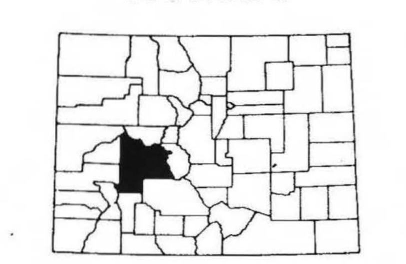

PROJECT AREA

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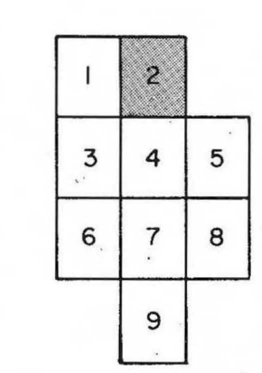

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drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL 1876

DEPARTMENT OF NATURAL RESOURCES
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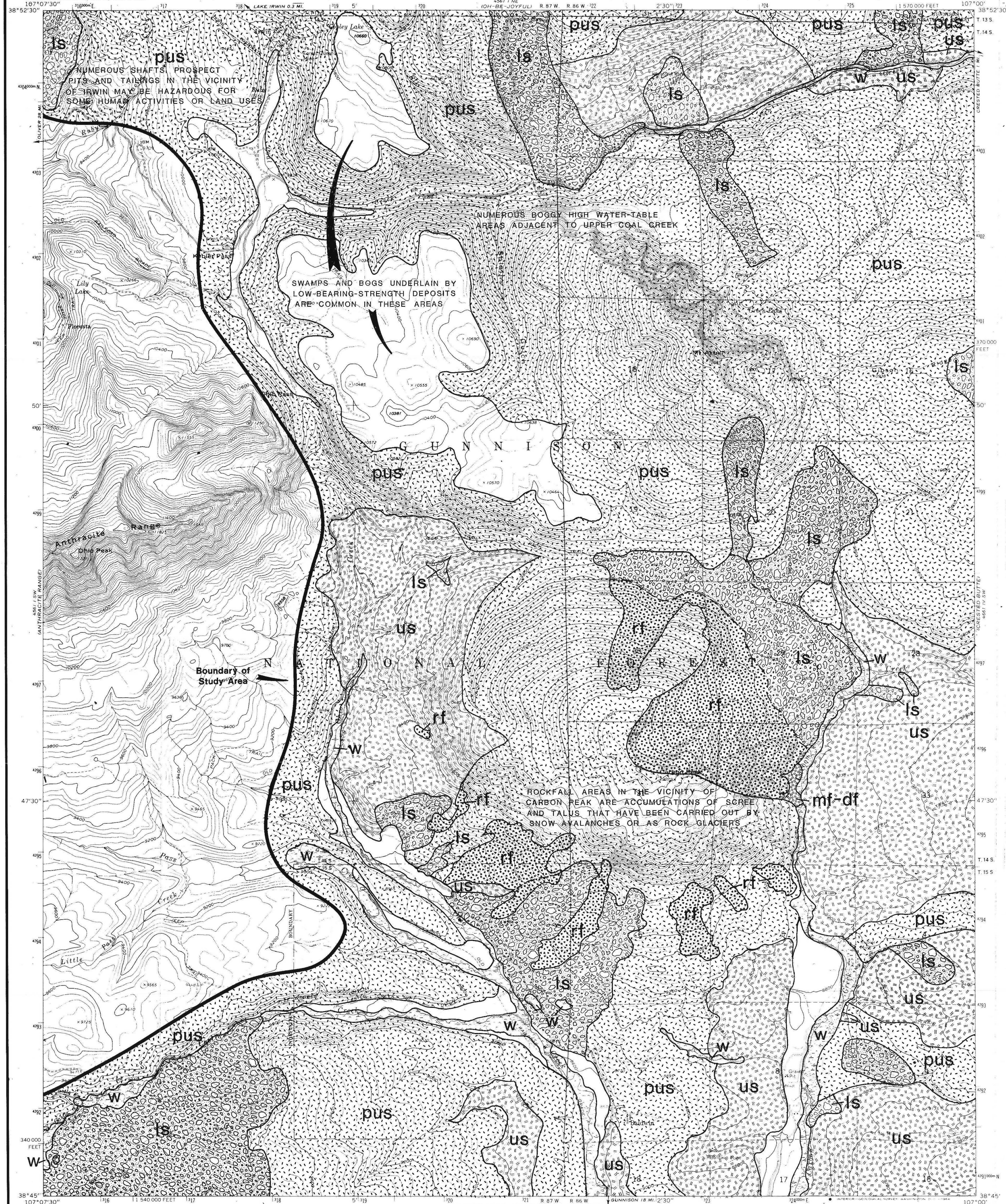
MT. AXTELL QUADRANGLE

COLORADO GEOLOGICAL SURVEY

OPEN-FILE REPORT
PLATE 3 OF 9



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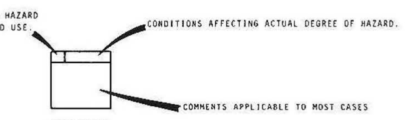
Landslide-earthflow area **ls**	3+ A B C D E F H	3 A B C D F H	3+ A B C D E F H	2 A B C E F H	1+ A B	3+ A B C F H	2+ A F H	1+ A B E
	REMEDIAL ENGINEERING TYPICALLY IS PROHIBITIVELY EXPENSIVE.	MAY BE POSSIBLE WITH CAREFUL ENGINEERING.	TYPICALLY NOT FEASIBLE WITHOUT CAREFUL ENGINEERING.	COMPATIBLE WITH OPEN-SPACE LAND USE	COMMONLY FEASIBLE. MAINTENANCE COSTS MAY BE HIGH.	MAINTENANCE COSTS PROBABLY WILL BE HIGH.	MAINTENANCE COSTS MAY BE HIGH.	USUALLY MINOR PROBLEMS EXCEPT FOR IRRIGATION DITCHES AND FENCES.
Unstable slope **us**	3 A C D E F H	2+ A C D E F H	3 A C D E F H	1+ A C F H	1 A F	3 A C D E F H	2 A F H	1 A D E
	REMEDIAL ENGINEERING USUALLY NECESSARY.	REMEDIAL ENGINEERING MAY BE NECESSARY.	REMEDIAL ENGINEERING USUALLY NECESSARY.	REMEDIAL ENGINEERING MAY BE NECESSARY.	COMMONLY FEASIBLE.	REMEDIAL ENGINEERING NECESSARY.	REMEDIAL ENGINEERING NECESSARY.	USUALLY MINOR PROBLEMS EXCEPT WHERE DITCH LEAKAGE CAUSES EARTHFLOWS.
Potentially unstable slope **pus**	3 C D E F	2 C D E F	2+ A C D E F H	1 C D E	0 F	2 A C F H	2 A C F H	0 E
	REMEDIAL ENGINEERING MAY BE NECESSARY.	REMEDIAL ENGINEERING MAY BE NECESSARY.	MAY EXPERIENCE DIFFICULTIES WITHOUT CAREFUL PLANNING/ ENGINEERING.	CAREFUL PLANNING CAN MINIMIZE HAZARD.	TYPICALLY NO DIFFICULTIES.	REMEDIAL ENGINEERING NECESSARY.	REMEDIAL ENGINEERING NECESSARY.	USUALLY MINOR PROBLEMS EXCEPT IN AREAS OF INTENSE CULTIVATION OF HILLSLOPES.
Rockfall area **rf**	3+ A B C F H	3 A B C F H	3 A B C F H	2 A B C H	1+ B	2 A B C H	2+ A B C F H	1 B
	RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	CAREFUL SITING TYPICALLY NECESSARY TO MINIMIZE HAZARD.	REMEDIAL ENGINEERING CAN MINIMIZE HAZARD.	CAREFUL PLANNING CAN MINIMIZE HAZARD.	CAREFUL SITING CAN MINIMIZE HAZARD.	MAINTENANCE COSTS PROBABLY WILL BE HIGH.	CAREFUL SITING CAN MINIMIZE HAZARD.	USUALLY FEW OR MINOR PROBLEMS.
Mudflow-debris fan area **mf-df**	3+ B C D F H	3 B C D F H	3 B D H	2 B F H	2 B	2 B C D F H	2 B D F H	0 B
	RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	COMPATIBLE ONLY WITH ELABORATE AND EXPENSIVE MITIGATION.	POSSIBLY EXCESSIVE MAINTENANCE NECESSARY.	COMMONLY FEASIBLE IF RISK IS ACCEPTABLE.	OCCASIONAL VERY HIGH MAINTENANCE COSTS CAN BE EXPECTED.	OCCASIONAL VERY HIGH MAINTENANCE COSTS CAN BE EXPECTED.	USUALLY FEW OR MINOR PROBLEMS.
High water table area **w**	3 G H	2+ G H	3 G H	0 G	1 G	2+ G H	2 G H	0 G
	BASEMENTS AND SEPTIC TANK SEWAGE DISPOSAL USUALLY NOT FEASIBLE.	BASEMENTS AND SEPTIC TANK SEWAGE DISPOSAL USUALLY NOT FEASIBLE.	USUALLY DIFFICULT - DEPENDS ON TYPE OF DEVELOPMENT. FLOOD PLAIN DETERMINATION MAY BE NECESSARY.	SOME REMEDIAL ENGINEERING MAY BE NECESSARY IN UNUSUAL CASES.	USUALLY LITTLE DIFFICULTY. POSSIBILITY OF FLOOD DAMAGE.	MAY REQUIRE SPECIAL CONSTRUCTION TECHNIQUES OR REMEDIAL ENGINEERING.	MAY REQUIRE SPECIAL CONSTRUCTION TECHNIQUES OR REMEDIAL ENGINEERING.	DESIRABLE FOR MANY KINDS OF AGRICULTURE.

EXPLANATION OF CHART SYMBOLS

3 HIGH HAZARD
2 MODERATE HAZARD
1 LOW HAZARD
0 VERY LOW, IF ANY HAZARD



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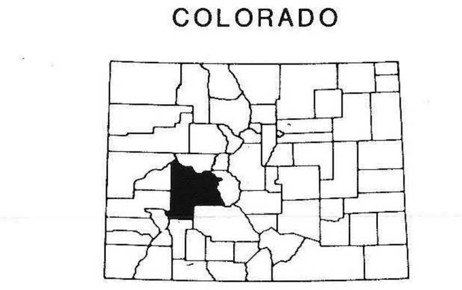
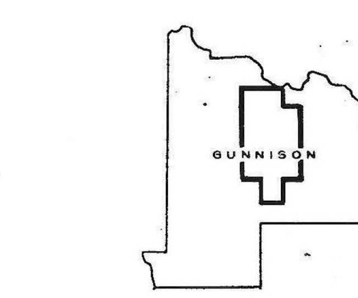
COLORADO



PROJECT AREA



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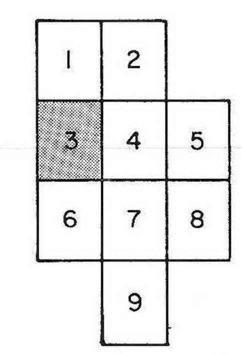


QUADRANGLE

1 Oh-Be-Joyful
2 Gothic
3 Mt. Axtell
4 Crested Butte
5 Cement Mtn.
6 Squirrel Creek
7 Flat Top
8 Almont
9 Gunnison

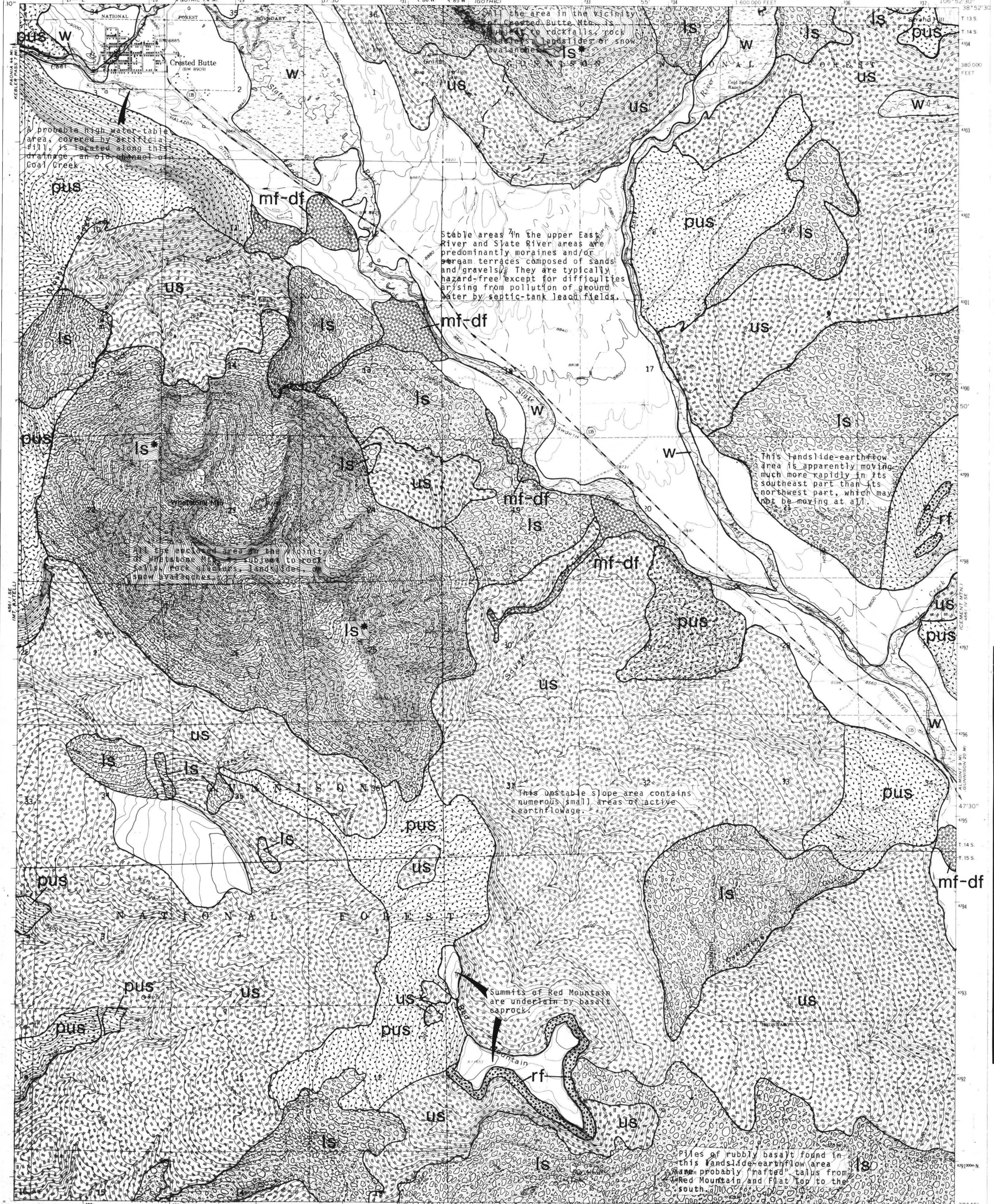
SCALE 1:24 000

drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
1876

CRESTED BUTTE QUADRANGLE

COLORADO GEOLOGICAL SURVEY



Base from U. S. Geological Survey
7-1/2-minute quadrangle

CONTOUR INTERVAL 40 FEET

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA GUNNISON COUNTY, COLORADO

by

James M. Soule

1976

GENERAL

Geologic hazards are natural geologic conditions that if unrecognized or inadequately planned for can result in loss of life, damage to structures, or high maintenance costs, especially for homes, roads, and utilities. The mapping units used on this map are a combination of genetically related features, processes, and/or conditions that could cause problems for human activities. These mapping units and their definitions conform to the terminology and definitions given in Colorado House Bill 1041 and the Colorado Geological Survey's Guidelines and Criteria for Identification and Land Use Controls in Geologic Hazard and Mineral Resource Areas (Rogers and others, 1974). In addition, hazard areas may include geologic hazards that vary greatly in degree depending on natural variation within the area and on various man-caused changes that may occur in the future. Because most of this quadrangle is presently in the natural state or is being used for low-intensity uses like agriculture and grazing, most of the mapped hazards cause no difficulties for existing human activities. No detailed quantification of geologic hazards is made in this study other than the table below which relates the degree of hazard to certain types of land use. In short, the actual degree of hazard depends as much, if not more, on human decisions affecting land use as it does on geologic factors.

SUGGESTIONS TO MAP USERS

This map should be used as an indicator of locations where a particular geologic hazard may adversely affect certain land uses. It is not intended to supplant detailed field investigations of individual sites, but rather to signal places where the indicated geologic conditions can be expected and should be specifically addressed in advance of any land-use change. If this map is used to designate geologic hazard areas as specified by H.B. 1041 (Rogers and others, 1974, p. 120-121), then it is suggested that this map serve as a basis for further investigation of individual sites. Detailed investigation and evaluation may serve as the basis for actual designs, or such studies might indicate that for economic or safety reasons the particular activity is not feasible. Land-use decisions in these areas should be based on technical reviews and planning evaluation of detailed studies and specific site plans.

EXPLANATION

ls — LANDSLIDE-EARTHFLOW AREA: area with demonstrably active natural movement of landslides and/or earthflows. Evidence for modern slope movement(s) includes distinctive physiography and disrupted vegetation or structures.

us — UNSTABLE SLOPE: slope with landslide-earthflow physiography, but where modern slope movement is not apparent or is uncertain. Such areas have undergone slope movement in the recent geologic past (late Pleistocene-Holocene). Owing to climate changes and other factors, some of these areas have become stabilized in the natural state, whereas other places included in this category are metastable or possibly even slowly failing (moving) at the present time.

pus — POTENTIALLY UNSTABLE SLOPE: slope with most attributes of an unstable slope, but where past or present slope failure is not apparent. The most significant of these attributes are composition of surficial and bedrock materials, proximity and geological similarity to slopes that have failed in the past or are failing now, slope angle and aspect, soil moisture conditions, and microclimate.

rf — ROCKFALL AREA: area subject to rapid, intermittent, nearly unpredictable rolling, sliding, bounding, or free-falling of large masses of rock, rocks and debris, or individual rock blocks. Such areas are most commonly adjacent to unvegetated, barren, steep and/or fractured and jointed bedrock cliffs.

mf-df — MUDFLOW-DEBRIS FAN AREA: area subject to rapid mud and debris movement after mobilization by heavy rainfall or snowmelt runoff. The essential elements of these areas are:

(1) a source of mud and debris, usually in the upper reaches of a drainage basin or its contiguous sideslopes; (2) a drainage-way or channel down which this mud and debris move; (3) a debris or alluvial fan formed by successive episodes of deposition of mud and debris.

w — HIGH WATER-TABLE AREA: area where ground water is at or near the ground surface much of the year. These areas, shown only in places adjacent to major drainages, are evidenced by riparian vegetation and streambank physiography. Numerous such areas too small to be shown at this map scale are found contiguous to smaller drainages or associated with ancient and modern landslides and earthflows.

* NOTE: Other hazards and discussion of individual hazard areas are indicated by notes on the map. Where applicable, snow avalanche hazard studies by Mears (1976a, 1976b) should be consulted.

GEOLOGIC HAZARDS FOR COMMON LAND USES

HAZARDS MAP UNIT	Residential Development: High density	Residential Development: Low density	Roads	Utilities	Open-space recreational complexes including ski areas, but not associated structures	Commercial and industrial development, including larger residential buildings such as condominiums and apt buildings	Low-value light-weight agricultural buildings	Agriculture uses grazing and similar
Landslide-earthflow area **ls**	3+ A B C D E F H REMEDIAL ENGINEERING TYPICALLY IS PROHIBITIVELY EXPENSIVE	3 A B C D F H MAY BE POSSIBLE WITH CAREFUL ENGINEERING.	3+ A B C D E F H TYPICALLY NOT FEASIBLE WITHOUT CAREFUL ENGINEERING.	2 A B C E F H COMPATIBLE WITH OPEN-SPACE LAND USE	1+ A B COMMONLY FEASIBLE. MAINTENANCE COSTS MAY BE HIGH.	3+ A B C F H MAINTENANCE COSTS PROBABLY WILL BE HIGH.	2+ A F H MAINTENANCE COSTS MAY BE HIGH.	1+ A B E USUALLY MINOR PROBLEMS EXCEPT FOR IRRIGATION DITCHES AND FENCES.
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Rockfall area **rf**	3+ A B C F H RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	3 A B C F H CAREFUL SITING TYPICALLY NECESSARY TO MINIMIZE HAZARD.	3 A B C F H REMEDIAL ENGINEERING CAN MINIMIZE HAZARD.	2 A B C H CAREFUL PLANNING CAN MINIMIZE HAZARD.	1+ B CAREFUL SITING CAN MINIMIZE HAZARD.	2 A B C H MAINTENANCE COSTS PROBABLY WILL BE HIGH.	2+ A B C F H CAREFUL SITING CAN MINIMIZE HAZARD.	1 B USUALLY FEW OR MINOR PROBLEMS.
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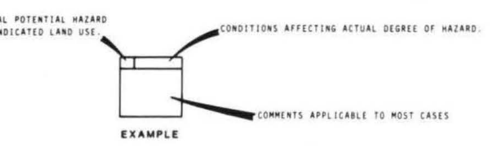

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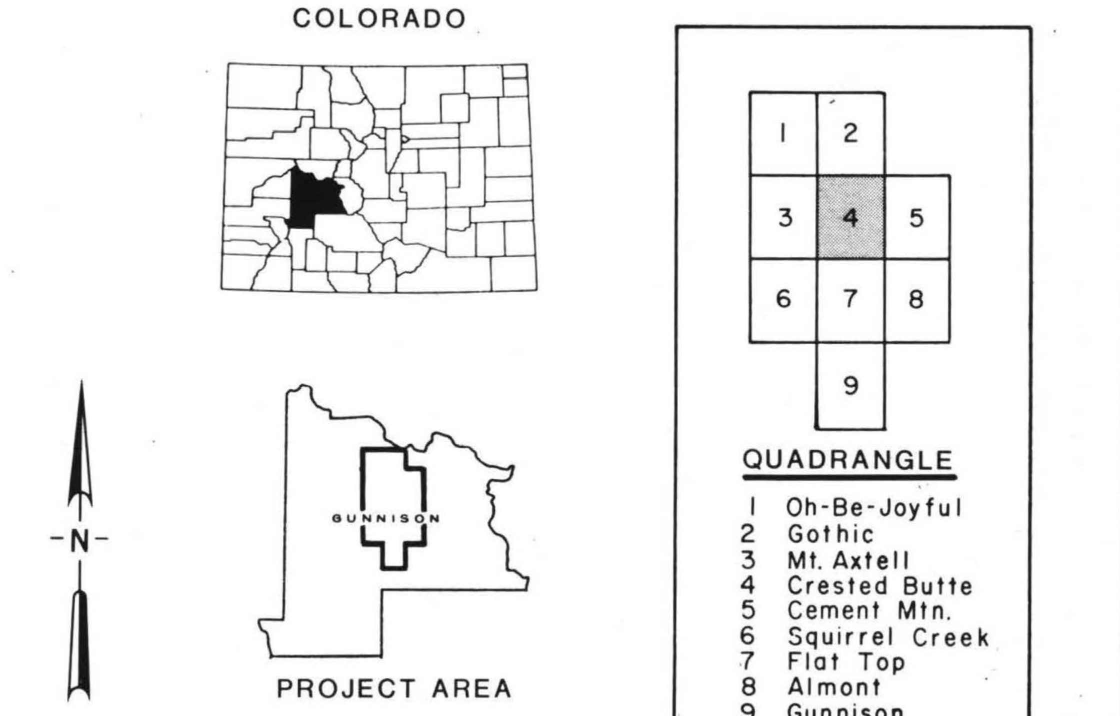
COLORADO



PROJECT AREA

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1 Oh-Be-Joyful
2 Gothic
3 Mt. Axtell
4 Crested Butte
5 Cement Mtn.
6 Squirrel Creek
7 Flat Top
8 Almont
9 Gunnison

SCALE 1:24000

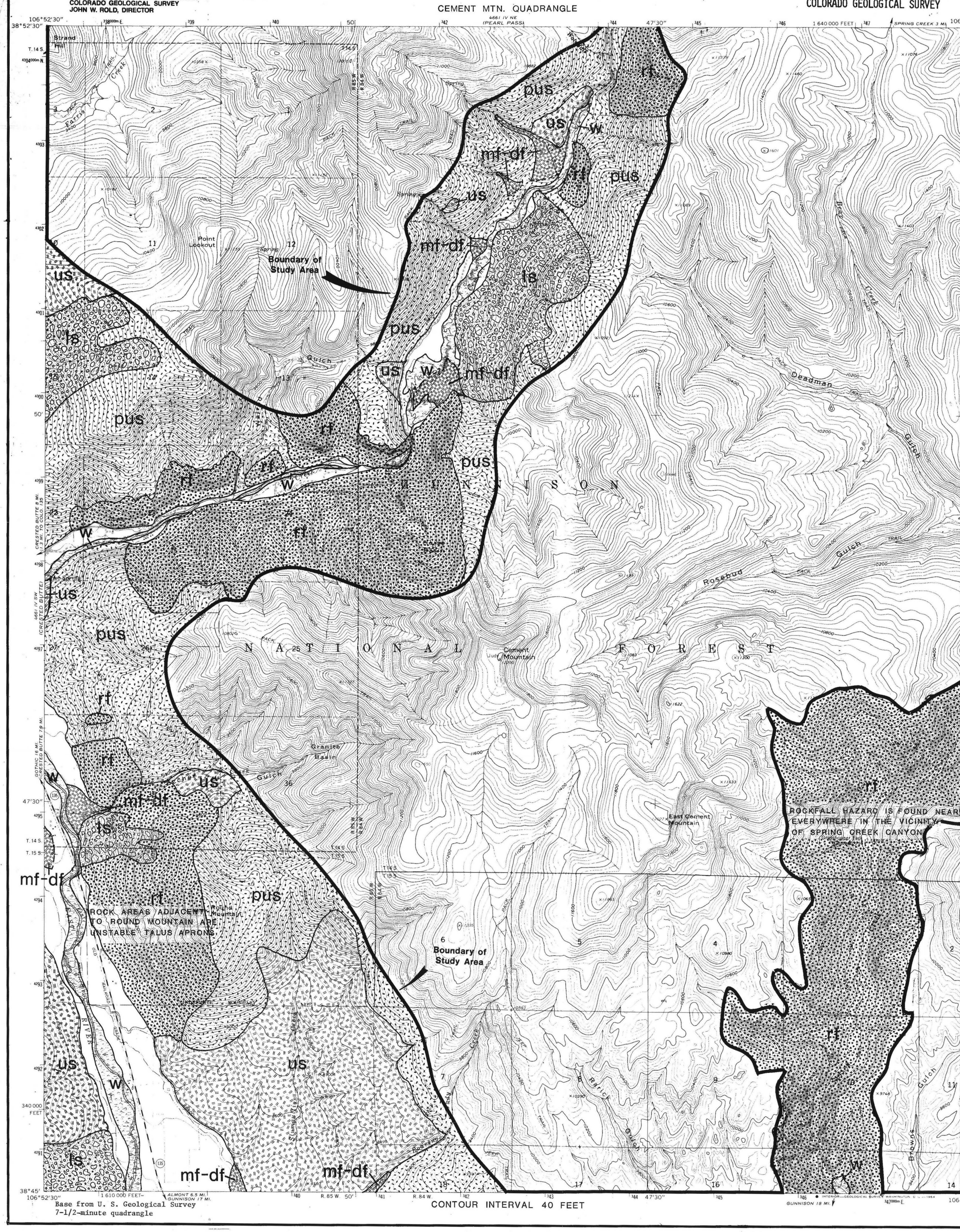
drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
1876

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

CEMENT MTN. QUADRANGLE

COLORADO GEOLOGICAL SURVEY



Base from U. S. Geological Survey
7-1/2-minute quadrangle

CONTOUR INTERVAL 40 FEET

SCALE 1:24 000

OPEN-FILE REPORT
PLATE 5 OF 9

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA
GUNNISON COUNTY, COLORADO

by

James M. Soule

1976

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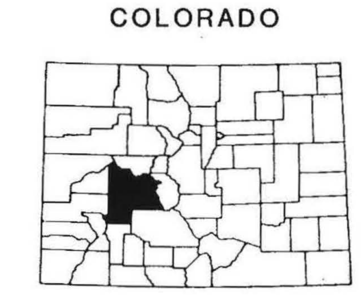
COLORADO



PROJECT AREA

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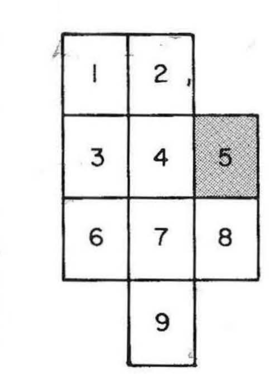

QUADRANGLE

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3 Mt. Axtell
4 Crested Butte
5 Cement Mtn.
6 Squirrel Creek
7 Flat Top
8 Almont
9 Gunnison

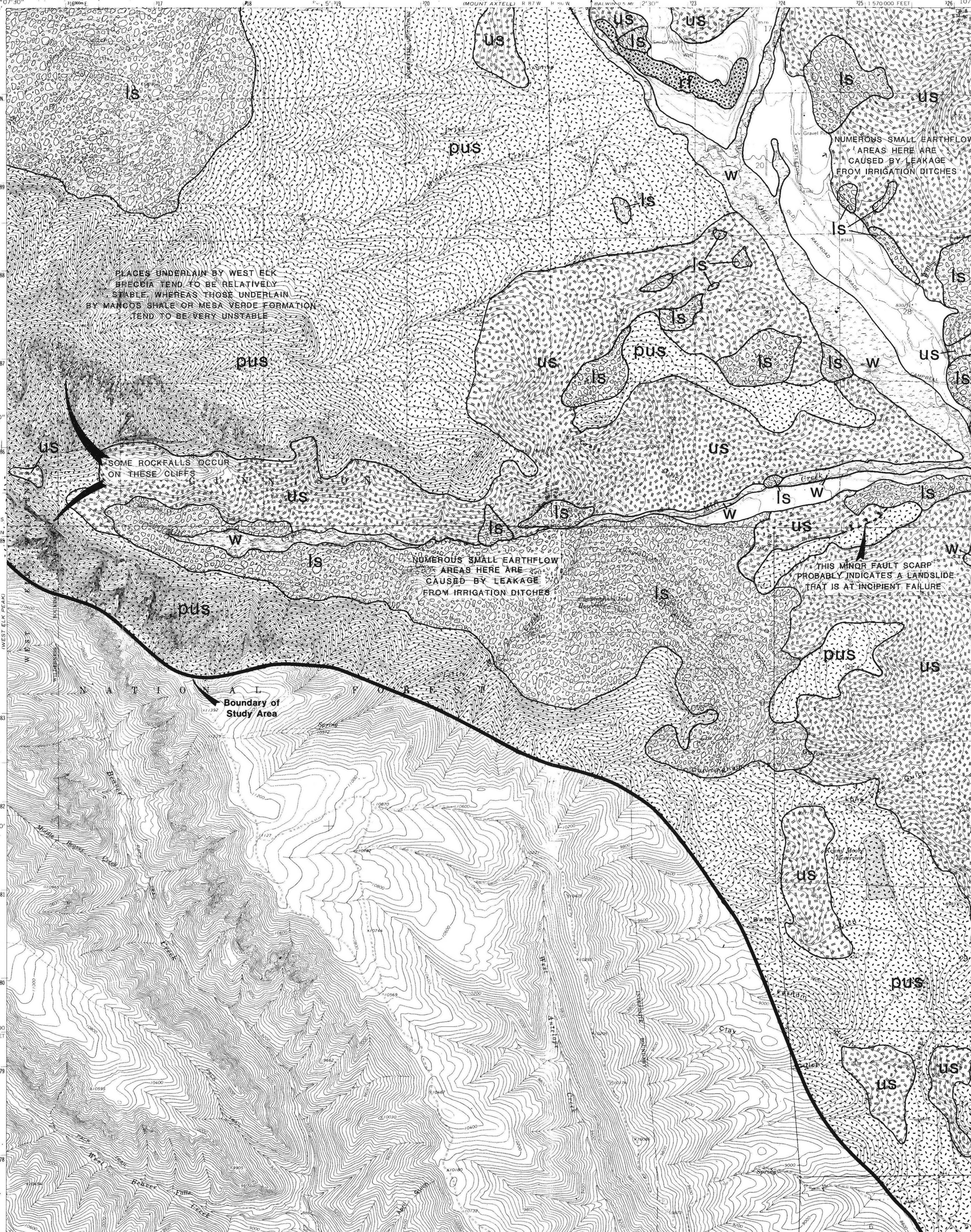
drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
1876

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

SQUIRREL CREEK QUADRANGLE

COLORADO GEOLOGICAL SURVEY



Base from U. S. Geological Survey
7-1/2-minute quadrangle

CONTOUR INTERVAL 40 FEET

OPEN-FILE REPORT
PLATE 6 OF 9

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA
GUNNISON COUNTY, COLORADO

by

James M. Soule

1976

GENERAL

Geologic hazards are natural geologic conditions that if unrecognized or inadequately planned for can result in loss of life, damage to structures, or high maintenance costs, especially for homes, roads, and utilities. The mapping units used on this map are a combination of genetically related features, processes, and/or conditions that could cause problems for human activities. These mapping units and their definitions conform to the terminology and definitions given in Colorado House Bill 1041 and the Colorado Geological Survey's Guidelines and Criteria for Identification and Land Use Controls in Geologic Hazard and Mineral Resource Areas (Rogers and others, 1974). In addition, hazard areas may include geologic hazards that vary greatly in degree depending on natural variation within the area and on various man-caused changes that may occur in the future. Because most of this quadrangle is presently in the natural state or is being used for low-intensity uses like agriculture and grazing, most of the mapped hazards cause no difficulties for existing human activities. No detailed quantification of geologic hazards is made in this study other than the table below which relates the degree of hazard to certain types of land use. In short, the actual degree of hazard depends as much, if not more, on human decisions affecting land use as it does on geologic factors.

SUGGESTIONS TO MAP USERS

This map should be used as an indicator of locations where a particular geologic hazard may adversely affect certain land uses. It is not intended to supplant detailed field investigations of individual sites, but rather to signal places where the indicated geologic conditions can be expected and should be specifically addressed in advance of any land-use change. If this map is used to designate geologic hazard areas as specified by H.B. 1041 (Rogers and others, 1974, p. 120-121), then it is suggested that this map serve as a basis for further investigation of individual sites. Detailed investigation and evaluation may serve as the basis for actual designs, or such studies might indicate that for economic or safety reasons the particular activity is not feasible. Land-use decisions in these areas should be based on technical reviews and planning evaluation of detailed studies and specific site plans.

EXPLANATION

ls — LANDSLIDE-EARTHFLOW AREA: area with demonstrably active natural movement of landslides and/or earthflows. Evidence for modern slope movement(s) includes distinctive physiography and disrupted vegetation or structures.

us — UNSTABLE SLOPE: slope with landslide-earthflow physiography, but where modern slope movement is not apparent or is uncertain. Such areas have undergone slope movement in the recent geologic past (late Pleistocene-Holocene). Owing to climate changes and other factors, some of these areas have become stabilized in the natural state, whereas other places included in this category are metastable or possibly even slowly failing (moving) at the present time.

pus — POTENTIALLY UNSTABLE SLOPE: slope with most attributes of an unstable slope, but where past or present slope failure is not apparent. The most significant of these attributes are composition of surficial and bedrock materials, proximity and geological similarity to slopes that have failed in the past or are failing now, slope angle and aspect, soil moisture conditions, and microclimate.

rf — ROCKFALL AREA: area subject to rapid, intermittent, nearly unpredictable rolling, sliding, bounding, or free-falling of large masses of rock, rocks and debris, or individual rock blocks. Such areas are most commonly adjacent to unvegetated, barren, steep and/or fractured and jointed bedrock cliffs.

mf-df — MUDFLOW-DEBRIS FAN AREA: area subject to rapid mud and debris movement after mobilization by heavy rainfall or snowmelt runoff. The essential elements of these areas are:

(1) a source of mud and debris, usually in the upper reaches of a drainage basin or its contiguous sideslopes; (2) a drainage-way or channel down which this mud and debris move; (3) a debris or alluvial fan formed by successive episodes of deposition of mud and debris.

w — HIGH WATER-TABLE AREA: area where ground water is at or near the ground surface much of the year. These areas, shown only in places adjacent to major drainages, are evidenced by riparian vegetation and streambank physiography. Numerous such areas too small to be shown at this map scale are found contiguous to smaller drainages or associated with ancient and modern landslides and earthflows.

NOTE: Other hazards and discussion of individual hazard areas are indicated by notes on the map. Where applicable, snow avalanche hazard studies by Mears (1976a, 1976b) should be consulted.

GEOLOGIC HAZARDS FOR COMMON LAND USES

HAZARDS MAP UNIT	Residential Development: High density	Residential Development: Low density	Roads	Utilities	Open-space recreational complexes including ski areas, but not associated structures	Commercial and industrial development, including larger residential buildings such as condominiums and apt buildings	Low-value light-weight agricultural buildings	Agriculture uses grazing and similar
Landslide-earthflow area **ls**	3+ A B C D E F H REMEDIAL ENGINEERING TYPICALLY IS PROHIBITIVELY EXPENSIVE.	3 A B C D F H MAY BE POSSIBLE WITH CAREFUL ENGINEERING.	3+ A B C D E F H TYPICALLY NOT FEASIBLE WITHOUT CAREFUL ENGINEERING.	2 A B C E F H COMPATIBLE WITH OPEN-SPACE LAND USE	1+ A B COMMONLY FEASIBLE. MAINTENANCE COSTS MAY BE HIGH.	3+ A B C F H MAINTENANCE COSTS PROBABLY WILL BE HIGH.	2+ A F H MAINTENANCE COSTS MAY BE HIGH.	1+ A B E USUALLY MINOR PROBLEMS EXCEPT FOR IRRIGATION DITCHES AND FENCES.
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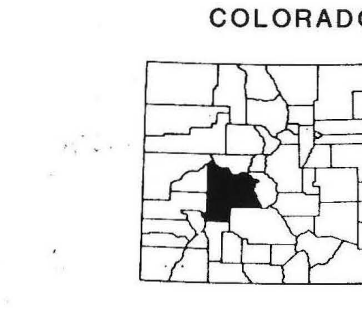

PROJECT AREA

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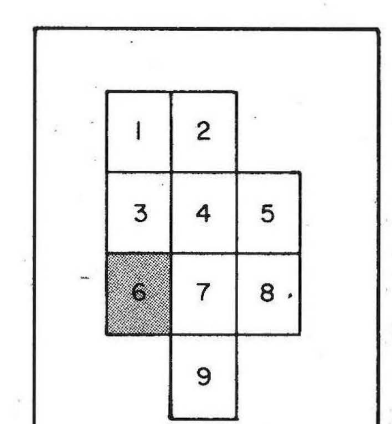

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SCALE 1:24 000

drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
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ALMONT QUADRANGLE

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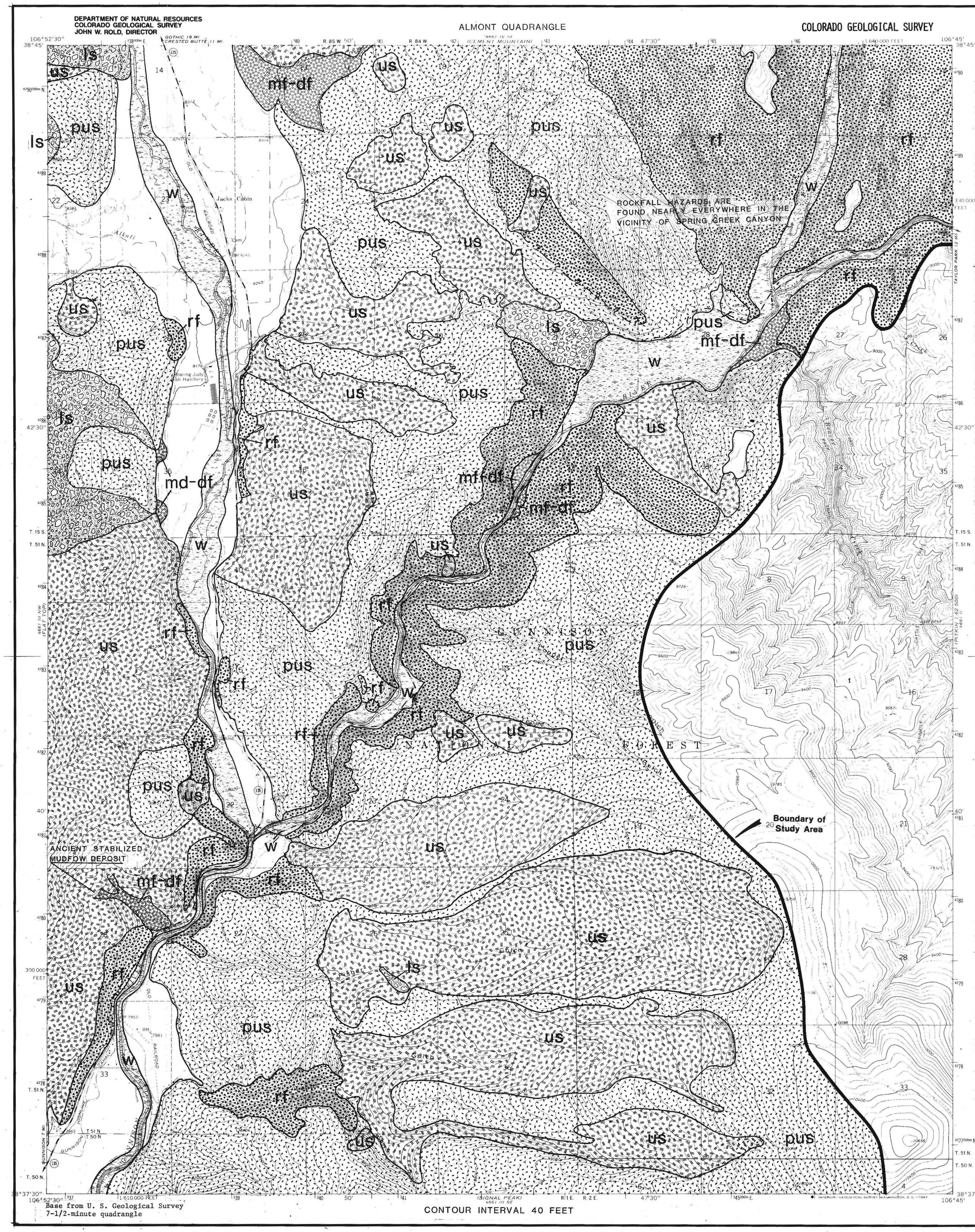

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CONTOUR INTERVAL 40 FEET

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PLATE 8 OF 9

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by

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1976

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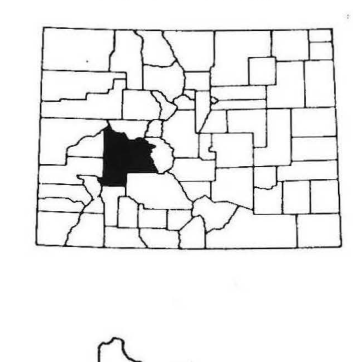

PROJECT AREA

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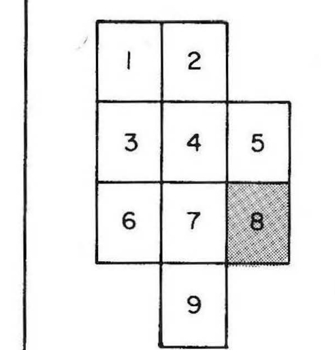

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DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
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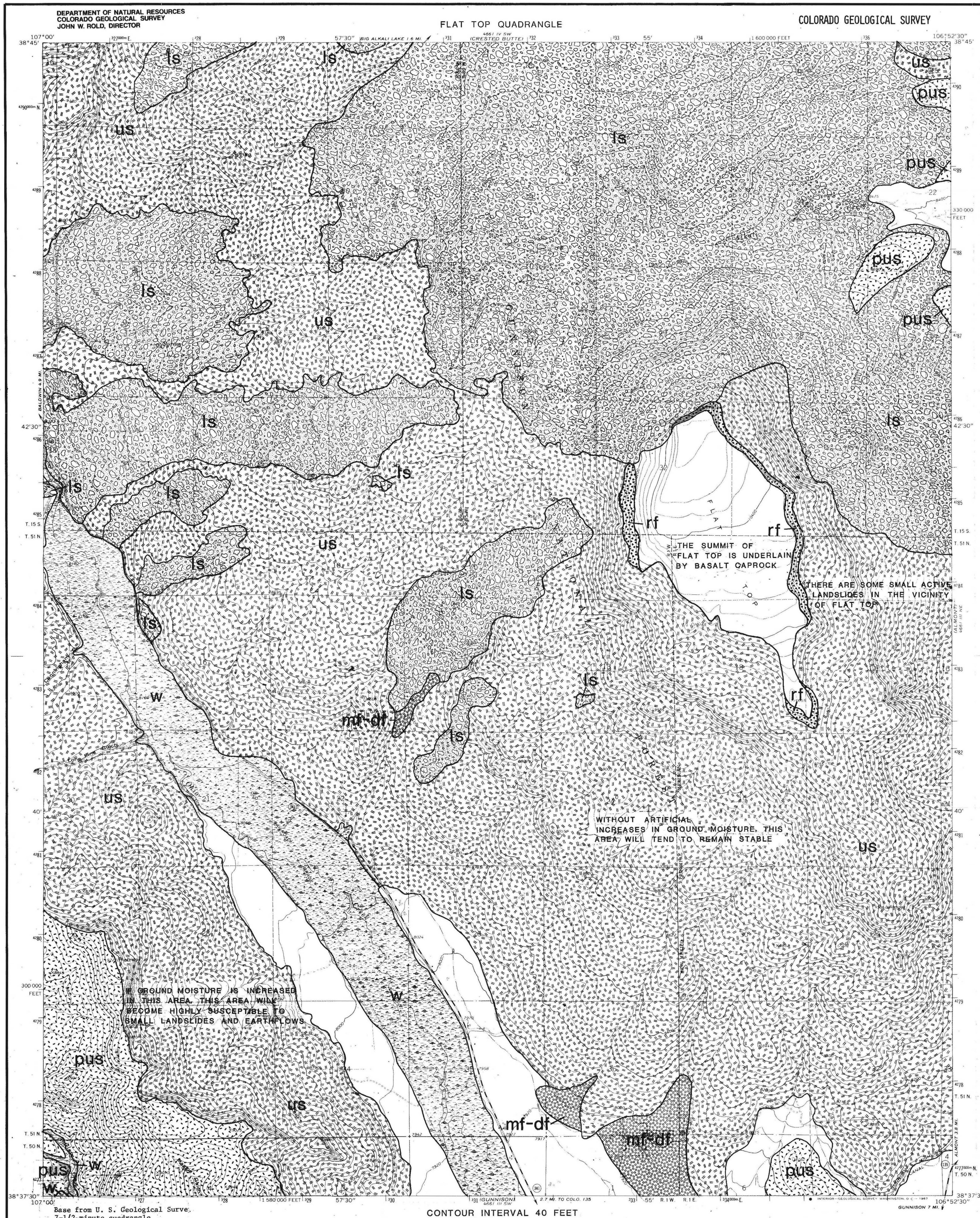
FLAT TOP QUADRANGLE

COLORADO GEOLOGICAL SURVEY



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This map should be used as an indicator of locations where a particular geologic hazard may adversely affect certain land uses. It is not intended to supplant detailed field investigations of individual sites, but rather to signal places where the indicated geologic conditions can be expected and should be specifically addressed in advance of any land-use change. If this map is used to designate geologic hazard areas as specified by H.B. 1041 (Rogers and others, 1974, p. 120-121), then it is suggested that this map serve as a basis for further investigation of individual sites. Detailed investigation and evaluation may serve as the basis for actual designs, or such studies might indicate that for economic or safety reasons the particular activity is not feasible. Land-use decisions in these areas should be based on technical reviews and planning evaluation of detailed studies and specific site plans.

EXPLANATION

ls — LANDSLIDE-EARTHFLOW AREA: area with demonstrably active natural movement of landslides and/or earthflows. Evidence for modern slope movement(s) includes distinctive physiography and disrupted vegetation or structures.

us — UNSTABLE SLOPE: slope with landslide-earthflow physiography, but where modern slope movement is not apparent or is uncertain. Such areas have undergone slope movement in the recent geologic past (late Pleistocene-Holocene). Owing to climate changes and other factors, some of these areas have become stabilized in the natural state, whereas other places included in this category are metastable or possibly even slowly failing (moving) at the present time.

pus — POTENTIALLY UNSTABLE SLOPE: slope with most attributes of an unstable slope, but where past or present slope failure is not apparent. The most significant of these attributes are composition of surficial and bedrock materials, proximity and geological similarity to slopes that have failed in the past or are failing now, slope angle and aspect, soil moisture conditions, and microclimate.

rf — ROCKFALL AREA: area subject to rapid, intermittent, nearly unpredictable rolling, sliding, bounding, or free-falling of large masses of rock, rocks and debris, or individual rock blocks. Such areas are most commonly adjacent to unvegetated, barren, steep and/or fractured and jointed bedrock cliffs.

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(1) a source of mud and debris, usually in the upper reaches of a drainage basin or its contiguous sideslopes; (2) a drainageway or channel down which this mud and debris move; (3) a debris or alluvial fan formed by successive episodes of deposition of mud and debris.

w — HIGH WATER-TABLE AREA: area where ground water is at or near the ground surface much of the year. These areas, shown only in places adjacent to major drainages, are evidenced by riparian vegetation and streambank physiography. Numerous such areas too small to be shown at this map scale are found contiguous to smaller drainages or associated with ancient and modern landslides and earthflows.

NOTE: Other hazards and discussion of individual hazard areas are indicated by notes on the map. Where applicable, snow avalanche hazard studies by Mears (1976a, 1976b) should be consulted.

GEOLOGIC HAZARDS FOR COMMON LAND USES

HAZARDS MAP UNIT	Residential Development: High density	Residential Development: Low density	Roads	Utilities	Open-space recreational complexes including ski areas, but not associated structures	Commercial and industrial development, including larger residential buildings such as condominiums and apt. buildings	Low-value light-weight agricultural buildings	Agriculture uses grazing and similar
Landslide-earthflow area	3+ A B C D E F H	3 A B C D F H	3+ A B C D E F H	2 A B C E F H	1+ A B	3+ A B C F H	2+ A F H	1+ A B E
	REMEDIAL ENGINEERING TYPICALLY IS PROHIBITIVELY EXPENSIVE.	MAY BE POSSIBLE WITH CAREFUL ENGINEERING.	TYPICALLY NOT FEASIBLE WITHOUT CAREFUL ENGINEERING.	COMPATIBLE WITH OPEN-SPACE LAND USE	COMMONLY FEASIBLE. MAINTENANCE COSTS MAY BE HIGH.	MAINTENANCE COSTS PROBABLY WILL BE HIGH.	MAINTENANCE COSTS MAY BE HIGH.	USUALLY MINOR PROBLEMS EXCEPT FOR IRRIGATION DITCHES AND FENCES.
Unstable slope	3 A C D E F H	2+ A C D E F H	3 A C D E F H	1+ A C F H	1 A F	3 A C D E F H	2 A F H	1 A D E
	REMEDIAL ENGINEERING USUALLY NECESSARY.	REMEDIAL ENGINEERING MAY BE NECESSARY.	REMEDIAL ENGINEERING USUALLY NECESSARY.	REMEDIAL ENGINEERING MAY BE NECESSARY.	COMMONLY FEASIBLE.	REMEDIAL ENGINEERING NECESSARY.	REMEDIAL ENGINEERING NECESSARY.	USUALLY MINOR PROBLEMS EXCEPT WHERE DITCH LEAKAGE CAUSES EARTHFLOWS.
Potentially unstable slope	3 C D E F	2 C D E F	2+ A C D E F H	1 C D E	0 F	2 A C F H	2 A C F H	0 E
	REMEDIAL ENGINEERING MAY BE NECESSARY.	REMEDIAL ENGINEERING MAY BE NECESSARY.	MAY EXPERIENCE DIFFICULTIES WITHOUT CAREFUL PLANNING/ ENGINEERING.	CAREFUL PLANNING CAN MINIMIZE HAZARD.	TYPICALLY NO DIFFICULTIES.	REMEDIAL ENGINEERING NECESSARY.	REMEDIAL ENGINEERING NECESSARY.	USUALLY MINOR PROBLEMS EXCEPT IN AREAS OF INTENSE CULTIVATION OF HILLSLOPES.
Rockfall area	3+ A B C F H	3 A B C F H	3 A B C F H	2 A B C H	1+ B	2 A B C H	2+ A B C F H	1 B
	RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	CAREFUL SITING TYPICALLY NECESSARY TO MINIMIZE HAZARD.	REMEDIAL ENGINEERING CAN MINIMIZE HAZARD.	CAREFUL PLANNING CAN MINIMIZE HAZARD.	CAREFUL SITING CAN MINIMIZE HAZARD.	MAINTENANCE COSTS PROBABLY WILL BE HIGH.	CAREFUL SITING CAN MINIMIZE HAZARD.	USUALLY FEW OR MINOR PROBLEMS.
Mudflow-debris fan area	3+ B C D F H	3 B C D F H	3 B D H	2 B F H	2 B	2 B C D F H	2 B D F H	0 B
	RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	RARELY COMPATIBLE WITHOUT ELABORATE AND EXPENSIVE MITIGATION.	COMPATIBLE ONLY WITH ELABORATE AND EXPENSIVE MITIGATION.	POSSIBLY EXCESSIVE MAINTENANCE NECESSARY.	COMMONLY FEASIBLE IF RISK IS ACCEPTABLE.	OCCASIONAL VERY HIGH MAINTENANCE COSTS CAN BE EXPECTED.	OCCASIONAL VERY HIGH MAINTENANCE COSTS CAN BE EXPECTED.	USUALLY FEW OR MINOR PROBLEMS.
High water table area	3 G H	2+ G H	3 G H	0 G	1 G	2+ G H	2 G H	0 G
	BASEMENTS AND SEPTIC TANK SEWAGE DISPOSAL USUALLY NOT FEASIBLE.	BASEMENTS AND SEPTIC TANK SEWAGE DISPOSAL USUALLY NOT FEASIBLE.	USUALLY DIFFICULT - DEPENDS ON TYPE OF DEVELOPMENT. FLOOD PLAIN DETERMINATION MAY BE NECESSARY.	SOME REMEDIAL ENGINEERING MAY BE NECESSARY IN UNUSUAL CASES.	USUALLY LITTLE DIFFICULTY. POSSIBILITY OF FLOOD DAMAGE.	MAY REQUIRE SPECIAL CONSTRUCTION TECHNIQUES OR REMEDIAL ENGINEERING.	MAY REQUIRE SPECIAL CONSTRUCTION TECHNIQUES OR REMEDIAL ENGINEERING.	DESIRABLE FOR MANY KINDS OF AGRICULTURE.

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REFERENCES

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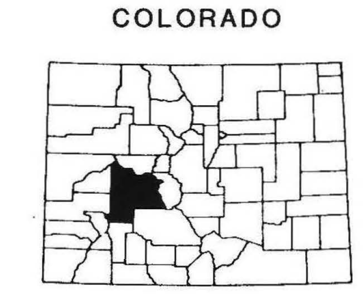
COLORADO



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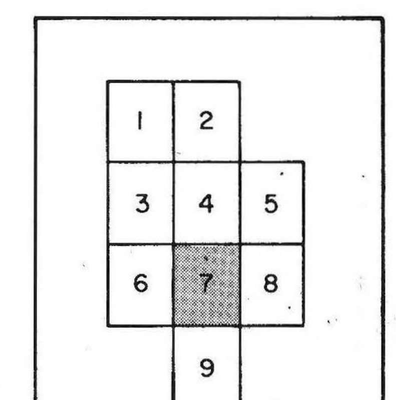


QUADRANGLE

1 Oh-Be-Joyful
2 Gothic
3 Mt. Axtell
4 Crested Butte
5 Cement Mtn.
6 Squirrel Creek
7 Flat Top
8 Almont
9 Gunnison

SCALE 1:24 000

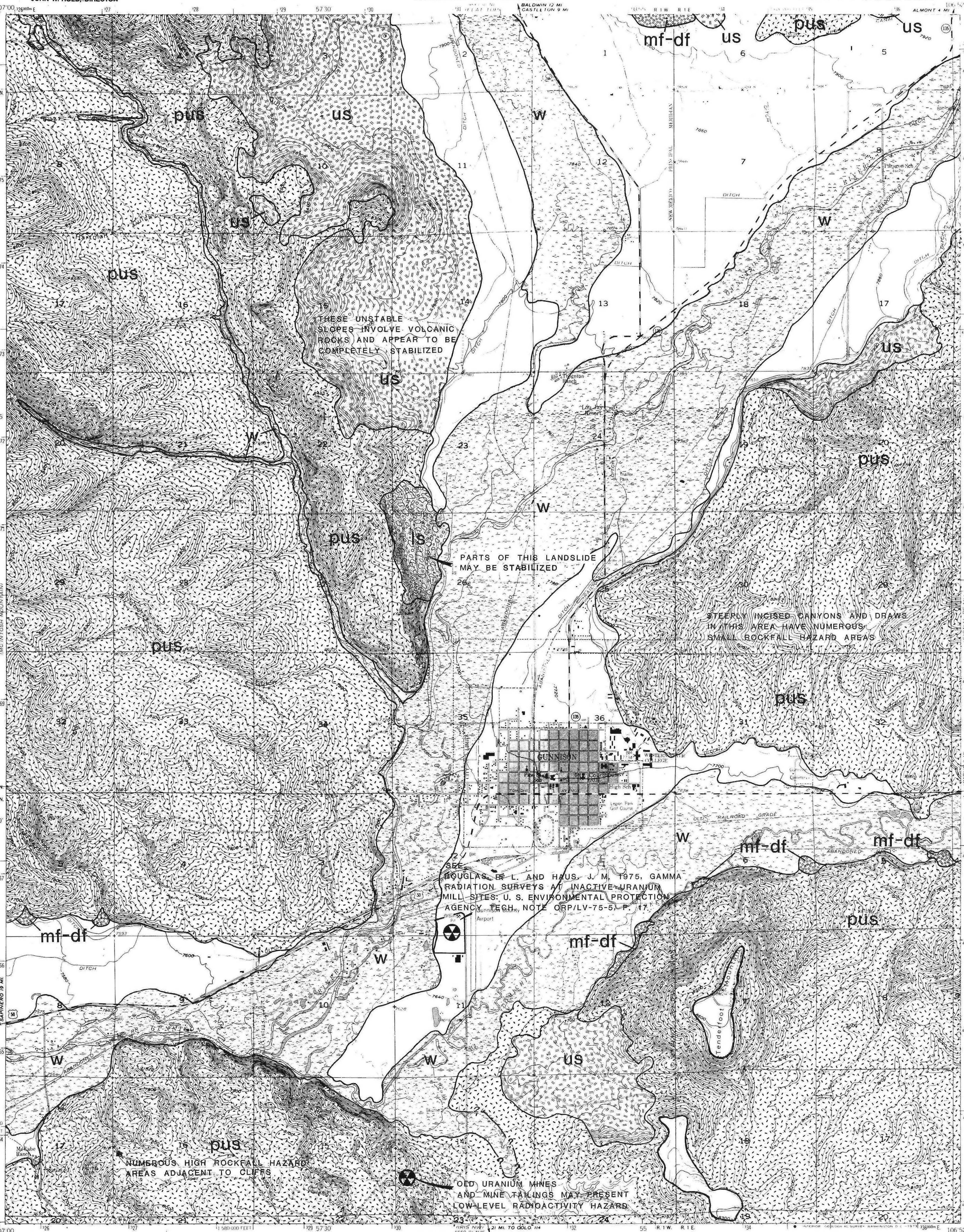
drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
1876

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

GUNNISON QUADRANGLE

COLORADO GEOLOGICAL SURVEY



Base from U. S. Geological Survey
7-1/2-minute quadrangle

CONTOUR INTERVAL 40 FEET

SCALE 1:24 000

OPEN-FILE REPORT
PLATE 9 OF 9

GEOLOGIC HAZARDS IN THE CRESTED BUTTE-GUNNISON AREA
GUNNISON COUNTY, COLORADO

by

James M. Soule

1976

GENERAL

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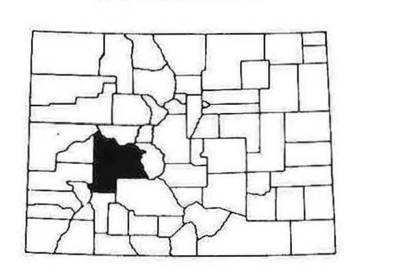

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drafting by: robert h. gast and raymond lokken

COLORADO CENTENNIAL
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