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QUATERNARY GLACIAL AND SLOPE-FAILURE DEPOSITS OF THE CRESTED BUTTE AREA, GUNNISON COUNTY, COLORADO

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INTRODUCTION

During the Quaternary Period, the region near Crested Butte, Gunnison County, Colorado was subjected to alpine glaciation. Glacial, periglacial and alpine processes have produced surficial deposits that are involved in the development of the area. The proposed molybdenum mine on Mount Emmons and expansion of the recreational industry have imposed strong development pressures. The genesis of the surficial deposits, on which much of the development will occur, has a profound impact on the engineering considerations for development.

Feasibility studies of the Mount Emmons molybdenum deposit by AMAX, Inc. are being conducted in the area around Crested Butte, Colorado. Engineering and environmental geologic mapping at scales ranging from 1:24,000 to 1:2,400 has been conducted over a three-year period beginning in June 1978 by Charles S. Robinson and Associates, now Converse Ward Davis Dixon, Inc., as part of these feasibility studies (fig. 1). The study of the surficial deposits led to a basic understanding of the late Pleistocene and Recent geologic history of the region.

Bedrock geologic studies of the area were conducted by Gaskill and others (1976, 1977) of the U.S. Geological Survey and by exploration geologists with Climax Molybdenum Company and AMAX, Inc. Geologic hazards were recognized by Soule (1976) of the Colorado Geologic Survey.

GENERAL GEOLOGY

The Crested Butte area is underlain by sedimentary rocks of Cretaceous and Tertiary age. The sedimentary rocks have been folded, faulted, and to different degrees indurated, hydrothermally altered, and metamorphosed by the intrusion of several Tertiary igneous bodies. Sedimentary rocks include the Mancos Shale and the Mesaverde Formation of Cretaceous age overlain by the Ohio Creek and Wasatch Formations of Tertiary age.

Numerous igneous bodies, including sills, dikes and laccoliths, have intruded the sedimentary rocks. The composition of the intrusives ranges from granodiorite to quartz monzonite. The intrusives are commonly porphyritic containing large euhedral phenocrysts of feldspars. The prominent geomorphic features, Crested Butte, Gothic Peak, Mount Whetstone, Carbon Peak and Mount Axtell, are formed by these intrusives. Basaltic flows of Miocene age cap Red Mountain and Flat Top Mountain.

Many faults dissect the sedimentary and igneous rocks. Faults show two predominant trends, northwest and northeast, and dip steeply to vertically. Offset, where recognizable, is usually normal with few lateral displacements recognized.

The Crested Butte area is within the Colorado Mineral Belt, and includes a wide variety of metallic elements that have been mined in the past. These include gold, silver, lead, zinc and copper. AMAX is currently conducting feasibility studies on a major molybdenum deposit under Mount Emmons. High quality coal has been mined from beds in the Mesaverde Formation throughout the area.

GLACIAL GEOLOGY

High cirque basins, deep trough-shaped valleys and deposits of till and erratics throughout the Colorado Rocky Mountains show the predominance of glaciers during Quaternary time. Large mountain ice caps covered much of the high mountains and fed valley glaciers that commonly flowed into valleys to form large piedmont lobes. Multiple glaciations are indicated by nested mo-

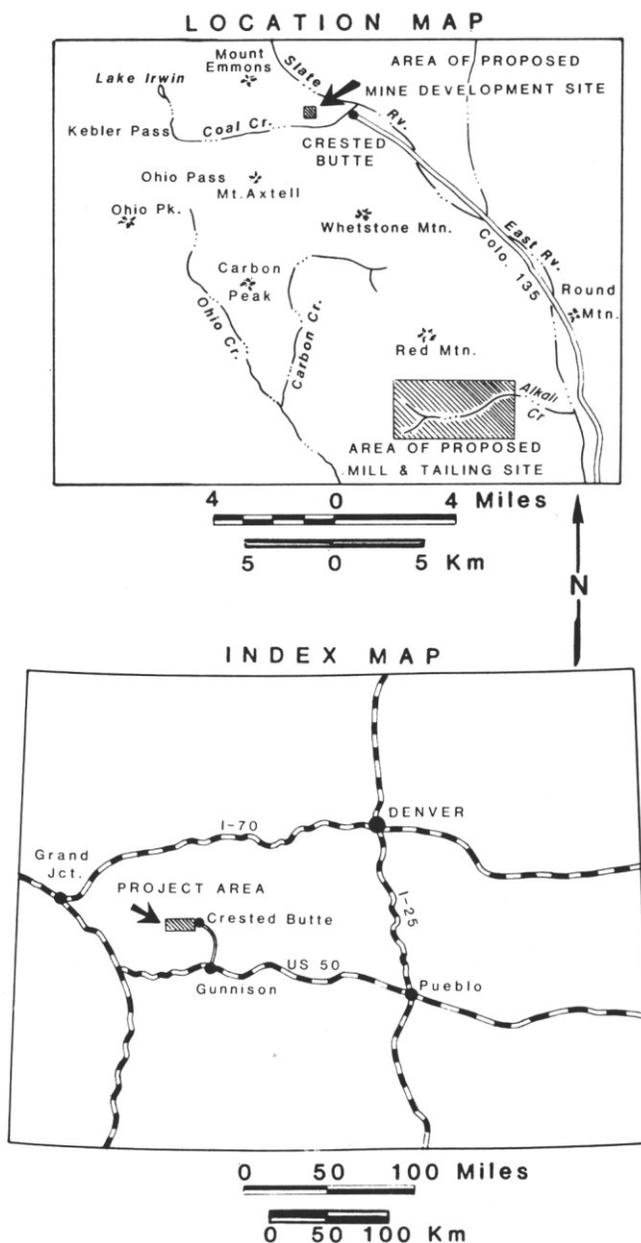


Figure 1. Index and location maps of the Crested Butte area.

conditions combined with oversteepening by stream bank erosion have caused many debris flows. Due to erosional modifications it often is difficult to differentiate between ground moraine and what were once well formed lateral moraines.

Ground moraines occur in the valley bottoms and on the floors of the cirque basins. They are recognized by low rolling, hummocky topography and lack the ridge-like form indicative of lateral moraines. Many large boulders or glacial erratics cover the surface of ground moraine. The till comprising ground moraines also contains many large boulders as seen in roadcuts along Coal Creek. The best preserved sequence of lateral moraines is near the Crested Butte municipal reservoir (fig. 2). The sharp crest and steep sides of the moraines, covered with many unweathered surface boulders, strongly support correlation to Pinedale-age deposits (Meierding and Birkeland, 1980; Richmond, 1965). Although it is likely that there are pre-Bull Lake and Bull Lake-age glacial deposits in the Crested Butte area, their age has not been documented yet. The upper extent of moraines, regardless of type, define a minimum upper ice elevation of the last glacier that occupied the valleys. The upper limit of till deposited by the main valley glacier in Coal Creek can be traced along the north side of Coal Creek on ridges separating four cirque basins. From west to east the cirque basins are Elk, Evans, Red Lady and Coon basins. Where the valley glacier began to narrow from the broad catchment area surrounding Lake Irwin (fig. 1), the ice rose to an altitude of at least 10,800 ft (3292 m). This is shown by morainal material on and slightly above the flat bench retaining Copley Lake located 1.6 km east of Lake Irwin. The ice level may have been higher here, as evidenced by a step-like series of flat benches on the ridge northeast of Copley Lake. The upper bench is at 11,275 ft (3437 m), due west of Elk Basin. Lack of significant well-preserved glacial deposits suggests that an older glacial event eroded the flat benches. Down valley to the east, between Elk and Evans basins, the highest deposit of till is at an altitude of 10,850 ft (3307 m). The ice is believed to have been higher than this, probably during an older glaciation, as suggested by erosional benches located upslope. The highest and most prominent bench is at an altitude of 11,150 ft (3399 m). A huge post- or periglacial landslide complex above the moraine and surrounding the erosional benches limits interpretation of the glacial deposits.

The minimum upper ice limit between Evans and Red Lady Basins is at 9,950 ft (3033 m). Limited deposits of till occur at this altitude as debris flows have removed most of the moraine. The upper limit of the glacial deposits in this area most commonly is defined by the presence of large glacial erratics of sandstone and latite porphyry up to 3 m in diameter. The minimum upper ice limit farther down valley is well marked by till on the slope between the creeks draining Red Lady and Coon Basins. From west to east the upper till limit extends from approximately 9,800 to 9,600 ft (2987 to 2926 m) over about 1 km. A thin veneer of till and many glacial erratics of latite porphyry clearly define the upper altitudes of glacial deposits across the entire kilometer distance.

The best preserved lateral moraines in the area are between the outlet of Coon Basin and the Slate River Valley (fig. 1). Here the glaciers flowing from the Coal Creek and the Slate River valleys met and deposited lateral moraines. The cross cutting relationship between the linear sharp crested lateral moraines in each valley shows the sequence of advances of the most recent Coal Creek and Slate River valley glaciers. A well defined lateral moraine deposited by the Coal Creek glacier extends from the southeast side of a bedrock knob at 9,525 ft (2903 m) about 120 m eastward to an altitude of 9,475 ft (2888 m) (C-1, fig. 2). This moraine trun-

cates a lateral moraine (S-1, fig. 2) deposited by the Slate River glacier that slopes southerly from an altitude of 9,650 ft (2941 m) to the Coal Creek lateral moraine. The elevation of this upper Slate River moraine above the Coal Creek lateral moraine indicates that the Slate River glacier must have initially been higher than the Coal Creek glacier, causing its ice to spill southwest into the Coal Creek Valley. The trend and slope of this moraine clearly indicates a source from the north—the Slate River valley glacier. Till and erratics cover the bedrock slopes above the moraines to an altitude

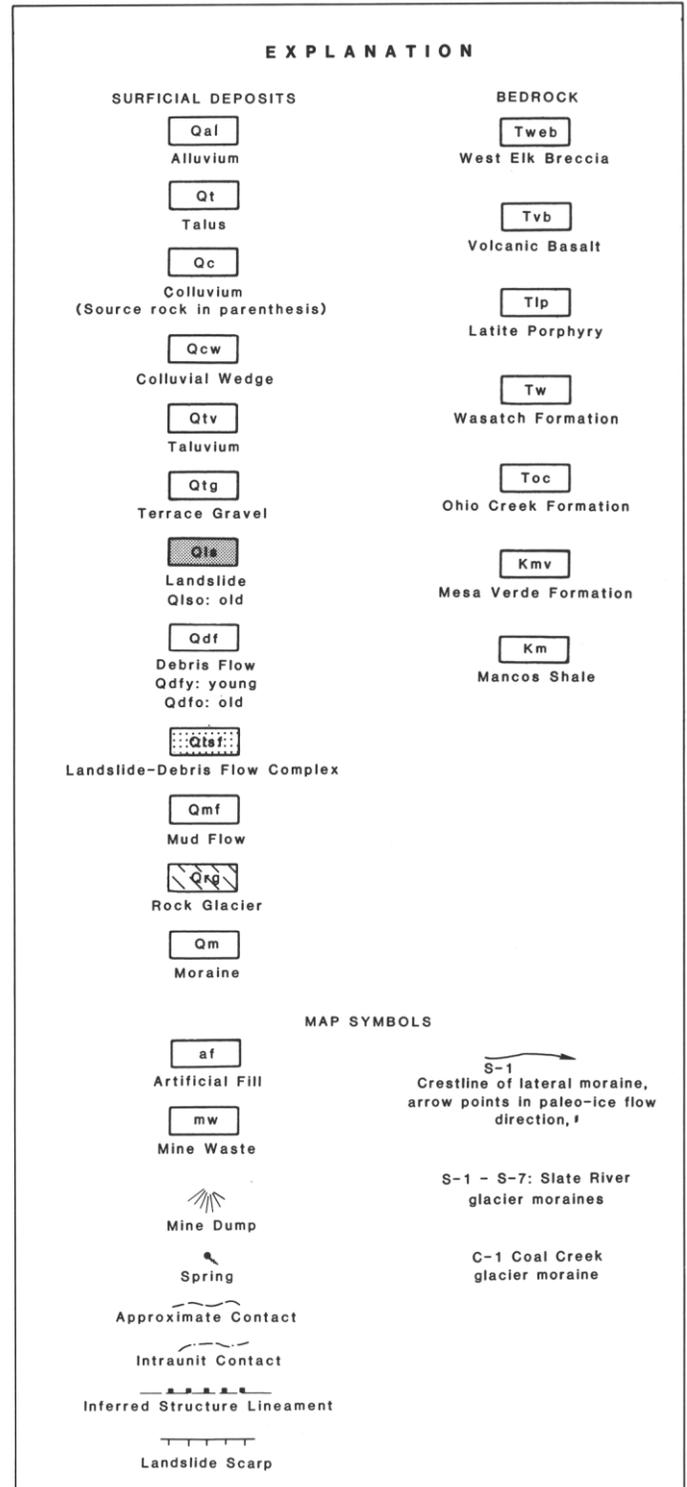


Figure 3. Explanation of geologic maps for Figures 2, 5 and 8.

of 9,825 ft (2995 m). This till also is believed to have been deposited by the Slate River glacier. Near the top of this slope, at 9,580 ft (2920 m), is a bedrock bench sprinkled with small erratics, which curves and slopes from the Slate River valley toward lower Coon Basin. This bench is also evidence of the Slate River valley glacier, and its higher altitude above the Coal Creek glacier. As the Slate River ice surface was lowered, and/or the Coal Creek glacier rose higher, the Coal Creek glacier dominated, as evidenced by the truncation of the upper Slate River lateral moraine (S-1) by the Coal Creek lateral moraine (C-1). The Coal Creek moraine was in turn truncated by the Slate River glacier during a readvance. This is indicated by another south-trending lateral moraine (S-2, fig. 2) that slopes from north to south and cuts off the Coal Creek moraine. This moraine forms the crest of the high ridge west of the Crested Butte municipal reservoir.

Extending from the south end of the reservoir are several more lateral moraines deposited by the Slate River glacier. The most prominent begins at 9,350 ft (2850 m) and passes along the east side of the reservoir trending southerly to the western limits of Crested Butte at an altitude of 8,995 ft (2742 m). This moraine is over a kilometer long and forms and dams the town reservoir (S-5, fig. 2). The location of the four smaller lateral moraines are shown in Figure 2 as S-3, S-4, S-6 and S-7. They parallel the Slate River valley and represent recessional stades of the Slate River glacier. Below the Coal Creek-Slate River valley junction the glaciers coalesced and flowed southeasterly through the present location of Crested Butte. As ice bypassed the present townsite it scoured out an arcuate face on the north side of Gibson Ridge, south of Crested Butte. The upper altitude of the steep arcuate slope is compatible with that of the erosional bench above the town reservoir. This indicates a minimum ice thickness of 180 m. Between the base of Gibson Ridge and the town of Crested Butte the ice deposited a large moraine, a kilometer long and 300 m wide. The ice eventually flowed 6.5 km south of Crested Butte to the present site of the Crested Butte airport, where it deposited a large hummocky terminal moraine. Ice also flowed from the mountains northeast of Crested Butte into the East River and Brush Creek valleys. The relationship between these glaciers and the Slate River glacier has not yet been documented.

The relative ages of the Coal Creek and Slate River glaciers can be determined from the relationships of the moraines at the Coal Creek-Slate River Valley junction. This sequence of moraines indicates that although the two adjacent glaciers were present simultaneously, their individual advances were not always in phase. The originally higher elevation of the Slate River glacier may have been due to its source areas being higher and much larger, with less southern exposure than the source area of the Coal Creek glaciers. Truncation of the Coal Creek lateral moraine by the Slate River moraine may be due to the more rapid deterioration of Coal Creek ice related to two reasons: 1) quick response time of a small ice mass to climatic changes; and 2) more southern exposure of the source areas. These differences must have been significant factors in ice accumulation. The Slate River Valley is much broader than the Coal Creek Valley, and would require more ice to fill it. Ice in the Coal Creek Valley also was able only to reach a limited elevation as ice near the upper valley spilled over ice passes to the south and west—Ohio and Kebler Passes which regulated the ice elevation in the valley. This is evidenced by deposits of till in the Kebler Pass area ranging from altitudes of 9,980 to 10,175 ft (3042 to 3101 m), and in the broad area between Ohio Pass and Splains Gulch to the east ranging from altitudes of 10,074 to 10,690 ft (3071 to 3258 m) (fig. 1). The Lake Irwin area is the only possible significant source area for ice that deposited the till with only a

minor contribution from Ohio Peak on the east end of the Anthracite Range (fig. 1).

The age of the glacial deposits in the Crested Butte area is not known, yet their similarity to other deposits in the Rocky Mountains suggests a late Pinedale age. Benedict (1973), Andrews and others (1975), and Carrara and Andrews (1973) have dated late Pinedale glaciation as ending at approximately 10,000 years B.P. (before present). This is compatible with a radiocarbon age date of $7,100 \pm 255$ years B.P. from iron bog sediments cored from west of the Keystone Mine on Mount Emmons (Fall, 1981, personal communication). This does not represent the oldest date of the bog since full penetration of the bog was not made.

One to three stades of glaciation are recognized in the Crested Butte area. Only one glacial stade is recognized in the Coal Creek Valley by the one lateral moraine. At least two, possibly three, stades of glacial advance are recorded by the Slate River glacial deposits. The upper lateral moraine (S-1) marks the first stade and the second highest lateral moraine (S-2) marks the second stade. The second stade moraine indicates a readvance of ice. It is differentiated from a recessional moraine, as it truncates the Coal Creek moraine. It is possible that the kilometer-long moraine (S-5) that dams the Crested Butte municipal reservoir marks a third stade as it appears to truncate the southeast end of a smaller recessional moraine (S-4). Three stades of Pinedale glaciation have commonly been recognized in Colorado in and near Rocky Mountain National Park (Richmond, 1960; Madole, 1969; Meierding, 1977). No definitive correlation of glacial stades between the Crested Butte area and other glaciated regions of Colorado has been confirmed to date.

Rock Glaciers

Rock glaciers are conspicuous features in the Crested Butte area. They flow or have flowed from cirque basins on mountains such as Mount Whetstone, Mount Axtell, and Mount Emmons. The rock glaciers occur at the base of cirque headwalls or steep valley sides and tongue down valley in a lobate form. The hummocky surfaces are covered with large angular blocks of rock. Studies by White (1971), Wahrhaftig and Cox (1959), Potter (1967) and many others, indicate that only the upper one-fourth to one-fifth thickness of the rock glacier is coarse blocky rubble. The inner parts are generally finer grained and resemble till. The coarse size provides large voids that allows rapid drainage of rain and melt water. The rock glaciers on Mount Emmons in Evans, Red Lady and Wolverine basins show only minor intra-flow features and appear relatively inactive, while those on the flanks of Mount Axtell and Whetstone Mountain show curvilinear transverse ridges and furrows indicative of dynamic movement (fig. 4). No flow-rate data have been collected on these rock glaciers. Annual flow rates on active rock glaciers in the Front Range, which appear similar to those on Mount Axtell and Whetstone Mountain, range from 5 to 9.7 cm in the Arapahoe Mountain area (White, 1971) and up to 60 cm at upper west Maroon Creek, less than 9 km north of Crested Butte (Bryant, 1971). Rock glaciers in the Crested Butte area have not been dated. However the rock glacier in Evans Basin (fig. 5) postdates the last major glacial occupation of the basin and the massive slope failure complex.

Many rock glaciers, some of which show activity, closely correlate to Late Pleistocene (Pinedale) and early Holocene glacial advances in Colorado (Benedict, 1973; Carrara and Andrews, 1973; Birkeland, 1973). It is tempting to conclude that rock glaciers and glacial advances are synchronous, but rock glaciers have a lower



Figure 4. Rock glacier on east side of Mount Axtell.

response time to climatic change. Fewer rock glaciers have originated in the last few thousand years in Neoglacial time than in Pleistocene time. A few Neoglacial rock glaciers, however, have been recognized in Colorado (Meierding and Birkeland, 1980).

SLOPE-FAILURE DEPOSITS

Slope-failure deposits in the Crested Butte area are the result of mass wasting of surficial deposits and bedrock during glacial and periglacial climatic conditions. Three different relationships of the glacial-periglacial processes to slope failures processes have been recognized: 1) failures comprised of material such as till deposited by glaciers; 2) failures comprised of colluvium weathered during freeze-thaw cycle during glacial and periglacial times; and 3) slope failures related to the retreat and removal of glacial ice that left steep slopes of surficial materials or rock unsupported. Slope failure deposits have resulted from debris flows and landslides. Debris flow deposits commonly consist of till derived from slope failure of moraines. Many of these occurred when retreating glaciers left saturated till unsupported on steep slopes. Cool and moist periglacial and Holocene climates also saturated the moraines causing slope failures. Slope failure deposits of till occur commonly along Coal Creek.

In certain areas weathering and freeze-thaw cycles, related to periglacial and alpine climates, weathered bedrock to form deposits of colluvium. Subsequent moist conditions and possible stream undercutting resulted in mobilization of large deposits of colluvium. They generally flowed as fluid to viscous debris and mudflows, commonly incorporating large blocks of bedrock. Most colluvium-related flows were derived primarily from the easily weathered Mancos Shale as in Alkali Creek area. Slope failures of colluvium, derived from the Mesaverde and Ohio Creek formations, occurred on the ridges between Elk, Evans and Red Lady basins.

Where bedrock was weathered by glacial processes and oversteepened by glacial erosion, or where talus deposits or lateral moraines formed margins to the ice, final retreat of the glaciers left

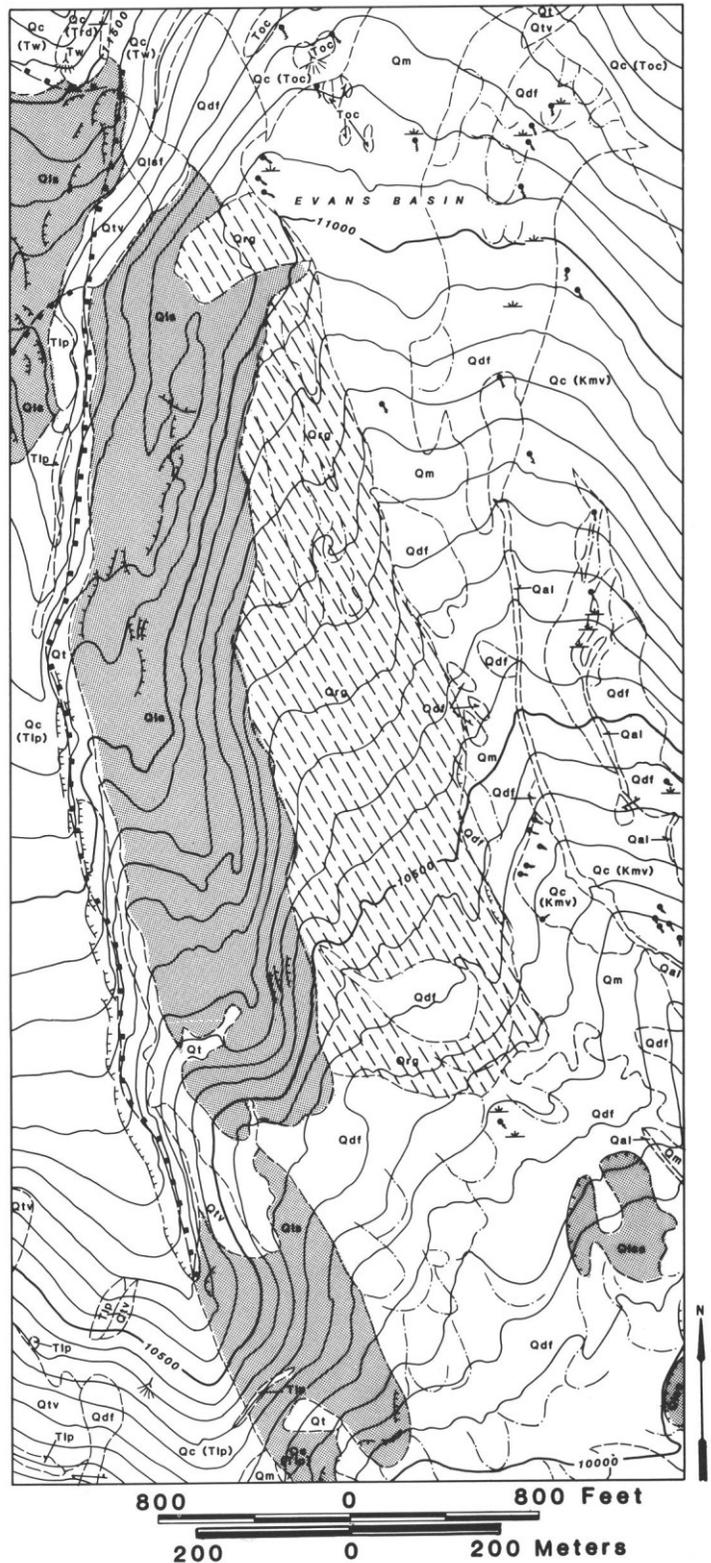


Figure 5. Surficial geologic map of Evans Basin landslide (see Figure 3 for explanation).

the bedrock or surficial deposits relatively unsupported, and failure occurred. Exposure of oversteepened bedrock slopes caused large landslides in Evans basins.

Two areas of massive slope failure in the Crested Butte area, Evans Basin and Alkali Creek, are discussed below. Although they are two of the more massive slope-failure deposits in the area, their nature and origin typify landslide-flow complexes in the Crested Butte area. The engineering implications of such deposits are briefly described.

Evans Basin Landslide-Flow Complex

The Evans Basin area was mapped at a scale of 1:2,400 to provide engineering geology for the proposed mine site (fig. 5). The slope-failure complex encompasses an area of approximately 700 m by 1,890 m ranging from 10,000 ft to 11,500 ft (3048 to 3505 m) in altitude. Evidence from drill holes indicates that at an altitude of approximately 10,250 ft (3125 m) the complex is over 61 m thick near its center. The slope failures include landslide deposits and debris flow deposits. A rock glacier has modified part of the landslide deposits. Figure 6 shows the headscarp area of the major landslide mass. The slope-failure complex is a result of the mass erosion of siltstone and sandstone that was intruded by a latite porphyry sill. The sedimentary rocks were removed by glacial ice that eroded the area and, as a result, there was a loss of lateral support of the sill. In addition, a strong joint set in the latite porphyry parallels the axis of the basin and the head scarp. From bedrock geologic mapping there is no evidence of offset related to the joints except as the results of the slope failure.

The slope-failure complex represents several movement events. The major failure occurred during the last stage of ice occupation. Steep sided margins of the complex indicate that there was still some ice in the basin during failure. This failure included the movement of blocks of latite porphyry, up to a few hundred meters on a side, eastward and downslope from the sill (figs. 6, 7).

During a period shortly after the last of the glacial ice left the basin, periglacial processes were still quite active and a rock glacier developed on the failed mass of latite porphyry. The front of the lobe-shaped rock glacier is a steep concentric ridge that is 3.6 to 7.6 m high. The eastern side is a steep continuous slope with blocks of latite porphyry up to 3 m in diameter nearly at the angle of repose. The surface of the deposit is marked by transverse and longitudinal ridges and furrows. Lengthwise, near the center of the rock glacier, is an irregular and meandering furrow with pits or depressions that indicates the rubble mass has deflated due to the melting of an ice core. Along the eastern side, and extending to

about midway around the front, the rock glacier is in sharp contact with the underlying moraine, which indicates the rock glacier over-ran the material deposited by the ice.

The last event was the development of debris flow deposits that were the result of a more fluid failure of unconsolidated material. Large debris flows occurred at the toe of the rock glacier. These debris-flow deposits are primarily till that was saturated by the meltwaters from the snow and ice pack upslope. The debris flows range in volume from a few tens of cubic meters to many thousands of cubic meters. They flowed downslope a short distance and were deposited where the slope flattened. Within any large debris flow deposit many individual flow units are recognized. These indicate that the large flows were a composite of many smaller failures. There are only minor failures, mostly as debris flows, presently occurring. The failures occur along the small creek that drains Evans Basin. The failures occur during periods of heavy spring runoff and during torrential summer thundershowers, and involve only a few cubic meters of material.

The large slope-failure complex was of concern in the siting of the Mount Emmons Project mine buildings and the disposal of mine development rock. Through detailed surficial geologic mapping it was determined that the large slope failures occurred during the last stages of glacial activity and soon after melting of the glacial ice. Only small debris flow failures occur under present climatic conditions and the occurrence of a large failure is considered unlikely. Engineering recommendations for the proposed mine site located in lower Evans Basin included minimizing cuts in the toes of old, stabilized slope-failures and minimizing fills at the heads of the slope-failure deposits. The complex nature of the slope failures and the material involved leads to an extreme heterogeneity of materials at the construction site. This makes the testing and evaluation of ground-water flow conditions difficult. Of primary importance to the planning for construction in the area is the consideration of ground and surface water.

Alkali Creek Landslide-Flow Complex

The Alkali Creek area was mapped at a scale of 1:2,400 to provide engineering geologic information for the proposed tailing disposal site. The area of slope-failure complexes is in a large basin at the headwaters of Alkali Creek immediately south of Red Mountain, 19 km south of Crested Butte (fig. 1). The types of slope-failure complexes that have occurred in the Alkali Creek area reflect the difference in materials and geomorphic processes between the Alkali Creek and the Evans Basin areas (fig. 7). The bedrock in much of the Alkali Creek area is the Mancos Shale. The weathering of the Mancos Shale results in predominantly fine-grained colluvium consisting of clay, silt and fine sand. As a result



Figure 6. Evans Basin landslide.



Figure 7. Headscarp and landslide blocks of Evans Basin landslide.



Figure 9. Headscarps and landslide–flow complex of Alkali Creek area looking north toward Red Mountain.

present morphology of the mudflows (Fig. 9) indicates that these masses had a greater degree of saturation and greater velocity at the time of failure than the debris flows. The large mudflows are believed to have occurred at a time of significantly higher precipitation than today. Small mudflow events have occurred in recent years, but these are restricted to small (less than 77 m³) flows that have resulted from oversteepened scarp slopes and along creek banks.

Debris flows are the most extensive of the slope-failure complexes in the Alkali Creek area. The debris flows consist of deposits of boulders and gravels from the basalt caps of Red Mountain and Flat Top Mountain intermixed with fine-grained colluvium derived from the Mancos Shale. These materials, when saturated with water, probably flowed downslope as a viscous fluid at a moderate rate (1.5 m/day). The debris flows may contain blocks of Mancos Shale up to 1 m in diameter near the heads of the flows. An exploration drill hole in the center of a large debris flow below Big Alkali Lake, north of Alkali Creek, at approximately 9,200 ft (2800 m) altitude revealed the deposit is over 61 m thick. Carbonized wood taken from the core of the hole at a depth of approximately 49 m was dated at about 8,000 years B.P.

The location of the proposed tailings dam is approximately in the center of the basin between two bedrock ridges. The stability of the slope failures was of concern when location of the tailings dam was proposed. Because of the size and complexity of the slope failures, traditional slope-failure analysis was inadequate and not applicable for planning purposes. Fortunately, lake sediments were discovered covering the toes of the large slope-failure that would be impacted by the tailings impoundment. The lake sediments consist of clay, silt and sand with interbedded organic materials and gravels near the margins of the former lake. On-going palynological studies of the lake sediments have given relatively reliable information as to the stability of the slope failures (Fall, 1981, personal communication). The study of pollen and carbonized wood preserved by the lake sediments has shown that a lake existed from at least 15,000 years B.P. to 3,000 years B.P. (Markgraf and Scott, 1981). The lake was probably formed when the drainage was blocked by at least one slope failure east of the proposed tailings dam alignment. The record shows that for the 12,000 years studied there was a constant rate of accumulation of sediment in the lake of approximately 30 cm/1,000 years. The constant sedimentation rate indicates that there have not been any slope failures into the lake for the past 15,000 years.

Periglacial and alpine geomorphic processes are postulated for the occurrence of such extensive slope failures. The paleoclimatic reconstruction based on the vegetation changes, as interpreted from the pollen sequence preserved in the lake sediments (Markgraf and Scott, 1981), is as follows: from at least 15,000 to 10,000 years B.P. a cool-moist climate with a spruce forest growing at an elevation of 9,000 ft (2750 m). From 10,000 to 4,000 years B.P. a slightly warmer drier climate dominated with a growing pine forest, somewhat less spruce and increased fir plus some additional steppe plants. Since approximately 4,000 years B.P. the climate has been essentially the same as it is today, again slightly warmer and dryer than the time of the slope failures with sagebrush steppe vegetation dominating the area at approximately 9,000 ft (2750 m). The stability of the slopes in the Alkali Creek area has been enhanced by the existence of the lake in the basin. If water was impounded over the toes of the slope failures in the past the saturated conditions would have created failures that reached equilibrium under those conditions. Furthermore the deposition of up to 18 m of fine-grained material on the toes of these failures would buttress them. The probability of large catastrophic failures appears to be very small. Partial filling of the basin with tailings from the milling process will further stabilize the slopes. Construction of roads, buildings and the water diversion structures above the tailings impoundment will require particular attention to the ground water and surface water.

SUMMARY

Detailed geologic mapping has shown the presence of deposits of till in the Crested Butte area that are of probable Pinedale age. Three stages which are comparable to glaciated mountains elsewhere in the Rocky Mountains appear likely. Deposition of saturated till on steep slopes resulted in many slope-failure complexes. Many of these probably occurred as ice retreated from the cirque valleys and basins. Other slope failure deposits consist of thick deposits of colluvium that formed from periglacial and alpine processes. Bedrock has also failed as massive landslides and was related to ice retreat.

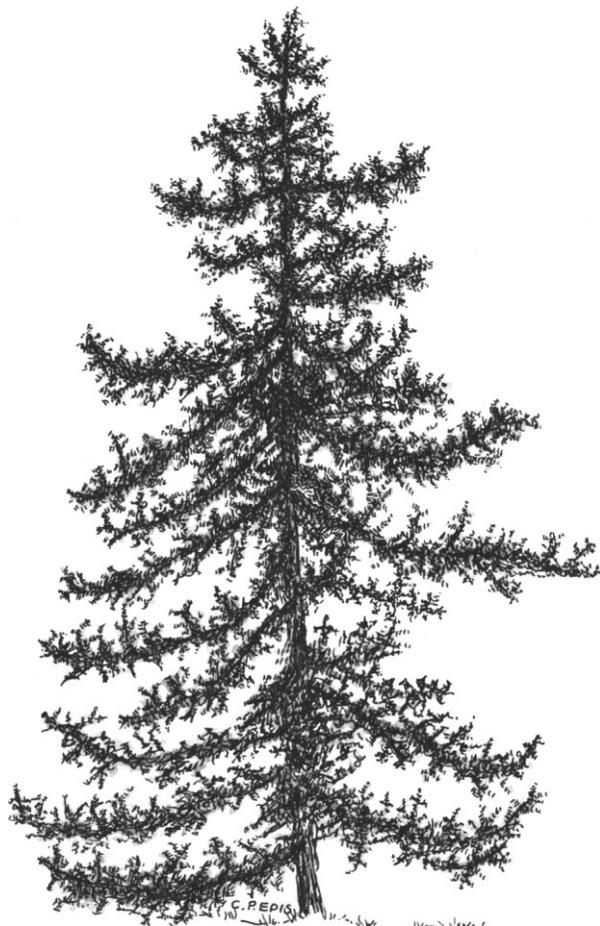
Slope failure deposits are of utmost concern to developmental activities in the Crested Butte area and throughout the Rocky Mountains. An understanding of the processes is essential in their identification. Detailed geologic mapping and air photograph interpretation cannot only aid in identifying the deposits but can provide evidence to determine their stability. Often many slope-failure deposits can be proven to be old and stable. The slope-failure deposits require detailed soil and geologic engineering examination to design for proper construction and development.

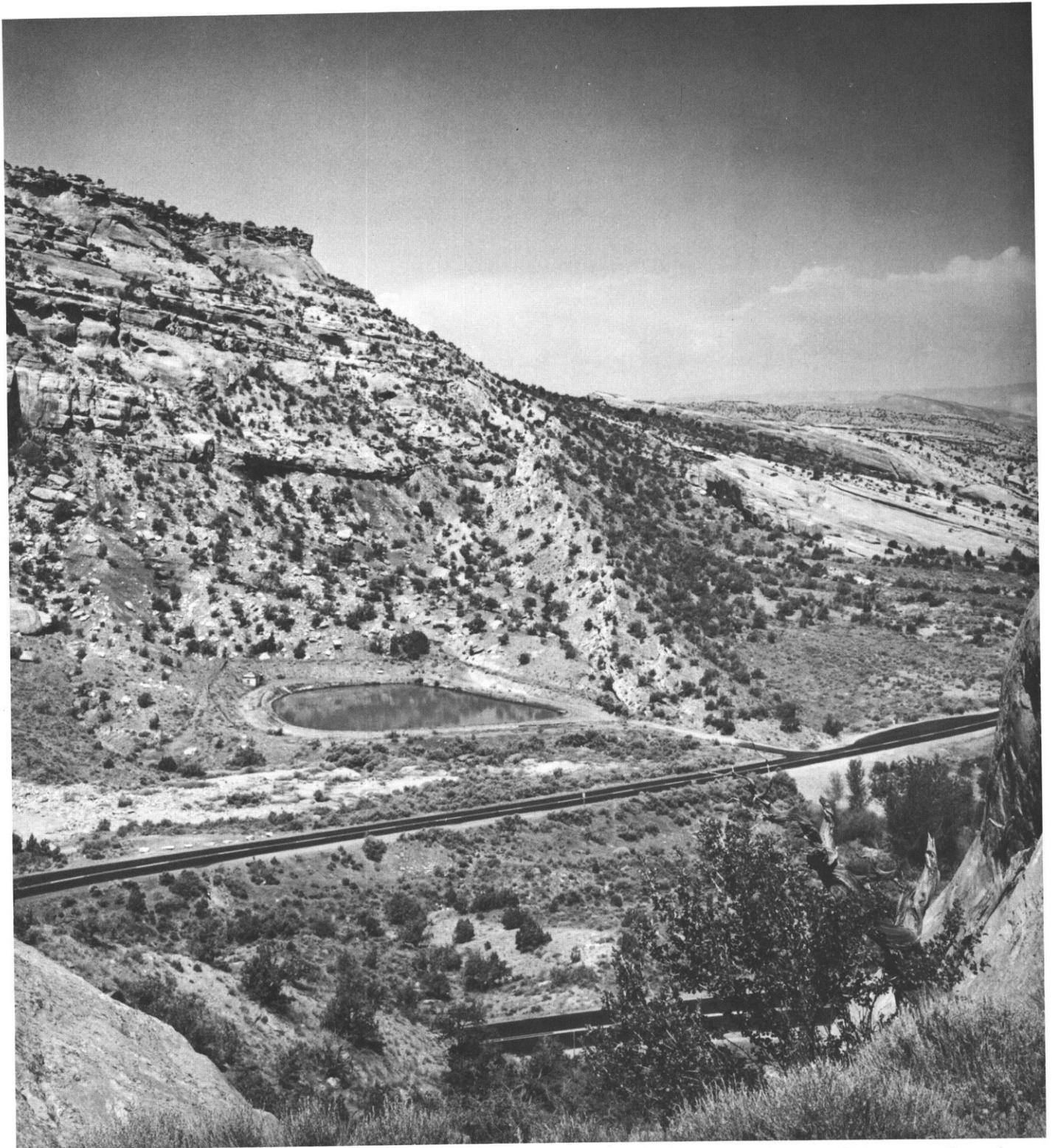
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Kodols Canyon fault, looking northwest across mouth of Fruita Canyon, at west entrance of Colorado National Monument. Here, along a normal fault dipping steeply northeastward, the 107-m cliff of Wingate Sandstone at upper left has been sheared and squeezed into only a few meters of broken rocks overlain by a steep slope of the Kayenta Formation covered by piñon and juniper. The 45-m cliffs at right are the Entrada Sandstone, which belong high atop the cliff at left. From color photograph by S. W. Lohman, U.S. Geological Survey.