Map Series 41

Geologic Map of the Mount Sopris Quadrangle, Garfield and Pitkin Counties, Colorado

By Randall K. Streufert

Bill Ritter Jr., Governor
State of Colorado

COLORADO
DEPARTMENT OF
NATURAL
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Colorado Geological Survey

Colorado Geological Survey
Denver, Colorado
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FOREWORD

The Colorado Department of Natural Resources is pleased to present the Colorado Geological Survey Map Series 41, *Geologic Map of the Mount Sopris Quadrangle, Garfield and Pitkin Counties, Colorado*. Its purpose is to describe the geologic setting of this 7.5-minute quadrangle, which includes parts of the valleys of the Roaring Fork River and Crystal River.

This mapping project was funded jointly by the U.S. Geological Survey (USGS) and the Colorado Geological Survey (CGS). USGS funds are competitively awarded through the STATEMAP component of the National Cooperative Geologic Mapping Program (agreement numbers 98HQAG2081 and 01HQAG0094). The CGS matching funds come from the Severance Tax Operational Account that is funded by taxes paid on the production of natural gas, oil, coal, and metals.

Vince Matthews,
State Geologist and Director,
Colorado Geological Survey

ACKNOWLEDGMENTS

This geologic map was funded in part by the USGS through the National Cooperative Geologic Mapping Program. The project was also supported by the State of Colorado General Funds and the Colorado Department of Natural Resources Severance Tax Operational Funds. The Severance Tax Funds are paid on the production of natural gas, oil, coal, and metals.

The original geologic map of the Mount Sopris quadrangle (Streufert, 1999) benefited from reviews by Bruce Bryant, Jim Cappa, Robert Kirkham, and Peter Birkeland. The following geologists provided helpful suggestions during the course of the study: Bruce Bryant, Robert Kirkham, Rich Madole, Jim Cappa, Bob Scott, Chuck Pillmore, Peter Birkeland, Karl Kellogg, Paul Carrara, Bill Perry, Florian Maldonado, Chris Carroll, Jon White, and Wendy Meyer. Sandin E. Phillipson provided a copy of his unpublished 1998 report on the Mount Sopris stock. Jane Ciener was the technical editor of the earlier CGS open-file report. Photogrammetric models of annotated aerial photographs were set by Jim Messerich on a Kern PG-2 plotter. Matt Morgan created the shaded relief map with geology overlay and the cross section profile from the USGS digital elevation model. Robert Kirkham was responsible for this updated version of the map and booklet, and Beth Widmann edited the updated version. The cooperation of the many helpful landowners and property managers is much appreciated.

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INTRODUCTION

OVERVIEW

Between 1993 and 2001 the Colorado Geological Survey (CGS) mapped the geology of twelve 7.5-minute quadrangles in the Glenwood Springs area in west-central Colorado (**Figure 1**). These maps were released to the public in varying formats, but many were "old-fashioned", hard-to-read, black-and-white diazo prints of hand-drafted, non-digital maps. During this same time period, map production involving computer-aided drafting and geographic information systems evolved rapidly.

This publication includes the digitally produced, full-color geologic map of the Mount Sopris 7.5-minute quadrangle. The digital map and accompanying booklet are slightly modified from an earlier publication released by the CGS as Open-File Report 99-7 (Streufert, 1999). The digital update was undertaken as part of the STATEMAP component of the National Cooperative Geologic Mapping Program, which is administered by the United States Geological Survey (USGS). In addition to the Mount Sopris quadrangle, six other quadrangles in the Glenwood Springs area are being digitally updated. They include the Glenwood Springs, Shoshone, Carbondale, Cottonwood Pass, Basalt, and Leon quadrangles (Fig. 1).

Most of the modifications to this updated digital geologic map of the Mount Sopris quadrangle relate to the discovery of widespread late Cenozoic evaporite collapse in the region (e.g. Kirkham, Streufert, and others, 2001; Kirkham, Scott, and Judkins, 2002) and to a collaborative investigation of that phenomenon by the CGS and USGS subsequent to the release of the CGS Open-File Report 99-7. The initial discovery of regional

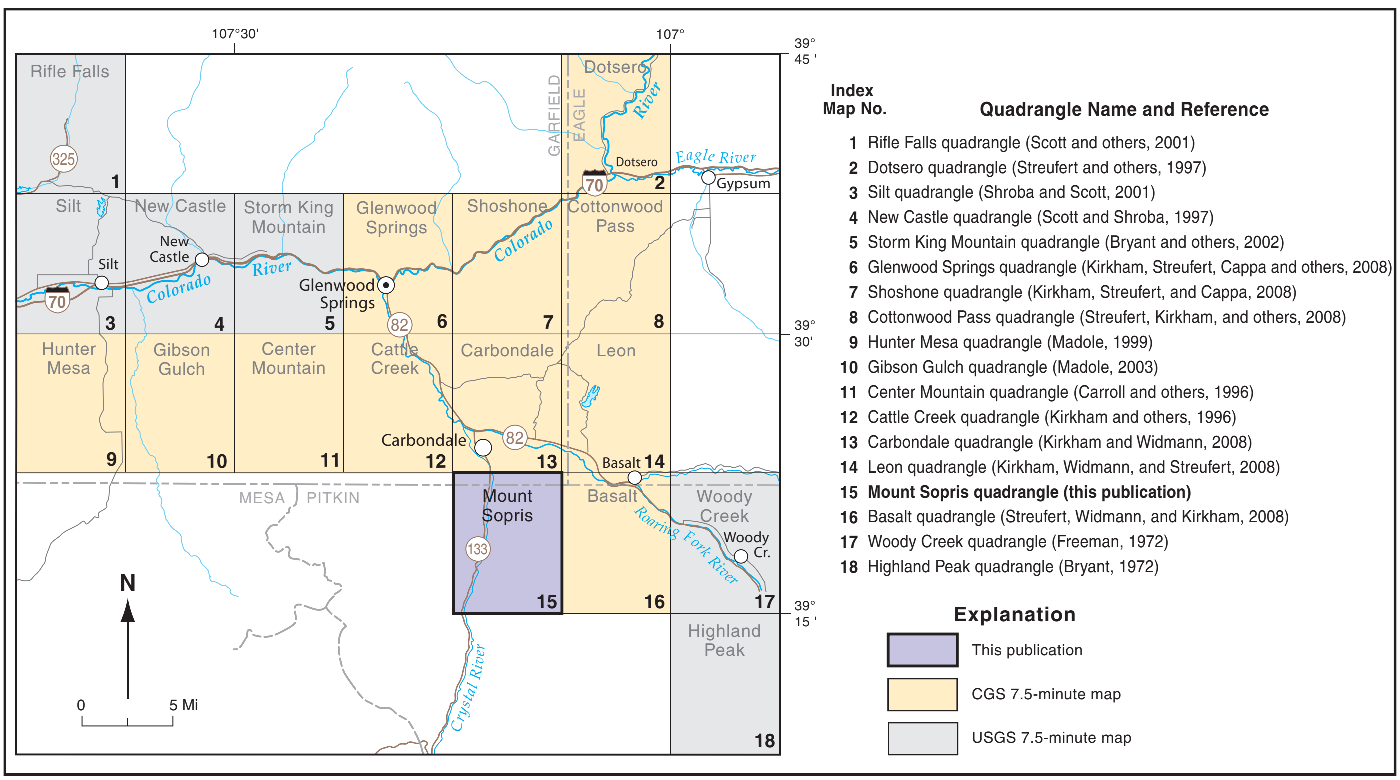


Figure 1. Geologic maps of 7.5-minute quadrangles in the vicinity of the Mount Sopris quadrangle.

evaporite collapse was made early during the mapping program, and new evidence of the collapse was found as additional quadrangles were mapped and as the data from the collaborative CGS-USGS investigation were interpreted. The conceptual model of the collapse process also evolved considerably during this time, which caused us to re-evaluate some of the structures and mapped units within the quadrangle.

Most other modifications to the map and booklet are a result of (1) edge matching the geology shown on the Mount Sopris quadrangle with adjacent quadrangles; (2) interpretation of the geology of the mapped area with respect to the regional knowledge acquired by mapping contiguous quadrangles; (3) expansion of the booklet to develop a consistent format for all digitally updated maps; and (4) editorial corrections. In addition to producing a block of full-color geologic maps in uniform digital format, the seven edge-matched quadrangles have compatible stratigraphic nomenclature and consistently use formation colors, patterns, and symbols.

Geologic maps produced by the CGS through the STATEMAP program are useful for many purposes, including land-use planning, geotechnical engineering, geologic-hazards assessment, analysis and mitigation of environmental problems, and mineral-resource and ground-water exploration and development. The maps describe the geology of the quadrangle at a scale of 1:24,000 and serve as a good basis for more detailed research and for regional and broad-scale studies.

The Mount Sopris quadrangle covers about 58 square miles in Garfield and Pitkin Counties, which are in west-central Colorado. The Crystal River flows from south to north across the quadrangle. The twin summits of Mount Sopris, both at altitude of 12,953 feet above mean sea level, form the highest parts of the quadrangle. Most land in the south half of the quadrangle is public land administered by the White River National Forest. Most land along the stream valleys and public roads in the north half is private, with the balance being public land managed by the Bureau of Land Management. The 1:24,000-scale topographic base map of the quadrangle was first published in 1961 and later updated in 1987 using aerial photographs taken in 1983.

R.K. Streufert prepared the original map and text published as open-file report 99-7 (Streufert, 1999). Robert M. Kirkham is responsible for the modifications in this updated digital product.

PRIOR GEOLOGIC MAPS

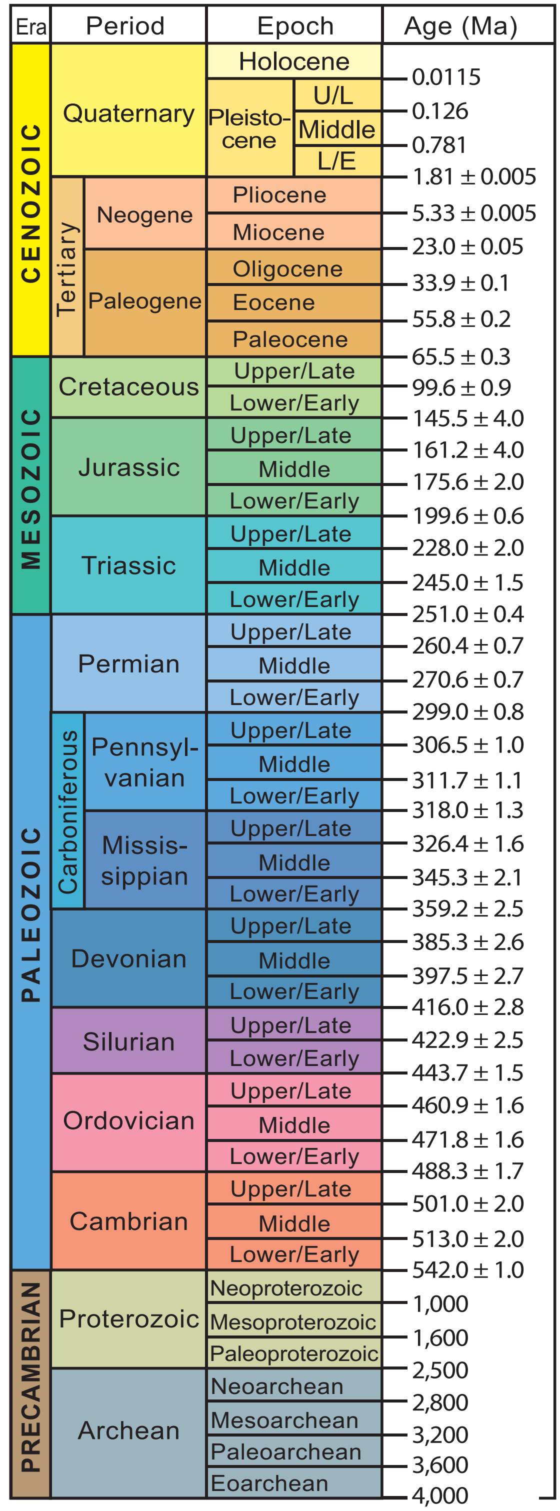
Previously published small-scale geologic maps of the Mount Sopris quadrangle include 1:500,000-scale maps by Burbank and others (1935) and Tweto (1979), the 1:250,000-scale map of Tweto and others (1978), and the 1:100,000-scale map of Ellis and Freeman (1984). F.M. Fox and Associates (1974) mapped the western and northern parts of the quadrangle at a scale of 1:48,000. CGS originally mapped the Mount Sopris quadrangle at a scale of 1:24,000 and released it as Open-File Report 99-7 (Streufert, 1999).

MAPPING METHODS AND TERMINOLOGY

Field work in the Basalt quadrangle was conducted during the 1997 field season. Traverses were made along all public roads and many of the private roads in the quadrangle. Numerous foot traverses were needed to access remote parts of the quadrangle. Aerial photography was used extensively during the project. Geologic information collected in the field was plotted on 1:24,000-scale or larger-scale photography using a pocket stereoscope. Geologic information drawn on the aerial photographs was transferred to a mylar base map using a Kern PG-2 plotter at the U.S. Geological Survey's photogrammetric facility in Denver.

Grain-size terminology used herein for the sedimentary deposits follows the modified Wentworth scale (Ingram, 1989). This classification system describes pebbles, cobbles, and boulders as differing sizes of gravel. Terms used for sorting are those of Folk and Ward (1957). Sedimentary clasts are defined in this study as rock fragments larger than 2 mm in diameter, whereas matrix refers to surrounding material that is 2 mm or less in diameter (sand, silt, and clay). In clast-supported deposits, the majority of the material consists of clasts that are in point-to-point contact. In matrix-supported deposits most clasts are separated by or embedded in matrix.

The divisions of geologic time and the age estimates of their boundaries are shown in **Figure 2**.



U. S. Geological Survey Geologic Names Committee, 2007, Divisions of geologic time - major chronostratigraphic and geochronologic units: U. S. Geological Survey Fact 2007-3015, March 2007.

Pleistocene internal ages from International Commision on Stratigraphy, 2007, International stratigraphic chart: downloaded December 2007 from www.stratigraphy.org/cheu.pdf

Figure 2. Geologic time chart.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

The surficial map units are classified by genesis and relative age. Surficial units shown on the map are generally more than about 5 ft thick, although some surficial deposits associated with distinct landforms may locally be thinner than 5 ft. Residuum and artificial fills of limited extent were not mapped. Contacts between many surficial units may be gradational and therefore should be considered as approximate boundaries. Age assignments for surficial deposits are based primarily upon the degree of erosional modification of original surface morphology, height above modern streams, stratigraphy, and the relative degree of clast weathering and soil development. Correlation of some terraces and interpretations of their ages are hindered by deformation related to underlying evaporitic bedrock and surficial deposits, altering their relative heights above modern streams.

HUMAN-MADE DEPOSITS—Materials placed by humans

af

Artificial fill (latest Holocene)—Composed mostly of unsorted silt, sand, and rock fragments deposited during construction projects. Maximum thickness is 40 ft.

ALLUVIAL DEPOSITS—Composed mostly of silt, sand, and gravel deposited in stream channels, flood plains, glacial outwash terraces and sheetwash areas along the Crystal River and its tributaries.

Qa

Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)—Includes modern stream channel deposits of the Crystal River, adjacent flood-plain deposits, and low terrace alluvium that is as much as 10 ft above modern stream level. Mostly clast-supported, silty, sandy, occasionally bouldery, pebble and cobble gravel in a sandy silt matrix locally interbedded with and commonly overlain by sandy silt and silty sand. Unit Qa is poorly to moderately well sorted and is moderately well to well bedded. Clasts are well rounded to subangular. Deposits in the Crystal River Valley contain clasts of Tertiary hypabyssal rocks and Paleozoic and Mesozoic sedimentary rocks. Unit may locally include organic-rich deposits. It may interfinger with younger debris-flow deposits (unit Qdfy) where the distal ends of fans extend into modern river channels. Maximum thickness is difficult to estimate owing to active sinkhole development in the area caused by dissolution and flowage of evaporitic bedrock below the Crystal River Valley.

Qsw

Sheetwash deposits (Holocene and late Pleistocene)—Includes deposits locally derived from weathered bedrock and surficial materials which are transported predominantly by sheetwash and deposited in valleys of ephemeral and intermittent streams, on gentle slopes, or in basinal areas. Sheetwash deposits typically consist of pebbly, silty sand and sandy and clayey silt. Maximum thickness is about 25 ft.

Qty

Younger terrace alluvium (late Pleistocene)—Chiefly stream alluvium underlying terraces in the Crystal River Valley that range from 10 to 45 ft above modern stream level. Unit is mostly poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand and silt matrix, but unit may include fine-grained overbank deposits. Clasts are mainly subrounded to rounded and are comprised chiefly of several types of middle Tertiary and younger hypabyssal rocks and Paleozoic and Mesozoic rocks, some of which are metamorphosed. These clasts are representative of rock types found in the drainage basin of the Crystal River. Clasts are generally unweathered or only slightly weathered. Unit correlates with younger terrace alluvium (unit Qty) of Kirkham and Widmann (2008) and may correlate with terrace T7 of Piety (1981), with terrace A of Bryant (1979), or with terrace gravel "a" (unit Qga) of Freeman (1972). Younger terrace alluvium was probably deposited late during the late Pleistocene Pinedale glaciation. Thickness averages 30 to 40 ft, although thicknesses may be greater in areas affected by salt-related subsidence.

Qtm

Intermediate terrace alluvium (late Pleistocene)—Composed of stream alluvium in terraces 80 to 120 ft above the Crystal River. The unit consists of poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand and silt matrix. Fine-grained overbank deposits may be locally present. Clasts are mainly subrounded to rounded and are comprised chiefly of several types of middle Tertiary and younger hypabyssal rocks and Paleozoic and Mesozoic rocks, some of which are metamorphosed. These clasts are representative of rock types found in the drainage basin of the Crystal River. Clasts generally are only slightly weathered at shallow depths. These terraces are frequently deformed by diapirism related to upwelling of evaporitic rocks. Intermediate terrace alluvium at the mouth of Avalanche Creek directly overlies evaporitic bedrock and is most likely deformed by diapiric movement of evaporite. A terrace on the east side of the Crystal River, south of the boundary between Garfield and Pitkin Counties, has been deformed and its surface now dips a few degrees to the east and away from the river. Thickness averages 80 ft. Thickness of unit may have been affected by salt-related subsidence. Unit Qtm correlates with intermediate terrace alluvium (unit Qtm) of Kirkham and Widmann (2008) and may correlate with terrace T6 of Piety (1981), with terrace B of Bryant (1979), or with terrace gravel "b" (unit Qbg) of Freeman (1972). Intermediate terrace alluvium was probably deposited early during the late Pleistocene Pinedale glaciation.

Qto

Older terrace alluvium (late middle Pleistocene)—Includes deposits of stream alluvium underlying terrace remnants that are about 120 to 200 ft above the Crystal River. The unit is generally a clast-supported cobble or pebble gravel in a sand and silt matrix, but may range to a matrix-supported gravelly sand or silt. Locally it may contain fine-grained overbank deposits. The unit consists of poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand and silt matrix. Clasts are mainly subrounded to rounded and are comprised chiefly of several types of middle Tertiary and younger hypabyssal rocks and Paleozoic and Mesozoic rocks, some of which are metamorphosed. These clasts are representative of rock types found in the drainage basin of the Crystal River. Clasts are slightly to moderately weathered at shallow depths. Thickness of most deposits ranges from 30 to 80 ft. The unit is correlative with older terrace alluvium (unit Qto) in the Carbondale quadrangle (Kirkham and Widmann, 2008) and in the Basalt quadrangle (Streufert, Widmann, and Kirkham, 2008), and it may correlate with terrace C in the Aspen area (Bryant, 1979) or with terrace gravel "c" (unit Qgc) in the Woody Creek quadrangle (Freeman, 1972). These sediments probably were deposited during the late middle Pleistocene Bull Lake glaciation (Fig. 2). A dot pattern is used on the geologic map to depict areas where thin veneers of gravel that probably are age equivalent to unit Qto mantle Tertiary sediments (unit Ts). These veneers are widespread near Prince Creek. In the original CGS geologic map of the quadrangle (Streufert, 1999), both the mantle of middle Pleistocene deposits and underlying Tertiary sediments were mapped as unit Qto. In this publication these areas are mapped as unit Ts with a pattern to indicate the thin veneer of younger alluvium.

Qtt

Oldest terrace alluvium (middle and early? Pleistocene)—Consists of stream alluvium underlying terraces that are about 400 to 600 ft above and on the west side of the Crystal River. The unit underlies two terrace remnants in sections 28, 33, and 34, T. 8 S., R. 88 W., south of the mouth of Thompson Creek. The deposit consists of poorly sorted to moderately well-sorted, clast-supported, slightly bouldery, cobble and pebble gravel with a sand matrix that locally contains lenses and beds of sandy silt and silty sand. Clasts are moderately to strongly weathered even at moderate depths. Clast lithologies are predominantly Tertiary hypabyssal rocks, including material from the Mount Sopris pluton and from various other Tertiary plutons, laccoliths, and stocks in the Elk and West Elk Mountains, with minor Paleozoic and Mesozoic sedimentary clasts, most of which are metamorphosed. These deposits typically are 20 to 50 ft thick. Thin veneers of gravel that probably are age equivalent to unit Qtt mantle Tertiary sediments (unit Ts) in a large part of the northwest corner of the quadrangle. In the original CGS geologic map of the quadrangle (Streufert, 1999), both the mantle of middle and early? Pleistocene deposits and underlying Tertiary sediments were mapped as unit Qtt. In this publication these areas are mapped as unit Ts but have a pattern that indicates the thin veneer of younger alluvium.

TERRACE ALLUVIUM OF THOMPSON CREEK

Qgt_1 **Younger terrace alluvium of Capital Creek (late Pleistocene)—**Chiefly stream alluvium underlying terraces from about 80 to 160 ft above Thompson Creek. The unit consists mostly of poorly sorted, clast-supported, bouldery, pebble and cobble gravel with a sand and silty sand matrix. Fine-grained overbank deposits are locally present. Clasts are well rounded to subangular and are comprised predominantly of basalt and Mesozoic sedimentary rocks. In places these deposits consist of over 50 percent rounded to well rounded, cobble- and boulder-sized clasts of vesicular basalt. These clasts likely were derived from basalt-rich surficial deposits or from Miocene lava flows that formerly existed west of the quadrangle. Clasts are slightly to moderately weathered. Maximum thickness is about 50 ft. The unit may correlate in part with older terrace alluvium (unit Qto) mapped along the Crystal River and its tributaries but is in part somewhat older.

Qgt_2 **Older terrace alluvium of Thompson Creek (middle Pleistocene)—**Composed of stream alluvium underlying terraces about 320 to 400 ft above Thompson Creek. Similar in texture, sorting, lithology, and genesis to younger terrace alluvium of Thompson Creek (unit Qgt_1), except clasts are moderately weathered. Maximum thickness is about 40 ft. Unit may be similar in age to the gravel of Nettle Creek (unit Qgn) and other older debris-flow deposits (unit Qdfo) in the quadrangle.

MASS-WASTING DEPOSITS—Sediments on valley sides, valley floors, and hillslopes that were mobilized, transported, and deposited primarily by gravity.

Qc **Colluvium (Holocene and late Pleistocene)—**Ranges from unsorted, clast-supported, pebble to boulder gravel in a sandy silt matrix to matrix-supported gravelly, clayey, sandy silt. Colluvium is derived from weathered bedrock and surficial deposits and is transported downslope primarily by gravity but aided by sheetwash. Locally it grades to sheetwash deposits on flatter slopes and to debris-flow deposits in some drainages. Deposits are usually coarser grained in upper reaches of a colluvial slope and finer grained in distal areas where sheetwash processes are more prevalent. Clasts typically are angular to subangular, except in those colluvial deposits that are derived from fluvial gravel deposits, in which case the clasts are rounded to subrounded. Colluvium commonly is unsorted or poorly sorted with weak or no stratification. Clast lithology is variable and dependent upon types of bedrock or surficial deposits occurring on slopes beneath and above the deposit. Locally the unit includes talus, landslides, sheetwash, and debris flows that are too small or too indistinct on aerial photography to be mapped separately. Unit Qc grades to and interfingers with alluvium and colluvium (unit Qac), colluvium and sheetwash (unit Qcs), younger debris-flow deposits (unit Qdfy), and sheetwash deposits (unit Qsw) along some tributary drainages and hillslopes. Maximum thickness is about 40 to 60 ft.

Qt **Talus (Holocene and late Pleistocene)—**Angular, cobbly, and bouldery rubble derived from outcrops of granodiorite of Mount Sopris and metamorphosed sediments of the Eagle Valley Formation that was transported downslope principally by gravity as rockfalls, rockslides, and rock topples. Unit commonly lacks matrix material. Talus deposition is active and widespread on the north and northwest sides of Mount Sopris, especially in the steep glacial cirques. Talus deposits may also accumulate at the toe of younger rock glaciers, such as those 7,000 to 7,500 ft north-northwest of the west summit of Mount Sopris. Thickness of unit generally increases downslope from source areas and typically is a maximum of about 50 ft thick. Talus deposits in the cirques of Mount Sopris may be somewhat thicker in low-relief areas adjacent to transverse ridges of younger rock glaciers. Talus deposits locally contain periglacial features that may be transitional into younger rock glaciers (unit Qrg_1).

Qls **Landslide deposits (Holocene and Pleistocene)—**Highly variable deposits consisting of unsorted, unstratified rock debris, gravel, sand, silt, and clay. They range in age from recently active landslides to long-inactive middle or early Pleistocene landslides. Unit includes rotational and translational landslides, complex slump-earthflows, earthflows, and extensive slope-failure complexes. Landslides are common and of considerable areal extent in the northeast part of the quadrangle in areas where relatively thick and mostly unconsolidated deposits of glacial till (unit Qti), and Tertiary sedimentary deposits (unit Ts), underlie the ground surface. Some of the isolated hills mapped as Tertiary sediments (unit Ts) in this area may be eroded remnants of landslide deposits. Landslide deposits also exist on the south face of Mount Sopris. These landslides occur in older colluvium (unit Qco), talus (unit Qt), and felsenmeer (unit Qf). Maximum thickness of landslide deposits is about 200 ft, but usually it is less than 100 ft thick.

Qco

Older colluvium (Pleistocene)—Occurs on drainage divides, ridge lines, and dissected hillslopes as erosional remnants of formerly more extensive deposits that were transported by gravity and aided by sheetwash. Unit occurs in a north-south-trending zone below the steep exposed west and northwest margins of the Mount Sopris stock. In this area the Crystal River Valley has a vertical relief of over 6,300 ft in about 2.6 miles, including steep slopes (30 to 45 degrees) of exposed granodiorite that often have over 4,000 ft of relief from base to top. Unit consists predominantly of material derived from the Pennsylvanian Eagle Valley Formation, with lesser amounts of granodiorite of Mount Sopris. Genesis, texture and bedding are somewhat similiar to colluvium (unit Qc), although these deposits most likely include significant rock-topple events and are very clast-rich. Unit locally contains relatively large blocks of intact rock, some of which are as much as 12 ft in length. These deposits are interpreted as resulting from large-scale shedding of metamorphosed clastic rocks from the steep-walled margin of the Mount Sopris pluton, possibly in response to subsidence and/or collapse related to dissolution of evaporitic bedrock. Maximum thickness may exceed 100 ft

ALLUVIAL AND MASS-WASTING DEPOSITS—These deposits include alluvial and mass-wasting material that is mapped as a single unit because (1) they are juxtaposed and are too small to show individually, or (2) they have contacts that are not clearly defined. Fan deposits are classified as mixed alluvial and mass-wasting deposits because in addition to alluvium, they also include significant volumes of debris-flow deposits, which are generally considered to be a form of mass wasting (e.g. Cruden and Varnes, 1996; Hungr and others, 2001).

Qdfy

Younger debris-flow deposits (Holocene)—Sediments deposited by debris flows, hyperconcentrated flows, streams, and sheetwash on active fans and in stream channels. The unit ranges from poorly sorted to moderately well-sorted, matrix-supported, gravelly, sandy, clayey silt to clast-supported, pebble and cobble gravel in a sandy, clayey silt or silty sand matrix. It may be bouldery, particularly near fan heads. Distal parts of some fans are characterized by mudflow and sheetwash and tend to be finer grained. Younger debris-flow deposits are locally interfingered or interbedded with modern alluvium (unit Qa) adjacent to stream channels. Younger debris-fan deposits derived from redbeds and evaporitic clastic sequences of the Pennsylvanian Maroon and Eagle Valley Formations occur at most tributary mouths along the Crystal River in the southern half of the quadrangle. In the northern half of the quadrangle deposits of younger debris flows commonly are derived from thick unconsolidated deposits, including Tertiary sediments (unit Ts), Pleistocene terrace deposits (units Qtm, Qto, Qtt), and landslide deposits (unit Qls). On the west side of the Crystal River large, coalescing debris fans extend well out from the valley wall and cover large areas of younger terrace alluvium (unit Qty). These large debris-fan complexes are derived from thick deposits of oldest terrace alluvium (unit Qtt). The original depositional surfaces formed on the unit are usually preserved, except where they are disturbed by human activities. Debris-flow bridges were built in numerous drainage gullies along the Sweet Jessup water ditch in sections 15 and 22, T. 8 S., R 88 W. to carry the frequently occurring debris-flow events over and beyond this irrigation ditch. Maximum thickness of unit is about 75 ft.

Qac

Alluvium and colluvium, undivided (Holocene and late Pleistocene)—Unit Qac consists chiefly of stream-channel, low-terrace, and flood-plain deposits along the valley floors of ephemeral, intermittent, and small perennial streams, colluvium and sheetwash on valley sides, and outwash in valleys that were glaciated. Deposits of alluvium and colluvium probably interfinger along valley margins. Locally unit Qac includes younger debris-flow deposits, or it may grade to debris-flow deposits in some drainages. The alluvial and outwash components typically are composed of poorly sorted to well-sorted, stratified, interbedded, pebbly sand, sandy cobble gravel, and sandy silt, whereas the colluvial component usually is unsorted, unstratified or poorly stratified, clayey, silty sand, bouldery sand, and sandy silt. Clast lithologies are dependent upon type of bedrock and surficial deposits in source areas. Thickness of unit Qac is commonly 5 to 20 ft, and its maximum thickness is about 40 ft.

Qcs **Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene)—**Unit Qcs is composed of colluvium on steeper slopes and sheetwash deposits on flatter slopes. This undivided unit is mapped where contacts between the two types of deposits are very gradational and difficult to locate. Refer to unit descriptions for colluvium (unit Qc) and sheetwash deposits (unit Qsw) for genetic, textural, and lithologic characteristics.

Qdfm **Intermediate debris-flow deposits (Holocene? and late Pleistocene)—**Similiar in texture, lithology, and depositional environment to younger debris-flow deposits (unit Qdfy). The geomorphic features of the original depositional surfaces are commonly recognizable, but ative channels are incised 10 ft or more into intermediate debris-flow deposits. Maximum thickness of unit Qdfm is about 60 to 80 ft.

Qdfo **Older debris-flow deposits (late and middle? Pleistocene)—**Three disconnected remnants of older debris-flow deposits were once part of large debris fan north of Mount Sopris. Modern Prince Creek and Thomas Creek have incised 40 to 120 ft into these deposits. Where exposed, the unit is a dark-gray to black, gravelly, sandy, clayey silt with scattered cobbles, occasional boulders of Mount Sopris granodiorite and minor pebble-sized sandstone fragments of Mancos Shale. These large fan remnants are frequently covered with a thin veneer of sheetwash rendering inspection difficult in most places. These deposits are located between morainal deposits (unit Qm) of probable Pinedale age to the south and Tertiary sedimentary deposits to the north. Unit Qdfo may in part correlate with the gravel of Nettle Creek (unit Qgn), which occurs in a somewhat similar geomorphic setting. Clasts are moderately to highly weathered. Thickness exceeds 200 ft in places.

Qaco **Older alluvium and colluvium, undivided (late and middle? Pleistocene)—**Includes deposits of alluvium and colluvium ranging from about 10 to 100 ft above and adjacent to perennial, intermittent, and ephemeral streams. Texture, bedding, clast lithology, sorting, and genesis are similiar to alluvium and colluvium (unit Qac). Unit Qaco locally includes debris-flow and sheetwash deposits.

Qgn **Gravel of Nettle Creek (middle ? Pleistocene)—**Consists of a single deposit south of Nettle Creek. The unit is poorly sorted, matrix-supported, occasionally bouldery, pebble and cobble gravel in a sandy, clayey silt, or silty sand matrix. It locally includes lenses of moderately well-sorted, gravelly, sandy, clayey silt that is both matrix- and clast-supported. Clasts are angular to subangular and consist of granodiorite of Mount Sopris, with subordinate amounts of Paleozoic and Mesozoic sedimentary rocks. Clasts are moderately to very highly weathered. Unit Qgn overlies Pennsylvanian and Permian redbeds of the Maroon Formation and is partially overlain at the eastern edge of its exposure by morainal deposits (unit Qm) and older rock glacier deposits (unit Qrg_2). The unit forms a bench-like, gently sloping surface that is covered with up to 4 ft of sheetwash. Nettle Creek is incised as much as 50 ft into this deposit. Maximum thickness of the deposit in the westernmost exposure is about 80 ft. The unit is well exposed along the private road above the Carbondale water-intake and chlorination plant. In this area the deposits resemble debris-flow sediments. Unit Qgn may be genetically similar to older debris- flow deposits (unit Qdfo) in the large, dissected debris-fan remnant north of Mount Sopris in upper Thomas and Prince Creek drainages.

PERIGLACIAL DEPOSITS—Coarse rock debris and minor sand, silt, and clay formed in cold environments by the processes of freeze-thaw action, nivation, and solifluction.

Qf **Felsenmeer (Holocene and late Pleistocene)—**Felsenmeer extensively mantles bedrock on the upper south slopes of Mount Sopris above 9,000 ft. It consists of angular to subangular boulders, cobbles, and pebbles in a sandy matrix. Clasts are composed of the immediately underlying rock units: the granodiorite of Mount Sopris and quartzite and hornfels of the Pennsylvanian Eagle Valley Formation. Unit locally is deformed by downhill flowage (solifluction). Deposits are probably similar to concentrations of coarse rock debris occurring on gently sloping surfaces on the summit of the Park Range (Madole, 1991). These deposits were interpreted as felsenmeer, which is chiefly the product of congeliturbation (the mechanical weathering, and differential mass-movement of rock debris by frost action), and, in places, transport by solifluction. The unit may locally include nivation deposits consisting of sediments derived from beneath and around the fluctuating margins of snowbanks, chiefly by frost action, melt-water transport, and solifluction. These deposits may be similar to nivation deposits found on gentle, high-level slopes along the summit of the Park Range that were not reoccupied by small glaciers during latest Pleistocene and Holocene time (Madole, 1991).

ROCK-GLACIER DEPOSITS—Very coarse rock debris and minor sand and silt transported and deposited by active and inactive rock glaciers.

Qrg_1 **Younger rock-glacier deposits (Holocene and late Pleistocene?)—**Deposits of unit Qrg_1 most likely consist of two layers of material. The cores of these deposits probably are mixtures of rock rubble and interstitial fine-grained sediments in a matrix of ice or permafrost. The outer layer consists of clast-supported, matrix-free, angular to subangular, predominantly boulder-sized rock fragments of granodiorite of Mount Sopris and metamorphosed sediments of the Pennsylvanian Eagle Valley Formation. Younger rock-glaciers occur as lobate, tongue-like deposits emanating from the steep cirques on the north and northwest sides of Mount Sopris. In some cases the cores of these rock glaciers may contain ice that is older than the rock material transported on the surface (B. Bryant, written commun., 1999). The coarse rock debris and other sediments in younger rock glaciers likely originated as talus and colluvium that was mostly deposited by rockfall and rock-topple events. Unit Qrg_1 may locally include sediments derived from landslide and snow avalanche events. In the heads of steep-walled cirques on Mount Sopris, talus grades into younger rock-glacier deposits. Younger rock glaciers are currently active and down-valley limits coincide with steep active fronts. Younger rock glaciers have a ropy, lobate surface morphology and have encroached on or overridden older landforms. Talus cones are locally developed along the active fronts. The unit is very sparsely vegetated to unvegetated. The presence of interstitial ice gives active rock glaciers an “inflated” appearance. Unit Qrg_1 includes material mapped as both latest Pleistocene (Pinedale) and Holocene (Neoglacial) rock-glacier deposits (Birkeland, 1973; Meierding and Birkeland, 1980).

Absolute ages of Colorado rock glaciers are problematic; however, a few radiocarbon dates used in conjunction with relative dating methods (Birkeland, 1973; Benedict, 1968, 1973; Miller, 1973; Carrara and Andrews, 1973) aid their age classification. Late Pleistocene and early Holocene rock- glacier deposits are recognized throughout the high mountains of Colorado (Meierding and Birkeland, 1980). Relative dating and stratigraphic studies suggest that material in the lower half of the rock glacier in the head of Thomas Creek is Pinedale (late Pleistocene) in age (Birkeland, 1973). This lower portion may also contain rock-glacier deposits of early Holocene age. In contrast, the upper half of this rock glacier, including active source areas in the upper cirque, contains material of suspected Neoglacial age (Birkeland, 1973). All of this material is actively moving down-valley out of these steep cirques. Documented rates of movement of active rock glaciers in Colorado are scarce, but include 3.9 inches/yr in the Front Range (White, 1971), 4.9 inches/yr in the Sawatch Range (Miller, 1973), and as much as 23.6 inches/yr in the Elk Mountains (Bryant, 1971)

Qrg_2 **Older rock-glacier deposits (Holocene and/or late Pleistocene)—**Consists of angular to subangular boulders and cobbles of granodiorite of Mount Sopris and Pennsylvanian Eagle Valley Formation in a matrix of unsorted rock fragments, sand, silt, and clay. Unit Qrg_2 is mostly clast-supported but may locally be matrix-supported. Deposits are genetically similar to younger rock glacier deposits (unit Qrg_1) but are inactive. The unit displays a similar morphology to that of younger rock glaciers (unit Qrg_1), except that their profiles appear more subdued. This may be due to the absence of interstitial ice and/or permafrost, which creates a "deflated" appearance. Older rock-glacier deposits are frequently covered with mature coniferous vegetation where there is a matrix. They underlie and generally extend outward past the current terminus of younger rock glacier deposits (unit Qrg_1). Unit Qrg_2 appears to overlie morainal deposits (unit Qm) in many places; however, this contact is very poorly exposed. The older rock-glacier deposit in the S ½ of sec. 7, T. 9 S., R. 87 W. overlies morainal deposits (unit Qm) that are of suspected Pinedale age. It is overlain by the terminus of a younger rock glacier (unit Qrg_1), which is of proposed Pinedale age on the basis of relative-dating and stratigraphic criteria (Birkeland, 1973). This suggests that the older, now inactive, rock-glacier deposit (unit Qrg_2) in this area represents a separate and distinct episode of rock-glacier formation subsequent to the Pinedale glaciation. Alternatively, the formation of rock glaciers may have been continuous since the end of Pinedale glaciation and that the older (unit Qrg_2) and younger (unit Qrg_1) rock-glacier deposits in this locality are gradational.

GLACIER DEPOSITS—Gravel, sand, silt, and clay deposited in moraines by, adjacent to, or beneath ice.

| Qm |

Morainal deposits, undivided (late and late middle? Pleistocene)—Heterogeneous deposits of gravel, sand, silt, and clay deposited as ground, lateral, and end moraines on the north and northeast sides of Mount Sopris. Morainal deposits are dominantly till, which consists of poorly sorted, unstratified or poorly stratified, matrix-supported, bouldery, pebble and cobble gravel with a matrix of silty sand, but may locally include glaciofluvial, debris-flow, and landslide deposits. Clasts are typically angular to subrounded pieces of granodiorite of Mount Sopris, with subordinate amounts of Paleozoic sedimentary rocks. The large apron of till that extends from the southeast corner of the quadrangle to Thomas Lakes is characterized by very hummocky knob and kettle topography. On the surface of these deposits boulders of Mount Sopris granodiorite are numerous and are unweathered to slightly weathered. Morphology and degree of weathering of clasts suggests that most of unit Qm was deposited during the late Pleistocene Pinedale glaciation. The morainal deposits were most likely deposited as disintegration moraine (ablation till) as the Pinedale glacier on the north-northeast side of Mount Sopris wasted in place (R. Madole, oral commun., 1998). The very hummocky landforms on these deposits make them difficult to differentiate from landslide deposits, particularly since morainal deposits are prone to landsliding. Deposits in section 11, the SE ¼ of section 10, and the E ½ of section 15, T. 9 S., R. 88 W. underlie lateral moraines. In places these deposits are steep sided, and have sharp moraine crests. In other places the moraine crests and slope profile is more subdued, or less well developed, and clasts are unweathered to moderately weathered. In these areas the morainal deposits may include both late middle Pleistocene Bull Lake till and late Pleistocene Pinedale till. Maximum thickness is estimated at 250 ft.

UNDIFFERENTIATED SURFICIAL DEPOSITS—

| Q |

Surficial deposits, undifferentiated (Quaternary)—Shown only on cross sections. May include any of the preceding surficial deposits.

BEDROCK

| Ts |

Sedimentary deposits (Miocene)—Consists of very weakly indurated to unconsolidated deposits of interbedded fluvial gravel, sand, and silt. Unit Ts includes pebble, cobble, and locally bouldery, clast-supported, unsorted to well- bedded, sandy gravel. Clasts are subrounded to well rounded and are composed of various rock types depending on location. Near Mount Sopris the deposits contain high percentages of clasts of middle Tertiary hypabyssal rock, whereas deposits located closer to the Roaring Fork River Valley are rich in Proterozoic plutonic clasts. This suggests that the Crystal River, Roaring Fork River, and ancestral Thomas and Prince Creeks all contributed sediment to this unit. All deposits contain minor amounts of basalt clasts. Unit Ts occurs in northeast portion of quadrangle where it underlies topographic highs. In outcrop these fluvial deposits are a minimum of about 1,500 ft thick. Perry and others (2002) reported a thickness of 3,700 ft on the basis of an interpreted seismic line. The Tertiary sediments apparently were deposited in and adjacent to a large and steadily subsiding topographic depression called Sopris Bowl that probably was related to dissolution or flowage of evaporitic bedrock. Apparently no evaporite still remains beneath the Tertiary sediments (Perry and others, 2002). This unusually thick deposit of Tertiary sediment now underlies topographically elevated ground and is an example of inverse topography. This unit and the large subsidence depression in which much of it was deposited are related to the Carbondale Collapse Center described by Kirkham and others (2002). Tertiary sediments in the Mount Sopris quadrangle are continuous with deposits mapped to the east in the Basalt quadrangle (Streufert, Widmann, and Kirkham, 2008) that overlie, and hence are younger than, ash-flow tuff that has an $^{40}Ar/^{39}Ar$ age of 35.21 ± 0.03 Ma (Kunk and others, 2002). A basalt flow that is interbedded with these sediments in the Basalt quadrangle yielded an $^{40}Ar/^{39}Ar$ age of 13.57 ± 0.05 Ma (Kunk and others, 2002).

Tgs

Granodiorite of Mount Sopris (Eocene)— The main body of the Mount Sopris stock is predominantly granodiorite, but the composition may range locally from monzodiorite to tonalite. Accessory minerals in the stock are biotite, magnetite, zircon, apatite, and sphene. The granitoid body (Bulldog stock) located beneath and south of Avalanche Creek, is mineralogically similar but has been affected by argillic, and possibly localized propylitic alteration. Texturally the Mount Sopris stock lacks distinct flow foliation, ranges from equigranular to prophyritic, and is medium to fine grained.

The granodiorite of Mount Sopris contains subhedral to anhedral phenocrysts of plagioclase and quartz in a fine-grained to cryptocrystalline, hypidiomorphic groundmass of plagioclase, quartz, and minor potassium feldspar. Plagioclase phenocrysts are both continuously and discontinuously zoned. Some plagioclase phenocrysts have a poikilitic texture enclosing quartz crystals, and locally contain embayments of fine-grained and/or microcrystalline groundmass. The lower and middle exposed portions of the Mount Sopris stock range from porphyritic to equigranular, and contain medium-grained, euhedral to anhedral phenocrysts of plagioclase, quartz, and biotite in a fine-grained groundmass of plagioclase, quartz, and subordinate potassium feldspar. On the east ridge and on both the east and west summits the granodiorite of Mount Sopris is porphyritic, fine-grained, and contains phenocrysts of zoned plagioclase and quartz in a cryptocrystalline groundmass, and locally contains spherulites. The spherulites are composed of fine-grained crystals of plagioclase and quartz in a microcrystalline groundmass.

The Bulldog stock, located along the south edge of the quadrangle and to the south of Avalanche Creek, is equigranular and contains euhedral to subhedral crystals of zoned plagioclase and quartz with accessory biotite. These rocks have been subjected to a fairly pervasive argillic alteration characterized by replacement of feldspar phenocrysts by clay minerals and alteration of biotite to chlorite. A thin section prepared from sample MSR-25 contains interstitial carbonate and possibly pyrite indicating that propylitic alteration may have occurred locally. Pillmore (1954) and Pilkington (1954) suggest that the Bulldog stock, and other granitoids peripheral to the main body of the Mount Sopris intrusive, may represent the first of two episodes of emplacement. Early consolidation in the Mount Sopris magma chamber may have produced a tonalitic border zone that was later intruded and cut by the main, further- differentiated, granodioritic body of Mount Sopris. In the NE ¼ of section 28, T. 9 S., R. 88 W. sediments of Eagle Valley and Maroon Formations have been deflected to the northwest by the intrusion of the Bulldog stock, and later partially cut by the intrusion of the main Mount Sopris stock. This suggests that the Bulldog stock is most likely older than the main body of the Mount Sopris stock. The Pennsylvanian/Permian sediments that are cradled in the contact between the two intrusives are metamorphosed to alabaster, hornfels, and marble.

The Mount Sopris stock was intruded to a high crustal level into a thick section of Paleozoic and Mesozoic sedimentary rocks. On its east and southeast sides it has concordantly upwarped and metamorphosed sediments of the late Paleozoic Eagle Valley and Maroon Formations. On the east ridge of Mount Sopris a sequence of hornfels-grade contact metamorphic rocks is well-exposed in a large roof pendant. These rocks are locally brecciated (intrusion breccia). The contact metamorphic aureole on Mount Sopris diminishes rapidly outward from the stock and is probably at a maximum 300 ft thick. Mineralogy within the aureole is typical of that found in medium- to high-grade (hornfels facies, pyroxene hornfels subfacies) zones located near the inner edge of contact metamorphism caused by the intrusion of batholiths into clayey carbonate sequences. The mineralogy, texture of metamorphic rocks, and the narrow width of the zone of contact metamorphism indicate a relatively dry intrusive event without appreciable exchange of volatile elements between the stock and intruded country rock. The thin zone of contact metamorphism is probably also a function of the relatively shallow depth of emplacement and rapid cooling of the Mount Sopris magma chamber (B. Bryant, written commun., 1999). The stock is discordant on its west side where it was intruded into complexly folded redbeds of the Pennsylvanian/Permian Maroon Formation that were most likely previously deformed by development of the Laramide Grand Hogback Monocline. Structure associated with the Mount Sopris stock on its north side may have been modified by Neogene collapse associated with formation of the Carbondale collapse area.

Previously published ages of the Mount Sopris stock include a K/Ar age of 34.2 ± 0.8 Ma on biotite and a fission-track date of 34.3 ± 4.1 Ma on zircon (Cunningham and others, 1994). A sample of the stock (MSR-24) was analyzed using the furnace incremental heating $^{40}Ar/^{39}Ar$ method (Esser and McIntosh, 1999). Biotite extracted from the sample yielded a hump-shaped age spectrum that failed to meet plateau requirements. The integrated age for the biotite was 34.74 ± 0.19 Ma, which probably records the time of cooling of the granodiorite through 350°C. Potassium feldspar separated from the sample yielded a plateau age of 31.14 ± 0.22 Ma for heating steps B-G, but the radiogenic yields did not rise above 66 percent and averaged only about 30 percent. The unusually low radiogenic yields and low K/Ca ratios from the feldspar probably indicate that significant alteration affects that age.

Km

Mancos Shale (Upper Cretaceous)—Predominantly medium- to dark-gray, carbonaceous, silty to sandy shale with minor bentonite beds, dark-gray limestone, and medium-gray, grayish-yellow-weathering, clayey sandstone. Unit Km may include the Fort Hays Limestone Member (unit Kmf of Freeman, 1972), a dark-gray, thickly bedded limestone that occurs about 300 ft above the base, and upper and lower sandstone members (units Kms & Kmsl of Freeman, 1972) mapped in the Woody Creek quadrangle to the east. The main body of the Mancos Shale is medium- to dark-gray, marine shale. Isolated outcrops of the unit occur north and northeast of Mount Sopris but are mostly covered by surficial deposits. The formation is highly faulted and broken and probably has been displaced vertically or tilted north into the Carbondale Collapse Center. Slopes underlain by Mancos Shale are frequently mantled with landslides. Total thickness of the Mancos Shale in the Woody Creek quadrangle to the east is 5,200 ft (Freeman, 1972).

Kdb

Dakota Sandstone and Burro Canyon Formation, undivided (Lower Cretaceous)—Dakota Sandstone consists of light-gray to tan, medium- to coarse-grained, moderately well-sorted quartz sandstone and conglomeratic sandstone in well-cemented, thick beds. The formation also contains beds of shale, carbonaceous shale, and coal. The underlying Burro Canyon Formation consists of greenish-gray claystone and yellowish-gray, medium-grained sandstone with lenses of green and red chert, and quartz pebbles. Sandstones of unit are very well indurated and generally form prominent outcrops. Freeman (1972) reported thicknesses for the Dakota Sandstone and Burro Canyon Formation as 200 ft and 225 ft, respectively, in the Woody Creek quadrangle to the east. Thickness of the combined unit in the Basalt quadrangle is 200 to 250 ft (Streufert, Widmann, and Kirkham, 2008). The best exposure of the unit is on the ridge north of Potato Bill Creek in sections 34 and 35, T. 8 S., R. 88 W. The Dakota Sandstone is conformable with the overlying Mancos Shale.

Jm

Morrison Formation (Upper Jurassic)—The Morrison Formation consists of pale-green, greenish-gray, and maroon variegated siltstone and claystone, buff to pale-yellowish-gray sandstone, and gray limestone. Sandstones are common in the lower half of the unit and may be equivalent to the Salt Wash Member in nearby areas. Thickness is variable but averages about 300 to 350 ft. The best exposure of the Morrison Formation is on the ridge north of Potato Bill Creek in sections 34 and 35, T. 8 S., R. 88 W. Contact with the overlying Dakota Sandstone and Burro Canyon Formation is sharp and unconformable.

Je

Entrada Sandstone (Upper Jurassic)—Composed of tan to white, medium- to fine-grained, well-sorted, poorly indurated, cross-bedded sandstone. Sand grains are mostly rounded to subrounded quartz grains. Thickness is about 40 to 60 ft. Exposure is generally poor due to the weakly cemented nature of the unit; however, it is well exposed on the ridge north of Potato Bill Creek in sections 34 and 35, T. 8 S., R. 88 W. Contact with overlying Morrison Formation is sharp and conformable.

Jme

Morrison Formation and Entrada Sandstone, undivided (Upper Jurassic)—Includes the Morrison Formation and Entrada Sandstone where poor exposures preclude mapping the formations separately.

Pℙm

Maroon Formation (Lower Permian and Upper Pennsylvanian)—Pale-red to pinkish-red, and grayish-red arkosic sandstone, conglomerate, siltstone, and mudstone, with shale and minor, thin beds of gray limestone comprise the Maroon Formation. All clastic rock types contain detrital mica. Sandstones are coarse to fine grained, moderately to poorly sorted, and contain sand grains that are generally angular to subangular. The formation crops out extensively in the western portion of the quadrangle, both in the Crystal River Valley and on ridges above Assignation and Camp Foster Creeks. The upper portion of the formation is well exposed on the ridge north of Potato Bill Creek in sections 34 and 35, T. 8 S., R. 88 W. The Triassic Chinle Formation and Permian/ Triassic State Bridge Formation are not identified in this exposure. The contact with the Entrada Sandstone is sharp and unconformable. Thickness of the unit in adjacent quadrangles to the north is 3,000 to 5,000 ft (Kirkham and others, 1996). Formation thickness in this quadrangle is difficult to assess because of structural complexities and limited exposure.

ℙe

Eagle Valley Formation (Middle Pennsylvanian)—Consists of interbedded reddish-brown, gray, reddish-gray, and tan siltstone, brownish-tan, fine- to coarse-grained, gypsiferous sandstone, gypsum, and carbonate rocks. Immediately adjacent to the Mount Sopris pluton these rocks have been contact metamorphosed to hornfels, quartzite, alabaster, and marble. The Eagle Valley Formation represents a stratigraphic interval in which the redbeds of the Maroon Formation grade into and intertongue with the predominantly evaporitic rocks of the Eagle Valley Evaporite. It includes rock types of both formations. The formation ranges from 500 to 3,000 ft thick to the north in the Carbondale quadrangle (Kirkham and Widmann, 2008), and it is less than 500 ft thick in the Basalt quadrangle (Streufert, Widmann, and Kirkham, 2008). Thickness of unit in the Mount Sopris quadrangle is variable but probably averages about 1,000 ft. The Eagle Valley Formation is conformable and intertongues with the overlying Maroon Formation and underlying Eagle Valley Evaporite. The contact with the Maroon Formation is placed at the top of the uppermost evaporite bed or light-colored clastic bed below the predominantly redbed sequence of the Maroon Formation.

In the Crystal River Valley the Eagle Valley Formation is frequently deformed by diapirism and flowage of evaporite. This is caused both by movement of intraformational evaporite and by diapirism from underlying beds of the Eagle Valley Evaporite. The formation is highly deformed in the core of the Elk Mountain Anticline on the south side of Perham Creek in the N ½ SW ¼ NE ¼ of section 20, T. 9 S., R. 88 W. This anticline may have been modified by salt tectonism after its formation.

The Eagle Valley Formation caps the east slopes of Mount Sopris in the southeast corner of the quadrangle. In this area the strata were concordantly deformed and contact metamorphosed by the intrusion of the granodiorite of Mount Sopris. This thin wedge of metamorphosed sedimentary rocks caps the east summit of the peak where all but the basal 40 ft of the formation have been removed by erosion. These sediments form a south-southeast dipping surface on the southeast and south sides of Mount Sopris. The contact zone between the Eagle Valley Formation and the granodiorite of Mount Sopris is well exposed on the east ridge of Mount Sopris in the NW ¼ of section 19, T. 9 S., R. 87 W. In this 1-mile-long exposure, the contact varies from sharp, with massive granodiorite immediately overlain by hornfels, quartzite, and marble, to a 10-ft-wide zone of brecciation in which granodiorite and contact metamorphosed rocks are complexly intermixed. Argillaceous beds in the Eagle Valley Formation have been metamorphosed to green to greenish-gray and white, banded and laminated to massive, diopside hornfels, all with a granoblastic texture. The diopside hornfels beds originally were probably dolomitic shale, siltstone, and fine-grained sandstone. Limestone beds in the contact metamorphic aureole have been altered to reddish-brown, dull-green, and white, massive, coarse- to medium-grained marble. Sandstone beds have been metamorphosed to granular, coarse-grained quartzites that locally contain blebs of magnetite. Brecciated zones are mineralogically similar to unbrecciated zones. A roof pendant of Eagle Valley Formation occurring 1,700 ft north of the west summit of Mount Sopris is a remnant of a magnetite skarn deposit formed in the zone of contact metamorphism (C. Pillmore, personal commun., 1998). The presence of this remnant magnetite skarn deposit, and magnetite-bearing quartzites, indicates that the intrusion of the granodiorite of Mount Sopris may have locally involved the exchange of volatile elements between the stock and the surrounding country rock.

Near the mouth of Avalanche Creek, beds of quartzite, marble, and alabaster, occurring in wedge of contact-metamorphosed Eagle Valley Formation, and Eagle Valley Evaporite are included in the mineable reserves of the Avalanche Creek Mine (see Economic Geology section).

Pee

Eagle Valley Evaporite (Middle Pennsylvanian)—The Eagle Valley Evaporite consists of a sequence of evaporitic rocks composed of massive to laminated gypsum, anhydrite, halite, and beds of light-colored mudstone and fine-grained sandstone, thin limestone, and black shale. Beds commonly are intensely folded, faulted, and ductily deformed by diapirism, flowage, dissolution-related subsidence or collapse, load metamorphism, hydration of anhydrite, and Laramide tectonism.

Gypsum beds are exposed on the west side of the Crystal River, across from the mouth of Avalanche Creek, in the core of the Elk Mountain Anticline. In this area thinly bedded clastic sediments of the overlying Eagle Valley Formation are intensely deformed in the exposed section located in the SE ¼ of section 20, T. 9 S., R. 88 W. This intense deformation occurs near exposures of the Eagle Valley Evaporite. Diaprism and/or flowage of evaporite may have modified this asymmetric anticline after its formation. Beds of white to gray, mottled, locally brecciated very fine-grained alabaster with veins of selenite occur in a zone of contact metamorphism just north of Avalanche Creek.

The base of the formation is not exposed in the quadrangle. To the north the thickness of the Eagle Valley Evaporite is reported to range from about 1,200 ft to perhaps 9,000 ft where it is tectonically thickened along the Grand Hogback (Mallory, 1971). A minimum thickness of 2,700 ft is reported by Kirkham and Widmann (2008) near Catherine, north of the quadrangle. On a seismic line described by Perry and others (2002) the formation appears to be as much as 4,600 ft thick in the Roaring Fork diapir, but no evaporite was identified east of the diapir beneath the Tertiary sediments. The contact with overlying Eagle Valley Formation is both conformable and intertonguing and is defined as the base of the lowest red bed. The Eagle Valley Evaporite may contain cavernous voids caused by near-surface dissolution of halite and gypsum.

GEOLOGIC SETTING

The Mount Sopris quadrangle is located at the northwest end of the Elk Mountains. The Mount Sopris stock is at the northwestern end of a series of mid-Tertiary plutons and associated intrusive bodies in the Elk Mountains. The quadrangle is located north of the Elk Range thrust fault and includes a portion of the Grand Hogback Monocline. Both of these features formed during the Laramide orogeny. The quadrangle also includes the Elk Mountain Anticline, an asymmetric fold that is possibly related to Laramide compressional tectonics, the emplacement of the granodiorite of Mount Sopris in the late Eocene, or both. This structure also was modified by salt tectonism. The west side of the Mount Sopris stock is 1.5 miles east of nearly vertical rocks in the Grand Hogback Monocline. In this narrow area, Pennsylvanian and Permian redbeds and evaporitic sequences are tightly folded across the Elk Mountain Anticline. Beds on the east limb of this structure dip to the east and northeast and are locally folded into a syncline adjacent to the Mount Sopris stock. The core of the Elk Mountain Anticline is very well exposed in Perham Creek in the NE ¼ of section 20, T. 9 S., R. 88 W. In this area highly deformed beds of the Eagle Valley Formation are characterized by thrusting and fault-bend-fold development within beds in the formation (intraformational deformation). This deformation may be related to diapiric movement of evaporite beneath the exposed core of the anticline in this area.

Mount Sopris stock has a concordant contact with bounding sediments on the east and south sides. Structure relating to the intrusion of the Mount Sopris stock on its northwest and north sides has been largely modified by post-intrusion deformation during the Neogene related to the formation of the Carbondale Collapse Center (Kirkham, Streufert, and others, 2002). The Carbondale Collapse Center is a regional structural depression formed in response to dissolution and flowage of evaporite in the Eagle Valley Evaporite and Eagle Valley Formation.

The southern margin of the Carbondale Collapse Center is on the north side of Mount Sopris. Thick sequences of Tertiary sediments were deposited in a localized depocenter called Sopris Bowl within the larger Carbondale Collapse center (Kirkham, Streufert, and others, 2002). The southern extent of the thick Tertiary sediments is interpreted as defining the margin of the collapse center in the Mount Sopris quadrangle. Perhaps the best exposure of the collapse margin is north and northeast of Potato Bill Creek where the Tertiary sediments are faulted against Mesozoic rocks. The impressive topographic relief on the north side of Mount Sopris probably is in part due to evaporite collapse.

Tertiary sediments within Sopris Bowl overlie and therefore are younger than an ash-flow tuff in the Basalt quadrangle (Streufert, Widmann, and Kirkham, 2008). Since the tuff was dated at 35.21 ± 0.03 Ma (Kunk and others, 2002), Sopris Bowl began to form after latest Eocene or early Oligocene time. A basalt flow interbedded with the Tertiary sediments in the Basalt quadrangle yielded an age of 13.57 ± 0.05 Ma, and basalt flows that lie stratigraphically at or near the top of the Tertiary sediments in Carbondale quadrangle have an average age of about 13.3 Ma (Kunk and others, 2002; Streufert, Widmann, and Kirkham, 2008; Kirkham and Widmann, 2008). The timing of collapse in Sopris Bowl on the north flank of Mount Sopris predates most deformation in other parts of the Carbondale Collapse Center. This evidence, along with the proximity of the Mount Sopris stock to Sopris Bowl, led Kirkham, Streufert, and others (2001, 2002) to speculate that an increased geothermal gradient and other hydrologic changes associated with the intrusion may have triggered the early collapse on the north flank of Mount Sopris. Clast lithologies in the Tertiary sediments within Sopris Bowl suggest that both the Crystal and Roaring Fork Rivers flowed into the collapse area.

Geologic Hazards and Constraints

Geologic hazards and constraints in the Mount Sopris quadrangle include debris flows, floods, unstable slopes, problematic soils, earthquakes, and subsidence. Areas mapped as younger debris-flow deposits (unit Qdfy) are prone to future debris flows, mud flows, and floods. Areas mapped as intermediate debris-flow deposits could be prone to these hazards in the event that active channels plug with debris and flood depths rise. Low-lying areas mapped as units Qa and Qac are subject to stream flooding, and areas mapped as units Qsw and Qcs may be affected by sheet flooding.

Landslide deposits (unit Qls) are relatively common in the quadrangle. They are especially abundant in areas underlain by the Mancos Shale and Tertiary sediments (unit Ts). Although no recently active landslides were identified in the quadrangle, areas mapped as landslide deposits are prone to reactivation, particularly if disturbed by human activities, and they are indicative of the types of geologic environments that are favorable for future slope failures. There is moderate to high potential for future rockfall below cliffs of well-indurated bedrock. Areas mapped as talus (unit Qt) on the flanks of Mount Sopris are very prone to rockfall. Some areas mapped as colluvium (unit Qc) also may have rockfall hazards.

The Mancos Shale and surficial deposits derived from it may pose swelling soil problems. The Eagle Valley Evaporite and surficial deposits derived from it may be corrosive. White (2002) developed a geologic hazard map that characterized collapsible soils in the northern part of the quadrangle and in the Roaring Fork River Valley further north. The derivative approach to collapsible soils used by White (2002) can be applied to the units throughout the Mount Sopris quadrangle. The hydrocompaction potential of sheetwash deposits (unit Qsw), fine-grained colluvium (unit Qc) and alluvium and colluvium, undivided (unit Qac) is moderate to high. These deposits, along with the older debris-flow deposits (unit Qdfo), also have moderate to high potential for settlement and piping.

Historic earthquakes have shaken the region on numerous occasions, most recently in 1984 when a swarm of small events occurred west of the quadrangle (Goter and others, 1988). Future earthquakes, some possibly strong enough to cause damage, casualties, and trigger secondary effects such as landslides and rockfall, may affect the quadrangle in the future.

Sinkholes and subsidence related to evaporite karst may affect areas underlain by the Eagle Valley Evaporite (White, 2002; Mock, 2002). Modern rates of ground movement related to regional and local evaporite collapse and diapirism are poorly constrained. If these rates are sufficiently high to pose hazards, then these types of deformation should be considered by geotechnical site investigations.

ECONOMIC GEOLOGY

The Pennsylvanian Eagle Valley Evaporite has been metamorphosed to alabaster north of Avalanche Creek in the S ½ NW ¼ of section 28, T. 9 S., R. 88 W. The alabaster bed, together with beds of marble and hornfels in the overlying Pennsylvanian Eagle Valley Formation, comprise the mineable reserves of Avalanche Creek Marble and Alabaster Company, Carbondale, Colo. (R. Congden, personal commun., 1998). The Avalanche Creek Mine works a thick bed of massive, locally selenite-veined, alabaster, mostly for statuary blocks. The company also produces tile in its cutting plant in Carbondale, Colo. In addition, beds of marble and quartzite stratigraphically above the alabaster beds are an identified resource at the mine (R. Congden, personal commun., 1998). These contact metamorphosed beds are part of a wedge of upper Paleozoic rock that is cradled between the Mount Sopris stock and the Bulldog stock, a satellite granitoid body of similar composition to the south.

An area of weakly developed lead-zinc-silver mineralization (Bulldog district) is localized along the contact of the Mount Sopris pluton with Pennsylvanian clastic rocks on the southeast side of Mount Sopris in the Redstone quadrangle. Schwartz and Park (1930) described galena with stromeyerite, argentite, covellite, and bornite from the Bulldog Mine. Foland (1967), Pilkington (1954), and Pillmore (1954) studied the petrology and petrography of Mount Sopris and all mention this metal occurrence. These vein deposits are small, occur only on the southeast side of the Mount Sopris pluton, and are localized at the intrusive contact. Similar veins were not observed during this study near the much less altered contacts in the Mount Sopris quadrangle. Many of the thick gravel deposits in the north half of the quadrangle are a source of sand and gravel. These thick gravel deposits are probably the most valuable mineral resource in the quadrangle.

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APPENDIX A

Appendix A: Major and trace element, whole-rock XRF analyses of igneous rocks in Mount Sopris quadrangle. Sample locations are given in the lower table and are also shown on the accompanying geologic map. All analyses by Chemex Labs Inc., Sparks, Nevada.

Major Elements						Weight Percent							
Sample ID	SiO_2	Al_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	TiO_2	LOI*	Total
MSR-1	68.64	15.80	1.61	<0.01	1.44	0.17	1.20	0.03	8.77	0.26	0.56	1.20	99.96
MSR-17	65.55	15.48	3.05	<0.01	3.32	3.50	1.22	0.05	4.85	0.23	0.55	0.85	98.65
MSR-18	65.08	15.64	2.94	<0.01	4.13	4.41	1.12	0.04	3.71	0.24	0.53	0.70	98.54
MSR-24	65.34	15.30	3.26	<0.01	4.24	3.65	1.29	0.05	3.99	0.24	0.55	1.08	98.99
MSR-25	63.02	15.76	3.71	<0.01	4.42	3.22	1.26	0.06	4.01	0.24	0.50	2.66	98.86
MSR-27	65.33	15.58	4.02	<0.01	0.74	0.44	0.16	0.03	8.07	0.27	0.54	3.39	98.57

*LOI=Loss On Ignition

Trace Elements					Parts Per Million					
Sample ID	Ba	Ca	Hf	La	Nb	Rb	Sr	Ta	Y	Zr
MSR-1	138	<1	6	54	13	5	143	<1	24	208
MSR-17	1365	<1	4	48	12	45	611	<1	26	184
MSR-18	1445	<1	5	38	12	79	600	<1	26	212
MSR-24	1215	<1	5	60	12	78	564	<1	25	200
MSR-25	1370	<1	4	43	7	57	664	<1	24	171
MSR-27	173	<1	5	41	11	19	170	<1	20	168

Sample Location (NAD27)			
Sample ID	Map Unit	Latitude	Longitude
MSR-1	Tgs	39.2614° N	107.1641° W
MSR-17	Tgs	39.2572° N	107.1515° W
MSR-18	Tgs	39.2553° N	107.2029° W
MSR-24	Tgs	39.2694° N	107.2014° W
MSR-25	Tgs	39.2507° N	107.2155° W
MSR-27	Tgs	39.2614° N	107.1641° W

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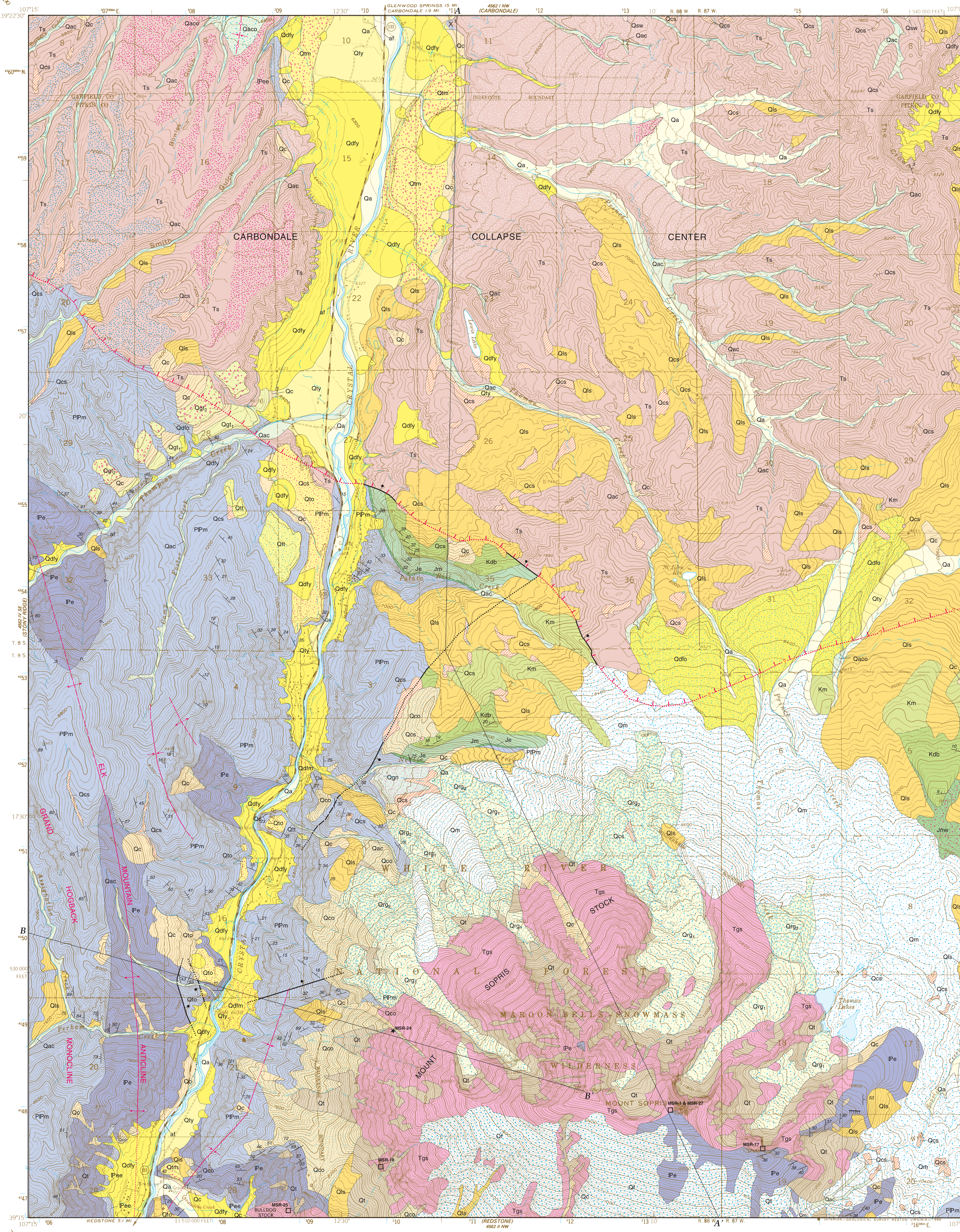
DENVER, COLORADO



Base from U.S. Geological Survey, 1987
Polyconic projection, 1927 North American datum
10,000-foot grid based on Colorado coordinate system, central zone

UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24,000

QUADRANGLE LOCATION

Geology mapped in 1998
Digital map prepared by Cheryl Brchan and Larry Scott

CONDENSED DESCRIPTION OF MAP UNITS

The complete description of map units and references is in the accompanying booklet.

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af — **Artificial fill (latest Holocene)**

ALLUVIAL DEPOSITS—Sediments deposited in stream channels, flood plains, glacial outwash terraces, and sheetwash areas

Qa — **Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)**—Mostly poorly sorted, clast supported gravel in a sandy or silty matrix. Includes terraces up to about 10 ft above modern river level

Qsw — **Sheetwash deposits (Holocene and late Pleistocene)**—Pebbly silty sand, sandy silt, and clayey silt deposited in ephemeral and intermittent stream valleys, on gentle hillslopes, and in basinal areas

Qty — **Younger terrace alluvium (late Pleistocene)**—Mostly poorly sorted, clast-supported, locally bouldery, pebble and cobble gravel in a sand and silt matrix. Underlies terraces about 10–45 ft above the Crystal River. May include fine-grained overbank deposits

Qtm — **Intermediate terrace alluvium (late Pleistocene)**—Deposits texturally and depositionally similar to younger terrace alluvium (Qty). Underlies terraces about 80 to 120 ft above the Crystal River

Qto — **Older terrace alluvium (late middle Pleistocene)**—Deposits texturally and depositionally similar to younger terrace alluvium (Qty). Clasts slightly to moderately weathered. Underlies terraces about 120 to 200 ft above the Crystal River and Prince Creek

Qtt — **Oldest terrace alluvium (middle and early? Pleistocene)**—Consists of poorly sorted to moderately well-sorted, clast-supported, slightly bouldery, cobble and pebble gravel with a sand matrix. May contain lenses and beds of sandy silt and silty sand. Clasts are moderately to strongly weathered. Underlies terraces about 400 to 600 ft above the Crystal River

Terrace Alluvium of Thompson Creek

Qgt1 — **Younger terrace alluvium of Thompson Creek (late Pleistocene)**—Chiefly poorly sorted, clast-supported, bouldery, pebble and cobble gravel in a sand and silty sand matrix. Clasts are predominantly vesicular basalt and sedimentary rocks. Unit underlies terraces that are about 80 to 160 ft above Thompson Creek

Qgt2 — **Older terrace alluvium of Thompson Creek (middle Pleistocene)**—Similar in texture, sorting, lithology, and genesis to younger terrace alluvium of Thompson Creek (Qgt1), except clasts are moderately to highly weathered. Unit underlies terraces that are about 320 to 400 ft above Thompson Creek

MASS-WASTING DEPOSITS—Sediments transported and deposited primarily by gravity on valley sides, valley floors, and hillslopes

Qc — **Colluvium (Holocene and late Pleistocene)**—Ranges from unsorted, clast-supported, pebble to boulder gravel in a sandy silt matrix to matrix-supported gravelly, clayey, sandy silt. Usually coarser grained in upper reaches of a colluvial slope and finer grained in distal areas

Qt — **Talus (Holocene and late Pleistocene)**—Angular, cobbly and bouldery rubble derived from outcrops of granodiorite of Mount Sopris (Tgs) and metamorphosed sediments of the Eagle Valley Formation (IPe)

Qls — **Landslide deposits (Holocene and Pleistocene)**—Highly variable deposits consisting of unsorted, unstratified rock debris, gravel, sand, silt, and clay that was deposited as rotational and translational landslides, complex slump-earthflows, and extensive slope-failure complexes. Range in age from recently active landslides to long-inactive landslides

Qco — **Older colluvium (Pleistocene)**—Found on drainage divides, ridge lines, and dissected hillslopes in a north-south-trending zone below the steep exposed west and northwest margins of the Mount Sopris pluton. Locally contains large blocks and rock-topple deposits. Generally not subject to future deposition except where adjacent to eroding hillslopes

ALLUVIAL AND MASS-WASTING DEPOSITS—Sediments in debris fans, stream channels, flood plains, and hillslopes along tributary valleys

Qdfy — **Younger debris-flow deposits (Holocene)**—Ranges from poorly sorted to moderately well-sorted, matrix-supported, gravelly, sandy, clayey silt to clast-supported, pebble and cobble gravel in a sandy, clayey silt or silty sand matrix. Fan heads tend to be bouldery, while distal fan areas are finer grained. Includes debris-flow, hyperconcentrated-flow, fluvial, and sheetwash deposits on active fans and in some drainage channels

Qac — **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Ranges from poorly sorted to well-sorted, stratified, interbedded, pebbly sand, sandy silt, and sandy gravel to unsorted and unstratified to poorly stratified, clayey, silty sand, bouldery sand, and sandy silt

Qcs — **Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene)**—Composed of colluvium (Qc) on steeper slopes and sheetwash deposits (Qsw) on flatter slopes. Mapped where contact between the two types of deposits are very gradational and difficult to locate

Qdfm — **Intermediate debris-flow deposits (Holocene? and late Pleistocene)**—Similiar in texture, lithology, and depositional environment to younger debris-flow de-posits (Qdfy). Geomorphic character of original deposi-tional surfaces are commonly recognizable, but the surfaces are 10 ft or more above active debris-flow channels

Qdfo — **Older debris-flow deposits (late and middle? Pleistocene)**—Occurs in three remnants of a large debris fan north of Mount Sopris near the heads of Prince and Thomas Creeks. Deposits are dark-gray to black, gravelly, sandy, clayey silt with scattered cobbles, and occasional boulders of Mount Sopris granodiorite (Tgs). Unit may correlate with the gravel of Nettle Creek (Qgn)

Qaco — **Older alluvium and colluvium, undivided (late and middle? Pleistocene)**—Deposits of alluvium and colluvium ranging from about 10 to 100 ft above and adjacent to perennial, intermittent, and ephemeral streams. Texture, bedding, clast lithology, sorting, and genesis are similiar to alluvium and colluvium (Qac). Unit locally includes debris-flow and sheetwash deposits

Qgn — **Gravel of Nettle Creek (middle? Pleistocene)**—Includes a single deposit south of Nettle Creek. Unit consists of poorly sorted, matrix-supported, occasionally bouldery, pebble and cobble gravel in a sandy, clayey silt, or silty sand matrix. Locally includes lenses of moderately well-sorted, matrix- to clast-supported, gravelly, sandy, clayey silt. Unit is probably of debris-flow origin

PERIGLACIAL DEPOSITS—Coarse rock debris and sediments deposited in cold environments by the processes of freeze-thaw action, nivation, and solifluction

Qf — **Felsenmeer (Holocene and late Pleistocene)**—Consists of angular to subangular boulders, cobbles, and pebbles in a sandy matrix that mantles the upper south slopes of Mount Sopris above 9,000 ft. Clasts are granodiorite of Mount Sopris (Tgs) and quartzite and hornfels of the Pennsylvanian Eagle Valley Formation (IPe)

ROCK-GLACIER DEPOSITS—Very coarse rock debris and sediments originating as talus and colluvium that were transported and deposited by rock glaciers

Qrg1 — **Younger rock-glacier deposits (Holocene and late Pleistocene?)**— Angular to subangular, predominantly boulder-sized rock fragments of granodiorite of Mount Sopris (Tgs) and metamorphosed sediments of the Pennsylvanian Eagle Valley Formation (IPe) mantling ice-cored, lobate, tongue-like, rock glaciers emanating from steep cirques on the north and northwest sides of Mount Sopris. Covering mantle is clast supported and matrix free. Cores are a mixture of rock rubble and interstitial fine-grained sediments in a matrix of ice or permafrost. Younger rock glaciers are currently active

Qrg2 — **Older rock-glacier deposits (Holocene and/or late Pleistocene)**—Consists of angular to subrounded, boulders and cobbles of Mount Sopris granodiorite (Tgs) and Pennsylvanian Eagle Valley Formation (IPe) in a matrix of unsorted rock fragments, sand, silt, and clay. Unit is mostly clast supported but may contain areas that are matrix supported. Deposits are genetically similar to younger rock glacier deposits (Qrg1) but are inactive

GLACIAL DEPOSITS—Gravel, sand, silt, and clay deposited by or adjacent to ice in moraines

Qm — **Morainal deposits, undivided (late and late middle? Pleistocene)**—Heterogeneous deposits of gravel, sand, silt, and clay deposited by, adjacent to, or beneath ice as ground, lateral, and end moraine on the north and northeast sides of Mount Sopris. Locally includes glacio-fluvial deposits. Dominantly poorly sorted, unstratified or poorly stratified, matrix-supported, bouldery, pebble and cobble gravel with a matrix of silty sand. Clasts are typically angular to subrounded pieces of granodiorite of Mount Sopris (Tgs), with lesser amounts of Paleozoic sedi-mentary rocks. May include deposits of Pinedale and Bull Lake ages

UNDIFFERENTIATED SURFICIAL DEPOSITS

Q — **Surficial deposits, undifferentiated (Quaternary)**—Shown only on cross sections. May include any of the above surficial deposits

BEDROCK

Ts — **Sedimentary deposits (Miocene)**—Moderately indurated to unconsolidated deposits of sandy gravel that are locally bouldery, gravelly sand and silt deposited in a large subsidence depression. Pattern indicates an erosion surface is present on the unit. Thin mantle of younger sediments overlies these erosion surfaces. Upper pattern indicates erosion surface and overlying sediments are late middle Pleistocene in age; middle pattern indicates middle and/or early Pleistocene age; lower pattern indicates early Pleistocene or late Tertiary age

Tgs — **Granodiorite of Mount Sopris (Eocene)**—Mount Sopris stock is predominantly granodiorite; however, the unit locally contains tonalite and quartz monzodiorite phases. Bulldog stock, located beneath and south of Avalanche Creek, is mineralogically similar but has been affected by argillic alteration. $^{40}Ar/^{39}Ar$ integrated date of 34.74 ± 0.19 Ma on biotite indicates the age of cooling of the Mount Sopris stock through 350°C (Esser and McIntosh, 1999)

Km — **Mancos Shale (Upper Cretaceous)**—Predominantly medium- to dark-gray, carbonaceous, silty to sandy shale with minor bentonite beds, dark-gray limestone, and medium-gray, grayish-yellow-weathering, clayey sandstone. May includes the Fort Hays Limestone Member, a dark-gray, thickly bedded limestone which occurs about 300 ft above the base

Kdb — **Dakota Sandstone and Burro Canyon Formation, undivided (Lower Cretaceous)**—Dakota Sandstone consists of light-gray to tan, medium- to coarse-grained, moderately well-sorted quartz sandstone and conglomeratic sandstone in well-cemented, thick beds. Dakota Sandstone also contains shale, carbonaceous shale, and coal beds. Burro Canyon Formation consists of greenish-gray claystone and yellowish-gray, medium-grained sandstone with lenses of green and red chert, and quartz pebbles

Jm — **Morrison Formation (Upper Jurassic)**—Pale-green, greenish-gray, and maroon variegated siltstone and claystone, buff to pale-yellowish-gray sandstone, and gray limestone. Sandstones are common in the lower half of unit and may be equivalent to the Salt Wash Member in nearby areas

Je — **Entrada Sandstone (Upper Jurassic)**—Tan to white, medium- to fine-grained, well-sorted, poorly indurated, cross-bedded sandstone. Sand grains are mostly rounded to subrounded quartz

Jme — **Morrison Formation and Entrada Sandstone, undivided (Upper Jurassic)**—Includes Morrison Formation (Jm) and Entrada Sandstone (Je) where contact between the two units is not mappable

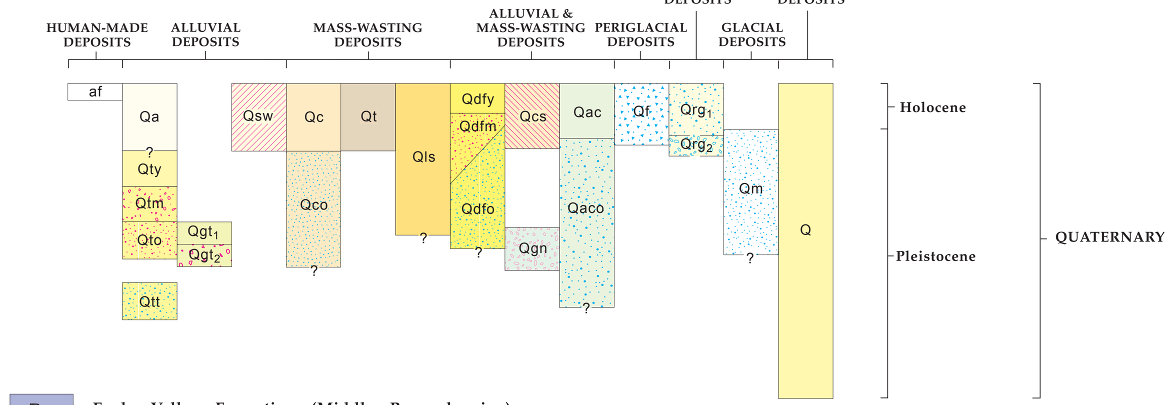
PIPm — **Maroon Formation (Lower Permian and Upper Pennsylvanian)**—Pale-red to pinkish-red, and grayish-red arkosic sandstone, conglomerate, siltstone, and mudstone, with shale and minor, thin beds of gray limestone. All rock types contain detrital mica. Sandstones are coarse to fine grained, moderately to poorly sorted. Sand grains are generally angular to subangular

IPm — **Eagle Valley Formation (Middle Pennsylvanian)**—Interbedded reddish-brown, gray, reddish-gray, and tan siltstone, brownish-tan, fine- to coarse-grained, gyp-siferous sandstone, gypsum, and carbonate rocks. Immediately adjacent to the Mount Sopris pluton these rocks have been contact metamorphosed to hornfels, quartzite, alabaster, and marble

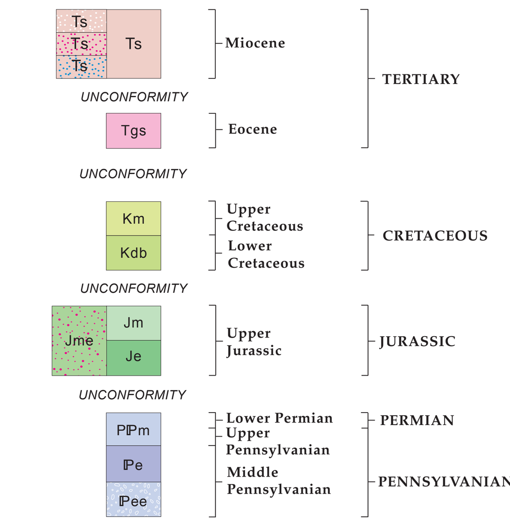
IPee — **Eagle Valley Evaporite (Middle Pennsylvanian)**—Sequence of evaporitic rocks consisting of massive to laminated gypsum, anhydrite, halite, and beds of light-colored mudstone and fine-grained sandstone, thin limestone, and black shale. Beds commonly are intensely folded, faulted, and ductily deformed by diapirism, flowage, dissolution-related subsidence or collapse, load metamorphism, hydration of anhydrite, and Laramide tectonism. Includes metamorphosed beds of alabaster

CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS



BEDROCK



MAP SYMBOLS

Contact—Dashed where approximately located; queried where uncertain

Fault—Dashed where approximately located; dotted where concealed; bar and ball on downthrown side

Anticline—Showing trace of axial surface; dashed where approximately located; dotted where concealed

Syncline—Showing trace of axial surface; dashed where approximately located; dotted where concealed

Asymmetric Syncline—Showing trace of axial surface; shorter arrow indicates steeper limb; dashed where approximately located; dotted where concealed

Synclinal sag or subsidence trough—Showing trace of axial surface of minor synclinal depression or swale related to dissolution and/or flowage of underlying evaporitic bedrock; dashed where approximately located

Margin of late Cenozoic collapse center—Collapse caused by evaporite tectonism; black line and red tick marks used where margin coincides with faults; dotted where concealed; queried where uncertain

X f — **Filled sinkhole**—Created by dissolution of evaporite; filled with collapse debris

9 — **Strike and dip of beds—Angle of dip shown in degrees**

A——A′ — **Alignment of cross sections**

Sackung feature—Ridgetop trench produced by deep-seated rock creep

MSR-24 — **Location and identification number of rock sample—with geochemical analysis (Table 1) and $^{40}Ar/^{39}Ar$ age date (Kunk and others, 2002). See Table 1 and Appendix A in booklet.**

MSR-17 — **Location and identification number of rock sample with geochemical analysis. See Table 1 and Appendix A in booklet.**

Mine portal

ACKNOWLEDGMENTS

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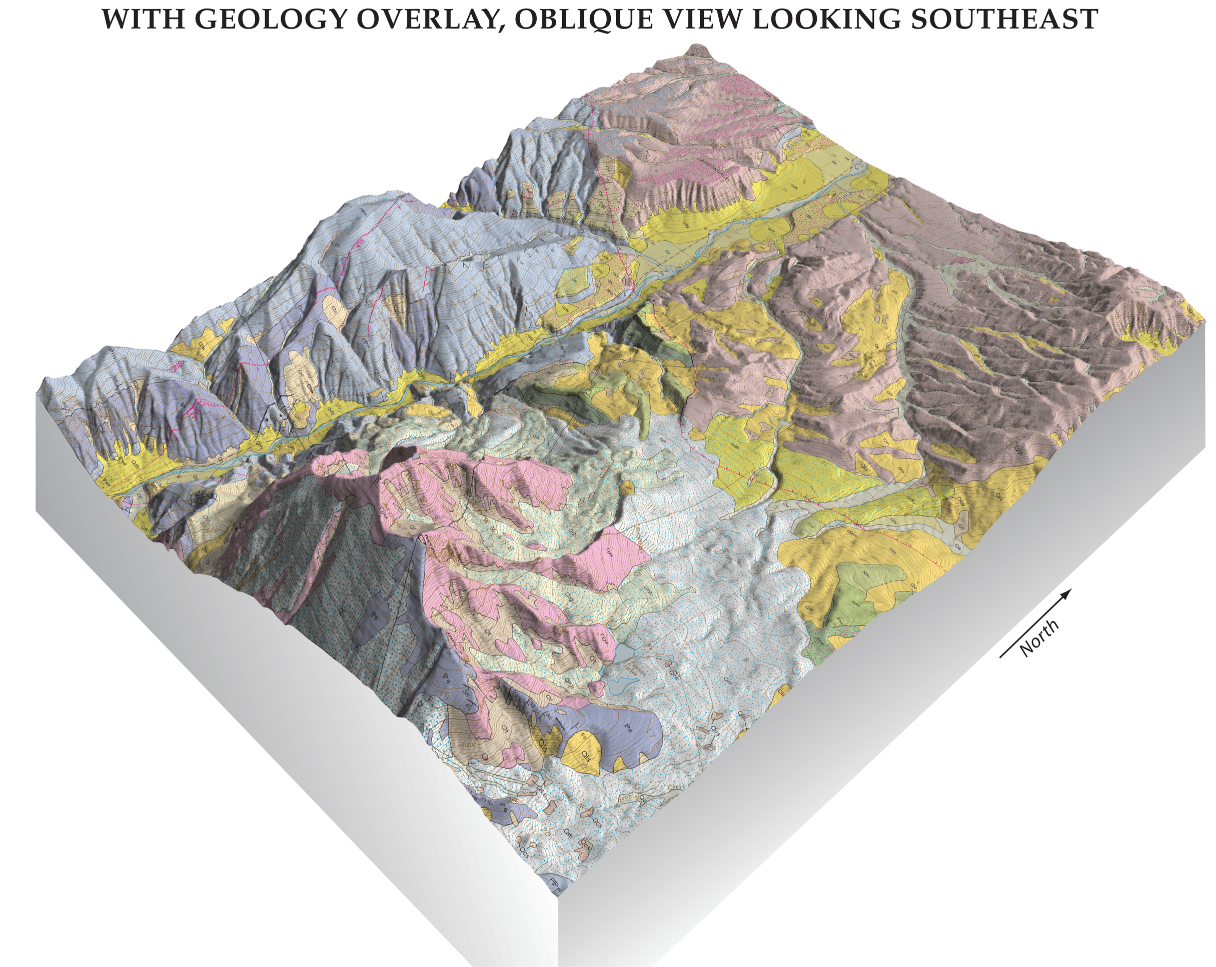
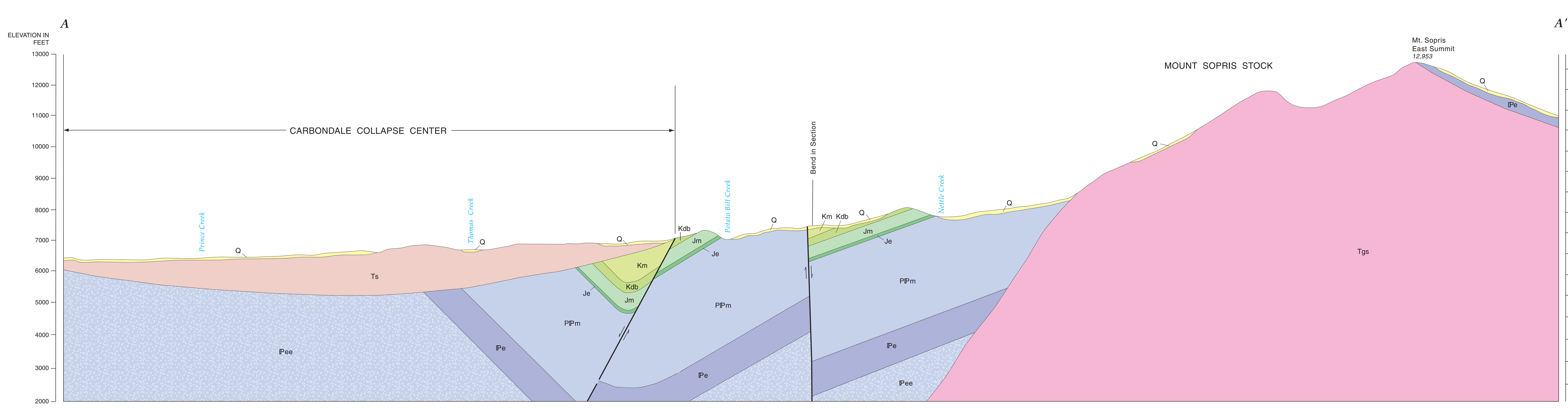
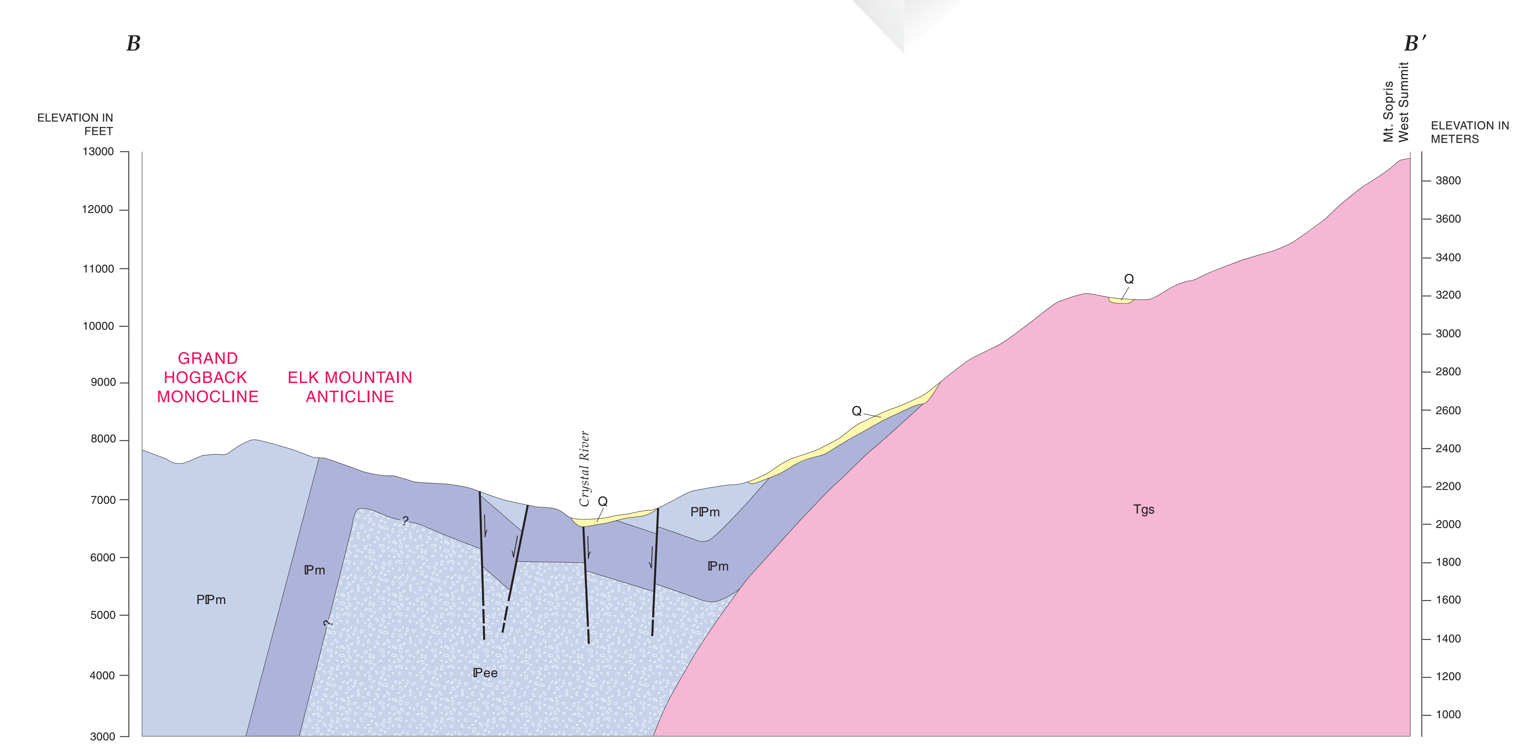
SHADED-RELIEF MAP OF THE MOUNT SOPRIS QUADRANGLE WITH GEOLOGY OVERLAY, OBLIQUE VIEW LOOKING SOUTHEAST







GEOLOGIC MAP OF THE MOUNT SOPRIS QUADRANGLE, GARFIELD AND PITKIN COUNTIES, COLORADO

By Randall K. Streufert
2008

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