Map Series 39

Geologic Map of the Basalt Quadrangle, Eagle, Garfield and Pitkin Counties, Colorado

By Randall K. Streufert, Beth L. Widmann, and Robert M. Kirkham

Bill Ritter Jr., Governor
State of Colorado

COLORADO
DEPARTMENT OF NATURAL RESOURCES

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State Geologist and Director
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FOREWORD

The Colorado Department of Natural Resources is pleased to present the Colorado Geological Survey Map Series 39, *Geologic Map of the Basalt Quadrangle, Eagle, Garfield and Pitkin Counties, Colorado*. Its purpose is to describe the geologic setting of this 7.5-minute quadrangle, which is located in the Roaring Fork River Valley and includes the town of Basalt.

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 1434-HQ-97-AG-01811 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 Basalt quadrangle (Streufert and others, 1998) benefited from reviews by Bruce Bryant and Jim Cappa. Jane Ciener was the technical editor of the earlier CGS open-file report. Beth Widmann edited the updated version. The following geologists provided helpful suggestions during the course of the study: Tim Schroeder, Dick Moore, Florian Maldonado, Val Freeman, Karl Kellogg, Dan Larsen, and Wendy Meyer. Sylvia White and Robin VerSchneider assisted with field work. Photogrammetric models of annotated aerial photographs were set by Jim Messerich on a Kern PG-2 plotter. We appreciate the many helpful landowners who gave permission to enter their properties.

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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 Basalt 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 98-1 (Streufert and others, 1998).

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 Basalt quadrangle, six other quadrangles in the Glenwood Springs area are being digitally updated. They include the Glenwood Springs, Shoshone, Carbondale, Cottonwood Pass, Mount Sopris, Basalt, and Leon quadrangles (Fig. 1).

Most other modifications to the map and booklet are a result of (1) edge matching the geology shown on the Basalt 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

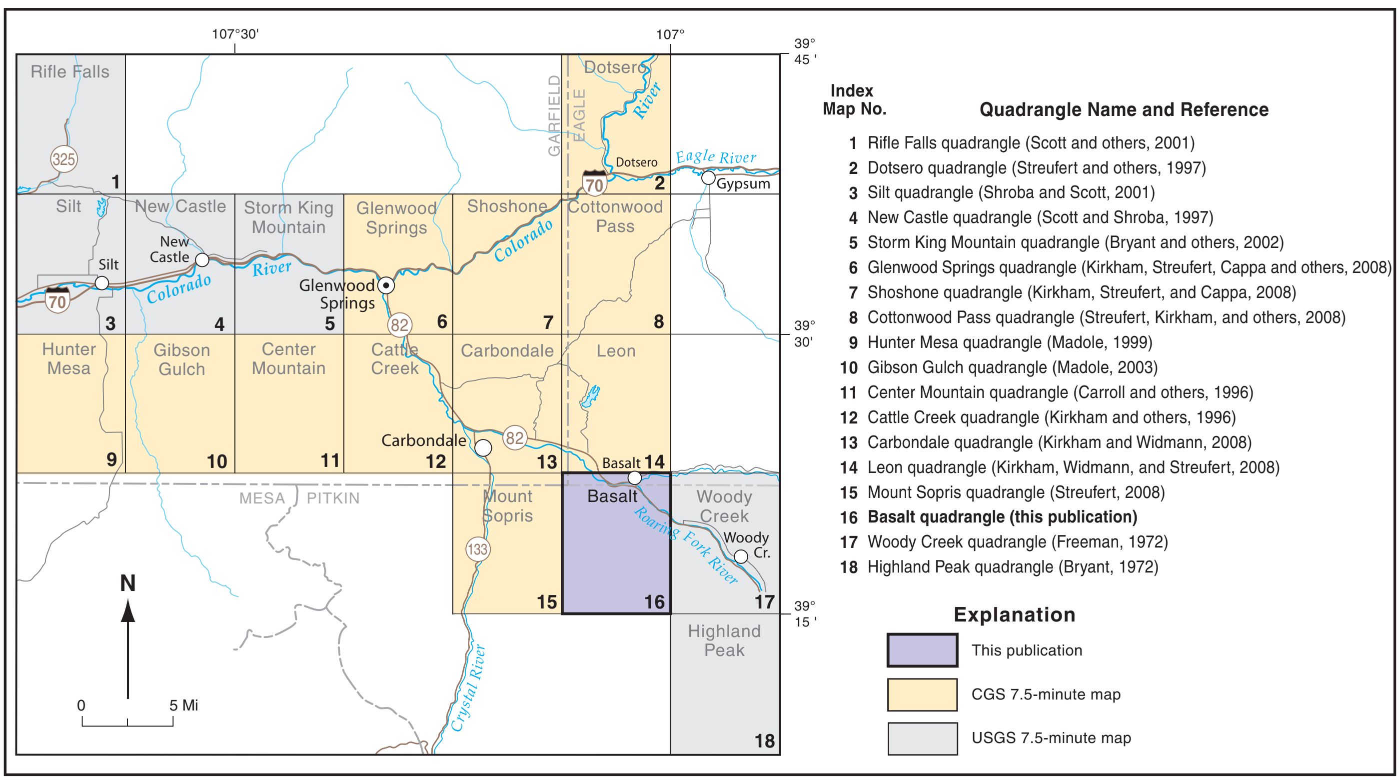


Figure 1. Geologic maps of 7.5-minute quadrangles in the vicinity of the Basalt quadrangle.

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 Basalt quadrangle covers about 58 square miles in Eagle, Garfield, and Pitkin Counties, which are in west-central Colorado. The Roaring Fork River flows from southeast to northwest across the northeast part of the quadrangle. Colorado highway 82 follows the Roaring Fork River Valley in the quadrangle. The town of Basalt lies at the confluence of the Frying Pan River and Roaring Fork River. Several important perennial creeks are within the quadrangle, including Capital Creek, East Sopris Creek, and West Sopris Creek. Most land in the southwestern part of the quadrangle is public land administered by the White River National Forest. The remainder of the quadrangle includes interspersed private property and public lands managed by either the U.S. Bureau of Land Management or Colorado Division of Wildlife. The 1:24,000-scale topographic base map of the quadrangle was first published in 1961 and later updated in 1982 using aerial photographs taken in 1979.

R.K. Streufert and B.L. Widmann mapped most of the bedrock and some of the surficial deposits. R.M. Kirkham mapped most of the surficial deposits and also is responsible for the current modifications to the original geologic map and booklet and for preparation of the updated digital product, which was reviewed by Ms. Widmann.

PRIOR GEOLOGIC MAPS

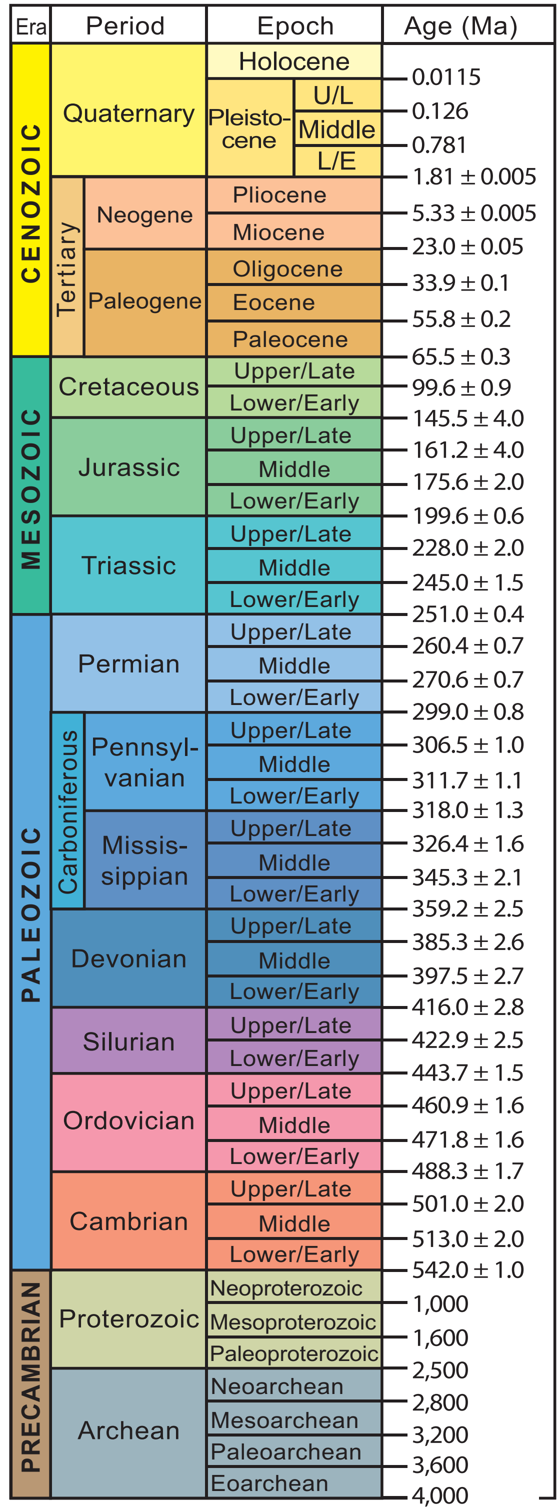
Previously published small-scale geologic maps of the Basalt quadrangle include 1:500,000-scale maps by Burbank and others (1935) and Tweto (1979), the 1:250,000-scale map of Tweto and others (1978), and the 1:100,000-scale map of Ellis and Freeman (1984). F.M. Fox and Associates (1974) mapped all but the southwestern part of the quadrangle at a scale of 1:48,000. CGS originally mapped the Basalt quadrangle at a scale of 1:24,000 and released it as Open-File Report 98-1 (Streufert and others, 1998).

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.

Volcanic rocks are classified on the basis of the total alkali-silica diagram of Le Bas and others (1986). 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. Deposits associated with distinct landforms may locally be thinner than 5 ft. Surficial deposits with a width less than about 25 ft are not shown on the map because they cannot be depicted on a 1:24,000-scale map. Artificial fill of limited areal extent and residuum were not mapped. Contacts between many surficial units may be gradational and therefore should be considered as approximate boundaries.

Most of the surficial deposits in the Basalt quadrangle are not well exposed. Therefore, the attributes of these units, such as thickness, texture, stratification, and composition, are based on observations made at only a few locations and on geomorphic characteristics. Since some of the intended users of this map will be interested in unconsolidated surficial materials and active surficial processes, the surficial deposits are subdivided into a relatively large number of map units compared to traditional bedrock-oriented geologic maps.

Characteristics such as the position in the landscape, degree of erosional modification of original surface morphology, and relative degree of weathering and soil development were used to estimate the relative ages for the surficial deposits. Prior age estimations of the terrace deposits along the Roaring Fork River by Piety (1981) were used in this map. Soil-horizon names used here are those of the Soil Survey Staff (1975) and Guthrie and Witty (1982), and the stages of secondary carbonate morphology are from Gile and others (1966), with the modifications of Machette (1985).

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 30 ft.

ALLUVIAL DEPOSITS—Silt, sand, and gravel deposited in stream channels, flood plains, glacial-outwash terraces, and sheetwash areas along the Roaring Fork and Fryingpan Rivers and their tributaries.

Qa

Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)—Includes modern stream channel deposits of the Roaring Fork River, Fryingpan River, and Capital Creek, 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 that is 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 both the Roaring Fork and Fryingpan Rivers contain clasts of Proterozoic plutonic 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 about 50 ft.

Qsw

Sheetwash deposits (Holocene and late Pleistocene)—Includes deposits locally derived from weathered bedrock and surficial materials that are transported predominantly by sheetwash and deposited in valleys of ephemeral and intermittent streams, on gentle slopes, or in basinal areas. Sheetwash deposits are common on gentle to moderate slopes underlain by landslide deposits. Sheetwash deposits typically consist of pebbly, silty sand and sandy silt. Locally gradational and interfingering with colluvium from steeper slopes above. Maximum thickness is about 25 ft.

Qty

Younger terrace alluvium (late Pleistocene)—Chiefly stream alluvium underlying terraces that range from about 14 to 50 ft above modern stream level. Younger terrace alluvium is mostly poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand and silt matrix, but the unit may include fine-grained overbank deposits or be capped by a single, thin loess sheet. Clasts are mainly subrounded to rounded and are comprised of a variety of lithologies reflecting the diverse types of bedrock found in the drainage basin. Deposits of younger terrace alluvium along the Roaring Fork and Fryingpan Rivers contain coarse-grained Precambrian plutonic clasts. Clasts generally are unweathered or only slightly weathered. Thickness averages 30 to 40 ft. Unit Qty may correlate with terrace T7 in the Glenwood Springs-Carbondale area of Piety (1981), with terrace A of Bryant (1979), or with terrace gravel "a" (Qga) of Freeman (1972). Younger terrace alluvium was probably deposited during the latter part of the late Pleistocene Pinedale glaciation.

Qtm

Intermediate terrace alluvium (late Pleistocene)—Composed of stream alluvium that underlies a terrace about 60 to 70 ft above the Roaring Fork River along the eastern edge of the quadrangle. Intermediate terrace alluvium consists of poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand matrix. Locally unit Qtm may be capped by a thin loess sheet. Clasts are chiefly subrounded to round and consist of various lithologies that reflect the types of bedrock found in the drainage basin. Clasts generally are only slightly weathered at shallow depths. The thickness of unit Qtm averages 20 to 50 ft. Intermediate terrace alluvium may correlate with deposits in terrace T6 in the Glenwood Springs-Carbondale area (Piety, 1981), with terrace B deposits of Bryant (1979), or with terrace gravel "b" (Qbg) of Freeman (1972), which probably were deposited during the early part of the late Pleistocene Pinedale glaciation.

Qto

Older terrace alluvium (middle and early? Pleistocene)—Includes deposits of stream alluvium in a terrace in the N ½ SW ¼ of Sec. 18, T.8 S., R. 86 W. Upper surfaces of unit Qto are about 200 ft above modern stream level. These terraces may have been deformed by diapirism related to upwelling of evaporitic rock units in the vicinity of the Basalt Mountain Fault. Older terrace alluvium generally consists of clast-supported cobble or pebble gravel in a sand matrix, but may range to a matrix-supported gravelly sand or silt. Locally it may contain fine-grained overbank deposits. Clasts are chiefly subround to round, with varied lithologies that reflect the rock types found in the drainage basin. Clasts are slightly or moderately weathered at shallow depths. Thickness ranges from about 30 to 60 ft. Unit Qto may correlate with deposits in terrace T5 of the Glenwood Springs-Carbondale area (Piety, 1981), in terrace C of Bryant (1979), or with terrace gravel "c" (Qgc) of Freeman (1972). Unit Qto was probably deposited during the late middle Pleistocene Bull Lake glaciation.

Qg

Gravel (Pleistocene)—Consists of a single occurrence of stratified, fluvial gravel along the north side of and about 80 to 120 ft above East Sopris Creek in the NW ¼ SE ¼ of Sec. 32, T. 8 S., R. 86 W., where it is exposed in a gravel pit. Unit Qg consists of stratified, clast-supported, pebble and cobble gravel in a sand and silt matrix, and gravelly silty sand. Clasts are subrounded to rounded, moderately weathered, mostly red or tan sandstone and hypabyssal igneous rocks, with lesser amounts of Proterozoic plutonic rocks, gray sandstone, and limestone. The presence of coarse-grained Proterozoic plutonic clasts suggests unit was deposited by an ancestral Roaring Fork River. Unit Qg may correlate with gravel deposits (unit Qgd) mapped by Freeman (1972) on Watson Divide in the Woody Creek quadrangle to the east. Exposed thickness in the gravel pit is about 25 ft.

TERRACE ALLUVIUM OF CAPITAL CREEK

Qt_1

Younger terrace alluvium of Capital Creek (late Pleistocene)—Chiefly stream alluvium that underlies terraces from about 15 to 70 ft above Capital Creek. Unit Qt_1 consists mostly of poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel with a sand and silty sand matrix that was deposited as glacial outwash. Fine-grained overbank deposits are locally present. Clasts are mainly subrounded to rounded and are comprised predominantly of red sedimentary rocks and hypabyssal igneous rock. Clasts are generally unweathered or only slightly weathered. Maximum thickness of the unit is about 60 ft. Unit Qt_1 is contiguous with a gravel deposit (unit Qga) in the Woody Creek quadrangle (Freeman, 1972) and probably is at least in part equivalent to youngest terrace alluvium (unit Qty) mapped in the Basalt quadrangle along the Roaring Fork River. Unit Qt_1 probably was deposited during the late Pleistocene Pinedale glaciation.

Qt_2 **Intermediate terrace alluvium of Capital Creek (late and/or middle Pleistocene)—** Composed of stream alluvium underlying terraces ranging from about 90 to 150 ft above Capital Creek. Unit Qt_2 is similar in texture, sorting, and lithology to younger terrace alluvium of Capital Creek (unit Qt_1), except the clasts within the deposit are slightly to moderately weathered. Maximum thickness of unit Qt_2 is about 50 ft. Stratigraphic and age relationships between the intermediate terrace alluvium of Capital Creek and alluvial deposits along the Roaring Fork River were not determined during this study.

Qt_3 **Oldest terrace alluvium of Capital Creek (middle or early Pleistocene?)—**Consists of stream alluvium underlying the terrace that caps McCartney Mesa. Older terrace alluvium of Capital Creek ranges from about 400 to 500 ft above adjacent creeks. The deposits are similar in texture, sorting and lithology to the younger terrace alluvium of Capital Creek (unit Qt_1), but tend to be finer grained and its clasts are moderately to highly weathered. Maximum thickness of unit Qt_3 is about 40 ft. Stratigraphic and age relationships with terraces along the Roaring Fork River and with unit Qg were not determined during this study.

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

Qlsr **Recent landslide deposits (latest Holocene)—** Includes a single, recently active landslide with fresh morphological features in the W ½ SW ¼ of Sec. 20, T. 9 S., R. 86 W. The deposit consists of unsorted, unstratified rock debris, sand, silt, and clay that likely moved as a debris avalanche. Maximum thickness of the recent landslide deposit is about 20 ft. The recent landslide initiated on a steep slope underlain by the Mancos Shale.

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. Locally, colluvium grades to sheetwash deposits on flatter slopes and to debris-flow deposits in some drainages. Deposits of colluvium are usually coarser grained in upper reaches and finer grained in distal areas where sheetwash processes are more common. Clasts in colluvium 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 occurring on slopes beneath and upslope of the deposit. Locally the unit includes talus, landslides, sheetwash, and debris flows that are too small or too indistinct on aerial photographs 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 the Dakota Sandstone and Burro Canyon Formation, Tertiary ash-flow tuff, and a sandstone bed in the Mancos Shale, and transported downslope principally by gravity as rockfalls, rockslides, and rock topples. Deposits of talus commonly lack matrix material. Locally talus is underlain by or incorporated into landslides. Maximum thickness is about 30 ft. Talus deposits derived from and occurring below outcrops of Tertiary ash-flow tuff locally have periglacial geomorphic features.

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. The unit includes rotational and translational landslides, complex slump-earthflows, and extensive slope-failure complexes. Landslides are common and of considerable areal extent on dip slopes formed in the Mancos Shale. In some areas the contact between the Mancos Shale and the Dakota Sandstone and Burro Canyon Formation served as the basal slip plane for landslides. Landslides are also abundant in Tertiary sediments (unit Ts) in the northwest corner of the quadrangle. Some of the isolated hills mapped as Tertiary sediments in this area may be eroded remnants of old landslide deposits. The large landslide complex north of the Roaring Fork River in the north-central part of the quadrangle involved Mancos Shale and overlying basalt flows. These deposits locally contain matrix-free basalt rubble. Maximum thickness of landslide deposits is about 200 ft, but usually they are less than 100 ft thick.

Qco **Older colluvium (Pleistocene)—**Eroded remnants of deposits of older colluvium occur on drainage divides, ridge lines, and dissected hillslopes. The genesis, texture, bedding, and clast lithology of older colluvium are similar to colluvium (unit Qc). Deposits of older colluvium average 10 to 25 ft thick and have a maximum thickness of about 60 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 is commonly very 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 alluvium (unit Qa) adjacent to stream channels. Clast lithology is diverse as debris-flow deposits involve most named bedrock units, including Tertiary sediments, landslide deposits, and colluvium. Large, coalescing debris-fans along both sides of the Roaring Fork Valley extend well out from the valley wall, covering considerable areas of younger terrace alluvium (unit Qty). The original depositional surfaces are usually preserved on deposits of younger debris-flow alluvium except where they are disturbed by human activities. Maximum thickness of younger debris-flow deposits is about 50 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. 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 (unit Qc) on steeper slopes and sheetwash deposits (unit Qsw) 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)—**Similar in texture, lithology, and depositional environment to younger debris-flow deposits (unit Qdfy). The geomorphic character of the original depositional surfaces are commonly recognizable, but active channels are incised 10 ft or more into intermediate debris-flow deposits. A younger debris-flow (unit Qdfy) was deposited upslope from and partially buries intermediate debris-flow deposits in the NE¼ SE¼ of Sec. 8, T. 9 S., R. 86 W. Maximum thickness of unit Qdfm is about 60 to 80 ft.

Qdfo **Older debris-flow deposits (Holocene? and Pleistocene)—**A single remnant of older debris-flow deposits lies in the NE ¼ SW ¼ of Sec. 18, T. 8 S., R. 86 W. The deposit is texturally, genetically, and lithologically similar to younger debris-flow deposits (unit Qdfy). Clasts within the deposit range from unweathered to moderately weathered. Modern valleys are incised about 20 to 60 ft into the older debris-flow deposits. Thickness of unit Qdfo varies from 10 to 40 ft.

Qaco **Older alluvium and colluvium, undivided (Pleistocene)—**Deposits of older alluvium and colluvium are similar in texture, bedding, clast lithology, sorting, and genesis to alluvium and colluvium (unit Qac), but they are older. Modern creeks are incised about 10 to 200 ft into deposits of older alluvium and colluvium. Unit Qac locally includes debris-flow and sheetwash deposits. Numeric subscripts used for some deposits in upper West Sopris Creek indicate the relative age of these deposits, with unit $Qaco_1$ being younger than unit $Qaco_2$.

Qp **Pediment deposits (late or middle Pleistocene)—**Pediment deposits consist of remnants of gravelly alluvium and debris-flow deposits that overlie gently sloping surfaces eroded into the Mancos Shale on the ridge between Capital Creek and Lime Creek in the southeast corner of the quadrangle. The deposits are poorly sorted, matrix-and clast-supported pebble gravel in a silty and clayey matrix. Clasts and matrix are entirely derived from upslope outcrops of Mancos Shale. The maximum observed thickness of pediment deposits is about 20 or 30 ft, but it could be greater in channel thalwags. The pediment surfaces appear to have been graded to and may be similar in age to intermediate terrace alluvium of Capital Creek (unit Qt_2).

GLACIAL DEPOSITS—Sediments deposited in moraines by, adjacent to, or beneath ice.

Qm **Morainal deposits (late and late middle Pleistocene—**Heterogeneous deposits of gravel, sand, silt, and clay deposited by ice as ground, lateral, and end moraine in the valleys of Capital, East Sopris, and West Sopris Creeks. The deposits are dominantly poorly sorted, unstratified or poorly stratified, matrix-supported, bouldery, pebbly, and cobbly silty sand. The unit may locally include undifferentiated outwash deposits that consist of clast-supported sandy cobble gravel. Clasts are typically angular to subrounded pieces of red sandstone, conglomeratic sandstone, and hypabyssal igneous rocks but may locally include other types of sedimentary rocks. Morainal deposits typically form very hummocky landforms that may be difficult to differentiate from landslide deposits, particularly since morainal deposits are prone to landsliding. Lateral and end moraines are usually steep sided and have well defined moraine crests. The unit probably was deposited during both the late Pleistocene Pinedale glaciation and late middle Pleistocene Bull Lake glaciation. Maximum thickness of the unit is estimated at 240 ft.

UNDIFFERENTIATED SURFICIAL DEPOSITS—

Q **Surficial deposits (Quaternary)—**Shown only on cross sections. The unit may include any of the above surficial deposits.

BEDROCK

Tb **Basaltic flows (Miocene)—**Light- to medium-gray basaltic flows crop out at the northwest end of Light Ridge near the center of Sec. 13, T. 8 S., R. 87 W. The flows generally are vesicular and sometimes amygdaloidal, but locally they are dense. Both phenocrysts and the groundmass are moderately to highly weathered. The unit is holocrystalline with a porphyritic texture. Phenocrysts include euhedral to subhedral plagioclase, pyroxene with iron-oxide weathering rinds, and minor olivine rimmed with iddingsite. The groundmass has an intergranular texture and consists of plagioclase, altered pyroxene, and opaque minerals. Two samples of basaltic flows were analyzed chemically (Appendix A). One sample (BR-6) plots in the trachyandesite field of Le Bas and others (1986), and the second (BA-36) plots on the boundary between the trachyandesite and trachydacite fields. The relatively high alkaline-oxide concentrations may be attributable to the high degree of alteration and weathering of the analyzed samples. The relatively high silicon-dioxide content (~59 weight percent SiO_2) may also be affected by alteration and weathering. The maximum exposed thickness of the unit is 50 to 75 ft. The flows are intercalated with Tertiary sediments (unit Ts), and cobbles and pebbles from the Tertiary sediments are locally included in the basal portion of the flows. Two basaltic samples were dated using $^{40}Ar/^{39}Ar$ methods (Kunk and others, 2002). They yielded preferred ages of 13.81 ± 0.25 Ma and 13.57 ± 0.05 Ma (Table 1).

Ts **Sedimentary deposits (Miocene)—**The Tertiary sedimentary deposits are very weakly indurated to unconsolidated and consist of clast-supported, sandy pebble and cobble gravels that locally include boulders. The matrix is silty sand. Clasts are subrounded to well rounded and composed of various rock types depending on location. The southern portions of the outcrop area of these deposits, which are nearer to Mount Sopris and the Elk Mountains, contain high percentages of clasts of middle Tertiary hypabyssal rock, whereas deposits located in or near the Roaring Fork River Valley are rich in Proterozoic plutonic clasts. All deposits contain minor amounts of basaltic clasts. Tertiary sedimentary deposits in northwest corner of quadrangle probably exceed 1,000 ft in thickness, and may be as much as 2,000 ft thick. These deposits overlie, and hence are younger than, an ash-flow tuff that yielded an $^{40}Ar/^{39}Ar$ age of 35.21 ± 0.03 Ma (Kunk and others, 2002; see Table 1). Tertiary sediments on Light Ridge thicken appreciably where they cross the margin of the Carbondale collapse center.

Taf **Ash-flow tuff (Eocene)—**Includes a sequence of bedded, non-welded ignimbrites consisting of ash-flow tuff, block-and-ash-flow tuff, and very fine-grained, cross-bedded, ashy, interbedded surge deposits. The unit caps a northeast-southwest-trending ridge in the northwestern portion of the quadrangle. The ash-flow tuffs are massive, cemented but unwelded, medium-grained, pyroclastic rocks containing scattered pumice fragments and lithic clasts. In thin section the ash-flow tuff contains euhedral phenocrysts of quartz, plagioclase, sanidine, and biotite in a matrix of glass and very tiny crystals of quartz, feldspar, and biotite. The texture is fragmental. Lithic clasts are pebble-sized fragments of Proterozoic plutonic rock that are more abundant in the basal ash-flow sheets. Two samples of tuff were chemically analyzed (Table 1). One sample (BR-8) plots in the dacite field of Le Bas and others (1986); the second sample (BR-1) is classified as a rhyolite. The block-and-ash-flow tuff deposits are similar to the ash-flow tuffs, but they additionally contain light- to medium-purplish, boulder- and cobble-sized, angular, lithic blocks of partially-devitrified dacite. Petrographically these lithic blocks contain microlites of quartz, plagioclase, opaque minerals, and minor sanidine in a matrix of volcanic glass. The texture is hyalopilitic. Comparatively these lithic blocks are also dacitic, although they are slightly more siliceous than ash-flow surge deposits occurring between ash-flow sheets. The entire ignimbrite package attains a maximum thickness of 300 ft. A preferred $^{40}Ar/^{39}Ar$ age of 35.21 ± 0.03 Ma was obtained on sanidine from sample K97-8-11F (Kunk and others, 2002), which was collected from the same outcrop as sample BR-8.

This deposit was interpreted as outflow from the somewhat younger Grizzly Peak caldera (Fridrich and others, 1991) located 32 miles to the southeast, which was dated at 34.31 ± 0.12 Ma by McIntosh and Chapin (2004). However, cross-bedding foresets in surge deposits indicate a transport direction of about N 30º E for these pyroclastic deposits. Large, angular, lithic blocks of dacite in the block-and-ash-flow deposits are interpreted as juvenile extrusive material which was incorporated into ash-flow deposits from the periodic collapse of a nearby developing siliceous dome (T. Schroeder, 1997, oral commun.). These data suggest that the tuff may be related to a much more proximal volcano than the Grizzly Peak caldera. Mount Sopris, located 5.7 miles to the southwest, is a possible source.

Km **Mancos Shale (Upper Cretaceous)—**Predominantly medium- to dark-gray, carbonaceous, silty to sandy shale with minor bentonite beds, gray limestone, and medium-gray, grayish-yellow-weathering, clayey sandstone. To the east in Woody Creek quadrangle Freeman (1972) mapped upper and lower sandstone members within the Mancos Shale, but these sandstone beds were not mapped separately in the Basalt quadrangle. Total thickness of entire undivided Mancos Shale in Woody Creek quadrangle is 5,200 ft (Freeman, 1972); however, the uppermost part of the formation is not present in Basalt quadrangle. Unit Km also includes the Fort Hays Limestone Member. Where exposures are adequate, the formation is divided into three members or units within the quadrangle: an upper unit (Kmu), the Fort Hays Limestone Member (unit Kmf), and a lower unit (Kml).

Kmu **Upper unit—**Dark-gray, silty to sandy, carbonaceous shale, medium-gray, fine-grained, grayish-yellow-weathering, clayey sandstone, and minor thin bentonite beds. The upper unit may include the upper and lower sandstone members of Freeman (1972). The upper-most strata in the upper unit are not present in quadrangle. Total thickness of upper unit probably exceeds 4,800 ft.

Kmf **Fort Hays Limestone Member—**Gray, thick-bedded, coarse-grained limestone containing interbeds of limy shale. The Fort Hays Limestone Member lies about 300 ft above the base of the Mancos Shale. It is about 40 to 50 ft thick.

Kml **Lower unit—**Medium- to dark-gray, carbonaceous, silty shale. The lower unit is mapped in areas where the overlying Fort Hays Limestone Member and under-lying Dakota Sandstone and Burro Canyon Formation are recognizable. The lower unit is about 300 ft thick.

Kdb **Dakota Sandstone and Burro Canyon Formation, undivided (Lower Cretaceous)—**The Dakota Sandstone consists of light-gray to tan, medium- to coarse-grained, moderately well-sorted quartz sandstone, quartzite, and conglomeratic sandstone in well-cemented, thick beds. The underlying Burro Canyon Formation consists of yellowish-gray, medium-grained sandstone containing quartz pebbles and lenses of green and red chert. The combined unit also contains some sandy shale intervals that are poorly exposed. Sandstones in the unit are generally very well indurated and form prominent outcrops that have talus aprons below them. 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 Basalt quadrangle is 200 to 250 ft. The unit is conformable with the over-lying Mancos Shale. It was deposited near shore in a transgressive environment.

Jm **Moririson Formation (Upper Jurassic)—**Pale-green, greenish-gray, and maroon variegated siltstone and claystone, buff to pale-yellowish-gray sandstone, and gray limestone comprise the Morrison Formation. Sandstones are common in the lower half of the formation and may be equivalent to the Salt Wash Member in nearby areas. A 10- to 20-ft thick bed of coarse-grained, oolitic, tan- and white-weathering, medium-dark-gray limestone at the base of the formation directly overlies the Entrada Sandstone. Thickness is variable but averages about 300 to 350 ft. Morrison strata are usually poorly exposed and frequently covered by surficial deposits. Sandstone beds within the Morrison Formation are, however, fairly well exposed along the East Sopris Creek road in Sec. 30, T. 8 S., R. 86 W. The contact with the overlying Dakota Sandstone and Burro Canyon Formation is sharp and unconformable. The Morrison Formation was probably deposited in a lacustrine-dominated, fluvio-lacustrine environment (Fairer and others, 1993).

Je **Entrada Sandstone (Upper Jurassic—**The Entrada Sandstone consists of tan to white, medium- to fine-grained, well-sorted, poorly indurated, cross-bedded sandstone. Sand grains are mostly rounded to sub-rounded quartz grains. Thickness is about 40 to 60 ft. Exposure is generally poor due to the weakly cemented nature of the unit. The Entrada Sandstone is well exposed, however, north of East Sopris Creek in the NW ¼ SE ¼ of Sec. 30, T. 8 S., R. 86 W. The contact with overlying Morrison Formation is sharp and conformable, and is placed at the top of the main sand-stone and immediately below a gray, coarse-grained, oolitic limestone. Cross-bed sets are large scale indicating an eolian origin possibly in an extensive dune field (Fairer and others, 1993)

Jme **Morrison Formation and Entrada Sandstone, undivided (Upper Jurassic)—**Includes the Morrison Formation and Entrada Sandstone in the southwest corner of the quadrangle in the vicinity of Dinkle Lake and near the Maroon Bells-Snowmass Wilderness bound-ary where poor exposures preclude mapping of units separately.

ŦRc **Chinle Formation (Upper Triassic)—**Consists of thin, even-bedded, and structureless red beds of dark-reddish-brown, orangish-red, and purplish-red, calcareous siltstone and mudstone containing scattered thin lenses of light-purplish-red and gray limestone and limestone-pebble conglomerate. The Chinle Formation may include a thin, basal conglom-eratic sandstone called the Gartra Member (Dubiel, 1992), but it was not recognized in the quadrangle. The contact with overlying Entrada Sandstone is sharp and unconformable. Good exposures of the Chinle are uncommon, although the formation is well exposed on the south flank of Light Ridge in the N ½ of Sec. 30, T. 8 S., R. 86 W., where the Chinle section is partially repeated by a northeast-trending fault, and on the cliff face south of Hooks in NE ¼ of Sec. 15, T. 8 S., R. 87 W. Thickness of the Chinle Formation is 100 to 200 ft. The formation thins from east to west across the Basalt quadrangle; however, to the east in the Woody Creek quadrangle the Chinle thickens to over 1000 ft (Freeman, 1972). The upper or red bed portions of the Chinle Formation are possibly lateral-accretion and flood-plain deposits, while the lower coarse-clastic portion (Gartra Member) was most likely deposited as active channel-fill and valley-fill fluvial sediments (Dubiel, 1992).

ŦɌPsb

State Bridge Formation (Lower Triassic and Permian)—Reddish-orange, grayish-red, and pale- reddish-pink, silty sandstone, clayey siltstone, arkosic sandstone, conglomeratic sandstone, and very minor gray dolomite comprise the State Bridge Formation. The formation includes the lower siltstone and sandstone member of Freeman (1971; 1972), which contains the South Canyon Creek Member. The South Canyon Creek Member is a medium-gray, silty and sandy limestone and dolomite (Bass and Northrup, 1950; Stewart and others, 1972) that occurs in lenses only 12 to 18 inches thick within the quadrangle. Sandstones in the formation are thin to thick, even bedded, very well sorted, equigranular, and fine to medium grained. Sand grains have a high degree of sphericity. Some bedding surfaces have parallel ripple marks with a 1 to 2 inch wavelength. Siltstones have scattered coarse sand grains with high sphericity. Conglomeratic sandstone beds are numerous, from 1 to 12 ft in thickness, and massive to very slightly crossbedded, containing mostly pebble-sized clasts of quartz, chert, sedimentary lithologies, and Proterozoic granitic rocks. All of the clastic strata in the State Bridge Formation contain mica, although in generally lesser concentrations than in the underlying Maroon Formation. The contact with the overlying Chinle Formation is sharp and unconformable. Thickness of the State Bridge varies greatly in the Basalt quadrangle. The lower part of the State Bridge Formation is 1000 ft thick north of the Roaring Fork River in the Basalt quadrangle and is overlain by another 1000 ft of strata in the upper part of the formation in the adjacent Woody Creek quadrangle (Freeman, 1972). Yet, the entire formation is only about 200 ft thick south of the Roaring Fork River near the crest of Light Ridge and southwest of the Basalt Mountain Fault. This disparity in thickness over such a short distance suggests that the Basalt Mountain Fault may have been active during deposition of the State Bridge and/or during the time between deposition of the State Bridge and the Chinle Formations. On the cliff face south of Hooks, near the west boundary of the quadrangle, the State Bridge Formation is about 1,300 ft thick. The State Bridge Formation of northwestern Colorado, which is equivalent to the Moenkopi Formation of the Colorado Plateau, may have formed in delta flood-plain and tidal-flat environments in the transitional zone between predominantly continental deposits to the east and marine deposits to the west (Stewart and others, 1972.

ŦɌPcs

Chinle and State Bridge Formations, undivided (Upper Triassic to Permian)—Includes the Chinle and State Bridge Formations where those units could not be shown separately on cross-section B—B′.

PIPm

Maroon Formation (Permian and Upper Pennsylvanian)—The Maroon Formation consists of grayish-red and pale-red to pinkish-red, arkosic sandstone, conglomerate, siltstone, and mudstone, with shale and minor, thin beds of gray limestone. All clastic rock types contain noticeably more detrital mica than the overlying State Bridge Formation. The Maroon Formation crops out at the base of both valley walls along the Roaring Fork River south and southeast of the town of Basalt. Sandstone beds are coarse to fine grained, moderately to poorly sorted, and contain sand grains that are generally angular to subangular with a low degree of sphericity. This distinguishes the Maroon Formation strata from the overlying State Bridge Formation, which contains sand grains that are consistently well sorted and high in sphericity. A color change also is locally useful in locating this contact, as the Maroon Formation tends to be pale reddish pink and the State Bridge Formation is orange red and brownish red. The contact between the Maroon and State Bridge Formations is best exposed at an elevation of 7,320 ft in the southwest-facing canyon wall in the SW ¼ of

Sec. 16, T. 8 S., R. 86 W. The upper part of the Maroon Formation may contain eolian deposits (loessite), which are characterized by homogeneous beds of sandy silt that lack sedimentary structure (Johnson, 1989). The upper contact is sharp and unconformable. Thickness of the unit in adjacent quadrangles to the west is 3,000 to 5,000 ft (Kirkham and others, 1996; Kirkham and Widmann, 2008). The Maroon Formation was deposited in the Central Colorado Trough in fluvial and eolian environments (Johnson and others, 1988).

Ŧℙcm **Chinle, State Bridge, and Maroon Formations, undivided (Upper Triassic and Upper Pennsylvanian)—**Includes the Chinle, State Bridge, and Maroon Formations in the southwest corner of the quadrangle and on the south side of Light Ridge, where these units are not mapped separately.

ℙe **Eagle Valley Formation (Middle Pennsylvanian)—**Composed of interbedded reddish-brown, gray, reddish-gray, and tan siltstone, gypsum, and carbonate rocks. The Eagle Valley Formation represents a stratigraphic interval in which the red beds of the Maroon Formation grade into and intertongue with the predominantly evaporitic rocks of the Eagle Valley Evaporite. The Eagle Valley Formation is less than 500 ft thick in the Basalt quadrangle, but is as much as 3,000 ft thick to the northwest in the Carbondale quadrangle (Kirkham and Widmann, 2008). It 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 red bed sequence of the Maroon Formation. The Eagle Valley Formation was deposited in the Central Colorado Trough on the margin of an evaporite basin in fluvial and marine environments.

ℙee **Eagle Valley Evaporite (Middle Pennsylvanian)—**The Eagle Valley Evaporite consists of gypsum, anhydrite, and halite interbedded with light-colored mudstone and fine-grained sandstone, thin limestone, and black shale. Gypsum beds range from massive to laminated. Strata commonly are intensely folded, faulted, and ductily deformed by diapirism, flowage, dissolution-related subsidence or collapse, load metamorphism, hydration of anhydrite, and Laramide tectonism. Massive gypsum beds are exposed along either side of the Basalt Mountain Fault in the W ½ of Sec. 18, T. 8 S., R. 86 W. Thickness of the formation may range from about 1,200 ft to perhaps 9,000 ft where it is tectonically thickened along the Grand Hogback (Mallory, 1971). Perry and others (2002) reported a thickness of 4,600 ft to the west in Mount Sopris quadrangle. A minimum thickness of 2,700 ft is described by Kirkham and Widmann (2008) to the north near Catherine. Complex deformation and lack of subsurface data preclude an accurate estimate of the thickness of the Eagle Valley Evaporite in the Basalt quadrangle. The contact with the overlying Eagle Valley Formation is both conformable and intertonguing and is defined as the base of the lowest red bed. The Eagle Valley Evaporite was deposited in a marine evaporitic basin known as the Eagle Basin that formed as the outlet for the Central Colorado Trough was restricted (Mallory, 1971). Schenk (1989) recognized multiple transgressive-regressive cycles in the formation near Gypsum and Eagle and suggested the gypsum was deposited in a subaqueous environment rather than in a sabkha.

ℙeu **Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)—**This combined unit is used in an area on the southwest side of the Wingo Graben where these formations are not mapped separately.

GEOLOGIC SETTING

The oldest rocks exposed in the Basalt quadrangle are the Pennsylvanian Eagle Valley Evaporite. These strata and the overlying Pennsylvanian Eagle Valley Formation, Permian and Pennsylvanian Maroon Formation, and Triassic and Permian State Bridge Formation were deposited within the Eagle Basin, a depocenter within the Central Colorado Trough. Abrupt and major thickness changes in the State Bridge and Maroon Formations in the region have been attributed to evaporite flow during the Triassic (Freeman, 1971, 1972; Tweto, 1977). Overlying the upper Paleozoic and early Mesozoic rocks is the Triassic Chinle Formation and Jurassic Entrada Sandstone and Morrison Formation. As the Western Interior Seaway invaded the region, the Cretaceous Burro Canyon Formation, Dakota Sandstone, and Mancos Shale were deposited.

All these older rocks were deformed during the late Cretaceous-early Tertiary Laramide Orogeny. Major Laramide structures in the region include the north-south-trending Grand Hogback Monocline, which lies west of the quadrangle, and the Elk Mountain Thrust, which is to the south. The most important Laramide structure within the quadrangle is the Basalt Mountain fault. To the north it is a high-angle, down-to-east, reverse fault with a minimum of 5,600 feet of throw (Streufert, Kirkham, and others, 2008; Kirkham, Widmann, and Streufert, 2008). The Basalt Mountain Fault is well exposed on the hillside near the railroad bridge at Wingo along the eastern boundary of the quadrangle. In the N ½ of Sec. 20, T. 8 S., R. 86 W., drag-folded rocks of the Jurassic Morrison Formation in the downthrown side of the fault are complexly faulted against the Pennsylvanian/Permian Maroon Formation. This segment of the Basalt Mountain Fault may have also behaved as a growth fault during Permian through early Triassic time, because the State Bridge Formation abruptly changes in thickness from about 200 to over 2,000 feet across the fault.

Within the Basalt quadrangle, the Basalt Mountain Fault also forms the western margin of the Wingo Graben. An unnamed subparallel fault on the east side of the Roaring Fork River Valley forms the eastern side of the graben. This unnamed fault may be the northwestern extension of the Castle Creek Fault. The Wingo graben may be a Laramide or Neogene structure, or it may have been active during both time periods. Tertiary sediments (units Ts) are downdropped into the graben across the Basalt Mountain Fault, therefore some movement must have occurred during the Neogene. The anticline and syncline near the mouth of West Sopris Creek, and the Roaring Fork Syncline in East Sopris Creek, are possible examples of Laramide age compressional features.

Rocks in the southwest corner of the quadrangle were deformed during the middle Tertiary by the emplacement of the Mount Sopris pluton west of the quadrangle. Here the strata dip east and are in concordant contact with the stock. An ash-flow tuff was deposited in the northwest part of the quadrangle at 35.21 ± 0.03 Ma ($^{40}Ar/^{39}Ar$ date on sanidine by Kunk and others, 2002), which is about when the Mount Sopris pluton cooled (Streufert, 2008). Fridrich and others (1991) suggested this tuff was erupted from the Grizzly Peak caldera in the Sawatch Range. However, a recent $^{40}Ar/^{39}Ar$ age of 34.31 ± 0.12 Ma was obtained on sanidine from the Grizzly Peak intracaldera tuff (McIntosh and Chapin, 2004), which is nearly a million years younger than the tuff in the Basalt quadrangle. The ash-flow tuff in the quadrangle has characteristics that suggest it is proximal to the eruptive center. Venting of the Mount Sopris pluton is a possible source for the tuff.

Sometime after the Laramide orogeny, perhaps initially during late Eocene time, a broad erosional surface was cut across the region (Scott, 1975). This surface was later modified by one or more subsequent periods of erosion (Kirkham, Kunk, and others, 2001; Steven, 2002). During the Miocene, the Colorado River and its tributaries began to downcut through the low-relief erosion surface, creating younger and topographically lower erosion surfaces inset into the regional late Eocene(?) erosion surface (Larson and others, 1975; Kirkham, Kunk, and others, 2001; Kunk and others, 2002). The Miocene and younger incision also triggered flow and dissolution of halite and gypsum in the Eagle Valley Evaporite, which led to widespread collapse of the ground surface in the region (Kirkham, Streufert, and others, 2001, 2002; Kirkham, Scott, and Judkins, 2002; Lidke and others, 2002; Scott and others, 2002).

The northwestern part of the Basalt quadrangle is within the Carbondale Collapse Center, one of two large evaporite collapse areas in the region. The Laramide-age Basalt Mountain Fault serves as the eastern margin of the Carbondale Collapse Center in the north-central part of the quadrangle, although the direction of collapse is opposite of its Laramide movement. The Tertiary sediments on Light Ridge, which were deposited in a paleovalley of the Roaring Fork River, thicken abruptly where the paleovalley probably crosses the margin of the collapse center. The southern margin of the collapse center is less well constrained within the quadrangle. Tertiary sediments in the northwest part of the quadrangle, as well as those in the adjacent Mount Sopris quadrangle, were deposited within the collapse center in a depocenter called the Sopris Bowl (Kirkham, Streufert, and others, 2001, 2002), therefore the collapse margin must be south of the Tertiary sediments. We suspect the collapse margin follows some of the high-angle normal faults that extend southwest and west from Light Ridge, but recognize that the margin could be further south than the position shown on the geologic map. Some of the high-angle faults on the northwest side of East Sopris Creek may result from evaporite deformation.

Evaporite deformation elsewhere in the Carbondale Collapse Center is mostly constrained to the late Cenozoic, and much of it is Pliocene or younger (Kirkham, Streufert, and others, 2001, 2002). However, stratigraphic evidence in Sopris Bowl suggests collapse may have initiated earlier here than in other areas. The Tertiary sediments within Sopris bowl overlie and therefore are younger than the 35.21 ± 0.03 Ma ash-flow tuff. This indicates Sopris Bowl began to form after latest Eocene or early Oligocene time. Basalt flows interbedded with the Tertiary sediments in the quadrangle yielded ages of 13.57 ± 0.05 Ma and 13.81 ± 0.25 Ma, and basalt flows that lie stratigraphically at or near the top of the Tertiary sediments in Carbondale quadrangle have an average of about 13.3 Ma (Kunk and others, 2002; Kirkham and Widmann, 2008). The proximity of the Mount Sopris pluton 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.

Halite and gypsum dissolved from the collapse areas eventually end up in the Colorado River. Chafin and Butler (2002) estimated that about 880,000 tons of salt are dissolved from the Eagle Valley Evaporite in the Carbondale and Eagle Collapse Centers every year. Yampa hot spring, which provides the water for the hot springs pool in the town of Glenwood Springs, discharges about 260 tons of dissolved halite and gypsum to the Colorado River daily (Barrett and Pearl, 1976). Many other hot springs in the area also discharge water that is enriched in dissolved evaporite minerals. These high salt concentrations indicate that the evaporite dissolution and collapse is active. Sinkholes and subsidence troughs in late Quaternary deposits support this conclusion.

Correlation and Age of Late Cenozoic Basaltic Rocks

Early during the collaborative CGS-USGS investigation of evaporite tectonism in the region, it was recognized that a thorough understanding of the late Cenozoic volcanic stratigraphy was needed to better characterize evaporite-related deformation. By tracing dated and correlated volcanic flows across the region, the lateral extent, amount of vertical deformation, and timing and rates of collapse could be assessed. To accomplish this goal, a comprehensive effort involving $^{40}Ar/^{39}Ar$ age dating and geochemical correlation of the volcanic rocks in the region was undertaken. 133 dates were obtained from 84 samples of late Cenozoic volcanic rocks (Kunk and others, 2002). Major-, minor-, and trace-element concentrations were determined for 220 samples, and 65 of these samples were analyzed for lead, strontium, and neodymium (Unruh and others, 2001). Budahn and others (2002) used the chemical analyses, age dates, and petrographic data to identify 46 distinct compositional groups of volcanic rocks. These compositional groups were erupted during significant pulses of basaltic volcanic activity spread across the region during the time intervals from 24 to 22 Ma, 16 to 13 Ma, and 11 to 9 Ma. Smaller eruptions occurred in the region about 7.8 to 7.7 Ma, 4 Ma, 3 Ma, 1.3 Ma, and 4 ka (Kunk and others, 2002).

Four samples of volcanic rocks from the Basalt quadrangle were either chemically analyzed and/or age dated as part of the collaborative CGS-USGS investigation (Table 1). Locations of all four samples are shown on the accompanying geologic map. Chemical analyses and the latitude and longitude of the sample locations are listed in Appendix A. Two of the samples (BR-8 and K97-8-11F) were from the ash-flow tuff and were not correlated with the younger basaltic rocks in the region. The two basaltic samples (BA-36 and BR-6) were erupted near the end of the 16 to 13 Ma interval of volcanic activity. Both basaltic rocks were included in compositional group 13a (Budahn and others, 2002).

Table 1. Compositional geochemical groups and preferred $^{40}Ar/^{39}Ar$ ages of volcanic rocks in the Basalt quadrangle (from Budahn and others, 2002; Kunk and others, 2002). Sample locations are shown on the accompanying geologic map and are described in appendix A.

Sample Number	Map Unit	Compositional Group	Preferred Age (Ma)
BA-36	Tb	13a	13.81 ± 0.25
BR-6	Tb	13a	13.57 ± 0.05
BR-8	Taf	U*	
K97-8-11F	Taf	U§	35.21 ± 0.03

* unknown compositional group
\# no uncertainty reported
§ sample collected from same outcrop as L-3, which is compostional group 6c

GEOLOGIC HAZARDS AND CONSTRAINTS

Geologic hazards and constraints in the Basalt quadrangle include debris flows, floods, unstable slopes, problematic soils, earthquakes, and perhaps 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 if 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) and shallow soil slips are relatively common in the quadrangle. They are especially abundant in areas underlain by the Mancos Shale and Tertiary sediments (unit Ts). Although only a single recently active landslide was identified in the quadrangle, areas mapped as landslide deposits are prone to reactivation, particularly if disturbed by human activities, and are indicative of the types of geologic environments that are favorable for future slope failures. The shallow soil slips, which involve thin-skinned soil failures and are common on steep slopes underlain by the Mancos Shale and landslide deposits, demonstrate the need for careful geotechnical investigations in those environments. There is moderate to high potential for future rockfall below cliffs of well-indurated bedrock. Areas mapped as talus (unit Qt) 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 and evaporite karst hazards 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 Basalt 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 (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 only valuable mineral resource in the quadrangle probably is sand and gravel. Alluvium (unit Qa) and terrace gravels (unit Qty, and Qtm) along the Roaring Fork Valley, and gravel in East Sopris Creek (unit Qg) contain sand and gravel resources. Tertiary sedimentary deposits (unit Ts) in the northwest corner of the quadrangle and beneath Light Ridge may also be a potential source of sand and gravel. Terrace deposits along Capital Creek (units Qt_1 and Qt_2) are probably less of a resource due to the higher percentage of fines, which increases processing costs. The older terrace gravel deposits (units Qto and Qt_3) are probably less desirable due to the degree of clast weathering.

Gypsum beds are mined in the region, but in the Basalt quadrangle, they generally are too deep below the surface or too limited in extent to constitute a major resource. Oil and gas resources potentially could exist in the quadrangle, but no test wells have been attempted. The most favorable source and reservoir rocks, which are Mesozoic in age, crop out or are at shallow depths in the quadrangle. Paleozoic sedimentary rocks, which probably exist deeper in the subsurface, offer some oil and gas possibilities.

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APPENDIX A

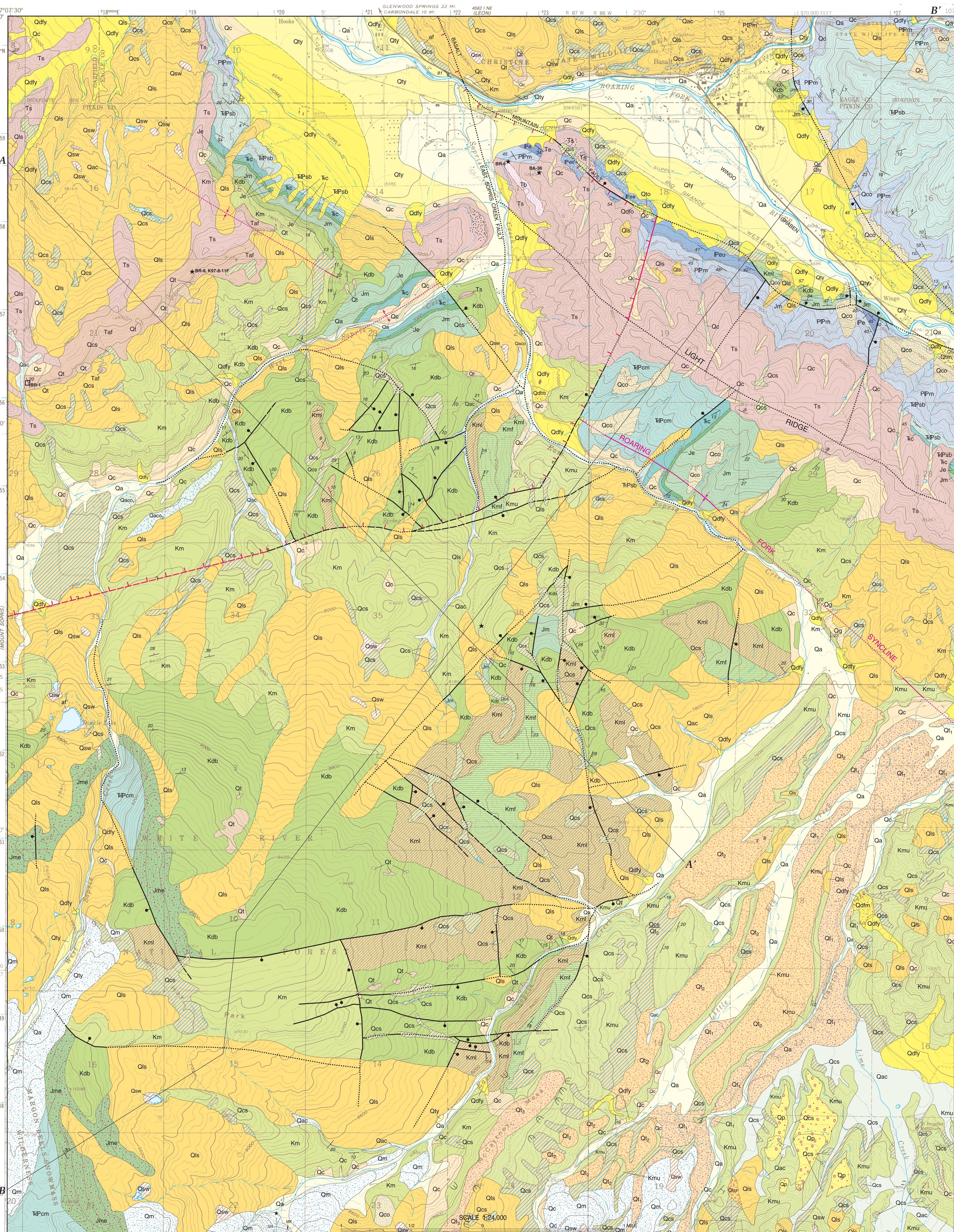
Appendix A: Major element, whole-rock XRF analyses of volcanic rocks in Basalt quadrangle. Sample locations are given in the second table and are also shown on the accompanying geologic map. All analyses by Unruh and others (2001) except for sample BR-1, which was analyzed by Chemex Labs Inc., Sparks, Nevada.

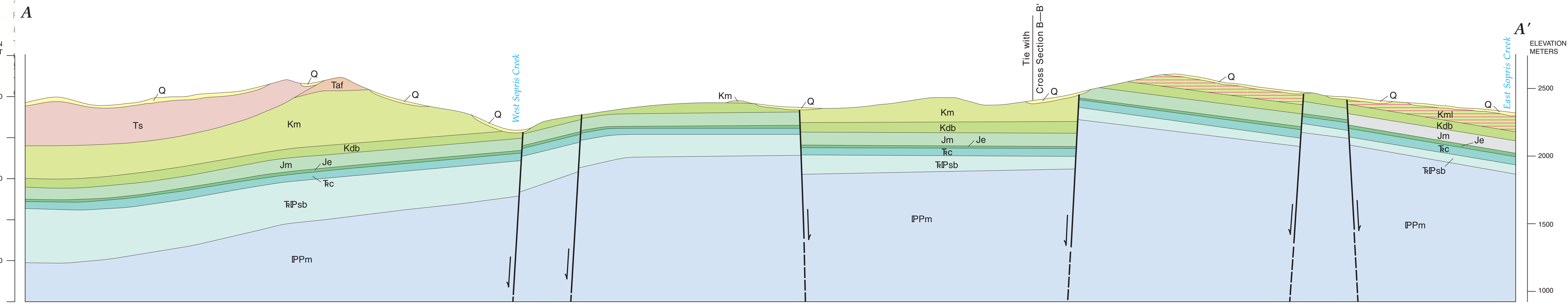
	Weight Percent											
Sample ID	**SiO_2**	**Al_2O_3**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**Fe_2O_3**	**MnO**	**P_2O_5**	**TiO_2**	**LOI***	**Total**
BA-36	59.37	16.09	4.31	1.34	4.08	4.49	5.91	0.07	0.45	1.09	1.92	99.11
BR-1	68.64	13.80	2.33	0.63	2.93	3.14	2.14	0.05	0.09	0.25	4.99	99.00
BR-6	59.16	16.36	4.14	1.41	4.00	4.30	6.51	0.06	0.45	1.16	1.73	99.11
BR-8	68.84	14.43	3.81	0.33	2.79	3.16	4.06	0.05	0.35	0.57	1.04	99.43

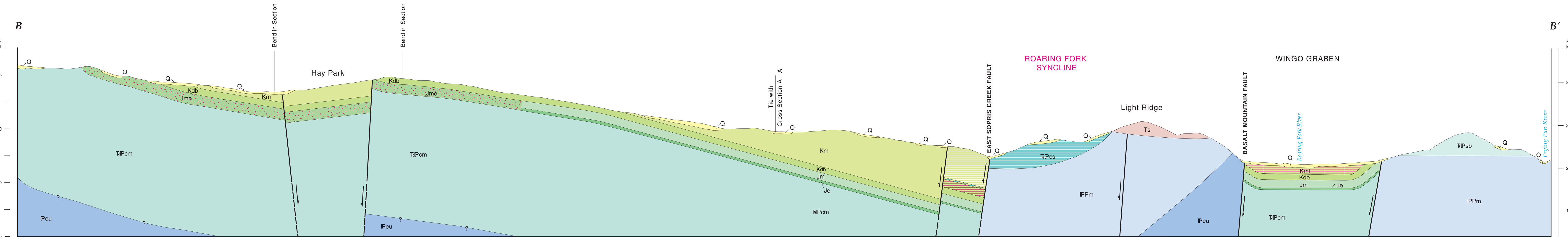
*LOI=Loss On Ignition

Sample Location (NAD27)			
Sample ID	**Map Unit**	**Latitude**	**Longitude**
BA-36	Tb	39.3589° N	107.0551° W
BR-1	Taf	39.3373° N	107.1225° W
BR-6	Tb	39.3600° N	107.0590° W
BR-8	Taf	39.3488° N	107.1007° W
K97-8-11F§	Taf	39.3488° N	107.1007° W

§ sample collected from same outcrop as sample BR-8







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 topographic depressions

Qty — **Younger terrace alluvium (late Pleistocene)**—Mostly poorly sorted, clast-supported, locally bouldery, pebble and cobble gravel in a sand and silt matrix. Deposited as glacial outwash. Underlies terraces about 14 to 50 ft above modern stream level. May include fine-grained overbank deposits

Qtm — **Intermediate terrace alluvium (late Pleistocene)**—Deposits texturally and depositionally similar to younger terrace alluvium (Qty). Underlies a terrace about 60 to 70 ft above the Roaring Fork River

Qto — **Older terrace alluvium (late middle Pleistocene)**— Deposits texturally and depositionally similar to younger terrace alluvium (Qty). Clasts slightly to moderately weathered. Underlies a terrace about 200 ft above the Roaring Fork River

Qg — **Gravel (Pleistocene)**—Chiefly stratified, clast-supported, pebble and cobble gravel in a sand and silt matrix, and gravelly silty sand. Clasts are moderately weathered. Occurs in one area along northeast side of and about 80 to 100 ft above East Sopris Creek

Terrace Alluvium of Capital Creek

Qt_1 — **Younger terrace alluvium of Capital Creek (late Pleistocene)**—Chiefly poorly sorted, clast-supported, occasionally bouldery, pebble and cobble gravel in a sand and silty sand matrix that underlies terraces about 15 to 70 ft above Capital Creek. May include fine-grained overbank deposits

Qt_2 — **Intermediate terrace alluvium of Capital Creek (late and/or middle Pleistocene)**—Composed of stream alluvium underlying terraces ranging from about 90 to 150 ft above Capital Creek. Similar in texture, sorting, and lithology to younger terrace alluvium of Capital Creek (Qt_1)

Qt_3 — **Oldest terrace alluvium of Capital Creek (middle or early Pleistocene?)**—Consists of stream alluvium underlying the terrace that caps McCartney Mesa. Deposits range from about 400 to 500 ft above adjacent creeks. Unit is similar in texture, sorting, and lithology to younger terrace alluvium of Capital Creek (Qt_1), but tends to be finer grained

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

Qlsr — **Recent landslide deposits (latest Holocene)**—Includes a single, recently active landslide with fresh morphological features. Contains unsorted, unstratified rock debris, sand, silt, and clay that moved as a debris avalanche

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 Dakota Sandstone and Burro Canyon Formation (Kdb), Tertiary ash-flow tuff (Taf), and Mancos Shale (Km)

Qls — **Landslide deposits (Holocene and Pleistocene)**—Highly variable deposits consisting of unsorted, unstratified rock debris, gravel, sand, silt, and clay. Range in age from recently active landslides to long-inactive landslides

Qco — **Older colluvium (Pleistocene)**—Similar to colluvium (Qc), but found on drainage divides, ridge lines, and dissected hillslopes

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

Qdfy — **Younger debris-flow deposits (Holocene)**—Poorly sorted to moderately well-sorted, matrix- and clast-supported deposits ranging from gravelly clayey silt to sandy, silty, cobbly, pebbly, and bouldery gravel. 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)**—Poorly sorted to well-sorted, stratified, interbedded pebbly or cobbly sand, sandy silt, and sandy gravel to unsorted, unstratified or poorly stratified, clayey, silty sand, bouldery sand, and sandy silt

Qcs — **Colluvium and sheetwash deposits, undivided (Holocene and late Pleistocene)**—Consists 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)**—Similar in texture, lithology, and depositional environment to younger debris-flow deposits (Qdfy). Geomorphic character of original depositional surfaces are recognizable but the surface is 10 or more feet above adjacent active debris-flow channels

Qdfo — **Older debris-flow deposits (Holocene? and Pleistocene)**— A single remnant of the unit is adjacent to the Basalt Mountain Fault southwest of Basalt. Deposits are texturally, lithologically, and genetically similar to younger debris-flow deposits (Qdfy)

Qaco — **Older alluvium and colluvium, undivided (Pleistocene)**—Deposits texturally and depositionally similar to alluvium and colluvium (Qac), but ranging from 10 to 200 ft above small perennial, intermittent, and ephemeral streams. Locally contains debris-flow and sheetwash deposits. Numeric subscripts used in upper West Sopris Creek indicate the relative age of these deposits, with $Qaco_1$ being younger than $Qaco_2$

Qp — **Pediment deposits (late or middle Pleistocene)**—Mostly poorly sorted, matrix- and clast-supported pebble gravel in a silty and clayey matrix deposited by streams and debris flows. Occurs at one and perhaps two levels that underlie gently sloping surfaces eroded into Mancos Shale on the ridge between Capital and Lime Creeks in the southeast corner of the quadrangle. Clasts and matrix are entirely derived from adjacent outcrops of Mancos Shale

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

Qm — **Morainal deposits (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 moraines along Capital, East Sopris, and West Sopris Creeks. Deposits are dominantly poorly sorted, unstratified or poorly stratified, matrix-supported, bouldery, pebble and cobble gravel with a matrix of silty sand

UNDIFFERENTIATED SURFICIAL DEPOSITS

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

BEDROCK

Tb — **Basaltic flows (Miocene)**—Light- to medium-gray, vesicular to dense, basaltic flows. Texture is porphyritic with phenocrysts of plagioclase, pyroxene, and minor olivine. Groundmass consists of plagioclase, pyroxene, and opaque minerals with an intergranular texture. Both phenocrysts and groundmass are highly weathered. Flows are interbedded with Tertiary sedimentary deposits (Ts). $^{40}Ar/^{39}Ar$ dates of 13.57 ± 0.05 Ma to 13.81 ± 0.25 Ma (Kunk and others, 2002)

Ts, Ts — **Sedimentary deposits (Miocene)**—Weakly indurated to unconsolidated deposits of sandy gravel, gravelly sand, and silt. Occasionally bouldery. Occurs on Light Ridge and in the northwestpart of quadrangle. Pattern indicates an erosion surface and middle Pleistocene sediments overlie unit Ts.

Taf — **Ash-flow tuff (Eocene)**—Sequence of bedded, non-welded, dacitic ignimbrites consisting of ash-flow tuff, block-and-ash-flow tuff, and very fine-grained, cross-bedded surge deposits. Ash-flow tuffs are composed of phenocrysts of quartz, feldspar, and biotite, with occasional pumice fragments and minor lithic clasts, in a matrix of glass and very tiny crystals of quartz, feldspar, and biotite. Block-and-ash-flow tuff deposits contain boulder- and cobble-sized, angular, lithic blocks of partially devitrified dacite with quartz, plagioclase, opaque minerals, and minor sanidine in a matrix of volcanic glass

Km — **Mancos Shale (Upper Cretaceous)**—Medium- to dark-gray, carbonaceous, silty to sandy shale and minor bentonite beds, gray limestone, and medium-gray, grayish-yellow-weathering, clayey sandstone. Locally the Mancos Shale is subdivided into the following three members:

Kmu — **Upper unit**—Dark-gray, silty to sandy, carbonaceous shale, medium-gray, fine-grained, grayish-yellow-weathering, clayey sandstone, and minor thin bentonite beds

Kmf — **Fort Hays Limestone Member**—Gray, thick-bedded, coarse-grained limestone with interbeds of calcareous shale

Kml — **Lower unit (Upper Cretaceous)**—Medium- to dark-gray, carbonaceous, silty shale

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, quartzose sandstone, quartzite, conglomeratic sandstone, and carbonaceous shale. Burro Canyon Formation consists of yellowish-gray, medium-grained sandstone containing quartz pebbles and lenses of green and red chert. Also contains some poorly exposed sandy shale intervals. Sandstones are generally very well indurated and typically form talus aprons below outcrops

Jm — **Morrison Formation (Upper Jurassic)**—Pale-green, greenish-gray, and maroon variegated siltstone and claystone, buff to pale-yellowish-gray sandstone, and gray limestone. A thick-bedded, coarse-grained, oolitic, tan- and white-weathering, medium-dark-gray limestone occurs at the base directly above the Entrada Sandstone (Je)

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

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

₮c — **Chinle Formation (Upper Triassic)**—Thin, even-bedded, and structureless beds of dark-reddish-brown, orangish-red, and purplish-red, calcareous siltstone and mudstone and scattered thin lenses of light-purplish-red and gray limestone and limestone-pebble conglomerate. Locally includes a thin, basal conglomeratic sandstone

₮Psb — **State Bridge Formation (Lower Triassic and Permian)**- Reddish-orange, grayish-red, and pale- reddish-pink, silty sandstone, clayey siltstone, arkosic sandstone, conglomeratic sandstone, and very minor gray dolomite. Locally includes the thin South Canyon Creek Member. Sandstones are very well sorted and equigranular and contain rounded to subrounded sand grains with a high degree of sphericity

₮Pcs — **Chinle and State Bridge Formations, undivided (Upper Triassic to Permian)**—Includes the Chinle and State Bridge Formations on cross-section B–B' where units could not be shown separately

PIPm — **Maroon Formation (Permian and Upper Pennsylvanian)**- Grayish-red and pale-red to pinkish-red, micaceous, arkosic sandstone, conglomerate, siltstone, mudstone, and minor shale and thin beds of gray limestone. Sandstones are coarse to fine grained, moderately to poorly sorted, and contain sand grains that are angular to subangular with a low degree of sphericity

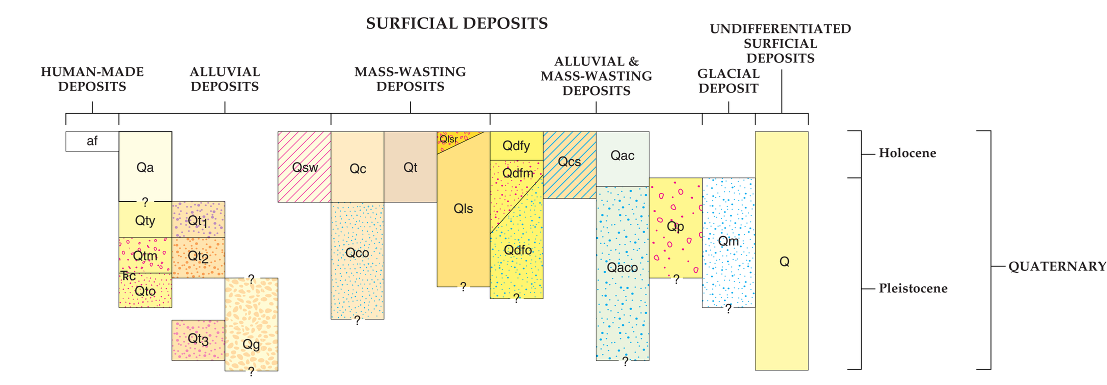
₮Pcm — **Chinle, State Bridge, and/or Maroon Formations, undivided (Upper Triassic to Upper Pennsylvanian)**—Includes Chinle, State Bridge, and/or Maroon Formations in the southwest corner of quadrangle where units are not mapped separately

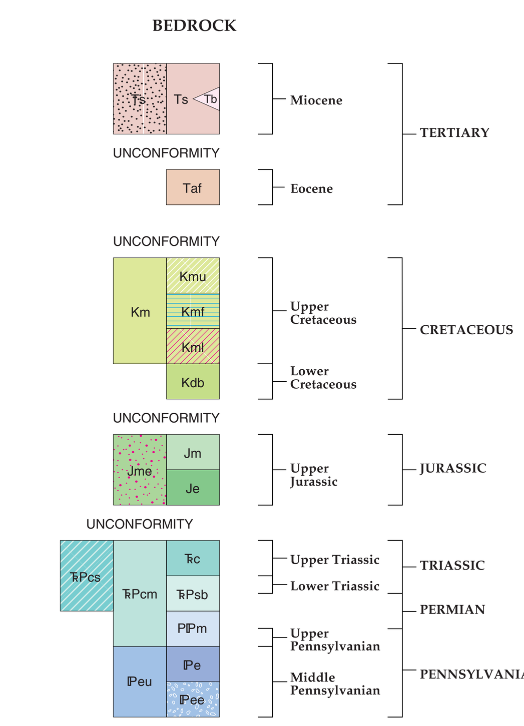
IPe — **Eagle Valley Formation (Middle Pennsylvanian)**- Interbedded reddish-brown, gray, reddish-gray, and tan siltstone, gypsum, and carbonate rocks. Represents a stratigraphic interval in which the red beds of the Maroon Formation grade into and intertongue with the predominantly evaporitic rocks of the Eagle Valley Evaporite. Includes rock types of both formations

IPee — **Eagle Valley Evaporite (Middle Pennsylvanian)**—Sequence of evaporitic rocks consisting of massive to laminated gypsum, anhydrite, halite, beds of light-colored mudstone and fine-grained sandstone, thin limestone, and black shale. May be deformed by diapirism, flowage, dissolution-related collapse, load metamorphism, hydra-tion of anhydrite, and Laramide tectonism

IPeu — **Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)**—Includes rocks of the Eagle Valley Formation and Eagle Valley Evaporite in an area on the southwest side of the Wingo Graben where poor exposures obscure the contact between units

CORRELATION OF MAP UNITS





ACKNOWLEDGEMENTS

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MAP SYMBOLS

Contact—Dashed where approximately located; queried where uncertain

Fault—Dashed where approximately located; dotted where concealed; bar and ball on downthrown side. U on upthrown side; D on downthrown side where entirely concealed

Anticline—Showing trace of axial surface; dashed where approximately located; dotted where concealed; arrow indicates direction of plunge

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

Margin of late Cenozoic collapse area—Collapse caused by evaporite tectonism; black line with red tick marks used where margin coincides with fault; dashed where approximately located; queried where uncertain (see Kirkham and others, 2002, for description of collapse)

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

65 — **Overturned beds**—Showing strike and dip

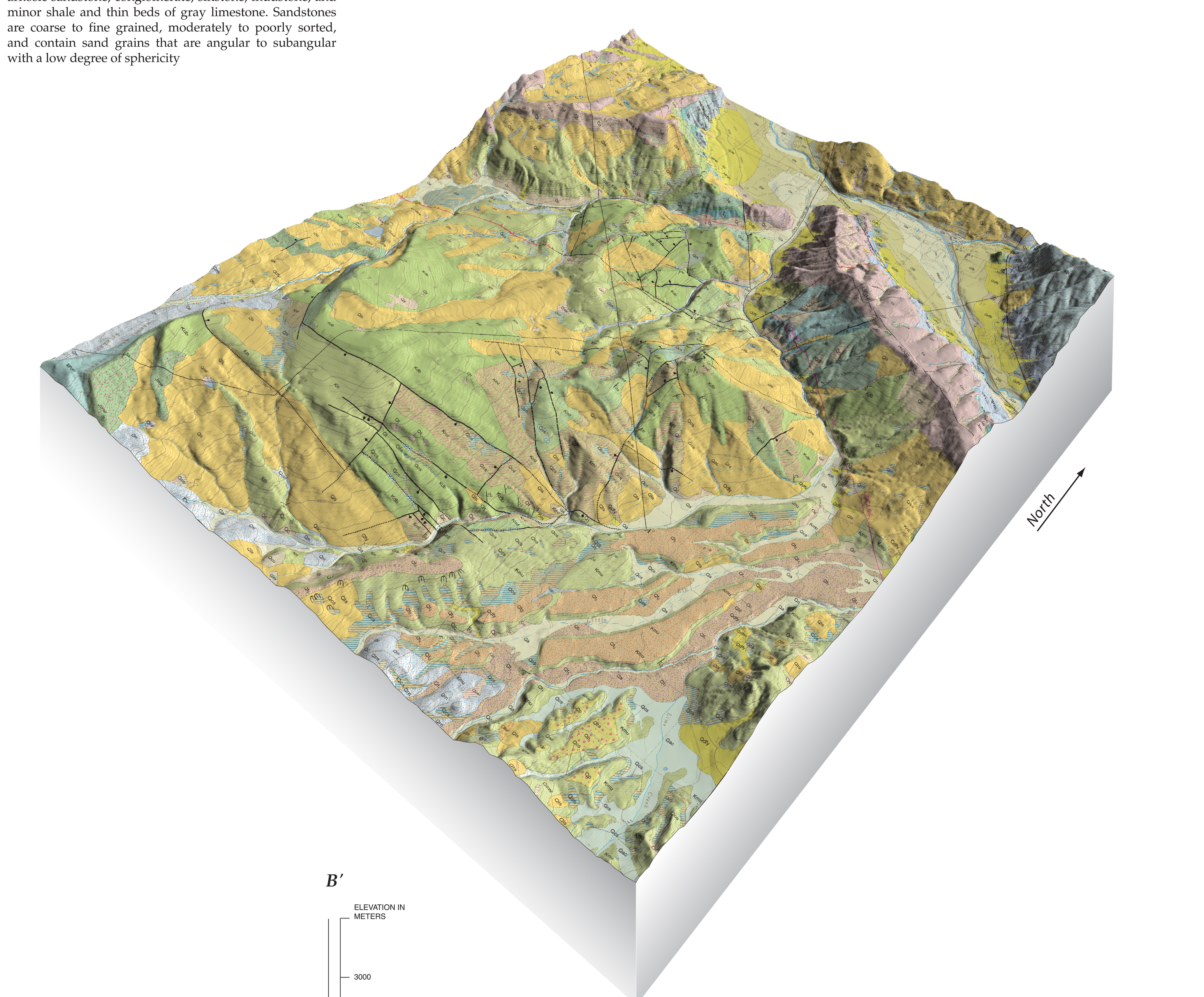
Soil slip—Showing area of localized slope failure

BR-8 — **Location and identification number of rock sample with geochemical analysis (Unruh and others, 2001; Budahn and others, 2002) and $^{40}Ar/^{39}Ar$ age date (Kunk and others, 2002). See Table 1 and Appendix A in booklet**

BR-1 — **Location and identification number of rock sample with geochemical analysis (Unruh and others, 2001; Budahn and others, 2002). See Table 1 and Appendix A in booklet**

A——A′ — **Alignment of cross section**

Qcs/Qt_2 — **Fractional unit**—Indicates a thin veneer of the deposit in the numerator overlies the depositshown in the denominator



GEOLOGIC MAP OF THE BASALT QUADRANGLE, EAGLE, GARFIELD, AND PITKIN COUNTIES, COLORADO

By Randall K. Streufert, Beth L. Widmann, and Robert M. Kirkham

2008

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