OPEN-FILE REPORT 98-1

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

Description of Map Units, Structural Geology, Economic Geology, and References

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

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey STATEMAP program of the National Geologic Mapping Act of 1992, Agreement No.1434-HQ-97-AG-01811.

Colorado Geological Survey
Division of Minerals and Geology
Department of Natural Resources
Denver, Colorado
1998

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits shown on the map are generally more than about 5 ft thick. Residuum and artificial fills of limited extent were not mapped. Contacts between surficial units may be gradational, and mapped units locally include deposits of another type. Divisions of the Pleistocene correspond to those of Richmond and Fullerton (1986). Age assignments for surficial deposits are based primarily upon the degree of erosional modification of original surface morphology, height above modern streams, and relative degree of clast weathering and soil development. Correlation of terraces and interpretations of their ages is hindered by their discontinuous distribution and by deformation which affects some terraces, altering their relative heights above stream level.

HUMAN-MADE DEPOSITS

af — **Artificial fill (latest Holocene)**—Composed mostly of unsorted silt, sand, and rock fragments deposited during construction projects. Maximum thickness is 30 ft. Artificial fill may be subject to settlement when loaded if not adequately compacted.

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, ocassionally bouldery, pebble and cobble gravel in a sandy silt matrix locally interbedded with and commonly overlain by sandy silt and silty sand. Unit 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 (Qdfy) where the distal ends of fans extend into modern river channels. Maximum thickness is about 50 ft. Low-lying areas are subject to flooding. Unit is commonly a good source of sand and gravel.

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. 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. Area is subject to future sheetwash deposition. Unit may be susceptible to hydrocompaction, settlement, and piping where fine grained and low in density.

Qty — **Younger terrace alluvium (late Pleistocene)**—Chiefly stream alluvium underlying terraces that range from about 14 to 50 ft above modern stream level. May be capped by a single, thin loess sheet. Stream alluvium is mostly poorly sorted, clast-supported, ocassionally 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 of a variety of lithologies reflecting the diverse types of bedrock found in the drainage basin. Young terrace deposits 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 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). Unit is probably in part equivalent to outwash of the Pinedale glaciation, which Richmond (1986) estimated to be about 12 to 35 ka. Unit is a good source of sand and gravel.

Qtm **Intermediate terrace alluvium (late Pleistocene)**—Composed of stream alluvium underlying a terrace about 60 to 70 ft above the Roaring Fork River. Locally the unit is capped by a thin loess sheet. It consists of poorly sorted, clast-supported, ocassionally bouldery, pebble and cobble gravel in a sand matrix. Fine-grained overbank deposits may be locally present. Clasts are chiefly subround 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. Thickness averages 20 to 50 ft. Unit may correlate with terrace T6 in the Glenwood Springs-Carbondale area of Piety (1981), with terrace B deposits of Bryant (1979), or with terrace gravel "b"(Qgb) of Freeman (1972). Unit is a good source of sand and gravel.

Qto **Older terrace alluvium (middle Pleistocene)** —Includes deposits of stream alluvium in a terrace in N1/2 SW1/4 Sec. 18, T. 8 S., R. 86 W. Upper surfaces of unit 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. Unit is generally a 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 to moderately weathered at shallow depths. Thickness ranges from about 30 to 60 ft. Unit may correlate with terrace T5 of the Glenwood Springs-Carbondale area of Piety (1981), with terrace C of Bryant (1979), or with terrace gravel "c" (Qgc) of Freeman (1972). Unit may be of Bull Lake age, which is thought to be about 140 to 150 ka (Pierce and others, 1976; Pierce, 1979) or about 130 to 300 ka (Richmond, 1986). Unit may be a source of sand and gravel.

Qg **Gravel (Pleistocene)**—Consists of a single occurrence of stratified, fluvial gravel along the north side of and about 80 to 100 ft above East Sopris Creek in the NW1/4 SE1/4 Sec. 32, T. 8 S., R. 86 W., where it is exposed in a gravel pit. Unit 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 may correlate with gravel deposits (Qgd) mapped by Freeman (1972) on Watson Divide in the Woody Creek quadrangle to the east. Exposed thickness in gravel pit is about 25 ft. Unit is a source of sand and gravel.

Terrace Alluvium of Capital Creek

Qt_1 **Younger terrace alluvium of Capital Creek (late Pleistocene)**—Chiefly stream alluvium underlying terraces from about 15 to 70 ft above Capital Creek. Unit 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 is about 60 ft. Unit correlates with the gravel deposit (Qga) mapped by Freeman (1972) in the Woody Creek quadrangle and probably is at least in part equivalent to youngest terrace alluvium (Qty) mapped herein along the Roaring Fork River. Unit Qt_1 may be of Pindedale age. It is a source of sand and gravel.

Qt_2 **Intermediate terrace alluvium of Capital Creek (late 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), except clasts are slightly to moderately weathered. Maximum thickness is about 50 ft. Stratigraphic relationships with terraces along the Roaring Fork River were not investigated during this study. Unit is a potential source of sand and gravel.

Qt_3 **Oldest terrace alluvium of Capital Creek (middle or early Pleistocene?)**—Consists of stream alluvium underlying the terrace that forms 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 and its clasts are moderately to highly weathered. Maximum thickness is about 40 ft. Stratigraphic relationships with terraces along the Roaring Fork River were not evaluated during this study. Unit is a potential source of sand and gravel.

COLLUVIAL DEPOSITS—Silt, sand, gravel, and clay on valley sides, valley floors, and hillslopes that were transported and deposited primarily by gravity, but frequently assisted by sheetwash, freeze-thaw action, and water-saturated conditions.

Qlsr

Recent landslide deposits (latest Holocene)—Includes a single, recently active landslide with fresh morphological features. Deposit consists of unsorted, unstratified rock debris, sand, silt, and clay that likely moved as a debris avalanche. Maximum thickness is about 20 ft. Recent landslide initiated on a steep face of Mancos Shale (Km) in the W1/2 SW1/4 Sec. 20, T. 9 S., R. 86 W., which has previously generated other landslides. Recent landslides may be prone to renewed or continued landsliding, and they are suggestive of the type of conditions which may produce future landslides in the current climatic regime.

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 colluvium 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 predominate. Clasts typically are angular to subangular, except in those colluvial deposits which are derived from fluvial gravel deposits, in which case clasts are rounded to subrounded. Commonly unit 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 above 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 grades to and interfingers with alluvium and colluvium (Qac), colluvium and sheetwash (Qcs), younger debris-flow deposits (Qdfy), and sheetwash deposits (Qsw) along some tributary drainages and hillslopes. Maximum thickness is about 40 to 60 ft. Areas mapped as colluvium are susceptible to future colluvial deposition and locally subject to sheetwash, rockfall, small debris flows, mudflows, and landslides. Fine-grained, low-density colluvium may be prone to hydrocompaction, piping, and settlement, particularily when derived from Maroon Formation or evaporitic rocks. May be corrosive when derived from evaporitic rocks.

Qt

Talus (Holocene and late Pleistocene)—Angular, cobbly and bouldery rubble derived from outcrops of the Dakota Sandstone and Burro Canyon Formation (Kdb), Tertiary ash-flow tuff (Taf), and sandstone beds in the Mancos Shale (Km), and transported downslope principally by gravity as rockfalls, rockslides, and rock topples. Unit commonly lacks matrix material. Locally it is underlain by or incorporated into landslides. Maximum thickness is about 30 ft. Areas mapped as talus are subject to rockfall, rockslide, and rock-topple hazards. Talus deposits derived from and occurring below outcrops of Tertiary ash-flow tuff (Taf) may have periglacial features or be affected by frost-heave activity. Area is subject to future talus deposition. Talus derived from the Dakota Sandstone and Burro Canyon Formation (Kdb) could be a source of riprap. Unit is difficult to excavate.

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, and extensive slope-failure complexes. Landslides are common and of considerable areal extent in areas where dipping Mancos Shale (Km) is exposed at the surface. In some areas the contact between the Mancos Sahle (Km) and Dakota Sandstone and Burro Canyon Formation (Kdb) has served as the basal slip plane for landslides. Landslides are also common in Tertiary sediments (Ts) in the northwest corner of the quadrangle. Some of the isolated hills mapped as Tertiary sediments (Ts) in this area may be eroded remnants of landslide deposits. The large landslide complex north of the Roaring Fork River on the south flank of Basalt Mountain involved Mancos Shale and overlying basalt flows. These deposits locally contain matrix-free basalt rubble. Maximum thickness is about 200 ft, but usually it is less than 100 ft thick. Area may be subject to future landslide activity; however, deeply dissected landslide deposits may be stable. Deposits may be prone to settlement when loaded. Low-density, fine-grained deposits may be susceptible to hydrocompaction. Local areas within this unit may have shallow groundwater.

Qco **Older colluvium (Pleistocene)**—Occurs on drainage divides, ridge lines, and dissected hillslopes on valley walls as erosional remnants of formerly more extensive deposits that were transported by gravity and aided by sheetwash. Genesis, texture, bedding, and clast lithology are similiar to colluvium (Qc). Unit averages 10 to 25 ft thick; maximum thickness about 60 ft. Generally is not subject to significant future colluvial deposition, except where adjacent to eroding hillslopes. Unit may be subject to collapse, piping, and settlement where fine grained and low in density.

ALLUVIAL AND COLLUVIAL DEPOSITS—

Silt, sand, gravel, and clay in debris fans, stream channels, flood plains, pediments, and adjacent hillslopes along tributary valleys. Depositional processes in stream channels and on flood plains are primarily alluvial, whereas, colluvial and sheetwash processes are prevalent on debris fans, hillslopes, pediments, and along the hillslope/valley floor boundary.

Qdfy **Younger debris-flow deposits (Holocene)**—Sediments deposited by debris flows, hyperconcentrated flows, streams, and sheetwash on active fans and in stream channels. 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 modern alluvium adjacent to stream channels. Clast lithology is diverse as debris-flow deposits involve most named bedrock units, including Tertiary sediments (Ts), landslide deposits (Qls), and colluvium (Qc). 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 (Qty). Original depositional surfaces are usually preserved, except where they have been disturbed by human activities. Maximum thickness is about 50 ft. Area is subject to flooding and to future debris-flow, hyperconcentrated-flood, and alluvial deposition following intense rainstorms, except on distal parts of some fans, where mudflow and sheetwash processes prevail. Younger debris-flow deposits are prone to settlement, piping, and hydrocompaction where fine grained and low in density, subject to sinkhole development by piping where underlain by cavernous evaporitic rocks, and are corrosive if derived from evaporitic rocks.

Qac **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Unit is chiefly stream-channel, low-terrace, and flood-plain deposits along valley floors of ephemeral, intermittent, and small perennial streams, with colluvium and sheetwash on valley sides. Deposits of alluvium and colluvium probably interfinger. Locally includes younger debris-flow deposits or may grade to debris-flow deposits in some drainages. Alluvium is typically composed of poorly sorted to well-sorted, stratified, interbedded pebbly sand, sandy silt, and sandy gravel, but colluvium may range to unsorted, unstratified or poorly stratified, clayey, silty sand, bouldery sand, and sandy silt. Clast lithologies are dependant upon types of rock in source areas. Thickness is commonly 5 to 20 ft; maximum thickness about 40 ft. Low-lying areas are subject to flooding. Valley sides are prone to sheetwash, rockfall, and small debris flows. Fine-grained, low-density deposits may be subject to settlement, piping, and hydrocompaction. Unit is a potential source of sand and gravel.

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 contacts between the two types of deposits are very gradational and difficult to locate. Refer to unit descriptions for colluvium (Qc) and sheetwash deposits (Qsw) for genetic, textural, and lithologic characteristics and for engineering properties and hazards.

Qdfm **Intermediate debris-flow deposits (Holocene? and late Pleistocene)**—Similiar in texture, lithology, and depositional environment to younger debris-flow deposits (Qdfy). Geomorphic character of original depositional surfaces are commonly recognizable, but the surfaces are 10 ft or more above active debris-flow channels which have been incised into them. This relationship occurs in the debris-flow deposits in the SW1/4 SE1/4 Sec. 24, T.8 S., R. 87 W. A younger debris-flow (Qdfy) was deposited above and partially covers intermediate debris-flow deposits (Qdfm) in the NE1/4 SE1/4 Sec. 8, T. 9 S., R. 86 W. Maximum thickness is about 60 to 80 ft. Area is generally not susceptible to future debris-flow activity unless a channel becomes blocked or an unusually large debris flow occurs. Hydrocompaction, piping, and settlement may occur where deposits are fine-grained and have low density.

Qdfo **Older debris-flow deposits (Holocene? and Pleistocene)**—Occurs as a remnant of a debris fan in the NE1/4 SW1/4 Sec. 18, T. 8 S., R. 86 W. in the vicinity of the Basalt Mountain Fault southwest of Basalt. Unit is texturally, genetically, and lithologically similiar to younger debris-flow deposits (Qdfy). Clasts range from unweathered to moderately weathered. Elevation difference between original depositional surface and adjacent drainage channels is about 20 to 60 ft. Thickness is estimated at 10 to 40 ft. Where fine grained and low in density, unit may be prone to piping, settlement, and perhaps hydrocompaction. It is corrosive when derived from evaporitic bedrock. Unit is a potential source of sand and gravel.

Qaco **Older alluvium and colluvium, undivided (Pleistocene)**—Deposits of alluvium and colluvium ranging from about 10 to 200 ft above adjacent small 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. Numeric subscripts used in upper West Sopris Creek indicate the relative age of these deposits, with $Qaco_1$ being younger than $Qaco_2$. Area is subject to active colluvial and sheetwash deposition where adjacent to hillslopes. Unit is a potential source of sand and gravel.

Qp **Pediment deposits (late or middle Pleistocene)**—Gravelly alluvium and debris-flow deposits at one and perhaps two levels that underlie gently sloping surfaces eroded into the Mancos Shale on the ridge between Capital and Lime Creeks in the southeast corner of the quadrangle. Deposit consists of poorly sorted, matrix- and clast-supported pebble gravel in a silty and clayey matrix. Clasts and matrix are entirely derived from adjacent outcrops of Mancos Shale. Maximum thickness is about 20 or 30 ft but could be thicker in channel thalwags. Pediment surfaces appear to have been graded to and may be similar in age or slightly younger than intermediate terrace alluvium of Capital Creek (Qt_2). Pediment deposits are prone to landsliding where exposed in steep slopes along their eroded margins. They may also be prone to expansive soil problems.

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

Qti **Till (late and middle Pleistocene)**—Heterogeneous deposits of gravel, sand, silt, and clay deposited by ice as ground, lateral, and end moraine along Capital, East Sopris, and West Sopris Creeks. Unit may include proglacial deposits along Capital Creek. Deposits are dominantly poorly sorted, unstratified or poorly stratified, matrix-supported, bouldery, pebble and cobble gravel with a matrix of silty sand, although proglacial deposits may be well stratified and well sorted. Unit may locally be clast-supported where composed mostly of gravel. Clasts are typically angular to subrounded pieces of red sandstone and conglomeratic sandstone and hypabyssal igneous rocks but may locally include other types of sedimentary rocks. Deposits of till typically form very hummocky landforms that may be difficult to differentiate from landslide deposits, particularly since till is prone to landsliding. Lateral and end moraines are usually steep sided and have well defined moraine crests. Unit probably includes deposits of Pinedale and Bull Lake age. Maximum thickness is estimated at 240 ft. Unit is very prone to landsliding. Unit is a potential source of sand and gravel.

UNDIFFERENTIATED SURFICIAL DEPOSITS

Q

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

BEDROCK

Tb

Basalt (Miocene?)—Unit occurs in the center of Sec. 13, T. 8 S., R. 87 W., at the northwest end of Light Ridge, as a lense-like remnant of a single flow of light- to medium-gray basaltic lava. Flow rocks generally are vesicular and sometimes amygdoloidal, but locally they are dense. Both phenocrysts and groundmass are highly weathered. Petrographically the unit is holocrystalline with a porphyritic texture. Phenocrysts are euhedral to subhedral plagioclase, pyroxene with iron-oxide weathering rinds, and minor olivine rimmed with iddingsite. Groundmass consists of plagioclase, altered pyroxene, and opaque minerals with an intergranular texture. Unit is geochemically a trachyandesite on the basis of whole-rock analyses, although relatively high alkaline-oxide concentrations may be attributable to the high degree of alteration and weathering of the analyzed sample. The relatively high silicon-dioxide content (59.20 percent SiO_2, wt. percent), which suggests the flow may have been andesitic, may also reflect alteration and weathering. Maximum exposed thickness is 50 to 75 ft. Flow is interbedded with and includes in its basal portion cobble-sized clasts of Tertiary sediments (Ts). Flow remnant dips at 12° to 15° to the northwest and may have been deformed post-depositionally due to collapse or sagging into a subsidence trough related to flowage or dissolution of near-surface evaporite.

Ts

Sedimentary deposits (Miocene)—Very weakly indurated to unconsolidated deposits of pebble- to cobble-sized, locally bouldery, clast-supported, fluvial gravel. Matrix is silty sand. Clasts are subrounded to well rounded and are of various rock types depending on location. The southern portions of the outcrop area of these deposits, which are nearer to Mt. 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 basalt clasts. Unit occurs in northwest corner of quadrangle where deposits exceed 1000 ft in thickness, and may be as much as 2000 ft in thickness. In this area Tertiary sediments apparently fill a large structural subsidence feature most likely related to dissolution or flowage of evaporite. This subsidence feature may be part of the Carbondale collapse center described by Kirkham and Widmann (1997). Tertiary sediment occurring on the northwest end of Light Ridge have been faulted down to near modern river level along the Basalt Mountain Fault. Ths surface is locally capped by Quaternary surficial deposits. Tertiary sediments in the northwest corner of the quadrangle overlie, and hence are younger than, ash-flow tuff (Taf) that has been dated by $^{40}Ar/^{39}Ar$ dating by laser fusion on sanidine at 34.22 ± 0.17 Ma (M. Kunk, , pers. commun., 1998). Unit also caps Light Ridge. Deposits capping Light Ridge range from 100 ft thick on the east boundary of quadrangle, where they dip northward at 8 degrees, to thicknesses approaching 1000 ft on the northwest end of the ridge where unit thickens as it approaches the Carbondale collapse center. Tertiary sedimentary deposits on Light Ridge were most likely deposited in an ancestral channel of the Roaring Fork River which drained into the subsidence basin mentioned above. On the northwest end of Light Ridge, Tertiary sedimentary deposits occurring in the Wingo Graben are offset by the Basalt Mountain Fault. Unit is a source of sand and gravel.

Taf

Ash-flow tuff (Eocene)—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. 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. Petrographically 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. Texture is fragmental. Lithic clasts are pebble-sized fragments of Proterozoic plutonic rock that are more abundant in the basal ash-flow sheets. Geochemically the ash-flow tuff is dacitic (Table 1). The block-and-ash-flow tuff deposits are identical to the ash-flow tuff deposits described above 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. Texture is hyalopilitic. Comparatively these lithic blocks are also dacitic, although they are slightly more siliceous than ash-flow tuff (Table 1). Sequence also contains thin (2 to 6 in.), very fine-grained, cross-bedded, ash-rich surge deposits occurring between ash-flow sheets. Entire ignimbrite package is up to 300 ft thick.

Tertiary ash-flow tuff (Taf) from this outcrop has a $^{40}Ar/^{39}Ar$ laser fusion age on sanidine of 34.22 ± 0.17 Ma (M. Kunk, pers. commun., 1998). This deposit has been interpreted as outflow from the somewhat younger 34 Ma Grizzly Peak caldera (Fridrich and others, 1991), located 32 miles to the southeast. Cross-bedding foresets in surge deposits indicate a transport direction of about N 30° 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 near-by developing siliceous dome (T. Schroeder, 1997, oral commun.). These data suggest that this pyroclastic deposit may be related to a much more proximal extrusive volcanic event. Mt. Sopris, located 5.7 miles to the southwest, is a possible source. Correlation of preliminary whole-rock data from ash-flow tuff (Sample No. BR-1, Table 1), with quartz monzonitic porphyry from the summit of Mount Sopris (Sample No. Mt. Sopris 1, Table 1) is inconclusive, although the total silica content (as SiO_2 wt. percent) of these two samples is identical (68.64 wt. percent). The very high Na_2O and low K_2O content of the sample from Mt. Sopris suggests that it is altered.

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. Includes the Fort Hays Limestone Member (Kmf), a gray, thickly-bedded limestone which occurs about 300 ft above the base. Undivided unit also includes the upper and lower sandstone members (Kms and Kmsl) mapped by Freeman (1972) in the Woody Creek quadrangle to the east. These sandstone beds were not mapped separately in the Basalt quadrangle. The main body of the Mancos Shale is medium- to dark-gray marine shale. The upper part of the formation is not present in the quadrangle. Mancos Shale crops out across much of the quadrangle; however, exposure is poor except for in the Capital Creek drainage. Unit is mapped where vegetative cover prohibits mapping of units separately. Slopes underlain by Mancos Shale are frequently mantled with landslides and other surficial deposits. Total thickness of the undivided Mancos Shale in Woody Creek quadrangle to the east is 5,200 ft (Freeman, 1972). Unit was deposited in a low-energy, off-shore marine environment. The Mancos Shale is very prone to landsliding. Unit is susceptible to shrink-swell problems where it contains expansive clays.

Kmu

Upper unit—Dark-gray, silty to sandy, carbonaceous shale, medium-gray, fine-grained, grayish-yellow-weathering, clayey sandstone, and minor thin bentonite beds. Unit may include upper and lower sandstone members (Kms and Kmsl) mapped by Freeman (1972) in Woody Creek quadrangle. Top of upper unit does not occur in quadrangle. Total thickness of upper unit probably exceeds 4,800 ft. Unit was deposited in a low-energy, off-shore marine environment. Unit is very prone to landsliding and is susceptible to shrink-swell problems where it contains expansive clays.

Kmf

Fort Hays Limestone Member—Gray, thick-bedded, coarse-grained limestone containing interbeds of limy shale. Occurs about 300 ft above base of Mancos Shale. Unit is mapped separately in the vicinity of East Sopris Creek. Maximum thickness is probably about 40 to 50 ft. Unit was deposited in a shallow-marine environment.

Kml

Lower unit—Medium- to dark-gray, carbonaceous, silty shale. Unit is mapped in the vicinity of East Sopris Creek where bounding outcrops of the Fort Hays Limestone Member of the Mancos Shale above, and the Dakota Sandstone and Burro Canyon Formation (Kdb) below, allow for recognition of the unit stratigraphically. Unit is 300 ft thick. Unit was deposited in a shallow-marine environment. Unit is very prone to landsliding.

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, quartzite, and conglomeratic sandstone in well-cemented, thick beds. Burro Canyon Formation consists of yellowish-gray, medium-grained sandstone containing quartz pebbles and lenses of green and red chert. Combined unit also contains some sandy shale intervals which are poorly exposed. Sandstones of unit are generally very well indurated and form prominent outcrops with talus aprons below. Freeman (1972) reports 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. Unit is conformable with the overlying Mancos Shale. Unit was deposited nearshore in a transgressive environment. Unit may present rockfall hazard when exposed in steep cliffs or embankments.

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 the unit 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 occurs at the base of the formation directly overlying the Entrada Sandstone (Je). Thickness is variable but averages about 300 to 350 ft. Unit is usually poorly exposed and is frequently covered with surficial deposits. Morrison Formation sandstone beds are, however, fairly well exposed along the East Sopris Creek road in Sec. 30, T. 8 S., R. 86 W. Contact with overlying Dakota Sandstone and Burro Canyon Formation (Kdb) is sharp and unconformable. Unit was probably deposited in a lacustrine-dominated, fluvio-lacustrine environment (Fairer and others, 1993). Shale and claystone beds in the unit are prone to landsliding.

Je

Entrada Sandstone (Upper Jurassic)—Tan to white, medium- to fine-grained, well-sorted, poorly indurated, cross-bedded sandstone. Sand fraction is mostly rounded to subrounded quartz grains. Thickness is about 40 to 60 ft. Exposure is generally poor due the weakly cemented nature of the unit. The Entrada Sandstone is well exposed, however, north of East Sopris Creek in the NW1/4 SE1/4 Sec. 30, T. 8 S., R. 86 W. Contact with overlying Morrison Formation is sharp and conformable, occurring at the top of the main sandstone 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 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 boundary where poor exposures preclude mapping of units separately. Shale and claystone portions of Morrison Formation may be prone to landsliding.

TRc

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. May include a thin, basal conglomeratic sandstone, the Gartra Member (Dubiel, 1992), which was not recognized in the quadrangle. Contact with overlying Entrada Sandstone is sharp and unconformable. Good exposures are uncommon, but the formation is well exposed on the south flank of Light Ridge in the N1/2 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 NE1/4 Sec. 15, T. 8 S., R. 87 W. Thickness is 100 to 200 ft. Unit thins from east to west across the Basalt quadrangle. The Chinle Formation thickens to over 1000 ft to the east in the Woody Creek quadrangle (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).

TRPsb **State Bridge Formation (Lower Triassic and Permian)**—Reddish-orange, grayish-red, and pale- reddish-pink, silty sandstone, clayey siltstone, arkosic sandstone, conglom-eratic sandstone, and very minor gray dolomite. Includes the lower siltstone and sandstone member of Freeman (1971; 1972), which contains the South Canyon Creek Member. The dolomite of South Canyon Creek, a medium-gray, silty and sandy lime-stone and dolomite (Bass and Northrup, 1950; Stewart and others, 1972), occurs in lenses only 12 to 18 inches thick. Sandstones of the unit 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. Conglom-eratic sandstone beds are numerous, from 1 to 12 ft in thickness, and massive to very slightly crossbedded, containing mostly peb-ble-sized clasts of quartz, chert, sediments, and Proterozoic granitic rocks. All of the State Bridge Formation contains mica, although in generally lesser concentrations than in the underlying Maroon Formation. Contact with the overlying Chinle Forma-tion is sharp and unconformable. Thickness of the State Bridge has large variations in the Basalt quadrangle. The lower part ot the State Bridge Formation is 1000 ft thick north of the Roaring Fork River in the Basalt quad-rangle and is overlain by another 1000 ft of the upper part in the adjacent Woody Creek quadrangle (Freeman, 1972). The unit is only 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 sug-gests 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 predomi-nantly continental deposits to the east and marine deposits to the west (Stewart and others, 1972).

TRPcs **Chinle and State Bridge Formations, undi-vided (Upper Triassic to Permian)**—Includes 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, arkosic sandstone, conglom-erate, siltstone, and mudstone, with shale and minor, thin beds of gray limestone. All rock types contain noticebly more detrital mica than in the overlying State Bridge Formation. Unit crops out at the base of both valley walls along the Roaring Fork River south and southeast of the town of Basalt. Sandstones are coarse to fine grained, mod-erately to poorly sorted, and contain sand grains that are generally angular to suban-gular with a low degree of sphericity. This distinguishes Maroon Formation rocks from overlying State Bridge Formation rocks, the sand grains of which are consistently well sorted and high in sphericity. A color change is locally useful in locating this contact, as the Maroon Formation tends to be pale red-dish pink, whereas the State Bridge Form-ation is orange red and brownish red. The contact is best exposed at an elevation of 7,320 ft in the southwest facing canyon in the SW1/4 Sec. 16, T. 8 S., R. 86 W., on the north side of the Roaring Fork Valley. Unit may contain eolian deposits (loessite) in its upper portions that are reflected in sand-stones with a predominance of sandy silt grain size, homogeneity, and lack of sedi-mentary structure (Johnson, 1989b). Upper contact is sharp and unconformable. Thickness of the unit in adjacent quadran-gles to the west is 3,000 to 5,000 ft (Kirkham and others, 1995; Kirkham and Widmann, 1997). The upper part of the Maroon Form-ation was deposited in the Central Colorado Trough in fluvial and eolian environments (Johnson and others, 1988). Formation is prone to rockfall where exposed in steep cliffs.

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

IPe **Eagle Valley Formation (Middle Pennsylvanian)**—Interbedded reddish-brown, gray, reddish-gray, and tan siltstone, gypsum, and carbonate rocks. Unit 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. It includes rock types of both formations. Unit ranges from 500 to 3000 ft thick to the northwest on the Carbondale quadrangle (Kirkham and Widmann, 1997). The Eagle Valley Formation is less than 500 ft thick in the Basalt quadrangle. The Eagle Valley Formation is conformable and intertongues with the overlying Maroon Formation and underlying Eagle Valley Evaporite. Contact with 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. It was deposited in the Central Colorado Trough on the margin of an evaporite basin in fluvial and marine environments. Unit may be susceptible to subsidence and sinkholes. Surficial deposits derived from it are prone to collapse, compaction, piping, and corrosion problems.

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. Massive gypsum beds are exposed along either side of the Basalt Mountain Fault in the W1/2 Sec. 18, T. 8 S., R. 86 W. Thickness of unit may 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 (1997) near Catherine to the west in the Carbondale quadrangle. Complex deformation and lack of subsurface data preclude an estimate of the thickness of the Eagle Valley Evaporite in the Basalt quadrangle. 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 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. The Eagle Valley Evaporite may contain cavernous voids caused by near-surface dissolution of halite and gypsum. The unit is prone to development of sinkholes into which overlying deposits may subside or be piped. Surficial deposits derived from unit may be subject to compaction, settlement, sinkhole, and corrosion problems. Gypsum and halite may be an exploitable resource within the formation.

IPeu **Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)**—Unit includes an area on the southwest side of the Wingo Graben where these formations are not mapped separately. Unit may be susceptible to development of sinkholes into which overlying deposits may subside or be piped. Prone to compaction, settlement, sinkhole, and corrosion problems.

STRUCTURAL GEOLOGY

The Basalt quadrangle is located east of the late Laramide age Grand Hogback Monocline and north of the Elk Mountain Thrust. It is northeast and east of the middle Tertiary Mount Sopris stock and due north of the Snowmass pluton. The northwestern portion of the quadrangle lies within a large area of Neogene age collapse of regional proportions called the Carbondale collapse center by Kirkham and Widmann (1997). The structural geology of the Basalt quadrangle involves deformational styles related to Laramide compression, middle Tertiary deformation related to the emplacement of Mt. Sopris pluton, and Neogene salt tectonism and collapse.

Deformation due to salt tectonism and collapse overprints older Laramide structures and possibly affects structures related to the Mt. Sopris intrusive event. The anticline and syncline pair near the mouth of West Sopris Creek, and the Roaring Fork Syncline in East Sopris Creek, are possible examples of Laramide age compressional features which have been modified by younger deformation. These structures are locally truncated by younger normal faulting that appears to be related to collapse.

Deformation related to the emplacement of the Mt. Sopris Pluton is evident in the very southwest corner of the quadrangle where Upper Pennsylvanian through Cretaceous rocks are folded upward against a concordant contact of the stock. The large fold in the Cretaceous rocks in the southern portion of the map area north of Hay Park defines part of the south limb of the Roaring Fork Syncline. This Laramide age structure may have been subsequently modified by the emplacement of the Mt. Sopris pluton. To the east of Hay Park the south limb of the Roaring Fork Syncline has been modified by probable Neogene age, graben- and stair-step-type, normal faulting which may be related to dissolution and flowage of Pennsylvanian evaporitic rocks in the subsurface.

The Basalt Mountain Fault, which enters the quadrangle from the north where it is buried by thick colluvial deposits on the west side of Basalt Mountain, is a complex structure with suspected multi-stage movement and has undergone down-to-the-west Neogene collapse due to salt dissolution and flowage (Streufert, and others, 1997a; Kirkham and Widmann, 1998). The Basalt Mountain Fault is a reverse fault on Cottonwood Pass quadrangle (Streufert and others, 1997a) and may also retain its high-angle reverse nature in the Leon quadrangle, although conclusive evidence is lacking (Kirkham and others, 1998). This structure enters Basalt quadrangle from the north, crosses the Roaring Fork Valley at Emma, and trends southeast along the northeast flank of Light Ridge. In the area of the northwest end of Light Ridge the Basalt Mountain Fault has offset Tertiary sediments (Ts) down to near modern valley level. These faulted Tertiary sediments (Ts) have been locally covered by Quaternary surficial deposits. The fault is well exposed on the hillside near the railroad bridge at Wingo along the eastern boundary of the quadrangle. In the N$^1/_2$ 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. West of this exposure a sequence of rocks including the Lower Cretaceous Dakota Sandstone and Burro Canyon Formation, and the Upper Cretaceous Mancos Shale, are faulted against Maroon Formation. This segment of the Basalt Mountain Fault may have also behaved as a growth fault during Permian through early Triassic time. This is suspected because of a rather abrupt thickness change in the State Bridge Formation (TRPsb) from 200 ft to well over 2000 ft across the fault. The Basalt Mountain Fault, and a valley-bounding, high-angle, down-to-the-southwest, normal fault on the northeast side of the Roaring Fork Valley, which may be the northwestward extension of the Castle Creek Fault, defines the Wingo Graben. The Wingo Graben may be of Laramide or Neogene age, or both.

In the northwest corner of the quadrangle at least 1,000 ft, and possibly as much as 2,000 ft, of fluvial gravel (Ts) was deposited in a large basin that may owe its origin to dissolution-related collapse of underlying evaporitic rocks. The fluvial gravels overlie late Eocene age ash-flow tuff (Taf), dated at 34.22 ± 0.17 Ma (M. Kunk, pers. commun., 1998) and hence are younger than this pyroclastic event. Basaltic lava, which has been tentatively dated at less than 14 Ma in the Carbondale quadrangle (Kirkham and Widmann, 1997) appears to overlie these fluvial sediments. The northwestern part of the Basalt quadrangle, which coincides in part with the basin containing the late Tertiary fluvial gravels (Ts), is probably within the Carbondale collapse center described by Kirkham and Widmann (1997). This unusually thick deposit of fluvial gravel (Ts) may be due, in part, to the dissolution of subsurface halite and/or gypsum triggered by the intrusion of the Mt. Sopris pluton. The precise boundary of the Carbondale collapse center, if occurring within the Basalt quadrangle, is difficult to accurately locate. Pervasive normal faulting in this quadrangle could be related to Neogene salt tectonism. Middle Tertiary ash-flow tuff (Taf) exposed in the quadrangle occurs within this proposed area of collapse and may have been down-dropped from its original position of emplacement in relation to a source on Mt. Sopris. The relatively large vertical relief of Mt. Sopris may in part be due to evaporite-related collapse around the north and northwest flank of the stock.

ECONOMIC GEOLOGY

The only valuable mineral resource in the quadrangle is probably sand and gravel. Alluvium (Qa) and terrace gravels (Qty, and Qtm) along the Roaring Fork Valley, and gravel in East Sopris Creek (Qg) contain sand and gravel resources. Tertiary sedimentary deposits (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 (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 (Qto and Qt_3) are probably less desirable due to degree of weathering in the clasts. Gypsum beds are mined to the northwest of the quadrangle, but in the Basalt quadrangle they generally are too deep below the surface or of limited lateral extent to constitute a resource.

Table 1. Whole-rock analyses of the Basalt and Mount Sopris quadrangles.
[Analyses conducted by Chemex Labs, Inc., Sparks, Nevada.]

Sample ID No.	PERCENT												
	Al_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2	LOI*	Total
BR-1	13.80	2.33	0.01	2.14	3.14	0.63	0.05	2.93	0.09	68.64	0.25	4.99	99.00
BR-6	15.50	4.23	0.01	6.42	3.91	1.25	0.06	3.84	0.39	59.20	1.15	1.72	97.68
BR-8	13.90	3.98	0.01	4.16	3.03	0.33	0.05	2.65	0.28	70.20	0.55	1.30	100.45
Mt. Sopris 1	15.80	1.61	0.01	1.44	0.17	1.20	0.03	8.77	0.26	68.64	0.56	1.20	99.69

*Loss on ignition

Sample Descriptions:

BASALT QUADRANGLE

BR-1—Tertiary ash-flow tuff (Taf) from the SW1/4 SW1/4 Sec. 21, T. 8 S, R. 87 W. Sample is an unwelded, dacitic, ash-flow tuff containing quartz, feldspar, and biotite phenocrysts with minor pebble-sized lithics.

BR-6—Tertiary basalt (Tb) from northwest end of Light Ridge in the SE1/4 NW1/4 Sec. 13, T. 8 S., R. 87 W. Sample is a very weathered, massive to vesicular, medium-gray basalt from a flow remnant near the mouth of Sopris Creek.

BR-8—Tertiary block-and-ash-flow tuff (Taf). Select grab of partially devitrified, dacitic, angular, extrusive dome material collected from within a bed of ash-flow tuff in the NW1/4 NW1/4 Sec. 22, T. 8 S., R. 87 W.

MOUNT SOPRIS QUADRANGLE

Mt. Sopris 1—Porphyritic quartz monzonite collected from the summit of Mt. Sopris.

SELECTED REFERENCES

Bass, N.W., and Northrop, S.A., 1950, South Canyon Creek Dolomite Member, a unit of Phosphoria age in Maroon Formation near Glenwood Springs, Colorado: American Association of Petroleum Geologists Bulletin, v. 34, no. 7, p. 1540–1551.

Bryant, Bruce, 1979, Geology of the Aspen 15-minute quadrangle, Pitkin and Gunnison Counties, Colorado: U.S. Geological Survey Professional Paper 1073, 146 p.

Bryant, B., and Shroba, R.R., in preparation, Revised preliminary geologic map of the Storm King Mountain quadrangle, Garfield County, Colorado: U.S. Geological Survey Open-File Report, scale 1:24,000.

Carroll, C.J., Kirkham, R.M., and Stelling, P.L., 1996, Geologic map of the Center Mountain quadrangle, Garfield County, Colorado: Colorado Geological Survey Open-File Report 96-2, scale 1:24,000.

Dubiel, R.F., 1992, Sedimentology and depositional history of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle Basins, northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 1787-W, 25 p.

Fairer, G.M., Green, M.W., and Shroba, R.R., 1993, Preliminary geologic map of the Storm King Mountain quadrangle, Garfield County, Colorado: U.S. Geological Survey Open-File Report 93-320.

Freeman, V.L., 1972, Geologic map of the Woody Creek quadrangle, Pitkin and Eagle Counties, Colorado: U.S. Geological Survey Map GQ-967, scale 1:24,000.

_______1971, Stratigraphy of the State Bridge Formation in the Woody Creek quadrangle, Pitkin and Eagle Counties, Colorado: U.S. Geological Survey Bulletin 1324-F, p. F1–F17.

Fridrich, C.J., Smith, R.P., DeWitt, Ed, and McKee, E.H., 1991, Structural, eruptive, and intrusive evolution of the Grizzly Peak caldera, Sawatch Range, Colorado: Geological Society of America Bulletin, v. 103, p. 1160–1177.

Johnson, S.Y., 1989a, The Fryingpan Member of the Maroon Formation-a lower Permian(?) basin-margin dune field in northwestern Colorado: U. S. Geological Survey Bulletin 1787-I, p. I1–I11.

_______989b, Significance of loessite in the Maroon Formation (Middle Pennsylvanian to Lower Permian), Eagle Basin, northwest Colorado: Journal of Sedimentary Petrology, v. 59, no. 5, p. 782–791.

Johnson, S.Y., Schenk, C.J., and Karachewski, J.A., 1988, Pennsylvanian and Permian depositional cycles in the Eagle Basin, northwest Colorado *in* Holden, G.S., ed., Geological Society of America field trip guidebook: Colorado School of Mines Professional Contributions 12, p. 156–175.

Kirkham, R.M., Bryant, B., Streufert, R.K., and Shroba, R.R., 1996, Fieldtrip guidebook on the geology and geologic hazards of the Glenwood Springs area, Colorado, *in* Thompson, R.A., Hudson, M.R., and Pilmore, C.L., eds., Geologic excursions to the Rocky Mountains and beyond; Fieldtrip guidebook for the 1996 annual meeting of the Geological Society of America: Colorado Geological Survey Special Publication 44, CD-ROM.

Kirkham, R.M., Streufert, R.K., and Cappa, J.A., 1998, Geologic map of the Glenwood Springs quadrangle, Garfield County, Colorado: Colorado Geological Survey Map Series 31, scale 1:24,000.

_______1995, Geologic map of the Glenwood Springs quadrangle, Garfield County, Colorado: Colorado Geological Survey Open-File Report 95-3, scale 1:24,000.

Kirkham, R.M., Streufert, R.K., Hemborg, T.H., and Stelling, P.L., 1996, Geologic map of the Cattle Creek quadrangle, Garfield County, Colorado: Colorado Geological Survey Open-File Report 96-1, scale 1:24,000.

Kirkham, R.M., and Widmann, B.L., 1998, Geologic map of the Leon quadrangle, Eagle and Garfield Counties, Colorado: Colorado Geological Survey Open-File Report 98-3, scale 1:24,000.

_______1997, Geologic map of the Carbondale quadrangle, Colorado: Colorado Geological Survey Open-File Report 97-3, scale 1:24,000.

Mallory, W.W., 1971, The Eagle Valley Evaporite, northwest Colorado—a regional synthesis: U.S. Geological Survey Bulletin 1311-E, 37 p.

Marvin, R.F., and Dobson, S.W., 1979, Radiometric ages—Compilation B, U.S. Geological Survey: Isochron West, v. 26, p. 3–14.

Murray, F.N., 1966, Stratigraphy and structural geology of the Grand Hogback Monocline, Colorado: Boulder, Colo.,University of Colorado, Ph.D. dissertation.

Pierce, K.L., 1979, History and dynamics of glaciation in the northern Yellowstone National Park area: U.S. Geological Survey Professional Paper 729-F, 90 p.

Pierce, K,L, Obradovich, J.D., and Friedman, I, 1976, Obsidian hydration dating and correlation of Bull Lake and Pinedale glaciations near

WestYellowstone, Montana: Geological Society of America Bulletin, v. 87, no. 5, p. 703–710.
Piety, L.A., 1981, Relative dating of terrace deposits and tills in the Roaring Fork Valley, Colorado: Boulder, Colo., University of Colorado, M.S. thesis, 128 p.
Richmond, G.M., 1986, Stratigraphy and correlation of glacial deposits of the Rocky Mountains, the Colorado Plateau, and the ranges of the Great Basin, *in* Sibrava, G.S., Bowen, D.Q., and Richmond, G.S., eds., Quaternary glaciations in the northern hemisphere: Quaternary Science Reviews, v. 5, p. 99-127.
Richmond, G.M., and Fullerton, D.S., 1986, Introduction to Quaternary glaciation in the United States of America, *in* Sibrava, G.S., Bowen, D.Q., and Richmond, G.S., eds., Quaternary glaciations in the northern hemisphere: Quaternary Science Reviews, v. 5, p. 3–10.
Schenk, C.J., 1989, Sedimentology and stratigraphy of the Eagle Valley Evaporite (Middle Pennsylvanian), Eagle Basin, Colorado: Boulder, Colo., University of Colorado, Ph.D. dissertation.
Soule, J.M., and Stover, B.K., 1985, Surficial geology, geomorphology, and general engineering geology of parts of the Colorado River Valley, Roaring Fork River Valley, and adjacent areas, Garfield County, Colorado: Colorado Geological Survey Open-File Report 85-1.
Stewart, J.H., Poole, F.G., and Wilson, R.F., 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 336 p.
Stover, B.K., 1986, Geological evidence of Quaternary faulting near Carbondale, Colorado with possible associations to the 1984 Carbondale earthquake swarm, *in* Rogers, W.P. and Kirkham, R.M., eds., Contributions to Colorado seismicity and tectonics-A 1986 update: Colorado Geological Survey Special Publication 28, p. 295–301.
Streufert, R.K., Kirkham, R.M., Widmann, B.L., and Schroeder, T.J., 1997a, Geologic map of the Cottonwood Pass quadrangle, Eagle amd Garfield Counties, Colorado: Colorado Geological Survey Open-File Report 97-4, scale 1:24,000.
Streufert, R.K., Kirkham, R.M., Schroeder, T.J., and Widmann, B.L., 1997b, Geologic map of the Dotsero quadrangle, Eagle and Garfield Counties, Colorado: Colorado Geological Survey Open-File Report 97-2, scale 1:24,000.
Welder, G.E., 1954, Geology of the Basalt area, Eagle and Pitkin Counties, Colorado: Boulder, Colo., M.S. thesis, University of Colorado, 72 p.

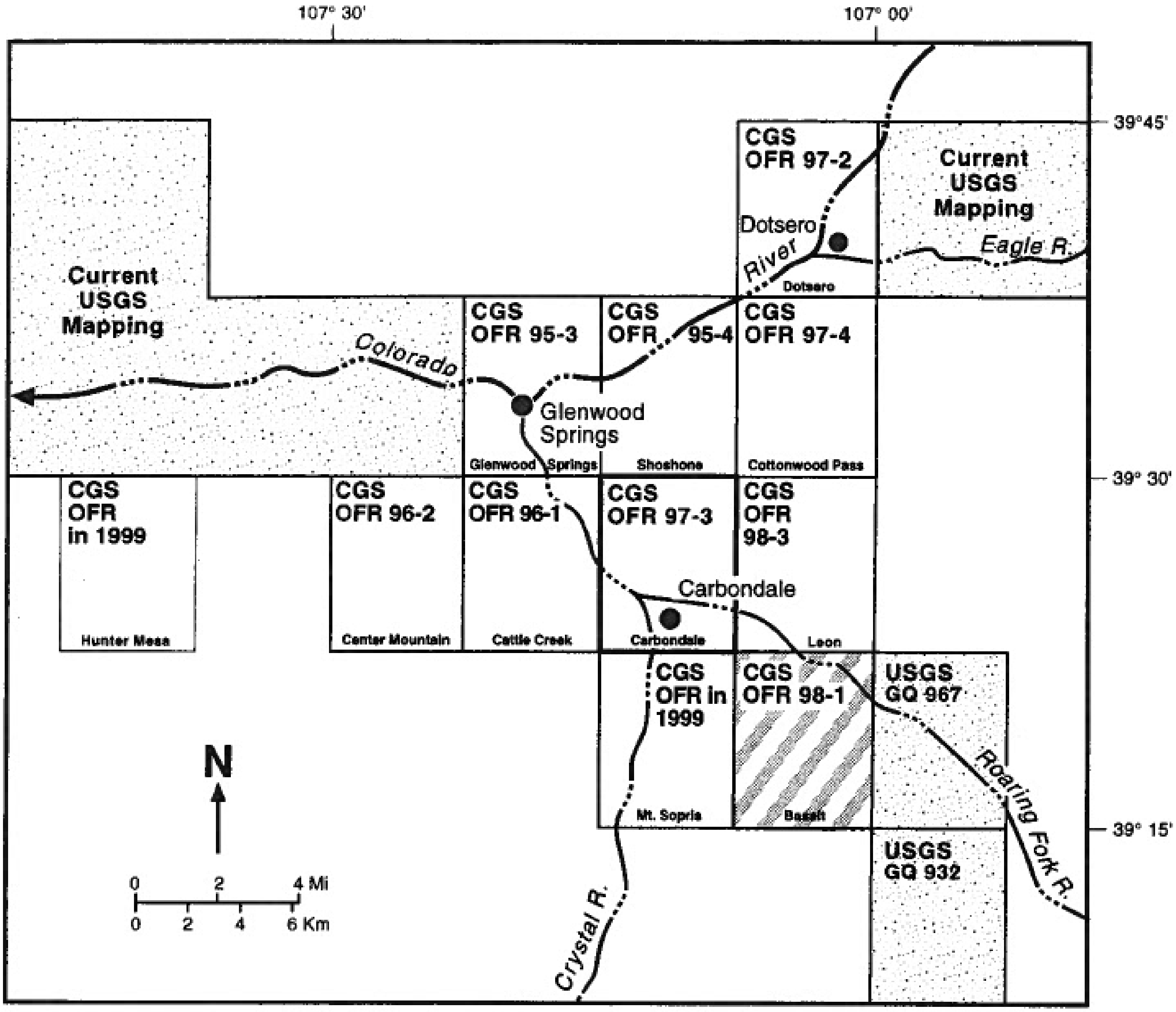
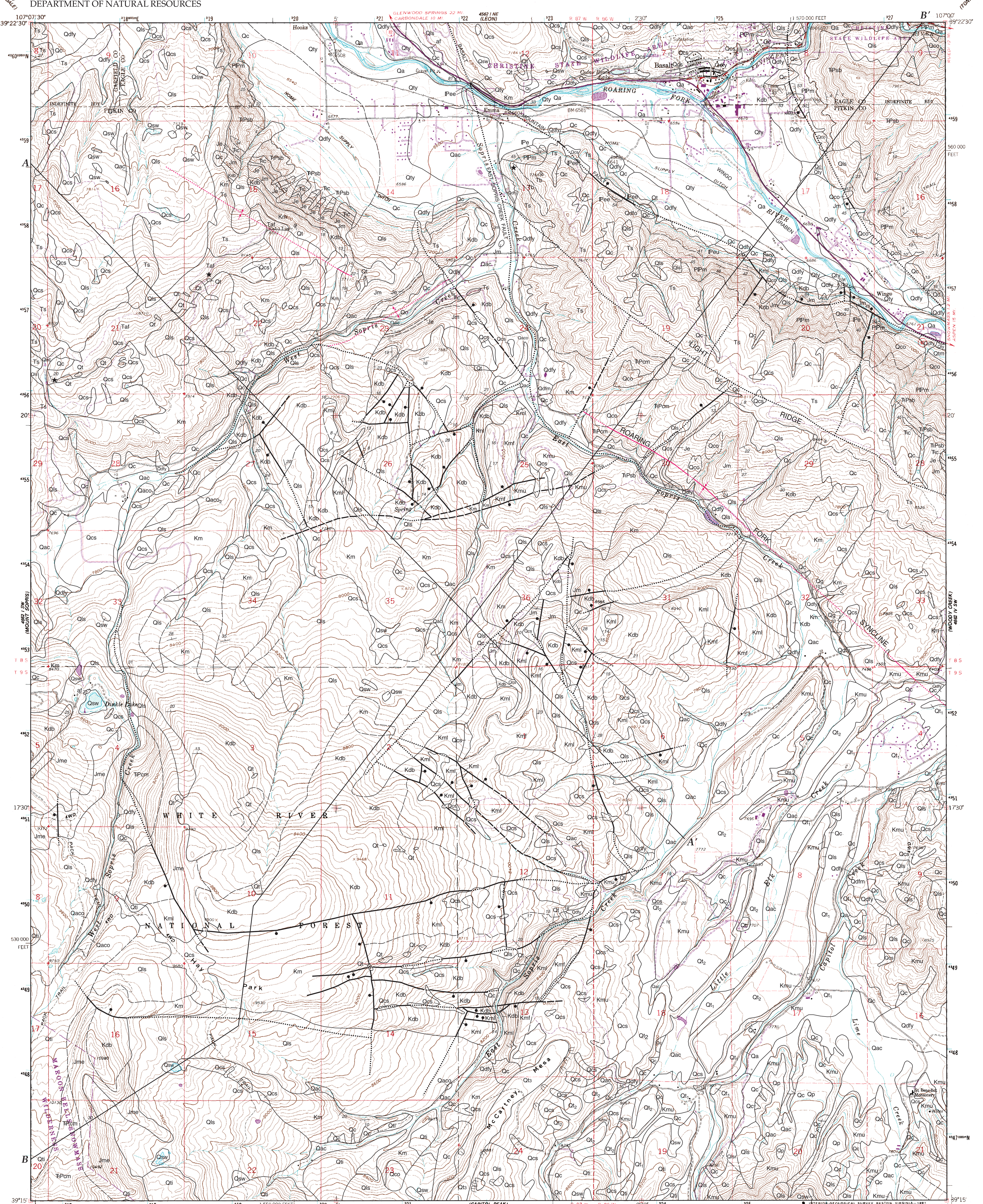


Figure 1. Status of geologic mapping of 7.5-minute quadrangles in the vicinity of Glenwood Springs.

COLORADO GEOLOGICAL SURVEY
VICKI J. COWART, DIRECTOR
DIVISION OF MINERALS AND GEOLOGY
DEPARTMENT OF NATURAL RESOURCES

OPEN FILE MAP 98-1
GEOLOGIC MAP OF THE BASALT QUADRANGLE
EAGLE, GARFIELD, AND PITKIN COUNTIES, COLORADO
Booklet accompanies map



Base from U.S. Geological Survey, 1982
Polyconic projection, 1927 North American datum
10,000-foot grid based on Colorado coordinate system, central zone

Geology mapped in 1997
Digital map prepared by Peter Hutson and Cheryl Brchan

UTM GRID AND 1982 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

COLORADO
QUADRANGLE LOCATION

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 ephem-eral 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 14–50 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 60–70 ft above the Roaring Fork River

Qto — **Older terrace alluvium (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 15–70 ft above Capital Creek. May include fine-grained overbank deposits

Qt_2 — **Intermediate terrace alluvium of Capital Creek (late 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

COLLUVIAL 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. Area is subject to future colluvial deposition

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). Area is subject to future talus deposition

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. Generally not subject to future deposition

ALLUVIAL AND COLLUVIAL 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 sheet-wash 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 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 Pleisto-cene)**—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)**-Deposits are texturally, lithologically, and genetically similar to younger debris-flow deposits (Qdfy). Occurs in a remnant of a debris fan in the vicinity of the Basalt Mountain Fault southwest of Basalt

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

Qti — **Till (late and middle Pleistocene)**—Heterogeneous deposits of gravel, sand, silt, and clay deposited by ice as ground, lateral, and end moraines along Capital, East Sopris, and West Sopris Creeks. May include proglacial deposits along Capital Creek. Deposits are dominantly poorly sorted, unstratified or poorly stratified, matrix-supported, bouldery, pebble and cobble gravel with a matrix of silty sand, although proglacial deposits may be well stratified and well sorted.

UNDIFFERENTIATED SURFICIAL DEPOSITS

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

BEDROCK

Tb — **Basalt (Miocene?)**—Light- to medium-gray, vesicular to dense, basaltic lava. 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. Includes a single flow located at the northwest end of Light Ridge. Flow is interbedded with Tertiary sedimentary deposits (Ts)

Ts — **Sedimentary deposits (Miocene?)**—Very weakly indurated to unconsolidated deposits of pebble and cobble fluvial gravel in a matrix of silty sand. Occasionally bouldery. Occurs as caprock on Light Ridge and in the northwest corner of quadrangle where it appears to have filled a structural depression related to dissolution and collapse of underlying evaporitic rocks

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. A sample of ash-flow tuff collected from the NW1/4NW1/4 Sec. 22, T. 8 S., R. 87 W. was age-dated by laser fusion $^{40}Ar/^{39}Ar$ at 34.22 ± 0.17 Ma (M. Kunk, personal commun., 1998)

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. Includes the Fort Hays Limestone Member, a thick-bedded, coarse-grained, gray limestone, except where it is mapped separately

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, car-bonaceous, 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, and conglomeratic sandstone. 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

TRc — **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

TRPsb — **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. Includes lenses of the dolomite of South Canyon Creek Member which are 12 to 18 inches thick. Sandstones are very well sorted and equigranular and contain rounded to subrounded sand grains with a high degree of sphericity

TRPcs — **Chinle and State Bridge Formations, undivided (Upper Tri-assic 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

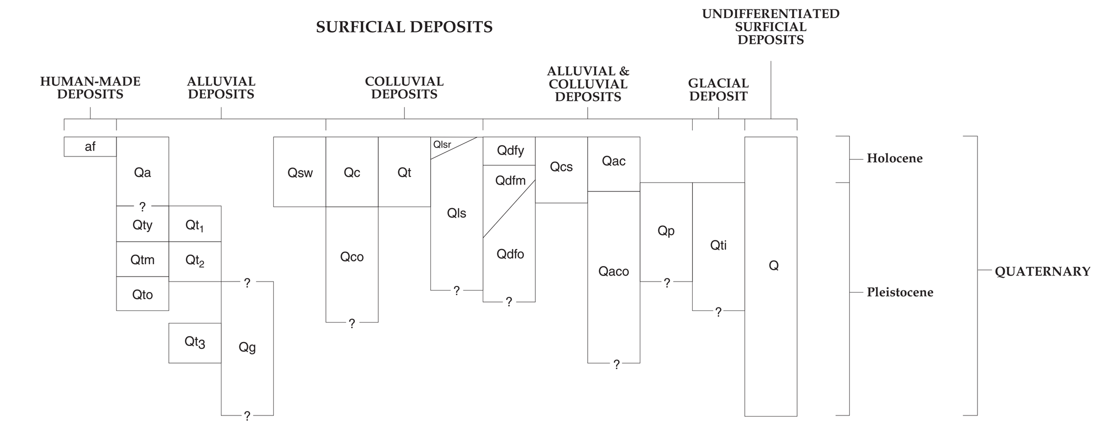
TRPcm — **Chinle, State Bridge, and/or Maroon Formations, undivided (Upper Triassic to Upper Pennsylvanian)**—Includes Chinle, State Bridge, and/or Maroon Formations in the southwest corner of quadrangle where units are not mapped separately

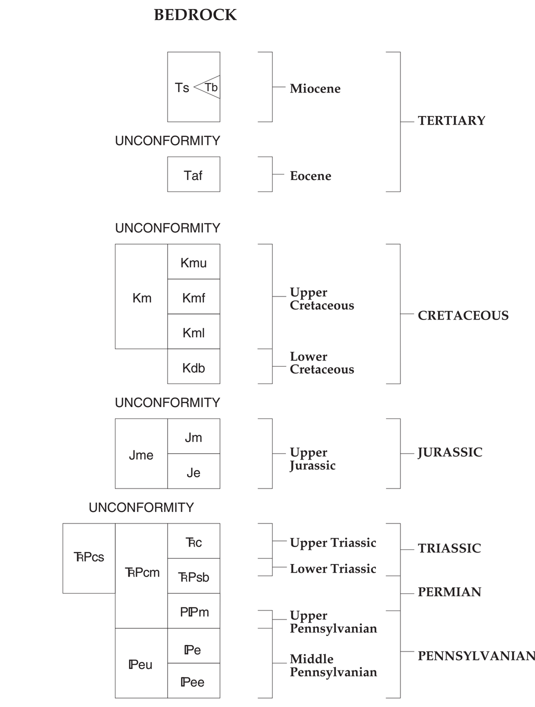
IPe — **Eagle Valley Formation (Middle Pennsylvanian)** —Interbedded reddish-brown, gray, reddish-gray, and tan siltstone, gypsum, and carbonate rocks. Represents a stratigraphic interval in which the red beds of the Maroon Formation grade into and intertongue with the predominantly evaporitic rocks 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, dis-solution-related collapse, load metamorphism, hydration 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





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

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

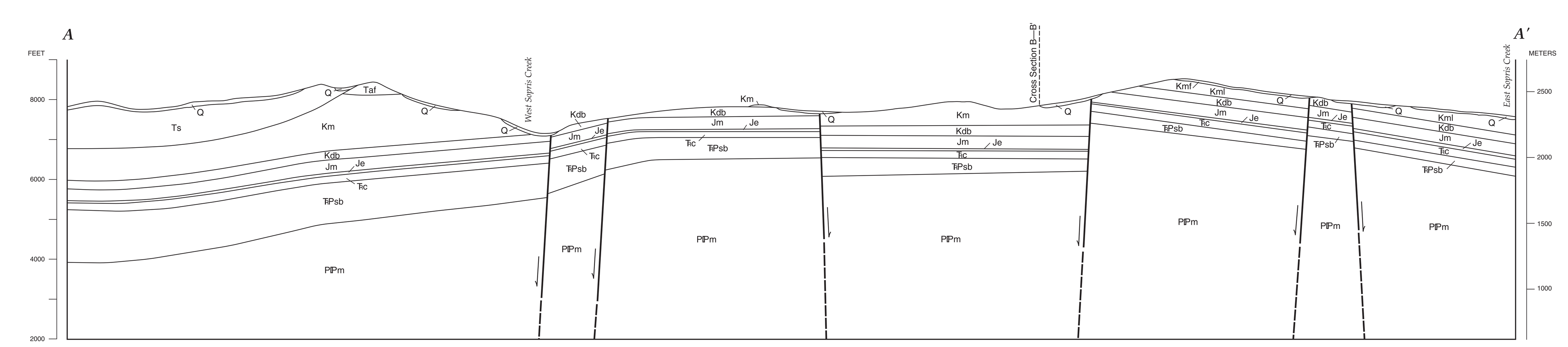
65 **Overturned beds**—Showing strike and dip

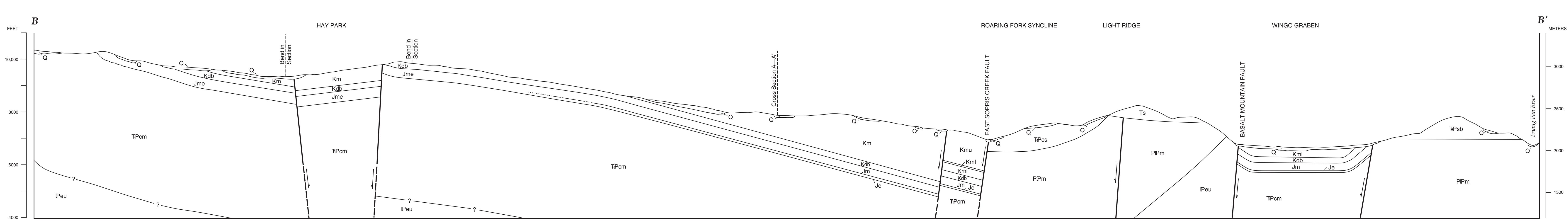
Soil slip—Showing area of localized slope failure

★ **Locality of rock sample**—A sample collected in NW1/4 NW1/4 Sec. 22, T. 8 S., R. 87 W. has been dated using the $^{40}Ar/^{39}Ar$ method

A——A′ **Alignment of cross section**

$\frac{Qcs}{Qt_2}$ **Fractional unit**—Indicates a thin veneer of the deposit in the numerator overlies the depositshown in the de-nominator





ACKNOWLEDGEMENTS

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey STATEMAP program of the National Cooperative Geologic Mapping Act of 1992, Agreement No. 1434-HQ-97-AG-01811.

This map was reviewed by Bruce Bryant and Jim Cappa. The following geologists provided helpful suggestions throughout 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. Mick Kunk was responsible for the $^{40}Ar/^{39}Ar$ dating. Whole-rock analyses were performed by Dan Unruh and Jim Budahn of the United States Geological Survey. A few geochemical analyses were provided by Chemex Labs, Inc., Sparks, Nevada.

We appreciate the many helpful landowners who gave permission to enter their properties. Jane Ciener served as technical editor for the map.

Photogrammetric models were set by Jim Messerich on a Kelsh PG-2 plotter.

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

By Randall K. Streufert, Beth L. Widmann, and Robert M. Kirkham
1998