OPEN-FILE REPORT 97-4

Geologic Map of the Cottonwood Pass Quadrangle, Eagle and Garfield Counties, Colorado

Description of Map Units, Economic Geology, Whole-Rock Analyses, and References

By Randall K. Streufert, Robert M. Kirkham, Beth L. Widmann, and Timothy J. Schroeder II

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-96-AG-01477.

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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 occasionally 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 soil development. Many of the surficial deposits are calcareous and contain varying amounts of both primary and secondary calcium carbonate.

HUMAN-MADE DEPOSITS—Materials placed by humans

af — **Artificial fill (latest Holocene)**—Fill placed by humans during the construction of small dams. Composed mostly of unsorted silt, sand, and rock fragments. Maximum thickness about 25 ft. May be subject to settlement when loaded if not adequately compacted.

ALLUVIAL DEPOSITS—Silt, sand, and gravel deposited in stream channels, flood plains, terraces, and sheetwash areas along the Colorado River and in tributaries. Includes minor lacustrine deposits.

Qa — **Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)**—Includes modern alluvium and other deposits underlying the Colorado River, adjacent flood-plain deposits, and low-terrace alluvium that is as much as about 15 ft above modern stream level. Mostly clast-supported, silty, sandy, occasionally bouldery, pebble and cobble gravel sometimes interbedded with and often overlain by sandy silt and silty sand. Unit is poorly to moderately well sorted and moderately well to well bedded. Clasts are subangular to well rounded, and their varied lithology reflects the diverse types of bedrock in their provenance. Unit includes a thick sequence of organic-rich, gray, silty clay of probable lacustrine origin. This sequence was encountered in test holes drilled by the Colorado Department of Transportation for Interstate Highway 70 in Glenwood Canyon. It was probably deposited in a lake formed behind a rockfall dam near the west end of Hanging Lake tunnel (Bowen, 1988; J. White and R. Pihl, 1996, oral commun.). Radiocarbon dates on wood debris contained within the sequence range from 9,800 ± 130 years B.P. to 3,890 ± 120 years B.P. (J.B. Gilmore, 1996, oral commun.). The lacustrine deposits are well sorted and well bedded. Maximum thickness of entire unit may be as much as 154 ft (Bowen, 1988). Flood-plain and terrace deposits included in this unit correlate with deposits in terrace T8 of the Carbondale-Glenwood Springs area of Piety (1981). Low-lying areas are subject to flooding. Unit frequently is 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 accumulate in ephemeral stream valleys, on gentle hillslopes, or in basinal areas. Unit is common on gentle to moderate slopes underlain by shale, basalt, red beds, and landslide deposits. Sheetwash deposits frequently fill the floor of sinkholes. They typically consist of pebbly, silty sand and sandy silt. Locally the deposits are gradational and interfingered with colluvium on steeper hillslopes and with lacustrine or slackwater deposits in closed depressions. Maximum thickness is probably about 30 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 in a terrace about 45 ft above the Colorado River. Consists of poorly sorted, clast-supported, silty, sandy, occasionally bouldery, cobble and pebble gravel that is overlain by 3 to 5 ft of fine-grained overbank deposits. Clasts are subround to round and are composed mainly of coarse-grained plutonic rocks, red sandstone, and basalt with lesser amounts of other lithologies, such as hypabyssal rocks. Clasts generally unweathered or only very slightly weathered. Exposed thickness about 35 ft, but likely is thicker.

West of the quadrangle at the rest area on Highway I-70 in West Glenwood Springs, peat interbedded with tufa that overlies a terrace deposit only 19 ft above the Colorado River yielded a ^{14}C date of 12,410 ± 60 years B.P. (Kirkham and others, 1995a; 1996). This dated terrace may in part correlate with or be slightly younger than younger terrace alluvium (Qty) in the Cottonwood Pass quadrangle. Unit may also correlate in part with younger terrace alluvium of Fairer and others (1993) in the Storm King Mountain quadrangle. Unit is probably in part equivalent to outwash of the Pinedale glaciation, which Richmond (1986) estimated to be about 12 to 35 ka. Unit frequently is a good source of sand and gravel.

Qgo **Older gravel deposits (Pleistocene)**—Stream alluvium that caps the eastern end of the ridge between Spring Gulch and Cottonwood Pass road along the eastern edge of the map area. It ranges from 160 to 280 ft above adjacent drainages. Unit is very poorly exposed. Texture varies from poorly sorted, clast-supported, silty, pebble and cobble gravel to poorly sorted, matrix-supported, sandy, pebbly silt. Clasts are rounded to subangular and are chiefly red sandstone with lesser amounts of quartzite, quartz, plutonic rocks, limestone, and tan to light-brown sandstone. Clasts are moderately weathered. Maximum thickness is around 30 ft. Age of unit is poorly constrained. Unit may be a source of sand and gravel.

QTg **High-level gravel (early Pleistocene and late Tertiary)**—Occurs as a single deposit of gravel along the eastern edge of the quadrangle, where it caps the ridge south of and about 400 to 450 ft above the floor of Spring Gulch. Unit is very poorly exposed. It probably is a clast-supported, sandy, silty, pebble and cobble gravel that locally is slightly bouldery. Clasts are rounded to subangular and are composed almost entirely of red sandstone and quartzite with minor amounts of quartz, limestone, and plutonic rocks. Clasts are moderately to very weathered. Unit is up to about 80 ft thick in Cottonwood Pass quadrangle and is about 110 ft thick immediately east of quadrangle. Age of unit is poorly constrained. It may be a source of sand and perhaps gravel.

COLLUVIAL DEPOSITS—Silt, sand, gravel, and clay deposited on valley sides, valley floors, and hillslopes that were mobilized, 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, narrow, elongate earthflow in upper Tom Creek that occurred during the spring of 1995. Deposit is a heterogeneous unit consisting of unsorted, unstratified clay, silt, sand, gravel, and rock debris derived from landslide deposits (Qls). Clasts are mainly angular to subangular basalt and rounded to subangular red sandstone. Thickness is probably a maximum of about 20 ft. Area is prone to renewed or continued landsliding.

Distribution of recent landslide deposits is suggestive of the type of geologic setting which may produce landslides in the current climatic regime. Deposit was water saturated and water was seeping to the surface from the base of the head scarp when examined in the fall of 1995. Deposits may be susceptible to settlement when loaded.

Qc **Colluvium (Holocene and late Pleistocene)**—Ranges from 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. Deposits are usually coarser grained in upper reaches of colluvium-covered slopes and finer grained in distal areas. Deposits derived from fine-grained bedrock are finer grained and matrix supported. Clasts typically are angular to subangular. Commonly unsorted or poorly sorted with weak or no stratification. Clast lithology is variable and dependent upon types of bedrock occurring beneath and above the deposit. Unit grades to and interfingers with alluvium and colluvium (Qac), younger debris-flow deposits (Qdfy), and sheetwash deposits (Qsw) along some tributary drainages and hillslopes. Locally it includes talus, sheetwash deposits, and debris flows that are too small or too indistinct on aerial photography to be mapped separately. Maximum thickness is probably about 50 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. May be corrosive when derived from evaporitic rocks. Excavation into colluvium may be difficult where it contains large boulders of basalt.

Qt

Talus (Holocene and late Pleistocene)— Angular, cobbly and bouldery rubble on steep slopes that was transported downslope principally by gravity as rockfalls, rockslides, and rock topples. Unit frequently lacks matrix material. It includes deposits derived from volcanic cliffs on Dock Flats, Cottonwood Divide, Buck Point, and Gobbler Knob, and from lower Paleozoic rocks in Glenwood Canyon. Locally it is underlain by or incorporated into landslides around the margin of Dock Flats, Cottonwood Divide, and Buck Point. Maximum thickness is estimated at about 50 ft. Areas mapped as talus are subject to severe rockfall, rockslide, and rock-topple hazards. Unit is a source of high quality riprap and aggregate.

Qls

Landslide deposits (Holocene and Pleistocene)—Highly variable deposits of unsorted, unstratified rock debris, clay, silt, sand, and gravel. Deposits range from currently active, slowly creeping landslides to long-inactive middle or perhaps even early Pleistocene landslides. Unit includes rotational landslides, translational landslides, complex slump-earthflows, and extensive slope-failure complexes. Maximum thickness is estimated at 200 ft. Large landslide on north side of Dock Flats includes long, linear toreva blocks of intact basalt at the head of the landslide that break apart and become incorporated into the slide mass downslope. Large landslide on east side of Cottonwood Divide also contains toreva blocks. Two landslides mapped in the NE1/4 Sec. 34, T. 5 S., R. 86 W., one of which is northeast of Blue Hill and the second in Mary Jane Gulch, may actually be "mega-subsidence" features related to large-scale collapse of the ground surface into voids or caves in the underlying Eagle Valley Evaporite. Mapped area may be subject to future landslide activity. Unit may be prone to settlement when loaded. Low-density, fine-grained deposits may be susceptible to hydrocompaction.

Qco

Older colluvium (Pleistocene)—Occurs on ridges, drainage divides, and dissected slopes on valley walls as erosional remnants of formerly more extensive deposits that were transported primarily by gravity and aided by sheetwash. Genesis, texture, bedding, and clast lithologies are similar to colluvium (Qc). Unit may include older landslide deposits (Qlso). Unit averages 10 to 25 ft thick, with a maximum thickness about 60 ft. Area is not subject to significant future colluvial deposition, except where adjacent to eroding hillslopes. Older colluvium (Qco) locally occurs as collapse debris or sink hole fill within beds of gypsum. It may be subject to hydrocompaction, piping, and settlement where fine grained and low in density. May be difficult to excavate where it contains large boulders of basalt.

Qlso

Older landslide deposits (Pleistocene and late Tertiary?)—Landslide deposits dissected by erosion that lack distinctive landslide geomorphologic features. Similar in texture, bedding, sorting, and clast lithology to landslide deposits (Qls). Type of landslide movement is generally not identifiable due to the eroded character of deposits. Maximum thickness is probably around 100 ft. Older landslide deposits (Qlso) are probably not prone to reactivation unless significantly disturbed by construction activities.

ALLUVIAL AND COLLUVIAL DEPOSITS— Silt, sand, gravel, and clay in debris fans, stream channels, flood plains, and adjacent hillslopes along tributary valleys. Depositional processes in stream channels and on flood plains are primarily alluvial, whereas colluvial and sheetwash processes are predominant on debris fans, hillslopes, 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 debris fans and in stream channels. Unit ranges from poorly sorted, matrix-supported, gravelly, sandy, clayey silt to clast-supported, pebble and cobble gravel with a sandy, clayey silt or silty sand matrix. Occasionally is very bouldery, particularly near fan heads. Distal parts of some fans are characterized by mudflow and sheetwash and tend to be finer grained. Locally is interfingered or interbedded with modern alluvium adjacent to stream channels. Clasts are mostly angular to subround sedimentary rock and basalt fragments as much as about 4 ft in diameter. Maximum thickness is about 50 ft.

Mapped areas are subject to flooding and future debris-flow activity following intense rainstorms, except on distal parts of some fans, where mudflow and sheetwash processes are predominant. Deposits are prone to settlement, piping, and hydrocompaction where fine grained and low in density. Unit is subject to sinkhole development by piping where underlain by cavernous evaporitic rocks and may be corrosive if derived from evaporitic rocks.

Qac — **Alluvium and colluvium, undivided (Holocene and latest Pleistocene)**—Sediments deposited by alluvial and colluvial processes in tributary valleys of small perennial, intermittent, and ephemeral streams. Chiefly stream-channel, low-terrace, and flood-plain deposits along valley floors, with colluvium and sheetwash common on valley sides. Deposits of alluvium and colluvium probably are interfingered. Locally includes younger debris-flow deposits. Alluvium is typically composed of poorly to well-sorted, stratified, interbedded pebbly sand, sandy silt, and sandy gravel; however, colluvium may range to unsorted, unstratified or poorly stratified, clayey, silty sand, bouldery sand, and sandy silt. Clast lithologies are dependant upon type of rock within provenance. Thickness is commonly 5 to 20 ft, with maximum thickness estimated at about 40 ft. Low-lying areas are subject to flooding. Valley sides are prone to sheetwash, rockfall, and small debris flows. Unit may be subject to settlement, piping, and hydrocompaction where low in density and fine grained. It is a potential source of sand and gravel.

Qaco — **Older alluvium and colluvium, undivided (Pleistocene)**—Deposits of alluvium and colluvium that underlie terraces and hillslopes about 10 to 50 ft above adjacent intermittent or ephemeral streams. Texture, bedding, clast lithology, sorting, and genesis are similar to alluvium and colluvium (Qac). Thickness is as much as 20 ft. Unit may be a source of sand and gravel.

Qdfo — **Older debris-flow deposits (Holocene and Pleistocene)**—Valley-filling deposits in tributaries to the Colorado River. Unit is genetically, texturally, and lithologically similar to younger debris-flow deposits (Qdfy). Locally is cemented with tufa. Clasts range from unweathered to slightly weathered. Elevation differences between original depositional surfaces and adjacent incised modern drainages range from about 20 to 60 ft. Thickness is generally about 10 to 60 ft, but may locally exceed 80 ft. Where fine grained and low in density, unit may be prone to hydrocompaction, piping, and settlement. Deposits are corrosive when derived from evaporitic bedrock. Unit may be a source of sand and gravel.

QTbg — **High-level basaltic gravel (early Pleistocene and late Tertiary?)**—Occurs on ridge between Spruce and Ike Creeks on western edge of map area and on north end of Spruce Ridge. Unit consists of slightly indurated, matrix-supported, cobbly, pebbly, and bouldery clayey, sandy silt. Clasts are primarily very weathered, rounded to subangular basalt with minor amounts of red sandstone and conglomerate, quartzite, quartz, pink granite, and chert. Deposits are 400 to 600 ft above Spruce Creek. They probably were deposited as debris flows, earthflows, colluvium, and landslides. Maximum thickness is about 60 ft. It may be difficult to excavate where large boulders are present. Unit may be a source of riprap or aggregate.

QTc — **Sediments of Cottonwood Bowl (Early Pleistocene and late Tertiary?)**—Locally derived gravel, sand, silt, and clay deposited in and near the topographic bowl bordered on the north and west by Cottonwood Divide and Dock Flats at the headwaters of East Coulter Creek. Deposits are preserved on small hills as eroded remnants of alluvial and colluvial sediments that overlie basalt. Unit is poorly exposed. Deposits appear to range from sandy and silty pebble, granule, or cobble gravel to gravelly, sandy silt. Clasts are predominantly subangular to subrounded, moderately to highly weathered, and consist of basalt, red, pink, and tan sandstone and siltstone, gray limestone, and quartz. Probably deposited in fluvial, sheetwash, and colluvial environments. Sediments of Cottonwood Bowl appear to have been deposited in a large collapse bowl that developed after emplacement of the basalt of Dock Flats. Stratigraphic relationship of these sediments with the late Tertiary volcanic rocks of Buck Point are not known. The collapse bowl probably formed in response to subsidence into a void caused by dissolution or flowage of underlying evaporitic rocks. Unit may be equivalent in age to Sediments of Missouri Heights (QTm) mapped by Kirkham and Widmann (1997) in the Carbondale quadrangle. Maximum thickness of sediments is estimated at 100 ft; however they likely were much thicker prior to erosion.

UNDIFFERENTIATED DEPOSITS

Q **Surficial deposits, undifferentiated (Quaternary)**—Shown only on cross section.

BEDROCK

Tag **Basaltic trachyandesite of Gobbler Knob (Pliocene)**—Gray to dark-gray and black, dense to vesicular erosional remnants of a basaltic trachyandesite flow. Contains phenocrysts of olivine and xenocrysts of quartz with reaction rims of clinopyroxene. Erosional flow remnants occur in two isolated outcrops which form the caprock on, and south of, Gobbler Knob. Since these flow remnants now occupy a ridge line, it is possible that erosion has caused a topographic inversion since emplacement of these deposits. Flow rocks on Gobbler Knob have whole-rock geochemistry similiar to that of cindery deposits in an eroded cone on Dock Flats 1 mile to the south. This eroded cone, which is the probable source of the Gobbler Knob basaltic trachyandesite flows, appears to overlie, and therefore is younger than, the basalt flows which cap Dock Flats. Preliminary $^{40}Ar/^{39}Ar$ analyses of basaltic trachyandesite from Gobbler Knob suggest a plateau age of 3.0 Ma (M. Kunk, 1997, written commun.). Unit is a potential source of high quality riprap or aggregate.

Tagc **Cinder deposits of Gobbler Cone (Pliocene)**— Red and red-brown, scoriaceous, unconsolidated, vesicular, cindery lava associated with an eroded eruptive center on Dock Flats. These cindery deposits overlie and hence are younger than the basalt flows that cap most of Dock Flats. Petrographically the deposit is an olivine basalt with quartz xenocrysts. On the basis of major-element, whole-rock geochemistry, deposit is basaltic trachyandesite. Geomorphic relationships suggest that this could be the eruptive vent for the lava flows on Gobbler Knob. Major-element, whole-rock analyses support this relationship for the Gobbler Knob flows. Cinder cone deposits are a potential source of light-weight aggregate.

Tbp **Basaltic trachyandesite of Buck Point (Pliocene)**—Medium- to dark-gray flows of basaltic trachyandesite with abundant olivine and partially to completely resorbed, sometimes recrystallized, quartz and feldspar. Groundmass is fine grained, containing plagioclase microlites and 1 to 5 percent opaque minerals. Groundmass ranges from holocrystalline to glassy. Phenocrysts are olivine and pyroxene. Contains xenocrysts of quartz that have reaction rims of pyroxene, carbonate, and biotite. Dense to slightly vesicular with a maximum of 10 percent by volume vesicles. Unit is probably the result of eruptions which emerged from a vent near Buck Point and occurs as a sequence of flat-bedded lava flows, with an approximate total thickness of 50 to 100 ft, and as an outcrop of massive columnar jointed lava approximately 100 to 150 ft thick. Columnar jointed lava is interpreted as the near-vent facies of the unit, while flat-bedded lavas are suspected to have flowed farther from the vent. However, true stratigraphic relationships are problematic due to poor exposure of the contacts between various occurrences of basaltic trachyandesite. Preliminary $^{40}Ar/^{39}Ar$ analyses of basaltic trachyandesite from Buck Point suggests a plateau age of 3.17 Ma (M. Kunk, 1997, written commun.). Unit may cause rockfall hazards where exposed in steep cliffs.

Tbpc **Cinder deposits of Buck Point (Pliocene)**—Red to brownish-red and black, loose to well-cemented breccia consisting of 1- to 20-inch diameter clasts of basaltic trachyandesite lava (Tbp). Most breccia clasts contain over 20 percent vesicles by volume and many contain up to 50 percent vesicles. Very few clasts contain less than 10 percent vesicles. Highly vesicular clasts are typically red and very oxidized. Less vesicular clasts closely resemble basaltic trachyandesite lava (Tbp). Unit is moderately well bedded to well bedded. It is most likely the result of a late stage, high gas content, explosive eruption which probably eminated from the Buck Point vent. This explosive eruption appears to post-date the eruption or series of eruptions which produced the flat-lying lava beds on the north and northwest sides of

Buck Point. The flow of columnar jointed lava exposed at the base of the south flank of Buck Point appears to grade upward into cinder deposits. Field relationships suggest that cindery ejecta was draped over the flat-lying lava beds, and perhaps over the columnar jointed lavas, producing a bedded cinder cone that is now mostly eroded away.

Tb

Basalt (Miocene)—Multiple flows of trachybasalt that are widespread across the west-central and south-central parts of the quadrangle. Ranges from massive to highly vesicular, with sparse amygdules of calcite. Groundmass is predominantly plagioclase and pyroxene, with minor amounts of olivine, glass, pigeonite, augite, and magnetite. Phenocrysts are euhedral to subhedral olivine that weathers to iddingsite along crystal edges and fractures. Unit is well exposed in the headscarps of two large landslides on the north and east sides of Dock Flats, where it consists of multiple, stacked flows of trachybasalt with a total exposed thickness of around 180 ft. A whole-rock sample collected from a flow in the middle of the exposed sequence on Dock Flats yielded an $^{40}Ar/^{39}Ar$ age date of 7.70 ± 0.04 Ma (L. Snee, 1996, written commun.). Thick flow sequence on Dock Flats extends southeast across Cottonwood Divide. It is sharply folded downward along the prominent escarpment that separates Cottonwood Bowl from Dock Flats and Cottonwood Divide. This escarpment marks the northern limits of a regional collapse basin that has resulted from dissolution and/or flowage of underlying evaporitic rocks. Basaltic flows exposed in Cottonwood Bowl and in the hills between East Coulter Creek and Association Gulch are correlative with those on Dock Flats and Cottonwood Divide on the basis of major-element, whole-rock geochemical analyses, and those of Leat and others (1988), and R.N. Thompson (1995, written commun.). This interpretation is supported by geologic field relationships. However, a K-Ar age of 11.1 ± 0.5 Ma was reported for a basalt flow on the south side of Cottonwood Pass road by Larson and others (1975). Preliminary $^{40}Ar/^{39}Ar$ analyses of basaltic rock from the north side of Cottonwood Pass road, from an outcrop immediately north of that dated by Larson and others (1975) suggests an age of 7.7 Ma (M. Kunk, 1997, written commun.).

On Spruce Ridge an erosional remnant of basalt appears to consist of a single flow ranging from about 2 to 8 ft thick. The flow on Spruce Ridge is associated with main-stem ancestral Colorado River gravels and occurs about 200 to 240 ft below the flows on Dock Flats. Stratigraphic relationships between this basalt flow and the Colorado River gravels are unclear. The gravels and flow lie about 2,300 ft above the Colorado River. The flow has major-element concentrations that are very similiar to the flows on Dock Flats, and preliminary $^{40}Ar/^{39}Ar$ analyses suggest a plateau age of 7.8 Ma (M. Kunk, 1997, written commun.).

Unit frequently is a source of rockfall debris where exposed in steep cliffs. It is a potential source of high quality riprap and aggregate.

Ts

Sedimentary deposits (Miocene)—Includes extensive deposits that underlie basalt flows near and south of Cottonwood Pass and a thin, areally limited deposit associated with the basalt on Spruce Ridge. Deposits near and south of Cottonwood Pass are generally poorly exposed, but field relationships suggest they underlie the basalt flows in this area. Unit appears to be mostly composed of silty, pebbly gravel and pebbly silt, but ranges to sandy and clayey silt east of Cottonwood Pass. May be predominantly a matrix-supported deposit. Clasts are round to subangular and consist mostly of red sandstone, quartz, and coarse-grained plutonic rocks. Metamorphic and hypabyssal lithologies occur less frequently. The hypabyssal clasts are similiar to ones in late Pleistocene Colorado River deposits upstream of Dotsero.

Deposit on Spruce Ridge is associated with a basalt flow, but stratigraphic relationships between the flow and the sediments are not clear. Deposit is very poorly exposed, but appears to consist of fluvial, clast-supported, silty, sandy pebble and cobble gravel that is slightly indurated. Clasts are well rounded to subrounded and chiefly composed of various types of plutonic granitic rocks, red sandstone, quartzite, quartz, and conglomeratic sandstone typical of a Colorado River provenance. Clasts are moderately to very weathered. Thickness of deposit on Spruce Ridge may be as much as about 50 ft, whereas deposits near and south of Cottonwood Pass could be over 200 ft thick. Unit is a potential source of sand and gravel.

TRPc **Chinle and State Bridge Formations, undivided (Upper Triassic and Permian)**—Chinle Formation consists of thin, even-bedded, and massive red beds of dark-reddish-brown, orangish-red, and purplish-red, calcareous siltstone and mudstone with ocassional thin lenses of light-purplish-red and gray limestone and limestone-pebble conglomerate. Underlying State Bridge Formation consists of pale red, grayish-red, reddish-brown, and greenish-gray, micaceous siltstone, clayey siltstone, and minor sandstone. Combined unit occurs in the southeast corner of the quadrangle where exposed in a large drag-folded, footwall syncline on the east or downdropped side of the Basalt Mountain Fault, a large reverse fault of Laramide age. Combined unit is poorly exposed rendering this red bed sequence undividable in the field. Total estimated thickness of combined unit is 385 ft. Environments of deposition for the combined unit include shallow marine and fluvial-lacustrine.

PPm **Maroon Formation (Lower Permian and Upper Pennsylvanian)**—Mainly red beds of sandstone, conglomerate, siltstone, mudstone, and shale with minor, thin beds of gray limestone. Frequently it is arkosic and micaceous. Total thickness of formation on adjacent quadrangles is 3,000 to 5,000 ft (Kirkham and others, 1995b, 1996); however, only parts of the formation occur in the quadrangle. In the northeast corner of the quadrangle only the lower 400 ft of the formation crops out. Rocks in this area are disrupted by faults that probably resulted from dissolution-related subsidence and flowage of underlying evaporitic rocks. In the southeast corner of the quadrangle the upper portion of the formation is mapped in the vicinity of Sawmill Creek, but is truncated against a northwest-southeast trending fault which is downdropped to the southwest. Formation was deposited in the Central Colorado Trough between the Ancestral Front Range and Uncompahgre Highlands in fluvial and perhaps eolian environments (Johnson and others, 1988). Formation is prone to rockfall where exposed in steep cliffs.

Pe **Eagle Valley Formation (Middle Pennsylvanian)**—Interbedded reddish-brown, gray, reddish-gray, and tan siltstone, shale, sandstone, 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. Thickness is variable, ranging from about 500 to 1,000 ft. Unit is both conformable and intertonguing with overlying Maroon Formation and underlying Eagle Valley Evaporite. Contact with Maroon Formation is placed at top of uppermost evaporite bed or light-colored clastic bed. Intertonguing relationship with underlying Eagle Valley Evaporite is well exposed on east side of Cottonwood Creek. Lower part of formation is frequently deformed by dissolution-related subsidence and flowage of underlying evaporite rocks. Large sinkholes can develop in these rocks as underlying evaporites dissolve or flow as shown on the ridge north of Spring Gulch. Formation was deposited in the Eagle Basin on the margin of an evaporite basin in fluvial, eolian, and marine environments. Unit may be susceptible to subsidence and sinkholes. Surficial deposits derived from it are prone to compaction, piping, and corrosion problems where evaporitic rocks occur near land surface.

Pee **Eagle Valley Evaporite (Middle Pennsylvanian)**—Sequence of evaporitic rocks consisting mainly of massive to laminated gypsum, anhydrite, and halite, interbedded with light-colored mudstone and fine-grained sandstone, thin carbonate beds, and black shale. Beds commonly are intensely folded, faulted, and ductily deformed by diapirism, flowage, load metamorphism, dissolution, hydration of anhydrite, and regional tectonism. Thickness of formation averages 1,800 ft, but varies due to flowage and diapiric activity. Generally is poorly exposed except along east side of Cottonwood Creek, where there are excellent exposures. Contact with overlying Eagle Valley Formation is both conformable and intertonguing and is defined as the base of the lowest red bed within the Eagle Valley Formation. Evaporite diapirically intrudes older colluvium (Qco) locally. Formation was deposited in the Eagle Basin which formed as the outlet for the Central Colorado Trough was restricted (Mallory, 1971). Schenk (1989) recognized multiple transgressive-regressive sedimentary cycles in the formation near Gypsum and Eagle and suggested the gypsum was deposited in a subaqueous environment rather than in a sabkha. Formation may include eolian deposits similar to those reported by Schenck (1987).

The Eagle Valley Evaporite contains voids and caverns that have resulted from near-surface dissolution of evaporite rocks and is prone to development of sinkholes into which overlying surficial deposits may be piped. Distribution of sinkholes on ridges adjacent to Mary Jane Gulch is striking. The large area of disturbed ground at the head of the gulch, which is mapped as a "mega-subsidence complex", may be due to large-scale subsidence over caverns. Surficial deposits derived from the Eagle Valley Evaporite may be subject to compaction, settlement, and corrosion problems.

ℙeu

Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)—Includes Eagle Valley Formation and Eagle Valley Evaporite on the west side of upper Cottonwood Creek where heavy ground vegetation prohibits mapping of the contact between units. May be prone to subsidence, sinkholes, compaction, settlement, and piping where evaporitic rocks occur near land surface.

ℙb

Belden Formation (Lower Pennsylvanian)—Medium-gray to black, and dark-brown, calcareous and locally micaceous shale and coarse-grained, gray, fossiliferous limestone containing interbeds and lenses of fine-grained, micaceous, greenish-tan sandstone. Upper 100 ft of unit contains four or five prominent beds of conglomeratic, very coarse-grained, lithic-rich wackes and subarkoses which are probably equivalent to the Minturn Formation that crops out in the Dotsero quadrangle (Streufert and others, 1997). Unit may contain discontinuous gypsum beds occurring at any interval, but most commonly near the upper contact. Locally is very fossiliferous (Bass and Northrup, 1963). Unit is 1,150 to 1,270 ft thick across quadrangle. Entire unit, including basal and upper contacts, is well exposed along the east wall of lower Cottonwood Creek valley. It is conformably overlain by a massive bed of gypsum which forms the base of the overlying Eagle Valley Evaporite (Mallory, 1971). Formation was deposited over a widespread area in the Central Colorado Trough between the Uncompahgre and Front Range Highlands. Shale-limestone sequences in the lower part of the formation record low-energy sedimentation at a distance from source areas. Conglomeratic beds near the top of the Belden may reflect activation of nearby fault-blocks in response to Pennsylvanian mountain building (Streufert and others, 1997). The Belden Formation is prone to landsliding on steep slopes.

Ml

Leadville Limestone (Mississippian)—Light- to medium-gray, bluish-gray, massive, coarse to finely crystalline, fossiliferous, micritic limestone and dolomite. Unit contains lenses and nodules of dark-gray to black chert as much as 0.3-ft thick in the lower one-third of the formation. Upper half of the formation locally contains coarse-grained oolites. Carbonate veinlets with disseminated silt-sized quartz grains are common. Top of unit contains collapse breccias, filled solution cavities, and "locally" a red to reddish-purple claystone regolith (Molas Formation), all of which formed on a paleokarst surface. The Leadville Limestone is very fossiliferous and contains abundant crinoid and brachiopod fragments. Upper contact is irregular and unconformable with overlying Belden Formation. Unit averages 180 to 200 ft thick. Rocks in this unit formed in a marine environment in the sub-littoral zone by the accumulation of biogenic and oolitic sediment. Unit can be chemically pure and has been mined as metallurgical grade limestone west of the quadrangle. Also is a source of riprap and aggregate. Solution features including caves and solution pockets are common in these rocks. Unit may be susceptible to sinkholes and subsidence where karst features occur near the surface, and it may be a source of rockfall debris where exposed in cliffs.

Dc

Chaffee Group (Upper Devonian)—Sequence composed of dolomite, limestone, quartzite, dolomitic sandstone, and shale. The Chaffee Group includes in descending order the Gilman Sandstone, Dyer Dolomite, and the Parting Formation. Total thickness of the Chaffee Group in Glenwood Canyon is 252 ft (Soule, 1992). Unit may be a source of rockfall debris.

Gilman Sandstone consists of tan to yellow, laminated, fine to very fine-grained calcareous sandstone. Laminae are generally less than 1 inch in thickness and consist of beds of fine sand which locally display weak planar-tabular cross-bedding and minor load structures. Some laminae contain discontinuous lenses of quartz arenite with relict casts of carbonate rhombohedron. Contact with the overlying Mississippian Leadville Limestone is unconformable.

Dyer Dolomite is divided into two members on the White River Uplift. The upper Coffee Pot Member consists of crystalline, micritic dolomite, dolomitic gray shale, and micritic limestone. Member is somewhat sandy, especially near the top. The lower Broken Rib Member consists of gray, nodular, crystalline limestone. Unit is characterized by abundant rip-up clasts, intraformational breccia, and bioturbated bedding (Soule, 1992).

Parting Formation consists of beds of white to buff, massive orthoquartzite containing feldspar and rock fragments, micaceous green shale with discontinuous lenses of quartzite, and gray, sandy micritic dolomite. Orthoquartzite beds range in thickness from 0.5 to 1.0 ft and give the formation its popular name, "Parting quartzite".

Om

Manitou Formation (Lower Ordovician)—Consists predominantly of medium-bedded, brown dolomite, limestone, sandstone, and thin beds of gray, flat-pebble limestone conglomerate interbedded with greenish-gray calcareous shale. In Glenwood Canyon the Manitou Formation is 156 ft thick according to Bass and Northrop (1963) and 167 ft thick as measured by Soule (1992). It may be a source of rockfall debris. Formation is divided into two members, the Tie Gulch Member and the underlying Dead Horse Conglomerate Member.

Tie Gulch Member consists of massive, micritic, brown- and orange-weathering, crystalline, somewhat siliceous dolomite and minor limestone. Member becomes somewhat sandy near the top. Some beds are glauconitic although considerably less so than the underlying beds of the Dead Horse Conglomerate Member. Contact with the overlying Devonian Chaffee Group is unconformable, occurring at a thin shale bed which may be a paleosol (Soule, 1992).

Dead Horse Conglomerate Member consists mostly of thin-bedded, gray, flat-pebble limestone conglomerate, thin-bedded limestone, shaly limestone, and two beds of massive, dolomitic orthoquartzite. Member is glauconitic, especially in its lower part.

Ꞓd

Dotsero Formation (Upper Cambrian)—Thinly bedded, tan to gray, silty and sandy dolomite; dolomitic sandstone; green dolomitic shale; limestone and dolomite conglomerate; limestone; and pinkish- to light-gray algal limestone. Unit contains abundant glauconite. Formation is divided into two members: the Clinetop Member and underlying Glenwood Canyon Member.

Clinetop Member consists of a bed of stromatolitic limestone with well preserved algal-head crinkle structures which overlies a 5-ft-thick bed of matrix-supported limestone pebble conglomerate with abundant rip-up clasts.

Glenwood Canyon Member consists of thinly bedded dolomite, dolomitic sandstone, conglomeratic limestone, coarse-grained fossilliferous limestone, and dolomitic shale. Member is 90 to 100 ft thick.

Ꞓs

Sawatch Quartzite and unnamed overlying rocks, undivided (Upper Cambrian)—White and buff to gray-orange, brown-weathering, vitreous orthoquartzite, in beds from 1 to 3 ft thick. Unit includes beds of massive, brown, sandy dolomite, which are a suggested equivalent of the Peerless Formation described by Tweto and Lovering (1977) and Bryant (1979) at Minturn and Aspen, respectively, and overlying unnamed beds of sandy dolomite and white dolomitic quartzite. These upper unnamed beds are possibly disconformable with sediments of the Sawatch Quartzite below and the overlying Dotsero Formation. Total thickness of this combined unit is 500 ft. Formation is prone to rockfalls, rockslides, and rock avalanches. Unit may be a source of aggregate.

pꞒ

Precambrian rocks, undivided (Proterozoic)—Igneous and metamorphic rocks. Shown only on cross section.

ECONOMIC GEOLOGY

In 1995 Eagle Gypsum Company produced 400,000 tons of gypsum from an open pit developed in the Eagle Valley Evaporite at their Eagle Gypsum Mine, located 4 miles northeast of the Cottonwood Pass quadrangle. The gypsum was manufactured into wallboard and other products at a calcining and production facility located at Gypsum, Colorado (J. Cappa, 1996, oral commun.).

Scoriaceous basalt mined from the 4,000-year-old Dotsero crater by Mayne Block Company northeast of the quadrangle is crushed and used as light-weight filler in the manufacture of cinder blocks. This material is also marketed as landscaping aggregate and road cinders (J. Cappa, 1996, oral commun.). A cinder cone on Dock Flats consists of similar scoriaceous material, but is remotely located.

Other potential mineral resources in the quadrangle include high-grade limestone, sand, gravel, and crushed rock.

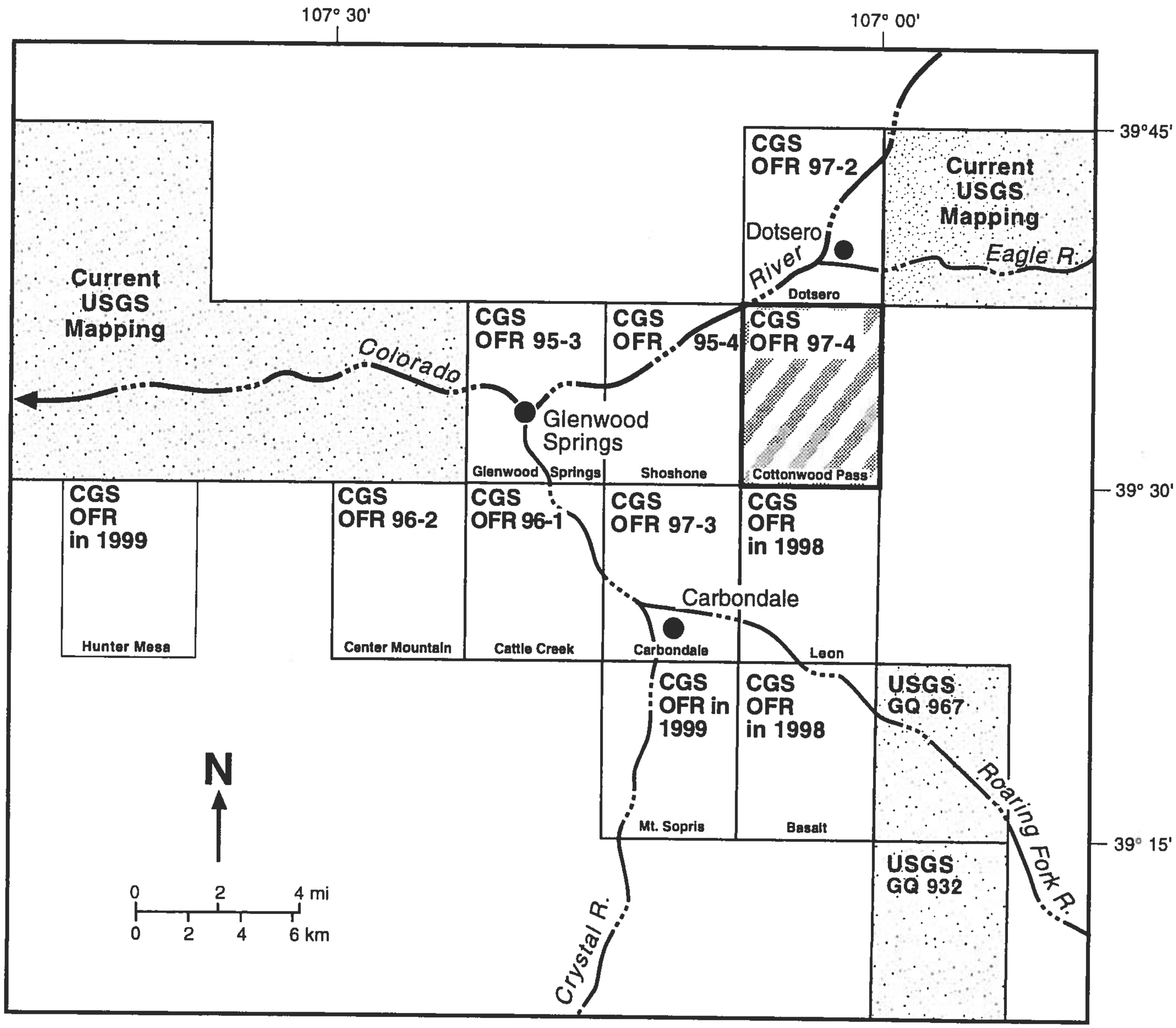

Figure 1. Status of geologic mapping of 7.5-minute quadrangles in the vicinity of Cottonwood Pass quadrangle.

TABLE

Table 1. Whole rock data.

SAMPLE #	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	LOI
CP 76	50.3	15.1	10.8	7.15	7.881	3.10	2.10	1.73	0.63	0.15	0.40
CP 77	50.3	15.1	10.9	7.51	7.82	3.15	2.17	1.77	0.66	0.16	0.16
CP 83	49.9	15.3	11.2	6.86	8.01	3.21	2.19	1.79	0.70	0.16	0.33
CP 86	50.8	15.8	10.1	6.52	7.57	3.20	3.24	1.63	0.65	0.16	0.11
CP 88	51.2	15.3	10.8	6.64	7.34	3.23	2.49	1.81	0.72	0.16	0.09
CP 89	47.8	14.7	11.5	8.14	8.27	2.94	2.21	1.82	0.74	0.16	1.59
CP 106	50.0	15.3	11.0	7.40	8.02	3.19	2.23	1.81	0.71	0.16	0.24
CPV-2	49.9	15.6	10.1	6.65	8.15	3.33	2.54	1.64	0.68	0.16	0.94
CPV-3	50.9	16.0	10.1	6.11	7.28	3.16	3.27	1.62	0.66	0.16	0.25
CPV-4	50.4	16.0	10.1	6.28	7.16	3.09	3.19	1.64	0.55	0.15	0.50
KH-95-32	50.3	15.1	10.7	7.48	7.79	3.21	2.28	1.76	0.69	0.15	0.01
KH-95-30	50.8	15.3	10.6	6.87	7.56	3.26	2.30	1.77	0.68	0.15	0.12
KH-95-29	49.9	15.1	11.2	7.29	7.92	3.18	2.29	1.78	0.69	0.16	0.06
KH-95-26	52.4	15.9	8.70	5.46	7.40	3.45	3.42	1.50	0.69	0.15	0.26
CP-39	51.3	15.1	8.91	5.47	7.31	3.27	3.23	1.41	0.66	0.14	0.95
CP 8	49.3	14.5	11.1	7.21	7.31	2.98	2.24	1.69	0.60	0.15	0.20

[LOI=Loss on ignition]

Sample Locations:

CP 76. Trachybasalt; lower flow in landslide scarp-east of Cottonwood Divide; Lat. 39.54105°; Long. 107.06679

CP 77. Trachybasalt; upper flow in landslide scarp-east of Cottonwood Divide; Lat. 39.54107°; Long. 107.06670

CP 83. Trachybasalt; uppermost of 3 flows-northeast end of Dock Flats; Lat. 39.55847°; Long. 107.06318°

CP 86. Basaltic trachyandesite; columnar jointed lava of Buck Point; Lat. 39.51120°; Long. 107.11521°

CP 88. Trachybasalt; adjacent to Cottonwood Pass Road; Lat. 39.52646°; Long. 107.11763°

CP 89. Trachybasalt; Cottonwood Pass-Larson's 11.1 Ma whole rock date; Lat. 39.53079°; Long. 107.06875°

CP 106. Trachybasalt; Joy Ranch; Lat. 39.49837°; Long. 107.05296°

CPV-2. Basaltic trachyandesite; flat-lying flows northeast of Buck Point; Lat. 39.51769°; Long. 107.10532°

CPV-3. Basaltic trachyandesite cinders; upper unit on Buck Point; Lat. 39.51661°; Long. 107.11188°

CPV-4. Basaltic trachyandesite; flat-lying flows north of Buck Point; Lat. 39.52119°; Long. 107.11380°

KH-95-32. Trachybasalt; Spruce Ridge; Lat. 39.58444°; Long. 107.09670°

KH-95-30. Trachybasalt; upper flow on Dock Flats; Lat. 39.57232°; Long. 107.11148°

KH-95-29. Trachybasalt; underlying flow on Dock Flats; Lat. 39.57259°; Long. 107.11138°

KH-95-26. Basaltic trachyandesite; flow on Gobbler Knob; Lat. 39.58028°; Long. 107.07616°

CP 8. Trachybasalt; upper flow on Dock Flats; Lat. 39.57359°; Long. 107.10553°

CP 39. Basaltic trachyandesite; flow on Gobbler Knob; Lat. 39.58058°; Long. 107.07637°

Samples CP8 and CP39 were analyzed by XRAL Laboratories, Denver, CO.
Sample CP86 was analyzed by Chemex Lab, Inc., Sparks, NV.
All other samples were analyzed by the U.S. Geological Survey, Denver, CO.

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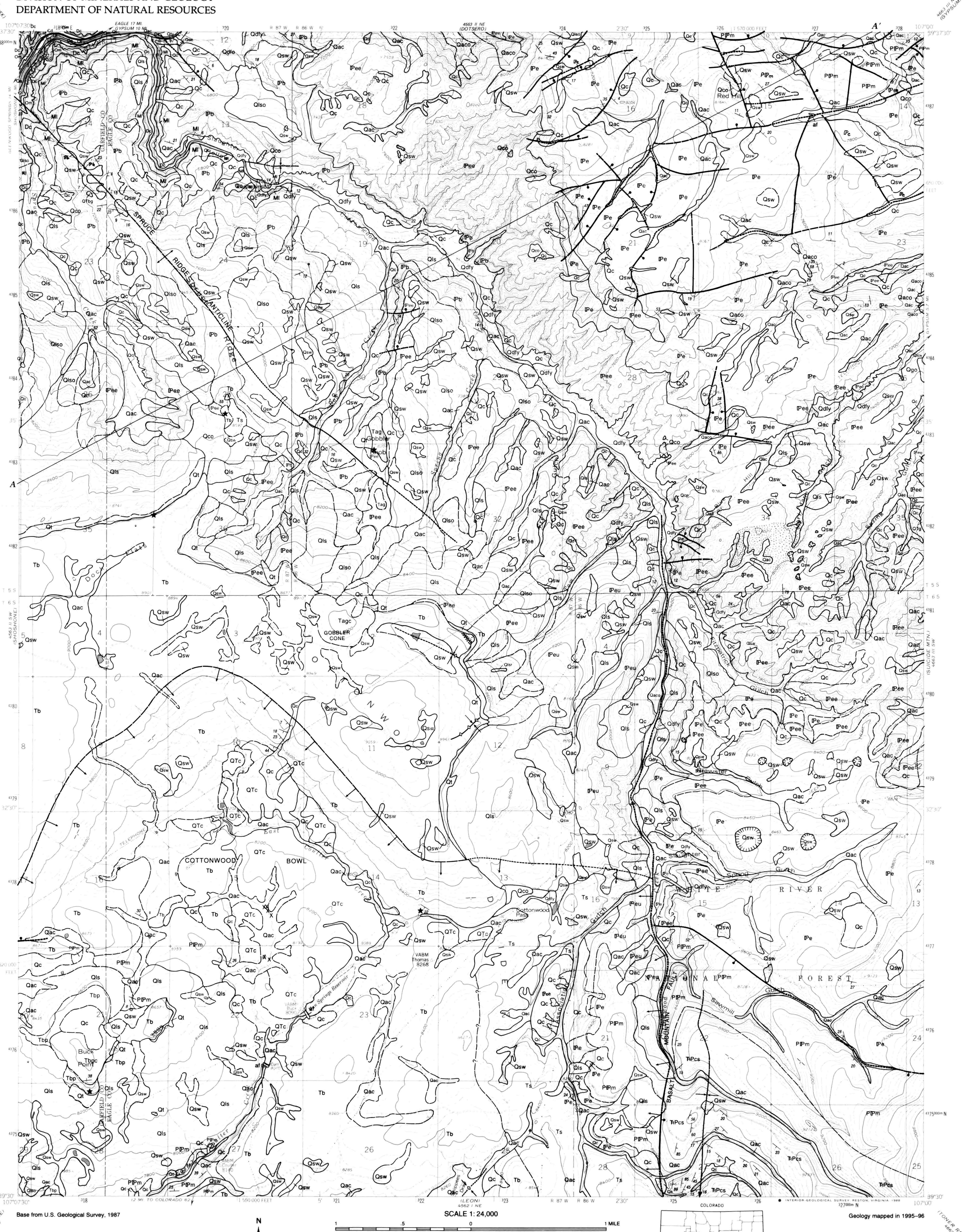
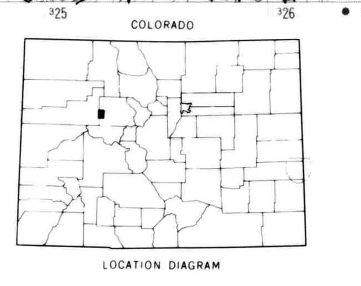
COLORADO GEOLOGICAL SURVEY
DIVISION OF MINERALS AND GEOLOGY
DEPARTMENT OF NATURAL RESOURCES

OPEN FILE MAP 97-4
GEOLOGIC MAP OF THE COTTONWOOD PASS QUADRANGLE,
EAGLE AND GARFIELD COUNTIES, COLORADO
Booklet accompanies map





CONDENSED DESCRIPTION OF MAP UNITS

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

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS—Material placed by humans

af **Artificial fill (latest Holocene)**

ALLUVIAL DEPOSITS—Silt, sand, and gravel deposited in stream channels, flood plains, terraces, and sheetwash areas along the Colorado River and in tributaries

Qa **Stream-channel, flood-plain, and low-terrace deposits (Holocene and late Pleistocene)**—Mostly clast-supported, silty, sandy, occasionally bouldery, pebble and cobble gravel. Poorly to moderately well sorted. Includes modern alluvium and other deposits underlying the Colorado River, adjacent flood-plain deposits, and low-terrace alluvium. Unit includes a thick sequence of organic-rich, gray, silty clay of probable lacustrine origin

Qsw **Sheetwash deposits (Holocene and late Pleistocene)**—Pebbly, silty sand and sandy silt. Occurs on gentle to moderate slopes underlain by shale, basalt, red beds, and landslide deposits. Frequently fills the floor of sinkholes. Gradational and interfingering with colluvium on steeper hillslopes and with lacustrine and slackwater deposits in closed depressions

Qty **Younger terrace alluvium (late Pleistocene)**—Consists of poorly sorted, clast-supported, silty, sandy, occasionally bouldery, cobble and pebble gravel. Chiefly stream alluvium in a terrace about 45 ft above the Colorado River. Overlain by 3 to 5 ft of fine-grained overbank deposits. Clasts are generally unweathered or only very slightly weathered

Qgo **Older gravel deposits (Pleistocene)**—Varies from poorly sorted, clast-supported, silty, pebble and cobble gravel to poorly sorted, matrix-supported sandy, pebbly silt. Caps the eastern end of the ridge between Spring Gulch and Cottonwood Pass road. Deposits range from about 160 to 280 ft above adjacent drainages

QTg **High-level gravel (early Pleistocene and late Tertiary)**—Occurs as a single deposit of gravel along the eastern edge of the quadrangle. Poorly exposed. Most likely a clast-supported, sandy, silty, pebble and cobble gravel that is locally bouldery. Unit caps ridge south of and about 400 to 450 ft above the floor of Spring Gulch

COLLUVIAL DEPOSITS—Silt, sand, gravel, and clay on valley sides, valley floors, and hillslopes that were mobilized, transported, and deposited primarily by gravity

Qlsr **Recent landslide deposits (latest Holocene)**—Includes a single, narrow, elongate, earthflow in upper Tom Creek that occurred during the spring of 1995. Consists of unsorted, unstratified, clay, silt, sand, gravel, and rock debris derived from landslide deposits. Clasts are mainly angular to subangular basalt and rounded to subangular red sandstone

Qc **Colluvium (Holocene and late Pleistocene)**—Ranges from clast-supported, pebble to boulder gravel in a sandy silt matrix to matrix-supported, gravelly, clayey, sandy silt. Deposits are typically 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 on steep slopes that was transported downslope by gravity as rockfalls, rockslides, and rock topples. Unit frequently lacks matrix material. Locally underlain by or incorporated into landslide deposits

Qls **Landslide deposits (Holocene and Pleistocene)**—Highly variable deposits of unsorted, unstratified, rock debris, clay, silt, sand, and gravel. Deposits range in age from recently active, slowly creeping landslides to long-inactive, middle or perhaps early Pleistocene landslides. Unit includes rotational and translational landslides, complex slump-earthflows, and extensive slope-failure complexes

Qco **Older colluvium (Pleistocene)**—Occurs on ridge lines, drainage divides, and dissected slopes on valley walls as erosional remnants of formerly more extensive deposits. Genesis, texture, bedding, and clast lithologies are similiar to colluvium (Qc)

Qlso **Older landslide deposits (Pleistocene and late Tertiary?)**—Landslide deposits dissected by erosion. Similiar in texture, bedding, sorting, and clast lithology to landslide deposits (Qls). Deposits lack distinctive landslide geomorphologic features

ALLUVIAL AND COLLUVIAL DEPOSITS—Silt, sand, and clay in debris fans, stream channels, flood plains, and adjacent hillslopes along tributary valleys

Qdfy **Younger debris-flow deposits (Holocene)**—Unit ranges from poorly sorted, matrix-supported, gravelly, sandy, clayey silt to clast-supported, pebble and cobble gravel with a sandy, clayey silt or silty sand matrix. Deposited by debris flows, hyperconcentrated flows, streams, and sheetwash on active debris fans and in stream channels. Occasionally very bouldery, particularly near fan heads

Qac **Alluvium and colluvium, undivided (Holocene and latest Pleistocene)**—Alluvium is typically poorly to well-sorted, stratified, interbedded pebbly sand, sandy silt, and sandy gravel. Colluvium may range to unsorted, unstratified or poorly stratified, clayey, silty sand, bouldery sand, and sandy silt. Occurs in tributary valleys of small perennial, intermittent, and ephemeral streams. Deposited by alluvial and colluvial processes

Qaco **Older alluvium and colluvium, undivided (Pleistocene)**—Underlies terraces and hillslopes about 10 to 50 ft above adjacent intermittent or ephemeral streams. Texture bedding, clast lithology, sorting, and genesis are similiar to alluvium and colluvium (Qac)

Qdfo **Older debris-flow deposits (early Holocene and Pleistocene)**—Occur as valley-filling deposits in tributaries to the Colorado River. Unit is genetically, texturally, and lithologically similiar to younger debris-flow deposits (Qdfy). Elevation differences between original depositional surfaces and adjacent incised modern drainages range from 20 to 60 ft

QTbg **High-level basaltic gravel (early Pleistocene and late Tertiary?)**—Unit consists of slightly indurated, matrix-supported, cobbly, pebbly, and bouldery clayey, sandy silt. Occurs on ridge between Spruce Creek and Ike Creek on western edge of map area and on north end of Spruce Ridge. Probably deposited as debris flows, earthflows, colluvium, or landslides

QTc **Sediments of Cottonwood Bowl (early Pleistocene and late Tertiary?)**—Locally derived gravel, sand, silt, and clay deposited in and near the topographic bowl bordered on the north and west by Cottonwood Divide and Dock Flats. Deposits range from sandy and silty pebble, granule, or cobble gravel to gravelly, sandy silt. Deposited in fluvial, sheetwash, and colluvial environments in a large collapse bowl that developed after emplacement of the basalts of Dock Flats

UNDIFFERENTIATED SURFICIAL DEPOSITS

Q **Surficial deposits, undifferentiated (Quaternary)**—Shown only on cross-section

BEDROCK

Tag **Basaltic trachyandesite of Gobbler Knob (Pliocene)**—Gray to dark-gray and black, dense to vesicular, basaltic trachyandesite. Contains phenocrysts of olivine and xenocrysts of quartz with reaction rims of clinopyroxene. Occurs as two elongate, narrow, flow remnants which cap Gobbler Knob and part of the ridgeline extending south. Flow was probably erupted from a small cinder cone located on Dock Flats about 1 mile to the south

Tagc **Cinder deposits of Gobbler Cone (Pliocene)**—Red and red-brown, scoriaceous, unconsolidated, vesicular, cindery lava on an eruptive vent on Dock Flats. Cindery deposits overlie and are younger than the basalt flows (Tb) that cap Dock Flats

Tbp **Basaltic trachyandesite of Buck Point (Pliocene)**—Medium- to dark-gray flows of basaltic trachyandesite with phenocrysts of olivine and pyroxene and xenocrysts of resorbed quartz and feldspar. Occurs as lava flows and as columnar jointed lavas on and near Buck Point

Tbpc **Cinder deposits of Buck Point (Pliocene)**—Red to brownish-red and black, loose to well-cemented, moderately well-bedded breccia consisting of clasts of slightly to highly vesicular basaltic trachyandesite (Tbp). Probably deposited during a late-stage, high gas content, explosive eruption which eminated from the Buck Point vent. Deposit overlies and appears to have a gradational contact with columnar jointed lava flow exposed on south flank of Buck Point

Tb **Basalt (Miocene)**—Multiple stacked flows of massive to highly vesicular trachybasalt that are widespread across the west-central and south-central parts of the quadrangle. Groundmass is plagioclase and pyroxene with minor olivine, glass, pigeonite, augite, and magnetite. Phenocrysts are euhedral to subhedral olivine. Unit is well exposed in the headscarps of two large landslides on the north and east sides of Dock Flats

Ts **Sedimentary deposits (Miocene)**—Unit composed mostly of silty, pebbly gravel and pebbly silt but ranges to sandy and clayey silt. Includes extensive deposits that underlie basalt flows near and south of Cottonwood Pass, and a thin, areally limited deposit associated with basalt on Spruce Ridge. May be predominantly a matrix-supported deposit. Clasts are rounded to subangular and consist mostly of red sandstone, quartz, and coarse-grained plutonic rocks

TRPcs **Chinle and State Bridge Formations, undivided (Permian to Upper Triassic)**—Chinle Formation consists of thin, even-bedded, and structureless red beds of dark-reddish-brown, orangish-red, and purplish-red siltstone and mudstone with a few beds of limestone. State Bridge Formation consists of pale red, grayish-red, reddish-brown, and greenish-gray siltstone, clayey siltstone, and minor sandstone

PPm **Maroon Formation (Lower Permian and Upper Pennsylvanian)**—Red beds of sandstone, conglomerate, siltstone, mudstone, and shale with minor, thin beds of gray limestone. Frequently arkosic and micaceous

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

Pee **Eagle Valley Evaporite (Middle Pennsylvanian)**—Sequence of evaporitic rocks consisting mainly of massive to laminated gypsum, anhydrite, and halite, interbedded with light-colored mudstone and fine-grained sandstone, thin carbonate beds, and black shale. Beds commonly deformed by diapirism, flowage, load metamorphism, dissolution, hydration of anhydrite, and regional tectonism. Frequently contains cavernous voids and sinkholes caused by near-surface dissolution

Peu **Eagle Valley Formation and Eagle Valley Evaporite, undivided (Middle Pennsylvanian)**—Includes Eagle Valley Formation and Eagle Valley Evaporite where contact between the formations is not mappable

Pb **Belden Formation (Lower Pennsylvanian)**—Medium-gray to black, and dark-brown, calcareous and locally micaceous shale and coarse-grained, gray, fossiliferous limestone. Upper 100 ft of unit contains four or five prominent beds of conglomeratic, very-coarse-grained, lithic-rich wackes and subarkoses that may be equivalent to the Minturn Formation mapped by Streufert and others (1997) in the Dotsero quadrangle. May contain discontinuous beds of gypsum at any interval in section

Ml **Leadville Limestone (Mississippian)**—Light- to medium-gray, bluish-gray, massive, coarse to finely crystalline, fossiliferous limestone and dolomite. Unit contains lenses and nodules of dark-gray to black chert in lower one-third of formation. Top of unit contains collapse breccias, filled solution cavities, an[illegible]ally derived reddish claystone regolith, all of which fo[illegible] on a paleokarst surface

Dc **Chaffee Group (Upper Devonian)**—Includes in descending order: Gilman Sandstone-tan to yellow, fine-grained, dolomitic sandstone; Dyer Dolomite-limestone and dolomite; and Parting Formation-white to buff orthoquartzite, green shale, and gray dolomite

Om **Manitou Formation (Lower Ordovician)**—Consists predominantly of medium-bedded, brown dolomite, limestone, sandstone, and thin beds of gray, flat-pebble limestone interbedded with greenish-gray calcareous shale

€d **Dotsero Formation (Upper Cambrian)**—Thinly bedded, tan to gray, silty and sandy dolomite, dolomitic sandstone, green dolomitic shale, limestone and dolomite conglomerate, limestone, and pinkish- to light-gray algal limestone. Unit contains abundant glauconite

€s **Sawatch Quartzite and unnamed overlying rocks, undivided (Upper Cambrian)**—White and buff to gray-orange, brown-weathering, vitreous orthoquartzite in beds from 1 to 3 ft thick. Unit includes unnamed beds of massive, brown, sandy dolomite and white quartzite

p€ **Precambrian rocks, undivided (Proterozoic)**—Shown only on cross-section

MAP SYMBOLS

Contact—Dashed where approximately located; queried where uncertain

Fault—Dashed where approximately located; dotted where concealed; bar and ball on downthrown side; arrows on Basalt Mountain Fault indicate direction of Neogene collapse along the fault due to dissolution and/or flowage of evaporite

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

Syncline—Showing trace of axial surface; dashed where approximately located; dotted where concealed; arrow and number indicate direction and angle of plunge of axial trace

Synclinal sag—Showing approximate axial trace of syncline related to evaporite dissolution and/or flowage; dotted where concealed

Collapse basin—Drawn on approximate outer edge of regional structural depression due to dissolution and/or flowage of underlying evaporite; arrows indicate direction of collapse; dotted where concealed

Strike and dip of beds—Angle of dip shown in degrees; attitudes in basalt were measured on top of flow surfaces

Inclined beds—Showing approximate attitude of bedding in sedimentary rocks and the upper flow surface in volcanic rocks as determined from stereographic models set on a Kelsh PG-2 plotter

Strike and dip of foliation—Angle of dip shown in degrees

Locality of rock sample—Radiometrically dated using the $^{40}Ar/^{39}Ar$ method

A——A′ **Alignment of cross section**

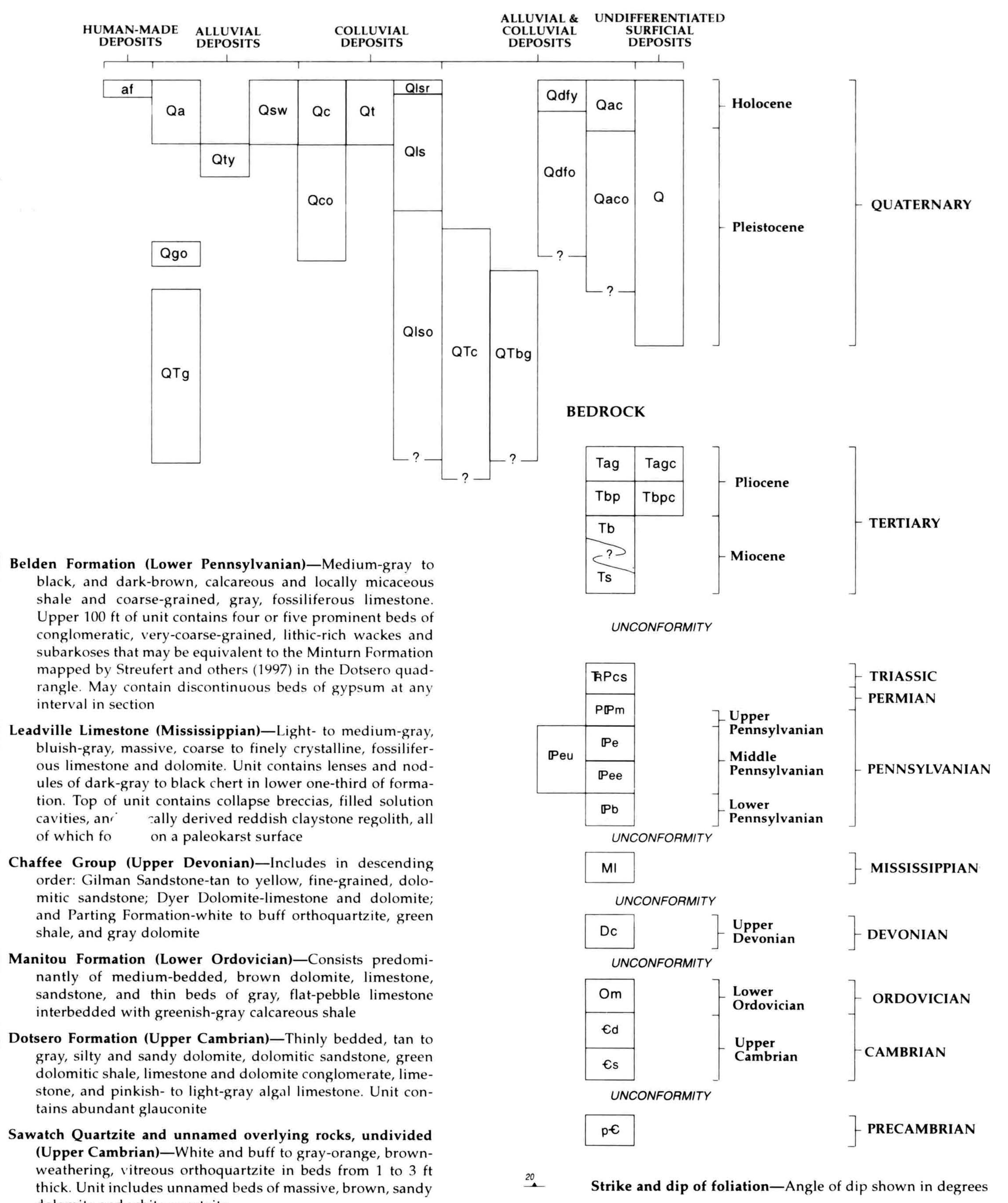
X **Sinkhole**—Created by subsidence over voids in the Eagle Valley Evaporite or by piping of surficial deposits into such voids; "X" indicates location of small sinkholes; floors of many sinkholes are filled with sheetwash deposits

Mega-subsidence complex—Large area of hummocky ground inferred to have resulted from regional subsidence into cavernous voids within the Eagle Valley Evaporite

Tension fracture—In basalt above headscarp of landslide

Adit—Small 20 ft long exploration tunnel into gypsum bed

CORRELATION OF MAP UNITS



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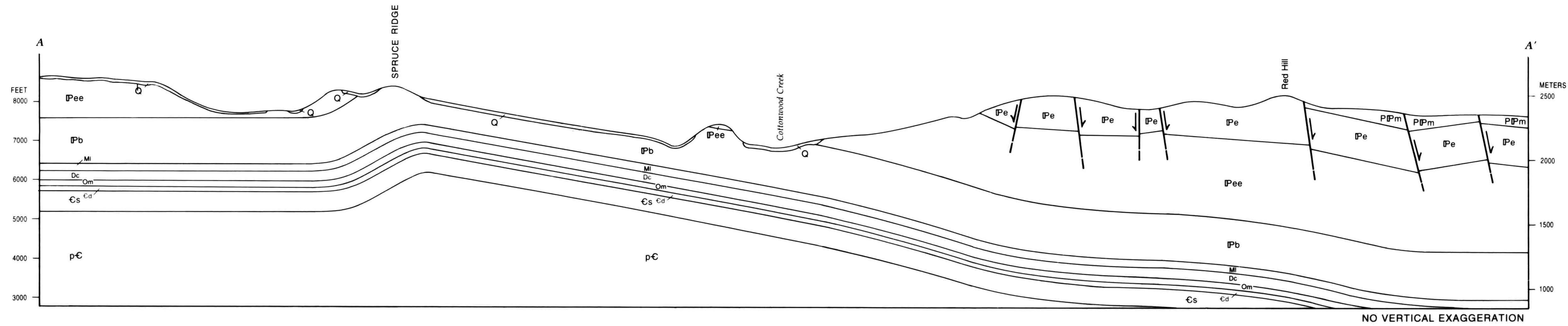

GEOLOGIC MAP OF THE COTTONWOOD PASS QUADRANGLE, EAGLE AND GARFIELD COUNTIES, COLORADO

By
Randall K. Streufert, Robert M. Kirkham, Beth L. Widmann, and Timothy J. Schroeder II
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