U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE EAGLE QUADRANGLE, EAGLE COUNTY, COLORADO

By

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Pamphlet to accompany
MISCELLANEOUS FIELD STUDIES MAP
MF–2361

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits shown on this map are generally at least 1 m thick. Thin, discontinuous colluvial deposits, residual material on bedrock, and some artificial fills were not mapped. All contacts of surficial deposits with adjacent units are shown as solid lines on the map; however, most of these contacts are only approximately located because (1) they are commonly poorly exposed and gradational and (2) many of the surficial deposits vary abruptly and irregularly in thickness from greater than 1 m thick to less than 1 m thick, particularly near contacts.

Divisions of Quaternary time shown below are approximate and modified from Richmond and Fullerton (1986): Holocene, 0–11.5 ka (ka, thousand years ago); late Pleistocene, 11.5–127 ka; middle Pleistocene, 127–778 ka; and early Pleistocene 778–1,806 ka (Lidke, 1998; Carrara, 2001).

Age assignments for surficial deposits are based mainly on stratigraphic relationships and the degree of erosional modification of original surface morphology. In addition, age assignments for alluvial deposits are based on the height of the deposit above modern river levels. More specifically, age assignments for the alluvial deposits are inferred on the basis of a regional rate of stream incision of about 0.13 m/ky (ky, thousand years). This incision rate is based on a value for stream incision since the deposition of the 640-ka Lava Creek B volcanic ash (M.A. Lanphere, USGS, oral commun., 2000), where it is present about 85 m above the Eagle River near Dotsero, Colo. (Izett and Wilcox 1982; Streufert and others, 1997), and about 80 m above the White River near Meeker, Colo. (Whitney and others, 1983).

Grain-size terminology for surficial deposits is based on visual estimates and follows the modified Wentworth grade scale (American Geological Institute, 1982). In descriptions of surficial deposits, the term “clast” refers to the fraction greater than 2 mm in diameter, whereas the term “matrix” refers to particles less than 2 mm in size.

Artificial fill

af **Artificial fill (latest Holocene)**—Compacted and uncompacted fill material composed mostly of varying amounts of silt, sand, and rock fragments. Unit includes fill beneath Interstate 70 and part of the tracks of the Denver and Rio Grande Western Railroad (sec. 5, T. 5 S., R. 64 W.). Thickness ranges from about 1 to 15 m

Alluvial deposits

Qalc **Stream-channel and flood-plain deposits along Eagle River (Holocene)**—The upper 1–2 m of the unit is commonly a light-yellowish-brown to pale-reddish-brown, massive, silty, fine- to medium-grained sand that locally contains minor amounts of pebbles and cobbles in lenses generally less than 20 cm thick. The lower part of the unit, poorly exposed and of unknown thickness, consists of well-sorted, rounded and well-rounded, pebble and cobble gravel derived from a variety of sedimentary, igneous, and metamorphic rocks. Clasts in this unit consist predominantly of light- to dark-gray basalt, white quartzite, red sandstone, light-colored granite and granodiorite, and dark-colored schist and gneiss. Some clasts have a thin, white carbonate coat. Matrix in lower, gravelly part consists of very pale brown, sandy silt and silty sand. Unit may include low terraces along the flood plain. Unit subject to periodic flooding. Thickness estimated to be 5–10 m

Qa **Stream-channel and flood-plain deposits along Brush Creek (Holocene and latest Pleistocene?)**—Includes stream-channel, flood-plain, and some sheetwash deposits. Main channel deposits consist of matrix-supported, poorly sorted, subrounded to rounded, pebble- and cobble-size clasts of red sandstone; white, tan, and pink quartzite; white granite and granodiorite; and dark schist and gneiss in a matrix of pale-brown to reddish-brown, silty sand. Unit generally contains more red sandstone clasts than do similar deposits along the Eagle River (such as Qalc). Mapped only along Brush Creek, south of Eagle River. Unit subject to periodic flooding. Thickness estimated to be 5–10 m

Qty **Younger terrace alluvium (late Pleistocene)**—Alluvium deposited by the Eagle River, underlying terraces about 6–8 m above river. Unit consists of well-sorted, imbricated, rounded and well-rounded, pebble and cobble gravel. Clasts consist predominantly of white and pink, coarse-grained granite; white and gray, fine-grained granite and granodiorite; dark gneiss and schist; white, pink, and tan quartzite; fine- to medium-grained, red sandstone; and light- to dark-gray basalt. Matrix consists of pale-brown, silty sand and sand. Gravel is commonly overlain by about 1 m of massive, pale-yellowish-brown to pale-reddish-brown, silty fine sand and fine sand. Wedges of undivided alluvium and colluvium (Qac) and younger fan deposits (Qfy) commonly overlie and cover terrace margins. Unit is probably equivalent in part to outwash of the Pinedale glaciation, which is about 12–35 ky old (Richmond, 1986, chart 1A). Unit is a potential gravel resource. Thickness commonly 5–10 m

Qtm **Intermediate terrace alluvium (late to middle Pleistocene)**—Alluvium deposited by the Eagle River and Brush Creek, underlying terrace remnants about 20 m above Eagle River near mouth of Brush Creek and along lower part of Brush Creek. Unit consists of moderately well sorted, rounded and well-rounded, pebble and cobble gravel with sparse boulders. Unit is similar in clast composition and character to younger and older terrace alluviums (Qty and Qto), but contains more red sandstone clasts, and matrix is commonly more reddish in color, particularly where exposed in Brush Creek drainage. Covered by aprons of undivided alluvium and colluvium (Qac) along much of Brush Creek drainage. Intermediate in age and height between younger and older terrace alluviums (Qty and Qto). Unit may be equivalent to outwash deposited during late stages of the Bull Lake glaciation, which is about 140–150 ky old (Pierce and others, 1976). Unit is a potential gravel resource. Thickness commonly about 10 m

Qto **Older terrace alluvium (middle Pleistocene)**—Alluvium deposited by the Eagle River, underlying small terrace remnants about 25–30 m above Eagle River. Unit consists of well-sorted, rounded and well-rounded, pebble and cobble gravel with sparse boulders. Clasts consist mostly of white and pink, coarse-grained granite; gray, fine-grained granite and granodiorite; dark gneiss and schist; white, pink, and tan quartzite; fine- and medium-grained, red sandstone; and light- to dark-gray basalt. Matrix consists of pale-brown, silty sand. Gravel is commonly overlain by about 1 m of massive, light-yellowish-brown, silty, fine sand that may be loess. Wedges of undivided alluvium and colluvium (Qac) and older fan deposits (Qfo) commonly overlie and cover terrace margins. Unit may be equivalent to outwash deposited during early to middle stages of the Bull Lake glaciation, which is about 140–150 ky old (Pierce and others, 1976). Unit is a potential gravel resource. Preserved thickness commonly 3–5 m

Oldest terrace alluvium (middle? to early? Pleistocene)—Alluvium deposited by the Eagle River, underlying terrace remnants at elevations above the Eagle River of about (1) 63–69 m (Qtpl), (2) 110–115 m (Qtpm), and (3) 150–155 m (Qtpu). Deposits underlying all three terrace levels contain rounded to well-rounded, pebble- to boulder-size clasts of white, pink, and tan quartzite; white to pale-gray granite and granodiorite; porphyritic granite with pink feldspar phenocrysts; dark schist and gneiss; and minor red sandstone and dark-gray basalt. Matrix is pale-brown sandy silt and silty sand. Clasts rich in mafic and feldspathic minerals are weathered and friable, particularly in higher two terraces. Alluvial gravels underlying the lower terrace (Qtpl) are locally associated with a volcanic ash deposit (SE1/4SW1/4, sec. 24, T. 4 S., R. 84 W.). The stratigraphic relationship of the ash deposit to the terrace alluvium is not entirely clear; however, it appears that the ash overlies the lower terrace alluvium (Qtpl) and is overlain by a thin remnant of an old fan deposit that contains reworked clasts of higher and older terrace alluvium. Both the ash and the fan material are too thin and cover too small an area to be shown on the map. The geochemical signature of the ash suggests it may be the 640-ka Lava Creek B ash (P.E. Carrara and Andrei Sarna-Wojcicki, USGS, written commun., 1999), which would imply that the lower terrace (Qtpl) is about 640,000 years old (middle Pleistocene). A 640-ky age for this terrace might imply either (1) a post-640 ka incision rate of about 0.1 m/ky for this region, which is a lower rate than the 0.13 m/ky incision rate cited in the introductory statements for surficial deposits or (2) possibly an incision rate higher than 0.1 m/ky obscured by post-640-ka sagging, collapse, or faulting related to underlying evaporitic rocks of the Eagle Valley Evaporite (IPee). Terrace alluvium underlying the middle and upper oldest terraces (Qtpm and Qtpu) may range in age from about 850,000 to 1,550,000 yr old (early Pleistocene), based on the suggested age for the lower terrace and on a regional stream incision rate ranging from about 0.1 to 0.13 m/ky. Unit may be a potential gravel resource. Maximum thickness estimated to be about 10–12 m

Qtpl **Lower oldest terrace alluvium (middle? Pleistocene)**—Alluvium underlying terrace remnants at elevations of about 63–69 m above the Eagle River

Qtpm **Middle oldest terrace alluvium (early? Pleistocene)**—Alluvium underlying terrace remnants at elevations of about 110–115 m above the Eagle River

Qtpu **Upper oldest terrace alluvium (early? Pleistocene)**—Alluvium underlying terrace remnants at elevations of about 150–155 m above the Eagle River

Tg **Tertiary gravel (early Miocene or Oligocene)**—Gravelly alluvium containing clasts likely deposited by an ancestral Eagle River or its tributaries. Unit is present in southeastern and west-central parts of map area, where it forms poorly exposed, remnant, gravelly patches that commonly underlie basaltic flows (Tb). Consists of rounded to well-rounded, pebble and cobble gravel with sparse boulders of resistant rock types. Clasts are primarily white, tan, and pink quartzite; red, fine- to medium-grained sandstone; and very sparse clasts of granite and gneiss. Commonly covered by, or littered with, debris from overlying basaltic flows. Locally may include gravelly colluvium (Qcg). Remnants of unit occur about 300 m above modern Eagle River. Remnants of unit probably too thin and patchy to be a potential gravel resource. Maximum preserved thickness about 5 m

Alluvial and colluvial deposits

Qfy **Younger fan alluvium and colluvium (Holocene and latest Pleistocene)**—Unit forms fan-shaped deposits at mouths of some intermittent tributaries of Eagle River. Consists of pebble- to boulder-size, angular to subrounded, locally derived clasts that are mostly matrix supported in massive fine sand, silt, and clay. Commonly overlies younger terrace deposits (Qty) or stream-channel and flood-plain deposits of Eagle River (Qalc). Unit includes a mixture of debris-flow, sheetwash, and alluvial deposits. Unit may be subject to channel modification and debris flows during intense or prolonged rainstorms. Maximum thickness estimated to be about 7–10 m

Qac **Alluvium and colluvium, undivided (Holocene to middle Pleistocene)**—Sediments deposited in tributary valleys of Eagle River and as broad alluvial and colluvial aprons that overlap and cover terrace deposits along Eagle River. Includes interbedded stream-channel, flood-plain, fan, sheetwash, and probable loess deposits. Character and composition are variable and dependent on local source rocks, topography, and relative position within drainage. Locally covers steep canyon bottoms and is shown terminating against younger fan deposits (Qfy) near canyon mouths; the contact with the fan deposits is gradational and based on the differing geomorphic form of the fan deposits. Unit is most prominent and widespread where it covers and flanks exposures of the Eagle Valley Formation (IPe) and Eagle Valley Evaporite (IPee) in southern and central parts of map area. These relatively erodable source rocks (IPe and IPee) commonly form light-brown alluvial and colluvial deposits of sand, silt, and clay with some subangular to subrounded, locally derived pebbles and cobbles that are commonly matrix supported. Unit is locally evaporitic where it is derived from nearby evaporitic rocks. Gullies within unit may be subject to flash floods and, near canyon mouths, may be subject to debris flows related to unusually intense rainstorms. Fine-grained deposits of unit may be susceptible to hydrocompaction- and piping-related subsidence (particularly evaporite-bearing deposits). Expansive clays may be present in deposits derived from Benton Shale (Kb). Maximum thickness estimated to be about 10 m

Qp **Pediment deposit of Brush Creek area (late or middle Pleistocene)**—Debris-flow, sheetwash, and alluvial deposits that overlie pediment surface along Brush Creek in south-central part of map area. Clast- and matrix-supported, poorly sorted, unstratified to poorly stratified, pebble- to cobble-size clasts in light-tan matrix of silt, sand, and clay. Clasts consist mainly of subangular to subrounded, red sandstone; pale-green siltstone and sandstone; and gray limestone derived from the Eagle Valley and Maroon Formations. This unit and the underlying pediment surface were later dissected by Holocene stream channels; unit now caps low, broad, gently north-sloping ridges. Mostly overlies beveled Eagle Valley Evaporite, but locally appears to overlie small remnants of terrace alluvium that may be equivalent to older terrace alluvium (Qto); these terrace remnants are too small to map separately and are not shown on map. Maximum thickness about 3 m

Qfo **Older fan alluvium and colluvium (middle Pleistocene)**—Light-brown, poorly sorted silt, sand, and clay with matrix-supported, subangular to rounded, pebble- to boulder-size clasts of locally derived sandstone and other rock types. Forms low-gradient fan deposits adjacent to the Eagle River and some large tributaries of the Eagle River. Commonly overlies and locally completely covers older terrace gravels (Qto). Some deposits of undivided alluvium and colluvium (Qac) may be eroded remnants of similar older fan deposits. Unit may be subject to channel modification and debris flows during intense or prolonged rainstorms. Fine-grained deposits may be susceptible to hydrocompaction- and piping-related subsidence, particularly evaporite-bearing deposits. Maximum thickness estimated to be about 5 m

Colluvial deposits

Colluvium (Holocene and late Pleistocene)—Grains and rock fragments transported by gravity and deposited on and at base of hill slopes. Clast- and matrix-supported deposit consisting mostly of angular to subangular, pebble- to boulder-size clasts in sand, silt, and clay matrix, all derived from weathered bedrock. Clast lithology, size of clasts, and character of matrix support are variable and dependent mostly on source rocks, slope gradient, and relative position on slope. Easily eroded source rocks tend to form finer grained, matrix-supported deposits with fewer and smaller clasts; resistant source rocks, such as the Dakota Sandstone (Kd), tend to form blocky, clast- and matrix-supported, coarser grained deposits with more abundant and larger clasts. Colluvium that is derived predominantly from the Dakota Sandstone (Kd), from various gravelly alluvium units (Qtpm, Qtpu, Qp, and Tg), and from basaltic flows (Tb and Tbv) is distinctive and is differentiated in many places on the map (Qcd, Qcg, and Qcv). Locally may include talus, landslide, sheetwash, and debris-flow deposits that are too small or indistinct to map separately. Areas of colluvium may be susceptible to debris flows, rock falls, and small slumps and landslides. Fine-grained deposits may be prone to settlement from piping and hydrocompaction, particularly deposits derived from evaporitic rocks. Maximum thickness as much as 15 m, but generally much thinner

Qc **Colluvium, undifferentiated**—Unsorted to poorly sorted deposits of sand, silt, and clay that include matrix-supported, angular, pebble- to boulder-size clasts derived from bedrock upslope of deposit. Thickness variable, commonly 1–5 m

Qcd **Colluvium of Dakota Sandstone**—Unsorted to poorly sorted, angular, pebble- to large boulder-size clasts of white to tan sandstone and orthoquartzite in matrix of sand, silt, and clay. Derived from upslope exposures of the Dakota Sandstone (Kd) and locally contains sandstone blocks as long as 3 m. Commonly 1–5 m thick

Qcg **Gravelly colluvium**—Unsorted to poorly sorted, reworked gravelly deposits derived from Quaternary and Tertiary gravelly alluvium (Qtpm, Qtpu, Qp, and Tg). Forms distinctive gravelly slopes near depositional sites of gravelly source alluvium. Distinguished from alluvial deposits principally by its position on slope beneath and adjacent to ridge-capping alluvial deposits; locally may include some in-place alluvium. Gravelly colluvium west of Brush Creek, in south-central part of map area, occurs at elevations as high as about 115 m above Brush Creek and may include some in-place alluvium that could be related to the middle oldest terrace alluvium (Qtpm) present along Eagle River. Thickness about 1–3 m

Qcv **Basalt-rich colluvium**—Unsorted to poorly sorted deposits derived primarily from Tertiary basaltic flows (Tb and Tbv). Forms distinctive basaltic rubble deposits downslope from these rock units. Unit consists primarily of angular to subrounded, pebble- to boulder-size basalt clasts in a dark-brown matrix of sand, silt, and clay. Unit also commonly contains some clasts of rounded to well-rounded gravel apparently derived from Tertiary alluvial gravels known to commonly underlie basaltic flows and volcaniclastic rocks of units Tb and Tbv. Commonly about 1–5 m thick, but locally may be as much as 10 m thick

Qls **Landslide deposits (Holocene to middle? Pleistocene)**—Includes a variety of materials, from relatively intact masses of bedrock to unconsolidated surficial material and rock fragments that have moved down slopes. Deposits mostly formed as rock falls and topples, translational and rotational rock and debris slides, and rock and debris flows. These differing types of mass movement deposits are broadly lumped under the term “landslide” after Varnes (1978). Many of the landslide deposits mapped are complex in that they include two or more of the general types mentioned. Scarps and remnants of scarps within many of these deposits suggest some parts of the deposits moved recurrently. Scarps and pressure (buckle) ridges shown on map were mostly identified on aerial photographs. The strike and dip of contorted beds in some landslide masses is locally shown to help depict the internal structure of the landslide materials. Where feasible in map area, and as described below, landslide deposits were subdivided broadly, based on material and dominant type of slope movement. Landslide deposits that include a variety of reworked bedrock and surficial units, however, were not subdivided. Thickness estimates for the subdivided types of landslides are shown below, and the few other landslides mapped probably have a maximum thickness of about 10 m

Qlsv **Landslide debris of volcanic rocks**—Unconsolidated to poorly consolidated volcanic rock debris consisting primarily of matrix-supported, angular to subangular, pebble- to large boulder-size clasts of basalt and minor gravel in a silt- and clay-rich matrix. Present adjacent to and downslope of basaltic flows (Tb and Tbv) in northern and southeastern parts of map area. Distinguished from compositionally similar basalt-rich colluvium (Qcv) by the presence of some scarps and a more hummocky surface topography. Maximum thickness about 10 m

Qlsn **Landslide derived from Niobrara Formation**—Niobrara Formation (Kn) shale and limestone beds in extensive slide masses that formed on north-facing, bedding-plane dip slopes. Niobrara rocks appear relatively intact, but they are folded or warped above one or more north-dipping zones of landslide failure planes in north-dipping shale of the Niobrara. Principal bedding-plane zone of failure commonly occurred in shale just above basal limestone of the Niobrara Formation. Probably formed principally by slow, deep creep that probably was most active during wet periods of the late and middle Pleistocene. Slide masses may be susceptible to creep; however, active creep unknown. Maximum thickness estimated to be about 20–25 m

Qlsb **Landslide derived from Benton Shale**—Relatively intact, but deformed Benton Shale (Kb), in extensive slide masses that formed on north-facing, bedding-plane dip slopes. Similar in all fundamental characteristics, origin, and age to landslides of the Niobrara Formation (Qlsn). Principal bedding-plane zone of failure commonly occurred in shale just above basal, sandy transition zone with the underlying Dakota Sandstone (Kd). Slide masses may be susceptible to creep; however, active creep unknown. Soil and other surficial materials derived from Benton slide masses may contain expansive clay. Maximum thickness estimated to be about 20–25 m

Qdy **Younger debris-flow deposits (Holocene and late Pleistocene)**—A series of debris-flow deposits and minor amounts of stream alluvium derived from steep slope and cliffs north of Eagle River in east-central part of quadrangle. Consists mostly of matrix-supported and some clast-supported, poorly sorted, unstratified to poorly stratified, angular to subangular pebbles, cobbles, and boulders of locally derived red, pink, and white sandstone, pale-green siltstone and sandstone, and light- and dark-gray limestone in a red matrix of silty sand and sandy silt. May include some alluvium. Maximum thickness may exceed 20 m

Qdu **Undifferentiated debris-flow and landslide deposits of Eby Creek (late or middle Pleistocene)**—Primarily a large debris-flow deposit along upper part of Eby Creek in northwestern part of quadrangle, but includes a few small landslide deposits derived from cliffs of Dakota Sandstone (Kd) present along southwest margin of Eby Creek. Unit consists mainly of poorly sorted, unstratified, angular to subangular, matrix- and clast-supported, pebble- to boulder-size clasts of basaltic flows (Tbv) and Dakota Sandstone (Kd) in grayish-brown, silty sand to clay-rich matrix. Small landslides within unit consist almost entirely of Dakota Sandstone (Kd) clasts. Boulders are as long as 4 m. Locally includes rounded to well-rounded, pebble- to boulder-size clasts of fluvial gravel, which probably were derived from Tertiary alluvial gravels that are known to underlie basaltic and volcaniclastic rocks (Tbv) present nearby. Maximum thickness estimated to be about 15 m

Qdo **Older debris-flow deposits (middle? and early? Pleistocene)**—Mostly consists of poorly sorted, unstratified, angular to subangular, matrix- and clast-supported, pebble- to boulder-size clasts of weather-resistant, locally derived sedimentary rock and basalt in a light-tan, sandy silt to silty sand matrix; basalt clasts are common to abundant in these deposits. Includes boulders as long as 3 m. Locally, parts of these deposits consist of stratified to poorly stratified, subrounded to rounded, locally derived fluvial gravels. Deposits may be old pediment fan deposits that graded to the oldest terrace alluvium of the Eagle River (Qtpl, Qtpm, and Qtpu) and probably represent several debris-flow events during the middle and early Pleistocene. Locally may be as much as 10 m thick

QTbr **Basalt rubble (early Pleistocene or Pliocene)**—Rubble consisting almost entirely of basalt clasts mantling areas along ridge directly west of Castle Creek in north-central part of map area. Consists of matrix- and clast-supported, poorly sorted, unstratified, angular to subangular, pebble- to boulder-size clasts of basalt and very sparse clasts of Dakota Sandstone (Kd) in a pale-gray to pale-brown sand, silt, and clay matrix. Unit may consist primarily of early Pleistocene or Pliocene, basalt-rich debris flows derived from nearby basaltic flows in unit Tbv, which have since been extensively incised. Maximum thickness estimated to be 15–20 m

BEDROCK UNITS

Tbv **Basaltic flows, volcaniclastic rocks, and conglomerate (Miocene)**—Consists primarily of basaltic flows and lenses or channels of volcaniclastic rocks, which commonly overlie a basal fluvial conglomerate in north-central part of map area. Basaltic flows are light- to dark-gray; contain phenocrysts of olivine, plagioclase, and pyroxene; are vesicular to nonvesicular, locally amygdaloidal; and are similar in appearance to basaltic flows (Tb) present in west-central and southeastern parts of map area. Olivine is commonly altered to iddingsite. Unit typically is poorly exposed and weathered to basaltic rubble. Volcaniclastic rocks consist of unstratified to poorly stratified, poorly sorted, matrix-supported, subangular to subrounded basalt and sedimentary rock clasts in a white to light-tan, poorly lithified sandy, tuffaceous, and locally ashy matrix. Base of unit commonly is a thin (2–5 m), weakly lithified conglomerate that consists of clast-supported, rounded to well-rounded pebbles, cobbles, and boulders of white and tan quartzite, white to grayish-white granite-granodiorite, dark schist and gneiss, and basalt in a pale-brown to yellowish-brown matrix of silty sand. Conglomerate is similar in appearance to alluvial gravels (Tg) that commonly underlie basaltic flows (Tb) in southeastern part of map area. Total thickness may exceed 50 m

Tb **Basaltic flows (lower Miocene)**—Dark- to light-gray and orangish-red, vesicular to nonvesicular basaltic flows. Contains phenocrysts of olivine and pyroxene as long as 5 mm in a devitrified and altered, microgranular to pilotaxitic groundmass of plagioclase, pyroxene, olivine, and iron oxides. Olivine commonly altered to iddingsite. Present as remnants of basaltic flows in southeastern and west-central parts of map area. Commonly weathers to rounded knobs covered by basaltic rubble and is poorly exposed, but probably consists of two or more flow units that were not mapped separately. Basaltic flows in southeastern part of map area are continuations of a more extensively exposed area of basaltic flows directly east of map area in Wolcott quadrangle (Lidke, 1998). X-ray fluorescence analyses of two samples from the Wolcott quadrangle gave chemical compositions of basaltic trachyandesite, and $^{40}Ar/^{39}Ar$ analyses of these samples yielded ages of about 22–23 Ma (Kunk and Snee, 1998; Lidke, 1998). Estimated to be as much as 100 m thick in west-central part of map area

Ku **Niobrara Formation and Benton Shale, undivided (Upper Cretaceous)**—Mapped only in northwestern part of map area, northeast of Eby Creek, where Niobrara Formation (Kn) and Benton Shale (Kb) are very poorly exposed and largely covered by a thin veneer of basaltic and gravelly colluvium that locally includes basalt boulders as long as 2 m; larger patches of colluvium are mapped as basalt-rich colluvium (Qcv). Unit probably includes slump and fault blocks that are common directly to the southeast

Kn **Niobrara Formation (Upper Cretaceous)**—Light- to dark-gray and brownish-gray, calcareous shale and very light gray, dense, conchoidal-fracturing, sparsely fossiliferous limestone. Upper 70 m is mostly medium-gray and brownish-gray, silty, calcareous shale. Middle 185 m is dark-gray shale that commonly weathers to paper shale with white to light-gray surface coatings. Lower 75 m is interbedded light-gray, fissile, calcareous shale, shaly limestone, and dense, blocky- to massive-weathering limestone. Limestone forms ledges, and base of unit is marked by prominent ledge-forming, light-gray limestone with some interbedded, light-gray, limey shale. Contains marine mollusks and, in upper part, cycloid fish plates and bone fragments (Stauffer, 1953; Wanek, 1953). Conformably overlies black shale assigned to the top of the Benton Shale (Kb). Unit may be susceptible to translational sliding and creep on dip slopes. Directly east of map area, near the town of Wolcott, Colo., total thickness is about 335–365 m (Lidke, 1998). Top not exposed in map area; unit is a minimum of about 330 m thick

Kb **Benton Shale (Upper Cretaceous)**—Predominantly black and dark-gray, slightly calcareous, platy shale with thin bentonite stringers and thin, white to tan, carbonaceous, fine-grained sandstone lenses. Upper part consists of 6–10 m of black shale that overlies about 3 m of thinly and unevenly laminated, sandy, gray, brown-weathering, fetid, crystalline limestone that contains abundant marine mollusk shells and some small fish teeth (Stauffer, 1953; Wanek, 1953; Hubert, 1954). Sandy limestone is commonly underlain by a few meters of white- to tan-weathering, fine-grained, calcareous sandstone interbedded with black shale. Remainder of unit is mostly black shale. Lower 10–15 m contains numerous 1- to 15-cm-thick beds and lenses of buff sandstone and siliceous, dull-greenish-gray to black siliceous shale; fucoid casts locally present in lower part. Basal contact is gradational and conformable with underlying Dakota Sandstone (Kd). Weathers to rounded slopes and valleys and generally is poorly exposed. Well exposed directly east of map area in cliffs north and east of Wolcott, Colo. Unit may be susceptible to translational sliding and creep on dip slopes. Total thickness 125–135 m

Kd **Dakota Sandstone (Upper? and Lower Cretaceous)**—Cliff-forming, crossbedded, tan, white, and light-greenish-gray, medium- to coarse-grained, silica-cemented, well-sorted sandstone and orthoquartzite interbedded with black, yellowish-gray, and sparse, pale-purplish-red shale. Contains scattered lenses of chert and quartz-pebble conglomerate; commonly, a thin conglomerate bed is present at or near base of unit. Where well exposed, divisible into three parts (not distinguished on map) that vary in thickness. Upper part consists of tan, well-sorted, well-cemented, medium- to coarse-grained, blocky- to massive-bedded sandstone and orthoquartzite. Middle part is interbedded, lenticular, dark-gray to black and yellowish-gray shale and lenticular, tan, pale-greenish- to yellowish-gray, and white sandstone. Lower part is crossbedded, thin- to medium-bedded, light-gray to tan sandstone interbedded with thin lenticular, gray shale and sparse lenses of pebble conglomerate; conglomerate clasts consist of black chert and quartz in iron-stained matrix of medium-grained to very coarse grained, silica-cemented sand. In the vicinity of Eagle, the stratigraphic position of the boundary between Upper and Lower Cretaceous rocks is not known. Existing data suggest that the boundary may be present within the Dakota Sandstone (Wanek, 1953; W.A. Cobban, USGS, oral commun., 1998). Upper part is well exposed in many localities in northern part of map area; middle and lower parts are best exposed east of map area near Wolcott, Colo., where basal contact with underlying Morrison Formation (Jm) is sharp and associated with pebble conglomerate, and no angular unconformity is apparent (Lidke, 1998). Highly resistant to weathering and contributes to blocky landslide deposits and other blocky colluvial deposits in northern part of map area. On map, colluvial deposits composed primarily of Dakota Sandstone clasts are labeled Qcd. Commonly jointed Dakota Sandstone cliffs are very susceptible to rock falls. Total thickness about 60–70 m

Jm **Morrison Formation (Upper Jurassic)**—Interbedded, calcareous sandstone, siltstone, mudstone, shale, and limestone. Upper 90–120 m is predominantly interbedded and lenticular red, green, and purplish-gray siltstone, mudstone, and shale interbedded with greenish-gray calcareous sandstone and gray limestone. Lower 30 m consists of four or more 1- to 3-m-thick, white, lenticular, calcareous, fine-grained, crossbedded sandstone beds interbedded with pale-greenish-gray, sandy siltstone and shale; oolitic, light-gray limestone beds are locally present in lower part. White crossbedded sandstone beds in lower part are similar to white sandstone at top of Entrada Sandstone (Je) and contact appears to be gradational. Basal contact with underlying Entrada Sandstone (Je) mapped beneath lowermost greenish-gray siltstone or shale in sandy lower part. Poorly exposed throughout most of map area; commonly weathers to rounded slopes covered by colluvium and rock-fall deposits derived from Dakota Sandstone (Kd). Best exposed along southern flank of Greenhorn Mountain in northwestern part of map area. Total thickness 125–135 m

Je **Entrada Sandstone (Middle Jurassic)**—Fine- to medium-grained, well-sorted, well-rounded, crossbedded, calcareous, cliff-forming sandstone. Upper 1.5–3 m consists of white, crossbedded, calcareous sandstone similar to sandstone in lower part of Morrison Formation. Large-scale, low- to moderate-angle, tangential crossbedding is common and, combined with frosted sand grains, suggests eolian deposition in dune fields. Weathers to form distinctive yellowish-white to salmon-pink, blocky to rounded cliff faces in which crossbedding is often obscured. Best exposed in cliffs along southwestern flank of Greenhorn Mountain in northwestern part of map area. Contact with underlying red shale and siltstone of Chinle Formation (₮c) is sharp and unconformable; locally shows slight angular discordance. Total thickness 27–35 m; thickens to west

₮c **Chinle Formation (Upper Triassic)**—Brownish-, purplish-, and orangish-red, calcareous shale, siltstone, mudstone, and very fine grained sandstone. Contains distinctive limestone-pebble conglomerate in beds ranging from 15 cm to 2 m thick and some thin mottled red and gray limestone beds. Limestone-pebble conglomerate consists of limestone and red sandstone pebbles in light-gray or reddish-brown, sandy limestone matrix. Paleosols, identifiable in good exposures, have been described by Dubiel (1992). Gartra Sandstone Member (not mapped separately) forms base of unit in eastern part of map area and consists of 3–8 m of purplish-red and reddish-brown, fine-grained to very coarse grained and pebbly, silica-cemented sandstone that locally is conglomeratic; commonly weathers to blocky or massive sandstone ledges. In and adjacent to map area, Stauffer

(1953), Wanek (1953), and Hubert (1954) all mapped the Shinarump Formation below the base of the Chinle Formation, apparently based on previous nomenclature (Lovering and Johnson, 1933; Thomas and others, 1945) and on the presence of petrified wood fragments. Their descriptions, thickness estimates, and stratigraphic placements of the Shinarump below the base of the Chinle suggest that the Gartra, identified at base of Chinle in this report and by Dubiel (1992), constitutes most of their Shinarump Formation. Petrified wood fragments are present in float at a few localities, but are sparse in outcrop. The Gartra is poorly exposed in central part of map area, apparently thins rapidly to the west, and is absent in western part of map area along flanks of Greenhorn Mountain. Base of Chinle Formation along flanks of Greenhorn Mountain placed at base of distinctive 1- to 2-m-thick limestone-pebble conglomerate that may occupy about the same stratigraphic position as the Gartra farther east. Basal contact with underlying State Bridge Formation (ŦPs) is sharp and easily located where the distinctive Gartra or limestone pebble conglomerate is well exposed and rests unconformably on reddish-brown and orangish-red, very fine grained sandstone and siltstone of the underlying State Bridge Formation (ŦPs). In map area, total thickness about 115 m. Unit thins to east and northeast and is only about 80 m thick about 10 km east of map area, directly east of Wolcott, Colo. (Lidke, 1998). Hubert (1954) reported a total thickness of as much as 253 m directly south of map area and noted rapid thinning of Chinle to the north and northeast

ŦPs **State Bridge Formation (Lower Triassic and Upper and Lower Permian)**—Orangish-red to reddish-brown, even-bedded, calcareous siltstone and very fine grained sandstone. Near top of formation, a 3- to 6-m-thick, fine-grained, cross-bedded, orangish-red sandstone commonly forms ledges. Lower part locally contains a thin zone (0.5–2 m thick) of medium-gray, finely crystalline limestone or light-gray dolomite beds that may be correlative with the South Canyon Creek Dolomite Member that is recognized west of map area (Murray, 1958; Bass and Northrop, 1963; Freeman, 1971), and (or) correlative with the Yarmony Limestone Member that has been mapped north of map area near State Bridge, Colo. (Sheridan, 1950; Hubert, 1954). North of map area, Sheridan (1950) subdivided the State Bridge into three members, a subdivision that defines a thin limestone-dolomite member (Yarmony Limestone Member) as a thin middle member between much thicker upper and lower members. Directly east of map area, Hubert (1954) measured a 50-m-thick lower unit, overlain by a 0.6-m-thick middle unit of gray limestone, which is, in turn, overlain by an 88-m-thick upper unit. The State Bridge was not subdivided into members in map area, but where exposed, the base of the dolomite and limestone zone is shown on map as an internal contact (or marker bed) within the State Bridge. Basal contact of the State Bridge is sharp and easily located in most of map area where the underlying Schoolhouse Member of the Maroon Formation (Pms) is exposed. Contact is mapped at base of a sequence of reddish-brown to orangish-red State Bridge sandstone and siltstone and directly above distinctive, white-weathering, fine- to coarse-grained sandstone of the Schoolhouse Member (Pms). Formation is best exposed along southwestern flank of Greenhorn Mountain, in northwestern part of map area. Total thickness about 125 m

Maroon Formation (Lower Permian to Middle Pennsylvanian)—Predominantly red beds of sandstone and sandy siltstone with minor shale and sparse lenticular beds of pebble conglomerate. Light-colored sandstone of Schoolhouse Member (Pms) at top of formation mapped separately; usage of nomenclature "Schoolhouse Member of the Maroon Formation," after Johnson and others (1990)

Pms **Schoolhouse Member (Lower Permian)**—White- to buff-weathering, grayish-white to pale-grayish-green, feldspathic and micaceous, medium- to coarse-grained, locally pebbly sandstone with some interbeds of grayish-red and pale-reddish-brown sandstone and siltstone. Well exposed along southwestern flank of Greenhorn Mountain near western border of map area and in cliffs north of Eagle River near eastern border. Maximum thickness about 20–30 m. Thins to east and pinches out about 8 km east of map area (Lidke, 1998)

PIPm **Main body (Lower Permian to Middle Pennsylvanian)**—Mostly interbedded, red, reddish-brown, and some orangish-red, micaceous, fine- to medium-grained, arkosic sandstone, siltstone, and shale. Shale is sparse and present mainly as thin beds and partings at silty tops of blocky sandstone beds. Locally contains coarse-grained to pebbly sandstone lenses, thin, mottled gray and red, argillaceous limestone interbeds, and light-greenish-gray to white sandstone interbeds. Green reduction spots and mottles locally common in red beds. Cliff forming and blocky weathering. Sedimentary structures include ripple cross-laminations, low-angle parallel and tangential crossbedding, and, locally, mud cracks. Contact with the underlying Eagle Valley Formation (IPe) is gradational and placed at prominent color change between bright-red rocks of the Maroon Formation and pale-reddish-brown rocks of the upper part of the Eagle Valley Formation (IPe). Color change also coincides closely with uppermost medium- to dark-gray, micritic limestone in the underlying Eagle Valley Formation. Hubert (1954) used same criteria to define base of the Maroon, but mapped underlying rocks as the Minturn Formation. Hubert measured 323 m of the Maroon below the Schoolhouse Member (Pms) in western part of map area, in cliffs directly south of Eagle River. Main body of the Maroon thickens rapidly to the west in map area. Total thickness ranges from about 335 m in eastern part of map area to about 540 m in western part

IPe **Eagle Valley Formation (Middle Pennsylvanian)**—Reddish-brown, reddish-gray, gray, light-green, and tan shale, siltstone, and fine-grained to very fine grained sandstone interbedded with distinctive, dark- to light-gray, micritic to finely crystalline limestone. Limestone beds range from about 5 cm to 2 m thick and are present throughout formation, but are particularly common in middle and lower part of unit. Locally contains evaporite interbeds; most are near base and are part of a 50- to 90-m-thick basal transition into thick evaporite of the underlying Eagle Valley Evaporite (IPee).

Tweto and others (1978) first mapped the Eagle Valley Formation in this region and defined it as fine-grained clastic rocks transitional between the coarse-grained clastic rocks of the Minturn and Maroon Formations and evaporitic rocks of the Eagle Valley Evaporite. Precise correlations among these Pennsylvanian and Permian formations remain unresolved. Hubert (1954) mapped rocks assigned to the Eagle Valley Formation and Eagle Valley Evaporite in the Wolcott quadrangle as Minturn Formation and speculated that the upper limestone of his Minturn Formation correlated with the Jacque Mountain Limestone Member, which is defined as the top of the Minturn Formation farther east (Tweto and Lovering, 1977). Schenk (1992), however, presented evidence that the Jacque Mountain Limestone Member is present near the bottom of the sequence mapped as Eagle Valley Formation in this report. Rocks assigned to the Eagle Valley Formation in this report and in Tweto and others (1978) differ distinctly from the Maroon and Minturn Formations and from the Eagle Valley Evaporite. In map area, the Eagle Valley Formation everywhere underlies the Maroon Formation (PIPm) and overlies the Eagle Valley Evaporite (IPee). In much of southern part of map area, north and south of Eagle River, a typical sequence of Eagle Valley Formation was found to be present between the Maroon Formation (PIPm) and Eagle Valley Evaporite (IPee), where reconnaissance mapping by Tweto and others (1978) had shown the Eagle Valley Formation as absent. Unit is best exposed in cliffs directly south of Eagle River near eastern border of map area. Basal contact with underlying Eagle Valley Evaporite (IPee) appears to be conformable and gradational over about 50–90 m, but it is commonly deformed by salt diapirism of evaporite interbeds and evaporite in the underlying Eagle Valley Evaporite (IPee). Contact difficult to locate precisely or consistently; placed approximately at base of predominantly clastic sequence and above thick, massive evaporite. Evaporite interbeds may be susceptible to ground subsidence from solution voids and to diapiric swelling. Soils and other surficial materials derived from evaporite interbeds may also be susceptible to subsidence from hydrocompaction and piping of evaporitic material. Evaporite-bearing solutions derived from bedrock, soils, or surficial deposits may be corrosive to materials such as conventional concrete and metal pipes. Total thickness as much as 900 m

ℙee **Eagle Valley Evaporite (Middle Pennsylvanian)**—Light- to dark-gray and white evaporitic sequence consisting mostly of gypsum with interbeds of tan-weathering, light- to dark-gray shale and argillaceous limestone, tan, very fine grained sandstone, and sparse, red silty sandstone. Exposures of evaporite beds are commonly poor and consist mostly of white- to pale-gray-weathering gypsum commonly weathered to rounded slopes and covered by thin residuum of gypsum-rich silt that shows a popcorn-like texture from wetting and drying. Drill-hole data indicate that anhydrite and halite are present in subsurface evaporite sequences, but these minerals are rare or absent in surface exposures (Mallory, 1969). Evaporitic rocks and interbedded limestone are commonly brecciated and breccia may be collapse related, resulting from dissolution of evaporitic rocks. Unit is also commonly contorted and faulted by salt diapirism, flow, and volume changes related to hydration and dehydration reactions of gypsum and anhydrite. Much of the deformation was likely episodic and related to burial depths, uplift and erosion, and water saturation, but some of the deformation probably is related to regional tectonic events. Locally contains dissolution voids as much as a few meters in diameter and several meters deep. Unit is susceptible to ground subsidence from solution voids and may be susceptible to diapiric and hydration swelling. Soils and surficial deposits overlying or derived from unit may also be susceptible to settlement from hydrocompaction and piping of evaporitic materials. Evaporite-bearing solutions derived from evaporitic bedrock, soils, or surficial units may be corrosive to materials such as conventional concrete and metal pipes. Base of unit not exposed in map area, and poor exposures and contortion of unit precludes accurate thickness estimates. Distribution of unit in map area suggests that total thickness may be as much as 2,000 m

DISCUSSION OF STRUCTURAL FEATURES

Faults and folds in the map area probably represent more than one episode of deformation, but the ages of individual structures are only broadly constrained. In general, the map area can be crudely divided into two structural domains: (1) a domain north of the Eagle River and (2) a domain south of the Eagle River. Evaportie-rich and evaporite-bearing rocks of the Eagle Valley Evaporite (ℙee) and the Eagle Valley Formation (ℙe), respectively, are exposed throughout much of the southern part of the map area and they probably underlie the northern part of the map area at depth. In the southern part of the map area, these evaporitic units are much more folded than are the overlying stratigraphic units to the north. Folds in these evaporitic units may be mostly related to episodic diapiric movement and other types of flow of evaporite. Some deformation in these units, however, probably is related to Pennsylvanian to Permian and Laramide (Late Cretaceous to early Tertiary) mountain-building events that are known to have affected the entire region. Distinguishing deformation related to regional tectonics from local, salt-related (evaporite) deformation, or from tectonic-induced salt deformation, is difficult and speculative throughout this region. It seems likely that the deformation and folding of the Eagle Valley Evaporite and Eagle Valley Formation in the southern part of the map area probably reflect both salt-related and tectonic-induced salt deformation.

North of the Eagle River, the map area is underlain by a north- to northeast-dipping homoclinal sequence that is locally modified by faults and folds. This northerly dipping homocline exposes the oldest rock units, the Eagle Valley Evaporite (ℙee), directly north of the Eagle River; progressively farther north in this homocline, younger rock units and the entire stratigraphic sequence of the map area are exposed. This homoclinal sequence is cut by some high-angle, northwest- and west-northwest-striking faults and cut by a few high-angle, northeast-striking faults. Some of theses faults cut Miocene volcanic rocks, indicating that at least the latest, and perhaps all, movement along these faults is Miocene or younger in age. A few northwesterly trending folds are also present in this homoclinal sequence and these folds deform rocks as young as the Late Cretaceous Benton Shale; therefore, these folds are no older than Late Cretaceous in age. These folds may represent Laramide (Late Cretaceous to early Tertiary) compressional features. Cross section A–A' cuts nearly perpendicular across the homoclinal sequence and across many of the folds and faults of this region north of the Eagle River.

South of the Eagle River, the map area is underlain by contorted and folded rocks of the Eagle Valley Evaporite and overlying Eagle Valley Formation. Folds in these evaporite-rich and evaporite-bearing rocks have diverse trends, and these folds pre-date emplacement of Miocene basaltic flows that are locally present as erosional remnants disconformably overlying the folded evaporitic rocks. The folds appear to be confined to the Eagle Valley Evaporite and Eagle Valley Formation and mostly confined to exposures of these units south of the Eagle River. Continuations of these rock units directly east of the map area in the Wolcott quadrangle show a similar contorted pattern of folding. Lidke (1998) interpreted these folds as representing both early and late phases of Laramide compressional deformation that was associated with decoupling of the Eagle Valley Evaporite and lower part of the Eagle Formation from the overlying parts of the stratigraphic sequence that do not express these folds. Alternatively, however, these folds could be partly or entirely related to (1) Pennsylvanian to early Permian deformation related to formation of the ancestral Rocky Mountains or (2) flow and diapiric activity of evaporitic rocks at some time during Pennsylvanian to middle Tertiary time. Cross section B–B' cuts across folded evaporitic rocks and less deformed basaltic flows of this region south of the Eagle River.

Post early Miocene high-angle faulting in the map area is indicated by steeply dipping faults that cut Miocene volcanic and volcaniclastic rocks (Tb and Tbv) north and south of the Eagle River. It is not clear if this faulting is related to late Tertiary, regional, extensional tectonics, or related to more local structural events related to salt tectonism resulting from dissolution or flow of evaporitc rocks at depth. Erosional remnants of basaltic flows in the southeastern part of the map area appear to be a continuation of more extensively exposed basaltic flows that are present directly to the east in the Wolcott quadrangle (Lidke, 1998). The basaltic flows in the Wolcott quadrangle have yielded $^{40}Ar/^{39}Ar$ ages of about 22–23 Ma (Kunk and Snee, 1998; Lidke, 1998) and these flows appear to have collapsed as much as 430 m in that area (Lidke, 1998). The sagging or collapse of these basaltic flows apparently is related to removal, by dissolution or flow, of underlying evaporite-rich rocks of the Eagle Valley Evaporite (Hubert, 1954; Lidke, 1998; Scott and others, 1998, 1999). The similarity in elevation and apparent connection of basaltic flows (Tb) in the map area with collapsed flows in the Wolcott quadrangle suggests that the basaltic flows in the southeastern part of the map area probably also have been downdropped and reflect a continuation of the northwest-trending collapse feature that is better expressed to the east in the Wolcott quadrangle. Similarly, it is possible that much of the faulting in the map area is related to flow or dissolution of evaporite at depth, although a pure tectonic origin for some, if not all, of the faulting is also possible.

The axial region of a poorly expressed, unmapped diapiric anticline may roughly coincide with the Eagle Valley in the Eagle quadrangle. Benson and Bass (1955) described an easterly trending anticline that is present along the Eagle Valley west of the map area, near Gypsum, Colo.; they suggested that this anticline probably reflects arching caused by diapiric upwelling of the Eagle Valley Evaporite along the course of the Eagle River, and that the arching was probably caused by the greater load of overlying rocks on both sides of the valley, which caused the evaporite to flow towards and diapirically rise beneath the intervening valley. Lidke (1998) mapped a broad, northeast-trending anticline (Horn Ranch anticline) along Eagle Valley directly east of the map area and suggested a similar diapiric interpretation as one of the possible origins for the Horn Ranch anticline. The Eagle quadrangle includes most of the Eagle Valley between the Eagle River and Horn Ranch anticlines. In the Eagle quadrangle some evidence suggests that the axial region of an anticlinal feature may roughly coincide with the Eagle Valley and connect the Eagle River and Horn Ranch anticlines. Although the complexity of folds in the Eagle Valley Evaporite and Formation in the southern part of the quadrangle makes identification of this anticlinal feature speculative, the map pattern of these evaporitic units suggests that a relatively young (possibly post early Miocene) anticline arches the previously folded evaportic units across the Eagle Valley as is shown in cross section B–B'.

GEOLOGIC HAZARDS

Four types of potential geologic hazards were identified in the Eagle quadrangle. These potential hazards, briefly discussed below, consist of: (1) landslides, (2) floods, (3) ground subsidence, and (4) expansive and corrosive soils.

LANDSLIDES

As used in this report, "landslide" is a general term that includes a wide variety of mass-movement deposits and processes involving the slow to rapid downslope transport of surficial materials and bedrock blocks by gravity. This definition includes various types of flows, slumps, slides, and combinations thereof, which are discussed by Varnes (1978) and Cruden and Varnes (1996). Most of the landslide deposits shown on this geologic map are also shown on the landslide map of Colton and others (1975). Landslide deposits were recognized by a combination of field observations and air photo analysis. Basically, landslide deposits were identified by (1) hummocky topography, including closed depressions, (2) the deflection of stream channels at the toes of deposits, (3) headwall scarps and depressions, (4) vegetation differences between landslide and adjacent stable areas, (5) anomalous strikes and dips of bedrock blocks, and (6) intact masses of material downslope of their sources. Low sun angles in the early morning or late afternoon highlight the subdued topography of many old landslide deposits and facilitate their identification in the field.

The most extensive landslide masses (Qlsb and Qlsn) occur in the northeastern part of the map area. Here, shaly rocks of the Cretaceous Benton Shale and Niobrara Formation failed similarly and commonly form large masses of relatively intact, but folded or rumpled shaly beds that have detached and slipped downhill above moderately dipping bedding surfaces of the underlying stable bedrock. The hummocky surfaces that develop on these deposits are most spectacular on aerial photographs, where the entire extent of the rumpled surfaces of individual landslide masses can be viewed. The type of slope failure and movement suggested by the surface character of these landslide masses is deep creep (Varnes, 1978). Deep-creep slide masses characteristically move imperceptibly slow, but over long periods of time they may move tens to hundreds of meters, causing deformation of shaly bedding layers within the slide masses. In the map area, much of the movement is probably Late Pleistocene or older in age; however, imperceptible, slow creep might locally still be active in some deposits. Human activities or natural events, such as road cuts, stream incision along the toes of landslides, and increased precipitation, may aid in reactivating creep in parts of these deposits. These deposits locally appear to be as much as 25 m thick.

Other landslide deposits in the map area (Qls and Qlsv) are composed of broken and chaotic bedrock debris mixed with surficial deposits; these landslide masses are relatively common on south- and southwest-facing slopes in the northern and east-central parts of the map area, and form two landslide deposits on a north-facing slope in the southeastern part of the map area. Clasts and blocks of bedrock in these deposits were derived from bedrock upslope of these deposits and, locally, these deposits contain sandstone or basalt clasts as long as 2 m. In the north-central and southeastern parts of the map area, landslide deposits were derived primarily from adjacent basaltic volcanic rocks (Tb and Tbv) and these landslide deposits are shown as unit Qlsv on the map. Individual slide masses of units Qls and Qlsv commonly are complex and they include components of slides, flows, and even rock falls and rock topples near cliffs and cliffy headwall scarps. These landslides probably are late Pleistocene to Holocene in age and they appear to be inactive and relatively stable; however, unconsolidated material in these slides has the potential for becoming destabilized by human activity such as road cuts and by natural or human-induced increases in water saturation.

Debris-flow deposits (Qdy, Qdu, and Qdo) were mapped in several localities north of the Eagle River. Fan deposits (Qfy and Qfo) and undivided alluvium and colluvium (Qac) also probably in part consist of debris-flow deposits. Varnes (1978) and Cruden and Varnes (1996) classify debris-flow deposits as a type of landslide deposit. The older debris-flow deposits (Qdo) are relatively old deposits that are preserved as erosional remnants of once more extensive deposits that now cap ridges. These deposits consist of a mixture of bedrock clasts and blocks and surficial material that has some potential for failure as small slumps, slides, or debris flows where this material is present along slopes, particularly if incised and water saturation is increased by natural or human-induced processes. Basaltic rubble (QTbr) caps a ridge between Castle and Eby Creeks and may represent an even older debris-flow deposit; the rubbly character of this material suggests it also has a potential similar to the older debris-flow deposits (Qdo) for future failure along slopes. Younger debris-flow deposits (Qdy) were mapped in the east-central part of the map area, where they appear to have largely followed old (Holocene to late Pleistocene), steep-gradient valleys down a prominent, relatively steep, south-facing slope. Active channels of modern, intermittent streams have incised these younger debris-flow deposits (Qdy). Intense or prolonged rainfall has the potential to reactivate parts of these debris-flow deposits (Qdy), and to create new debris-flow deposits elsewhere along valleys that drain this relatively steep, south-facing slope—particularly if preceded by natural or human-induced deforestation of this slope.

Other relatively unconsolidated deposits on slopes, such as colluvium (Qc, Qcg, Qcv, and Qcd), also have some potential to become destabilized and form small slump, slide, or debris-flow masses. The potential for rock-fall hazards exists along nearly all of the steep, cliffy slopes in the map area, particularly those containing sandstone ledges. The Dakota Sandstone (Kd) cliffs appear to be particularly susceptible to rock falls as is evident from the abundant large sandstone boulders on slopes and at the base of slopes beneath cliffs of the Dakota Sandstone.

FLOODS

The flood plain of the Eagle River is narrow throughout most of the map area, as defined by the stream-channel and flood-plain deposits (Qalc) along the Eagle River. The Eagle River flood plain has potential for flood hazard during prolonged or high precipitation and runoff events. Other areas of possible flood hazard during such events include low-lying areas along Brush Creek, as defined by its stream-channel and flood-plain deposits (Qa), as well as low-lying areas along Eby and Castle Creeks. In addition to these locations, low-lying areas near the mouths of some of the large gulches may also be prone to rare floods and debris-flow events caused by intense thunderstorms in their headward regions. Numerous relatively low-lying locations in the map area underlain by undivided alluvium and colluvium (Qac) and fan deposits (Qfy and Qfo) may be susceptible to local flooding accompanied by rapid erosion and gullying during cloudburst or prolonged thunderstorm conditions.

GROUND SUBSIDENCE

In the map area and in nearby localities elsewhere in Eagle and Garfield Counties, property losses have resulted from ground subsidence related to solution voids in evaporitic rocks, and from subsidence related to hydrocompaction of soils and low-density, surficial materials containing depositional voids or soluble minerals such as evaporitic minerals (J.M., Soule, Colorado Geological Survey, oral commun., 1998). The Eagle Valley Evaporite (ℙee) and the Eagle Valley Formation (ℙe) are the principal evaporite-rich and evaporite-bearing rock units, respectively, in the map area. These two units are widely exposed in the southern part of the map area. In Eagle and Garfield Counties, evaporite-related collapse features (sinkholes) commonly are a few meters to tens of meters in length and width, and show surface collapses of about 1 m to several meters; many of these have formed relatively recently, a few within the last several years.

Areas underlain by and near evaporitic rocks also have potential for high-salinity surface and ground water from dissolution of the evaporitic rocks and surficial deposits derived from them. The Eagle and Colorado Rivers are known to have high salinities downstream from the map area, and a large percentage of that salinity is probably derived from dissolution of evaporitic rocks and evaporitic surficial deposits (Kirkham and others, 1997, 1999; Scott and others, 1998, 1999).

EXPANSIVE AND CORROSIVE SOILS

Soils that tend to swell or shrink due to changes in moisture content are commonly known as expansive soils. Expansive soils are common in those areas underlain by sedimentary rock containing expansive clay minerals, or in areas underlain by colluvial and alluvial deposits derived from those rocks. Expansion and contraction of these soils can cause structural damage to rigid materials, such as foundations, pipes, and septic systems sitting on or buried in these expansive soils. In the map area the Benton Shale (Kb) is known to contain some bentonite, which is an expansive clay mineral. Soils developed directly on these units or on alluvium, colluvium, and landslide deposits derived from these units probably should be tested for expansive properties prior to new construction.

Potentially corrosive soils, surficial deposits, and bedrock in the map area are associated with those areas underlain by evaporite-bearing rocks—the Eagle Valley Evaporite (ℙee) and, to a lesser degree, the Eagle Valley Formation (ℙe). In combination with moisture, the readily dissolved evaporite minerals (principally gypsum) can be highly corrosive to conventional concrete and uncoated metal pipes. Testing of soils, rock, and surficial deposits for the presence of corrosive evaporite minerals and proper selection of construction materials can mitigate evaporite-related corrosion.

During wet conditions, dirt roads become extremely slippery to impassable in rock units that form clay-rich or evaporite-rich soils. The most notable units in the map area that form these road conditions are Tertiary basaltic rocks (Tb and Tbv), Niobrara Formation (Kn), Benton

Shale (**Kb**), Morrison Formation (**Jm**), Eagle Valley Formation (**IPe**), Eagle Valley Evaporite (**IPee**), and alluvial and colluvial deposits derived from these rock units (**Qac**, **Qfy**, **Qfo**, **Qc**, **Qcv**, **Qlsv**, **Qlsn**, and **Qlsb**).

ECONOMIC GEOLOGY

The map area has mostly a low potential for extractable mineral resources. There are no producing oil or gas wells in the map area or in areas nearby. The one exploratory well in the south-central part of the map area, as well as the few exploratory wells that have been drilled nearby to the west, have all been reported as dry (Tom Hemborg, Colorado Geological Survey, oral commun., 1997). No sign of mining prospects was found, no active mining claims are present, and no evidence could be found for intrusive rocks, veins, and associated mineralization and alteration.

The map area has some potential for sand and gravel resources along the Eagle River and for gypsum in the southern part of the map area. The largest and potentially most exploitable sand and gravel deposits are in the younger terrace alluvium of the Eagle River (**Qty**). Sand and gravel is currently being mined in the map area and has been mined in the past. Unmined areas of the younger terrace alluvium (**Qty**) probably underlie at shallow depths some of the undivided alluvium and colluvium (**Qac**) and fan deposits (**Qfy** and **Qfo**) that flank much of the Eagle River. The Eagle Valley Evaporite (**IPee**) is exposed or shallowly buried in several localities in the southern part of the map area. This unit is actively mined for gypsum to the west near the town of Gypsum. Although the Eagle Valley Evaporite is a potential gypsum resource in this part of the map area, most of the localities underlain by the evaporite are undergoing rapid residential development. Larger undeveloped areas of evaporite are exposed in several areas west of the map area.

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CONVERSION FACTORS

Multiply	By	To obtain
centimeters (cm)	0.394	inches
meters (m)	3.281	feet
kilometers (km)	0.621	miles