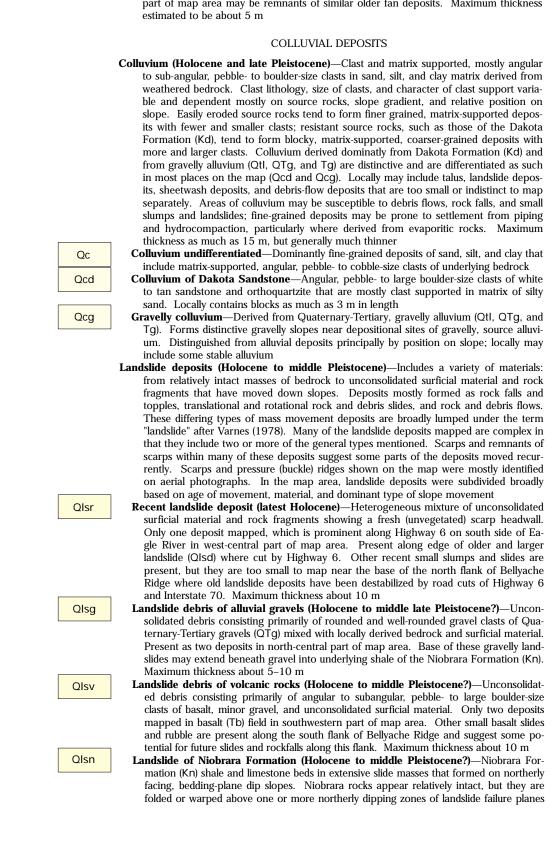


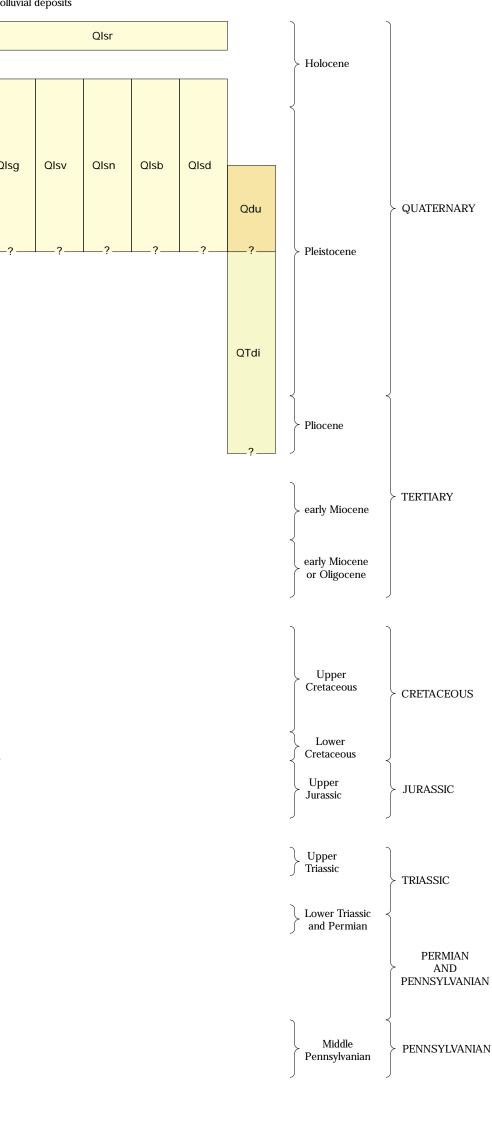
**DESCRIPTION OF MAP UNITS** 



CONVERSION FACTORS



**USGS** 



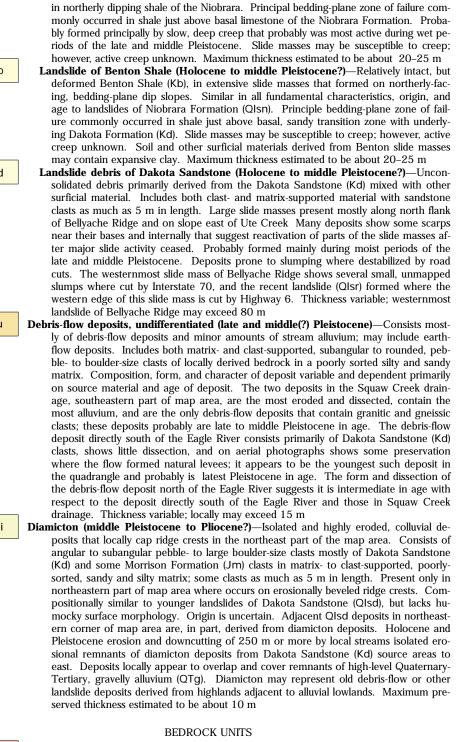
margins. Unit is probably equivalent in part to outwash of the Pinedale glaciation, which is about 12-35 k.y. old (Richmond, 1986, chart 1A). Unit is a potential gravel resource. Thickness commonly 5–10 m Older terrace alluvium of Eagle River (middle Pleistocene)—Alluvium deposited by Ea gle River that underlies small terrace remnants about 25-30 m above Eagle River. Uni consists of well-sorted, rounded and well-rounded, pebble-cobble gravel. Clasts consist mostly of white and pink, coarse-grained granite, gray, fine-grained granite and grano diorite, dark gneiss and schist, white, pink, and tan quartile, fine-and medium-graine red sandstone, and light- to dark-gray basalt. Matrix consists of pale-brown, silty sand Gravel is commonly overlain by about 1 m of overbank materials consisting of massive, light-yellowish-brown, silty fine sand. Unit found at two localities in the map area: (1) underlying a terrace remnant just west of junction of Squaw Creek and Eagle River, southeast part of map area, and (2) a few patches of terrace remnants are present on spur ridges north of Eagle River in west-central part of map area. A wedge of undivided alluvium and colluvium (Qac) overlaps and covers much of the terrace near Squaw Creek. Unit probably equivalent in part to outwash of the Bull Lake glaciation, which is about 140-150 k.y. old (Pierce and others, 1976). Terrace remnants too small to be

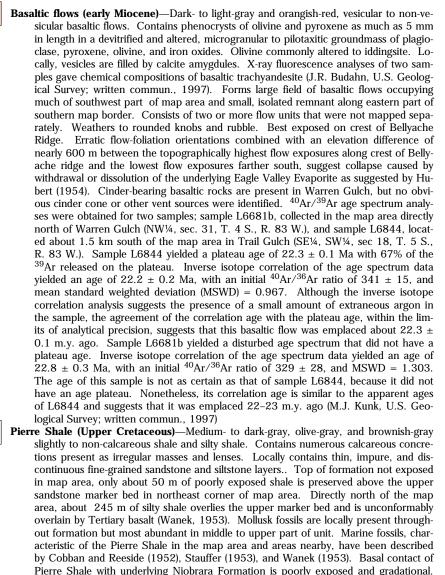
Alluvium (early Pleistocene to Pliocene?)—Gravelly alluvium containing clasts likely deposited by an ancestral Eagle River or its tributaries. Present as several gravelly patches in northeast part of map area where it is characterized by poorly exposed grave rubble and yellowish-brown, silty, fine and medium sand matrix material. Consists of rounded and well-rounded, pebble-boulder gravel capped by and mixed with subangu lar to subrounded pebble-boulder clasts of basalt. Rounded and well-rounded gravel clasts consist primarily of white and tan quartzite, red sandstone, and sparse clasts of granite and granodiorite and dark gneiss and schist; clast composition similar to terrace deposits along Alkali and Muddy Creeks (Qtl) and to Tertiary alluvium (Tg) in southwestern part of map area. Locally may include gravelly colluvium (Qcg). Rem nants of unit about 150-300 m above modern Eagle River. Maximum preserved thickness about 5 m Alluvium (early Miocene or Oligocene)—Gravelly alluvium containing clasts likely deposited by an ancestral Eagle River or it's tributaries. Unit present as several remnant, gray elly patches in southwest part of map area where unit locally appears to underlie basa (Tb). Poorly exposed, mainly as numerous patches of gravelly rubble in southwestern part of map. Consists of rounded to well-rounded pebble-cobble gravel (sparse bould ers) of weather-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 basalt. Locally may include gravelly colluvium (Qcq). Remnants of unit about 300–670 m above modern Eagle River; large elevation range of unit may reflect post-depositional collapse of this gion related to dissolution or movement of the underlying Eagle Valley Evaporite Pee). Similar in appearance and clast composition to gravelly alluvium north of Eagle River (QTg and Qtl). Maximum preserved thickness about 5 m ALLUVIAL AND COLLUVIAL DEPOSITS Younger fan alluvium and colluvium (Holocene and latest Pleistocene)—Unit forms alluvial and colluvial fans along Eagle River. One small, low-gradient fan is present along east side of Eagle River in east-central part of map area. Several steeper-gradient, co alesced, alluvial and colluvial fans present along south side of Eagle river in west-central part of map area were collectively mapped as a single fan complex. Consists of

potential gravel resource. Preserved thickness commonly 1-3 m

pebble- to boulder-size, angular to subrounded, locally derived clasts that are mostly matrix supported in massive fine sand, silt, and clay. Unit may be subject to channel modification and debris flows during intense or prolonged rainstorms. Maximum thickness estimated to be about 7–10 m Undivided alluvium and colluvium (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 the Eagle River. Includes stream-channel, flood-plain, fan, sheetwash and colluvial deposits that interfinger. Character and composition variable and dependent on local source rocks, topography, and relative position within drainage. In northern part of quadrangle, where Cretaceous shales unde lie most valley areas, deposits are chiefly light-gray to grayish-brown silty clay and clayey silt with some matrix-supported, angular to sub-rounded shale and sandstone clasts; deposited principally as interfingered colluvium and sheetwash. These northern deposits are commonly overlain by gravel clasts that appear to be lag gravels of older. high-level. Quaternary-Tertiary alluvium (QTg) present nearby. In southern part of quadrangle unit is more variable: along Squaw Creek, gravelly alluvium interfingers with small fan and colluvial deposits; most other southern deposits are fine sand, silt, and clay derived principally from the Eagle Valley Formation and Eagle Valley Evapore ite, and many of these deposits are evaporite-rich. 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 hydro compaction- and piping-related subsidence (particularly evaporite-bearing deposits), and expansive clays may be present in deposits derived from Benton and Pierre Shales Kb and Kp). Maximum thickness estimated to be about 10 m Older fan alluvium and colluvium (middle Pleistocene)—Light-brown, poorly sorted silt, sand, and clay with matrix-supported, subangular to rounded, pebble-cobble gravel of locally derived sandstone and other rock types. Forms low-gradient fan deposits at base of some landslide deposits in northeastern part of map area. The older fan deposits cut and are younger than these landslide deposits. Present adjacent to intermit tent tributaries of Eagle River at elevations 25–45 m above active channels of Ute and Cache Creeks. Some undifferentiated alluvium and colluvium (Qac) in northwestern part of map area may be remnants of similar older fan deposits. Maximum thickness estimated to be about 5 m

COLLUVIAL DEPOSITS **Colluvium (Holocene and late Pleistocene)**—Clast and matrix supported, mostly angular to sub-angular, pebble- to boulder-size clasts in sand, silt, and clay matrix derived from weathered bedrock. Clast lithology, size of clasts, and character of clast support 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 those of the Dakota Formation (Kd), tend to form blocky, matrix-supported, coarser-grained deposits with more and larger clasts. Colluvium derived dominatly from Dakota Formation (Kd) and from gravelly alluvium (Qtl, QTg, and Tg) are distinctive and are differentiated as such in most places on the map (Qcd and Qcg). Locally may include talus, landslide depos its, sheetwash deposits, 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 where derived from evaporitic rocks. Maximum thickness as much as 15 m, but generally much thinner **Colluvium undifferentiated**—Dominantly fine-grained deposits of sand, silt, and clay that include matrix-supported, angular, pebble- to cobble-size clasts of underlying bedrock Colluvium of Dakota Sandstone—Angular, pebble- to large boulder-size clasts of white to tan sandstone and orthoguartzite that are mostly clast supported in matrix of silty sand. Locally contains blocks as much as 3 m in length Gravelly colluvium—Derived from Quaternary-Tertiary, gravelly alluvium (Qtl, QTg, and Tg). Forms distinctive gravelly slopes near depositional sites of gravelly, source alluvium. Distinguished from alluvial deposits principally by position on slope; locally may include some stable alluvium 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 flow 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 the map were mostly identified on aerial photographs. In the map area, landslide deposits were subdivided broadly based on age of movement, material, and dominant type of slope movement Recent landslide deposit (latest Holocene)—Heterogeneous mixture of unconsolidated surficial material and rock fragments showing a fresh (unvegetated) scarp headwall. Only one deposit mapped, which is prominent along Highway 6 on south side of Eagle River in west-central part of map area. Present along edge of older and larger landslide (QIsd) where cut by Highway 6. Other recent small slumps and slides are present, but they are too small to map near the base of the north flank of Bellyache Ridge where old landslide deposits have been destabilized by road cuts of Highway 6 and Interstate 70. Maximum thickness about 10 m Landslide debris of alluvial gravels (Holocene to middle late Pleistocene?)-Unconsolidated debris consisting primarily of rounded and well-rounded gravel clasts of Quaternary-Tertiary gravels (QTg) mixed with locally derived bedrock and surficial material Present as two deposits in north-central part of map area. Base of these gravelly landslides may extend beneath gravel into underlying shale of the Niobrara Formation (Kn). Maximum thickness about 5–10 m Landslide debris of volcanic rocks (Holocene to middle Pleistocene?)-Unconsolidated debris consisting primarily of angular to subangular, pebble- to large boulder-size





Niobrara Formation is overlain by dark-gray, silty, slightly calcareous to non-calcar ous, concretion-bearing shale assigned to Lower Pierre Shale. About 825 m thick in northeast part of map area but top not exposed. Directly north of map area, Wanek (1953) measured a total thickness of about 1,070 m beneath the Tertiary unconformity present there Sandstone marker beds in Pierre Shale—Two prominent ledge-forming sandston marker beds (Kps) are present about 700 m above base of Pierre Shale (Kp). Marker beds are wavy-bedded, shaly, silty, micaceous, fine-grained to very fine grained, salt and-pepper sandstone that contains rusty-weathering nodules, fucoid casts and impres sions, and some thin, discontinuous, silty shale interbeds. Upper sandstone market bed is about 45 m thick and lower sandstone marker is about 10 m thick. Marker beds separated by about 70 m of dark-gray, silty, wavy-bedded shale that contains thin, lenticular sandstone interbeds 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 marked by prominent ledge-forming, lightgray 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 Formation. Unit may be susceptible to translational sliding and creep on dip slopes. Total thickness about 335-365 m Benton Shale (Upper Cretaceous)—Dominantly black and dark-gray, slightly calcareous, platy shale with thin bentonite stringers and thin, buff, carbonaceous, fine-grained sandstone lenses. Upper part consists of 6-10 m of black shale that underlies Nic brara Formation. Beneath upper shale is about 3 m of thinly and unevenly laminated.

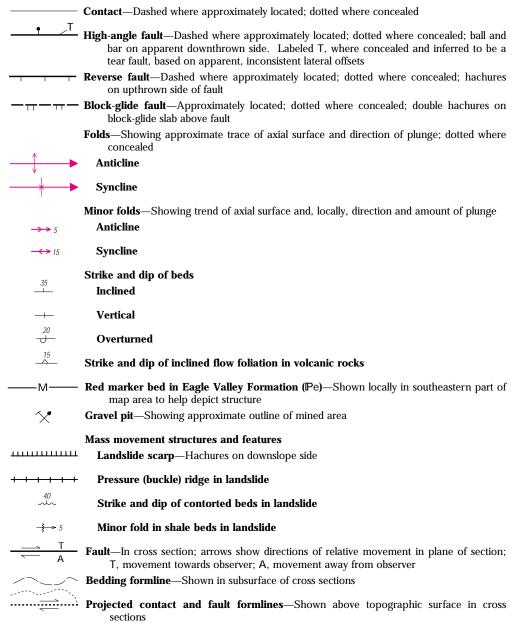
Contact approximately located where medium to dark-gray shale assigned to uppe

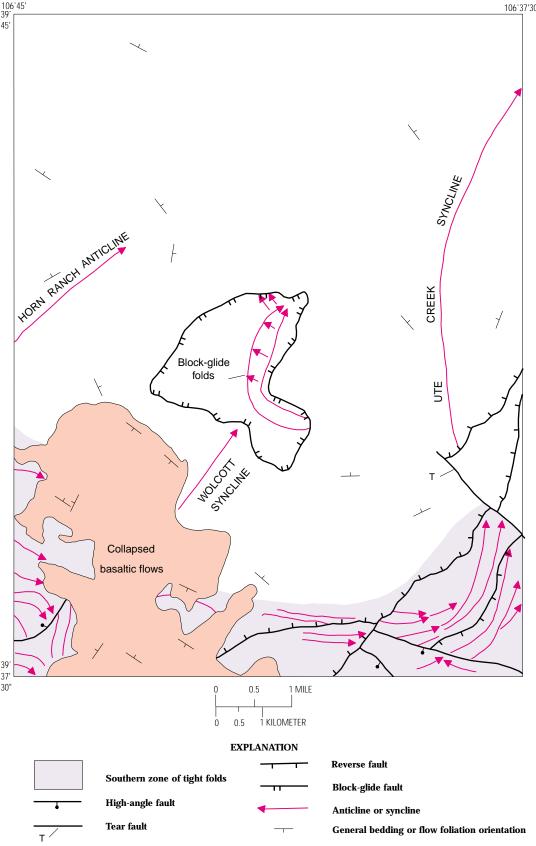
sandy, gray, brown-weathering, fetid, crystalline limestone that contains abundant marine mollusk shells and some small fish teeth (Stauffer, 1953; Wanek, 1953; Hubert, 1954). Remainder of unit is mostly black shale. Lower 10-15 m contains numerous 1-15-cm-thick beds and lenses of buff sandstone and siliceous, dull-greenish-gray to black siliceous shale; fucoid casts locally present in lower shale. Basal contact appears gradational and conformable with underlying Dakota sandstone. Weathers to rounded slopes and valleys and generally poorly exposed. Best exposed, particularly upper part, in cliffs directly north and east of Wolcott along Eagle River. Unit may be susceptible to translational sliding and creep on dip slopes. Total thickness 115-125 m 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, palepurplish-red shale. Contains scattered lenses of chert and quartz-pebble conglome te; commonly a thin conglomerate bed is present at or near base of unit. Where well exposed, divisible into three parts (not distinguished on the map) that vary in thickness. Upper part consists of tan, well-sorted, well-cemented, medium- to coarsegrained, blocky- to massive-bedded sandstone and orthoguartzite. 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 nedium-bedded, light-gray to tan sandstone interbedded with thin lenticular, gray shal and sparse lenses of pebble conglomerate; conglomerate consists of black chert and quartz clasts in iron-stained matrix of medium-grained to very coarse grained, silicacemented sand. In the vicinity of Wolcott, the stratigraphic position of the boundary between Upper and Lower Cretaceous rocks is not known. Existing data suggests that the boundary probably is present within the Dakota Sandstone (Wanek, 1953; W.A. Cobban, U.S. Geological Survey, oral commun., 1998). Dakota Sandstone is best exposed in cliffs along north side of Eagle River north and west of Wolcott. Basal contact with underlying Morrison Formation (Jm) is sharp but rarely exposed, and is associated with pebble conglomerate: no angular unconformity is apparent. Forms northerly dipping slope along northern flank of central and eastern parts of Bellyach Ridge. Highly resistant to weathering and forms abundant blocky landslide deposits and other colluvial deposits in many localities in map area. On the map, Colluvial d posits composed primarily of Dakota Sandstone clasts are labeled Qcd and landslid deposits labeled QIsd; diamictite deposits (QTdi) are also composed mostly of Dakota Sandstone clasts. Commonly jointed, and Dakota Sandstone cliffs are very susceptible to rock falls. Total thickness about 60–85 m Morrison Formation (Upper Jurassic)—Interbedded, calcareous sandstone, siltsone, mud-

stone, shale, and limestone. Upper 90-120 m is dominantly 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 1–3-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 cross-bedded sandstone beds in lower part are similar to white sandstone at top of Entrada Sandstone (Je Basal contact with underlying Entrada Sandstone (Je) mapped beneath lowermost greenish-gray siltstone or shale of sandy lower part. Poorly exposed throughout most of map area: commonly weathers to rounded slopes covered by colluyium and rock-fal deposits derived from Dakota Sandstone. Best exposed along ridge west of Red Canyon near eastern border of map area. Total thickness 120–155 m Entrada Sandstone (Upper Jurassic)—Primarily salmon-pink, fine- to mediumwell-sorted, well-rounded, crossbedded, calcareous, cliff-forming sandstone. Upper 1.5-3 m consists of white, crossbedded, calcareous sandstone similar to sandstone i lower part of Morrison Formation. Large-scale, low- to moderate-angle, tangential crossbedding is common and, combined with frosted sand grains, suggests eolian dep osition in dune fields. Weathers to form distinctive, salmon-colored, blocky to rounded, cliff faces in which crossbedding is often obscured. Entrada sandstone is best exposed in cliffs directly north of Eagle River in western part of map area. Contact with underlying red shale and siltstone of Chinle Formation (Rc) is sharp and unconformable: locally shows slight angular discordance. Total thickness 17–25 m **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 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 the map area, Stauffer (1953), Wanek (1953), and Hubert (1954) all mapped the Shinarump Formation at 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 at the base of the Chinle suggest that the Gartra Sandstone, identified at base of Chinle in this report and by Dubiel (1992), comprises most of their Shinarump Formation. Petrified wood fragments are present in float at a few localities, but are sparse in outcrop. Basal contact with underlying State Bridge Formation (RPsb) is sharp and easily located where the distinctive Gartra Sandstone is well exposed: the Gartra rests unconformably on reddish-brown and orangish-red, very fine grained sandstone and siltstone of the underlying State Bridge Formation (RPsb). Where the Gartra Sandstone is poorly exposed or absent, contact appears gradational and is difficult to locate precisely. In map area, unit thickness ranges from about 80 to 110 m; unit thins to east and northeast. Hubert (1954) reported a total thickness of as much as 253 m directly south of map area and noted rapid thinning of Chinle to northeast State Bridge Formation (Lower Triassic and Permian)-Orangish-red to reddish-brown, even-bedded, calcareous siltstone and very fine grained sandstone. Near top of formation is a 3-6-m-thick, fine-grained, crossbedded, orangish-red sandstone that commonly forms ledges. Lower part locally contains a 0.5–1-m-thick bed of medium-gray, finely crystalline limestone or light-gray dolomite that may be correlative with the South Canyon Creek Dolomite Member (Hubert, 1954), which is mapped farther west (Murray, 1958; Bass and Northrop, 1963; Freeman, 1971). North of map area. Sheridan (1950) subdivided the State Bridge Formation into three members, a subdivision that defines the thin South Canyon Creek Dolomite Member as the middle mem-

ber between much thicker upper and lower members. In western part of the map area Hubert (1954) measured a 50-m-thick lower unit. overlain by a 0.6-m-thick mic dle unit of gray limestone (South Canyon Creek Member?), which is, in turn, overlain by an 88-m-thick upper unit. The State Bridge Formation was not subdivided in map area because the thin, middle limestone-dolomite does not appear to be present consistently and the upper and lower parts are not sufficiently distinct from one another. The basal contact of the State Bridge Formation is sharp and easily located in most of map area where the underlying Schoolhouse Member of the Maroon Formation (PPms) is present. Where the Schoolhouse Member is present, the contact was map ped at the base of reddish-brown to orangish-red State Bridge sandstone and siltstone and directly above distinctive, light-colored, fine to coarse-grained sandstone of th Schoolhouse Member. Where Schoolhouse Member is absent, in easternmost part of

assigned to Maroon Formation (PPm). The State Bridge Formation thins abruptly in eastern part of the map area, north of the Eagle River. If the thin, light-gray dolomite present there is equivalent to South Canyon Creek Dolomite Member, then the lower part of the State Bridge Formation is absent as well as the Schoolhouse Member of the Maroon Formation (PPms) and perhaps part of the main body of the Maroon Formation (PPm)-suggesting the presence of an unconformity in the middle to lower part of the State Bridge Formation or unidentified faults. Total thickness ranges from about 145 m in western part of map area to about 100 m in eastern part Maroon Formation (Lower Permian and 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 (PPms) at top of formation mapped separately where present. Usage of the nomenclature "Schoolhouse Member of the Maroon Formation," after Johnson and others (1990) Schoolhouse Member of Maroon Formation-White- to buff-weathering, grayishwhite to pale-grayish-green, feldspathic and micaceous, medium- to coarse-grained, and locally pebbly sandstone with some interbeds of gravish-red and pale-reddish brown sandstone and siltstone. Well exposed in cliffs north and south of Eagle Rive in western part of map area. Thins to east and northeast. Can be traced discontinuously from just east of basalt field (Tb) eastward around nose of Bellyache Ridge to where Schoolhouse Member pinches out abruptly northward, about 0.8 km south of Eagle River. Member is entirely absent north of Eagle River in eastern part of map area. Where exposed along east flank of Bellyache Ridge, consists of white, mediumgrained, noncalcareous sandstone that grades downward through limey, white sandstone into white, crystalline limestone. Directly north of Eagle River a thin bed of light-gray dolomite, assigned to base of the State Bridge Formation (RPsb), occupies about same stratigraphic position as the absent Schoolhouse Member. Maximum thickness about 14 m Main body of Maroon Formation-Mostly interbedded, brick-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, syneresis cracks. Contact with underlying Eagle Valley Formation (Pe) is gradational and placed at prominent color change between bright-red rocks of the Maroon Formation and pale-reddish-brown rocks of upper Eagle Valley Formation. Color change also coincides closely with uppermost medium- to dark-gray, micritic limestone in underlying Eagle Valley Formation. Hubert (1954) used same criteria to define base of Maroon. but mapped underlying rocks as Minturn Formation. Hubert measured 323 m of Maroon Formation below Schoolhouse Member in the western part of map area, in cliffs directly south of the Eagle River. Main body of the Maroon formation thins rapidly to east. Total thickness ranges from about 335 m in western part of map area to 160 m in eastern part where Schoolhouse Member is absent 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 for mation, but particularly common in middle and lower part of unit; seventeen individual limestone beds were identified in a partial section measured in the south-central part of the map area, on south flank of Bellvache Ridge near axis of Wolcott syncline (C.D. Blome, U.S. Geological Survey, oral commun., 1997). Locally contains evapor ite interbeds; most are near base and are part of a 50–90-m-thick basal transition into thick evaporite of the underlying Eagle Valley Evaporite (Pee). Tweto and others (1978) first mapped the Eagle Valley Formation in this region and defined it as finegrained clastic rocks transitional between coarse-grained clastic rocks of the Minturn and Maroon Formations and evaporitic rocks of the Eagle Valley Evaporite. Precise correlation among these Pennsylvanian and Permian Formations remains 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 correlated with the Jacque Mountain Limestone, 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 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 the map area, the Eagle Valley Formation everywhere underlies the Maroon Formation (PPm) and overlies the Eagle Valley Evaporite (Pee). In the south-central part of the area, along the south flank of Bellyache Ridge, a typical section of Eagle Valley Formation was found to be present between the Maroon Formation (PPm) and Eagle Valley Evaporite (Pee), where reconnaissance mapping by Tweto and others (1978) had shown the Eagle Valley Formation as absent. Unit i well exposed along south flank of Bellyache Ridge and in cliffs south of Eagle River directly west of map area. Basal contact with underlying Eagle Valley Evaporite (Pee) is conformable, gradational over 50–90 m, and commonly deformed by salt diapirism of evaporite interbeds and evaporite in the underlying Eagle Valley Evaporite (Pee) Contact difficult to locate precisely or consistently; placed approximately at base of dominantly 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. Evap orite-bearing solutions derived from bedrock, soils, or surficial deposits may be corrosive to materials such as conventional concrete and metal pipes. Total thickness about 700 m Eagle Valley Evaporite (Middle Pennsylvanian)-Light- to dark-gray and white evaporitic sequence consisting mostly of gypsum with interbeds of tan-weathering, light- to darkgray shale and argillaceous limestone, tan, very fine grained sandstone, and sparse, red silty sandstone. Exposures commonly poor and consist mostly of dirty-gray 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. Fresh exposures are light to dark gray. Evaporitic rocks and interbedded limestone are commonly brecciat ed and breccia may be collapse-related, resulting from dissolution of evaporitic rocks. Unit is also commonly contorted and faulted by salt diapirism, flowage, and volume changes related to hydration and dehydration reactions of gypsum and anhydrite, respectively. Much of the deformation was likely episodic and related to burial depths, uplift and erosion, and water saturation. Some deformation in the unit probably is related to Laramide and younger tectonic events, but distinction of deformation related to regional tectonics from local, salt-related deformation, or from tectonic-induced salt deformation is difficult and speculative in map area. 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 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 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, but exposures directly east of map area suggest unit is at least 500 m thick





GEOLOGIC MAP OF THE WOLCOTT QUADRANGLE, EAGLE COUNTY, COLORADO David J. Lidke

## the map area, contact was mapped at base of 0.6-1-m-thick, light-gray dolomite that pinches out abruptly northward (South Canvon Creek Dolomite?). Farther north, contact was placed where finer grained, orangish-red beds of State Bridge Formation overlie interbedded, reddish-brown and light-grayish-green, coarser grained sandstone

**Figure 1.** Sketch map of structural features in the Wolcott quadrangle, Colorado

ic movement of evaporitic rocks of the Eagle Valley Evaporite (Pee). The north and central parts of the quadrangle contain gently north-dipping Pennsylvanian to Late Cretaceous strata that re deformed by three north- to northeast-trending folds. From west to east they are the Horn Canch Anticline and the Wolcott and Ute Creek Synclines. Rock units of the Middle Pennsylvanian Eagle Valley Formation and the Eagle Valley Evaporite are exposed in the southern part of the quadrangle; these strata are complexly deformed by tight, closely-spaced folds that are cut by nornal and reverse faults. In the southwestern part of the quadrangle, early Miocene basaltic flows unformably overlie previously folded rocks of the lower part of the Eagle Valley Formation and the Eagle Valley Evaporite. These basaltic flows apparently have collapsed as much as 430 m due to dissolution and removal of underlying evaporitic rocks. In the central part of the quadrangle, a crescent-shaped anticline and syncline pair and smaller cross folds formed in a large, block-glide landslide that consists mainly of the Dakota Sandstone. These structural features are labeled on gure 1 and described, from oldest to youngest, in greater detail below. SOUTHERN FOLD AND FAULT ZONE Complexly deformed strata of the Eagle Valley Formation and Eagle Valley Evaporite in the outhern part of the map area comprise a structural domain referred to here as the "southern zone of folds and faults" (fig. 1). Folds in this zone are tight and have variable to sinuous trends, and in places are cut by steep to moderately dipping normal and reverse faults. Fold axes trend eastsoutheast to east-west in the western and central part of the zone, but they are bent and refolded into a northerly configuration in the eastern part of the zone where they wrap around the east limb of the Wolcott syncline. Folds in the eastern part of the zone are cut by north- to northeast-striking reverse faults. Early Miocene basaltic rocks are unaffected by the folds and many of the faults

DISCUSSION OF STRUCTURAL FEATURES

fost faults and folds appear to be related to deep-seated, regional tectonism. Some folds and a

arge sag in the southwestern part of the map area, however, probably are local features related to

ravity block-glide landsliding, and to collapse or upheaval of rock units due to dissolution and dia-

Structural features in the map area include faults and folds of differing ages and origin (fig. 1).

that deform the underlying Pennsylvanian rocks. This indicates that the folding and faulting in the southern zone is Pennsylvanian or younger but older than the early Miocene basaltic rocks that truncate these structures. Folds and many of the faults in the southern zone are the oldest structures identified in the map area, because they are deformed by younger structures like the Wolcott syncline. Folds in the outhern zone may have initially developed during (1) Pennsylvanian to early Permian deformation related to formation of the ancestral Rocky Mountains, (2) Laramide deformation (Late Cretaceous to Eocene) that initiated the formation of the present Rocky Mountains, or (3) flowage and diapiric activity of evaporitic rocks in the Eagle Valley Evaporite at sometime during Pennsylvanian to pre late Laramide time. The folds in the southern zone are principally confined to the lower part of the Eagle Valley Formation and the underlying Eagle Valley Evaporite, and they appear to have had consistent west-northwest trends prior to refolding by the northerly trending folds. The pattern of consistent initial trends of these folds probably argues against an origin from diapiric movement of the evaporite, which might be expected to produce folds with more chaotic trends and less continuity. Both Pennsylvanian to early Permian and Laramide deformation are known to have had components of north-northeast/south-southwest-oriented compression in the region (Hongzhuan and others, 1996; Warner, 1956; Burbank and Lovering, 1933), either of which could acount for the origin of these features. Near the contact of the Eagle Valley Formation and the Eagle Valley Evaporite, smaller scale folds were locally observed that are cut or detached along lowngle faults. These relations may suggest that the relatively incompetent rocks of the Eagle Valley Formation and Eagle Valley Evaporite served in part as de'collement horizons during compressional deformation related to Pennsylvanian to Permian and (or) Laramide tectonic episodes. NORTHERLY TRENDING FOLDS

Mesozoic and Paleozoic strata in the north and central parts of the quadrangle are deformed by hree north- to northeast-trending folds; the Ute Creek syncline, Wolcott syncline, and Horn Ranch anticline. In the eastern part of the map area, the Ute Creek syncline has a very gentle dipping west limb, but a very steep to overturned east limb that contains at least two northeast-trending reverse faults. The northern part of the Ute Creek syncline trends northeast, but its southern part bends to a north-northwest trend. The Wolcott syncline is a broad, northeast-trending fold in the central part of the quadrangle. The Horn Ranch anticline is a broad, northeast-trending anticline in the western part of the quadrangle that shares its western limb with the Wolcott syncline. The Ute reek syncline affects rocks at least as young as the Late Cretaceous Pierre Shale, and the Wolcott yncline and Horn Ranch anticline deform rocks as young as the early to late(?) Cretaceous Dakota Sandstone. Therefore, these folds are all Cretaceous or younger in age and probably mostly related to Laramide (Late Cretaceous to Eocene) episodes of deformation; Locally, however, these folds nay be related to, or modified by, Cretaceous or younger salt tectonism ne northerly trending folds and reverse faults and an inferred northwest-trending tear fault (fig. 1) all appear to be related in age and collectively suggest west-northwest/east-southeast-orientd compression during their formation. I have inferred the presence of a buried, northwest-trend-

ing tear fault directly south and southeast of the Ute Creek syncline in the Eagle River Valley. Tear

faults commonly form nearly perpendicular to related folds and reverse faults and they serve as artitions between domains of rock in which a common magnitude of shortening has been achieved in different ways (Davis, 1984). In my interpretation, the inferred tear fault provided a partition (zone of lateral slip) that allowed different sets of northerly trending folds and reverse faults, north and south of the tear, to accommodate shortening related to west-northwest/east-southeastoriented compression. In the Red Canyon area, about 22 km to the north, Beckett (1955) found similar relations among northeast-trending folds that deform northwest-trending folds, which are all cut and truncated by a northwest-trending tear, or strike-slip fault. Folds and faults in the Red Canon area are Laramide in age (Beckett, 1955). Similar to the Red Canyon area, north- to northast-trending folds and reverse faults and the tear fault in the map area may be related to the latest episodes of Laramide deformation, and the northwesterly trending folds in the southern zone ight similarly be related to the earliest phase of Laramide deformation. The Horn Ranch anticline may have also formed during the west-northwest/east-southeast, aramide compression discussed above, however, the Horn Ranch anticline appears to connect with an unnamed, easterly trending anticline that deforms early Miocene basaltic rocks near Gypsum and Eagle directly west of the map area. This unnamed anticline appears to reflect diapiri upwelling of the Eagle Valley Evaporite (Pee) along the Eagle River Valley (M.R. Hudson, U.S. eological Survey, unpubl. mapping, 1997; Scott and others, 1998). The Horn Ranch Anticline o exists in the Eagle River Valley and may also reflect salt tectonism from diapiric rise of the Eagle Valley Evaporite (Pee) at depth, which would account for this anticline as a product of salt tecnism and not Laramide compressional deformation. Laramide compressional deformation and Neogene salt tectonism appear to be equally valid interpretations for the origin of this broad anti-COLLAPSED BASALTIC FLOWS

In the southwest part of the quadrangle, early Miocene basaltic flows overlie highly folded Midle Pennsylvanian rocks (fig. 1). Mapped relations suggest the basaltic rocks collapsed into a sag feature that formed in the underlying Middle Pennsylvanian strata. Collapse of the basaltic flows opears to have resulted from dissolution and removal of evaporitic rocks from the underlying Eae Valley Evaporite (Pee) (Hubert, 1954). On Bellyache Ridge, these basaltic rocks are at an altiude of about 2,750 m and dip about 20-25 degrees southwest toward the central part of the collapse or sag feature. In this area, Middle Pennsylvanian to Jurassic strata that underlie the basalt ip in the opposite direction, to the northeast, at about 20–30 degrees. In the central part of the In suggesting billapse feature, the base of the basaltic flows is at an altitude as low as about 2,320 m, suggesting that the basalt collapsed about 430 m relative to its exposure along the crest of Bellyache Ridge as as suggested by Hubert (1954). The orientations of flow foliation of flows in the central part of the collapse feature are erratic and the rocks are commonly rubbly and poorly exposed, but it appears that the folds in the Eagle Valley Formation (Pe) and Eagle Valley Evaporite (Pee) were erosionally beveled and partly covered with Early Miocene or Oligocene gravel prior to emplacement and later collapse of the basaltic flows. Structural relations between the northeast-dipping Pennsylvanian-Jurassic rocks and southwestdipping basaltic rocks along the northeastern margin of the collapse feature suggest that the Pennsy vanian-Jurassic rocks dipped more steeply (by about 20-25 degrees) to the northeast when the basaltic flows were originally deposited. Restoration of the southwest-dipping basaltic flows to their original sub-horizontal orientation would require that the underlying Pennsylvanian-Jurassic rocks also be restored to a pre-collapse orientation where existing northeast dips would increase from about 25 to 45 degrees or greater. The most likely explanation for this collapse feature is Neogene removal of a rge volume of evaporitic rocks of the underlying Eagle Valley Evaporite by groundwater dissolution and transport. Neogene removal of evaporite apparently was most active beneath the central part of the collapse feature, but evaporite removal was probably also active beneath the northeastern margin of the collapse, which would account for subsequent down-dropping and related rotation of both the sedimentary and basaltic rocks. Similar large areas of collapsed early Miocene basaltic flows have een recognized in the vicinity of Carbondale, Eagle, Gypsum, and State Bridge; existing information suggests that these collapse features resulted from evaporite removal after about 8 Ma over a period f a few to several million years, and suggests that evaporite removal is still active in some areas (Kirkham and others, 1997; Kunk and others, 1997; Scott and others, 1998). Collapse features and processes characterisic of the Carbondale region, are described and interpreted in Kirkham and Widmann (1997) and Kirkham (1997). Some of the same features and processes appear to characterize

BLOCK-GLIDE FOLDS In the central part of the quadrangle, a crescent-shaped anticline-syncline pair and associated smaller-scale, west-trending folds are in a large landslide block composed mostly of the Dakota Formation and parts of the underlying Morrison Formation and overlying Benton Shale. I interpret these folds to represent internal deformation related to block-glide landsliding. The block slid essentially intact down-slope to the northeast on a glide plane consisting of lithologically unstable shale, mudstone, and siltstone in the upper part of the underlying Morrison Formation. The slip surface at the base of the slide is primarily a bedding-plane fault that is poorly exposed or covered throughout the map area. The southeast margin of the block appears to have slipped along a steeper edge of the plane, which cut the Dakota Sandstone and separated Dakota Sandstone involved in the blockglide from Dakota Sandstone that was not involved. Folds are present in similar block-glide landslides composed of the Dakota in several localities along the Colorado Front Range (Braddock, 1978). Braddock has shown that those folds are essentially fault-bend folds that reflect the ramp-flat geometry of the underlying slip surface. The crescent-shaped axes of the anticline-syncline pair in he map area suggest that these folds may reflect an underlying crescent-shaped ramp along the basal, block-glide fault, a segment of which is depicted in cross section *B-B*'. The west-trending cross folds, which are present between the crescent-shaped folds, may be mainly buckle folds that indicate most of the movement and buckling of the block was down-dip to the north-northeast and at an oblique to nearly perpendicular angle to western segments of the crescent-shaped, ramp-related folds. **GEOLOGIC HAZARDS** 

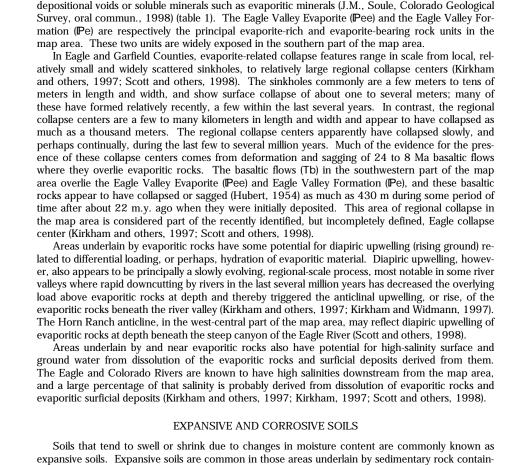
LANDSLIDES

collapse in the map area and elsewhere in the Eagle-Gypsum region (Scott and others, 1998).

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. In the map area, landslides and landslide deposits are very common along the north flank of Bellyache Ridge and in the northern part of the quadrangle; they commonly occur on north-facing slopes in Cretaceous-age shale and sandstone whose bedding layers also dip north at moderate inclinations. Landslide deposits cover about 10% of the map area. Landslide types that are present in the map area include; earth flows, earth slumps, debris flows, debris slumps, rock-block slides, translational slides, rock falls, and complex landslides (Varnes, 1978; Cruden and Varnes, 1996). Many of the extensive landslide deposits in the map area were first mapped by Colton and others (1975) in their overview of Colorado landslides. 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 highlighted the subdued topography of many old landslide deposits and facilitated their identification in the field. For the most part, landslides in the map area were subdivided based on source material, which appears to exert a fundamental control on the types of landslide deposits developed (table 1). The most common and largest landslide deposits are derived from the Cretaceous Formations. Specifically the Dakota Sandstone (Kd), Benton shale (Kb), and Niobrara Formation (Kn). Shaly rocks of the Benton and Niobrara fail 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 humocky 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. Particularly striking in this regard are the Benton Shale landslide masses (OIsb) in the Milk Creek drainage in the northwest part of quadrangle. The type of slope failure and movement suggested by the surface character of these posits is deep creep (Varnes, 1978). Deep creep slide masses characteristically move impereptibly slow, but over long periods of time they may move tens to hundreds of meters, causing de formation 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. In the Milk Creek drainage these deposits locally appear to be as much as 30 m thick, whereas in the eastern part of the north Flank of Bellyache Ridge the deposits probably do not exceed about 15 m. The Dakota Sandstone commonly forms landslide deposits (QIsd) composed of broken and chaotic debris mixed with surficial materials and locally these deposits contain sandstone blocks as much as a few meters in length. These deposits formed by slope movement processes ranging from debris and rock slides to debris flows as defined by Varnes (1978). Individually mapped slide masses commonly are complex in that they include components of slides, flows, and even rock falls and topples near cliffs and cliffy headwall scarps. Most of the large slide masses derived from the Dakota Sandstone appear to be relatively old and relatively stable, probably principally late Pleistocene and older, but 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. For example, a road cut (Highway 6, now the frontage road of I-70) destabilized the edge of an old landslide (QIsd) and that edge reactivated to form the recent landslide deposit QIsr), which episodically reactivates during moist periods. Several smaller, recent slumps and slides (not mapped) along Interstate 70 east of the QIsr deposit are also examples of recent slope failures that have resulted from destabilization of these relatively old, unconsolidated, landslide deposits. Other unconsolidated deposits on slopes, such as colluvium (Qc, Qcd, Qcg) and diamicton (QTdi), also have some potential to become destabilized and form small slump or slide masses. Near the crest of Bellyache Ridge, the Dakota Sandstone (Kd) and the uppermost part of the Morrison Formation (Jm) have also failed as a large, essentially intact, block-glide mass that slid northward down slope. The toe of this large block-glide appears to have been folded above its underiving block-glide fault as it slid (see map, cross section B-B', and discussion of structural features). Braddock (1978) has discussed and described similar large block-glide masses that involve the Dakota Sandstone and Morrison Formation in several locations along the Colorado Front Range. The Bellyache Ridge block glide formed before formation of the landslide deposits (QIsd)

that cover its northern edge; therefore, movement of the block-glide mass probably occurred in the early Pleistocene or earlier. The potential for rock-fall hazards exist along nearly all of the steep cliffy slopes in the map area, particularly those containing sandstone ledges. The Dakota Sandstone 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. The flood plain of the Eagle River is very narrow throughout most of the map area, as deed by the stream channel and flood-plain deposits (Qalc) along the Eagle River. The Eagle River floodplain has potential for flood hazard during prolonged or high precipitation and runoff events (table 1). Other areas of possible flood hazard during such events include lowlying areas along Squaw Creek and it's tributaries and low-lying areas along Alkali, Muddy and Red Canyon Creeks. In addition to these locations, low-lying areas near the mouths of Rube, Milk, and Alkali Creeks 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), particularly fine-grained deposits in the northern part of the quadrangle, may be susceptible to local flooding accompanied by rapid erosion and gullying during cloudburst or prolonged thunderstorm conditions.

GROUND SUBSIDENCE Nearby the map area and in localities elsewhere in Eagle and Garfield counties, significant 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



ng expansive clay minerals, or in areas underlain by colluvial and alluvial deposits derived from hose 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) and Pierre Shale (Kp) are known to contain bentonite, which s an expansive clay mineral (table 1). Soils developed directly on these units or on alluvium, colluium, and landslide deposits derived from these units 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 evap te 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 ninerals 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 basalt (Tb). Pierre Shale (Kp), Niobrara Formation (Kn), Benton Shale (Kb) agle Valley Formation (Pe), Eagle Valley Evaporite (Pee), and alluvial and colluvial deposits derived from these rock units (Qac, Qc, Qlsv, Qlsn, and Qlsb). ENVIRONMENTAL HAZARD

The Eagle County landfill is in the map area, about 2.5 km north of Wolcott, near the head of the west fork of Ute Creek, which is an intermittent tributary of the Eagle River. Of the two landfills (If) shown on the map in that area, the southern one is an older reclaimed landfill, whereas the northern one is an active landfill. These sites are in shaly rocks of the Pierre Shale (Kp) and Niobrara Formation (Kn). These shaly rocks, unless fractured, should be relatively impervious to any seepage towards underlying ground water. Unusual precipitation events related to major storms might potentially cause some erosion of these landfills and, in a worst-case scenario, transport material down Ute Creek and into the Eagle River. ECONOMIC GEOLOGY The map area has a low potential for extractable mineral resources. There have been no exploratory oil and gas wells drilled in the map area and no producing wells are located nearby. The ew 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, ins, and associated mineralization and alteration The map area has some potential for small deposits of sand and gravel resources along the Eaale River and for gypsum in the southern part of the map area. The largest and potentially most xploitable sand and gravel deposits are in the younger terrace alluvium of the Eagle River (Qty). Mining of this gravel has occurred in the past. A golf course along the north side of the Eagle Riv , in section 23, now occupies one of the larger terrace remnants. The Eagle Valley Evaporite (Pee) 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 under lain by the evaporite are undergoing rapid residential development. Larger undeveloped areas of evaporite are exposed in several areas west of the map area. ACKNOWLEDGMENTS

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Table 1.—Map units associated with potential geologic hazards in the Wolcott quadrangle Tg Qlsv Tb Qc Qlsn Kn Qcd Qlsb Kb Qcg Qlsd Kd Qlsr Qdu

<sup>1</sup>Includes landslides, debris flows, rockfalls and rock topples.

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