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Geologic Map of the Palisade Quadrangle, Mesa County, Colorado

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Pamphlet to accompany
MISCELLANEOUS FIELD STUDIES
MAP MF–2326

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DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Surficial deposits shown on this map are generally at least 1 meter thick, thinner deposits are not shown. Thin, discontinuous colluvial deposits, residual material on bedrock, and some artificial fills were not mapped. Many contacts of surficial deposits are approximate because the contacts are poorly exposed or gradational (for example, the contacts between landslides and pediment gravel, or basaltic rubble and other units).

Divisions of Pleistocene time are modified from Richmond and Fullerton (1986); Holocene, 0 to 11,390 yr ago; late Pleistocene, 11,390 to 127,000 yr ago; middle Pleistocene, 127,000 to 778,000 yr ago; and early Pleistocene 778,000 to 1,806,000 yr ago (D.S. Fullerton, written communication, 1997).

Age assignments for surficial deposits are based chiefly on stratigraphic relationships, the degree of erosional modification of original surface morphology, and degree of soil development. In addition, age assignments for alluvial deposits are also based on the height of the deposit above the Colorado River. Age assignments for units Qt3 and Tg are inferred chiefly on the basis of regional rates of stream incision of about 0.13 m/k.y. (k.y. = thousand years) and about 0.16 m/k.y. The first incision rate is based on a value for stream incision since the deposition of the 630 k.y. Lava Creek B volcanic ash about 80 m above the White River near Meeker, Colorado (Whitney and others, 1983). The second incision rate is based on about 1525 m of downcutting by the Colorado River since the deposition of 9.7±.05 m.y. (m.y. = million years) basalt on Grand Mesa (Marvin and others, 1966).

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

Dry matrix colors of the surficial deposits in the map area were determined by comparison with a Munsell Soil Color Chart (Munsell Color, 1973).

MAN-MADE DEPOSITS

af Artificial fill (latest Holocene)--Compacted and uncompacted fill material composed mostly of varying amounts of silt, sand, and rock fragments. Unit includes fills beneath; Interstate 70, the tracks of the Denver and Rio Grande Western Railroad, Cabin Reservoir Dam (SE 1/4, sec. 18, T.11 S., R . 97 W.), Guild Reservoir Dam (NW 1/4, sec. 1, T. 2 S., R. 98 W.), segments of Colorado Highway 6, and dams of various small stock ponds. Fill beneath I-70 consists of massive, pale olive (5Y 6/3) silty sand containing scattered pebble and cobble-sized angular clasts derived from Mesaverde Group (Kmv) sandstone. Fill beneath the tracks of the Denver and Rio Grande Western Railroad consist of unstratified, well-sorted, pebble and cobble-size angular to subangular basalt. Thickness ranges from about 1 to 15 m.

ALLUVIAL DEPOSITS

Qalc1 Stream channel and floodplain deposits along the Colorado River (Holocene)--The upper 1 to 2 m of the unit, commonly an overbank deposit, consists of a light yellowish-brown (10YR 6/4), massive, silty fine sand to medium 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 a well sorted, rounded and well rounded pebble-cobble gravel derived from a variety of sedimentary, igneous, and metamorphic rocks. Clasts consist predominately of: basalt, quartzite, red sandstone, and fine and medium-grained granitic rocks. Some clasts have thin, white carbonate coats. Matrix in gravel part of unit consists of very pale

brown (10YR 7/4) sandy silt and silty sand. Unit may include low terraces along the floodplain. Unit subject to periodic flooding. Based on the thickness of similar gravels on terraces bordering the floodplain the gravel thickness in this unit is estimated to be 5 to 10 m.

Qalc2 Alluvium (Holocene and latest Pleistocene)--Alluvium deposited by the Colorado River that underlies a low terrace or terraces at two localities; (1) along the north side of the Colorado River south of the town of Palisade, and (2) along the south side of the Colorado River east of town. These terraces are about 3 to 5 m above the river and are not considered to be part of the active floodplain (Qalc1). Unit is poorly exposed; in places, rounded and well rounded pebble-cobble gravel of Colorado River lithologies are exposed at surface or in shallow excavations. Clasts include mainly; basalt, red sandstone, white and pink coarse-grained granitic rocks, gray fine-grained granitic rocks, and quartzites. Some clasts have a thin, white carbonate coat. Gravels are commonly overlain by 1 to 2 m of overbank and possibly eolian materials consisting of massive, light yellowish-brown (10YR 6/4) silty fine sand and fine sand. South of the river, low gradient coalescing alluvial fans (Qfy1), composed of locally derived fine-grained sediment, deposited by Watson Creek and an unnamed tributary to the east have obscured the southern limit of this unit. The boundary separating these two units was taken from Schwochow (1978). Lower parts of unit may be subject to flooding by infrequent large events. Based on the thickness of similar gravels on terraces bordering the floodplain the gravel thickness in this unit is estimated to be 5 to 10 m.

Qt1 Younger terrace alluvium (late Pleistocene)--Alluvium deposited by the Colorado River that underlies a prominent terrace along the north side of the river, on which the town of Palisade is located. The terrace is about 8 to 10 m above the river. Unit consists of well sorted, imbricated, rounded and well rounded pebble-cobble gravel. Clasts consist mainly of; coarse-grained granitic rocks (27%), quartzite (20%), fine-grained red sandstone (16%), fine-grained granitic rocks (16%), oil shale (9%), and basalt (4%). Some clasts have a thin, white carbonate coat. Matrix, comprising about 5 to 10% of the unit, consists of pale brown (10YR 6/3) silty sand and sand. Gravels are commonly overlain by 1 to 2 m of overbank and possibly eolian materials consisting of massive, light yellowish-brown (10YR 6/4) silty fine sand and fine sand. An alluvial and colluvial (Qac) wedge has spread southward from the Book Cliffs and covered the northern boundary of this unit (Schwochow, 1978). Hence, the northern boundary is only an approximation where the alluvial and colluvial cover is thought to be less than 2 m thick. Unit is probably equivalent in part to outwash of the Pinedale glaciation, which is about 12-35 k.y. (Richmond, 1986, chart 1A). Unit is a potential gravel resource. Thickness commonly 5 to 10 m.

Qt2 Terrace alluvium (middle Pleistocene)--Alluvium deposited by the Colorado River that underlies prominent terraces about 25 to 30 m above the Colorado River. Unit consists of well sorted, rounded and well rounded pebble-cobble gravel. Clasts consist mainly of; basalt (29%), quartzite (25%), fine-grained granitic rocks (15%), and fine-grained red sandstone (11%). All oil shale clasts in exposures were either highly shattered or thoroughly weathered. Matrix consists of pale brown (10YR 6/3) silty sand and sand, comprising about 5 to 10% of the unit. Gravels are commonly overlain by 1 to 2 m of overbank materials consisting of massive, light yellowish-brown (10YR 6/4) silty fine sand and fine sand. Unit is found at two localities in the map area; (1) underlying a terrace remnant about 2.5 km northeast of the town of Palisade that was extensively mined for gravel during the construction of I-70 (Schwochow, 1978), and (2) underlying the northern part of East Orchard Mesa, south of the Colorado River along the western edge of the map. On East Orchard Mesa this unit is overlain at its southern limit by an alluvial and colluvial (Qac) wedge, composed of fine-grained sediment, that has spread northward from hills to the south (Schwochow, 1978). Hence, the southern boundary is only an approximation where the alluvial and colluvial cover is thought to be less than 2 m (Schwochow, 1978). Unit is probably equivalent in part to outwash of the Bull Lake glaciation, which is about 140-150 k.y. (Pierce and others, 1976). Unit is a potential gravel resource. Thickness commonly 5 to 10 m.

Qt3 Terrace alluvium (early Pleistocene)--Alluvium, deposited by the Colorado River, underlying two small terrace remnants about 120 m above the Colorado River. Unit occurs along northern map border (NW 1/4, sec. 2, T. 11 S., R. 98 W). Poorly exposed; surface contains rounded and well rounded pebble-cobble gravel of resistant lithologies. Clasts consist mainly of; quartzite (29%), basalt (25%), fine-grained granitic rocks (17%), and fine-grained red sandstone (16%). Terraces along the Colorado River farther upvalley that are about 80 m above the river are correlative with other terraces that contain (or are overlain) by the 630-k.y. Lava Creek B volcanic ash (Shroba and others, 1995) indicating a regional rate of stream incision of about 0.13 m/ k.y. Hence, these two small terrace remnants in the map area may be about 925,000 yr. Maximum thickness about 5 m.

Tg Alluvium (Pliocene?)--Alluvium containing lithologies deposited by the Colorado River. Unit found at one locality, on ridge between Cottonwood and Watson Creeks (NW 1/4, sec. 13, T. 11 S., R. 98 W) about 610 m above the river. Unit is poorly exposed; surface contains rounded and well rounded pebble-cobble gravel of weather-resistant lithologies. Clasts consist predominately of quartzites (about 80%), but includes basalt, granitic rocks, and red sandstone. Unit may be about 3.8 m.y. in age based on a whole-rock potassium-argon age of 9.7±0.5 m.y. for the basalt on top of Grand Mesa that indicates an average rate of downcutting of about 0.16 m/k.y. for the Colorado River (Marvin and others, 1966). Maximum thickness about 2 m.

ALLUVIAL AND COLLUVIAL DEPOSITS

Qfy1 Fan alluvium of Watson Creek (Holocene and latest Pleistocene)--Unit forms low-gradient coalescing alluvial fans along the south side of the Colorado River deposited by Watson Creek and unnamed tributaries to the east and west. Poorly exposed, unit contains pale brown (10YR 6/3), massive, silty clay and clayey silt. Contains scattered sandstone and basalt clasts derived from head of drainages and deposited by flash flood or debris flows. Limit of this unit and unit to north (Qalc2) was taken from Schwochow (1978). Unit may be subject to flash floods or debris flows from Watson Creek. Maximum thickness estimated to be about 10 m.

Qfy2 Fan alluvium (Holocene and latest Pleistocene)--Unit forms two small fans located near western edge of map along the south side of the Colorado River and a small fan on the southwest side of Horse Mountain. Unit is poorly exposed; surface contains mainly subrounded and rounded basalt cobbles and boulders. Fans near the Colorado River also contain minor amounts of river gravels reworked from above terrace alluvium (Qt2). Unit may be subject to flash floods. Maximum thickness estimated to be about 10 m.

Qac Undivided alluvium and colluvium (Holocene and late Pleistocene).--In areas underlain by Mancos Shale, upper part of unit consists of various beds including: (1) beds of light-brownish gray (10YR 6/2) and pale brown (10YR 6/3), massive to poorly bedded, sand, silty sand, sandy silt, silt, and silty clay 0.15 to 3 m thick. (2) Well-bedded, well-sorted, beds and lenses of pale brown (10YR 6/3) sand and fine sand 0.15 to 1 m thick. (3) Well-sorted beds or lenses of a pebble and cobble gravel 10 to 25 cm thick. Clasts consist of subrounded and rounded basalt in a grayish-brown (2.5Y 5/2) silty sand matrix. (4) Poorly sorted beds or lenses, 15 to 25 cm thick, of light yellowish-brown (2.5Y 6/4) sandy silt containing angular and subangular pebbles of basalt and sandstone. Basal part of unit, when exposed, commonly contains: (1) a poorly-bedded pebble, cobble, and boulder gravel 45 to 100 cm thick. Clasts in basal part are mainly subrounded and rounded basalt in a pale brown (10YR 6/3) silty sand matrix. Largest boulders about 1 m in diameter. (2) Poorly bedded pebble and cobble gravel. Clasts consist of subangular to subrounded basalt and angular fragments derived from the Mancos Shale (Km). In other areas, unit is mainly pale brown (10YR 6/3), massive, fine sand, silty sand, and sandy silt, 2 to 3 m thick, containing scattered pebble beds and lenses generally less than 25 cm thick. Unit subject to piping (erosion by percolating water resulting in the formation of tunnels or pipes through which fine-grained material is removed) and gullying. Gullies within unit subject to flash floods. In those areas where unit is derived from

Mancos Shale (Km) it may contain swelling clays. In addition, unimproved roads in these areas become sticky and very slippery when wet, and are virtually impassable. Maximum thickness about 10 to 15 m.

Qpu Undifferentiated pediment deposits (Holocene and Pleistocene)--Unit includes; (1) Pediment deposits that could not be correlated to the below surfaces with any certainty. Consists of clast supported, unsorted, unstratified to poorly stratified pebbly, cobble-boulder gravel with a pale brown (10YR 6/3) or pale yellow (2.5Y 7/4) silty sand to sandy silt matrix. Clasts consists of subrounded to rounded basalt (50%) of cobble and boulder size and subangular to rounded sandstone (50%) pebbles and cobbles derived from the Mesaverde Group (Kmv). Surface clasts consist of angular and subangular basalt cobbles and boulders, many have a rock varnish coating. Clasts in upper 1 m have thin coating of calcium carbonate. Largest boulders about 1 m along edge. Thickness about 3 to 6 m. (2) Reworked deposits derived from older pediment deposits. Consists of clast supported, unsorted, unstratified to poorly stratified pebbly, cobble-boulder gravel with a pale brown (10YR 6/3) or pale yellow (2.5Y 7/4) silty sand to sandy silt matrix. Clasts consists of angular to subrounded basalt (>85%) of cobble and boulder size with minor amounts of angular to subangular sandstone pebbles and cobbles derived from the Mesaverde Group (Kmv). Surface clasts consist of angular and subangular basalt cobbles and boulders, many have a rock varnish coating. Clasts in upper 1 m have thin coating of calcium carbonate. Largest boulders about 1 m along edge. Maximum thickness about 5 m. (3) Scattered small deposits east of Watson Creek consisting of Mesaverde Group (Kmv) rubble overlying a Mancos Shale (Km) surface. Consists of clast supported, unsorted, unstratified to poorly stratified pebbly, cobble-boulder gravel with a pale brown (10YR 6/3) or pale yellow (2.5Y 7/4) silty sand to sandy silt matrix. Clasts consists of angular to subangular sandstone derived from the Mesaverde Group (Kmv). Maximum thickness about 5 m.

Qp1 Pediment deposit of the Halls Basin area (late? Pleistocene)-- Debris-flow and alluvial deposits that underlie an upland surface, about 12 to 70 m above the Hall Basin area, immediately north of Halls Basin in the south-central map area. Unit deposited mainly by a series of debris flows originating from large landslide mass on Grand Mesa. Unit consists of clast supported, unsorted, unstratified to poorly stratified pebbly, cobble-boulder gravel with a silty sand to sandy silt matrix. Clasts consists mainly of subangular to rounded basalt of pebble, cobble, and boulder size with subordinate amounts of pebble and cobble sandstone clasts derived from the Mesaverde Group (Kmv). Largest boulders about 1 m in diameter. Thickness about 3 to 4 m at distal margins.

Qp2 Pediment deposit of Long Mesa (middle Pleistocene)--Debris-flow and alluvial deposits that underlie the Long Mesa surface in the south-central map area. Surface is as much as 100 m above surrounding areas and about 50 m above Qp1 surface. Unit consists mainly of unsorted, unstratified to poorly stratified, pebbly, cobble-boulder gravel with a sandy silt to silty sand matrix. Clasts consists mainly of subangular to rounded basalt (77%) of pebble, cobble, and boulder size with subordinate amounts of pebble and cobble size sandstone (23%) derived from the Mesaverde Group (Kmv). Unit also includes; (1) well-bedded, well-sorted, pebble gravel, consisting of angular to subrounded basalt and sandstone clasts in a sand and silty sand matrix. (2) Massive, light yellowish-brown (2.5Y 6/4), silty beds and lenses 0.25 to 1 m thick. Clasts in upper 1 m have thin coating of calcium carbonate. Largest boulders about 2 m in diameter. Unit is a potential aggregate resource. Thickness about 3 to 12 m at distal margins.

Qp3 Pediment deposit of Reeder Mesa (middle to early? Pleistocene)--Debris-flow and alluvial deposits that underlies the Reeder Mesa surface in the southeastern map area. Surface is 120 to 140 m above Whitewater Creek and adjacent Qp2 surface. Unit consists mainly of unsorted, unstratified to poorly stratified, pebbly, cobble-boulder gravel with a sandy silt to silty sand matrix. Clasts consists mainly of subangular to rounded pebble, cobble, and boulder-size basalt, with subordinate amounts of pebble and cobble size sandstone clasts derived from the Mesaverde Group (Kmv). Clasts in upper 1 m have thin coating of calcium carbonate. Largest boulders about

1 m in diameter. Unit is a potential aggregate resource. Thickness about 3 to 4 m at distal margins.

Qp4 Pediment deposit north of Sink Creek (early? Pleistocene)--Debris-flow and alluvial deposits that underlies two isolated upland surfaces in the west-central map area. Surfaces are about 75 m above surrounding drainages. Unit consists of unsorted, unstratified to poorly stratified, pebbly, cobble-boulder gravel with a very pale brown (10YR 7/4), sandy silt to silty sand matrix. Clasts consists of subangular to subrounded basalt (55%) of cobble and boulder size and subangular to rounded sandstone (45%) pebbles and cobbles derived from the Mesaverde Group (Kmv). Surface clasts consist of angular and subangular basalt cobbles and boulders, many have a rock varnish coating. Clasts in upper 1 m have thin coating of calcium carbonate. Largest boulders about 1 m in diameter. Surface overlain locally by thin (<50 cm.), discontinuous areas of pale brown (10YR 6/3) eolian silt. In places, unit overlies Colorado River gravels consisting of well-sorted, well-rounded pebbles and cobbles, about 1 to 1.5 m thick, indicating that debris flows of unit covered terraces of the Colorado River. These Colorado River gravels, found along edge of pediment, ranged in height from 135 to 195 m above river. Because this unit now consists of two isolated remnants, a substantial amount of time is considered to have elapsed since it was deposited, hence it is estimated to be early Pleistocene (or older) in age. Unit is a potential aggregate resource. Thickness about 3 to 6 m at distal margins.

QTp5 Pediment deposit of Horse Mountain (early Pleistocene or Pliocene)--Debris-flow deposits that underlie the Horse Mountain surface and two smaller surfaces west of Horse Mountain in the west-central map area. Surfaces are as much as 230 m above surrounding drainages. Unit consists of clast supported, unsorted, unstratified to poorly stratified pebbly, cobble-boulder gravel with a light yellowish-brown (10YR 6/4) or pale yellow (2.5Y 7/4) silty sand to sandy silt matrix. Clasts consists of subrounded to rounded basalt (50%) of cobble and boulder size and subangular to rounded sandstone (50%) pebbles and cobbles derived from the Mesaverde Group (Kmv). Surface clasts consist of angular and subangular basalt cobbles and boulders, many have a rock varnish coating. Clasts in upper 1 m have thin coating of calcium carbonate. Largest boulders about 3 m along edge. Surface overlain locally by thin (<50 cm), discontinuous areas of pale brown (10YR 6/3) eolian silt. In places, unit overlies Colorado River gravels consisting of well-sorted, well-rounded pebbles and cobbles, about 1 to 2 m thick, indicating that the debris flows comprising this unit covered terraces of the Colorado River. These Colorado River gravels were found along the edge of pediment up to at least 190 m and possibly as much as 340 m above the river. Unit forms smooth surface rising to the southeast (overall gradient; 100 m/km). Because Horse Mountain is now separated from the source area for its underlying debris-flow deposits (Grand Mesa and the underlying Mesaverde Group slopes) by a saddle 150 m deep this amount of dissection postdated the deposition of the Horse Mountain pediment deposit, implying a substantial amount of time, hence it is estimated to be early Pleistocene or Pliocene in age. Unit is a potential aggregate resource. Maximum thickness, at southeastern end of Horse Mountain, 20 m; thickness at distal margins about 10 m.

COLLUVIAL DEPOSITS

Qls1 Recent landslide deposits (latest Holocene)--Heterogeneous mixture of unconsolidated surficial material and rock fragments possessing a fresh (unvegetated) scar at their head. Unit includes two deposits near the northeastern corner of the map and two deposits above the Blowout, a large bowl-shaped depression cut into the Mesaverde Group (Kmv) near the head of Watson Creek. All these landslide deposits occur within the Wasatch Formation (Tw) or within a preexisting landslide developed in the Wasatch Formation. One deposit (NE 1/4, sec. 8, T. 11 S., R. 97 W.) appears to be an earthflow that developed from an initial rotational slump in the Wasatch Formation (Tw). Maximum thickness about 10 m.

Qls2 Landslide deposits (Holocene and late Pleistocene)--Includes mainly rotational, translational, and flow types of movement resulting in a wide array of landslide types including; rock slumps, earth slumps, rock slide, debris slides, and earth flows (Varnes, 1978). Unit consists of heterogeneous mixture of unconsolidated surficial material and rock fragments in a wide range of sizes. The size and lithology of the clasts and grain-size of the matrix depend on the various bedrock and surficial units involved in the landslide. Landslide deposits derived from the Wasatch Formation (Tw) consist of unsorted, unstratified, pale yellow (5Y 7/4), light yellowish-brown (2.5Y 6/4), and dark grayish-brown (10YR 4/2) silty sand and sandy silt. These deposits commonly contain angular and subangular sandstone clasts derived from within the Wasatch Formation as well as angular to rounded basalt clasts, as large as 1 m in diameter, derived from Grand Mesa. Clasts commonly comprise only about 10 percent of the deposit. Landslide deposits derived from the Mesaverde Group (Kmv) consist of unsorted, unstratified material containing angular and subangular gravel-size sandstone clasts, as large as 1 to 1.5 m in diameter, in a very pale-brown (10YR 7/3) to pale brown (10YR 6/3) silty sand and sandy silt matrix. Deposits range from clast supported to matrix-supported, where clasts comprise as little as 10 percent of the deposit. Landslides deposits derived from the Mancos Shale (Km) are unstratified, pale brown (10YR 6/3), sandy silt, silt, clayey silt, and silty clay. These deposits commonly contain about 5 to 10 percent angular to subangular basaltic cobbles and boulders derived from the higher slopes. Largest boulders about 1 m in diameter. Unit locally includes small alluvial and talus deposits. Based on aerial extent of larger landslides and limited exposures in cliff faces, thickness of larger landslide deposits probably exceed 100 m in places.

Qt Talus (Holocene and late Pleistocene)--Talus consisting of boulders deposited by rockfall at the base of cliffs and steep slopes. Unit found along the slopes bordering Grand Mesa along the east-central border of the map. Unit consists of crudely sorted, equi-dimensional, angular to subangular, blocky basaltic boulders. Surface boulders commonly 1 m on a side, largest boulders greater than 2 m on a side. Limited exposures suggests unit may grade into finer material at depth. Upper reaches of unit rest at the angle of repose and is therefore potentially unstable. In places, toe of deposit is lobate indicating rock glacier-like flowage. Many boulders on lower reaches of unit support a heavy lichen cover suggesting limited movement or activity in the last several hundred or thousand years. Upper reaches of unit are prone to serious rockfall hazards. Unit is a potential aggregate resource, although unit could be rendered unstable by excavations or roadcuts. Thickness probably exceeds 15 m locally.

Qdy Debris-flow deposits of Watson Creek (Holocene and late Pleistocene)--Unit deposited by a series of debris flows originating from the Blowout or from the large landslide mass above the Blowout. Unit consists of mostly debris-flow deposits and minor amounts of stream alluvium underlying the gently sloping surface in the Watson Creek drainage. Unit includes; (1) massive to well-bedded yellowish-brown (10YR 6/3 and 10YR 6/4) silty sand and sandy silt beds commonly 1 to 2 m thick, containing granule and pebble and pebble and cobble lenses as much as 1 m thick. (2) Well-bedded pebble-cobble gravel beds, generally less than 25 cm thick. Clasts are predominantly subangular to rounded sandstone (75%) derived from Mesaverde Group (Kmv) with minor amounts of basalt clasts. (3) Poorly sorted and unstratified clast supported pebble-cobble gravel with some boulders in a brown and pale brown (10YR 5/3 and 6/3) silty sand matrix. Clasts are mainly angular and subangular sandstone and subangular to subrounded basalt. Largest clasts are about 1 m in diameter. (4) Massive, light brown (7.5YR 6/4), silty sand and sand, 1 to 2 m thick, containing scattered angular and subangular basalt cobbles and boulders comprising about 20 percent of deposit. Clasts in upper 1 m of unit have thin coating of calcium carbonate and in places fines may contain stage III calcium carbonate (Gile and others, 1966). One location on unit was mined for riprap during the construction of I-70. Low lying areas within unit may be subject to flash floods or debris flows from Watson Creek. In addition, unit also prone to gullying. In places, such as in the exposure along the road ascending to East Orchard Mesa (SW 1/4, sec 2, T. 1 S., R. 2 E.), unit overlies terrace alluvium (Qt2) of the Colorado River consisting of a well-sorted, well-

rounded pebble-cobble gravel, about 1 to 2 m thick containing a very pale brown (10YR 7/4) silty sand and sandy silt matrix. Thickness as much as 30 m.

Qdu Debris-flow deposits of Rapid Creek (late and middle? Pleistocene)--Unit deposited by a series of debris flows originating from a large landslide mass at the head of Rapid Creek. Unit consists of mostly debris-flow deposits and minor amounts of stream alluvium in and above the channel of Rapid Creek (and Cottonwood Creek in one place) and underlying the fan surface at the mouth of Rapid Creek, along the Colorado River, at the north-central map border. Unit consists of poorly sorted, poorly stratified, cobble-boulder gravel. Clasts consists of mainly subrounded to rounded basalt with minor amounts of sandstone clasts derived from the Mesaverde Group (Kmv). Clasts in upper 1 m have thin coating of calcium carbonate. Contains numerous boulders 1 m in diameter, largest boulders about 2 m in diameter. Matrix consists of pale brown (10YR 6/3) coarse sand. Limited exposures, along lower reaches of Rapid Creek, display buried soils of stage III carbonate in places indicating unit was constructed over long expanse of time by a series of events. Unit is a potential gravel and aggregate resource. Low-lying areas within unit may be subject to flash floods or debris flows. Thickness locally exceeds 30 m.

QTbr Basalt rubble (Pleistocene and Pliocene?)--Rubble consisting of mainly basalt clasts mantling areas along ridges between Watson and Cottonwood Creeks and between Cottonwood and Rapid Creeks. Also, mantles hill and slopes near head of Rapid Creek and hill and slopes near Blackbird Mine (NE 1/4, sec. 1, T. 12 S., R. 98 W.), in south-central map area, and in the southeastern map area. Unit may in part consist of early Pleistocene or Pliocene debris flows deposited on a preexisting topography that has since undergone extensive downcutting. Unit mapped in southeastern map area is in part derived from the backwasting of a pediment surface (Qp3). Surface contains angular and subangular basalt cobbles and boulders. Largest boulders about 2 m in diameter. Many of the surface clasts have a rock varnish coating. Shallow road cuts expose clasts containing thin carbonate coatings. Matrix consists of pale brown (10YR 6/3) silty sand and sandy silt. Exposures lacking, but if unit is in part derived from debris flows it probably consists of clast supported, unsorted, unstratified basalt gravel. Maximum thickness estimated to exceed 10 m.

BEDROCK UNITS

Tb Basalt of Grand Mesa (Miocene)--Multiple flows of basalt, olivine basalt, and basaltic andesite. Flows range from massive and non-vesicular to highly vesicular with amygdules of calcite. Groundmass is dominantly plagioclase and pyroxene with lesser amounts of olivine, pigeonite, augite, and magnetite (Kirkham and others, 1997). Unit only mapped in small area along eastern edge of map, but forms a resistant cap over much of Grand Mesa to east of the Palisade Quadrangle. A whole-rock potassium-argon determination of basalt, along State Highway 65 near Mesa Lake, about 22 km east-southeast of the town of Palisade, (W. E. Yeend, 1997, personal communication) yielded an age of 9.7±0.5 m.y. (Marvin and others, 1966). The dated sample was taken from about the middle of a series of flows about 240 m thick. Unit prone to toppling and is a source of rockfall debris where exposed in steep cliffs. Potential source of high quality riprap and aggregate. Thickness in the map area about 90 m (J.R. Donnell, personal communication, 1997).

Tgr Green River Formation (Eocene)--Interbedded light gray, light tan, yellowish-brown, and dark-brown sandstone, siltstone, and oil shale. Unit contains thin beds of limestone and is conglomeratic in lower part. Contact with underlying Wasatch Formation is indistinct. Unit shown only in cross-section B--B'. Thickness in map area estimated to be about 60 m (J.R. Donnell, personal communication, 1997).

Tw Wasatch Formation (Eocene and Paleocene)--Poorly exposed in map area, consists of interbedded purple, lavender, red, and gray claystone and shale with local lenses of gray and brown sandstone, conglomeratic sandstone, and volcanic sandstone. Predominantly fluvial and

lacustrine in origin. Coarse clastic beds are trough crossbedded and vary in thickness, whereas fine-grained clastic beds are commonly thin. All beds are laterally discontinuous and in general are lenticular. Unit uncomformably overlies the Mesaverde Group rocks. Unit prone to failure, forming large translational slides. Along the flanks of Grand Mesa unit commonly forms large translational landslides, as much as 100 m thick. Thickness in map area about 700 m.

Kmv Mesaverde Group (undifferentiated) (Upper Cretaceous)--Gray to brown sandstone, siltstone, shale and coal. Locally, contains conglomerate, conglomeratic sandstone, and a kaolinitic zone in the upper part (Ohio Creek Member of the Hunter Canyon Formation). Deposited mainly by streams on coastal plains, containing coal swamps, marshes, and mudflats, in backshore areas. Sandstone beds in the lower part of the Mesaverde Group were deposited in shoreline areas. Contains commercially important coal beds in the lower part. As mapped in this area, the lower part of the Mesaverde Group includes three well-defined cliff-forming sandstone units, separated from one another by tongues of Mancos Shale; from top to bottom these are the Rollins Sandstone, Cozzette Sandstone, and Corcoran Sandstone Members of the Mount Garfield Formation. The Rollins Sandstone Member (top of member marked by line on map) is a light-gray to white, fine to medium grained, prominent, massive sandstone, about 25 to 35 m thick in the map area (Gill and Hail, 1975). It is stratigraphically equivalent to the Trout Creek Sandstone Member of the Iles Formation (Collins, 1976) and is locally baked a dull red color due to coal fires in the overlying Cameo coal zone. The Cozzette Sandstone Member consists of a 30 to 40 m thick interval of interbedded tan sandstone and gray shale containing horizonal to low-angle cross laminations (Johnson, 1989). The Corcoran Sandstone Member consists of a 20 to 30 m thick sequence of interbedded tan sandstone containing ripple and low-angle cross laminations and gray shale (Johnson, 1989). The Palisade coal zone overlies the Corcoran Member while minor coal beds overlie the Cozzette Member. Above the Rollins Member, the Mesaverde Group is prone to landsliding forming large rotational slump blocks. Thickness of the unit in the map area is about 550 m.

Km Mancos Shale (Upper Cretaceous)--Mostly a thick sequence of gray to black fissile shale with minor tan siltstone and fine sandstone beds generally less than 25 cm thick. Marine in origin. Fossiliferous in places. Intertongues with the lower part of the of the Mesaverde Group (Kmv). On this map, the upper boundary of the Mancos Shale is put at the base of the Corcoran Sandstone Member of the Mount Garfield Formation. Mancos Shale slopes underlying pediment surfaces are in places veneered with a thin (< 1 m) mantle of basalt boulders not shown on this map. Mancos Shale slopes beneath outcrops of Mesaverde sandstone may also be covered with a thin mantle of sandstone boulders not shown on this map. Unit prone to landsliding when underlying steep slopes, such as along the sides of pediment surfaces. Unit may have moderate to high swelling potential and may contain evaporite minerals that are corrosive to conventional concrete and metal pipes. When wet, the surface of the Mancos Shale becomes sticky and very slippery; unimproved roads are virtually impassable when wet. Thickness of the unit in the Grand Valley area is about 1,160 m (Lohman, 1965).

Kd Dakota Sandstone (Upper Cretaceous)--Light gray to tan, medium to very coarse-grained, quartzose sandstone interbedded with carbonaceous siltstone, sandstone, and shale. Sandstone commonly well sorted, with angular to subrounded sand grains. Basal part of unit consists of a conglomerate or conglomeratic sandstone, about 12 m thick, overlain by carbonaceous and lignitic shale and lignite (Lohman, 1965). Conglomeratic clasts generally consists of black and white pebble-sized chert and quartz (Kirkham and others, 1997). Unit shown only in cross-section A--A'. Thickness in the map area may exceed 60 m (Lohman, 1965).

GEOLOGIC HAZARDS

Various geologic hazards exist on the Palisade Quadrangle, these include: various types of landslides, erosional processes, such as gullying and piping, expansive soils, and flooding. These hazards are commonly associated with specific geologic units (Table 1).

LANDSLIDES

As used in this report, landslide is a general term that includes a wide variety of mass movement landforms and processes involving the slow to rapid downslope transport of surficial materials and bedrock blocks by gravity. This definition includes various types and combinations of flows, falls, slumps, and slides. Landslide deposits cover about 25% of the map area, and are very common along the margins of Grand Mesa and along the margin of pediment surfaces. Landslide types that were recognized in the map area include: earth flows, earth slumps, debris flows, debris slumps, rock-block slides, translational slides, rockfalls and complex landslides (Varnes, 1978). 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 including: (1) their hummocky topography, including closed depressions and ponds on hillsides, (2) the deflection of stream channels at the toes of the deposits, (3) their 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 angle in the early morning and late afternoon highlighted the subdued topography of many old landslide deposits and facilitated their identification in the field.

In the map area, landslides commonly form on steep slopes where fine-grained, weakly-indurated, sedimentary rocks of low shear strength, such as those of the Mesaverde Group, Wasatch Formation and Mancos Shale, are capped by lava flows or pediments gravels. These landslide deposits range from a few meters to more than 100 m in thickness. For instance, the large landslide on the northeastern side of Horse Mountain has a relief of about 275 m from headscarp to toe and probably approaches a thickness of 90 m in places. The large landslides on the slopes of Grand Mesa along much of the eastern border of the map probably exceed 100 m in thickness.

Different geologic formations in the map area have their own characteristic type of failure. The Wasatch Formation (Tw) fails as large translational slides that, in several areas, extend for as much as 1.5 km beyond the limits of the formation. For instance, the large tongue of landslide material, near the center of the map, extending west from Grand Mesa has slid over and obscured cliffs of the Mesaverde Group (Kmv). In the lower part of the Mesaverde Group, above the Rollins Sandstone Member, large rotational slumps are common in the weak shales and siltstones. Landslides in the Mancos Shale (Km), that contains rocks of low shear strength, are common in the map area on steep slopes, such as those along the edges of pediments. Rockfall hazard in the map area is present at the base of basalt (Tb) cliffs along the perimeter of Grand Mesa and at the base of steep slopes below the massive sandstone cliffs of the Mesaverde Group (Kmv).

Landslides in the map area probably encompass a wide range of ages. Landsliding may have begun in the Pliocene when the initial dissection of Grand Mesa exposed weak underlying rocks, and has continued to the present. Landslides along the upper flanks of Grand Mesa are known to be young (latest Holocene) (Yeend, 1969; 1973). Fresh, steep and unvegetated landslide deposits (Qls1) are present in the map area.

The map area contains numerous landslide deposits some of which may pose significant hazards to persons and buildings or other man-made structures. For instance, Cabin Reservoir, part of the water supply for the town of Palisade, is surrounded by landslide deposits. Movement of material by landsliding into the reservoir could possibly pose a hazard to the dam. Small debris flows originating from the steep Mancos Shale slopes north of I-70 near the town of Palisade can close the highway as they did in September 1997 during a period of high rainfall. At risk from rockfall is a home and other buildings located on a hillside in the vicinity of the Midwest Mine, about 3 km east of the town of Palisade. Here, large blocks of sandstone derived from the above cliffs are scattered about the house. Although these blocks may have fallen some time ago, they clearly indicate a potential hazard to these buildings should more blocks fall from the cliffs.

PIPING

Piping is the process whereby erosion by percolating water results in the formation of tunnels (pipes) through which fine-grained material is removed. In the Palisade Quadrangle, unit Qac is prone to piping in some areas. Piping can lead to the formation of large cavities, which may be prone to collapse endangering roads, irrigation systems, power lines and structures.

GULLYING

Gullying is the process whereby erosion by running water of soil or soft rock forms distinct, narrow channels. Usually these channels carry water only during and immediately after heavy rains. In the Palisade Quadrangle, units Qac and Qdy are prone to gullying. Over time the process of gullying can lead to the formation of deep channels that can disrupt roads and irrigation systems, clog downstream areas with excess sediment, and ruin the environmental and aesthetic attraction of areas.

EXPANSIVE SOILS

Soils that shrink or swell in response to changes in moisture content are commonly known as expansive soils. Expansive soils are common in those areas underlain by sedimentary rock containing certain clay minerals or colluvium derived from those rocks. The potential volume change of a given soil depends on the type and amount of clay minerals it contains. Due to differential expansion, concrete foundations, floors, and walls may develop cracks, doors may not close, and the building may tilt slightly. It has been estimated that as many as 60 percent of homes built on swelling clays will undergo minor damage while 10 percent may suffer significant damage (Jones and Holtz, 1973). In semiarid areas, such as the Palisade quadrangle, soils containing swelling clays will often have a characteristic “popcorn” texture when dry. On the map, those areas underlain by the Mancos Shale (Km) or alluvium and colluvium (Qac) derived from the Mancos Shale are known to contain varying amounts of swelling clays. These areas may have moderate to high swelling potential and may also contain evaporite minerals that are corrosive to conventional concrete and metal pipes. When wet, the surface of the Mancos Shale becomes sticky and very slippery, and unimproved roads across it are virtually impassable.

FLOODING

The town of Palisade, primarily situated on a probable Pinedale age (12-35 k.y.) terrace about 8 to 10 m above the Colorado River, is relatively safe from any flood hazard from the river. However, as the town expands, care should be taken to avoid those areas south of town mapped as Qalc1 as these areas are thought to be prone to periodic flooding. Other areas of possible flood hazard include low lying areas near the mouths of Watson Creek and the other small drainages to the east. In addition, some areas may be prone to flash floods caused by intense thunderstorms in their headward regions. Examples of such areas are two small fans located near the western edge of map along the south side of the Colorado River as well as low lying areas near the mouths of Cottonwood and Rapid Creeks (north on the map). Large, greater than 1m in diameter, basalt boulders in these channels indicate past floods of large magnitude

ECONOMIC GEOLOGY

SAND AND GRAVEL RESOURCES

The Palisade quadrangle contains abundant sand and gravel resources. Sand and gravel resources underlie the terrace alluviums (Qt1, Qt2, and Qt3). These deposits consist mainly of well sorted, rounded and well rounded pebble-cobble gravel commonly 5 to 10 m thick and do not appear to contain materials deleterious to cement, such as chert and sulfide minerals. Clasts consist predominately of fine-grained red sandstone, coarse-grained granitic rocks, fine-grained granitic rocks, dark-colored gneisses, basalts, and quartzites. The gravels also contain about 5 to as much as 10 percent oil shale clasts, of low bearing strength, derived from the Green River Formation. Hence, these gravels are suitable for road base, but may be unsuitable as an aggregate for concrete and asphalt. In the map area, terrace alluvium (Qt2), underlying a small terrace remnant about 2.5 km northeast of the town of Palisade, was mined for gravel during the construction of I-70 (Schwochow, 1978).

COAL

Coal, mainly bituminous and subbituminous, occurs in the Mesaverde Group (Kmv) and has been mined at various locations in the eastern half of the map area. As mapped in this area, the lower part of the Mesaverde Group includes three well-defined cliff-forming sandstone members, separated from one another by coal seams, shales, siltstones, and tongues of Mancos Shale; from top to bottom these sandstone units are the Rollins Sandstone, Cozzette Sandstone, and Corcoran Sandstone Members of the Mount Garfield Formation. Two main coal zones are present in the map area, the Cameo coal zone, which overlies the Rollins Member, and the Palisade coal zone, which overlies the Corcoran Member. Minor coal beds overlie the Cozzette Member.

Mines shown and labeled on the map base include the Palisade Mines, Mt. Lincoln Mine, and Farmers Mine north of I-70. The Go Boy Mine, about 1.1 km east of the Colorado River, along the northern edge of the map. The Midwest Mine, 0.25 km east of the Colorado River, above the Orchard Mesa Canal, and the Blackbird Mine in the south-central map area. The Go Boy and Blackbird Mines are in the Cameo coal zone, all the others appear to be in the Palisade coal zone. For more information on the coal resources of the area see Lee (1912) and Schwochow (1978).

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Table 1. Geologic hazards in the Palisade 1:24,000 Quadrangle.

Mass Wasting[1]		Gullying	Piping[2]	Expansive Soils	Flooding	
Qls1	Tb	Qac	Qac	Qac	Qalc1	Qac
Qls2	Tw	Qdy		Km	Qalc2	Qdy
Qt	Kmv				Qfy1	Qdu
Qdy	Km				Qfy2	
Qdu						

[1] Includes earth flows, earth slumps, debris flows, debris slumps, rock-block slides, translational slides, rockfalls and complex landslides.

[2] Defined as; erosion by percolating water resulting in the formation of tunnels (pipes) through which fine-grained material is removed.

CONVERSION FACTORS

Multiply	By	To obtain
centimeters (cm)	0.394	inches
meters (m)	3.28	feet
kilometers (km)	0.621	miles