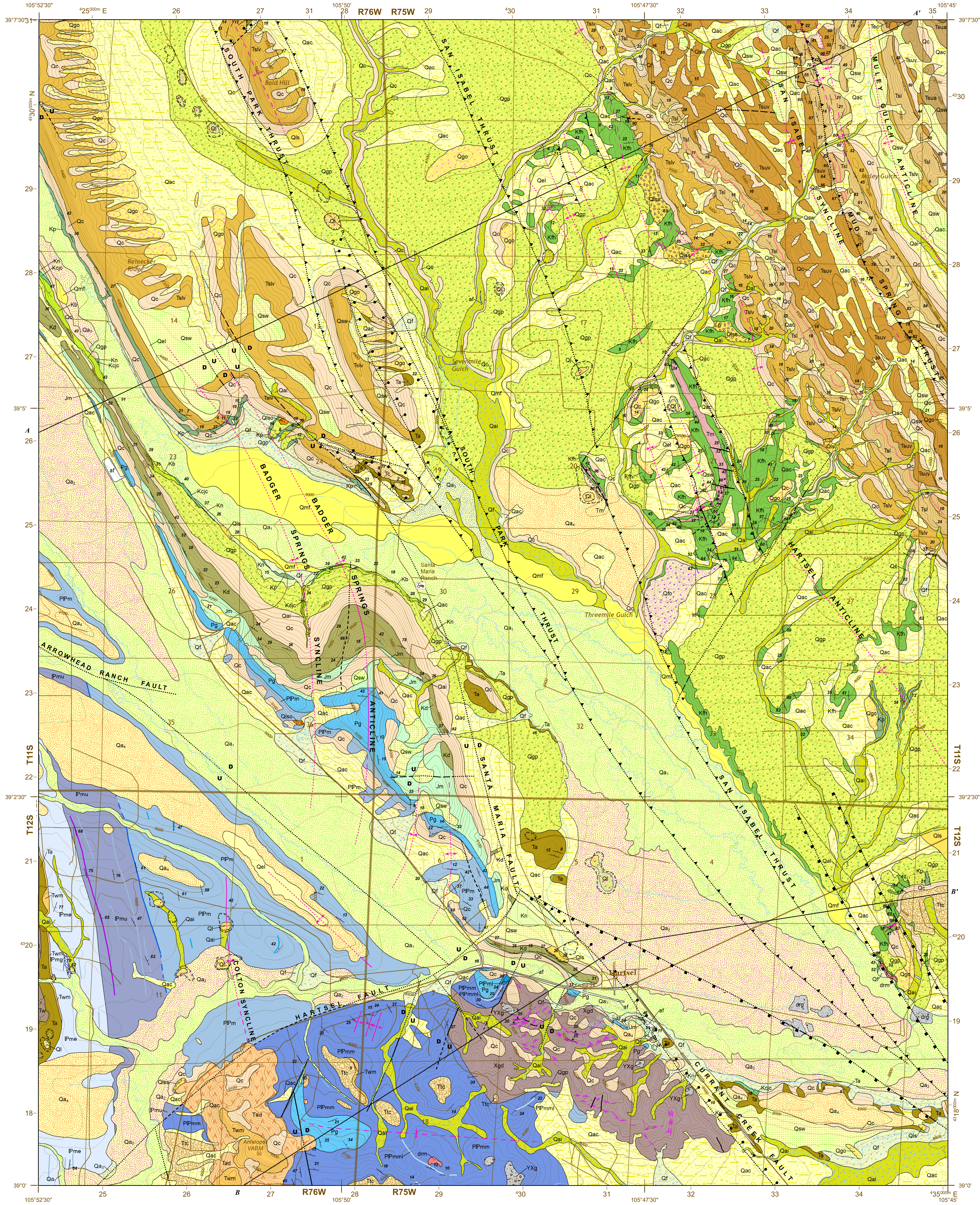


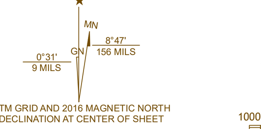
Geology mapped in 2016
GIS and cartography by Pangaea Geospatial LLC

Coordinate System: NAD 1983 UTM Zone 13N
Projection: Transverse Mercator
Datum: North American 1983

This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

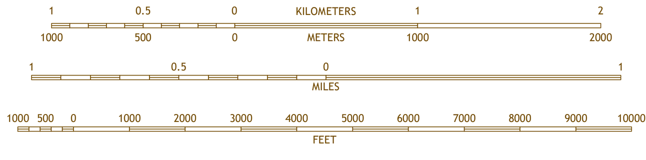
Initial styling of this map document was provided by the US Geological Survey. The edited content in this document is neither done by nor endorsed by the USGS.

Contours................................National Elevation Dataset, 2002
Roads....................................U.S. Census Bureau, 2015-2016
Names...................................GNIS, 2016
Hydrography...........................National Hydrography Dataset, 2013
Boundaries.............................Multiple sources; see metadata file, 1972-2016
Public Land Survey System...........BLM, 2011
Wetlands...............................FWS National Wetlands Inventory, 1977-2014



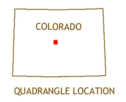
UTM GRID AND 2016 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24,000



CONTOUR INTERVAL 20 FEET

This mapping project was funded jointly by the Colorado Geological Survey and the U.S. Geological Survey through the National Cooperative Geologic Mapping Program under STATEMAP agreement G16AC00189.



QUADRANGLE LOCATION

Fairplay East	Elkhorn	Eagle Rock
Garo	Hartsel	Sulphur Mountain
Antero Reservoir	Antero Reservoir NE	Guffey NW

ADJOINING QUADRANGLES

GEOLOGIC MAP OF THE HARTSEL QUADRANGLE, PARK COUNTY, COLORADO

By Peter E. Barkmann, Karen J. Houck, Marieke Dechesne, Jonathan R. Lovekin, and Erinn P. Johnson

2017

DESCRIPTION OF MAP UNITS[1]

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af — **Artificial fill (uppermost Holocene)** — Unsorted sand, silt, gravel, or rock fragments locally used as fill; includes fill used for highway embankments and railroad grades. Depending on age, construction, location, aspect, and material, these deposits may be prone to slope failure and differential settlement. Maximum thickness is approximately 25 ft (7.6 m).

drg / drm — **Disturbed or reclaimed ground (uppermost Holocene)** — Unsorted sand, silt, gravel, or rock fragments in disturbed areas. Inactive gravel pits are designated ***drg*** and inactive mining areas are designated ***drm***. Depending on age, location, aspect, and material, these deposits may be prone to slope failure and differential settlement. Thickness may be up to 20 ft (6 m).

ALLUVIAL DEPOSITS

Qa_1 — **Alluvium one (Holocene)** — Mainly poorly sorted, clast supported, unconsolidated, sandy gravel of all sizes, gravelly sand, silty sand, and sandy silt in modern channels, floodplains, and adjacent low-lying terraces that are approximately 5 ft (1.5 m) or less above modern channels. Most deposits in alluvial unit one are stratified and may have cut-and-fill channels. Beds of organic-rich sediment or peat are locally present. Most gravel clasts within the unit are unweathered to slightly weathered. Clasts are subround to subangular and rarely round or angular. Clast composition is polymictic, dominated by Paleozoic quartzite, sandstone, and felsic and intermediate igneous rocks with lesser amounts of granite and gneiss. Areas underlain with this unit are prone to frequent and seasonal flooding. Thickness of the unit is estimated to range from about 3 to 15 ft (1 to 5 m) but could be greater in places.

Qa_2 — **Alluvium two (Upper Pleistocene)** — Alluvium two contains stratified, poorly sorted, clast supported, sandy cobble and pebble gravel, gravelly sand, silty sand, and sandy silt. Most clasts are subround to subangular and are unweathered or very slightly weathered. Streams are incised about 5 to 15 ft (1.5 to 4.6 m) into alluvium two. This unit corresponds topographically with the Quaternary alluvium two of Kirkham and others (2007). Clast composition is similar to that of alluvium unit one. Areas underlain with this unit are prone to flooding. The unit is a local source of gravel. Thickness of the unit is estimated to range from about 3 to 15 ft (1 to 5 m) but could be greater in places.

Qa_3 — **Alluvium three (Middle Pleistocene)** — Sediment in unit Qa_3 is similar to that contained in unit Qa_2, but it is usually higher in the landscape. Typically, the original depositional surfaces associated with alluvium three are about 10 to 40 ft (3 to 12 m) above adjacent streams. Gravel clasts are slightly or moderately weathered. Clast composition is similar to that of alluvium unit two. The unit is a local source of gravel and was targeted for placer gold exploration in the early 1900s near the Middle Fork and South Fork South Platte River confluence where it was completely removed. Thickness of the unit is estimated to range from about 3 to 15 ft (1 to 5 m) but may be greater locally.

Qa_4 — **Alluvium four (Middle Pleistocene)** — Alluvium four is typically greater than 40 ft (12 m) above adjacent stream channels and is higher in the landscape than alluvium three. Clast composition is similar to that of alluvium unit three. Thickness of the unit is estimated to range from about 3 to 15 ft (1 to 5 m) but may be greater locally.

Qai — **Alluvium of intermittent drainages (Holocene and Upper Pleistocene)** — Unsorted and unstratified to stratified clay, silt, sand, and gravel of intermittent drainages deposited during sudden high-energy, high-volume storm events. Clast composition and sizes vary depending on units exposed in the watershed; some boulders may reach 6 ft (2 m) in diameter. Contains locally derived angular to subangular clasts. The unit forms channel fill of predominantly poorly sorted, clast supported, and massive deposits, although gravel-filled scour channels may be present. Locally includes distinct fan-shaped deposits. Areas underlain by these deposits are prone to flooding and, in some cases, debris flows. Thickness is estimated to be 5 to 20 ft (1.5 to 6 m).

Qsw — **Sheetwash deposits (Holocene and Upper Pleistocene)** — Poorly stratified to stratified locally derived clay, silt, sand, and pebble to boulder-sized clasts. Sediments are deposited on gentle slopes primarily by non-channelized water but also by gravity. May transition to colluvium on steeper slopes where gravity transport dominates. Areas underlain by Qsw are prone to flooding, mud flows, and hydrocompaction or settlement. Thickness may be up to 6 ft (2 m).

Qgo — **Old gravel deposits (Middle and lower Pleistocene)** — Deposits of poorly sorted clay, sand and silt with subrounded to subangular boulder gravels. These deposits form a series of elevated and dissected gravel bodies with a variety of geometries and origins. They are now inverted, positive features in the landscape. These deposits form "flatirons" where modern dissection incises through steep hillsides especially along northern and eastern Reinecker Ridge. Thickness of the unit is estimated to range from 3 to 15 ft (1 to 5 m) but may be greater locally. Thickness may range up to 30 ft (10 m).

Qgp — **Pediment gravel deposits (Middle and lower Pleistocene)** — Poorly to moderately sorted, sandy, pebble- to cobble-sized alluvial gravel deposited on gently sloping bedrock surfaces (pediments) flanking strike ridges. May include old alluvial, sheetwash, and colluvial deposits. Modern dissection through these deposits resulted in benches above modern alluvial surfaces, some of which may be expansive elevated surfaces and others small isolated knobs. The unit is a local source of gravel. Thickness may be up to 10 ft (3 m).

ALLUVIAL AND MASS-WASTING DEPOSITS

Qf — **Fan deposits (Holocene and Upper Pleistocene)** — Includes sediment beneath geomorphically distinct fans at the mouths of tributary valleys deposited as distributive alluvial channels or debris flows. In some areas, the deposits from adjacent valleys merge to form fan complexes. Fan deposits are chiefly poorly sorted, clast-supported sandy gravel and gravelly sand deposited as alluvium during storm events. Locally, they include debris-flow deposits that are composed of matrix supported, poorly sorted, silty or sandy gravel. Clasts contained in fan deposits are mainly subangular to angular. Areas underlain by fan deposits are prone to slope instability, hydrocompaction, flooding, and debris flows. Maximum thickness of fan deposits is estimated at 25 ft (7.6 m).

Qfo — **Old fan deposits (Middle and lower Pleistocene)** — Deposits similar to Qf in geomorphically distinct fans, but are on benches isolated above the modern tributary valleys.

Qmf — **Mud-fan deposits (Holocene and Upper Pleistocene)** — Deposits of poorly sorted, poorly consolidated, clayey to sandy silt deposited in valley-head and valley-side alluvial fans, tributary stream valleys, and coalescing fans in local basins. Surface slope gradients are typically lower than surface gradients of coarser-grained fan deposits. Areas underlain with mud-fan deposits are prone to flooding, debris flows, and hydrocompaction. Individual mudflow events may result in deposits only several inches thick but the unit can be up to 6 ft (2 m).

Qac — **Alluvium and colluvium deposits, undivided (Holocene and Upper Pleistocene)** — This unit consists of several components: (1) alluvial sediments in local channels, floodplains, low terraces, and small tributary drainages, (2) alluvial sediments forming small coalescing alluvial fans on slopes below ridges and hills, (3) sheetwash deposits along valley margins and shallow hillslopes, and (4) colluvium on shallow hillslopes. The components are mapped as a single unit where two or more grade laterally from one to another with differentiation not appropriate for this map scale. The alluvial component of the unit is very poorly to well sorted and ranges from sandy pebble, cobble, and boulder gravel to stratified fine sand and silt. Clasts in the alluvial component are subangular to subround. The colluvial part consists of very poorly sorted, unstratified or poorly stratified, gravelly to silty sand, sandy to silty gravel, and gravelly sandy silt. Clasts in the colluvial part are chiefly angular to subangular. The unit may locally include debris flow deposits, which typically are matrix-supported gravelly silt, and also small landslides or soil slips. In many areas, evidence of solifluction and soil creep is present in deposits of colluvium. Thickness of the unit is estimated to range from 3 to 20 ft (1 to 6 m). Areas underlain with this unit are prone to flooding, debris flows, landslides, and hydrocompaction.

MASS-WASTING DEPOSITS

Mass-wasting deposits accumulate on hillslopes and adjacent valley floors. They are transported downslope primarily by gravity. Colluvium and landslide deposits are the principal types of mass-wasting deposits in the quadrangle. The classification system of Cruden and Varnes (1996) is used to describe the type of slope movement. Solifluction features are commonly found in mass-wasting deposits.

Qc — **Colluvium (Holocene and Upper Pleistocene)** — Includes deposits of poorly sorted, sandy or silty, fine to coarse gravel, gravelly sand, and gravelly silt on hillslopes or at the foot of the hillslope. Colluvium can be rich in boulders below cliffs and rocky outcrops. As used here, colluvium generally follows the definition of Hilgard (1892) in that it (1) is derived locally and transported only short distances, (2) is not distributed by channelized water flow, (3) contains clasts of varying size, (4) has little or no sedimentary structures or stratification, features which are typically caused by channelized flow of water, and (5) may include minor amounts of sheetwash and debris-flow deposits. Unit Qc may locally include landslide, talus, or rockfall deposits that are either too small to differentiate at the map scale or are difficult to clearly discern on aerial photographs. Loess is a common interbedded material within the deposits. Clasts in colluvium are typically angular to subangular, except where sourced in bedrock or surficial deposits that contain well-rounded clasts. In many areas, deposits of colluvium are affected by solifluction and may be burrowed by modern mammals. Solifluction is indicated by the presence of lobate to circular mounds 2 to 6 ft (0.6 to 1.8 m) high and up to 30 ft (33 m) long that indicate solifluction processes of slow, viscous, downslope flowage of water-saturated surficial deposits over frozen ground. Areas mantled by colluvium are prone to rockfall, debris flows, and slope failure. Where local deposits of loess occur within the unit, the deposit is prone to hydrocompaction. Maximum thickness of colluvium is estimated to be 20 ft (6 m).

Qls — **Landslide deposits (Holocene and Upper Pleistocene)** — Recent landslide deposits consisting of heterogeneous, mostly unsorted and unstratified debris that is commonly characterized by hummocky topography with well-defined morphological features (e.g. headscarps and toes). Areas underlain by landslide deposits are prone to additional slope failures. The mapped landslides may be between 10 and 20 ft (3 and 6 m) in thickness and are composed of upland bedrock materials.

Qlss — **Landslide deposits with solifluction features (Holocene and Upper Pleistocene)** — Hummocky deposits of heterogeneous and unsorted clay, silt, sand, and cobble- and boulder-sized rock fragments. The surface of the landslides are marked by lobate mounds 2 to 6 ft (0.6 to 1.8 m) high that indicate solifluction processes. Areas underlain with this unit are prone to additional slope failures. Thickness may be up to 10 ft (3 m).

Qlso — **Old landslide deposits (Middle and lower Pleistocene)** — Heterogeneous deposits consisting of unsorted and unstratified clay, silt, sand, and cobble- to boulder-sized rock fragments. These landslide deposits are older, relative to Qls deposits, because their morphological features (e.g. headscarps and toes) are less distinct than recent landslides; however, hummocky ground is present in some areas. Areas underlain with old landslide deposits are prone to additional slope failures. The mapped landslides may be up to 10 ft (3 m) in thickness and are composed of upland bedrock materials.

LACUSTRINE DEPOSITS

Lacustrine deposits in this quadrangle are localized fine-grained deposits restricted to small natural depressions.

Ql — **Lacustrine deposits (Holocene and Upper Pleistocene)** — Unconsolidated, moderately to well sorted and stratified, silt, and clay deposited in natural depressions that are intermittently filled with water. Because of restricted overland flow and high evaporation rates, the soils within the depressions may be very alkaline or saline resulting in cream to white crusts or "blooms" and are commonly called "playas." Areas underlain with this unit are prone to flooding and hydrocompaction. Thickness is less than 7 ft (2 m).

EOLIAN DEPOSITS

Qel — **Loess deposits (Holocene to Upper Pleistocene)** — Deposits of wind-blown fine-grained silt with some clay. Loess is commonly intermingled with other surficial deposits. Exposures are rare and are typically in arroyos, gullies, and other deeply incised areas within the quadrangle. Areas underlain with this unit are highly erodible and may be prone to hydrocompaction. Estimated thickness is less than 10 ft (3 m).

SPRING DEPOSITS

Qtr — **Travertine deposits (Middle Pleistocene?)** — Gray, nodular to granular limestone, irregularly bedded with open cavities and shelves. Contains rare grains of quartz and feldspar. This deposit is found approximately 1,575 ft (480 m) southeast of the modern hot spring at Hartsel adjacent to the northwest-striking Currant Creek fault suggesting deep groundwater flow through the fault zone. The height above the modern course of the South Fork South Platte River is approximately 50 to 60 ft (15 to 18 m). The deposit is incised and partially buried by Holocene and Upper Pleistocene fan deposits (Qf) suggesting a possible Middle Pleistocene age, which is supported by the height above the modern floodplain. Areas underlain with this unit are prone to collapse. The base is not exposed and the thickness exceeds 5 ft (1.5 m) based on depth of incision.

BEDROCK GEOLOGY

TERTIARY SEDIMENTARY AND IGNEOUS ROCKS

Tm — **Mafic Intrusions (Tertiary?)** — Mafic intrusions occur in two bodies in the vicinity of Threemile Gulch in the north-central part of the quadrangle. The largest is an intrusive complex consisting of a layered sill concordant with the Upper Cretaceous Fox Hills Sandstone (Khf) that is connected with discordant dikes at its southern end. The smaller body lies to the west and appears to be a concordant sill. Composition is predominantly mafic with the larger sill body layered with alternating mafic and intermediate phases between 3 and 10 ft (1 and 3 m) in thickness. The intermediate phase contains plagioclase feldspar (70%) supported by both clinopyroxene and orthopyroxene (20%), olivine (5%), biotite (3%), and magnetite (2%) classifying this as a diorite. Whole-rock analysis of the intermediate phase indicates a composition of 54.1% SiO_2, 17.35% Al_2O_3, 6.14% Fe_2O_3, 3.79% CaO, 2.19% MgO, 5.69% Na_2O, and 5.1% K_2O. The mafic phase contains plagioclase feldspar (35%) supported by both clinopyroxene and orthopyroxene (15%), altered olivine (10%), biotite (15%), and magnetite (10%) classifying this as a magnetite-biotite gabbronorite. Whole-rock analysis of the mafic phase indicates a composition of 41.9% SiO_2, 12.7% Al_2O_3, 15% Fe_2O_3, 8.9% CaO, 5.84% MgO, 3.69% Na_2O, and 2.65% K_2O. The mafic zones vary in the size of the crystals. Near the contact with the Fox Hills Sandstone the groundmass is predominantly aphanitic; whereas, within the sill the texture is phaneritic with crystals as large as 0.1 in (0.5 cm). Steep exposures are prone to rockfall. Thicknesses of the intrusive bodies are quite variable, ranging from less than 1.5 ft (0.5 m) for the dikes at the southwest up to approximately 200 ft (60 m) for the main sill.

Tw — **Wagontongue Formation (Miocene)** — Gray, clast-supported conglomeratic sandstone to conglomerate, with cobbles and pebbles in a matrix of coarse sand. The rounded gravel clasts include volcanic rocks, granitic rocks, quartz sandstone, chert, and other lithologies. The formation is thickly bedded to massive, and forms low ridges. It occurs only in a narrow band in the southwest part of the quadrangle near Badger Road. There are no complete sections of the formation on the quadrangle, but on the adjoining Garo quadrangle it is up to 750 ft (230 m) thick (Kirkham and others, 2007).

Tc — **Tertiary conglomerate (Miocene-Oligocene?)** — Poorly sorted and poorly lithified, polymictic, coarse-grained conglomerate with sub-rounded to well-rounded cobbles and boulders up to 1 ft (0.3 m) and occasional boulders of limestone up to 3ft (1 m). Clasts consist of mixed volcanic porphyries, occasional large clasts of andesite, quartzite, and Paleozoic Maroon and Minturn Formations. This conglomerate resembles the South Park Formation upper volcaniclastic conglomerate (Tsuv); however, it rests on top of the Oligocene Antero Formation (Ta) and contains large boulders of gray micritic lacustrine limestone. It may represent reworked South Park Formation (Tslv). The unit is up to 10 ft (3 m) and is prone to rockfall on steep slopes.

Ta — **Antero Formation (Oligocene)** — The Antero Formation is a mix of fluvial and lacustrine sediments characterized by high volcaniclastic content and the presence of lacustrine limestone. The formation tends to be dominated by fine-grained and poorly indurated sediments and is a valley former. The formation is found in the quadrangle in two distinct areas geographically isolated from each other and the stratigraphic relation from one area to the other is not clear. The first area is along the southwest edge of the quadrangle where it is composed of light-gray, tuffaceous mudstone, cream-colored tuff, and light-tan limestone that is roughly equivalent to the informal tuffaceous member recognized on the adjoining Garo quadrangle. No outcrops of this lithofacies were found in the quadrangle, and the lithologies were inferred from float. Limestone fragments occur mainly at the base of the formation. They are recrystallized, with plant debris, ooids, and stromatolites. This lithofacies of the Antero Formation is a valley former, estimated to be approximately 200 ft (60 m) thick, and is found on slopes underneath ridges of Wagontongue Formation where it is characterized by numerous small slumps. Depending on aspect and slope, the Antero Formation may be prone to slumping. The second area where the formation is found is in the central part of the quadrangle on the east side of the Santa Maria and Currant Creek faults. In this area it consists of gray to brown muddy sandstone and conglomeratic muddy sandstone that weathers tan. This sandstone is fine to coarse, and matrix-rich. Occasional lenses contain pebbles up to 1.6 in (4 cm) in diameter, which are composed of micritic limestone or chert. The sand is lithic arkose with chalky, white feldspars. Fine sandstone is thinly bedded, and coarse sandstone is thickly bedded and often cross-bedded. Coaly plant debris, petrified wood, and unionid bivalves were observed in an outcrop along Bathouse Ditch in the southeastern corner of the quadrangle. The unit is exposed in banks along the Middle Fork South Platte River from the Santa Maria Ranch south to its confluence with the South Fork South Platte River where is may be at least 150 ft (45 m) thick. Beneath the sandstone is a different lithofacies consisting of red to maroon slightly indurated, clay-rich siltstone with nodular calcareous layers interbedded, with sandstone and light-gray organic mudstone. Weathered outcrops are often characterized by reddish coloration that resembles weathered outcrops of the Jurassic Morrison Formation (Jm) or Permian Maroon Formation (PIPm). The lithofacies on the east side of the Santa Maria and Currant Creek faults do not resemble typical Antero Formation in that the light-colored tuffaceous component is conspicuously absent. Pollen analysis of a sample of an organic mudstone exposed north of the Santa Maria Ranch yielded an Oligocene age (P. Zippi, Biostratigraphy.com, LLC, written communication, 2017). Previous geologic maps have shown this as either South Park Formation, Echo Park Alluvium, or Antero Formation (Scarbrough, 2001; Rulman and others, 2011) but because of the possible Oligocene date, it is mapped as Antero Formation on this quadrangle. Similar sediments in the Antero Reservoir NE quadrangle just to the south are being mapped as Eocene Echo Park Alluvium. The base of this lithofacies is not exposed and it is estimated to be at least 200 ft (60 m) thick.

Ttc — **Tallahassee Creek Conglomerate (Eocene)** — Light-tan, matrix-supported conglomerate with pebbles, cobbles, and boulders in a matrix of poorly lithified sand, granules, mud, and volcanic ash. Boulders are up to 6 ft (1.8 m) in diameter. Common boulder lithologies include granite, granodiorite, quartzite, quartz sandstone, porphyritic volcanic rocks, and Wall Mountain Tuff (Twm). The unit lacks bedding. However, its cobbles and boulders litter the landscape over a much wider area, implying that it was originally much more extensive. This unit is prone to rockfall on steep slopes. In the southern part of the Hartsel quadrangle, the conglomerate commonly occurs as isolated deposits capping hilltops, where it is up to 115 ft (35 m) thick.

Twm — **Wall Mountain Tuff (Eocene)** — Light- to dark-gray, welded, crystal-vitric ash flow tuff that weathers to a tan color. Crystals make up approximately 30% of the tuff and include plagioclase, sanidine, pyroxene, biotite, and hornblende. In most places, the tuff is devitrified, but some pieces of glassy vitrophyre were found in the eastern limb of the High Creek syncline. Whole-rock analysis indicates a composition of 68.6% SiO_2, 15.9% Al_2O_3, 2.04% Fe_2O_3, 1.49% CaO, 0.24 % MgO, 3.83% Na_2O, and 6.37% K_2O. McIntosh and Chapin (2004) reported an average $^{40}Ar/^{39}Ar$ age of 36.69 ± 0.09 Ma for the Wall Mountain Tuff on the basis of five analyzed samples from elsewhere in the region. The Wall Mountain Tuff is a ridge-former and a cliff-former on the Hartsel quadrangle. At Antelope Bench Mark (VABM) in the southwestern part of the quadrangle, the unit is approximately 200 ft (60 m) thick, and has undergone severe hydrothermal alteration. The base of the tuff contains numerous fragments of the underlying andesitic and dacitic volcanic rocks. This unit is prone to rockfall on steep slopes. In the region, the Wall Mountain Tuff (Twm) is recognized as a source of dimension stone. It is less than 100 ft (30 m) thick in this quadrangle at the southwest edge of the quadrangle.

Tad — **Andesitic and dacitic volcanic rocks (Eocene)** — Purple volcanic breccias and lahars, dark-gray lava flows, and minor pinkish-tan conglomeratic sandstone. Lava flows occur at the base of the formation and northeast of the Antelope VABM, near the Garo Sandstone outcrop. They are porphyritic, with 0.04 to 0.12 in (0.1 to 0.3 cm) crystals of plagioclase, biotite, and pyroxene set in an aphanitic groundmass. Whole-rock analysis of the andesitic phase indicates a composition of 69% SiO_2, 14.2% Al_2O_3, 5.07% Fe_2O_3, 3.2% CaO, 0.53% MgO, 3.1% Na_2O, and 3.36% K_2O. The unit appears to be equivalent to andesite and dacite volcanic rocks in the Lone Hills on the adjacent Garo quadrangle (Kirkham and others, 2007). The silica content is higher; however, the sample appears to be hydrothermally altered. Flows are up to 20 ft (6 m) thick. The volcanic breccias contain angular pebbles to boulders of the original volcanic rocks in a matrix of volcanic ash. The volcanic lahars contain angular pebbles and cobbles of volcanic rocks, such as andesite and tuff, set in a matrix of mud, ash, sand, and granules. Large pieces of sandstone from the Maroon Formation (PIPm) and Garo Sandstone (Pg), up to a few feet long, also occur in the breccia and lahar deposits. The conglomeratic sandstone contains subangular granules and pebbles of volcanic rock set in a sandy matrix. Presence of sandstone interbedded with the breccias and lahars indicates that periods of sedimentary deposition occurred between multiple episodes of volcanic activity. The various layers of andesitic and dacitic volcanic rocks are not all the product of a single large eruption. These rocks form a large, steep hill underneath the Wall Mountain Tuff (Twm) at the Antelope VABM in the southwestern part of the quadrangle. This unit is prone to rockfall on steep slopes. The andesite and volcanic rocks have undergone hydrothermal alteration, and are about 200 ft (60 m) thick.

Tec — **Elkhorn conglomerate (Eocene?)** — Tan, poorly sorted conglomerate containing subangular to sub-rounded boulders and cobbles with a matrix of coarse-grained sand. This unit was recognized by Ruleman and others (2011) as the syntectonic conglomerate unit but is given the informal name of Elkhorn conglomerate, herein to associate with a type locality. Clasts as large as 6.5 ft (2 m) are derived from pink granite and light-gray gneissic granite. Most igneous clasts in unit are slightly weathered. Ruleman and Bohannon (2008) interpreted this unit to be coeval with displacement along the west-verging Elkhorn thrust, just to the east, that places Precambrian granite and gneiss above the South Park Formation. This unit is prone to rockfall on steep slopes. Larger boulders may be a source for landscape material. The unit is approximately 30 ft (9 m) thick in a small exposure at the northeastern corner of the quadrangle where it is nearly flat-lying above an angular unconformity that separates it from the underlying Paleocene South Park Formation.

South Park Formation (Paleocene-Eocene?)

Regionally, the South Park Formation is recognized to include Upper Cretaceous volcanic rocks at its base (Ruleman and others, 2011). Only Paleocene members have been identified on this quadrangle.

Tsua — **South Park Formation, upper arkosic conglomerate member (upper Paleocene)** — Coarse-grained, angular to rounded boulder conglomerate composed almost entirely of granitic and metamorphic Precambrian clasts. This unit has not been recognized as a separate member in nearby quadrangles (Kirkham and others, 2007; Ruleman and Bohannon, 2008; Bohannon and Ruleman, 2009; Ruleman and others, 2011); however, because of its position and composition, it has been given an informal name herein. It may be time-equivalent to the fine-grained arkosic member recognized farther to the north (Wyant and Barker, 1976; Ruleman and Bohannon, 2009; Ruleman and others, 2011). Matrix is arkosic, poorly sorted and unconsolidated coarse, granular sandstone with larger clasts ranging up to 8 ft (2.4 m) in diameter. The unit forms distinct ridges on the east side of the quadrangle where beds dip concordantly with other beds of the South Park Formation. There is no indication of mixing with volcanic sources. Scarce flow directions are to the southwest. The upper part is truncated by the Elkhorn thrust, east of the map area. This unit is prone to rockfall on steep slopes. Larger boulders may be a source for landscape material. Estimated thickness exposed within this quadrangle is at least 460 ft (140 m).

Tsuv — **South Park Formation, upper volcaniclastic member (upper to middle Paleocene?)** — Poorly sorted and poorly lithified, polymictic, coarse-grained conglomerate with clasts ranging from rounded to well-rounded cobbles and boulders up to 1 ft (0.3 m). This unit has not been recognized as a separate member in nearby quadrangles (Kirkham and others, 2007; Ruleman and Bohannon, 2008; Bohannon and Ruleman, 2009; Ruleman and others, 2011); however, because of its position above the Link Springs Tuff Member, it has been given an informal name herein. It is a conglomerate much like the South Park Formation lower volcaniclastic conglomerate; however, clast variety is more diverse with mostly mixed volcanic porphyries, occasional large clasts of andesite containing disseminated chlorite, more abundant clasts of quartzite, more clasts of Paleozoic Maroon and Minturn Formations (PIPm, IPm), and occasional vein quartz within the deposit. Granitic clasts are rare. The upper part of unit is finer grained and grades into a series of red paleosols developed in fine-grained sandstone and siltstone. It interfingers with the upper arkosic conglomerate member (Tsca) toward its top. This unit is prone to rockfall on steep slopes. Larger boulders may be a source for landscape material. Estimated thickness is at least 575 ft (175 m).

Tsl — **South Park Formation, Link Springs Tuff Member (middle to lower Paleocene)** — Interval of predominantly fine- to medium-grained sandstones, siltstones and tuffs, exposed on the east side of the quadrangle. This occurrence is south of the Link Springs Tuff type section (Sawatzky, 1967). In this quadrangle, the base is defined by the first occurrence of arkosic sandstone containing angular granitic pebbles and cobbles. Some 6.6 to 26 ft (2-8 m) intervals of polymictic, predominantly volcanic, coarse well-rounded cobble to 1 ft (0.3 m) boulder conglomerate are present near the base. At least two distinct, laterally continuous, beds of cream-colored volcanic ash are present in the upper part of the unit. The beds are only locally exposed on the east side of the unit's extent. Locally, the ash appears to be reworked by fluvial transport and in others relict lapilli are well preserved. A lower ash bed is predominantly fine grained, while the upper can be coarser grained with pumice clasts up to 0.2 in (0.5 cm). Fossil tree trunks are common, often associated with fragments of distinct red chert. Bryant and others (1981) reported an age of 59.7 ± 2.0 Ma from $^{40}Ar/^{39}Ar$ on biotite in an ash bed from near the type locality. Pollen analysis of a sample of a mudstone near the base, and below the ash beds, yielded a late-early Paleocene age (P. Zippi, Biostratigraphy.com, LLC, written communication, 2017) which is consistent with a middle Paleocene age for an ash bed stratigraphically above. This unit is prone to collapse and rockfall on steep slopes. Thickness of this unit in this quadrangle is approximately 360 ft (110 m).

Tslv — **South Park Formation, lower volcaniclastic member (lower Paleocene)** — Poorly sorted and poorly lithified, polymictic, coarse-grained conglomerate with clasts ranging from rounded to well-rounded cobbles and boulders up to 8 ft (2.4 m). This unit was previously mapped as the coarse-grained conglomerate member (Kirkham and others, 2007), or the conglomerate member of the South Formation (Ruleman and others, 2011); however, because there are other conglomerate members in this area, it has been given a more unique informal name herein. Basal boulders of the conglomerate predominantly consist of volcanic porphyry likely derived from the Reinecker Ridge Volcanic Member of the South Park Formation (Sawatzky, 1967; Wyant and Barker, 1976; Widmann and others, 2005; Kirkham and others, 2006). Above its base, boulders quickly grade to fine-grained porphyries derived from western sources in the Sawatch and northern Mosquito Range (Widmann and others, 2005). White (Pando) porphyry, Paleozoic quartzites, hornfels and red well-sorted quartz-rich sandstone clasts derived from the Maroon and Minturn Formations (PIPm, IPm) appear successively upward in unit. On the east side of the quadrangle, white porphyry is extremely rare. Volcaniclastic boulders and cobbles can be deeply weathered. Rare pebbles of black chert, possibly from the basal Dakota Sandstone (Kd), well-sorted quartz sandstone cobbles from the Garo (Pg) or Dakota Sandstones, and large, well-indurated limestones and dolomites from Paleozoic sources are also part of the conglomerate, except at its base. Matrix within the conglomerates is rarely exposed, but is more common on the east side of the quadrangle where it is consists of poorly sorted, angular, medium-grained volcaniclastic sandstone. Cross bedding is usually placer lined with heavy minerals, which are often strongly magnetic. Scarce paleocurrent measurements in this area indicate transport towards the east or southeast. In localized areas, such as South Reinecker Ridge, red soil horizons are present in a fine-grained sandstone and siltstone interval that is 20 ft (6 m) thick; this interval separates coarse conglomerate intervals that are up to 60 ft (18 m) thick. On the east side of the quadrangle, fossilzed wood and tree remains are common in the upper part of unit. The most complete preservation of the unit is found in the eastern part of the quadrangle. Outcrops are often poorly exposed, consisting of fault-bound blocks scattered across the landscape, but occasionally they form local, well-indurated ridges on the east side of the quadrangle. Its age must be younger than clasts of the Reinecker Ridge Volcanic Member found in the basal part of the unit, which are reported to be 66.94 ± 0.25 Ma using $^{40}Ar/^{39}Ar$ analysis on hornblende from a sample near Como (Widmann and others, 2005). Andesitic clasts collected from the unit on Reinecker Ridge, north of this quadrangle, yielded $^{40}Ar/^{39}Ar$ ages between 64.08 ± 0.11 Ma (Widmann and others, 2005) and 66.6 Ma ± 0.5 on biotite (Kirkham and others, 2006). Its upper age is constrained by a late-early Paleocene age from the Link Springs Tuff Member pollen analysis described above. At Reinecker Ridge, approximately 165 ft (50 m) is exposed, but a clear top is not preserved. In this quadrangle, an angular unconformity separates this unit from underlying folded and faulted Fox Hills Sandstone and Pierre Shale. This unit is prone to rockfall on steep slopes. Boulders may be a source for landscape material. Thickness is estimated to be up to 500 ft (150 m) in the eastern part of the quadrangle.

MESOZOIC SEDIMENTARY ROCKS

Kfh — **Fox Hills Sandstone (Upper Cretaceous)** — Light-tan to white, very fine- to medium-grained, cross-bedded to massive sandstone that grades downward into gray, thinly interbedded, silty marine shale and fine-grained sandstone. The sandstone is often stained orange by interstitial iron oxide. Rare thin beds of soft lignite were noted in drainage ditches along tributaries to Threemile Gulch. In some locations, the Fox Hills Sandstone consists of multiple overlapping shingles of upward-coarsening marine lower shoreface to backshore deposits (Dechesne and others, 2011). Limited exposure and complex structural deformation within this quadrangle limits the ability to determine whether there is one, or a series of multiple shingles. The indurated to very friable sandstone facies occasionally forms knobby ledges. The finer-grained interbedded shale and sandstone facies typically forms low hills or is only exposed in ditches and deep ravines. This facies is transitional with the upper part of the Pierre Shale (Kp) stratigraphically below, and differentiation is based on the relative content of thin sandstone beds; a cut-off of approximately 50% sandstone was generally used. Previous geologic maps of the area have included this facies as part of the Pierre Shale (Kp) (Scarbrough, 2001; Ruleman and Bohannon 2008; Bohannon and Ruleman, 2009; and Ruleman and others, 2011). However, because of the gradational relationship with the massive sandstone facies, it is mapped as the Fox Hills Sandstone herein. The Middle Fork South Platte River exposes a highly deformed section of the thinly interbedded facies of the unit at the east edge of the quadrangle revealing a face of symmetric ripples with axes oriented northeast to southwest. Where shale content is high, the unit is prone to landslides and dipping thin beds of bentonite can result in differential heaving bedrock. Total unit thickness is difficult to estimate because of structural deformation, but it may reach 390 ft (120 m) where exposed in the quadrangle.

Kp — **Pierre Shale (Upper Cretaceous)** — Medium- to dark-gray, calcareous, marine shale with thin beds of brownish-gray to olive-drab sandstone and siltstone. The formation underlies the Quaternary deposits in the valley floors of the Middle Fork South Platte River and the unnamed gulch heading northeast of Bald Hill. Outcrops of the Pierre Shale are rare in the quadrangle. The best exposures are in deep recent ravines and gullies along the east bank of the Middle Fork South Platte River and along the axis of the Hartsel anticline in the southeastern part of the quadrangle. Tan to gray fine-grained sandstone interbeds in gullies at the base of Reinecker Ridge, approximately 1.9 mi (3 km) northeast of Santa Maria Ranch may be the Apache Creek Sandstone Member recognized in the subsurface. The Pierre Shale conformably overlies the Niobrara Formation. The Pierre Shale is prone to landslides and differential heaving bedrock of the dipping strata. In nearby quadrangles, Barker and Wyant (1976) and Wyant and Barker (1976) estimated a total thickness of about 6,000 ft (1,830 m). In the northwestern part of this quadrangle, an unknown thickness of upper Pierre strata was removed by erosion prior to deposition of the South Park Formation.

Kn — **Niobrara Formation (Upper Cretaceous)** — Regionally, the Niobrara Formation is divided into two members, the Fort Hays Limestone Member and the overlying Smoky Hill Shale Member (Barker and Wyant, 1976; Wyant and Barker, 1976; Widmann and others, 2005). The Fort Hays Limestone Member is the only member exposed in this quadrangle and consists of chalky, creamy-white to light-gray marine limestone exposed in the west banks of the Middle Fork South Platte River. The Smoky Hill Shale Member is concealed by surficial deposits and residuum. The Niobrara Formation disconformably overlies the Benton Group. Shale beds in this unit are prone to landslides. Total thickness of the Niobrara Formation is estimated to be 390 to 460 ft (120 to 140 m); however, only up to 50 ft (15 m) of the Fort Hays Member are exposed in this quadrangle.

Benton Group (Upper Cretaceous)

Kcjc — **Carlile Shale — Juana Lopez and Codell Sandstone members, undifferentiated** — Light-brown, fossiliferous, fetid, calcarenite that forms distinct ledges along the banks of the Middle Fork South Platte River. Locally, it may contain medium-brown fragments of *Inoceramus* of varying sizes up to 1.2 in (3 cm). The matrix consists primarily of calcareous prisms. In this quadrangle, the limestone is estimated to be up to 10 ft (3 m) thick and overlies a tan to gray, fine- to medium-grained calcareous sandstone that grades downward into gray fissile shale. The sandstone is thinly bedded with occasional oscillation ripple cross beds. The limestone has the potential to be used for dimension stone and landscape material. Total thickness of the sandstone is estimated to be 13 ft (4 m).

Kb — **Benton Group, undivided** — Light- to medium-gray shale, with a thin bed of brown limestone intermittently exposed along the west bank of the Middle Fork South Platte River. Regionally, three formations are recognized in this group (Barker and Wyant, 1976; Wyant and Barker, 1976) including in ascending order: the Graneros Shale, Greenhorn Limestone, and Carlile Shale. In this quadrangle, the Benton Group is generally concealed by surficial deposits and residuum and the individual formations were not differentiated. Shale within the Benton Group is prone to landslides and differential heaving bedrock of the dipping strata. The total estimated thickness in this quadrangle is between 200 and 250 ft (60 and 75 m).

Kd — **Dakota Sandstone (Lower Cretaceous)** — White to light-gray, fine- to medium-grained, well-sorted, ridge-forming quartzose sandstone weathering white to orange brown. Fossil burrows are common and the sandstone is typically cross-bedded throughout. Thin beds of chalky, silty gray shale are present in the middle part of the formation in the exposure immediately west of the town of Hartsel. Lenses of conglomerate are reported to occur at the base of the formation (Widmann, 2005); however, conglomeratic lenses were not observed in this quadrangle. Rip-up clasts of mudstone are present near the top of the unit in the hogback ridge west of Hartsel. Quartz-filled deformation bands are common along the Red Hill hogback above the west bank of the Middle Fork South Platte River. The unit can be brittle and often highly fractured. The Dakota Sandstone is differentiated from sandstone in the underlying Morrison Formation by the lack of interstitial clay. This unit is prone to rockfall on steep slopes and slopes below outcrops are usually blanketed with unstable colluvium. The sandstone has the potential to be used for dimension stone and landscape material. Estimated thickness in this quadrangle is 250 ft (75 m) and it is separated from the underlying Morrison Formation by a disconformity.

Jm — **Morrison Formation (Upper Jurassic)** — Generally recessive, interbedded fine- to medium-grained sandstone, sandy shale, shale, siltstone, conglomerate, and limestone that weathers to various shades of greenish-gray, red, orange, and yellow. Discontinuous beds and lenses of light-gray micritic limestone less than 3 ft (1 m) thick are prevalent in the lower part of the formation and can form a distinct marker horizon. The formation grades progressively upward from limestone, shale, and mudstone at its base to interbedded shale and well-sorted, fine-grained, quartz-rich sandstone near the top. The sandstone typically contains pearly-white interstitial clay. Locally, a creamy-white brittle silicified mudstone in the upper part of the unit forms distinct porcelain-like colluvium on slopes and in gullies. The shale beds within the unit are prone to landslides and the sandstone layers are prone to rockfall from steep exposures. Estimated thickness in this quadrangle is 330 ft (100 m) and it is separated from the underlying Garo Sandstone by a disconformity.

Pg — **Garo Sandstone (Jurassic or Permian)** — Pinkish-tan, very fine- to medium-grained sandstone that is rounded and well sorted. Sand grains are mostly quartz with minor feldspar. Quartz grains are generally round or subround and coarser grains are frequently frosted. The formation contains large planar cross beds, 3 to 4 ft (1 to 1.2 m) high. Quartz-filled deformation bands are common along the Red Hill hogback above the west bank of the Middle Fork South Platte River. The sandstone tends to be highly fractured and rubbly and does not form distinct outcrops in most places, yet it is resistant and forms ridges. Age of the Garo Sandstone is uncertain with some workers assigning it to the Permian (DeVoto, 1965), and others correlating it with the Jurassic Entrada Sandstone (Stark, 1949). Widmann and others (2005) and Kirkham and others (2011) have adopted the Permian age from DeVoto (1965), who described a conformable relationship with the underlying Maroon Formation in the exposure above Badger Springs in this quadrangle. The base of the formation in this area was found to be concealed with colluvium and the conformable relationship could not be verified. This unit is prone to rockfall on steep slopes and since it is often highly fractured; slopes below outcrops are usually blanketed with unstable colluvium. The sandstone has the potential to be used for dimension stone and landscape material. Estimated thickness varies between 65 and 215 ft (20 and 65 m).

PALEOZOIC SEDIMENTARY ROCKS

PIPm — **Maroon Formation (Pennsylvanian to Permian (?))** — Red, pink, and gray sandstone, siltstone, shale, conglomerate, and limestone. The sandstones and siltstones are fine grained to coarse grained. They are arkosic, with abundant pink feldspar. The fine-grained lithologies commonly are laminated or ripple cross-laminated. The coarser lithologies are bedded, trough cross-bedded, or planar cross-bedded. The conglomerates contain granules, pebbles, and cobbles of quartz, feldspar, and granitic rocks, set in a matrix of coarse feldspathic sand. The limestones are shown as line features on the map. They are light gray to medium gray, blocky, and micritic. They occur in discontinuous beds up to 5 ft (1.5 m) thick and 1000 ft (304 m) long. They are resistant to weathering and tend to form small ridges. The Maroon Formation sits conformably on the Minturn Formation. The Hartsel quadrangle lacks a complete, unfaulted section, but at least 2,400 feet (730 m) of section are present in the Colton syncline. On the adjoining Fairplay East quadrangle, the Maroon Formation is about 5,300 to 5,600 feet (1,615 to 1,705 m) thick (Kirkham and others, 2006).

PIPml — **Maroon Formation, unnamed limestone beds**

Minturn Formation (Middle Pennsylvanian)

IPmu — **Minturn Formation, upper interval** — Gray, pink, and red sandstone, siltstone, shale, conglomerate, and limestone. Sandstones are fine grained to coarse grained and conglomeratic. Conglomerates contain granules, pebbles, and cobbles up to 5 inches (13 cm) in diameter. Sand is angular or subangular; gravel is subrounded. The sandstones and conglomerates are arkosic, with abundant pink feldspar. Limestones are micritic or recrystallized. The unit contains intraclasts of similar composition, stromatolites, gastropods, and possibly phylloid algae. Shale and siltstone are thinly bedded to laminated or ripple cross-laminated. Sandstone and conglomerate are thinly to thickly bedded, with trough cross beds and planar cross beds. Limestones are thickly bedded and blocky. The upper interval typically forms valleys; however, the limestone and conglomerate beds form small ridges. The interval is about 2,000 ft (610 m) thick.

IPmjm — **Minturn Formation, Jacque Mountain Member** — Numerous beds of gray, micritic or recrystallized limestone, interbedded with red siltstone, pink sandstone, and gray or pink conglomerate are shown as a line feature on the map. The limestone beds are about 2 to 5 ft (0.6 to 1.5 m) thick; several contain intraclasts of similar composition. The sandstones and conglomerates are arkosic, and are about 10 to 20 ft (3 to 6 m) thick. The conglomerates are unusually coarse, with cobbles up to 5 in (12 cm) in diameter. The siltstones are calcareous, and are about 10 ft (3 m) thick. It is the highest prominent and laterally extensive limestone-bearing horizon in the upper interval. The member is about 60 ft (18 m) thick.

IPml — **Minturn Formation, unnamed limestone beds**

IPmr — **Minturn Formation, Robinson Member**—Numerous beds of gray, finely crystalline limestone and dolostone, interbedded with light-brown siltstone and very-fine grained sandstone shown as a line feature on the map. The carbonates are about 5 to 10 ft (1.5 to 3 m) thick. The siltstones are about 10 to 15 ft (3 to 4.5 m) thick, and the sandstones are about 2 to 5 ft (0.6 to 1.5 m) thick. Both the sandstones and siltstones have planar laminae. It is the lowest prominent and laterally extensive limestone-bearing horizon in the upper interval. The member is about 40 ft (12 m) thick.

IPme — **Minturn Formation, evaporite facies**—Light-gray to dark-gray shale, gypsiferous mud shale, limestone, gypsum, and fine sandstone; limestone and sandstone weather to a tan color. The shales and sandstones are laminated to thinly bedded and the sandstones are arkosic. The limestones are micritic or stromatolitic and contain ooids and intraclasts; some of the limestone beds are vuggy resembling tufa. Where exposed, the gypsum is very coarsely crystalline. In some places the gypsum has a nodular texture with thin, dark stringers of other minerals separating nodules, often referred to as "chicken wire" structure; in other places, relict laminae are present. It occurs in a massive bed up to 100 ft (30 m) thick near Badger Road in the southwest part of the quadrangle. The evaporite facies forms valleys where it tends to form cryptogamic soils and sinkholes. The Minturn Formation evaporite facies can form corrosive soils and has the potential for collapse. Dissolution can form karst features. Its total thickness is unknown, but at least 1,950 ft (595 m) of the facies is present on the Hartsel quadrangle.

IPmg — **Minturn Formation, gypsum bed**

PIPmm — **Minturn and Maroon formations, undifferentiated (Pennsylvanian to Permian (?))** — Red, pink, and gray sandstone, siltstone, shale, conglomerate, and limestone. The sandstones and siltstones are fine- to coarse-grained, thinly bedded, and arkosic. The conglomerates contain granules, pebbles, and cobbles of quartz, feldspar, granitic rocks, sandstone, siltstone, and micritic limestone up to 10 in (25 cm) in diameter, set in a matrix of coarse feldspathic sand. Limestones are gray, light purple, or pink. They are micritic or recrystallized, and occur in discontinuous bodies up to 20 ft (6 m) thick and 2800 ft (850 m) long. The limestones contain stromatolites, crinoid columnals, and bellerophont gastropods. The limestone bodies are resistant to weathering and tend to form small ridges. The undifferentiated Minturn and Maroon formations are mapped south of the Hartsel fault, on the Hartsel uplift. The unit sits nonconformably on Precambrian igneous rocks. The upper surface of the igneous rocks shows a weathering zone of massive, dark maroon, granular and sandy siltstone. This unit is up to 200 ft (61 m) thick; it thins and pinches out in the eastward direction near the town of Hartsel.

PIPmml — **Minturn and Maroon formations, undifferentiated, unnamed limestone beds**

PRECAMBRIAN IGNEOUS ROCKS

Yp — **Pegmatite bodies (Mesoproterozoic?)**—Pink, equigranular, granite pegmatite within the granodiorite of the Hartsel uplift. The pegmatite consists primarily of potassium feldspar, plagioclase, quartz, muscovite and minor biotite in sheet-like bodies with irregular thickness up to 10 ft (3 m) and up to 1.6 mi (0.5 km) long. The bodies are repeatedly layered in a sheet-like fashion anywhere from 30 to 100 ft (9 to 30 m) apart. On the east side of a north-to-northeast trending fault just west of Hartsel, the sheets have an east-west to northwest strike and dip gently to the north; on the west side of the fault the sheets have a northeasterly strike, and dip gently to the northwest. The bodies are more resistant than the host granodiorite and form distinct ledges on slopes. There are associated aplitic and phaneritic extensions that branch off of the sheeted pegmatite bodies. This unit is prone to rockfall on steep slopes.

YXg — **Granite (Mesoproterozoic-Paleoproterozoic?)**—Pink, equigranular granite in the Hartsel uplift in the southern part of the quadrangle. Occurs as small bodies within the host granodiorite and is more resistant than the host rock. The granite consists of potassium feldspar, plagioclase, quartz, muscovite and minor biotite and ranges in crystal size from 0.4 to 0.8 in (1-2 cm).

Xgd — **Granodiorite (Paleoproterozoic?)**—Pink, non-foliated, granodiorite with salt and pepper texture containing phenocrysts of potassium feldspar within a finer-grained phaneritic groundmass of quartz, plagioclase, biotite, and up to 2% magnetite. This unit comprises a majority of the Hartsel uplift. Granodiorite forms rolling hills where deeply weathered that contrasts with cross-cutting pegmatite bodies. Spheroidal weathering rinds and exfoliation textures are common on fresh exposures. The erosional contact between the granodiorite and the overlying Maroon Formation is occasionally mineralized with malachite and azurite. This unit is prone to rockfall on steep slopes.

MAP SYMBOLS

Contact — Approximately located

Fault — Dashed where approximately located, dash-dot where inferred, dotted where concealed; U = upthrown side, D = downthrown side where known

Normal fault — Dashed where approximately located, dash-dot where inferred; ball and bar on downthrown block

Thrust fault — Dashed where approximately located, dash-dot where inferred, dotted where concealed; sawteeth on upper plate

Reverse fault — Dashed where approximately located, dotted where concealed; rectangles on upthrown block

Anticline — Identity and existence certain, dashed where approximately located, dotted where concealed

Syncline — Identity and existence certain, dashed where approximately located, dotted where concealed

Landslide scarp — Active, sharp, distinct, and accurately located. Hachures point down scarp

Closed depressions — Tics on internally drained side of a natural closed depression

Alignment of cross section (A — A')

Strike and dip of inclined bedding — Showing direction and angle of dip in degrees.

Strike of vertical bedding

Strike and dip of overturned bedding — Showing direction and angle of dip in degrees

Strike and dip of fault — Showing direction and angle of dip in degrees

Strike and dip of intrusive rocks — Showing direction and angle of dip in degrees

Estimated strike of inclined bedding — Shown where dip could not be measured in field

[1] Age assignments follow the International Commission on Stratigraphy International Chronostratigraphic Chart v. 2017/02 (Cohen and others, 2013; updated)

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