

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

**Disturbed and/or reclaimed ground (uppermost Holocene)** — Deposits in areas where the land has been disturbed as a result of mining or quarrying operations. Target resource fill material or imported fill material. Fill materials can vary from sand, silt, and clay to gravel and boulders and may include refuse of many types including household and industrial wastes. Some locations have been contoured and re-vegetated to mimic the surrounding landscape. Other areas have been adapted to other uses or have been left vacant. The average thickness of the unit is 20 feet.

**Artificial fill (uppermost Holocene)** — Riprap, fill, and refuse placed during construction of roads, railroads, buildings, dams, and landfills. Generally consists of unsorted silt, sand, clay, and rock fragments. The average thickness of the unit is less than 20 feet. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted.

**Lake deposits (uppermost Holocene)** — Clay, silt, and fine sand deposits in footprint of human-made lakes and irrigation ponds. Can contain refuse and other debris from human activities on and adjacent to the impoundment. Old lake deposits are unconsolidated, unstable, and subject to settling and slumping.

ALLUVIAL DEPOSITS

**Alluvium one (Holocene to Upper Pleistocene)** — Tan to medium-brown, poorly to moderately sorted, poorly to moderately consolidated, sand, gravel, silt, and minor clay and sparse boulders. Deposits in the currently active stream channels, or in low stream-terrace deposits less than 7 feet higher than the current stream channel that are flooded during most spring run-off seasons, are designated Qa1, and those between 7 and 15 feet higher than the active channel that are flooded only in very high run-off seasons, are designated Qa2. Clasts are surrounded by well rounded and the dominant sediment is sand with a sandy silt matrix, with localized gravels. Deposits associated with the Yampa River consist of up to 7 feet of sand and silt over a medium bedded pebble and cobble gravel of granitic gneiss, hornblende gneiss, vein quartz, occasional red quartzitic sandstone and rare vesicular basalt. The alluvium deposited along Fortification Creek and Elkhead Creek consists of at least 10 feet of sand and silt over a pebble and cobble gravel of granite, gneiss, quartzite, chert, basalt, and rare andesite. Maximum exposed thickness of the unit locally exceeds 10 feet. The unit is connected to modern perennial and intermittent stream courses and is subject to frequent flooding and is a source of sand and gravel.

**Alluvium, undivided (Holocene to Upper Pleistocene)** — Brown to tan, poorly to moderately sorted, moderately to well consolidated, sand and silt in valley heads and in tributary streams. The unit often covers broad floors of deep arroyos carved into bedrock or older Quaternary sediments. Thickness may exceed 10 feet. It is commonly saturated with groundwater in otherwise dry badlands and may have local depressions filled with stagnant water. Areas underlain by the unit may be subject to flooding.

**Older gravel deposits (Pleistocene)** — Variably colored, poorly sorted, fine to coarse sand interbedded with pebble and cobble gravel. Clasts are moderately to well rounded with diameters generally less than 6 inches. Matrix consists predominantly of quartz, feldspar, and lithic fragments. Clasts consist of granite, gneiss, quartzite, chert, sandstone, basalt, and rare andesite. Sources of gravel and matrix are exposures of Fort Union and Wasatch Formations with likely reworking of older bedrock gravel deposits and transport of volcanic clasts from the Elkhead Mountains. In places, the unit may be equivalent with Qamf where the finer-grained silt and clay has been eroded away leaving the coarse-grained gravel. The unit locally exceeds 15 feet in thickness. The deposit forms a stable building surface and is a potential source of sand and gravel.

**Older alluvium of Elkhead Creek (Pleistocene)** — Tan to gray-tan, poorly sorted, fine to coarse sand interbedded with pebble and cobble gravel. Fines are dominant at the top of the unit and may include, and be indistinguishable from, overlapping colluvium and sheetwash deposits. Clasts are subrounded to well rounded with sizes generally less than 6 inches that may be weakly weathered, or coated with CaCO3. Matrix consists predominantly of quartz, feldspar, and lithic fragments derived from multiple sources. Clasts consist of quartz, granite, gneiss, quartzite, dark white and gray chert, sandstone, and vesicular basalt, massive basalt, andesite, and dacite. Sources are exposures of Fort Union and Wasatch Formations with likely reworking of older bedrock gravel deposits as well as transport of volcanic clasts from the Elkhead Mountains. The deposits underlie terraces between 10 and 120 feet above the modern floodplain. The unit locally exceeds 10 feet in thickness. The deposit forms a stable building surface and is a potential source of sand and gravel.

**Older alluvium of Fortification Creek (Pleistocene)** — Medium-tan to grayish-brown, poorly sorted, fine to coarse sand interbedded with pebble and cobble gravel. Clasts are subrounded to well rounded with diameters generally less than 6 inches that may be weakly weathered, or coated with CaCO3. Matrix consists predominantly of quartz, feldspar, and lithic fragments derived from multiple sources. Clasts consist of granite, gneiss, quartzite, chert, sandstone, basalt, and rare andesite. Sources of gravel and matrix are exposures of Fort Union and Wasatch Formations with likely reworking of older bedrock gravel deposits and transport of volcanic clasts from the Elkhead Mountains. The deposit locally exceeds 10 feet in thickness and underlies terraces between 10 and 120 feet above the active stream channel. The lower terraces are subject to flooding during high discharge events. The deposit forms a stable building surface and is a potential source of sand and gravel.

**Older alluvium of the Yampa River (Pleistocene)** — Medium-gray to grayish-brown, poorly sorted, fine to coarse sand, interbedded with pebble and cobble gravel. Fines are dominant at the top of the unit and may include, and be indistinguishable from, overlapping colluvium, mud fan, and sheetwash deposits. Clasts are subrounded to well rounded, with sizes generally less than 8 inches, although rare clasts can reach 2.5 feet in diameter that may be weakly weathered, or coated with CaCO3. Matrix consists predominantly of quartz, feldspar, and lithic fragments derived from multiple sources. Clasts consist of granite, gray diorite, pink, white, and black gneiss, quartz, red quartzite sandstone, brown and gray chert, and rare vesicular basalt. The unit is generally unconsolidated, but occasionally may be cemented with CaCO3. The deposit underlies terraces between 10 and 200 feet above the modern floodplain and thickness can locally exceed 20 feet. In many areas the unit has been quarried for sand and gravel. The deposit forms a stable building surface.

ALLUVIAL FAN DEPOSITS

**Alluvial fan deposits (Holocene to Upper Pleistocene)** — Variably colored, well to poorly sorted, poorly consolidated, sand and gravel deposited in broad, fan-shaped alluvial fans, and coalescing fans in local basins over surfaces with moderate slopes. The sediments were deposited primarily by muddy debris flows with occasional input from sheetwash, and water-flood flows. Areas mapped as Qaf may be subject to future flash floods and debris flow events. Qaf deposits may exceed 25 feet in thickness in valley-head and valley-side areas and could be a local source of sand and gravel. The unit is gradational with Qamf, which is differentiated by the dominance of fine-grained material on lower depositional slopes.

**Alluvial fan, sheetwash, and colluvial deposits, undivided (Holocene to Upper Pleistocene)** — Variably colored, locally derived, silt, sand, and gravel, color and composition depends on source material. Occurs in small stream channels and floodplains along valley floors of ephemeral, intermittent, and small perennial streams, on gentle hillslopes, and as colluvium along valley sides. Alluvium and sheetwash deposits are typically composed of poorly to well sorted, stratified, interbedded, pebbly sand, sandy silt, and sandy gravel. Colluvium may range from unsorted, clay-supported, pebbles to boulder grade, sandy matrix to matrix-supported, gravelly, clayey sand. The unit may be prone to hydrocompaction. Maximum thickness of the unit is approximately 15 feet.

**Alluvial, mud flow and mud fan deposits (Holocene to Upper Pleistocene)** — Variably colored, well to poorly sorted, poorly consolidated, clayey to sandy silt, sand and gravel, deposited in valley-head and valley-side alluvial fans, tributary stream valleys, and coalescing fans in local basins over surfaces with very gentle slopes. Proportion of fine-grained material to coarse is gradational depending on bedrock source material in the local watershed. The deposits comprise a complex system of deposits that may extend for miles along tributary stream reaches. The basins and valley-floored sediments were deposited primarily by muddy debris flows with occasional input from sheetwash, hyperconcentrated flows, and water-flood flows. Areas mapped as Qamf may be subject to future flash floods and debris flow events, especially in non-irrigated valley-head and valley-side areas and within the deeply dissected modern arroyo channels. The deposit may be prone to significant collapse from dispersion, hydrocompaction, or slope failure when wetted or loaded. Qamf deposits have been used for agriculture as cropland and pasture, although irrigation is required. Qamf deposits may exceed 5 feet in thickness in valley-head and valley-side areas and may exceed 15 feet in thickness along the valley reaches and in the basins. Many of the tributary-stream mudflow deposits and coalescing fans have been deeply dissected by stream erosion during the late Holocene, resulting in narrow, steep-walled arroyos that are 5 to 20 feet deep along the valley bottoms in most areas. The unit is gradational with Qaf, which is differentiated by the dominance of coarse-grained material on steeper, more distinct fan-shaped depositional slopes.

**Older alluvial, mud flow, and mud fan deposits (Pleistocene)** — Composition and mode of deposition similar to Qamf; however, the unit is approximately 10-15 feet higher than the younger Qamf deposits. Exposures in arroyo walls often indicate graded material with coarse gravel lag sand and gravel overlain with finer-grained silt and clay. The unit may be prone to hydrocompaction.

MASS-WASTING DEPOSITS

**Landslide deposits (Holocene to Upper Pleistocene)** — Heterogeneous deposits consisting of unsorted and unstratified clay, silt, sand, and cobble- and boulder-sized rock fragments. Unit includes rotational and translational slides and complex earthflow mass movements. Generally, head scarps (near-vertical detachment scars) exposed at the top of and sides of the landslides are readily recognizable; however, some scarps may be eroded or not pronounced. Other common diagnostic features include hummocky topography, closed depressions, sag ponds, fissures, terraces, tension cracks, and pressure ridges at the toe of the mobilized mass. Landslide areas are subject to future movement during episodes of heavy rain or snowmelt or may be reactivated by human-made disturbances such as cutting of slopes for roads, quarries, grades for housing developments, and irrigation and septic systems. Landslide deposits are prone to settlement when loaded or wetted. The deposits may contain expansive soils there derived from shale and mudstone formations. Thickness of landslide deposits locally exceeds 10 feet.

**Colluvial deposits (Holocene to Upper Pleistocene)** — Weathered rock fragments, free-standing, or in a sandy silt matrix to matrix-supported, gravelly, clayey, sandy silt. Unit contains angular to subangular clasts, and is weakly stratified. Colluvium of large cobble- and boulder-sized rock fragments may include rockfall debris beneath outcrops of ledge-forming sandstone units. Deposits locally exceed 15 feet in thickness. Areas mapped as colluvium are susceptible to future rockfall events.

EOLIAN DEPOSITS

**Eolian deposits (Holocene to Upper Pleistocene)** — Yellowish-brown to reddish-brown, fine to medium sand and silt deposited primarily by wind. Grains are subangular to subrounded. The deposits form blankets, or occasionally drifts and small dunes, that are thickest on northeast-facing slopes. Dryland farming is common in areas underlain by these deposits especially where silt dominates. These eolian deposits are moderately compacted and easily excavated; however, they can hold surface water. Unit may reach 15 feet in thickness.

BEDROCK UNITS

**Wasatch Formation (Eocene)**  
**Wasatch Formation, conglomerate facies** — Weakly stratified conglomerate consisting of gravel to cobble-sized clasts of white quartz, granite, gneiss, red sandstone, chert, and petrified wood fragments. Represents a gradational coarsening upward facies of the mudstone facies (Twm). Maximum thickness of the Wasatch Formation conglomerate facies in the mapped area is approximately 100 feet and is found on hillslopes south of Hayden Cutoff.

**Wasatch Formation, mudstone facies** — Variegated reddish-brown, lavender, yellow, and tan mudstone and siltstone with buff colored sandstone and conglomerate near the unconformable basal contact with the underlying Fort Union Formation. The mudstone typically contains flakes of mica (muscovite) that give the unit a whitish sheen and differentiates the mudstone from underlying mudstone of the Fort Union Formation. The conglomerate is weakly stratified and consists of gravel to cobble-sized clasts of white quartz, granite, red sandstone, chert, petrified wood fragments, andesite, and dacite. Mudstone, shale, and rare gneiss. Zones of poorly cemented, crossbedded sandstone up to 5 feet thick, are interbedded with the conglomerate which is typically weakly cemented. Lateralizing banding (iron staining) is common in the sandstone along with rare, thin (<3-in thick) mudstone. Maximum thickness of the Wasatch Formation mudstone facies in the mapped area is approximately 150 feet. A mudstone with leaf imprints near the top of this facies yields a pollen age date of either Eocene or Paleocene zone 6 (J. O'Keefe, MSU-DESS personal comm., 2016). <sup>40</sup>Ar/<sup>39</sup>Ar radiometric age date analysis of Plagioclase from the andesite clasts yields a date of 56.43 ± 0.19 Ma (D. Migdis, OSU <sup>40</sup>Ar/<sup>39</sup>Ar Geochronology Laboratory, personal comm., 2016). This indicates that the gravel is younger than 50.4 Ma.

**Fort Union Formation (Paleocene to Upper Cretaceous)**  
**Fort Union Formation, upper mudstone facies** — Olive-gray to brown mudstone and siltstone interbedded with tan to brown fine-grained sandstone. Tends to be recessive, forming gentle slopes. The unit corresponds to the upper part of the Fort Union Formation of Honey and Hettiger (1989) and Beaumont (1979). Locally, a thick, arkosic sandstone exhibiting large planar cross-beds may be found at the top that consists of pebbles of quartz, feldspar, and granite. This sandstone contains thin beds of organic mudstone and lignitic material that yielded a Paleocene zone 3 palynology date (J. O'Keefe, MSU-DESS personal comm., 2016).

**Fort Union Formation, middle coal-bearing facies** — Gray shale and siltstone interbedded with dark-brown carbonaceous shale, coal, and brown, tan, and gray sandstone. Forms moderate recessive slopes interrupted with small sandstone ledges. Sandstone typically occurs in lenticular beds that are trough cross stratified, weakly cemented, moderately friable, planar bedded, and convolute bedded. Plant imprints and evidence of bioturbation are common. Some surfaces contain ripple marks. Sandstone is fine to medium grained with occasional gravel clasts up to 1-inch in diameter. Coal beds have variable thickness, typically less than 10 feet thick, may not be laterally continuous, and may grade into carbonaceous shale. The unit corresponds to the coal-bearing interval above the "unnamed Cretaceous and Tertiary sandstone" of Honey and Hettiger (1989).

**Fort Union Formation, lower sandstone facies** — Yellow, to tan, to cream-colored, well cemented sandstone interbedded with gray mudstone above the basal conglomerate of the unit. Can form prominent ledges and promontories. Sandstone is fine to medium-grained with occasional gravel up to 1/4-inch in diameter; coarser overall grain size distinguishes the Fort Union from the underlying Lance Formation. Clasts consist of quartz feldspar, chert, hornblende, and lithic fragments. Lithology of clasts includes: tan to white quartzite, variegated chert, dark-brown to black petrified wood, rare fossiliferous chert (containing horn coral), silicified breccias, rhyolite, andesite, rare limestone, and ironstone. Quartz, feldspar, granite and gneiss are conspicuously rare or absent in the clasts. Lithology suggests a source where Paleocene and Precambrian meta-sediments were exposed, possibly the Uinta uplift to the south and southwest. The unit is up to 30 feet thick in the mapped area and often forms gravel lag deposits on top of the Lance Formation (Kfci). The unit corresponds to the conglomerate zone of the "unnamed Cretaceous and Tertiary sandstone" of Honey and Hettiger (1989). Informally named "Ma<sup>7</sup>" by D. Migdis, OSU <sup>40</sup>Ar/<sup>39</sup>Ar Geochronology Laboratory, personal comm., 2016. This constrains the age of the gravel to less than 85.8 Ma.

**Fort Union Formation, mafic conglomerate** — Tan to brown sandstone containing abundant rounded to sub-rounded pebbles and small cobbles that form rounded knobs and hills. Matrix is a friable, poorly sorted, medium- to coarse-grained sandstone composed of quartz, feldspar, chert, and lithic fragments. Clast sizes range from small pebbles up to 4 inches across that are often coated with iron oxide. Locally, the conglomerate may be cemented with iron oxide forming a rough-textured ferrite. Lithology of clasts includes: tan to white quartzite, variegated chert, dark-brown to black petrified wood, rare fossiliferous chert (containing horn coral), silicified breccias, rhyolite, andesite, rare limestone, and ironstone. Quartz, feldspar, granite and gneiss are conspicuously rare or absent in the clasts. Lithology suggests a source where Paleocene and Precambrian meta-sediments were exposed, possibly the Uinta uplift to the south and southwest. The unit is up to 30 feet thick in the mapped area and often forms gravel lag deposits on top of the Lance Formation (Kfci). The unit corresponds to the conglomerate zone of the "unnamed Cretaceous and Tertiary sandstone" of Honey and Hettiger (1989). Informally named "Ma<sup>7</sup>" by D. Migdis, OSU <sup>40</sup>Ar/<sup>39</sup>Ar Geochronology Laboratory, personal comm., 2016. This constrains the age of the gravel to less than 85.8 Ma.

**Lance Formation (Upper Cretaceous)**  
**Lance Formation, sandstone of Fortification Creek** — Tan to beige, fine to medium-grained, moderately to well-indurated, calcareous, arkosic sandstone with grains of black chert that give it a "salt and pepper" appearance. Coarse grains include lithic fragments. This sandstone unit forms a prominent, resistant ledge at the top of the Lance Formation and the prominent second sandstone bluff on the north side of Fortification Creek north of Craig. The unit is typically massive and contains large trough crossbeds, horizontal laminated beds, and convoluted beds. It appears to interfinger with the underlying mudstone facies of the Lance Formation. A thin, gray mudstone at the top of the unit yielded a Maastrichtian pollen age (D. Kline, Denver Museum of Nature and Science, personal comm., 2013). Where crossbedding is well exposed, flow direction indicates a northeasterly flow direction. Thickness varies but may reach 100 feet. The unit is prone to rockfall when exposed. The unit may be equivalent to the lower part of the unnamed sandstone unit of Honey and Hettiger (1989).

**Lance Formation, main body** — Gray and yellowish-brown, very fine- to medium-grained arkosic sandstone with grains of black chert that give it a "salt and pepper" appearance. It is interbedded with grayish-green and gray carbonaceous shale. Sandstone occurs in discontinuous, tabular and lenticular beds ranging in thickness from less than 1 foot to over 20 feet with a massive, bioturbated texture, contains trough cross-beds (some surfaces contain ripple marks), and occasional convoluted bedforms. Trace fossils are common and include worm tracks and burrows. Thin beds of coal are interbedded with sandstone and shale near the base and give the unit a banded appearance that is visible in aerial photos. Where cross-bedding is well exposed, forest orientation indicates a generally northward flow direction. Unit is approximately 900 to 1100 feet thick in the mapped area.

**Fox Hills Sandstone (Upper Cretaceous)** — Tan to cream-colored, moderately to well indurated sandstone that forms ledges and the prominent sandstone bluff on the north side of Craig. The unit consists of upper, very fine to medium sand containing quartz, lesser feldspar, and rare black grains of chert cemented with CaCO3. Massive to large trough cross-bedded main body up to 60 feet thick that grades downward to thin horizontally to hummocky cross-bedded sandstone beds interbedded with gray marine shale. Trace fossils are common and include *Ophiomyia* that often form interconnected galleries. The top is marked by a laterally continuous tabular bed approximately 1 to 4 feet in thickness that often appears rock-marked on the surface. Surface texture may be from bioturbation, including numerous dinosaur tracks or "dino-turbation". The unit may be prone to rockfall. Total unit thickness is 60 to 80 feet.

**Lewis Shale (Upper Cretaceous)**  
**Lewis Shale, main body** — Gray to brownish-gray thin-bedded, fossiliferous, marine mudstone containing thin beds of silt and fine to very fine-grained sandstone. It is light gray where silt content is high and weathers to pale to moderate yellowish brown. The unit is recessive, resulting in a gentle rolling landscape with natural exposures of undisturbed bedding limited primarily to deeply eroded gullies and landslide scarps. High bentonite content gives this shale a high swell/shrink capacity and the unit is prone to landsliding. Approximately 2,000 to 2,200 feet of Lewis Shale are exposed in this quadrangle; however that thickness may be modified by faulting.

**Lewis Shale, Dad Sandstone Member** — Distinctive, ledge-forming, calcareous marine sandstone bodies in the upper part of the Lewis Shale. Individual beds grade upward from thin-bedded silt shale to fine sand consisting of quartz, minor feldspar and black chert with local rip-up clasts of mudstone cemented by CaCO3. Tabular beds exhibit planar horizontal bedding, convoluted bedding, hummocky bedding, and low-angle crossbedding. Total thickness of individual beds ranges from approximately 20 feet to over 60 feet. One mappable bed of the Dad Sandstone, approximately 160 to 200 feet thick, is exposed in the mapped area below the Fox Hills Sandstone separated by approximately 400 feet of Lewis Shale (Kis). Steep exposures may be prone to rockfall.

**Williams Fork Formation (Upper Cretaceous)** — Shown on cross section only.

MAP SYMBOLS

- Contact — Approximately located
- Fault — Approximately located; U on upthrown side, D on downthrown side; dotted where concealed, queried (?) where inferred
- Reverse fault — Approximately located; teeth on upthrown side; dotted where concealed, queried (?) where inferred
- Syncline — Dashed where approximately located, arrow in direction of plunge
- Anticline — Dashed where approximately located, arrow in direction of plunge
- Landslide scarp — Top of scarp; tic marks point downhill
- Eolian dune face — Top of scarp; tic marks point downhill
- Fluvial terrace bench — Top of scarp; tic marks point downhill
- Strike and dip of inclined bedding — Showing direction and angle of dip
- Estimated strike and dip of bedding — Showing direction and angle of dip, as estimated from aerial photographs and digital elevation model
- Alignment of cross section
- Geochronology sample location — Showing reported age: Numeric value in Ma for <sup>40</sup>Ar/<sup>39</sup>Ar; K for Upper Cretaceous, P1 to P6 for Paleocene zones 1 through 6, and E for Eocene as analyzed by Missouri State University (J. O'Keefe, MSU-DESS, personal comm., 2015 and 2016).

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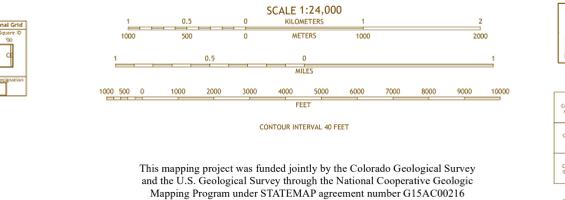
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Coordinate System: NAD 1983 UTM Zone 13N  
Projection: Transverse Mercator  
Datum: North American 1983

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Contours: ..... National Elevation Dataset, 2003  
..... USGS National Wetlands Inventory, 2015-2016  
Names: ..... GIS, 2016  
Hydrography: ..... GIS, 2016  
Boundaries: ..... Multiple Sources; see metadata file, 1972-2016  
Public Land Survey: ..... BLM, 2016  
Wetlands: ..... FWS National Wetlands Inventory, 1977-2016



Geology mapped in 2014 and 2015  
Cartography by Karen Morgan, Colorado Geological Survey and Pangaea Geospatial, LLC

Unit	Symbol	Color	Pattern
Wasatch Formation, conglomerate facies	Twc	Light tan	None
Wasatch Formation, mudstone facies	Twm	Light tan	Diagonal lines
Fort Union Formation, upper mudstone facies	Tfm	Light tan	None
Fort Union Formation, middle coal-bearing facies	Tfmc	Light tan	None
Fort Union Formation, lower sandstone facies	Tfl	Light tan	None
Lance Formation, sandstone of Fortification Creek	Lfc	Light tan	None
Lance Formation, main body	Lm	Light tan	None
Fox Hills Sandstone	Fhs	Light tan	None
Lewis Shale, main body	Ls	Light tan	None
Lewis Shale, Dad Sandstone Member	Lsd	Light tan	None
Williams Fork Formation	Wff	Light tan	None