Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1970. Field checked 1971

Projection and 10,000-foot grid ticks: Colorado coordinate system, north zone (Lambert conformal conic) 1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue. 1927 North American Datum

Fine red dashed lines indicate selected fence lines

To place on the predicted North American Datum 1983 move the projection lines 6 meters north and 53 meters east as shown by dashed corner ticks

Map photoinspected 1973
No major culture or drainage changes observed

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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 number G11AC20250

QUADRANGLE LOCATION

Geology mapped in 2011
GIS and cartography by Karen Morgan

1 Craig
2 Ralph White Lake
3 Rock Spring Gulch
4 Castor Gulch
5 Hayden
6 Hamilton
7 Pagoda
8 Hayden Gulch

ADJOINING 7.5' QUADRANGLES

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

HUMAN-MADE DEPOSITS

af

Artificial Fill (latest Holocene) — Riprap, engineered 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 typically less than 20 feet, although high embankments can be more. Artificial fill may be subject to settlement, slumping, and erosion if not adequately compacted or designed for drainage control.

dr

Disturbed and/or reclaimed ground (latest Holocene) — Deposits in areas where the land has been disturbed as a result of mining, quarrying, or oil and gas production. Natural landform has been modified and surface is covered by either disturbed locally derived material or imported material. Material can be highly variable from fine sand silt and clay to gravel and boulders and may include refuse of many types including household and industrial sources. Some locations have been contoured and revegetated to match surrounding natural areas. Other areas have been adapted to other uses or have been left vacant.

ALLUVIAL DEPOSITS

Qay_{1a}

Qay_{1b}

Alluvium one of the Yampa River (Holocene to late 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 5 feet higher than the current stream channel that are flooded during most spring run-off seasons are designated Qay_{1a} and those between 5 and 12 feet higher than the active channel that are flooded only in very high run-off seasons are designated Qay_{1b}. Clasts are subrounded to well rounded and the dominant sediment is sand with a sandy silt matrix. Deposits associated with the Yampa River consist of up to 7 feet of sand and silt over a medium pebble and cobble gravel of granite, granitic gneiss, hornblende gneiss, vein quartz, occasional red quartzitic sandstone, and rare vesicular basalt. 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.

Qayo

Older gravel deposits of 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 sub-rounded to well rounded with sizes generally less than eight inches, although rare clasts can reach 2.5 feet in diameter. 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 quartzitic sandstone; brown and gray chert; and rare vesicular basalt. Generally unconsolidated, but occasionally may be cemented with $CaCo_3$. The deposits form 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 gravel. The deposit forms a stable building surface and is a potential source of sand and gravel.

ALLUVIAL FAN DEPOSITS

Qfsc

Alluvial fan, sheetwash, and colluvial deposits, undifferentiated (Holocene to late Pleistocene) — Stream channel and flood plain deposits along valley floors of ephemeral, intermittent, and small perennial streams, sheetwash on slopes, and colluvium along valley sides. Alluvial deposits are typically composed of poorly to well-sorted, stratified, interbedded, pebbly sand, sandy silt, and sandy gravel derived from local sources. Sheetwash deposits are similar to alluvial deposits, but may contain more fine-grained material and are not found in distinct channels. Colluvium may range from unsorted, clast-supported, pebble to boulder gravel in a sandy matrix to matrix-supported, gravelly, clayey sand. Maximum thickness of the unit is 15 feet.

Qamf

Alluvial, mud flow and mud fan deposits (Holocene to late Pleistocene) — Light-grayish-reddish-brown to pale-orange-yellow, well to occasionally 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. The deposits comprise a complex system of deposits that may extend for miles along tributary stream reaches. The basin- and valley-fill sediments were deposited primarily by muddy debris flows with occasional input from sheetwash, hyperconcentrated flows, and water-flood flows. The deposits consist of poorly defined silt layers, typically less than an inch to a few inches thick, which record individual mudflow depositional events. Some layers show incipient soil development that was curtailed by burial during subsequent events. Areas mapped as Qamf may be subject to future flash floods and debris flow events, especially in non-incised valley-head and valley-side areas and within the deeply dissected modern arroyo channels. The deposits 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. Typically, irrigation is required, and where deposits are sulfate-rich, the quality of these lands for agriculture can be relatively poor. 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.

Qamfo

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 in elevation above modern streams than the younger Qamf deposits. Unit can form inverted topography and geometry may be modified by erosion.

Qgo

Older gravel deposits (Pleistocene) — Gray to grayish brown, poorly sorted, fine to coarse sand interbedded with pebble, cobble and boulder gravel. Clasts are sub-rounded to well rounded from multiple sources and occupy paleo-stream valleys that are no longer in depositional contact with modern drainages. Large boulders of basalt up to 4 feet in diameter are common. The paleo-valleys are now inverted, positive features in the landscape and may display remnant morphology of the original channels or fans. The unit locally exceeds 10 feet in thickness. It can form a stable building surface and is a potential source of sand and gravel.

MASS-WASTING DEPOSITS

Qcs

Colluvial and sheetwash deposits (Holocene to late Pleistocene) — Unsorted and unstratified to stratified, reddish-brown to pale brown, pebble to boulder size rock fragments in a sandy silt and clay matrix on slopes up to 30 percent grade. Unit contains locally derived angular to subangular clasts that can be either clast-support, or matrix-support, and often form wedge-shaped deposits below ledge-forming bedrock. May include rockfall debris and the unit can be transitional with landslide deposits and is differentiated by the lack of a well-defined scarp. Sheetwash deposits consist of local materials transported on moderate slopes (~10 percent grade) by sheetflow but also includes some sediment delivered by runoff in rills and minor gullies and can grade up to colluvial deposits. Deposits locally exceed 15 feet in thickness. Areas mapped as colluvium are susceptible to future rockfall events.

Qls

Landslide deposits (Holocene to late Pleistocene) — Heterogeneous deposits consisting of unsorted and unstratified clay, silt, and sand, and cobble- and boulder-size rock fragments. Unit includes rotational and translational slides and complex earthflow mass movements. In most places, landslides show obvious geomorphic expression that disrupts the profile of the slopes. 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 covered and not pronounced. Other common diagnostic features include hummocky topography, closed depressions, sag ponds, fissures, terracettes, 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 snowfall or may be reactivated by human-made disturbances such as cutting of slopes for roads, quarries, grading for housing developments, and irrigation and septic systems. Landslide deposits are prone to settlement when loaded or wetted. The deposits may contain expansive soils where derived from shale and mudstone formations. Thickness of landslide deposits locally exceeds 10 feet.

Qlf

Earthflow deposits (Holocene to late Pleistocene) — Landslide deposits that are comprised primarily of remobilized shale and mudstone. Deposits display a lobate shape; can be on very low slopes; and are characterized by irregular topography, numerous scarps and crevices, and tilted or deformed vegetation.

Qlso

Older landslide deposits (Pleistocene) — Heterogeneous deposits consisting of unsorted and unstratified clay, silt, and sand, and cobble- and boulder-size rock fragments. Found on ridges and hill-tops well above modern drainages but lacking source area scarps, and have geometries modified by weathering and erosion.

QTbb

Basalt boulder deposits (early Pleistocene to Pliocene? or Miocene?) — Assemblages of large basalt boulders ranging in size from less than 6 inches to over 5 feet. Consists of both massive and vesicular basalt, with occasional surfaces retaining original flow textures. Angular to sub-angular boulders are clast-supported with a matrix of smaller cobbles and boulders along with brown to dark brown organic-rich silt and clay. Fines may be wind-derived soil. Deposits form small isolated knobs and linear ridges. Boulders show little evidence of long-range transport and may be old talus deposits with no remaining local cap-rock sources. Ar/Ar analysis by the New Mexico Geochronology Laboratory of a sample of non-vesicular basalt yielded a date of 23.11 ± 0.013 million years (Ma) (M. Heizler, personal communication 2013).

EOLIAN DEPOSITS

Qe

Eolian deposits (Holocene to late Pleistocene) — Yellowish-brown to reddish-brown, fine- to medium- grained sand and silt deposited primarily by wind. Grains are subangular to subrounded. The deposits form blankets, or occasionally drifts, that are thickest on northeast-facing slopes. Dune forms are not present in the mapped area. Dryland farming is common is 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

Tbp

Browns Park Formation (Pliocene to Oligocene?) — Cream-colored, white to grey to tan, occasionally mottled rusty brown, fluvial sandstone interbedded with eolian sandstone, mudstone, and gravel. Generally recessive unit forms slopes and ledges. Fluvial sandstone is fine to coarse-grained, poorly to moderately sorted, moderately cemented, and occurs in lenticular beds up to ten feet thick that exhibit trough cross-beds and horizontal planar beds; multiple channel deposits can be stacked on top of each other. Where cross-bedding is well exposed, foreset orientation indicates a generally northwest to north current direction. Eolian sandstone is medium- to fine-grained, moderately well-sorted, friable, with poor internal structure or large scale trough cross-bedding. In places, white color and blocky texture suggests high ash content. Exposures are rare in elevated terrain, where presence of the unit is often indicated only by occurrence of abundant pebbles and cobbles of a basal conglomerate scattered on the surface. Basal conglomerate is shown as a dashed line on the map where observed. Clasts in the basal conglomerate are well-rounded and range from pebble size up to 6 inches, and consist of granite, quartz; quartzite white and black gneiss epidote-rich gneiss and limestone. Unit thickness is variable, up to 120 feet in this quadrangle.

Tdi

Diabase of Breeze Mountain, (Miocene) — Dark gray to mottled rusty brown diabase found in at least two sills and a feeder dike beneath Breeze Mountain. The sills are approximately 40 to 150 feet thick and dip approximately 15 to 20 degrees to the northeast, and have weak columnar joints perpendicular to bedding. The feeder dike is on the north slope of Breeze Mountain and is approximately 60 feet thick and dips approximately 35 to 40 degrees to the south, with columnar joints parallel to the cliff face. The feeder dike is in close alignment with the inferred fault on the north flank of the Buck Peak dome, suggesting that it may have intruded along the fault. The texture is massive and non-vesicular throughout, indicating that the bodies are intrusive. Locally, the surrounding Lewis Shale has been metamorphosed to hornfels. The diabase is composed of a fine-grained groundmass of plagioclase with lesser pyroxene and an opaque mineral (probably magnetite). Whole-rock analysis indicates a composition of 48.65% SiO_2, 13.9 Al_2O_3, 8.23% CaO, 8.38 % MgO, 3.55% Na_2O, and 2.325% K_2O; classifying this as a trachybasalt. Ar/Ar analysis by the New Mexico Geochronology Laboratory yielded a date of 8.757 ± 0.014 million years (Ma) (M. Heizler, personal communication 2013).

Tb

Basalt (Oligocene) — Dark gray to dusky bluish-gray basalt in a small flow found in a rotated landslide block northeast of Buck Peak. The flow is less than 5 feet thick and caps the Browns Park Formation. The basalt is vesicular and is composed of a fine-grained groundmass of plagioclase with lesser pyroxene and opaque mineral (probably magnetite). Whole-rock analysis indicates a composition of 50.5% SiO_2, 15.3 Al_2O_3, 8.81% CaO, 6.69% MgO, 3.24% Na_2O, and 0.99% K_2O; classifying this as a basalt. Ar/Ar analysis by the New Mexico Geochronology Laboratory yielded a date of 24.58 ± 0.02 million years (Ma) (M. Heizler, personal communication 2013) for the lower main flow.

Kl

Lance Formation (Upper Cretaceous) — Gray and yellow-brown very fine-grained to medium-grained sandstone, interbedded with gray-green and gray carbonaceous shale, and thin seams of coal. The unit is moderately recessive and forms slopes and ledges. Sandstone occurs in beds ranging in thickness from less than 1 to over 20 feet that are tabular as well as lenticular and discontinuous exhibiting massive, bioturbated texture, trough cross-bedding, ripple cross-bedding, and occasional convoluted bedding. Thin beds of coal are interbedded with sandstone and shale near the base and give the unit a banded appearance in air photos. The unit is exposed in only one locality at the north edge of this quadrangle along the Moffat and Routt county boundary, where less that 20 feet are exposed just below a high terrace capped by Quaternary gravel of the Yampa River (Qayo).

Kfh

Fox Hills Sandstone (Upper Cretaceous) — Tan to cream-colored moderately to well-indurated sandstone ledge-former that forms the prominent sandstone bluffs on the north side of Craig. The unit consists of upward-coarsening, very fine to medium grained sand containing quartz, lesser feldspar, and rare black grains of chert cemented with $CaCO_3$. Massive to large trough cross-bedded main body up to 60 feet in thickness that grades downward to thin horizontally to hummock cross-bedded sandstone beds interbedded with gray marine shale. Trace fossils are common and include *Ophiomorpha* 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 pock-marked on the surface. Surface texture may be from bioturbation, including numerous dinosaur tracks or "dino-turbation". Total unit thickness is 60 to 80 feet.

Lewis Shale (Upper Cretaceous)

Kls

Lewis Shale, main body — Gray to brownish-gray thin-bedded, fissile, 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.

Klsd

Dad sandstone member — Distinctive tan, ledge-forming, calcareous marine sandstone bodies in the upper part of the Lewis Shale. Individual bodies grade upward from thin-bedded silty shale to fine-grained sand consisting of quartz, minor feldspar and black chert, with local rip-up clasts of mudstone cemented by $CaCO_3$. 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

Klst

Tongues of Lewis Shale — Tongues of the Lewis Shale underlie and are upwardly transitional with the Twentymile Sandstone Member (Kwtm), and Sub-twentymile sandstone member (Kwst) of the Williams Fork Formation, forming distinctive low-sloping benches beneath the ledge-forming sandstones. Tongues are similar in composition and bedding as the main Lewis Shale body. Thickness varies from less than 20 feet to almost 200 feet. The tongues tend to thin and become dominated by thin beds of sandstone to the west.

Williams Fork Formation (Upper Cretaceous)

Kwtw

Three white sandstones member — White to tan, moderately to well-indurated sandstone, interbedded with marine and non-marine shale with minor coal beds. Well indurated, forming cliffs, distinct ledges, and “hoodoos”. Three distinct, upward-coarsening, very fine to medium grained sandstone intervals can be present, although all three are usually only seen together in steep valley wall exposures. Ledge-forming sandstones are shown as dashed lines on the map. Beds of grey marine shale 20 to 40 feet thick separate the sandstone beds and are mapped as Lewis Shale (Kls) in this area. Sandstone consists of moderately well sorted grains of quartz, feldspar, and grains of black chert or hornblende, with a $CaCO_3$ cement. Bedding grades upward from horizontally laminated thin beds of sand, silt and shale, to sandstone beds up to 100 feet thick, displaying large-scale, trough cross-bedding, local hummocky cross-bedding, and massive-bioturbated intervals. Toward the top, bedding becomes sub-horizontal and the surface is typically planar and often pock-marked or bioturbated. Carbonaceous shale with occasional thin beds of coal may cap the sandstone intervals. Oyster shells can be abundant in the shale above the sandstone bodies. Bivalve hash may also be present in thin tabular sandstone beds. Locally, resistant knobs of brown very fine- to fine-grained irregularly bedded to ripple-bedded sandstone rise above more easily eroded friable sandstone. These irregular knobs of more resistant sandstone appear to be cemented by iron-rich calcite and are more common in the lower-most sandstone interval, giving it a distinctive appearance. Total unit thickness of the Three white sandstones member is 200 to 300 feet. Regionally, the unit becomes more marine to the east as the sandstone intervals thin, become finer-grained, and non-marine shale and coal beds pinch out. The unit may be equivalent to the Almond Formation as recognized in the subsurface to the north in the Sand Wash and Washakie Basins (Roehler, 1987).

Kwu

Williams Fork Formation, upper part — Interbedded sandstone, non-marine shale, and coal that form ledges and slopes. Brown, rusty brown, and tan to gray lenticular to tabular sandstone beds consist of fine- to medium-grained quartz and feldspar with black grains of chert or hornblend. Beds range from less than 1 to over 20 feet in thickness, and exhibit ripple cross-bedding, horizontal bedding, trough cross-bedding, local convoluted bedding, and local non-organized bioturbated intervals. Shale beds are grey to pale grey and can be lignitic. Coal beds as thick as ten feet comprise the Upper Coal Group of the Yampa Coal Field. In many exposures the coals have naturally burned, baking and fusing adjacent beds of shale to a distinctive brittle red “klinker”. Total unit thickness is 300 to 400 feet.

Kwbw

Big white sandstone member(Pleistocene) — Cream-white to pale-orange ledge-forming sandstone member in the upper part of the Williams Fork Formation that forms distinctive cliffs in the east side of the quadrangle. It consists of one or more, amalgamated sandstone bodies that are laterally continuous in some places and lenticular in other places. The beds contain hummocky and low-angle cross-bedding near the base and horizontal planar bedding near the top. The member is ranges from 0 to 80 feet in thickness.

Kwtm

Twentymile Sandstone Member — Cream-white to pale-orange, well indurated sandstone that forms a band of distinctive cliffs and ledges. The sandstone coarsens upward from the gradational contact with the underlying slope-forming tongue of the Lewis Shale (Klst), to fine- to medium-grained sand at the top. In places the unit consists of a single cliff-forming sandstone body as thick as 120 feet and in other locations, where it is more recessive, it consists of multiple sandstone beds up to 15 feet thick separated by thin shale stringers. Sand grains consist of quartz, feldspar, and grains of black chert or hornblende, cemented by $CaCO_3$. Bedding grades from horizontally laminated thin beds of sand, silt and shale, upward to massive sandstone that can often be structureless and bioturbated, or may display large trough cross-bedding up to 6 feet high, planar bedding, or local hummocky cross beds. The top is typically capped by tabular beds of horizontally bedded sandstone less than three feet thick displaying a rough bioturbated surface. Locally, the top can be incised by distinct brown, resistant, channel-shaped bodies of trough cross-bedded very fine- to fine- grained sandstone up to 10 feet thick. Total thickness of the member ranges from 100 to 150 feet.

Kwst

Sub-twentymile sandstone member — Tan to light brown indurated sandstone, interbedded with shale, overlain and underlain by tongues of Lewis Shale (Klst), forming ledges and slopes. Sandstone beds 20 to 80 feet thick consist of fine- to medium-grained quartz, feldspar, and black grains of chert and hornblende and exhibit trough cross-bedding, hummocky cross-bedding, horizontal planar bedding, or can appear structureless and bioturbated. Trace fossils include *Ophiomorpha* and rare worm burrows. Beds of grey shale up to 5 feet thick separate the individual sandstone beds. Total unit thickness is variable ranging from 120 feet to over 200 feet.

Kwl

Williams Fork Formation, lower part — Interbedded sandstone, non-marine shale, and coal, that form ledges and slopes less resistant than the overlying Sub-twentymile sandstone member (Kwst). Brown, rusty brown, and tan to gray, lenticular to tabular sandstone beds consist of fine- to medium-grained quartz and feldspar with black grains of chert or hornblend. Beds range from less than 1 to over 20 feet in thickness and exhibit ripple cross-bedding, horizontal bedding, trough cross-bedding, local convoluted bedding, and local non-organized bioturbated intervals. Shale beds are grey to pale grey and can be lignitic. Coal beds as thick as 10 feet comprise the Middle Coal Group of the Yampa Coal Field. In many exposures the coals have naturally burned, baking and fusing adjacent beds of shale to distinctive brittle red “klinker”. Total unit thickness is 250 to 300 feet.

Kway

Yampa ash bed — Cream to rose-colored tonstein in the lower part of the Williams Fork Formation. The bed has often been baked by naturally burning coals into a distinctive brittle porcelanite. Can be massive and fresh appearing with small crystals of biotite, It locally contains casts of gastropods, bivalves or plant material. The bed is up to 10 feet thick and forms distinctive cream or rose-colored bands on slopes. It is difficult to distinguish from light grey shale beds where the burning coal has not baked the bed to porcelanite. A field scintillometer indicates gamma-ray radiation can be elevated above background in this area (up to 62 mr/min as compared to 30 to 35 mr/min). The bed is described in detail by Brownfield and Johnson (2008).

Iles Formation (Upper Cretaceous)

Kitc

Trout Creek Sandstone Member — Cream, white, to tan-colored, well indurated sandstone that forms a conspicuous band of cliffs below the Williams Fork Formation. It typically appears as a single interval of sandstone, but in places it may consist of up to three, distinct ledge-forming beds separated by thin layers of shale. It consists of sand containing quartz, feldspar, and grains of black chert or hornblende, cemented by $CaCO_3$, that coarsens upward from very fine- to fine-grained. Rare rip-up clasts of shale can be present in the sandstone. The base is gradational with the slope-forming tongue of the Mancos Shale (Kmt) beneath. Bedding grades upward from horizontally laminated, thin beds of sand, silt and shale, to a thick bed of sandstone up to 120 feet thick, displaying trough cross-bedding, local hummocky cross-bedding, local convoluted bedding, and intervals that are structureless and bioturbated. The top may be capped by tabular beds of sandstone less than 3 feet thick, displaying a rough pock-marked, bioturbated surface. *Ophiomorpha* burrows may be present. Total thickness ranges from 100 to 150 feet. The unit is genetically tied to the overlying Williams Fork Formation, representing eastward shoreline progradation above the Mancos Shale tongue (Kmt) and transition from a marine through delta/shoreline to non-marine coastal plain setting. However, it has historically been mapped as the upper member of the Iles Formation (Bass and others, 1955), as shown herein.

Kiu

Iles Formation, upper part — Interbedded well-indurated sandstone, siltstone, carbonaceous and marine shale, and minor coal, forming slopes and ledges that tend to be more recessive than the lower part of the Iles Formation (Kil). Tan to brown, whitish to grey, and pale orange beds of sandstone up to 25 feet thick can be lenticular to tabular and laterally continuous, and consist of very fine- to fine-grained quartz, feldspar, and grains of black chert or hornblende, cemented by $CaCO_3$. Sandstone beds can have ripple cross-bedding, trough cross-bedding, sub-horizontal planar bedding, contorted bedding, and structureless bioturbated intervals. Sandstone occasionally has liesegang iron oxide banding. Rip-up clasts of mudstone can be present. Where planar cross bed forests are well exposed, the orientation indicates general south to southeast current direction. Shale beds are light to medium grey to tan. Palm frond imprints and gastropod and bivalve shell fragments may be present in the sandstone. Fragments of light brown to tan petrified wood can also be present. Total unit thickness is between 600 and 700 feet.

Kidl

Double ledge sandstone member — The uppermost distinctive, laterally continuous interval of well-indurated sandstone in the lower part of the Iles Formation. Forms a series of ledges and cliffs that rim the steep canyons of the Williams Fork Mountains. The sandstone is tan to pale grayish-orange and consists of one to three, thick, tabular sandstone bodies separated by shale and thin-bedded sandstone stringers. In places, the lower-most interval is up to 80 feet thick. Sandstone intervals consists of upward-coarsening, very fine- to fine-grained sand containing quartz, feldspar, and grains of black chert or hornblende cemented by $CaCO_3$. Bedding can be large-scale trough cross-bedding to sub-horizontal planar bedding to massive and bioturbated. Mud drapes and mud rip-up clasts can be present. The tops of each ledge are typically planar and pock-marked. Some pock marks may be crude dinosaur tracks. Total unit thickness is 40 to 80 feet. The unit is source for large-clast alluvial fan deposits and rockfall debris in canyon floors.

Kil

Iles Formation, lower part — Interbedded sandstone, siltstone, carbonaceous shale, marine shale, and minor coal that forms slopes, small cliffs, and ledges. A number of laterally continuous, ledge-forming intervals of sandstone, that Crabaugh (2001) describes as shoreline tongues within the Iles clastic wedge, make the lower part of the Iles Formation more resistive to erosion, producing rougher topographic relief than the upper part. Light-brown, to whitish, to very-pale orange beds of sandstone up to 40 feet thick can be lenticular to tabular, and laterally continuous, and consist of very fine to fine grained quartz, feldspar, and grains of black chert or hornblende. Sandstone beds can have ripple cross-bedding, trough cross-bedding, sub-horizontal planar bedding, hummocky cross-bedding, contorted bedding, and structureless-bioturbated intervals. Shale beds are light to medium grey to tan. The coal beds comprise the Lower Coal Group of the Yampa Coal Field. Locally, the coals have naturally burned, baking and fusing adjacent beds of shale to distinctive brittle red “klinker”. Total unit thickness is between 300 and 400 feet. The unit is a source for large-clast alluvial fan deposits and rockfall debris in the canyon floors.

Kito

Tow Creek Sandstone Member — The lowermost distinctive, cliff-forming, well indurated sandstone interval of the lower part of the Iles Formation. It consists of tan to cream colored to pale orange, upward-coarsening, very fine to fine-grained sandstone in gradational contact with the underlying tongue of the Mancos Shale (Kmt). It consists of multi-storied bodies of sandstone displaying sub-horizontal bedding, hummocky cross-bedding, large-scale trough cross-bedding, channel scours, and thin tabular beds with ripple cross-bedding. Mud-draped surfaces can be present. *Ophiomorpha* burrows and bivalve fossils can be present. Total unit thickness is 60 to 100 feet.

Mancos Shale (Upper Cretaceous)

Kmu

Mancos Shale, upper part of main body — Olive-gray to pale yellowish-brown, non-calcareous, silty to sandy, marine mudstone that forms recessive slopes below the Iles Formation. Thin, sheet-like, hummocky cross-bedded sandstone beds near the top form small ledges that step up to the base of the steeper, cliff forming Iles Formation. Overall thickness is 1,250 to 1,450 feet but only the uppermost 20 to 40 feet are found in the quadrangle.

Kmt

Tongue of the Mancos Shale — A tongue of the Mancos Shale underlies, and is upwardly transitional with, the Trout Creek Sandstone member (Kitc). It forms a distinctive gently-sloping bench beneath the ledge-forming sandstone. It is similar in composition and bedding form as the main body. Thickness ranges between 40 and 120 feet. It is highly prone to landsliding, and the benches above the Iles Formation are often sites of conspicuous earth flows.

Contact—Approximately located

U
D
Fault—Dashed where inferred, dotted where concealed, dash-dot where inferred and concealed; U on upthrown side, D on downthrown side

Reverse fault—Dashed where approximately located, dash-dot where inferred and concealed; teeth shown on overthrust block side of fault

Syncline—Approximately located; axial arrow shows direction of plunge

Anticline—Approximately located; axial arrow shows direction of plunge

Monocline—Approximately located; axial arrow shows direction of plunge

Landslide scarp above a landslide deposit (Qls) where source material is highly deformed. Hachure in slope direction

Scarp above displaced bedrock block— Bedrock is not deformed other than by lateral or rotational movement and maintains map symbol. Hachure in slope direction

Possible fault scarp—Hachure in slope direction

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Strike and dip of inclined bedding—Showing direction and angle of dip

Horizontal bedding

A——A′ **Alignment of cross section**

GEOLOGIC MAP OF THE BREEZE MOUNTAIN QUADRANGLE, MOFFAT AND ROUTT COUNTIES, COLORADO

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