GEOLOGIC MAP OF THE DONKEY FLAT QUADRANGLE, UINTAH COUNTY, UTAH

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Cover photo: The Red Fleet, a set of geomorphic features that resemble a fleet of battleships plying the sea, is formed by the differential erosion of the Triassic Chinle Formation and the Triassic-Jurassic Nugget Sandstone. The Red Fleet is located north of Red Fleet State Park, Uintah County. View to the east.

SCALE: 1:24,000

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GEOLOGIC MAP OF THE DONKEY FLAT QUADRANGLE, UINTAH COUNTY, UTAH

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OVERVIEW

The Donkey Flat quadrangle is less than 10 miles north-northeast of Vernal, Utah, along the south flank of the Uinta Mountains in Uintah County. It includes Red Fleet State Park, a popular recreational area, and is crossed by U.S. Highway 191, which is designated as a National Scenic Byway.

The geology is well exposed and relatively uncomplicated within the quadrangle, making a dramatic landscape with thick sandstone cliffs and varicolored to drab gray slopes. The quadrangle contains a variety of unconsolidated deposits of Holocene and Pleistocene age that range from stream alluvium to piedmont gravel to eolian sand. The quadrangle's namesake is one of several geomorphic surfaces mantled by piedmont gravel deposits. Bedrock generally dips southward; the Permian-Pennsylvanian Weber Sandstone exposed in the northwest part of the quadrangle is the oldest bedrock formation, and the Upper Cretaceous Mancos Shale is the youngest bedrock unit and dominates the southern half of the quadrangle. Dips range from about 5° to 30° and decrease southward, reflecting the structural influence of the Island Park syncline mapped in the southeast part of the quadrangle. We also mapped minor folds within the Mancos Shale in the southwest part of the quadrangle, and some of the anticlines were targets for oil and gas exploration. No faults were mapped within the quadrangle.

Of special stratigraphic note, we have applied the informal name “formation of Bell Springs” to the map unit that lies between the overlying Nugget Sandstone and the underlying Chinle Formation. This lithostratigraphic unit has been previously recognized and described in the Uinta Mountain area (Thomas and Krueger, 1946; Kinney, 1950; Sikich, 1960; Poole and Stewart, 1964; Sikich, 1965; High and Picard, 1967; High and others, 1969; Picard, 1975; Lucas, 1993; Jensen and Kowallis, 2005; Sprinkel and others, 2011b; Irmis and others, 2015) with various names and ranks. Thomas and Krueger (1946) placed these strata, as well as the underlying Chinle Formation, into a new formation they called the Stanaker Formation with a type section within the Donkey Flat quadrangle "measured north of Vernal, Uintah County, Utah, from section 7, T. 3 S., R. 22 E., SLB&M, northward to a tributary of Brush Creek near the northwest corner of section 32, T. 2 S., R. 22 E., SLB&M, and west of the Vernal-Manila highway" (U.S. Highway 191). Sikich (1960, 1965) measured additional sections of the Stanaker Formation within the Donkey Flat quadrangle. In all of these measured sections, approximately the upper 100 feet of the Stanaker Formation is equivalent to the formation of Bell Springs as defined here. The Stanaker Formation is defined by these authors never came into general usage with other workers in the area who continued to use terminology from either the Colorado Plateau or from Wyoming. Lucas (1993) elevated this interval from a member to a formation of the Chinle Group in the Uinta Mountain region. We have chosen to use the informal name (formation of Bell Springs) because we have not fully evaluated the regional correlation with other current and former names and their stratigraphic ranking. The formation of Bell Springs is conformable with the overlying Nugget Sandstone and is unconformable with the underlying Chinle Formation. The unconformity is thought to be regional by some stratigraphers, separating correlative units in Wyoming, southeastern Idaho, northern Utah, and on the Colorado Plateau (High and Picard, 1967; Pipiringos, 1968; High and others, 1969; Picard, 1975; Lucas, 1993; Lucas and others, 1997). However, the unconformity may be local in the eastern Uinta Mountains (Poole and Stewart, 1964; Jensen and Kowallis, 2005; Sprinkel and others, 2011b). Age of the Bell Springs is Rhaetian (Late Triassic), constrained by aetosaur tracks in the lower part of the overlying Nugget Sandstone (Lockley and others, 1992; Lockley, 2011; Sprinkel and others, 2011b), by palynological data (Irmis and others, 2015), and by isotopic dating (U-Pb zircon) of correlative underlying strata of the Chinle Formation in Arizona (Ramezani and others, 2011).

Geologic resource development within the quadrangle includes active phosphate mining associated with the Park City Formation, and a sand and gravel pit associated with piedmont gravel deposits. Other geologic resources that have been explored include oil and gas in the Buckskin Hills area and minor coal deposits in the Frontier Formation. Three unsuccessful oil and gas exploration drill holes are located in the southwest part of the quadrangle (plate 1). The deepest drill hole was drilled by Cities Services Company/Adams (table 1). The Brush Creek 1 (A-3; API 4304710702; SESE section 30, T. 3 S., R. 22 E., SLB&M) drilled to 5522 feet and reached the Weber Sandstone. No shows or tests were reported by the operator. The other two drill holes drilled less than 5000 feet of section in which the Promontory Oil Company Buckskin Hills 19-1 (A-1; API 4304710937; SNNW section 19, T. 3 S., R. 22 E., SLB&M) reached the Moenkopi Formation and the Sunray...
Table 1. Formation tops from wells drilled in the Donkey Flat 7.5-minute quadrangle.

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DESCRIPTION OF MAP UNITS

Quaternary Surficial Map Units

Boundary age for Quaternary series shown in the correlation of surficial units are from Cohen and others (2013).

Human-Modified Deposits

Qhd  Red Fleet Reservoir dam (Historical) – Dam embankment fill consisting of clay, silt, sand, gravel, and boulders of Paleozoic and Neoproterozoic clasts from local piedmont gravel deposits.

Qhm  Phosphate strip mine (Historical) – Local surficial deposits and the Park City Formation modified to such a degree that the original bedding is no longer expressed in areas where mining is active; inactive parts of the mine are reclaimed with fill and seeded with native vegetation (see below for formation descriptions); bedrock configuration in the unmined areas within the mine property may change over time as mining continues; variable thickness.

Qhml Mine tailing pond (Historical) – Area where mine tailings are stored; includes impoundment structure; covers Triassic Moenkopi and Dinwoody Formation (see below for formation descriptions); as much as 150 feet deep.

Alluvial Deposits

Qal1 Youngest stream alluvium (Holocene) – Unconsolidated silt, sand, gravel, and cobbles in active channels of perennial and intermittent creeks; commonly stratified; fine-grained material generally derived from locally weathered formations; may contain cobbles and boulders from formations exposed upstream; less than 30 feet thick.

Qal2 Older stream alluvium (Holocene) – Unconsolidated silt, sand, gravel, and cobbles 40 to 50 feet above Big and Little Brush Creek, Brush Creek, Cottonwood Wash, and some of their tributaries; commonly stratified; fine-grained material generally derived from locally weathered formations; may contain cobbles and boulders from formations exposed upstream; less than 30 feet thick.

Qal3 Oldest stream alluvium (Holocene) – Unconsolidated silt, sand, and cobbles 60 to 80 feet above Big and Little Brush Creek and Brush Creek; commonly stratified; fine-grained material generally derived from locally weathered formations; may contain cobbles and boulders from formations exposed upstream; less than 30 feet thick.

Qap1 Level 1 piedmont gravel (Holocene[?] and Pleistocene) – Unconsolidated to poorly consolidated, pebble to boulder, clast-supported gravel; well-rounded to subrounded and moderately sorted; mixed mostly Neoproterozoic Uinta Mountain Group and subordinate Paleozoic (mostly carbonate) clasts; development of pedogenic calcium carbonate coating on underside of some clasts; gravel mantles pediment-like geomorphic surfaces and forms small gravel-capped mesas, like Donkey Flat, that are about 160 to 200 feet above Brush Creek; the surfaces generally slope south-southwest mostly between about 5600 and 5800 feet; gravel surfaces are local and not regional like Qap3 1 to 20 feet thick.

Qap2 Level 2 piedmont gravel (upper Pleistocene) – Unconsolidated to moderately consolidated, pebble to boulder, clast-supported gravel; well-rounded and moderately sorted; mixed mostly Neoproterozoic Uinta Mountain Group and subordinate Paleozoic (mostly carbonate) clasts; development of pedogenic calcium carbonate varies from coating on underside of clasts to pervasive coating of clasts and matrix; gravel mantles pediment-like geomorphic surfaces and forms gravel-capped mesas that are about 300 to 500 feet above Brush Creek; the surfaces generally slope south-southwest mostly between about 6000 and 6200 feet; these gravelled surfaces are more regional than Qap3 and may represent a dissected regional surface along the lower slope of the Uinta Mountains; 5 to 50 feet thick.

Qap3 Level 3 piedmont gravel (middle Pleistocene) – Unconsolidated to poorly consolidated, pebble to boulder, clast-supported gravel; well-rounded and mod-
erately sorted; mixed mostly Neoproterozoic Uinta Mountain Group (90%), Paleozoic carbonate (7%), and Paleozoic sandstone (3%) clasts; development of pedogenic calcium carbonate varies from coating on underside of clasts to pervasive coating of clasts and matrix; U-series ages of 173 ± 4 ka to 187 ± 11 ka from innermost layer of calcium carbonate on clasts obtained from samples on the Diamond Mountain Plateau (north of the quadrangle) (Sprinkel and others, 2013); gravel mantles pediment-like geomorphic surfaces and forms the highest gravel cap on the Buckskin Hills that is 1100 to 1400 feet above Brush Creek; the surface generally slopes south-southwest mostly between about 6500 and 6800 feet in the quadrangle and between 7200 and 7500 feet on the Diamond Mountain Plateau; these gravedes are found on the Diamond Mountain and Yampa Plateaus along the south flank of the Uinta Mountains, and on a few topographically high outliers within the Uinta Basin, suggesting a basin-wide deposit that represents a dissected regional mantled surface along the lower slope of the Uinta Mountains; less than 500 feet thick.

Qaf Alluvial-fan deposits (Holocene) – Unconsolidated mud, silt, sand, and gravel (cobbles to boulders); poorly sorted; may grade to stream alluvial deposits (Qal); forms typical fan-shape deposit at the mouths of drainages to broad coalescing deposits along the base of highlands that have several drainages along their length; less than 30 feet thick.

Colluvial Deposits

Qc Colluvium (Holocene and Pleistocene) – Unconsolidated sand and gravel with some silt and few cobbles deposited on slopes by gravity and locally derived from surficial map units and bedrock formations; less than 10 feet thick.

Qcg Colluvial gravel (Holocene and Pleistocene) – Unconsolidated gravel-dominated colluvium with some sand and silt deposited on slopes by gravity and derived locally from weathered piedmont gravel deposits; less than 10 feet thick.

Qcs Colluvial sand (Holocene and Pleistocene) – Unconsolidated sand-dominated colluvium with some silt and few cobbles deposited on slopes by gravity and locally derived from sand-rich surficial map units and sandstone bedrock formations; less than 10 feet thick.

Eolian Deposits

Qes Eolian sand (Holocene and upper Pleistocene) – Unconsolidated, well-sorted, fine- to medium-grained sand; forms small dunes or thin deposits that mound up on vegetation; may grade to Qecs deposits; derived from and deposited on the Nugget Sandstone; less than 10 feet thick.

Mass-Movement Deposits

Qms Landslide deposits (Holocene and Pleistocene) – Locally derived, mixed clay to boulders, bedrock, and blocks in rotational slumps, translational slides, and earth flows; commonly forms hummocky and irregular topography that includes closed depressions and sag ponds, internal scarps, and chaotic bedding attitudes; commonly formed in fine-grained and clay-rich bedrock units such as the Mancos, Mowry, Morrison, and Chinle Formations; landslides in the map area are commonly triggered by increased (and often rapid) soil moisture such as high-intensity rainfall events, above-normal precipitation, rapid snowmelt, or excessive irrigation; relative ages of mass-movement deposits to indicate recent versus older slides were not differentiated because research indicates that even landslides considered old and inactive actually may continue to move by slow creep, are capable of renewed movement, and pose a risk (Ashland, 2003); variable thickness.

Mixed-Environment Deposits

Qac Mixed alluvium and colluvium, sand and silt deposits (Holocene) – Unconsolidated, well- to moderately sorted, locally derived, mixed silt and fine-grained sand; minor coarser material may be present; generally deposited on Chinle, Carmel, Dakota, Mowry, and Frontier Formations, mostly around Red Fleet Reservoir, by both alluvial and colluvial processes; less than 10 feet thick.

Qacg Mixed alluvium and colluvium, gravel-dominated deposits (Holocene) – Unconsolidated gravel with some sand and silt derived from locally weathered Qap deposits; deposited by both alluvial and colluvial processes; located along a drainage east of Little Brush Creek in section 31, T. 2 S., R. 23 E., SLB&M; less than 30 feet thick.

Qacs Mixed alluvium and colluvium, sand-dominated deposits (Holocene) – Unconsolidated, well- to moderately sorted, locally derived, mixed fine-grained sand and silt; generally deposited on Nugget Sandstone and Gartra Member of Chinle Formation by both alluvial and colluvial processes; less than 10 feet thick.

Qaci Mixed alluvium and colluvium, silt-dominated deposits (Holocene) – Unconsolidated, well- to moderately sorted, locally derived, mixed silt and fine-grained sand; generally deposited on fine-grained bedrock formations like the Morrison, Stump, and
Chinle Formations by both alluvial and colluvial processes; less than 10 feet thick.

Qecs Mixed eolian sand and colluvium deposits (Holocene) – Unconsolidated, well-sorted, mixed fine-grained sand and silt; may grade to Qes deposits; generally deposited on Nugget Sandstone by both eolian and colluvial processes; less than 10 feet thick.

Bedrock Units

Kms Mancos Shale (Upper Cretaceous, Campanian to Coniacian) – Shale, dark to medium gray; marine origin; little color and lithologic variability throughout; forms badlands topography; pediment deposits typically cap Mancos hills; oil and gas drill holes penetrated about 2000 to 3700 feet of Mancos Shale in the west and southwest part of the quadrangle but regionally is as much as 5000 feet thick.

Kf Frontier Formation (Upper Cretaceous, Turonian) – Sandstone, shale, and coal; formation can be divided into an upper cliff-forming sandstone and lower slope-forming shale; upper cliff-forming sandstone is light to moderate yellow brown, medium to coarse grained, thin bedded to massive, cliff and ledge forming; includes interval of medium- to dark-gray shale and coal; coal is dark gray to black, low-grade bituminous, 6 to 9 feet thick, and preserved between two cliff-forming sandstone units in the upper part of the formation (Doelling and Graham, 1972); lower slope-forming shale includes an upper moderate-brown shale unit and lower medium-gray shale unit; formation contains large concretions (“cannonballs”) up to 6 feet in diameter mostly in the lower part of the cliff-forming sandstone; 125 to 230 feet thick.

Km Mowry Shale (Upper and Lower Cretaceous, Cenomanian to Albian) – Shale, bluish gray, interbedded with thin bentonic ash beds; weathers characteristically in small, hard “chips”; contains abundant fish scales, fish bone, teeth, and coprolites (Anderson and Kowallis, 2005); marine origin; 110 to 140 feet thick.

Kd Dakota Formation (Lower Cretaceous, Albian) – Sandstone and shale, interbedded; sandstone is commonly light brown to yellowish gray, coarse grained with conglomerate lenses, limonite stained, and ledge to cliff forming; shale is dark gray, carbonaceous, and forms slope; typically upper and lower sandstone separated by carbonaceous shale; may include a thin basal dark-gray marine shale (Sprinkel and others, 2012); 125 to 300 feet thick.

Kcm Cedar Mountain Formation (Lower Cretaceous, Albian to Aptian) – Mudstone interbedded with carbonate, conglomerate, and minor sandstone lenses and beds; mudstone is pinkish gray, reddish brown, medium to very light gray, and grayish purple; contains calcic paleosols that weather to form limestone nodules; the formation also contains chert pebbles and gastroliths that commonly weather out; contains dinosaur fossils; slope forming; fluvial-lacustrine origin; 80 to 160 feet thick.

K-1 unconformity

Jm Morrison Formation (Upper Jurassic, Tithonian to Kimmeridgian) – Mudstone interbedded with sandstone, siltstone, and conglomerate that comprises four members; in descending order they are the Brushy Basin, Salt Wash, Tidwell, and Windy Hill Members; Brushy Basin Member (fluvial-lacustrine) is mudstone, mostly light gray in the upper part with a thin interval of variegated (grayish purple, grayish green, light gray, and pale pink hues) mudstone in the lower part, and slope forming; Salt Wash Member (fluvial) is a variegated interval of interbedded sandstone, conglomerate, siltstone, and silty mudstone; sandstone is very light brown, fine to medium grained, well sorted to moderately sorted, cross-bedded, and forms channels; conglomerate is pebble to cobble clast supported, poorly sorted, and cross-bedded; siltstone and silty mudstone is reddish brown to grayish green; sandstone and conglomerate beds are ledge forming; may include a basal sandstone that is light brown gray, fine to medium grained, well sorted, cross-bedded; Tidwell Member (tidal flat) is interbedded mudstone, siltstone, and sandstone; light gray to greenish gray with minor reddish brown; sandstone is very fine grained, rippled and cross-bedded; includes distinctive beds of light-red to pinkish amygdaloidal chert; Windy Hill Member (marine) is siltstone and sandstone, light gray to green gray; sandstone is thin bedded, rippled, cross-bedded, and glauconitic; the Windy Hill is restricted to northeastern Utah and is thought by some to rest unconformably (J-5) on the Stump Formation (Peterson, 1988; Turner and Peterson, 1999); however, others do not recognize an unconformity (Currie, 1997; Bilbey and others, 2005); we saw no clear evidence for an unconformity; 630 to 725 feet thick.

J-5 unconformity(?)

Js Stump Formation (Upper Jurassic, Oxfordian) – Sandstone and limestone interbedded with marine shale; limestone beds are light brown, sandy, oolitic, cross-bedded, and ledge forming; shale is olive brown, contains gypsum and belemnites; sandstone is very light gray, coarse grained, cross-stratified, contains glauconite, and is usually slope forming; 125 to 200 feet thick.
J-3 unconformity

**Entrada Sandstone** (Middle Jurassic, Callovian) – Two eolian sandstone beds bounded by terrestrial silt and mudstone beds; sandstone is very light gray and pale yellowish brown, medium grained, friable, commonly slope forming; mudstone is moderate reddish orange, slope forming; 200 to 250 feet thick.

**Carmel Formation** (Middle Jurassic, Callovian to Bajocian) – Upper siltstone and lower limestone with gypsum, mudstone, and sandstone; siltstone is pale green, very light gray, and moderate reddish brown, fine grained, slope forming; limestone is medium gray, sandy, fossiliferous, with jasperized fossils, contains beds of altered volcanic ash; local and regional $^{40}\text{Ar}/^{39}\text{Ar}$ dating of sanidine and biotite crystals and U-Pb dating of zircon crystals yield ages between 166 and 168 Ma (Sprinkel and others, 2011a); 160 to 190 feet thick.

J-1 unconformity

**Nugget Sandstone** (Lower Jurassic to Upper Triassic, Toarcian to Rhaetic) – Sandstone, light brown to light pinkish gray, medium to fine grained, massive weathering with large-scale high-angle cross-beds; forms cliffs, ledges, monoliths, arches, and spires; commonly jointed; weathers into loose sand commonly reworked by wind; predominantly eolian with thin fluvial lenses near base; also contains light brown to very light brown sandy dolomite and reddish brown siltstone of interdunal lacustrine origin typically 150 to 200 feet below top of formation; contains Early Jurassic dinosaur tracks in upper part and Late Triassic aetosaur tracks in the lower 30 feet of formation (Sprinkel and others, 2011b); 500 to 1140 feet thick.

**Formation of Bell Springs** (Upper Triassic, Rhaetian) – Sandstone, siltstone, and mudstone; mudstone is grayish red to moderate brown, often mottled with light-grayish-green reduction spots, locally has mudcracks and bioturbation; siltstone is moderate reddish orange to dark reddish brown, forming small (1–10 cm) ledges between mudstones; sandstone is very light gray to moderate reddish orange, fine to medium grained, ripple laminated to cross-bedded, locally with crinkly beds, salt casts, rip-up clasts, bioturbation and locally massive weathering; forms prominent ledges and slopes beneath the Nugget Sandstone within the quadrangle forming, what looks like, the bows of battleships locally called the Red Fleet, but becomes more slope forming eastward outside the quadrangle; predominantly fluvial-lacustrine with some eolian beds; 90 to 200 feet thick.

**Chinle Formation, upper unnamed member** (Upper Triassic, Rhaetic[?] to Carnian) – Siltstone, mudstone, and sandstone interbedded with conglomerate and carbonate lenses; siltstone is moderate to dark reddish brown, fine grained, and slope forming; mudstone is grayish yellow, pale reddish purple, or variegated, fine-grained, ashly, and erodes to form badlands topography; sandstone is moderate reddish brown, fine grained, and very thin bedded; can be divided into an upper reddish unit dominated by moderate- to dark-reddish-brown siltstone, mudstone, and sandstone, a middle “ochre” unit dominated by grayish-yellow mudstone, and a lower mottled unit dominated by pale-reddish-purplish siltstone and mudstone; 105 to 230 feet thick.

**Gartra Member of Chinle Formation** (Upper Triassic, Carnian) – Conglomerate and sandstone; conglomerate is very light gray with pebble-size clasts of mixed lithologies including chert and permineralized wood; sandstone is pale reddish brown to light gray, medium to coarse grained; forms cliffs; fluvial with channel-form base that cuts into underlying Moenkopi Formation; 15 to 100 feet thick.

**Moenkopi Formation** (Lower Triassic, Olenekian to Induan) – Siltstone and sandstone interbedded with gypsum; siltstone is moderate reddish orange, fine grained, ripple laminated, thinly bedded, and forms ledges and slopes; sandstone is moderate brown, fine grained, and massive, forms ledges at the top; locally interbedded with thin gypsiferous beds; gypsum is massive and forms a prominent ledge in the middle of the unit; marginal marine to fluvial; 550 to 1120 feet thick.

**Dinwoody Formation** (Lower Triassic, Induan) – Marine shale and gypsum interbedded with sandstone; shale is very light gray to light gray, forms slopes; sandstone beds are light gray, medium grained, micaceous, and form thin beds; 375 to 625 feet thick.

**Park City Formation** (Middle to Lower Permian, Guadalupian to Cisuralian) – Dolomite beds interbedded with siltstone and shale of the upper Franklin Member of the Park City Formation; dolomite beds are very light to medium gray, brownish gray, and dark greenish gray, glauconitic, sandy, and form prominent ledges; siltstone is reddish orange and
forms a slope; the underlying Meade Peak Member of the Phosphoria Formation, which lies on the Weber Sandstone in the quadrangle, is dark-gray, marine shale, contains chert, and is mined for phosphate in the quadrangle; the lower Grandeur Member of the Park City Formation is missing within the quadrangle; 90 to 170 feet thick.

**Weber Sandstone** (Lower Permian to Middle Pennsylvanian, Artinskian[?] to Moscovian) – Sandstone, light gray to light brown, fine to medium grained; large-scale cross-bedding characterizes formation; lower part of formation contains sandstone and thin beds of limestone; lower sandstone is light brown, medium grained, glauconitic, cross-bedded; limestone is medium gray, thin bedded, and fossiliferous; forms massive-weathering cliffs; dominantly eolian with interbedded marine beds containing glauconite in lower part; locally contains large-scale fluid-escape structures; 1015 to 1275 feet thick.

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GEOLOGIC MAP OF THE DONKEY FLAT QUADRANGLE, UTAH COUNTY, UTAH

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