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Prehistoric Animal Tracks at Red Fleet State Park, Northeastern Utah

Alden H. Hamblin[1], Sue Ann Bilbey[2], and James Evan Hall[3]

ABSTRACT

Red Fleet State Park sits on the southern flank of the Uinta Mountains in northeastern Utah. Rock strata in and around Red Fleet Reservoir dip steeply to the south resulting in surface exposure of eleven Mesozoic formations. These formations range in age from Early Triassic to Late Cretaceous. Five formations are known to contain fossil footprints in the Red Fleet area. Tracks in the Moenkopi, Chinle and Carmel Formations near Brush Creek were recorded in the 1940s and 1950s, long before the reservoir was constructed. In 1987, several years after the reservoir filled, a major track site with more than 350 tracks was found on an eroded shoreline formed by the fluctuating lake levels that impacted the Glen Canyon Sandstone (Navajo/Nugget Sandstone). The following year, tracks were also discovered on the lake shoreline in the Carmel Formation. Subsequent investigations have lead to the discovery of tracks in the Chinle Formation, both on the shoreline and hills northeast of the reservoir, as well as dinosaur tracks associated with thin coal beds in the Frontier Formation near Red Fleet Dam. Other fluvial and littoral formations in this area have excellent potential for vertebrate ichnofossils, as these units have similar fossils elsewhere in the intermountain west.

INTRODUCTION

Red Fleet State Park is located 19 kilometers (12 miles) northeast of Vernal, Utah (figures 1 and 2). It is situated on the southeastern flank of the Uinta Mountain arch with exposed sedimentary strata that dip steeply to the south (Kinney, 1955; Rowley, and others, 1985). Mapping expeditions beginning in the 1870s, under the auspices of the United States Territorial Survey (later Geological Survey) of Ferdinand Hayden (1872), Clarence King (1877), and John Wesley Powell (1876), established landmark studies for all subsequent geological work in the Uintas. The geology of the Uinta Basin and Uinta Mountains is remarkably complex, and a comprehensive review of their geology is beyond the scope of this synthesis. This presentation, however, is a brief overview of the Mesozoic geologic history of the Uintas near Red Fleet State Park.

In geological terms, the Uinta Mountains and Uinta

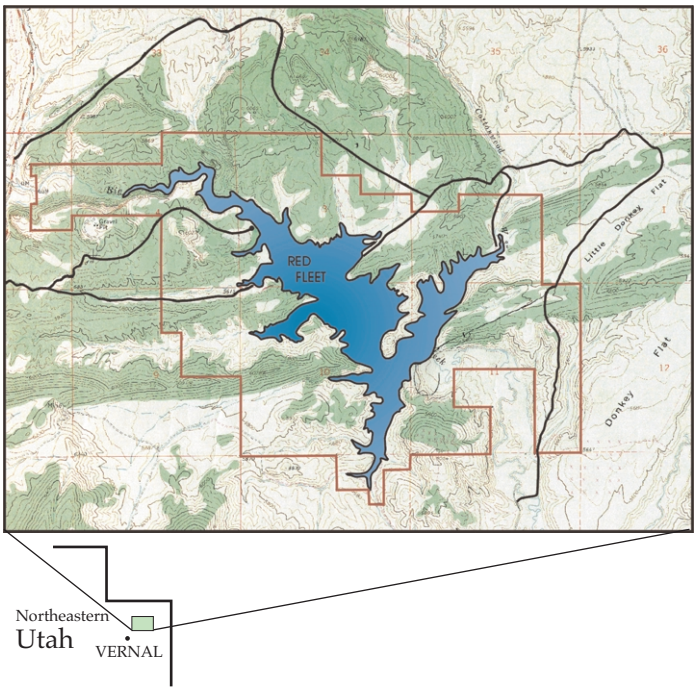

Figure 1. Location of Red Fleet State Park in northeastern Utah with park boundaries indicated relative to the area of the reservoir.

[1]*Fremont Indian State Park, Sevier, UT 84766*
[2]*Utah Field House of Natural History, Vernal, UT 84078*
[3]*Uinta Paleontological Associates, Inc., Vernal, UT 84078*

Figure 2. Photograph of Red Fleet State Park from the hills west of the dam looking northwest.

Basin formed relatively recently during the Tertiary (Crowley, 1955; Untermann and Untermann, 1964; Hansen, 1986). Geological formations exposed in the Red Fleet State Park region represent more than 150 million years of earth history, primarily strata from the Mesozoic Era. The most recent geological events are the erosional processes of the Quaternary that have formed the spectacular canyons of Brush Creek and its drainage where the reservoir is now located The absolute ages of the geological time periods as used here are defined in Hintze (1988). In the following discussion "mya" denotes million years ago.

In a linear distance of approximately 4 kilometers (2.5 miles) trending southeast from the second access road as one travels north on US Highway 191 to the dam, twelve Mesozoic formations are exposed in the Red Fleet Reservoir area (Kinney, 1955; Rowley and others, 1985)(figure 3). Fossil animal tracks described as “swim” tracks were first reported in the Moenkopi Formation in an area just northwest of the present-day reservoir by Peabody (1948; 1956). Shortly thereafter, G.E. and B.R. Untermann (1949) reported track sites in the Chinle and Carmel Formations from nearby rock exposures north and east of Vernal. Red Fleet Dam was constructed and the reservoir filled in 1980. Dinosaur tracks were discovered in the Glen Canyon Sandstone (Navajo/Nugget Sandstone) along the shoreline in 1987. In 1988, dinosaur tracks were found in the Carmel Formation, also along the shoreline. Additional exploration in succeeding years has led to the discovery of tracks in the Chinle Formation along the shoreline and in the hills northeast of the reservoir, and of tracks in the Frontier Formation near the dam site (Hamblin, 1992). Several additional track sites have been discovered recently during a U. S. Bureau of Reclamation paleontological resource survey (Vincent Santucci, verbal communication, 1999; Utah Field House collections).

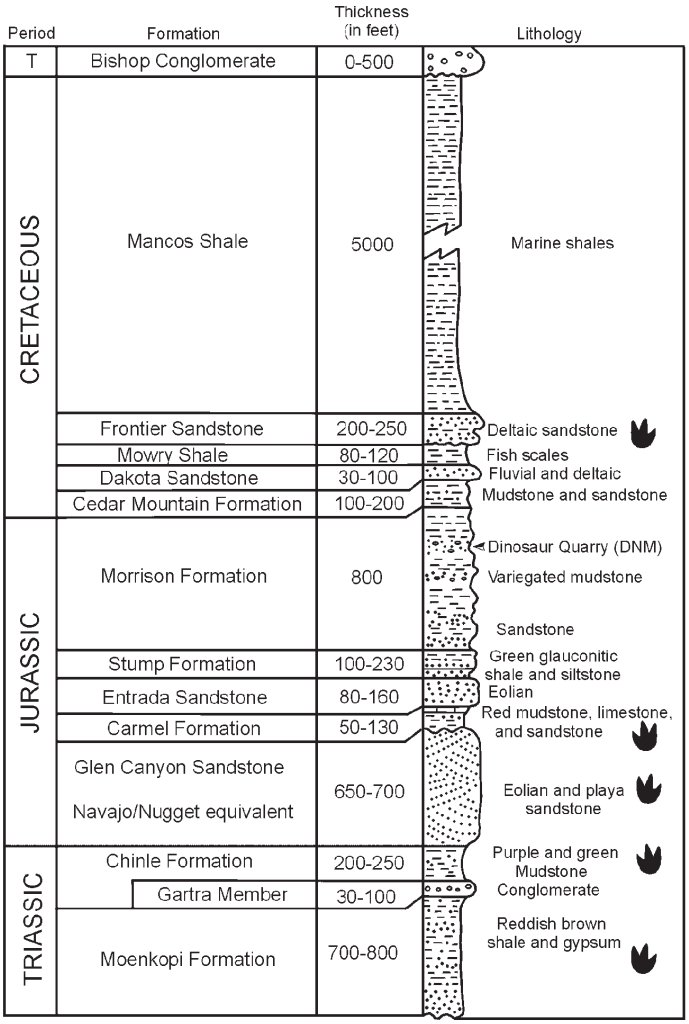

Figure 3. Stratigraphic column of Red Fleet Area (adapted from Hintze, 1988). Track prints indicate units that preserve vertebrate track sites. Position of the Dinosaur National Monument quarry is indicated as well.

TRIASSIC PERIOD - 245 mya to 208 mya

Dinwoody and Moenkopi Formations - Early Triassic

The Early Triassic Dinwoody and Moenkopi Formations introduce the first rock units of the Mesozoic Era in northeastern Utah. As part of a regressional sequence, the thin light gray, nearshore marine shales and siltstones of the Dinwoody Formation quickly gave way to red mudflats of the Moenkopi Formation. The Moenkopi Formation is identifiable by the brick-red, micaeous shale and mudstone interbedded with thin layers of gypsum. In western Utah and Idaho, the upper Dinwoody and Thaynes formations are the marine equivalents of the Moenkopi (Hintze, 1988).

Thin red mudstone units of the Moenkopi Formation preserve tracks identified as phytosaurs and amphibians that lived in the area (Peabody, 1948, 1956). Peabody (1956) reported that “. . . extensive surfaces bearing

Figure 4. "Swim" track casts from Moenkopi Formation northeast of Red Fleet State Park. Scale is in 10 cm blocks.

"swim" tracks are fairly common, subaerial tracks are rare. One trackway of a small tetrapod (? reptile) showing an undulate tail mark was found in the lower beds exposed approximately 2 miles up an eastern tributary of Brush Creek north of Vernal. The trackway was preserved as a cast on the under surface of a stratum of massive mudstone and could not be collected readily." Figure 1 of Plate 79 in Peabody (1956) shows the upside-down layer with "swim" track casts. Similar "swim" track casts have been found by the authors northeast of the reservoir in an area assumed to be close to Peabody's site (figure 4). Specimens of these tracks are displayed at the Utah Field House of Natural History State Park Museum in Vernal.

Chinle Formation - Late Triassic

At the close of Moenkopi time, the sea retreated and coarse-grained fluvial sediments were being shed from the Uncompagre Uplift (southeast of the present Uinta Basin)(Dubiel, 1992). Evidence of this transition is preserved as an angular unconformity between these units, although some of the unconformity may be the result of erosional trenching by the encroaching streams of the Gartra Member of the Chinle Formation (Poole and Stewart, 1964a and b; Dubiel, 1992). As in the basal conglomerate members of the Chinle Formation elsewhere, petrified wood is preserved in the conglomeratic fluvial channel deposits of the Gartra Member in the Red Fleet area (Kinney, 1955; Untermann and Untermann, 1964).

The Late Triassic Chinle Formation in the Uinta Basin is the result of tectonic processes that were taking place near the end of the Triassic: the uplift of the Ancestral Rockies to the east, the Uncompagre Uplift to the southeast, as well as island arch volcanic activity to the west (Poole and Stewart, 1964a and b; Dubiel, 1992). Fluvial

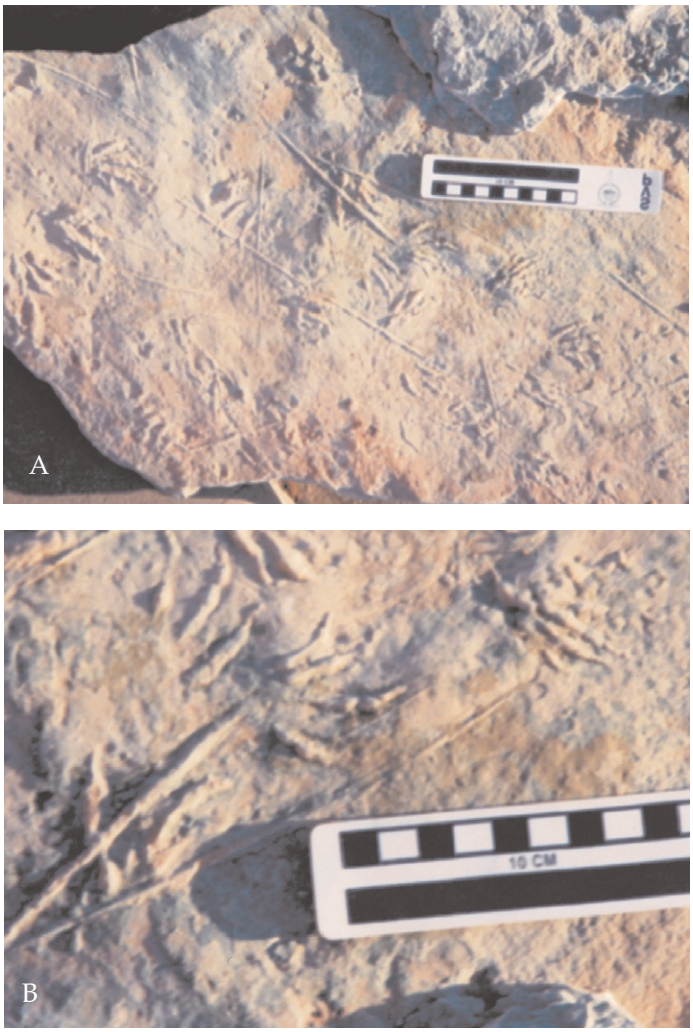

Figure 5a and 5b. Recently discovered footprint casts of Brachycheirotherium with tail drag marks from the Chinle Formation at Red Fleet State Park. Scale is in centimeters.

systems from Colorado carried abundant clastic debris into northeastern Utah, where deltaic and lacustrine conditions predominated. In addition, volcanic ash, later devitrified to smectitic claystone, was carried into the area by west winds. Dark green and purple variegated lacustrine claystone beds dominate the lower portion of the formation north of Vernal, but thin fluvial sandstones with associated overbank deposits are more abundant in the upper portions. The upper variegated Chinle mudstones are intermittently covered with a thin sheet, sandstone units and eventually by the Glen Canyon Group (sometimes known locally as the Navajo or Nugget Sandstone), an eolian sandstone unit that was deposited in Early Jurassic time (Peterson, 1988).

Untermann and Untermann (1964, 1969) reported finding tracks in the Chinle Formation along the south flank of the Uinta Mountains in the Red Mountain area just west of Red Fleet State Park. The senior author discovered two track sites in the Chinle Formation, one along the shoreline of the lake and the other in the hills northeast

of the reservoir. These were reported as "Red Fleet West" site and "Red Fleet North" site in Lockley and others, (1992). "Red Fleet North" consists of several footprints that belong to the ichnogenus Agialopus, a small three-toed dinosaur. These tracks are similar to a track type known as Grallator. Footprints at the "Red Fleet West" site are from a quadruped, possibly an aetosaur. These tracks belong to the ichnogenus, Brachycheirotherium. Similar track sites have been found near Dinosaur National Monument and are described by Lockley and others (1992).

Recently during a paleontological resource survey for the U.S. Bureau of Reclamation another track site was discovered in the Chinle Formation along the southern shoreline in the northern end of the reservoir (Vincent Santucci, verbal communication, 1999) (figures 5a and 5b). These tracks are similar to Brachycheirotherium–a four-toed quadruped with associated tail drag marks (up to 22 cm long). However, the footprints are smaller (3.5 cm) than the trackway reported from Cub Creek near Dinosaur National Monument (Lockley and others, 1992). The Red Fleet tracks are cast impressions and occur in a tan fine-grained sandstone that overlay variegated green to reddish-gray siltstone and mudstone as recognized from a few adhering layers.

JURASSIC PERIOD - 208 mya to 144 mya

Glen Canyon Sandstone - Early Jurassic

In the Late Triassic - Early Jurassic, continental plate movements pushed the North American continent over a portion of the East Pacific Rise. A subduction zone with its corresponding island arc and continental uplift was developing in western Nevada and California (Stokes 1986). Erg (wind-blown sand) deposits of the Glen Canyon Sandstone (Wingate, Kayenta, and Navajo Formations as well as the Nugget Sandstones elsewhere) suggest the presence of continental desert conditions over much of the Rocky Mountain province during the Early Jurassic (Lawton, 1994).

The senior author discovered an extensive track site in the Glen Canyon (Navajo/Nugget) Sandstone along the shore of Red Fleet Reservoir in 1987 (Hamblin, 1992). The tracks were found at a popular swimming and diving area of the lake, but had gone unnoticed until their discovery seven years after the lake had filled. Details of this site were reported by Hamblin and Bilbey (1999). More than 350 footprints are recorded in nine different layers of the horizontally-bedded calcareous sandstone (figures 6a and 6b). Two track types were recognized, Grallator and Eubrontes, representing two sizes of bipedal, tridactyl dinosaur track-makers in a series of red to yellow, bioturbated, oasis or playa deposits. There are two hypotheses explaining these track ways: 1) Both track types were made by one species of dinosaur, but represent different age groups; or 2) These are the tracks of two different species of theropod dinosaurs (Hamblin and Bilbey, 1999). Grallator and Eubrontes tracks are fairly common in Early Jurassic rocks in other areas, particularly the Connecticut Valley of Massachusetts, USA, where they were first studied and identified. The general interpretation of these tracks elsewhere is that they represent two species of dinosaurs (Lockley, 1991).

Figure 6a and 6b. Grallator and Eubrontes footprints from Glen Canyon (Navajo/Nugget) Sandstone from Red Fleet State Park. Scale is 10 centimeters.

Another small site was found by Evan Hall in the Glen Canyon Sandstone on the north side of the Brush Creek channel of the lake. The site is approximately 15 meters (50 feet) above the water line and stratigraphically lower than the Hamblin track site. Splayed quadrupedal footprints cross a parallel-laminated bed within the larger cross-bedded sandstone units of the Glen Canyon Sandstone. They are possibly underprints, round with no toe marks and are about 1.5 cm long. These are probably of the track type Brasilichnium which are similar to modern mammal tracks and are thought to be tracks of a mammal-like reptile (?therapsid). These have been reported elsewhere in the Navajo Sandstone (Lockley and Hunt, 1995; Hamblin, 1998; Hamblin and Foster, in this publication).

Some faint tridactyl footprints about 50 cm in length were also observed at this site. These tracks, found on parallel-laminated beds, suggest an occasional rise in the ground water table in the great erg desert of the Glen Canyon Sandstone. Similar tracks have been found in the Nugget Sandstone near Heber, Utah (Albers, 1975).

Carmel Formation - Middle Jurassic

In the Middle Jurassic, marine incursions into the Western Interior of the United States emerged from the north as the Sundance Sea developed and expanded (Hinman, 1957; Freeman, 1976; Imlay, 1980; Peterson, 1988). The Carmel and Stump Formations are the result of two Jurassic transgressions of the Sundance Seaway (Pipiringos and Imlay, 1979; Imlay, 1980). Deposited between these units are the regressional eolian sandstone beds of the Entrada Formation.

The Carmel Formation is composed of mudflat and shoreline deposits of red claystone, light-greenish-gray, clayey limestone, light-gray sandstone, and gypsum that correlate with the marine Twin Creek Formation in central Utah (Hinman, 1957; Rigby, 1964; Imlay, 1980). A year after discovery of the Glen Canyon track site, Utah State Park Ranger Paul Dixon discovered small dinosaur footprints in a sandstone unit in the Carmel Formation along the western shore of the lake. Subsequent investigation revealed two distinctive layers of sandstone with tracks. The lower layer contains elongate tridactyl footprints measuring 7 cm long and 4 cm wide and the upper layer has nearly symmetrical tridacty prints measuring 6.2 cm long and 6.0 cm wide (Lockley and others, 1998) (figure 7). The dissimilarity in footprint sizes in the lower horizon may suggest the occurrence of two distinct ichnospecies or it may be an artifact of preservation differences for the same species. The better detail of footprints from the upper layer led Lockley and others (1998) to attribute these tracks to Carmelopus, a new Middle Jurassic ichnogenus. These tracks were described from the Red Fleet State Park and Dinosaur National Monument areas. Although this is a significant discovery, Untermann and Untermann (1949) reported occurrences of similar tridactyl dinosaur tracks in the Carmel Formation near Dinosaur National Monument. Examples of these tracks were collected by the Untermanns and are on display in the Utah Field House.

During a Utah State University research project, Emil Stockton discovered a single footprint near the entrance road of the state park. Although this is a solitary footprint, its morphological detail is identical to those found on the shoreline and it occurs in a similar fine-grained, light-gray sandstone. Apparently dinosaurs were feeding along a sandy beach and left their tracks in the sand. These are the only evidence of Middle Jurassic dinosaurs known from this area. No fossil bone has been found in this unit, only tracks and an abundance of marine invertebrate shells (Sohl, 1965).

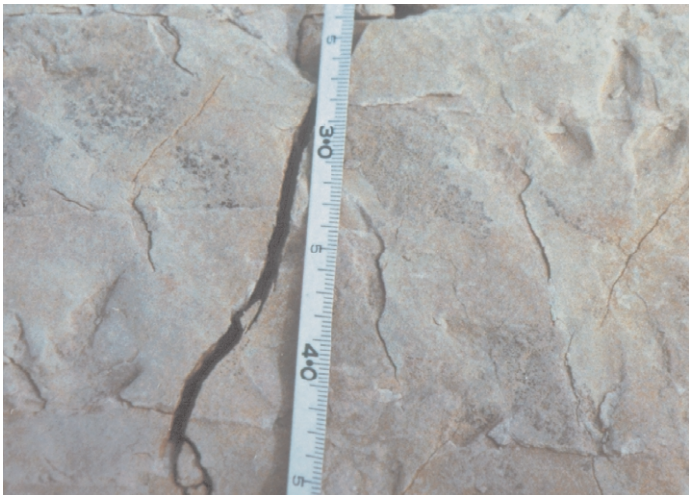

Figure 7. Carmelopus footprints from the Carmel Formation from Red Fleet State Park. The scale interval is 30 to 40 centimeters.

Entrada Sandstone and Stump Formation - Middle Jurassic

During a brief intermediary regression of the Sundance Sea, winds reworked shoreline sands and deposited the eolian, cross-bedded sandstone of the Entrada Sandstone (Otto and Picard, 1976). Fossils of any type are rare in the Entrada near Vernal, but the inferred depositional environment of the sandstone suggests potential for preservation of ichnofossils similar to those found in this stratigraphic unit near Moab (Lockley and Hunt, 1995). Next, the Stump Formation includes three distinctive marine units: the lower Curtis Member, the Redwater Shale, and the Windy Hill Member (a regressive limestone and sandstone unit sometimes grouped with the Upper Jurassic Morrison Formation but more appropriately placed in the lithostratigraphic grouping of the marine Stump Formation) (Peterson, 1988; Bilbey, 1998). The Curtis Member is composed of near-shore, flaggy-bedded sandstone deposits. The Redwater Member is a transgressive, greenish to dark-gray marine shale. The Windy Hill Member is a regressional unit with nearshore limestone and beach sandstone deposits (Hoggan, 1970). Although no tracks have been found in the Stump Formation, fossil remains of marine reptiles–Icthyosaurs and Pliosaurs–have been discovered near Red Fleet (Bilbey and others, 1990).

Morrison Formation - Late Jurassic

Overall regional uplift of the craton to the west and southwest (the Nevadan and the beginning Sevier orogenies) caused the final northward withdrawal of the Sundance Sea. Continental deposition (fluvial, lacustrine, and paleosol) dominated a large alluvial plain extending from southwestern Utah and northern Arizona to Montana and eastward to Kansas (Stokes, 1944; Craig and others, 1955; Dawson, 1970; Dodson and others, 1980; Imlay, 1980; Brenner, 1983).

This continental sequence began with the deposition

of the Morrison Formation, world renown for its dinosaur fauna (Gilmore, 1924; 1936; Madsen and Miller, 1979; Dodson and others, 1980; Turner and Peterson, 1999; Engelmann, 1999), and continued with the Cedar Mountain and Dakota Formations. Regional uplift to the west and southwest exhumed late Paleozoic and early Mesozoic sedimentary rock that was carried eastward into the depositional basin. Volcanic ash from the emerging island arc and scattered plutons in western Utah and eastern Nevada provided much of the volcanic detritus incorporated in these formations (Cadigan, 1967; Craig and others, 1955; Armstrong and Suppe, 1973; Bilbey, 1992, 1998). Silica released during the devitrification of the ash cemented many of the sandstone units, formed intraformational silcrete horizons, and petrified many of the dinosaur bones (Cadigan, 1967; Bilbey and others, 1974; Bilbey, 1992; 1998). Bones of other, much smaller animals such as mammals, salamanders, turtles, and crocodiles, (Chure and others, 1998) as well as petrified wood (Tidwell, 1990a and b) and small fresh water invertebrates (Yen, 1952; Evanoff and others, 1998) have also been found. Non-dinosaurian animals are quite rare and are preserved primarily in crevasse splay, pond, or overbank deposits. There are a variety of fossil vertebrates and plants known from Morrison Formation in the Red Fleet area. Although no dinosaur tracks have been found in the Morrison Formation near Red Fleet, the abundance of vertebrate fossils suggests that there is potential for the discovery of tracks.

CRETACEOUS PERIOD - 141 mya to 66.4 mya

Cedar Mountain Formation - Early Cretaceous

The Sevier orogeny, which caused uplift and overthrusting throughout central Utah, north to south, as well as eastern Nevada, southwestern Wyoming and western Montana, began in earnest in the Early Cretaceous (Allmendinger and Jordan, 1981; Heller and Paola, 1989). Great detrital sheets of conglomerate record that activity in the western Colorado Plateau and eastern Basin and Range provinces. In northeastern Utah, eastward-thinning conglomerate lenses appear as early as Morrison time, but are more prevalent in the Lower Cretaceous Cedar Mountain Formation (Young, 1960, 1987; Kirkwood, 1976; Bilbey, 1992). Dinosaurs, other terrestrial vertebrates, and freshwater invertebrates are also found in the Cedar Mountain Formation near Vernal, but are locally less abundant than in the Morrison Formation (Stokes, 1944; 1952; Galton and Jensen, 1979; Kirkland and others, 1993; several papers in Lucas and others, 1998; Kirkland and others, 1999). Plant material found in the Cedar Mountain Formation suggests one of the earliest occurrences of angiosperms in North America (Tidwell, 1983). Dinosaur tracks are not common in the Cedar Mountain Formation, but occasionally they are found in crevasse splay deposits particularly in the San Rafael Swell area (Lockley and others, 1999).

Figure 8. Dinosaur footprint cast from Frontier Formation near the south end of Red Fleet State Park. Scale is in 10 centimeters or 4 inches.

Dakota Sandstone and Mowry Formation - Early Cretaceous

Counteracting the uplift west of the Colorado Plateau region was midcontinental subsidence to the east and the major transgressions of epicontinental seas (Young, 1960, 1987). In the Early Cretaceous a sea encroached from the north depositing first the littoral sands of the Dakota Sandstone and later the marine Mowry Formation.

Interfingering littoral (beach) and fluvial deposits of the Dakota Sandstone (light brown to yellow sandstone with minor coal and gray claystone) are the first evidence of the Cretaceous epicontinental sea incursions. Although no vertebrate trace fossils have been found in this unit in the Red Fleet area, marine invertebrate ichnofossils, like Callianasa burrows, are common. However, dinosaur tracks are known from the Dakota Formation elsewhere, for example, the Alameda Tracksite near Morrison, Colorado (Lockley and Hunt, 1995), so there is potential for finding tracks in the Vernal area.

Overlying the Dakota is the Mowry Formation, a thin-bedded marine shale with minor bentonite beds. The bentonitic clay is indicative of continued volcanic activity primarily to the west and northwest (Stokes, 1986). Silver-gray weathering shale with numerous fish bones, teeth, and scales (Enchodus, Xenyllion, icthyodectiform fishes, and sharks), less common marine reptiles (pliosaur and sea crocodile), and cephalopods, particularly Neogastropolites, help identify this formation (Cockerell, 1915, Stewart and others, 1993).

Frontier Formation - Late Cretaceous

The Frontier Formation, near Vernal, is a fairly thin sequence (90 meters) of interbedded facies of fluvial and beach sandstone, coal, and barrier bar sandstone. These were formed near the eastern extent of a large river delta which prograded from the Sevier Highland into the Cretaceous Mancos epicontinental seaway (Untermann and Untermann, 1964; Armstrong, 1968; Maione, 1971). Farther west along the trend of the Uinta Mountains, the Frontier Formation thickens to more than 3,000 meters of deltaic and marine sandstone units, with interfingering fluvial sandstones, coal, and overbank deposits (Hale, 1959; Ryer, 1977; Molenaar and Wilson, 1990).

Footprints of large bipedal tridactyl dinosaurs, probably ornithopods, have been found associated with thin coal beds in the Frontier Formation near the Red Fleet dam site (figure 8). Another site near the southwest shore of the lake has a possible four-toed footprint. These tracks are significant because few dinosaurs are known from the Turonian Stage of the Cretaceous Period in North America.

Mancos Shale - Late Cretaceous

In northeastern Utah, the Mancos Shale makes up the majority of the Cretaceous rocks, reaching a thickness of more than 1,700 meters (Untermann and Untermann, 1964). It is a dark-gray to light-brownish-gray, marine shale with relatively few fossils. A few types of benthic mollusks, a variety of pelagic ammonites, and a few marine reptiles are occasionally found. The paucity of bottom dwelling invertebrates is due primarily to the inhospitable character of the clay sea bottom (Fouch and others, 1983). The Mancos Shale is the youngest Mesozoic unit exposed at Red Fleet Reservoir. Interfingering with the Mancos and eventually overlying it are fluvial and deltaic deposits of the Mesaverde Group. Although not present at Red Fleet, these beds are found on the southern edge of Ashley Valley, just south of Vernal. These continental units also contain dinosaur tracks that are particularly abundant in the ceilings of coal mines in central Utah and northwestern Colorado.

TERTIARY AND QUATERNARY PERIODS - 66.4 MYA to the Present

After Tertiary folding, faulting, and uplift of the Uinta Mountains associated with the Laramide orogeny, a period of peneplanation occurred. The resulting erosion formed the Bishop Conglomerate, a moderately consolidated unit of conglomerate with sandstone and minor volcanic ash beds, that unconformably overlies small amounts of the Mesozoic and much of Paleozoic and Precambrian rocks in the eastern Uinta Mountains (Hansen, 1986). This unit was deposited primarily in streams flowing from the higher Uinta Mountains, as evidenced by the abundance of Uinta Mountain Group metaquartzite clasts. Biotite from the ash beds has been dated as far back as the Oligocene (Hansen, 1986). The Bishop Conglomerate is intermittently exposed in the Red Fleet area, capping exposed Mesozoic bedrock.

Quaternary uplift has caused entrenchment of existing streams that flow south from the Uinta Mountains, forming steep canyons like Brush Creek, Ashley Creek, and Dry Fork Canyons. The recent artificial dams on some of these streams form local reservoirs–Red Fleet and Steinaker State Parks.

SUMMARY

Red Fleet State Park is an excellent location area where fossil footprints of animals spanning much of the Mesozoic Era can be examined in a distance of four kilometers (2.5 miles). Footprints ranging in age from Early Triassic to Late Cretaceous are found near the reservoir at eight sites in five different formations. The Glen Canyon Sandstone locality is a large site where tracks can be examined in the field. Seven smaller sites provide important study and exhibit material. Other formations such as the Entrada Sandstone, Morrison Formation, Cedar Mountain Formation and Dakota Sandstone contain fossil tracks in other geographic areas and have potential for fossil footprints around Red Fleet State Park.

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REFERENCES

Albers, Cheryl, 1975, Paleoenvironment of the Upper Triassic-Lower Jurassic(?) Nugget(?) Sandstone near Heber, Utah: Salt Lake City, University of Utah, M.S. thesis, 94 p.

Allmendinger, R.W. and Jordan, T.E., 1981, Mesozoic evolution, hinterland of the Sevier orogenic belt: Geology, v. 9, p. 308-313.

Armstrong, R.L., 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, p. 429-458.

Armstrong, R.L., and Suppe, John, 1973, Potassium-argon geochemistry of Mesozoic igneous rocks in Nevada, Utah, and southern California: Geological Society of America Bulletin, v. 84, p. 1375-1392.

Bilbey, S.A., 1992, A study of the Upper Jurassic - Lower Cretaceous rocks at the Cleveland-Lloyd Dinosaur

Quarry with a comparison to the Dinosaur National Monument Quarry, Utah: Salt Lake City, University of Utah, Ph. D. dissertation, 295 p.

—1998, Cleveland-Lloyd Dinosaur Quarry–age, stratigraphy, and depositional environments: Modern Geology, v. 22, p. 87-120.

Bilbey, S.A., Hall, J.E., and Welles, S.P., 1990, Pliosaurian plesiosaur found in Redwater Member of the Stump Formation (Jurassic–Oxfordian) of northeastern Utah [abs.]: Society of Vertebrate Paleontology Meeting, Oct. 1990.

Bilbey, S.A., Kerns, R.L., Jr., and Bowman, J.T., 1974, Petrology of the Morrison Formation, Dinosaur Quarry Quadrangle, Utah: Utah Geological and Mineral Survey Special Studies 48, 15 p.

Brenner, R.L., 1983, Late Jurassic tectonic setting and paleogeography of Western Interior, North America, *in* Reynolds, M.W., and Dolly, E. D. editors, Mesozoic paleogeography of west-central United States: Denver, Rocky Mountain Section Society of Economic Paleontologists and Mineralogists, p. 119-132.

Cadigan, R.A., 1967, Petrology of the Morrison Formation in the Colorado Plateau region: U.S. Geological Survey Professional Paper 556, 113 p.

Chure, D.J., Carpenter, Kenneth, Litwin, Ron, Hasiotis S.T., and Evanoff, Emmett,1998, The fauna and flora of the Morrison Formation: Modern Geology, v. 23, part 2, p. 507-537.

Cockerell, T.D.A., 1915, Some American Cretaceous fish scales, with notes on the classification and distribution of Cretaceous fishes: U.S. Geological Survey Bulletin 603, p. 34-57.

Craig, L.C., Holmes, C.N., Cadigan, R.A., Freeman, V.L., Mullens, T.E., and Weir, G.W., 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region–a preliminary report: U.S. Geological Survey Bulletin 1009-E, 168 p.

Crowley, A.J., 1955, A structural history of northwestern Colorado and parts of northeastern Utah: Intermountain Association of Petroleum Geologists and Rocky Mountain Association Geologists, Guidebook to the Geology of Northwest Colorado, p. 53-55.

Dawson, J.C., 1970, The sedimentology and stratigraphy of the Morrison Formation (Upper Jurassic) in northwestern Colorado and northeastern Utah: Madison, University of Wisconsin, Ph.D. dissertation, 125 p.

Dodson, Peter, Behrensmeyer, A.K., Bakker, R.T., and McIntosh, J.S., 1980, Taphonomy and paleoecology of the dinosaur beds of the Jurassic Morrison Formation: Paleobiology, v. 6, no. 2, p. 208-232.

Dubiel, R.F., 1992, Sedimentology and depositional history of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle basins, northwestern Colorado and northeastern Utah: U.S. Geological Survey Bulletin 1787-W, 25 p.

Elder, W.P., and Kirkland, J.I., 1993, Cretaceous biogeography of the Colorado Plateau and adjacent areas, *in* Morales, Michael, editor, Aspects of Mesozoic geology and paleontology of the Colorado Plateau: Museum of Northern Arizona Bulletin 59, p. 129-152.

Englemann, G.F., 1999, Stratigraphic and geographic distribution of fossils in the upper part of the Upper Jurassic Morrison Formation of the Rocky Mountain region, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Studies 99-1, p. 115-120.

Evanoff, Emmett, Good, S.C., and Hanley, J. H., 1998, An overview of the freshwater mollusks from the Morrison Formation (Upper Jurassic, Western Interior, USA): Modern Geology, v. 22, no. 1-4, p. 324-451.

Fouch, T.D., Lawton, T.F., Nichols, D.J., Cashion, W.B., and Cobban, W.A., 1983, Patterns and timing of synorgenic sedimentation in Upper Cretaceous rocks of central and northeast Utah, *in* Reynolds, M.W. and Dolly, E.D., editors, Mesozoic paleogeography of west-central United States: Denver, Rocky Mountain Section of Society of Economic Paleontologists and Mineralogists, p. 305-336.

Freeman, W.E., 1976, Regional stratigraphy and depositional environments of the Glen Canyon Group and Carmel Formation (San Rafael Group), *in* Hill, J.G., editor, Symposium on geology of the Cordilleran hingeline: Rocky Mountain Association of Geologists, p. 247-260.

Galton, P.M., and Jensen, J.A. , 1979, Remains of ornithopod dinosaurs from the Lower Cretaceous of North America: Brigham Young University Geology Studies, v. 25, part 1, p. 1-10.

Gilmore, C.W., 1924, The Dinosaur National Monument and its fossils: Washington Academy of Science Journal, v. 19, no. 15., p. 381.

Hale, L.A., 1959, Intertonguing Upper Cretaceous sediments of northeastern Utah-northwestern Colorado, *in* Haun, J.D. and Weimer, R.J., editors, Symposium on Cretaceous rocks of Colorado and adjacent areas: Rocky Mountain Association Geologists, p. 55-66.

Hamblin, A.H., 1992, Tracking Dinosaurs through 100 million years at Red Fleet State Park, twelve miles north of Vernal, Utah [abs.]: Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 24, no. 6, p. 16.

—1998, Mesozoic vertebrate footprints in the Grand Staircase-Escalante National Monument, Utah: Journal of Vertebrate Paleontology, v. 18, Supplement to no. 3 p. 48A.

Hamblin, A.H. and Bilbey, S.A., 1999, A dinosaur track site in the Navajo-Nugget Sandstone, Red Fleet Reservoir, Uintah County, Utah, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Publication 99-1, p. 51-57.

Hansen, W.R., 1986, Neogene tectonics and geomorphology of the eastern Uinta Mountains in Utah, Colorado and Wyoming: U.S. Geological Survey Professional Paper 1356, 78 p.

Hayden, F.V., 1872, Preliminary report of the United States Geological Survey of Wyoming and portions of the contiguous territories, Washington, D.C., Government Printing Office, p. 41-70.

Heller, P.L., and Paola, C., 1989, The paradox of Lower Cretaceous gravels and the initiation of thrusting in the Sevier orogenic belt, United States Western Interior: Geological Society of America Bulletin, v. 101, p. 864-975.

Hinman, E.E., 1957, Jurassic Carmel - Twin Creek facies of northern Utah: The Compass of Sigma Gamma Epsilon, v. 34, no. 2, p. 102- 119.

Hintze, L.F., 1988, Geologic history of Utah: Brigham Young University Geology Studies, Special Publication 7, 202 p.

Hoggan, R.D., 1970, Paleontology and paleoecology of the Curtis Formation in the Uinta Mountains area, Daggett County, Utah: Brigham Young University Geology Studies, v. 17, part 2, p. 31-65.

Imlay, R.W., 1980, Jurassic paleobiogeography of the conterminous United States in its continental setting: U. S. Geological Survey Professional Paper 1062, 134 p.

Kinney, D.M., 1955, Geology of the Uinta River-Brush Creek area, Duchesne and Uintah Counties, Utah: U.S. Geological Survey Bulletin 1007, 185 p.

King, Clarence, 1877, Report of the geological exploration of the Fortieth Parallel, descriptive geology by Arnold Hague and Emmons S. F.: Professional Paper of the Engineering Department United States Army, no. 18, p. 191-309.

Kirkland, J.I., Cifelli, R.L., Britt, B.H., Burge, D.L., DeCorten, F.L., Eaton, J.G., and Parrish, J.M., 1999, Distribution of vertebrate faunas in the Cedar Mountain Formation, east-central Utah, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Publication 99-1, p. 201-217.

Kirkwood, S.G., 1976, Stratigraphy and petroleum potential of the Cedar Mountain and Dakota Formations, northwestern Colorado: Golden, Colorado School of Mines, M.S. thesis, 193 p.

Lawton, T.F., 1994, Tectonic setting of Mesozoic sedimentary basins, Rocky Mountain region, U.S., *in* Caputo, M.V., Peterson J.A., and Franczyk , K.J., editors, Mesozoic systems of the Rocky Mountain region USA: Rocky Mountain Section Society for Sedimentary Geology, p. 1-26.

Lockley, M.G., 1991, Tracking dinosaurs: Cambridge, Cambridge University Press, 238 p.

Lockley, M.G., Conrad, Kelly, Paquette, Marc, and Farlow, J. O., 1992, Distribution and significance of Mesozoic vertebrate trace fossils in Dinosaur National Monument, *in* Plumb, G.E. and Harlow, H.J., editors, National Park Service Research Center 16th Annual Report, p. 74-85.

Lockley, M.G., and Hunt, A.P., 1995, Dinosaur tracks and other fossil footprints of the western United States: New York, Columbia University Press, 338 p.

Lockley, M.G., Hunt, A.P., Paquette, Marc, Bilbey, S.A., and Hamblin, A.H., 1998, Dinosaur tracks from the Carmel Formation, northeastern Utah–Implications for Middle Jurassic paleoecology: Ichnos, v. 5, p. 255-267.

Lockley, M.G., Kirkland J.I., DeCorten, F.L., Britt, B.B., and Hasiotis, S.T.,1999, Dinosaur tracks from the Cedar Mountain Formation of eastern Utah–A preliminary report, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Publication 99-1, p. 253-258.

Lucas, S.G., Kirkland, J.I., and Estep, J.W., 1998, Lower and Middle Cretaceous terrestrial ecosystems: New Mexico Museum of Natural History and Science Bulletin 14, 330 p.

Madsen, J.H., Jr., and Miller, W.E., 1979, The fossil vertebrates of Utah, an annotated bibliography: Brigham Young University Geology Studies, v. 26, part 4, 147 p.

Maione, S.J., 1971, Stratigraphy of the Frontier Sandstone Member of the Mancos Shale (Upper Cretaceous) on the south flank of the eastern Uinta Mountains, Utah and Colorado: Earth Science Bulletin, v. 4, p. 27-58.

McCormick, C.D., and Picard, M.D., 1969, Stratigraphy of the Gartra Formation (Triassic), Uinta Mountain area, Utah and Colorado: Intermountain Association of Geologists 16th Annual Conference Guidebook - Uinta Mountains, p. 169-180.

Molenaar, C.M., and Wilson, B.W., 1990, The Frontier Formation and associated rocks of northeastern Utah and northwestern Colorado: U.S. Geological Survey Bulletin 1787-M, p. M1-M21.

Otto, E.P., and Picard, M.D., 1976, Petrology of Entrada Sandstone (Jurassic), northeastern Utah, *in* Hill, J.G., editor, Symposium on geology of the Cordilleran hingeline: Rocky Mountain Association of Geologists, p. 231-246.

Peabody, F.E.,1948, Reptile and amphibian track ways from the Lower Triassic Moenkopi Formation of Arizona and Utah: Berkeley, University of California Publication, Department of Geological Science., v. 27, p. 295-468.

—1956, Ichnites from the Triassic Moenkopi Formation of Arizona and Utah: Journal of Paleontology, v. 30, no. 3., p. 731-740.

Peterson, Fred, 1988, Stratigraphy and nomenclature of Middle and Upper Jurassic rocks, western Colorado Plateau, Utah and Arizona: U.S. Geological Survey Bulletin 1633-B, p. 17-56.

Pipiringos, G.N., and Imlay, R.W., 1979, Lithology and subdivisions of the Jurassic Stump Formation in southeastern Idaho and adjoining areas: United States Geological Survey Professional Paper 1035-C, p. C1-C25.

Poole, F.G., and Stewart, J.H., 1964a, Chinle Formation and Glen Canyon Sandstone in northeastern Utah and northwestern Colorado, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta Basin–Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists Guidebook on

Uinta Basin, 13th Annual Field Conference, p. 93-104.
—1964b, Chinle Formation and Glen Canyon Sandstone in northeastern Utah and northwestern Colorado: U. S. Geological Survey Professional Paper 501-D, p. D30-D39.
Powell, J.W., 1876, Report on the Geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto: United States Geological and Geographic Survey of the Territories (Rocky Mountain region), Washington D.C., Government Printing Office, 218 p.
Rigby, J.K., 1964, Some observations of the stratigraphy and paleoecology of the Carmel and Twin Creek Formations in the Uinta Mountains, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta Basin–Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists Guidebook on Uinta Basin, 13th Annual Field Conference, p. 109-114.
Rowley, P.D., Hansen, W.R., Tweto, Ogden. and Carrara, P. E., 1985, Geologic Map of the Vernal 1° x 2° Quadrangle, Colorado, Utah, and Wyoming: U.S. Geological Survey Map I-1526, scale 1:250,000.
Ryer, T.A., 1977, Patterns of Cretaceous shallow-marine sedimentation, Coalville and Rockport areas, Utah: Geological Society of America Bulletin, v. 88, p. 177-188.
Sohl, N.F., 1965, Marine Jurassic Gastropods, central and southern Utah: U.S. Geological Survey Professional Paper 503-D, 34 p.
Stewart, J.D., Bilbey, S.A., Chure, D.J., and Madsen, S.K. 1994, Vertebrate fauna of the Mowry Shale (Cenomanian) in northeastern Utah [abs.]: Society of Vertebrate Paleontology 1993 Meeting, v. 14, Supplement to Number 3, p 47A.
Stokes, W.L., 1944, Morrison Formation and related deposits in and adjacent to the Colorado Plateau: Geological Society of America Bulletin v. 55, no. 8, p. 951-992.
—1952, Lower Cretaceous in Colorado Plateau: American Association of Petroleum Geologists Bulletin, v. 36, no. 9, p. 1766-1776.
—1986, Geology of Utah: Utah Museum of Natural History and Utah Geological and Mineral Survey, Occasional Paper 6, 280 p.
Tidwell, W.D., 1983, Paleoecology of a small Lower Cretaceous swamp near Ferron, Utah [abs.]: Geological Society of America, Rocky Mountain/Cordilleran Regional Meeting, v. 15, p. 286.
—1990a, Preliminary report on the megafossil flora of the Upper Jurassic Morrison Formation: Hunteria, v. 2, no. 8, 12 p.
—1990b, A new Osmundaceous species (Osmundacaulis lemonii n. sp.) from the Upper Jurassic Morrison Formation, Utah: Hunteria, v. 2, no. 7, 11 p.
Turner, C.E. and Peterson, Fred, 1999, Biostratigraphy of dinosaurs in the Upper Jurassic Morrison Formation of the Western Interior, USA, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Studies 99-1, p. 77-114.
Untermann, G.E., and Untermann, B.R., 1949, Geology of Green and Yampa River Canyons and vicinity, Dinosaur National Monument, Utah and Colorado: American Association of Petroleum Geologists Bulletin, v. 33, no. 5, p. 683-694.
—1964 (revised 1968), Geology of Uintah County: Utah Geological and Mineral Survey Bulletin 72, 112 p.
—1969, Geology of the Uinta Mountain area, Utah-Colorado, *in* Lindsay, S.B., editor, Geologic guidebook of the Uinta Mountains–Utah's Maverick Range: Intermountain Association of Geologists and Utah Geological Society, p. 79-86.
Yen, Teng-Chien, 1952, Molluscan fauna of the Morrison Formation: U. S. Geological Survey Professional Paper 233-B, p. 21-51.
Young, R.G., 1960, Dakota Group of the Colorado Plateau: American Association Petroleum Geologists Bulletin v. 44, no. 2, p. 156-194.
—1987, Triassic and Jurassic rocks in the Dinosaur Triangle, *in* Averett, W.R., editor, Paleontology and geology of the Dinosaur Triangle guidebook: Grand Junction, Museum of Western Colorado, p. 5-21.