GEOLOGY OF THE INTERMOUNTAIN WEST

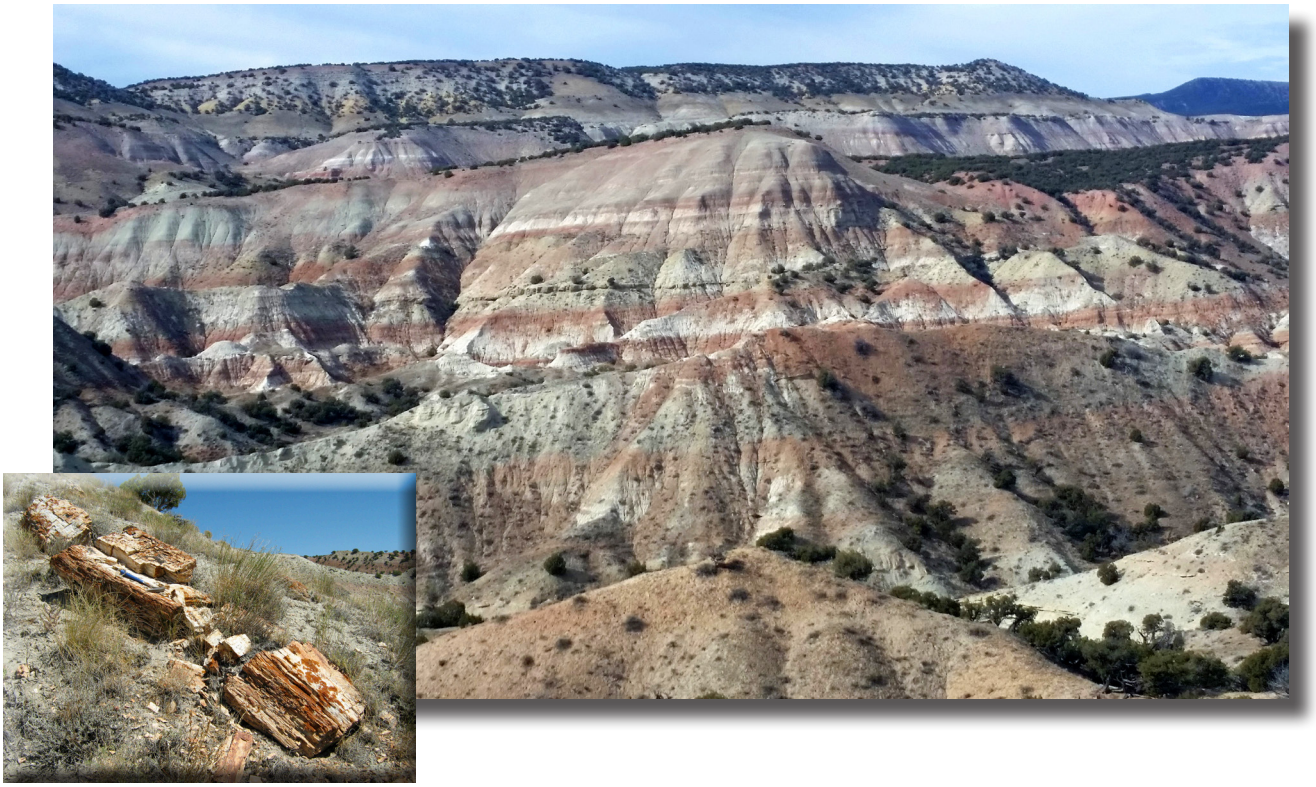
an open-access journal of the Utah Geological Association

ISSN 2380-7601

Volume 6 ***2019***

STRATIGRAPHIC SETTING OF FOSSIL LOG SITES IN THE MORRISON FORMATION (UPPER JURASSIC) NEAR DINOSAUR NATIONAL MONUMENT, UINTAH COUNTY, UTAH, USA

Douglas A. Sprinkel, Mary Beth Bennis, Dale E. Gray, and Carole T. Gee



Theme Issue
An Ecosystem We Thought We Knew—
The Emerging Complexities of the Morrison Formation
SOCIETY OF VERTEBRATE PALEONTOLOGY
Annual Meeting, October 26 – 29, 2016
Grand America Hotel
Salt Lake City, Utah, USA

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West view of the Morrison Formation at Rainbow Draw. The fossil log horizon is in the greenish-colored siltstone beds near the center of the photograph. The Cretaceous Cedar Mountain through the Frontier Formations are exposed on the distant ridge. See figure 7 for details. Inset photo of a fossil log typically found in Rainbow Draw.

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Stratigraphic Setting of Fossil Log Sites in the Morrison Formation (Upper Jurassic) near Dinosaur National Monument, Uintah County, Utah, USA

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ABSTRACT

The outcrop belt of the Upper Jurassic Morrison Formation in the northeastern Uinta Basin and southeastern flank of the Uinta Mountains is particularly rich in dinosaurian and non-dinosaurian faunas, as well as in fossil plants. The discovery of several well-preserved, relatively intact, fossil logs at several locations in Rainbow Draw and one location in Miners Draw, both near Dinosaur National Monument (Utah), has provided an opportunity to study the local paleobotany, stratigraphy, and sedimentology of the Morrison Formation in northeastern Utah.

The Morrison Formation in northeastern Utah consists of four members. In ascending chronostratigraphic order, they are the Windy Hill, Tidwell, Salt Wash, and Brushy Basin Members. The lithology (including the presence of glauconite grains) and fossil assemblage of the lower two members (Windy Hill and Tidwell) indicate a marine to marginal marine (coastal plain) depositional environment, whereas the lithology, fossil flora and fauna assemblage of the upper two members (Salt Wash and Brushy Basin) indicate a fluvial–lacustrine depositional environment.

At least 10 fossil log sites in Rainbow Draw have been documented so far, and geologic mapping indicates that the logs and wood all occur in the same stratigraphic interval within the Salt Wash Member, approximately 17 to 27 m above the base of the member. The unit containing the logs and wood is about 11 m thick and consists of very fine to fine-grained sandstone and siltstone with indistinct bedding and no discernible sedimentary features. The logs are siliceous, some have a coaly exterior, and they range in exposed length from 0.5 to 11 m and reach diameters up to 1.1 m. In the Miners Draw area, a single siliceous log is documented in the upper part of the Salt Wash Member within a silty sandstone unit that is 4 m thick; its exposed length is about 6 m. Although the correlation of the Miners Draw log-bearing interval to the interval in Rainbow Draw is uncertain, both units are lithologically similar and both occur in the upper part of the Salt Wash Member. The logs have been identified as araucariaceous conifers that pertain to the same taxon originally described as *Araucarioxylon hoodii* Tidwell et Medlyn 1993 from Mt. Ellen in the Henry Mountains of southern Utah. Concurrent systematic work will prompt a nomenclatural transfer of this species to the genus *Agathoxylon.*

Based on the abundance of large fossil logs and wood in the same stratigraphic interval in Rainbow Draw, we hypothesize that the area was covered by stands of moderately large trees of araucariaceous conifers. The sedimentological evidence suggests that the trees were not transported far from their original site of growth before they were deposited in a low-energy floodplain environment.

Citation for this article.
Sprinkel, D.A., Bennis, M., Gray, D.E., and Gee, C.T., 2019, Stratigraphic setting of fossil log sites in the Morrison Formation (Upper Jurassic) near Dinosaur National Monument, Uintah County, Utah, USA: Geology of the Intermountain West, v. 6, p. 61–76.

INTRODUCTION

The Upper Jurassic Morrison Formation is a spectacular and easily recognizable formation across the Colorado Plateau, and is distinctive because of its array of rainbow-colored mudstone, siltstone, and sandstone beds that typically form a "badlands" landscape. In northeastern Utah, it is well-exposed along the south flank of the Uinta Mountains (figure 1) and around Split Mountain and the Yampa and Blue Mountain Plateaus in and around Dinosaur National Monument (figure 2). The Morrison gained its fame from the discovery of well-preserved dinosaur bones on the south flank of Split Mountain in August 1909 by Earl Douglass, a paleontologist with the Carnegie Museum of Pittsburgh (Douglass, 2009). Subsequent development of the Carnegie Quarry (figure 2) produced a rich and diverse dinosaur assemblage (Elder, 1999; Engelmann, 1999; Turner and Peterson, 1999; Chure and others, 2006; Carpenter, 2013). In addition to dinosaurs, the Morrison has produced other vertebrate fossils (e.g., pterosaurs, crocodylomorphs, and mammals), invertebrate fossils, and fossil insects (Engelmann, 1999; Evans and Chure, 1999; Hasiotis, 2004; Chure and others, 2006). Fossil wood is also commonly found in the Morrison Formation, but it is mostly scrappy pieces preserved in channel sandstone

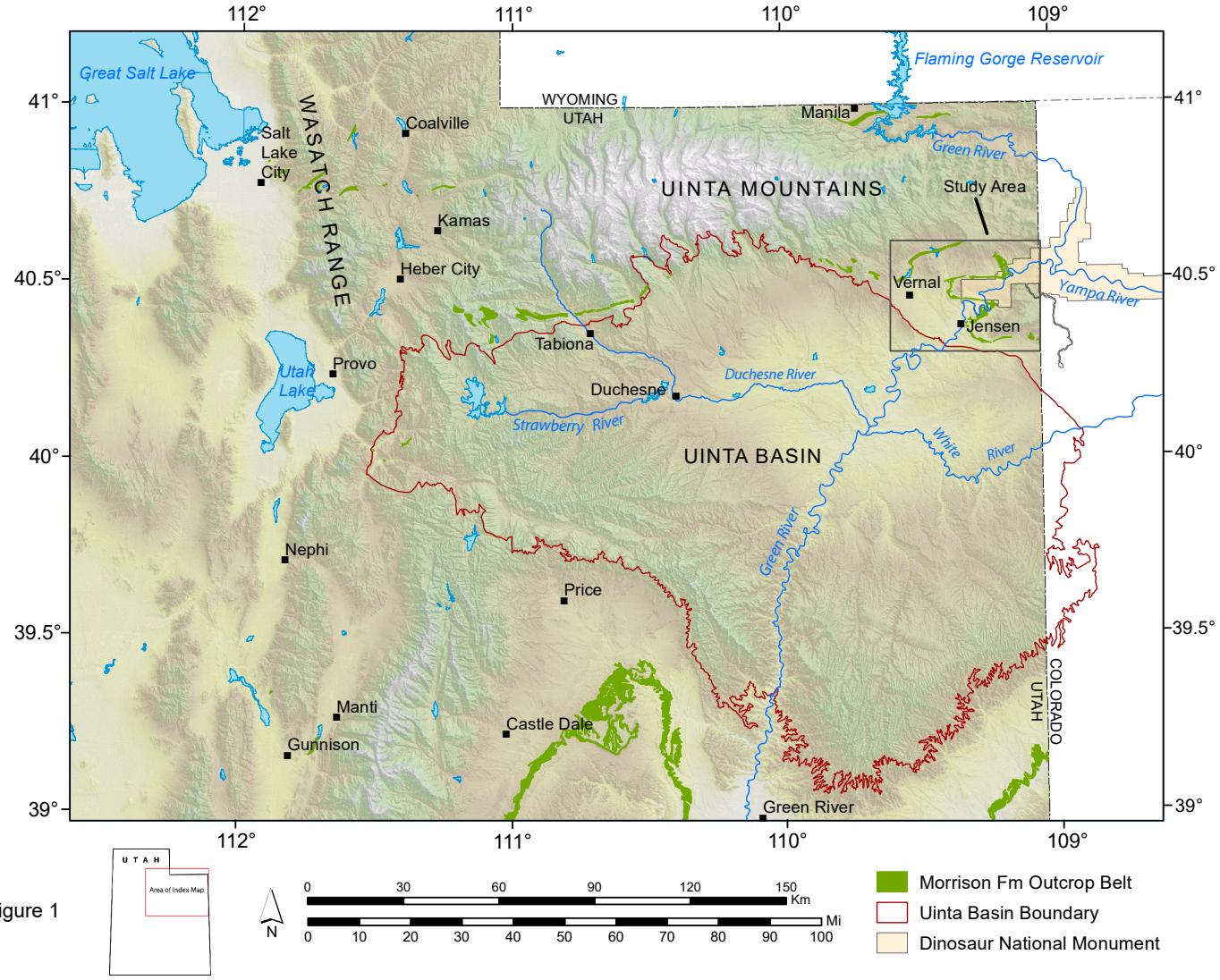

Figure 1

Figure 1. Regional map showing the Morrison Formation study area in the eastern Uinta Mountains of northeastern Utah, USA. Morrison outcrop locations from Hintze and others (2000).

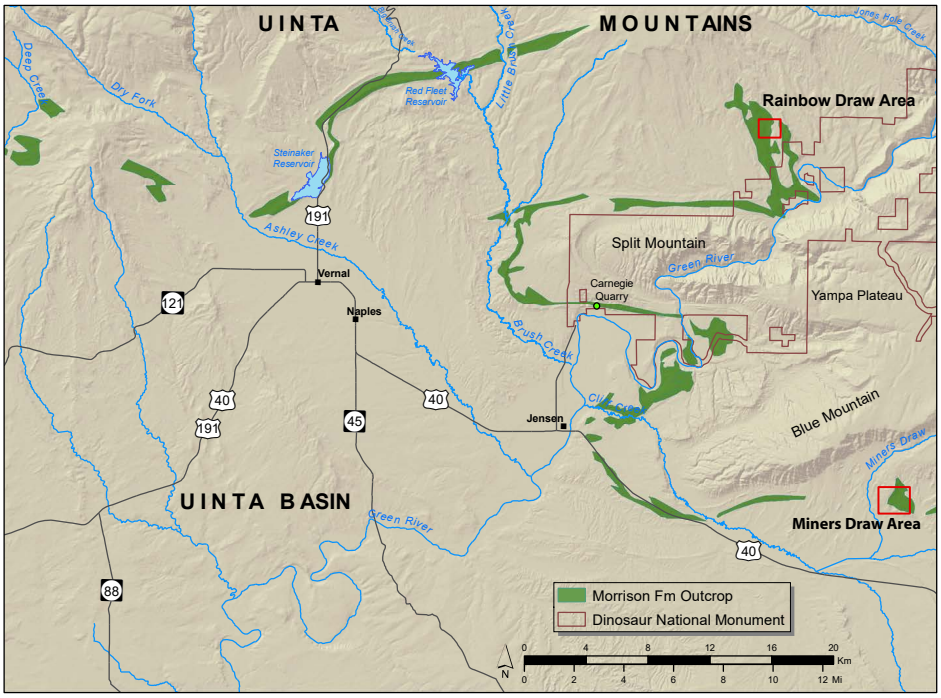

Figure 2. Map showing the Morrison Formation outcrop belt (marked in green) in and around Dinosaur National Monument and the location of the renowned Carnegie Quarry. The Miners Draw area is south of the Blue Mountain Plateau and Rainbow Draw is due north of Dinosaur National Monument. Both areas are east of the city of Vernal, Utah. Morrison outcrop locations from Hintze and others (2000).

and conglomeratic depositional units in the Salt Wash and Brushy Basin Members (Engelmann, 1999; Gee and others, 2014). In some places, the Morrison contains fossil logs of varying sizes, which occur as solitary logs or in clusters (Gee, unpublished data). Engelmann (1999) surveyed several National Park Service units in Utah and surrounding states and documented 34 sites where log segments a few meters in length were found in the Morrison Formation. He described one site at Dinosaur National Monument as "…a large area covered by silicified logs of considerable diameter, possibly a log jam"(Engelmann, 1993). Escalante Petrified Forest State Park, near the town of Escalante in south-central Utah, is another location with a concentration of fossil logs in the Morrison Formation. These silicified (agatized) logs occur in a conglomerate bed in the upper part of the Brushy Basin Member (Morgan and others, 2012). Many other unpublished sites in Utah had concentrations of fossil logs in the Morrison, but many of these sites have been picked clean over the years by collectors (James Kirkland, Utah Geological Survey, verbal communication, March 2018).

A reconnaissance paleontological survey of the Morrison Formation by Mary Beth Bennis and Dale Gray (Utah Field House of Natural History State Park Museum) on Bureau of Land Management lands east of Vernal, Utah, and outside Dinosaur National Monument, identified two areas that have large, relatively intact, and well-preserved fossil logs. One area is located south of Blue Mountain Plateau near Miners Draw, and the other area is north of Dinosaur National Monument in Rainbow Draw (figure 2). The Rainbow Draw area is of particular importance because it contains a concentration of as many as 11 logs in a relatively small area (240,000 m^2 or about 60 acres).

The Miners Draw site is located in an unnamed tributary of Miners Draw (figure 2) where a single log was found at the base of a Morrison Formation slope (figure 3). The Rainbow Draw area is located northeast of Vernal and north of Dinosaur National Monument (figure 2). There, 10 fossil logs were discovered in beds in the area. The logs are concentrated into two groups within the 60-acre surveyed area. In each group, the fossil logs were somewhat dispersed, except for one site in the western group with a cluster of three large logs (site 3). It is unclear if this cluster of logs represents three individual trees or if it represents only one tree trunk that has broken into segments that have moved downslope. All fossil logs in the Miners Draw and Rainbow Draw areas were found in the Salt Wash Member of the Morrison Formation, but it was not clear at the time of the survey if the logs were at the same stratigraphic horizon

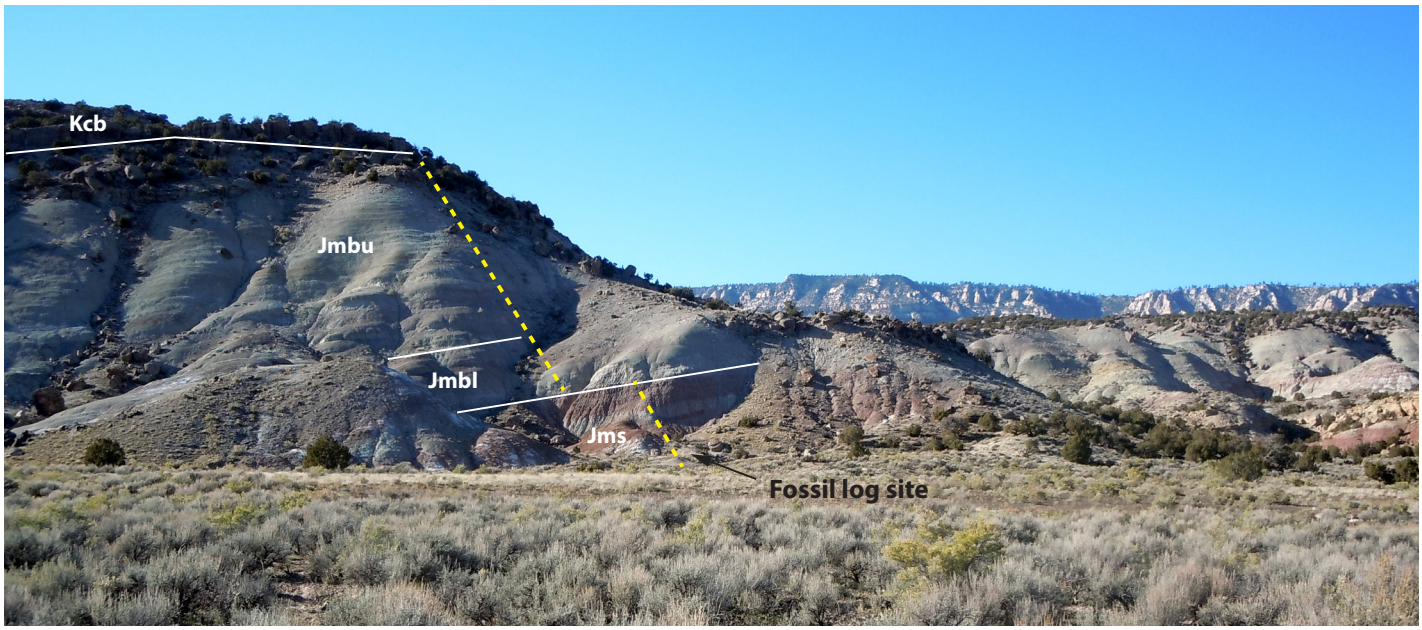

Figure 3. Fossil log site in the Miners Draw area in the upper Salt Wash Member of the Morrison Formation (Jms). The Brushy Basin Member of the Morrison Formation is divided into a lower banded unit (Jmbl) and an upper gray unit (Jmbu). The Buckhorn Conglomerate of the Cedar Mountain Formation (Kcb) caps the Morrison Formation. The yellow dashed line represents the upper part of the Trail Creek measured section. Blue Mountain Plateau is the highland in the distance. View to the northwest.

or if they were merely preserved in strata of similar depositional environments. Subsequent visits to both areas were made to measure the logs, collect hand samples for paleobotanical analysis, and describe and measure Morrison Formation sections. Geologic mapping was conducted in the field on aerial photographs and imagery to help trace member contacts and key beds. The purpose of this study is to describe the Morrison Formation strata, especially those related to the fossil logs, and to place the logs within a stratigraphic framework for the interpretation of the depositional environment of the log-bearing intervals at both locations.

GEOLOGIC SETTING OF THE FOSSIL LOG SITES

The Miners Draw and Rainbow Draw areas are situated along the flanks of highlands—Blue Mountain Plateau, Yampa Plateau, and Split Mountain—that formed during the Laramide uplift of the Uinta Mountains (figure 2) (Stone, 1993; Gregson and others, 2010). The highlands rose mostly along high-angle reverse faults, Miners Draw fault to the south and Island Park fault to the north. The formations within the highlands were folded into a series of monoclines and asymmetrical anticlines (Hansen and others, 1983; Hansen, 1986; Sprinkel, 2006, 2007). The bedrock stratigraphy in the Miners Draw and Rainbow Draw areas include (in ascending chronostratigraphic order) the Upper Jurassic Stump and Morrison Formations, the Lower Cretaceous Cedar Mountain and Dakota Formations, and the Upper Cretaceous Mowry and Frontier Formations. In the Miners Draw area, the formations wrap around a gently plunging anticlinal nose that is faulted on the north limb (figure 4). Three partial stratigraphic sections were measured to produce a composite section from the top of the Stump Formation to the base of the Cedar Mountain Formation because of the distance between the exposed base and top of the Morrison Formation and stratigraphic position of the fossil logs. Key marker beds were used to offset between the section segments. In Rainbow Draw, the formations generally dip less than 20° southwest, although the Morrison Formation is very gently folded into a broad, low-amplitude syncline (figure 5).

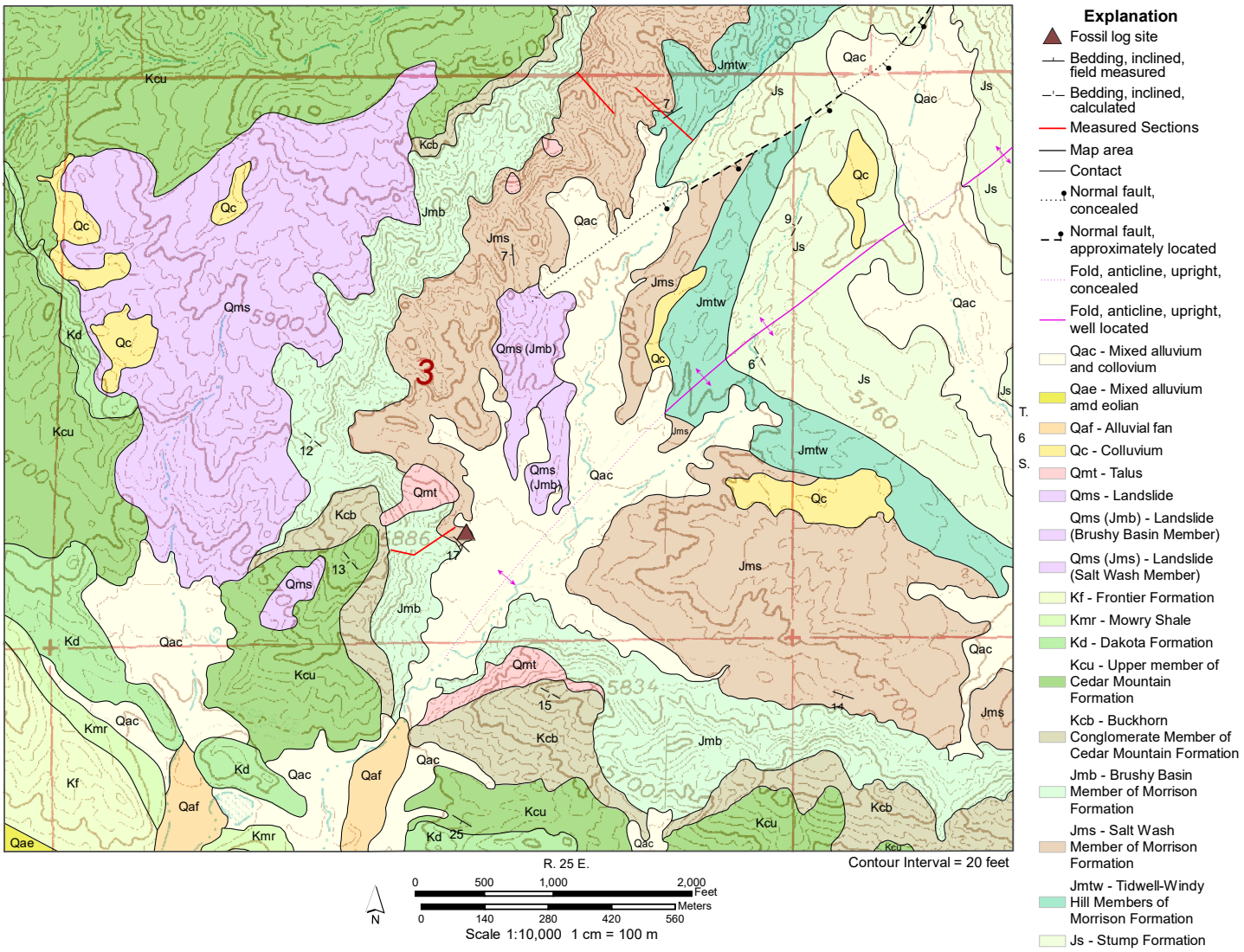

Figure 4. Geologic map of the Miners Draw area fossil log site. The Morrison Formation overlies the Stump Formation and underlies the Buckhorn Conglomerate Member of the Cedar Mountain Formation. The Morrison includes the Windy Hill, Tidwell, Salt Wash, and Brushy Basin Members. We further divided the Brushy Basin Member into a lower banded unit and an upper gray unit. We measured the members of the Morrison in three sections at Blue Mountain; the Windy Hill to the lower banded member is in the northeast part of the map area, whereas the top of the Salt Wash Member, the lower banded and upper gray unit of the Brushy Basin are in an offset section in the southwest part of the map area because of folding, faulting, and landslides. The fossil log site occurs in the upper part of the Salt Wash Member, about 17 m below the Brushy Basin Member, along the southwest offset measured section.

MORRISON FORMATION STRATIGRAPHY

The Morrison Formation in northeastern Utah consists of four members. In ascending chronostratigraphic order, they are the Windy Hill, Tidwell, Salt Wash, and Brushy Basin Members. The Windy Hill Member is composed of siltstone, mudstone, and thin-bedded rippled limestone that ranges from 4 to 20 m thick (figures 6A and 6B), and the invertebrate fossil assemblage and glauconite grains indicate marine deposition (Turner and Peterson, 1999). The Tidwell Member is composed of cross-bedded and rippled siltstone and sandstone, and thin shale beds (figure 6C). Marine

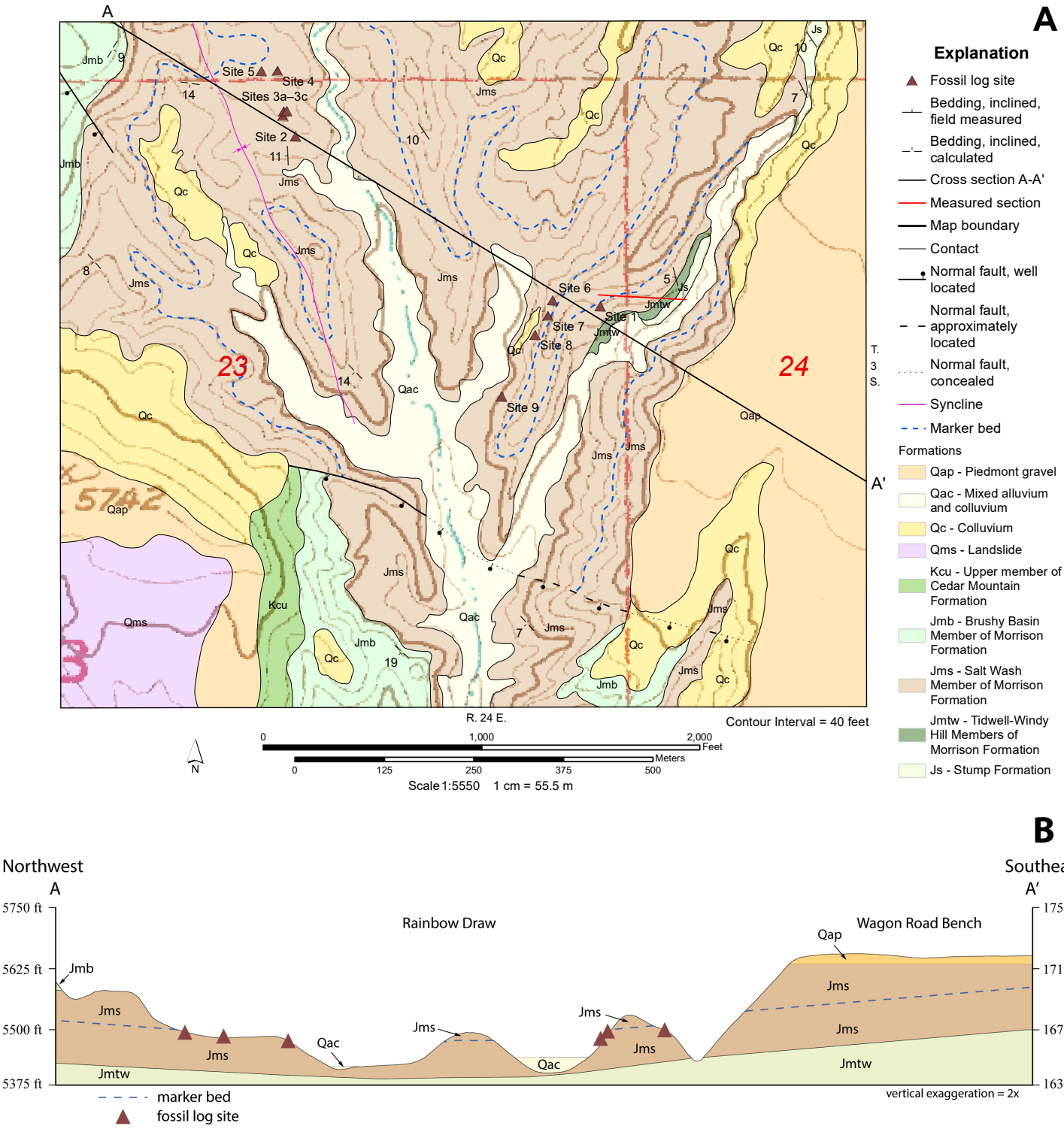

Figure 5. (A) Geologic map and (B) cross section of the Rainbow Draw area fossil log sites. The Morrison Formation overlies the Stump Formation and underlies the Cedar Mountain Formation in Rainbow Draw. In the mapped area, the Morrison includes the Windy Hill, Tidwell, Salt Wash, and Brushy Basin Members. The fossil log sites are concentrated in two groups on separate ridges. Both groups of logs occur in light-colored, fine-grained sandstone and siltstone below a mostly reddish-colored siltstone that was used as a marker bed (blue dashed line).

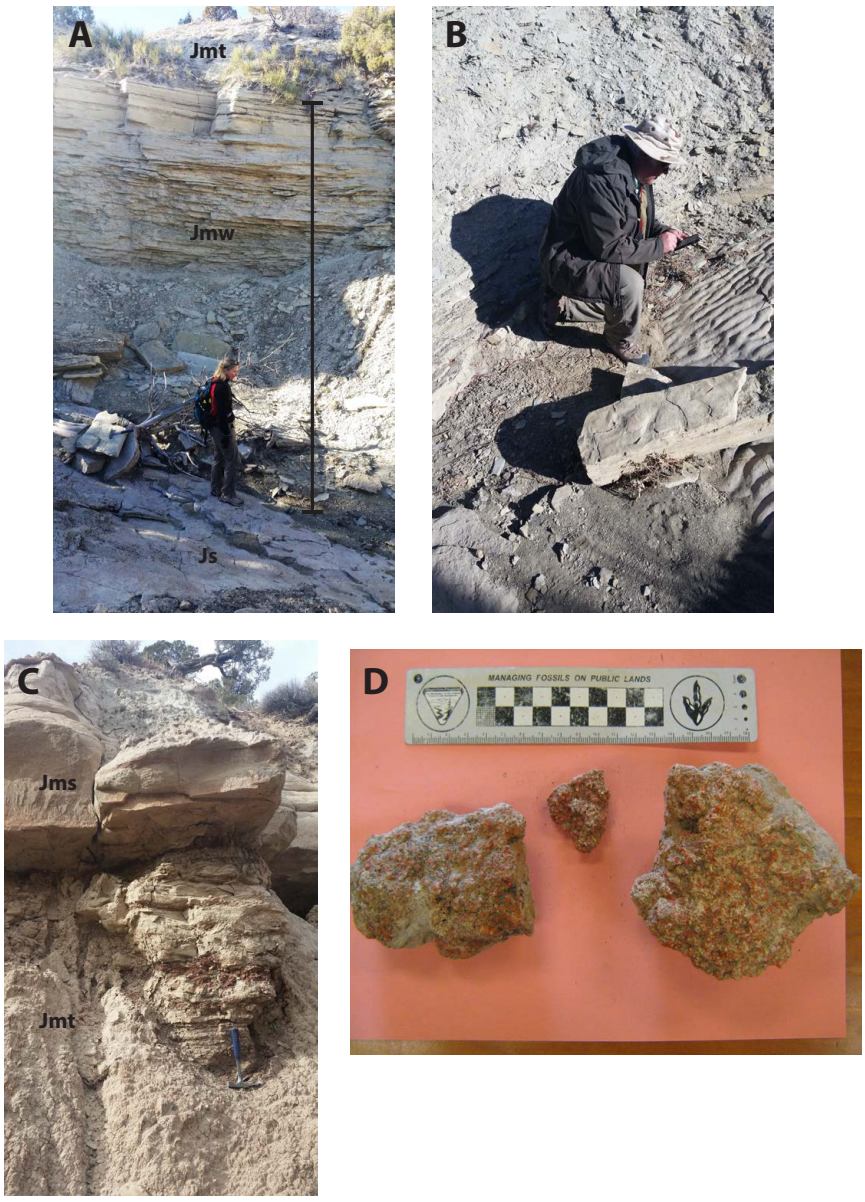

Figure 6. Photographs of lower members of the Morrison Formation and contacts within the study area. (A) The Windy Hill Member of the Morrison Formation (Jmw) overlies the Stump Formation (Js) and underlies the Tidwell Member on the north flank of Split Mountain. The Windy Hill is composed of siltstone, mudstone, and thin-bedded rippled limestone. (B) Rippled limestone in the Windy Hill Member on the north flank of Split Mountain. (C) Contact between the Tidwell and Salt Wash Members of the Morrison Formation near the measured section in Rainbow Draw. (D) Example of the botryoidal chert commonly found near the base of the Tidwell Member. Specimen collected south of the Green River between Split Mountain and Blue Mountain Plateau.

fossil dinoflagellate tests were recovered from the Tidwell Member near Dinosaur National Monument, and some glauconitic sandstone occurs as well (Turner and Peterson, 1999). The Tidwell also contains abundant pinkish-colored botryoidal chert (figure 6D) (also referred to as "welded chert") near or at the base of the member, which has been recognized throughout the region (King and Merriam, 1969; Peterson, 1980). A marginal marine to coastal plain (supralittoral) depositional environment is indicated for the Tidwell Member in northeastern Utah (Turner and Peterson, 1999), but it may be somewhat fluvial near the top as indicated by the bioturbated and mottled beds (appendix). The Tidwell Member in northeastern Utah ranges from 9 to 17 m thick. The Salt Wash Member is composed of interbedded sandstone, siltstone, and mudstone with some beds of channel-form pebble sandstone, as well as conglomerate that ranges from 75 to 80 m thick (figure 7A). The Salt Wash was deposited in a fluvial system (Peterson, 1980; Turner and Peterson, 1999, 2004). The capping Brushy Basin Member is composed of a lower banded unit of siltstone, silty sandstone, and clay-rich mudstone (about 12 to 16 m thick) as well as an upper gray unit of predominately popcorn-weathering mudstone (about 70 to 88 m thick) and ranges from 82 to 104 m thick (figures 3 and 7B). The Brushy Basin Mem-

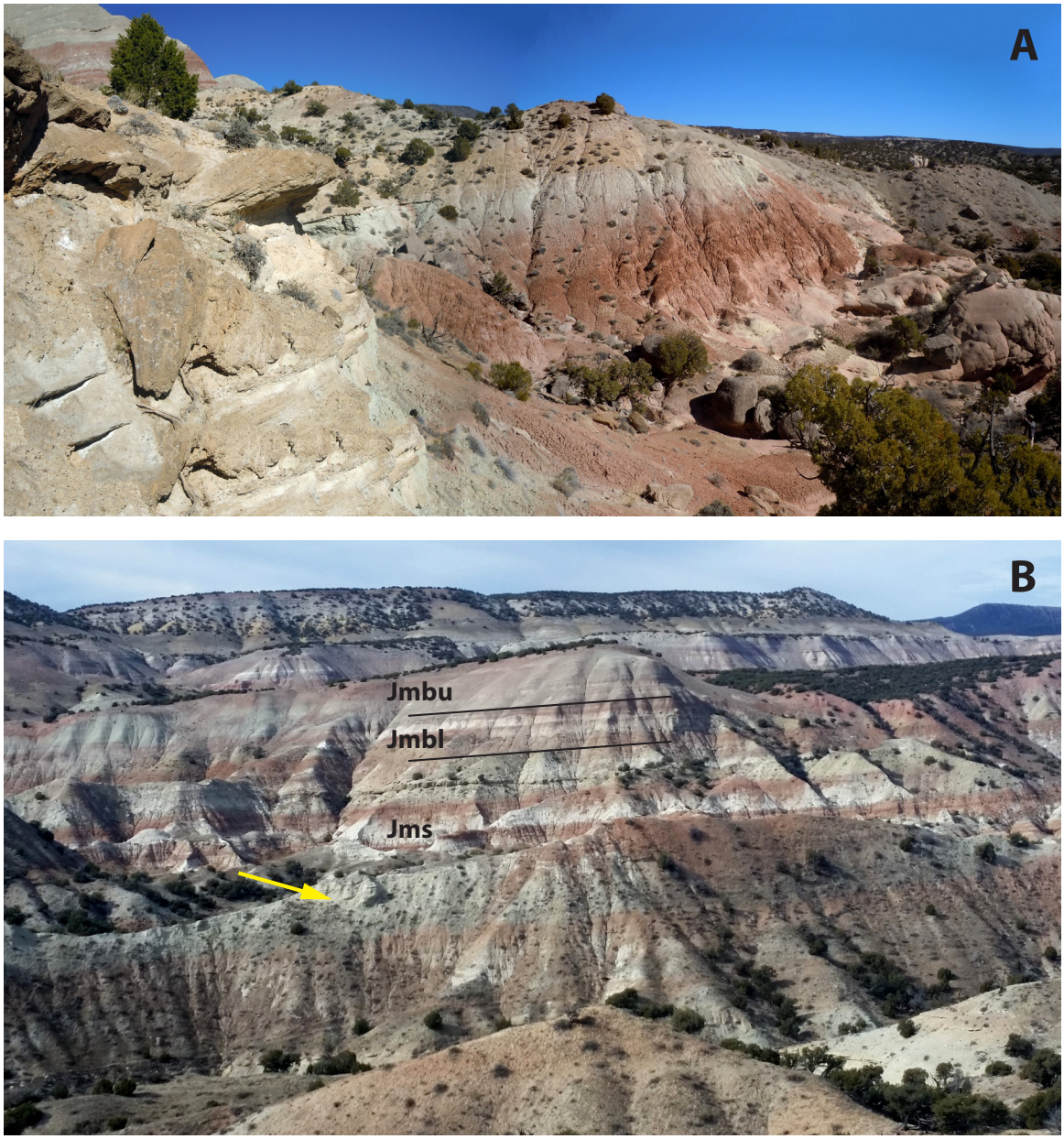

Figure 7. Photographs of the Salt Wash and Brushy Basin Members of the Morrison Formation. (A) Salt Wash Member near the measured section at Miners Draw showing varicolored siltstone beds and the brownish-gray channel sandstone beds; view to the northeast. (B) View of the Salt Wash and Brushy Basin Members from near the top of the measured section at Rainbow Draw; view to the west. The yellow arrow points to the fossil log-bearing interval, which is overlain by the reddish-colored marker bed. The Brushy Basin is divided into a lower banded unit and an upper gray unit. The Cretaceous Cedar Mountain through the Frontier Formations are exposed on the distant ridge.

ber was deposited in a fluvial–lacustrine environment (Turner and Peterson, 1999, 2004) with significant input of volcanic ash (Turner and Fishman, 1991; Christiansen and others, 2015).

The Morrison Formation overlies the Stump Formation throughout northeastern Utah. The nature of the contact between the Stump and Morrison is complex, however. Conventional thinking is that the contact in northeastern Utah is unconformable (the J-5 unconformity of Pipiringos and O'Sullivan [1978]), similar to ex-

posures in east-central Utah where the Tidwell Member of the Morrison unconformably overlies the Summerville and older formations (Peterson, 1988). However, Turner and Peterson (1999) noted that the J-5 surface is unconformable in some areas and conformable in others. Other workers in northeastern Utah showed the boundary as conformable in the eastern Uinta Mountains and Uinta Basin (e.g., Currie, 1998; Bilbey and others, 2005). Our examination of the contact in the Miners Draw and Rainbow Draw areas indicates that it appears to be gradational and conformable.

The Upper Jurassic Morrison Formation is unconformably overlain by the Lower Cretaceous Cedar Mountain Formation. Picking the contact between the two formations can be difficult, despite being an unconformity (K-1), because their similar lithologies are easily weathered to clay flats or clay-covered slopes. Lithostratigraphic, biostratigraphic, and chemostratigraphic criteria are emerging that will help identify the contact (see Cifelli and others, 1997; Kirkland and others, 1999, 2003, 2011, 2016; Ludvigson and others, 2003, 2015; Greenhalgh and Britt, 2007; Kirkland, 2007; Kirkland and Madsen, 2007; Sprinkel and others, 2012). For example, the basal unit of the Cedar Mountain Formation can include the Buckhorn Conglomerate Member, a cobble and boulder conglomerate that varies in thickness and typically forms a resistant cliff above the Morrison Formation (Stokes, 1952; Kirkland and others, 2016), as it does in the Miners Draw area (figure 8A). Where the Buckhorn Conglomerate is missing, the basal bed of the Cedar Mountain Formation is typically mottled, yellowish-orange, chert-pebble-bearing mudstone that underlies the first Cedar Mountain calcrete bed (Sprinkel and others, 2012; Kirkland and others, 2016), as it is in the Rainbow Draw area (figure 8B).

STRATIGRAPHY OF THE FOSSIL LOG SITES

Sections of the Morrison Formation were measured at the Miners Draw and Rainbow Draw areas to describe beds and place the fossil log sites in stratigraphic and sedimentological context. At the Miners Draw area, several sections were measured to capture the entire Morrison Formation (Windy Hill, Tidwell, Salt Wash, and Brushy Basin Members) and the stratigraphic horizon of the fossil log site because distance between base and top of the Morrison is large and complicated by being exposed on the nose of a southwest-plunging anticline (figure 4). The contact between the lower banded and upper gray units of the Brushy Basin Member was used to trace around the Miners Draw area to the fossil log site. The section measured at Rainbow Draw included the Windy Hill, Tidwell, and part of the Salt Wash Members; the Salt Wash Member was measured only through the fossil log-bearing unit to a light greenish- to reddish-colored siltstone marker unit, which was overlain by a light-gray sandstone unit that capped the ridge. This distinctive marker unit was mapped and used to correlate between the two groups of fossil logs sites within the Rainbow Draw area.

Salt Wash Member at the Miners Draw Area

The Salt Wash Member at Miners Draw consists of fine- to coarse-grained, cross-bedded sandstone with some conglomeratic sandstone and conglomerate beds, silty sandstone, and siltstone (figure 9). The coarse-grained sandstone, conglomeratic sandstone, and conglomerate beds are mostly shades of brownish gray. The fine-grained and silty sandstone beds are light brownish-gray to greenish gray and medium reddish-brown. The siltstone beds are greenish gray to dark reddish-brown, somewhat clayey, and have a pseudo popcorn-weathering appearance. Black and orange-colored accessory grains are common in the sandstone beds. The coarser grained beds typically form resistant ledges and may include fossil wood and bone fragments, whereas the finer grained beds tend to be slope forming (appendix). The fossil log-bearing interval at Miners Draw is light greenish-gray to brownish-gray, silty to very fine grained sandstone that is slightly clay rich with indistinct bedding and no discernable sedimentary features. The interval is weakly cemented and poorly exposed but the log weathers out in relief. The interval is 4.3 m thick and the fossil log occurs 3.0 m above the base of the unit and 7.8 m below the top of the Salt Wash Member (figure 3). The fossil log is about 6 m long and its long axis is oriented east–west (see Gee and others, 2019, for additional log dimensions).

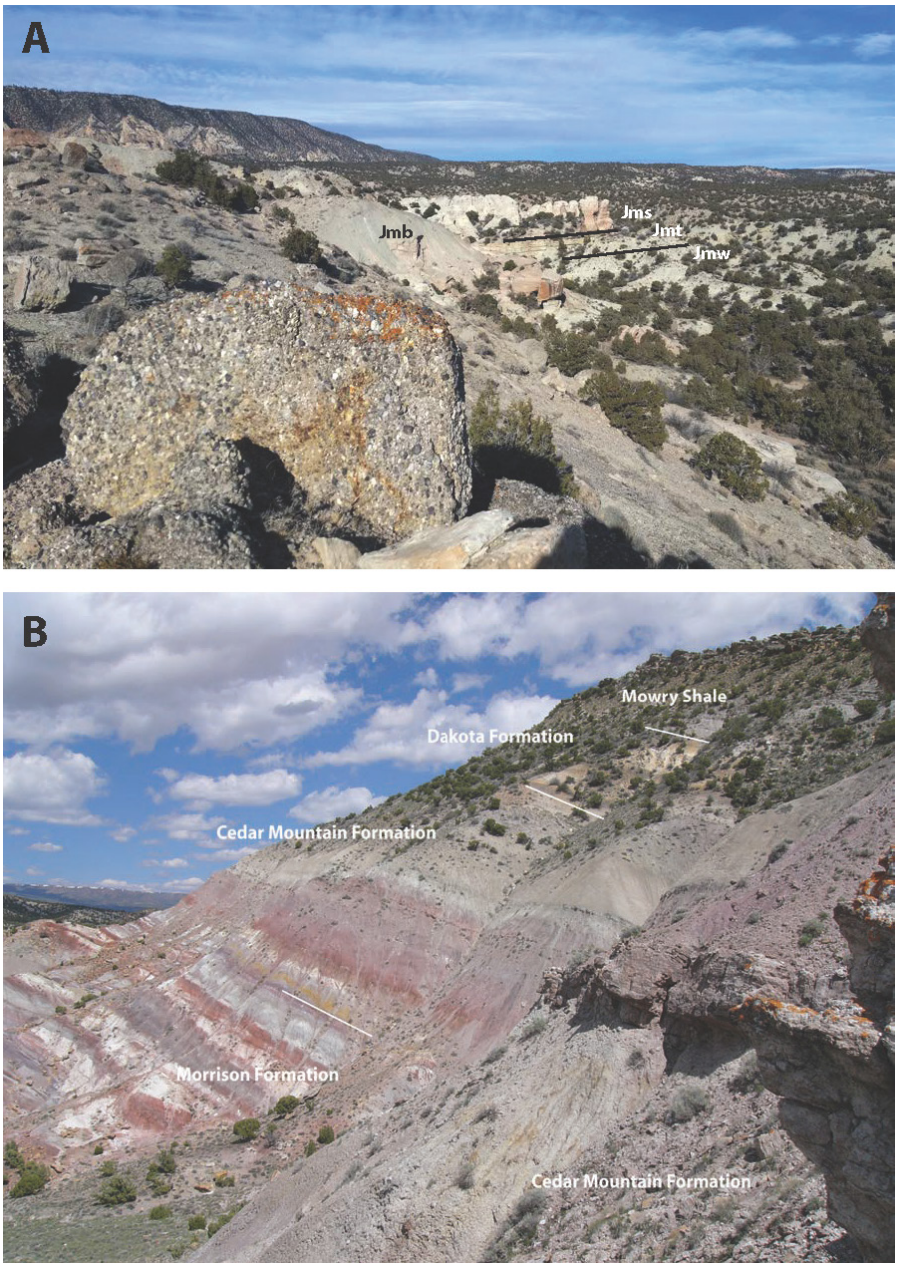

Figure 8. The Lower Cretaceous Cedar Mountain Formation unconformably overlies the Brushy Basin Member of the Morrison Formation. (A) In the Miners Draw area, the Buckhorn Conglomerate Member of the Cedar Mountain (conglomerate boulder in the foreground) makes it easy to locate the contact between the two formations; view to the northeast. (B) In many places, the contact between the Morrison and Cedar Mountain Formations is difficult to locate where the Buckhorn Conglomerate Member is missing. Here the contact (white line) is placed at a chert-pebble, mottled, yellowish-orange mudstone that underlies the first Cedar Mountain calcrete bed. Photograph taken south of U.S. Highway 40 between Steinaker and Red Fleet Reservoirs; view to the northeast.

Salt Wash Member in the Rainbow Draw Area

The Salt Wash Member in Rainbow Draw consists of very fine to fine-grained sandstone, some medium- to coarse-grained sandstone, siltstone, and mudstone (figure 9; appendix). The sandstone beds are very light gray and light to medium greenish-gray and are medium to thin bedded and tabular with small-scale planar

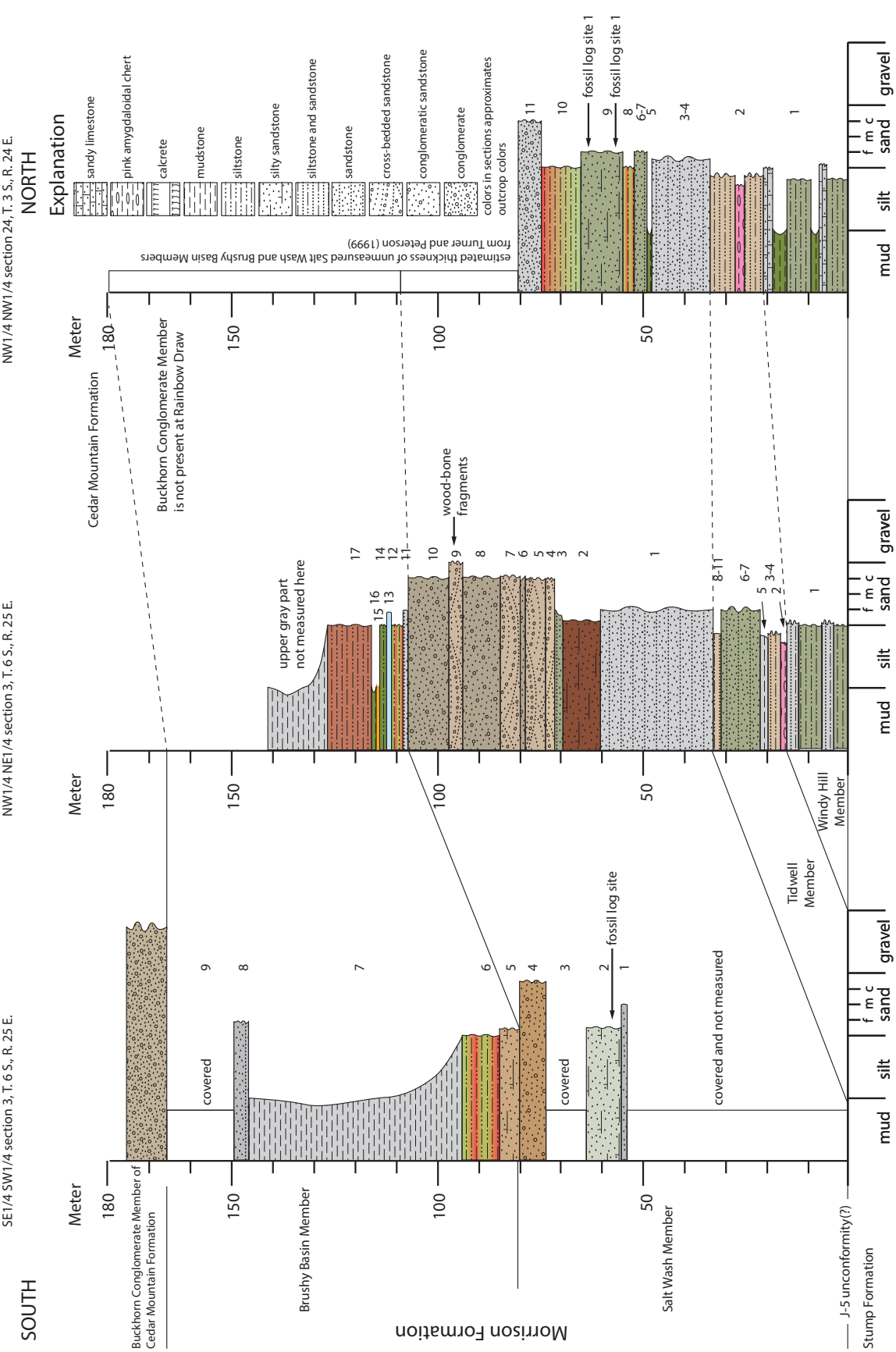

Figure 9

Figure 9. Stratigraphic sections measured in the Miners Draw and Rainbow Draw areas showing the fossil log-bearing intervals. Label numbers refer to measured section units in appendix.

cross-beds and some ripple laminations. The siltstone beds are light to medium greenish-gray and mottled reddish-brown, whereas the mudstone beds are dark greenish-gray, somewhat clayey, slightly micaceous, and fissile.

The fossil logs are concentrated in two groups. The measured section of the Salt Wash Member began at the eastern group of logs along a small drainage that contains the top of the Stump Formation to the top of a ridge where the fossil log-bearing interval and the overlying marker bed are exposed (figure 5A). The fossil log-bearing interval along the measured section is light to medium greenish-gray, very fine to fine-grained, friable sandstone and siltstone with indistinct bedding and no discernable sedimentary structures. The interval is generally slope forming and has fossil wood fragments scattered on the slope. The fossil log along the measured section at site 1 is 11 m in length, moderately well exposed, and fairly intact (figure 10). The log-bearing interval is 10.8 m thick, and the fossil log occurs 1.9 m below the base of the overlying marker bed and 29.7 m above the base of the Salt Wash Member (figure 9). A short fossil log is located a short distance along strike of the measured section. That log occurs about 2 m above the base of the Salt Wash Member. Other fossil log sites of the eastern group are along the ridge within the log-bearing interval. These sites were also in the light to medium greenish-gray, very fine to fine-grained, friable sandstone and siltstone at slightly varying stratigraphic levels within the interval, except the logs at site 9 (see figure 5A). **T**he log at site 9 is about 10 to 12 m lower than the other logs on the ridge. The only other fossil log measured in the eastern group is at site 7 (see figure 5A) where it is partially exposed in the hillside, is slightly more than 0.5 m in length, and has a convoluted wood grain on its surface.

The western group of logs is located along a low ridge about 500 m northwest of the eastern group. No sections were measured through the western group, but detailed geologic mapping and comparison of the stratigraphy indicates that the log-bearing interval in the western group occurs in the same stratigraphic interval as the eastern group (figure 5). As in the eastern group, the log-bearing interval in the western group is light to medium greenish-gray, very fine to fine-grained, friable sandstone and siltstone with indistinct bedding and no discernable sedimentary structures. The measured lengths of the fossil logs range from about 1.3 to 2.3 m, with diameters ranging from 0.5 to 1.1 m.

Figure 10. Fossil log at site 1 in Rainbow Draw (see figure 5A). This fossil log occurs along the measured section in the Salt Wash Member of the Morrison Formation. The fossil log-bearing interval is a light to medium greenish-gray, very fine to fine-grained, friable sandstone and siltstone with indistinct bedding and no discernable sedimentary structures. The log is 11 m in length and is oriented east–west; view is to the east.

All sites within each group contain a single log, with the exception of site 1 (eastern group), which has two closely spaced logs, and site 3 (western group), which has multiple closely spaced log segments. The log segments at site 3 may represent multiple logs or a single log that has moved downslope because of erosion and broken apart. The measured azimuths of the long axis of the fossil logs in Rainbow Draw area indicate that they are randomly oriented.

GENERAL DESCRIPTION OF THE FOSSIL WOOD

Only a basic description of the fossil logs is presented here because a detailed description is being made by Gee and others (2019). The fossil logs in both the Miners Draw and Rainbow Draw areas are shades of light to medium brown in color and siliceous, and some have a

coaly exterior (figure 11). The logs are large, mostly intact and have exposed lengths that range from 0.5 to 11 m and diameters up to 1.1 m. The fossil logs have been compressed somewhat due to compaction or have been unevenly abraded so that they have a long and short diameter (figure 12). The logs are well preserved and can be identified to species level from thin sections made from hand samples collected from both areas. The fossil logs have been identified as conifers that pertain to the same taxon originally described as *Araucarioxylon hoodii* Tidwell et Medlyn 1993 in the family Araucariaceae from Mt. Ellen in the Henry Mountains of southern Utah (Gee and others, 2019). Concurrent systematic work will prompt a nomenclatural transfer of this species to the genus *Agathoxylon* (Gee and others, 2019).

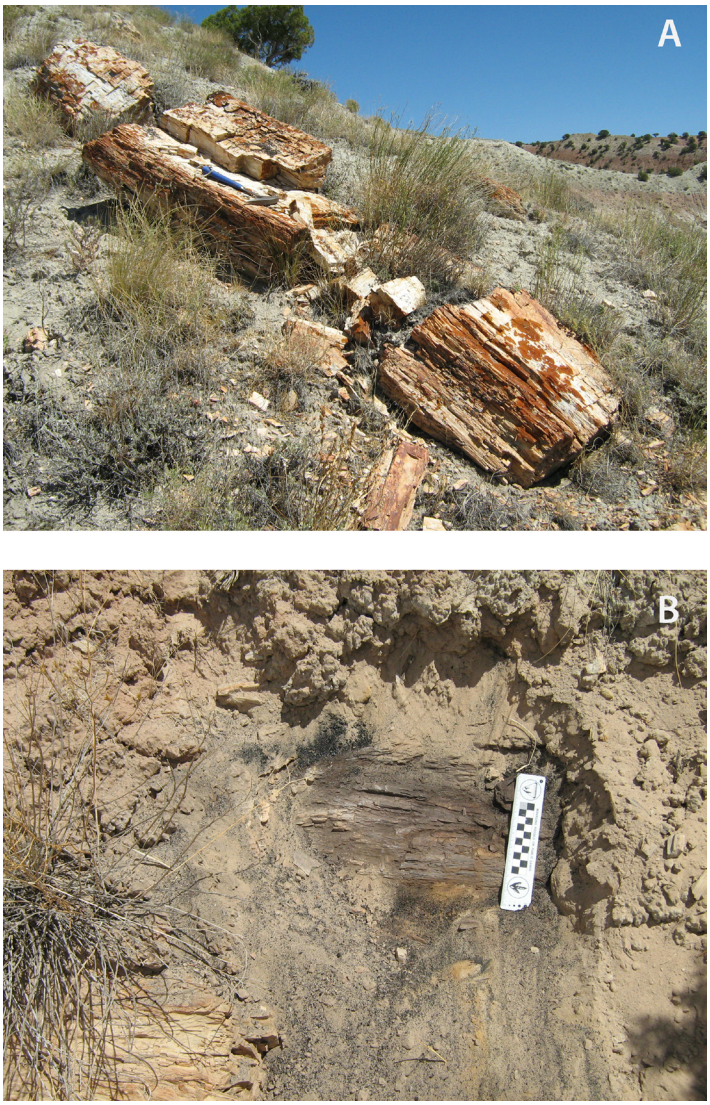

Figure 11. The fossil logs in both the Miners Draw and Rainbow Draw areas are shades of light to medium brown and mostly siliceous; some have a coaly preservation. (A) Typical log in the Rainbow Draw area; view to the north. (B) Example of wood with a coaly material; note the black organic matter.

DISCUSSION

The fossil logs in both the Miners Draw and Rainbow Draw areas occur in the Salt Wash Member of the Morrison Formation. The single fossil log at Miners Draw is found in a silty to very fine grained, slightly clay-rich sandstone, which is 4.3 m thick and located 17 m below the base of the Brushy Basin Member. Unfortunately, the base of the Salt Wash Member is not exposed at the fossil log site, but the Salt Wash is 78 m thick in the section measured to the northeast. Similarly, we have mapped all the fossil log sites in the Rainbow Draw area to a single log-bearing interval, a very fine to fine-grained sandstone and siltstone having indistinct bedding and no discernable sedimentary features (lithologically like the Miners Draw interval) that is 10.8 m thick. Most fossil logs are found in the upper part of the log-bearing interval, but logs are near the base of the interval as well, indicating that the entire interval may contain logs. We did not measure the entire Salt Wash Member at Rainbow Draw, but Turner and Peterson (1999) indicated that this member in Rainbow Draw is about 80 m thick. Our measured thickness to the top of the log-bearing interval is 31.5 m, and we calculate the thickness of the remaining Salt Wash, from the top of the log-bearing interval to the base of the Brushy Basin, to be about 40 m thick. Thus, the measured and calculated thickness of the Salt Wash is about 72 m, which would place the log-bearing interval just below the middle of the Salt Wash Member. Though we may be inclined to correlate the log-bearing intervals at Miners Draw and Rainbow Draw as the same stratigraphic horizon because the strata of all sites are lithologically very similar, the log-bearing interval at Miners Draw seems to be stratigraphically higher in the section and probably does not correlate to the interval at Rainbow Draw.

The Salt Wash Member was deposited in a large flu-

Figure 12. The fossil logs are large and mostly intact, range in exposed length from 0.5 to 11 m, and reach diameters of as much as 1.1 m. The fossil logs have been abraded so that they have a longer and a shorter diameter. The logs are well preserved and can be identified to the species level from thin sections made from hand samples (see Gee and others, 2019) collected from the Rainbow Draw and Miners Draw areas (under permit from Bureau of Land Management).

vial floodplain system of mostly meandering and braided channels, migrating bar sand, and fine-grained overbank deposits (Peterson and Roylance, 1982; Turner and Peterson, 2004; Kjemperud and others, 2008). Both high- and low-energy deposition is indicated by the range in grain sizes. Much of the fossil wood found in the Salt Wash Member occurs in channel sandstone and conglomeratic sandstone beds, but the fossil logs in the Miners Draw and Rainbow Draw areas are in an interval of very fine to fine-grained sandstone and siltstone beds that lack any discernable sedimentary structures. We interpret the log-bearing intervals as overbank deposits in the floodplain depositional environment. In addition, we speculate that the fossils logs may not have been transported far from their growth locations because of the fine-grained and structureless strata in which they are preserved. We are uncertain if the logs were transported by low-energy currents during a period of flooding or if the trees were toppled by a high-wind event. The concentration of fossil logs into two groups in Rainbow Draw suggests that there may have been at least two stands of conifers in this area, if not a larger forest of moderately tall trees.

SUMMARY

Although scraps of fossil wood are commonly found in the Morrison Formation, large fossil logs occur in both the Salt Wash and Brushy Basin Members in northeastern Utah near Dinosaur National Monument. In Rainbow Draw, the fossil logs occur in the middle of the Salt Wash Member based on its measured and calculated thickness. The log-bearing interval is a very fine to fine-grained sandstone and siltstone that lacks sedimentary features, suggesting the logs are preserved in floodplain overbank deposits. The fossil log at Miners Draw is preserved in similar strata in the upper part of the Salt Wash Member and is thought to be deposited in the same depositional environment as the logs in Rainbow Draw. The log-bearing intervals at Miners Draw and Rainbow Draw seem to be at two different stratigraphic horizons and do not correlate with one another. The nature of the sediments in which they are encased suggests that the logs did not travel far from their growth locations, but we are uncertain if the fossil logs were transported by low-energy currents or by some other mechanism. Paleobotanical study of samples collected from both sites indicate the logs pertain to conifers of the family Araucariaceae.

ACKNOWLEDGMENTS

We would like to thank the Utah Geological Survey for their support during this project. We also thank Steve Sroka (Utah Field House of Natural History State Park Museum) for his assistance in measuring the fossil logs in Rainbow Draw. Thanks also go to the reviewers, John Foster (Museum of Moab), Grant Willis and Stephanie Carney (both Utah Geological Survey), for their constructive comments and suggestions to improve the manuscript and figures. Finally, we are grateful to ReBecca Hunt-Foster (Utah Bureau of Land Management, Canyonlands District) for permission to collect the hand samples of fossil wood for analysis, and Lisa Baldwin (Dinosaur National Monument) for providing the internal paleontological resources report.

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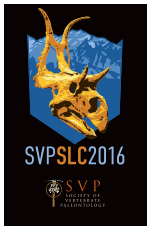

APPENDIX

MINERS DRAW SECTION (SOUTHWEST OFFSET)

General area of the *Camptosaurus* Site
Along the K Ranch Road along an unnamed tributary of Miners Draw, south of Blue Mountain Plateau
SE1/4 SW1/4 section 3, T. 6 S., R 25 E., Uintah County, Utah
Vernal 1:100,000, Snake John Reef 1:24,000
Section measured by Douglas A. Sprinkel, Mary Beth Bennis, and Dale E. Gray; October 22, 2013
N40°19.603', W109°5.350' (NAD83/WGS84, UTM 12: 662333 easting, 4465775 northing); offset southward along top of lower banded subunit (unit 17 of north section); elevation 1718 m; dip direction 328°, dip 7°

DESCRIPTION	THICKNESS (METERS) Interval	Total
BUCKHORN CONGLOMERATE MEMBER OF CEDAR MOUNTAIN FORMATION		
10. conglomerate, light brownish-gray, poorly sorted, planar bedding, black chert pebbles to cobbles, massive weathering, forms a resistant cap on Morrison Formation		NM
MORRISON FORMATION		
BRUSHY BASIN MEMBER		
Upper gray part		
9. Covered with abundant Buckhorn Conglomerate debris, measured to base of first conglomerate bed	14.9	86.6
8. Sandstone, light-gray (unweathered) that weathers to light brownish-gray, fine-grained with coarse-grained beds, moderately well sorted, calcareous, mud rip-ups at the base of coarse-grained beds, slightly cross-bedded	2.9	71.7
7. Claystone, mudstone, and siltstone interval, medium-gray (unweathered) and weathers light-gray, popcorn weathering, calcite veins weathering out on slope	52.3	68.8
Total upper gray unit		**70.1**
Lower banded unit		
6. Siltstone to silty sandstone, alternating greenish-gray and reddish-brown, contains thin resistant fine-grained sandstone, resistant sandstone 5 to 10 cm thick, unit is slope-forming, scattered manganese and carbonate nodules on slope	9.0	16.5
5. Silty sandstone, light brownish-gray, very fine grained, forms slope, poorly exposed	7.5	7.5
Total lower banded unit		**16.5**
Total Brushy Basin Member		**86.6**
SALT WASH MEMBER (incomplete; base of member is covered); dip direction 190°, dip 17°		
4. Sandstone, brownish-gray, coarse-grained, poorly to moderately sorted, subangular to subrounded, 1% accessory grains of orange and black, highly cross-bedded	7.5	22.3
3. Covered	9.0	14.8
2. Silty sandstone, light greenish-gray to brownish-gray, very fine grained and slightly clay rich, no discernable sedimentary features, weakly cemented, mostly slope covered, and poorly exposed, contains large fossil log that weathers out in relief, azimuth of log direction is 255°, log is 3.0 m above the base of unit 2	4.3	5.8
1. Sandstone, light-gray, fine- to medium-grained, subrounded, moderately well sorted, planar cross-bedding, forms low ledge; paleocurrent measurement 220°, 130°, 170°, 230°, 240°, 220°, and 290°	1.5	1.5
Base of Salt Wash Member is covered		
Total Salt Wash Member (incomplete)		**22.3**

APPENDIX

MINERS DRAW CREEK SECTION (MIDDLE OFFSET)

Along the K Ranch Road along an unnamed tributary of Miners Draw, south of Blue Mountain Plateau
NW1/4 NE1/4 section 3, T. 6 S., R 25 E., Uintah County, Utah
Vernal 1:100,000, Snake John Reef 1:24,000
Section measured by Douglas A. Sprinkel, Mary Beth Bennis, and Dale E. Gray; October 22, 2013
N 40°20.086', W109°5.034' (NAD83/WGS84, UTM 12: 662761 easting, 4466677 northing) with offset southwest along top of lower banded part (unit 17) that underlies upper gray part of Brushy Basin Member; see section and coordinates below; elevation 1755 ft; dip direction 328°, dip 7°

DESCRIPTION	THICKNESS (METERS) Interval	Total
MORRISON FORMATION		
BRUSHY BASIN MEMBER (incomplete)		
Upper gray unit		
18. Claystone, mudstone, and siltstone interval, medium-gray (unweathered) and weathers light-gray, popcorn weathering, calcite veins weathering out on slope		NM
Lower banded part		
17. Siltstone, reddish-gray, interbedded thin resistant (but subdued) sandstone beds, approximately 5 to 10 cm thick	14.1	17.0
16. Mudstone, claystone, and silty mudstone, dark greenish-gray with alternating reddish-gray, forms slope, popcorn weathering, intervals of calcium carbonated nodules weathering out on slope, iron manganese zone	0.3	2.9
15. Iron manganese zone	0.3	2.6
14. Siltstone to silty mudstone, medium greenish-gray, slightly fissile, calcareous, forms slope	2.0	2.3
13. Calcrete, calcium carbonate densely cemented with rounded coarse sand grains	0.3	0.3
Total Brushy Basin Member (lower banded unit)		**17.0**
SALT WASH MEMBER		
12. Siltstone, greenish-gray to dark reddish-gray, mottled, slightly clayey, slightly slope-forming, pseudo popcorn weathering	2.6	78.3
11. Sandstone, light-gray (unweathered) and weathers medium-brown, very fine grained, subangular to subrounded, scattered dark grains, well-sorted, laminated (bedding parallel laminations), cross-bedded, calcareous, forms subdued resistant ledge	0.7	75.7
10. Sandstone, brownish-gray (like unit 8), fine-grained, slope covered, contains a 0.8 m thick iron manganese limonitic zone that is about 2.3 m from base of unit	10.0	75.0
9. Sandstone, similar to unit 4, resistant and ledge-forming, scrappy wood, slopes below bare scrappy bone and wood	3.6	65.0
8. Sandstone, brownish-gray, coarse-grained, moderately to poorly sorted, cross- laminated, calcareous, resistant ledge-forming	9.4	61.4
7. Sandstone, same as unit 4, but forms slope	4.5	52.0
6. Sandstone, brownish-gray, poorly sorted, coarse-grained, graded, fining up, cross-bedded like unit 4, resistant ledge-forming	0.9	47.5
5. Sandstone, same as unit 4 but more slope forming	5.2	46.6
4. Sandstone, light brownish-gray, coarse-grained, poorly sorted, clasts are subangular to subrounded, graded, fining up, cross-bedded, calcareous, abundant reddish-colored chert, limestone clasts, resistant ledge-forming	2.6	41.4
3. Sandstone, greenish-gray, very fine grained, subrounded, well-sorted, calcareous, slope-forming, more resistant in the top 0.8 m	2.3	38.8
2. Silty sandstone, medium reddish-gray, very fine grained, subrounded, some clay, calcareous, weathers to smooth slopes	9.6	36.5

APPENDIX

1. Sandstone, light-gray, fine-grained, well-sorted, subrounded, scattered black- and orange-colored accessory grains (~1% total; dark grains are more abundant) calcareous, moderate-scale planar cross-bedding, massive weathering,	26.9	26.9
Total Salt Wash Member		**78.3**

MINERS DRAW SECTION (NORTHEAST OFFSET) — Tidwell and Windy Hill Members
Along the K Ranch Road along an unnamed tributary of Miners Draw, south of Blue Mountain Plateau
NW1/4 NE1/4 section 3, T. 6 S., R 25 E., Uintah County, Utah
Vernal 1:100,000, Snake John Reef 1:24,000
Section measured by Douglas A. Sprinkel, Mary Beth Bennis, and Dale E. Gray; June 12, 2017
N 40°20.07342', W109°05.00.312' (NAD83/WGS84, UTM 12: 662894.01 easting, 4466657.27 northing); elevation 1755 m; dip direction 325°, dip 6°

DESCRIPTION	THICKNESS (METER) Interval	Total
MORRISON FORMATION		
SALT WASH MEMBER (measured in middle offset section)		
12. Sandstone, light brownish-gray to very light gray, fine-grained, abundant large-scale planar and trough cross-beds, very thickly bedded		NM
TIDWELL MEMBER		
11. Siltstone as in unit 9; lumpy siltstone and sandstone as unit 10 but bioturbated	0.5	0.5
10. Sandstone, light brownish-gray to light greenish-gray, fine-grained, well-sorted, parallel bedded	0.4	0.9
9. Siltstone, reddish-brown with light greenish-gray mottling, ripple laminated with some soft-sediment deformation, some mud rip-up clasts	0.6	1.5
8. Sandstone, light greenish-gray, fine-grained, lumpy, bioturbated	0.5	2.0
7. Sandstone as unit 6 but forms ledges; interbedded shale as in unit 5	7.4	9.4
6. Sandstone, very light yellowish-brown, fine-grained, friable, forms slope	2.0	11.4
5. Shale, dark-gray, fissile, forms slope	1.9	13.3
4. Sandstone, light yellowish-brown, very fine grained, forms slope	1.4	14.7
3. Siltstone, light-gray, thinly bedded, forms slope	0.8	15.5
2. Chert, pink, botryoidal, replaced calcite or gypsum forms base of Tidwell Member	1.1	16.6
Total Tidwell Member		**16.6**
WINDY HILL MEMBER		
1. Siltstone and sandstone–interbedded; siltstone, light-gray, thin-bedded, small-scale ripples; sandstone, light-gray to light greenish-gray, fine-grained, well-sorted, abundant glauconite with some black accessory grains, thin-bedded, rippled	16.1	16.1
Total Windy Hill Member		**16.1**
STUMP FORMATION (REDWATER MEMBER)		
Limestone, light-gray to greenish-gray, finely crystalline (sparite), sandy, glauconitic, rippled		NM

NM = not measured

Total Brushy Basin Member (south offset section)	**86.6**
Total Salt Wash Member (north section)	**78.3**
Total Tidwell Member	**16.6**
Total Windy Hill Member	**16.1**
TOTAL MORRISON FORMATION (COMPOSITE SECTION)	**197.6**

APPENDIX

RAINBOW DRAW SECTION

Measured west of Wagon Bench road along east side of Rainbow Draw
NW1/4NW1/4 section 24, T. 3 S., R 24 E., Uintah County, Utah
Dutch John 1:100,000, Island Park 1:24,000
Salt Wash Member section measured by Douglas A. Sprinkel, Mary Beth Bennis, Dale Gray, and Larry R. Edwards; October 23, 2013
N 40°33.065, W109°10.850 (NAD83/WGS84, UTM 12: 654032 easting, 4490515 northing); elevation 1707 m
Tidwell and Windy Hill Members section measured by Douglas A. Sprinkel, Mary Beth Bennis, and Dale Gray; November 20, 2014
N 40°33.136, W109°10.813 (NAD83/WGS84, UTM 12: 654081 easting, 4490648 northing); elevation 1724 m; dip direction 263°, dip 5°

DESCRIPTION	THICKNESS (METER) Interval	Total
MORRISON FORMATION (INCOMPLETE)		
SALT WASH MEMBER (incomplete)		
11. Sandstone, light-gray, medium- to coarse-grained, subangular to subrounded, moderately well sorted, approximately 30% accessory grains (equal black, orange and yellow), forms resistant ledges through slope, thick- to medium-bedded, cross-bedded	NM	
10. Siltstone, light-gray to light greenish-gray becoming mostly reddish-brown at top, forms slope, channel sandstone within unit not along the line of section; channel sandstone is 9 m long and maximum 1.5 m thick, channel sandstone, light-gray, very fine to fine-grained, subrounded to subangular, well sorted, contains 5% accessory grains, mostly black with some orange	10.5	42.06
9. Sandstone and siltstone, light to medium greenish-gray, fine- to very fine grained, well-sorted, subrounded, less than 1% orange and dark accessory grains, poorly cemented, friable, forms slope, scattered fossil wood weathering out on slope; fossil log segment possibly in place along section at 8.8 m from base of unit 10 (2 m above base of unit 9 and 22.76 m above the base of the Salt Wash Member); fossil log site 1 is 1.9 m below base of unit 10 (8.9 m above base of unit 9 and 29.66 m above base of the Salt Wash Member)	10.8	31.56
8. Siltstone, mottled reddish-gray to greenish-gray, fine-grained, well-sorted, bedding indistinct, forms slope	1.5	20.76
7. Sandstone, same as unit 4 but well cemented	0.06	19.26
6. Sandstone, medium greenish-gray, well-sorted, fine-grained, subrounded, calcareous	2.7	19.2
5. Mudstone, dark greenish-gray, silty, slightly clayey, slightly micaceous, fissile, calcareous	1.3	16.5
4. Sandstone, same as Unit 1 but poorly exposed, forms slope	13.7	15.2
3. Sandstone, very light gray, very fine grained, well-sorted, less than 1% dark accessory grains, calcareous, medium- to thin-bedded, tabular-bedded, small planar cross-bedding, some ripple laminations	1.5	1.5
Total Salt Wash Member		**42.06**
TIDWELL MEMBER; dip direction 233°, dip 6°		
2. Siltstone and sandstone (poorly exposed); siltstone light brownish-gray, forms slope; sandstone, light-gray, fine-grained, well-sorted, abundant pink botryoidal chert and sparsely glauconitic, calcareous, medium to thin bedded, tabular-bedded, small-scale cross-bedding, symmetrical ripples; forms resistant ledges	17.1	17.1
Total Tidwell Member		**17.1**

APPENDIX

WINDY HILL MEMBER; dip direction 233°, dip 6°

1.	Siltstone, mudstone, and limestone (calcarenite) mostly covered; siltstone and mudstone, greenish-gray, forms slope; limestone, sandy, light greenish-gray, fine-grained, well-sorted, sparsely glauconitic, calcareous, thin-bedded, tabular-bedded, small-scale cross-bedding, ripples; forms resistant ledges	20.4	20.4
Total Windy Hill Member			**20.4**
TOTAL MORRISON FORMATION (INCOMPLETE)			**79.56**

REDWATER SHALE MEMBER OF STUMP FORMATION: Limestone (calcarenite), light brownish-gray to greenish-gray, fine-grained, scattered ooids to oolitic, pelecypod shell hash ..... NM

NM=not measured

Total Brushy Basin Member (south offset section)	**NM**
Total Salt Wash Member (incomplete)	**42.06**
Total Tidwell Member	**17.1**
Total Windy Hill Member	**20.4**
TOTAL MORRISON FORMATION (INCOMPLETE SECTION)	**79.56**