FINAL REPORT

Inventory and Salvage of Key Fossil Assemblages from the Upper Triassic Chinle Formation of the new Bears Ears National Monument, Utah

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RESEARCH NEEDS AND QUESTIONS ADDRESSED

Our multi-institutional team conducted a synergistic study of the paleontology and paleoenvironment of the Chinle Formation in the Indian Creek area (San Juan County), southeastern Utah.

The December 2016 founding presidential proclamation for Bears Ears National Monument (BENM) in southeastern Utah emphasized the importance of paleontological resources in preserving this area as a national monument: "*The paleontological resources in the Bears Ears area are **among the richest and most significant in the United States**, and protection of this area will provide important opportunities for further archaeological and paleontological study.*" In particular, the proclamation called out the plant, invertebrate, and vertebrate fossils "*in Indian Creek's Chinle Formation, dating to the Triassic Period*" as being one of the most significant paleontological resources in the monument. This geologic formation, which is well exposed in Indian Creek and surrounding areas that are part of BENM, preserves extensive fossil assemblages from the very beginning of the Age of Dinosaurs, including fossil wood, leaves, bivalves, snails, ray-finned fishes, amphibians, crocodile-like phytosaurs, armored aetosaurs, and the footprints of early dinosaurs.

Our major goal was to systematically prospect, inventory, and salvage paleontological resources from the Upper Triassic Chinle Formation within BENM, focusing on the Indian Creek area, and use these data to better understand Late Triassic ecosystem change.
Paleontological resources within BENM have never been systematically evaluated or inventoried, and the vast majority of Chinle Formation exposures within the Monument have never been prospected. As such, there is little knowledge of the number and quality of paleontological localities, but preliminary work suggests a diverse, extensive, and world-class record of the beginning of the age of dinosaurs. Therefore, we covered as much ground as possible during three weeks of fieldwork to identify as many paleontological sites and their geologic context, and where appropriate, collect significant fossil specimens that are at risk to erosion and weathering.

METHODOLOGY AND PERSONNEL

Field work was conducted by joint crews from the St. George Dinosaur Discovery Site at Johnson Farm (SGDS) and Natural History Museum of Utah (NHMU) along with selected volunteers from Utah Friends of Paleontology (UFOP). Field camp was based at the mouth of

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by

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Indian Creek and crews would either prospect on a daily basis, or assist in the excavation of three separate quarries.

Prospecting methods:
During inventory crews walked in teams of two to three abreast over exposed bedrock, recording in detail via GPS, notebooks, standardized forms, and photographed the location of any significant fossil resource encountered. Collection techniques consist of photo documenting the site and re-acquiring GPS data prior to collection, along with the recording of the rock context and associated fossils. Sites yielding more than one element are mapped using meter grids. Site maps are subsequently digitized for archival purposes.

Excavation methods:
The quarries included two separate, nearly complete phytosaur skulls, a partial phytosaur skeleton, and several associated partial skeletons of aetosaurs. All sites required some removal of loose overburden using standard hand tools such as picks, shovels, and pry bars. Once down to solid bedrock, hammers, chisels, pry bars, sledge hammers, and portable gas-powered rock saws were used to dig down to levels slightly above the productive fossil layers. In removal of overburden, careful attention is taken to make sure fossils above the targeted stratigraphic level are recorded and/or collected.

Excavation of the fossil-bearing horizons are undertaken in a slower manner to reduce damage of specimens. Fossils are carefully uncovered and stabilized with consolidates (acryloid B-72 dissolved in acetone). The positions of fossils and larger blocks to be removed are mapped in detail using a one-meter grid, corresponding to an accurate GPS point (or datum), and a north-south trending datum line. Wet toilet paper is then applied to surfaces containing fossils and associated rock and then strips of burlap dipped in plaster-of-Paris are used to create protective jackets around fossils and salvaged matrix. Jackets are then numbered and inventoried, then transported to vehicles by hand, backpack, and/or medical backboards.

NHMU staff included Dr. Randall Irmis (Curator), Tylor Birthisel (Fossil Preparator & Field Manager), and Carolyn Levitt-Bussian (Collections Manager). SGDS staff included Andrew R.C. Milner (Site Paleontologist and Curator).

The total field crew comprised: Randall Irmis, Andrew Milner, Tylor Birthisel, Carolyn Levitt-Bussian, Conner Bennett, Matt Bennett, Savhannah Carpenter, Patrick Cunningham, Jimena Diaz, Bob Douglass, Rob Gay, Catherine Groseclose, David Harris, Adam Huttenlocker, Fred Lacy, Carol Masheter, Cathleen McKenzie, Danielle Montague-Judd, Elena Payne, Eliza Peterson, Cody Rock, Jon Rock, David Slauf, Vincent Sun, Brian Switek, John Tripi, and Lori Tripi. The people listed above are either staff or volunteers from NHMU, SGDS, and UFOP, or researchers working with Milner and Irmis on specific projects.

PROJECTED RESULTS

1. Prospect for, inventory, collect, and scientifically describe these diverse new plant, invertebrate, and vertebrate fossil assemblages. Comprehensive prospecting in the large amount of unexplored outcrop within BENM will undoubtedly yield additional major discoveries, which will be crucial in building our dataset to a sample size and quality necessary to understand the

latest Triassic vertebrate faunal dynamics in these regions, and how they compare in composition with those further south (e.g., New Mexico and Arizona).

2. Place these fossils in a detailed lithostratigraphic framework. To understand any ecosystem and environmental changes that may have occurred through time in the strata preserved in BENM, we will place fossil and relevant paleoenvironmental data into detailed measured stratigraphic sections at meter-scale accuracy. This is critical to assessing the stratigraphic distribution of fossils, and their change or stability through time, particularly in comparison to accompanying paleoenvironmental proxies.

3. Reconstruct the paleoenvironmental context of this biota using new data from sedimentology, plant fossils, invertebrate fossils, and carbon stable isotopes. A key aspect of understanding potential latitudinal differences is a detailed understanding of the paleoenvironment, and how it may have been similar or different to other areas.

4. Compare these data to similar records we have developed from contemporaneous strata in Ghost Ranch, New Mexico to test whether latitudinally-influenced environmental differences promoted and maintained biotic differences during the closing days of the Triassic Period, just before one of the five largest mass extinctions in earth history.

ACTUAL RESULTS

We were able to spend 22 days conducting fieldwork, and our team was very successful in achieving our goals. ***We conducted 880 person hours (or 110 person days) of fieldwork in March over one week, and 848 person hours of fieldwork (or 106 person days) over two weeks in August.*** Major results are as follows:

1. Our 2018 work focused on the Upper Triassic Chinle Formation in the Indian Creek area of San Juan County: particularly along Lavender Canyon and the road leading to Beef Basin. This work was done under BLM paleontology permit UT07-023S-SW.

We recorded 108 new paleontological sites, collected 104 significant vertebrate specimens, 3 significant invertebrate fossil specimens and 4 significant fossil plant specimens. This work confirmed that both the Owl Rock and Church Rock members of the Chinle Formation are highly fossiliferous, with abundant plant fossils, invertebrate body and trace fossils, and vertebrate body and trace fossils. Particularly important was the discovery of new fossil-bearing layers at the base of the Owl Rock Member, just above the Kane Springs beds. From our March 2018 fieldwork, the most significant discovery during this time was a nearly complete pseudopalatine phytosaur skull in a down-dropped block from the top of the Owl Rock Member on the west side of Lavender Creek (UMNH VP Loc 2412). We were able to collect the specimen in a number of sections separated along natural fractures. In the immediate vicinity, we also discovered numerous other significant fossils, including fossil fishes (UMNH VP Locs 2415, 2421), beautifully preserved reptile footprints of *Atreipus*, *Gwyneddichnium*, and *Grallator* (UMNH VP Locs 2413, 2418, 2419), and the most complete specimen of the plant *Sanmiguelia* from Indian Creek (UMNH PB loc 164). In August 2018, we discovered yet another complete pseudopalatine phytosaur skull in the Owl Rock Member (UMNH VP Loc 2450), and several associated partial aetosaur skeletons from the same layer nearby (UMNH VP Loc 2449).

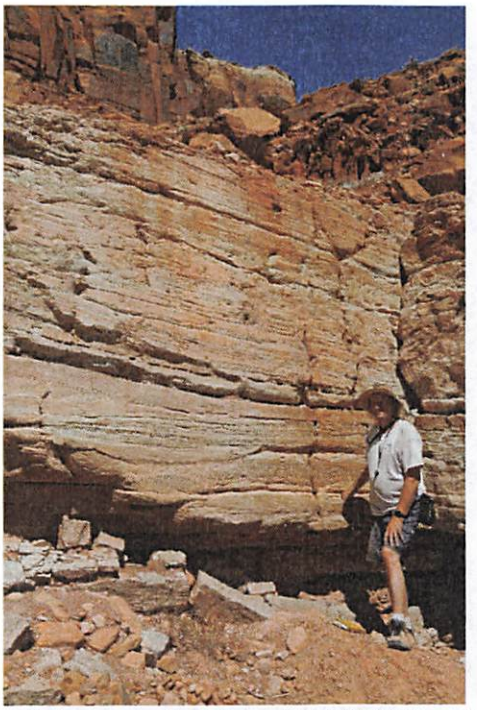
Working further south along these outcrops, we discovered additional important material in the lowest part of the Owl Rock Member, including the first occurrence of the aetosaur *Rioarribasuchus* from Utah (UMNH VP Locs 2444 & 2464), an associated partial phytosaur skeleton (UMNH VP Loc 2441), and a layer containing bone-bearing coprolites (UMNH VP Loc 2439). Prior to this work, metoposaurid amphibian material has been exceedingly rare in Indian Creek. These discoveries provide important insights into Late Triassic non-marine ecosystems of Utah, which previously have been poorly represented in the fossil record compared to correlative strata from Arizona, New Mexico, and west Texas.

Though not part of the specific Triassic goals of the project, our work also documented important fossil sites and specimens from BENM in the ~300 million-year-old latest Carboniferous-early Permian Cutler Group, some 70 million years before the first dinosaurs. Crucially, we successfully relocated a site (UMNH VP Loc 2408; PB Loc 162) discovered in the 1960s by Lyn Ottinger containing an articulated tetrapod (limbed vertebrate), which was excavated by UCLA paleontologist Peter Vaughn in 1968. Incredibly, we discovered three separate fossil-bearing horizons, with more associated bones (2018ICC0321-01-B) in the same layer as Vaughn's specimen, tetrapod bones in the overlying siltstone (2018ICC0321-01-C), a higher siltstone with beautiful leaf fossils (2018ICC0321-01-D), and a thin freshwater limestone containing abundant bones (2018ICC0321-01-D) including ray-finned fishes, associated lungfish, aistopod lepospondyl amphibians, small temnospondyl amphibians, and other tetrapod material. We also relocated and placed precisely in stratigraphic section two Smithsonian Institution plant fossil localities (USNM Locs 43577 & 43582) in the Cedar Mesa Sandstone from Indian Creek that were published by DiMichele et al. (2014).

All fossil specimen and locality details were reported to the BLM and Utah Geological Survey at the end of the 2018 and are on file with these agencies as well as SDGS and NHMU.

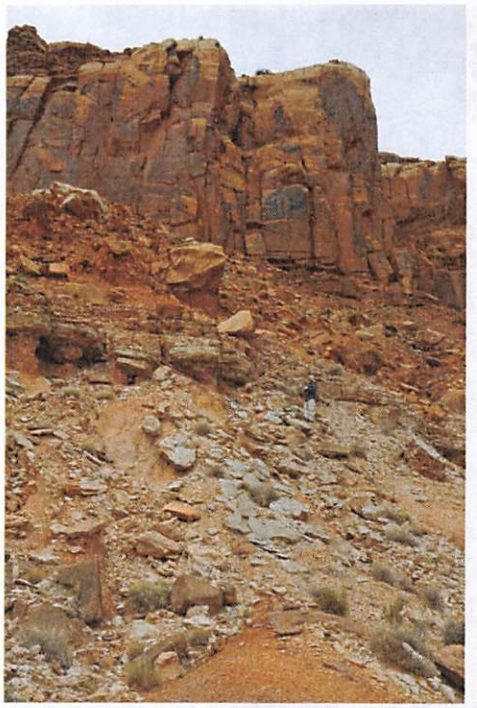
Photo of phytosaur skull block at UMNH VP Loc 2412 in Indian Creek.

Phytosaur skull from UMNH VP Loc 2412 after removal of posterior portion and snout.



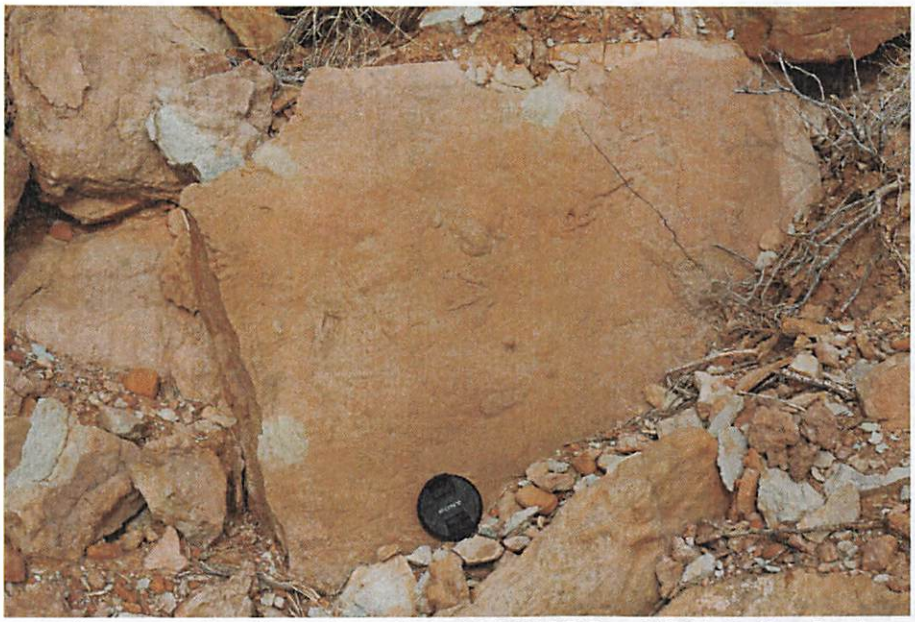
Andrew Milner at site of phytosaur skull from UMNH VP Loc 2450 in Indian Creek.

Close-up of in situ snout of phytosaur skull from UMNH VP Loc 2450 in Indian Creek.



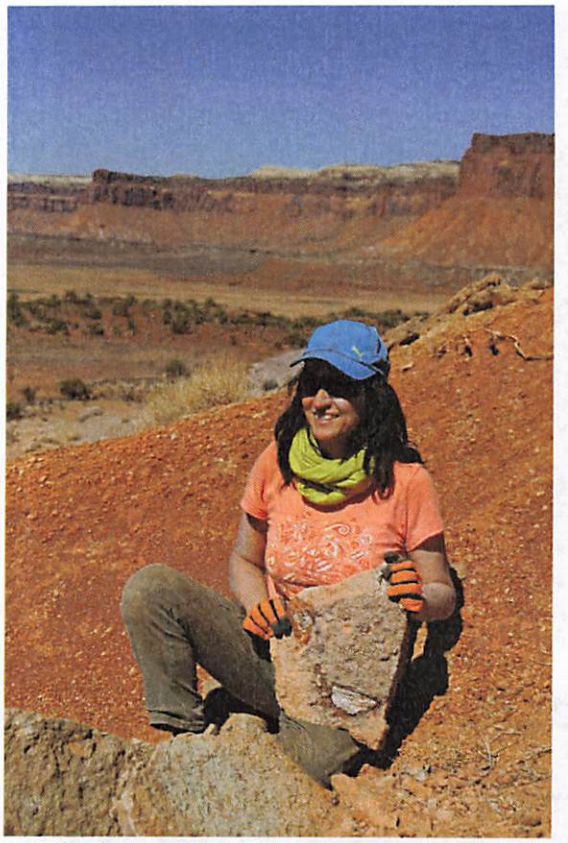
Site of associated typothoracine aetosaur material at UMNH VP Loc 2449 in Indian Creek.

In situ aetosaur osteoderm (armor plate) at UMNH VP Loc 2449 in Indian Creek.



Well-preserved reptile trackway from UMNH VP Loc 2470 in Indian Creek.

Nearly complete *Sanmiguelia* frond from UMNH PB Loc 164 in Indian Creek.



NHMU volunteer Jimena Diaz holds block with metoposaurid amphibian jaw from UMNH VP Loc 2456 of Indian Creek.

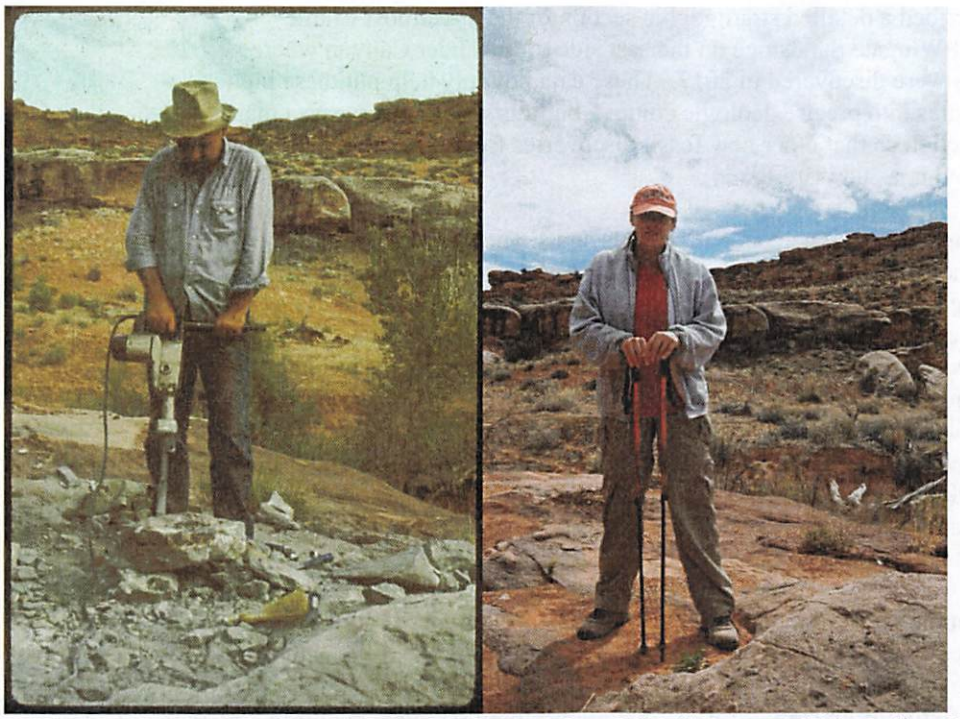


Photo of the Permian Ottinger/Vaughn site (UMNH VP Loc 2408 / PB Loc 162) in Indian Creek from 1968 (left) and March 2018 (right).

Lungfish tooth from limestone at UMNH VP Loc 2408 / PB Loc 162 in Indian Creek.

2. We measured and described a detailed stratigraphic section of the uppermost Chinle Formation and lowermost Wingate Sandstone on the east side of Lavender Canyon where important aetosaur fossils were discovered in 2017. These data not only help put these high-priority important fossil sites into precise geologic context, but this will also serve as a main reference stratigraphic section so that other new fossil discoveries from the Chinle Formation of Indian Creek can be slotted in as they are found.

3. Our fieldwork discovered five new paleobotanical sites and six new invertebrate paleontological sites in Indian Creek. These new data included a rare very complete specimen of the enigmatic leaf *Sanmiguelia* in the Chinle Formation of this area. These data will be crucial for reconstructing the paleoenvironment of this area between 220-200 million years ago. The measured stratigraphic section (see #2 above) includes sedimentological data on fossil soils (paleosols) that existed on the ancient floodplain during this time. The sedimentology indicates a highly seasonal sub-tropical environment, with very dry and very wet seasons and generally hot temperatures. We also collected several geologic samples, including sandstones for U-Pb zircon dating, representative rock samples to make petrographic thin sections to study their mineralogy, and fossil soil carbonate nodules to examine the stable isotope geochemistry of the strata. These samples are currently being processed and analyzed.

4. Although we are still in the midst of the research on newly collected fossils and geological samples from the 2018 field season, we have already reached some preliminary conclusions. For example, initial analysis of phytosaur specimens from Indian Creek indicate that they are new species to science, and different from similar forms found in northern Arizona and northern New Mexico (e.g., Ghost Ranch). In contrast, the aetosaurs (*Typothorax* and *Rioarribasuchus*) appear to be the same species as those found in New Mexico and Arizona. Fish sites from Indian Creek preserve a minimum of 4 new species. Detailed interpretation of the paleoenvironment awaits final analysis of the samples mentioned above (#3), but the first data from sedimentological description indicate that the dry season in southeastern Utah was even more intense than what we have observed in northern New Mexico, consistent with a latitudinal difference in climate. Documented tracksites are some of the most abundant and well-preserved in southeastern Utah, demonstrating that certain reptile groups were common in these ecosystems, and providing insights into their behavior (e.g., swim tracks, running tracks, frequenting river/stream margins, etc.), as well as being the only evidence for early dinosaurs in the Triassic of southern Utah.

CONCLUSIONS & APPLICATION OF RESEARCH RESULTS TO FUTURE EDUCATIONAL AND INTERPRETIVE EFFORTS

This research has been spectacularly successful. In just over 1700 person hours of fieldwork (~218 person days), we discovered over 100 new significant paleontological sites, collected over 100 important fossil specimens, and investigated the detailed paleoenvironment and geological context of these ancient organisms from 200-220 million years ago in southeastern Utah. We were able to complete excavation of two major sites discovered during prior work; these fossils are now under preparation at NHMU and SGDS. These data will be critical in understanding how latitudinal differences in climate affected ecosystems on land in the run-up to the end-Triassic mass extinction. Furthermore, they are critical in documenting and preserving the unique paleontological resources in BENM and vicinity.

Fossils discovered during this project are on display to the public at the fossil preparation labs at both SDGS (~55,000 visitors per year) and NHMU (~300,000 visitors per year). Specimens were also on display at NHMU's Behind the Scenes collections open house event in November 2018, which saw over 2,700 come through the collections over one weekend. Discoveries from this project were also discussed in two K-12 school presentations given by Milner over the 2017-2018 school year. As fossil preparation and research are completed in the near future, these data will be presented in scientific talks and posters at conferences, published in peer-reviewed journals, and featured in new special exhibits at SDGS and NHMU. We also hope to include casts (replicas) of some specimens in the Teaching Toolboxes and the Museum on the Move programs run by NHMU, which reach nearly 40,000 elementary school children across Utah each year.

Our 2018 work in BENM was featured in coverage from two different national news media outlets, which reach millions of viewers/listeners/readers nationwide:
- PBS NewsHour: https://tinyurl.com/ybwgz3ay
- ScienceFriday: https://tinyurl.com/y99vw4y5 ('*Utah is a Gold Mine for Fossils*')
  https://tinyurl.com/y43x5cy8 ('*Cold Case of Triassic Phytosaurs*')
  https://tinyurl.com/ybn3a7jo ('*The Mass Extinction Detectives*')
  https://tinyurl.com/y2sa2np7 ('*A Day With Fossil Hunters*')

During 2018, we discussed results from this project in the following presentations:

Invited Presentations
- Irmis, R.B. – Moab Information Center
- Irmis, R.B. – Humanists of Utah Darwin Day, Salt Lake City
- Irmis, R.B. – Dept of Geology & Geophysics Open House, University of Utah
- Milner, A.R.C. – Snow Canyon State Park Lecture Series
- Milner, A.R.C. – Rock-On Geology Club, Mesquite, Nevada
- Milner, A.R.C. – Guest lecturer for Geology course, Dixie State University
- Milner, A.R.C. – BLM Lecture Series, Mesquite, Nevada

FUTURE RESEARCH NEEDS

Despite the spectacular volume of new fossil sites and specimens from our work in 2015, we have systematically prospected less than 20% of the Chinle Formation exposures in the Indian Creek drainage and surrounding areas (e.g., Beef Basin). These outcrops clearly have very high potential to produce incredibly important new fossils, but they are at continued risk from erosion, weathering, and human impact. Therefore, a continued long-term project is necessary to systematically document these fossil resources and collect and excavate significant specimens for study and preservation. These discoveries also need to continue to be placed in detailed geologic context, as they are critical for understanding climate change, biogeography, and extinction during the beginning of the age of dinosaurs. Future research support is necessary to understand what these new fossils tell us about such lost ecosystems (e.g., are they new species, how abundant/diverse was each species, what was their ecology, etc.), and to support museum collections visits to compare them with previous discoveries from other Triassic fossil assemblages.

REFERENCES

DiMichele, W.A., C.B. Cecil, D.S. Chaney, S.D. Elrick, and W.J. Nelson. 2014. Fossil floras from the Pennsylvanian-Permian Cutler Group of southeastern Utah. *Utah Geological Association Publication* 43: 491-504.