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Bryce Canyon National Park

Paleontological Resource Inventory (Public Version)

A rainbow visible from Inspiration Point, overlooking the Paleogene Claron Formation at BRCA.
NPS/PETER DENSMORE

Bryce Canyon National Park: Paleontological resource inventory (public version)

Science Report NPS/SR—2024/123

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Abstract

Originally designated as a national monument in 1923, Bryce Canyon National Park (BRCA) is recognized for its exceptional pink-orange hoodoo landscapes. Its iconic hoodoos, consisting of the Paleocene–Eocene Claron Formation, are only part of the geology of BRCA, which includes a nearly uninterrupted sequence of Late Cretaceous Western Interior Seaway evolution and diverse depositional environments from approximately 100 to 77 million years ago. This sequence consists of the coastal Naturita Formation, the marine Tropic Shale, the transitional Straight Cliffs Formation, and the terrestrial Wahweap Formation. These strata, and the Claron Formation, preserve diverse paleontological resources. Fossils at BRCA have received little visibility for most of the park's history, despite relatively rapid advances in the study of Late Cretaceous and Paleogene paleontology in neighboring public lands, especially Grand Staircase-Escalante National Monument (GSENM) to the east.

The best documentation of paleontological resources at BRCA was produced through concerted field inventory of the park conducted by Dr. Jeff Eaton and several cohorts of interns and students from 1988 to 2015. In that time, Eaton's team documented nearly 200 paleontological localities within the park that yielded clams, snails, fish, frogs, turtles, lizards, snakes, crocodilians, dinosaurs, and mammals from the Straight Cliffs and Wahweap Formations and invertebrates, plants, and trace fossils in the Claron Formation. Eaton's survey resulted in several publications, including the description of new microvertebrate species from the Straight Cliffs and Wahweap Formations. Despite this body of work, the park did not develop an internal paleontological resources management program.

A new paleontological resources program at BRCA was advanced in response to construction activities that impacted several fossil localities in the Wahweap Formation. Newly hired paleontological staff conducted two seasons of field inventory (2022–2023), relocating as many of Eaton's sites as possible and recording new fossil occurrences along the way. In this timeframe, BRCA paleontologists encountered more than 150 localities. They also conducted detailed literature review, examined the park's paleontological collections data, and cultivated partnerships with outside researchers to better comprehend the current state and future potential of the park's paleontological resources.

This document synthesizes the total current body of knowledge on paleontological resources at BRCA to create a comprehensive paleontological inventory report. It combines historical data from the scientific literature, previous work conducted in the park, and recent fieldwork to cover BRCA's geologic history and fossil diversity and the history of paleontological study, education, and resources management in the park.

Acknowledgments

Paleontological inventories are massive undertakings that require input, coordination, and dedication from numerous people with specialized skills and knowledge to complete. This inventory is no exception, and the authors would like to thank those who helped us for their contributions.

Several current and former BRCA and NPS staff are recognized for their help in this project. Dakota Pittinger relentlessly dedicated himself to BRCA paleontology as a Scientists in Parks intern in 2022. Many additional staff, interns, and volunteers also assisted with prospecting and monitoring in the 2022–2023 field season. These include Bob Stwalley, Melanie “Mel” Henderson-Sjoberg, Keoki Thompson, Emily Nochowicz, Alyssa Sanchez, Greta Forner, Nazbah Stanley, Lyra Martin, Rhiannon Garrard, Dr. Arianna Harrington, Brian and Marnie Engh, Cecil Byles, and Brandy Nisbet-Wilcox. The authors thank you for your time, curiosity, and enthusiasm in joining BRCA paleontologists in the field.

Tran would like to specifically thank Emily Nochowicz and Keoki Thompson for their expertise in GIS data management and field data collection. Their aid in this inventory project has streamlined the data collection and management process for all future paleontological work at BRCA.

BRCA Chief of Resources Management Brett Cockrell has shown unwavering support of the park’s developing paleontology program. Importantly, Cockrell secured the funding crucial to the completion of this project. BRCA Curator Paige Hoskins offered their insights into BRCA and NPS collections management and policy and facilitated the curation of newly collected fossil specimens. Dr. Tyra Olstad, BRCA Physical Scientist from 2021 to 2022, is thanked for recruiting Tut Tran to this project. Dr. Olstad also completed the permit application and set up the remote data collection that facilitated the 2022 field season. BRCA Interpretive Rangers Paula Eastman, B. J. Cluff, and Amiee Ginnever from BRCA helped in obtaining interpretive documents and facilitating geologic and paleontological trainings for interpretive staff. BRCA Superintendent Jim Ireland and other staff—too many to list—have also been greatly supportive throughout the course of this inventory and are thanked here.

Many NPS staff outside of BRCA helped with this project. Tim Connors of the NPS Intermountain Region (formerly of the NPS Geological Resources Division) produced geologic and paleontological potential maps of BRCA. Connors also helped coordinate with peer reviewers for the preparation of this report for publication. The authors thank Conni O’Connor (FLFO) and Amanda Charobee (NPS GIS Specialist) for offering additional guidance on paleontological data collection and management in GIS, which will steer BRCA’s monitoring program moving forward.

Several individuals outside of BRCA and the NPS must also be thanked for their contributions to this report. Dr. Jeffrey G. Eaton has been pivotal to this project. Importantly, he provided park staff access to 25 years’ worth of field notes on paleontological localities in BRCA. These notes are crucial in carrying out the inventory and monitoring program. Furthermore, Dr. Eaton continues to share his wealth of knowledge and resources toward the cause of understanding and preserving the park’s fossils.

Gayle Pollock, Director of the Bryce Canyon Association (formerly the Bryce Canyon Natural History Association) is also recognized here. Pollock very generously and enthusiastically shared his knowledge and perspective on the history of geology and paleontological work at BRCA and the surrounding region. He has also helped identify newly collected marine invertebrates from the Tropic Shale at BRCA.

We also thank our colleagues at the Utah Geological Survey. Don DeBlieux, Assistant State Paleontologist at the Utah Geological Survey, facilitated fieldwork in 2023. DeBlieux helped BRCA staff reassess a productive vertebrate site in the park's Wahweap Formation and trained staff in photogrammetry scanning of the park's first recorded instance of dinosaur footprints. Dr. James Kirkland, State Paleontologist at the Utah Geological Survey, helped conduct emergency salvage of Wahweap localities at BRCA in 2020 and continues to be a source of historical knowledge for paleontology in the BRCA region. Senior Geologist at the UGS Southern Regional Office Tyler Knudsen is also thanked here for sharing his knowledge of ongoing geologic studies in the BRCA region.

We also recognize the staff of the Prehistoric Museum, especially Curator of Paleontology Dr. Josh Lively and Collections Manager Katherine Corneli. Dr. Lively and Corneli are facilitating the development of a long-term repository agreement with BRCA. Dr. Lively has also aided BRCA staff in fieldwork, namely in assessing the productive Wahweap Formation vertebrate fossil locality alongside Don DeBlieux.

Dr. Greg McDonald is recognized here for his expertise in paleontological collections management within the Department of the Interior. His insights have helped Tran navigate the dense paleontological collections data (and policy) necessary for the writing of many sections of this report. Furthermore, Dr. McDonald is also drafting BRCA's long-term repository agreement with the Prehistoric Museum.

The authors also extend their thanks to the staff of the Natural History Museum of Utah, especially Curator of Paleontology Dr. Randy Irmis, Paleontology Collections Manager Carrie Levitt-Bussian, undergraduate researcher Justin McKee, and preparator Tylor Birthisel. Dr. Irmis and Levitt-Bussian extended an impromptu invitation for Tran to visit the BRCA paleontological collections reposited at the museum during the proceedings of the 14th Symposium on Mesozoic Terrestrial Ecosystems in June 2023. Levitt-Bussian and McKee helped Tran arrange a more comprehensive collections visit in December 2023. These in-person collections visits were integral in giving Tran a better understanding of the scope of the material that Eaton recovered in the park. McKee and Birthisel have provided helpful discussions on the identifications and stratigraphic context of some of BRCA's dinosaur specimens at NHMU.

We gratefully acknowledge the cooperation and permission of Indiana University Press, Glen Canyon Conservancy, and Dr. Jeffrey Eaton, Dr. James Kirkland, and Dr. Randall Nydam (Midwestern University) for the use of images from the authors' chapters in "At The Top Of The Grand Staircase."

We also recognize several additional people for sharing their insights on the anatomical and taxonomic identification and status of BRCA specimens, even if in passing. These individuals include Dr. Josh Lively, Dr. Heather Smith, Brent Adrian (turtles), Dr. James Gardner, Dr. Zbyněk Roček (amphibians), Dr. Bucky Gates (hadrosaurs), Andrew Milner (hadrosaur tracks), and Dr. Charl Cilliers (plants). Thank you for sharing your time—even just a few moments—to help the authors understand the park's fossil diversity and paleontological context in the Intermountain Region.

Dedication

The authors dedicate this report to Dr. Jeffrey G. Eaton, Professor Emeritus of Geosciences at Weber State University. Dr. Eaton has devoted almost 50 years of concerted research effort into the geology and paleontology of southwestern Utah, including BRCA. The development of an internal paleontology program at BRCA in 2022–2023 and the authorship of this inventory report would have been impossible without the foundation of paleontological inventory and study that he spearheaded.

Thank you, Dr. Eaton.

Dr. Jeffrey G. Eaton and his trusted companion, Canaan, in Kodachrome Basin State Park, east of BRCA (JEFFREY EATON).

Introduction

Bryce Canyon National Park (BRCA) (Figure 1), Utah, was established to preserve its scenic geologic resources, including colorful pinnacles, walls, and spires in horseshoe-shaped amphitheaters. Many of these features are formed from rocks of the Claron Formation, discussed below. BRCA was initially proclaimed as a national monument June 8, 1923. It was redesignated as Utah National Park on June 7, 1924, and became Bryce Canyon National Park February 25, 1928. Its boundaries have changed several times: May 12, 1928; June 13, 1930; January 5, 1931; February 17, 1931; May 4, 1931; and March 7, 1942. BRCA currently encompasses 14,501.94 ha (35,835.08 acres), all but 1.01 ha (2.50 acres) of which are under federal administration.

BRCA is located in southwestern Utah, spanning parts of southwestern Garfield County and northwestern Kane County. It is bordered on the east and south by Grand Staircase–Escalante National Monument (GSENM), and on the west and northeast by two separate parcels of Dixie National Forest. BRCA occupies part of the eastern Paunsaugunt Plateau. The Pink Cliffs, formed in the Claron Formation, are oriented north to south through BRCA. The White Cliffs, another prominent member of the series of cliffs in the BRCA–Grand Staircase area, are found to the south. Several of southwestern Utah's High Plateaus are in the vicinity, with the Sevier Plateau to the north, the Aquarius and Awapa Plateaus to the northeast, the Kaiparowits Plateau to the east, and the Markagunt Plateau to the west. Structurally, BRCA is near a pair of large Basin and Range faults: the Paunsaugunt Fault runs through extreme eastern BRCA, and the Sevier Fault is found to the west (Davis and Pollock 2010). The East Fork of the Sevier River flows near the western border of BRCA. Cedar City is 71 km (44 mi) to the west, and St. George is over 120 km (75 mi) to the southwest.

This report provides detailed information on the paleontological resources of BRCA, including the history of paleontological work in the lands now within the park, geologic units, taxonomic groups, localities, museum collections, research, interpretation, and management and protection. In addition to the main body of text, there are six appendices: Appendix A, tables of paleontological species arranged by stratigraphy; Appendix B, museum collections data; Appendix C, contact information for repositories; Appendix D, paleontological resource law and policy; Appendix E, paleontological locality data; and Appendix F, a geologic time scale.

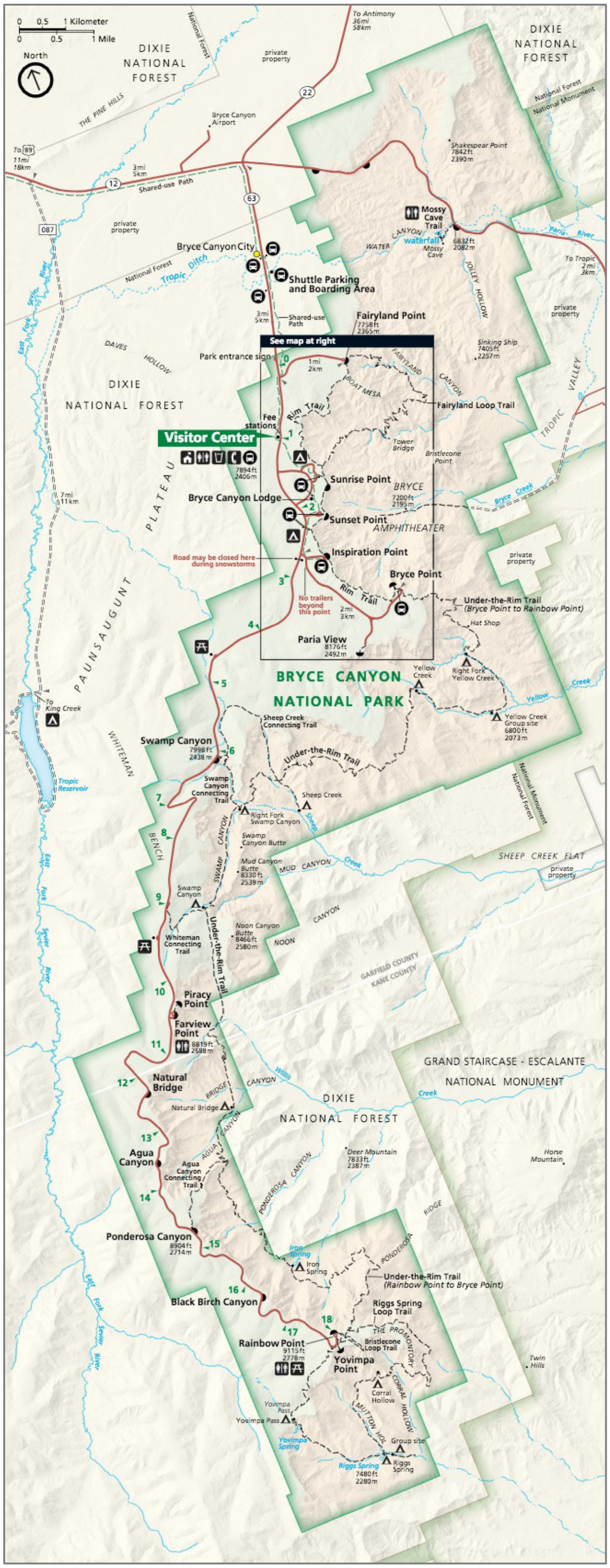

Figure 1. Park map of BRCA (NPS).

Significance of Paleontological Resources at BRCA

BRCA is primarily known for its unique geologic vistas, features, and history. The paleontological resources preserved at BRCA are not as widely recognized by the public and the NPS staff responsible for the park's resources management. However, BRCA does possess an important fossil record and the potential to produce additional significant fossil discoveries over the course of future scientific studies and management activities, which will contribute to the understanding and education about the park's geologic history.

The BRCA Foundation Document (NPS 2014) identifies paleontology as one of its "Other Important Resources and Values." The Foundation Document acknowledges the importance and scientific and educational potential of the park's fossil resources in the following statements:

Bryce Canyon National Park preserves a scientifically important and somewhat rare fossil record within late Cretaceous rocks of the Paunsaugunt Plateau. The Tropic Shale, Wahweap, and Straight Cliffs formations contain fossil plants, invertebrates, and a diverse assemblage of vertebrate fossils and microfossils including bony fish, amphibians, turtles, lizards, crocodilians, dinosaurs, and mammals, which reveals the plant and animal life in the region 97 to 35 million years ago.

Bryce Canyon National Park is a scientist's laboratory. Its geophysical setting, range in elevation through three climatic zones, and dynamic terrain provide for study of diverse biological and physical processes and resources important to the understanding and management of Colorado Plateau environments of the past, present, and future.

A paleontological inventory was conducted between 2006 and 2010 in conjunction with Weber State University. Many of the localities discovered are rich in fossils and could be further studied to improve awareness of taxonomic diversity in the park.

A variety of trace fossils have been recently found within the Claron Formation and provide a potential opportunity for additional research.

Purpose and Need

The NPS is required to manage its lands and resources in accordance with federal laws, regulations, management policies, guidelines, and scientific principles. Those authorities and guidance directly applicable to paleontological resources are cited below in Appendix D. Paleontological resource inventories have been developed by the NPS in order to compile information regarding the scope, significance, distribution, and management issues associated with fossil resources present within parks. This information is intended to increase awareness of park fossils and paleontological issues in order to inform management decisions and actions that comply with these laws, directives, and policies. Options for paleontological resource management are locality-specific, and may include no action, surveys, site monitoring, cyclic prospecting, stabilization and reburial, shelter construction, excavation, closure, patrols, and alarm systems or electronic surveillance. See Appendix D for additional information on applicable laws and legislation.

Project Objectives

This park-focused paleontological resource inventory project was initiated to provide information to BRCA staff for use in formulating management activities and procedures that would enable compliance with related laws, regulations, policy, and management guidelines. Additionally, this project will facilitate future research, proper curation of specimens, and resource management practices associated with the paleontological resources at BRCA. Methods and tasks addressed in this inventory report include:

- Locating, identifying, and documenting paleontological resource localities through field reconnaissance and perusal of archives, using photography, GPS data, standardized forms, and cave surveyor reports.
- Relocating and assessing historical localities.
- Assessing collections of BRCA fossils maintained within park collections and in outside repositories.
- Documenting current information on faunal assemblages and paleoecological reconstructions.
- Interviewing park staff to gather information on the current status of paleontological resources, to aid in formulating plans for management, ideas for interpretation, and recommendations.
- Conducting a thorough search for relevant publications, unpublished geologic notes, and outside fossil collections from BRCA.

History of Paleontological Work at BRCA

Paleontological work at BRCA has only intensified in the last two decades. Nonetheless, knowledge of fossils in and immediately around BRCA dates to the earliest decades of the park's history.

One of the oldest known documents directly indicating the presence of fossils in the Bryce Canyon area is a United States Geological Survey E&R (Examination and Report on Referred Fossils) report by Reeside (1922), which mentions a specimen of the bivalve *Unio* near the head of Bryce Canyon Creek. Although the specimen may not be from inside the modern park boundary, its proximity to the park indicates an interest in paleontological resources within the immediate geographic area. This interest would continue into the 1930s, which is evidenced by additional reports by Reeside (1937, 1939) on collections made by H. E. Gregory in and around BRCA. Gregory had collected many gastropods, bivalves, and ammonites from the Tropic Shale near and inside BRCA in 1937. In 1939, Gregory's fossil collection expanded to include invertebrates of the Claron (formerly Wasatch) Formation, with specific references to known BRCA sites including Sunset Point and New Natural Bridge (Reeside 1937, 1939). R. C. Moore also measured a stratigraphic section of the "north wall of Bryce Canyon" and reported poorly preserved plant fossils in the upper portion of the Straight Cliffs Formation there (Gregory and Moore 1931). Gregory (1951) later reported vertebrate, invertebrate, and plant fossils from the southern part of the Paunsaugunt Plateau, likely south of BRCA. These included the turtles *Adocus, Baena,* and *Basilemys,* the bivalve *Unio*, and multiple genera of snails, angiosperms, and conifers, all identified by Gilmore and Reeside (Gregory 1951). Gregory (1951) originally referred these fossils to the Kaiparowits Formation, but they would later be referred to the middle of the Wahweap Formation (Titus 2013). Gregory also noted the presence of "rare shells and rarer leaf impressions" in the Claron (formerly the Wasatch) Formation. Issues of the educational publication "Zion-Bryce Nature Notes" in the 1930s also refer to BRCA's fossils. In one issue, Thornton (1931) noted the presence of travertine pieces containing leaf fossils in the park museum. In a later issue, Wilson (1935) reported the presence of the snail *Physa* in the Claron Formation, snails and turtle carapace material in the sandstone beneath the Claron (likely the Wahweap and Straight Cliffs Formations) and the bivalve *Unio* in the shales beneath that sandstone (Tropic Shale) (*Unio* is a freshwater bivalve, so this may be a misidentification of a similar-looking taxon).

The documents mentioned above comprise the most concrete references to fossils in and around BRCA in the early 20th century. Even so, fossils referable to the Tropic Shale, the Straight Cliffs, the Kaiparowits (now referable to the Wahweap), and the Claron Formations were accessioned into the museum collections from the 1930s through the 1970s, collected mostly by members of the public local to the BRCA area. A notable specimen collected in this period is BRCA 588 by Ellis LeFevre in 1967. The specimen was originally identified as a mammoth jaw or tooth by the first Park Paleontologist at Dinosaur National Monument, Dr. Theodore "Ted" White. This diagnosis persisted until 2006, when NPS paleontologist Jason Kenworthy corrected the identification to a partial hadrosaur jaw during a site visit to BRCA.

The only study to explicitly mention fossils from BRCA in the mid-20th century (1930–1980) is a report on a well core log near Paria View by Marine (1963). In this report, Marine includes lists of fossils by formation derived from Gregory's (1951) work on the Paunsaugunt and Kaiparowits regions overall, instead of making specific reference to fossils encountered during the excavation of the well.

A new period of paleontological research at BRCA began in 1988 with preliminary survey by Dr. Jeffrey Eaton, now Professor Emeritus of Geosciences at Weber State University. Eaton's early work in the park resulted in the documentation of just a handful of fossil sites until early 2003. Screen-washing of park sediments in that year revealed the park's potential to produce highly productive Late Cretaceous microvertebrate localities (see below). Just two other notable paleontological studies occurred in the 1990s while Eaton was beginning to survey BRCA. One of these was a study of Quaternary sediments and packrat middens by Agenbroad et al. (1992), which recovered ~300-year-old insect remains and rodent feces. The other study was led by Dr. Bill Cobban of the USGS, who surveyed the invertebrates of the Tropic Shale in BRCA under permit BRCA-1996-SCI-001 (Cobban 1996). Among the invertebrate fossils collected was the large, rare, and stratigraphically informative ammonite (nautilus-like mollusk with chambered shell) *Mammites nodosoides*.

Paleontological work at BRCA proliferated after 2003. Before this time, Eaton had noted only two microvertebrate localities of any quality in the park: one in the Wahweap Formation (UMNH VP Locality 77; Eaton et al. 1998; Munk 1998) and one in the upper Straight Cliffs Formation (UMNH VP Loc. 424). Screen-washing by Eaton during 2003 and 2004 resulted in the discovery of several new productive localities in the John Henry Member of the Straight Cliffs Formation (discussed below) (Eaton 2005). Following this, a multi-year paleontological inventory was initiated at BRCA, with the cooperation of the Bryce Canyon Natural History Association (now the Bryce Canyon Association), Bryce Valley High School, the Geological Society of America's GeoCorps America program, the NPS, Southern Utah University, and Weber State University. By 2013, the inventory documented and collected fossils from 172 localities within the park. Of these, one was documented in the Tropic Shale, 87 in the Straight Cliffs Formation, 62 in the Wahweap Formation, and 18 in the Claron Formation. The first six years of the inventory (2005–2010) focused on the mostly terrestrial Straight Cliffs and Wahweap Formations. Among other results, this effort documented the best record of vertebrates from the middle Late Cretaceous (Coniacian and Santonian stages) in the Western Hemisphere, and the most complete record of Late Cretaceous ostracods ("seed shrimp" crustaceans) in the world (Eaton et al. 2009). The paleontological resource inventory continued in 2011 and 2013, during which the focus shifted toward the invertebrate, plant, and trace fossils of the Claron Formation. Localities inventoried in 2013 were mostly documented by BRCA GeoCorps paleontology intern Stephanie Lukowski.

Many of the localities in the Straight Cliffs and Wahweap Formations documented during the entire survey produced microfossils that have since been described in the scientific literature, including rays, fish, frogs, lizards, crocodilians, dinosaur teeth, and micromammals, among them type specimens (see "Type Specimens" below; Eaton et al. 1998; Munk 1998; Roček et al. 2010, 2013; Eaton 2013; Gardner et al. 2013, 2016; Irmis et al. 2013; Kirkland et al. 2013; Nydam 2013; Titus et al. 2016). The inventory also recorded multiple localities outside of the park that have been discussed in the literature, including an iguanodontian (large beaked dominantly bipedal herbivorous dinosaur) and nodosaur (armored dinosaur lacking a tail club) remains identified low in the John Henry Member of the Straight Cliffs Formation east of BRCA (Gates et al. 2013; Loewen et al. 2013a). The abundance of fossils recovered from this inventory led BRCA administrators to recognize paleontological resources as an "Other Resource of Value" in the park's Foundation Document (NPS 2014).

Eaton's multi-year inventory for fossil resources at BRCA ended after 2013. Plans for field work in 2014 to study the trace fossils of the Claron Formation fell through when collaboration with the University of Kansas failed to materialize. Eaton completed a final field study at BRCA in 2015, which he initiated in response to construction that impacted a known locality along Utah State Route 12 (SR 12). No new localities were documented in this study, and Eaton sampled previously documented localities for additional specimens of charophyte algae, ostracods, and other invertebrates (Eaton 2015). He continued to work on fossils of the Claron Formation in the Sweetwater Creek area north of BRCA, leading to multiple publications on charophytes, ostracods, and the first occurrence of vertebrates in the unit (Sanjuan and Eaton 2016; Eaton et al. 2018; Sanjuan et al. 2020; Antonietto et al. 2022). Despite this work on neighboring lands, BRCA would not see well-documented paleontological study inside the park for five years after Eaton completed his most recent year of fieldwork in 2015, and the park would not implement the data Eaton compiled to develop a management program during this hiatus.

Some additional paleontological work was conducted at BRCA in 2015, but not by Eaton. Based on specimens recovered during a 2023 inventory of interpretive collections, multiple localities in the Claron Formation were sampled by Dr. Larry Davis, Professor Emeritus of the College of St. Benedict and St. John's University. Davis worked for the Bryce Canyon Natural History Association in the mid-2010s, utilizing his role as the first Geoscientist-in-Residence at the park to drive much of BRCA's interpretive programming (NPS 2015). The localities he recorded produced hundreds of trace fossil specimens referable to *Eatonichnus* sp. (see Bown et al. 1997). These fossils, along with petrographic samples, ultimately led to two presentations at meetings of the Geological Society of America (Davis et al. 2015; Singler et al. 2015). However, there is no record of this research in the NPS Internal Resources Management Applications system or the BRCA museum collections database. In turn, none of the specimens he collected were catalogued or accessioned into the museum collections.

The most recent period of paleontological work at BRCA was triggered by a massive landslide along SR 12 in 2017 (Eaton 2022). Eaton had previously documented localities in the Wahweap Formation within the affected area. Recognizing the imminent threat that construction activities would pose to these localities, Eaton contacted BRCA staff, along with Utah State Paleontologist Dr. James Kirkland and NPS Senior Paleontologist Vincent Santucci, to request increased study and salvage (Eaton 2022). However, BRCA remained largely unresponsive and failed to recognize the threat to paleontological resources. This may have been due to a lack of properly trained staff, such as a Physical Scientist or Park Paleontologist. No mention of paleontological resources was made in park documents during the planning for the construction activities, namely an Environmental Assessment

(EA) that led to a Finding of No Significant Impact (FONSI) approved by the Superintendent at the time.

BRCA remained unresponsive to both Eaton's and Santucci's requests for an assessment and monitoring for paleontological resources in the impacted area until September 2020, when Brett Cockrell, recently hired as Chief of Resources Management, was contacted by Santucci. Cockrell's involvement led to a meeting between BRCA, Eaton, Kirkland, and Steven W. Carothers and Associates (SWCA) paleontologist Vicki L. Meyers in October 2020 (Meyers and Knauss 2021). During this meeting, Kirkland confirmed the Utah state mandate for paleontological monitoring during construction activities, as this was a Utah Department of Transportation (UDOT) project. SWCA was ultimately contracted by BRCA and UDOT to conduct paleontological monitoring of the construction from October to December 2020. Kirkland aided Meyers in a pre-construction assessment of the area, and Eaton sampled as many localities as possible in that timeframe under his Utah state research permit (Meyers and Knauss 2021; Eaton 2022). SWCA paleontological monitors ultimately collected samples from 24 out of 27 total localities documented. The fossils recovered from their collection include clams, snails, fish, crocodilians, turtles, dinosaurs, and mammals (Meyers and Knauss 2021). Additionally, Eaton recovered charophytes from UMNH PB Locality 210 using finer screens than SWCA during screen-washing (Eaton 2022). Ultimately, most of the localities in the area were destroyed over the course of the ground disturbance activities (Figure 2).

Figure 2. Photographed progress of the construction along an outcrop of Wahweap Formation at SR 12 in December 2020 (SWCA ENVIRONMENTAL CONSULTANTS).

The fossil resources recovered and the destruction of several localities during the SR 12 construction in 2020 highlighted to Cockrell and other BRCA staff that a full-time paleontological management program would be necessary to properly protect and maintain these nonrenewable and scientifically significant resources. Soon after construction was completed, Cockrell began to secure funding to establish BRCA's first internal team of paleontological staff. The hiring of Dr. Tyra Olstad as BRCA Physical Scientist was an important step forward in this effort. Throughout 2021 and the early part of 2022, she created the first maps that future staff would use to collect data in the field, using files provided by Eaton to accurately map existing locality data into up-to-date NPS GIS standards. Olstad and Cockrell's efforts during this time set the framework for a new paleontological inventory in summer 2022 (see "Summary of 2022–2023 Paleontological Survey" below).

Summary of 2022–2023 Paleontological Survey

The BRCA Paleontological Resources Inventory project formally began in the summer of 2022 with the hiring of Tut Tran, a NPS Seasonal Physical Science Technician, and Dakota Pittinger, a Scientists in Parks Paleontology Assistant. The initial plan was to revisit as many fossil localities documented during the Eaton survey as could be reached by round-trip day hikes. The field season lasted from late May to early November, in which time Tran and Pittinger documented 64 new localities and revisited 46 previously recorded by Eaton and colleagues. Of the 110 localities documented, four were in the Tropic Shale, 51 were in the Straight Cliffs Formation, 37 were in the Wahweap Formation, and 18 were in the Claron Formation. Tran ultimately surface-collected vulnerable and scientifically informative specimens from six of the new localities.

Field work in the second summer (2023) began in late April, as snowmelt from the winter season began to reveal new sites. Fieldwork proliferated after the arrival of Alexandra Bonham, GSA SIP intern for the 2023 season. Bonham assisted Tran (re-hired at BRCA through the American Conservation Experience Emerging Professionals in Conservation [ACE EPIC] program) in relocating previously documented localities that Tran and Pittinger could not reach in 2022. Material was also collected from previously documented significant localities with the aid of the Utah Geological Survey (UGS) and the Prehistoric Museum in Price, Utah (CEUM). By November 2023, Bonham and Tran had documented 30 new localities and relocated 15 of Eaton's previously documented sites that had not been reached in 2022. They also monitored 29 of the localities discovered in 2022, most of which were in stable condition based on the scoring of NPS Form Paleo-2. Preliminary results of the 2022–2023 inventory were shared in public outreach events and at scientific conferences (Tran 2023a, 2023b; Tran et al. 2023).

The 2022 field work was performed under permit BRCA-2022-SCI-0011, and the 2023 field work was performed under BRCA-2023-SCI-0001.

Geology

Geologic History

The geology and paleontology of BRCA are discussed in a number of documents, including: Gregory (1940, 1951); Spitznas (1949); Vokes (1952); Brox (1961); Marine (1963); Davis and Krantz (1986); Lundin (1989); Bowers (1991); Eaton (1994, 1999a, 2005, 2013); Eaton et al. (1998, 2009); Munk (1998); NPS (1999); Ott (1999); Johnson et al. (2000); Tilton (2001); Koch and Santucci (2002); Pollock and Davis (2004); Sable and Hereford (2004); Goodin (2005); Hoffman (2005); Thornberry-Ehrlich (2005); Kenworthy (2006); Emerson et al. (2007); Williams and Lohrengel (2007); Doelling (2008); Pearce (2009); Davis and Pollock (2010); Santucci and Kirkland (2010); Williamson et al. (2011); Gardner et al. (2013); Kirkland et al. (2013); Nydam (2013); Biek et al. (2015); Tweet and Santucci (2015, 2018); and Tweet et al. (2016). The Geologic Resources Division of the NPS coordinated a geologic resources inventory scoping session for BRCA during July 1999 (NPS 1999) and produced a geologic resources evaluation report for the park in 2005 (Thornberry-Ehrlich 2005). The initial paleontological resource inventory and summary was prepared by Koch and Santucci (2002) as part of a Northern Colorado Plateau Inventory & Monitoring Network (NCPN) paleontological resources summary. A more detailed inventory and summary was prepared by Tweet et al. (2012) for an updated NCPN paleontological resources summary. The Bryce Canyon Association (formerly the Bryce Canyon Natural History Association) funded the creation of a new geologic map of the BRCA area by the Utah Geological Survey, which remains unpublished at the time of writing (Knudsen et al. in prep.).

The oldest rocks exposed at BRCA were deposited around 100 Ma (million years ago), shortly before a shallow continental sea called the Western Interior Seaway or Cretaceous Interior Seaway began to encroach upon the area (see Appendix F for a geologic time scale). These rocks, part of the Naturita Formation (formerly called the Dakota Formation, Sandstone, or Group), include the onset of several cycles when the Seaway transgressed (advanced) and regressed (retreated) over the land (Gustason 1989; Aubrey 1991; Ulicny 1999). The Seaway extended from the Arctic to the Gulf of Mexico, bisecting North America (Elder and Kirkland 1993, 1994). Its advances and retreats influenced the geology of numerous NPS units both within and outside of the NCPN. Because of BRCA's location at the western margin of the Seaway, only one large transgression-regression cycle is represented by a dominantly marine unit (the Tropic Shale) at the park (Figure 3). The Tropic Shale was deposited during the greatest transgression of the Seaway (Albright et al. 2007a). At the time it was forming, the western margin of the seaway was near Cedar City and the Pine Valley Mountains, just 70 km (40 mi) west of BRCA (Gustason 1989; Eaton et al. 2001; Tibert et al. 2003). Coincidentally, this transgression also occurred at about the same time (~94 Ma) as an ocean anoxic event that is related to significant marine extinctions (Elder 1991; Kirkland 1996). At the same time the Seaway was present, volcanoes in an island arc near the present California–Nevada border introduced large amount of ash, which over time have altered to bentonitic clays. The Seaway retreated from BRCA following the deposition of the Tropic Shale (Davis and Pollock 2010). The shallow sea was replaced by beach and coastal plain environments. Sediments deposited in these environments became the transitional Straight Cliffs Formation (Peterson 1969a; Anderson et al. 2010; Davis and Pollock 2010) and the fully terrestrial Wahweap Formation (Titus et al. 2005; Davis and Pollock 2010).

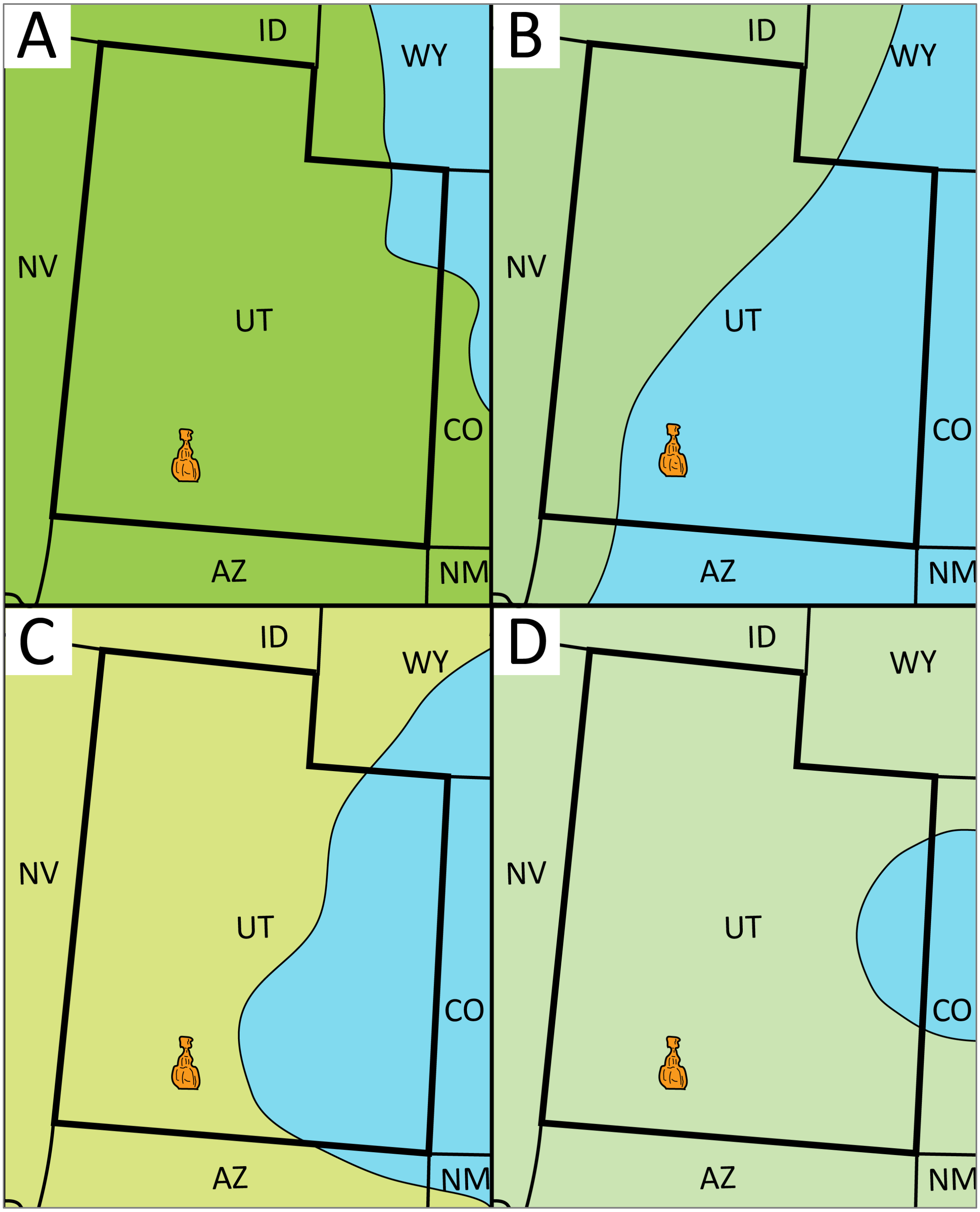

Figure 3. BRCA's geographic location (symbolized by the iconic "Thor's Hammer" hoodoo) relative to the margin of the Western Interior Seaway during deposition of the **A)** Naturita Formation (Cenomanian), **B)** Tropic Shale (Turonian), **C)** Straight Cliffs Formation (Santonian), and **D)** Wahweap Formation (Campanian). **A**, **C**, and **D** are modified from Figures 7, 13, and 16 in Robinson Roberts and Kirschbaum (1995); B is modified from Figure 7A in Elder and Kirkland (1993). Colors from Biek et al. (2015) (NPS / TUT TRAN).

Throughout much of western North America, the final withdrawal of the Seaway happened concurrently with the beginning of the Laramide Orogeny (mountain-building event) (Cather 2003). This event took place from the Late Cretaceous to the Eocene and was responsible for much of the present form of the Rocky Mountains (Aubrey 1991). The Colorado Plateau was less deformed in comparison, instead forming a series of broad uplifts and monoclines (step-like folds) (Tindall 2000; Davis and Bump 2009). The nearest such feature is the Kaibab uplift to the east and southeast of the park (Davis and Pollock 2010). Tectonic activity led to three periods of faulting at BRCA: between about 90 and 50 Ma, related to the Laramide Orogeny; between about 25 and 20 Ma, related to the growth and collapse of the southern Marysvale Volcanic Field (see below); and from about 15 Ma to the present, related to east–west Basin and Range extension (Davis and Pollock 2010). The modern topography of the BRCA area formed in response to increased erosion following recent uplifts and reorganization of the Colorado River drainage system (Davis and Pollock 2010).

The stratigraphic record at BRCA contains a gap of uncertain duration, possibly as much as 20 million years, between the Wahweap Formation and the next youngest rocks (the Claron Formation), during which deposition, if any, was not preserved. Much of the exposed rock at BRCA belongs to the Claron Formation., most likely deposited primarily during the early Eocene. This formation was deposited as part of a depositional system that transitioned from predominantly fluvial to predominantly lacustrine (Davis and Pollock 2010), and is related to a series of lakes that formed in central and eastern Utah during the Paleogene (Davis et al. 2009). Erosion and weathering of the colorful Claron Formation produced the park's outstanding scenery. Younger rocks and sediments at BRCA are limited to isolated exposures of gravelly units and Quaternary sediments (Davis and Pollock 2010).

In addition to periods of uplift, the Colorado Plateau, especially along its western margin, underwent widespread igneous activity during the late Eocene, Oligocene, and Miocene. The Cenozoic igneous activity of south-central Utah is dominated by the Marysvale volcanic field. Named for Marysvale, 86 km (53 mi) north of BRCA, Marysvale volcanics extend from Salina and the Fish Lake Plateau in the northeast to the Markagunt Plateau in the southwest (Rowley et al. 1975). Volcanism began in the Marysvale field by around 36 Ma and tailed off by around 14 Ma, but small-scale eruptions occurred as recently as the latest Pleistocene or possibly early Holocene (Rowley et al. 1994; Biek et al. 2011). The nearest preserved Marysvale volcanics are at the south end of the Sevier Plateau, immediately northwest of BRCA, and it is likely that volcanics covered the park at some point before being eroded. The southern part of the volcanic field, nearest BRCA, collapsed under its own weight around 20 Ma, which led to unusual thrust faulting and folding at the park (Davis and Pollock 2010). Southwest of the Marysvale volcanic field are shallow igneous intrusions known as the Iron Axis, mostly formed between 22 and 20 Ma (Hacker et al. 2007). More recently, during the Pliocene and Quaternary, small basaltic volcanic eruptions occurred on Markagunt and Paunsaugunt Plateaus, marking the northern edge of the Western Grand Canyon basaltic field (Johnson et al. 2010; Biek et al. 2011, 2015).

As the Pleistocene began approximately 2.6 Ma and continental glaciers formed over wide areas of the Northern Hemisphere, alpine glaciation occurred in Utah where elevations and precipitation were sufficient (Richmond et al. 1965). Small glaciers were present on both the Sevier Plateau to the north (Osborn and Bevis 2001) and on Brian Head just north of Cedar Breaks National Monument (CEBR), 48 km (30 mi) to the west (Madsen et al. 2002; Biek et al. 2011); glaciation did not directly affect BRCA, though. People were present in the Colorado Plateau by 12,000 years ago (Davis and Pollock 2010). Neighboring GSENM has evidence of the Clovis culture, which existed before 11,000 years ago (Agenbroad 1997).

Rock units exposed at BRCA include, from oldest to youngest, the Naturita Formation (formerly Dakota Formation), Tropic Shale, Straight Cliffs Formation, and Wahweap Formation (Late Cretaceous); the Claron Formation (Paleocene–middle Eocene); the conglomerate at Boat Mesa (late Eocene); and various Miocene?–Quaternary rocks and sediments (Figure 4) (Bowers 1991; Thornberry-Ehrlich 2005; Davis and Pollock 2010; Biek et al. 2015; Knudsen et al. in prep.). (Note that “lower” and “upper” refer to stratigraphic position, whereas “early” and “late” refer to geochronological age. These terms are capitalized if officially defined, lowercase if not, e.g., Upper or Late Cretaceous; lower or early Eocene.) The Naturita Formation, Tropic Shale, Straight Cliffs Formation, Wahweap Formation, and rarely the Claron Formation have yielded in situ fossils at BRCA, and the conglomerate at Boat Mesa has reworked fossils from Paleozoic formations. The other formations are potentially fossiliferous (Table 1). A visual overview of in-context fossil taxa recovered from BRCA is shown in Figure 5. Collections of BRCA fossils are held both at the park and outside museums.

The formational nomenclature for the rocks present at BRCA is convoluted, an incongruous situation for a setting with such expansive and impressive rock exposures. Historically, particular trouble areas are the identity of the rocks between the lower Straight Cliffs Formation and the Claron Formation, and the nomenclature used to describe the rocks currently included in the Claron Formation. This is partly due to east–west changes in Upper Cretaceous strata deposited during regression of the Western Interior Seaway, and partly due to stratigraphers working in different areas of the well-exposed Kaiparowits Plateau, the moderately well-exposed Paunsaugunt Plateau, and the poorly exposed Markagunt Plateau. Recent geologic mapping has now established correlation of Upper Cretaceous strata across these plateaus. Historical usages are mentioned below for reference.

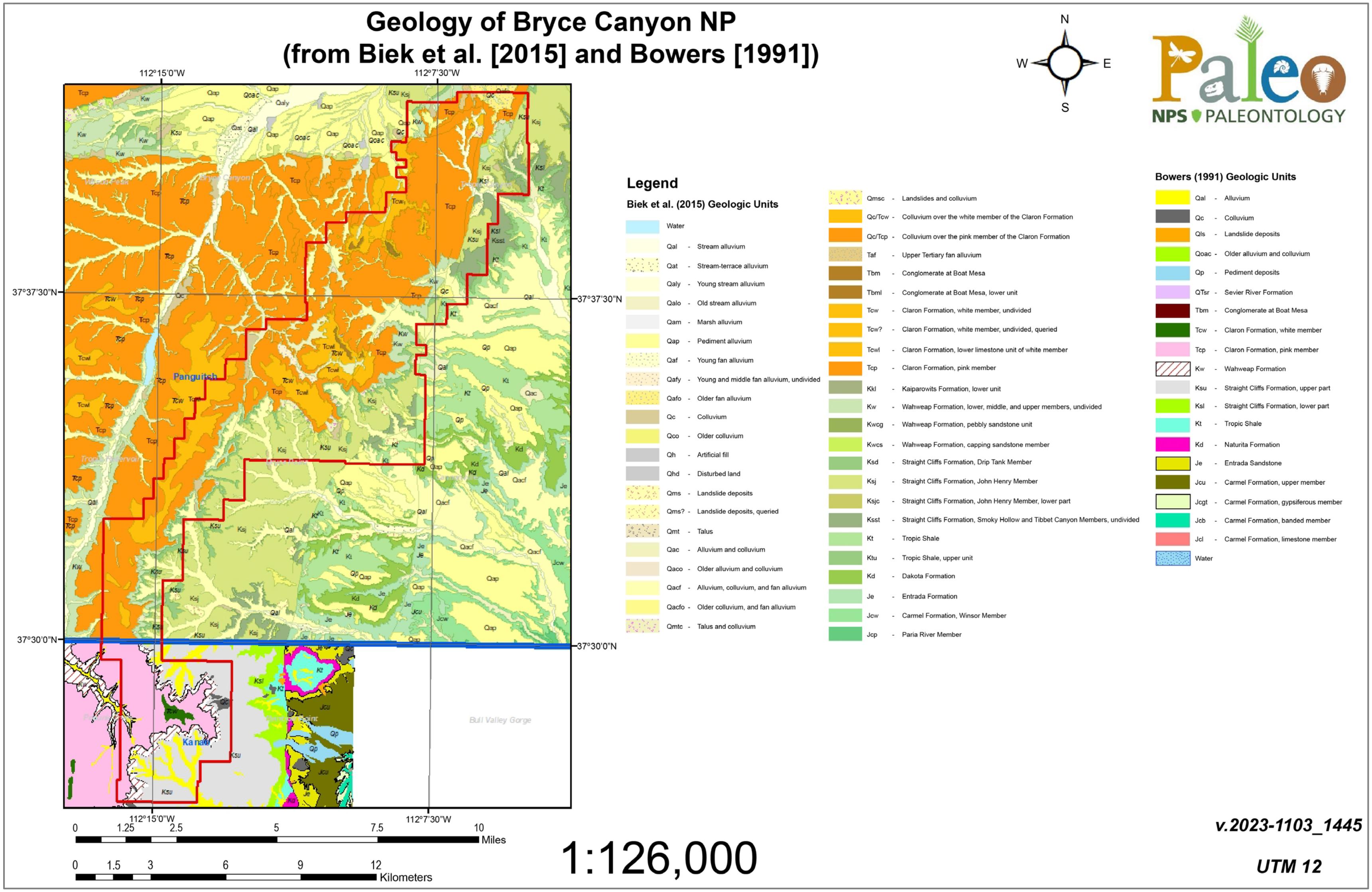

Figure 4. Geologic map of BRCA, derived from Bowers (1991) and Biek et al. (2015) (NPS / TIM CONNORS).

Table 1. Summary of BRCA stratigraphy, fossils, and depositional settings in descending order of age, from youngest to oldest. Details and references can be found in the text and in Tweet et al. (2012).

Formation	Age	Fossils Within BRCA	Depositional Environment
Quaternary sediments	Pleistocene–Holocene	None to date; packrat middens and isolated large mammal bones are most likely	Alluvial, colluvial, landslide, and pediment deposits
Upper Cenozoic alluvial deposits (formerly Sevier River Formation)	Miocene?–Pliocene?	None to date; microbial and invertebrate fossils are most likely	Alluvial fans, valley fill, and minor fluvial and lacustrine deposition
Conglomerate at Boat Mesa	late Eocene	Reworked Permian invertebrates	Fluvial and overbank settings
Claron Formation	Paleocene–middle Eocene	Charophytes, angiosperm leaves, hackberry seeds, bivalves, gastropods, ostracods, a gar scale, a bone (probably reworked from an older formation), microbial filaments, root traces, invertebrate trails, invertebrate nests, unspecified invertebrate trace fossils, and unspecified eggshell	Fluvial, alluvial, and lacustrine settings
Wahweap Formation	Late Cretaceous	Charophytes, angiosperm leaves, petrified wood, bivalves, gastropods, crabs, ostracods, diverse vertebrates mostly represented by microvertebrate remains (cartilaginous and bony fish, albanerpetontids, salamanders, frogs, turtles, lizards, crocodilians, dinosaurs, and mammals), invertebrate trails, hadrosaur tracks, coprolites, and unspecified eggshell	Fluvial settings
Straight Cliffs Formation	Late Cretaceous	Charophytes, angiosperm leaves, wood and other plant fossils, bivalves, gastropods, ostracods, and diverse vertebrates mostly represented by microvertebrate remains (cartilaginous and bony fish, albanerpetontids, salamanders, frogs, turtles, lizards, snakes, crocodilians, dinosaurs, and mammals), and coprolites	Heterogeneous coastal deposition, including fluvial, floodplain, deltaic, beach, marsh, and lagoon settings
Tropic Shale	Late Cretaceous	Marine bivalves, ammonites, gastropods, and invertebrate trails	Open marine
Naturita Formation (formerly Dakota Formation)	Late Cretaceous	None to date; petrified wood, invertebrates and microvertebrate fossils are common in the region	Terrestrial (especially fluvial) becoming shallow marine over time

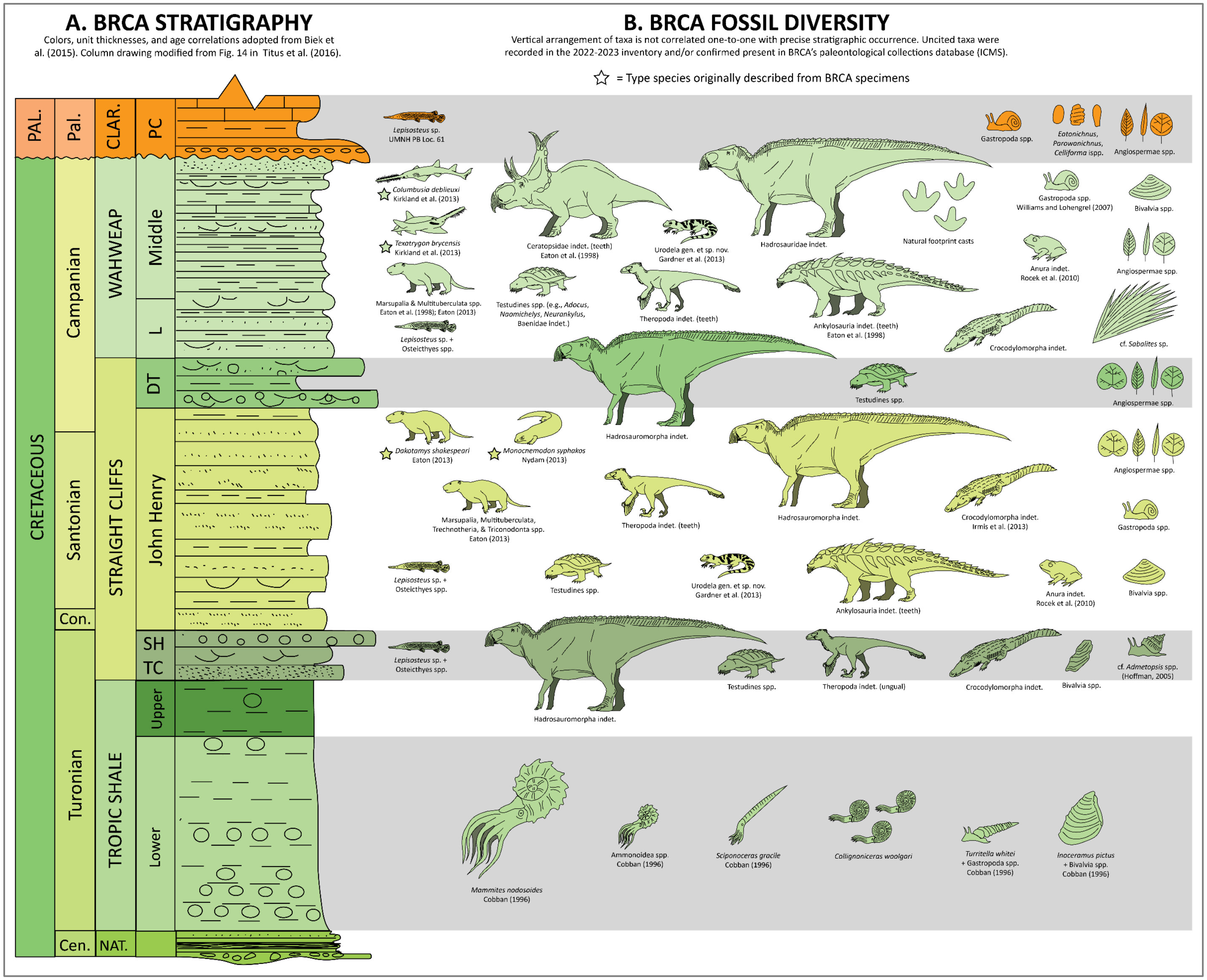

Figure 5. Overview of the (A) stratigraphy and (B) overall fossil diversity at BRCA, modified from Tran (2023b). Stratigraphic column drawing modified from Titus et al. (2016); colors and thicknesses of units modified from Biek et al. (2015) (NPS / TUT TRAN).

Geologic Formations

Naturita Formation (Upper Cretaceous)

Description: The Naturita Formation is a heterogeneous rock unit that crops out between the underlying Lower Cretaceous Cedar Mountain Formation (not exposed at BRCA) and the overlying Upper Cretaceous Tropic Shale (see "Tropic Shale" below) on the Colorado Plateau (Doelling and Davis 1989; Sable and Hereford 2004; Biek et al. 2009). Historically, this unit in Utah was identified by various geologists as the Dakota Formation (or Sandstone or Group) with varying levels of certainty due to its apparent similarities to rocks described as the "Dakota" in Nebraska and other areas in the midwestern United States (Hayden 1871; Carpenter 2014). This nomenclature was used even though the Upper Cretaceous rocks of the Colorado Plateau and those of the Midwest represent opposite shorefronts of the Western Interior Seaway (Carpenter 2014).

The first use of the term "Naturita Formation" was proposed by Young (1960) after the Naturita type section occurring on the Colorado Plateau. Despite this initial usage, "Naturita" did not gain traction in most geological studies, though some other researchers opposed the use of the name "Dakota" (Witzke and Ludvigson 1994). The most recent argument for the use of "Naturita Formation" to describe the shales and sandstones between the Cedar Mountain Formation and Tropic Shale in Utah was posed by Carpenter (2014), who provided a comprehensive historical review of the misuse and changing interpretation of the "Dakota" nomenclature. Carpenter (2014) underscored that the lithological and stratigraphic differences between the "Dakota" in Utah and the "Dakota" to the east were well-documented early in the study of these units (Hayden 1871). These differences rendered the use of "Dakota" to describe Utah strata inappropriate (Carpenter 2014). Instead, researchers should use the term "Naturita Formation" to describe the strata above the Cedar Mountain Formation and below the Mancos Shale (western Colorado, eastern Utah), Mowry Shale (northeastern Utah) or Tropic Shale (southwestern Utah, i.e., the BRCA region), based on the definition proposed by Young (1960, 1965). Subsequent publications, including this one, have agreed with Carpenter (2014), and the use of the name "Dakota" to describe this unit in Utah has phased out of the formal scientific literature (Biek et al. 2015; Knudsen et al. in prep.).

The Naturita Formation is exposed in small areas of BRCA. In the park and its immediate surroundings, it is composed of alternating sandstone, mudstone, carbonaceous mudstone, and coal, with a basal conglomerate, and is 55 to 90 m (180 to 300 ft) thick (Bowers 1991). The Naturita Formation of the Colorado Plateau is often divided into three informal members, with a conglomeratic base, a heterogeneous coaly middle, and an upper marine sandstone. This division reflects environments changing from channels at the base, to floodplains and coastal plains in the middle, to barrier islands and coastal deposits at the top as the Western Interior Seaway approached from the east and flooded the surface (Kirkland et al. 1997). The age of the formation differs geospatially, because different areas were affected by the encroaching sea at different times, but overall it was deposited within a few million years of the Early–Late Cretaceous boundary of approximately 100 Ma. In GSENM, the middle of the formation was deposited around 96.0 Ma (Titus et al. 2005).

Fossils found within BRCA: None to date.

Fossils found elsewhere: Fossils found in the Naturita Formation of the surrounding Paunsaugunt Plateau and vicinity include organic debris (Sable and Hereford 2004), palynomorphs (organic microfossils such as spores and pollen) (May and Traverse 1973), silicified logs (Marine 1963; Sable and Hereford 2004), plant fragments, local concentrations of bivalves and gastropods (Gregory 1951), ammonites (Sable and Hereford 2004), freshwater sharks, rays, lungfish, frogs, turtles, lizards, crocodile relatives, dinosaurs, and mammals including broadly rodent-like multituberculates and marsupials (Eaton 1993a; Santucci and Kirkland 2010). Most of the vertebrate remains come from the upper middle portion (Eaton 1993a). The palynomorphs described by May and Traverse (1973) came from nearby Willis Creek Canyon, and included fern spores, conifer pollen, and angiosperm pollen.

Naturita Formation outcrops of the nearby Kaiparowits Plateau and the rest of GSENM have also yielded diverse fossils. These include algae, foraminifera ("amoebas with shells") (Tibert et al. 2003), coal, palynomorphs (May and Traverse 1973), petrified wood (Doelling 1977), leaves (Erwin 1997), bivalves, gastropods, ostracods (Tibert et al. 2003), ammonites (Foster et al. 2001), a dragonfly nymph (Titus et al. 2005), invertebrate traces (Tibert et al. 2003), sharks, rays, ray-finned fish, lungfish, amphibians, turtles, lizards, several types of crocodilians and crocodile relatives, small theropods (carnivorous dinosaurs) such as dromaeosaurids and troodontids, tyrannosaurids, armored dinosaurs, hypsilophodonts (small bipedal herbivorous dinosaurs), hadrosaurids (duckbills), mammals (Eaton and Cifelli 1997; Eaton et al. 1999a; Eaton and Kirkland 2001, 2003; Titus et al. 2005), and footprint sites (Hamblin and Foster 2000). Most fossils there were found in floodplain settings of the middle unit, with some from lacustrine rocks (Eaton and Cifelli 1997; Eaton et al. 1999a), and algae, foraminifera, bivalves, gastropods, ostracods, and burrows from the upper part (Tibert et al. 2003).

Tropic Shale (Upper Cretaceous)

Description: . In BRCA and immediate vicinity, the Tropic Shale is mostly composed of gray claystone with minor amounts of sandstone and mudstone near the top and bottom. It is 215 m (705 ft) thick near Tropic, Utah (Bowers 1991; Biek et al. 2015). There is no depositional hiatus between the Tropic Shale and the overlying Straight Cliffs Formation (Davis and Pollock 2010), and the two formations interfinger in some locations (Tilton 2001). Biek et al. (2015) and Knudsen et al. (in prep.) map the Tropic Shale in BRCA as two units, Kt (Tropic Shale) and Ktu (Tropic Shale, upper unit). Biek et al. (2015) describe the upper unit as a 60 m (200 ft)-thick mudstone/sandstone that transitions into the overlying Tibbet Canyon Member of the Straight Cliffs Formation north of Tropic. The Tropic Shale represents the maximum marine transgression of the Western Interior Seaway. Because the marine transgression reached different areas at different times, deposition occurred over a range of time during the early Late Cretaceous (Tibert et al. 2003), roughly between 94 and 90.5 Ma (Titus et al. 2005; Albright et al. 2007b). In the BRCA region, the ammonites indicate that the Tropic Shale here was deposited after approximately 94 Ma and before 92.5 Ma (Bowers 1991; Cobban et al. 2006). The Tropic Shale is roughly equivalent to the lower Mancos Shale found to the east (Leckie et al. 1997; Tibert et al. 2003), correlating to the Tununk Member of eastern Utah (Elder and Kirkland 1993, 1994; Albright et al. 2007a). The depositional setting was offshore marine, grading to foreshore and shoreface as the sea began to regress (Sable and Hereford 2004).

Fossils found within BRCA: The Tropic Shale of BRCA is described as abundantly fossiliferous (Marine 1963). Gregory collected several invertebrate fossils from the Tropic Shale of BRCA, including bivalves, ammonites, and gastropods (Reeside 1937, 1939). One site identified in this unit at the park in 2008 has yielded bivalves and gastropods (S. Eagan, pers. comm., October 2010). In the BRCA area, limestone concretions have yielded marine fossils (Bowers 1991). A specimen of a particularly large ammonite, *Mammites nodosoides*, was collected by Cobban and Pollock from the Tropic Shale of BRCA (Cobban 1996; G. Pollock, pers. comm., 2023; Figure 6). This ammonite is significant for its role as an index fossil in determining the Cenomanian–Turonian boundary (G. Pollock, pers. comm., 2023). The ammonite *Collignoniceras woollgari* was also recorded at a new locality discovered in the 2022 survey (BRCA 64; see "Notable Localities in the Tropic Shale" below). Invertebrate trails have also been observed in the field.

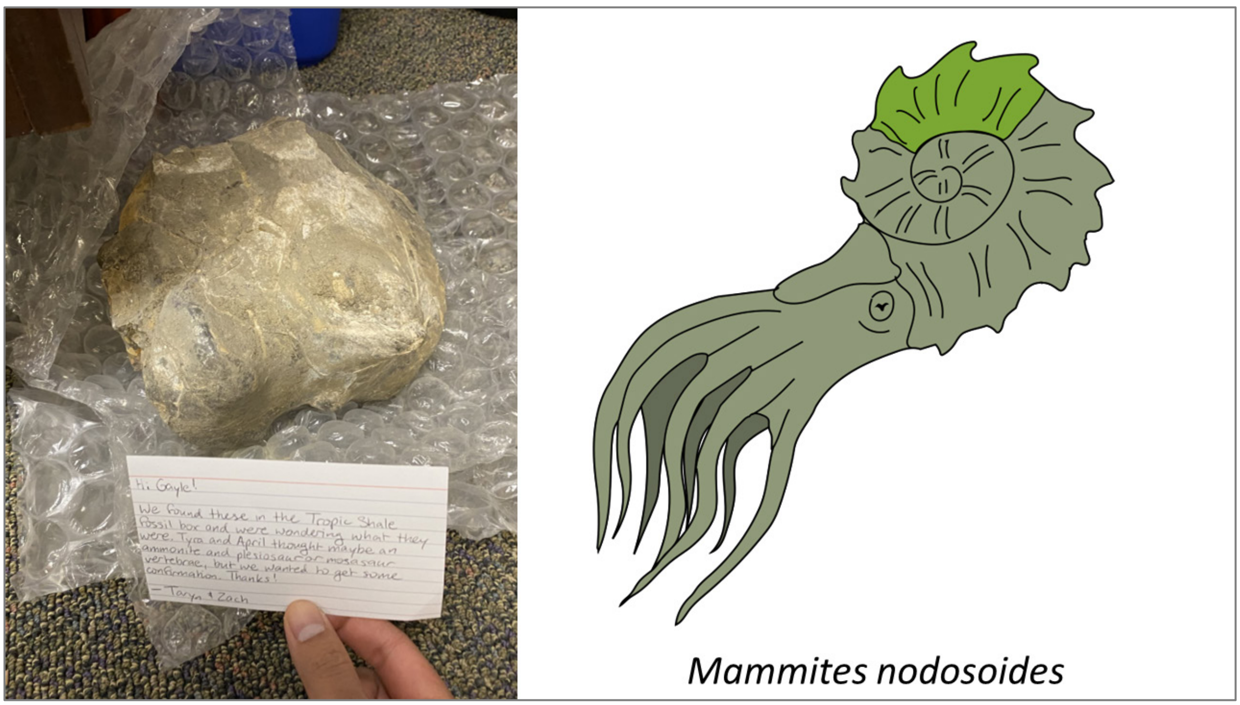

Figure 6. A specimen of *Mammites nodosoides* recovered during an inventory of interpretive collections in winter 2022–spring 2023 (fossil left, life restoration right). The specimen was originally collected by Cobban and Pollock in the 1990s (NPS / TUT TRAN).

Fossils found elsewhere: Most fossils in the Tropic Shale are marine. Coal, wood (Gregory 1951), foraminifera (Tibert et al. 2003; McCormick 2006), corals, bivalves, ammonites, gastropods (Gregory 1951), ostracods (Hazel 1969), serpulid worm tubes (Gregory 1951), ammonite shell impressions (Landman and Cobban 2007), other invertebrate trace fossils (Peterson 1969b), sharks (Hunt et al. 2006; Santucci and Kirkland 2010), bony fish, turtles, plesiosaurs (marine reptiles) (Albright et al. 2007a, 2007b), mosasaurs (marine reptiles related to monitor lizards) (Peterson

1969b; Polcyn et al. 2023), and a therizinosaurid dinosaur (Zanno et al. 2009) are known to date (Albright et al. 2013). The therizinosaurid, a long-necked long-clawed bipedal herbivore, is an unusual find so far from land (Gillette 2007). Fossil pearls are also known (Pollock and Davis 2004; Santucci and Kirkland 2010). The Tropic Shale of the Paunsaugunt Plateau has yielded corals, bivalves, ammonites, gastropods, and worm tubes. The prevalent fine-grained rocks have marine forms, while the sandstone beds have marine and brackish-water forms (Gregory 1951).

Most vertebrate finds in the Tropic Shale come from an area near Big Water, Utah, 64 km (40 mi) southeast of BRCA (Albright et al. 2007a, 2007b, 2013). These sites have yielded fossils from the lower part of the Tropic Shale, deposited between approximately 93.5 to 92 Ma (Albright et al. 2007a). The mollusks, bentonite beds, and limestone beds within the rocks permit high stratigraphic resolution (Eaton et al. 1987; Elder 1991). So far, researchers working in this area have found foraminifera (McCormick 2006), bivalves, ammonites, and vertebrates. Vertebrates recovered include the sharks *Squalicorax, Cretoxyrhina,* and *Ptychodus*, the bony fishes *Ichthyodectes* and *Xiphactinus*, the turtles ?*Desmatochelys* and *Naomichelys*, at least four species of plesiosaurs from two short-necked lineages (pliosaurid *Brachauchenius lucasi* and polycotylids *Eopolycotylus rankini*, *Palmulasaurus quadratus*, *Scalamagnus tropicensis*, and *Trinacromerum* ?*bentonianum*), and the therizinosaurid *Nothronychus graffami* (Albright et al. 2007a, 2007b, 2007c, 2013; Gillette et al. 2005; Zanno et al. 2009, 2013; McKean 2012; Clark et al. 2023). Before 2023, mosasaurs had not been recorded in the Tropic Shale. However, a new taxon from Glen Canyon National Recreation Area (GLCA) was recovered in 2012 and named in 2023 (Polcyn et al. 2023). The new taxon, *Sarabosaurus dahli*, represents the oldest mosasaurid known from North America and is more similar to the smaller plioplatecarpine mosasaurs than the large mosasaurines of the Campanian and Maastrichtian stages (Polcyn et al. 2023).

Straight Cliffs Formation (Upper Cretaceous)

<u>Description</u>: The Straight Cliffs Formation is a heterogeneous unit deposited in multiple paleoenvironmental settings. Rocks from the Straight Cliffs Formation weather into the Gray Cliffs of southern Utah (Davis and Pollock 2010). The Straight Cliffs Formation of south-central Utah is divisible into four members, based on exposures from the Kaiparowits Plateau. From oldest to youngest, these are the Tibbet Canyon Member, the Smoky Hollow Member, the John Henry Member, and the Drip Tank Member (Peterson 1969a). At BRCA, Bowers (1991) mapped the Tibbet Canyon and Smoky Hollow Members as the lower Straight Cliffs Formation, and the John Henry and Drip Tank Members as the upper Straight Cliffs Formation. Biek et al. (2015) follow Bowers (1991) in mapping the Smoky Hollow and Tibbet Canyon Members together but map the John Henry and Drip Tank Members separately following the example of Doelling and Willis (1999). The two lower members combine for a thickness of 100 to 120 m (320 to 400 ft), and the two upper members combine for a thickness of 274 to 395 m (900 to 1,300 ft) (Bowers 1991). Davis and Pollock (2010) report the Drip Tank Member as absent at BRCA, but this is incorrect (Biek et al. 2011, 2012, 2015).

The Tibbet Canyon Member is a cliff-forming sandstone that was deposited in beach and shallow marine settings. It grades out of the Tropic Shale and into the Smoky Hollow Member (Peterson 1969a) (Figure 7). The top of the Tibbet Canyon Member might represent fluvio-deltaic deposition

(Titus et al. 2005). In the BRCA area, it is orange-gray in color and has abundant bivalves in the upper strata (Tilton 2001). It was deposited during the early Late Cretaceous (Eaton et al. 1999a), approximately 92 Ma. Bowers (1991) mapped the Tibbet Canyon Member with the overlying Smoky Hollow Member as "Straight Cliffs Formation, lower part." More recent maps follow the example of Bowers (1991) by mapping these lower members of the Straight Cliffs Formation in an undifferentiated unit (Ksst "Smoky Hollow and Tibbet Canyon Members, undivided," in Biek et al. 2015). Eaton (1988 through 2013, unpublished notes) assigned localities in these areas to the overlying Smoky Hollow Member as opposed to the Tibbet Canyon Member due to the prevalence of lignitic coal beds. Although Biek et al. (2015) map the Smoky Hollow and Tibbet Canyon Members together, they note that the Tibbet Canyon Member is just 12–15 m (40–50 ft) thick on the eastern flank of the Paunsaugunt Plateau, which is where the member crops out in BRCA. The in-preparation map of Knudsen et al. maps the Tibbet Canyon Member separately from the overlying Smoky Hollow Member but agrees with Biek et al. (2015) in reporting that the member is relatively thin at BRCA.

The Smoky Hollow Member is a heterogeneous unit of mudstone, limy mudstone, sandstone, and coal (Figure 8). It formed in fluvial, floodplain, lagoonal, and marsh environments, and can be divided into three parts: a lower coal/limy mudstone unit from lagoonal and marsh settings, a middle fluvial sandstone/floodplain mudstone unit, and the upper fluvial Calico sandstone (Peterson 1969a). In the BRCA area, the lower part is mostly gray mudstone with thin carbonaceous shale near the base, the middle section is orange-gray sandstone and gray mudstone, and the Calico sandstone is composed of white to grayish orange pebbly or granular sandstone. There is a disconformity between the middle and Calico sandstone strata (Tilton 2001). The Smoky Hollow Member was deposited during the early Late Cretaceous (Parrish 1999), at a time when the sea had retreated (Eaton and Cifelli 1997). Titus et al. (2013) propose U-Pb and Ar-Ar ages of ~91.9 Ma for a bentonite in the upper portion of the Smoky Hollow Member (~0.5 m [1.6 ft] below the Calico bed).

The John Henry Member is a mixed unit similar to the Smoky Hollow Member (Figure 8). It was mostly deposited under nonmarine conditions west of the Kaiparowits Plateau, and under marine conditions east of it (Eaton and Cifelli 1988). This unit interfingers with the overlying Drip Tank Member. Multiple coal beds are present (Peterson 1969a). The John Henry Member of the BRCA area is composed of alternating grayish orange sandstone and gray to red-purple mudstone (Figure 8) in a roughly 2:1 ratio (Tilton 2001) and is 240 to 335 m (800 to 1100 ft) thick (Bowers 1991; Biek et al. 2015). It was deposited during the middle Late Cretaceous (Eaton et al. 1999a), between about 87 and 84 Ma, during another marine transgression (Eaton and Cifelli 1997). Biek et al. (2015) map a lower section in BRCA, possibly Coniacian in age, separately from the remaining upper portion of the unit (Ksjc, "John Henry Member, lower part"). They describe this unit as a 25 to 30 m (80 to 100 ft) thick conglomeratic white to gray sandstone that may be equivalent to the Calico bed. Knudsen et al. (in prep.) use the same symbology but refer this unit directly to the Calico bed instead. Magnetostratigraphic study of the upper portion of the John Henry Member and the Drip Tank Member by Albright and Titus (2016) revealed that they are both of normal polarity and correspond to the C34n Superchron, concordant with a Santonian depositional age.

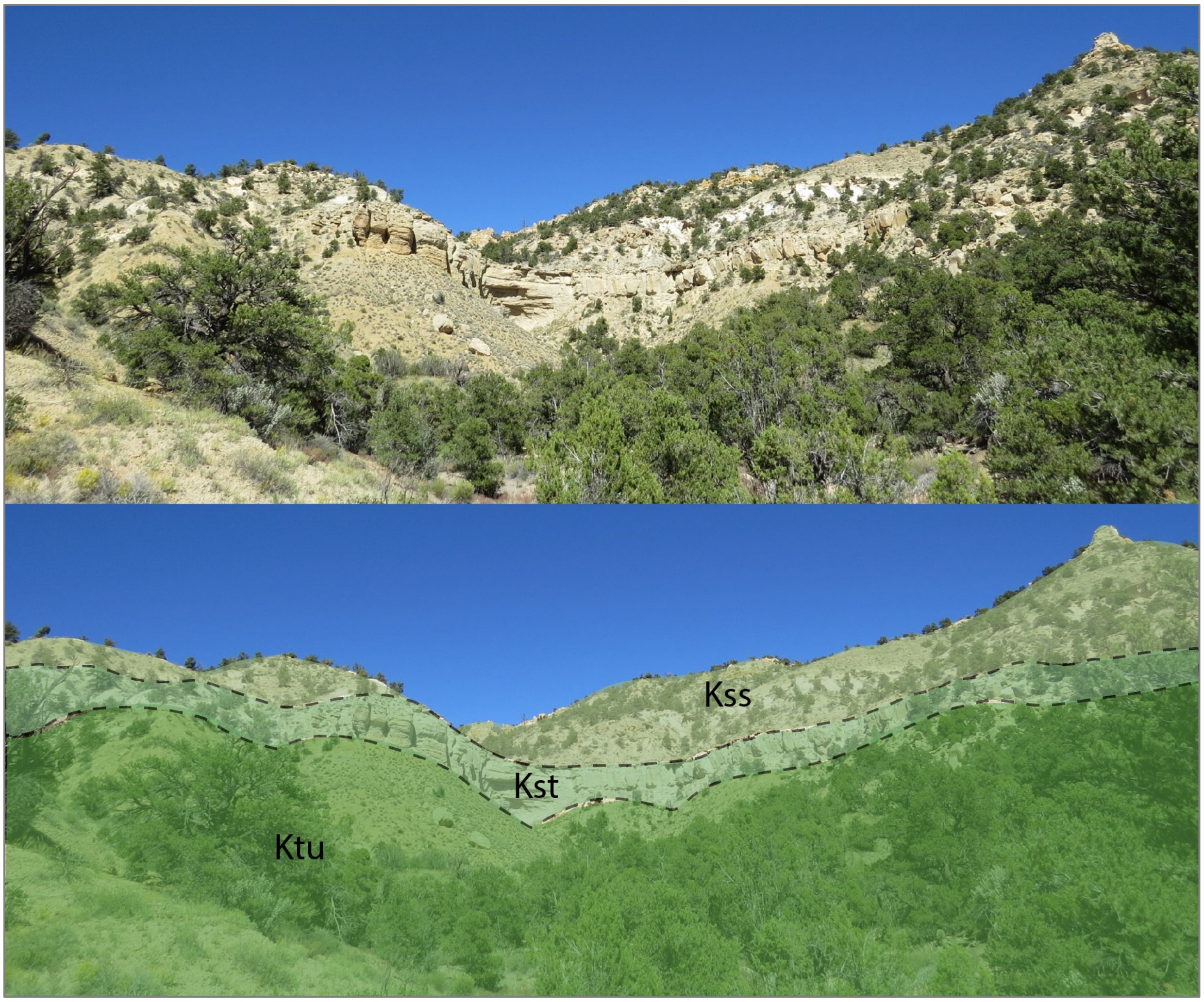

Figure 7. Overview of the upper part of the Tropic Shale (**Ktu**), the thick sandstone of the Tibbet Canyon Member of the Straight Cliffs Formation (**Kst**), and the overlying Smoky Hollow Member of the Straight Cliffs Formation (**Kss**) in BRCA. Abbreviations and colors from Biek et al. (2015) (NPS / TUT TRAN).

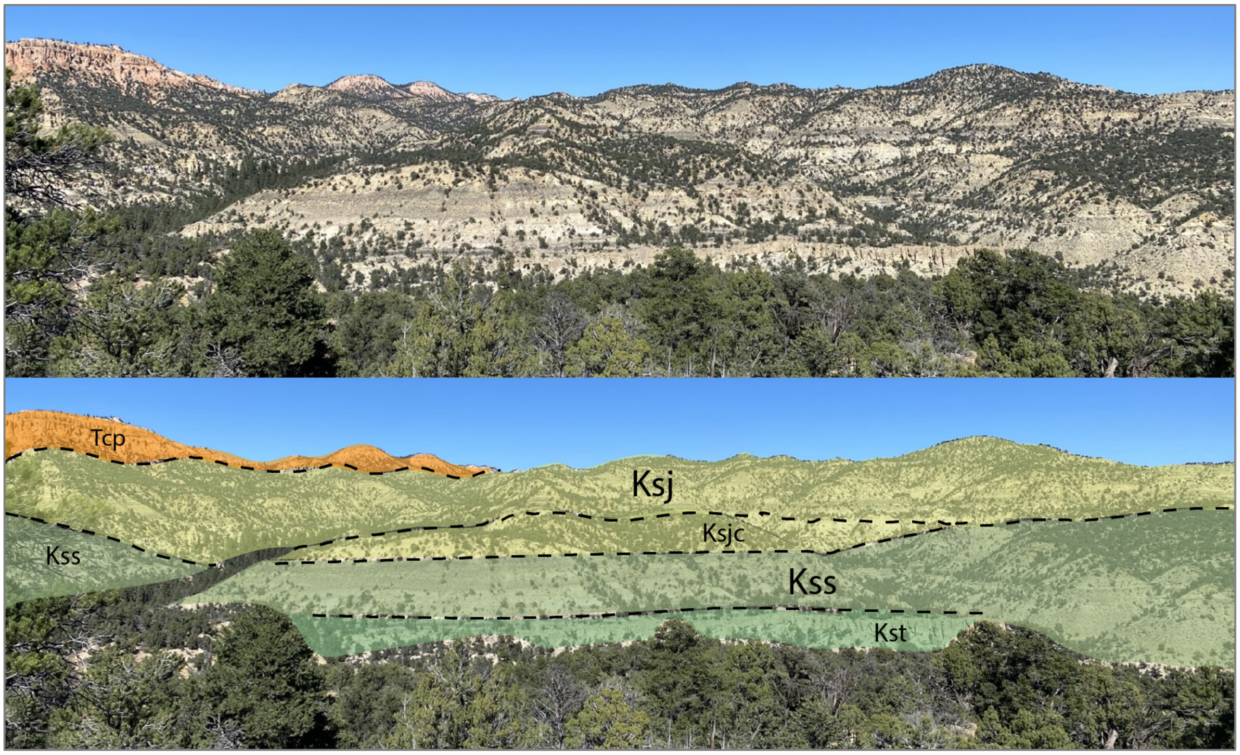

Figure 8. Overview of the pink member of the Claron Formation (**Tcp**) and the John Henry (**Ksj**), Calico bed (**Ksjc**), Smoky Hollow (**Kss**), and Tibbet Canyon (**Kst**) Members of the Straight Cliffs Formation in BRCA. Abbreviations and colors from Biek et al. (2015) (NPS / TUT TRAN).

The Drip Tank Member is a fluvial cliff-forming sandstone (Peterson 1969a). In the BRCA area, this unit is a white to light gray sandstone with conglomerate beds appearing in the upper portion of the unit (Tilton 2001; Biek et al. 2015). It interfingers with the overlying Wahweap Formation (McCord 1997). It was deposited during the middle Late Cretaceous (Eaton et al. 1999a), about 84 Ma. Beveridge et al. (2022) recovered a single detrital zircon indicating that the maximum depositional age of the Drip Tank Member on the Kaiparowits Plateau is ~83.5 Ma, suggesting early Campanian deposition for the unit.

<u>Fossils found within BRCA</u>: Three of the four members of the Straight Cliffs Formation are known to be fossiliferous in BRCA; the exception is the Tibbet Canyon Member. A few localities have been recorded from the Smoky Hollow Member. Pearce (2009) briefly described fossils from a Utah Museum of Natural History locality (UMNH IP 24) within the park. The most fossiliferous level is a carbonaceous siltstone above a lignite that is 15.5 m (51 ft) above the base of the unit. The site is interpreted as a brackish-water lagoon environment, with fossils of bivalves, gastropods, ostracods, sharks, rays, bowfins, gars, other bony fish, and crocodiles or crocodile relatives. It is part of a regressive sequence that began during deposition of the upper part of the underlying Tibbet Canyon Member. Adjacent depositional environments, both vertically and laterally, include swamps (represented by lignite beds) and barrier beaches (represented by sandstones) (Pearce 2009). Hoffman (2005) described a brackish-water mollusk site in this member (MNA-996; see “Notable Localities in the Straight Cliffs Formation” below). The 2022 survey encountered multiple

vertebrate-producing sites that included fish, turtle, crocodilian, and dinosaur material, which included a partial theropod claw. One vertebrate locality in the Smoky Hollow Member that was originally recorded by Eaton was relocated in 2023 (MNA-1132, now BRCA 148).

The John Henry Member is the most fossiliferous member at BRCA to date. There are 107 documented fossil sites from this member at the park. Fossils from these sites include wood and other plant fossils, bivalves, gastropods, ostracods, and bones and teeth of fish, turtles, crocodilians and crocodile relatives, and dinosaurs, among others (S. Eagan, pers. comm., October 2010). There are several published microvertebrate localities in this unit at the park. Most of the localities are high in the member, with one low in the member (Eaton 2005). Williamson et al. (2011) reported on screen-washed fossils from locality UMNH VP 1156 (BRCA 21). Notably, UMNH VP Loc. 1156 and Loc. 424 (BRCA 124) produced one holotype specimen each. These holotypes represent the multituberculate mammal *Dakotamys shakespeari* (Eaton 2013) and the scincomorph lizard *Monocnemodon syphakos* (Nydam 2013). Several other studies include descriptions and analyses of specimens collected from UMNH VP Loc. 424 and other localities from the John Henry Member of BRCA (Brinkman et al. 2013; Eaton 2013; Gardner et al. 2013; Irmis et al. 2013; Kirkland et al. 2013). Specimens included coprolites (fossil feces) and fossils of freshwater ostracods, fish, frogs, lizards, snakes, mammals—including multituberculates, symmetrodonts, and marsupials—and, unusually, a tooth of the chimaera-like marine cartilaginous petalodontiform fish *Brachyrhizodus*. Loc. 424 has been considered the most productive microvertebrate locality in the John Henry Member yet discovered (Titus et al. 2016).

The 2022–2023 survey returned several fossiliferous localities within the John Henry Member at BRCA. Vertebrate fossils documented on the surface include turtles, crocodilians, and dinosaurs, mostly hadrosauromorphs. Plant fossils are well-preserved along the contact between the John Henry and Drip Tank Members of the formation. Numerous localities preserving angiosperm leaf impressions identifiable to the genus level occur along this contact throughout the park (see "Notable Localities in the Straight Cliffs Formation" below). Vertebrate sites also occur in concreted sandstones at the base of the Drip Tank Member, often just a few meters above nearby fossil leaf sites. Eight localities in total have been documented in the Drip Tank Member at BRCA.

<u>Fossils found elsewhere</u>: Fossils are well-known from the various members at nearby GSENM (McCord 1998). Fossils from the Tibbet Canyon Member include marine invertebrates (McCord 1997), sharks, rays, gars, crocodilians, and marsupials (Eaton and Cifelli 1997; Eaton et al. 1999a). Fossils from the Smoky Hollow Member include dicotyledonous angiosperm leaf compressions (possibly in this unit) at Alvey Wash (Erwin 1997), sharks, rays, ray-finned fish such as bowfins and gars, the unusual amphibian *Albanerpeton*, frogs, turtles, lizards, several types of crocodilians and crocodile relatives, small theropods such as dromaeosaurids and troodontids, tyrannosaurids, armored dinosaurs, hypsilophodonts, hadrosaurids, and symmetrodont, marsupial, and possible eutherian mammals (Eaton et al. 1999a). Among the named mammals from the Smoky Hollow Member is the multituberculate *Bryceomys*, named not for BRCA but instead for its recovery in Bryce Valley, in what is now GSENM (Eaton 1995). Reexamination of dinosaur microfossils that Eaton and Cifelli collected from the Smoky Hollow Member in GSENM revealed a basal ceratopsomorph similar to

Zuniceratops, hadrosauromorphs similar to *Jeyawati*, *Bactrosaurus* and *Eotrachodon*, dromaeosaurs, tyrannosaurs, and small theropod teeth referrable to the enigmatic morphotaxon "*Richardoestesia"* (McCuen and Zanno 2023). Regionally, this member's fossil assemblage includes coal (Peterson 1969a), leaves (Erwin 1997), sparse petrified wood fragments and plant impressions (Sable and Hereford 2004), foraminifera, bivalves, gastropods, ostracods (Eaton et al. 2001), sharks, rays, ray-finned fish such as bowfins and gars, *Albanerpeton*, frogs, turtles, lizards, several types of crocodilians and crocodile relatives (Eaton et al. 1999a), pterosaurs (flying reptiles) (Titus et al. 2005), small theropods such as dromaeosaurids and troodontids, tyrannosaurids, armored dinosaurs, hypsilophodonts, hadrosaurids (Eaton et al. 1999a), and multituberculate (Eaton 1995), symmetrodont, marsupial, and possible eutherian mammals (Eaton et al. 1999a). The dinosaurs are represented by teeth from the middle of the member (Parrish 1999). Microvertebrate fossils are abundant in the middle interval (Titus et al. 2005).

Fossils in the John Henry Member include coal (Hamblin and Foster 2000), palynomorphs (McCord 1997), bivalves, ammonites (Eaton 2006a), footprints (Hamblin and Foster 2000), sharks, rays, ray-finned fish like bowfin and gars, *Albanerpeton*, frogs, turtles, lizards, several types of crocodilians and crocodile relatives (Irmis et al. 2013), dromaeosaurids, armored dinosaurs, hadrosauroids (Eaton et al. 1999a; Gates et al. 2013), and multituberculate, symmetrodont, and marsupial mammals (Eaton 2006a; Eaton and Cifelli 2013). Finally, the Drip Tank Member has produced turtle, crocodilian, and dinosaur fragments, along with plant fossils (Eaton et al. 1999a; Foster et al. 2001; Titus et al. 2005). Few diagnostic macrofossils are known from this member (Titus et al. 2005). Regionally, its fossils include palynomorphs (Christensen and Lawton 2005), petrified logs (Peterson 1969a), fish scales (Titus et al. 2005), and fragments of turtles, crocodilians (Eaton et al. 1999a), and dinosaurs (Titus et al. 2005). In the BRCA area, it includes locally abundant log casts (Tilton 2001).

Wahweap Formation (Upper Cretaceous)

Description: The Wahweap Formation is a heterogeneous formation deposited on alluvial plains by fluvial and floodplain processes (Sable and Hereford 2004). At BRCA, rocks assigned to the Wahweap Formation crop out in several areas (Bowers 1991; Davis and Pollock 2010; Biek et al. 2015). Rocks assigned to the Wahweap Formation at BRCA by Bowers (1991) make up a sequence of buff to brown sandstone and gray to tan mudstone, 60 to 120 m (200 to 400 ft) thick (Figure 9). Bowers (1991) reported that Wahweap strata are 0 to about 200 m (0 to 700 ft) thick at BRCA and that the variation in thickness is due to erosional truncation under the sub-Claron Formation unconformity. The entire formation is about 290–320 m (950–1050 ft) thick on the west flank of the Paunsaugunt Plateau, and about 230 m (760 ft) thick on the Markagunt Plateau (Biek et al. 2015).

Figure 9. Exposed outcrop of the lower/middle Wahweap Formation (**Kw**) beneath the pink member of the Claron Formation (**Tcw**) in BRCA. Abbreviations and colors from Biek et al. (2015) (NPS / TUT TRAN).

On the neighboring Kaiparowits Plateau, the Wahweap Formation has traditionally been divided into four informal members: the lower, middle, upper, and capping sandstone members (Eaton 1991; see Beveridge et al. 2022). The three members below the capping sandstone are generally composed of sandstone and mudstone and are interpreted as having been deposited by meandering streams flowing to the north or northeast. The capping sandstone also includes conglomeratic and siltstone beds, and is thought to represent braided stream deposition, with flow to the east and southeast (Lawton et al. 2003; Titus et al. 2005). The capping sandstone includes minor windblown deposits in the Kaiparowits Basin east of BRCA (Simpson et al. 2008). Fossils are abundant in all four members (Titus et al. 2005). Unlike underlying formations, the Wahweap Formation lacks coal (McCord 1997).

The Wahweap Formation is regarded as entirely nonmarine in deposition (Eaton 1991; McCord 1997; Jinnah 2013). The Western Interior Seaway, which had been retreating out of south-central Utah during deposition of the underlying Tropic Shale and lower Straight Cliffs Formation, was absent from the BRCA area during deposition of the Wahweap Formation (Gregory 1951). The climate appears to have become more arid toward the end of deposition, with possibly semi-arid to arid conditions (Simpson et al. 2008, 2010a). Faulting occurred during deposition in the Kaiparowits Basin (Tindall et al. 2010). Sediment deposition was probably not continuous, with the capping sandstone member in particular differing from the rest of the formation. This member has disconformable contacts at its base and top (Kirkland and DeBlieux 2010). Jinnah et al. (2009) posited a depositional age of 81 to 77 Ma based on Ar-Ar dating of a volcanic ash bed in the Wahweap Formation on the Kaiparowits Plateau, 40 m (130 ft) above the base of the formation. Beveridge et al. (2022) refined the chronostratigraphic framework of the Wahweap Formation using ash-fall bentonites and detrital zircon analyses. They determined that the lower and upper age limits of the Wahweap are 82 and 77 Ma, respectively (Beveridge et al. 2022), in the early to middle Campanian stage.

In refining the chronostratigraphy of the Wahweap Formation, Beveridge et al. (2022) proposed new names for the four informal members described by Eaton (1991) on the Kaiparowits Plateau. These are, in ascending order, the Last Chance Creek Member (lower), Reynolds Point Member (middle), Coyote Point Member (upper), and Pardner Canyon Member (capping sandstone). However, they cautioned against using these names to describe the formation along the Paunsaugunt and Markagunt Plateaus until similarly refined stratigraphic and geochronological study can be accomplished in those areas (Beveridge et al. 2022). BRCA staff should in the meantime adhere to that recommendation and continue to refer to the Wahweap Formation in the park using the four informal members (lower, middle, upper, and capping sandstone) as described in Eaton (1991).

Historically, determining whether the later Campanian Kaiparowits Formation is also present at BRCA has been difficult. For a long time, the Kaiparowits Formation was considered the youngest Cretaceous unit along the eastern flank of the Paunsaugunt Plateau (Gregory 1951). Early work by Eaton (1993b) supported this notion because of the composition of microvertebrate assemblages initially recovered from the Wahweap Formation at BRCA (namely, UMNH VP Locality 77). Eaton et al. (1998, 1999b) noted that the assemblage of mammals, along with the abundance of ceratopsian teeth and absence of sharks and rays, better matched the Kaiparowits fauna than the Wahweap fauna on the Kaiparowits Plateau to the east. However, Eaton (2013) located marker horizons and measured sections of several Cretaceous localities in BRCA and found that the uppermost sites occur in the lower or middle Wahweap Formation. Because of these measured sections, Eaton (2013) posited that just the lower and middle members of the Wahweap Formation are present in the park. However, both Biek et al. (2015) and Knudsen et al. (in prep.) map outcrops of the capping sandstone in the northeast portion of BRCA, first mapped as upper Straight Cliffs Formation by Bowers (1991). Comparison between the Cretaceous mammalian faunas on both the Paunsaugunt and Kaiparowits Plateaus revealed that the Wahweap fauna in both regions does not correlate well with the Kaiparowits fauna (Eaton 2013). These findings suggest that the Kaiparowits Formation is unlikely to be exposed at BRCA, if it is present at all.

Fossils found within BRCA: The Wahweap Formation is fossiliferous within BRCA. There are 94 documented localities from this formation in the park, with notable fossils of bivalves, gastropods, crabs, ostracods, fish, turtles, crocodilians and crocodile relatives, dinosaurs, and mammals (S. Eagan, pers. comm., October 2010; Eaton 2013). One published locality is UMNH VP Locality 77. This site has yielded fossils of sharks, rays, gars, bowfins, salamanders, frogs, turtles, lizards, crocodiles or crocodile relatives, dinosaurs (theropods, hadrosaurs, and armored dinosaurs), multituberculates, and marsupials (Eaton et al. 1998; Munk 1998; Eaton 1999a; Kirkland et al. 2013). Notably, UMNH VP Loc. 77 produced the two fossil holotype specimens from BRCA. These pertain to the sawfishes *Columbusia deblieuxi* and *Texatrygon brycensis* (Kirkland et al. 2013).

Assorted vertebrate fossils including vertebrae, ribs, shoulder bones, and a theropod tooth were recovered by Chris Shierup of John Day Fossil Beds National Monument in 1999 from locations in the western Paunsaugunt Plateau, including one within BRCA (Santucci and Kirkland 2010). Nearly 2,000 gastropods have been recovered from a site at BRCA, along with bowfin vertebrae, crocodilian or crocodile relative teeth, hadrosaur teeth, and bone fragments (Williams and Lohrengel 2007). The recent survey begun in 2022 returned the following fossils from the Wahweap Formation in BRCA: petrified wood, fossil palm fronds, gastropods, fish, turtles, crocodilians, dinosaurs (mainly hadrosaurs, including associated material of a juvenile animal), invertebrate burrowing traces, and hadrosaur footprint casts. See "Notable Localities in the Wahweap Formation" for detailed descriptions of recently documented sites and Appendix A for a full taxonomic list.

<u>Fossils found elsewhere</u>: Overall, including areas outside of BRCA, the paleontological resources of the Wahweap Formation are diverse. Bacteria, algae, and plants are represented by charophyte algae (Peterson 1969b), cryptobiotic soils (Simpson et al. 2010a), palynomorphs (Lawton et al. 2003), leaf impressions (Moore and Nealey 1993), compressed plant fossils (Kirkland et al. 2005), petrified wood (Titus et al. 2005), carbonized wood (Moore and Nealey 1993), and root traces (Simpson et al. 2008). Possible cycads, conifers, and angiosperms are among the plants that have been found (Erwin 1997). Petrified wood is common in channel-fill deposits of the various members, with specimens the size of large logs in some cases (Titus et al. 2005). Additionally, reworked palynomorphs from older formations have been found in the capping sandstone (Lawton et al. 2003).

Invertebrates are represented by bivalves, gastropods, ostracods (Peterson 1969b), crab claws (Eaton 1991), and invertebrate wood borings, which have been found in the upper and capping members (Moran et al. 2010). Mollusks sometimes form shell beds, which are most abundant in the middle mudstone-rich member (Kirkland et al. 2005).

Vertebrates of the Wahweap Formation are represented by freshwater sharks and rays, gars, bowfins, and other bony fish, salamanders, frogs, turtles, lizards, crocodilians and crocodile relatives, a variety of dinosaurs, and diverse early mammals (Eaton et al. 1999a, 1999b; Gregory 1951; Titus et al. 2005; Kirkland and DeBlieux 2010). Trace fossils include probable lungfish burrows (Simpson et al. 2008), dinosaur eggshell (Eaton 2004), crocodilian or crocodile relative tracks (Simpson et al. 2010b), dinosaur tracks (Simpson et al. 2010c; DeBlieux et al. 2013; Biek et al. 2015), and theropod digging traces associated with mammal burrows (Simpson et al. 2010d). Many of the trace fossil occurrences are known from the capping sandstone (Simpson et al. 2010b, 2010c, 2010d; Biek et al. 2015). The most abundant dinosaurs are horned dinosaurs and hadrosaurs (Titus et al. 2005), with tyrannosaurids, dromaeosaurids, troodontids, armored dinosaurs, pachycephalosaurs, and hypsilophodonts as well (Eaton et al. 1999a; Weishampel et al. 2004; Titus et al. 2005; Evans et al. 2013). Dinosaur bonebeds are present but rare (Kirkland et al. 2005).

To date, five dinosaur taxa have been formally named from the Wahweap Formation, all originating from the middle and upper members in GSENM. These are the centrosaurine ceratopsids *Diabloceratops eatoni* (Kirkland and DeBlieux 2010) and *Machairoceratops cronusi* (Lund et al. 2016), the brachylophosaurine hadrosaur *Acristavus gagslarsoni* (Gates et al. 2011), the lambeosaurine hadrosaur *Adelolophus hutchisoni* (Gates et al. 2014), and the large tyrannosaurid *Lythronax argestes* (Loewen et al. 2013b). Mammals have been extensively described, and include multituberculates, symmetrodonts, marsupials, insectivores, and other early forms (Eaton 2006b, 2013; Eaton and Cifelli 1988, 2005, 2013; Cifelli 1990; Eaton et al. 1999a, 1999b; Titus et al. 2005). Generally, microvertebrate remains are more common in sandstone channel lags, but there are significant microvertebrate sites in mudstone beds. The lack of articulated remains is attributed to the rarity of overbank deposits (Kirkland et al. 2005; DeBlieux et al. 2013).

Claron Formation (Paleocene–middle Eocene)

Description: The Claron Formation of BRCA is divided into an informal lower pink and upper white member, with a basal red or gray conglomerate (Bowers 1991) (Figure 10). The basal conglomerate can be up to 14 m (45 ft) thick in the vicinity of BRCA (Tilton 2001). The pink member is composed of interbedded sandy limestone, calcareous (lime-rich) mudstone, siltstone, and some sandstone and dolomite, and minor pebbly conglomerate. It is between 120 and 210 m (400 and 700 ft) thick, and ranges in color from pink to red to tan to orange to white. Depositional settings are thought to include low-energy fluvial, floodplain, and minor lacustrine settings. Differential erosion of the pink member is responsible for much of the scenery at BRCA (Bowers 1991). The white member is composed of white limestone and lesser amounts of calcareous mudstone, siltstone and sandstone. It is up to 90 m (300 ft) thick and is interpreted as having been deposited in lacustrine and low-energy fluvial settings. Biek et al. (2015) map the white member as an undivided unit (Tcw) and a lower micritic limestone unit (Tcwl) in BRCA. Exposures of the Claron Formation at BRCA predominate in the western half to two-thirds of the park. Exposures of the pink member are more widespread, with the white member mostly limited to the central part of the park (Bowers 1991; Davis and Pollock 2010).

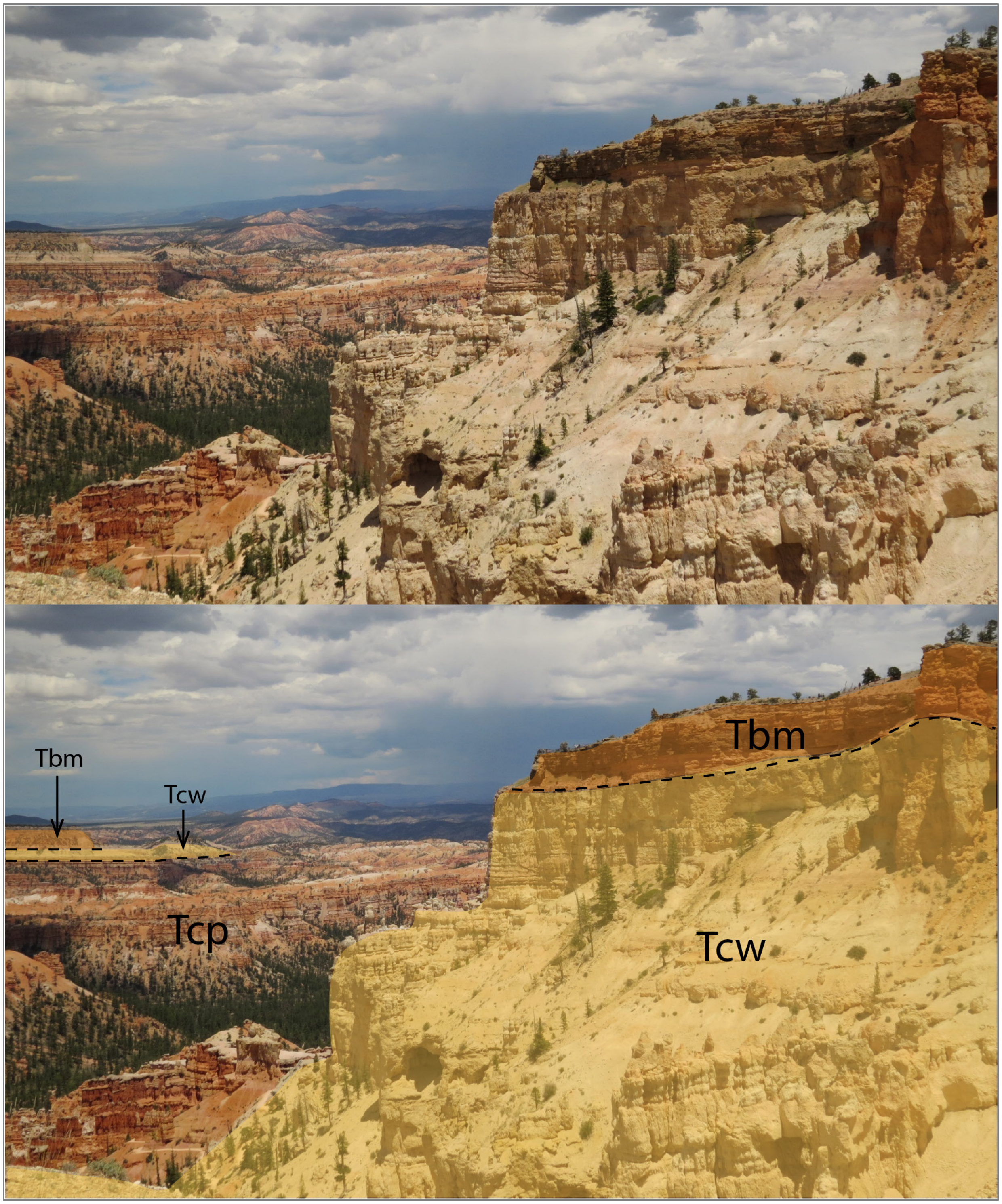

Figure 10. Overview of the pink member **(Tcp)** and white limestone member of the Claron Formation (**Tcw**) and overlying Boat Mesa Conglomerate (**Tbm**) below Inspiration Point at BRCA. Abbreviations and colors from Biek et al. (2015) (NPS / ALEXANDRA BONHAM).

The Claron Formation of southwestern Utah has a complicated nomenclatural history involving several informal formation names and differing conceptions of what these formations encompassed. The Claron Formation was originally identified as the Wasatch Formation, better known from northern Utah and Wyoming. This is particularly apparent in the works of geologist Herbert Gregory. Additionally, in some of his publications (Gregory 1945, 1949) the unit now known as the upper white limestone member of the Claron Formation was included in the Brian Head Formation. The use of the Wasatch Formation name for these rocks persisted into the 1970s (Bowers 1972). The modern lower (sometimes called pink or red) member of the Claron Formation was informally called the Cedar Breaks Formation (Schneider 1967), which did not attain wide usage. Shortly after, the Canaan Peak Formation and the Pine Hollow Formation were named from rocks formerly assigned to the lower "Wasatch" Formation on the Table Cliffs Plateau east of BRCA (Bowers 1972). Anderson and Rowley (1975) returned the upper white limestone to the Claron Formation and included all of Gregory's original Brian Head Formation rocks in the Claron Formation. The situation increased in complexity during the 1990s. First, a third formation (the Grand Castle Formation) was named from former lower Claron Formation rocks on the Markagunt Plateau (Goldstrand 1994; Goldstrand and Mullett 1997). Then, the Brian Head Formation was brought back into usage, limited to rocks above the Claron Formation's upper white limestone member (Anderson 1993; Sable and Maldonado 1997). While it is necessary for the researcher wishing to examine the literature on the Claron Formation to keep in mind the dramatically shifting nomenclature, fortunately the rocks themselves are usually simple to identify in publications from their descriptions: the modern lower Claron Formation is almost always identified as a distinctive pink or red unit, and the modern upper Claron Formation is almost always identified as a white limestone.

Biek et al. (2011) discussed the Claron Formation on the Markagunt and Paunsaugunt Plateaus and noted that the formation is restricted to non-volcanic strata bounded by two unconformities: a major Late Cretaceous–early Cenozoic unconformity at the base of the formation, and the unconformity associated with the conglomerate of Boat Mesa at the top. Recent work by Antonietto et al. (2022) examined the ostracod and other microfossil faunas of the Claron Formation outside of BRCA near the Sweetwater Creek area and proposed that the formation be divided into nine distinct depositional facies. However, Eaton (2022, pers. comm.) cautioned against using this organization to describe stratigraphic relationships in BRCA, as the nomenclature proposed by Antonietto et al. (2022) applies just to the Claron Formation on the Table Cliffs and Aquarius Plateaus and may not correlate to the strata at BRCA. Until similarly rigorous stratigraphic study can be accomplished at BRCA, staff and researchers should adhere to the historical division of lower pink and upper white members (Biek et al. 2015).

Historically, the Claron Formation was regarded as largely lacustrine, but fluvial processes are now more widely recognized. The pink member is mostly fluvial and alluvial in depositional environment, whereas the upper white member represents both lacustrine and low-energy fluvial environments (Goldstrand 1992; Bown et al. 1997; Ott 1999; Davis et al. [2009] erroneously regarded both members as shallow lacustrine). The lake transitioned from closed to open drainage around 42 Ma (Davis et al. 2009). Laramide-age uplifts to the northeast and northwest contributed sediment to the formation (Goldstrand 1992). The Claron Formation has been heavily affected by pedogenic (soil-forming) processes, which are thought to have destroyed most of its original depositional features and fossils (Mullett et al. 1988; Mullett 1989; Feist et al. 1997). Plant growth is interpreted as moderate, with moist soils that underwent periodic drying (Bown et al. 1997). The reddish coloration of the lower member is from iron staining, while the white of the upper member is thought to have resulted from leaching (Mullett 1989). Dissolution of Claron Formation limestone can produce sinkholes, which are abundant on the Markagunt Plateau to the west (Moore et al. 2004), and shallow caves (Hatfield et al. 2010; Spangler 2010), but these are rare on the Paunsaugunt Plateau. The formation weathers into thousands of rock chimneys at BRCA (Davis and Pollock 2010).

The age of the Claron Formation has been difficult to establish, because of its paucity of fossils, lack of volcanic debris, and the fact that it is bounded by unconformities; it is now widely considered to be Paleocene to latest middle Eocene in age (Goldstrand 1994; Eaton et al. 2001; Biek et al. 2011, 2015; Sanjuan et al. 2020; Antonietto et al. 2022). Mammal and ostracod fossils that had previously been reported from the upper Claron Formation were used to constrain the formation's upper age limit to the middle Eocene (Eaton et al. 2011). Although these fossils were correctly assigned to the Eocene, they had in fact originated from the Brian Head Formation, not the Claron (Eaton et al. 2018). Similarly, older reports of Oligocene-age rocks in the Claron Formation (Bowers 1991) are based on rocks now included in the Brian Head Formation. The upper age limit of the Claron Formation is constrained by detrital zircons in the unconformably overlying conglomerate at Boat Mesa, which were dated to around 38 Ma (Biek et al. 2015). Studies of charophytes (Sanjuan and Eaton 2016; Sanjuan et al. 2020) and ostracods (Antonietto et al. 2022) of the Claron Formation outside of BRCA have attempted to constrain the age limits of the formation and found these faunas to be consistent with Paleocene to early Eocene age ranges. Whether the Paleocene–Eocene boundary is in fact preserved within the Claron Formation remains uncertain (Sanjuan et al. 2020; Antonietto et al. 2022). Eaton continues to investigate the age of the Claron by sampling exposures on the nearby Table Cliffs and Aquarius Plateaus in GSENM and neighboring USFS lands. Thus far he has recovered charophytes and ostracods from the uppermost white member (J. Eaton, pers. comm., 2023).

Fossils found within BRCA: Fossils are known but have not been formally described from the Claron Formation of BRCA, although a popular science article by Vokes (1952) reports freshwater bivalves and gastropods in limestone and lime-rich sandstone beds of the park's upper cliffs and slopes. Specimens of the gastropod *Physa* have been found in the park, often located by park staff or visitors. Typically, these snail shells are found as float (loose specimens) along trails and near overlooks (Kenworthy 2006). Twenty-seven localities in the Claron Formation have been catalogued from BRCA, 17 of which were recorded during Eaton's multi-year inventory of the park's fossils (unpublished field notes). The remaining ten localities were recorded in the recent inventory that began in 2022. Trace fossils of hymenopteran burrows (e.g., ant, bee, and wasp burrows; Bown et al. 1997) are the most common fossil in the Claron Formation of BRCA. Larry Davis and colleagues collected more than 400 specimens of hymenopteran traces referrable to *Eatonichnus claronensis*, *E. utahensis*, and *Celliforma* from multiple localities at BRCA (Davis et al. 2015). Gastropods (e.g., *Physa*) and bivalves are the most common invertebrate body fossils, and leaf impressions and hackberry seeds are also known from the pink member in the park (Eaton, unpublished field notes;

see “Notable Localities in the Claron Formation”). Ott (1999) recorded a 40 m (130 ft)-thick interval of limestone in the lower part of the pink member that included microbial filaments, charophytes, gastropods, and ostracods. Eaton observed eggshell fragments at two localities (BRCA 59 [UMNH IP 62] and 60 [UMNH IP 67, 68, and 69]). Although no definitive vertebrate localities have been reported from this unit in the park (as noted in Tweet et al. [2012], a potential bone is likely reworked), a single gar scale was found at a leaf locality in 2013 (UMNH PB. Loc. 61; see “Notable Localities in the Claron Formation”).

Fossils found elsewhere: Fossils have historically been difficult to find in the Claron Formation, because of pedogenic processes and other alteration. The most abundant fossils are microbial structures, mollusks, and arthropod traces. Microbial body fossils and traces from the Claron Formation include oncolites, stromatolites (Taylor 1993), and charophytes (Moore and Nealey 1993; Moore et al. 2004; Sanjuan and Eaton 2016; Sanjuan et al. 2020). These fossils are mostly found in the upper member (Moore and Nealey 1993; Moore et al. 2004). Plant fossils include palynomorphs (Goldstrand and Mullett 1997; Foster et al. 2001), leaf impressions (Gregory 1950), seeds (Schneider 1967), and root traces (Mullett et al. 1988; Mullett 1989; Taylor 1993). Invertebrate body fossils include small bivalved animals that could be bivalves, conchostracans (clam shrimp), or ostracods (Moore and Nealey 1993), bivalves, gastropods (Gregory 1950), and ostracods (Brouwers et al. 2000; Eaton et al. 2011; Antonietto et al. 2022). Shelled invertebrates may be found as molds or casts (Sable and Hereford 2004). Gastropods are known from the white member on Whiteman Bench just west of BRCA (Bowers 1991). Invertebrate trace fossils include ant nests, wasp and bee cocoons and brood cells with possible parasite traces, dung beetle nests (Bown et al. 1997), and crayfish burrows (Hasiotis and Bown 1997). The insect traces have been found in the clastic rocks of the lower member (Bown et al. 1997).

At CEBR, the lower Claron Formation has microbial structures, seeds (possibly of hackberry or the genus *Prunus*, which includes plants that produce almonds, cherries, peaches, and plums), and possible invertebrate burrows (Schneider 1967). The upper Claron Formation of CEBR has gastropods and insect trace fossils (Gregory 1950).

A fragmentary rodent jaw and fish bones had previously been reported from the Claron Formation (Eaton et al. 2011). This was later refuted because the fossils originated from the Brian Head Formation, not the Claron (Eaton et al. 2018). The first vertebrate fossils truly from the Claron Formation were reported by Eaton et al. (2018) from the Sweetwater Creek area north of BRCA. These included specimens of fish, amphibians, lizards, and crocodilians, and several mammal teeth, all early Eocene in age (Eaton et al. 2018).

Conglomerate at Boat Mesa (upper Eocene)

Description: There are several exposures of a conglomeratic unit in north-central BRCA, known informally as the conglomerate at Boat Mesa or the Boat Mesa Conglomerate (Figure 10 and Figure 11). It is a light-colored capping conglomerate between 12 and 30 m (40 and 100 ft) thick. The lower contact with the Claron Formation is a disconformity. The conglomerate lacks fossils that were contemporaneous with deposition, so its age can only be estimated indirectly. Lacking age control, Bowers (1991) and Davis and Pollock (2010) considered it to be Oligocene in age. However, Biek et al. (2015) reported a U-Pb detrital zircon age of 38 Ma from the Boat Mesa Conglomerate on the southwest Sevier Plateau, immediately northwest of BRCA. Additionally, the upper part of the overlying Brian Head Formation on the Sevier Plateau produced a U-Pb detrital zircon date of ~36 Ma (Biek et al. 2015; Sanjuan et al. 2017). Therefore, the conglomerate at Boat Mesa is likely late Eocene (Bartonian–Priabonian, 38–36 Ma) in age. The unit is interpreted as representing fluvial and overbank deposits (Davis and Pollock 2010).

Figure 11. The eponymous Conglomerate at Boat Mesa (**Tbm**), visible from the trail of Fairyland Loop at BRCA. The white and the pink members of the Claron Formation (**Tcw**, **Tcp**) underly the Conglomerate at Boat Mesa. Abbreviations from Biek et al. (2015) (NPS / TUT TRAN).

Fossils found within BRCA: The Boat Mesa Conglomerate has yielded reworked Permian invertebrates from chert clasts within BRCA (Santucci and Kirkland 2010).

Fossils found elsewhere: None to date.

Upper Cenozoic alluvial deposits (Miocene?–Pliocene?)

Description: Late Cenozoic alluvial-fan and volcaniclastic deposits, previously known as the Sevier River Formation, are exposed in several areas of southwestern Utah (Anderson and Rowley 1975; Rowley et al. 1975; Biek et al. 2011, 2015). They are the same as Gregory's (1945, 1950) Parunuweap Formation (Anderson and Rowley 1975). Within BRCA, these deposits are found only in the extreme northeastern part of the park (Bowers 1991), although they are widespread on the Paunsaugunt and Markagunt Plateaus (Biek et al. 2011, 2015). The geologic map included with Thornberry-Ehrlich (2005) depicts the "Sevier River Formation," but the text omits it. In the BRCA area, these deposits are composed of light-brown to brownish gray conglomeratic sandstone and conglomerate (Bowers 1991), interpreted as remnants of valley fill deposits left by the ancestral Sevier River system (Davis and Pollock 2010). The deposits also incorporate volcanic fragments and limestone pebbles (Bowers 1991). The sediments were deposited mostly as alluvial fans and fine-grained basin-fill (Gregory 1944, 1945), with minor fluvial and lacustrine deposits (Anderson and Rowley 1975; Rowley et al. 1975).

The age of the deposits at BRCA has not been established, but they are likely equivalent to latest Miocene–early Pliocene alluvial-fan deposits mapped on the east flank of the Markagunt Plateau (Biek et al. 2011). Fossils are not yet known from alluvial deposits in and near BRCA.

Fossils found within BRCA: None to date.

Fossils found elsewhere: Sparse fossils, mostly of algae and invertebrates, are known from similar deposits in southwestern Utah, but the stratigraphic relationships of these deposits with those at BRCA are not yet clear. The geographically nearest examples among these are Pliocene-age diatoms (a type of alga that secretes silica "shells") from lake deposits near Hillsdale, 22 km (14 mi) west of BRCA (Crawford 1951; Setty 1963).

Quaternary sediments (Pleistocene–Holocene)

Description: The Quaternary deposits of BRCA include a variety of alluvial, colluvial, landslide, and pediment deposits, with grain sizes ranging from clay to boulders. The thicknesses of these units can be as great as 30 m (100 ft) or more. Deposits are found scattered throughout the park (Bowers 1991; Biek et al. 2015; Knudsen et al. in prep.). Fossils are not currently known from these deposits at BRCA but may eventually be found. Pleistocene or Holocene pond sediments, which would be favorable places to search, are not present in any great quantities at BRCA.

Fossils found within BRCA: None have been reported from Quaternary deposits to date. However, plant and animal remains, including insects, were collected and catalogued from a late Holocene packrat midden in Water Canyon at BRCA (Agenbroad et al. 1992; see "Other Invertebrates" in the Taxonomy section). Packrat dung from this midden was radiocarbon-dated to 310 ± 50 years before present (1950) (Agenbroad et al. 1992). Packrat middens are collections of plant material and food waste constructed by packrats (*Neotoma* spp.) and cemented by their viscous urine. They can be well-preserved in dry caves and rock shelters, and illustrate the environment of the builder's foraging range. Middens are important tools for reconstructing the ecology and climate of the late Pleistocene and Holocene of the southwestern United States (Strickland et al. 2001). Reports of a mammoth tooth or jaw fragment from BRCA are in error, as the specimen in question is actually a hadrosaur jaw fragment with exposed columns of teeth (Figure 12) (Kenworthy 2006).

Figure 12. BRCA 588, a hadrosaur jaw that was incorrectly identified as a proboscidean (mammoth, mastodon, elephant, etc.) jaw or tooth. The specimen was correctly identified by NPS paleontologist Jason Kenworthy in 2006 (NPS / JASON KENWORTHY).

Fossils found elsewhere: Typical Quaternary fossils of the Colorado Plateau include isolated bones of large mammals (such as sloths, mastodons, mammoths, horses, camels, and bison) and fossil material useful for paleoecological and palaeoclimatological studies (such as pollen and packrat middens). Summaries of Quaternary fossil sites in southern Utah and the vicinity include Mulvey et al. (1984), Agenbroad and Mead (1989), Mead and Agenbroad (1992), Jefferson et al. (1994), Gillette and Miller (1999), Anderson et al. (1999, 2000), and Coats et al. (2008). Quaternary fossils are not as well-known from the BRCA region as their older counterparts. Finds have included a handful of pond or former pond localities with pollen and similar material, and wood and freshwater bivalves and gastropods from lake and other settings.

More probable paleoecologically useful fossils for BRCA include middens and phytoliths (microscopic bits of minerals found in the cells of some plants): ancient packrat middens are potential finds in alcoves and other protected recessed areas, while phytoliths could be present in the soil, as they are at Capitol Reef National Park (CARE) (Fisher et al. 1995). Should pond or bog fossils be found at BRCA, they would probably be comparable to lake finds from the vicinity, which include organic debris, peat, charcoal, spores, pollen, various macroscopic plant fossils (such as needles, cones, and wood), and aquatic insects (Mulvey et al. 1984; Anderson et al. 1999; Weng and Jackson 1999; Madsen et al. 2002). One such site is known from CEBR (Alpine Bog), with another (Lowder Creek Bog) just outside of the monument (Anderson et al. 1999). Fossiliferous Quaternary lake deposits are known from several places in Zion National Park (ZION), about 55 km (34 mi) west of BRCA (Hamilton 1979; Hevly 1979; Biek et al. 2009). Fossils of large mammals are probably more likely to be found just outside of BRCA in deposits in the vicinity of the Sevier River than they are to be found within the park; Agenbroad (1997) noted the presence of a number of large mammal finds on the Colorado Plateau, but most of these are isolated bones from terrace deposits near large rivers. The large mammals most frequently identified are sloths, mammoths, horses, tapirs, camels, bison, oxen, and mountain goats (Agenbroad 1997). Another possibility for river settings are mollusks; Pleistocene beds in the Red Creek Valley on the Paunsaugunt Plateau have freshwater bivalves and gastropods (Gregory 1951).

Taxonomy

See Appendix A for full lists of BRCA fossil taxa. Locality data for BRCA fossil sites can be found in Appendix E.

Fossil Plants

Fossilized (silicified or petrified) wood has been documented in the rocks of BRCA since the early 1930s. Wendell Bryce and Herman Pollock collected silicified wood from the park in 1947.

Charophytes (algal spores) have been collected by Eaton and Brouwers from the Straight Cliffs and Wahweap Formations in the park. Eaton collected charophytes from the Wahweap Formation as a pre-mitigation salvage of localities along SR 12 before the start of construction activities in 2020 (Eaton 2022).

The Claron Formation of BRCA has also produced plant fossils. Internal records show collections of “Anthophyta” seeds and leaf impressions from the Navajo Loop Trail in the 1970s (BRCA 608, 664, 665). Eaton also collected hackberry seed and leaf impressions from multiple localities documented the Claron Formation in 2013 (see “Notable Localities in the Claron Formation”).

During the 2022–2023 inventory, Pittinger, Bonham, and Tran recorded palm frond impressions from multiple localities in the Wahweap Formation (Figure 13) and highly concentrated angiosperm leaf impression localities in the John Henry and Drip Tank Members of the Straight Cliffs Formation (Figure 14; see “Notable Localities in the Straight Cliffs Formation”). Petrified wood was also documented in the Wahweap Formation and the Smoky Hollow Member of the Straight Cliffs Formation.

Figure 13. Palm frond impression (cf. *Sabalites* sp.) recovered and collected from BRCA 136 in the Wahweap Formation (NPS / ALEXANDRA BONHAM).

Figure 14. Diverse, well-preserved, and highly concentrated angiosperm leaf impressions in a manganese-enriched block of sandstone of the upper John Henry Member of the Straight Cliffs Formation at BRCA 119 (NPS / TUT TRAN).

Fossil Invertebrates

Invertebrate fossils are among the first fossil taxa to be reported and documented to the genus and species levels at BRCA.

Phylum Mollusca: Class Bivalvia (clams, oysters, etc.)

Freshwater unionid clams are known from multiple localities in the Claron Formation at BRCA (Eaton, unpublished field notes). Internal and external molds of clams are well-documented at multiple localities in the Wahweap Formation and the John Henry Member of the Straight Cliffs Formation. Oysters (e.g., *Ostrea* sp.) are abundant in the lignitic brackish-water layers of the Smoky Hollow Member of the Straight Cliffs Formation in the northeast portion of BRCA (Figure 15). Cobban (1996) recovered a diverse assemblage of bivalve taxa in the Tropic Shale at BRCA.

Figure 15. A fossil oyster, cf. *Ostrea* sp., recovered from BRCA 42 in the Smoky Hollow Member of the Straight Cliffs Formation. Oysters such as this are common in the member. Scale bar in cm (NPS / DAKOTA PITTINGER).

Phylum Mollusca: Class Cephalopoda (octopuses, squids, nautiloids, etc.)

Ammonites have been documented in the Tropic Shale of BRCA. Cobban (1996) recorded the presence of the rare ammonite *Mammites nodosoides* in this formation. Other ammonites documented by Reeside (1937) and Cobban (1996) include *Baculites* spp. and several other genera, which Eaton and collaborators also encountered at UMNH IP 34. In the upper Tropic Shale, concretions containing casts and molds of *Collignoniceras woollgari* have been found (G. Pollock, pers. comm., 2023; see "Notable Localities in the Tropic Shale").

Phylum Mollusca: Class Gastropoda (snails)

Snails are common within all of the fossiliferous strata at BRCA. The snail *Physa* has been well-documented in the Claron Formation of BRCA since the 1930s, based on internal collections databases (Figure 16). Snails of various taxa have been observed at numerous localities in the

Wahweap Formation (Williams and Lohrengel 2007), the Straight Cliffs Formation (Hoffman 2005) and the Tropic Shale (Cobban 1996). Notably, the Late Cretaceous gastropod *Admetopsis* has been recorded from a productive brackish-water locality in the Smoky Hollow Member of the Straight Cliffs Formation in BRCA (Hoffman 2005; see "Notable Localities in the Straight Cliffs Formation").

Figure 16. Gastropod specimens from the Claron Formation at BRCA, cf. *Physa* sp. (NPS / TUT TRAN).

Other Invertebrates

Arthropods are uncommon but have been documented in the fossiliferous units at BRCA. Ostracods (clam-like arthropods) are known from the park's Straight Cliffs and Wahweap Formations, notably from a locality recorded during the emergency salvage along SR 12 by Eaton (UMNH IP Locality 406). A crab claw was collected from the lower Wahweap Formation. Arthropods are also represented in the Claron Formation as trace fossils (see "Ichnofossils"). Ostracods have been recovered from the Straight Cliffs and Wahweap Formations in BRCA (Eaton, unpublished field notes; Meyers and Knauss 2021).

The most extensive catalog of arthropods collected from a single locality in BRCA is provided by Agenbroad et al. (1992), who sampled a historical-aged (310 ± 50 B.P.) packrat midden. The insects recovered from this study included beetles, grasshoppers, flies, true bugs, and ants (Agenbroad et al. 1992). These insect fossils are catalogued under a single specimen number (BRCA 8125) in the museum collections but have been missing since 2018.

Fossil Vertebrates

Class Chondrichthyes

Shark and ray teeth were formerly thought to be absent from the Wahweap Formation at BRCA, causing Eaton to consider the uppermost Cretaceous strata in the park to be better correlated with the Kaiparowits Formation on the Kaiparowits Plateau (Eaton et al. 1998). Further investigation proved this to be incorrect. The Straight Cliffs and Wahweap Formations at BRCA have since produced numerous specimens of sharks and rays. Chondrichthyes known from the Straight Cliffs Formation include *Lonchidion* sp. (Kirkland et al. 2013) and *Brachyrhizodus* sp. (Williamson et al. 2011).

Multiple chondrichthyan specimens have been recovered from a single locality in the Wahweap Formation at BRCA (BRCA 102/UMNH VP Locality 77). These include teeth that represent *Chiloscyllium missouriense, Cristomylus cifellii, Columbusia deblieuxi*, and *Texatrygon brycensis* (Kirkland et al. 2013). The type specimens for *C. deblieuxi* and *T. brycensis* were collected from BRCA 102/UMNH VP Locality 77.

Class Actinopterygii

Remains of bony fishes are commonly observable on the surface of Cretaceous strata at BRCA and are frequently recovered from screen-washed sediment samples. Among the most common elements observed on the surface are scales, teeth, and vertebrae referable to *Lepisosteus* sp. (gars) in the Straight Cliffs and Wahweap Formations. Brinkman et al. (2013) provided the most detailed description of numerous actinopterygian specimens recovered from BRCA, mostly from BRCA 124 (UMNH VP Locality 424; see "Notable Localities in the Straight Cliffs Formation"). Brinkman et al. (2013) describes several specimens referable indeterminate teleosts, including a hiodontid, acanthomorph, and otophysian. Fish fossils recovered from the Wahweap Formation at BRCA, but not known from the Straight Cliffs, include *Lepidotes* sp., *Micropycnodon* sp., *Amia* sp., and *Parabula* sp. (Brinkman et al. 2013). Higher in section, notably, one gar scale was recovered from the pink member of the Claron Formation at BRCA in 2013 (UMNH PB Loc. 61; see "Notable Localities in the Claron Formation").

Class Amphibia

Anurans (frogs) and salamanders have been recovered as a result of screen-washing bulk sediment samples of the John Henry Member of the Straight Cliffs Formation and the Wahweap Formation (Roček et al. 2010; Gardner and DeMar 2013; Gardner et al. 2013, 2016). Multiple anuran ilia (pelvic bones) were recovered from UMNH VP Loc. 424 and 77, which Roček et al. (2013) used to describe several anuran ilia morphotypes (distinct forms). At least one morphotype from this study (indeterminate Anura ilia group 1, morphotype 2) was referrable to the species *Scotiophryne pustulosa* (Roček et al. 2010, 2013). Several lumbar vertebrae from these localities, along with vertebrae collected from localities of the Smoky Hollow Member of the Straight Cliffs Formation outside of BRCA, are assignable to an as-of-yet unnamed new genus and species of salamander (Gardner et al. 2013; Gardner, Eaton, and Roček, pers. comm., 2023).

Class Reptilia

Reptiles are among the most common fossil vertebrates at BRCA. Turtles are commonly observed as carapace fragments on the surfaces of Cretaceous strata in the park. Taxa known from both the

Straight Cliffs and Wahweap Formations at BRCA include *Adocus* sp., *Neurankylus* sp., indeterminate baenids, and the brackish water turtle *Naomichelys*, based on collections by Eaton and Jared Morrow later identified by J. Howard Hutchison (BRCA ICMS). The recovery of *Naomichelys* in the Straight Cliffs and Wahweap Formations at BRCA is consistent in age with the Iron Springs Formation (in part equivalent to the Straight Cliffs Formation) to the west and the Wahweap of the Kaiparowits Plateau to the east, where this taxon is also known (Eaton 1999b; Albright et al. 2013). Trionychids (soft-shelled turtles) are also known from the Straight Cliffs and Wahweap Formations of BRCA. *Aspideretes* sp., *Compsemys* sp. (Eaton et al. 1998), *Bothremys*, and chelydrids (snapping turtles) are known only from the Wahweap Formation (BRCA ICMS).

The small size of lizard and snake fossils makes them difficult to identify on the surface, and they are best identified by screen-washing. Through this method, these taxa have been collected from the Straight Cliffs and Wahweap Formations at BRCA and described in the literature (Eaton et al. 1998; Munk 1998; Nydam 2013). Munk (1998) noted the presence of *Chamops segnis* and *Contogenys* sp. in screen-washed samples of UMNH VP Loc. 77, and the snake *Coniophis* sp. was recovered from UMNH VP Loc. 424 (BRCA 124). To date, BRCA has produced one holotype specimen of a fossil herptile (amphibian or reptile) from the John Henry Member of the Straight Cliffs Formation. This holotype represents the scincomorph lizard *Monocnemodon syphakos* (Nydam 2013).

Like turtle fossils, crocodilian remains are common. Isolated osteoderm ("bony armor") fragments occur frequently among Straight Cliffs and Wahweap float fossils. Crocodilian teeth have also been recovered in screen-washing of bulk sediment samples. Irmis et al. (2013) described mesoeucrocodylian and neosuchian teeth from multiple BRCA localities in the Straight Cliffs Formation. Isolated teeth and osteoderms encountered during the 2022–2023 survey in the Wahweap and Straight Cliffs Formations at BRCA are consistent with those of Irmis et al. (2013).

Incomplete dinosaur material is also common as float on exposures of BRCA's terrestrial Cretaceous strata. Fragments of ornithischian dinosaur vertebrae, ribs, and limbs are the most common dinosaur fossils documented in the park. However, jaw fragments are also known from multiple localities in the Straight Cliffs Formation, and teeth are known from both the Straight Cliffs and Wahweap Formations. These fossils are assignable to hadrosauromorphs (relatives of hadrosaurid or "duck-billed dinosaurs") in the Straight Cliffs Formation and hadrosaurids in the Wahweap Formation. Three hadrosauromorph dentaries recovered from BRCA are cited as examples of morphological diversity within the clade in the Straight Cliffs Formation by Gates et al. (2013; BRCA 6386/UMNH VP17037/UMNH VP Loc. 787; BRCA 7235/UMNH VP14266/UMNH VP Loc. 528; BRCA 8026/UMNH VP17434/UMNH VP Loc. 833) (Figure 17). Ceratopsians (horned dinosaurs) are represented only by teeth from a single locality (Eaton et al. 1998; BRCA 102/UMNH VP Loc. 77). Ankylosaur (armored dinosaur) fossils are rare but have been documented from the Wahweap Formation (Eaton et al. 1998) and the Straight Cliffs Formation.

Figure 17. BRCA 8026/UMNH VP 17434, a hadrosaur jaw collected from the Straight Cliffs Formation at BRCA by Jeffrey Eaton in 2007. This specimen, along with most of the material collected by Eaton, is reposited at the Natural History Museum of Utah (NPS / TUT TRAN).

Theropod fossils have also been recorded in BRCA. Eaton has noted several instances of theropod teeth (likely maniraptoran) while screen-washing samples from the Wahweap Formation. Four theropod fossils were recovered during the recent inventory in 2022–2023: two dromaeosaur teeth (BRCA Locs. 6 and 74) and a partial theropod phalanx (BRCA Loc. 133) from the Wahweap Formation, and a partial theropod ungual from the Smoky Hollow Member of the Straight Cliffs Formation (BRCA Loc. 111).

Class Mammalia

Micromammals of the Cretaceous rocks of BRCA have been well-studied and represent a diverse assemblage of taxa. The best preserved and most identifiable fossils of small mammals are their teeth, so fossil mammal material is infrequently observed on the surface and usually only identified as a result of screen-washing bulk sediment samples. Fossil mammals identified in the BRCA paleontological collections include multituberculates, triconodonts, trechnotherians, and marsupials from the Straight Cliffs and Wahweap Formations (Eaton 2013; Tweet and Santucci 2015). Of the fossiliferous strata at BRCA, the John Henry Member of the Straight Cliffs Formation has produced the most mammal taxa.

To date, BRCA has produced one holotype specimen of a multituberculate mammal from the John Henry Member of the Straight Cliffs Formation. This represents the species *Dakotamys shakespeari* (Eaton 2013).

Ichnofossils

Ichnofossils (trace fossils) are common among the fossils observed within the Claron Formation but have rarely been collected by staff for scientific purposes. The most common trace fossils encountered in the Claron Formation at BRCA are referrable to the ichnotaxa *Eatonichnus* and *Parowanichnus*, ovaloid traces interpreted as internal molds of hymenopteran (ants, bees, and wasps) burrows (Bown et al. 1997). Invertebrate trails are also present in the Tropic Shale and Wahweap Formation, as observed during the 2022–2023 field work.

Coprolites (fossilized feces) have been collected by Eaton from UMNH VP Locality 424 (John Henry Member of the Straight Cliffs Formation) and Loc. 427 (Wahweap Formation). These are represented by eight catalog numbers in the BRCA paleontological collections.

One archosaur track is documented in the BRCA paleontological collections but lacks sufficient locality and collector data to determine whether this fossil is indeed from the park. The first confirmed dinosaur tracks in the park were observed at BRCA 44 in the Wahweap Formation near the Hat Shop area (see “Notable Localities in the Wahweap Formation”).

Fossil Localities

Paleontological Localities Within BRCA

Notable Localities in the Tropic Shale

UMNH IP Locality 34: This locality was recorded by Lidya Tarhan and Jeff Eaton on July 24, 2008. It is the only locality within the Tropic Shale that was recorded during the Eaton-led surveys from 1988 to 2013. The locality produced invertebrate fossils typical of this unit, namely oysters and other bivalves, gastropods, and some specimens of the ammonite *Baculites*. This is the first locality in the Tropic Shale in BRCA recorded since work by Gregory (Reeside 1937, 1939) and Cobban (1996).

BRCA 64: This locality was recorded by Pittinger and Tran on August 9, 2022. It is notable for producing a high concentration of casts and molds of small, tightly coiled ammonites in orange concreted sandstone lenses within brown/grey highly laminated shale. The ammonites are likely *Collignoniceras woollgari*, which constrains this section of the Tropic Shale to an early Turonian age (G. Pollock, pers. comm., 2023) (Figure 18).

Figure 18. Ammonite specimens observed at BRCA 64. These are likely referable to the Turonian taxon *Collignoniceras woollgari* (NPS / TUT TRAN).

Notable Localities in the Straight Cliffs Formation

MNA 996: This locality was recorded by Eaton on September 21, 1987. Several specimens of the Late Cretaceous gastropod *Admetopsis* were collected and served as the basis for the Master's thesis of Hoffman (2005). Eaton believed these specimens were at one point returned to the BRCA museum collections at ZION (pers. comm., 2023); however, corroboration with BRCA curator Hoskins confirmed that none were returned by the University of Wisconsin and that the thesis manuscript (Hoffman 2005) was not saved in the BRCA archives. The status of the specimens described by Hoffman (2005) is unknown at the time of writing.

BRCA 12: This locality was recorded by Pittinger and Tran on June 21, 2022. It is notable for having produced several microfossils (turtle, crocodilian, dinosaur) from the John Henry Member. A large, intact crocodilian tooth was discovered by Pittinger and Tran upon initial recording of the locality. Tran and Stwalley surface collected that tooth on August 31, 2022.

BRCA 13 (Swamp Canyon Leaf Litter): This locality was recorded by Pittinger and Tran on June 22, 2022. This was the first of several broad-leafed angiosperm localities to be discovered near the top of the John Henry Member over the course of the 2022–2023 inventory (Figure 19). Most of these localities preserve leaves with sufficient venation to diagnose them to the genus level. In total, these include BRCA 13, 85, 114, 117, 119, 122, 123, 127, and 155. Based on the map of Biek et al. (2015), several of these localities occur along the contact between the John Henry and Drip Tank Members. Their proximity to each other in space and geologic section may offer opportunities for refined stratigraphic study..

Figure 19. A sandstone block containing concentrated angiosperm leaf impressions at BRCA 13. Rock hammer for scale (NPS / DAKOTA PITTINGER).

BRCA 21 (UMNH VP Loc. 1156): This locality was recorded by Eaton and Tabitha Bergout on July 7, 2009. It is notable for producing multiple micromammals, including the holotype specimen of the multituberculate *Dakotamys shakespeari* (Eaton 2013). Additional material recovered from screen-washed samples from this locality include specimens of fish and frogs, and teeth of the cartilaginous fish *Brachyrhizodus* (Roček et al. 2010; Williamson et al. 2011; Brinkman et al. 2013; Gardner et al. 2013). Tran relocated and assessed the locality on July 5, 2022.

BRCA 42 (UMNH IP 24 and 33): This locality was originally recorded as two separate sites. UMNH IP 24 was recorded by Eaton on July 27, 2007, and UMNH IP 33 was recorded by Shayne Pearce on July 19, 2008. They are notable for producing abundant oysters and gastropods from a prominent lignite- or coal-rich layer in the Smoky Hollow Member of the Straight Cliffs Formation. Eaton noted that UMNH IP 33 was "probably just a continuation to the north of UMNH IP 24" (Eaton, unpublished field notes). Based on this interpretation, along with the abundance of similar fossils and lithology, Tran and Pittinger combined these localities under a single BRCA locality number when they relocated them on July 26, 2022.

BRCA 63: This locality was recorded by Tran on August 8, 2022. The locality produced the largest and most abundant hadrosauromorph elements in the upper part of the John Henry Member encountered during the 2022 inventory (Figure 20). These included large limb condyles (rounded articulation surfaces) and two jaw fragments with intact alveoli (tooth sockets). Tran surface-collected several of these fossils along with a large crocodilian osteoderm on Sept 29, 2022, and later collected several surface fragments of two large baenid turtles on June 28, 2023.

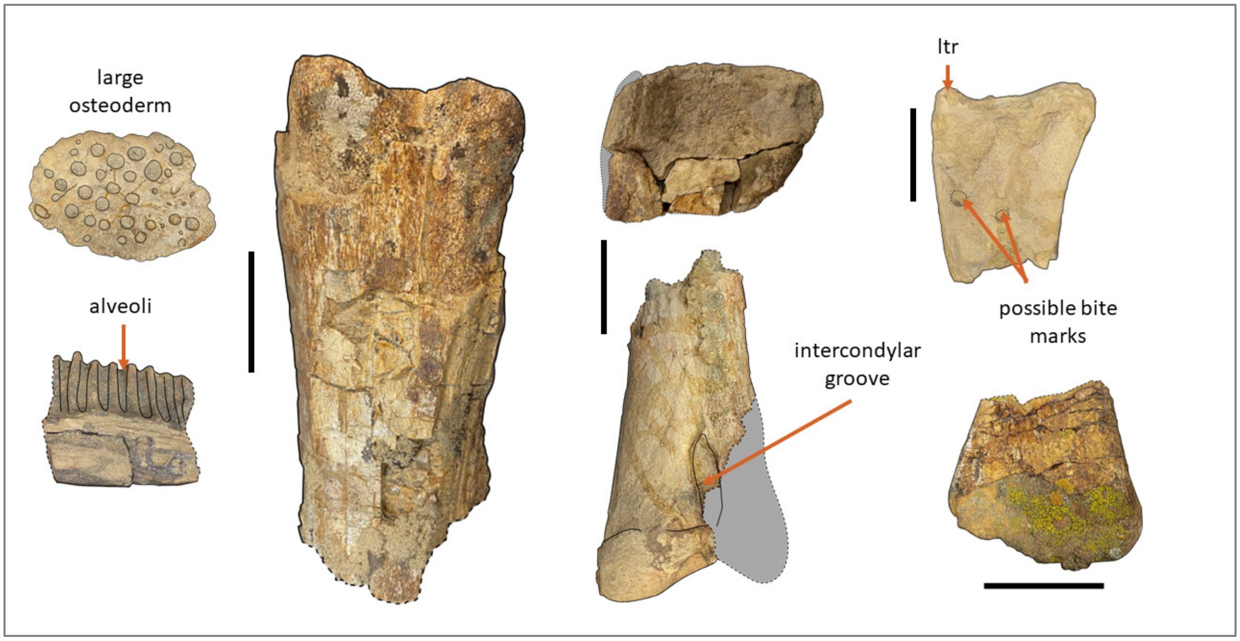

Figure 20. Hadrosauromorph elements, plus a large crocodilian osteoderm, recovered from BRCA 63 during the 2022 field season. Notable anatomical features are indicated with orange arrows. Abbreviations: **ltr**. left trochanter. Scale bars equal 5 cm (2 in) (NPS / TUT TRAN).

BRCA 78 (UMNH VP 569): This locality was recorded by Eaton and Morrow on July 29, 2004. They collected five sacks of matrix for screen-washing. Among the recovered screen-washed specimens were fossils of ostracods, sharks, gars, teleost fish, turtles, crocodilians, dinosaurs, and multituberculates. Amphibian remains from this locality have been described and published (Roček et al. 2010). Tran relocated the locality on Aug 24, 2022, and discovered closely associated fragments of a dinosaur limb along a drainage atop soft mudstone at the locality.

BRCA 79 (UMNH VP 568): This locality was recorded by Eaton and Morrow on July 29, 2004. They collected a partial hadrosaur jaw from the concreted sandstone layer at this site, just 1 m (3 ft) below a stark red sandstone. Tran relocated the locality on Aug 24, 2022. Tran did not locate additional hadrosaur material but did find multiple turtle individuals comprised of closely associated carapace fragments.

Reevaluation of the BRCA museum collections reposited at the Natural History Museum of Utah by Justin McKee recovered the hadrosaur jaw collected from this locality (J. McKee, pers. comm., 2023). This specimen (BRCA 7235/UMNH VP14266) was, in fact, figured along with another hadrosaur jaw (BRCA 6386/UMNH VP17037) in Gates et al. (2013). However, BRCA 7235 is cited with the incorrect UMNH catalog number in the figure caption and chapter text, listed as UMNH VP17187 instead of UMNH VP14266.

BRCA 106: This locality was recorded by Tran and Mel Henderson-Sjoberg on October 26, 2022. It produced multiple associated fragments of an alligatoroid maxilla with identifiable alveoli (Figure 21). Other fossils encountered included turtle and snail fragments. Tran and Henderson-Sjoberg surface-collected the maxilla fragments.

Figure 21. Fragments of closely associated crocodilian maxilla collected from BRCA 106 (NPS / TUT TRAN).

BRCA 111: This locality was recorded by Tran on November 1, 2022. BRCA 111 produced the first diagnostically theropod fossil, a partial claw, recorded on the surface during the 2022 survey. Tran surface-collected this specimen (Figure 22) upon recording the locality.

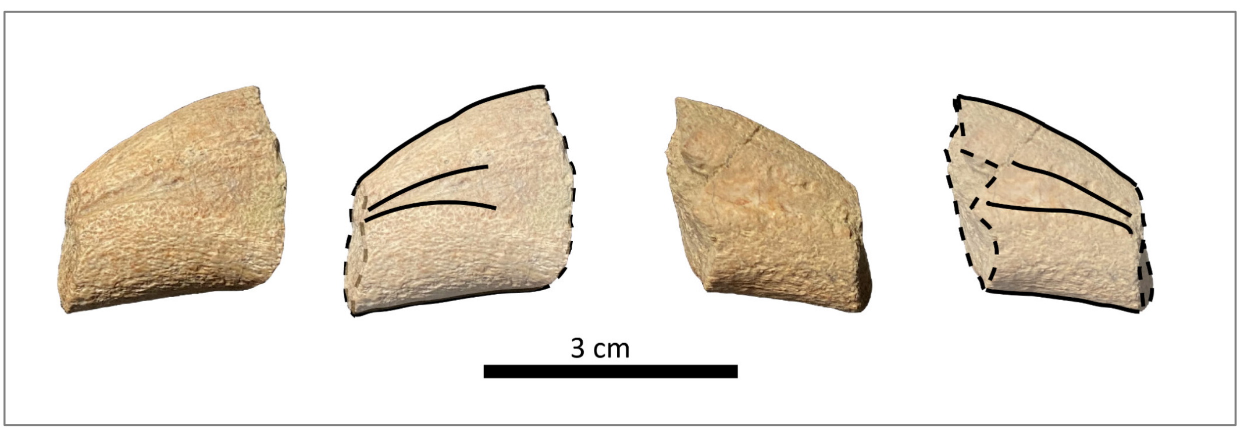

Figure 22. Partial theropod claw recovered from BRCA 111 (NPS / TUT TRAN).

BRCA 118: This locality was recorded by Tran on May 30, 2023. It is notable for having produced ~13 articulating fragments of hadrosaur long bone, each 5–8 cm (2–3 in) long. The site occurs at the contact between the John Henry and Drip Tank Members. Tran and Alexandra Bonham surface collected these fragments on July 7, 2023 (Figure 23). The pieces articulate to form the largest and most intact single long bone recorded in the 2022–2023 inventory and may represent a hadrosauromorph fibula. Only the distal condyle is missing from this specimen.

Figure 23. Hadrosauromorph fibula collected from BRCA 118. Reconstruction (left); scale bar equals 10 cm (4 in). Tran surface collecting articulating fragments of the fibula near the contact between the John Henry and Drip Tank Members of the Straight Cliffs Formation at locality BRCA 118 (right) (NPS / ALEXANDRA BONHAM).

BRCA 124 (UMNH VP 424): This locality was recorded by Eaton on August 1, 2003. It is notable for producing the holotype specimen for the scincomorph lizard *Monocnemodon syphakos* (Nydam 2013) along with abundant other microvertebrate fossils in the John Henry Member of the Straight Cliffs Formation, which have been figured and described in the scientific literature (Roček et al.

2010; Brinkman et al. 2013; Eaton 2013; Gardner et al. 2013; Irmis et al. 2013; Kirkland et al. 2013; Nydam 2013) (Appendix B). This locality has been considered the most fossiliferous locality in the member so far discovered within BRCA (Titus et al. 2016). The locality's productivity underscores its future research potential. Outside institutions have shown interest in this locality during the development of BRCA's internal paleontology program.

Notable Localities in the Wahweap Formation

BRCA 6: This locality was recorded by Pittinger and Tran on June 14, 2022. The site produced abundant and highly concentrated gastropods, along with fragments of crocodilian osteoderms and turtle carapace. Bonham and Tran collected a theropod tooth from this locality on August 17, 2023.

BRCA 20: This locality was recorded by Tran on June 28, 2022. The site is notable for having produced well-preserved and diverse surface fossils (Figure 24). The largest of these are multiple (10–12) associated vertebrae of at least one juvenile hadrosaur, identifiable by the unfused articular surfaces. A partial juvenile frontal bone was also found. Microfossils encountered include a hadrosaur tooth, bowfin fish vertebrae and teeth, and gastropods (Figure 25).

The abundance of hadrosaur material, all showing juvenile features (unfused articular surfaces), and diverse microfossil float suggested (1) the potential of this site to produce additional juvenile dinosaur bones and (2) the presence of a productive microsite. Tran and Henderson-Sjoberg surface-collected these fossils (BRCA 020-01 through -23) on October 19, 2022. Vincent Santucci (NPS Paleontology Program lead) and Brett Cockrell developed a Task Agreement with the Utah Geological Survey in early 2023 to assess and potentially excavate BRCA 20 that summer.

Figure 24. Juvenile hadrosaur vertebrae recovered from the surface of BRCA 20. Scale bar in centimeters (NPS / TUT TRAN).

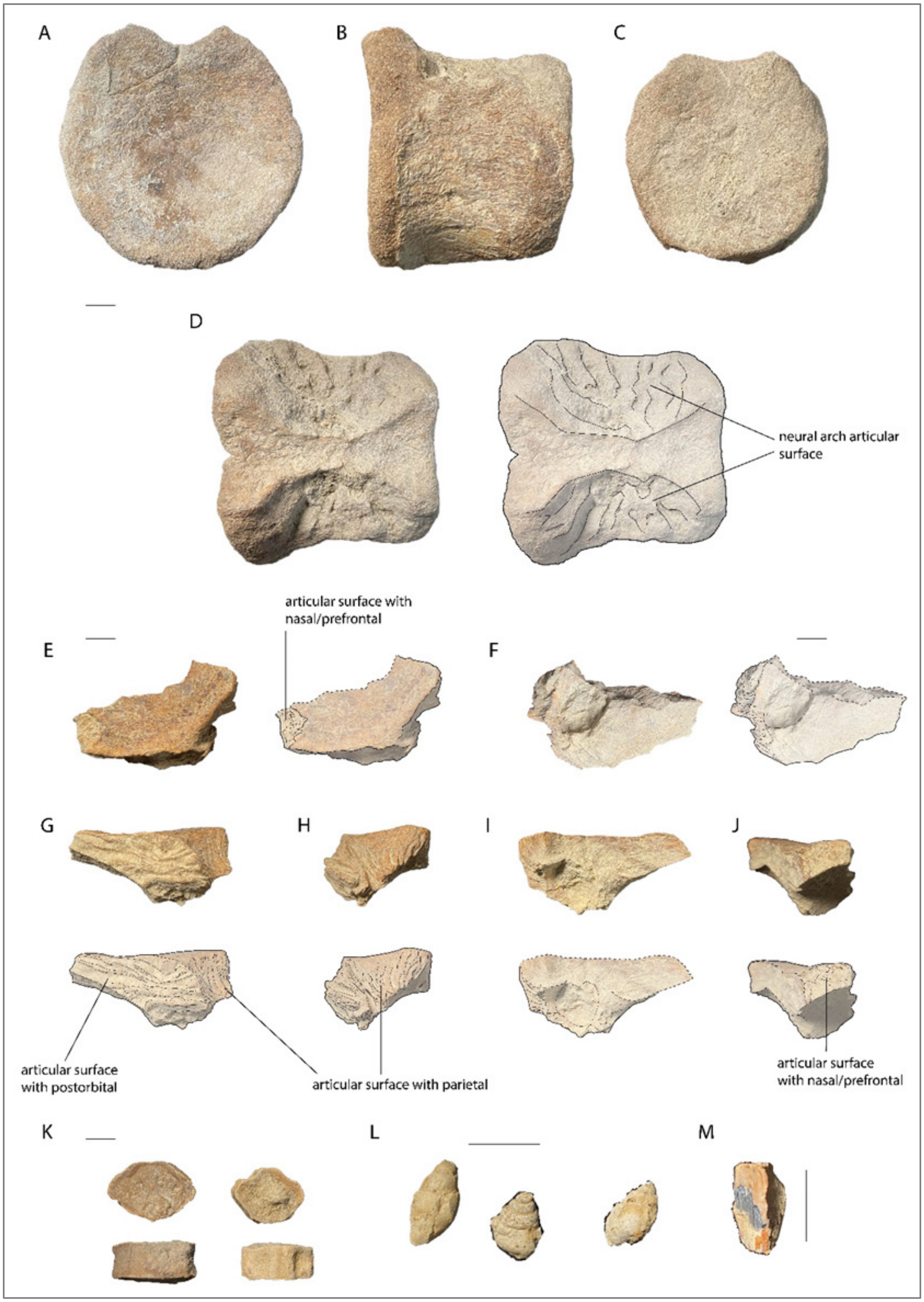

Figure 25. Diagnostic fossils surface collected from BRCA 20. These include a juvenile hadrosaur tail vertebra (**A–D**), a partial juvenile hadrosaur frontal (skull) bone (**E–J**), bowfin fish vertebrae (**K**), gastropods (**L**), and a hadrosaur tooth (**M**). Unfused sutures characteristic of juvenile dinosaurs indicated in **D–J**. All scale bars = 1 cm (0.4 in) (NPS / TUT TRAN).

Tran, Bonham, and Cockrell relocated and assessed BRCA 20 on June 21, 2023. The site produced several new microfossil specimens and a few new pieces of hadrosaur remains, namely phalanges. The pre-excavation evaluation scheduled through the previously mentioned Task Agreement was conducted by Don DeBlieux (UGS) and Dr. Joshua Lively (Prehistoric Museum), with support from Tran and Bonham, on June 27, 2023. They dug several test pits at the estimated productive horizon for the site's microfossils and an additional test pit at the approximate position of the surface hadrosaur vertebrae. However, the sandstone layer that was likely producing the vertebrae and phalanges was not uncovered because the site is obscured by thick muds and concretions. This prevalence of mud prevented DeBlieux and Lively from locating the in situ position of large bones in sandstone, which they estimated was the most likely lithology to produce bones of the size and intactness observed. DeBlieux and Lively recommended sampling matrix from BRCA 20 for microfossils and conducting cyclic monitoring until further erosion by rain and snow reveals the in situ productive horizon for large bones.

BRCA 40: This locality was recorded by Pittinger and Tran on July 19, 2022. Bones are present at this locality, mostly consisting of fragmentary dinosaur ribs and vertebrae. A probable crocodilian skull fragment and multiple turtle carapace pieces were found among the vertebrate fossils.

BRCA 44 (Dakota's Hadtrosaur Trackway): This locality was recorded by Pittinger and Tran on July 27, 2022. It is notable for producing the first confirmed record of dinosaur tracks at BRCA. Specifically, Pittinger and Tran observed three three-toed natural footprint casts that were left by a hadrosaur (Figure 26). Tran submitted TAR 26732 to the NRSS/GRD to aid in conducting photogrammetry on these footprints.

Tran reassessed the locality on May 30, 2023. Tran found the locality to be in stable condition but noted that one of the three footprints originally reported could not be unequivocally proven as such. DeBlieux (UGS) joined Tran for an additional visit on June 28, 2023, to conduct photogrammetry on the two exposed footprints. In surveying the rest of the locality for additional traces, DeBlieux flipped a sandstone slab to reveal a previously unreported and intact footprint (Figure 27). This specimen was photogrammetry scanned along with the two that were previously known. Based on this finding, DeBlieux recommended cyclic monitoring.

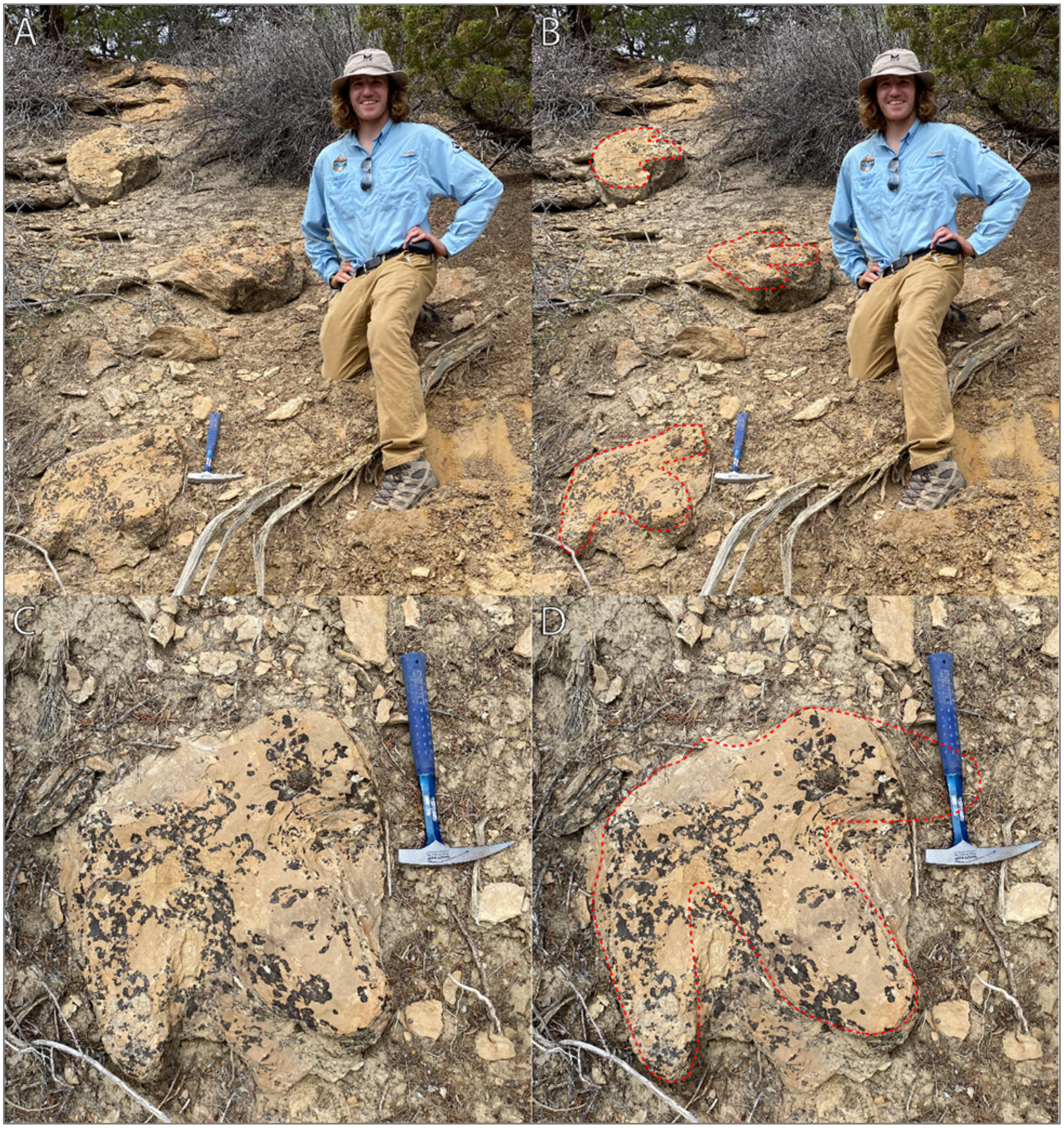

Figure 26. Overview of the hadrosaur footprint casts discovered at BRCA 44 pictured with Dakota Pittinger and rock hammer for scale (NPS / TUT TRAN). **A** and **C** are unmodified; red lines have been added to **B** and **D** to make it easier to identify the fossils.

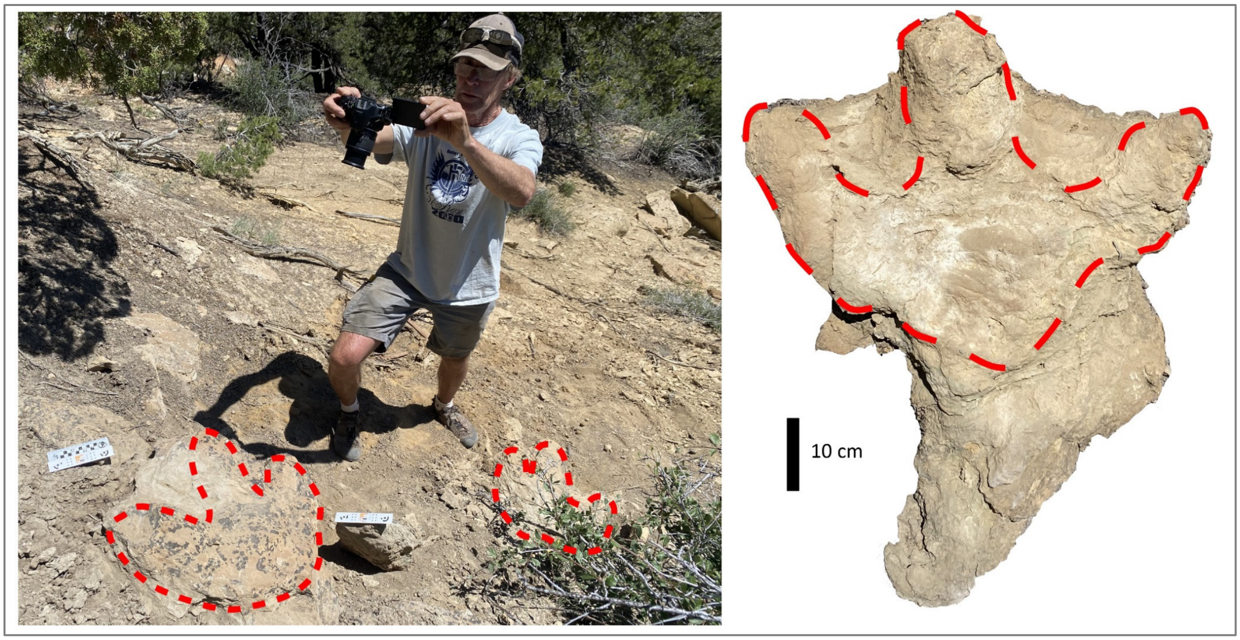

Figure 27. Utah Assistant State Paleontologist Don DeBlieux conducts a photogrammetry scan of two of the three footprints discovered at BRCA 44 (left). The footprint discovered by DeBlieux and Tran on June 28, 2023 is pictured on the right. Scale bar equals 10 cm (4 in) (NPS / TUT TRAN).

BRCA 74 (UMNH IP Locality 63): This locality was recorded by Eaton on July 9, 2011The locality was originally recorded for its unionid bivalves, gastropods, and vertebrate fragments preserved in a sandstone lag. Vertebrate fossils included a gar scale and tooth fragment that led Eaton to deduce the presence of a microsite. Tran relocated and assessed the locality on August 18, 2022. Tran surface-collected an isolated dromaeosaurid tooth that day (BRCA 074-01; Figure 28).

Figure 28. Partial dromaeosaurid tooth recovered by Tran from BRCA 74 (UMNH IP Loc. 63), with the pick end of an Estwing hammer for scale (NPS / TUT TRAN).

BRCA 81 (UMNH VP Loc. 776): This locality was recorded by Jessica Simpson, Casey Pentz, and Eaton on July 9, 2006. It is notable for producing many gastropods (~2,000) in screen-washed samples and having turtle, crocodilian, and hadrosaur float on the surface (Eaton, unpublished field notes; Williams and Lohrengel 2007). Tran relocated the locality on August 29, 2022.

BRCA 94: This locality was recorded by Tran on September 28, 2022.. It is notable for producing an in situ but rapidly eroding hadrosaur ulna (Figure 29) in a channel lag deposit. Tran collected this specimen on May 3 and May 8, 2023.

Figure 29. Hadrosaur limb bone documented at BRCA 94 (NPS / TUT TRAN).

BRCA 99: This locality was recorded by Tran on October 13, 2022. It produced various surface microfossils, including snails, gar scales, turtle fragments, crocodilian and hadrosaur teeth (potentially including specimens of the button-toothed crocodilian *Brachychampsa*), and a potential reptile or fish jaw. A large hadrosaur limb shaft 10 m (33 ft) below the microsite was the initial discovery. Tran noted that this locality has strong potential to be a productive microsite and should be sampled for screen-washing in the future. Tran and Bonham relocated and assessed the BRCA 99 on August 3, 2023. The locality is in stable condition. Originally, it was interpreted as occurring in the Straight Cliffs Formation based on the geologic map of Bowers (1991). However, the more recent map of Biek et al. (2015) shows BRCA 99 occurring in the Wahweap Formation, consistent with the lithology observed.

BRCA 102 (UMNH VP Locality 77): This locality was recorded by Eaton on June 22, 1997. It was the first locality in the Wahweap Formation of BRCA to be formally described (Eaton et al. 1998; Munk 1998) and is notable for producing microvertebrates, which include the holotype specimens of the sawfishes *Columbusia deblieuxi* and *Texatrygon brycensis* (Kirkland et al. 2013). Other microfossils recovered from screen-washed samples from this locality include material of turtles, lizards, crocodilians, dinosaurs (including teeth of ceratopsians, ankylosaurs, hadrosaurs, and theropods), and mammals (Eaton et al. 1998; Eaton 1999a, 2002, 2013; Roček et al. 2010; Kirkland et al. 2013; Nydam 2013). Tran relocated UMNH VP Loc. 77 on October 14, 2022, during the new inventory.

BRCA 153 (UMNH IP Loc. 39): This locality was recorded by Eaton and Justin Williamson on July 10, 2009. The locality was originally referred to the John Henry Member of the Straight Cliffs Formation and noted for producing invertebrates and bone from a sandstone horizon. Tran relocated the locality on October 16, 2023 and referred it to the Wahweap Formation based on the more recent geologic maps of Biek et al. (2015) and Knudsen et al. (in prep.).

BRCA 153 is included here because of the recent identification of a ceratopsian occipital condyle (the base of the braincase, which articulates with the first vertebra in the neck) that had been collected at this locality (BRCA 8494/UMNH VP19113). This identification was made by Justin McKee, who has been reevaluating preliminary identifications of BRCA specimens reposited at the Natural History Museum of Utah (J. McKee, pers. comm., 2023). McKee's recent reassessment of BRCA 8494, which was originally recorded as merely a "vertebra" or "terminal bone," is significant because it may represent the first recorded instance of any skeletal material referrable to a ceratopsian dinosaur at BRCA. Furthermore, the site's location relative to the geologic maps of Biek et al. (2015) and Knudsen et al. (in prep) suggest the locality may be in the Wahweap Formation, not the Straight Cliffs Formation. This would suggest that BRCA 8494 represents a ceratopsian similar in stratigraphic position and age to the centrosaurines *Diabloceratops eatoni* (Kirkland and DeBlieux 2010) or *Machairoceratops cronusi* (Lund et al. 2016).

Notable Localities in the Claron Formation

"Pupa Ridge": This locality was recorded by Dr. Larry Davis and Gayle Pollock in 2015. It is notable for having produced numerous hymenopteran (wasp, bee, ant) pupae in the Claron Formation. Davis and Pollock did not officially document the locality or the collected specimens in the BRCA archives or museum database at the time. Tran relocated several fossils from Pupa Ridge while conducting an inventory of interpretive collections in April 2023.

UMNH PB Loc. 59: This locality was recorded by Stephanie Lukowski on July 3, 2013. The locality is notable for producing leaf impressions possessing secondary venation in gray limestone. Lukowski recorded a second leaf locality, UMNH PB Loc. 61, on July 31, 2013.

UMNH PB Loc. 60: This locality was recorded by Kevin Rafferty on July 31, 2013. Like UMNH PB Loc. 59 and 61, this locality produced leaf impressions possessing secondary venation. However, this locality is also notable for having produced the only vertebrate fossil reported in the Claron Formation at BRCA, a single gar scale.

BRCA 2: This locality was recorded by Pittinger and Tran on June 7, 2022. It is notable for preserving in situ hymenopteran burrows.

BRCA 34: This locality was recorded by Pittinger and Tran on July 13, 2022. The locality is notable for producing mollusk fragments and invertebrate burrows.

BRCA 37: This locality in recorded by Pittinger and Tran on July 13, 2022. Burrow traces and a well-preserved gastropod are among the most significant fossils found at this locality.

BRCA 57 (UMNH IP 59): This locality was recorded by Jeff Eaton and Jonathan Munnikhuis on July 24, 2011. It is notable for having produced hymenopteran traces referrable to the *Eatonichnus* ichnogenus. Larry Davis relocated the locality on August 5, 2015, after email correspondence with Eaton, and they collected hundreds of hymenopteran pupae specimens from the site (Figure 30). These specimens contributed to the results of Davis et al. (2015) but were never officially documented in the BRCA museum database. Tran, Pittinger, and Eaton relocated UMNH IP 59 on August 3, 2022, but none had knowledge of the location of the Davis and Singler collections at the time. These fossils, along with others that Davis and colleagues had collected in 2015, were assigned accession number BRCA-00599 and transported to the Prehistoric Museum in Price, Utah for storage and curation.

Figure 30. Numerous hymenopteran trace fossils collected by Davis and Singler from BRCA 57 (UMNH IP 59) in 2015. These specimens have been transported to Prehistoric Museum in Price, Utah for storage and curation under accession number BRCA-00599 (NPS / TUT TRAN).

BRCA 89 (UMNH IP 5): This locality was recorded by John Howard Hutchison on September 1, 1997. The BRCA 89 produced unionid bivalves in float, but the fossil horizon was not located. Eaton revisited and redescribed the locality on July 27, 2006, and was also unable to locate the fossil-producing horizon.

Tran and Thompson relocated this site on September 16, 2022. They encountered mollusk fragments and insect traces. Notably, the site had been disturbed by humans in the time between Eaton's last assessment in 2006. Tran and Thompson discovered an abandoned cache of undocumented personal effects (sleeping bags, a blanket, and a backpack containing cut slabs of calcite and a steak knife) under a dead tree. Eaton confirmed that the objects did not belong to him. Tran reported these results to law enforcement ranger Austin Harding. Tran and Bonham reassessed the locality on August 1, 2023, and found the aforementioned cache undisturbed since its discovery in 2022. Bonham reported the cache to BRCA Chief Ranger Tyla Guss.

BRCA 93 (UMNH PB 62). This locality was recorded by Eaton and Stephanie Lukowski on August 22, 2013. This locality is notable for being the only locality in BRCA's Claron Formation that has produced hackberry seeds to date. Gastropods and insect traces were also documented. Tran relocated and assessed BRCA 93 on September 20, 2022.

BRCA 113. This locality was recorded by Tran on April 25, 2023. For several years, BRCA 113 was known to multiple staff to have produced specimens of insect traces (e.g., *Eatonichnus* and *Parowanichnus* sp.).

Paleontological Localities Near BRCA

Eaton recorded several localities on the western flank of the Paunsaugunt Plateau (Eaton 2013; Titus et al. 2016). Eaton also recorded several localities east of BRCA in Bryce Valley in what would become GSENM, in the Smoky Hollow and John Henry Members of the Straight Cliffs Formation. These localities produced several mammal taxa (e.g., *Bryceomys* spp.; see Eaton 1995, 2006a).

Notable fossil localities in the Tropic Shale, Straight Cliffs, and Wahweap Formations of GSENM, which borders BRCA to the east, are numerous. Particularly notable sites have been included in the scientific literature (Eaton et al. 1999a; Foster et al. 2001; Titus et al. 2005, 2016; Kirkland and DeBlieux 2010; Eaton and Cifelli 2013; Loewen et al. 2013b; Beveridge et al. 2022).

Multiple localities of note were documented in the Smoky Hollow and lower John Henry Members of the Straight Cliffs Formation in Dixie National Forest east of BRCA. These include a nodosaur cervical spine (Loewen et al. 2013c) and the posterior portion of a hadrosauromorph (Gates et al. 2013) documented by Eaton in the late 2000s/early 2010s. The hadrosauromorph site was excavated by Eaton, Kirkland, and DeBlieux, who collected limbs and a nearly complete pelvis (J. Kirkland, pers. comm., 2022). The site has not been revisited since initial excavation in 2010 due to extremely limited access.

Cultural Resource Connections

There are many ways for paleontological resources to have connections to cultural resources. Examples of paleontological resources in cultural contexts include, but are not limited to: fossils used by people for various purposes, such as petrified wood used for tools, spear points, and other artifacts, or fossil shells picked up as charms or simply because they looked interesting; associations of prehistoric humans with paleontological resources, such as kill sites of mammoths, prehistoric bison, and other extinct animals; incorporation of fossils into cultural records, such as fossils in American Indian lore, "tall tales" of mountain men, and emigrant journals; and fossils in building stone. Kenworthy and Santucci (2006) presented an overview and cited selected examples of National Park Service fossils found in cultural resource contexts. It would not be unusual to find examples of paleontological resources used in cultural contexts at BRCA, but none have been reported to date.

Museum Collections and Paleontological Archives

Museum Collections and Curation

Park Collections

As of October 2023, there were 1,761 catalog numbers representing 12,476 elements in the BRCA paleontological collections. Of this total, 237 catalog numbers were curated at BRCA's museum collections in the multi-park repository at Zion National Park (ZION) (Appendix B). Twenty-nine catalog numbers were in the collections of the Museum of Northern Arizona (Flagstaff, Arizona) (Appendix B). Six catalog numbers curated at the MNA were in fact accessioned in the BRCA paleontological collections in error (collected from MNA Locality 1124, which is not inside the park; G. Gallenstein, pers. comm., 2023). The remaining 1,489 catalog numbers in the BRCA paleontological collections were curated at the Natural History Museum of Utah (formerly the Utah Museum of Natural History, UMNH, Salt Lake City, Utah). A further 318 paleontological specimens were in the catalog backlog.

A total of 58 accession numbers represents the BRCA paleontological collections in their entirety: 35 accession numbers represent the collections reposited at ZION, 18 represent those at the UMNH, and just 3 represent specimens curated at the MNA.

Jeff Eaton and Georgia Knauss cataloged several paleontological specimens collected during the SR 12 salvage in 2020 at the beginning of FY 2023 (P. Hoskins, pers. comm., March 2023).

Collections in Other Repositories

Fossils surface-collected at BRCA during the 2022–2023 inventory have been reposited at the Prehistoric Museum in Price, Utah (formerly the College of Eastern Utah Museum, CEUM) under the accession number BRCA-00598. Material from the Claron Formation at BRCA collected by Larry Davis and colleagues has also been reposited at CEUM under accession number BRCA-00599. Tran transported these accession lots to CEUM on December 12, 2023. The storage of these fossils will be made possible by a repository agreement between BRCA and CEUM which will be finalized by late 2023/early 2024.

Numerous specimens from the BRCA paleontological collections housed at outside repositories have been described and figured in the scientific literature (Munk 1998; Eaton 2002, 2013; Roček et al. 2010; Brinkman et al. 2013; Gardner and DeMar 2013; Gardner et al. 2013; Kirkland et al. 2013; Nydam 2013). A full list of figured specimens organized by literature cited can be found in Appendix B.

Type Specimens

To date four species have been named from fossils collected from BRCA, two each from the John Henry Member of the Straight Cliffs Formation and the Wahweap Formation (Table 2; Figure 31).

Table 2. Fossil taxa named from specimens found within BRCA.

Taxon	Citation	Age, Formation	Type Specimen	Notes
Columbusia deblieuxi	Kirkland et al. 2013	Cretaceous, Wahweap	UMNH VP 18878 (BRCA 8432)	Sclerorhynchid batoid cartilaginous fish
Texatrygon brycensis	Kirkland et al. 2013	Cretaceous, Wahweap	UMNH VP 18885 (BRCA 8439)	Ptychotrygonid batoid cartilaginous fish
Dakotamys shakespeari	Eaton 2013	Cretaceous, Straight Cliffs	UMNH VP 19160 (BRCA 3020)	Multituberculate mammal
Monocnemodon syphakos	Nydam 2013	Cretaceous, Straight Cliffs	UMNH VP 17384 (BRCA 7996)	Paramacellodid scincomorph lizard

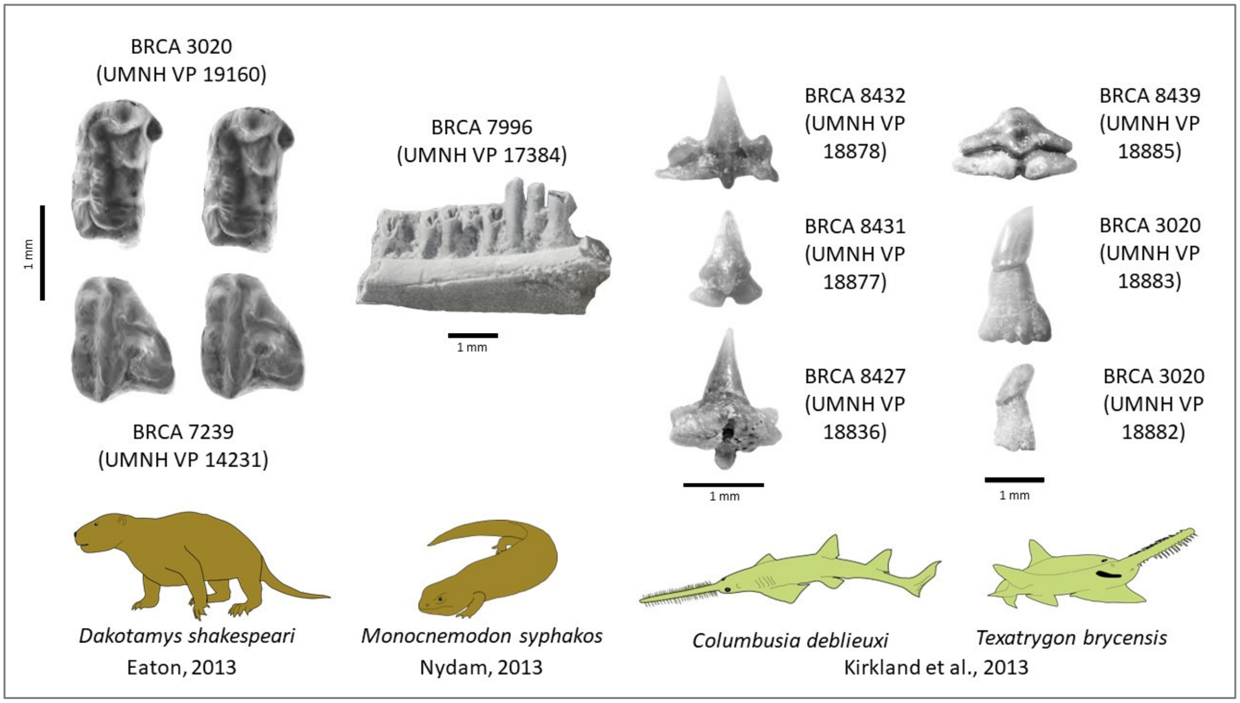

Figure 31. Photographs of the fossil type specimens collected from BRCA and described and figured in Eaton (2013: fig. 15-6K and L), Nydam (2013: fig. 16-9A), and Kirkland et al. (2013: fig. 9-19A, E, and K and fig. 9-21A, C, and H), with restorations of the respective animals. Colors adopted from Bowers (1991) for the Straight Cliffs Formation (brown) and Wahweap Formation (green). Scale bars equal 1 mm (0.04 in) (Illustrations NPS / TUT TRAN, fossil figures reused from cited articles in "At The Top Of The Grand Staircase" with cooperation and permission of authors, Glen Canyon Conservancy, and Indiana University Press).

Archives

NPS Paleontology Archives

All data, references, images, maps and other information used in the development of this report are maintained in the NPS Paleontology Archives and Library. These records consist of both park-specific and service wide information pertaining to paleontological resources documented throughout the NPS. If any resources are needed by NPS staff at BRCA, or additional questions arise regarding paleontological resources, contact the NPS Senior Paleontologist & Paleontology Program Coordinator Vincent Santucci, vincent_santucci@nps.gov. Park staff are also encouraged to communicate new discoveries to the NPS Paleontology Program, not only when support is desired, but in general, so that this information can be incorporated into the archives. A description of the Archives and Library can be found in Santucci et al. (2018).

E&R Files

E&R files (from "Examination and Report on Referred Fossils") are unpublished internal USGS documents. For more than a century, USGS paleontologists identified and prepared informal reports on fossils sent to the survey by other geologists, for example to establish the relative age of a formation or to help correlate beds. The system was eventually formalized as a two-part process including a form sent by the transmitting geologist and a reply by the survey geologist. Sometimes the fossil identifications were incorporated into publications, but in many cases this information is unpublished. These E&R files include documentation of numerous fossil localities within current NPS areas, usually predating the establishment of the NPS unit in question and frequently unpublished or previously unrecognized. Extensive access to the original files was granted to the NPS by the USGS beginning in 2014 (Santucci et al. 2014). A handful of such reports is known for BRCA, primarily associated with Herbert Gregory's work in the late 1930s.

Photographic Archives

The physical and photographic archives at BRCA are curated and maintained by museum staff at ZION. See Appendix C for contact information.

Park Paleontological Research

Current and Recent Research

Since the late 1980s, 37 permits have been issued for projects at BRCA that were either paleontological in focus, or a geological project with paleontological significance. They are listed below in chronological order by project (note that some projects that spanned multiple years were issued multiple permits, the existing system was not in place for the earliest permits, and it is not always clear what is a distinct permit or new project as opposed to a continuation).

- BRCA-1988-SCI-, principal investigator Douglas J. Mullett of Kent State University, project "*Sedimentation, pedogenesis and diagenesis of the Paleogene Claron Formation, Southwest Utah*", issued for 1987–1989.
- BRCA-1989-SCI-, principal investigator Douglas J. Mullett of Kent State University, project "*Stratigraphy, sedimentology and diagenesis of the Paleogene Claron Formation, Southwest Utah*", issued for 1987–1991.
- BRCA-1989-SCI-0003, principal investigator Patrick Goldstrand of the University of Nevada, project "*Tectonostratigraphy of Late Cretaceous and Paleocene nonmarine rocks of southwest Utah*", issued for 1987–1990.
- BRCA-1988-SCI-0001, principal investigator Patrick Goldstrand of the University of Nevada, project "*Timing and Style of Syntectonic Sedimentation in Southwest Utah*", issued for 1988–1991.
- BRCA-1988-SCI-88-2, principal investigator Jeffrey Eaton of Weber State University, project "*Cretaceous Fossils of Bryce Canyon National Park*", issued for 1988–1990.
- BRCA-1989-SCI-89-6, principal investigator Jeffrey Eaton of Weber State University, project "*Stratigraphy and geologic history of Cretaceous Rocks of the Paunsaugunt Plateau*", issued for 1989–1991.
- BRCA-1990-SCI-90-5, principal investigator Jeffrey Eaton of Weber State University, project "*Paleontology and stratigraphy of the Upper Cretaceous Rocks, Paunsaugunt Plateau, Utah*", issued for 1990–1991.
- BRCA-1991-SCI-, principal investigator Jeffrey Eaton of Weber State University, project "*Paleoecology of the Upper Cretaceous, Bryce Canyon NP*", issued for 1991–1992.
- BRCA1992AFGB, principal investigator Florian Maldonado of the U.S. Geological Survey, project "*Micropaleontology Study of Basin and Range - Colorado Plateau Transition in SE Nevada, SW Utah and NW Arizona (BARCO)*", issued for 1992.
- BRCA1992AFGE, principal investigator Larry Agenbroad of Northern Arizona University, project "*Quaternary paleoenvironmental studies of the Colorado Plateau*", issued for 1992.
- BRCA-92-SCI-92-2, principal investigator Elisabeth Brouwers of the U.S. Geological Survey, project "*Paleontological studies in Southwest Utah Basin and Range and Colorado Plateau*", issued for 1992–1996; project appears to include BRCA-93-SCI-92-2 with slightly revised title.

- BRCA-1996-SCI-0001, principal investigator W. A. Cobban of the U.S. Geological Survey, project "*Inventory of the Upper Cretaceous Marine Fossils of Bryce Canyon National Park*", issued for 1996–1997.
- BRCA1997ASGW, principal investigator Heidi Munk, project "*Presence of Kaiparowits Formation in Bryce Canyon National Park*", issued for 1997.
- BRCA1997ASGX, principal investigator Amy Ott of Washington State University, project "*Stable isotope geochemistry and detailed internal stratigraphy of Paleocene-Oligocene Claron Formation in Bryce Canyon National Park*", issued for 1997; this project was continued in 1998 under BRCA1998otta.
- BRCA1997ASGZ, principal investigator Stonnie Pollock of New Mexico State University, project "*Aerial distribution and stratigraphy of the conglomerate at Boat Mesa, Bryce Canyon National Park, Utah*", issued for 1997.
- BRCA19984, principal investigator Jeffrey Eaton of Weber State University, project "*Paleontology of Cretaceous Rocks within Bryce Canyon National Park*", issued for 1998.
- BRCA19984, principal investigator Stonnie Pollock of New Mexico State University, project "*Provenance, Geometry, Depositional Lithofacies, and Age of the Wahweap Formation, Cordilleran Foreland Basin, Southern Utah*", issued for 1998.
- BRCA-1999-SCI-, principal investigator Chris Schierup of Northern Illinois University, project "*Dinosaur Fauna of the Paunsaugunt Plateau*", issued for 1999.
- BRCA-2001-SCI-0002, principal investigator Jeffrey Eaton of Weber State University, project "*Paleoecology of the Upper Cretaceous, Bryce Canyon National Park*", issued for 2001.
- BRCA-2001-SCI-0003, principal investigator Heidi Munk of Weber State University, project "*The Presence of the Kaiparowits Formation in Bryce Canyon National Park*", issued for 2001–2002 (apparently a continuation from permits 98-3 and 2000-5, not in RPRS).
- BRCA-2003-SCI-0014, principal investigator Amy Christensen of New Mexico State University, project "*Stratigraphically controlled petrographic and paleocurrent variability, Drip Tank Member of Straight Cliffs Formation, Kaiparowits and Paunsaugunt Plateaus, southwestern Utah*", issued for 2003–2004.
- BRCA-2005-SCI-0002, principal investigator Jeffrey Eaton of Weber State University, project "*Fossil Inventory and Integrated Study of Cretaceous Microvertebrates, Bryce Canyon National Park, southern Utah*", issued for 2005–2008 (listed as cancelled in RPRS, but an annual report was provided for 2005; superseded by other permits?).
- BRCA-2006-SCI-0008, principal investigator Jeffrey Eaton of Weber State University, project "*Bryce Canyon National Park Inventory of Paleontological Resources in Cretaceous Rocks*", issued for 2006–2008; this project was continued in 2009 under BRCA-2009-SCI-0002 and 2010 under BRCA-2010-SCI-0001.

- BRCA-2011-SCI-0008, principal investigator Robert Biek of the Utah Geological Survey, project "*Geologic Map of the Panguitch 30'x60' Quadrangle, Garfield, Iron, and Kane Counties, Utah*", issued for 2011–2012.
- BRCA-2011-SCI-0009, principal investigator Jeffrey Eaton of Weber State University, project "*Santonian (Late Cretaceous) Microvertebrates of Bryce Canyon National Park, Paleontological Exploration of the Claron Formation, and Geology of Faulted Cretaceous Rocks Along Highway 12*", issued for 2011; this project was continued in 2012 under BRCA-2012-SCI-0001.
- BRCA-2013-SCI-0001, principal investigator Jeffrey Eaton of Weber State University, project "*Continued Paleontological Exploration of Cretaceous and Paleogene Rocks in Bryce Canyon National Park*", issued for 2013; this project was continued in 2014 under BRCA-2014-SCI-0006.
- BRCA-2015-SCI-0007, principal investigator Jeffrey Eaton of Weber State University, project "*Fossil charophytes and newly exposed strata in Bryce Canyon National Park*", issued for 2015.
- BRCA-2022-SCI-0011, principal investigator Tyra Olstad of the National Park Service, project "*Bryce Canyon Initial Paleontological Inventory and Assessment 2022*", issued for 2022.
- BRCA-2023-SCI-0001, principal investigator Derek Tran of the National Park Service, project "*Bryce Canyon Continued Paleontological Inventory and Collection 2023*", issued for 2023.

Paleontological Research Permits

See the National Park Service Natural Resource Management Reference Manual DO-77 section on Paleontological Resource Management, subsection on Scientific Research and Collection (https://irma.nps.gov/DataStore/Reference/Profile/572379). NPS Management Policies 2006, section 4.8.2.1 on Paleontological Resources, states that

The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit.

Any collection of paleontological resources from an NPS area must be made under an approved research and collecting permit. The NPS maintains an online Research Permit and Reporting System (RPRS) database for researchers to submit applications for research in NPS areas. Applications are reviewed at the park level and either approved or rejected. Current and past paleontological research and collecting permits and the associated Investigator's Annual Reports (IARs) are available on the RPRS website (https://irma.nps.gov/RPRS/). Additional information on NPS law and policy can be found in Appendix D.

Interpretation

Current Long Range Interpretive Plan

Paleontology is mentioned just once in the 2022 Long Range Interpretive Plant (LRIP) for BRCA (NPS 2022). The LRIP mentions paleontology in outlining Goal J1, which aims to

> *Broaden interpretive focus beyond foundational topics of geology and night skies to interpret stories including but not limited to: air quality, soundscapes, climate, wilderness, flora and fauna, human history and culture including NPS history, fire ecology, ecosystem dynamics, hydrology, paleontology, and others.*

Interpretive Collections

BRCA's interpretive collection contains representative specimens of strata and taxa of the park's fossiliferous units and those of the surrounding areas (e.g., GSENM, ZION, Red Canyon), most of which were collected by interpretive rangers over several years (B. Cockrell, pers. comm., 2023). BRCA Chief of Resources Management Brett Cockrell forbade park staff from collecting educational fossils from surrounding public lands c. 2020–2021 (B. Cockrell, pers. comm.). The remainder of the interpretive collection was originally purchased or privately collected by Dr. Larry Davis, which he utilized in outreach programs during his tenure as Geoscientist-in-Residence under the Bryce Canyon Natural History Association (now the Bryce Canyon Association) in the mid-2010s (NPS 2015). These objects, which number in the hundreds and represent several thousands of dollars of materials, were donated to the Bryce Canyon Association upon his retirement (Pollock, Cluff, Ireland, and Ginnever pers. comm., 2023). The material is expansive in its taxonomic, geologic, and temporal extent, ranging from abundant dinosaur casts to diverse assemblages of multiple classes of invertebrates, along with numerous fossils and rock specimens purchased from Ward's Science. A preliminary inventory of interpretive props was completed in the 2021–2022 winter season by BRCA education technicians Taryn Withers and Zach Gorski (G. Pollock, pers. comm., 2023; P. Eastman, pers. comm., 2023). However, the Withers and Gorski inventory was incomplete, having focused primarily on pre-made lesson kits and omitting the hundreds of individual specimens amassed by BRCA staff and donated by Davis. Tran completed a detailed inventory to aid interpretive staff in locating and understanding the fossils and rocks in their collection in spring 2023.

While most of the BRCA interpretive collections are not from the park, an important highlight of these objects is the inclusion of two boxes of ichnofossils collected by Davis and Singler in August of 2015. Notably, these were collected from at least one known locality, UMNH IP 59 (now BRCA 57). Davis collected from at least two other localities in the Claron Formation of BRCA which produced snails and ichnofossils. At the time of inventory, there was no record of locality data available in BRCA databases. The ichnofossils and petrographic samples collected from these localities served as the basis for two presentations at the Geological Society of America meeting in 2015 (Davis et al. 2015; Singler et al. 2015). Tran transported these specimens to the Prehistoric Museum at Price, Utah for storage and curation on December 12, 2023. They will be accessioned into the BRCA museum collections under number BRCA-00599.

Exhibits

BRCA exhibited specimen BRCA 588 (Figure 12). This was collected by Ellis LeFevre (likely a Panguitch/Tropic local) in the 1960s and was identified by Dr. Theodore White, first paleontologist of Dinosaur National Monument, as a proboscidean jaw or tooth. BRCA 588 was on display in the Visitor Center with that identification label until NPS paleontologist Jason Kenworthy reidentified the specimen as a hadrosaur jaw in 2006. The specimen was returned to the multi-park museum repository at ZION when the Visitor Center exhibits underwent reconstruction and renovation c. 2015.

The 2015–2017 Visitor Center renovation produced an interpretive exhibit on the geology of the Grand Staircase region. Several casts representative of each of the steps of the Grand Staircase are integral to the exhibit (Figure 32). These include casts of *Eocyclotosaurus* and *Grallator* sp. representing the Moenkopi and Navajo Sandstone Formations of ZION and the Escalante area, an ammonite representing the Tropic Shale of GSENM and BRCA, and *Parowanichnus* sp. from the white member of the Claron Formation in BRCA.

A cast of the large mosasaur *Tylosaurus proriger* was, for a time, prominently displayed in a glass case inside the front of the Visitor Center (Figure 33). The cast was intended to represent the vertebrates of the Tropic Shale at BRCA, although mosasaurs had not been formally described from the formation until recently. In 2023, the case was moved near the restrooms for unknown reasons. Coincidentally, a new mosasaur from the Tropic Shale in the Glen Canyon Recreation Area (GLCA) was named and published in June 2023. This taxon, *Sarabosaurus dahli*, represents the oldest member of the group in the Western Interior Seaway (Polcyn et al. 2023) and opens the possibility of recovering mosasaur material from the Tropic Shale at BRCA.

Figure 32. The most prominent display of fossil casts in the BRCA Visitor Center main exhibit hall. This display is intended to broadly represent the fossils of the Grand Staircase region. From left to right: A snail (Claron Formation), mosasaur tooth (Tropic Shale), *Grallator* dinosaur track (Navajo and Kayenta Formations), and a damaged *Eocyclotosaurus* cast (Moenkopi Formation) (NPS / TUT TRAN).

Figure 33. A cast of a skull of the mosasaur *Tylosaurus proriger*, intended to represent the vertebrate fauna of the Tropic Shale at BRCA, positioned by the women's restroom inside the park's Visitor Center (NPS / TUT TRAN).

Paleontology-Themed Events

BRCA organizes an annual two-day Geology Festival (GeoFest). Historically, fossils have featured as a geologically related topic in activities targeted at school-aged children. This was especially true in 2019, when the Bryce Canyon Natural History Association heavily incorporated Cretaceous paleontology in its GeoFest advertising. However, GeoFest has rarely shone a spotlight on the fossils recorded inside the park. The arrival of dedicated paleontology staff at BRCA in 2022 allowed this to change. That summer, Scientists in Parks intern Dakota Pittinger compiled photographs of specimens from the BRCA museum collections to represent the faunas of the park's fossiliferous strata. BRCA paleontology featured more prominently in the 2023 GeoFest due to the efforts of Tran and Bonham. They ran an outreach table amidst a large group of paleontologists and geologists from several partner organizations (ZION, the Bureau of Land Management, several Utah state parks, the Utah Geological Survey, Dixie National Forest, Southern Utah University, and the St. George Dinosaur Discovery Site). Furthermore, Tran specifically highlighted the ongoing paleontological inventory at

BRCA in a public evening program and invited naturalist Christa Sadler to lead a similar presentation on the fossils of GSENM.

Although paleontology should share space with other geological topics at GeoFest, the event presents an opportunity to share and translate ongoing fossil research in the park to the public in a more engaging and up-to-date manner than is feasible through everyday interpretive operations. The 2023 BRCA GeoFest highlights the event's potential to expound upon geological and paleontological education in the southern Utah region, especially to an international public audience of park visitors.

BRCA has not yet hosted a National Fossil Day (NFD) event. However, Tran supported and participated in the NFD event hosted by ZION on October 11, 2023. ZION's NFD event, much like BRCA's 2023 Geology Festival, gathered paleontologists, resources managers, and interpreters from the region (e.g., Glen Canyon National Recreation Area, BRCA, Grand Canyon-Parashant National Monument, Tule Springs Fossil Beds National Monument, Dixie National Forest, St. George Dinosaur Discovery Site) to conduct outreach on southern Utah's paleontological resources. Future BRCA staff should act similarly in supporting and participating in partner organizations' NFD events to promote interagency synergy in outreach messaging.

Recommended Interpretive Themes

I. General Paleontological Information

All of the following interpretation topics include a section instructing visitors how to be paleontologically aware while in the park. The ranger will provide the visitor with advice on why fossils are important, how paleontologists look for fossils, what to do if fossils are found, and reminders to be aware that fossils exist and should be respected within park boundaries.

- Fossils are non-renewable resources that possess scientific and educational information and provide insight into what Earth was like thousands and even hundreds of millions of years ago.
- When paleontologists survey for paleontological resources, the most important tool for planning is a geologic map. Paleontological resources are more common in certain geologic units, so knowing where those units are exposed is important for a successful search. Other tools that a paleontologist takes into the field include a field notebook for recording data and observations, small picks and brushes, consolidants to stabilize fossils, GPS, camera, topographic maps, and appropriate First Aid and safety equipment. It might be helpful to provide examples of these items for visitors when giving an interpretive talk.
- If fossils are found in the park by a visitor, the visitor should photograph it and notify a ranger of where the resource was found, but most importantly, they should leave the fossil where they found it. It is extremely important for scientific and resource management purposes for locational information to be preserved. Visitors should be informed that park fossils are protected by law.

II. Fossils of BRCA

- A program could be developed to educate the public on what types of fossils are present in BRCA and what they tell scientists about Earth's dynamic history. The goal of this program is to increase visitors' understanding of local geology and paleontology. Therefore, information regarding fossils from the vicinity of BRCA can be included.
- BRCA interpretive have developed educational social media posts about fossils from the park in 2022 and 2023, utilizing visuals such as Figure 34. Staff should continue to promote the park's paleontology program through these channels.

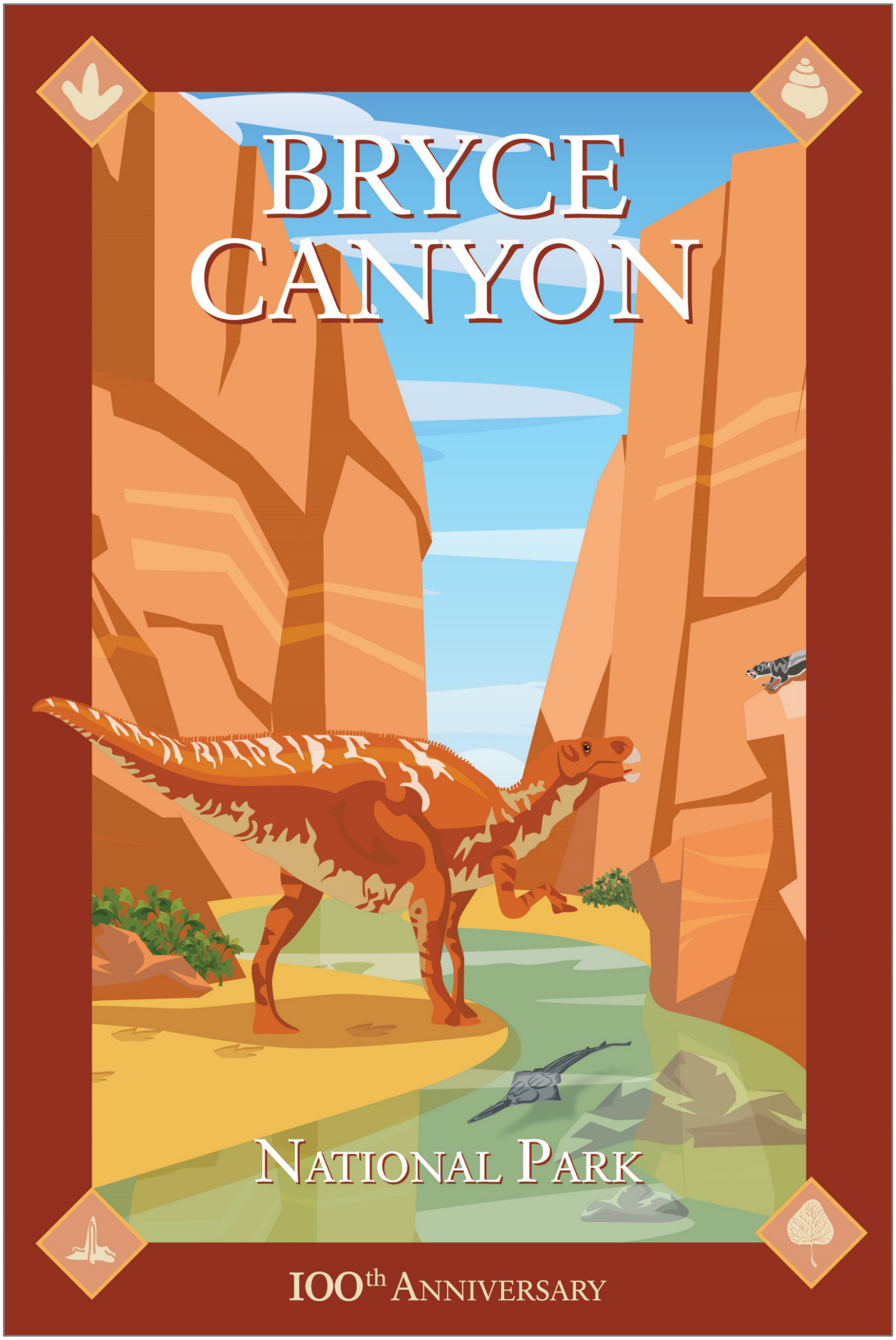

Figure 34. Reconstruction of the Wahweap Formation at BRCA, representing the hadrosaur natural footprint casts recorded at BRCA 44, *Texatrygon brycensis* (Kirkland et al. 2013), and a multituberculate mammal. Illustrated by Tom Conant – Studio 105 (NPS)

III. Further Interpretation Themes

BRCA should be sure to promote their paleontological resources and provide additional opportunities or programs for visitors to learn about fossils on National Fossil Day, celebrated annually on Wednesday of the second full week in October (National Earth Science Week). For more information on this event visit: https://www.nps.gov/subjects/fossilday/index.htm. The NPS coordinates the National Fossil Day partnership and hosts fossil-focused events across the country. Conducting one or more paleontology-focused activities on this day would be a perfect opportunity to not only increase public awareness about paleontological resources in BRCA, but also to connect with other parks and museums that are also participating in this national event. The NPS Geologic Resources Division can assist with planning for National Fossil Day activities and provide Junior Paleontologist Program supplies including activity booklets, badges, posters and other fossil-related educational resources (https://www.nps.gov/subjects/fossils/junior-paleontologist.htm).

Paleontological Resource Management and Protection

National Park Service Policy

Paleontological resources are non-renewable remains of past life preserved in a geologic context. At present, there are 429 official units of the National Park System, plus national rivers, national trails, and affiliated units that are not included in the official number. Of these, 286 are known to have some form of paleontological resources, and paleontological resources are mentioned in the enabling legislation of 18 units. Fossils possess scientific and educational values and are of great interest to the public; therefore, it is exceedingly important that appropriate management attention be placed on protecting, monitoring, collecting, and curating these non-renewable paleontological specimens from federal lands. In March 2009, the Paleontological Resources Preservation Act (PRPA) was signed into law as part of the Omnibus Public Land Management Act of 2009. The new paleontology-focused legislation includes provisions related to inventory, monitoring, public education, research and collecting permits, curation, and criminal/civil prosecution associated with fossils from designated Department of Interior (DOI) lands. More information on laws, policies, and authorities governing NPS management of paleontological resources is detailed in Appendix D. Paleontological resource protection training is available for NPS staff through the NPS Paleontology Program. The Paleontology Program is also available to provide support in investigations involving paleontological resource theft or vandalism.

Between 2009 and 2022 an interagency coordination team including representatives from the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), National Park Service (NPS) and U.S. Fish & Wildlife Service (FWS) developed the DOI final regulations for PRPA. The draft DOI regulations were published in the Federal Register in December 2016 and were available for 60 days to allow for public comment. The interagency team has reviewed public comments provided for the draft regulation and have incorporated these into the final regulation. The final regulation was surnamed by the DOI Solicitor's Office and each of the four bureau directors. On August 2, 2022 the DOI Paleontological Resources Preservation Act final regulation was published in the Federal Register. After 30 days the Office of Management and Budget approved the final DOI PRPA regulation, which is available at the following website: https://www.federalregister.gov/documents/2022/08/02/2022-16405/paleontological-resources-preservation. For more information regarding this act, visit https://www.nps.gov/subjects/fossils/fossil-protection.htm.

2006 National Park Service Management Policies (section 4.8.2.1) state

> *… Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion.*

Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.

The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.

All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

Fossils have scientific, aesthetic, cultural, educational, and tourism value, and impacts to any of these values impairs their usefulness. Effective paleontological resource management protects fossil resources by implementing strategies that mitigate, reduce, or eliminate loss of fossilized materials and their relevant data. Because fossils are representatives of adaptation, evolution, and diversity of life through deep time, they have intrinsic scientific values beyond just the physical objects themselves. Their geological and geospatial contexts provide additional critical data concerning paleoenvironmental, paleogeographic, paleoecologic, and a number of other conditions that together allow for a more complete interpretation of the physical and biological history of the earth. Therefore, paleontological resource management must act to protect not only the fossils themselves, but to collect and maintain other contextual data as well.

In general, losses of paleontological resources result from naturally occurring physical processes, by direct or indirect human activities, or by a combination of both. These processes or activities influence the stability and condition of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). The greatest loss of associated contextual data occurs when fossils are removed from their original geological context without appropriate documentation. Thus, when a fossil weathers and erodes from its surrounding sediments and geologic context, it begins to lose significant ancillary data until, at some point, it becomes more a scientific curiosity than a useful piece of scientific data. A piece of loose fossil “float” can still be of scientific value. However, when a fossil has been completely removed from its original context, such as an unlabeled personal souvenir or a specimen with no provenance information in a collection, it is of very limited scientific utility. Similarly, inadvertent exhumation of fossils during roadway construction or a building excavation may result in the loss or impairment of the scientific and educational values associated with those fossils. It is not necessary to list here all of the natural and anthropogenic factors that can lead to the loss of paleontological resources; rather it is sufficient to acknowledge that anything that disturbs native sediment or original bedrock has potential to result in the loss of the paleontological resources that occur there, or the loss of associated paleontological resource data.

Cave localities are in a distinct class for management due to the close connection with archeological resources and unique issues affecting cave resources. See Santucci et al. (2001) for additional discussion of paleontological resources in cave settings.

Management strategies to address any of these conditions and factors could also incorporate the assistance of qualified specialists to collect and document resources rather than relying solely on staff to accomplish such a large task at BRCA. Active recruitment of paleontological research scientists should also be used as a management strategy.

Baseline Paleontology Resource Data Inventories

A baseline inventory of paleontological resources is critical for implementing effective management strategies, as it provides information for decision-making. This inventory report has compiled information on previous paleontological research done in and near BRCA, taxonomic groups that have been reported within BRCA boundaries, and localities that were previously reported. This report can serve as a baseline source of information for future research, inventory reports, monitoring, and paleontological decisions. The Paleontological Resource Inventory and Monitoring reports for the Northern Colorado Plateau I&M Network completed by Koch and Santucci (2002) and Tweet et al. (2012) and the references cited within were important baseline paleontological resource data sources for this BRCA-specific report.

Paleontological Resource Monitoring

Paleontological resource monitoring is a significant part of paleontological resource management, and one which usually requires little to implement beyond time and equipment already on hand, such as cameras and GPS units. Monitoring enables the evaluation of the condition and stability of in situ paleontological resources (Santucci and Koch 2003; Santucci et al. 2009). A monitoring program revolves around periodic site visits to assess conditions compared to a baseline for that site, with the periodicity depending on factors such as site productivity, accessibility, and significance of management issues. For example, a highly productive site which is strongly affected by erosion or unauthorized collection, and which can be easily visited by park staff, would be scheduled for more frequent visits than a less productive or less threatened site.

A monitoring program is generally implemented after an inventory has been prepared for a park and sites of concern have been identified, with additional sites added as necessary. Because each park is different, with different geology and paleontology among other factors, ideally each park that has in situ fossils or significant accumulations of reworked fossils would have its own monitoring protocol to define its monitoring program. Data accumulated via monitoring is used to inform further management decisions, such as the following questions: Is the site suitable for interpretation and education? Does the site require stabilization from the elements? Is collection warranted? Is there a need for some form of law enforcement presence?

Collection is recommended to be reserved for fossils possessing exceptional value (e.g., rare or high scientific significance) or at immediate risk of major degradation or destruction by human activity and natural processes. Therefore, paleontological resource monitoring is a more feasible potential management tool. The first step in the establishment of a monitoring program is identification of localities to be monitored, as discussed previously. Locality condition forms are then used to evaluate factors that could cause loss of paleontological resources, with various conditions at each locality rated as good, fair, or poor. Risks and conditions are categorized as Disturbance, Fragility, Abundance, and Site Access. "Disturbance" evaluates conditions that promote accelerated erosion or mass wasting resulting from human activities. "Fragility" evaluates natural conditions that may influence the degree to which fossil transportation is occurring. Sites with elevated fragility exhibit inherently soft rapidly eroding sediment or mass wasting on steep hillsides. A bedrock outcrop that is strongly lithified has low fragility. "Abundance" judges both the natural condition and number of specimens preserved at the locality as well as the probability of being recognized as a fossil-rich area by non-paleontologists, which could lead to unpermitted collecting. "Site Access" assesses the risk of a locality being visited by large numbers of visitors or the potential for easy removal of large quantities of fossils or fossil-bearing sediments. A locality with high access would be in close proximity to public use areas or other access (along trails, at roadcuts, at beach or river access points, and so on).

Each of the factors noted above may be mitigated by management actions. Localities exhibiting a significant degree of disturbance may require either active intervention to slow accelerated erosion, periodic collection and documentation of fossil materials, or both. Localities developed on sediments of high fragility naturally erode at a relatively rapid rate and would require frequent visits to document and/or collect exposed fossils in order to prevent or reduce losses. Localities with abundant or rare fossils, or high rates of erosion, may be considered for periodic monitoring in order to assess the stability and condition of the locality and resources, in regard to both natural processes and human-related activities. Localities that are easily accessible by road or trail would benefit from the same management strategies as those with abundant fossils and by occasional visits by park staff, documentation of in situ specimens, and/or frequent law enforcement patrols. Further information on paleontological resource monitoring can be found in Santucci and Koch (2003) and Santucci et al. (2009).

Foundation Documents and Resource Stewardship Strategies

Foundation documents and Resource Stewardship Strategies are two types of park planning documents that may contain and reference paleontological resource information. A foundation document is intended to provide basic guidance about a park for planning and management. It briefly describes a given park and its purpose, significance, fundamental resources and values, other important resources and values, and interpretive themes. Mandates and commitments are also identified, and the state of planning is assessed. Foundation documents may include paleontological information and are also useful as a preliminary assessment of what a park's staff know about their paleontological resources, the importance they place on these resources, and the present state of these non-renewable resources. A foundation document for BRCA has been published (NPS 2014).

A Resource Stewardship Strategy (RSS) is a strategic plan intended to help park managers achieve and maintain desired resource conditions over time. It offers specific information on the current state of resources and planning, management priorities, and management goals over various time frames. An RSS for BRCA has not been published, but there is a natural resource condition assessment (Baril et al. 2018).

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at or beneath the land surface (Evans 2016). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the age and lowercase letters indicating the formation's name. The American Geosciences Institute website (https://www.americangeosciences.org/environment/publications/mapping) provides more information about geologic maps and their uses. The NPS Geologic Resources Inventory (GRI) has been digitizing existing maps of NPS units and making them available to parks for resource management.

Geologic maps are one of the foundational elements of a paleontological resource management program. Knowing which sedimentary rocks and deposits underlie a park and where they are exposed are essential for understanding the distribution of known or potential paleontological resources. The ideal scale for resource management in the 48 contiguous states is 1:24,000 (maps for areas in Alaska tend to be coarser). Whenever possible, page-sized geologic maps derived from GRI files are included in paleontological resource inventory reports for reference, but it is recommended that GRI source files be downloaded from IRMA for use. The source files can be explored in much greater detail and incorporated into the park GIS database. Links to the maps digitized by the GRI for BRCA can be found in IRMA at https://irma.nps.gov/DataStore/Reference/Profile/2164782. It should be noted that the digital files are based on Bowers (1991), and newer source maps have not yet been incorporated. In addition to a digital GIS geologic map, the GRI program also produces a park-specific geologic resource evaluation report discussing the geologic setting, distinctive geologic features and processes within the park, highlighting geologic issues facing resource managers, and describing the geologic history leading to the present-day landscape of the park. The report for BRCA is Thornberry-Ehrlich (2005).

Paleontological Resource Potential Maps

A paleontological resource potential map is included in this report (Figure 35). The map shows the distribution of geologic units within a park that are known to have yielded fossils within the park (green on Figure 35), or have not yielded fossils within the park but are fossiliferous elsewhere (yellow). This map gives a quick indication of areas where fossils may be discovered, which in turn can provide suggestions for areas to survey or monitor, or areas where the discovery of fossils may be of concern during work that disturbs the ground (road work, building construction, etc.).

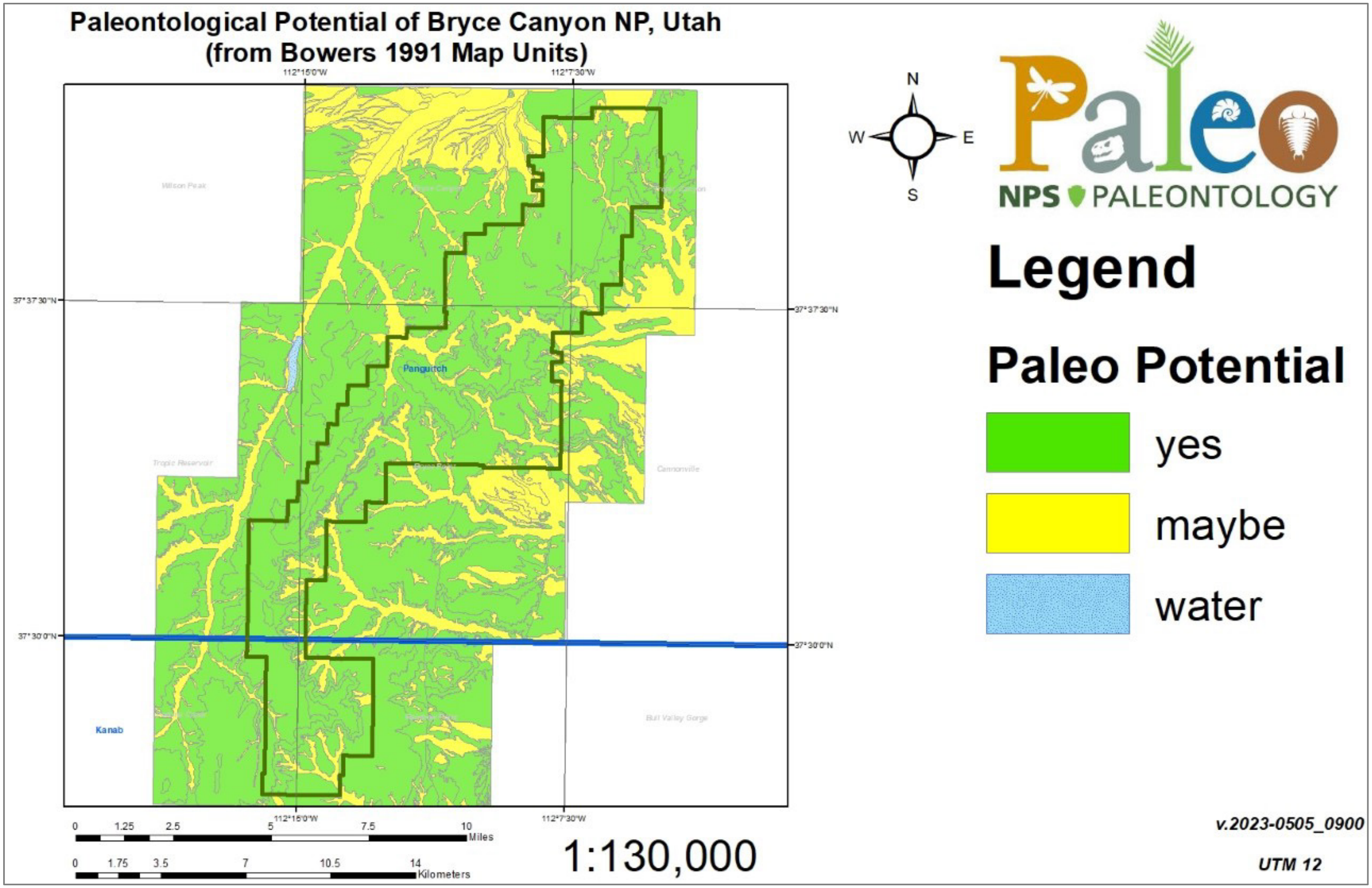

Figure 35. Map indicating paleontological potential of geologic map units in BRCA (NPS / TIM CONNORS).

Paleontological Resource Management Recommendations

The paleontological resource inventory at BRCA has documented diverse and previously unrecognized paleontological resources. This report captures the scope, significance, and distribution of fossils at BRCA as well as provides recommendations to support the management and protection of the park's non-renewable paleontological resources.

- BRCA staff should be encouraged to observe exposed rocks and sedimentary deposits for fossil material while conducting their usual duties. To promote this, staff should receive guidance regarding how to recognize common local fossils. When opportunities arise to observe paleontological resources in the field and take part in paleontological field studies with trained paleontologists, staff should take advantage of them, if funding and time permit.
- BRCA staff should photo-document and monitor any occurrences of paleontological resources that may be observed in situ. Fossils and their associated geologic context (surrounding rock) should be documented but left in place unless they are subject to imminent degradation. A Geologic Resource Monitoring Manual published by the Geological Society of America and NPS Geologic Resources Division (GRD) includes a chapter on paleontological resource monitoring (Santucci et al. 2009). Santucci and Koch (2003) also present information on paleontological resource monitoring.
- Fossil theft is one of the greatest threats to the preservation of paleontological resources and any methods to minimize these activities should be utilized by staff. Any occurrence of paleontological resource theft or vandalism should be investigated by a law enforcement ranger. When possible, incidents should be fully documented and the information submitted for inclusion in the annual law enforcement statistics.
- Fossils found in a cultural context should be documented like other fossils but will also require the input of an archeologist or a cultural resource specialist. Any fossil which has a cultural context may be culturally sensitive as well (e.g., subject to NAGPRA) and should be regarded as such until otherwise established. The Geologic Resources Division can coordinate additional documentation/research of such material.
- The park may fund and recruit paleontology interns as a cost-effective means of enabling some level of paleontological resource support. The Scientists in Parks Program is an established program for recruitment of geology and paleontology interns.
- Contact the NPS Paleontology Program for technical assistance with paleontological resource management issues.

If fossil specimens are found by BRCA staff, it is recommended they follow the steps outlined below to ensure proper paleontological resource management.

- Photo-document the specimen without moving it from its location, if it is loose. Include a common item, such as a coin, pen, or pencil, for scale if a ruler or scale bar is not available.
- If a GPS unit is available, record the location of the specimen. If GPS is not available, record the general location within BRCA and height within the outcrop, if applicable. If possible,

revisit the site when a GPS unit is available. Most smartphones also have the ability to record coordinates; if no GPS unit is available, attempt to record the coordinates with a phone.

- Write down associated data, such as rock type, general description of the fossil, type of fossil if identifiable, general location in BRCA, sketch of the fossil, position within the outcrop or if it is loose on the ground, any associated fossils, and any other additional information.
- Do not remove the fossil unless it is loose in an area of heavy traffic, such as a public trail, and is at risk of being taken or destroyed. If the fossil is removed, be sure to wrap in soft material, such as tissue paper, and place in a labeled plastic bag with associated notes.

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Appendix A: Paleontological Species

The following table (Table 3) documents the fossil plant, invertebrate, and vertebrate taxa found at BRCA in stratigraphic context, as reported in the literature, in museum collections, and through personal observations. The rows are organized systematically, placing taxa of the same broad groups together. The columns are organized by formation, which are presented in ascending order (oldest to youngest) left to right. The columns also include the taxon (first column) and references (last column; included in "Literature Cited" above). Taxa listed without references were encountered during the 2022–2023 field inventory, recorded in the BRCA museum collections, or both. If a taxon is present in a given formation at a locality that can be placed within BRCA, that cell is marked "Y". A null record is marked "–". Fossils not identifiable beyond a general level (e.g., petrified wood) are not included.

Abbreviations: **Kt**, Tropic Shale; **Ks**, Straight Cliffs Formation, undifferentiated; **Kss**, Straight Cliffs Formation, Smoky Hollow Member; **Ksj**, Straight Cliffs Formation, John Henry Member; **Ksd**, Straight Cliffs Formation, Drip Tank Member; **Kw**, Wahweap Formation; **Tc**, Claron Formation.

Table 3. Fossil taxa reported from BRCA in stratigraphic context. References are provided where appropriate.

Group	Taxon	Kt	Ks	Kss	Ksj	Ksd	Kw	Tc	References
Plantae: Angiosperms	*Celtis* sp.	–	–	–	–	–	–	Y	–
	cf. *Cercidiphyllum*	–	–	–	Y	–	–	–	–
	cf. *Sabalites*	–	–	–	–	–	Y	–	–
	cf. *Saliciphyllum*	–	–	–	Y	–	–	–	–
	Menispermaceae indet.	–	–	–	Y	–	–	–	–
Mollusca: Bivalvia	*Anomia* sp.	Y	–	–	–	–	–	–	Reeside 1939
	Bivalvia indet.	–	–	–	–	–	Y	–	Meyers and Knauss 2021; Eaton 2022
	Corbicula (*Cyrena*) *securis*	Y	–	–	–	–	–	–	Reeside 1939
	Corbicula (*Cyrena*) *sequilateralis*	Y	–	–	–	–	–	–	Reeside 1939
	Corbula sp.	–	Y	–	–	–	–	–	–
	Exogyra columbella	Y	–	–	–	–	–	–	Reeside 1939
	Inoceramus pictus	Y	–	–	–	–	–	–	Cobban 1996
	Inoceramus sp.	Y	–	–	–	–	–	–	Reeside 1937; Cobban 1996
	Nymphalucina juvensis	Y	–	–	–	–	–	–	Cobban 1996
	Ostrea prudentia	Y	–	–	–	–	–	–	Reeside 1937
	Ostrea soleniscus	Y	–	–	–	–	–	–	Reeside 1939
	Phelopteria sp.	Y	–	–	–	–	–	–	–
	Psilomya meeki	Y	–	–	–	–	–	–	Cobban 1996
	Pycnodonte newberryi	Y	–	–	–	–	–	–	Cobban 1996
	Unionidae indet.	–	–	–	–	–	–	Y	–
	Volsella sp.	Y	–	–	–	–	–	–	Reeside 1939
Mollusca: Ammonoidea	*Allocrioceras annulatum*	Y	–	–	–	–	–	–	Cobban 1996
	Ammonoidea indet.	Y	–	–	–	–	–	–	–
	Baculites gracilis	Y	–	–	–	–	–	–	Reeside 1937
	Baculites sp.	Y	–	–	–	–	–	–	–
	Baculites yokoyamai	Y	–	–	–	–	–	–	Cobban 1996
	Burroceras irregulare	Y	–	–	–	–	–	–	Cobban 1996

Table 3 (continued). Fossil taxa reported from BRCA in stratigraphic context. References are provided where appropriate.

Group	Taxon	Kt	Ks	Kss	Ksj	Ksd	Kw	Tc	References
Mollusca: Ammonoidea (continued)	*Collignoniceras woollgari*	Y	–	–	–	–	–	–	G. Pollock, pers. comm., 2023
	Euomphaloceras septemseriatum	Y	–	–	–	–	–	–	Cobban 1996
	Mammites nodosoides	Y	–	–	–	–	–	–	Cobban 1996
	Metoicoceras geslinianum	Y	–	–	–	–	–	–	Cobban 1996
	Prionocyclus hyatti	Y	–	–	–	–	–	–	Cobban 1996
	Sciponoceras gracile	Y	–	–	–	–	–	–	Cobban 1996
Mollusca: Gastropoda	*Admetopsis* sp.	–	–	Y	–	–	Y	–	Hoffman 2005
	Euspira sp.	Y	–	–	–	–	–	–	Cobban 1996
	Mesocochliopa sp.	–	–	–	–	–	Y	–	Cobban 1996
	Neritina bellatula	Y	–	–	–	–	–	–	Reeside 1937
	Neritina incompta	Y	–	–	–	–	–	–	Cobban 1996
	Perissoptera prolabiata	Y	–	–	–	–	–	–	Cobban 1996
	Physa cf. *P. bridgerensis*	–	–	–	–	–	–	–	Reeside 1939
	Physa pleromatis	–	–	–	–	–	–	Y	Reeside 1939
	Physa sp.	–	–	–	–	–	Y	Y	Cobban 1996
	Reesidella sp.	–	–	–	–	–	Y	–	Cobban 1996
	Turritella whitei	Y	–	–	–	–	–	–	Cobban 1996
	Viviparus sp.	Y	Y	–	–	–	Y	Y	Cobban 1996
Arthropoda: Ostracoda	Ostracoda indet.	–	Y	–	–	–	Y	–	Meyers and Knauss 2021; Eaton 2022
Chondrichthyes	*Brachyrhizodus* sp.	–	–	–	Y	–	–	–	Williamson et al. 2011
	Chiloscyllium missouriense	–	–	–	–	–	Y	–	Kirkland et at. 2013
	Columbusia deblieuxi	–	–	–	–	–	Y	–	Kirkland et al. 2013
	Cristomylus cifellii	–	–	–	–	–	Y	–	Kirkland et al. 2013
	Lonchidion sp.	–	–	–	Y	–	–	–	Kirkland et al. 2013
	Texatrygon brycensis	–	–	–	–	–	Y	–	Kirkland et al. 2013
Osteichthyes	Acanthomorpha gen and sp. indet.	–	–	–	Y	–	Y	–	Brinkman et al. 2013
	Amia sp.	–	–	–	–	–	Y	–	Brinkman et al. 2013

Table 3 (continued). Fossil taxa reported from BRCA in stratigraphic context. References are provided where appropriate.

Group	Taxon	Kt	Ks	Kss	Ksj	Ksd	Kw	Tc	References
Osteichthyes (continued)	Euteleostei gen and sp. indet. U-4	–	–	–	Y	–	–	–	Brinkman et al. 2013
	Hiodontidae gen and sp. indet.	–	–	–	Y	–	–	–	Brinkman et al. 2013
	Lepidotes sp.	–	–	–	–	–	Y	–	Brinkman et al. 2013
	Lepisosteus sp.	–	–	Y	Y	–	Y	Y	Brinkman et al. 2013; UMNH PB Loc. 61
	Micropycnodon sp.	–	–	–	–	–	Y	–	Brinkman et al. 2013
	Otophysi gen and sp. indet.	–	–	–	Y	–	Y	–	Brinkman et al. 2013
	Parabula sp.	–	–	–	–	–	Y	–	Brinkman et al. 2013
	Teleostei gen and sp. indet. Type O	–	–	–	Y	–	–	–	Brinkman et al. 2013
Amphibia	Albanerpetontidae gen and sp. indet.	–	–	–	Y	–	Y	–	Gardner and DeMar 2013
	Anura indet. morph 1	–	–	–	–	–	Y	–	Roček et al. 2010; Gardner et al. 2016
	cf. *Albanerpeton nexuosum*	–	–	–	Y	–	–	–	Gardner and DeMar 2013
	Gen and sp. indet.	–	–	–	Y	–	–	–	Roček et al. 2010; Gardner and DeMar 2013
	Habrosaurus sp.	–	–	–	Y	–	–	–	Gardner and DeMar 2013; Gardner et al. 2013
	Nezpercius dodsoni	–	–	–	–	–	Y	–	Gardner and DeMar 2013
	Opisthotriton kayi	–	–	–	–	–	–	–	Gardner and DeMar 2013
	Opisthotriton sp.	–	–	–	Y	–	–	–	Gardner and DeMar 2013; Gardner et al. 2013
	Scapherpeton tectum	–	–	–	–	–	Y	–	Gardner and DeMar 2013
	Scapherpeton sp.	–	–	–	Y	–	Y	–	Gardner and DeMar 2013; Gardner et al. 2013
	Scotiophryne pustulosa	–	–	–	Y	–	Y	–	Roček et al. 2010, 2013; Gardner and DeMar 2013
	Urodela new gen. and sp.	–	–	–	Y	–	Y	–	Gardner et al. 2013
Reptilia: Testudines	*Adocus* sp.	–	–	–	Y	–	Y	–	Meyers and Knauss 2021
	Aspideretes sp.	–	–	–	–	–	Y	–	–
	Baenidae indet.	–	Y	–	–	–	Y	–	–
	Bothremys sp.	–	–	–	–	–	Y	–	–

Table 3 (continued). Fossil taxa reported from BRCA in stratigraphic context. References are provided where appropriate.

Group	Taxon	Kt	Ks	Kss	Ksj	Ksd	Kw	Tc	References
Reptilia: Testudines (continued)	Chelydridae indet.	–	–	–	–	–	Y	–	–
	Compsemys sp.	–	–	–	–	–	Y	–	Eaton et al. 1998; Meyers and Knauss 2021
	Naomichelys sp.	–	Y	–	–	–	Y	–	Eaton 1999a
	Neurankylus sp.	–	Y	–	–	–	Y	–	–
	Trionychidae indet.	–	Y	–	–	–	Y	–	–
Reptilia: Squamata	Autarchoglossa fam. indet. Morphotype D	–	–	–	Y	–	–	–	Nydam 2013
	cf. *Colpodontosaurus* sp.	–	–	–	Y	–	–	–	Nydam 2013
	Chamops segnis	–	–	–	–	–	Y	–	Eaton et al. 1998
	Coniophis sp.	–	–	–	Y	–	–	–	Nydam 2013
	Contogenys sp.	–	–	–	–	–	Y	–	Eaton et al. 1998
	Monocnemodon syphakos	–	–	–	Y	–	–	–	Nydam 2013
	Platynota fam. indet. morphotype B	–	–	–	Y	–	–	–	Nydam 2013
	Platynota fam. indet. morphotype C	–	–	–	Y	–	–	–	Nydam 2013
	Scincomorpha indet.	–	–	–	Y	–	–	–	Nydam 2013
Reptilia: Crocodylomorpha	Crocodylomorpha indet.	–	–	Y	Y	Y	Y	–	–
	Eusuchia indet.	–	–	–	Y	–	–	–	Irmis et al. 2013
	Mesoeucrocodylia indet.	–	–	–	Y	–	–	–	Irmis et al. 2013
	Neosuchia indet.	–	–	–	Y	–	–	–	Irmis et al. 2013
	Unnamed clade of Atoposauridae + Eusuchia indet.	–	–	–	Y	–	–	–	Irmis et al. 2013
Reptilia: Theropoda	Dromaeosauridae indet.	–	–	–	–	–	Y	–	–
	Theropoda indet.	–	Y	Y	–	–	Y	–	–
Reptilia: Ornithischia	Ankylosauria indet	–	–	–	Y	–	Y	–	Eaton et al. 1998
	Ceratopsidae indet.	–	–	–	–	–	Y	–	Eaton et al. 1998
	Hadrosauridae indet.	–	–	–	–	–	Y	–	Eaton et al. 1998
	Hadrosauromorpha indet.	–	Y	Y	Y	Y	–	–	–

Table 3 (continued). Fossil taxa reported from BRCA in stratigraphic context. References are provided where appropriate.

Group	Taxon	Kt	Ks	Kss	Ksj	Ksd	Kw	Tc	References
Mammalia: Multituberculata	?*Cimolomys* sp. A	–	–	–	Y	–	–	–	Eaton 2013
	Cedaromys sp. cf. *C. hutchisoni*	–	–	–	Y	–	Y	–	Eaton 2013
	Cimolodon similis	–	–	–	Y	–	Y	–	Eaton 2002
	Cimolodon sp.	–	–	–	–	–	Y	–	Eaton 2013
	Cimolodon sp. cf. *C. foxi*	–	–	–	Y	–	–	–	Eaton 2013
	Cimolodon sp. cf. *C. similis*	–	–	–	Y	–	–	–	Eaton 2013
	Cimolomys sp.	–	–	–	–	–	Y	–	Eaton 2013
	Cimolomys sp. B	–	–	–	Y	–	Y	–	Eaton 2002
	Dakotamys shakespeari	–	–	–	Y	–	–	–	Eaton 2013
	Gen. et sp. indet.	–	–	–	–	–	Y	–	Eaton 2002
	Meniscoessus sp.	–	–	–	–	–	Y	–	Eaton 2013
	Mesodma sp.	–	–	–	Y	–	–	–	Eaton 2013
	Mesodma sp. cf. *M. formosa*	–	–	–	–	–	Y	–	Eaton 1993b, 2013
	Mesodma sp. cf. *M. minor*	–	–	–	Y	–	Y	–	Eaton 2013
Mammalia: Triconodonta	cf. *Alticonodon* sp.	–	–	–	Y	–	–	–	Eaton 2013
	Gen, et sp. indet	–	–	–	Y	–	–	–	Eaton 2013
Mammalia: Trechnotheria	?*Spalacotheridium* sp.	–	–	–	Y	–	–	–	Eaton 2013
	Symmetrodontoides sp.	–	–	–	Y	–	–	–	Eaton 2013
Mammalia: Marsupialia	"Didelphomorphia" gen. et sp. indet.	–	–	–	Y	–	–	–	Eaton 2013
	?*Leptalestes* sp.	–	–	–	Y	–	–	–	Eaton 2013
	?*Varalphodon* sp.	–	–	–	Y	–	–	–	Eaton 2013
	Apistodon sp. cf. *A. exiguous*	–	–	–	Y	–	–	–	Eaton 2013
	Didelphidae indet.	–	–	–	Y	–	–	–	Eaton 2013
	Eodelphis sp.	–	–	–	Y	–	–	–	Eaton 2013
	Pediomyidae gen. et sp. indet.	–	–	–	–	–	Y	–	Eaton 2013

Table 3 (continued). Fossil taxa reported from BRCA in stratigraphic context. References are provided where appropriate.

Group	Taxon	Kt	Ks	Kss	Ksj	Ksd	Kw	Tc	References
Mammalia: Marsupialia (continued)	Pediomyidae sp.	–	–	–	Y	–	–	–	Eaton 2013
	Varalphadon sp. cf. *V. creber*	–	–	–	Y	–	–	–	Eaton 2013

Appendix B: Museum Collections Data

This appendix includes data for BRCA's paleontological collections. As of October 2023, the collections are reposited in three institutions: internally (ZION; Table 4), the Museum of Northern Arizona (MNA; Table 5), and the Natural History Museum of Utah (formerly the Utah Museum of Natural History; the acronym UMNH is retained for collections). Note that NHMU is not given a table. This is because there are currently 1,489 BRCA catalog numbers representing more than 12,000 individual specimens reposited at NHMU, which makes containing all pertinent data in a table here impractical. Researchers should contact BRCA and NHMU curatorial staff for data on specimens reposited at NHMU (see Appendix C).

A third table is included in this appendix to list the numerous specimens in the BRCA paleontological collections that have been figured and described in the scientific literature (Table 6). This information has not been previously available to park staff in an easily accessible format. Publications in Table 6 are listed in alphabetical order by author and year, and specimens are listed by ordered appearance in the cited text.

Abbreviations: **Jm**, Morrison Formation (not present in BRCA); **Kn**, Naturita Formation; **Kt**, Tropic Shale; **Ks**, Straight Cliffs Formation; **Kw**, Wahweap Formation; **Kk**, Kaiparowits Formation (not present in BRCA, but some BRCA records are misidentified as such); **Tc**, Claron Formation; **Q seds**., Quaternary sediments; **Fm**, formation; **Mbr**, member.

Table 4. Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 6	BRCA-00028	Kt	Mollusca: Ammonoidea	–
BRCA 21	BRCA-00032	Kt	Mollusca: Bivalvia	–
BRCA 26	BRCA-00033	–	Mollusca: Bivalvia	–
BRCA 35	BRCA-00037	Kk	Reptilia	Reptilia bone
BRCA 43	BRCA-00039	–	Plantae	Silicified wood
BRCA 45	BRCA-00041	Kt	Mollusca: Ammonoidea	–
BRCA 47	BRCA-00017	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 48	BRCA-00017	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 49	BRCA-00017	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 50	BRCA-00017	Tc	Mollusca: Gastropoda	–
BRCA 51	BRCA-00017	Tc	Mollusca: Gastropoda	–
BRCA 52	BRCA-00017	Tc	Reptilia	Reptilia vertebrae
BRCA 53	BRCA-00017	Tc	Reptilia	Testudines carapace
BRCA 54	BRCA-00017	Tc	Reptilia	Reptilia bone
BRCA 55	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 56	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 57	BRCA-00017	Tc	Mollusca: Gastropoda	–
BRCA 58	BRCA-00017	Tc	Mollusca: Gastropoda	–
BRCA 59	BRCA-00017	Tc	Mollusca: Gastropoda	–

Table 4 (continued). Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 60	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 61	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 62	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 63	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 64	BRCA-00017	Tc	Mollusca: Gastropoda	–
BRCA 102	BRCA-00018	Kt	Mollusca: Ammonoidea	–
BRCA 103	BRCA-00018	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 104	BRCA-00017	Tc	Mollusca: Bivalvia	–
BRCA 105	BRCA-00018	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 106	BRCA-00018	Kt	Mollusca: Bivalvia	–
BRCA 107	BRCA-00018	Kt	Mollusca: Bivalvia	–
BRCA 108	BRCA-00019	Kk	Mollusca: Bivalvia	–
BRCA 109	BRCA-00019	Kk	Mollusca: Bivalvia	–
BRCA 110	BRCA-00019	Kk	Mollusca: Bivalvia	–
BRCA 111	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 112	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 113	BRCA-00019	Kk	Mollusca: Bivalvia	–
BRCA 114	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 115	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 116	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 117	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 118	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 119	BRCA-00019	Kt	Mollusca: Bivalvia	–
BRCA 120	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 121	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 122	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 123	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 124	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 125	BRCA-00019	Kt	Mollusca: Cephalopoda	–
BRCA 126	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 127	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 128	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 129	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 130	BRCA-00019	Kt	Mollusca: Cephalopoda	–
BRCA 131	BRCA-00019	Kt	Mollusca: Cephalopoda	–
BRCA 132	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 133	BRCA-00019	Kt	Mollusca: Ammonoidea	*Baculites*
BRCA 134	BRCA-00019	Kt	Mollusca: Cephalopoda	–
BRCA 135	BRCA-00019	Kt	Mollusca: Cephalopoda	–

Table 4 (continued). Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 136	BRCA-00019	Kt	Mollusca: Cephalopoda	–
BRCA 137	BRCA-00019	Kt	Mollusca: Cephalopoda	–
BRCA 138	BRCA-00019	Kt/Kk	Brachiopoda	–
BRCA 139	BRCA-00019	–	Mollusca: Gastropoda	–
BRCA 140	BRCA-00019	Kk	Mollusca: Gastropoda	–
BRCA 141	BRCA-00019	Kk	Mollusca: Gastropoda	–
BRCA 142	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 143	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 144	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 145	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 146	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 147	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 148	BRCA-00019	Kt	Mollusca: Gastropoda	–
BRCA 149	BRCA-00020	Kt	Mollusca: Gastropoda	–
BRCA 228	BRCA-00023	–	Plantae	Anthophyta prints
BRCA 268	BRCA-00051	–	Reptilia	Reptilia bone
BRCA 269	BRCA-00051	–	Mollusca: Ammonoidea	–
BRCA 270	BRCA-00051	–	Invertebrata: Annelida	Annelida trail
BRCA 271	BRCA-00051	–	Plantae	Cycadaceae
BRCA 272	BRCA-00051	–	Plantae	–
BRCA 285	BRCA-00051	–	Reptilia: Archosauria	Archosauria track
BRCA 286	BRCA-00051	–	Plantae: Angiospermae	Dicotyledoneae mold
BRCA 289	BRCA-00051	–	Plantae: Angiospermae	Dicotyledoneae
BRCA 290	BRCA-00051	–	Plantae	–
BRCA 291	BRCA-00051	–	Plantae	–
BRCA 292	BRCA-00051	–	Reptilia	–
BRCA 293	BRCA-00051	–	Reptilia	–
BRCA 294	BRCA-00051	–	Reptilia	–
BRCA 295	BRCA-00051	–	Plantae	Betulaceae
BRCA 296	BRCA-00051	–	Reptilia	–
BRCA 297	BRCA-00051	–	Plantae: Gymnospermae	Petrified Coniferophyta
BRCA 298	BRCA-00051	–	Plantae: Angiospermae	Dicotyledoneae mold
BRCA 299	BRCA-00051	–	Plantae: Gymnospermae	Petrified Coniferophyta
BRCA 300	BRCA-00051	–	Reptilia	–
BRCA 301	BRCA-00051	–	Reptilia	–
BRCA 302	BRCA-00051	–	Reptilia	–
BRCA 303	BRCA-00051	–	Reptilia	–
BRCA 304	BRCA-00051	–	Plantae: Gymnospermae	Petrified Coniferophyta
BRCA 306	BRCA-00051	–	Mollusca: Gastropoda	–

Table 4 (continued). Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 307	BRCA-00051	–	Mollusca: Gastropoda	–
BRCA 308	BRCA-00051	–	Mollusca: Gastropoda	–
BRCA 309	BRCA-00051	–	Mollusca: Gastropoda	–
BRCA 310	BRCA-00051	–	Mollusca: Gastropoda	–
BRCA 311	BRCA-00051	–	Mollusca: Bivalvia	–
BRCA 312	BRCA-00051	–	Plantae	–
BRCA 320	BRCA-00051	–	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 322	BRCA-00051	–	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 323	BRCA-00051	–	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 324	BRCA-00051	–	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 325	BRCA-00051	–	Plantae: Angiospermae	Monocotyledoneae
BRCA 326	BRCA-00051	–	Plantae	Cycadaceae
BRCA 337	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 338	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 339	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 340	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 341	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 342	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 343	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 344	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 345	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 346	BRCA-00054	Kt/Kn	Reptilia	–
BRCA 347	BRCA-00054	Kt/Kn	Plantae: Gymnospermae	Petrified Coniferophyta
BRCA 348	BRCA-00054	Kt/Kn	Plantae: Gymnospermae	Petrified Coniferophyta
BRCA 356	BRCA-00058	Kt/Kn	Plantae: Gymnospermae	Petrified Coniferophyta
BRCA 357	BRCA-00058	Jm	Plantae	Silicified wood
BRCA 371	BRCA-00062	Kk	Reptilia: Archosauria	Archosauria bone
BRCA 372	BRCA-00062	Kk	Plantae	Silicified wood
BRCA 414	BRCA-00064	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 422	BRCA-00067	Kt	Mollusca: Bivalvia	*Gryphaea newberryi*
BRCA 429	BRCA-00067	Kt	Mollusca	–
BRCA 430	BRCA-00067	Ks	Plantae	Petrified wood
BRCA 434	BRCA-00067	Kk	Mollusca: Bivalvia	–
BRCA 502	BRCA-00073	Tc	Mollusca: Gastropoda	–
BRCA 554	BRCA-00080	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 586	BRCA-00095	–	Mollusca: Bivalvia	–
BRCA 587	BRCA-00095	–	Mollusca: Bivalvia	–
BRCA 588	BRCA-00096	–	Reptilia: Ornithischia	Hadrosauromorph dentary (originally identified as a proboscidean jawbone)

Table 4 (continued). Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 589	BRCA-00097	–	Mollusca: Gastropoda	–
BRCA 604	BRCA-00101	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 605	BRCA-00102	–	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 608	BRCA-00105	Tc	Plantae: Angiospermae	Anthophyta seeds
BRCA 609	BRCA-00106	Tc	Mollusca	–
BRCA 611	BRCA-00108	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 612	BRCA-00109	Tc	Mollusca: Gastropoda	*Physa pleromatis*
BRCA 664	BRCA-00129	Tc	Plantae: Angiospermae	Anthophyta mold
BRCA 665	BRCA-00129	Tc	Plantae: Angiospermae	Anthophyta mold
BRCA 666	BRCA-00129	–	Mollusca: Gastropoda	–
BRCA 667	BRCA-00129	–	Plantae	Fossilized wood
BRCA 924	BRCA-00225	Kt	Mollusca: Gastropoda	–
BRCA 925	BRCA-00225	–	Mollusca	Mollusca sp.
BRCA 926	BRCA-00224	Tc	Plantae	Fossilized wood
BRCA 927	BRCA-00225	Kt	Mollusca: Gastropoda	–
BRCA 928	BRCA-00225	Kt	Mollusca: Bivalvia	–
BRCA 929	BRCA-00225	Kt	Mollusca: Gastropoda	–
BRCA 930	BRCA-00225	Kt	Brachiopoda	–
BRCA 931	BRCA-00222	Kt	Mollusca: Gastropoda	–
BRCA 932	BRCA-00222	Kt	Mollusca: Gastropoda	–
BRCA 1600	BRCA-00225	Kt	Plantae	Silicified wood
BRCA 1601	BRCA-00225	Kt	Mollusca: Gastropoda	–
BRCA 1602	BRCA-00223	Tc	Mollusca: Gastropoda	–
BRCA 2548	BRCA-00238	Ks	Reptilia: Testudines	*Neurankylus* epiplastron
BRCA 2549	BRCA-00238	Ks?	Reptilia: Testudines	Trionychidae
BRCA 2550	BRCA-00238	Ks?	Reptilia: Testudines	*Adocus*
BRCA 2551	BRCA-00238	Ks	–	Indet. fossil samples
BRCA 2552	BRCA-00238	Ks?	Mollusca: Gastropoda	–
BRCA 2553	BRCA-00238	Kw	–	Indet. fossil samples
BRCA 2554	BRCA-00238	Kw	Reptilia: Testudines	Trionychidae
BRCA 2555	BRCA-00238	Kw	Reptilia: Testudines	*Adocus*
BRCA 2556	BRCA-00238	Kw	Reptilia: Testudines	Baenidae
BRCA 2557	BRCA-00238	Kw	Reptilia: Testudines	Trionychidae
BRCA 2558	BRCA-00238	Kw	Reptilia: Crocodylomorpha	Crocodilia
BRCA 2559	BRCA-00238	Kw	–	Indet. fossil fragments
BRCA 2560	BRCA-00238	Kw	Reptilia: Testudines	*Compsemys*
BRCA 2561	BRCA-00238	Kw	Reptilia: Testudines	*Adocus*
BRCA 2562	BRCA-00238	Kw	Reptilia: Testudines	*Naomichelys*
BRCA 2563	BRCA-00238	Kw	Reptilia: Testudines	Baenidae

Table 4 (continued). Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 2564	BRCA-00238	Kw	Animalia: Chordata	Indet. fossil bone
BRCA 2565	BRCA-00238	Kw	Reptilia: Testudines	*Compsemys*
BRCA 2566	BRCA-00238	Kw	Reptilia: Testudines	Baenid
BRCA 2567	BRCA-00238	Kw	Reptilia: Testudines	Trionychidae
BRCA 3788	BRCA-00238	Kw	Animalia: Chordata	Indet. bones
BRCA 3789	BRCA-00238	Kw	Animalia: Chordata	Indet. teeth
BRCA 3790	BRCA-00238	Kw	Animalia: Chordata	Indet. tooth
BRCA 3791	BRCA-00238	Kw	–	–
BRCA 3792	BRCA-00238	Kw	Reptilia: Testudines	*Compsemys*
BRCA 3793	BRCA-00238	Kw	Reptilia: Testudines	Trionychidae
BRCA 3794	BRCA-00238	Kw	Reptilia: Testudines	*Bothremys*
BRCA 3795	BRCA-00238	Kw	Reptilia: Testudines	*Adocus*
BRCA 3796	BRCA-00238	Kw	Reptilia: Testudines	*Neurankylus*
BRCA 3797	BRCA-00238	Kw/Kk?	Mollusca: Gastropoda	–
BRCA 3798	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Adocus*
BRCA 3799	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Trionychidae
BRCA 3800	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Trionychidae
BRCA 3801	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Chelydrid
BRCA 3802	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Adocus*
BRCA 3803	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Trionychidae
BRCA 3804	BRCA-00238	Kw/Kk?	Mollusca: Gastropoda	–
BRCA 3805	BRCA-00238	Kw/Kk?	–	Indet. fossils
BRCA 3806	BRCA-00238	Kw/Kk?	–	Indet. fossils
BRCA 3807	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Trionychidae
BRCA 3808	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Naomichelys*
BRCA 3809	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Aspideretes*
BRCA 3810	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Baenid
BRCA 3811	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Trionychidae
BRCA 3812	BRCA-00238	Kw/Kk?	–	Indet. fossil
BRCA 3813	BRCA-00238	Kw/Kk?	–	Indet. bone
BRCA 3814	BRCA-00238	Kw/Kk?	Mollusca: Gastropoda	–
BRCA 3815	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Neurankylus*
BRCA 3816	BRCA-00238	Kw/Kk?	Reptilia: Testudines	Trionychidae
BRCA 3817	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Adocus*
BRCA 3818	BRCA-00238	Kw/Kk?	Reptilia: Testudines	*Naomichelys*
BRCA 3819	BRCA-00238	Kw/Kk?	Mollusca: Gastropoda / Animalia: Chordata	Indet. gastropods and bone
BRCA 3820	BRCA-00238	Kw/Kk?	Animalia: Chordata	Indet. tooth
BRCA 3821	BRCA-00238	Kw/Kk?	Animalia: Chordata	Indet. tooth

Table 4 (continued). Paleontological specimens cataloged exclusively in the BRCA paleontological collections.

Catalog #	Accession #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID
BRCA 3822	BRCA-00352	Q seds.	Plantae	–
BRCA 3823	BRCA-00352	Q seds.	Plantae: Gymnospermae	*Pinus edulis* Englm.
BRCA 3824	BRCA-00352	Q seds.	Plantae: Gymnospermae	*Pinus ponderosa* Lawson
BRCA 3825	BRCA-00352	Q seds.	Mammalia: Rodentia	*Neotoma* sp.
BRCA 3826	BRCA-00352	Q seds.	Plantae: Angiospermae	*Oryzopsis hymenoides* (R.& S.) Ricker
BRCA 3827	BRCA-00352	Q seds.	Plantae: Angiospermae	*Echinocereus* sp.
BRCA 3828	BRCA-00352	Q seds.	Animalia: Chordata	Vertebrata indet.
BRCA 3829	BRCA-00352	Q seds.	Plantae: Angiospermae	*Rhus trilobata* Nutt.
BRCA 3830	BRCA-00352	Q seds.	Plantae: Gymnospermae	*Pseudotsuga menziesii* (Mirb.) Franco
BRCA 3831	BRCA-00352	Q seds.	Plantae: Angiospermae	*Quercus* sp.
BRCA 3832	BRCA-00352	Q seds.	Plantae: Angiospermae	*Quercus gambelii* Nutt.
BRCA 3833	BRCA-00352	Q seds.	Plantae: Angiospermae	*Berberis repens* Lindl
BRCA 3834	BRCA-00352	Q seds.	Plantae: Angiospermae	*Juniperus* sp.
BRCA 3835	BRCA-00352	Q seds.	Plantae: Angiospermae	*Juniperus osteosperma* (Torr.) Little
BRCA 3836	BRCA-00352	Q seds.	Plantae: Angiospermae	*Juniperus scopulorum sarg.*
BRCA 3837	BRCA-00352	Q seds.	–	Composite
BRCA 6362	BRCA-00238	Kw	Reptilia: Ornithischia	Hadrosauridae
BRCA 6363	BRCA-00238	–	Reptilia: Ornithischia	Hadrosauridae
BRCA 6364	BRCA-00238	Kw	Reptilia: Ornithischia	Hadrosauridae
BRCA 6365	BRCA-00238	Kw	Reptilia: Ornithischia	Hadrosauridae
BRCA 6366	BRCA-00238	Kw	Reptilia: Ornithischia	Hadrosauridae
BRCA 6367	BRCA-00238	Kw	Reptilia: Ornithischia	Hadrosauridae
BRCA 6368	BRCA-00238	Kw	Reptilia: Ornithischia	Hadrosauridae
BRCA 8125	BRCA-00352	Q seds.	Arthropoda: Insecta	–

Table 5. Table of BRCA paleontological specimens curated and reposited at the Museum of Northern Arizona (MNA).

Catalog #	Accession #	MNA Catalog #	Fm/Mbr	General Taxonomic ID	Specific Taxonomic ID	Locality #
BRCA 2941	BRCA-00447	MNA N9694	Ks	Mollusca: Bivalvia	*Corbula*	MNA-1125
BRCA 2942	BRCA-00447	MNA N9695	Ks	Mollusca: Bivalvia	*Corbula*	MNA-1126
BRCA 2943	BRCA-00447	MNA VN9696	Ks	Mollusca: Bivalvia	*Corbula*	MNA-1128
BRCA 2944	BRCA-00447	MNA N9697	Ks	Mollusca: Gastropoda	–	MNA-1128
BRCA 2945	BRCA-00447	MNA N9698	Kw	Mollusca: Gastropoda	–	MNA-1133
BRCA 2946	BRCA-00447	MNA N9699	Kw	Mollusca: Gastropoda	–	MNA-1133
BRCA 2947	BRCA-00447	MNA V10548	Kw	Osteichthyes	Lepisosteiformes	MNA-1124
BRCA 2953	BRCA-00447	MNA V10554	Ks	Osteichthyes	Lepisosteiformes	MNA-1125
BRCA 2954	BRCA-00447	MNA V10555	Ks	Osteichthyes	–	MNA-1125
BRCA 2955	BRCA-00447	MNA V10556	Ks	Osteichthyes	Lepisosteiformes	MNA-1128
BRCA 2956	BRCA-00447	MNA V10557	Ks	Reptilia: Testudines	–	MNA-1128
BRCA 2957	BRCA-00447	MNA V10558	Ks	Reptilia: Crocodylomorpha	–	MNA-1128
BRCA 2958	BRCA-00447	MNA V10559	Ks	Reptilia	–	MNA-1128
BRCA 2959	BRCA-00447	MNA V10560	Ks	Reptilia: Ornithischia	–	MNA-1132 / BRCA 148
BRCA 2960	BRCA-00447	MNA V10570	Kw	Reptilia	–	MNA-1133
BRCA 2961	BRCA-00448	MNA V10564	Ks	Reptilia: Testudines	–	MNA-1210
BRCA 6851	BRCA-00238	MNA N9700	Kw	Mollusca: Gastropoda	–	MNA-1191
BRCA 6852	BRCA-00238	MNA N9701	Kw	Mollusca: Gastropoda	–	MNA-1191
BRCA 6853	BRCA-00238	MNA V10573	Kw	Reptilia: Testudines	Testudines	MNA-1197
BRCA 6854	BRCA-00448	MNA V10565	Ks	Reptilia: Testudines	Testudines	MNA-1210
BRCA 6855	BRCA-00448	MNA V10566	Ks	Reptilia: Testudines	Testudines	MNA-1210
BRCA 6856	BRCA-00448	MNA V10567	Ks	Reptilia: Crocodylomorpha	Crocodylia	MNA-1210
BRCA 6857	BRCA-00448	MNA V10568	Ks	Undetermined	Coprolite	MNA-1210
BRCA 6858	BRCA-00448	MNA V10569	Ks	Reptilia	–	MNA-1210
BRCA 6859	BRCA-00238	MNA V10561	Ks	Reptilia: Ornithischia	Ornithischia	MNA-1175 / BRCA 154
BRCA 6860	BRCA-00238	MNA V10562	Kw	Reptilia: Ornithischia	Ornithischia	MNA-1190
BRCA 6861	BRCA-00238	MNA V10563	Kw	Reptilia: Ornithischia	Ornithischia	MNA-1194
BRCA 6862	BRCA-00238	MNA V9341	Kw	Reptilia: Saurischia	Theropoda	MNA-1184
BRCA 6863	BRCA-00238	MNA V9342	Kw	Reptilia: Saurischia	Theropoda	MNA-1188

Table 6. Specimens in the BRCA paleontological collections that have been figured and/or described in the scientific literature. This table is organized by cited publication, and specimens are ordered by appearance in the cited text. Holotype specimens are indicated with an asterisk (*) and shown **bolded**. **Anatomical abbreviations**: **D,** deciduous (milk tooth); **L**, upper left; **l**, lower left; **mx**, molar X; **px**, premolar X; **R**, upper right; **r**, lower right.

Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Brinkman et al. 2013	10.20A	Otophysi indet. Type U-3	BRCA 8113	UMNH VP 19137	BRCA 124	UMNH VP 424	centrum
	10.21A	Otophysi indet. Type U-3	BRCA 8114	UMNH VP 19138	BRCA 124	UMNH VP 424	centrum
	10.23B	Euteleostei indet. Type U-4	BRCA 8112	UMNH VP 19136	BRCA 124	UMNH VP 424	centrum
	10.28C	Acanthomorpha indet.	BRCA 8115	UMNH VP 19139	BRCA 124	UMNH VP 424	centrum
Eaton 2002	20A, B	*Cimolodon similis*	BRCA 5653	UMNH VP 7592	BRCA 102	UMNH VP 77	Rp4
	23H, I	Cimolomyidae indet.	BRCA 5660	UMNH VP 7599	BRCA 102	UMNH VP 77	Rp4
Eaton 2013	15.4A	Triconodontidae indet.	BRCA 8458	UMNH VP 19003	BRCA 124	UMNH VP 424	rm?
	15.4B	cf. *Alticonodon* sp.	BRCA 7899	UMNH VP 17292	BRCA 124	UMNH VP 424	Rm?
	15.4C	*Mesodma* sp. Cf. *M. minor*	BRCA 7204	UMNH VP 14128	BRCA 124	UMNH VP 424	Rm1?
	15.4D	*Mesodma* sp. Cf. *M. minor*	BRCA 7206	UMNH VP 14130	BRCA 124	UMNH VP 424	Lm1
	15.4F	*Mesodma* sp. Cf. *M. minor*	BRCA 7220	UMNH VP 14144	BRCA 124	UMNH VP 424	rm1
	15.4G	*Mesodma* sp. Cf. *M. minor*	BRCA 7278	UMNH VP 14413	BRCA 124	UMNH VP 424	rm1
	15.4H	*Mesodma* sp. Cf. *M. minor*	BRCA 7209	UMNH VP 14133	BRCA 124	UMNH VP 424	rm1
	15.4IJ	*Mesodma* sp.	BRCA 7943	UMNH VP 17332	BRCA 124	UMNH VP 424	lp4
	15.4KL	?*Mesodma* sp.	BRCA 7254	UMNH VP 14246	BRCA 124	UMNH VP 424	rp4
	15.4M, N	?*Mesodma* sp.	BRCA 7207	UMNH VP 14131	BRCA 124	UMNH VP 424	lp4
	15.5C	*Cimolodon* sp. cf. *C. foxi*	BRCA 7218	UMNH VP 14142	BRCA 124	UMNH VP 424	Lm1
	15.5D	*Cimolodon* sp. cf. *C. foxi*	BRCA 7974	UMNH VP 17336	BRCA 124	UMNH VP 424	Rm1
	15.5E	*Cimolodon* sp. cf. *C. foxi*	BRCA 7885	UMNH VP 17278	BRCA 124	UMNH VP 424	rm1
	15.5G, H	*Cimolodon similis*	BRCA 7262	UMNH VP 14254	BRCA 124	UMNH VP 424	Rp4
	15.5K	*Cimolodon similis*	BRCA 7234	UMNH VP 14227	–	UMNH VP 420	rm2
	15.6B	*Cimolodon* sp. cf. *C. similis*	BRCA 7936	UMNH VP 17325	BRCA 124	UMNH VP 424	lm1
	15.6G	*Cimolodon* sp. B	BRCA 1894	UMNH VP 12859	–	UMNH VP 420	lm2
	15.6H, I	?*Cimolomys* sp. A	BRCA 7446	UMNH VP 17208	BRCA 124	UMNH VP 424	rp4
	15.6K	***Dakotamys shakespeari* ***	**BRCA 3020**	**UMNH VP 19160**	**BRCA 21**	**UMNH VP 1156**	**lm1**
	15.6L	*Dakotamys shakespeari*	BRCA 7239	UMNH VP 14231	BRCA 124	UMNH VP 424	rm2

Table 6 (continued). Specimens in the BRCA paleontological collections that have been figured and/or described in the scientific literature. This table is organized by cited publication, and specimens are ordered by appearance in the cited text. Holotype specimens are indicated with an asterisk (*) and shown **bolded**. **Anatomical abbreviations**: **D,** deciduous (milk tooth); **L**, upper left; **l**, lower left; **mx**, molar X; **px**, premolar X; **R**, upper right; **r**, lower right.

Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Eaton 2013 (continued)	15.6M	*Cedaromys* sp. cf. *C. hut*chisoni	BRCA 7225	UMNH VP 14149	BRCA 124	UMNH VP 424	Lm1
	15.6N	*Cedaromys* sp. cf. *C. hutchisoni*	BRCA 7201	UMNH VP 14125	BRCA 124	UMNH VP 424	rm2
	15.7A, B	?*Spalacotherium* sp.	BRCA 7227	UMNH VP 14151	BRCA 124	UMNH VP 424	Rm6 or 7
	15.7C, D	?*Spalacotherium* sp.	BRCA 7901	UMNH VP 17294	BRCA 124	UMNH VP 424	Lm4?
	15.7EF	*Symmetrodontoides* sp.	BRCA 5885	UMNH VP 12860	BRCA 124	UMNH VP 424	Lm6?
	15.7G	*Symmetrodontoides* sp.	BRCA 7223	UMNH VP 14147	BRCA 124	UMNH VP 424	rm4?
	15.8A	“Didelphimorphia” indet.	BRCA 7679	UMNH VP 18769	BRCA 124	UMNH VP 424	lm2
	15.8B	“Didelphimorphia” indet.	BRCA 7680	UMNH VP 18770	BRCA 124	UMNH VP 424	lm2?
	15.8C	*Apistodon* sp. cf. *A. exiguus*	BRCA 7212	UMNH VP 14136	BRCA 124	UMNH VP 424	rm2
	15.8D	*Apistodon* sp. cf. *A. exiguus*	BRCA 7240	UMNH VP 14232	BRCA 124	UMNH VP 424	rm2
	15.8E	*Apistodon* sp. cf. *A. exiguus*	BRCA 7443	UMNH VP 17205	BRCA 124	UMNH VP 424	lm2
	15.8G	*Apistodon* sp. cf. *A. exiguus*	BRCA 7226	UMNH VP 14150	BRCA 124	UMNH VP 424	rm2
	15.8H	*Apistodon* sp. cf. *A. exiguus*	BRCA 7942	UMNH VP 17331	BRCA 124	UMNH VP 424	rm2
	15.8I	*Apistodon* sp. cf. *A. exiguus*	BRCA 7935	UMNH VP 17324	BRCA 124	UMNH VP 424	rm2
	15.8J, K	*Apistodon* sp. cf. *A. exiguus*	BRCA 7992	UMNH VP 17380	BRCA 124	UMNH VP 424	rm3
	15.8M	*Apistodon* sp. cf. *A. exiguus*	BRCA 7881	UMNH VP 17274	BRCA 124	UMNH VP 424	rm4
	15.9B	?*Varalphodon* sp.	BRCA 7257	UMNH VP 14249	BRCA 124	UMNH VP 424	rm3
	15.9C	?*Varalphodon* sp.	BRCA 7202	UMNH VP 14126	BRCA 124	UMNH VP 424	rm3
	15.9D	?*Varalphodon* sp.	BRCA 7453	UMNH VP 17215	BRCA 124	UMNH VP 424	lm4
	15.9E	?*Varalphodon* sp.	BRCA 7454	UMNH VP 17216	BRCA 124	UMNH VP 424	lm4
	15.10A, B	Indeterminate didelphid	BRCA 7249	UMNH VP 14241	BRCA 124	UMNH VP 424	RDp3
	15.10C, D	Indeterminate didelphid	BRCA 7876	UMNH VP 17269	BRCA 124	UMNH VP 424	Lm1
	15.10E, F	Indeterminate didelphid	BRCA 3019	UMNH VP 19159	BRCA 21	UMNH VP 1156	Rm1 or 2
	15.10G, H	Indeterminate didelphid	BRCA 7281	UMNH VP 14146	BRCA 124	UMNH VP 424	Lm1

Table 6 (continued). Specimens in the BRCA paleontological collections that have been figured and/or described in the scientific literature. This table is organized by cited publication, and specimens are ordered by appearance in the cited text. Holotype specimens are indicated with an asterisk (*) and shown **bolded**. **Anatomical abbreviations**: **D,** deciduous (milk tooth); **L**, upper left; **l**, lower left; **mx**, molar X; **px**, premolar X; **R**, upper right; **r**, lower right.

Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Eaton 2013 (continued)	15.10K, L	Indeterminate didelphid	BRCA 7216	UMNH VP 14140	BRCA 124	UMNH VP 424	Lm4?
	15.10M, N	Indeterminate didelphid	BRCA 3026	UMNH VP 19166	BRCA 21	UMNH VP 1156	Lm4
	15.11A	*Eodelphis* sp.	BRCA 7677	UMNH VP 18767	BRCA 124	UMNH VP 424	Rmx
	15.11B	Pediomyidae indet.	BRCA 7967	UMNH VP 17356	BRCA 124	UMNH VP 424	LDp3
	15.11C	?*Leptalestes* sp.	BRCA 7215	UMNH VP 14139	BRCA 124	UMNH VP 424	rm1?
	15.12A	?*Paracimexomys* sp.	BRCA 7637	UMNH VP 17972	–	UMNH VP 807	Rm2
	15.12B	?*Paracimexomys* sp.	BRCA 7913	UMNH VP 17309	–	UMNH VP 792	Lm2
	15.12C	*Cedaromys* sp. cf. *C. hutchisoni*	BRCA 8337	UMNH VP 17491	–	UMNH VP 807	Lm1
	15.12D	*Cedaromys* sp. cf. *C. hutchisoni*	BRCA 5930	UMNH VP 7664	BRCA 102	UMNH VP 77	Rm2
	15.12H	*Mesodma* cf. *M. formosa*	BRCA 5964	UMNH VP 14273	BRCA 102	UMNH VP 77	Lm2
	15.12J	*Cimolomys* sp.	BRCA 7640	UMNH VP 17975	–	UMNH VP 807	Lm2
	15.12L	*Meniscoessus* sp.	BRCA 8338	UMNH VP 17492	–	UMNH VP 807	Lm1
	15.13H	*Varalphadon* sp. cf. *V. creber*	BRCA 5667	UMNH VP 7560	BRCA 102	UMNH VP 77	rm2 or 3
	15.14A	Pediomyidae indet.	BRCA 7661	UMNH VP 7600	BRCA 102	UMNH VP 77	LDp3?
Gardner and DeMar 2013	2b	cf. *Albanerpeton nexuosum*	BRCA 7283	UMNH VP 14459	BRCA 124	UMNH VP 424	premaxillae
Gardner et al. 2013	11.5A–D	*Opisthotriton* sp.	BRCA 3042	UMNH VP 19189	BRCA 124	UMNH VP 424	atlantal centrum
	11.5E–H	*Opisthotriton* sp.	BRCA 3043	UMNH VP 19190	BRCA 124	UMNH VP 424	atlantal centrum
	11.5I–L	*Opisthotriton* sp.	BRCA 3044	UMNH VP 19192	BRCA 124	UMNH VP 424	trunk vertebra
	11.7A–F	*Habrosaurus* sp.	BRCA 3048	UMNH VP 19201	BRCA 124	UMNH VP 424	atlantal centrum
	11.8H, I	Urodela gen. et sp. nov.	BRCA 3051	UMNH VP 19204	BRCA 124	UMNH VP 424	trunk vertebra
	11.8J	Urodela gen. et sp. nov.	BRCA 3056	UMNH VP 19209	BRCA 102	UMNH VP 77	trunk vertebra
Gates et al. 2013	19.1A	Hadrosauromorpha indet.	BRCA 7235	UMNH VP 14266	BRCA 79	UMNH VP 568	toothless dentary
	19.1B	Hadrosauromorpha indet.	BRCA 6386	UMNH VP 17037	–	UMNH VP 787	toothless dentary

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Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Irmis et al. 2013	17.2A, B	Mesoeucrocodylia indet.	BRCA 7269	UMNH VP 14403	BRCA 124	UMNH VP 424	tooth
	17.2C, D	Neosuchia indet.	BRCA 7269	UMNH VP 14403	BRCA 124	UMNH VP 424	tooth
	17.2E, F	Eusuchia indet.	BRCA 7865	UMNH VP 17258	BRCA 124	UMNH VP 424	tooth
	17.2G, H	Neosuchia indet.	BRCA 7865	UMNH VP 17258	BRCA 124	UMNH VP 424	tooth
	17.2I, J	Eusuchia indet.	BRCA 7865	UMNH VP 17258	BRCA 124	UMNH VP 424	tooth
	17.2K, L	Neosuchia indet.	BRCA 7865	UMNH VP 17258	BRCA 124	UMNH VP 424	tooth
Kirkland et al. 2013	9.6CC, DD	Lonchidion sp.	BRCA 8451	UMNH VP 18922	BRCA 103	UMNH VP 417	tooth
	9.10A–E	*Chiloscyllium missouriense*	BRCA 8434	UMNH VP 18880	BRCA 102	UMNH VP 77	tooth
	9.10F–I	*Chiloscyllium missouriense*	BRCA 8436	UMNH VP 18882	BRCA 102	UMNH VP 77	tooth
	9.10J–L	*Chiloscyllium missouriense*	BRCA 8440	UMNH VP 18886	BRCA 102	UMNH VP 77	tooth
	9.10M–N	*Chiloscyllium missouriense*	BRCA 8441	UMNH VP 18887	BRCA 102	UMNH VP 77	tooth
	9.10O–R	*Chiloscyllium missouriense*	BRCA 8442	UMNH VP 18888	BRCA 102	UMNH VP 77	tooth
	9.10T-W	*Chiloscyllium missouriense*	BRCA 8435	UMNH VP 18881	BRCA 102	UMNH VP 77	tooth
	9.16J, K	*Cristomylus cifellii*	BRCA 6646	UMNH VP 17404	BRCA 102	UMNH VP 77	tooth
	9.16EE, FF	*Cristomylus cifellii*	BRCA 6643	UMNH VP 17401	BRCA 102	UMNH VP 77	tooth
	9.19A–C	*Columbusia deblieuxi*	BRCA 8431	UMNH VP 18877	BRCA 102	UMNH VP 77	tooth
	9.19D	*Columbusia deblieuxi*	BRCA 8433	UMNH VP 18879	BRCA 102	UMNH VP 77	tooth
	9.19E	*Columbusia deblieuxi*	BRCA 8427	UMNH VP 18836	BRCA 102	UMNH VP 77	tooth
	9.19F–J	*Columbusia deblieuxi*	BRCA 8430	UMNH VP 18876	BRCA 102	UMNH VP 77	tooth
	9.19K–O	***Columbusia deblieuxi* ***	**BRCA 8432**	**UMNH VP 18878**	**BRCA 102**	**UMNH VP 77**	**tooth**
	9.21A, B	*Texatrygon brycensis*	BRCA 8437	UMNH VP 18883	BRCA 102	UMNH VP 77	tooth
	9.21C, D	*Texatrygon brycensis*	BRCA 8436	UMNH VP 18882	BRCA 102	UMNH VP 77	tooth
	9.21E	*Texatrygon brycensis*	BRCA 8445	UMNH VP 18891	BRCA 102	UMNH VP 77	tooth
	9.21F	*Texatrygon brycensis*	BRCA 8446	UMNH VP 18892	BRCA 102	UMNH VP 77	tooth

Table 6 (continued). Specimens in the BRCA paleontological collections that have been figured and/or described in the scientific literature. This table is organized by cited publication, and specimens are ordered by appearance in the cited text. Holotype specimens are indicated with an asterisk (*) and shown **bolded**. **Anatomical abbreviations**: **D,** deciduous (milk tooth); **L**, upper left; **l**, lower left; **mx**, molar X; **px**, premolar X; **R**, upper right; **r**, lower right.

Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Kirkland et al. 2013 (continued)	**9.21G–K**	***Texatrygon brycensis* ***	**BRCA 8439**	**UMNH VP 18885**	**BRCA 102**	**UMNH VP 77**	**tooth**
	9.21L–P	*Texatrygon brycensis*	BRCA 8443	UMNH VP 18889	BRCA 102	UMNH VP 77	tooth
	9.21Q	*Texatrygon brycensis*	BRCA 8444	UMNH VP 18890	BRCA 102	UMNH VP 77	tooth
	9.21R	*Texatrygon brycensis*	BRCA 8438	UMNH VP 18894	BRCA 102	UMNH VP 77	tooth
	9.21S	*Texatrygon brycensis*	BRCA 8447	UMNH VP 18893	BRCA 102	UMNH VP 77	tooth
	9.21T	*Texatrygon brycensis*	????	UMNH VP 18896?	BRCA 102	UMNH VP 77	tooth
Nydam 2013	**16.9A**	***Monocnemodon syphakos* ***	**BRCA 7996**	**UMNH VP 17384**	**BRCA 124**	**UMNH VP 424**	**dentary**
	16.9D–F	cf. *Colpodontosaurus*	BRCA 3071	UMNH VP 19246	BRCA 124	UMNH VP 424	dentary
	16.9G	Platynota morphotype B	BRCA 3070	UMNH VP 19245	BRCA 124	UMNH VP 424	jaw fragment
	16.9H–K	Platynota morphotype C	BRCA 3072	UMNH VP 19247	BRCA 124	UMNH VP 424	dentary
	16.9L–N	Autarchoglossa morphotype D	BRCA 7620	UMNH VP 17928	BRCA 124	UMNH VP 424	frontal
	16.9O	Scincomorpha indet	BRCA 7953	UMNH VP 17342	BRCA 124	UMNH VP 424	osteoderms
	16.10A–D	*Coniophis* sp.	BRCA 3067	UMNH VP 19242	BRCA 124	UMNH VP 424	vertebra
	16.10E–L	*Coniophis* sp.	BRCA 3068	UMNH VP 19243	BRCA 124	UMNH VP 424	vertebra
Roček et al. 2010, 2013 (those from latter marked with *)	10Bgg-1, 2	Anura indet.	BRCA 6569	UMNH VP 18482	BRCA 124	UMNH VP 424	premaxilla
	10Aa-1, 2	Anura indet.	BRCA 7658	UMNH VP 18401	BRCA 124	UMNH VP 424	maxilla
	10Ab-1, 2	Anura indet.	BRCA 6775	UMNH VP 19341	–	UMNH VP 427	maxilla
	10Ac-1, 2	Anura indet.	BRCA 6776	UMNH VP 19342	–	UMNH VP 427	maxilla
	10Ae-1, 2	Anura indet.	BRCA 6620	UMNH VP 18318	–	UMNH VP 420	prearticular
	10Ad	Anura indet.	BRCA 6579	UMNH VP 18492	BRCA 124	UMNH VP 424	prearticular
	10Al-1–3	Anura indet.	BRCA 6800	UMNH VP 18386	BRCA 124	UMNH VP 424	trunk vertebra
	10Am-1–3	Anura indet.	BRCA 6802	UMNH VP 18388	BRCA 124	UMNH VP 424	trunk vertebra
	10Ak-1, 2	Anura indet.	BRCA 6804	UMNH VP 18390	BRCA 124	UMNH VP 424	trunk vertebra
	10Ah-1, 2	Anura indet.	BRCA 6806	UMNH VP 18392	BRCA 124	UMNH VP 424	trunk vertebra

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Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Roček et al. 2010, 2013 (those from latter marked with *) (continued)	10Ai-1–3	Anura indet.	BRCA 6557	UMNH VP 18470	BRCA 124	UMNH VP 424	trunk vertebra
	10Aj-1–4	Anura indet.	BRCA 6559	UMNH VP 18472	BRCA 124	UMNH VP 424	trunk vertebra
	10Ag-1, 2	Anura indet.	BRCA 3805	UMNH VP 18391	BRCA 124	UMNH VP 424	sacral vertebra
	10Af-1–3	Anura indet.	BRCA 6587	UMNH VP 18500	BRCA 124	UMNH VP 424	sacral vertebra
	10Bcc-1–3	Anura indet.	BRCA 6798	UMNH VP 18384	BRCA 124	UMNH VP 424	urostyle
	10Bdd-1–3	Anura indet.	BRCA 6799	UMNH VP 18385	BRCA 124	UMNH VP 424	urostyle
	10Bff-1, 2	Anura indet.	BRCA 6578	UMNH VP 18491	BRCA 124	UMNH VP 424	scapula
	10Bx	Anura indet.	BRCA 6811	UMNH VP 18397	BRCA 124	UMNH VP 424	humerus
	10Bq	Anura indet.	BRCA 6638	UMNH VP 18399	BRCA 124	UMNH VP 424	humerus
	10Bn	Anura indet.	BRCA 7657	UMNH VP 18400	BRCA 124	UMNH VP 424	humerus
	10Bu	Anura indet.	BRCA 7920	UMNH VP 18453	BRCA 124	UMNH VP 424	humerus
	10Bs	Anura indet.	BRCA 7921	UMNH VP 18454	BRCA 124	UMNH VP 424	humerus
	10Bv	Anura indet.	BRCA 7922	UMNH VP 18456	BRCA 124	UMNH VP 424	humerus
	10Bt	Anura indet.	BRCA 6556	UMNH VP 18469	BRCA 124	UMNH VP 424	humerus
	10Bm	Anura indet.	BRCA 6565	UMNH VP 18478	BRCA 124	UMNH VP 424	humerus
	10Br	Anura indet.	BRCA 6568	UMNH VP 18481	BRCA 124	UMNH VP 424	humerus
	10Bo	Anura indet.	BRCA 6590	UMNH VP 18503	BRCA 124	UMNH VP 424	humerus
	10Bw	Anura indet.	BRCA 6591	UMNH VP 18504	BRCA 124	UMNH VP 424	humerus
	10Bp	Anura indet.	BRCA 6592	UMNH VP 18505	BRCA 124	UMNH VP 424	humerus
	10Bz-1, 2	Anura indet.	BRCA 6616	UMNH VP 18314	–	UMNH VP 420	ilium
	10Bd-1, 2; 12.9*	Anura indet.	BRCA 6626	UMNH VP 18344	BRCA 78	UMNH VP 569	ilium
	10Ba-1, 2; 12.9*	Anura indet.	BRCA 6808	UMNH VP 18394	BRCA 124	UMNH VP 424	ilium
	10Bc-1, 2; 12.9*	Anura indet.	BRCA 6809	UMNH VP 18395	BRCA 124	UMNH VP 424	ilium

Table 6 (continued). Specimens in the BRCA paleontological collections that have been figured and/or described in the scientific literature. This table is organized by cited publication, and specimens are ordered by appearance in the cited text. Holotype specimens are indicated with an asterisk (*) and shown **bolded**. **Anatomical abbreviations**: **D,** deciduous (milk tooth); **L**, upper left; **l**, lower left; **mx**, molar X; **px**, premolar X; **R**, upper right; **r**, lower right.

Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Roček et al. 2010, 2013 (those from latter marked with *) (continued)	10Bbb-1–3; 12.9*	Anura indet.	BRCA 6810	UMNH VP 18396	BRCA 124	UMNH VP 424	ilium
	10Bb-1, 2; 12.9*	Anura indet.	BRCA 6558	UMNH VP 18471	BRCA 124	UMNH VP 424	ilium
	10Baa-1,2; 12.9*	Anura indet.	BRCA 6560	UMNH VP 18473	BRCA 124	UMNH VP 424	ilium
	10Bi; 12.9*	Anura indet.	BRCA 6561	UMNH VP 18474	BRCA 124	UMNH VP 424	ilium
	10Bg; 12.9*	Anura indet.	BRCA 6562	UMNH VP 18475	BRCA 124	UMNH VP 424	ilium
	10Bk; 12.9*	Anura indet.	BRCA 6563	UMNH VP 18476	BRCA 124	UMNH VP 424	ilium
	10Be; 12.9*	Anura indet.	BRCA 6564	UMNH VP 18477	BRCA 124	UMNH VP 424	ilium
	10Bf; 12.9*	Anura indet.	BRCA 6566	UMNH VP 18479	BRCA 124	UMNH VP 424	ilium
	10Bh; 12.9*	Anura indet.	BRCA 6567	UMNH VP 18480	BRCA 124	UMNH VP 424	ilium
	10Bj; 12.9*	Anura indet.	BRCA 6570	UMNH VP 18483	BRCA 124	UMNH VP 424	ilium
	10Bl; 12.9*	Anura indet.	BRCA 6571	UMNH VP 18484	BRCA 124	UMNH VP 424	ilium
	10By; 12.9*	Anura indet.	BRCA 6593	UMNH VP 18506	BRCA 124	UMNH VP 424	ilium
	10Bee	Anura indet.	BRCA 6588	UMNH VP 18501	BRCA 124	UMNH VP 424	ischia pair
	14q-1, 2	Anura indet.	BRCA 6589	UMNH VP 18502	BRCA 124	UMNH VP 424	maxilla
	14o	Anura indet.	BRCA 8096	UMNH VP 18185	BRCA 102	UMNH VP 77	prearticular
	14m-1, 2	Anura indet.	BRCA 8092	UMNH VP 18181	BRCA 102	UMNH VP 77	urostyle
	13ii-1–3	Anura indet.	BRCA 6627	UMNH VP 19344	BRCA 100	UMNH VP 1074	urostyle
	14n	Anura indet.	BRCA 8085	UMNH VP 18174	BRCA 102	UMNH VP 77	humerus

Table 6 (continued). Specimens in the BRCA paleontological collections that have been figured and/or described in the scientific literature. This table is organized by cited publication, and specimens are ordered by appearance in the cited text. Holotype specimens are indicated with an asterisk (*) and shown **bolded**. **Anatomical abbreviations**: **D,** deciduous (milk tooth); **L**, upper left; **l**, lower left; **mx**, molar X; **px**, premolar X; **R**, upper right; **r**, lower right.

Literature Cited	Figure #	Taxonomic ID	BRCA catalog #	Other catalog #	BRCA Locality #	Other Locality #	Description
Roček et al. 2010, 2013 (those from latter marked with *) (continued)	13ff	Anura indet.	BRCA 6634	UMNH VP 19351	BRCA 100	UMNH VP 1074	humerus
	14h; 12.10*	Anura indet.	BRCA 8045	UMNH VP 18134	BRCA 102	UMNH VP 77	ilium
	14d; 12.10*	Anura indet.	BRCA 8050	UMNH VP 18139	BRCA 102	UMNH VP 77	ilium
	14f	Anura indet.	BRCA 8051	UMNH VP 18140	BRCA 102	UMNH VP 77	ilium
	14b	Anura indet.	BRCA 8065	UMNH VP 18154	BRCA 102	UMNH VP 77	ilium
	14j-1, 2; 12.11*	Anura indet.	BRCA 8091	UMNH VP 18180	BRCA 102	UMNH VP 77	ilium
	14l-1, 2; 12.11*	Anura indet.	BRCA 8093	UMNH VP 18182	BRCA 102	UMNH VP 77	ilium
	14e; 12.10*	Anura indet.	BRCA 8094	UMNH VP 18183	BRCA 102	UMNH VP 77	ilium
	14g	Anura indet.	BRCA 8095	UMNH VP 18184	BRCA 102	UMNH VP 77	ilium
	14c	Anura indet.	BRCA 8099	UMNH VP 18188	BRCA 102	UMNH VP 77	ilium
	14p-1–3; 12.10*	Anura indet.	BRCA 6595	UMNH VP 18319	BRCA 102	UMNH VP 77	ilium
	14a; 12.10*	Anura indet.	BRCA 6596	UMNH VP 18320	BRCA 102	UMNH VP 77	ilium
	14i	Anura indet.	BRCA 6597	UMNH VP 18321	BRCA 102	UMNH VP 77	ilium
	14k-1, 2; 12.11*	Anura indet.	BRCA 6614	UMNH VP 18338	BRCA 102	UMNH VP 77	ilium
	13y; 12.11*	Anura indet.	BRCA 6628	UMNH VP 19345	BRCA 100	UMNH VP 1074	ilium
Santucci and Kirkland 2010	8	Hadrosauromorpha indet.	BRCA 8026	UMNH VP 17434	–	UMNH VP 833	dentary

Appendix C: Repository Contact Information

Contact information for institutions known to have collections from BRCA is included below. Addresses, links, and email addresses to departments are included as available. This information is subject to change, particularly hyperlinks.

Zion National Park (ZION)

1 Zion Park Blvd, State Route 9, Springdale, UT, 84767 | https://www.nps.gov/brca/learn/historyculture/museum-collections.htm | https://www.nps.gov/zion/learn/historyculture/zion-archives.htm

Paige Hoskins | Museum Curator for ZION, BRCA, and Cedar Breaks National Monument | paige_hoskins@nps.gov | (435) 772-0146

Emily Moran | BRCA Lead Archivist | emily_moran@partner.nps.gov | (435) 772-0166

The Prehistoric Museum (Utah State University Eastern)

155 East Main, Price, Utah 84501

Joshua Lively, Ph.D. | Curator of Paleontology | josh.lively@usu.edu | (435) 613-5752

Katharine Corneli | Collections Manager/Conservator | katharine.corneli@usu.edu | (435) 613-5645

Natural History Museum of Utah (University of Utah)

301 Wakara Way, Salt Lake City, UT 84108 | https://nhmu.utah.edu/collections-research

Randall Irmis, Ph.D. | Curator of Paleontology | irmis@umnh.utah.edu | (801) 585 0561

Carrie Levitt-Bussian | Paleontology & Mineralogy Collections Manager | clevitt@nhmu.utah.edu | (801) 581 5578

Museum of Northern Arizona (Northern Arizona University)

3100 N. Ft. Valley Rd., Flagstaff, AZ 86001| https://musnaz.org/collections/

Gwenn M. Gallenstein | Museum Curator, Flagstaff Area National Monuments (Sunset Crater Volcano, Walnut Canyon, and Wupatki) | gwenn_gallenstein@nps.gov | (928) 527-0322

Note: As of 2023, MNA has no paleontological staff. Gallenstein is the NPS liaison at MNA, making her the best person to contact for questions about BRCA specimens at MNA.

Appendix D: Paleontological Resource Law and Policy

The following material is reproduced in large part from Henkel et al. (2015); see also Kottkamp et al. (2020).

In March 2009, the Paleontological Resources Preservation Act (PRPA) (16 USC 460aaa) was signed into law (Public Law 111–11). This act defines paleontological resources as

> *…any fossilized remains, traces, or imprints of organisms, preserved in or on the [E]arth's crust, that are of paleontological interest and that provide information about the history of life on [E]arth.*

The law stipulates that the Secretary of the Interior should manage and protect paleontological resources using scientific principles. The Secretary should also develop plans for

> *…inventory, monitoring, and deriving the scientific and educational use of paleontological resources.*

Paleontological resources are considered park resources and values that are subject to the "no impairment" standard in the National Park Service Organic Act (1916). In addition to the Organic Act, PRPA will serve as a primary authority for the management, protection and interpretation of paleontological resources. The proper management and preservation of these non-renewable resources should be considered by park resource managers whether or not fossil resources are specifically identified in the park's enabling legislation.

The Paleontological Resources Management section of NPS Reference Manual 77 provides guidance on the implementation and continuation of paleontological resource management programs. Administrative options include those listed below and a park management program will probably incorporate multiple options depending on specific circumstances:

- **No action**—no action would be taken to collect the fossils as they erode from the strata. The fossils would be left to erode naturally and over time crumble away, or possibly be vandalized by visitors, either intentionally or unintentionally. This is the least preferable plan of action of those listed here.
- **Surveys**—will be set up to document potential fossil localities. All sites will be documented with the use of GPS and will be entered into the park GIS database. Associated stratigraphic and depositional environment information will be collected for each locality. A preliminary fossil list will be developed. Any evidence of poaching activity will be recorded. Rates of erosion will be estimated for the site and a monitoring schedule will be developed based upon this information. A NPS Paleontological Locality Database Form will also be completed for each locality. A standard version of this form will be provided by the Paleontology Program of the Geologic Resources Division upon request and can be modified to account for local conditions and needs.

- **Monitoring**—fossil-rich areas would be examined periodically to determine if conditions have changed to such an extent that additional management actions are warranted. Photographic records should be kept so that changes can be more easily ascertained.
- **Cyclic prospecting**—areas of high erosion which also have a high potential for producing significant specimens would be examined periodically for new sites. The periodicity of such cyclic prospecting will depend on locality-specific characteristics such as rates of sediment erosion, abundance or rarity of fossils, and proximity to visitor use areas.
- **Stabilization and reburial**—significant specimens which cannot be immediately collected may be stabilized using appropriate consolidants and reburied. Reburial slows down but does not stop the destruction of a fossil by erosion. Therefore, this method would be used only as an interim and temporary stop-gap measure. In some situations, stabilization of a locality may require the consideration of vegetation. For example, roots can destroy in situ fossils, but can also protect against slope erosion, while plant growth can effectively obscure localities, which can be positive or negative depending on how park staff want to manage a locality.
- **Shelter construction**—it may be appropriate to exhibit certain fossil sites or specimens in situ, which would require the construction of protective shelters to protect them from the natural forces of weathering and erosion. The use of shelters draws attention to the fossils and increases the risk of vandalism or theft, but also provides opportunities for interpretation and education.
- **Excavation**—partial or complete removal of any or all fossils present on the surface and potentially the removal of specimens still beneath the surface which have not been exposed by erosion.
- **Closure**—the area containing fossils may be temporarily or permanently closed to the public to protect the fossil resources. Fossil-rich areas may be closed to the public unless accompanied by an interpretive ranger on a guided hike.
- **Patrols**—may be increased in areas of known fossil resources. Patrols can prevent and/or reduce theft and vandalism. The scientific community and the public expect the NPS to protect its paleontological resources from vandalism and theft. In some situations, a volunteer site stewardship program may be appropriate (for example the "Paleo Protectors" at Chesapeake & Ohio Canal National Historical Park).
- **Alarm systems/electronic surveillance**—seismic monitoring systems can be installed to alert rangers of disturbances to sensitive paleontological sites. Once the alarm is engaged, a ranger can be dispatched to investigate. Motion-activated cameras may also be mounted to visually document human activity in areas of vulnerable paleontological sites.

National Park Service Management Policies (2006; Section 4.8.2.1) also require that paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. In 2010, the National Park Service established National Fossil Day as a celebration and partnership organized to promote public awareness and stewardship of fossils, as well as to foster a greater appreciation of their scientific and educational value (https://www.nps.gov/subjects/fossilday/index.htm). National Fossil Day occurs annually on Wednesday of the second full week in each October in conjunction with Earth Science Week.

Related Laws, Legislation, and Management Guidelines

National Park Service Organic Act

The NPS Organic Act directs the NPS to manage units

> *…to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner as will leave them unimpaired for the enjoyment of future generations.* (16 U.S.C. § 1).

Congress reiterated this mandate in the Redwood National Park Expansion Act of 1978 by stating that the NPS must conduct its actions in a manner that will ensure no

> *…derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress.* (16 U.S.C. § 1 a-1).

The Organic Act prohibits actions that permanently impair park resources unless a law directly and specifically allows for the acts. An action constitutes an impairment when its impacts

> *…harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources and values.* (Management Policies 2006 1.4.3).

Paleontological Resources Protection Act (P.L. 111-011, Omnibus Public Land Management Act of 2009, Subtitle D)

Section 6302 states

> *The Secretary (of the Interior) shall manage and protect paleontological resources on Federal land using scientific principles and expertise. The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources, in accordance with applicable agency laws, regulations, and policies. These plans shall emphasize interagency coordination and collaborative efforts where possible with non-Federal partners, the scientific community, and the general public.*

Federal Cave Resources Protection Act of 1988 (16 USC 4301)

This law provides a legal authority for the protection of all cave resources on NPS and other federal lands. The definition for "Cave Resource" in Section 4302 states

> *Cave resources include any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems.*

NPS Management Policies 2006

NPS Management Policies 2006 include direction for preserving and protecting cultural resources, natural resources, processes, systems, and values (National Park Service 2006). It is the goal of the NPS to avoid or minimize potential impacts to resources to the greatest extent practicable consistent with the management policies. The following is taken from section 4.8.2.1 of the NPS Management Policies 2006, "Paleontological Resources and their contexts":

> *Paleontological resources, including both organic and mineralized remains in body or trace form, will be protected, preserved, and managed for public education, interpretation, and scientific research. The Service will study and manage paleontological resources in their paleoecological context (that is, in terms of the geologic data associated with a particular fossil that provides information about the ancient environment).*
>
> *Superintendents will establish programs to inventory paleontological resources and systematically monitor for newly exposed fossils, especially in areas of rapid erosion. Scientifically significant resources will be protected by collection or by on-site protection and stabilization. The Service will encourage and help the academic community to conduct paleontological field research in accordance with the terms of a scientific research and collecting permit. Fossil localities and associated geologic data will be adequately documented when specimens are collected. Paleontological resources found in an archeological context are also subject to the policies for archeological resources. Paleontological specimens that are to be retained permanently are subject to the policies for museum objects.*
>
> *The Service will take appropriate action to prevent damage to and unauthorized collection of fossils. To protect paleontological resources from harm, theft, or destruction, the Service will ensure, where necessary, that information about the nature and specific location of these resources remains confidential, in accordance with the National Parks Omnibus Management Act of 1998.*
>
> *Parks will exchange fossil specimens only with other museums and public institutions that are dedicated to the preservation and interpretation of natural heritage and qualified to manage museum collections. Fossils to be deaccessioned in an exchange must fall outside the park's scope of collection statement. Systematically collected fossils in an NPS museum collection in compliance with 36 CFR 2.5 cannot be outside the scope of the collection statement. Exchanges must follow deaccession procedures in the Museum Handbook, Part II, chapter 6.*
>
> *The sale of original paleontological specimens is prohibited in parks.*
>
> *The Service generally will avoid purchasing fossil specimens. Casts or replicas should be acquired instead. A park may purchase fossil specimens for the park museum collection only after making a written determination that*

- *The specimens are scientifically significant and accompanied by detailed locality data and pertinent contextual data;*
- *The specimens were legally removed from their site of origin, and all transfers of ownership have been legal;*
- *The preparation of the specimens meets professional standards;*
- *The alternatives for making these specimens available to science and the public are unlikely;*
- *Acquisition is consistent with the park's enabling legislation and scope of collection statement, and acquisition will ensure the specimens' availability in perpetuity for public education and scientific research.*

All NPS construction projects in areas with potential paleontological resources must be preceded by a preconstruction surface assessment prior to disturbance. For any occurrences noted, or when the site may yield paleontological resources, the site will be avoided or the resources will, if necessary, be collected and properly cared for before construction begins. Areas with potential paleontological resources must also be monitored during construction projects.

(See Natural Resource Information 4.1.2; Studies and Collections 4.2; Independent Research 5.1.2; and Artifacts and Specimens 10.2.4.6 in NPS 2006, available here. Also see 36 CFR 2.5.)

NPS Director's Order-77, Paleontological Resources Management

DO-77 describes fossils as non-renewable resources and identifies the two major types, body fossils and trace fossils. It describes the need for managers to identify potential paleontological resources using literature and collection surveys, identify areas with potential for significant paleontological resources, and conduct paleontological surveys (inventory). It also describes appropriate actions for managing paleontological resources including: no action, monitoring, cyclic prospecting, stabilization and reburial, construction of protective structures, excavation, area closures, patrols, and the need to maintain confidentiality of sensitive location information.

Excerpt from Clites and Santucci (2012):

Monitoring

An important aspect of paleontological resource management is establishing a long-term paleontological resource monitoring program. National Park Service paleontological resource monitoring strategies were developed by Santucci et al. (2009). The park's monitoring program should incorporate the measurement and evaluation of the factors stated below.

Climatological Data Assessments

These assessments include measurements of factors such as annual and storm precipitation, freeze/thaw index (number of 24-hour periods per year where temperature fluctuates above and below 32 degrees Fahrenheit), relative humidity, and peak hourly wind speeds.

Rates of Erosion Studies

These studies require evaluation of lithology, slope degree, percent vegetation cover, and rates of denudation around established benchmarks. If a park does not have this information, there may be opportunities to set up joint projects, because erosion affects more than just paleontological resources.

Assessment of Human Activities, Behaviors, and Other Variables

These assessments involve determining access/proximity of paleontological resources to visitor use areas, annual visitor use, documented cases of theft/vandalism, commercial market value of the fossils, and amount of published material on the fossils.

Condition Assessment and Cyclic Prospecting

These monitoring methods entail visits to the locality to observe physical changes in the rocks and fossils, including the number of specimens lost and gained at the surface exposure. Paleontological prospecting would be especially beneficial during construction projects or road repair.

Periodic Photographic Monitoring

Maintaining photographic archives and continuing to photo-document fossil localities from established photo-points enables visual comparison of long-term changes in site variables

Appendix E: Paleontological Locality Data

This appendix lists all paleontological localities recorded in BRCA and their associated data. The data is split between two tables. Table 7 includes locality names, coordinates, and overall remarks; Table 8 contains lithological descriptions and specimen data.

Data for BRCA 004, 007, 008, 009, and 032 are included in this appendix. However, these localities have been considered for removal because of (1) a paucity of scientifically significant fossils, (2) potential misidentification of fossils observed, and (3) because these localities were recorded early in the 2022 field season, when Tran and Pittinger were still calibrating a consistent standard of abundance, spatial concentration, and significance.

Abbreviations:

- Formation (**Fm**)/Member (**Mbr**) (abbreviations adopted from Biek et al. [2015] and Knudsen et al. [in prep.]): **Kt**, Tropic Shale; **Ks**, Straight Cliffs Formation (undifferentiated); **Kss**, Straight Cliffs Formation, Smoky Hollow Member; **Ksj**, Straight Cliffs Formation, John Henry Member; **Ksjc**, Straight Cliffs Formation, John Henry Member (Coniacian); **Ksd**, Straight Cliffs Formation, Drip Tank Member; **Kw**, Wahweap Formation; **Tcp**, Claron Formation, lower pink member; **Tcw**, Claron Formation, upper white limestone member
- Other Numbers: **UMNH**, Natural History Museum of Utah; **VP,** vertebrate paleontology; **IP**, invertebrate paleontology; **PB**, paleobotany; **MNA**, Museum of Northern Arizona
- Type of Locality: **I**, Invertebrate; **P**, Plant; **T**, Trace; **V**, Vertebrate

Table 7. Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
001	–	T	–
002	–	T	Tapered burrow (0.75–3.25 cm [0.3–1.3 in] wide).
003	–	V, P	Fluvial deposit.
004	–	P	No need to revisit. Density of fossils at this locality is low.
005	–	V, I	This site possesses high potential for vertebrate, invertebrate fossils. However, it is well-isolated from human disturbance. Should visit 1–2 times per season. 15 m (49 ft) east along the same bedding plane—large boulders containing pebble lenses with bone and invertebrate fragments (~5 mm [0.2 in]).
006	–	I, V	Very high preservation quality. Very loose substrate, high potential for additional vertebrate and invertebrate discoveries. Will be very important to revisit and collect. Rate of erosion is potentially high due to loose silty sand.
007	–	T	No revisit necessary.
008	–	V	No revisit necessary. We were unable to identify the source of the bone fragments. “In situ” fragments and gar scale found in large boulders, probably rockfall from above.
009	–	I, T	No revisit necessary. Produces few fossils over large area (10–12 m [33–39 ft] long), less than 4 m (13 ft) below ridge top.
010	UMNH VP 828 (SC 7-28-07-1)	V, P	Revisit at most once per year.
012	–	V	Revisit at least once a year. Highly diagnostic fossils found, good preservation.
013	–	P	Revisit at least once a year. Leaf impressions exposed to weathering and erosion.
014	–	V, I	Revisit no more than once per year.
015	UMNH VP 834 (SCB 8-3-07-1)	V	Revisit at least once per year. Site was previously sampled by Dr. Jeff Eaton in 2007.
016a	–	V	Revisit at least once per year.
016b	–	–	Visit annually, may be good for collecting. may not be related to the bone horizon at BRCA 016a but similar size to the condyle cap that lies there near the well-preserved vert.
017	–	V, P, I	No revisit necessary. Fossils extremely localized. Scree, other debris (plants) make identifying the fossil horizon and additional fossils difficult.
018	–	V	Tran collected nine bags of at least one fragmentary dinosaur limb condyle, probably a femur. Two of the bags are limb shaft fragments that were excavated from a small test pit at or very near the likely productive horizon, in a gray mud-silt/sandstone.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
019	UMNH VP 1072; UMNH VP 1073 (BH 7-16-08-2)	V	No revisit necessary. Site was previously sampled by Dr. Jeff Eaton, Lidya Tarhan, and Natasha Kubricky. Bones only found at original locality for UMNH VP 1073, none at UMNH VP 1072.
020	–	V, P	Revisit this site. Bones well-preserved, weathered but not bleached, and highly localized. There may be an articulated tail/hind limbs of a hadrosaur at this locality.
021	UMNH VP 1156	V, P	No need to revisit. Previously recorded and collected by Dr. Jeff Eaton & students in 2010. other than few pieces of surface fossil wood, no new significant vertebrate fossils at 1156. This is the type locality for *Dakotamys shakespeari* (Eaton 2013).
022	UMNH VP 1159; VP 1160	V	No need to revisit. Coordinates represent former UMNH VP 1160. Only 1 limb fragment found at former UMNH VP 1160 locality. Bone flakes at 1159.
023	UMNH VP 1161	V, P	Former UMNH VP 1161 does not require revisit. No new bone. A partial dinosaur limb previously collected. Petrified wood near locality is localized, may need one revisit per year.
024	UMNH VP 1162	V	May require at least one revisit per season. Previously noted as highly productive, some diagnostic bones (weathered reptile jaw; turtle carapace; croc osteoderm fragments) remain.
025	UMNH VP 1158	V	Bone fragments at SP 7-10-09-3 seem to be unnaturally compiled, may not require further revisits. Fragments are undiagnostic.
026	UMNH VP 1157	V, I	No revisit necessary. Eaton previously documented and collected from this locality.
027	–	I, T	May require at least one revisit per season. Soft mud may produce more fossils, plus proximity to trail may warrant increased monitoring and protection.
028	UMNH VP 783	I, V	Dr. Eaton notes this site as having high potential for microfossils. Gastropods in situ and on the surface is consistent with this recommendation. Should return to collect more microfossil sample bags.
029	UMNH 829 (SC 7-28-07-2)	V	May require one revisit per season.
030	–	I	Revisit at least once per season.
031	–	I, T	Return to locality every 6 months.
032	–	I	Come back frequently. Lots of rudist fragments eroding out from soft mud. (Gayle Pollock later reidentified fragments as structure-in-structure traces, not rudist bivalves, based on photographs provided by Tut Tran).
033	–	T	Revisit a few times a year. Did not locate productive horizon upon discovery.
034	–	I, T	Visit at least annually.
035	–	T	–
036	–	T	–

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
037	–	I, T	Revisit at least once per season.
038	–	V, T	Revisit once per year. Slender fragments probably fit together and likely did not travel very far.
039	–	P	Visit annually.
040	–	V, I, P	Return annually.
041	–	V, T	Visit annually. Bone largely bleached (pale orange to white) so moderate erosion/exposure.. Also very near old UMNH sites (may combine with this one when revisit after 7-20-22).
042	UMNH IP 24; UMNH IP 33	I	Visit annually. High abundance of oyster and snail fossils.
043	–	P, I, V	Visit occasionally (every 2–5 years). Low density of fossils, but relatively high diversity, especially if more plant fossils are produced.
044	–	T	Visit regularly (2–5 years), if not annually.
045	–	V	Visit regularly (2–5 years). Bone is highly bleached, so low exposure rate. May be worth collecting a microfossil sample bag.
046	UMNH VP 1163	V	Visit occasionally (once every 10 years). Bone is very heavily bleached and has likely been exposed since 2009, when the site was originally excavated by Dr. Jeff Eaton.
047	UMNH VP 1067	V	Visit this site annually. Original UMNH VP 1067 locality was thoroughly collected by Dr. Jeff Eaton in 2009, but several meters west shows diverse bone (croc, turtle, possible theropod vertebrae and ribs). Bone there is bleached but otherwise good condition.
048	UMNH VP 1068	V, I	Visit every 2–5 years. Bones and clams highly localized, but bone fragments undiagnostic.
049	–	V, I, P	Visit annually. Bone horizon may be gone from above highest sandstone layer, but bone is preserved in sizeable articulated fragments, mostly orange. Test pit on 8-1-22—some brown pieces buried right under sandstone layer, not necessarily in situ.
050	–	V	Visit annually. Dark brown bone suggests recent exposure. Bone produced from several points.
051	UMNH VP 1071	V	Visit every other year. Locality was previously sampled by Dr. Jeff Eaton, but the site may produce more fossils bone. Fragments scattered all across locality area.
052	UMNH VP 1070	V	No revisit necessary. Bone is undiagnostic, fragmentary, and heavily bleached. Previously sampled by Dr. Jeff Eaton in 2009.
053	–	V, P	Visit annually. Observed some bones in proximity to coordinates that were broken in small pieces but together. Steepness of slope probably makes bone erode fairly quickly, pink color throughout.
054	UMNH VP 1077	V	Visit annually. Bone is bleached so has been exposed for some time, sampled by Dr. Eaton in 2008. The producing horizon for this locality may be the same as BRCA 53.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
055	UMNH VP 807	V	No revisit necessary. Surface bone heavily bleached, and no in situ bone was previously recovered by Dr. Eaton.
056	UMNH VP 806; UMNH VP 848	V, P	Visit at least every two years. Bones are bleached, fit together despite being sampled by Dr. Jeff Eaton in ~2007–08.
057	UMNH IP 59	T	No revisit necessary. Surface exhibits trace fossils but no body fossils were recovered from surface or sample bags in 2011.
058	UMNH IP 60; UMNH IP 61	I, T	Visit every 2–5 years. Dr. Eaton collected from UMNH IP 60, 61 and found whole snails. Should collect in future.
059	UMNH IP 62	I, T	Visit every 2–5 years. Gastropod fragments. Dr. Jeff Eaton sampled in 2011 (2 bags) and found whole snails and some eggshell. Should collect more in the future.
060	UMNH IP 67; UMNH IP 68; UMNH IP 69	I, T	Visit every 2–5 years.
061	–	V, P, I	Visit every 2–5 years. Bone is sparse across the locality, but some intact in dropdown blocks.
062	–	V	Visit every 2–5 years. Bone is identifiable but not abundant. Most diagnostic piece is vertebral and low on the hill.
063a	–	V	Visit annually. (Tut Tran collected multiple times in 2022 and 2023).
063b	–	–	Marked to improve accuracy/ability for future workers to locate which bones were collected from which areas.
063c	–	–	Marked to improve accuracy/ability for future workers to locate which bones were collected from which areas.
063d	–	–	Marked to improve accuracy/ability for future workers to locate which bones were collected from which areas.
063e	–	–	Marked to improve accuracy/ability for future workers to locate which bones were collected from which areas.
064	–	I	Visit annually. Substrate is soft and will likely expose more ammonite fossils after rains.
064b	–	–	Visit annually. Site will continue to produce ammonites.
065	–	V	Visit annually. Bone is spread out, but most diagnostic elements are rib heads and multiple fragments of a reptile jaw. Soft substrate may produce additional diagnostic elements on an annual basis.
066	UMNH IP 40	I	No revisit necessary. Dr. Eaton must have collected all identifiable snails from the producing horizon, and the site has not produced more since 2009.
067	UMNH VP 1154; UMNH VP 1155	V	Visit every 5–10 years. Bone is very sparse, fragmented, and has been exposed for multiple seasons at a time.
068	UMNH VP 1153; UMNH PB 31	V, P	Visit annually. Dr. Eaton noted this site as highly productive; found gar scales while screen-washing samples from turtle horizon.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
069	–	P, V	Return annually. Bone is sparse but in good condition where found.
070	–	V, I	Visit annually.
070b	–	–	–
071	UMNH IP 54; UMNH VP 1090	I, V	Visit every 2–5 years. No fossils on surface, but may be worth collecting microfossils and screen-washing samples based on productivity determined by Dr. Eaton.
072	UMNH IP 23; UMNH VP 1143; UMNH VP 1177	I, V	Visit every 2–5 years. Originally designated as vertebrate localities. Area may still be useful for microfossil samples.
073	UMNH 827; UMNH 1091	V	Visit at least every 2 years. Probable source for bone fragments found at BRCA 72.
074	UMNH IP 63	V, I	Visit annually. Dr. Eaton found gastropods, ostracods, and vertebra fragments previously and hypothesized presence of good microsite under sandstone.
075	–	V, I, P	Visit annually. Some bone here is quite freshly exposed.
076	–	P	Visit every 2 years at the least. Site has potential to produce large slabs of diverse leaves.
077	UMNH VP 785	V	Visit no more than once every 10 years. Bone is heavily bleached,
078	UMNH VP 569	V	Visit at least every 2 years to start. Dr. Eaton collected 5 sample bags and collected all surface fossils.
079	UMNH VP 568	V	Visit every 2–5 years. Bones here mostly bleached, hadrosaur jaw pit empty now.
080	–	V	Visit annually to observe rate of weathering, then decrease monitoring. Bones here are weathered so possible exposed a few seasons ago.
081	UMNH VP 776	V, I	Visit every 2–5 years. May be worth sampling for more microfossils due to the abundance of snails.
082	UMNH VP 778	V	Visit every 2–5 years. Bone has been exposed since 2006 but is spread out and not diagnostic. Sampled by Dr. Eaton in 2006.
083	UMNH VP 777	V	Visit every 2–5 years. Bone is fragmented but concentrated.
084	UMNH VP 786	V, P	No revisit necessary. Sandstone blocks have collapsed over the original dig site, fossils here are almost nonexistent.
085	–	P	Visit every 2–5 years. Leaves are in excellent shape and eroding out from resistant sandstone blocks.
086	–	V	Visit every 2 years, if not annually. Bone is moderately abundant but site could provide more diagnostic material.
087	–	I	Visit annually. Snails are fragmentary.
088	UMNH IP 66	I	Visit annually. Snails fragmentary for now.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
089	UMNH IP 5	I, T	Visit every 2 years if not annually.
090	–	P	Visit every 2 years. Sandstone is quite broken and scattered along the slope but leaves are concentrated near the top.
091	–	V	Visit every other year, if not annually. Assortment of bone is diverse.
092	UMNH IP 86	I, T	Visit every 5–10 years, if not every 2–5. Surface fragments are undiagnostic. Dr. Eaton screen-washed in 2013, found diverse snails. May be worth sampling again in the future.
093	UMNH PB 62	P, I, T	Visit every 5–10 years. TT did not ID hackberry seeds upon rediscovery, but difficult to eliminate possibility. May need to bring Dr. Eaton back to site in order to help ID. If no more hackberries, do not revisit. Snails and burrows better elsewhere.
094	–	V	Visit annually. Wall may produce bone from higher up. Should collect this bone within this season. Most of the distal portion of the limb is gone but may be buried within talus under the bone. (Tut Tran collected in 2023).
095	–	V	Visit annually until the bone horizon is located.
096	–	I, T	Visit every 2–5 years. Slope is eroding fairly quickly.
097	–	P	Visit annually. This is one of the better logs observed in the 22 season and highly prone to erosion by rain/ice.
098	–	V	Visit every 2–5 years. Bone on the surface is large but not especially abundant. SS likely holding more bone in channel lags. Did not see more in situ.
099	–	V, I	Visit annually, and collect sample bags to screen-wash.
100	UMNH VP 1074; UMNH VP 1076	V	Visit no more frequently than every 10 years. Fossils are sparse here and have been exposed since Eaton sampled in 2008.
101	–	V, I, T	Visit annually until microfossil bags have been collected. Bone here is white to orange (heavy to moderate bleaching).
102	UMNH VP 77	V	Visit every ten years at the most, if you must. Important to know that this is the type locality for 2 batoid fishes (Kirkland et al. 2013). Originally discovered in 1997. Site does not change much.
103	UMNH IP 42, UMNH VP 417	I, V	Visit every 2–5 years. Larger turtle pieces are relatively fresh (brown-orange).
104	UMNH VP 1166, UMNH VP 1167	V	Visit every 2–5 years, if not annually. Must have been exposed more recently than when Eaton last sampled in 2009.
105	–	V	Visit 2–5 years if not annually. Rate of weathering may be slow, but presence of small bits of turtle, croc, incl. vertebrae may indicate decent microsite.
106	–	V, I	Visit annually. Sample as a microsite. Bone here is bleached but also very diagnostic.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
107	–	V	Visit annually. Deep in wilderness, but bones are being exposed and eroded quickly. Sample this as a microsite.
108	–	V	Visit annually. Bones here are moderately bleached but heavily fragmented, easily transported into drainages below.
109	–	V	Visit every 2–5 years. Area worth scouting more due to contact between John Henry and Smoky Hollow Members—Coniacian age is very rare on the continent.
110	–	V, P	Visit annually. Bones have been exposed for a few seasons but their position in a drainage makes them vulnerable.
111	–	V	Visit annually. This is close to another productive site. Also one of the most diagnostic elements of the [2022 field] season.
112	–	I	Visit annually.
113	–	T	Visit annually. B Cockrell has noted high abundances of wasp traces.
114	–	P	Visit every 2–5 years.
115	UMNH VP 423	V	Visit once every 5–10 years. Check notes if Jeff ever discovered bone horizon.
116	UMNH IP 25	I	Visit every 2–5 years.
117	–	P	Visit every 2–5 years.
118	–	V	Visit annually.
119	–	P	Visit every 2–5 years. Lithology best matches BRCA 13 which also had purple ss leaf impressions.
120	–	I	Return every couple of years, the shell bed is abundant and continuous
121a	–	V, P	Visit annually. High concentration of bones at points in washes of loose sand, bone fairly fresh (rusty orange pink white).
121b	–	V, P	–
122	–	P	Visit 2–5 years, though be aware that some leaves and the bark have tumbled down.
123	–	V, P	Visit annually. Plan to collect the turtle, it would be a good fossil prep project and mostly(?) complete.
124	UMNH VP 424	V	Visit every 2 years. Eaton sampled extensively 2003–12. Forty bags of matrix were collected and screen-washed. Research interest in this site (to date, the most productive micromammal/vertebrate site in the John Henry Member of the Straight Cliffs) persists to this day.
125	UMNH IP 31	I	Visit as available (5–10 years). Oysters are highly fragmentary, not enough numbers of complete in situ specimens to warrant collection.
126	–	V, I, P	Visit annually. High abundance of bone and deep orange color show recent exposure.
127	–	P, V	Visit every 2–5 years.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
128	–	V	Visit annually. Very high potential for good microsite.
129	–	P	Visit 2–5 years. Point is at best spot for leaves at the moment but are probably coming from the ledge, will move pt later.
130a	–	V	Visit annually. Bone, relatively good condition, bone horizon not located.
130b	–	–	Bones range from highly weathered to fresh and are between 130a and 130b, though they extend higher with some large vertebra pieces but become sparser over the sandstone ledge.
131	–	V	Diverse fossils, especially turtle carapace variety. Bone fragments continue laterally. Likely multiple bone horizons between 130a and 130b.
132	–	V	Difficult to access and sparse vertebra fragments. All bone extremely weathered. Map says alluvium but clearly in situ outcrop—maybe Drip Tank?
133a	–	V	Remarkably similar vertebra size to BRCA 16. Along same bedding plane.
133b	–	–	–
133c	–	–	This horizon is the same as 133b but higher by about 1 m (3 ft) than 133a.
134	–	V	134 could be a good potential microsite contender for sieving.
135	–	V	Fossiliferous continuity to site 16—may be worth a revisit to assess for number and types of turtle genera.
136	–	P	Palm frond may be worth collecting, appears similar to or may be a *Sabalites* which is well established in Late Cretaceous Campanian rocks of North Dakota and Canada.
137	–	P	Visit every 2–5 years. Marked because very few plant/leaf sites in Wahweap, but better examples in the Straight Cliffs. May be equivalent to plant material at BRCA 20 to the south.
138a	–	V	Visit annually, see 138 b for more.
138b	–	–	Visit annually, slope is steep and bone surface is relatively fresh. Largest vertebra find in the ’22–23 season, seems to be weathering out of sandy lenses but may have come from sandy ledge just atop the calcareous bluff, hard to ascertain.
139	–	P	Visit every 2–5 years. Made into a locality because this is the first record of leaves in the area and may correlate with other leaf sites in the park
140a	–	P	Visit every 2–5 years. Marking because collecting a diagnostic leaf, lobes distinct from other angiosperm specimens seen. Also correlative potential with other leaf localities in the area.
140b	–	–	–
141	UMNH VP 809	V	Visit only as available. Jeff’s notes say this was productive in 2007 but there’s very little on the surface. Potential microfossil site.
142	UMNH VP 846	V	Visit 2–5 years. Still has good potential to yield informative microfossils.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
143	UMNH VP 808	V	Visit 2–5 years. Eroding slowly.
144	UMNH VP 805; MNA 1127	V	Visit annually.
145	UMNH VP 1151	V	Visit every 5–10 years. Some bound found but not much, especially not at highest bone found by Eaton in 2009 (*Naomichelys*).
146	UMNH VP 1150	V	Visit every 10 years if at all. Bone is super weathered, indeterminate fragments.
147	–	I	Monitor as available. First oyster site logged in this area but might be equivalent to other material. Not high priority.
148	MNA 1132	V	Visit annually, productive microsite.
149	–	P	Visit 2–5 years. Probably equivalent to BRCA 139 and 140, marking because it extends the lateral continuation of this bed.
150	–	P	Visit 2–5 years. Similar to leaf sites in this area.
151	UMNH VP 836	V	Visit every 2–5 years. Very difficult to reach from the west, not a lot of identifiable bone.
152	UMNH VP 835	V	Visit 2–5 years. Jeff writes that bone horizon is garbage concretion layer.
153	UMNH IP 39	I	Visit 2–5 or 5–10, snails in nice condition. Site not super productive but worth periodically checking.
154	MNA-1175	V	No revisit necessary. Many more productive sites in the John Henry Member elsewhere.
155	–	P	Visit every 2–5 years. Leaf horizon at this site may be equivalent to horizon below BRCA 124 (UMNH VP 424).
156	–	V	Visit annually.
–	MNA-996	V	–
–	MNA-1124	V	–
–	MNA-1126	V	–
–	MNA-1128	V	–
–	MNA-1129	V	–
–	MNA-1130	V	–
–	MNA-1131	V	–
–	MNA-1168	V	–
–	MNA-1169	V	–
–	MNA-1170	V	–

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
–	MNA-1184	V	–
–	MNA-1185	V	–
–	MNA-1186	V	–
–	MNA-1187; UMNH VP 420	V	The unit lying on the white sandstone is a dark mudstone which produces rare but delicately preserved small vertebrate bones and teeth. Overlying the mudstone is a friable white sandy unit that produces larger white bone.
–	MNA-1188	V	–
–	MNA-1189	V	–
–	MNA-1190	V	–
–	MNA-1191	V	–
–	MNA-1192	V	–
–	MNA-1193	V	–
–	MNA-1194	V	–
–	MNA-1198	V	Several horizons in the sandstone contain gastropods and some bivalves (lower in sandstone, 2 m (7 ft) above base.
–	MNA-1199	V	Gastropods in second sandstone Wahweap.
–	UMNH VP 79	V	–
–	UMNH VP 80	V	–
–	UMNH VP 421	V	Brown sandstone lag deposit that is underlain by red, gray, and tan variegated siltstones. Dinosaur bone fragments and teeth, turtle carapace fragments, and a single crab claw.
–	UMNH VP 425	V	Large bone recovered in tan sandy concretionary unit. Gar scale on surface.
–	UMNH VP 427	V	Material washed very well and produced delicate bone of salamanders, fish, lizards, as well as 2 mammal tooth fragments
–	UMNH VP 428	V	Turtle and dino bone.
–	UMNH VP 772	V	Just above thick sandstone base of Wahweap. Bone, gastropod, croc tooth, bivalve impression. Screen-washed.
–	UMNH VP 773	V	8 m (26 ft) above prior locality. Gar-scale rich concretions.
–	UMNH VP 774	V	Bone float, no producing horizon.
–	UMNH VP 775	V	Large bone in conglomerate. Turtle shell and partial dino tail vertebra.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
–	UMNH VP 779	V	One bone, some turtle, little in wash.
–	UMNH VP 780	V	Above ironstone, large dino bone in gray siltstone.
–	UMNH PB 27	P	Plant imprints in ironstone.
–	UMNH IP 22	I	Gastropods and bivalves.
–	UMNH PB 28	P	–
–	UMNH VP 787	V	Large poorly preserved bone, pebbly sandstone.
–	UMNH VP 789 and UMNH VP 790	V	Some large (dinosaur?) bone.
–	UMNH VP 791	V	Nice small bone.
–	UMNH VP 792	V	Large dino toe bone, more bone in concretionary ss. Large bone in gray mudstone above pink silt.
–	UMNH VP 793	V	Massive sandstone lower Wahweap. Misc bone and gastropods.
–	UMNH VP 794	V	Theropod and fish tooth.
–	UMNH VP 795	V	Massive ss ledge, maybe weathering out of gray ss.
–	UMNH VP 800	V	Large bone 6 m (20 ft) below ss.
–	UMNH VP 801	V	Fine white ss below brown coarse. Coprolites, fish scale, bone, theropod and hadrosaur teeth.
–	UMNH VP 802	V	Two large vertebrae were located, gastropods.
–	UMNH VP 803	V	Many pieces of turtle together at one spot at the base of the thick ridge forming sandstone.
–	UMNH VP 813	V	*Trionyx* and a small hadrosaur tooth found at surface, probably from a gray siltstone on flat above an orange concretionary layer.
–	UMNH VP 814	V	Poorly preserved bone often in concretionary nodules.
–	UMNH VP 833	V	Hadrosaur mandible and a little bone scrap.
–	UMNH IP 26	I	Oysters. No producing horizon, found just above a lignitic horizon.
–	UMNH VP 840	V	Large bone, gar scale, and gastropod molds weathering out of the sandstone.
–	UMNH VP 841	V	Poorly preserved bone fragments, 1 croc tooth.
–	UMNH VP 849	V	In a light sandy surface underlain by an orange concretionary sandstone. Some bone and turtle.
–	UMNH VP 851	V	–
–	UMNH VP 852	V	–
–	UMNH VP 853	V	–

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
–	UMNH VP 854	V	From a pink siltstone on flats below a tan sandstone and above a sideritic horizon.
–	UMNH VP 855	V	Invertebrate molds.
–	UMNH VP 858	V	Large croc tooth and a few bone scraps.
–	UMNH VP 859	V	Well preserved bone coming from a thin horizon.
–	UMNH VP 867	V	–
–	UMNH VP 868	V	Bone.
–	UMNH VP 869	V	Bluish bone.
–	UMNH VP 1062	V	Big bone.
–	UMNH VP 1063	V	Dinosaur bone on surface well preserved and light colored, non-concretionary bed. Found croc tooth in place.
–	UMNH IP 30	I	Bone and bivalve casts and some bivalve shell material on sandy flat.
–	UMNH PB 29	P	“Plant locality”, no other detail.
–	UMNH VP 1066	V	Hadrosaur tooth, bone scrap.
–	UMNH VP 1069	V	A garbagy concretionary horizon above a gray gypsiferous carbonaceous horizon.
–	UMNH IP 32	I	Bivalve horizon.
–	UMNH VP 1075	V	Big bone.
–	UMNH IP 34	I	Contains oysters, and some *Baculites*, bivalves, and gastropods.
–	UMNH VP 1145	V	Bone over wide area. Gnats.
–	UMNH VP 1146	V	Large crocodilian tooth was found on the surface and gar scales.
–	UMNH VP 1147	V	Bone scatter in gray siltstone.
–	UMNH VP 1148	V	Scattered weathered bone including a hadrosaur tail vertebra.
–	UMNH IP 36	I	–
–	UMNH IP 37	I	Bivalves are common in this slabby to massive sandstone.
–	UMNH VP 1149	V	Piece of turtle and other bone in flat covered with much sandstone rubble.
–	UMNH VP 1152	V	Large fragmentary bone found on a gray flat.
–	UMNH VP 1164	V	Large croc scute material and other bone.
–	UMNH VP 1165	V	Large dinosaur bone and turtle at original collection site
–	UMNH VP 1168	V	Recovered croc, turtle, and miscellaneous bone.

Table 7 (continued). Paleontological locality numbers and remarks.

BRCA #	Other #	Locality Type	Remarks
–	UMNH IP 41	I	"A few bivalve molds, one very nice, and higher a little bone".
–	UMNH IP 65	V	Both trace fossils and peloidal carbonates with possible ostracods present.
–	UMNH VP 1665	V	Bone found on surface including big bone, turtle, crocodilian, and more delicate bone. Found gar scales, croc tooth, etc. in place at this horizon.
–	UMNH IP 84	I	Unionids. There is a white carbonate above where the unionid were found.
–	UMNH IP 85	I	Gastropods and bivalves. A little bone and gar scale in the sandstone.
–	UMNH PB 59	P	Leaf impressions on gray limestone. Secondary venation is present, but no leaf margins. Insect trace fossils.
–	UMNH PB 60	P	Leaf impressions with secondary venation, lateral invertebrate burrows and one gar scale.
–	UMNH PB 61	P	Leaf impressions exhibiting secondary venation and some leaf margins. Several whole leaves were discovered.
–	UMNH VP 3139; UMNH IP 406; UMNH PB 210	V, I, P	–

Table 8. Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 001	Tcp	Orange limestone/medium grained calcareous sandstone.	Several burrows of varied size (max 35 cm [14 in] length, 5 cm [2 in] thick), parallel with bedding plane.	NONE
BRCA 002	Tcp	Orange cross-bedded medium-coarse grained calcareous sandstone beneath a resistant, ledge-forming conglomerate/sandstone layer.	Burrows (invertebrate).	NONE
BRCA 003	Kw	Yellow coarse sandstone with conglomerate lenses.	Bone fragments (incl. ex situ rib frag) in-and-ex situ, iron concretions, petrified wood, plant frond/palm.	NONE
BRCA 004	Ksd	Orange coarse grained sandstone with iron staining. Coarse sandstone is surrounded by pale tan friable sandstone.	Fossil mold of wood eroding from orange coarse-grained sandstone. Locality also exhibits a fine-grained friable sandstone that exhibits either rip-up clasts or invertebrate traces. Wood mold eroding in pieces <5 cm (2 in) long, some still in situ.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 005	Kw	Massive yellow cross-bedded sandstone ledge/wall (40 m [130 ft] long, ~6–8 m [20–26 ft] tall).	Vertebrates—1 crocodilian osteoderm, ex situ in cobble, plus other bone fragments in the same cobble, and ex situ elsewhere in the locality. Multiple invertebrates (gastropods).	NONE
BRCA 006	Kw	Yellow-tan blocky sandstone. All fossils found ex situ atop loose silty sand.	The locality is rich in well-preserved gastropods, some bivalves. Vertebrates include fragments of turtle shell, large indet. bone fragments (3–4 cm [1.2–1.6 in] long). Fossiliferous layer was not identified but could be 1–2 m (3–7 ft) above highest occurrence of bone (~7 m [23 ft] above the bottom of the wash).	YES
BRCA 007	Tcw	Massive white calcareous mudstone, heavily bioturbated.	Burrows (1 m [3 ft] long, 3 cm [1.2 in] thick), lower 2 m (7 ft) of a 3 m (10 ft) tall white mudstone block.	NONE
BRCA 008	Ks	Blocky cross-bedded medium-coarse-grained tan/brown/yellow sandstone with occasional pebble/gravel lenses.	1 gar scale in situ. 2 partial vertebrae fragments. Several indeterminate bone fragments (~1–2 mm [0.04–0.08 in] thick, 4–5 mm [0.16–0.20 in] long).	NONE
BRCA 009	Tcp	Loose but hard red/orange sandstone pebbles eroding out of a steep hill/ridge. Some in situ outcrop exposed below probable fossil horizon.	Clam fragments, ex situ burrows (6 cm [2.4 in] long maximum, 1–2 cm [0.4–0.8 in] thick).	NONE
BRCA 010	Ks	Fossils found ex situ on loose fine-medium grained pale tan sand. Sand likely sourced from underlying friable cross-bedded sandstone, which is exposed on lower parts of the ridge.	Bone fragments (max ~ 6 cm [2.4 in]). Includes bleached turtle fragments (neural). Petrified wood. Biggest bone fragments found near the original UMNH VP 828 location. Petrified wood consistently found across east–west extent of the ridge.	NONE
BRCA 012	Ksj	Fossils found ex situ on red/purple loose mud/paleosol.	Possible *Deinosuchus* tooth (3 cm [1.2 in] conical croc tooth)? Fish tooth. Well-preserved hadrosaur tooth. Several other bone fragments (turtle carapace).	YES
BRCA 013	Ksj	Massive medium-coarse grained sandstone. Leaves likely parallel to bedding plane.	Leaf impressions (n=~50) in two large (1 m [3 ft] by 0.5 m [1.6 ft] area) sandstone blocks.	NONE
BRCA 014	Ksj	Medium-coarse grained orange sandstone conglomerate, poorly sorted. Iron concretions and oncolites abundant.	Bone fragments (max 6 cm [2.4 in]) cemented into the medium-coarse grained sandstone conglomerate. Also invertebrate hash?	NONE
BRCA 015	Ksd	Fine grained gray/yellow sandstone. Pebble lenses/scree common. Locality is on a NE/SW trending ridge and is just below the contact between the lower Wahweap Formation and Drip Tank Member.	Bone fragments of various size. Largest, most diagnostic fragment consists of one probably dorsal or caudal vertebra, with most pre/post-zygapophyses preserved, but no neural spine. Turtle fragments, some gastropods.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 016a	Kw	Massive sandstone with abundant iron concretions. Fossils found on surface of gray silt/sand.	Very complete bone. Large fragments of long bone (Femur? Humerus?) ~10 cm (4 in) long; metacarpal/tarsal condyle; vertebra with partial transverse processes and complete neural cavity; odd pentagonal bone ~5 cm (2 in) long (turtle carapace?).	NONE
BRCA 016b	Kw	Medium grained grey beige sandstone, sitting right above purple lens.	Femur? large bone, in many fragments at least 2 pieces articulate. Two condyles one big chunk of shaft.	NONE
BRCA 017	Kw	Gray/tan mud sitting atop blocky tan cross-bedded sandstone. Red/orange iron concretions abundant.	Small (1–3 cm [0.4–1.2 in]) fragments of bone, petrified wood, and 1 gastropod.	NONE
BRCA 018	Kw	Loose gray/tan mudstone ~4–5 m (13–16 ft) below massive cross-bedded sandstone.	Large (10–13 cm [4–5.1 in] long) fragments of limb bones (dinosaur). Largest fragments consistent with proximal and distal ends of ornithischian (hadrosaur) dinosaur scapula.	YES
BRCA 019	Kw	Bone fragments found ex situ on gray silt/mud ~1–2 m (3–7 ft) below blocky cross-bedded tan sand. Originally described by Eaton to be ~6 m (20 ft) above cliff-forming sand.	Bone fragments, very sparse and heavily bleached.	NONE
BRCA 020	Kw	Fossils found ex situ on a gray mud. Slope where fossils were found also had tan/yellow and purple muds.	Multiple dinosaur (hadrosaur) tail vertebrae (3–4), limb condyle fragments, and fragments of other vertebrae. Fossil leaf found ~6 m (20 ft) lower, ~20 m (66 ft) west.	YES
BRCA 021	Ks	Gray/tan mud	Petrified wood pieces. No new bone at 1156.	NONE
BRCA 022	Ks	Tan mud with abundant iron concretions	1160—1 bone fragment—Eaton and students documented and collected (?) a limb bone in 2010. Bone flakes found at 1159.	NONE
BRCA 023	Ks	Tan mud with abundant iron concretions	Found several localized petrified wood pieces ~4–5 m (13–16 ft) below locality, to the northeast. Eaton and students collected a partial dinosaur limb from this locality in 2010.	NONE
BRCA 024	Ks	Gray mud on a mud flat	Bone fragments—previously noted by Eaton and students in 2010. Found partial reptile jaw upon site rediscovery today.	NONE
BRCA 025	Ks	–	Several pieces of long bones at SP 7-10-09-3 coordinates. Pieces of ribs at UMNH VP 1158.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 026	Ks	Gray/tan mud along the top of the ridge	Two bone fragments. Bivalves and gastropods had previously been collected by Dr. Jeff Eaton and students in 2009/2010.	NONE
BRCA 027	Kw	Multicolored—gray, tan, red—mud beds below massive yellow sandstone.	Gastropod, multiple pieces of burrows.	NONE
BRCA 028	Kw	Tan, grey, fine-grained sandstone.	Several gastropods, in situ and surface, along with bone fragments.	NONE
BRCA 029	Ksj	Blocky concreted orange sandstone, medium-coarse grained.	1 *Adocus* turtle carapace fragment, multiple indeterminate bone fragments. Orange color, no bleaching.	NONE
BRCA 030	Kt	Loose tan silt/mud eroding out from larger sandstone blocks (~5–6 m [16–20 ft] above, where it's in situ).	Multiple loose sandstone blocks (~20 cm [8 in]) containing clams, molds and casts of clams, and a mold of a snail.	NONE
BRCA 031	Kt	Purple/reddish tan shale/laminated siltstone.	Ammonites, bivalves, moving/grazing traces, possible *Ophiomorpha*.	NONE
BRCA 032	Kt	Loose dark brown/gray mud	Rudist bivalve fragments.	NONE
BRCA 033	Tcp	White/pink silty limestone. Burrows discovered on the surface of loose red silt below blocky white limestone	Ex situ burrow fragments.	NONE
BRCA 034	Tcp	Massive pink/red sandstone/limestone	Burrows ex and in situ. Mollusk fragments, some whole snails	NONE
BRCA 035	Tcp	Massive fine-medium grained limestone/calcareous sandstone, gray color.	Burrows ~1 m (3 ft) long along the side of a 2 m (7 ft) tall limestone block.	NONE
BRCA 036	Tcp	Massive pink/red calcareous sandstone/limestone.	Several localized and extremely well-preserved in situ burrows.	NONE
BRCA 037	Tcp	Loose red/pink mud	1 very well-preserved snail, ex situ	NONE
BRCA 038	Kw	Loose gray/tan mud eroding from friable sandstones slightly higher (<1 m [3 ft]).	Several similarly sized slender bone fragments in a 2 m x 1 m (7 ft x 3 ft) area, probably from a dinosaur vertebra neural spine. Also petrified wood, 1 gar scale ~6 m (20 ft) east.	NONE
BRCA 039	Kw	~4 large fragments of petrified wood	Gray mud on the surface, eroding out from friable massive gray sandstone.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 040	Kw	Loose gray/tan mud under massive sandstone blocks.	Several surface bone fragments up to 10 cm (4 in) long. First bone discovery at BRCA 40 was a large bone fragment on the foot path. Dinosaurs: distal and proximal ribs, limb shafts, processes of vertebrae, possible skull pieces. 2 turtle carapace fragments. 1 probable croc skull roof fragment. Bones range in color from white (heavily bleached) to orange (mildly weathered) to chocolatey brown and even black higher in section (freshly exposed). Several gastropods. 1 petrified wood fragment at the top of the ridge.	NONE
BRCA 041	Kw	Loose tan silt below massive yellow sandstone blocks.	Several small bone fragments, largest was a turtle plastron. Burrows observed in gray sandstone blocks.	NONE
BRCA 042	Kss	Loose tan mudstone interbedded with organic ridge coaly beds (lignite layers).	Surface oysters and snails. Eroding bedrock has in situ corkscrew snails.	NONE
BRCA 043	Ksj	Loose tan mud below massive cross-bedded sandstone blocks	Multiple leaf impressions and clam casts/molds found on pieces of surface sandstone. 2 unidentifiable bone fragments also.	NONE
BRCA 044	Kw	Tan medium-grained sandstone blocks.	3 large hadrosaur pes underprints (footprints). Petrified wood, bone fragments (including 1 mostly complete vertebra) and some snails	NONE
BRCA 045	Ksj	Loose tan mud under/eroding from platy silty sandstone	Croc fragments, including several pieces of osteoderm (<2 cm [0.8 in]), 1 complete peripheral osteoderm, 1 fragment of possible long bone, 1 vertebra or rib fragment. Small burrow fragments.	NONE
BRCA 046	Ksj	Loose gray mud below gray sandstone blocks.	Multiple fragments of croc osteoderm and rib. Very heavily bleached.	NONE
BRCA 047	Ksj	Gray mud with abundant ironstone pebbles.	One turtle bone at the original UMNH VP 1067 locality, but several meters west has diverse turtle, croc, and possible theropod remains (vertebrae, at the very least).	NONE
BRCA 048	Ksj	Gray mud with abundant sandstone pebbles and ironstone fragments.	Clams, highly localized bone fragments below clams.	NONE
BRCA 049	Ksj	Tan mud ~3 m (10 ft) below a blocky sandstone ridge cap.	Hadrosaur vertebrae and ribs, turtle fragments, molds of wood, snails, and clams.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 050	Ksj	Gray mud/silt on a mud flat. Bone found atop and along the edges of the mud flat.	Bone—several large fragments of turtle carapace and possible dinosaur. Bones range from dark brown to white in color.	NONE
BRCA 051	Ksj	Tan mud in a saddle	Bone fragments, including turtle carapace and some limb ends.	NONE
BRCA 052	Ksj	A tan mud flat	Small bone fragments <1 cm (0.4 in).	NONE
BRCA 053	Kw	Gray/tan mud immediately under a small sandstone ledge.	Bone. Large vertebral chunks, ribs, long bones, limb ends. Probably belonging to large ornithischian dinosaur. One croc osteoderm.	NONE
BRCA 054	Kw	Gray mud on a flat saddle	Many fragments of bone in close proximity, including a possible croc tooth.	NONE
BRCA 055	Kw	Gray mud atop a cliff-forming sandstone.	Small slivers of bleached bone. Site previously sampled by Dr. Jeff Eaton and yielded no in situ bone at the time (2007).	NONE
BRCA 056	Kw	Gray mud at the base of the major cliff-forming sandstone	Several large bone fragments, orange to pink in color. Pieces found in close proximity fit together. Vertebral fragments, large pieces of turtle carapace.	NONE
BRCA 057	Tcp	Interbedded white and orange calcareous sandstone hill.	Burrow fragments litter the surface of the locality.	NONE
BRCA 058	Tcp	Orange calcareous siltstone	Snail fragments, some are complete.	NONE
BRCA 059	Tcp	Red silt/mudstone.	Snail fragments on surface. Dr. Eaton sampled this site and found some eggshell fragments in 2011. Uncertain whether eggshell was on surface or found during screen-washing.	NONE
BRCA 060	Tcp	Orange and tan siltstone	Burrow casts on the surface. Snail fragments, 1 eggshell fragment found in/beside a dolomite-capped orange sandstone butte just southwest of the locality (formerly UMNH IP 68).	NONE
BRCA 061	Kw	Massive tan/yellow sandstone	Heavily bleached bone cemented in massive sandstone. Smaller bones (verts, ribs, turtle pieces) found on surfaces of pebble conglomerate. Biggest bone, possibly femur, found in massive medium grained sandstone.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 062	Kw	Tan mud under massive sandstone conglomerate blocks	Bone fragments—vertebra, rib, turtle.	NONE
BRCA 063a	Ksj	Tan mud 1–2 m [3–7 ft] above a cliff-forming sandstone.	Many clearly identifiable bones in good to decent condition. 2 ornithischian jaw fragments. Several large limb condyles. 1 especially large croc osteoderm. 1 possible large ankylosaur osteoderm (or ceratopsian horn?).	YES
BRCA 063b	Ksj	–	–	–
BRCA 063c	Ksj	–	–	–
BRCA 063d	Ksj	–	–	–
BRCA 063e	Ksj	–	–	–
BRCA 064	Kt	Gray-brown mud	Molds of ammonites, some body fossils of small ones.	NONE
BRCA 064b	Kt	Surface of the site is a muddy dark gray shale, but the ammonites are in a heavily concreted orange sandstone.	Ammonites in orange concrete sandstone, fragments of which litter the surface of the gray mud. Hammering concretions reveal ammonites embedded within. Horizon unclear.	YES
BRCA 065	Ksj	Gray mud with highly abundant concretions,	Several fragments of ribs and rib heads, plus fragments of a possible reptile jaw. Bone is orange to white in color	NONE
BRCA 066	Ksj	Slumped medium-grained sandstone atop tan silt.	Dr. Eaton had previously collected snails from the top layer of slabby sandstone at the site. No snail fossils observed by TT upon rediscovery.	NONE
BRCA 067	Ksj	Two gray lignite-rich knobs forming a saddle with tan mud in the middle. Iron concretions highly abundant.	Small scraps of turtle bone spread across the perimeter of each knob. Coordinates are at UMNH VP 1154, which is slightly more abundant than the original UMNH VP 1155 coordinates.	NONE
BRCA 068	Ksj	Tan sandy silt and massive sandstone blocks	Orange turtle carapace, vertebrae, and limb fragments. Petrified wood also found several meters above.	NONE
BRCA 069	Ksj	Gray-brown mud between alternating layers of massive sandstone.	Multiple bones, including long bone and vertebral fragments, plus two pieces of turtle shell. Initial discovery consisted of several plant fossils (leaves, petrified wood).	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 070	Kw	Tan silty mud ~5 m (16 ft) below and ~2 m (7 ft) above the nearest massive sandstone layers. Sandstone erodes into blocks and platy sheets.	Bones. Several large limb and vertebral fragments (including one well-preserved transverse process of a cervical vertebra? and a possible phalanx or carpal/tarsal bone).Includes associated turtle shell pieces and 1 croc osteoderm.	YES
BRCA 070b	–	–	–	–
BRCA 071	Kw	Beige mud/silt under a massive sandstone cliff.	Previously sampled by Dr. Eaton, who found gastropods, ostracods, and gar scales in screen-washing. No fossils on surface 8-18-22.	NONE
BRCA 072	Kw	Variegated mud.	Small fragments of snail, burrow fragments, clam, and a single bone found at the foot of the hill. May be remnants of the old producing horizon (unlikely?) or they are sourced from the top of the hill (see BRCA 73).	NONE
BRCA 073	Kw	Tan silty mud (lag deposit?)	Bone—multiple fragments, 1 large croc osteoderm. Bone is eroding from top of hill.	NONE
BRCA 074	Kw	Blocky sandstone atop tan mud. surface is littered with variegated rounded pebbles	Previously sampled by Dr. Eaton in 2009. New specimen is 1 raptor tooth in and among large loose sandstone blocks	YES
BRCA 075	Kw	Gray and tan mud 2 m (7 ft) below rocky sandstone.	Large fragments of bone (large fragments of dinosaur limb and turtle shell). Highest layer has snails at coordinates. Layer is laterally continuous and produces more limb bone to the south.	NONE
BRCA 076	Ksd	Orange, purple, and beige sandstone sheets atop gray silt. Leaves most abundant ~2 m (7 ft) below the ridgetop.	Specimens of at least 2, maybe 3 types of deciduous leaves. Leaves are most frequent in the orange sandstone sheets and are orange to brown in color.	NONE
BRCA 077	Ksd	Iron-rich orange and purple sandstone litter the surface of gray sandy silt.	Turtle fragments, heavily bleached. some fragments are large, possibly rib or limb shaft.	NONE
BRCA 078	Ksj	Gray mud with abundant iron concretion pebbles.	Closely associated fragments of a proximal dinosaur femur—pieces fit together, must have been exposed between the time Dr. Eaton collected from this site and now.	NONE
BRCA 079	Ksj	Gray/pink sandy silt immediately under a 2 m (7 ft) thick red sand.	Multiple turtle individuals, one especially good turtle consisting of several closely associated fragments at the base of the red sandstone	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 080	Ksj	Beige silty sand with abundant iron concretions	Multiple orange to white fragments of turtle. Largest bone is a weathered rib or vert.	NONE
BRCA 081	Kw	Sheets of platy sandstone atop gray silt.	Snails and fragments of bone.	NONE
BRCA 082	Ksj	Orange ironstone concretions eroding out of a tan sandy ridge saddle.	Turtle carapace fragments sparsely scattered along the top and sides of the saddle. Orange to white in color.	NONE
BRCA 083	Ksj	Gray and tan sandy silt	Several large fragments of turtle carapace and other bones. The original sample pit dug by Dr. Eaton in 2006 is empty	NONE
BRCA 084	Ksj	Blocky cross bedded sandstone	2 fragments of bone. Dr. Eaton collected petrified wood here in 2006.	NONE
BRCA 085	Ksj	Blocky tan sandstone	Fossil leaves in the blocky sandstone, orange to purple in color.	NONE
BRCA 086	Ksj	Orange/red/purple concreted sandstone just under tan loose sand.	Several small fragments of bone, including vertebrae and rib pieces of a potentially juvenile dinosaur. Site also produces turtles and a gar scale, good potential for vertebrate microsite.	NONE
BRCA 087	Tcp	Blocky calcareous sandstone	Black mollusk fragments.	NONE
BRCA 088	Tcp	Red yellow gray sandstone	Snail fragments, some large snail cores, burrow fragments.	NONE
BRCA 089	Tcp	Orange/red cobbly mud	Unionid bivalve fragments. Site has been disturbed since 2006—sleeping bag, blanket, and city calcite tiles have been stashed under the dead tree. Checked in with Dr. Eaton on the evening of 9/16. He says he has no connection with the stashed items.	NONE
BRCA 090	Ks	Cross-bedded beige sandstone	Several fossil leaves, gray to brown in color with good venation.	NONE
BRCA 091	Ks	Blocky tan sandstone	Several bone fragments, including large pieces of turtle carapace, dinosaur causal vertebrae and other diagnosable pieces. Bone at the coordinates is mostly small, and is probably eroding out from the blocky sandstone. Found 1 piece cemented in.	NONE
BRCA 092	Tc	Loose fragments of calcareous sandstone atop pink mud.	Gastropod fragments. Productive horizon not located in 2013 but probably within 1 m (3 ft) below top of ridge knob	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 093	Tc	Orange/gray calcareous mud	Small fragments of snail and burrows. Dr. Eaton originally found hackberry seeds at this site in 2013, did not find more when sample was screen-washed.	NONE
BRCA 094	Kw	Channel lag deposit	One partially intact 35 cm (14 in) dinosaur limb eroding out of the massive sandstone. One rib also below limb bone.	YES
BRCA 095	Ksj	Loose tan sand sourced from massive sandstone	The bones have been transported within a large drainage	NONE
BRCA 096	Kw	Massive pink/tan blocky sandstone	Snails cemented in blocky sandstone. 1 block shows excellent burrows and some clams. Small burrow fragments litter the surface.	NONE
BRCA 097	Kw	Loose gray sandy silt below blocky tan sandstone. Multicolored cobbles litter the surface.	1 large (30 cm [12 in] long by 15 cm [6 in] diameter) segment of petrified log. Log was likely originally cemented in on-site sandstone, as half of it remains in a sandstone block. Middle of log sits directly in large drainage and has broken into small fragments.	NONE
BRCA 098	Kw	2+ m (7+ ft) thick blocky sandstone above layers of gray and purple silt. Coordinates are at the base of the 1 m (3 ft) thick purple mud, 6 m (20 ft) below the ss. Biggest bones found at base of mud	A handful of large bone fragments (dinosaur limb) along a drainage feeding from the thick blocky ss layer. Bone at coordinates is orange.	NONE
BRCA 099	Kw	Gray mud/silt between two 2 m (7 ft) thick sandstone.	Microvertebrate site. Diagnostic material includes teeth of *Brachychampsa* croc, hadrosaur, gar scale, potential reptile jaw, abundant turtle. Snails also present. Dino limb found	NONE
BRCA 100	Kw	Gray mud flats interbedded between orange and yellow block sandstone.	UMNH VP 1074 has scraps of crocodilian and turtle exhibiting very heavy bleaching (entirely white). VP 1076 has very little bone, none of which is diagnosable. Both sites have been unaltered since Dr. Eaton sampled them in 2008.	NONE
BRCA 101	Kw	Gray/tan mud nose with abundant ironstone concretions and burrows. Fossils eroding from within 12 m (39 ft) of top of the nose, all along the perimeter. Biggest bones at top.	Small fragments of bone, including turtle, gar, and many fragments of bigger verts and ribs. Some possible skull material, heavily weathered. High potential for good microvertebrate material, should be collected.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 102	Kw	Variegated mud (gray-yellow-pink)	Heavily bleached fragments of vertebrae. No fresh bone at this site.	NONE
BRCA 103	Ks	Massive brown sandstone conglomerate with highly abundant clams. Bones eroding from mud deposit just below sandstone layer.	Clams. Small bone fragments (turtle) eroding from below coquina.	NONE
BRCA 104	Kw	Thick massive cliff forming sandstone	Multiple large fragments of ring and vert, probably dinosaur. Moderately bleached, pale orange color.	NONE
BRCA 105	Kw	Blocky 1–2 m (3–7 ft) thick tan sandstone atop tan/gray silt.	Bone fragments, moderate to heavy weathering. Most pieces are rib, turtle, and some croc. May produce decent microsite. Biggest bone is split in half. Possible heavily weathered limb condyle?	NONE
BRCA 106	Ksj	Base of a pink/purple mud	Multiple fragments of croc maxilla, osteoderms, plus turtle and snails lower on the hill on surface of tan and gray sands. Croc eroding from pink layer.	NONE
BRCA 107	Kss	Gray organic rich mud	Several small orange fragments of croc and turtle. Biggest bone was three pieces of indet. limb condyle. Bone found consistently eroding from near the top of the dark gray layer.	NONE
BRCA 108	Kss	Gray mud. Bones are probably eroding from within the top 2 m (7 ft) of gray mud.	Fragments of ribs, vertebrae, turtle shell in an 8 m (26 ft) by 4–5 m (13–16 ft) area. Most diagnostic pieces are vertebra and one possible manual or pedal phalanx. Also gar scale	NONE
BRCA 109	Ksj	Tan sandstone scree. Bones eroding from the base of in situ 1 m (3 ft) sandstone layer. 1–6 m (3–20 ft) above the top of the Calico layer in the Smoky Hollow Member.	Multiple fragments of large verts and ribs eroding from within or just below 1–2 m (3–7 ft) thick sandstone layer, ~6 m (20 ft) above top of Calico layer.	NONE
BRCA 110	Kss	Dark brown mud. Bones are eroding into a large drainage, much is broken.	Several moderately bleached—orange to white—drags of vertebra centra, neural spines, and ribs. Some fragments of distal caudals are interesting due to placement of zygapophyses. At least one large and intact dorsal or causal centrum.	NONE
BRCA 111	Kss	Dark gray/brown mud	Theropod or croc claw, possible jaw with tooth, plus assorted indet. bone fragments.	YES
BRCA 112	Tcp	Calcareous ss	Snail bits, incl. cores and small fragments.	NONE

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 113	Tcp	Massive pink calcareous sandstone.	Sparsely occurring wasp traces (*Eatonichnus* sp) and molluscs fragments	NONE
BRCA 114	Ksj	Blocky massive tan sandstone. Leaves eroding under knob of massive sandstone with abundant rip-up clasts.	Leaf impressions—angiosperms—in massive sandstone eroding on the surface of the site.	NONE
BRCA 115	Kw	Blocky ss above variegated mudstone. Jeff described site as 1/2 up slope above Drip Tank equivalent. marking first recovered surface bone at point.	Heavily bleached turtle plastron, dinosaur fragments.	–
BRCA 116	Ksj	Massive tan sandstone with cross bedding. Fossil clams occur in a laterally continuous ~30 cm (12 in) shell hash layer.	Fossil clams—external, internal molds + some intact shell.	–
BRCA 117	Ksj	Blocky sandstone	Angiosperm leaf impressions.	–
BRCA 118	Ksd	Bone fragments are embedded in a silty sand on the surface but are likely eroding from a dark purple concreted layer.	Large fragments of a dinosaur femur(?). One limb condyle and most of the shaft is preserved well, but the other end is gone. Fragments 5–8 cm (2–3 in) long, 4–6 cm (1.6–2.4 in) wide. Other bone incl. turtle, ribs, skull?	YES
BRCA 119	Ksd	Massive purple sandstone under massive tan sandstone. the highest occurrence of leaf fossils is at the boundary between purple and tan.	Large angiosperm leaf impressions. Some of the largest are 8+ cm (3+ in) wide. Good 3-dimensionality of impressions in many specimens found today.	–
BRCA 120	Kss	E–W swale in river wash, Loose beige/tan fine to medium SANDSTONE, silty. Gastropods at base of bed, oysters 2 m (7 ft) above in continuous layer.	Gastropods, whole and up to 6 cm (2.4 in). Oysters purple to blue and grey with boring and encrusters such as *Cliona*.	–
BRCA 121a	Ksj	East facing side of the slope containing both 121a and 121b. Orange concrete sandstone scattered across beige loose sand.	Dinosaur vertebrae, large turtle fragments (baenid?) and one leaf impression piece.	–
BRCA 121b	Ksj	Siderite rich concretions scattered across fine beige sand.	Large bone fragments—limb condyle, ribs. Rusty orange to bleached white in color.	–
BRCA 122	Ksj	Fine-mesh grained sand ranging gray to orange.	Leaves ranging in color from white to beige to orange to maroon. Site named for fossilized pine? bark. Sparse bivalve imps and some notable bone higher up.	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 123	Ksj	Blocky sandstone spilling onto the surface of loose beige sand under two channel ledges.	One turtle in multiple fragments of sandstone concretion. Many pieces scattered on sand surface. 1 big vertebra under the nearest ledge, which is probably the producing horizon.	YES
BRCA 124	Ksj	Gray mud.	Little bone scraps (croc and turtle) probably eroding from the now buried quarry bone horizon.	–
BRCA 125	Kss	Fine beige silty sand	Fragmented oysters, pieces up to 3 cm (1.2 in) long.	–
BRCA 126	Ksj	Beige silt under blocky tan sandstone ledges.	High abundance of bone in good condition (deep orange color). Hadrosaur vertebra material and diversely textured turtle carapace. Gar scale, leaves also.	YES
BRCA 127	Ksj	Platy tan sandstone atop a flat knoll	Leaf impression fossils eroding out of the platy sandstone. Some as large as 10 cm (4 in). Moderately abundant, not as obvious as at other leaf sites in the Straight Cliffs Formation.	–
BRCA 128	Ksj	Soft beige/gray silt knoll f	Scores of bone fragments. Most diagnostic pieces were baenid and *Neoclemys* pieces, pieces of large verts. 1 fish tooth encountered.	–
BRCA 129	Ksd	Massive sandstone ledge in the John Henry Member of the Straight Cliffs.	Leaf fossils, all angiosperms. Some have very good contrast from the matrix.	–
BRCA 130a	Kw	Fine beige to gray silty sand, concentration of largest bone fragments below sandy shelf.	One large vertebra and small dentary frag alongside many fragments of limb and rib bones, lots of turtle carapace fragments with different patterns. multiple genera and diverse ecology here.	–
BRCA 130b	Kw	Fine beige to grey silty sand, turtle shell concretion in grey dolomitic block about 30 cm by 30 cm (12 in by 12 in).	Bone fragments well above locale and 131a. potential turtle shell concreted. Many types of turtles.	–
BRCA 131	Ksd	Ledgy blocky massive beige sandstone with fine lamination on cm scale. Bone outcropping just beneath rock shelter.	Very weathered maroon vertebral fragments and misc. bone fragments—trabecular surface visible. Fragments on order of 3 to 7 cm (1.2–2.8 in).	–
BRCA 132	Kw	Purple fine silty sandstone with interbeds of fine laminated beige sandstone and coquina scree.	Scallop impressions, well preserved vertebra material, snails and bivalves and turtle fragments.	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 133a	Kw	Dark grey to beige silty sand and shale with small purple patches in between beige medium grained set ledges.	Turtle carapace; lots of variation in type and size. Three notable vertebrae—one extremely well preserved. Potential phalange bones. snails higher up—extremely well preserved.	–
BRCA 133b	Kw	Beige siltstone bound by sandstone ledges above and below—pile of bones on flat, including one Theropoda manual phalange potentially.	Theropoda phalange, maybe turtle fragments or just unidentified vertebra fragments, shards of large croc tooth on same horizon 1 m (3 ft) east.	–
BRCA 133c	Kw	Beige siltstone bound by two ledges of sandstone.	Turtle carapace and bones, exceptionally preserved snails, one or two vertebral fragments.	–
BRCA 134	Kw	Fine friable beige sandstone flat above large blocky sandstone ledge.	Bunches of turtle fragments, all collecting in a micro site.	–
BRCA 135	Kw	Grey shaley siltstone slope, soft gradation into purple and beige under beige sandstone ledge.	Many turtle fragments, painterly in preservation.	–
BRCA 136	Kw	Large buff sandstone ledge with intermittent fine cross beds up to 40 cm (16 in) total thickness and finely laminate coal seems in cross beds.	A palm frond(?) impression—large! Small turtle fragments too.	YES
BRCA 137	Kw	Platy beige gray sandstone	Very faded broad-leafed angiosperm impressions.	–
BRCA 138a	Kw	Fine to medium beige loose sandy lenses capped by calcareous sandstone with coquina lenses, 2 verts lying on muddy slope and other fragments. One large complete croc tooth and large snails and bivalve internal molds.	Dinosaur vertebrae, croc tooth, bivalves and gastropods and turtles.	–
BRCA 138b	Kw	Fine medium sandstone lenses capped by calcareous grey sandy ledges.	Large verts, two total on this horizon alongside other fragments and turtle bits—petrified wood too and large gastropods in the calcareous stuff. One croc tooth too.	–
BRCA 139	Ksj	Platy beige sandstone. The pt is the best leaf specimens and most accessible spot, but the layer is laterally continuous to the west where it is steeper.	Angiosperm leaves, orange to brown in contrast to the beige sandstone. Similar preservation to BRCA 13 and 42.	–
BRCA 140a	Ksj	Beige platy sandstone interbedded between slope forming beige silt. Pt indicates southernmost extent of site and the point where BRCA 140-1 was collected.	Faded leaf impressions, incl. 1 lobed large leaf that was collected.	YES
BRCA 140b	Ksj	–	–	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 141	Ksj	Gray mudstone. Original coordinates were off so the new ones 2023 are correct.	Flaky white bone scraps in the area, super weathered.	–
BRCA 142	Ksj	Gray mudstone flat with very little veg. Pt is at the bottom of a productive drainage from which Eaton and Cory Redman sampled 2 microfossil bags.	Bone fragments incl. ossified tendons. Still productive, bones are orange to white.	–
BRCA 143	Ksj	Gray mud below purple siderite.. Jeff found this in 2007.	White bone fragments. Turtle, dino. Maybe rib heads too, indet.	–
BRCA 144	Ksj	Gray mudstone.	Bone fragments, orange in color. Cortical surfaces highly intact. Multiple pieces preferable to croc osteoderm, pitting similar to BRCA 63 but smaller animal.	–
BRCA 145	Ksj	Grey mud covered in orange siderite beneath a sandstone cap.	Small orange bone fragments at the bottom of the wash, especially on the south side of the outcrop.	–
BRCA 146	Ksj	Flat of gray mud among siderite concretions.	Very white bone fragments.	–
BRCA 147	Kss	1 m (3 ft) thick lignite/coal layer above a thick orange white sandstone.	Well-formed oysters and clams in the coal layer.	–
BRCA 148	Kss	Beige silt. This may be eq to MNA 1132 but does not lie on the original point.	Bone fragments, microsite. Vertebral pieces, fish scales and teeth, 2 pieces hadrosaurid tooth.	–
BRCA 149	Ksj	East facing drainage of platy tan sandstone.	Angiosperm leaves.	–
BRCA 150	Ksjc	Beige platy sandstone.	Angiosperm leaves, orange and large. Highly concentrated in a single set of beds.	–
BRCA 151	Kw	Grey silt beneath tan sandstone.	Heavy concreted bone fragments, indet.	BRCA 151
BRCA 152	Kw	Beige mud ~4 m (13 ft) below major tan ss horizon.	Highly concentrated bone frags, bleached, concreted. Vertebrae and associated elements.	–
BRCA 153	Kw	Beige sandstone litters the surface of locality. Collected pit filled in with gray mud. Eaton wrote that producing horizon was a sandstone.	Snails, clams, bone bits.	–
BRCA 154	Ksj	Gray platy sandstone atop a gentle gray knob, lots of orange-purple concretion in the polygon. Originally found in 1989 by Eaton.	Jeff photographed specimens of orange bones in 2008/09. No bones observed in three polygons today, coordinates and locality photo seems right but maybe they vacuumed the surface?	–
BRCA 155	Ksj	Platy orange-purple-gray sandstone	Diverse angiosperm leaves.	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
BRCA 156	Ksj	Beige sandy silt.	Pieces of a hadrosaur vertebra. Bone pieces led to an isolated but well-preserved and large hadrosaur vertebral centrum.	–
MNA-996	Kss	–	–	–
MNA-1124	Kw	–	–	–
MNA-1126	Ksj	–	–	–
MNA-1128	Ksj	–	–	–
MNA-1129	Kw/Ksj	–	–	–
MNA-1130	Kw/Ksj	–	–	–
MNA-1131	Kw/Ksj	–	–	–
MNA-1168	Ks	–	–	–
MNA-1169	Ks	–	–	–
MNA-1170	Ks	–	–	–
MNA-1184	Kw	–	–	–
MNA-1185	Kw	–	–	–
MNA-1186	Kw	–	–	–
MNA-1187; UMNH VP 420	Ksj	Above a prominent white quartzose sandstone (arenite?). The locality is on a small flat	The unit lying on the white sandstone is a dark mudstone which produces rare but delicately preserved small vertebrate bones and teeth. Overlying the mudstone is a friable white sandy unit that produces larger white bone.	–
MNA-1188	Kw	–	–	–
MNA-1189	Kw	–	–	–
MNA-1190	Kw	–	–	–
MNA-1191	Kw	–	–	–
MNA-1192	Kw	–	–	–
MNA-1193	Kw	–	–	–
MNA-1194	Kw	–	–	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
MNA-1198; UMNH IP 21	Kw	Several horizons in sandstone.	Gastropods and some bivalves (lower in sandstone, 2 m (7 ft) above base).	–
MNA-1199	Kw	Sandstone.	Gastropods.	–
UMNH VP 79	Kw	–	–	–
UMNH VP 80	Kw	–	–	–
UMNH VP 421	Kw	Brown sandstone lag deposit that is underlain by red, gray, and tan variegated siltstones.	Dinosaur bone fragments and teeth, turtle carapace fragments, and a single crab claw.	–
UMNH VP 425	Ksj	Tan sandy concretionary unit.	Large bone recovered. Gar scale on surface.	–
UMNH VP 427	Ksj	Pink horizon below a gray layer.	Material washed very well and produced delicate bone of salamanders, fish, lizards, as well as 2 mammal tooth fragments.	–
UMNH VP 428	Ksj	Top of a brown sandstone below white sandy siltstone.	Turtle and dinosaur bone.	–
UMNH VP 772	Kw	Just above thick sandstone base of Wahweap.	Bone, gastropod, croc tooth, bivalve impression. Screen-washed.	–
UMNH VP 773	Kw	–	8 m (26 ft) above prior locality. Pink siltstone overlain by gray; top = gar-scale rich concretions.	–
UMNH VP 774	Kw	–	Bone float, no producing horizon.	–
UMNH VP 775	Ksd	Sandstone conglomerate.	Large bone. Turtle shell and partial dinosaur tail vertebra.	–
UMNH VP 779	Kw	–	One bone, some turtle, little in wash.	–
UMNH VP 780	Kw	–	Above ironstone, large dino bone in gray siltstone.	–
UMNH PB 27	Ksj	–	Plant imprints in ironstone.	–
UMNH IP 22	Kw	–	Thick sequence of pinkish to green variegated siltstones overlain by a ~4 m (13 ft) thick sandstone with gastropods and bivalves.	–
UMNH PB 28	Kw	–	–	–
UMNH VP 787	Ksd	–	Large poorly preserved bone, pebbly sandstone.	–
UMNH VP 789 and UMNH VP 790	Kw	–	Some large (dinosaur?) bone.	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
UMNH VP 791	Kw	–	Nice small bone.	–
UMNH VP 792	Kw	–	Large dino toe bone, more bone in concretionary ss. Large bone in gray mudstone above pink silt.	–
UMNH VP 793	Kw	–	Massive ss lower Wahweap. Misc bone and gastropods.	–
UMNH VP 794	Kw	–	Theropod and fish tooth.	–
UMNH VP 795	Kw	–	Massive ss ledge, maybe weathering out of gray ss.	–
UMNH VP 800	Kw	–	Large bone 6 m (20 ft) below ss.	–
UMNH VP 801	Kw	–	Fine white ss below brown coarse. Coprolites, fish scale, bone, theropod and hadrosaur teeth.	–
UMNH VP 802	Kw	–	Two large vertebrae were located, gastropods.	–
UMNH VP 803	Kw	–	Many pieces of turtle together at one spot at the base of the thick ridge forming sandstone.	–
UMNH VP 813	Ksj	–	*Trionyx* and a small hadrosaur tooth found at surface, probably from a gray siltstone on flat above an orange concretionary layer.	–
UMNH VP 814	Kw	–	Poorly preserved bone often in concretionary nodules.	–
UMNH VP 833	Ksj	–	Hadrosaur mandible and a little bone scrap.	–
UMNH IP 26	Kss	–	Oysters. No producing horizon, found just above a lignitic horizon.	–
UMNH VP 840	Ksj	Sandstone.	Large bone, gar scale, and gastropod molds.	–
UMNH VP 841	Ksj	–	Poorly preserved bone fragments, 1 croc tooth.	–
UMNH VP 849	Ksj	In a light sandy surface underlain by an orange concretionary sandstone.	Some bone and turtle.	–
UMNH VP 851	Ksj	–	–	–
UMNH VP 852	Ksj	–	–	–
UMNH VP 853	Ksj	–	–	–
UMNH VP 854	Ksj	From a pink siltstone on flats below a tan sandstone and above a sideritic horizon.	–	–
UMNH VP 855	Ksj	–	Invertebrate molds.	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
UMNH VP 858	Ksj	–	Large croc tooth and a few bone scraps.	–
UMNH VP 859	Ksj	–	Very nicely preserved bone coming from a thin horizon.	–
UMNH VP 867	Ksj	Mottled gray siltstone.	–	–
UMNH VP 868	Ksj	–	Bone.	–
UMNH VP 869	Ksj	Gray siltstone.	Beautiful bluish bone.	–
UMNH VP 1062	Ksj	Purple ironstone	Big bone.	–
UMNH VP 1063	Ksj	Light colored, non-concretionary bed. Layer with croc tooth is organic rich with ironstone.	Dinosaur bone on surface well preserved and light colored, non-concretionary bed. Found croc tooth in place.	–
UMNH IP 30	Ksj	–	Bone and bivalve casts and some bivalve shell material on sandy flat.	–
UMNH PB 29	Ksj	–	"Plant locality", no other detail.	–
UMNH VP 1066	Kw	–	Hadrosaur tooth, bone scrap.	–
UMNH VP 1069	Ksj	A garbagy concretionary horizon above a gray gypsiferous carbonaceous horizon.	–	–
UMNH IP 32	Ksj	–	Bivalve horizon.	–
UMNH VP 1075	Kw	~ 1–2 m (3–7 ft) below prominent cliff forming yellowing sandstone.	Big bone locality.	–
UMNH IP 34	Kt	Brownish shale which overlies a dark bentonitic bed. The horizon appears to be fossiliferous throughout.	Oysters, and some *Baculites*, bivalves, and gastropods.	–
UMNH VP 1145	Ksj	–	Bone over wide area. Gnats.	–
UMNH VP 1146	Ksj	–	Large crocodilian tooth was found on the surface and gar scales.	–
UMNH VP 1147	Ksj	Gray siltstone.	Bone scatter.	–
UMNH VP 1148	Ksj	–	Scattered weathered bone including a hadrosaur tail vertebra.	–
UMNH IP 36	Tcp	–	–	–
UMNH IP 37	Ksj	–	Bivalves are common in this slabby to massive sandstone.	–

Table 8 (continued). Lithological information and specimen data for paleontological localities.

Park/Alt #	Fm/Mbr	Lithology	Specimens Observed	Specimens Collected?
UMNH VP 1149	Ksj	–	Piece of turtle and other bone in flat covered with much sandstone rubble.	–
UMNH VP 1152	Ksj	–	Large fragmentary bone found on a gray flat.	–
UMNH VP 1164	Ksj	–	Large croc scute material and other bone.	–
UMNH VP 1165	Ksj	–	Large dinosaur bone and turtle at original collection site.	–
UMNH VP 1168	Kw	–	–	–
UMNH IP 41	Ksj	–	"A few bivalve molds, one very nice, and higher a little bone"	–
UMNH IP 65	Tcp	Orange-red flats.	Both trace fossils and peloidal carbonates with possible ostracods present.	–
UMNH VP 1665	Kw	Found material in place in a very sandy, gritty stream bottom.	Bone found on surface including big bone, turtle, crocodilian, and more delicate bone. Found gar scales, croc tooth, etc. in place at this horizon.	YES
UMNH IP 84	Tcw	White carbonate above where the unionids were found.	Unionids were found on the flats in the saddle and on the south side of the hill south of the saddle.	YES
UMNH IP 85	Kw	Ironstone rich friable sandstone in out of place blocks low on the slope.	Gastropods and bivalves. A little bone and gar scale in the sandstone.	–
UMNH PB 59	Tcp	Gray limestone.	Leaf impressions. Secondary venation is present, but no leaf margins. Insect trace fossils.	–
UMNH PB 60	Tcp	The plant and invertebrate traces are found in yellow mudstone.	Leaf impressions with secondary venation, lateral invertebrate burrows and one gar scale.	YES
UMNH PB 61	Tcp	Yellowish grey calcareous mudstone on a slope.	Leaf impressions exhibiting secondary venation and some leaf margins. Several whole leaves were discovered.	–
UMNH VP 3931; IP 406; PB 210	Kw	–	Bone fragments, fish, shark, and ray teeth. Ostracod carapace. Plant cuticle, seed pods, and charophyte spores.	YES

Appendix F: Geologic Time Scale

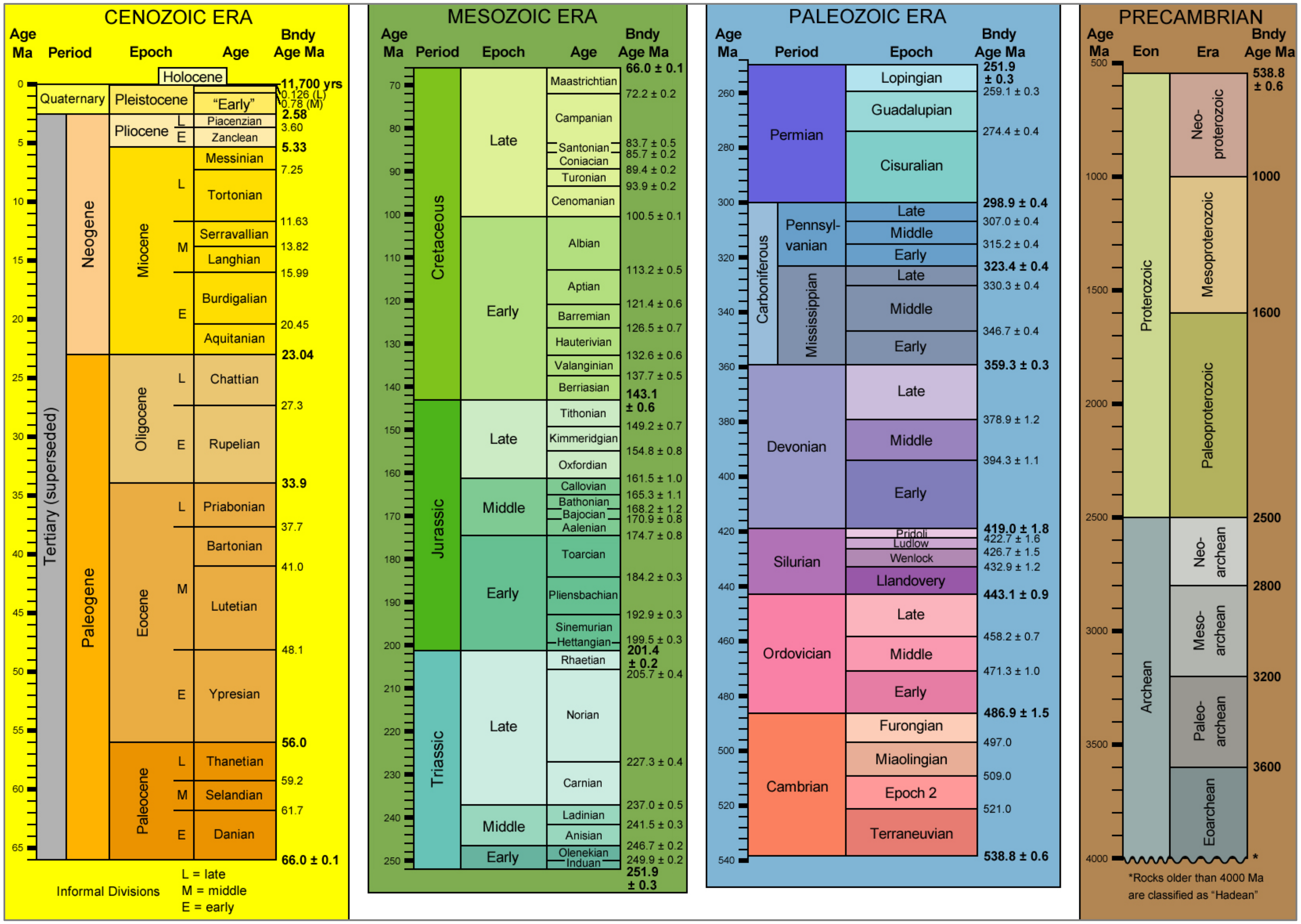

Figure 36. Geologic Time Scale. Ma=Millions of years old. Bndy Age=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://rock.geosociety.org/net/documents/gsa/timescale/timescl-1999.pdf). Dates after Gradstein et al. (2020).

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