Paleontology of the Bears Ears National Monument: history of exploration and designation of the monument

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ABSTRACT

Bears Ears National Monument (BENM) is a new, landscape-scale national monument jointly administered by the Bureau of Land Management and the Forest Service in southeastern Utah as part of the National Conservation Lands system. As initially designated, BENM encompasses 1.3 million acres of land with exceptionally fossiliferous rock units. These units comprise a semi-continuous depositional record from the Pennsylvanian Period through the middle of the Cretaceous Period. Additional Quaternary and Holocene deposits are known from unconsolidated river gravels and cave deposits. The fossil record from BENM provides unique insights into several important paleontological periods of time, including the Pennsylvanian-Permian transition from fully aquatic to more fully terrestrial tetrapods; the rise of the dinosaurs following the Triassic-Jurassic extinction; and the response of ecosystems in dry climates to sudden temperature increases at the end of the last ice age and across the Holocene. While the paleontological resources of BENM are extensive, they have historically been under-studied. Here we summarize prior paleontological work in BENM and review the data used to support paleontological resource protection in the 2016 BENM proclamation.

INTRODUCTION

Southeastern Utah has a diverse and significant paleontological record of the Late Paleozoic through mid-Mesozoic Eras. The first published paleontological work in the region dates back to the late 1890s, but interest and exploration among local Navajo and Ute communities predates the late 19th century and extends to Ancestral Puebloan communities (Mayor 2005; Smith et al. 2016; pers. comm, W. Greyeyes, 2017). Today, paleontological research in the region is advancing our understanding of critical evolutionary events, major extinctions, biogeography and ecology of extinct and extant organisms, and the morphologic and taxonomic diversity of life on Earth.

Illegal excavations and collections have been prevalent in recent times (R. Gay, J. Uglesich, pers. obs.; R. Hunt-Foster, pers. comm.). Despite stronger enforcement and education of paleontological laws over the past several decades (United States vs. Larson, 1997; Public Law 111-11, Title VI, Subtitle D; 16 U.S.C. §§ 470aaa - 470aaa-11), looting of paleontological resources remains a prevalent problem in southeastern Utah, hindering past, present, and future geoscience research. In December 2016, President Barack Obama declared 1.35 million acres of southeastern Utah as Bears Ears National Monument (BENM) (Obama, 2016), under the authority delegated by the Antiquities Act of 1906. The monument is named for two resistant sandstone-capped buttes reminiscent of bear's ears, which are sacred to the Navajo, Hopi, Ute, and New Mexico pueblo peoples. BENM's natural beauty provides the backdrop to lands incredibly rich in paleontological and cultural resources, both of which are explicitly protected in the monument proclamation (Obama, 2016).

Geographical and Geological Setting

Bounded by Canyonlands National Park on the north and west, the San Juan River to the south, and, roughly, highway 191 to the east, BENM lies in the heart of what is known as Utah's Canyon Country (Figure 1). It is part of the larger Colorado Plateau uplift and has experienced local uplift as well. A prominent structural feature of the region is the Monument Upwarp, a broad north-south trending anticlinal fold, 110 miles long and 40-60 wide, which has been altered by smaller-scale anticlines and synclines, expressed most prominently at Comb and Elk ridges (Sears, 1956). Uplift events, millions of years of river downcutting, and erosion have carved the landscape into the stunning, unforgiving lands we see today (Barnes, 1993). In the last two millennia, this region gave rise to Ancestral Puebloan cultures, whose remaining ruins and artifacts were one of the driving forces behind the creation of BENM (Obama, 2016).

Erosion in BENM has also exposed over 150 million nearly-continuous years of geologic time, from the Middle Pennsylvanian Paradox Formation to the “middle” Cretaceous Burro Canyon Formation (Lewis et al., 2011). Vertebrate, invertebrate, plant, and trace fossils are found throughout the majority of the formations exposed within BENM. Though several unconformities exist, a mostly continuous record of geologic time is uniquely captured in these generally flat-lying to low-dipping strata (Figure 2).

LATE PALEOZOIC

Geology and paleontology

The oldest rocks exposed in BENM are the Middle-Upper Pennsylvanian Hermosa Group--known for extensive potash and oil deposits in the four-corners region (Stokes, 1986)--which regionally includes the Middle Pennsylvanian Paradox Formation and the Upper Pennsylvanian Honaker Trail Formation. In the early Pennsylvanian much of Utah was covered by ocean and rocks deposited during that time are primarily marine. Uplift of the Ancestral Rockies, regionally manifested as the Uncompahgre, took place during the Pennsylvanian period. Located along the Colorado/Utah border and oriented north-northwest to south-southeast, this uplift was rapid in geologic terms (12-15 thousand feet in a few million years) and, as a consequence, erosion rates were extremely high. The only non-marine deposits in Utah from the Pennsylvanian are located in the Uncompahgre (east-central Utah). The Paradox Basin formed immediately to the south of the uplift and filled with eroded sediments of the Uncompahgre uplift, creating the the the Paradox formation, which is not fossiliferous and is composed of highly deformed limestones, sandstones, shales, and weathered gypsum. **(**Stokes, 1986; Condon, 1997). The overlying Honaker Trail Formation, with cyclically bedded limestone, sandstone, and shale, is known for its diversity of invertebrate fossils (Condon, 1997; Lewis et al., 2011). Fossils from the Honaker Trail Formation include multiple species of conodonts, brachiopods, bryozoans, and fusulinids (Williams, 1949; Condon, 1997; Ritter et al., 2002). The cyclic and laterally-continuous horizontal beds and the occurrences of conodonts within these cycles have allowed for successful correlation of Pennsylvanian marine with midcontinent cycles, through conodont sequence biostratigraphy (Ritter et al., 2002).

Overlying the Hermosa Group is the Upper Pennsylvanian-Lower Permian Cutler Group (Lewis et al., 2011), a continuous record of the diversification of life on land and the rise of amniotes. The Permian climate was warm and arid. The geology of the Cutler Group reveals a landscape of shallow seasonal lakes, alluvial fans, and shifting dune fields. These dune fields are preserved as the White Rim and Cedar Mesa Sandstones. Little, if any, White Rim Sandstone is preserved in BENM. In the early Permian, marine incursions from the west covered nearly the entirety of Utah. Later, a marine incursion from the south (present-day Gulf of Mexico) called the Kaibab Sea penetrated nearly to the Salt Lake Basin. These warm shallow, seas supported abundant life, and created red beds. (Stokes, 1986; Condon, 1997).

Ray-finned and lobe-finned fishes, *Eryops, Seymouria,* and sail-backed amphibians like *Platyhistrix*, along with synapsids like *Sphenacodon* and *Dimetrodon,* are found throughout the terrestrial Permian exposures of BENM, as are exceptionally well-preserved plant remains (Vaughn, 1962; Vaughn, 1964; Vaughn, 1966; Vaughn, 1973; Berman et al., 1981; Lockley and Madsen, 1993; Condon, 1997; Sumida et al., 1999a; Sumida et al., 1999b; Sumida et al., 1999c; Hasiotis and Rasmussen 2010; A. Huttenlocker, pers. comm., 2017). Relatively few continuous stratigraphic records of this time period exist in other parts of the North America, so BENM deposits provide a rare and relatively complete look at the ecosystems that developed prior to the devastating Permo-Triassic extinction (DiMichele et al., 1992).

Ongoing work: Currently, teams from the University of Southern California and the Natural History Museum of Utah are working several important sites in Indian Creek as well as historic localities in the Valley of the Gods. This work is in its earliest stages but already a fauna consistent with other Paleozoic localities in North America is emerging, though with some significant differences (Huttenlocker, pers. comm).

UPPER TRIASSIC

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Geology: Southeastern Utah was covered by marginal mudflats in the early Triassic which created the Moenkopi red beds found across western BENM. Limestone tongues are also found in BENM early Triassic outcrop. The Moenkopi Formation is sparsely fossiliferous in terms of body fossils, but preserves abundant traces of invertebrates, reptiles, and amphibians. In the Middle Triassic a high elevation zone called the Mesocordilleran High formed in present-day Nevada which prevented further marine incursions (Stokes, 1986). As the climate of southeastern Utah became increasingly arid toward the end of the Triassic Period, northwestward-flowing rivers of the Chinle Formation began draining more quickly as the ocean to the northwest retreated and sand dunes encroached upon the eastern half of the state (Martz et al., 2014; Britt et al., 2016). As a result, dune fields formed across Utah in the late Triassic and early Jurassic, which are preserved as the Wingate formation (almost entirely barren of fossils) (Stokes, 1986).

No other geologic formation in BENM has attracted more research attention than the Upper Triassic Chinle Formation (Parrish and Good, 1987; Parrish, 1999; Fraser et al., 2005; Gay and St. Aude, 2015, Martz et al., 2017; Figure 3). Within BENM, the Chinle Formation can be divided into six members, from oldest to youngest: the Shinarump, Monitor Butte, Moss Black, Petrified Forest, Owl Rock, and Church Rock Members (Lewis et al., 2011). Recent geological work by Martz et al. (2014) has shown that in southeastern BENM only the Church Rock is present as an upper unit, and the Moss Back and Monitor Butte members are undifferentiated (Lewis et al., 2011) and will be referred to as the Monitor Butte Member, following Gay and St. Aude (2015). Church Rock Member and Kane Springs beds dominate the Chinle exposures in northern BENM, as in Moab and Lisbon Valley (Martz et al., 2014), while the Chinle of southwestern BENM is understudied; lithologic descriptions for this area will generally follow Stewart et al. (1972).

The swamp and lake deposits of the Monitor Butte Member, characterized by coal beds, bentonites, and generally anoxic or reduced depositional environments, is the lowermost unit of the Chinle Formation (Gay and St. Aude, 2015 and references therein). At the base of the Monitor Butte Member is the Shinarump (Conglomerate) Member, which appears in lenses throughout BENM (Lewis et al., 2011). The uppermost shale unit of the Chinle Formation is the Church Rock Member (Martz et al., 2014). This steep, generally oxidized reddish-brown unit contains abundant channel sands and occasional coquina deposits. Above the Church Rock Member, Big Indian Rock Beds may be present locally, and are likely Chinle as well, representing the early encroachment of the Triassic-Jurassic Wingate erg (Martz et al., 2014).

History of geological and paleontological exploration: The earliest publication on fossils from the region that is now BENM described the first occurrence of a phytosaur from southern Utah (Lucas, 1898). Phytosaurs were semi-aquatic, crocodile-like reptiles that were globally distributed and abundant during the Late Triassic (Stocker and Butler, 2013) and are perhaps the most common vertebrate fossil from the Chinle Formation in BENM (Martz et al., 2014 and references therein). Their remains continue to be found throughout the region (McCormick and Parker, 2017; pers. observ.)

In the early part of the 20th century, scientific exploration in BENM generally focused on archaeology and oil exploration along the San Juan River (e.g. Wengerd, 1952). In the 1950s, exploration in the Chinle Formation shifted away from fossils and toward another resource: uranium. The post-World War II boom inspired mining claims throughout southeastern Utah, and the Chinle Formation became one of the country's most productive formations for uranium (Ringholz, 1989). The impacts of this uranium boom can still be felt by paleontologists who work in BENM in unexpected ways, for example, old uranium roads provide access to sites that would otherwise be inaccessible, as the Chinle Formation often forms steep, inaccessible badlands within BENM. Uranium readily replaces calcium in bone (Neuman et al., 1949), and in areas with high concentrations of radioactive minerals, radioactive fossilized bone and wood are common (R. Gay, pers. observ.). Historical archaeological signs of the uranium boom, including mine shafts and assorted machinery, core sample holes, mining haul roads, and abandoned camps can be found across BENM wherever Triassic deposits are abundant.

Following the seminal work on Chinle stratigraphy by Stewart et al. (1972), paleontological reconnaissance of the Chinle Formation across southeastern Utah was performed from 1983 through 1988 by Michael Parrish, Steven Good, and Russell Dubiel. Prior to field excursions by Parrish and colleagues, fossil occurrences in the Chinle of what is now BENM had been limited and isolated, largely due to the rough terrain and lack of systematic prospecting (though see Schaeffer (1967) for an example Triassic discoveries in Utah outside of BENM prior to Parrish). Parrish (1999) notes that, in the 1980s and 1990s, the Chinle Formation in Arizona and New Mexico had produced rich fossil assemblages, but no comparable sites had been located in Utah.

During their mid-1980s surveys, Parrish, Good, and Dubiel discovered vertebrate fossils in the Shinarump, Monitor Butte, Moss Back, and Petrified Forest Members of the Chinle in southeastern Utah (Parish and Good, 1987; Parrish, 1999). Among the vertebrates discovered were metoposaurs, phytosaurs, and parts of an aetosaur (Parish and Good, 1987). Discovery of three specimens of the phytosaur, including "*Rutiodon tenuis*" (=*Machaeroprosopus pristinus*, Long and Murry (1995)), and a partial scute from the aetosaur, *Typothorax*, allowed for the correlation of the Petrified Forest Member in the White Canyon region of BENM with the upper unit of the Petrified Forest Member in Arizona and New Mexico (Parish and Good, 1987), in line with the work of Stewart et al. (1972). In addition to vertebrates, Parrish, Good, and Dubiel also discovered invertebrate fossils, including bivalves, gastropods, ostracods, and conchostracans, specifically *Triasamnicola assiminoides*, *Diplodon gregori*, and *Antediplodon sp.* and *Unio sp.* (Parrish and Good, 1987).

The most significant published discoveries from the 1980s fieldwork were two separate localities within the Chinle Formation in BENM that preserve small vertebrates. The first was discovered in the Monitor Butte Member in Red Canyon: Parrish discovered several vertebrae, limb elements, and armor plates of at least two individual diminutive crocodylomorphs pertaining to the same taxon, as well as three additional armor plates distinct from the unidentified crocodylomorphs, but was unable to provide any taxonomic information beyond "archosauriform" (Parrish, 1999). This region--including Parrish's locality-- was included in the original monument proposal (Bears Ears Intertribal Coalition, 2016) but omitted in the final declaration (Obama, 2016). The second locality, found in the Petrified Forest Member of the Chinle Formation in White Canyon, produced vertebrae and claws from a possible theropod dinosaur and a fragmentary right mandible from a possible ornithischian dinosaur (Parrish, 1999). These represent the only published occurrence of dinosaur body fossils from the Triassic

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of Utah, and as such are highly significant. This site and the surrounding region are currently protected within BENM (Obama, 2016).

Ongoing Work: Parrish and Good were the first researchers to reveal the potential for significant Chinle sites within BENM. Three decades later, the list of institutions involved in active research in the Chinle Formation in BENM has grown significantly. Paleontologists and crews associated with the Museums of Western Colorado, the Museum of Moab, the Natural History Museum of Utah, the Saint George Dinosaur Discovery Site, the Natural History Museum of Los Angeles, Petrified Forest National Park, Appalachian State University, and the University of California, Berkeley have teamed up to cover as much Chinle outcrop in BENM as possible. In a large collaborative effort that is becoming the new direction in paleontological research, paleontologists from these institutions are working to fill in the gaps in our understanding of the Late Triassic Period (Gay et al., 2017, Gay et al., in prep.).

Recent work by several teams has generated substantial collections from BENM, much of which awaits preparation or analyses. An astounding union of archaeology and paleontology, there is evidence in BENM of ancestral puebloans intentionally utilizing fossils in pueblo construction (Smith et al., 2016). Another important recent discovery is a diverse microvertebrate assemblage from the base of the Chinle Formation at Comb Ridge (Gay et al., 2016). This site has already produced over 400 specimens without extensive screenwashing (which is planned for 2018), and the faunal diversity is greater than virtually all Upper Triassic microvertebrate sites in the United States. Finally, Gay et al. (2017) report a new bone bed in Church Rock Member of the Chinle Formation. Fieldwork conducted at this site in September of 2017 suggests that the bone bed is a laterally-extensive, multispecies assemblage unlike anything previously discovered in BENM. Further, it likely represents a unique Triassic assemblage for the state of Utah as well. Fieldwork in 2017 also demonstrated that illegal collections had been made at the site within the past two decades highlighting the fragility of this extremely significant locality and others like it.

THE TRIASSIC-JURASSIC BOUNDARY

In several areas throughout BENM, the Triassic-Jurassic transition is preserved without gaps in geologic time (Lewis et al., 2011). Dinosaurs evolved at the start of the Late Triassic and, by the beginning of the Jurassic, became the dominant life form for the next 140 million years (Irmis et al., 2007). Understanding how dinosaurs not only survived, but thrived, after the Triassic-Jurassic Extinction is fascinating in and of itself, but can also provide insights to terrestrial life's responses to rapid climate change (Britt et al., 2016; Barnosky et al., 2017). Overlying the Chinle Formation is the Upper Triassic-Lower Jurassic Wingate Sandstone, an indurated aeolian sandstone that acts as a "cap" to the less resistant mudstones of the Chinle Formation (Lucas et al. 2006b). One notable exposure of these continuous strata is the east limb of the Monument Upwarp, a nearly 80-mile long north-south trending monocline known as Comb Ridge (Sears, 1956). Much of northern BENM is flanked by Wingate Cliffs, as well; specifically Indian Creek, Harts Draw, and Lockhart basin. The Wingate has yet to produce diagnostic body fossils. However, numerous biostratigraphically important Wingate trackways have been found north of BENM--in Dinosaur National Monument, Colorado National Monument, near Moab, Utah, and near Gateway, Colorado--as well as to the south, in northeastern Arizona (Lockley et al., 1992; Lockley and Hunt, 2005; Schults-Pittman et al., 1996; Lockey et al., 2004; Smith and Foster, 2004). In the Upper Triassic Wingate, these tracks come from *Grallator, Brachychirotherium, Eosauropus,* and synapsids. Up section in the Lower Jurassic portion of the Wingate, tracks of *Grallator, Batrachopus, Eubrontes,* and *Otozoum* have been found as well (Lucas et al., 2006b). Within BENM, Wingate tracks are commonly found north of the Abajos (M.A. Stegner, personal observation, 2017).

JURASSIC

Southeastern Utah remained, for the most part, a sand erg from the Early Jurassic until the Middle Jurassic (Sertich and Loewen, 2011). Kayenta Sandstone, of aeolian and fluvial origin, was deposited in the Early Jurassic. Abundant body fossils--including hybodont and osteichthyan fishes, amphibians, caecilians, turtles, crocodylomorphs, dinosaurs, cynodonts, dicynodonts, and mammals (Lucas et al., 2005)--as well as tracks--*Grallator* and *Eubrontes* (Lockley and Hunt, 1995)--have been discovered in Kayenta outcrop in the Four Corners region

(Lucas et al., 2005). There has been little study of the Kayenta Formation in southeastern Utah to date.

The Lower Jurassic Navajo Sandstone, a white-colored aeolian deposit characterized by large-scale cross-bedding, was also generated by the sand erg that covered much of Utah, Arizona, and Nevada during the Early Jurassic (Verlander, 1995). Trace fossils appear as tracks and burrows in small lacustrine deposits between sand dunes (Riese et al., 2011), and although body fossils are sparse in the Navajo Formation, they reveal a diverse vertebrate assemblage, as well as stromatolites, various plants, and ostracods (Irmis, 2005; Lucas et al., 2006a). One remarkable find within Navajo Sandstone of BENM is the gravesite of the geologically oldest dinosaur with a binomial name described from Utah, found northwest of Bluff . Published in 2011, *Seitaad ruessi* is a basal sauropodomorph that was smothered by a collapsing dune (Sertich and Loewen, 2011).

Towards the close of the Jurassic Period, the climate across western North America became wetter, leading to the development of networks of meandering rivers and braided streams flowing between broad vegetated floodplains (Stokes, 1986; Kjemperud et al., 2008). In the northern part of BENM, the resulting variegated mudstones and channel sandstones make up the Upper Jurassic Morrison Formation, one of—if not the—richest dinosaur-bearing formation in the North America (Foster, 2007 and references therein). During this time, iconic dinosaurs such as *Allosaurus*, *Camarasaurus*, *Brachiosaurus*, *Stegosaurus*, and *Apatosaurus* lived across this 700,000 square mile basin across which Morrison sediments were deposited, leaving behind footprints and dozens of multispecies bone beds (Stokes, 1986). Morrison plant localities have been discovered in BENM and from these we have been able to reconstruct Late Jurassic environments (Parrish et al., 2004; Kirkland, pers. comms.)

Ongoing Work*:* The Morrison Formation of BENM has been hard-hit by illegal fossil collection over the last several decades, with numerous looted sites discovered by the most cursory BLM surveys in 2016 (J. Uglesich, pers. observ). While much of the Morrison Formation has been explored in other areas--like north of Moab (Foster, 2007)--outcrops within BENM are only now being extensively surveyed by professional paleontological field crews.

Since late 2016, the Utah Geological Survey has been actively surveying BENM Morrison Formation and, while much ground has been covered, most of the exposures have yet to be prospected. As with all formations, erosion continuously reveals new fossils. Given the richness of the Morrison formation in other areas where it is exposed, it is almost a certainty that significant fossil resources remain undiscovered (Kirkland and DeBlieux, personal communication). Preliminary survey results demonstrate that ongoing and future explorations within BENM will continue to expand the depth and breadth of our paleontological knowledge of Jurassic biodiversity within the region.

UPPER MESOZOIC

Although the vast majority of BENM fossils are known from mid-Mesozoic and older rocks, some exposures of Cretaceous terrestrial deposits exist with the monument boundaries. The Burro Canyon Formation is found on the eastern side of BENM, in the vicinity of and capping the Black Mesa area. Just beyond the monument boundaries, east of Blanding, rich vertebrate trace fossils are known from the Burro Canyon Formation (Milan et al., 2015) and survey work by the Utah Geological Survey and others is in early phases.

QUATERNARY

During the Oligocene, the laccolithic Abajo and La Sal mountains formed. The uplift of these ranges, paired with subsequent glacial-interglacial cycles during the Quaternary, was the primary driver of the erosional process that carved Canyon Country. The La Sals were glaciated repeatedly during the glacial-interglacial cycles of the Quaternary; the slightly older and lower Abajos were either not glaciated, or glaciers there were considerably smaller. Each interglacial period induced a sequence of glacial melting, followed by alluviation, and finally erosion (Richmond, 1962; Stokes, 1986; Barnes, 1993)

There are no pre-Quaternary Cenozoic deposits in BENM, but Quaternary cave deposits generated by packrats are abundant across the region. Packrat middens from across the Southwest document past insect, vertebrate, and plant diversity, and because these sites are extremely common in desert environments, networks of middens can be used to understand past life and ecology, including biogeography, species-environment interactions, demographic and population changes, diets of extinct and extant mammals, and so on. In BENM, caves and alcoves large enough to accumulate packrat middens for thousands of years are found in Cutler dune deposits (primarily White Rim and Cedar Mesa Formations), Navajo Formation, and Slickrock Entrada. Fossil-bearing quaternary gravels have been reported in the region, but little research has been conducted to date (A. Stegner, R. Gay, pers. observs.).

The Colorado Plateau was considerably cooler and more mesic during the last glacial period of the Pleistocene (before ~14 ka) than it is today. In BENM and surrounding regions, modern plant communities were shifted 700-900m lower in elevations during the last glacial maximum than they are today (Cole, 1990; Anderson et al., 2000). Climatically, the early Holocene was cooler than today, but more mesic than the Late Glacial because the summer monsoon was strengthened (Weng and Jackson, 1999); this is also when the modern monsoon boundary was established (Betancourt, 1984). This cool mesic period gave way to an arid and warm mid-Holocene, from about 8.5-6 ka (Weng and Jackson, 1999; Reheis et al., 2005). From ~6-3 ka, cool-wet conditions returned (Betancourt, 1984; Reheis et al., 2005). Fossil pollen from the Abajos suggests that Maize agriculture was present in the vicinity of BENM around 3120 cal ybp (Betancourt and Davis, 1984). Analysis of eolian and alluvial deposition in Canyonlands National Park suggests that from 2 ka to the present, drier conditions set in, as evidenced by greater mobility of dune sand (Reheis et al., 2005)

In the 1980s and 1990s crews from Northern Arizona University and USGS documented cave deposits generated by packrats across the Four Corners region; concentrated on National Park units, and many sites were documented in the Canyonlands National Park Needles district just north of BENM (Elias et al., 1992; Tweet et al., 2012). While these sites contain ample small vertebrate bone, large mammals and plant macrofossils were the primary focus and most of the small vertebrates remain unpublished. Remains of *Oreamnos harringtoni*, and extinct mountain goat, were found alongside pack rat middens in a rockshelter in Natural Bridges National Monument, within BENM (Mead et al., 1987). Plant macrofossils and dung reveal diet of this extinct species, as well as that early Holocene vegetation was dominated by species found at higher in elevations today, including rose, Englemann spruce, limber pine, and Douglas fir

(Mead et al., 1987). Two important plant macrofossil localities--specifically, Allen Canyon Cave in the southern Abajos and and Fishmouth Cave in the Comb Ridge (Betancourt, 1984; Coats et al., 2008)--reveal that xeric- as well as mesic-adapted plants were present in the region at the end of the Last Glacial Maximum, and modern dominant species like pinyon pine and ponderosa didn't appear until the mid-Holocene (Betancourt, 1984; Coats et al., 2008). These sites were historically important for shaping our understanding of desert plant communities. Additional dendrochronological work in Beef Basin (Pederson et al., 2011), White Canyon, Natural Bridges (Dean and Bowden, 1994; Stahle, 2016), and near the northernmost extent of Comb Ridge (Dean and Robinson, 1994) records aridification of BENM and surrounding areas during the Late Holocene. Paired with extensive archaeological research, dendrochronological research reveals a series of multi-decadal "megadroughts," beginning around 870-820 ybp, which has been a crucial to understanding why Ancestral Puebloans who lived in southeastern Utah and western Colorado migrated out of the region, concluding around 650 ybp (Grahame and Sisk, 2002; Benson and Berry, 2009).

Ongoing Work: In the last 5 years, work conducted by University of California Museum of Paleontology researchers has concentrated on the vertebrate faunas in mid- and late Holocene packrat middens from BENM (MA Stegner, 2016, pers. observation). Four small cave deposits--two less than 1 km north of BENM in the area called Dry Valley, and two northwest of the Abajos--have been excavated and extensively radiocarbon-dated by Stegner since 2013. These sites have begun to reveal how small vertebrates responded to environmental change during this period of Holocene climate warming and aridification. In the next several years, planned excavations of packrat middens in Beef Basin, the northwestern corner of BENM, will shed light on floral and faunal change in this understudied and remote grassland. Unpublished sites excavated in 2014 and 2015 by Stegner are currently under study, and record the presence of extant species not found in BENM today, like *Notiosorex crawfordii*. Because these deposits are young and the bones are extraordinarily well-preserved (MA Stegner, 2016, personal observation) they could be used for ancient DNA studies that would add many layers of nuance to our understanding of Colorado Plateau biogeography.

CONCLUSIONS

Paleontology in the 2016 Monument Proclamation

The idea of federally protecting the region now known as BENM was conceived as early as 1936--at that time, a proposed "Escalante National Monument" included what is not Grand-Staircase-Escalante National Monument, Glen Canyon National Recreation Area, Natural Bridges National Monument, and the majority of Canyonlands National Park (Davidson, 1991), and tracks well with scientific research on the fossils of the region (Figure 4). Heightened federal protection of this overall region has been piecemeal, with BENM the last major region to be designated. In 2016, public support for the idea of a national monument or national conservation area in southeastern Utah was gaining momentum. This was due in large part to the immense numbers of archaeological sites documented across the region, and the majority of outreach regarding monument designation and conservation was centered on these resources. The focus, however, was not on paleontological resources in the area. One of the authors (RG) spearheaded an effort to include paleontological resources as part of a comprehensive conservation package, in order to support research efforts in the region. After conversations stemming from the 2016 Celebrate Cedar Mesa conference in Bluff, Utah, two competing proposals both recognized the significance of paleontology within the area; one put forward by Utah's congressional delegation, known as "Utah's Public Lands Initiate" (or PLI) which included a broad-reaching rearrangement of public lands in the state of Utah, including the creation of a 1.4 million acre Bears Ears National Conservation Area (Bishop, 2016). The second was a proposal put forward by a coalition of five Native American tribes with historic and prehistoric connections to the region, calling for the creation of a 1.9 million acre Bears Ears National Monument (Bears Ears Intertribal Coalition, 2016). However, the only concerted follow-through on including meaningful paleontological resource protection in efforts going forward came from conservation groups interested in supporting a national monument designation. By September of 2016, it was clear that there would be some political action on the monument issue, but major questions remained: 1) what would the boundaries ultimately be and, 2) what specific resources would be protected. At the behest of the Obama administration via conservation agencies, R. Gay provided draft text of language that could be used to protect paleontological resources in any possible Antiquities Act proclamation, and was invited to Washington D.C. in October of 2016 to speak with the USDA Forest Service, Department of the Interior, and White House Council on Environmental Quality about the significance of the fossil resources . In late December 2016, BENM was established by a presidential proclamation which incorporated language that explicitly protected paleontological resources and the localities in which those resources are found, or have potential to be found (Obama 2016).

Future Work

As discussed above, many groups are working in various rock units across BENM currently. High-priority work is focused on a better understanding of the fin-to-limb transition preserved in the Cutler Group, comprehensive unified stratigraphy across the Chinle Formation in BENM, and a more comprehensive inventory of the Quaternary fossil resources of the monument. Each of these projects are currently ongoing and will take several years to over a decade to bring to fruition, meaning that long-term conservation of these resources are vital to advancing our understanding of these areas of Earth's history.

Paleontological Resource Protection

Perhaps more than any other formation in southeastern Utah, for over a century, fossils from the Morrison Formation have been the target of looting, illegal sale, and private collecting (J. Uglesich pers. observs.). These federal crimes are a management problem that BLM Law Enforcement has been fighting for years, but it's nearly impossible for limited staff to cover such vast regions, especially without additional funding. In 2016, the BLM partnered with conservation group "Tread Lightly" to launch the "Respect and Protect" campaign, a statewide initiative designed to eliminate looting and destruction of fossil and cultural sites through education and outreach about the significance and fragility of these resources (Uglesich and Hunt-Foster, 2016). Respect and Protect also sought to connect local communities with public lands by bringing paleontology outreach programming into neighboring schools and community centers, and to instill a sense of stewardship in these communities. Many tourists who come to visit Utah's wildlands are simply unaware of paleontological and cultural resource laws. Replacing souvenirs with science and emphasizing the importance of every fossil or artifact in understanding the greater Earth or human history is the future of public responsibility and stewardship.

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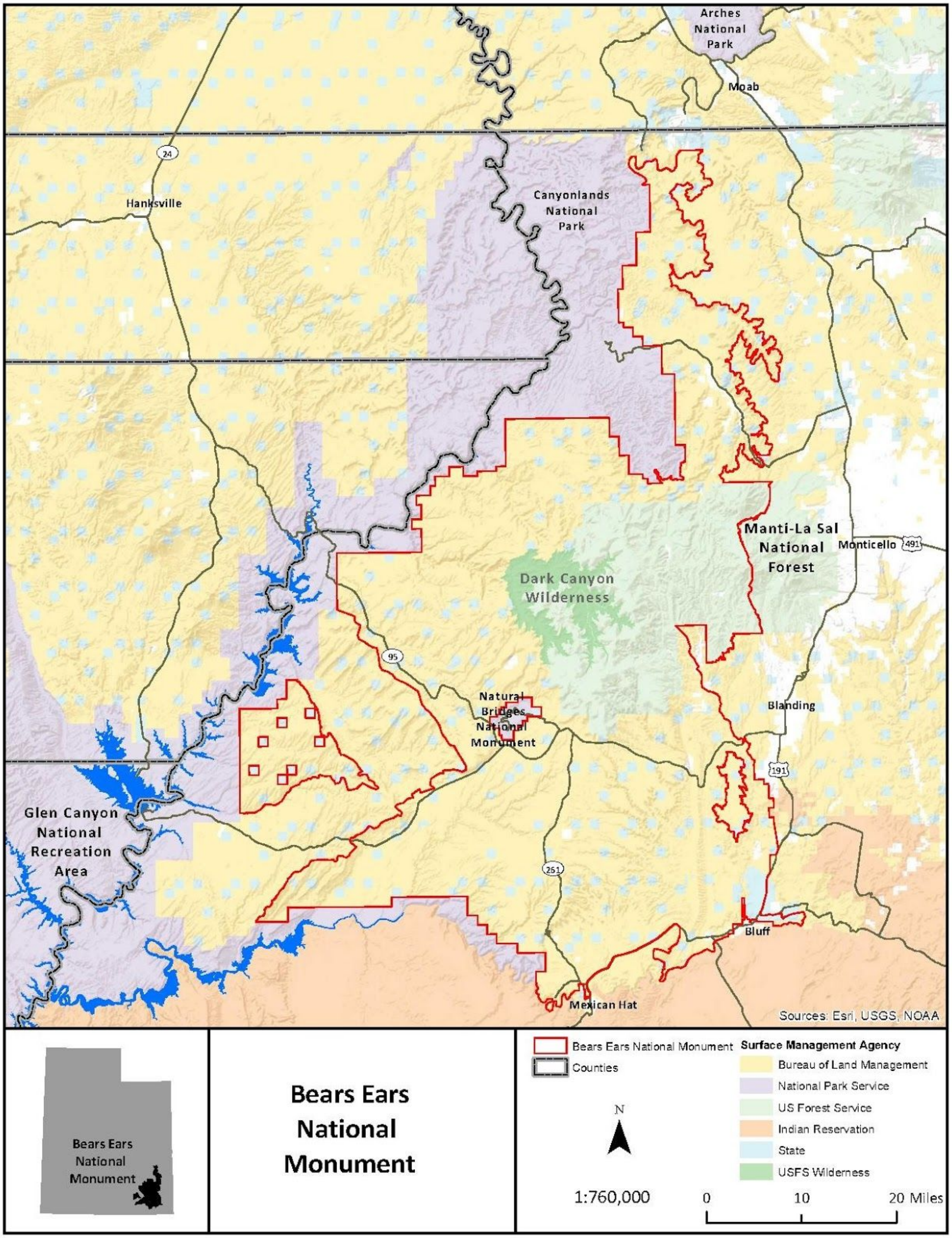
Arches National Park
Moab
Hanksville
24
Canyonlands National Park
Manti-La Sal National Forest
Monticello
491
Dark Canyon Wilderness
95
Natural Bridges National Monument
Blanding
191
Glen Canyon National Recreation Area
261
Bluff
Mexican Hat
Sources: Esri, USGS, NOAA
Bears Ears National Monument
Bears Ears National Monument
Bears Ears National Monument
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National Park Service
US Forest Service
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Figure 1: The boundaries of Bears Ears National Monument (BENM) as established by President Barack Obama on December 28th, 2016, and its location within the state of Utah. Map prepared by the US Forest Service and the US Department of Interior, image in public domain.

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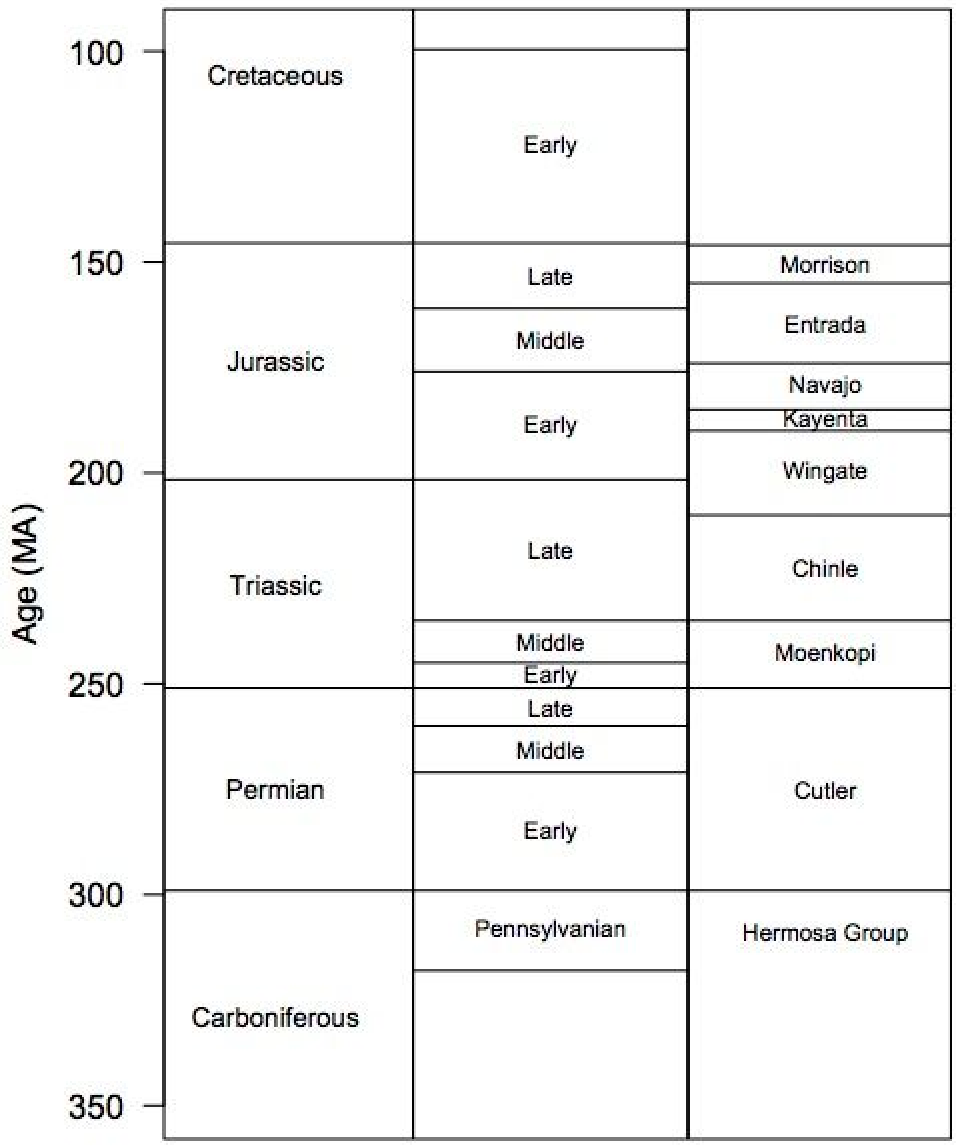

Figure 2: Simplified stratigraphic column of rocks exposed within BENM.

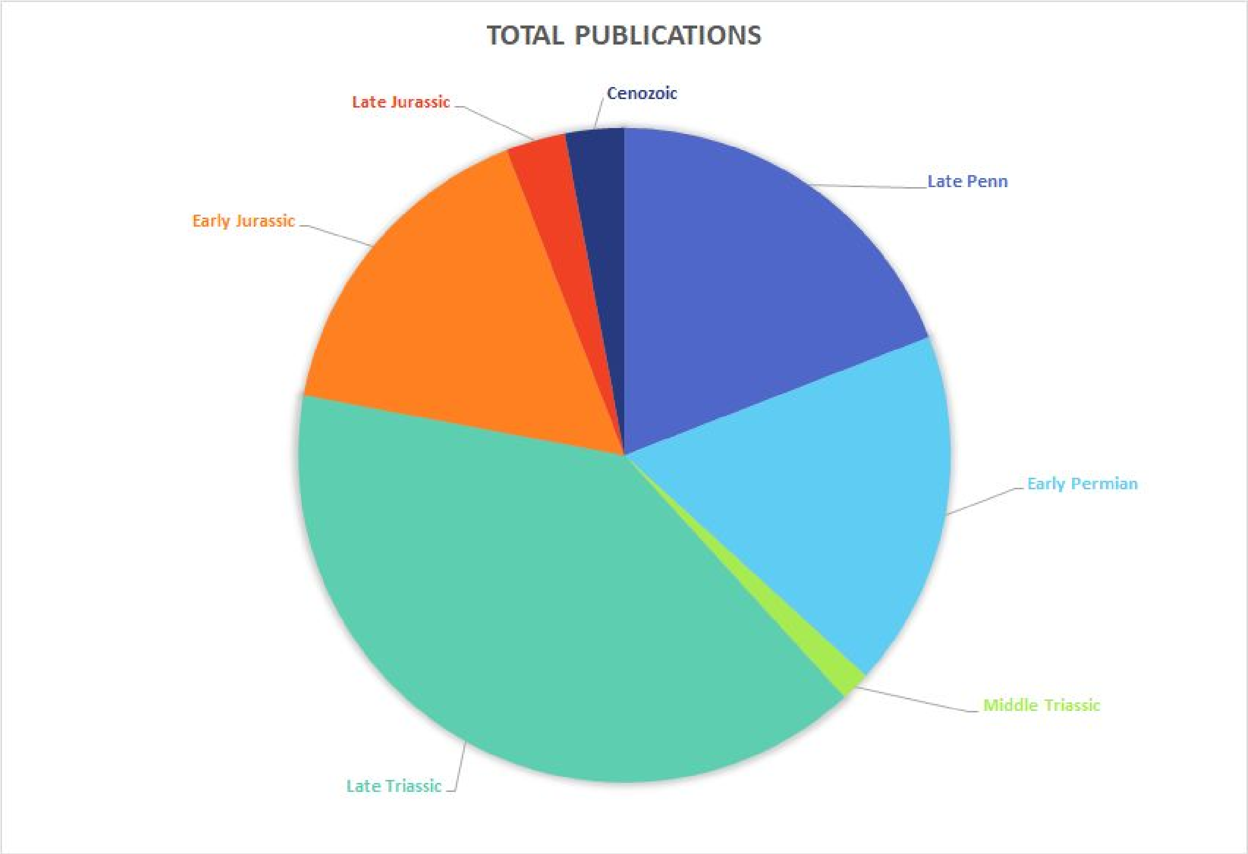

Figure 3: Publications on fossils from within BENM, sorted by topic. Publication data available in supplemental information.

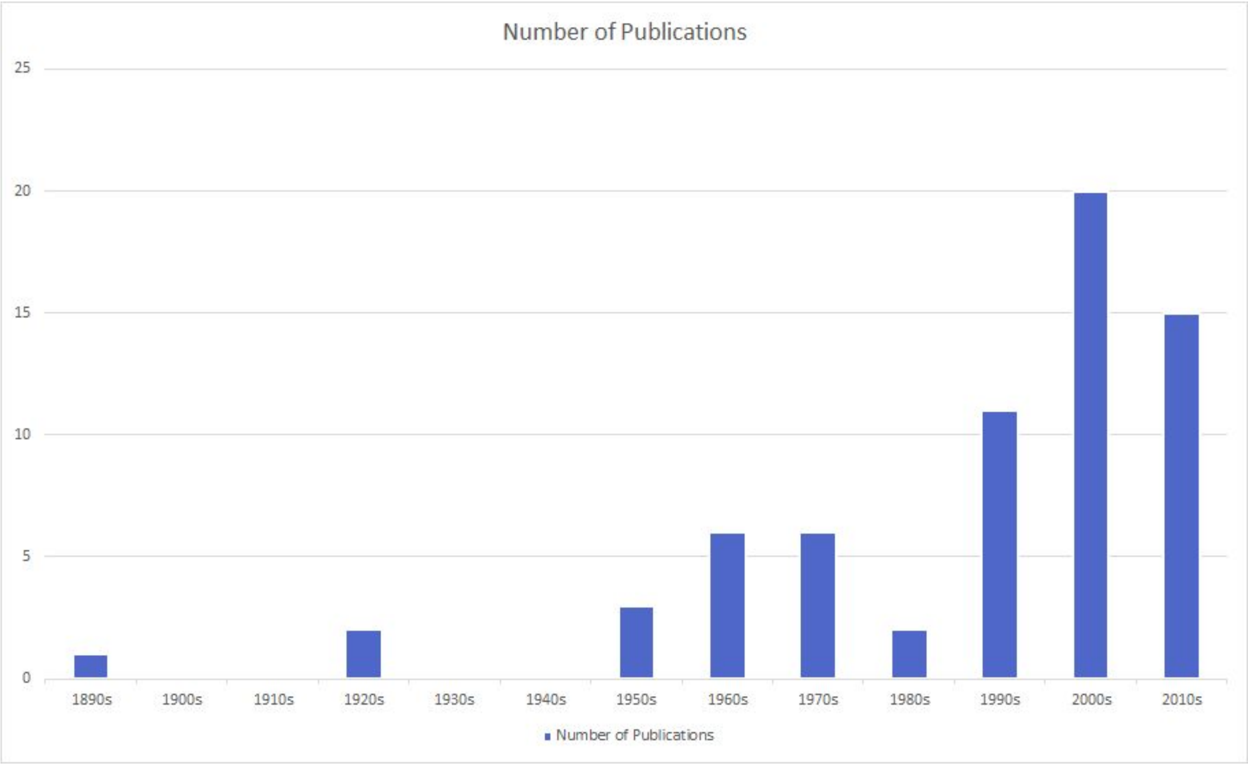

Figure 4: Number of publications on fossils from BENM, segregated by publication decade.

Publication data available in supplemental information.

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