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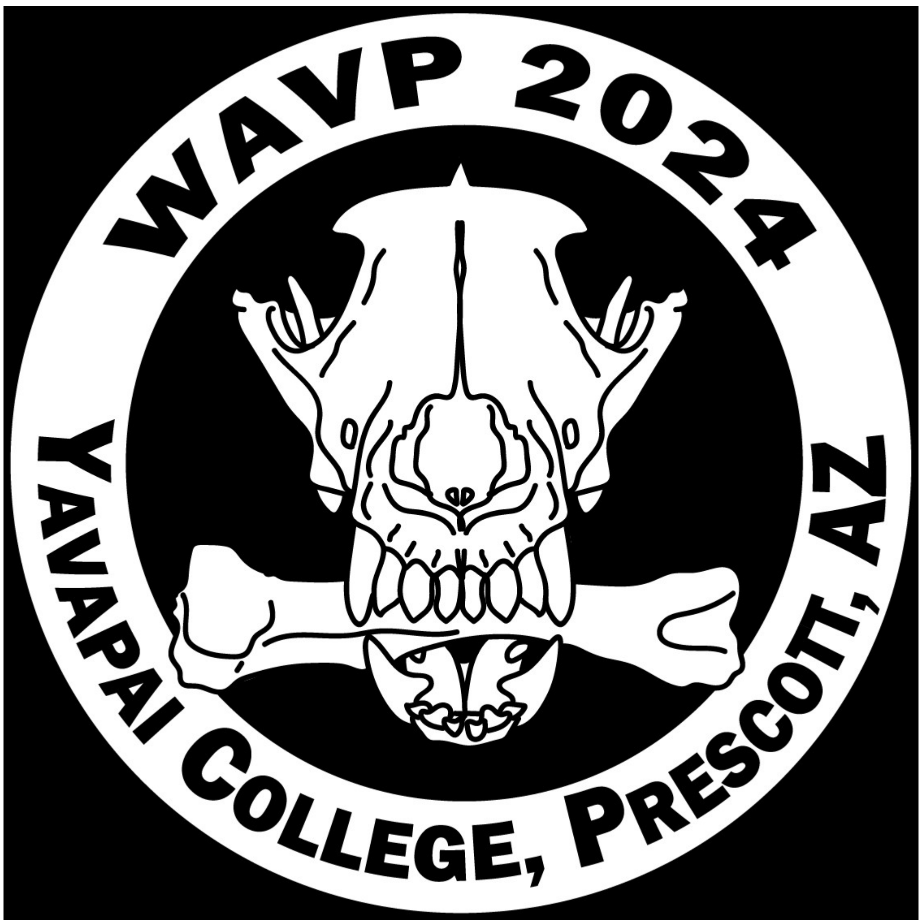

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WESTERN ASSOCIATION OF VERTEBRATE PALEONTOLOGY ANNUAL MEETING

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Yavapai College and the Milk Creek site,

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ABSTRACTS

Alphabetically by first author

NEW ADDITIONS TO THE CHONDRICHTHYAN FAUNAL ASSEMBLAGE FROM THE LATE CRETACEOUS "FINAL FRONTIER" OF WYOMING

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Marine vertebrate fossils—mainly reptiles, bony fish, and cartilaginous fish—from the Late Cretaceous of the Western Interior Seaway are well studied across many formations, yet the faunal composition of the Frontier Formation in Wyoming is poorly characterized by comparison. In 2021, the Raymond M. Alf Museum of Paleontology (RAM) first collected from the "Final Frontier" locality (RAM V-2021016) in Park County, Wyoming, a site that contains abundant vertebrate bone and tooth clasts in a sandstone and chert conglomerate matrix. Previously, only six chondrichthyan taxa had been reported but not described from the Frontier Formation across Wyoming. This includes *Ptychodus, Scapanorhynchus*, *Lamna*, *Myledaphus,* and *Ptychotrygon,* although all of these should be revisited using contemporary taxonomic definitions. In early 2023, three species of shark taxa were reported from four specimens collected from RAM; the current contribution provides an update.

In the past year, the "Final Frontier" locality has been constrained to approximately Cenomanian–early Turonian in age, and progress was made on identifying additional collected specimens. The updated faunal list includes eight chondrichthyan species from the Frontier Formation, including the new additions *Archaeolamna kopingensis, Cretoxyrhina agassizensis, Pseudohypolophus mcnultyi,* and *Pseudohypolophus* sp. Although these species are typical of other formations from the Cenomanian, this study presents their first occurrences in the Frontier Formation of Wyoming. The *Pseudohypolophus* material may account for previous reports of *Myledaphus*, a taxon otherwise only found in the Campanian and Maastrichtian. Compared to at least five other North American localities from the Late Cretaceous, this current faunal composition aligns similarly to those from Saskatchewan, containing species that were likely endemic to the Western Interior Seaway. In conjunction with current studies on recently discovered bony fish and marine reptiles from the "Final Frontier" at the Raymond M. Alf Museum, we are closer to understanding how the Frontier Formation fits into the Late Cretaceous paleoenvironment of the Western Interior Seaway.

THE FIRST JURASSIC PARK AND THE 'HIDDEN' LEGACY OF ALFRED RUSSEL WALLACE

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Pre-geologic western interpretations of fossil specimens were largely influenced from mythology, folklore, religion, and early philosophical discussions. Nicolaus Steno and Augustina Scilla were two of a handful of 17th century researchers who deduced that fossils were the remains of ancient life. By the 19th century, increased studies in geology led by a cadre of researchers and collectors supported the perspective of a long geologic history of life. William Smith's first geologic map and companion guide (1815, 1816) utilized invertebrate marine fossils to identify geologic strata. Mary Anning (1799-1847) is now recognized as a central figure in the early interpretations of fossil materials from the Jurassic Coast of southern England.

These 19th century interpretations of antediluvian life, filled with early discoveries of ammonites, plesiosaurs, pterosaurs, ichthyosaurs, and dinosaurs paved the way for both a scientific revolution of the history of life and in making this information accessible and popular. The public excitement in fossil megafauna led to the construction of the first 'Jurassic Park' with life sized statues of these prehistoric beasts on display at the Dinosaur Court of the Crystal Palace display, just south of London, in 1864. These replicas, created by Benjamin Waterhouse Hawkins under the direction of Richard Owen, who coined the term 'Dinosauria,' were thronged by thousands.

The geologist Charles Lyell pushed for an interpretation of expansive time to allow for the gradual geologic processes he studied. He and others noted major extinctions of many faunas over these geologic eras, delineated by specific fossil taxa. Though Lyell accepted the revolutionary notion of faunal extinctions, he treaded around any definitive natural mechanism for the direct transmutation or evolution of life. The development of this concept required independent efforts by two naturalists Charles Darwin and Alfred Russel Wallace. Each of them used and incorporated Lyell's geologic work and his appreciation of vast expanses of time into the foundations of our current understanding of evolutionary processes.

Though Darwin's name is currently lauded as the main driver for this evolutionary revolution, Wallace leveraged an unexpected and significant influence. This contemporary loss of Wallace's historic legacy is due to several factors, including the neo-Darwinian revolution of the early 20th century. Though Wallace lacked many of the social and academic advantages which Darwin received, both lives took a parallel development from common interests, readings, and work in natural history. Wallace spent a dozen years collecting and authoring his works on the natural history of the flora and fauna in the upper Amazon basin and across the Malay Archipelago. During this, Wallace gained a broad and supportive view of the many people and cultures which he lived, worked, and relied upon. This perspective of universal human ingenuity and abilities was far removed from the provincial Victorian attitudes he grew up with. It was in the eastern corner of the Malay Archipelago where Wallace independently developed a parallel theory to Darwin's natural selection and laid the foundation for modern biogeography. In 1858 Wallace sent this manuscript directly to Darwin, forcing Darwin into their co-publication.

FOSSIL RESEARCHERS AND THE CARNIVOROUS HABITS OF BOROPHAGINAE AT THE MILK CREEK SITE, YAVAPAI COUNTY, ARIZONA

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The first known reports of fossil bearing materials from the Walnut Grove or Milk Creek Formation in central Arizona were from local ranchers' reports in 1938. In 1948 scientific interest dawned when fossils were presented to Harold S. Colton of the Museum of Northern Arizona and subsequent research began from several institutions.

In 1949 the first significant survey and collection of the Milk Creek locality ensued with a joint venture effort from individuals at the Museum of Northern Arizona and the Arizona State Museum in Tucson. The most recent publications and reviews place the Milk Creek formation fauna in the Clarendonian NALMA. A survey in 1950, likely from members of the Arizona State Museum, added specimens to the University of Arizona Laboratory of Paleontology (UALP) collections.

Ted Galusha, a collector for Childs Frick began working here in 1956. Galusha's efforts have produced the largest single collection from this site, which are currently housed as a part of the Frick collection at the American Museum of Natural History in New York City.

After the 1949 and 1950 collections, John Lance, and then Ev Lindsay, at the University of Arizona collected materials beginning when Ted Galusha was active. Specimens from these efforts are housed at the UALP, UC Berkeley and at the Museum of Northern Arizona. Everett Lindsay persisted in bringing many students and researchers to the Walnut Grove localities and greatly enlarged upon the considerable specimens held at the UALP collection, representing their field site number one. The collections at the UALP now span efforts over portions of five decades.

Brian McClelland and Milo McDouglas of the Mesa Museum of Natural History and the Southwest Paleontological Society led some collecting at the Milk Creek formation in the mid 1990's. Norm Tessman of the Sharlot Hall Museum in Prescott, Arizona also established a small amount of materials from the mid 1990's. Since the 1990's efforts at this site have continued with Beth Boyd and Jeb Bevers from Yavapai College. Ongoing collecting efforts have now amassed the third largest collection of specimens, currently housed at Yavapai College.

The geologic range for the Milk Creek site is uncertain. There is a listed biochronological dating of Clarendonian NALMA for Milk Creek, yet two radioisotope data points have indicated zircon crystals of 23 Ma.

Most fossils located from the Milk Creek locality belong to two genera of protolabinae camelids, *Michenia yavapaiensis* and *Protolabus coartatus*. A few other mammalian herbivores are also located in this area. One of the predators which have been recovered are specimens of Borophaginae. I. Bevers and Weideman located specimens of this and I. Bevers recently (2023) discovered a borophagine coprolite. Only a handful of coprolites from borophagines have been located before, and none are listed from Arizona. This coprolite is filled with camelid tooth fragments and small fragments of undescribed bones. This supports direct feeding upon the local camelid fauna of Milk Creek by some of the borophagines.

MUSINGS ON ARIZONA'S CAMPANIAN MILE-HIGH CLUB: HIGH ELEVATION BOWFINS, TURTLES, AND CROCS, OH MY!

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In a recent isotopic survey of the Fort Crittenden unionid mussels, it was determined that the intermontane basins in which they lived potentially sat at an elevation greater than 2 km during the Campanian (~75 million years ago). Unionid mussels closely record the $\delta^{18}O$ values of the waters they live in; which, when used in conjunction with the Rayleigh Condensation Model, allows for calculation of basin and mountain peak paleoelevations. In the previous study, specimens from the Fort Crittenden Formation near Tucson were compared to previously published values for coeval unionid specimens from the Kaiparowits Formation of Southern Utah. If it is assumed that Kaiparowits specimens were from low- to sea-level elevations, the difference in average values ($\Delta\delta^{18}O$) allowed for an elevation in excess of 2 km for the Fort Crittenden basins.

This elevation revelation has led to renewed discussion of the presence of certain surprising members of this highland fauna. Among these unanticipated faunal members are giant bowfin fish (*Melvius* sp.), crocodilians, and turtles (trionychids and adocids). How did they get there? Were giant bowfin eggs or clingy small fry dropped off by pterosaurs coming in from the Western Interior Seaway Coast, or did they swim upstream to spawn like salmon? Utilizing phylogenetic bracketing, one might assume we would not find bowfin at such elevations, as they are in the modern day lowland fish, with few records from the Appalachian Piedmont (an elevation less than 0.5 km in elevation). Bowfin are, however, present, so we have two ideas to test: (1) pterosaur drop-off and (2) salmon analog. Both can be tested using isotopic sampling of bowfin scales. If hypothesis (1) were supported, we might expect a narrow range of more negative $\delta^{18}O$ values most similar to what we see in our unionid mussels (indicating a life spent solely at high elevation). If hypothesis (2) were supported, we might expect to see more positive $\delta^{18}O$ values similar to unionid mussels in the Kaiparowits Formation (reflecting coastal water values).

When it comes to the turtles and crocodilians, it isn't so much them getting to high elevation that is perplexing, it is what their presence might say about climate at 2 km elevation. Modern crocodiles and turtles cannot persist in freezing climates, so what was the climate like in these intermontane basins? Their presence can support a lowest temperature limit for the basin. Can we increase the resolution of this climatic environment? Of course we can, fish scales and unionid mussel shells to the rescue! As unionid shell δ18O values track water values, used in conjunction with fish scale δ18O values in a paleothermometer equation we can determine average annual water temperature and thus average annual atmospheric temperatures for the basin. These unanticipated taxa can yield surprising insights into the nature of the area around Tucson during Campanian times.

ULTRASAURUS TABRIENSIS IS ULTRA MESSY!

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Few specimens have as knotty a history as the South Korean bone DGBU-1973. This partial humerus has been labeled ichthyosaur, theropod, and sauropod. It has been identified as a rostrum, femur, ulna, and humerus and is said to come from the Gugyedong Formation (Albian-Aptian) in South Korea. It was even discovered independently twice! This, of course, led to dual streams of information for a period.

Kim discovered the bone originally in 1973 and argued in 1978 that it belonged to a giant ichthyosaur. In 1979, predating Jensen's announcements, he gave the world the first '*Koreanosaurus*,' a giant theropod, yet no holotype or proper description accompanied the press release. And in 1981, he somehow compared the material to *Supersaurus* podial elements, despite none having been discovered at the Dry Mesa Dinosaur Quarry. Ostrom's National Geographic article likely played a significant role in Kim's thinking name-wise.

In 1983, Kim formally described DGBU-1973, making it the holotype of *Ultrasaurus tabriensis*, the "Ultra Lizard from Tabri." Even this is mired in controversy as two versions of the publication exist, one lacking a species name and thus not meeting ICZN standards for a valid species. It is unclear which version appeared first or how or why this error transpired.

Based on South Korean conference papers and Jensen's letters, our research suggests Kim independently coined the term *Ultrasaurus* from James Jensen, who in 1972 had excavated what he thought was the longest and heaviest dinosaur ever discovered, one a visiting reporter dubbed "*Supersaurus*," and the name stuck. It would be joined in 1979 by another unofficial name, "*Ultrasaurus*," which he gave as the tentative name to a giant scapulocoracoid. In 1983, Kim published *U. tabriensis*. In 1985, Jensen, unaware of Kim's paper, formally ascribed a holotype, BYU 9044, to the name *Ultrasaurus macintoshi*, but despite the name being coined for the giant shoulder blade, the holotype was made a gigantic dorsal vertebra.

Correspondence of Jim Jensen to numerous associates in 1985 and 1986 resulted in him begrudgingly changing the name to *Ultrasauros* in 1987. He intended to keep the name sounding the same while acknowledging *U. tabriensis* seemed to meet the ICZN requirements, albeit barely. In 1988, Gregory Paul argued the bone, though not an ulna but a humerus and thus not titanically large, had a holotype and an ever-so-brief description. In 1996, Curtice demonstrated the holotype dorsal vertebra belonged to *Supersaurus*, making *Ultrasauros* a subjective junior synonym. In 1997, Lee also pointed out that DGBU-1973 was not an ulna but a humerus and suggested *U. tabriensis* is a *nomen dubium* based on misidentification and lack of diagnostic characteristics and systematic descriptions.

PRELIMINARY REVIEW OF THE HEMPHILLIAN HERBIVORE GUILD OF TURLOCK LAKE, MEHRTEN FORMATION, CENTRAL CALIFORNIA

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Turlock Lake in Central California is part of the Mehrten Formation, with deposits spanning the Hemphillian North American Land Mammal Age from 8 to 5 million years ago. These sites contain material representing the Siphon Canal, Coyote Hill, and Modesto Reservoir local faunas, including 46 vertebrate taxa, and the Turlock Lake local flora, including 25 plant taxa. Although Wagner (1981) described most of the Hemphillian Turlock Lake mammal species and Axelrod (1980) described the Turlock Lake local flora, and more recent studies have characterized unique taxa like the spike-toothed salmon (Sankey *et al.* 2016) as well as the Mehrten Formation's carnivore guild (e.g., Balisi *et al.*, 2018), focused examination of the herbivore guild at the site has been limited. Here, we review the relevant literature as well as Mehrten Formation specimens at the Natural History Museum of Los Angeles County, calculating summary statistics of number of identifiable specimens (NISP), minimum number of elements (MNE), and minimum number of individuals (MNI) of herbivore species. Across the herbivore guild, we counted 1,124 identifiable specimens, at least 1,647 elements, and a minimum of 142 individuals. The best represented species in the Mehrten Formation is the equid *Dinohippus interpolatus*, represented by at least 24 individuals (16% of herbivore MNI) from Late Hemphillian (5 Ma) deposits based on right upper first and second molars. A minimum of 37 equid individuals (*D. interpolatus* as well as *Nannipus* sp., *Neohipparion eurystyle*, and undescribed equid specimens) represent about 26% of herbivore MNI. While we are continuing to quantify the remaining herbivores (e.g., camelids), the presence of equids in the Mehrten herbivore guild starts to shed light on the local paleoenvironment. Based on the Turlock Lake local flora and the presence of an extinct tortoise (Biewer *et al.* 2016), Late Hemphillian Central California had a wet, mild, and low-frost climate relative to modern-day. The presence of numerous equids supports prior inference of a Late Hemphillian paleoenvironment consisting of a grassy oak woodland-savanna that would have sustained both grazers and mixed-feeders. Work is ongoing to characterize the rest of the Mehrten herbivores as grazers, browsers, or mixed feeders, as well as to sort them by body size, to maximize inferences about the region's paleoclimate and paleoenvironment.

This work was supported by an NSF iDigBio Natural History Collections Summer Internship to Aidan Clay in 2023.

THE EL GOLFO PROJECT – 30 YEARS OF COLLECTING AND RESEARCH

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El Golfo is a small fishing and tourist village along the coast of the Gulf of California near the terminus of the Colorado River Delta. Most fascinating in this northwestern most corner of Sonora, México are about 40 km of exposed middle Pleistocene Colorado River fluvio-deltaic deposits. These deposits are very fossiliferous and contain a diverse paleobiota of vertebrate and silicified wood specimens. Commencing in 1993, Arizona Western College teamed with La Brea Tar Pits and Museum personnel, and the support of Oscar Carranza-Castañeda, Center of Geociences of the National Autonomic University (Juriquilla, México) to systematically collect, identify, and research this paleobiota. Here we discuss the geological and tectonic setting, the age of the deposits, and the paleoecological interpretation of the Pleistocene lower Colorado River Delta. To date, nearly 14,500 mapped vertebrate and fossil wood localities are documented and over 120 species have been identified. These data are housed in a geographic information system that showcases distributions and patterns of the paleobiota maps.

TOOTH WEAR OF CANID PREDATORS FROM THE MCKITTRICK ASPHALT SEEPS, KERN COUNTY, CALIFORNIA

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The McKittrick asphalt seeps, in the San Joaquin Valley of California, preserve abundant fossils from ca. 40,000-15,000 years ago, toward the end of the Pleistocene epoch. Existing work on McKittrick has shown environmental and faunal differences from the contemporaneous Rancho La Brea (RLB) seeps in Los Angeles, 200 km southeast, making McKittrick a valuable locality for comparative Pleistocene studies. However, the ecology of McKittrick mammals thus far has been much less studied than RLB. For example, previous research shows a high frequency of tooth breakage in extinct predators at RLB, but such studies are absent at McKittrick.

In mammalian predators, tooth breakage and wear correlate with carcass utilization—predators processing meat and cracking bone—which can increase with competition and/or prey limitation. Frequent tooth fracture at RLB suggests that large predators experienced challenges as their large-bodied prey approached extinction 10,000-12,000 years ago. If prey limitation occurred similarly at McKittrick and large predators there—specifically canids; dire wolf *Aenocyon* (formerly *Canis*) *dirus* and coyote *Canis latrans*—encountered similar challenges as at RLB, then tooth wear should be like that found at RLB.

We assessed five wear levels—slight, slight-moderate, moderate, moderate-heavy, and heavy—in McKittrick canids at the University of California Museum of Paleontology, Berkeley. Though the total sample included >300 specimens of upper and lower jaws, we included only the 39 specimens (*Aenocyon dirus* n=16, *Canis latrans* n=23) that preserved at least three teeth including the carnassial, enabling us to characterize wear and breakage across multiple teeth per individual. We compared this sample to 86 RLB specimens (*A. dirus* n=31; *C. latrans* n=55) across four deposits (Pits 3, 4, 10, and 13) from late Pleistocene to early Holocene at the La Brea Tar Pits and Museum in Los Angeles, California.

At McKittrick, slight-moderate was the median wear category across both coyotes and dire wolves. Coyotes did not show heavy wear; dire wolves spanned the entire wear range. RLB canids generally showed lighter wear: slight was the most common category in both species. Coyotes across both sites tend to exhibit lighter wear than dire wolves, suggesting that Pleistocene coyotes were not bone or large-prey specialists but rather, like coyotes today, fed on diverse resources that enabled them to prey-switch when some prey sources depleted. In contrast, heavy dire wolf wear suggests bone-cracking and large-prey specialization; dire wolves therefore may have faced trouble adapting to shifting prey availability.

Our results suggest that times were tougher for canids at McKittrick than at RLB. While greater aridity or grit may have exacerbated wear at McKittrick, the wear difference is likely because of a wider resource base at RLB than McKittrick. In addition to potential marine subsidies at RLB, bison, horse, and camel are the most common herbivores. In contrast, at McKittrick—where prey choice already was restricted to terrestrial sources—horse and llama are common while camel and bison are rare, perhaps limiting prey and increasing predator competition. A radiocarbon chronology is in progress, providing context for further reconstruction of canid dental wear and diet at McKittrick.

This work was funded by a grant from the National Science Foundation - Division of Earth Sciences (project "Wolf RACE (Resource Availability and Competition in Ecosystems) - Insights from The McKittrick and Rancho La Brea Lagerstatte"; NSF Award #2138163).

ACTINOPTERYGII FROM THE FRONTIER FORMATION (LATE CRETACEOUS) OF THE BIGHORN BASIN, WYOMING

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Vertebrate fossils from the Late Cretaceous-aged (Cenomanian–Turonian) Frontier Formation of Wyoming remain poorly known, but include chondrichthyans, actinopterygians, turtles, and crocodylomorphs. Recently, crews from the Raymond M. Alf Museum of Paleontology (RAM) began collecting at the "Final Frontier" locality (RAM V2021016) in the northwestern Bighorn Basin. Fossils occur as tailings from previous mining operations, so are out of geological context. However, radiometric dates for the formation in the area suggest a maximum age of ~94.1 Ma (mid-Cenomanian). Here, we focus on the Actinopterygii (ray-finned fishes). Across Wyoming, previous researchers reported only unidentifiable fragments, lepisosteids (referred to *Atractosteus* sp.) and pycnodontids (*Anomaeodus* sp.). The "Final Frontier" locality adds additional records.

At RAM V2021016, lepisosteiform fish are reasonably common, represented primarily by isolated scales; none can be identified to a finer taxonomic level. Many unidentified fish fossils (vertebrae and other elements) are also common. Fossil teeth referable to *Enchodus* sp. are moderately abundant, resembling specimens from elsewhere referred to *E. shumardi* as well as *E. petrosus*, based on size and overall morphology. A single relatively complete palatine with the base of the tooth is particularly intriguing, showing some features resembling morphology seen in *E. dirus*. The *E. dirus*-like palatine shows a well-defined maxillary groove that terminates well behind the tooth (distinct from *E. ferox*), clear cutting edge, noticeable curve, and length/depth ratio of 0.4 (on the lower end of the *E. dirus* range of 0.40-0.55). If indeed *E. dirus*, this would predate other occurrences (which range from the late Santonian to early Maastrichtian). Additional study and collecting is needed. Overall, the actinopterygian assemblage known so far from the Frontier Formation resembles contemporaneous assemblages, providing an important new data point for studying temporal and latitudinal variation in the Western Interior Seaway.

LISSAMPHIBIANS FROM THE "MESAVERDE" FORMATION (UPPER CRETACEOUS) OF THE BIGHORN BASIN, WYOMING

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Although they are small, microfossils hold the power to document large-scale paleoenvironmental changes. During the Late Cretaceous, the Western Interior Seaway bisected North America; today, many formations throughout the Western Interior document the remains of this inland sea. Exposed in the Wind River and Bighorn Basins of central Wyoming, the "Mesaverde" Formation hosts a Campanian-aged (~78–76 Ma) faunal assemblage including marine, freshwater, and terrestrial elements. Previous research interpreted exposures in the Wind River Basin as representing a freshwater fluvial environment and exposures in the Bighorn Basin as estuarine in origin. To date, lissamphibians are reported from the "Mesaverde" Formation in the Wind River Basin, but not in the Bighorn Basin (including the Teapot Sandstone). Recent fieldwork by the Raymond Alf Museum of Paleontology at the Webb Schools (RAM) has focused on enriching knowledge of the faunal assemblage in the formation across the Bighorn Basin, through identification of new localities and collection of historic ones.

Here, we document 11 specimens referable to Lissamphibia (RAM 27517, 27520, 27797–27803, 27805, and 27806). All from locality RAM V2021019 (Teapot Sandstone of the eastern Bighorn Basin), the fossils include Urodela indet. atlantal centrum and trunk vertebra, a Scapherpetontidae trunk centrum, three each of *Scapherpeton* trunk vertebrae and atlantal centra, and two *Opisthotriton* atlantal centra. All compare closely with elements from other Late Cretaceous units in North America.

Locality RAM V2021019 includes abundant marine organisms, such as sharks, as well as terrestrial organisms such as dinosaurs and lissamphibians. This is consistent with previous interpretations of the horizon as an estuarine environment, resembling similar marine to nonmarine transitions from across the Western Interior Basin. For instance, some localities in the Dinosaur Park, Judith River, Foremost, and Aguja formations also

preserve environmentally transitional assemblages. These transitional sites are reported to display an inverse relationship between the abundance of lissamphibians and chondrichthyans, which is consistent with our findings. These coexisting taxa may indicate the long-distance transportation of fossil remains from inland to coastal areas; alternatively, they may suggest an interface between freshwater and marine in a local area's environment. Finally, this could indicate a time-averaged assemblage with reworking and mixing of material from different environments at different times. Continued study of amphibian fossils in the "Mesaverde" Formation will allow for a greater understanding of the paleoenvironments along the Western Interior Seaway.

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*These authors contributed equally to the research.

ADDITIONS TO THE TURTLE FAUNA OF THE MIDDLE EOCENE UINTA FORMATION OF NORTHEASTERN UTAH

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Although the Uinta Formation has been collected more or less continually since 1894, it continues to yield new records or species of turtles. While the Uinta fauna most closely resembles that of the earlier Bridger Formation of southwestern Wyoming, it has yet to yield dermatemydids, plastomenids or chelydrids. The new additions are a species of the kinosternid *Baltemys*, a probable new species of the planetochelyid *Planetochelys*, the trionychids "*Platypeltis" postera* Hay and a possible species of *Axestemys*. All of these are the youngest known records of their respective taxa. The absence of dermatemydids, plastomenids and perhaps chelydrids may reflect the rarity of lacustrine sediments and dominance of riparian sediments of the Uinta Formation compared to those of the Bridger Formation.

HOUSING HOLOTYPES: PLANNING MOUNTS FOR FOSSILS USED IN HOLOTYPE IDENTIFICATION

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In a paleontological research facility, the vault inevitably holds fossils of varying degrees of importance. Of these, those fossils used in identifying a holotype are arguably the most important and accessed more frequently than others in the collection. Recently the Research Laboratory at the Arizona Museum of Natural History began a review and re-housing of holotype fossils. There are several possible approaches in storing these fossils. Here we focus and identify one approach.

The initial research paper that identified the holotype is used as a planning guide for housing. Using images from the research paper, fossils are placed in the same grouping as in the paper. Fossils mounted according to the images allows for quick identification and frees researchers from looking through a variety of drawers. All fossils used in the identification of the holotype will be housed together in drawers marked as the holotype. Associated fossils, found later or not used in the identification of the holotype are housed in subsequent drawers for access by researchers. This process ensures that fossils used to identify the holotype can readily be found, identified and used in research.

RETHINKING THE TRIASSIC EVOLUTION OF VERTEBRATE GROUPS THROUGH REFINED MICROVERTEBRATE SAMPLING METHODS

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Wet screenwashing matrix for microvertebrate fossils is one of the most common collection methods employed by paleontologists. Screenwashing large amounts of material has been performed since at least 1847 in Europe and 1891 in North America. Methods have changed subtly over time, notably with washing the matrix in metal screens instead of burlap bags, but paleontologists still employ basic methods as described in the early part of the 20th Century. The quality of data and scientific hypotheses derived from screenwashing is tied to removing as much matrix as practical while simultaneously retaining small fossils as completely as possible. Here we describe further changes to screening methods sampling the Blue Mesa Member of the Upper Triassic Chinle Formation at Petrified Forest National Park.

Field crews excavated a quarry at Petrified Forest (PFV 456) in 2018–2021. The matrix is a sandy siltstone that likely represents a small pond or lake. The deposit preserves abundant coprolites, unionid bivalve steinkerns, plant fragments, a partial skeleton from the aetosaur *Calyptosuchus wellesi*, and microvertebrate fossils representing chondrichthyians, actinopterygians, coelacanths, lungfish, metoposaurid and lissamphibian temnospondyls, cynodonts, lepidosauromorphs, and archosauromorphs. Crews collected the aetosaur bones in field jackets and collected the microvertebrates via cohesive blocks of matrix in large, woven plastic bags resulting in a near 100% collection of the excavated stratum. Rather than washing matrix in large batches, individual blocks of matrix weighing ~5 lbs. were soaked in water for several hours in 5-gallon buckets and then gently agitated through individual screen boxes made with 0.5 mm stainless steel mesh mounted to polyvinyl chloride frames. A 40-gallon plastic cattle trough was used as a wash basin and each screen box was dried in the sun on a metal picnic table. Each batch of concentrate was dry screened through a column of 6.3 mm, 2 mm, 1 mm, and 0.5 mm meshes to size fractionate the batch. Microvertebrate fossils were picked from each batch of concentrate using fine tweezers, a 1 cm gridded tray, and a Leica MZ12 stereomicroscope. Individual elements in each batch like fragile tetrapod jaws that were broken into several pieces by the wet screening process were reassembled using the microscope, cyanoacrylate, and a custom wooden device combining entomology pins, microcrystalline wax, and design elements from a jeweler's ball vice.

7000+ catalogued specimens were collected from ~4000 lbs. of matrix at PFV 456, representing 60+ vertebrate taxa, many of which are first or earliest occurrences or entirely new taxa, making PFV 456 potentially the most species rich Triassic fossil locality in the world. The applications of these changes to screenwashing methods results in more complete elements that are easier to CT scan, making them far more scientifically significant than fragments of once-complete elements. The ability to reassociate all fossil elements from subunits of the bonebed offers future opportunities for taphonomic reconstruction. Further, these changes are widely applicable to other previously well-sampled units and may result in more complete elements of known taxa or the recovery of novel or rare taxa from 'well-understood' fossiliferous strata.

THEROPOD TEETH FROM THE LATE CRETACEOUS FORT CRITTENDEN FORMATION, SOUTHERN ARIZONA, U.S.A

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The Late Cretaceous Fort Crittenden Formation in southeastern Arizona offers a tantalizing glimpse of the biota unique in latitude, elevation, and time. It is among the southernmost Cretaceous faunas known in the United States along with the Aguja and Javelina Formations of Texas. Isotopic studies indicate that it is a high elevation site, perhaps more than 2 km! Recent work proposes that the age of deposition of the Fort Crittenden Formation spanned from 86 Ma to 76 Ma with all fossils coming from the Basal Shale Member, our basis for the 85 Ma assignment for the fossils used here.

There is an apparent gap in the occurrence of North American tyrannosaur and dromaeosaur fossils which localities in Arizona's Fort Crittenden Formation may fill. Dromaeosaurs are not known from North America between 108 Ma and 76.5 Ma. They are well represented in the Early Cretaceous Cedar Mountain Formation of Utah, via *Yurgovuchia* (~134 Ma) and *Utahraptor*, (~130 Ma), and *Deinonychus* (~108 Ma) of the Cloverly and Antlers Formations of Montana and Oklahoma, respectively. This gap extends until the appearance of *Dromaeosaurus* and *Saurornitholestes* in the Dinosaur Park Formation of Alberta (~76.5 Ma). Dromaeosaurid teeth from Arizona date to ~85 Ma and thus offer evidence of this clade's continued existence during this temporal gap.

North American pre-Campanian Late Cretaceous tyrannosauroids are represented by *Moros* (96 Ma) from the Cedar Mountain Formation of Utah and *Suskityrannus* (~90 Ma) from the Moreno Hill Formation of New Mexico, after which known tyrannosauroid remains are nearly entirely absent through the Coniacian and Santonian ages until the Campanian, during which tyrannosauroids are well represented across North America. Rare exceptions to this Coniacian-Santonian absence are tyrannosaur teeth from the Lomas Coloradas Formation in Sonora, Mexico (~86-83 Ma), and the teeth reported here, from the Fort Crittenden Formation of Arizona (~85 Ma). These teeth are large, the largest specimens approaching ~60 mm, placing them within the range of *Albertosaurus* and *Daspletosaurus*, perhaps suggesting an animal ~8-9 m in length. The adult size of *Suskityrannus* is unknown, but *Moros* (a highly fragmentary subadult) likely had an adult length of less than 4 m in length, suggesting a nearly three-fold length increase in just 11 million years or less as tyrannosaurs quickly evolved to fill the vacant niche left by the allosauroids.

During this time, there would have also been rapid diversification, as by 81 Ma, derived tyrannosaurines had already appeared in the form of *Lythronax*, implying numerous other splits, including the albertosaurine-tyrannosaurine split and the evolution of Tyrannosauridae, had already occurred. Currently, we cannot determine to which tyrannosauroid clade these teeth belong (though their median crown base ratio is most consistent with tyrannosaurinae), but their temporal position suggests that they may be key in understanding the inception and diversification of derived tyrannosauroids in North America.

A NEW SPECIMEN OF MERYCOIDODONTINE OREODONT (MAMMALIA: ARTIODACTYLA) FROM THE EARLY MIOCENE CHALK CANYON FORMATION OF CENTRAL ARIZONA

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Renewed investigations into the fossil-bearing outcrops of the early Miocene (Arikareean NALMA) volcaniclastic Chalk Canyon Formation on Agua Fria National Monument (Bureau of Land Management) have yielded new skull and postcranial skeletal material from a small oreodont. Oreodonts were a large group of herbivorous, hoofed mammals that were endemic to North America and varied widely in size and body shape over the duration of their existence, first appearing in the Eocene around 40 million years ago and last appearing in the late Miocene, approximately 5 million years ago. Their phylogenetic placement within the Order Artiodactyla has been famously murky, but current research suggests oreodonts were distantly related to camels, though they have left no modern descendants. Although they are very common throughout much of the western United States in Eocene, Oligocene, and Miocene deposits, they are quite rare in Arizona. Prior to this specimen, only two individuals have been reported, both from the Chalk Canyon Formation. The elements so far identified with the new specimen are mostly fragmentary and include partial maxillae, palate, mandible, pelvis, phalanges, and tibia. Of these, the mandible and tibia are mostly complete. The initial identification to oreodont grade is based on the distinctive tooth shape, and the dorsoventrally deep horizontal mandibular ramus with no diastema. An assignment to the merycoidodontine oreodont *Merychyus calaminthus* is likely, as this is the only genus identified from the region.

ANIMAL, ENVIRONMENTAL, AND HEALTH SAFETY CHALLENGES FACING PALEONTOLOGICAL COLLECTIONS IN SOUTHERN ARIZONA

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In the latter half of the 20th century, southern Arizona was home to a robust paleontological program centered on the University of Arizona's Laboratory of Paleontology (UALP). Their activities resulted in the collection of 23,730 specimens across 9,000+ localities. Beyond its far-reaching reputation as a city fascinated by fossils, Tucson also provides stewards of fossil collections with relative insulation from natural disasters compared to the Pacific, Midwest, and Eastern Seaboard regions. Collection degradation resulted from the shuttering of UALP in 1996. Some specimens were re-accessioned at the NMMNHS and the remainder were left unmaintained until 2018. Reduction in access to public fossil collections negatively impacts localized research and student training opportunities. Here we evaluate enduring local collections and recount challenges faced by their stewards. Commercial collections in the area are not accounted for here but may be affected by the same phenomena.

Significant vertebrate material remaining in the region includes the early Cretaceous brachiosaurid and Arizona state dinosaur *Sonorasaurus thompsoni* (Ratkevich 1998) from the Turney Ranch Formation, represented solely by ASDM 500. Other fossils housed in the ASDM include material from Cretaceous, Pleistocene, Pliocene, and possibly Miocene beds across Arizona. The "Empire Mountain Dinosaur", UALP 4638, is currently housed at the Flandrau Science Center and Planetarium on the UA campus. Much of the remaining UALP collection, mainly proboscidean and camelid material, is accessioned on Tumamoc Hill.

Collections here that utilize wooden cabinetry are vulnerable to infestation by the desert subterranean termite *Heterotermes aureus*. Termite damage has been observed to affect the physical integrity of cabinet drawers and result in the consumption of paper-based specimen labels. Termite infestations often arrive subsequent to monsoon flooding and low-lying settings are particularly vulnerable. In addition, rodents (particularly *Neotoma* sp.) are known to take up residency in unmaintained collections, resulting in significant fecal deposition and damage to electrical infrastructure including climate controls. Rodent feces are a vector of hantavirus transmission to humans and pose yet another work safety threat to collections staff.

In addition, a preliminary radiological evaluation of fossil material derived from the Turney Ranch Formation reveals emissions averaging ~3 μSv/hr1 or roughly 10 times typical background radiation levels. While further testing is needed to refine this figure, we provide an early indication that housing of these specimens with long-term worker safety in mind needs to mitigate the accumulation of radioactive gas within collection spaces to avoid exceeding EPA-defined limits.

Finally, drought and heatwaves that are locally forecast for southern Arizona to increase from climate change combine to exacerbate the risk and severity of wildfires; this poses the greatest risk to paleontological collections of all hazards listed here by far, especially for collections housed in rural areas. The potential for loss of irreplaceable collections by fire is exemplified by the 2018 burning of the Museu Nacional in Rio de Janiero, Brazil. Collections managers in southern Arizona must create evacuation policies and inter-institutional relationships with this contingency in mind.

EXAMINATION OF THE RELATIVE SIZE OF CRANIAL FOSSAE AND FENESTRAE IN NON-AVIAN THEROPODS

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It is commonplace and obvious that (non-avian) theropods had lightly built skulls, similar to those of pterosaurs - although (non-avian) theropods did not fly. However. this is so obvious that the architecture of theropod skulls has hardly been explored. Using graphics software ('ImageJ') the relative size of the openings in the theropod skull may be quantified. Here the areas of the openings have been measured in lateral projection and compared with that of the skull as a whole, for selected specimens. The openings examined comprise the nasal fossa, maxillary fenestra, antorbital fenestra, orbital fossa and laterotemporal fenestra. As might be expected, these do not vary in concert.

Yangchuanosaurus shangyuensis has the largest total proportion of the lateral projection occupied by openings, at approximately 39% (almost matched by that of *Sinraptor dongi*). Allosauroids seem to have had the largest proportion of the lateral projection taken up by openings, more than 30% in *Acrocanthosaurus*, *Allosaurus*, and *Asfaltovenator*. Abelisaurs and *Tyrannosaurus* tend to have the least 'open' skulls. Sebecosuchians, the most at least superficially similar to (non-avian) theropods in skull conformation, have only about 10% of the skull area taken up by openings. The maxillary fenestra is always less than 2% of the area of the skull, and usually less than 0.5%.

The antorbital fenestra is usually the largest occupying up to 19% of the lateral projection (in *Acrocanthosaurus*). It's relatively largest in *Acrocanthosaurus*, *Ceratosaurus*, and coelophysoids. The orbital fossa, on the other hand, is (relatively) largest in coelurosaurs (particularly dromaeosaurs, oviraptorosaurs, ornithomimosaurs) and basal lineages, such as coelophysoids. A very preliminary inspection suggests that it is relatively largest in the smaller taxa, as might be expected on other grounds.

One might also expect that the nasal fossa would be relatively largest in the smaller taxa, but this seems not to be the case. Instead it is relatively largest in *Allosaurus*, *Ceratosaurus* and *Ornitholestes*, all found in the Morrison Fm. Although provocative, this may well simply be a result of the small sample size thus far examined. The laterotemporal fenestra is (relatively) largest in oviraptorosaurs and *Ceratosaurus*. These are very preliminary results, all based on simple inspection, the sample sizes being too small for meaningful statistical analysis.

Are there more general conclusions? Clearly derived theropods (possibly excluding birds) have a different cranial architecture than derived synapsids (i.e. mammals), derived crurotarsans, and turtles. Basal crurotarsans, such as *Ornithosuchus* and *Postosuchus*, have similar cranial architectures, but generally not as extreme. On other hand some sauropods also have noticeably 'open' skulls, raising the possibility that this kind of cranial architecture might be characteristic of derived non-volant saurischians. Pterosaurs too have a similarly 'open' skull structure, presumably independently derived. While the selective impetus for such a structure in pterosaurs is obvious, if untested, the possible driver of such a structure in saurischians is less clear.

TRACKWAYS OF A METER-LONG, DIADECTID-REPTILIOMORPH AMPHIBIAN AND A CAPTORHINID REPTILE AT A NEWLY DISCOVERED TRACKSITE IN THE LOWER PERMIAN COCONINO SANDSTONE OF NORTHERN ARIZONA

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I report here a previously undescribed tracksite within the Lower Permian Coconino Sandstone, in the North Fork of Soap Creek Canyon, a seldom visited, difficult-to-access tributary of the Colorado River in northern Arizona. Ichnotaxonomy of the vertebrate ichnofauna of the Coconino Sandstone has recently undergone a comprehensive revision. Based on the revised nomenclature, I identify two ichnospecies that are exposed at this site: (1) *Varanopus curvidactylus* (the track of a captorhinid reptile), and (2) *Ichniotherium sphaerodactylum* (the track of a diadectid-reptiliomorph amphibian). Both types of trackways occur within a very thick set of crossbeds that dip 16° toward the west. All of the trackways at this site record the trackmakers heading directly up the slope.

The *Ichniotherium sphaerodactylum* tracks at this site are especially significant. With a high degree of confidence, this ichnospecies has previously been interpreted to represent the tracks of the Lower Permian diadectid reptiliomorph *Orobates pabsti*. Several other trackways of this ichnospecies have been reported within the Coconino Sandstone, however all of the previously reported occurrences are in fallen blocks of rock. The *I. sphaerodactylum* tracks reported here occur in a very conspicuous, well preserved, 4-meter-long, *in situ* trackway. This is the longest known trackway of this ichnospecies, and its *in situ* presence in the strata permits an analysis of the steepness of the slope the trackmaker was traversing; it was headed straight up the 16°-west-dipping slope.

In quadrupedal trackways, the gleno-acetabular distance (GAD)—the distance between the pelvic and pectoral girdles—can be estimated based on the length of the line segment that unites the midpoints of lines between two contralateral manus prints and two contralateral pes prints that belong to the same step cycle. In the *I. sphaerodactylum* trackway at this site, the GAD is 28 cm. Reconstructed skeletons of *Orobates pabsti*, the associated trackmaker, show that the total body length is 3.6 times the GAD. Using this multiplier, the diadectid reptiliomorph trackmaker that created the trackway exposed at this site had an estimated total body length of 1.01 m.

I gratefully acknowledge assistance from hiker Richard Radomske, who alerted me about this tracksite and led me there. I also appreciate the useful discussions from Wayne Ranney about stratigraphy and from Lorenzo Marchetti for ichnotaxonomy.

A BIOMECHANICAL RECONSTRUCTION OF THE THERIZINOSAUR *NOTHRONYCHUS* USING AN AVIAN MODEL

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Therizinosaurs were a group of rapidly evolving omnivorous to herbivorous non-avian theropods close to the origin of birds from the upper Cretaceous of North America and Asia. The derived therizinosaur *Nothronychus* is known from elements of two individuals from southern Utah and west-central New Mexico. The Utah specimen, *N. graffami*, is unusual in that it is preserved in the marine Tropic Shale. The bones are well-preserved and many are only minimally taphonomically distorted, permitting some muscle reconstruction and the creation of a biomechanical model during a passive stance and slow locomotion. Running is not considered possible in this animal.

The ilium can be subdivided into pre-acetabular and post-acetabular blades. As in extant wide-bodied birds, the pre-acetabular blade is larger than the post-acetabular one. *Nothronychus* was a knee-propelled animal, so movement of the femur was tightly constrained, serving as little more than a shock-absorber. The tail and M. caudofemoralis longus are reduced, so the center of mass is transferred anterior to the acetabulum. Major retractive muscles would be *M. iliofibularis brevis* inserting distal to the knee and *M. obturatorius*. An important protractive muscle is *M. iliotibialis* 1 and 2. The center of mass is typically medial to the acetabulum while standing. During locomotion, *M. iliotibialis* 3 and *M. iliotrochantericus* had an abductive component to counteract the ground reaction force as the center of mass shifted from side to side induced by a waddling gait. These muscle patterns are not present in the basal therizinosaur *Falcarius* but are observed in Neornithes. Therefore, they reflect pronounced convergence and must have evolved more than once within theropods.

A NEW CTENOCHELYID SEA TURTLE FROM THE NEYLANDVILLE MARL FORMATION (MAASTRICHTIAN) OF TEXAS: IMPLICATIONS FOR EARLY CHELONIID BIOGEOGRAPHY IN NORTH AMERICA

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The occurrence of the Western Interior Seaway at the beginning of the Late Cretaceous in North America generated a dramatic global climatic shift which was a driver of biotic evolution. The Middle Cenomanian Lewisville Formation in Texas is one of the earliest terrestrial deposits in Appalachia and captures the period after the opening of the seaway and is exceptionally diverse. Its position at the opening of the seaway makes it a continental hotspot for turtle diversity, largely due to its geographical location as a peninsula extending into the WIS. The paleobiogeographical implications of the WIS for Late Cretaceous North American turtles include: geographic range constraint and sharp increase in diversity and derived evolution in Baenidae, first appearance and rapid continental scale invasion by the Asian family Trionychidae, first radiation of Pleurodires of Gondwanan origins, and increased competition for the relict helochelydrid *Naomichelys*. The WIS also facilitated the initial evolution of modern sea turtle lineages.

The marine turtle family Ctenochelyidae is currently considered to be among the earliest representatives of modern sea turtles (Pan-Cheloniidae). The clade was broadly distributed across Upper Cretaceous deposits of the Atlantic Coastal Plain and Mississippi Embayment, and it was comprised of four previously described genera: *Prionochelys*, *Peritresius*, *Ctenochelys*, and *Asmodochelys*. Here, we describe a large carapace representing a novel taxon of ctenochelyid from the Maastrichtian Neylandville Marl Formation in northeastern Texas. This specimen represents the first vertebrate reported from the unit, which otherwise has a diverse and well documented assemblage of marine invertebrates. It was discovered eroding from the north bank of the South Sulphur River in Hunt County, Texas and generously donated to the Heard Natural Science Museum & Wildlife Sanctuary where it was prepared and is currently reposited.

The Neylandville ctenochelyid displays a unique combination of autapomorphic characters, plus the suite of characteristics that define the Ctenochelyidae and shared synapomorphies with one or more of the other ctenochelyid genera. As in other ctenochelyids, its carapace is cordiform and displays a midline ridge of epineural ossifications. It is unique in possessing a large carapacial length (~120 cm); epineurals at N1/2, N3/4, N5/6, and N7/8; extensive contact between costal 1 and peripherals 1-2; lack of postnuchal fontanelle; pronounced anterior projection of peripheral 1; and weakly serrated lateral peripheral edges. It shares with *Prionochelys* a deep anterior embayment involving the nuchal and first peripherals, relatively wide neurals 1-8, and a preneural. The specimen was scored for the full character set from Gentry et al. (2019), and a maximum parsimony phylogenetic analysis was conducted in TNT v1.6. In the resulting majority-rule consensus tree, the Neylandville ctenochelyid was consistently positioned at the base of Ctenochelyidae in an unresolved polytomy with *Asmodochelys parhami* and the clade (*Peritresius ornatus* + *Prionochelys matutina* + *Ctenochelys acris* + *Ctenochelys stenoporus*). The presence of a new Maastrichtian ctenochelyid from Texas reveals greater taxonomic diversity and geographic extent of the clade than has previously been recognized prior to their disappearance from the fossil record at the K-Pg boundary.