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Cover

A theropod dinosaur scans the horizon as sauropodmorphs walk to the river, which flows across the Early Jurassic landscape. The sediments deposited by the river systems will eventually become the Kayenta Formation. Artwork by Brian Engh, livingrelicproductions.com used by permission.

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The First Dinosaur Postcranial Body Fossils from the Lower Jurassic Kayenta Formation of Utah

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ABSTRACT

The vertebrate assemblage of the Lower Jurassic Kayenta Formation is known for its preservation of post-end Triassic mass extinction lineages, including lissamphibians, lepidosaurs, turtles, mammaliamorphs, crocodylomorphs, pterosaurs, and ornithischian, theropod, and sauropodomorph dinosaurs. Most of the body fossils from the formation are known from its 'silty facies' in north-central Arizona and southwestern Utah, whereas the sandier 'typical facies' of northeastern Arizona preserves few body fossils, and until recently they were completely absent in the typical facies of southeastern Utah. A 2011 team conducting a paleontological survey of Arches National Park discovered the first body fossils from the typical facies of the Kayenta Formation in Utah, here identified as belonging to a single individual of a saurischian dinosaur, likely a theropod. The fossil elements include a partial centrum articular face, a prezygapophysis, part of a caudal vertebra, the distal end of a left radius, part of the distal end of a left femur, a shaft fragment from the left fibula, the distal end of right metatarsal I, and the proximal portion of left metatarsals III and IV. This specimen from Arches National Park underscores the importance of federally protected land in fossil resource management and suggests that the typical facies of the Kayenta Formation may be undersampled and could preserve more vertebrate bones than previously thought.

INTRODUCTION

The Lower Jurassic Kayenta Formation unconformably overlies the Upper Triassic-Lower Jurassic Moenave Formation or Wingate Sandstone, depending on the location (the J-sub-K unconformity; Riggs and Blakey, 1993; Blakey, 1994). It interfingers with the higher Navajo Sandstone (Figure 1A), forming a sequence of strata that records erg sands blowing over fluviolacustrine deposits as the North American plate moved north into an arid climate belt (Harshbarger et al., 1957; Riggs et al., 1993; Blakey, 1994; Priddy and Clarke, 2020). The Kayenta Formation preserves an important vertebrate assemblage that represents the terrestrial biotic recovery following the end-Triassic mass extinction in Western North America. Fossils discovered in the formation include lissamphibians, lepidosaurs, turtles, mammaliamorphs, pterosaurs, crocodylomorphs, and dinosaurs (Clark and Fastovsky, 1986; Sues et al., 1994; Lucas et al., 2005; Tykoski, 2005). This assemblage is best known from the 'silty facies' of parts of northern Arizona and southwestern Utah (Figure 1B), but its sandier 'typical facies' like what is present at its type section at Comb Ridge, Arizona, also preserves vertebrate fossils, primarily as tracks (Lockley and Hunt, 1994, 1995; Hunt and Lucas, 2006). As Harshbarger et al. (1957, p. 17) observed, "the typical and silty facies of the Kayenta

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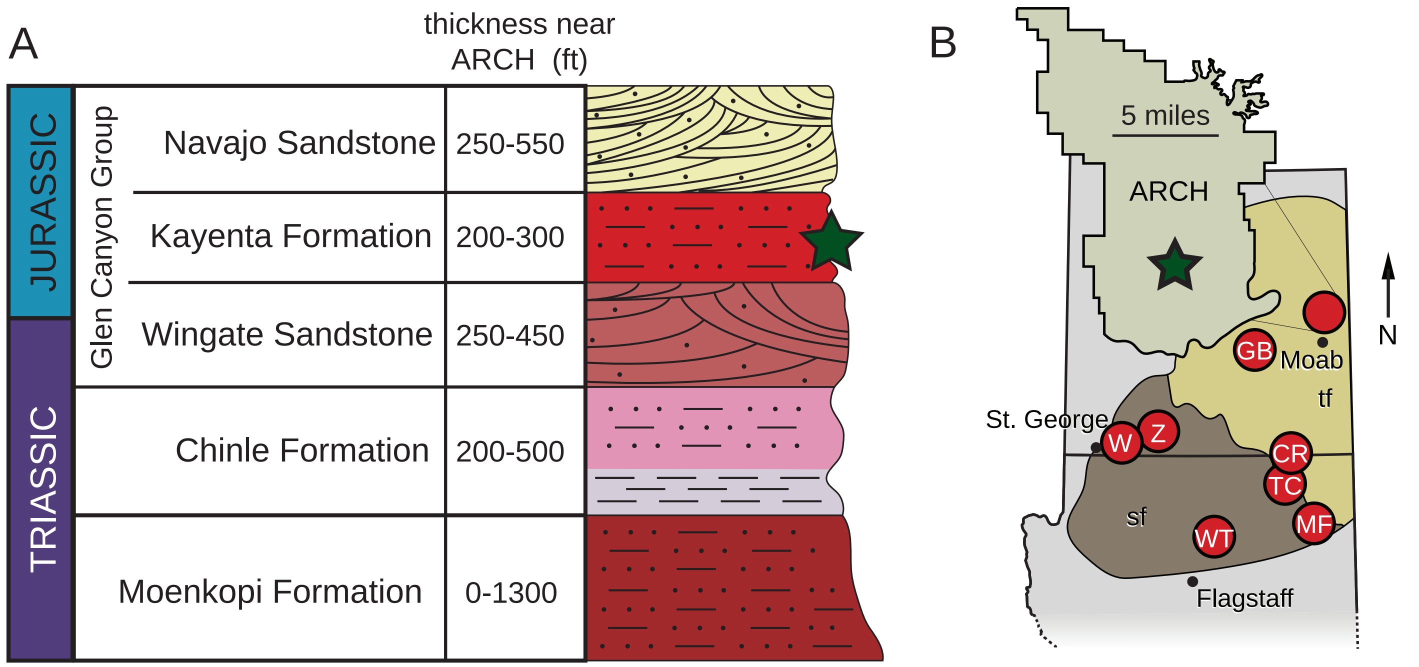

Figure 1. Selected fossil localities in the Kayenta Formation of Arizona and Utah. (A) Map of northern Arizona and southern Utah showing localities and Arches National Park, the extent of Kayenta Formation facies is shown as brown and tan; (B) Stratigraphic context of the Glen Canyon Group near Arches National Park. Locality specimen ARCH 71v shown as a green star. Abbreviations: ARCH, Arches National Park; CR, Comb Ridge; GB, Goblin Valley; MF, Many Farms; sf, silty facies; TC, Tsegi Canyon; tf, typical facies; W, Warner Valley; WT, Ward Terrace, including the Echo and Adeii Eechi Cliffs; Z, Zion National Park. Approximate extent of the silty facies and typical facies of the Kayenta Formation modified from Priddy and Clarke (2020).

Formation represent a lateral variation of deposition within a single basin."

This perceived disparity of the presence of body fossils in the two facies of the Kayenta Formation may be the result of different depositional processes, the fact that the typical facies tends to form cliffs rather than more accessible slopes, or geographic sampling bias. If the latter is true, then increased inventory of the typical facies of the Kayenta Formation should result in the discovery of more body fossils. This hypothesis was tested by a paleontological inventory that was undertaken within Arches National Park (ARCH) in 2011, resulting in the discovery of fragmentary fossil bones from the Kayenta Formation (Figure 2). Here, we describe that specimen (ARCH 4012) as the first dinosaur bones from the typical facies of the Kayenta Formation in Utah. This specimen highlights the importance of fossil resources on federally protected land and suggests that more vertebrate bones may be present elsewhere in the typical facies of the Kayenta Formation.

MATERIALS AND METHODS

A two-week paleontological field survey of the Phanerozoic strata of ARCH was led by the Utah Geological Survey (UGS) in 2011 under cooperative agreement #H230097080 with the U.S. National Park Service (NPS; Geologic Resources Division). A previous NPS ARCH survey was accomplished in 2000 (Swanson et al., 2005) but it focused on the Chinle Formation (Upper Triassic), Curtis Formation (Middle Jurassic), Morrison Formation (Upper Jurassic), and Cedar Mountain Formation (Lower Cretaceous). Paleontological localities identified or monitored during the 2011 survey were photographed and documented in the NPS and UGS databases (Madsen et al., 2012), and scientifically significant fossils were collected, including ARCH 4012. The ARCH collection, formerly at a regional NPS facility in Moab, Utah, was rehoused with archival materials in 2020 and is reposited at Petrified Forest National Park (PEFO) with other fossil collections from the NPS

Southeastern Utah Group. Photographs of ARCH 4012 were taken with a Nikon D90 digital camera equipped with a Nikon AF-S NIKKOR 24–85 mm lens. ARCH 4012 was laser scanned at PEFO using an Artec Space Spider on Artec Studio 16 Professional (16.0.5.114). The resulting surface files can be accessed at https://www.morphosource.org/projects/000572397.

INSTITUTIONAL ABBREVIATIONS

ARCH, Arches National Park, Utah, USA.; MNA, Museum of Northern Arizona, Flagstaff, Arizona, USA.; PEFO, Petrified Forest National Park, Arizona, USA.; TMM, Texas Vertebrate Paleontology Collections, The University of Texas at Austin, Austin, Texas, USA.; UCMP, University of California Museum of Paleontology, Berkeley, California, USA.

SYSTEMATIC PALEONTOLOGY

AVEMETATARSALIA Benton, 1999 sensu Nesbitt et al., 2017

DINOSAURIA Owen, 1842 sensu Padian and May, 1993

SAURISCHIA Seeley, 1887 sensu Gauthier, 1986

THEROPODA Marsh, 1881 sensu Gauthier, 1986

(Figures 2 and 3)

Referred Specimen

Specimen ARCH 4012, fragmentary skeletal elements likely belonging to a single individual (Figures 2 and 3), including part of a presacral centrum and prezygapophysis, a caudal centrum, the distal end of a left radius, the distal end of a left femur, a shaft fragment from the proximal half of a left fibula, the distal end of right metatarsal I, and the proximal ends of left metatarsals III and IV.

Justification for Identification

The specimen can be attributed to the Saurischia because of the presence of a hypantrum on the presacral vertebra, as well as the presence of a groove separating the lateral condyle and tibiofibular crest on the distal end of the femur (Figures 2P and 2R), both of which are present in early-diverging saurischian dinosaurs (Nesbitt, 2011; Stefanic and Nesbitt, 2019) and absent in the ornithischian *Scutellosaurus lawleri* found in the Kayenta Formation (Colbert, 1981; Breeden and Rowe, 2020; Breeden et al., 2021). If our identifications of the proximal ends of metatarsal III and metatarsal IV of ARCH 4012 are correct, the proximal shapes more closely resemble those of the neotheropod *Dilophosaurus wetherilli* than those of the sauropodomorph *Sarahsaurus aurifontanalis* (Figure 3), which are the two saurischians present in the Kayenta Formation in the same size range as ARCH 4012, suggesting a neotheropod affinity rather than that of a sauropodomorph.

Locality, Horizon, and Age

Locality ARCH 71v, near the Garden of Eden, about 2.5 km northwest of the Windows area of ARCH (Figure 1B); typical facies of the Kayenta Formation; "bone was found eroding from red mudstone next to exposed area of white sandstone" (Madsen et al., 2012, p. 16–17). The Kayenta Formation is Early Jurassic in age (Figure 1A), likely Pliensbachian-Sinemurian, and the middle of the silty facies of the Kayenta Formation in northeastern Arizona may be as young as about 183 Ma (Padian, 1989; Marsh et al., 2014; Suarez et al., 2017; Marsh, 2018).

DESCRIPTION

Axial Skeleton

Presacral Vertebrae

The partial centrum preserves less than half of what we hypothesize to be the posterior articular facet in posterior view (Figure 2A). We identify it as belonging to the posterior cervical or trunk series because the angle formed by the posterior and ventral margins in lateral view is rather acute; this angle is larger in anterior cervical centra that tend to be more parallelogram in shape in *Dilophosaurus wetherilli* (e.g., specimen UCMP 37302)

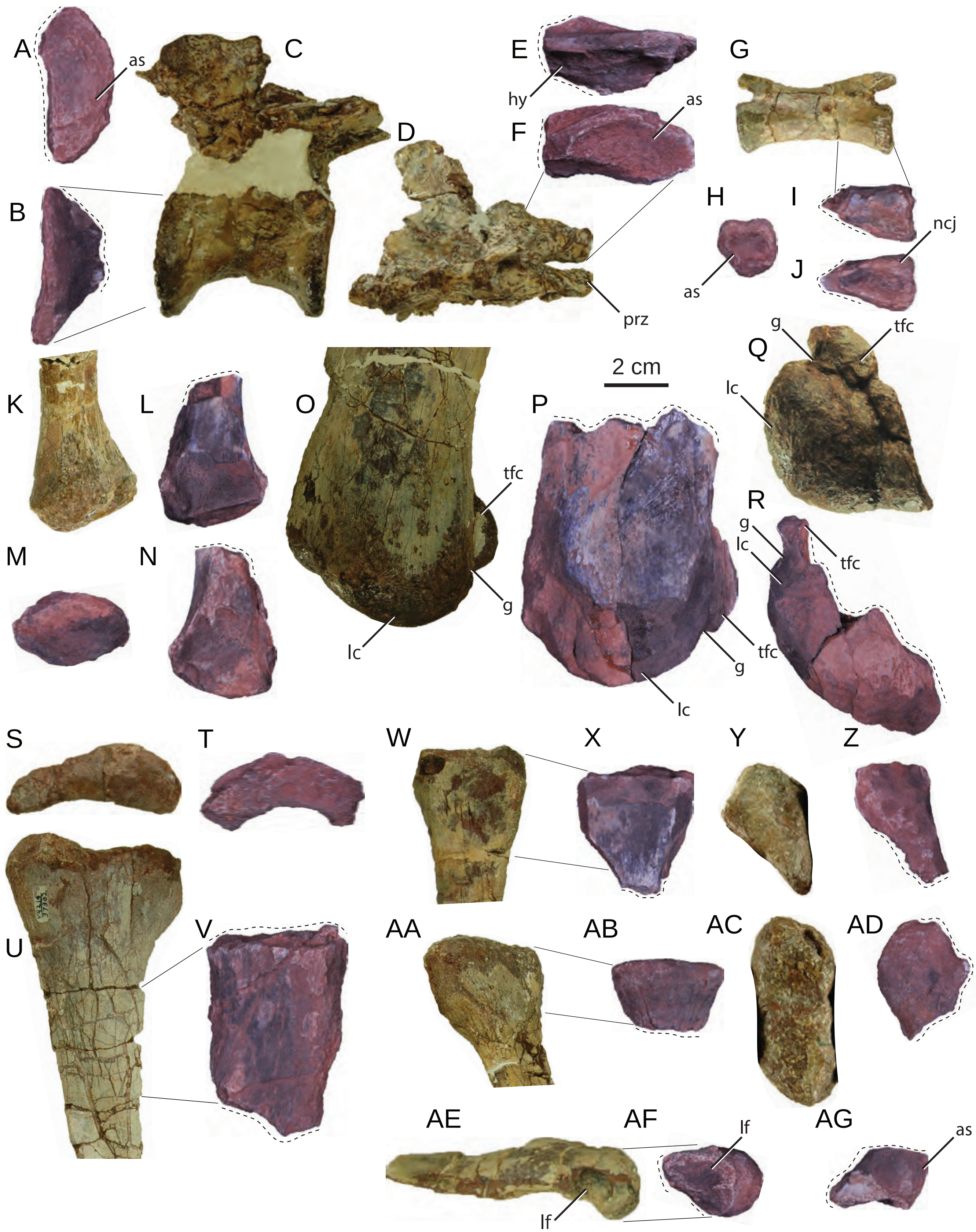

Figure 2. Caption is on the following page.

Figure 2 (figure is on the previous page). Preserved fragments of ARCH 4012 compared with elements of *Dilophosaurus wetherilli*, UCMP 37302. ARCH 4012, centrum face (A, B) in ?posterior (A) and ?right lateral view (C); UCMP 37302, vertebra 15 (C, D) in right lateral (C) and dorsal view (B); ARCH 4012, trunk prezygapophysis (E, F) in medial (E) and dorsal view (F); UCMP 37302, vertebra 54 in left lateral view (G); ARCH 4012, partial caudal centrum (H through J) in ?posterior (H), ?left lateral (I), and dorsal view (J); UCMP 37302, left radius in lateral view (K); ARCH 4012, distal end of ?left radius (L–N) in ?lateral (L), distal (M), and ?medial view (N); UCMP 37302, distal end of right femur, reversed (O, Q) in lateral (O) and distal view (Q); ARCH 4012, distal end of left femur (P, R) in lateral (P) and distal view (R); UCMP 37302, proximal end of left fibula (S, U) in proximal (S) and lateral view (U); ARCH 4012, fragment of ?left fibula shaft (T, V) in proximal (T) and lateral (V) view; UCMP 37302, proximal end of left metatarsal IV (W, Y) in lateral (W) and proximal view (Y); ARCH 4012, proximal end of ?left metatarsal IV (X, Z) in lateral (X) and proximal view (Z); UCMP 37302, proximal end of left metatarsal III (AA, AC) in ventral (AA) and proximal view (AC); ARCH 4012, proximal end of ?left metatarsal III (AB, AD) in ventral (AB) and proximal view (AD); UCMP 37302, right metatarsal I in lateral view (AE); ARCH 4012, distal end of ?right metatarsal I (AF, AG) in lateral (AF) and dorsal view (AG). Abbreviations: as, articular surface; hy, hypantrum; lc, lateral conyle; lf, ligament fossa; g, groove; ncj, neurocentral junction; prz, prezygapophysis; tfc, tibiofibular crest. Elements of UCMP 37302 are not to scale. Dashed lines indicate broken margins.

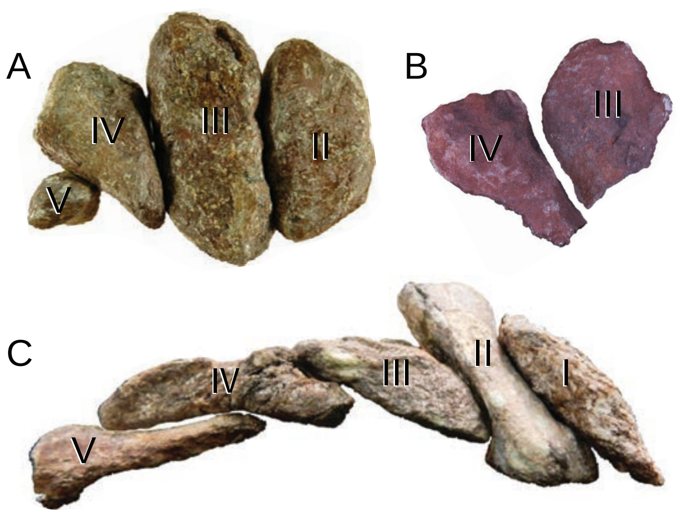

Figure 3. Left metatarsi of larger-bodied saurischians in the Kayenta Formation in proximal view. (A) *Dilophosaurus wetherilli*, UCMP 37302 (modified from Marsh and Rowe, 2020); (B) Theropoda, ARCH 4012; (C) *Sarahsaurus aurifontanalis*, TMM 43646-3 (reversed, modified from Marsh and Rowe, 2018). Elements are not to scale. Roman numerals identify each digit.

and *Sarahsaurus aurifontanalis* (e.g., specimen TMM 43646-2). The prezygapophysis preserves the relatively flat dorsal articular surface for the preceding postzygapophysis and the concave medial margin that would have formed the hypantrum (Figure 2F), which is present on the trunk vertebrae in *Dilophosaurus wetherilli* (e.g., UCMP 37302) and *Sarahsaurus aurifontanalis* (e.g., TMM 43646-2).

Caudal Vertebra

Less than half of the element is preserved as seen in lateral view (Figure 2I). The articular face is concave rather than flat, and the dorsal ridges that form the junction with the neural arch are present. The ventral margin of the articular face lacks the sloped surface that would have articulated with a haemal arch, indicating that this caudal vertebra was likely far enough back in the tail to be posterior to the last haemal arch.

Forelimb and Radius

The distal end of the ?left radius is identical to that of *Dilophosaurus wetherilli* (e.g., UCMP 77270) and *Sarahsaurus aurifontanalis* (e.g., TMM 43646-2). In lateral/medial view (Figures 2L and 2N), the posterior margin is relatively straight, and the anterior margin is concave. The distal outline is subelliptical (Figure 2M).

Hindlimb

Femur

Only the lateral sides of the lateral condyle and tibiofibular crests are preserved. A concavity is present on the lateral side of the tibiofibular crest that continued distally to form a groove between the tibiofibular crest and the lateral condyle (Figure 2P). In distal view the lateral margin of the lateral condyle is subcircular (Figure 2R).

Fibula

A portion of the proximal end of the shaft is present, identified by the cross-sectional shape in proximal view (Figure 2T). This is likely the shaft of a fibula and not a fragment of the shaft of the femur because what would be the medial side has a small patch of cortical bone that would not be present inside a femur. The fibula fragment would have been too proximal to preserve the ridge present in *Dilophosaurus wetherilli* (e.g., UCMP 37302) and *Sarahsaurus aurifontanalis* (e.g., TMM 43646-2) that represents the insertion site for the *M. iliofibularis* (Parrish, 1993; Nesbitt, 2011).

Metapodials

Half of the distal articular surface of metatarsal I is present (Figures 2AF and 2AG). It preserves a ligament fossa as well as the ventral expansion found in *Dilophosaurus wetherilli* (e.g., UCMP 37302) but not *Sarahsaurus aurifontanalis* (e.g., TMM 43646-3). The identifications of metatarsals III and IV are based on the shape of the partial proximal ends of each element (Figure 3B). Metatarsal III is broken ventrally but the dorsal margin is roughly parallelogram-shaped in proximal view (Figure 2AD), similar to that of *Dilophosaurus wetherilli* (e.g., UCMP 37302; Figure 3A). The shape of the proximal end is also consistent with that of *D. wetherilli* in ventral view. The dorsal and medial margins of the proximal end of metatarsal IV are complete, but the ventral portion is broken. In proximal view (Figure 2Z), the remaining bone is roughly subtriangular in shape, consistent with metatarsal IV of *Dilophosaurus wetherilli* (e.g., UCMP 37302).

DISCUSSION

Vertebrate Body Fossils and Age of the Kayenta Formation

Two major lithologic regimes are represented in the Kayenta Formation, described as the sandier 'typical facies' (i.e., what is present at the type section; Baker et al., 1936) and the finer-grained 'silty facies' (Averitt et al., 1955; Harshbarger et al., 1957). The delineation of these regimes bisects northern Arizona and southern Utah (Figure 1B) such that the typical facies is present northeast of Tuba City, Arizona, including southeastern Utah, and the silty facies occurs at the Adeii Eechi Cliffs southeast of Tuba City and in southwestern Utah. These two facies have a dramatic difference in vertebrate body fossil occurrence, which drove differing age interpretations for the formation and the location of the Triassic-Jurassic boundary within the Glen Canyon Group since the early part of the 20th century.

Arizona

The Kayenta Formation was recognized as a different unit from the Todilto Formation of the Middle Jurassic San Rafael Group and ultimately named for its type section at Comb Ridge near Kayenta, Arizona (Baker et al., 1936). At that time, the formation was thought to be Triassic in age and its only reported fossils were plant "stems" (Baker et al., 1936, p. 5), unionid bivalves (Baker, 1933), and dinosaur footprints (*Eubrontes* and *Anchisauripus* according to R. Lull, Yale Peabody Museum, written communication, 1917; Gregory, 1917, p. 56). Age interpretations for the Kayenta Formation oscillated between the Late Triassic and Early Jurassic in subsequent decades, justified primarily by two major fossil discoveries within the formation published in the same year of 1954.

The first was the discovery of two skeletons of a relatively large hypothesized *Megalosaurus*-like theropod dinosaur from near the base of the silty facies near Moenave, Arizona (Welles, 1954); this taxon was later named *Dilophosaurus wetherilli* (Welles, 1970). Welles (1984) used the size and proportions of limb elements to argue Early Jurassic affinities for this new dinosaur, now hypothesized to be only distantly related to European Middle Jurassic tetanuran theropods (Marsh and Rowe, 2020). The type locality of *Dilophosaurus wetherilli* is across the road from a famous megatracksite at the base of the Kayenta Formation (Welles, 1971; Morales and Colbert, 1986; Lucas et al., 2005; Marsh, 2018).

The second major discovery was of a tritylodontid cynodont skeleton associated with a protosuchid crocodyliform (Lewis, 1958) near the top of the typical facies near Comb Ridge in Kayenta, Arizona (Figure 1B; Averitt et al., 1955; Harshbarger et al., 1957). The tritylodontid represented the first of its kind in the Western Hemisphere at the time and was first thought to more closely resemble 'Old World' taxa from the Triassic of China and South Africa (Averitt et al., 1955). Thus, during the late 1950s the silty facies of the Kayenta Formation seemed to provide a younger age estimate for the formation than the typical facies. Subsequent work helped to clarify this chronological uncertainty, including extensive revisions of the stratigraphic relationships and major unconformities of the Kayenta Formation and stratigraphically adjacent units (e.g., Lewis et al., 1961; Pipiringos and O'Sullivan, 1978; Peterson and Pipiringos, 1979; Clark and Fastovsky, 1986), more refined understanding of Triassic/Jurassic strata and vertebrate assemblages around the world (e.g., Olsen and Sues, 1986; Luo and Wu, 1994; Fang et al., 2000; Huang, et al., 2005; Bordy et al., 2020), revisions in the anatomy and taxonomy of theropods and tritylodontids (e.g., Kermack, 1982; Welles, 1984; Sues, 1986a, 1986b, 1986c), and the eventual use of U-Pb detrital zircon geochronology within the Glen Canyon Group (Dickinson and Gehrels, 2003, 2010; Marsh et al., 2014). The entire Kayenta Formation is now accepted to be Early Jurassic in age (Sinemurian-Pliensbachian) and the end-Triassic mass extinction and Triassic-Jurassic boundary (now chronologically decoupled; Blackburn et al., 2013) occur within the underlying Dinosaur Canyon Member of the Moenave Formation and the lateral equivalent of the Wingate Sandstone (Figure 1A; Lucas et al., 1997; Donohoo-Hurley et al., 2010; Martz et al., 2017; Suarez et al., 2017). Other than the tritylodontid (and others later found at the same site) and protosuchid mentioned above (Lewis, 1958), the only other vertebrate fossils from the typical facies of Arizona occur near Tsegi Canyon and include hybodont shark teeth and a potential batoid tooth (Curtis and Padian, 1999); however, it has been suggested that the latter is likely the result of screen wash contamination from a concurrent Cretaceous microvertebrate sampling effort at MNA (Milner et al., 2006).

The tritylodontid *Kayentatherium wellesi* was named from the silty facies near Many Farms, Arizona (Figure 1B; Kermack, 1982), and is considered the senior synonym of the only named tritylodontid from the typical facies of far northeastern Arizona (Lewis, 1956). Most of the vertebrate assemblage of the Kayenta Formation is known from sites in the silty facies spanning the Echo and Adeii Eechii Cliffs along Ward Terrace (Figure 1B). This area includes the type localities of *Dilophosaurus wetherilli* (Welles, 1954), '*Syntarsus*' *kayentakatae* (Rowe, 1989), *Sarahsaurus aurifontanalis* (Rowe et al., 2010), *Scutellosaurus lawleri* (Colbert, 1981), *Rhamphinion jenkinsi* (Padian, 1984), *Kayentasuchus walkeri* (Clark and Sues, 2002), *Eopneumatosuchus colberti* (Crompton and Smith, 1980), *Calsoyasuchus valliceps* (Tykoski et al., 2002), *Kayentachelys aprix* (Gaffney et al., 1987), *Navajosphenodon sani* (Simões et al., 2022), *Prosalirus bitis* (Shubin and Jenkins, 1995), *Eocaecilia macropodia* (Jenkins and Walsh, 1993), *Dinnebitodon amarali* (Sues, 1986b), and *Dinnetherium nezorum* (Jenkins et al., 1983). In addition to these taxa, the silty facies in that area also produced a larger-bodied thyreophoran (Padian, 1989), unnamed protosuchid crocodyliforms (Clark and Sues, 2002), an *Oligokyphus*-like tritylodontid (Sues, 1985), a lungfish (Kirkland, 1987; Milner and Kirkland, 2006), and microvertebrates including actinopterygians (Clark and Fastovsky, 1986; Curtis and Padian, 1999; Milner et al., 2006), hybodontoid sharks, potential salamanders, and a haramiyid mammaliaform (Curtis and Padian, 1999).

Utah

The Kayenta Formation in Utah includes the typical facies in the eastern region near Moab and the silty facies in the western region around St. George (Figure 1B; Harshbarger et al., 1957; Priddy and Clarke, 2020), the latter being underlain by the Springdale Sandstone as a second lower unit in the formation (Lucas and Tanner, 2006). The Springdale Sandstone, the silty facies, and the typical facies of the Kayenta Formation frequently preserve trace fossils of various dinosaurs and other archosaurs, including megatracksites in the St. George area (DeBlieux et al., 2004, 2006; Hamblin et al., 2006; Milner et al., 2012 and references therein; Lockley et al., 2018).

The silty facies of Utah preserves semionotid fish scales at Zion National Park (Lockley, 1984; DeBlieux et al., 2004, 2006; Milner and Kirkland, 2006), coelacanths, semionotid and paleoniscoid fish, and potential crocodylomorph bones at Warner Valley (Milner et al., 2012), as well as unpublished articulated semionotids and teeth belonging to actinopterygians, crocodylomorphs, ornithischians, theropods, and a possible pterosaur from a more recent roadcut near St. George (Figure 1B; Milner et al., 2017). The typical facies also preserves other fish in Utah, including a semionotid fish skeleton from near Moab (Milner et al., 2006) on exhibit at the Moab Museum, and a lungfish tooth plate west of Goblin Valley (Frederickson and Cifelli, 2017). Despite occurring within what would otherwise be mapped as the typical facies of the Kayenta Formation (Figure 1B), the ARCH dinosaur described here occurs in interbedded red mudstone and white sandstone in the northern part of the Paradox Basin (Madsen et al., 2012), which may have been providing more syndepositional accommodation owing to salt dissolution in the underlying Pennsylvanian Paradox Formation and thus deposit more silt than would otherwise be expected in the typical facies in the broader region (Bromley, 1991).

Other Dinosaur Fossils from Arches National Park

Dinosaur fossils are relatively common in the Mesozoic units within the boundaries of ARCH and are mostly represented by tracks. The Church Rock Member of the Upper Triassic Chinle Formation preserves the ichnogenus *Grallator*, likely made by a small-bodied coelophysoid theropod (Lockley and Gierliński, 2009; Martz et al., 2017). *Grallator* is also known from the base of the overlying Wingate Sandstone (Swanson et al., 2005; Madsen et al., 2012). At least the lower part of the Wingate Sandstone is Late Triassic in age owing to the presence of a phytosaur in the nearby Lisbon Valley south of Moab (Morales and Ash, 1993; Martz et al., 2017). A single zygapophysis was found as float during a survey of the Wingate Sandstone (Madsen et al., 2012), but it is rather large for contemporaneous dinosaurs and because the source stratum was not found it is more parsimonious to consider it to have come down from the overlying Kayenta given the rarity of body fossils from the Wingate Sandstone (Tweet and Santucci, 2018).

In addition to the ARCH dinosaur body fossils described here, the Kayenta Formation also preserves indeterminate theropod tracks (Swanson et al., 2005), and the overlying Lower Jurassic Navajo Sandstone includes *Grallator* (Madsen et al., 2012) and tracks of sauropodomorph dinosaurs (*Navahopus* or *Otozoum*; Tweet et al., 2018). In the lower Upper Jurassic units there are tridactyl tracks within the Moab Tongue Member of the Curtis Formation (Swanson et al., 2005). The famous Moab Megatracksite (including ARCH) at the contact of the Moab Tongue Member and the overlying Summerville Formation preserves innumerous tracks and trackways referred to the larger ichnogenera *Megalosauripus* and *Therangospodus* (Lockley, 1991, 2022). Higher in the section, the Upper Jurassic Morrison Formation preserves sauropod postcranial bones including a partial apatosaurine skeleton (Doelling, 1985; Swanson, et al. 2005). The Ruby Ranch Member of the Lower Cretaceous Cedar Mountain Formation preserves numerous dinosaurian ichnotaxa, including those belonging to iguanodontid ornithischians, sauropods, and theropods including dromaeosaurids (Swanson et al., 2005; Madsen et al., 2012; Lockley et al., 2014).

CONCLUSIONS

The ARCH specimen described here is important because (1) it represents the first body fossils of a dinosaur from the Kayenta Formation of Utah outside of teeth from a roadcut locality near St. George, and (2) it represents the only unambiguous dinosaur body fossil from the Kayenta Formation within Arches National Park. The U.S. National Park Service has 286 units known to contain fossils (67% of all units as of March 2023; https://www.nps.gov/subjects/fossils/fossil-parks-list.htm) and not all have been surveyed, but only 16 were established explicitly to protect paleontological resources (Tweet and Santucci, 2021). ARCH was founded to protect geologic resources, and though paleontological resources are considered important resources, they are not considered fundamental resources to the park (https://www.nps.gov/arch/learn/management/foundation-document.htm#CP_JUMP_5740030). This discovery shows the potential for more vertebrate body fossils from the typical facies of the Kayenta in Arizona and Utah, highlighting the importance of inventory and monitoring of fossil resources in federally protected areas.

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