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A new species of polycotylid plesiosaur (Reptilia: Sauropterygia) from the Lower Turonian of Utah: Extending the stratigraphic range of *Dolichorhynchops*

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ABSTRACT

Recent work in the Tropic Shale by the Museum of Northern Arizona reveals a high biodiversity for plesiosaurs along the western margin of the Cretaceous Western Interior Seaway during the Cenomanian and the Turonian. This paper describes a new species of polycotylid plesiosaur from the Tropic Shale, *Dolichorhynchops tropicensis*, which adds to the known biodiversity from this time period. The identification is based on two specimens, a well-preserved, nearly complete skeleton including the skull and an additional specimen with only fragmentary skeletal elements. The material shares several synapomorphic characters with *Dolichorhynchops*, including the shape of the temporal fenestrae, the shape of the sagittal crest, the trend of the ectopterygoids, the morphology of the teeth, and the number of teeth within the mandibular symphysis. *D. tropicensis* differs from other species of *Dolichorhynchops* in a greater size range of the teeth, moderately constricted dorsal vertebrae, angled anterior processes on the coracoids, and the presence of well-defined facets on the propodials. The specimens are of Early Turonian age (based primarily on ammonite biostratigraphy and bentonite marker beds), and their discovery extends the known stratigraphic range for *Dolichorhynchops* back by approximately seven million years. This suggests that *Dolichorhynchops tropicensis* and *Trinacromerum bentonianum*, a closely related polycotylid, co-existed in the Western Interior Seaway.

1. Introduction

The Late Cretaceous Tropic Shale of southern Utah contains an abundance of marine invertebrates, including ammonites, which serve as excellent biostratigraphic indicators (Cobban and Hook, 1984). However, until recently few marine vertebrates had been found and studied within the Tropic Shale and its partially equivalent formation, the Mancos Shale (Elliott et al., 1997; Gillette et al., 1999). Recent work conducted by the Museum of Northern Arizona (MNA) has begun to establish the vertebrate biodiversity of the Tropic Shale in southern Utah, particularly within Grand Staircase-Escalante National Monument and Glen Canyon National Recreation Area. During the past ten years, new plesiosaur specimens have been discovered at several dozen sites within the Tropic Shale in southern Utah (Albright et al., 2007a, b, in press).

The plesiosaurs described by MNA suggest a high biodiversity along the western margin of the Cretaceous Western Interior Seaway. Two specimens of *Brachauchenius lucasi*, a type of short-necked plesiosaur within the family Pliosauridae, have been identified (Albright et al., 2007a). In addition, several plesiosaurs from the Family Polycotylidae have been recognized, including *Trinacromerum bentonianum* and two new species in two newly defined subfamilies, *Eopolycotylus rankini* (subfamily Polycotylinae) and *Palmulasaurus quadratus* (subfamily Palmulasaurinae; Albright et al., 2007b, c). While O'Keefe did not recover these new subfamilies in his phylogenetic analysis in 2008, he noted that they are based on a sound character and are therefore worth keeping, pending further evidence. The majority of the large marine vertebrates discovered by MNA are located in late Cenomanian and early Turonian deposits (Albright et al., 2007b, in press).

The specimens described in this paper (MNA V9431/GLCA 23761, MNA V10046/GLCA 23189) were discovered during the summers of 2000 and 2003, respectively, by MNA field crews prospecting for fossils in the Tropic Shale in southern Utah. The sites, MNA localities 1483 and 1627, are located within Glen Canyon National Recreation Area (GCNRA) near the border with Grand Staircase-Escalante National Monument (GSENM). Precise locality information regarding these sites is on file at the Museum of Northern Arizona. Permits were obtained for prospecting and excavation.

MNA V9431 was found in float and therefore consists of fragmentary remains that include six vertebrae, rib fragments, partial scapulae, partial proximal ends of the coracoids, the left ilium, proximal articular ends of the ischia and a pubis, and many

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unidentified fragments. The first round of excavation for MNA V10046 was conducted during the fall of 2004, with a full excavation conducted during the summer of 2005. The specimen is nearly complete and includes the skull, a nearly complete set of teeth, an incomplete set of vertebrae and ribs, scapulae, coracoids, nearly complete forelimbs, ilia, ischia, pubes, and nearly complete hindlimbs. All of the bones, except for the left femur, were close together with several of the bones overlapping. The left femur was displaced approximately 30 cm from the rest of the skeletal elements. There were 289 gastroliths associated with the skeleton (Schmeisser and Gillette, 2009).

The skeleton of MNA V10046 was disarticulated, although some elements were associated (see Schmeisser and Gillette, 2009, fig. 2, for quarry map). The skull was articulated in the quarry with the mandible in occlusion with the skull. The teeth were located either in the alveoli of the skull or close to the rostrum. The pectoral girdle and forelimbs were relatively close to each other. The pelvic girdle and hindlimbs were also relatively close to each other. All paddle elements were disarticulated in the quarry. The vertebrae were scattered throughout the quarry, but were grouped in series in places. The cervical vertebrae were located near the skull. The ribs were scattered throughout the quarry. Gastroliths were situated largely at the back of the skull and in the surrounding area. The majority of the gastroliths were clustered in groups in the shale, but many were situated on top of bones in the quarry. The majority of the larger elements of the skeleton were ventral side up. These observations indicate that the carcass came to rest in the belly-up position and remained relatively undisturbed prior to burial.

Well-defined facets on the propodials, as well as a broad and extended posterior margin on the coracoid indicate that MNA V10046 is an adult. The lack of supernumerary ossifications associated with the specimen and the fusion of only two neural arches to dorsal vertebrae suggest the specimen is probably an early adult. The elements of MNA V9431 are nearly identical in size to MNA V10046, suggesting that it is also an early adult. The total length, estimated from the more complete skeleton, MNA V10046, is projected to be 3.2 m. MNA V9431 and V10046 are assignable to *Dolichorhynchops tropicensis*, a new species within the genus *Dolichorhynchops* in the family Polycotylidae. These specimens are biostratigraphically important as they provide the earliest known occurrence for the genus *Dolichorhynchops*.

2. Geologic setting

The Tropic Shale is an Upper Cretaceous formation located within the Kaiparowits Basin in southern Utah. It consists of thinly laminated clayey to sandy, dark gray shale that forms broad, rolling flats and low-angle slopes (Gregory and Moore, 1931). The Tropic Shale is characterized by numerous bentonite beds that are typically white or light gray in color and form erosional terraces or ledges that are easily recognizable from a distance (Gregory and Moore, 1931). The formation was deposited along the western margin of the Cretaceous Western Interior Seaway during the Greenhorn Cyclothem, the period of maximum transgression. The time range of the Tropic Shale has been constrained using ammonite biostratigraphy; it spans from the late Cenomanian through the middle Turonian (Cobban and Hook, 1984). The base of the Tropic Shale is sandier, and is underlain by the Dakota Formation. The Tropic Shale is also sandier upsection and forms steep slopes leading upward to the overlying Straight Cliffs Formation. The Tropic Shale varies in thickness from 180 to about 425 m (Gregory and Moore, 1931), but is typically 200 m thick around the study area (Albright et al., 2007b). The Tropic Shale correlates with the Tununk Shale Member of the Mancos Formation in northern Arizona (Leithold, 1994), approximately 100 km (about 160 miles) southeast of MNA localities 1483 and 1627.

MNA localities 1483 and 1627 can be placed within the known stratigraphy of the Tropic Shale using ammonite biostratigraphy, limestone beds, and bentonites (see Albright et al., 2007b, figs. 1 and 2 for exact location of the site of MNA V10046). The sites are located within the Early Turonian, in a span between 93.5 and 92.0 Ma (Albright et al., 2007b).

Institutional abbreviations. AMNH, American Museum of Natural History, New York, New York; FHSM, Sternberg Museum of Natural History, Hays, Kansas; KUVP, Kansas Museum of Natural History, Lawrence, Kansas; MCZ, Museum of Comparative Zoology, Cambridge, Massachusetts; MNA, Museum of Northern Arizona, Flagstaff, Arizona; ROM, Royal Ontario Museum, Toronto, Ontario, Canada; RSM, Royal Saskatchewan Museum, Regina, Saskatchewan, Canada; UCM, University of Colorado Museum, Boulder, Colorado; USNM, Smithsonian Institution, Washington, DC.

3. Systematic paleontology

Sauropterygia Owen, 1860
Plesiosauria De Blainville, 1835
Plesiosauroidea Welles, 1943
Polycotylidae Cope, 1869
Polycotyilnae Albright et al., 2007

Dolichorhyhchops Williston, 1903

Genotypic species. D. osborni Williston, 1903

Revised diagnosis. Short and high sagittal crest, short and wide temporal fenestra, vertical suspensorium, ectopterygoid lacking an anterior process, broadened posterior end of parasphenoid, pterygoid extends posterior to interpterygoid vacuity, 17–20 pairs of teeth in mandibular symphysis, 19–21 cervical vertebrae, posterior bend in midshaft of scapula, epipodials shorter than broad, lateral spur on coracoids.

Dolichorhynchops tropicensis sp. nov.
Figs. 1–10

Derivation of name. The species is named after the Tropic Shale, the formation from which this specimen and many other notable plesiosaur specimens have been discovered.

Holotype. MNA V10046, complete skull, nearly complete dentition, an incomplete set of vertebrae and ribs, scapulae, coracoids, ilia, ischia, pubes, nearly complete forelimbs and hindlimbs.

Referred specimen. MNA V9431, vertebrae, rib fragments, partial fragments of the scapulae, coracoids, ischia, and pubis, complete ilium, and many unidentified fragments.

Type locality and age. Tropic Shale, Kane County, Utah; Early Turonian.

Diagnosis. Relatively small polycotylid plesiosaur, flat anterior margin of parasphenoid, greater size range in teeth than other species of *Dolichorhynchops*, moderately constricted dorsal vertebral centra, chevron facets on anterior and posterior margins of caudal vertebrae, straight anterior margin and narrowed distal end of scapula, anterior processes of coracoids divergent without meeting at midline, lack of clavicular notch on coracoids, curved ilium, sacral end of ilium broad and laterally flattened, well-defined facets for epipodials on propodials.