

# Ornithopod and Sauropod Dinosaur Remains from the Maastrichtian Al-Khod Conglomerate, Sultanate of Oman

Ann S. Schulp\*, Patrick M.O'Connor\*\*, David B. Weishampel\*\*\*, Abdul Razak Al Sayigh, Abdulrahman Al-Harthy\*\*\*\*, John W.M. Jagt and Axel F. Hartman\*\*\*\*\*.

*Natuurhistorisch Museum Maastricht, De Bosquetplein 6/7, NL6211KJ Maastricht, The Netherlands, \*Email: anne.schulp@maastricht.nl; \*\*Ohio University, Department of Biomedical Sciences, 228 Irvine Hall, Athens, OH 45701, USA;\*\*\* Johns Hopkins University, School of Medicine, Center for Functional Anatomy & Evolution, 1830 E Monument Street, Baltimore, MD 21205, USA;\*\*\*\* Department of Sciences, College of Science, Sultan Qaboos University, P.O.Box 36, Al-Khod 123, Muscat, Sultanate of Oman; \*\*\*\*\*Brunei Shell Petroleum, EPE/21 BSP Brunei, P.O. Box 245, NL 2501CE Den Haag, The Netherlands.*

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**ABSTRACT:** Fieldwork in the Upper Cretaceous (Maastrichtian) Al-Khod Conglomerates in the Sultanate of Oman led to the discovery of a large bone fragment tentatively identified as a partial distal left humerus of a sauropod and an ornithopod dorsal vertebra. The very fragmentary state of preservation of the dorsal vertebra makes specific attribution difficult, but it shows remarkable similarities to the rhabdodontid dinosaurs *Rhabdodon* and *Zalmoxes*.

**KEYWORDS:** Sultanate of Oman; Late Cretaceous; Maastrichtian; Dinosauria; Ornithopoda; Sauropoda.

## 1. Introduction

**D**inosaur fossils in the Sultanate of Oman were recognized for the first time by Nolan *et al.* (1990) while logging the type section of the Al-Khod Conglomerate Formation. A short reconnaissance in 1997 by two of us (ASS and AFH) confirmed the potential of the Al-Khod Conglomerate outcrops for further vertebrate palaeontological fieldwork. During this reconnaissance, one of us (AFH) discovered a theropod caudal vertebra (Schulp *et al.*, 2000). Subsequent fieldwork in 1998 (e.g. Buscalioni *et al.*, 2004) yielded additional material, of which an ornithopod dorsal vertebra and a fragmentary sauropod humerus are described in the present contribution.

## 2. Material

*Institutional abbreviations* – All fossil material recovered from Al-Khod is permanently deposited in the collections of the Sultan Qaboos University, Sultanate of Oman. The specimens described here are numbered SQU-2-65 and SQU-2-76, respectively, where ‘2’ refers to the Al-Khod-locality.

*Locality* – Both elements described here were recovered from the type locality of the Al-Khod Conglomerate Formation (Nolan *et al.* 1990; Schulp *et al.*, 2000; Buscalioni *et al.*, 2004), located approximately 30 km west of Muscat, Sultanate of Oman.

*Age* – The Al-Khod Conglomerate Formation has previously been assigned a Maastrichtian age (see Nolan *et al.*, 1990; Schulp *et al.*, 2000). The stratigraphy and sedimentology of these deltaic deposits are described in detail in these contributions, and is not repeated here. Recent analysis (by AA-S) of microfossils from the base of the Jafnayn Formation (which conformably overlies the Al-Khod Conglomerate) confirms the Maastrichtian age of the Al-Khod Conglomerate.

### SYSTEMATIC PALAEONTOLOGY

DINOSAURIA Owen, 1842

SAURISCHIA Seeley, 1888

SAUROPODA Marsh, 1878

(Figure 1A-C)

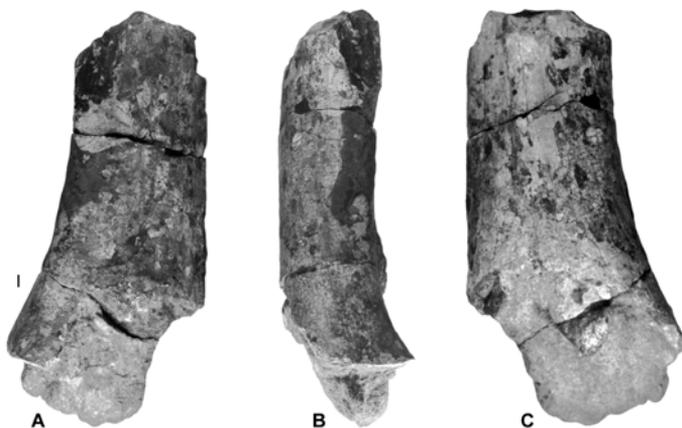


Figure 1. SQU-2-65 – Sauropod left distal humerus from the Maastrichtian Al-Khod Conglomerate Formation, Sultanate of Oman, in cranial (A), medial (B) and caudal (C) views. Scale bar equals 10 mm.

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*Specimen* – SQU-2-65 is a partial distal left humerus, collected by AFH as three isolated fragments in float from the lowermost part of the section.

*Description* – Although the specimen was collected as three separate fragments, morphology of the fracture surfaces allows a confident assembly of the individual pieces into a single element (Figure 1). We tentatively interpret the specimen to represent the distal half of a left humeral diaphysis of an indeterminate sauropod, spanning from just below mid-shaft to the expanded region just proximal to the ulnar and radial condyles. The medial edge of the element is better preserved than the lateral, the former extending approximately 6 cm further distally than the latter (Figure 1A). The element exhibits a maximum length (proximodistal) of 34 cm, with a 31.5 cm diaphyseal circumference at the proximal end. The proximal surface is elliptical in cross-section, with the long axis oriented transversally (11.5 cm mediolaterally by 8.5 cm craniocaudally). The distal end of the diaphysis is deflected cranially (Figure 1B). Although incomplete distally, it is apparent that the mediolateral flaring characteristic of sauropod humeri is asymmetric, being more pronounced along the medial edge. A slight ridge is present on the craniomedial edge of the element (Figure 1A) and forms the medial border of a shallow fossa on the cranial surface. The caudal aspect is poorly preserved (Figure 1C), with original bone surface only remaining on the proximal two-third of the element. Although the proximal portion of the olecranon fossa is preserved (Figure 1C), incomplete preservation of the caudodistal end renders the determination of either (1) the size and position of supracondylar ridges (and thus the relative development the olecranon fossa) or (2) the shape, position, and relative sizes of the radial and ulnar condyles impossible.

ORNITHISCHIA Seeley, 1888

ORNITHOPODA Marsh, 1881

(Figure 2A-D)

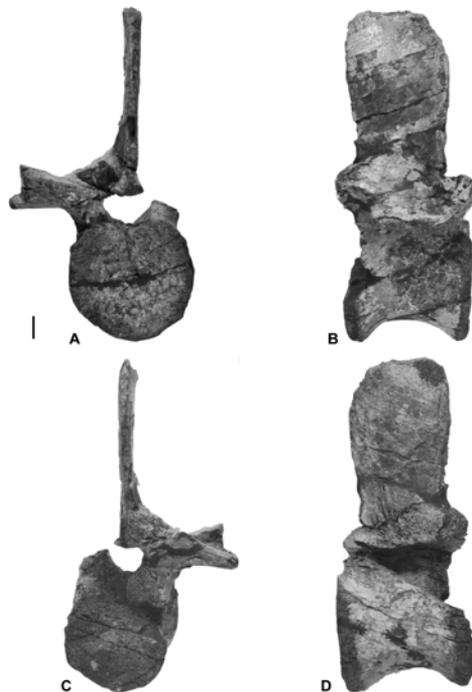


Figure 2. SQU-2-76 – Ornithomimid dorsal vertebra from the Maastrichtian Al-Khod Conglomerate Formation, Sultanate of Oman, in posterior (A), left lateral (B), anterior (C) and right lateral (D) views. Scale bar equals 10 mm.

*Specimen* – SQU-2-76 is a vertebral centrum with partially preserved neural arch.

*Description* – This mid-dorsal vertebra of an as yet undetermined rhabdodontid dinosaur is undeformed and nearly complete, lacking only the left transverse process, the adjoining quarter of the caudal aspect of the centrum, and the pre- and postzygapophyses. The centrum is broadly spindle shaped, slightly longer than high – the axial length is 60 mm while the centrum is 58 mm wide and 53 mm tall. The cranial and caudal surfaces are parallel to each other in lateral view and both are relatively circular (with a small dorsal indentation for the neural canal) and slightly amphiplatyan. In lateral view, the centrum has a prominent ventral concavity between the cranial and caudal margins. Here it forms a gently rounded surface that is continued as the compressed lateral walls of the centrum. Only a faint expression of the neurocentral suture is visible on the right side of the specimen, probably indicating that the individual was close to reaching skeletal maturity. The thick pedicle arches laterally to form the base of the transverse process. The neural canal, surrounded by the pedicle and stout lamina that forms the base of the neural spine, is ovate and of moderate size (transverse diameter of the neural canal is 40% transverse diameter of the centrum). The neural arch and spine extend nearly the entire length of the centrum. The neural spine is moderately thick, tall, and rectangular. Its dorsal edge is only slightly expanded. The parapophysis, for the capitulum of the associated rib, is positioned beneath the intersection of the pedicle and transverse process.

### 3. Discussion

Asymmetric flaring of the sauropod distal humerus in SQU-2-65 is reminiscent of the condition observed in several lithostrotians such as *Rapetosaurus* (Curry Rogers and Forster 2001, Figure 3E), *Paralititan* (Smith *et al.*, 2001, Figure 2A), and to a lesser degree *Malawisaurus* (Gomani, 2005, Figure 20). Moreover, it is unlike the symmetrical flaring observed in saltasaurids (i.e., derived lithostrotians; see Upchurch, 1998, Figure 12), not to mention many other (non-lithostrotian) sauropod taxa (e.g., diplodocoids). Although the absence of other diagnostic features in SQU-2-65 does not allow for a more specific assignment, the potential lithostrotian affinities outlined for it are generally consistent with the known distribution of specific sauropod subclades in Maastrichtian-age strata. The latest Cretaceous sauropod record of Afro-Arabia is extremely limited (Weishampel *et al.*, 2004) and includes only three Maastrichtian occurrences, an associated basal titanosauriform hind limb from Morocco (Pereda-Suberbiola *et al.*, 2004), a possible ‘brachiosaurid’ femur from Egypt (Rauhut and Werner, 1997), and a dorsal vertebra referred to Titanosauria from Jordan (Wilson *et al.*, 2006). From the Arabian Peninsula, the only sauropod occurrences thus far reported (e.g., fragmentary vertebrae; tracks) are from Jurassic strata exposed in northern Yemen (Jacobs *et al.*, 1999; Schulp *et al.*, 2008).

Although SQU-2-76 lacks apomorphies known for Rhabdodontidae or the three members of this group (see Weishampel *et al.*, 2003), the vertebra from Oman is closely similar to the dorsals of those ornithopods of about the size and phylogenetic position as species of *Rhabdodon* and *Zalmoxes*. However, they differ from those of *Tenontosaurus*, the latter being dorsoventrally ovate in cranial/caudal views (Ostrom, 1970) and of *Thescelosaurus* and *Dryosaurus*, which have highly elevated transverse processes (Gilmore, 1915; Galton 1974, 1981). The latest Cretaceous ornithopod record of Afro-Arabia is even more limited than the sauropod record (Weishampel *et al.*, 2004; Lamanna *et al.*, 2004; see also Martill *et al.*, 1996), which underscores the palaeobiogeographical significance of the Al-Khod Conglomerate.

### 4. Conclusion

The Maastrichtian Al-Khod dinosaurian fauna comprises at least three taxa: a medium-sized theropod (Schulp *et al.*, 2000), a small ornithopod, and a medium-sized sauropod. Based on the presence of the three dinosaurian taxa, along with two previously reported crocodyliforms (Buscalioni *et al.*, 2004) and other as yet undescribed forms (e.g., turtles), the Al-Khod Conglomerate Formation has yielded the taxonomically most diverse terrestrial vertebrate fauna from the latest Cretaceous of the Middle East. Moreover, it represents one of

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the very few temporally constrained Late Cretaceous vertebrate-bearing locales in all of Afro-Arabia. The generally poor state of preservation however, is most unfortunate, as it in most cases precludes specific taxonomic assignment.

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