

RESEARCH/REVIEW ARTICLE

The oldest plesiosaur (Reptilia, Sauropterygia) from Antarctica

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Abstract

Antarctic plesiosaurs are known from the Upper Cretaceous López de Bertodano and Snow Hill Island formations (Campanian to upper Maastrichtian), which crop out within the James Ross Basin region of the Antarctic Peninsula. Here we describe the first plesiosaur fossils from the Lachman Crag Member of the Santa Marta Formation, north-western James Ross Island. This material constitutes the stratigraphically oldest plesiosaur occurrence presently known from Antarctica, extending the occurrence of plesiosaurians in this continent back to Santonian times (86.3–83.5 Mya). Furthermore, MN 7163-V represents the first plesiosaur from this region not referable to the Elasmosauridae nor *Aristonectes*, indicating a greater diversity of this group of aquatic reptiles in Antarctica than previously suspected.

Plesiosaurs (=clade Plesiosauria herein) have been found in Mesozoic aquatic deposits ranging from the Upper Triassic to Upper Cretaceous (e.g., O'Keefe 2001). They were top marine predators, achieving a wide variety of body forms and a cosmopolitan distribution during the Jurassic Period (Rieppel 1997; Gasparini et al. 2003). By the mid-Jurassic, plesiosaurs dispersed to the Southern Hemisphere, with registers from South America and Australia (Kear 2003; Hiller 2005; Gasparini 2007 and references therein). Eventually, they reached the Antarctic continent, with records from Late Cretaceous deposits (Martin & Crame 2006).

The first record of this clade of marine reptiles in the Antarctic region was made by Del Valle et al. (1977) on James Ross and Vega islands in the Antarctic Peninsula (Fig. 1). Since then, other expeditions have found limited and fragmentary plesiosaur specimens on the islands of that same area. All those occurrences are referred to the Elasmosauridae, to *Aristonectes* (regarded as an

Elasmosauridae or an Aristonectidae) or as Plesiosauria indet. (Chatterjee 1982; Gasparini et al. 1984; Chatterjee & Small 1989; Fostowicz-Frelic & Gazdzicki 2001; Gasparini et al. 2003; Martin & Crame 2006; Martin et al. 2007; Ketchum & Benson 2010). Most of these came from Seymour and Vega islands, from the López de Bertodano and Snow Hill Island formations, of the Marambio Group.

The only plesiosaurian remains recorded from James Ross Island consist of fragmentary vertebrae, isolated ribs and a few autopodial elements described by Del Valle et al. (1977) and one isolated vertebra mentioned by Martin & Crame (2006). All came from the Naze region, where the Cape Lamb Member of the Snow Hill Island Formation crop out, but no specimen was described in detail or figured.

In the austral summer of 2006/2007, during fieldwork by a team from the National Museum of the Federal University of Rio de Janeiro (UFRJ) on James Ross Island

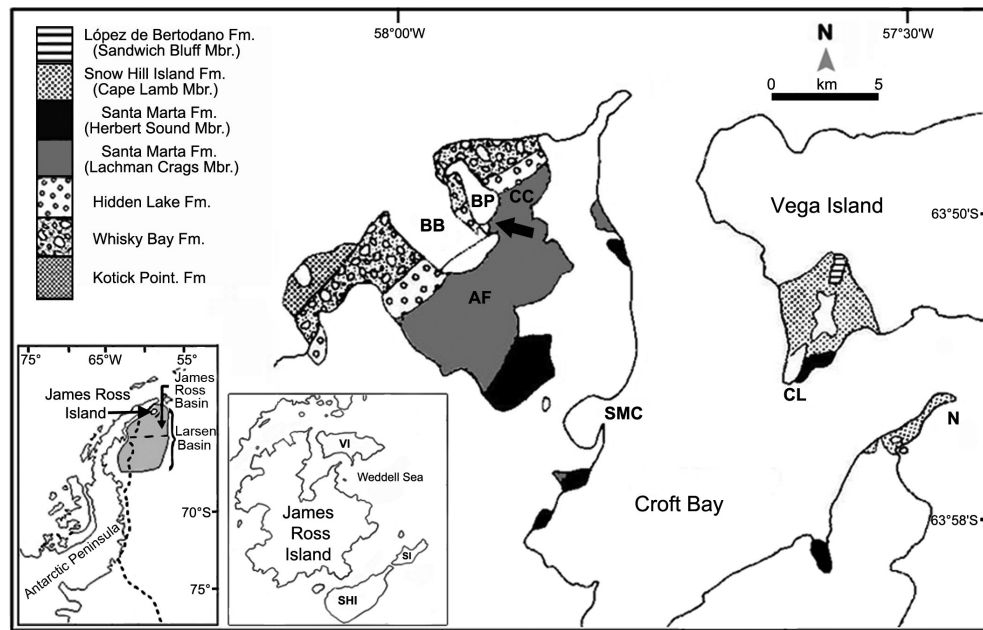


Fig. 1 A schematic map of north-west James Ross Island and its outcropping strata from the Gustav and Marambio groups. The arrow points to the location where MN 7163-V was found near the base of Bibby Point Plateau (BP). Also indicated are Brandy Bay (BB), Abernethy Flats (AF), Santa Marta Cove (SMC), Crame Col (CC), Cape Lamb (CL), the Naze (N), Snow Hill Island (SHI); Seymour Island (SI) and Vega Island (VI). Figure based on an illustration by Pirrie et al. (1992).

(Fig. 1), over 2500 kg of fossils and rock samples were collected, mostly consisting of invertebrates and plant material. Among the few vertebrate specimens found were 19 plesiosaurian vertebrae, propodial and autopodial elements regarded as belonging to the same individual. Despite the incompleteness of the material, this specimen (identification number MN 7163-V, housed at the National Museum/UFRJ) is the oldest member of this group known from Antarctica so far, extending the plesiosaur record on the continent to the Santonian (86.3–83.5 Mya).

Geological background and area description

The James Ross Basin, part of the Larsen Basin at the distal end of the Antarctic Peninsula (Fig. 1), was formed as a back-arc basin relative to the island arc created during the subduction of the Protopacific plate beneath Southern Gondwana. James Ross Island contains some of the oldest sedimentary units of this basin, and certainly the oldest ones within the James Ross Basin insular area. These include: the Gustav Group, with four successive formations in James Ross Island, which is Lower to Upper Cretaceous (Coniacian); and the Santa Marta and Snow Hill Island formations, from the Marambio Group, with the first one corresponding to upper Coniacian–upper

Campanian and the second one to upper Campanian–lower Maastrichtian. Thinly interbedded ash beds and black mudstones from the Nordenskjöld Formation (Upper Jurassic–Lower Cretaceous) occur enclosed within the Gustav Group deposits in the form of allochthonous small clasts and large isolated blocks (Pirrie et al. 1992; McArthur et al. 2000; Crame et al. 2004; Svojtka et al. 2009). The older units of this basin are particularly found in the north-west areas of the island, where the expedition team camped and undertook geological and palaeontological studies.

The plesiosaur remains were found in an area near the south-eastern base of the Bibby Point Plateau, between Crame Col and Brandy Bay (Fig. 1). The outcrop strata in this region belong to the Lachman Crags Member of the Santa Marta Formation (the old Alpha and Beta members as defined by Olivero et al. 1986). These deposits have been interpreted as having been formed in a marine mid-to outer shelf below storm wave base, with a volcanoclastic sediment supply from the neighbouring arc (Pirrie et al. 1992). Both micro- and macrofossil invertebrates have been previously found here, including ammonite, belemnite and inoceramid molluscs, as well as dinoflagellate cysts (Keating 1992; Pirrie et al. 1992; Svojtka et al. 2009).

Systematic palaeontology

Sauropterygia Owen, 1860

Plesiosauria de Blainville, 1835 gen. indet.

Referred specimen

MN 7163-V. Parts of a propodial bone, numerous autopodial elements and cervical and caudal vertebrae (Figs. 2, 3). The material is fragmentary due to the extreme weather conditions of Antarctica. These were all found over a small area of roughly 2 m² and belong to a single animal.

Description

Vertebrae

We were able to identify 19 vertebral centra. Ten out of these exhibited strongly concave articular faces with rounded edges (Fig. 2a). The fact that no single structure resembling a vertebral condyle was found—such robust elements are more likely to be preserved—leads us to believe that these elements constitute amphicoelous vertebrae. These are present in both cervical and caudal regions of plesiosaurs. The ventral nutritive foramina always occur in pairs and are of similar size in relation one to another on the same centrum, characteristic of cervical centra (Fig. 2b). These foramina extend into the

central part of the vertebra, forming a cylindrical channel that can be seen in internal view (Fig. 2c, d). On the vertebral centra MN 7163-V/1-6, the rib facets are positioned ventrolaterally, another characteristic of cervical elements of plesiosaurs (Fig. 2a). In the vertebrae MN 7163/3-5, the cervical rib facets and the subcentral foramina are more distinctly visible (Fig. 2b). Two small fragments of vertebral centra possess chevron facets on them, indicating they belong to the caudal region (Fig. 2e). The chevron facets are small, and the best preserved one is placed at the end of a longitudinal ridge at the base of the centrum.

Propodial

The proximal portion of one of the propodial bones is present in the form of separate small-sized pieces, which form an overall strongly convexly shaped structure when reconstructed (Fig. 3a). Its surface is marked by rugosities, which in association with the shape of the head indicate the specimen had a hemispherical cape of cartilage covering the head in its articulation with the girdle. Numerous small nutritive foramina are visible as well (Fig. 3b), which in life formed passage channels for blood vessels into the propodial bone. A ventro-lateral ridge between the head and the shaft of this bone is preserved, marking the border between these two regions of the propodial, which is also enhanced by the difference on their surface textures.

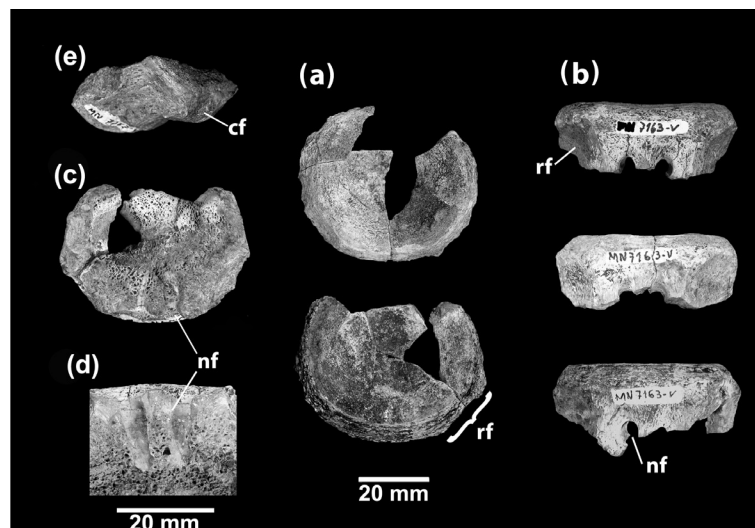


Fig. 2 Vertebrae: (a) cervical vertebrae MN 7163-V/4 and 5 in anterior/posterior view; (b) cervical vertebrae in ventral view, from top down MN 7163-V/3-5; (c) internal view of MN 7163-V/5; (d) detailed image of subcentral foramina of cervical vertebra MN 7163-V/3 on internal view; and (e) caudal vertebra in postero-lateral view. The following features are indicated: chevron facet (cf); nutritive foramen (nf); and rib facet (RF).

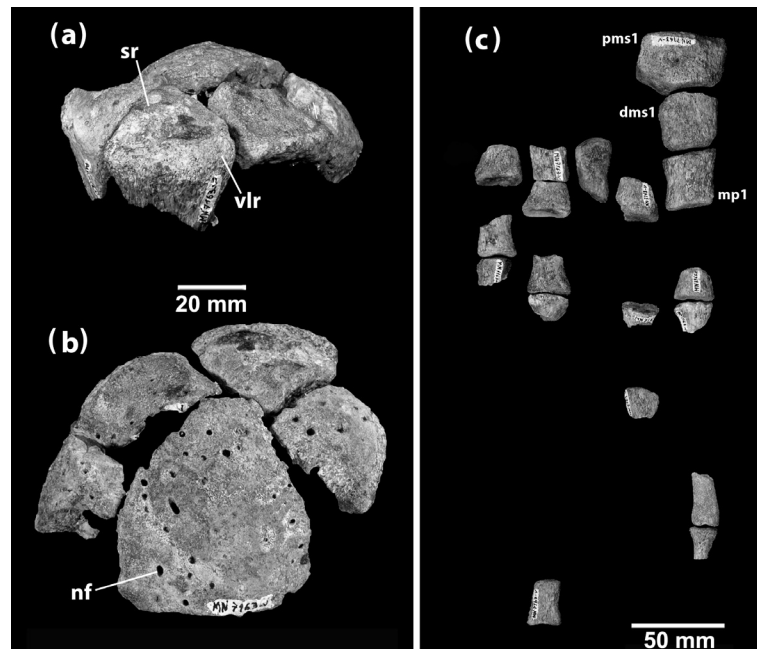


Fig. 3 Paddle elements of MN 7163-V: (a) propodial head partially reconstructed in ventral view; (b) propodial head in proximal view; (c) autopodium elements, including some digit I articulated proximal elements. The first distal mesopodial (dms1), first metapodial (mp1), first proximal mesopodial (pms1), surface rugosities (sr) and ventrolateral ridge (vlr) are indicated.

Autopodium

Along with the vertebrae and propodial head, elements belonging to one of the paddles of the plesiosaur were found (Fig. 3c). However, it cannot be assured whether these belong to the fore or hind paddles of the specimen, since plesiosaur autopodium elements from both regions are quite similar to each other. Nonetheless, the elements we found from the head of the propodial belong to a single bone (Fig. 3a, b). Therefore, it is possible that most of the paddle elements belong to this same single member. The reconstruction of the paddle is based on the articular facets of these elements and their relative size to each other. This material includes the first proximal mesopodial element (radiale or tibiale [Fig. 3c]), the first distal mesopodial and the first metapodial element (first metatarsal or metacarpal). The other elements, which are either metapodials or phalanxes, are quite fragmentary. Most preserved only their epiphysal ends, which are wider and more robust than their shafts.

Discussion and conclusion

During most of the Cretaceous, mosasaurs, ichthyosaurs and plesiosaurs were the predominant marine tetrapods in the oceans all over the world and were the first groups to which we tried to associate MN 7163-V. The presence of amphicoelous vertebrae with rounded subcentral

nutritive foramina distinguishes MN 7163-V from mosasaurs, which have also been reported from Antarctica (Postowicz-Frelie & Gazdzicki 2001; Martin & Crame 2006). Ichthyosaurs, whose fossil record reaches only the Cenomanian (Lucas 1997; McGowan & Motani 2003), could also be ruled out on the basis of the presence of ventral foramina in the material studied here. The paddle elements, along with the paired ventral nutritive foramina indicated that the material represents a plesiosaur, but the problem remained to establish which clade within the group.

Except for some very fragmentary and incomplete specimens that did not allow any particular taxonomic identification (Del Valle et al. 1977; Martin & Crame 2006), all records in Antarctica are either assigned to the Elasmosauridae or to *Aristonectes*, a genus which has been previously related to the Cimoliasauridae (= *Aristonectidae* sensu O'Keefe & Street [2009]) by O'Keefe (2001, 2004) and to the Elasmosauridae (Gasparini et al. 2003; Sachs 2005; Ketchum & Benson 2010). Elasmosaurids are diagnosed by the presence of platycoelous cervical articular faces, as well as depressed facets for the cervical ribs (Druckenmiller & Russel 2008; Ketchum & Benson 2010). *Aristonectes* also possesses platycoelous articular faces, along with a constriction on the ventral side of it, creating a "dumbbell" outline (Gasparini et al. 2003). In the new material reported here, the articular faces are

strongly concave with rounded edges, and the facets for the cervical ribs are not depressed. Therefore, the material is not referable to the Elasmosauridae nor *Aristonectes*, indicating the presence of another plesiosaur group in Antarctica. Unfortunately, MN 7163-V is too incomplete to show features that would allow its assignment to any other major plesiosaurian clades confidentially recorded in Late Cretaceous deposits such as the Polycotylidae and the Pliosauridae (Kear 2003; Ketchum & Benson 2010).

Strontium isotope ratios ($^{87}\text{Sr}/^{86}\text{Sr}$) indicate the lowest levels of the Santa Marta Formation (including the Lachman Crag Member) were deposited 87.1 Mya, corresponding to the late Coniacian (McArthur et al. 2000). Using a different methodology, Svojtka et al. (2009) assigned the same layers to the late Coniacian to early Santonian. Since MN 7163-V was collected close to the lower limits of Lachman Crag Member (Fig. 1), we regard this specimen as being of Santonian age (86.3–83.5 Mya).

Despite its incompleteness, MN 7163-V is the oldest plesiosaur known so far from Antarctica and the first one not referable to the Elasmosauridae nor to *Aristonectes* from this region, indicating a higher diversity of this group of aquatic reptiles in this continent than previously suspected. Although potentially belonging to a new species, which—as in other fossil groups—is based on stratigraphic and geographic data (e.g., Kellner 2010), there is no particular anatomical feature or combination of characters that could diagnose a new taxon and more field activity in the area to uncover new and more complete material is needed.

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