FIRST RECORD OF MOSASAURS (LEPIDOSAURIA: MOSASAURIDAE) FROM THE LATE CRETACEOUS (MAASTRICHTIAN) OF THE MAGALLANES BASIN

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ABSTRACT

Mosasaurs were a specialized clade of marine squamates with global distribution during the Upper Cretaceous and their presence is relatively frequent in Maastrichtian levels of Central Chile and Antarctica. However, until now, the group was absent in Cretaceous units from Southern Chile. Herein we report for the first time the presence of this clade in Upper Cretaceous levels of the Dorotea Formation, Magallanes Region. The material comprises a concretionary block with caudal vertebrae recovered from Sierra Dorotea, near Puerto Natales. Despite the fragmentary nature of the specimen, this record confirms the presence of mosasaurs in the Magallanes Basin, adding new taxa to the known local diversity of marine reptiles so far just represented by elasmosaurid plesiosaurs. This new record allows to making connections with the previous occurrences of mosasaurs from the James Ross Basin in Antarctica, adding new data to the marine herpetofauna in the Weddellian Biogeographic Province.

Keyword: Mosasauridae, Maastrichtian, Biogeographic Weddellian Province

RESUMEN

Primer registro de Mosasaurio (Lepidosauria: Mosasauridae) del Cretácico Tardío (Masstrichtiano) de la Cuenca de Magallanes. Los mosasaurios son un clado especializado de Squamata marinos de amplia distribución global durante el Cretácico superior y su presencia es relativamente frecuente en depósitos marinos del Maastrichtiano de Chile Central y Antártica, sin embargo, hasta ahora, el grupo estába ausente del registro fósil en el extremo sur de Chile. Aquí documentamos, por primera vez, la presencia del clado en niveles del Cretácico Superior de la Formación Dorotea, en la Región de Magallanes. El material consiste en un bloque con vértebras caudales recuperado en la localidad de Sierra Dorotea, en las cercanías de Puerto Natales. A pesar de la naturaleza fragmentaria del espécimen, el material permite confirmar la presencia de mosasaurios en la Formación Dorotea, junto con la previamente conocida diversidad local de reptiles marinos hasta ahora representada por plesiosaurios elasmosáuridos. Este nuevo registro permite establecer conexiones con existencias previas de mosasaurios de la Cuenca de James Ross en Antártica, agregando nuevos datos para la herpetofauna compartida en la Provincia Biogeográfica Wedelliana.

Palabras clave: Mosasauridae, Maastrichtian, Biogeographic Weddellian Province

INTRODUCTION

Mosasaurs (Squamata, Mosasauroidea) are a clade of aquatic lizards widely distributed along the Late Cretaceous seas, with a fossil record documented at least since the Cenomanian (Caldwell and Palci 2007, Bardet *et al.* 2008) until the upper Maastrichtian (Jagt 2005, Gallagher *et al.* 2012, Mulder *et al.* 2013). Inhabiting of epicontinentals seas and even of freshwater courses (Makádi *et al.* 2012), the mosasaurs have been found worldwide, including records from Antarctica (Novas *et al.* 2002, Fernández and Martin 2009). The traditional definition of "mosasaur" involves characters such as the acquisition of hydrodynamic adaptions of the skeleton, derived from a terrestrial ancestral condition that includes deep modifications of the vertebrae, limbs and pelvic girdle (Russell 1967), as well as the bony microanatomy (Houssaye *et al*. 2013), the integument (Lindgren *et al.* 2011) and the presence of heterocercal fin tail (Lindgren *et al.* 2013). However, some of these novelties were acquired independently in different mosasaur lineages (Bell and Polcyn 2005, Caldwell and Palci 2007, Caldwell 2012).

The fossil record of South American mosasaurs includes occurrences from the Cenomanian?-Maastrichtian of Brazil (Price 1957, de Carvalho and Azevedo 1988, Vilas Bóas and de Souza Carvalho 1999, Bengtson and Lindgren 2005), the Turonian-Campanian of Colombia (Páramo-Fonseca 2000, Páramo-Fonseca 2012, Páramo-Fonseca 2013), the Turonian of Venezuela (Sánchez-Villagra *et al*. 2008), the Santonian of Perú (Caldwell and Bell 1995) and the Campanian-Maastrichtian of Argentina (Ameghino 1893, Fernández *et al.* 2008, Fernández and Gasparini 2012, Gasparini et *al*. 2001). Mosasaur remains from Chile are restricted to few localities along the central part of the country. This record includes isolated teeth of indeterminate mosasaurs from lower Maastrichtian beds of Algarrobo (Otero *et al.* 2012), teeth of Tylosaurinae and other indeterminate mosasaurs from Loanco, Maule Region (Jiménez-Huidobro *et al.* 2014, Otero 2012, Otero and Suárez 2009), and cranial remains of mosasaurs (possibly Halisaurinae) from Cocholgüe (Suárez 1999, Suárez *et al.* 2003, Jiménez-Huidobro *et al.* 2014), the last two localities are late Maastrichtian in age (Salazar *et al*. 2010). However, the presence of this group the southernmost part of the country was previously unknown. Unlikely this apparently discontinuous presence of mosasaurs along the southeastern margin of the Pacific, these squamates are very common in Upper Cretaceous levels of the Larsen Basin of Antarctica (Fernández and Gasparini 2012). Older records include the endemic tylosaurine species *Taniwhasaurus antarcticus* (Novas *et al.* 2002, Fernández and Martin 2009) from the upper Campanian of the Santa Marta Formation in James Ross Island, Antarctica. In addition, abundant but fragmentary remains have been recovered from lower Maastrichtian levels of Snow Hill Island Formation in Vega Island, as well as from upper Maastrichtian levels of the López de Bertodano Formation in Seymour (=Marambio) and Vega islands, Antarctica (Gasparini and del Valle 1981, Martin 2006). On the other hand, the close phylogenetic relationship between some tylosaurine mosasaurs from the Campanian of Antarctica and New Zealand (Martin and Fernández 2007, Novas *et al*. 2002) are consequence of a high degree of endemism in the Weddellian Biogeographic Province (Zinsmeister 1979, 1982).

In the present study, we describe the first remains referable to the clade Mosasauridae, from upper levels of Dorotea Formation, Magallanes Region, southernmost Chile. Besides being the first regional record, the material studied is relevant because it evidences the continuous presence of mosasaurids along Antarctica and the Magallanes Basin during the late Maastrichtian.

LOCALITY AND GEOLOGICAL SETTING

The specimen was collected by the first author from the western hillside of Cerro Dorotea, 2 km NE of Puerto Natales, Última Esperanza Province, Magallanes Region (Figure 1). The material was embedded in a transported block of grey, very hard, fine-grained and partially silicified limestone. Such lithology can be correlated with upper beds of the section cropping out in the Sierra Dorotea (Figure 2). These levels are part of the Dorotea Formation (Katz 1963), a mostly marine sedimentary unit that extents in almost continous way from Sierra Baguales in the northern limit of the Última Esperanza Province, to Dumestre (at least), S of Puerto Natales. This unit overlies the Tres Pasos Formation (Katz 1963), the latter assigned to the Campanian based on biostratigraphy. The roof of Dorotea Formation likely contacts through an erosive discordance with the Man Aike/Río Turbio formations, of middle-upper Eocene age. The Dorotea Formation corresponds to transitional marine deposits from deep-to-shallow facies, composed mostly by sandstones variable in color from green, gray, yellowish, brown and reddish, commonly with lenticular conglomerates and intercalations of clay levels. Calcareous levels and concretionary nodules are present in the upper levels hosting a rich fossil diversity which includes abundant invertebrates (Katz 1963, Mourgues 2014) while vertebrates are well represented by chondrichthyans (Otero and Suárez 2009, Otero *et al.* 2013), elasmosaurid plesiosaurs (Otero *et al.* 2009, 2015; Otero and Rubilar-Rogers 2010) and dinosaurs (Rubilar-Rogers *et al.* 2013, Soto–Acuña *et al.* 2014). The age of this formation was formerly assigned to the Campanian-Maastrichtian based on fossil invertebrates (Katz 1963, Pérez and Reyes 1978), later constrained to the Maastrichtian based on microfossils (Martínez-Pardo 1965). Radioisotopics dates (U-Pb SHRIMP) obtained from sandstones sampled at the base of the Cerro Dorotea give a 67.4±1.5 Ma (Hervé *et al.* 2004) which allows to assign an upper Maastrichtian age for the marine reptile-bearing levels of this section.

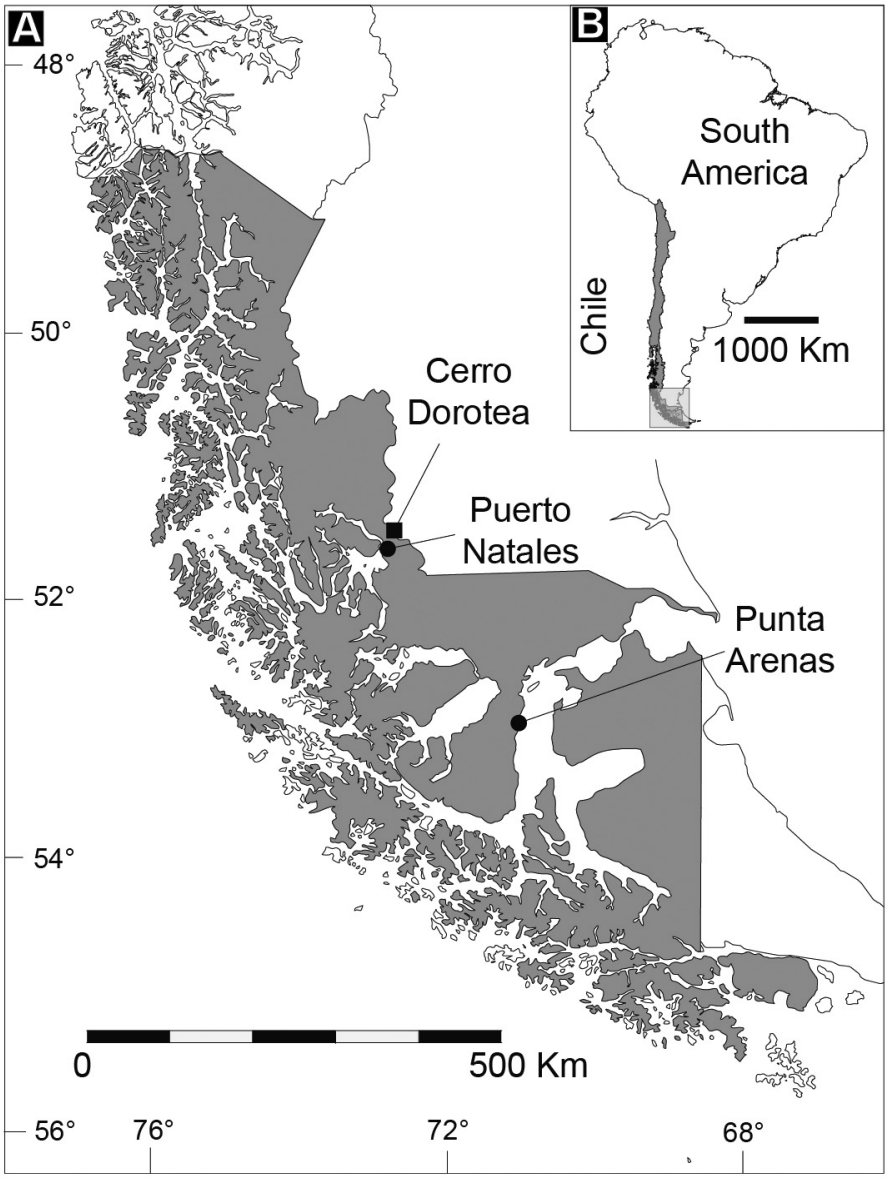

FIGURE 1: Map indicating the locality where the material was collected. A, Cerro Dorotea locality, Magallanes Region. B, Frontiers of Chile within South America.

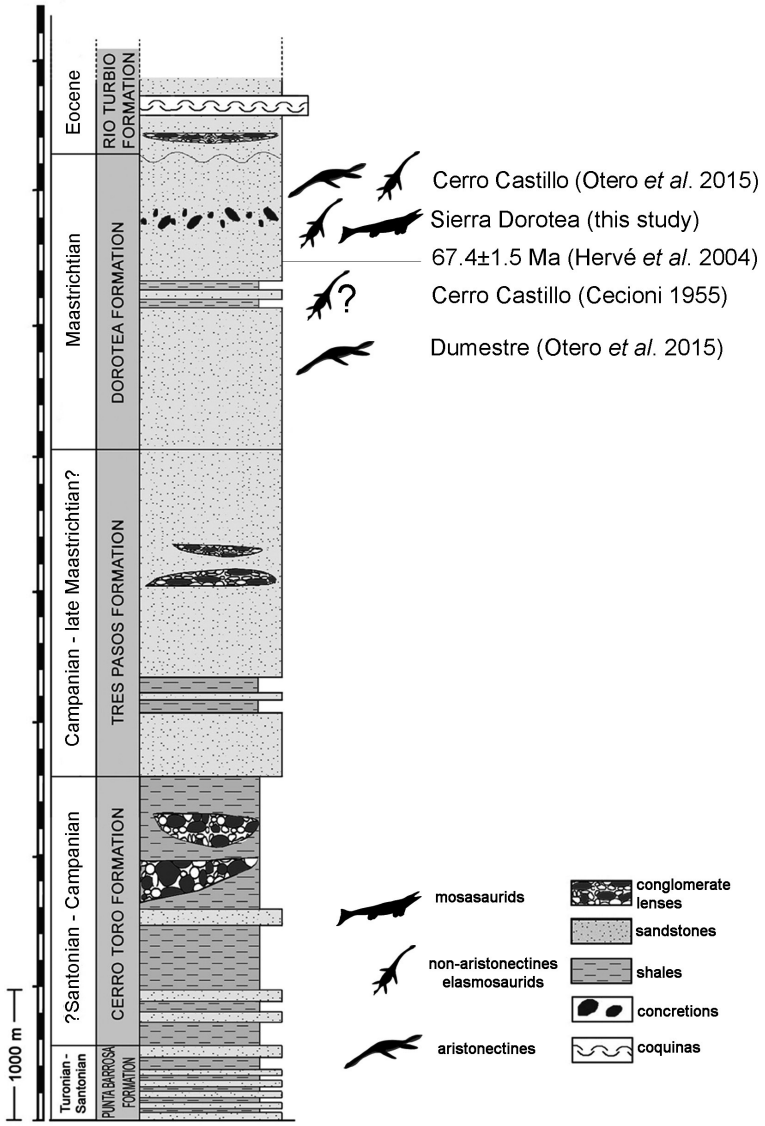

FIGURE 2: Scheme of general stratigraphic column indicating the relative placement of the marine reptiles-bearing levels exposed on the studied locality. The wave line at the top of the Dorotea Formation indicates the discordant contact with the Eocene Río Turbio Formation.

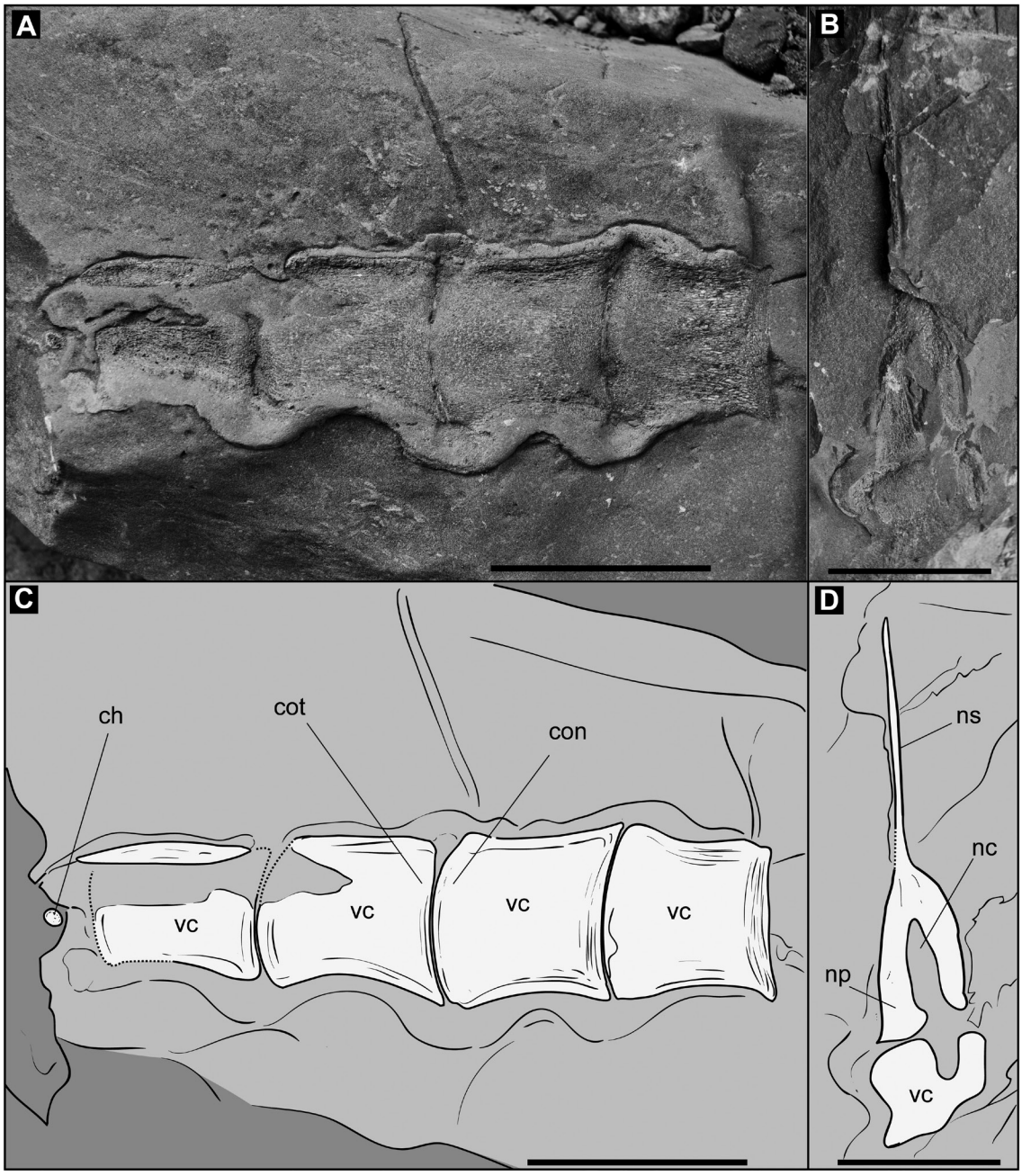

FIGURE 3: Mosasauridae indet. SGO.PV.6566, from Cerro Dorotea, Dorotea Formation, upper Maastrichtian. A, four caudal vertebrae in ventral view. B, neural arch in transversal section. C and D, interpretative schemes of A and B respectively. Anatomical abbreviations: ch, chevron; con, posterior condyle; cot, anterior cotyla; na, neural arch; nc, neural canal; np, neural peduncle; ns, neural spine; vc, vertebral centrum. Scale bars = 50 mm.

Institutional Abbreviations: SGO.PV., Paleontología de Vertebrados, Museo Nacional de Historia Natural, Santiago, Chile.

SYSTEMATIC PALEONTOLOGY

Clase Reptilia Linnaeus, 1758
Subclase Diapsida Osborn, 1903
Orden Squamata Oppel, 1811
Superfamilia Mosasauroidea Gervais, 1853
Familia Mosasauridae Gervais, 1853
Mosasauridae gen. et sp. indet.
(Figure 3)

Material—SGO.PV.6566, four articulated caudal centra, a partial neural arch and fragments of chevrons.

Locality, horizon and age—Cerro Dorotea, Última Esperanza Province, Magallanes Region. Upper levels of Dorotea Formation, upper Maastrichtian.

Description—SGO.PV.6566 comprises an articulated axial portion preserving four centra exposed in ventral view. The surface of the bone is eroded; therefore, the longitudinal section of the vertebrae is visible, showing the internal tissue with the typical trabecular pattern. The centra are markedly procoelous with a condyle-cotyle articulation, and the length and width are subequal at least in the three first centra. In ventral view, the mid portion of each centra is slightly compressed, with the lateral surface gently concave. The neural arch of the last preserved vertebra is partially exposed in transverse cross-section, having a high and very sharp neural spine, an oval neural channel dorso-ventrally elongated and neural peduncles in contact with the centrum. The neural arch is twice as high as the last centrum. Near to the last centrum there is a subcircular-shaped bony fragment, presumably a chevron in cross section, differing from a transverse process which are usually elongated in cross section. We refer the material to a caudal portion based on the presences of chevrons, however the poor preservation does not allow us to identify the region of the tail which it belongs.

Remarks—Among marine reptiles, the presence of procoely in the centrum is diagnostic of squamates lepidosaurs (Estes *et al.* 1988), with the exception of some Gekkota which have an amphycoelous condition (Kluge 1987). Although procoely is also diagnostic of eusuchians crocodyliforms, the centrum the latter have a markedly hourglass-shaped morphology (Huxley 1875). Within squamates, Mosasauridae, Dolichosauridae and Aigialosauridae can be distinguished from other lizards such as varanoids by the lack of a "condylar lip" or "condylar flange" which is an expansion of the centrum in the condylar border, having a nearly cylindrical morphology (Caldwell 2012). The relatively major size of the mosasaur vertebrae compared to aigialosaurs and dolichosaurs (Caldwell *et al.* 1995, Lee and Caldwell 2000, Smith and Buchy 2008) allow us to refer the studied material to Mosasauridae, however, the absence of true synapomorphies in the preserved specimen prevent a more exclusive identification.

DISCUSSION AND CONCLUSIONS

The studied material represents the first record of a mosasaur from Maastrichtian units of the Magallanes Region, being also one of the southernmost findings of the group in South America. There is only more record from the Austral/Magallanes Basin that consists of isolated teeth (Ameghino, 1893) recovered from Lago Argentino, Santa Cruz Province, however this material was not figured and its repository is unknown (Fernández y Gasparini 2012). Regardless of the fragmentary nature of the Dorotea specimen, this new find confirms the presence of mid-sized mosasaurs in the upper Maastrichtian of Dorotea Formation, occurring in coexistence with other marine reptiles such as plesiosaurs (Otero *et al*. 2009). The late Maastrichtian age assigned for the material also allows comparisons with contemporaneous records from the Quiriquina Basin, which includes large-sized tylosaurines mosasaurs (Jiménez-Huidobro

et al. 2014) and small indeterminate mosasaurs (Suárez 1999). However, the morphology and size of the scarce material from the Quiriquina Formation differs from Cerro Dorotea specimen. On the other hand, the studied specimen presents a similar vertebral morphology with coeval specimens recovered from upper levels of López de Bertodano Formation in Seymour Island, Antarctica (SSA direct obs.), providing the common presence of likely the same mosasaur taxa of closely related forms along Antarctica and the Magallanes Basin at least during the late Maastrichtian. Similar ecological relationships have been revealed by the plesiosaur record from Magallanes when compared with that from Antarctica, instead, differing of the coeval herpethofaunal composition so far recognized from the Pacific (Otero *et al.* 2014, 2015). This reinforces the existence of close ecological relationships between Antarctica and the Magallanes fauna during the end of the Cretaceous, an expected result in the context of the Weddellian faunal endemism.

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