

## NOTA CIENTÍFICA

**NOTE ON NEW PTEROSAUR REMAINS (ARCHOSAURIA: PTERODACTYLOIDEA) FROM CERRO LA ISLA, ATACAMA REGION, NORTHERN CHILE**Jhonatan Alarcón-Muñoz<sup>1\*</sup>, Karina E. Buldrini<sup>2</sup>, Dániel Bajor<sup>1</sup>, David Rubilar-Rogers<sup>2</sup><sup>1</sup>Red Paleontológica U-Chile, Laboratorio de Ontogenia y Filogenia, Departamento de Biología, Facultad de Ciencias, Universidad de Chile, Las Palmeras 3425, Santiago, Chile.<sup>2</sup>Área de Paleontología, Museo Nacional de Historia Natural, Santiago, Chile. Interior Parque Quinta Normal s/n., Santiago, Chile.\*Corresponding author: [alarconmunoz@ug.uchile.cl](mailto:alarconmunoz@ug.uchile.cl)

## ABSTRACT

In this study, new isolated fragmentary pterosaur bones are described from Lower Cretaceous outcrops exposed at Cerro La Isla, a site located approximately 95 km east of Copiapó city, Atacama Region, northern Chile. The material consists of a jaw fragment with broken teeth, the caudal portion of a mid-cervical vertebra and the distal portion of a femur. Based on their morphology, the jaw and cervical fragments are assigned to the Ctenochasmatidae, a group of pterodactyloid pterosaurs that has been previously reported from this locality, while the femur lacks diagnostic characters that would allow its referral to a more exclusive taxon than Pterodactyloidea indet. This new material confirms the previously proposed presence of ctenochasmatid pterosaurs in the Cretaceous outcrops of Cerro La Isla and increases the diversity of their skeletal elements discovered at the site.

**Key words:** Pterosauria, Quebrada Monardes Formation, Lower Cretaceous, Atacama Desert

## RESUMEN

**Nota sobre restos de pterosaurios (Archosauria: Pterodactyloidea) de Cerro La Isla, región de Atacama, norte de Chile.** En este estudio, se describen nuevos huesos aislados y fragmentarios de pterosaurios de afloramientos del Cretácico Inferior expuestos en Cerro La Isla, un sitio ubicado aproximadamente a 95 km al este de la ciudad de Copiapó, Región de Atacama, norte de Chile. El material consiste en un fragmento de rostro con dientes rotos, la porción caudal de una vértebra cervical media y la porción distal de un fémur. En función de su morfología, los fragmentos de mandíbula y de la vértebra cervical se asignan a Ctenochasmatidae, grupo de pterosaurios pterodactiloideos que se ha reportado previamente en esta localidad, mientras que el fémur carece de caracteres diagnósticos que permitan su inclusión en un taxón más exclusivo que Pterodactyloidea indet. Este nuevo material confirma la presencia previamente propuesta de pterosaurios ctenocasmátidos en los afloramientos cretácicos del Cerro La Isla, y aumenta la diversidad de sus elementos esqueléticos descubiertos en el sitio.

**Palabras clave:** Pterosauria, Formación Quebrada Monardes, Cretácico Inferior, desierto de Atacama

## INTRODUCTION

Pterosaurs (Archosauria: Pterosauria) were a successful group of flying archosaurs that lived alongside dinosaurs during the Mesozoic (Wellnhofer, 1991). Unlike other South American countries such as Brazil and Argentina, pterosaurs are poorly known in the fossil record of Chile (Soto-Acuña *et al.* 2015, Alarcón-Muñoz *et al.* 2020, 2021). So far, four localities with pterosaur remains are known in Chile, all within the Antofagasta and Atacama regions (Bell and Suárez 1989, Martill *et al.* 2000, Alarcón-Muñoz *et al.* 2018, 2020, 2021). However, knowledge concerning their morphology, phylogenetic and biogeographic relationships is still limited.

The site with the highest abundance of pterosaur remains in Chile is Cerro La Isla, approximately 95 km east of Copiapó city in the Atacama Region, where Lower Cretaceous outcrops of the Quebrada Monardes Formation are exposed (Bell and Suárez 1989). The bones at the site are preserved disarticulated in a single layer of sandstone, which has been interpreted as the consequence of a high-energy sediment flow (Bell and Padian 1995). The high abundance of bones, which includes juvenile remains, led Bell and Padian (1995) to propose that the site may represent a large pterosaur colony that would have existed in what is now northern Chile during the Early Cretaceous.

Based on the study of some isolated bones, it has been concluded that the Cerro La Isla pterosaurs belong to the family Ctenochasmatidae (Martill *et al.* 2006, Alarcón-Muñoz *et al.* 2020). Ctenochasmatids are a group of pterodactyloids characterized by having long necks and long snouts with multiple fine teeth, which would have allowed them to feed by water filtration (Martill *et al.* 2006, Qvarnström *et al.* 2019).

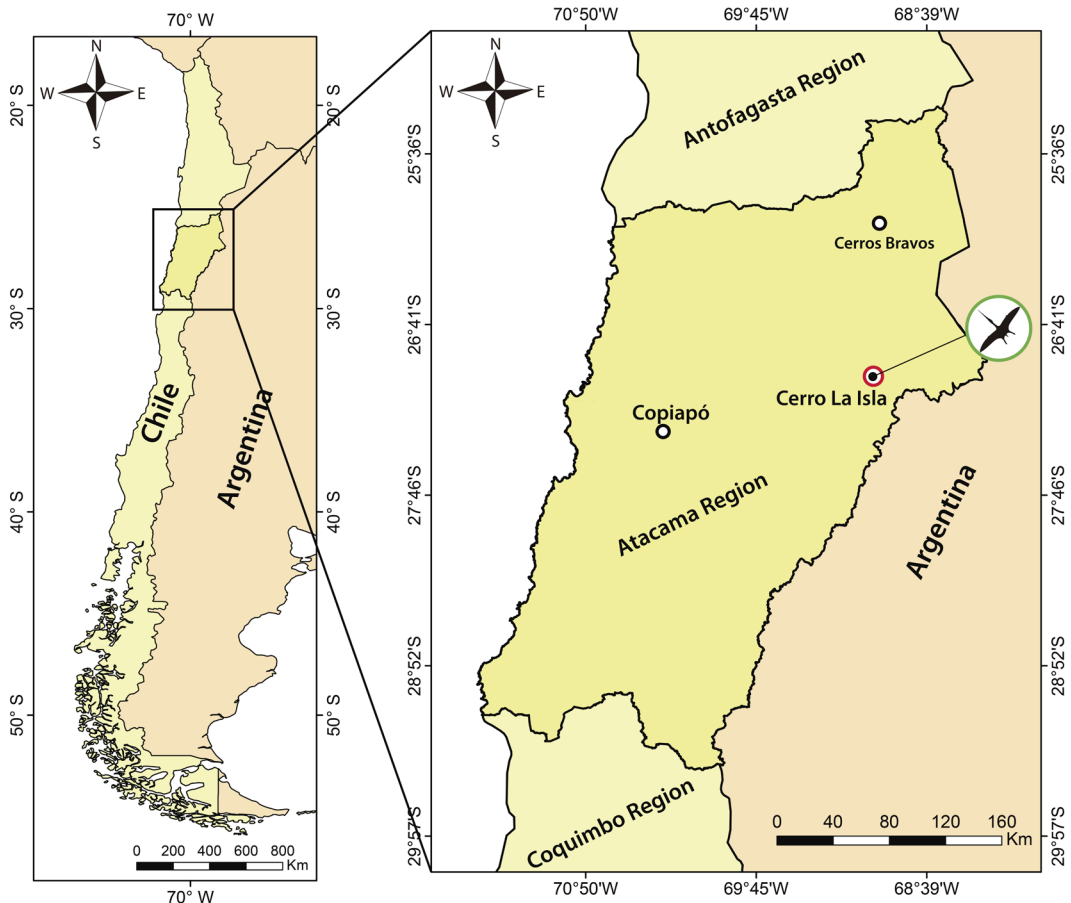
The purpose of this contribution is to describe new isolated pterosaur remains from Cerro La Isla, complementing the information available on their anatomy and systematics.

#### LOCALITY AND GEOLOGICAL SETTING

The site with pterosaur remains is located approximately 95 km northeast of Copiapó, in the sector of Cerro La Isla (Fig. 1). The Quebrada Monardes Formation, defined by Mercado (1982), outcrops in the Precordillera of Copiapó, in the Atacama Region of northern Chile (Covacevich 1985). These deposits extend for approximately 200 km from north to south between 26°-28°S and 69°-70° W (Bell and Suárez 1989). The Quebrada Monardes Formation is constituted by a succession of red clastic rocks of continental origin, mainly red arkosic sandstones, pebbled sandstones, conglomerates, siltstones, evaporites and shales (Bell and Suárez 1985, Bell 1991, Bell and Suárez 1993). The sediments of the Quebrada Monardes Formation were probably deposited during the Lower Cretaceous, since Upper Jurassic rocks underlie them, such as the probably Tithonian-Valanginian marine limestones of the Pedernales Formation (Mpodozis *et al.* 2012) and they are overlain by Upper Cretaceous geological units, such as the volcanic rocks of the Quebrada Seca Formation (Chong 1976, Muzzio 1980, Mercado 1982, Naranjo and Puig 1984, Covacevich 1985, Cornejo *et al.* 1998). A recent detrital zircon U-Pb age of  $144,8 \pm 1,8$  Ma was obtained from the Pulido River, making the uppermost layers of the Quebrada Monardes Formation Berriasian in age (Martínez *et al.* 2015). However, the earliest age of the Quebrada Seca Formation obtained by radiometric dating is close to 72 million years old (Iriarte *et al.* 1999), which still leaves a wide margin of uncertainty about the age of the pterosaur bearing levels.

#### MATERIALS AND METHODS

The pterosaur fossils represent isolated and fragmentary remains from a single bed of sandstones and conglomerates exposed on the southern slope of Cerro La Isla. These bones were collected at Cerro La Isla in 1988 by researchers Larry Marshall, Michael Bell, Patricia Salinas and Manuel Suárez. The material is housed in the Área de Paleontología of the Museo Nacional de Historia Natural (MNHN) of Santiago, Chile, under the acronym SGO.PV. Institutional abbreviations — **SGO.PV.** Área Paleontología, Museo Nacional de Historia Natural; **MIC**, Museo Interactivo de Ciencias, Universidad Nacional de San Luis, San Luis, Argentina.



**Figure 1.** Map of the Atacama Region in which the location of Cerro La Isla is indicated.

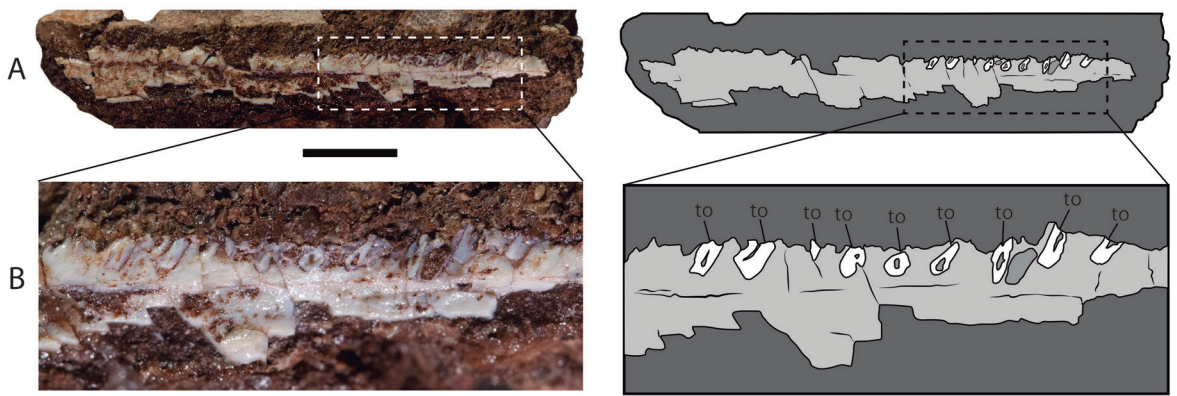
## RESULTS

Systematic paleontology  
 Archosauria Cope, 1862  
 Pterosauria Kaup, 1834  
 Pterodactyloidea Plieninger, 1901  
 Archaeopterodactyloidea Kellner, 1996  
 Ctenochasmatidae Nopcsa, 1928  
 Ctenochasmatidae indet. (Figs. 2 and 3)

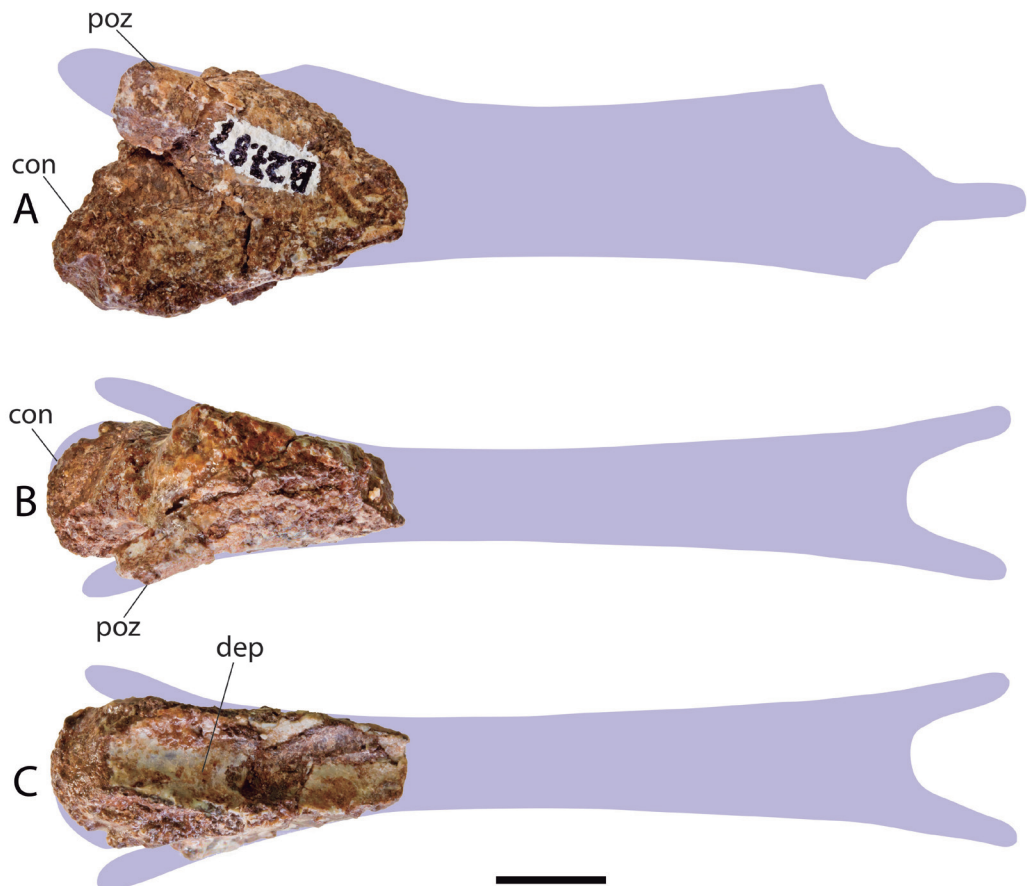
**Material.** A fragmentary tooth bearing element that most likely represents part of a rostrum exposed in ventral view, with broken teeth (SGO.PV.347-c), the caudal portion of a mid-cervical vertebra (SGO.PV.22910).

## DESCRIPTION

**Jaw fragment.** Specimen SGO.PV.347-c corresponds to a fragmentary tooth bearing element with broken teeth (Fig. 2). Its preserved length is 5.3 cm. The teeth are closely-spaced (~6 teeth/cm), and the preserved dental bases suggest that they were gracile and obliquely orientated with respect to the longitudinal axis of



**Figure 2.** Ctenochasmatidae indet. (SGO.PV.347-c), mandibular fragment in occlusal view (A), and detail of the teeth (B). Schematic interpretations are shown. Abbreviations: to, tooth. Scale bars: 10 mm.



**Figure 3.** Ctenochasmatidae indet. (SGO.PV.22910), caudal portion of a mid-cervical vertebra in right lateral (A), dorsal (B) and ventral (C) views. Abbreviations: dep, depression; co: condyle; poz, postzygapophysis. Scale bar: 10 mm.

the element. Although due to its fragmentary nature, it is difficult to determine with certainty whether it was part of the upper- or lower jaw; SGO.PV.347-c is tentatively interpreted here as part of a rostrum exposed in ventral view.

SGO.PV.347-c shows several similarities with other previously published fragments of tooth-bearing elements. SGO.PV.377 was also discovered at Cerro La Isla and interpreted as a post-symphyseal dentary fragment by Alarcón-Muñoz *et al.* (2020). It has subparallel margins; its medial wall is thinner than the lateral and it bears approximately 9 teeth/cm. In addition, SGO.PV.378 is also a dentary fragment from the same locality, which shows the same morphology and dental density as SGO.PV.377. By contrast, SGO.PV.347-c shows a medially wide osseous surface (identified as medial based on the orientation of the preserved tooth bases), making it more consistent with either a symphyseal mandibular portion, or a rostrum. Given that dental density tends to diminish posteriorly rather than anteriorly (9 teeth/cm in SGO.PV.377 and 378, as opposed to 6 teeth/cm), SGO.PV.347-c is most likely a rostral fragment from the medial or posterior region of the snout, making the tooth bearing element the right maxilla. Therefore, the overall morphology and dental features of SGO.PV.347-c agree with those observed in other remains from the same fossil-bearing layer exposed at Cerro La Isla, which were assigned to the Ctenochasmatidae in previous studies (Martill *et al.* 2006, Alarcón-Muñoz *et al.* 2020b).

**Vertebra.** Specimen SGO.PV.22910 corresponds to the posterior portion of a mid-cervical vertebra (Fig. 3). The preserved anteroposterior length is 3.2 cm. The fragment is quite eroded. This portion of the vertebra is dorsoventrally high and mediolaterally compressed. Only part of the right postzygapophysis is preserved, which is dorsoventrally tall and dorsolaterally oriented. The posterior condyle is quite eroded but robust, with concave lateral surfaces, as in two other mid-cervical vertebrae from the same site (SGO.PV.350 and SGO.PV.351) assigned to the Ctenochasmatidae (Alarcón-Muñoz *et al.* 2020). The postexapophyses are not preserved. The ventral surface is markedly concave, which is another shared feature with previously reported ctenochasmatid vertebrae from Cerro La Isla (Alarcón-Muñoz *et al.* 2020).

Pterodactyloidea indet. (Fig. 4)

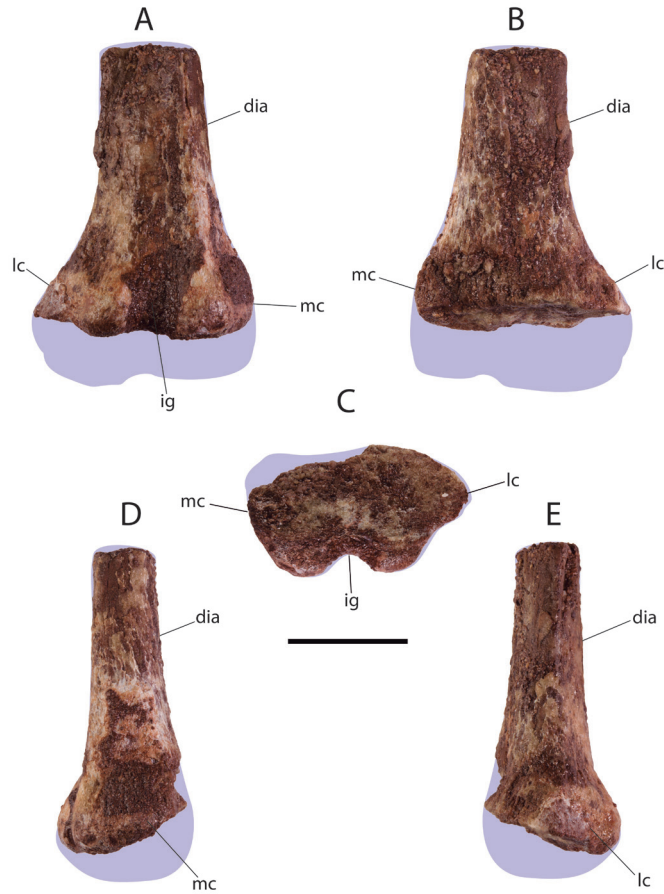
**Material.** Distal portion of a right femur (SGO.PV.22913)

#### DESCRIPTION

*Femur* — Specimen SGO.PV.22913 corresponds to the distal portion of a right femur. The shaft is mediolaterally expanded and anteroposteriorly narrow. The epiphysis is only partially preserved. In anterior view, a wide intercondylar groove separates the two robust condyles, which extends proximally. The lateral condyle projects farther laterally in anterior and posterior views than the medial condyle, which is rounded and robust. The posterior surface of the distal end of the fragment is severely eroded.

#### DISCUSSION

Although the newly described fossils are fragmentary, they preserve enough diagnostic features to enable a taxonomic assignment for all three elements. The rostral fragment (SGO.PV.347-c) only conserves broken teeth, whose original length cannot be determined. However, the broken dental bases show that the teeth were gracile and tubular. This morphology, together with the high dental density (approximately 6 teeth/cm) and the oblique orientation of the teeth with respect to the longitudinal axis of the snout are features consistent with the known morphology within the family Ctenochasmatidae, a group of filter-feeding pterosaurs with fine, closely-spaced teeth (Wellnhofer 1991, Martill *et al.* 2006, Qvarnström *et al.* 2019). This group has been previously reported from Cerro La Isla, based on fragmentary mandibular remains, a rostral fragment, and cervical vertebrae (Martill *et al.* 2006, Alarcón-Muñoz *et al.* 2020).



**Figure 4.** Pterodactyloidea indet. (SGO.PV.22913), distal portion of a right femur in anterior (A), posterior (B), distal (C), medial (D) and lateral (E) views. Abbreviations: dia, diaphysis; ig, intercondylar groove; lc, lateral condyle; mc: medial condyle. Scale bar: 10 mm.

As the rostral fragment, the partial cervical vertebra also shows characters observed in ctenochasmatids (Andres and Ji. 2008). Additionally, the morphology of this vertebral fragment (mainly the marked development of the posterior condyle and the presence of a ventral concavity) is consistent with that of the mid-cervical vertebrae described by Alarcón-Muñoz *et al.* (2020).

The femoral fragment is too incomplete to determine its taxonomic affinity within the Pterodactyloidea. Although all the pterosaur bones identified so far at Cerro La Isla belong to the Ctenochasmatidae, it is not possible to rule out that they coexisted with members of another group of pterosaurs at the site. Therefore, the femoral fragment is conservatively identified here as belonging to an indeterminate pterodactyloid.

This new material constitutes further evidence of the presence of ctenochasmatids at Cerro La Isla, suggesting that this group may have been the dominant element of the pterosaur fauna at the site. However, new surveys are necessary to confirm this, as well as for the collection of more complete material, which would allow the identification of a potentially new taxon and the study of its relationships in a phylogenetic context.



## CONCLUSIONS

New pterosaur remains are described, whose characters allow them to be assigned to the Ctenochasmatidae. This is consistent with the identification of other mandibular, rostral and axial remains described in previous studies. This finding suggests that the remains of ctenochasmatids may be predominant in the exposed fossil layer at Cerro La Isla, a hypothesis that must be corroborated by further discoveries. Furthermore, the collection and study of more complete and informative specimens is necessary to determine if the Cerro La Isla ctenochasmatids constitute a new pterosaur species.

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