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New plesiosaur records from the Lower Cretaceous of the Neuquén Basin, west-central Argentina, with an updated picture of occurrences and facies relationships

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ABSTRACT

In this work new records of elasmosaurid plesiosaurs are described from the Lower Cretaceous Agrio Formation of the Neuquén Basin (west-central Argentina) and their bearing facies and taphonomic modes are analyzed. New records from both members of the upper Valanginian–Hauterivian Agrio Formation are described along with a careful revision of previous records from the Pilmatué Member. These records include the first elasmosaurids reported from the upper Hauterivian of South America. Even though the studied materials comprise solely fragmentary postcranial elements, they suggest the presence of at least two different elasmosaurid taxa. Additionally, the rarity of cervical centra with a ventral notch in the articular faces among pre-Cenomanian elasmosaurids is confirmed. In terms of plesiosaur taphonomy and bearingfacies the studied plesiosaurs from the Agrio Formation were recorded in two different taphonomic modes, 1) preservation of disarticulated but closely associated postcranial elements within dark-grey shales, that probably resulted from bloating, drifting and eventually sinking of carcasses to a muddy and calm seafloor under oxic to suboxic conditions, without further transport or physical reworking; and 2) preservation of isolated plesiosaur bones in shell beds, including mostly weathered and encrusted isolated vertebrae. These taphonomic modes are not randomly distributed in the studied marine succession, but closely follow cycles of changes in the relative sea level and can be linked to fourth-order high frequency cycles. Taphonomic mode 1 includes better preserved specimens deposited in highstand systems tract intervals subjected to higher sedimentation rate while taphonomic mode 2 is related to transgressive systems tract intervals subjected to a reduced sedimentation rate and higher time of exposure of remains on the seafloor, resulting in poorly preserved specimens.

1. Introduction

Plesiosaurs constitute a monophyletic group of cosmopolitan marine reptiles encompassing the Late Triassic–Late Cretaceous time interval (Ketchum and Benson, 2010). The most extensive plesiosaur records are known from the Jurassic of Europe and Upper Cretaceous of USA, while Lower Cretaceous plesiosaurs are far less common worldwide (Benson et al., 2010; Ketchum and Benson, 2010; Vincent et al., 2011). Recently, Early Cretaceous plesiosaurs have received more attention; a few new species have been described while revisions were performed on classic specimens (Druckenmiller, 2002; Druckenmiller and Russell, 2006, 2008; Kear, 2005; Kear et al., 2006a; Kear and Barret, 2011; Ketchum, 2011; Benson et al., 2013a,b; Hampe, 2013), but their systematics and diversity are still poorly understood when compared to those of other time periods.

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Early Cretaceous plesiosaur records are very informative, as apparently there was a faunal turnover at the end of the Jurassic caused by a decreasing diversity of Late Jurassic cryptoclidids and pliosaurids and their replacement by a Cretaceous plesiosaur fauna dominated by polycotylids, elasmosaurids, leptocleidids and brachauchenines (Benson and Druckenmiller, 2014). Therefore, new plesiosaur records from the Lower Cretaceous are important to improve an overall poor fossil record of the group, and to clarify their evolutionary history just after the faunal turnover.

Previous occurences of Lower Cretaceous plesiosaurs of the Southern Hemisphere comprise abundant materials from Australia (Kear, 2003, 2005; Kear et al., 2006a,b) and other records from South America. The latter comprise only undetermined elasmosaurids from the upper Valanginian–lower Hauterivian Pilmatué Member of the Agrio Formation of the Neuquén Basin of west-central Argentina (Lazo and Cichowolski, 2003; revised herein) and the elasmosaurid *Callawayasaurus colombiensis* (Welles, 1962) from the upper Aptian "Leiva Shale", Paja Formation, of Colombia (Welles, 1962; Goñi and Gasparini, 1983; Carpenter, 1999). However, this paucity of records probably reflects a collection bias rather than a true low abundance, since new field work performed recently in the Agrio Formation provided the new materials studied herein.

The main goals of this article are as follows, 1) to describe new plesiosaur specimens and to revise previously described ones from the Lower Cretaceous Agrio Formation of the Neuquén Basin, west-central Argentina; 2) to date the study materials using a refined biostratigraphic framework based on ammonoids and calcareous nannofossils; 3) to discuss the affinities and diversity of the studied plesiosaurs; and 4) to describe and interpret the plesiosaur bearing-facies, taphonomic modes and paleoecological traits in the Agrio Formation.

Institutional abbreviations: **GWWU**, Geomuseum der Westfaelischen Wilhems-Universitaet, Münster, Germany; **LEICT**, New Walk Museum, Leicester, UK; **MOZ**, Museo Juan Olsacher, Zapala, Neuquén Province, Argentina; **NHMUK**, Natural History Museum, London, UK; **SCARB**, Rotunda Museum, Scarborough, UK.

Anatomical abbreviations: **azyg**, anterior zygapophyses; **cap**, capitulum; **cf**, coracoids facet; **cr**, cervical rib; **di**, diapophyses; **gf**, glenoid facet; **lr**, lateral longitudinal ridge; **na**, neural arch; **nc**, neural canal; **ns**, neural spine; **pa**, parapophyses; **pez**, prezygapophyses; **pg**, posterior groove; **poz**, postzygapophyses; **sf**, scapular facet; **tr**, transverse ridge; **tub/troch**, tuberosity/trochanter; **vf**, ventral foramina.

2. Geological setting

The Neuquén Basin, located in west-central Argentina along the Andean foothills, extends through most of the Neuquén Province and part of the Mendoza, Río Negro and La Pampa provinces (Fig. 1). During the Early Cretaceous the basin was located not far from its

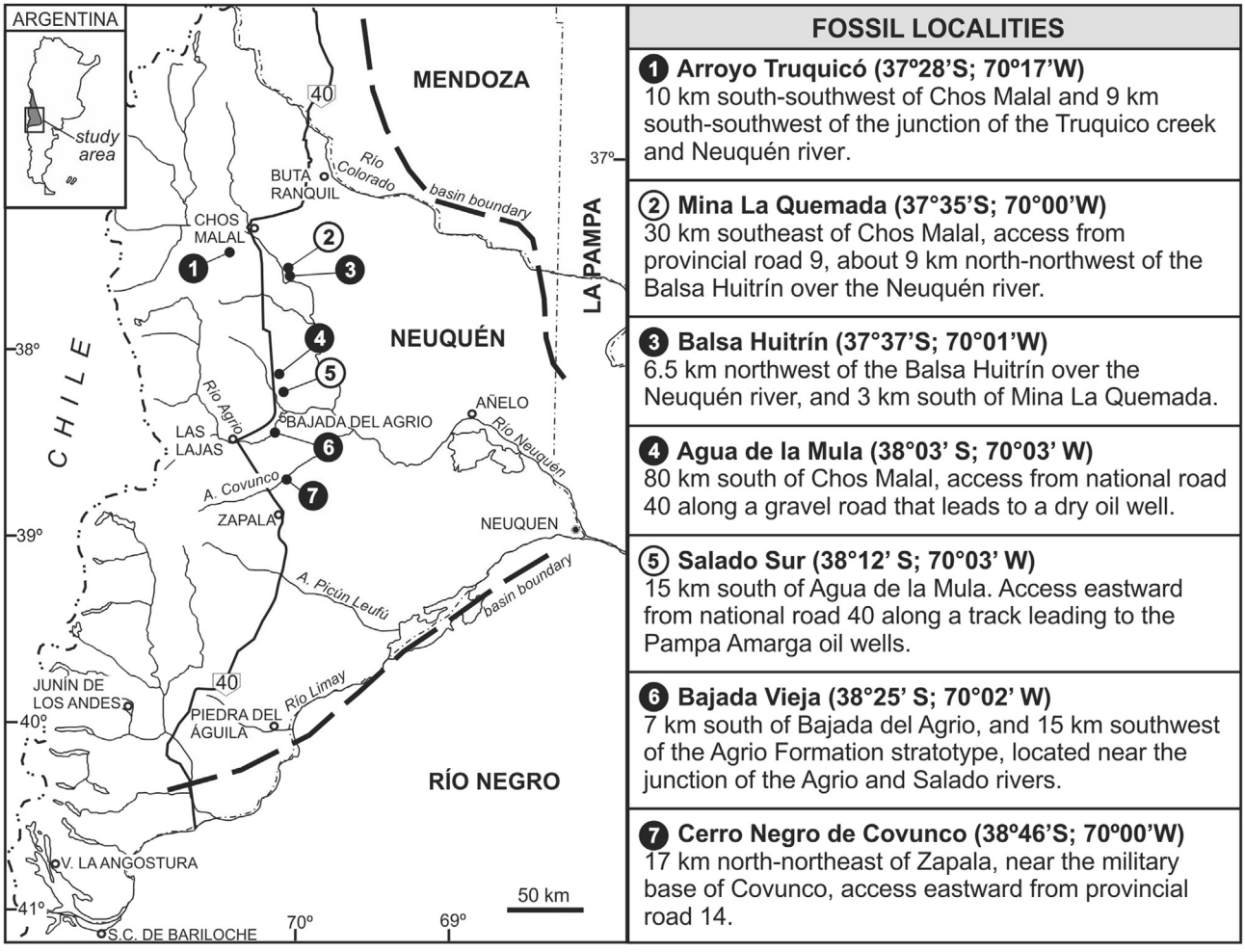

Fig. 1. Map of west-central Argentina showing the fossil localities with Early Cretaceous plesiosaur remains from the Agrio Formation. Localities with black circle and white number correspond to the Pilmatué Member; localities with white circle and black number correspond to the Agua de la Mula Member.