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FIRST RECORD OF AN AMIID FISH (HALECOMORPHI, AMIIFORMES, AMIIDAE) FROM THE UPPER CRETACEOUS ARAÇATUBA FORMATION, WESTERN SÃO PAULO STATE, BRAZIL

Primer registro de un pez ámido (Halecomorphi, Amiiformes, Amiidae) en el Cretácico Superior de la Formación Araçatuba, oeste del Estado de São Paulo, Brasil

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Abstract. We present a new record of amiid fish discovered during field works carried out in 2019-2020 in rocks of the Upper Cretaceous Araçatuba Formation, Western São Paulo State, southeastern Brazil. Although the fish fauna of the Bauru Group is still poorly known, mainly based on isolated remains, the discoveries of amiid remains (including the one here presented) along distinct geological formations and localities and the reinterpretation of previous records bolster it was an abundant group in the continental environments of the Bauru Group during the Late Cretaceous.

Key words. Bauru Group, Fauna, Amiidae, Cretaceous.

Resumen. Presentamos un nuevo registro de pez ámido descubierto durante trabajos de campo realizados en 2019-2020 en rocas de la Formación Araçatuba (Cretácico Tardío), oeste del Estado de São Paulo, sureste de Brasil. Aunque la ictiofauna del Grupo Bauru es aún poco conocida, principalmente basada en restos aislados, los descubrimientos de restos de ámidos (incluido el que aquí se presenta) a lo largo de distintas formaciones geológicas y localidades y la reinterpretación de registros ya publicados apoyan la idea que era un grupo abundante en los ambientes continentales del Grupo Bauru durante el Cretácico Superior.

Palabras clave. Grupo Bauru, Fauna, Amiidae, Cretácico.

INTRODUCTION

Only one living species represents the actinopterygian clade Amiiiformes, namely *Amia calva* (bowfin), which is restricted to freshwater environments of eastern North America. However, the clade has a very complex evolutionary history which started deep into the Mesozoic (e.g., Chalifa and Tchernov, 1982; Patterson and Longbottom, 1989; Taverne, 1997; Grande and Bemis, 1998; Brito *et al.*, 2008). The Cretaceous fossil record of Amiiiformes in South America includes three species of Vidalamiinae (Amiidae) that were discovered in Lower Cretaceous rock of the north-east portion of Brazil and isolated remains discovered in Lower and Upper Cretaceous units of Brazil and Argentina. The formally described species includes *Calamopleurus cylindricus* from the Aptian/Albian Crato and Santana formations, *Cal. mawsoni* from the ?Hauterivian-Barremian Marfim Formation (Maisey, 1991; Grande and Bemis, 1998), and *Cratoamia gondwanica* from the Aptian Crato Formation (Brito *et al.*, 2008). The Lower Cretaceous isolated record includes material from the Aptian Açú Formation, Potiguar Basin, (Veiga *et al.*, 2019) and from the Aptian Quiricó Formation, Sanfranciscana Basin (Carvalho and Santucci, 2021), Brazil.

The Late Cretaceous record includes isolated remains discovered in the Turonian Cotinguiba Formation, Sergipe Basin (northeastern Brazil; Gallo *et al.*, 2007), in the Santonian-Campanian Adamantina (Brito *et al.*, 2017) and Maastrichtian Serra da Galga (Martinelli *et al.*, 2013; Soares *et al.*, 2021) formations, Bauru Basin (southeastern Brazil), and in the early Maastrichtian Allen Formation, Malargüe Group (north Patagonia, Argentina; Bogan *et al.*, 2010).

In this contribution we describe a new record of a Late Cretaceous amiid fish, based on an isolated partial maxilla, discovered near Coronel Goulart, in the outskirts of the Presidente Prudente Municipality, western

São Paulo State, Brazil. It represents the first amiid record from the lacustrine levels of the Araçatuba Formation, enlarging its temporal and geographical distribution within the Bauru Basin and highlights the abundance of amiids in fresh-water environments before the end of the Mesozoic Era.

MATERIALS AND METHODS

The specimen MPM 440 reported here was discovered during exploratory field work conducted in 2019-2020 in rocks of the Bauru Group (Fernandes and Coimbra, 1996; Fernandes *et al.*, 2003) along the region of Presidente Prudente and vicinities, State of São Paulo, southeastern Brazil (Figure 1). The outcrop consists of a succession of siltstones and very fine sandstones of greenish-gray color, referred to the Araçatuba Formation of the Bauru Group (Fernandes *et al.*, 2003) (Figure 1). The formational composition of the Bauru Group is still under discussion; however, the Araçatuba, Adamantina (~Vale do Rio do Peixe Formation; Fernandes and Coimbra, 2000), Uberaba, Serra da Galga, and Marília formations are widely recognized by most authors (e.g., Batezelli and Ladeira, 2016; Soares *et al.*, 2021) (Figure 2D). This unit has been interpreted as lacustrine deposits (e.g., Batezelli *et al.*, 2003; Fernandes and Ribeiro, 2015) and its age ranges from Coniacian to Campanian (see Menegazzo *et al.*, 2016 and Delgado *et al.*, 2021).

The outcrop is located near Coronel Goulart, southwest of the Presidente Prudente city, south to the State Route 270 (Figure 1), in direction to the city of Álvarez Machado. In the same outcrops there were found isolated scales of lepisosteiforms (Figure 2A), carapace fragments of pleurodiran turtles, and bone remains of titanosaur dinosaurs. The specimen MPM 440 is housed in the Collection of the Museu de Paleontologia de Marília (MPM), Marília, São Paulo State.

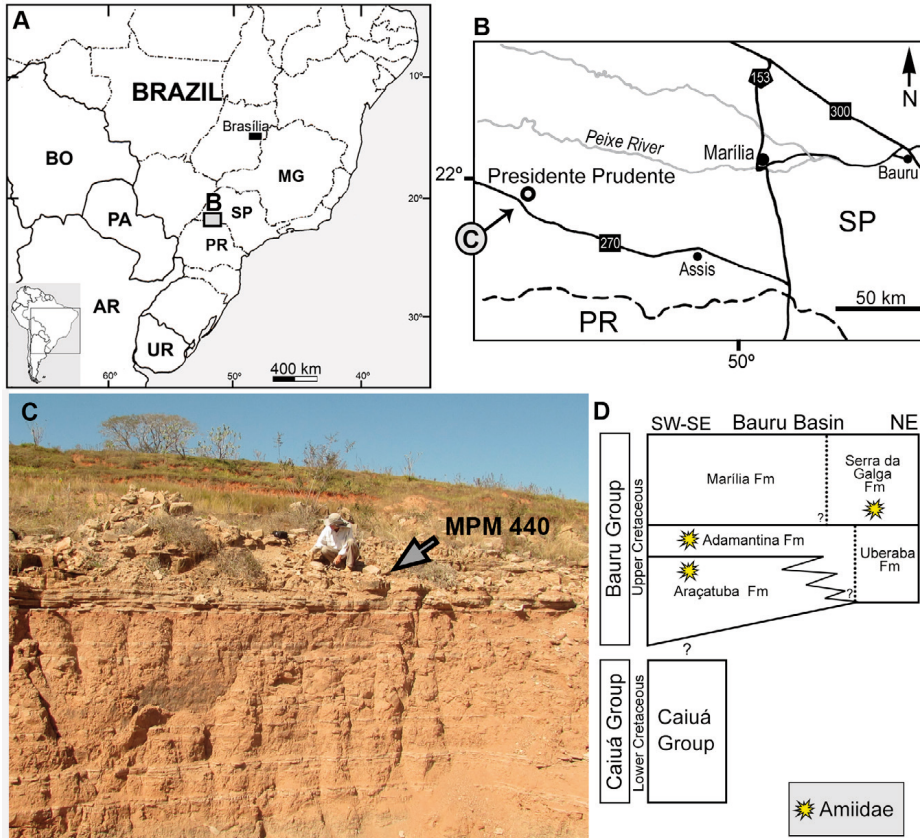


Figure 1- Location map of the outcrop where the amiid specimen MPM 440 was found (A-B), near Presidente Prudente city, São Paulo State, Brazil, and detail of the outcrop indicating the fossiliferous layer within the Araçatuba Formation (Bauru Group) (C). Litho- and chronostratigraphic chart of the Bauru Basin (D) (modified from Soares *et al.*, 2021), with record of amiid fishes. Abbreviations: AR, Argentina; BO, Bolivia; Fm, Formation; MG, Minas Gerais; PA, Paraguay; PR, Paraná; SP, São Paulo; UR, Uruguay.

The fossil material is very fragile and is embedded in a hard sedimentary matrix, which difficult its preparation.

SYSTEMATIC PALEONTOLOGY

Actinopterygii Cope, 1887

Halecostomi Regan, 1923

Amiiformes Hay, 1929

Amiidae Bonaparte, 1838 (*sensu* Grande and Bemis, 1998)

Cf. Vidalamiinae Grande and Bemis, 1998
Gen. et sp. indet.

Referred material. MPM 440, partial left maxilla (Figure 2A-B).

Description. The specimen MPM 440 consists of a partial left maxilla, lacking the anterior tip of the articular process with the premaxilla and its posterior portion. Its total preserved length is ~40 mm. It preserves ten tooth positions, some of them with small remnant of tooth fragments.

The external surface of the maxilla is mostly smooth, with very few ridges observed in medial wall of the maxilla. It has a subcircular cross-section in its anterior

tooth-bearing portion. The anterior process of the maxilla is large, anterodorsally projected, and forms an angle of about 140 degrees with regard to the tooth-bearing portion of the maxilla (measured the medial profile, in ventral view) (Figure 2A). The medial wall of the anterior process starts just medial to the level of the second tooth position. In ventral view, the medial profile of the maxilla is concave, lacking a distinctive vertex at the conjunction of the anterior process and the tooth-bearing portion. The anterior process bears a wide, long and concave depression that faces

ventro-anteriorly to accommodate the premaxillary bone (Figure 2A).

The tooth-bearing portion of the maxilla widens dorso-ventrally to the rear, with a slightly convex medial wall. Its lateral wall is resting on the rock. There is no supramaxillary notch in the preserved portion.

Tooth fragments are preserved in the first, third, fifth, seventh, ninth and tenth position whereas the remaining ones represent empty sockets. Teeth and sockets are disposed in an almost straight line. The crown of the teeth is not preserved in any

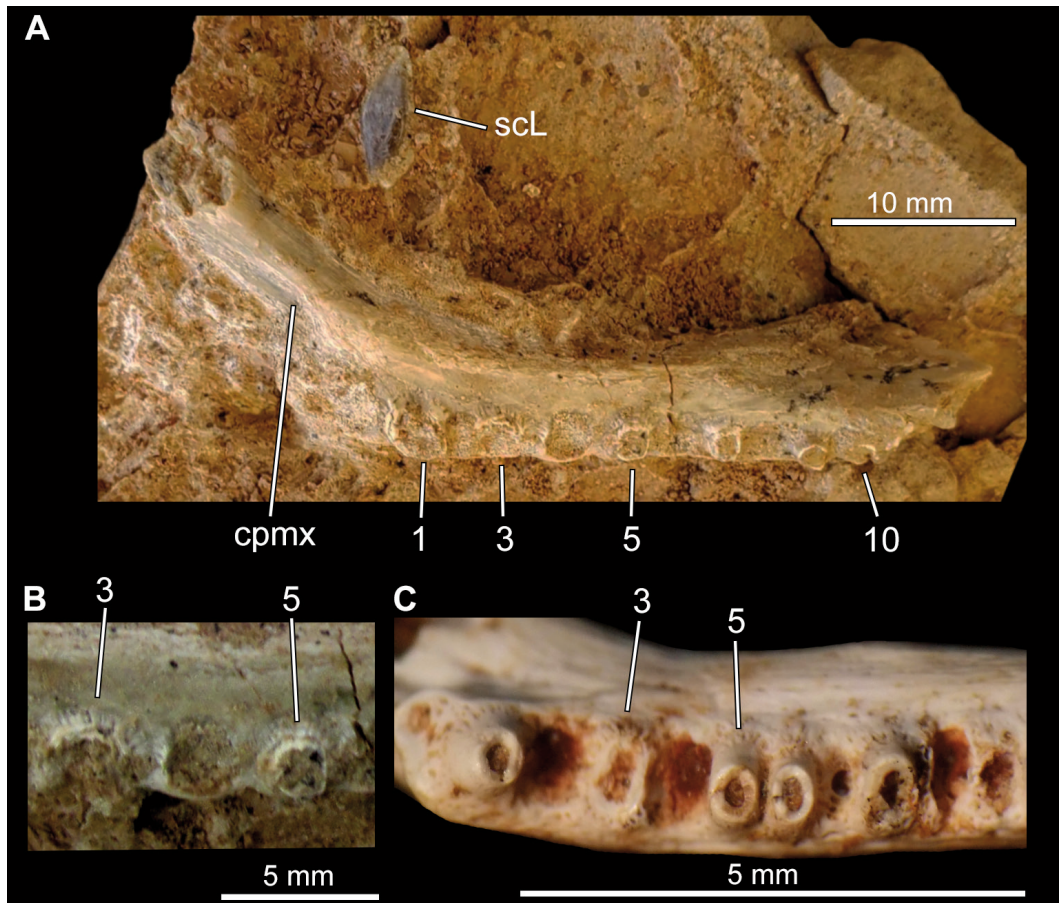


Figure 2- Specimen MPM 440, partial left maxilla of Amiidae indet. from the Araçatuba Formation. **A**, ventro-medial view, **B**, detail of the third to fifth tooth positions compared with part of the maxilla of Amiidae indet. from the Adamantina Formation (Brito *et al.*, 2017), **C**, in ventral view.

position and their bases have a circular cross-section, fused to the maxillary bone where there are tiny pits, furrows and ridges of connective tissue (Figure 2A-B). The first, third and fifth tooth bases and the fourth socket are similar in size and larger than the following ones (Figure 2A), which decrease in size posteriorly.

DISCUSSION

The Upper Cretaceous rocks of the Bauru Group in southeastern Brazil have a quite diverse, although still poorly known, fish fossil record (e.g., Gayet and Brito, 1989; Bertini *et al.*, 1993; Brito *et al.*, 2006, 2017; Alves *et al.*, 2013, 2019, 2020; Martinelli *et al.*, 2013; Martinelli and Teixeira, 2015). Among them, amiids were first recognized in the Bauru Group in rocks of the Serra da Galga Formation (formerly Serra da Galga Member of the Marília Formation; see Soares *et al.*, 2021), exposed at Uberaba Municipality (Minas Gerais State) (Martinelli *et al.*, 2013). Further, published isolated teeth from this latter unit and from the Adamantina Formation at São Paulo State, which were originally referred to erythrinid-like Characiformes fishes, were interpreted as of amiids (Martinelli *et al.*, 2013). More complete materials from the Adamantina Formation discovered from two localities (Adamantina and Oscar Bressane municipalities) bolstered the presence of amiids in these units (Brito *et al.*, 2017).

Specimen MPM 440 has a gross morphology similar to that of the maxilla of vidalamiine amiids (*sensu* Grande and Bemis, 1998), including a straight tooth-bearing portion and a long and anterodorsally projected anterior process. This process has an elongate and deep depression to accommodate the premaxilla, which is a feature found in Vidalaminae amiids (Grande and Bemis, 1998). In addition, the apparent absence of a supramaxillary

notch and a sub-circular cross-section of the anterior portion of the maxilla are features common in most members of this subfamily of amiids (Bryant, 1987; Grande and Bemis, 1998; Brito *et al.*, 2008, 2017; Martinelli *et al.*, 2013). As the previously records of amiids from the Adamantina and Serra da Galga formations, MPM 440 from the Araçatuba Formation is referred as Cf. Vidalaminae and further materials are mandatory to improve the taxonomy of the specimens from the Bauru Basin.

MPM 440 differs from the maxilla MPM 185 from the Adamantina Formation (Brito *et al.*, 2017) in having (a) relatively larger teeth and sockets; (b) circular tooth bases in cross-section (they are more transversely oval in specimen MPM 185) (Figure 2); (c) anterior tooth bases larger than the posterior ones (in MPM 185 anterior teeth seems to be smaller than the remaining ones); (d) medial base of the anterior process of the maxilla (observed in ventral view) starting just anterior to the level of the second tooth (in MPM 185 the medial wall of the process slopes the tooth-bearing portion of the maxilla at the level of the fourth tooth position); and (e) smooth to weakly ornamented maxillary surface (in MPM 185 there are conspicuous ridges on the entire preserved surface; Brito *et al.*, 2017). MPM 440 is about twice the size of MPM 185, thus, some features (e.g., a, b) can be results of variations during ontogeny if they represent the same or closely related species. MPM 440 differs from the maxillae described for the Serra da Galga Formation (Martinelli *et al.*, 2013) in having more ornamented maxillary surface (although not to the degree of MPM 185) and they share the presence of relatively large anterior teeth and that the medial base (observed in ventral view) of the anterior process of the maxilla starts just anterior to the level of the first tooth. Comparisons with the Late Cretaceous record from northern Patagonia (Bogan *et al.*, 2010) are not possible due to the lack of homologous elements.

The specimen MPM 440 here reported represents the first record of an amiid fish for the Araçatuba Formation and a new one for the Bauru Group. In addition, this new specimen seems to represent a different morphotype in comparison to the already described for the Adamantina and Serra da Galga formations (Martinelli *et al.*, 2013; Brito *et al.*, 2017). Similarly to the specimens collected from those formations, the new record comes from a fresh-water setting, contrasting with the Early Cretaceous species that inhabited marine environments (Grande and Bemis, 1998; Brito *et al.*, 2017). All the amiid records from the Bauru Group indicate that the colonization of continental fresh-water systems took place before the beginning of the Cenozoic and persisted until today, with the living bowfin (Grande and Bemis, 1998).

Comparisons among the maxillae found in the three units of the Bauru Group together with other amiid records from this geological group (Martinelli *et al.*, 2013; Brito *et al.*, 2017) indicate that amiids were a diversified clade of fishes that lived in the fresh-water continental environments at the southeastern Brazil during the Late Cretaceous. Although, intraspecific variations are still unknown and the real diversity of amiids has to be addressed with more complete materials.

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