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First record of cartilaginous fishes (Chondrichthyes) from the early Miocene of Chilean Patagonia

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Abstract. Early Miocene shallow marine deposits of Patagonia are well-known for their abundant and diverse fossil invertebrate faunas. In contrast, vertebrate remains are generally scarce and poorly documented. In this communication, we present the first record of early Miocene cartilaginous fishes in the Chilean Patagonia. The fossils came from two different localities in Aysén and Magallanes, and are comprised by isolated teeth referable to indeterminate lamnids. Two general morphotypes can be distinguished; the first one having wide and triangular crowns, while the second has slender, narrow and slightly sigmoidal crowns. They indicate the presence of large-to-medium sized lamnids with a discrete or monotypic diversity. This discovery complements the temporal gap in the local fossil record of the group, providing the shedding light on the drastic changes suffered between the pre-Oligocene chondricthyofauna in the Austral (Magallanes) Basin, and thos faunasfrom the post-Oligocene southwest Pacific.

Key words: Chondricthyans, faunal turnover, Austral Basin, *Patagonian* Sea

1. Introduction

To date, the fossil record of cartilaginous fishes (Chondrichthyes) from Chile has major gap during the Oligocene. After that, early Miocene findings (Suárez et al., 2006) and especially late Miocene records (Suárez et al., 2004; Suárez, 2015) document a rich diversity along the Pacific, with close affinities to extant forms. The recent discovery of chondrichthyans in Neogene sediments of the Chilean Patagonia shed light on a likely turnover experimented by the chondricthyan diversity during the middle Cenozoic. Paleogene records from southernmost Chile are mostly middle to late Eocene in age (Otero et al., 2012; 2013). At that time, a diverse assemblage with more than 30 species was present on shallow marine-to-estuarine facies, with several taxa also represented in Antartica. Although the new materials studied here are fragmentary and preclude fine taxonomic determinations, they allow assessing ecological and biogeographical aspects, contributing to understanding the southern evolution of the group, and the kind of interactions that might exist between the Pacific and the South Atlantic faunas.

2. Materials and Methods

The fossils were collected from sedimentary deposits of two distinct localities of the Aysén and Magallanes regions of southern Chile (Figure 1). Both places form part of upper sequences of the Patagonian fold-and-thrust belt of the Austral (Magallanes) retro-foreland Basin (Malumián and Náñez, 2011, Ramos, 1989).

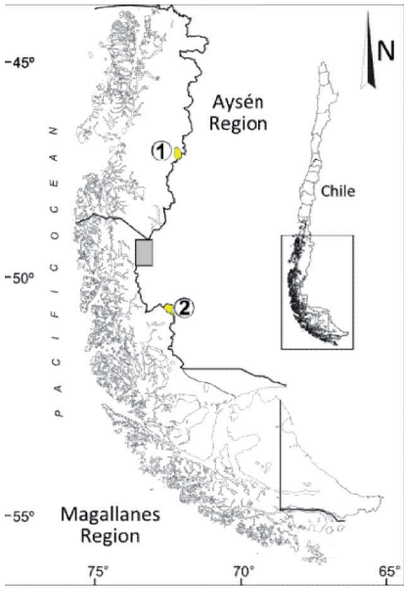

Figure1. Map indicating the studied areas. 1: Quebrada Honda,Chile Chico, General Carrera province, Aysén. 2: Río de las Murallas, Sierra Baguales, Última Esperanza Province, Magallanes.

The tooth set was collected by D. Frasinetti in 1986 from the Quebrada Honda area, 20 km south from Chile Chico, Aysén Region (Figure 1). The fossils are presently housed in the Área Paleontología of the Museo Nacional de Historia Natural (National Museum of Natural History; MNHN), in Santiago.

The second tooth set comes from exposures at the Río de las Murallas, Sierra Baguales, Última Esperanza Province, Magallanes. The remains were collected during summer 2015 by N. Refferand, J.L. Oyarzún. The material is currently housed at the J.L. Oyarzún Paleontological

Collection, in Puerto Natales. From the same locality and stratigraphic horizon, E. Bostelmann collected a third tooth set presumably belonging to a single specimen. These remains are not yet catalogued, however, they will be deposited in the Área Paleontología of the MNHN.

3. Geological context

Geochronology and lithology—the exposures at both localities represent regional facies of a wide extended transgressive Atlantic event, commonly referred as the *Patagonian* transgression or *Patagonian* Sea. Radiometric and isotopic dating between 22 and 17.8 Ma (Parras et al., 2012; Cuitiño et al., 2013), plus an abundant marine fossil fauna, allow together assigning these levels to a Burdigalian age (early Miocene).

Quebrada Honda—The *Patagonian* units at this locality have been traditionally mapped as part of the Guadal Formation (De La Cruz and Suárez, 2008). Preliminary observations (Bostelmann, *pers. obs.*) indicate that new fieldwork campaigns are required to validate this previous assignation. There are not available information on the fine stratigraphy of the horizons where the fossils were originally collected.

Río de Las Murallas—The lithostratigraphic succession on this locality belongs to the Estancia 25 de Mayo Formation (Cuitiño and Scasso, 2010; Gutiérrez et al., 2013; Bostelmann et al., this congress; Figure 2). In Sierra Baguales the total thickness of this unit is 143.8 m, with a basal contact generally covered and a evident top with a gradual environmental change from estuarine/marginal marine to continental deposits referred to the Santa Cruz Formation (Ugalde et al., this congress).

The integrated section along the Alto Río Bandurrias and their tributaries, like the Río de las Murallas (Figure 2),begins with a base formed by greyish, poorly preserved vegetation-bearing mudstones with parallel lamination. It is follow by packages dominated by fine to medium bluish massive sandstones, interbedded with tabular marine invertebrate-rich levels, and calcareous concretions.The fossil fauna includes a diverse array of echinoderms, brachiopods, gastropods, bivalves, crustaceans and several ichnofossils (Griffin et al., 2014, Bostelmann et al., this congress). Shark remains were collected at the top of these levels in direct association with the remaining fauna. Directly overlying these levels is a whitish tabular ~1.55-2m dacitic tuff, referred as the *Lower Pyroclastic Level* by Cuitiño and Scasso (2010). This horizondenotes a regional volcanic event of great magnitude, which act as a conspicuous regional guide level. U/Pb dated samples of this tuff in localities south of Lago Argentino at Estancia Quién Sabe produces a 19.1 Ma age (Cuitiño et al., 2013). Massive mudstones and concretion levels with decapod crustaceans dominate the next section. To the top is characterized by massive fine sandstones, with lesser fossil content (36–74 m). Middle to coarse sandstone levels continues with a relative increment in the fossil invertebrates (90.8–109.5 m). Bioclastic-dominated massive levels of aggregated and disarticulated specimens of *Ostrea hatcheri* marks the top this sandstones. The last portion has massive or structure-bearing, middle to coarse inverse sandstone grading (114.2-143.7m). The initial 74 m of the section corresponds to the Quién Sabe Member, while the last 52.9 m are associated to theRío Bandurrias Member, both originally described by Cuitiño and Scasso (2010).

Depositional environments—the main sedimentary facies of the section are composed by fine and middle massive sandstones at the base, with anincrement in caliber to the superior half. The change, associated to the differences between members, allow identifying variations in the depositional system, with basal levels representing a sub-tidal marine environment, with homogeneous sedimentary input and low energy conditions (0–74 m).The middle levels reflect a shallow intertidal zone, with brief pulses of higher energy (90.8–114.2 m).The upper levels mark the transition from a marginal marine/estuarine environment, and higher to medium energy sedimentary supply, to levels with low energy, fluvial interaction.

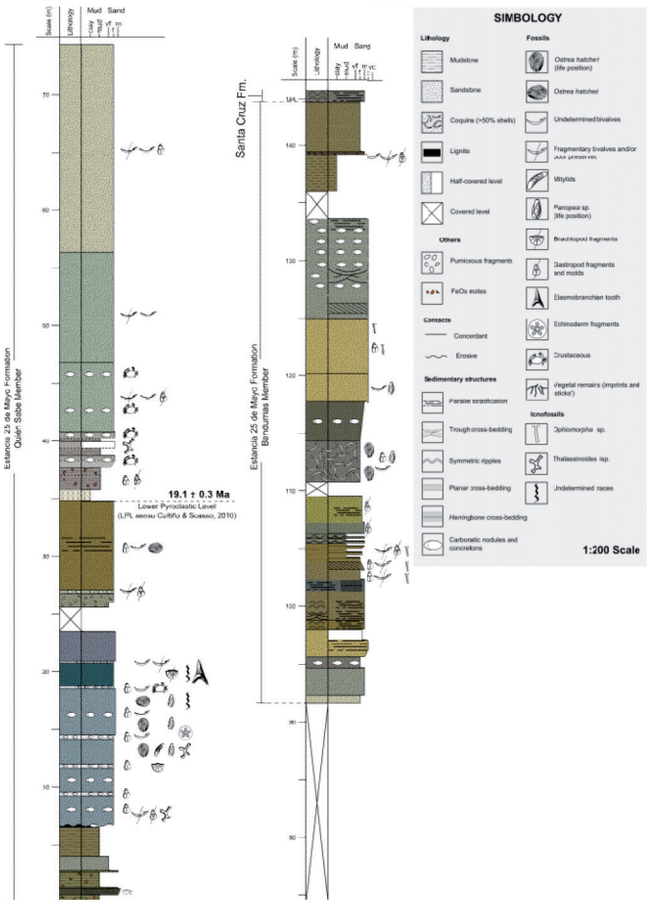

Figure2. Integrated stratigraphic section of the Estancia 25 de Mayo Formation in the Alto Río Bandurrias and its tributaries, Sierra Baguales, Magallanes.

4. Systematic Paleontology

Chondrichthyes Huxley, 1880
Elasmobranchii Bonaparte, 1838
Neoselachii Compagno, 1977
Lamniformes Berg, 1958
Lamnidae Müller y Henle, 1838

Lamnidae gen. et sp. indet.
(Fig. 3)

Material—SGO.PV.6600. 10 incomplete isolated teeth.
Locality, horizon and age—Quebrada Honda, south of the town ofChile Chico, Aysén Region.Guadal Formation, early Miocene.

Description—The material shows triangular crowns with lingual and flat convex labial faces, unequivocally corresponding to teeth of the upper jaw. They lack serrated edges. The crown enamel has a blue-to-grey color, with some cracks resulting from weathering. All the roots are damaged indicating mechanical abrasion, possibly because of weathering and/or transportation. A second morphotype corresponds to tall, narrow and slightly sigmoidal crowns, which can be interpreted as the lower dentition of the same taxon, or else, as belonging to a different lamnid, closely related to *Isurus oxyrinchus* Rafinesque. Unfortunately, the roots of this second morphotype also are absent, making impossible a taxonomic assignment to any genus or species.

Figure3: SGO.PV.6600. Lamnidae indet. 6 superior tooth (up) and 4 inferior tooth (bottom), all in lingual view. Scale bar = 10 mm.

Lamnidae gen. et sp. indet.
(Fig. 4)

Material—CPJLO.160. 15 incomplete teeth and 5 dental fragments.
Locality, horizon and age—Río de las Murallas in the Alto Río Bandurrias area, Sierra Baguales, Magallanes Region. Quién Sabe Member of the Estancia 25 de Mayo Formation, early Miocene.

Description—the material shows triangular contour crowns generally being twice high as broad. Some specimens preserved partial remains of their roots, which allow appreciating the absence of lateral cusps. The roots likely have squared branches which are divergent laterally nor ventrally.

Figure4: CPJLO.160. Lamnidae indet. Assorted upper teeth and and one lower tooth (right), all in lingual view. Scale bar = 10 mm.

5. Discussionand conclusions

Although both records do not allow generic nor specific determinations, it is interesting the general similarity observed between both tooth sets. These correspond to two different morphotypes composed by: 1) teeth having wide and triangular crowns with a different degree of posterior inclination, and 2) teeth with high, slender and slightly sigmoidal crowns. In the first case, these are typical of the upper jaw in lamniform lamnids. The inclination of each crown varies according to its anatomical position, being straight in the upper anterior teeth and progressively recurved caudally in upper posterior ones (Cappetta, 1987). The second morphotype allow two interpretations. Narrow high crowns are present in the lower jaw of big lamnids like '*Cosmopolitodus* '(=*Carcharodon*) *hastalis*. Similar crowns are also present in lamnids like *Isurus oxyrinchus* Rafinesque, a common taxon from the Miocene and onwards until the present (Suárez, 2015). Among teeth from Sierra Baguales, some specimens preserve root fragments. These show that both branches are not divergent, while the crown has no lateral cusps, meaning that these teeth are morphotypically similar to those of '*C*' *hastalis*.
During the Paleogene, the southern fossil record shows the presence of medium to large lamnids represented by *Macrorhizodus praecursor*, a frequent species in Eocene rocks of La Meseta Formation in Antarctica (Long, 1992; CioneandReguero, 1995) and the middle/late Eocene of Magallanes (Otero et al., 2012; 2013).Additional findings of *Macrorhizodus praecursor* were recovered from middle to late Eocene beds of the Maule Region (Otero, this congress). The only Chilean record of chondrichthyans tentatively referred to the Oligocene comes from Chiloé Island, were dental plates of myliobatids and an upper anterior tooth referred to '*Isurus xiphodon*' by Quiroz et al. (2003)were collected. After the Oligocene, medium-to-large lamnids are described from Pacific deposits, reaching cosmopolitan distribution during the Miocene (Cappetta, 1987). Particularly, records referred to '*C*' *hastalis* are known from the early Miocene Navidad Formation (Suárez et al., 2006), from late Miocene-Pliocene rocks of the Lo Abarca (Encinas et al., 2000) and Bahía Inglesa formations (Suárez, 2015),and from the Pisco Formation in Perú

(Ehret et al., 2009).The presence of lamnids in the early Miocene of Patagonia demonstrates the continuity of the group in the Western Austral Basin, as well as along the South Pacific. This is precisely the lapse where the fossil record of the group is scarce and little known in southern South America. The increase of the chondrichthyan fossil record begins to show a biogeographic pattern on high latitudes, with the persistence of lamnids between the Eocene and Miocene.

The opening of the Gulf of Tasmania and the deepening of the Drake Channel occurred near the Eocene/Oligocene boundary, have been linked to the establishment of the oceanic currents from Antarctica into the Pacific, and the beginning of the cooling of Antarctica (Lawver and Gahagan, 2003). These events are associated to an observed temperature gradient along the Cenozoic seas, which passes from warm conditions during the late Eocene, to probably cold temperate conditions during the Oligocene, culminating with the establishment of cold currents like the Humboldt Current along the eastern Pacific during the Miocene. Nowadays, the presence of medium-to-large lamnids is currently documented in temperate waters (Compagno, 1984). Interestingly, the fossil record complemented with our findings shows a gradual latitudinal and temporal shifting into the north across the Paleocene-Neogene transition, which is consistent with such temperature gradient.

Tectonics and isostatic changes in the Austral Basin determined its gradual regression on southeast direction, limiting the possibility of additional records of marine forms during the upper Neogene. In this sense, the studied material has great significance since it represents one of the latest chondrichthyan assemblages from the western boundary of the basin.

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