New Paleogene records of cartilaginous fishes (Chondrichthyes) from central Chile, including the oldest lamnid diversity from the southeastern Pacific (#116570)

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New Paleogene records of cartilaginous fishes (Chondrichthyes) from central Chile, including the oldest lamnid diversity from the southeastern Pacific

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Background. The Paleogene chondrichthyan diversity of the southern hemisphere is mostly known in Antarctica, southernmost South America and New Zealand, but records from the southeastern Pacific remain sparse to date. Among these, lamnid sharks (the lineage of the great white shark) are one of the scarcer groups in the southern hemisphere prior to the Eocene; moreover, their occurrences prior to the Neogene remained unreported in the southeastern Pacific. This contribution presents new Paleogene chondrichthyans recovered from two different horizons at Loanco, in central Chile, including the first local records of lamnids, with the description of a new species.

Methods. Sections of two geologic units were studied. These provided new dental pieces of chondrichthyans, as well as a single associated tooth set plus fragments of jaw cartilague and vertebrae. The material was taxonomically identified and compared with other local occurrences and other coeval assemblages from the southern hemisphere.

Results. This research recognizes a lower Paleocene-lower Eocene assemblage including material referable to *Palaeohypotodus* sp., *Megasqualus* sp. and Hexanchidae indet., the latter being the oldest known record in the southwestern Pacific. In addition, material from upper Eocene-lower Oligocene levels include dental pieces referable to the lamnids *Macrorhizodus praecursor* Leriche, and to a new species, *Lethenia carranzaensis* sp. nov., the latter represented by an exceptional specimen preserving a dental set, mandibular cartilage and vertebrae. Although discrete, this fauna shows the presence of Paleocene-lower Eocene elements commonly present in Antarctica and the Austral Basin, suggesting a typical Weddellian distribution during that timespan. On the contrary, the presence of the genus *Lethenia* reinforces the evidence of direct a vertebrate interchange with the north Atlantic during the late Eocene - early Oligocene, previously suspected by the shared presence of blochiid billfishes. Evidence of such bioceanic interchange is also present during the late Paleocene, based on the previous reports of *Palaeogaleus*, *Physogaleus*, and *Premontreia*, genera with similar known geographic occurrences. The new records of *Macrorhizodus* and *Lethenia* also represent the oldest known record of Lamnidae in the southwestern Pacific, proving its early presence previous to its widespread and abundant occurrence during the Neogene.

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Abstract

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Introduction

Paleogene marine ~~vertebrates~~ from the southern Pacific are well-known in Antarctica, New Zealand and the Austral (=Magallanes) Basin, representing a valuable source of paleoenvironmental, paleogeographic and paleobiologic information. The faunal affinities present in different austral localities since the Late Cretaceous until the Eocene, worked as major support for the Weddellian Biogeographic Province (Zinsmeister, 1979; WBP hereafter), a concept initially based on the common distribution of marine invertebrates, later proved to apply also for marine vertebrates (Reguero et al. 2012; 2022 and references therein).

In this scenario, ~~the~~ Paleogene marine vertebrate diversity from the southwestern Pacific (particularly from central Chile) is relevant by providing mid-latitude records, although, these have been historically disattended. Fortunately, in recent years new research allowed fresh insights, but detailed comparisons to known assemblages from other parts of the WBP remain unpracticed.

This contribution presents new discoveries from central Chile, including both late Paleocene-early Eocene, and late Eocene-early Oligocene chondrichthyan material. The new elements adds to previous records allowing a first paleogeographic approach, suggesting a faunal continuity of the typical WBP diversity during the late Paleocene, but coupled to the interchange of few chondricthtyan taxa typical of the north Atlantic. These conditions seem to persist during the late Eocene-early Oligocene, pointing to a stronger influence of the north Atlantic fauna during that time span, therefore, suggesting a latitudinal range and chronostratigraphic lapse for the declination of the WBP.

Locality and ~~Geologic~~ Setting

Locality—Loanco is a small cove in the Región del Maule (Maule Region, administrative division of Chile) placed ca. 350 km south from Santiago (Fig. 1A).

~~Geologic~~ Setting—In its coast line crops out different sedimentary units deposited during a transgressive-regressive cycle that spanned between the late Campanian to the Eocene/Oligocene boundary. The basement rocks are conformed by Paleozoic metamorphic rocks. From base to roof, the older sedimentary rocks belong to the Quiriquina Formation (Biró-Bagóczky, 1982), followed by a small section referable to the Lebu Group (Cecioni, 1968), and by a larger section of the Millongue Formation (Tavera, 1942). Covering most of these outcrops, there are Neogene marine terraces likely correlated to the Navidad Formation (Darwin, 1846). The detailed description of the fossil-bearing units studied is provided as following:

Lebu Group (Cecioni, 1968; Le Roux et al., 2008)—A small section of soft, yellowish sandstones of variable thickness below 5 m (Fig. 1B), it overlies through an angular unconformity to a large anticline (ca. 900 m) of the Quiriquina Formation. These levels yielded material referable to the chondrichthyan genus *Palaeohypotodus* (this study), thus, suggesting a Paleocene age. This unit is segregated from the Quiriquina Formation based on the unconformable contact and different lithology. It is here correlated to the basal levels of the Lebu Group, particularly with the marine Pilpilco Formation (Muñoz-Cristi, 1968), which represents a first moment of the transgressive cycle. The Pilpilco Formation was regarded as ca. 150 m of fine-grained, greenish sandstones with clay intercalations (Muñoz-Cristi, 1968). The studied section is consistent with this lithology but much narrower in thickness, suggesting a likely relict of the Pilpilco Formation or else, a different Paleocene marine transgression.

Millongue Formation (Tavera 1942; Muñoz Cristi 1946, 1973; García, 1968; Pineda, 1983)— 2.5 km south from Loanco crops out another fossiliferous sedimentary unit characterized by brownish, clayly sandstones of variable grain size (Fig. 1A, B). The contact between these levels and those of the Quiriquina Formation is covered by recent sands. Fossil content includes ~~bivalvians~~ (*Pinna* sp., Pectinidae), serpulids (aff. *Rotularia* isp.), terebratulid brachiopods, nautiloids (*Aturia* sp.), decapods (*Minohellenus araucanus*), and endemic blochiid fishes (Otero, 2019). The lithology and age of the studied outcrops allow correlating them to the middle-to-upper Eocene Millongue Formation (~~Tavera~~ 1942; ~~Muñoz Cristi~~ 1946).

Stratigraphic Sections—Otero (2024) provided several Upper Cretaceous stratigraphic sections exposed in different points along the coast close to Loanco, numbered as point 1 to point 5. Two of the stratigraphic sections studied here are equivalent to the points 1 (point A of this study) and the upper levels at point 2 (point B of this study) of Otero (2024). Two additional sampling point are here added, consistently labeled as point C and point D. All these are described as following:

Point A (35º 33' 14.1" S; 72º 36' 45.8" W)—Former point 1 of Otero (2024). The base of this section is covered by recent sands. From base to roof: 4,4 m of a massive clayly sandstone, regularly soft, grey to reddish, with fine to coarse grain and small fossiliferous concretions. The level dips ca. 30° west, being partially overlain by landslides. Fossils include typical vertebrates and invertebrates representative of the Quiriquina Formation (see Otero, 2024). In the northern visible flank of the anticline, teeth referable to *Megasqualus* sp. and to Hexanchidae indet. (this study) were recovered. The roof of this level shows frequent traces (*Thalassinoides* isp.) and decapod remains (*~~Protocallianasa~~ saetosa*). It overlays to levels of the Quiriquina Formation (which conforms the anticline); 6,7 m of sub-horizontal, grey, compact, hard sandstone with concretions, overlying in angular unconformity. It shows probable bioturbation near its roof; 5,7 m of grey-to-yellowish, fine sandstone, laminated in its base and having abundant reddish, hard, ferruginous nodules; 3,5 m of fine compact sandstone, with abundant traces (*Skolithos* isp.).

Point B (35º 33' 37.8" S; 72º 37' 04.8"W)—Former point 2 of Otero (2024). The base of this section belongs to the Quiriquina Formation and is located close to the anticline axis. From base to roof: 6 m of green to grey, hard sandstone with abundant fossiliferous concretions of variable size; 4 m of poorly consolidated, clayly sandstones, lying in angular unconformity over the anticline. Near its ~~base~~ there are reworked fossils (actinopterygian scales and fragments *Pacitrigonia hanetiana*). A single *in situ* tooth was recovered from this level (referred to *Palaeohypotodus* sp. ~~on~~ this study); 8,5 m grey, unconsolidated, fine sandstones without fossils.

Point C (35º 33' 46.8" S; 72º 37' 53.8"W)—The base of this section is covered by recent sands. 3 m of greenish sandstones with serpulid banks; 0.5 m with no outcrop; 2 m of reddish sandstones; 2 m with no outcrop; 1.8 m of brown mid-grained sandstone with micaceous fragments, and having a fine conglomerate near its base. Fossils in this level include teeth of *Macrorhizodus praecursor* (this study), a phragmocone of the nautiloid *Aturia* sp. (SGO.PI.6776), and an articulated individual of *Minohellenus* ('*Imaizula*') *araucanus*; 14.3 m of mid-grained, yellow-to-green sandstone with lenses including banks of Terebratulidae indet.;

pectinids and carbonized wood fragments occur near the roof of the level; 6 m of mid-grained, reddish to brown sandstones, with several *in situ* individuals of *Pinna* sp. in life position. This level also includes an isolated lamniform vertebra (*in situ*), serpulid traces, carbonized wood fragments, and *Teredolites* isp.

Point D (35°36'12.39"S; 72°38'13.26"W)—Following Valdés (2019), this section comprises ca. 30 m of quartz sandstones, intercalated by brownish and green sandstones with few glauconitic levels. The section is very fossiliferous, diminishing in abundance from base to roof. Grain size increases from base to roof. The upper part of the exposed section becomes orange near the roof. The brownish levels are comparatively prominent with respect to the green sandstones, showing better resistance to the tidal erosion. Most of the brownish levels lack bivalvians, but contains frequent traces of calcareous worms (*Rotularia* sp.) and occasional terebratulid brachiopods. On the contrary, green levels include bivalvians, terebratulids, and marine vertebrates (associated chondrichthyan teeth, SGO.PV.6635).

Age of the Outcrops ~~Studied Here~~—The presence of *Palaeohypotodus* (with ~~well-~~preserved crown and ~~cusplets~~) on the younger unit (here correlated to the Pililco Formation at points A and B), suggests a Paleocene age based on the known biochron of this genus (Cappetta, 2012), although austral occurrences of *Palaeohypotodus* are also known in the ~~lower~~ Eocene (Long, 1992; Kriwet, 2005; Reguero et al., 2013; Otero and Soto-Acuña, 2015; Kriwet et al., 2016), thus, supporting a local Paleocene-early Eocene age.

The younger unit (Millongue Formation, points C and D) crops out in the southern part of the studied locality. Its eventual contact with the Quiriquina Formation is obscured by recent coastal deposits. The presence of *Aturia* sp. and *Minohellenus araucanus* constrain the unit to an Eocene age, suggesting an eventual extension into the Oligocene (Nielsen et al., 2006; Schweitzer and Feldmann, 2002; Schweitzer et al., 2010). In addition, the local presence of blochiid fishes (Otero, 2019) ~~suggest~~ a middle-to-late Eocene age based on the known biochron of blochiids (Fierstine and Monsch, 2002), while the presence of the genus *Lethenia* (see further text) suggests a late Eocene or even lower Oligocene age, considering the age of the unique previously known record of the genus (Baut and Génault, 1999). The relative age of these outcrops, their distinctive lithology and ~~its~~ marine environment~~,~~ support a correlation with the Millongue Formation (~~Tavera~~ 1942) ~~which~~ is present in southern and northern localities of the Arauco Basin (Tavera, 1942; Muñoz-Cristi, 1958; Tavera, 1980). The age of the Millongue Formation was independently constrained to the middle-to-late Eocene based on fossil invertebrates in other localities of central Chile (Tavera, 1942~~;~~ 1980). The faunal assemblage locally recognized in Loanco (points C and D) indicates a late Eocene or even ~~a~~ early Oligocene age for these outcrops.

Materials & Methods

Institutional Abbreviations—SGO.PV., Área Paleontología, Museo Nacional de Historia Natural, Santiago, Chile.

The studied material was collected in several fieldworks. The specimen SGO.PV.6635 was collected by the author on 2008~~,~~ and subsequently prepared by hand tools. Natural crackings of the original sandstone block affected several teeth. These were separated from the matrix and later re-joined with cyanocrilate, although the contact surfaces were damaged in few cases. Few teeth are preserved in hardened nodules. Then, ~~its~~ preparation was risky considering the presence of very delicate lateral cusplets.

The remaining teeth were recovered as isolated elements during successive field works between 2010~~-~~2015, being later separated from its hosting matrix by hand tools.

~~Results:~~ Systematic Paleontology

Chondrichthyes Huxley, 1880
Elasmobranchii Bonaparte, 1838
Neoselachii Compagno, 1977
Squaliformes Compagno, 1973
Squalidae de Blainville, 1816
Genus *Megasqualus* Herman, 1982

Megasqualus sp.
(Fig. 2A-B)

Centrophoroides sp.: Suárez and Otero, 2008
Centrophoroides sp.: Otero, 2015.

Type Species—'*Notidanus orpiensis*' Winkler, 1874, upper Paleocene of Belgium.

Material—SGO.PV.6625, a single lateral tooth.

Locality and Horizon—Loanco, Point A, basal marine unit of the Lebu Group (Pilpilco Formation), Paleocene-lower Eocene.

Description—Squalid large tooth (6 mm wide~~)~~ with a crown strongly recurved ~~backwards~~, having a nearly straight cutting edge with ~~few~~ irregular slight serrations over its mesial ~~margin~~. The crown has slightly protruding uvula. The labial apron is broken, but its contour is preserved. This shows a basal projection that does not reach the root base. The root base is concave and it has a rhomboidal outline. There are no mesial or distal hollows, indicating that the dental overlap is weak in this taxon.

Remarks—SGO.PV.6625 was initially referred to as *Centrophoroides* sp. by Suárez and Otero (2008). After additional preparation, the basal projection of the labial apron was revealed. This is basally projected but not extended beyond the root base, differing from the typical local teeth of the Arauco Basin referred to *Centrophoroides*, which have a large apron that basally surpasses the entire root (Otero, 2024). The crown cutting edge of SGO.PV.6625 is almost straight, also differing from the local records referable to *Centrophoroides*, which have comparatively higher crowns with irregularly serrated cutting edges, ~~and~~ in some cases, a differentiated mesial cutting edge with fine serrations and a distal cutting edge with a higher angle and more marked irregular serrations, resembling a separation between the lateral cusp and the crown (Otero, 2024).

The Upper Cretaceous austral record of Squaliformes includes similar ecomorphotypes. Particularly, *Protosqualus argentinensis* Bogan et al. (2016) was described from ~~upper~~ Maastrichtian beds of Argentinean Patagonia. This taxon has unusually irregular serrations, a high triangular crown posteriorly recurved, and a triangular, lingually projected uvula. These traits are not present in SGO.PV.6625. Moreover, the low crown highly recurved ~~backwards~~, the shallowly projected apron and the slight serrations are characters described for the genus *Megasqualus* (see Cappetta, 1987: p. 55). SGO.PV.6625 is slightly larger than the typical *Centrophoroides* teeth found in the Arauco Basin, which rarely exceeds 5 mm in length (Otero, 2024). The genus *Megasqualus* has been reported ~~in the upper~~ Paleocene-~~lower~~ Eocene of Belgium and England (Gurr, 1962; Herman, 1982; Cappetta, 1987~~;~~ 2012), and the lower-middle Paleocene of New Zealand (Mannering and Hiller, 2008).

Hexanchiformes de Buen, 1926
Hexanchidae Gray, 1851

Hexanchidae ~~indet~~.

(Fig. 2C)

cf. *Echinorhinus* sp.: Suárez and Otero, 2008; Otero, 2015.

Material—SGO.PV.6626, an isolated crown fragment.

Locality and Horizon— Loanco, Point A, basal marine unit of the Lebu Group (Pilpilco Formation), Paleocene-lower Eocene.

Description—Triangular cusp strongly recurved ~~backwards~~, with complete cutting edges. Its labial face is flat and the lingual face convex. The preserved cusp ~~bears basal wrinkles~~ and ~~few~~ longitudinal striations over the enameloid. Over the cutting edges, small radial striations are visible. A small fragment of the root is attached to the cusp base, which allows delimiting the complete cusp height.

Remarks—This cusp was previously considered to be related to the genus *Echinorhinus* (Suárez and Otero, 2008). However, the presence of a convex lingual face differs from the very flat crown present in homodont teeth of *Echinorhinus* (Cappetta, 1987; 2012). ~~Even more~~, the longitudinal striations over the lingual face of the cusp and the radial striations associated to the cutting edges are features seen in hexanchids such as *Notidanodon* (see Bogan et al., 2016: fig. 2B). The isolated cusp SGO.PV.6626 is not enough for a generic identification, reason why it is kept as an indeterminate hexanchid.

The eventual presence of hexanchids in pre-Neogene units of central Chile was first regarded by Philippi (1887) who referred to *Notidanus* few teeth from the lower Maastrichtian of Algarrobo, central Chile. Auspiciously, the material was figured by Philippi (1887: ~~Plate~~ 55, figs. 11a, b), revealing that these indeed belong to teeth of squaliforms (likely *Centrophoroides*), thus, discarding its adscription to hexanchids.

Previous to this research and considering the updated information, hexanchids were known in central Chile from the Miocene and onwards. Thus, SGO.PV.6626 is the first and to date the unique evidence of this clade in the Paleocene-~~lower~~ Eocene of the southeastern Pacific. On the contrary, WBP hexanchids have been frequently reported in the upper Campanian-lower Maastrichtian ~~of~~ James Ross Island, Antarctica (Richter and Ward, 1990), the upper Maastrichtian of Seymour Island, Antarctica (Grande and Chatterjee, 1987) and the upper Maastrichtian of the Austral Basin (Bogan et al., 2016). During the Paleogene, hexanchids have been reported in all the main localities within the WBP (Cione and Reguero, 1994; Kriwet, 2005; Mannering and Hiller, 2008; Reguero et al., 2012; 2022; Otero et al., 2012; 2013; Kriwet et al., 2016), except the southeastern Pacific.

Lamniformes Berg, 1958
Odontaspididae Müller and Henle, 1838
Genus *Palaeohypotodus* Glickman, 1964

Type species—‘*Odontaspis*’ (=*Palaeohypotodus*) *rutoti* Winkler, 1874. Late Paleocene of Belgium.

Palaeohypotodus sp.
(Fig. 2D, E)

Triakidae indet.: Otero, 2015.

Material—SGO.PV.6780, a single posterior tooth.

Locality and Horizon—Loanco, point B, basal marine unit of the Lebu Group (Pilpilco Formation), Paleocene-lower Eocene.

Description—Posterior tooth with a low triangular crown. Its labial face has strong folds that fade into the tip, while the lingual face ~~has~~ a smooth enameloid. Labially, the crown overhangs to the root by a bulge. The distal side has two triangular and robust cusplets, and the mesial side lacks any cusplet. The root has two separated and thick lobes with a shallow medial nutritious groove.

Remarks—This tooth was first referred by Otero (2015) as an indeterminate triakid, without providing its repository neither figuring it. Additional preparation revealed the presence of a triangular crown, two distal cusplets and absence of mesial cusplets. Such features resemble teeth of several Carcharhiniformes (e.g., the genus *Galeorhinus*). However, the root has two prominent, divergent lobes and a shallow medial nutritious groove, differing from all Carcharhiniformes (i.e., Scyliorhinidae, Proscyllidae, Pseudotriakidae, Triakidae and Carcharhinidae), which possess deep medial grooves, and a medial part of the root thicker than the root lobes, the latter being rarely divergent (Cappetta, 2012).

SGO.PV.6780 current reassessment allows recognizing informative features. First, the separated lobes and shallow groove are coincident with those of posterior teeth of odontaspidids. The lack of mesial cusplets can be explained due to a very posterior tooth position. In addition, the two distal cusplets are both triangular and they are medially recurved. The separated root lobes, the labial bulge separating the crown and the root, and the strong labial enameloid folds are features present in the odontaspidid genus *Paleohypotodus* (Cappetta, 1987~~;~~ 2012).

Lamnidae (Müller and Henle, 1838)
Genus *macrorhizodus* Glikman, 1964
Macrorhizodus praecursor (Leriche, 1905)
(Fig. 2F-I)

Macrorhizodus praecursor: Otero, 2015

Type Species—*Isurus praecursor* (Leriche, 1905). Middle Eocene, Belgium.

Locality and Horizon—Loanco, Point C. Millongue Formation, upper Eocene-lower Oligocene.

Referred Material—SGO.PV.6633. Two complete lateral teeth.

Description—The larger tooth has a high triangular crown with complete, non-serrated cutting edges. The labial face is flat, while the lingual face is convex. The root has two slightly divergent lobes with a squared contour. Its general shape suggests a lower anterior position. The smallest tooth has similar features. Its crown is comparatively short and mesiodistally larger, with the tip recurved backwards, evidencing its lateral position. The mesial side of the tooth is broken. The root, the cutting edges and the enameloid show signs of erosion, indicating transportation prior its burial.

Remarks—Eocene teeth of this lamnid morphotype found in Antarctica have been first adscribed to the genus *Isurus* (Cione and Reguero, 1994; Reguero et al., 2012; Kriwet et al., 2016). However, the genus *Isurus* has extant species (*Isurus oxyrhincus* and *Isurus paucus*) with teeth much different possessing slender and sigmoidal crowns, and roots with divergent lobes (Compagno, 2001). In addition, the cutting edge is complete in teeth of *Macrorhizodus* whereas in teeth of *Isurus* it generally does not reach the base (Cappetta, 2012; Carlsen and Cuny, 2014). Similar lamnid teeth have been found in two middle-to-late Eocene localities of southernmost Chile, being referred to *Macrorhizodus praecursor* based on the differences listed above (Otero et al., 2012; 2013), but also considering their similarity to Neogene taxa such as ‘*Carcharodon*’ *hastalis* and *Carcharodon carcharias* (Ehret et al., 2012), characterized by large, triangular upper anterior teeth. Following these criteria, the new specimens from central Chile are also referred to *Macrorhizodus praecursor*.

Genus *Lethenia* Baut and Génault, 1999

Type Species—'*Odontaspis Van der Broecki*' (Winkler, 1880; p. 77-78), lower Oligocene of Limburg, Belgium.

Lethenia carranzaensis sp. nov.
lsid:zoobank.org:act:012B0463-22D3-4A40-916A-F005532BD09B
(Fig. 3A-Q)

Isurolamna sp.: Suárez and Otero, 2010
Isurolamna sp.: Otero, 2015
Isurolamna sp.: Otero, 2019

Holotype—SGO.PV.6635. Associated remains of a single specimen including five anterior or near anterior teeth, four lateral teeth, one posterior tooth, two vertebrae and manibular cartilage fragments.

Locality and Horizon—Loanco, Point D. Millongue Formation, upper Eocene-lower Oligocene.

Diagnosis—Species within *Lethenia* having two blunt triangular lateral cusplets in anterior, lateral and posterior teeth.

Etymology—After the toponymy of Carranza lighthouse, north Loanco, Región del Maule, central Chile.

Description—Anterior teeth with straight cusp in lateral and profile views, with complete cutting edges. The main cusp has a D-shaped section, without ornamentation. There are two lateral cusplets with triangular outline on each side of the main cusp. The larger cusplet is blunt and it has complete cutting edges. The base of the larger cusplet is detached from the main cusp. The smallest cusplets are mesially and distally placed. These are triangular but having rounded tips. The root is mesiodistally larger than the main cusp height. Roots have a slightly squared contour without divergent lobes. Labiolingually, the roots are thin, without any bulk or projection.

Remarks—The originally monotypic genus *Lethenia* Baut and Génault (1999) included only the species *Lethenia vanderbroecki* (Winkler, 1880). This taxon was diagnosed by the presence of low lateral cusplets without any ornamentation and well-separated from the crown, with sub-circular cross-section, plus very compressed root branches without divergent branches. SGO.PV.6635 shares with *Lethenia vanderbroecki* the unornamented cusplets separated from the crown, as well as the distinctive compressed shape of the root branches. On the contrary, it differs from the latter species by possessing two lateral cusplets on each side, and by having cusplets comparatively blunter, with a triangular outline, contrary to the sharp and thin cusplets of *Lethenia vanderbroecki* (Winkler, 1880: p. 77; Baut and Génault, 1999: fig. 11; Nolf, 1988: pl. 47). While *Lethenia vanderbroecki* was originally described based on twenty complete but isolated teeth, the Chilean specimen represents a partial dental set of a single individual, plus ~~few~~ other associated skeletal remains. This set allows assessing the morphology of the anterior, lateral and posterior teeth. All the teeth similarly possess two cusplets on each side of the crown (this can be assessed in the incomplete teeth based on the basal section of the missing cusplets) On posterior-most teeth, the crown and the cusplets appear as immediately adjacent elements without an evident separation, differing from the separated crown and cusplets considered as a diagnostic trait of *Lethenia* (Baut and Génault, 1999: p. 23). However, the specimens figured by Nolf (1988: pl. 467, figs. 2 and 3) show its crown and cusplets with a complete contact between them. Thus, the variable separation between the crown and cusplets could be related to the individual tooth growth, being presumably contacted in recently replaced teeth, but acquiring a marked separation in old, mature teeth. If this is the case, this trait should be abandoned as part of the diagnosis of the genus.

Previous to this research, SGO.PV.6635 was considered to be related to the genus *Isurolamna* Cappetta (1976), mostly based in the non-divergent root branches observed in the first teeth recovered from the matrix during its preparation (Suárez and Otero, 2010; Otero, 2015*;* Otero, 2019). However, SGO.PV.6635 dental set shows that the crown of all teeth is straight, contrary to the sigmoidal profile regarded in the diagnosis of *Isurolamna* (Cappetta, 1976; 1987). SGO.PV.6635 also lacks a marked heterodonty (as described for *Isurolamna* by Cappetta, 1976), ~~instead~~ having a low heterodonty, mostly relying on the posterior curvature of the crown of lateral and posterior teeth. Based on the available set, there is also no evidence of a dignathic heterodonty on SGO.PV.6635. Moreover, the crowns of the known species within *Isurolamna* (i.e., *Isurolamna barajunasi* Glikman and Zhelezko, 1985; *Isurolamna inflata* Leriche, 1905 and *Isurolamna gracilis* Le Hon, 1871) are high and sigmoidal, comparatively blunter in the case of *I. gracilis* and *I. barajunasi*, and the roots show divergent branches in the three species. On the contrary, all the material historically referred to the genus *Lethenia*, shows straight crowns and non-divergent root branches. While the species *Lethenia vanderbroecki* has been included within *Isurolamna* by some authors (e.g., Dutheil, 1991), the traits discussed by Baut and Génault (1999) for supporting *Lethenia* as a taxon different from *Isurolamna,* are verified here on the basis of the first available associated dental set including anterior, lateral and posterior elements of a single individual. Considering these facts, this research proposes a second species within *Lethenia*, being its first occurrence in the southern hemisphere. On contrary, the dental features of *Isurolamna* are still based on artificial sets (Le Hon, 1871; Cappetta, 1976; Zhelezko and Koslov, 1999) and likely, the genus may represent a wastebasket taxon.

Discussion

Previous Records of Paleogene Chondrichthyans in central Chile—Earliest reports include the mention of *Odontaspis elegans* ~~from~~ Eocene beds of central Chile (Oliver-Schneider, 1936), although~~,~~ the material was never figured ~~and~~ its repository is currently unknown. Suárez and Marquardt (2003) referred to '*Myliobatis* sp.' several plates from the Eocene of Algarrobo, but their repository was not provided and the specimens were not figured, making impossible its reassessment. Later, Muñoz-Ramirez et al. (2007) described a ~~rich~~ chondrichthyan ~~diversity~~ from Talcahuano (ca. 135 km south from the localities studied here) considering them as part of the Late Cretaceous Quiriquina Formation (Biró-Bagóczky, 1982), and including ~~the taxa~~ *Squalus* sp~~.~~ *Squatina* sp., *Cretorectolobus* sp., *Carcharias* sp., *Palaeohypotodus* sp., *Scapanorhynchus* sp., *Palaeogaleus* sp., *Galeorhinus* sp., *Paraorthacodus* sp., *Dasyatis* sp., *Rhinoptera* sp.~~,~~ ?Dasyatidae indet. Suárez and Otero (2010) described the presence of *Isurolamna* sp. on Loanco, Región del Maule, which is the material here described as a new species of *Lethenia*. After, Groz and Palma-Heldt (2013) reviewed the assemblage described by Muñoz-Ramirez et al. (2007), recognizing that several known biochrons were indeed restricted to the Paleocene. Suárez (2015) reviewed (among others) the Paleogene record from central Chile, listing all these previous records. Otero (2015) mentioned the presence of *Macrorhizodus praecursor* in the middle-to-upper Eocene of Loanco. The specimens were not figured nor repository was indicated then. These are described here for the first time. ~~Later,~~ Fernández-Jiménez et al. (2016) ~~reported~~ additional chondrichthyans referred to *Carcharias “hopei”, Carcharias* sp., *Striatolamia macrota*, and *Myliobatis* sp., reinforcing the presence of Paleocene-Eocene levels at Talcahuano.

More recently, Rodriguez et al. (2023) reported additional late Paleocene chondrichthyans from Talcahuano in central Chile, with ~~material~~ referred to ~~the taxa~~ *Paraorthacodus clarkii*, *Squalus minor*, *Squalus orpiensis*, *Centrophorus* sp., *Squatina prima*, *Anomotodon novus*, *Striatolamia striata*, *Carcharias* spp., *Sylvestrilamia teretidens*, *Odontaspis winkleri*, *Palaeohypotodus speyeri*, *Palaeohypotodus rutoti*, *Isurolamna inflata*, *Premontreia gilberti*, *Physogaleus secundus*, *Palaeogaleus vincenti* ~~and~~ *Hypolophodon sylvestris*. It must be observed that this diversity needs a critical review. The identification of three squalid taxa (i.e., *Squalus minor*, *Squalus orpiensis* and *Centrophorus* sp.) was ~~based~~ on a single ~~tooth, respectively~~. Squalidae are characterized by ~~poor~~ monognathic and dignathic heterodonty, meaning that teeth from the upper and lower jaw are similar and the teeth of each jaw are also similar in different dental positions (Cappetta, 2012: fig. 12C). ~~m~~oreover, teeth of different squalid genera can reach similar general shape during individual tooth growth. Because of this, ~~usage~~ of isolated squalid teeth is problematic for granting specific determinations. A similar problem occurs among Odontaspididae and Mitsukurinidae. These groups have marked dignathic dentition and they also have a marked dental variation along each jaw; however, different genera can show remarkably similar teeth depending on their dental position ~~or~~ jaw (Cunningham, 2000; Cappetta and Nolf, 2005). For preventing these issues, a large sampling is recommended and has proved to work on other local fossil odontaspidids and squalids (e.g., the Late Cretaceous record of *Carcharias gracilis* was based on 196 teeth from the same locality and level; see Otero, 2024). On the other hand, part of the specimens of Rodriguez et al. (2023) are reported to be abraded (i.e., *Centrophorus* sp., *Squatina* sp.), leaving the possibility of reworked material from older strata. Both squalid and squatinid sharks are known in local older underlying units such as the Quiriquina and Cosmito formations (Suárez et al., 2003; Muñoz-Ramirez et al., 2007; Groz and Palma-Heldt, 2013).

With these considerations, ~~this~~ contribution recommends that the specific identifications of squatinids, mitsukurinids and odontaspidids based in a single sample as provided by Rodriguez et al. (2023), should kept under open nomenclature awaiting larger samplings that could support their specific adscription, with the exception of *Striatolamia striata* and *Hypolophodon sylvestris* which are supported by a fair number of dental pieces. On the other hand, the records of *Sylvestrilamia teretidens* (n=1; Rodriguez et al., 2023: fig. 7N, O) and *Isurolamna inflata* (based on n=1; Rodriguez et al., 2023: fig. 8C,D) likely represent posterior teeth of other odontaspidids and are difficult to assure even to genus level ~~on the grounds of~~ a single available tooth.

A summary of the Paleogene chondrichthyan records from central Chile with remarks on their status (after the comments above)~~, are~~ provided in Table 1.

Paleobiographic Relevance of the Studied Material—The new material of *Palaeohypotodus* sp. adds to previous undifferentiated Paleocene (Muñoz~~-~~Ramirez et al., 2007; Groz and ~~Palma~~, 2013) and late Paleocene records of the genus (Rodriguez et al., 2023) in central Chile. Additional records of *Palaeohypotodus* in the WBP are known in lower Eocene units of the Austral Basin (Otero and Soto-Acuña, 2015) and Antarctica (Long, 1992; Kriwet, 2005; Reguero et al., 2013; Kriwet et al., 2016), although, the genus remains unreported in coeval units of New Zealand. Otherwise, in the northern hemisphere, *Palaeohypotodus* was restricted to the Danian-Thanetian of Europe, North America, central Asia and northern Africa (Cappetta, 2012). Thus, their current southeastern Pacific records (=central Chile) are coeval with those records from the northern hemisphere, but comparatively older than known high-latitude austral occurrences of *Palaeohypotodus*. These age differences likely represent an extension of the former Danian-Thanetian biochron of *Palaeohypotodus* (Cappetta, 2012) into the lower Eocene (in Antarctica and the Austral Basin), suggesting that the taxon was a relict in high latitudes of the southern hemisphere prior to its extinction.

Occurrences of the genus *Megasqualus* in the WBP have been reported in the Danian-Selandian of New Zealand (Mannering and Hiller, 2008), while northern records are known in the middle Paleocene-lower Eocene of Europe (Cappetta, 2012 and references therein). The current material from central Chile represents the second known occurence of *Megasqualus* in the WBP.

On the other hand, the new occurrence of *Macrorhizodus praecursor* in middle-to-late Eocene levels of Loanco represents the northernmost occurrence of the taxon in the WBP. Their previous austral records were restricted to the Eocene of Antarctica (Cione and Reguero, 1994; Reguero et al., 2012) and the Eocene of the Austral Basin in southern South America (Otero et al., 2012; 2013). A closely related lamnid taxon likely occurs in the Paleocene of New Zealand but the material was incomplete for an accurate taxonomical referral (Mannering and Hiller, 2008: fig. 15). Otherwise, the genus *Macrorhizodus* had a widespread distribution along Europe, Atlantic Africa and Asia during the ~~lower~~ Eocene - ~~lower~~ Oligocene (Cappetta, 2012 and references therein).

In addition, the description of *Lethenia carranzaensis* sp. nov. represents the first occurrence of the genus in the southern hemisphere. Previous reports are known in the ~~lower~~ Oligocene of Belgium (Baut and Génault, 1999), France and Kazakhstan (Cappetta, 2012), and the ~~upper~~ Oligocene of Europe (Cappetta, 2012).

Finally, the presence of and indeterminate hexanchid represents its current oldest record along the southeastern Pacific. Austral record of hexanchids can be tracked back to the Late Jurassic of New Zealand (Cappetta and Grant-Mackie, 2018). There is a major gap during the austral Cretaceous. The group was frequently reported in the James Ross Basin since the Late Cretaceous until the Eocene (Grande and Chatterjee, 1987; Richter and Ward, 1990; Long, 1992; Cione and Reguero, 1994; Kriwet et al., 2006; Reguero et al., 2012; Engelbrecht et al., 2017). Hexanchids are also known in the Paleocene of New Zealand (Mannering and Hiller, 2008). ~~On~~ South America, the oldest hexanchid records in the Austral (=Magallanes) Basin are known in the Maastrichtian of Calafate Lake (Bogan et al., 2016). Younger records are relatively frequent and broadly distributed along the entire basin during the Eocene (Otero et al., 2012~~;~~ 2013). On the contrary, records of hexanchids along the southeastern Pacific are known since the Miocene and onwards (Long, 1993; Carrillo-Briceño et al., 2013; Suárez, 2015; Chávez-Hoffsmeister and Villafaña, 2023), but its local presence before the Miocene remained unreported until now.

Palaeogeography —The Paleocene chondrichthyan diversity previously described from central Chile (Muñoz-Ramirez et al., 2007; Groz and Palma-Heldt, 2013; Rodriguez et al., 2023) includes several genera with widespread representation along the WBP or even being cosmopolitan (i.e., genera *Squatina*, *Carcharias*, *Palaeohypotodus*, *Scapanorhynchus*, *Galeorhinus*, *Paraorthacodus*, *Dasyatis*, *Rhinoptera*, *Centrophorus*, *Anomotodon*, *Striatolamia*, *Odontaspis* and *Hypolophodon*). Exceptions are the single record of a worn tooth of *Cretorectolobus* sp. (Muñoz-Ramirez et al., 2007) that might belong to reworked material from older units, considering its known bichron restricted to the Hauterivian-Maastrichtian (Cappetta, 2012).

The new Paleocene-lower Eocene records of *Palaeohypotodus* sp., *Megasqualus* sp. and Hexanchidae indet. extend their known distribution in the WBP. The same applies for the new record of *Macrorhizodus praecursor*, also present in austral Eocene WBP localities.

On the contrary, the reported presence of *Palaeogaleus*, *Physogaleus*, and *Premontreia* in the upper Paleocene of central Chile (Rodriguez et al., 2023) ~~support~~ an early connection with the North Atlantic. While these taxa remain unreported in high latitudes of the WBP, the three genera are known in Europe, North America, north and west Africa, and the Near East (Cappetta, 2012). In addition, the new record of the genus *Lethenia* (represented by *Lethenia carranzaensis* sp. nov.), complements a similar scenario during the late Eocene-early Oligocene. Previous to this research, the genus *Lethenia* was exclusively reported in the Oligocene of Europe and central Asia (Baut and Génault, 1999; Cappetta, 2012), remaining unreported in any coeval locality of the southern hemisphere.

This pattern of an Atlantic influence into the WBP, likely beginning in the late Paleocene and extending into the early Oligocene, is reinforced by the similar distribution of the billfish clade Blochiidae, a group firstly described in the Eocene of Italy (Fierstine and Monsch, 2002), but later shown to be present in the middle-to-late Eocene of central Chile (particularly in

Loanco, the locality ~~here studied~~), represented by an endemic genus and species (Otero, 2019). This suggests an emerging picture for a temporal and latitudinal declination of the WBP. While endemic taxa indeed occur (i.e., *Lethenia carranzaensis*, *Loancorhynchus catrillancai*: Otero, 2019; this study), their closest relatives are known in the North Atlantic.

These faunal interchanges and its chronostratigraphic occurrences were expectable, considering the composition of the Neogene chondrichthyan fauna known in central and northern Chile (Carrillo-Briceño et al., 2013; Suárez, 2015; Chávez-Hoffsmeister and Villafaña, 2023), which contrasts in diversity to the Eocene assemblages of southernmost Chile and Antarctica (Long, 1992; Kriwet, 2005; Kriwet et al., 2016; Reguero et al., 2012; 2022; Otero et al., 2012~~;~~ 2013). Previous to this research, there was no evidence of a latitudinal segment in the southeastern Pacific, neither a time span for the beginning of such faunal turnover.

These faunal interchanges occurred in a moment of major global geographic and climatic dynamics which especially affected the southern hemisphere by the opening of the Tasmanian Gateway, the deepening of the Drake Passage (Lawver and Gahagan, 2003; Case, 2007), the extension of the Antarctic ice sheet, plus variations in the Antarctic ocean circulation patterns (Goldner et al., 2014) and sea temperature (Kennedy et al., 2015). Although sparse, the new material described in this contribution sheds the first insights on the marine vertebrate faunal changes coupled to these global dynamics along the southern Pacific coast of South America.

Conclusions

New Paleogene chondrichthyan remains from central Chile are here studied. The oldest studied sections correlates with the Paleocene-lower Eocene Pilpilco Formation, which includes the northernmost occurrences along the Pacific of ~~the taxa~~ *Palaeohypotodus* sp., *Megasqualus* sp. and Hexanchidae indet. The new record of *Megasqualus* is the second known in the WBP, while the material referred to Hexanchidae indet. represents the earliest known evidence of the group in the southeastern Pacific.

Two additional sections of a second younger unit (Millongue Formation) have yielded material referable to lamnid sharks, represented by *Macrorhizodus praecursor* (Leriche), and by *Lethenia carranzaensis* sp. nov., ~~here described~~. The new record of *Macrorhizodus* represents its northernmost occurrence in the WBP, although this was a cosmopolitan taxon during the Eocene. On the contrary, the new record of *Lethenia* represents its first occurrence in the southern hemisphere. Its distribution has a similar pattern previously recognized in coeval billfishes of the clade Blochiidae. Moreover, both taxa share a similar distribution with the chondrichthyan genera *Palaeogaleus*, *Physogaleus*, and *Premontreia*, previously reported in the upper Paleocene of central Chile. All these taxa remain unreported in higher latitudes of the WBP but they are known in the Atlantic realm during the same time span, suggesting that a southeastern Pacific-north Atlantic faunal interchange occurred at least since the upper Paleocene until the lower Oligocene. Such interchange could represent the starting point of the WBP declination as a recognizable bioprovince, prior to the establishment of typical Neogene marine vertebrate faunas along the southeastern margin of the Pacific Ocean.

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References

Baut JP, Génault B. 1999. Les élasmobranches des Sables de Kerniel (Rupélien), à Gellik, Nord Est de la Belgique. *Memoirs of the Geological Survey of Belgium* **45:**1–61.

Berg LS. 1958. System der rezenten und fossilen Fischartigen und Fische. Veb Deutscher Verlag Der Wissenschaften **4:**310. 263 fig.

Biró-Bagóczky L. 1982. Revisión y redefinición de los 'Estratos de Quiriquina', Campaniano-Maastrichtiano, en su localidad tipo, en la Isla Quiriquina, 36–370 Lat. Sur, Chile, Sudamérica, con un perfil complementario en Cocholgüe. *III Congreso Geológico Chileno (Concepción), Actas* **1:**A29–A64.

Bogan S, Agnolin FL, Novas FE. 2016. New selachian records from the Upper Cretaceous of southern Patagonia: paleobiogeographical implications and the description of a new taxon. *Journal of Vertebrate Paleontology* **36:**e1105235. 9 p.

Bonaparte CL. 1838. Selachorum tabula analytica, Systema Ichthyologicum. *Memoires de la Societe Neuchateloise des Sciences Naturelles* **2:**1–16.

Cappetta H. 1976. Sélaciens noveaux du London Clay de L'Essex (Yprésien du Bassin de Londres). *Geobios* **9:**551–575.

Cappetta H, Grant-Mackie J. 2018. Discovery of the most ancient *Notidanodon* tooth (Neoselachii: Hexanchiformes) in the Late Jurassic of New Zealand. New considerations on the systematics and range of the genus. *Palaeovertebrata* **42:**1–8.

Cappetta H, Nolf D. 2005. Révision de quelques Odontaspididae (Neoselachii: Lamniformes) du Paléocène et de l'Eocène du Bassin de la mer du Nord. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* **75:**237–266.

Cappetta H. 1987. Chondrichthyes II: Mesozoic and Cenozoic Elasmobranchii. In: Schultze HP, ed., *Handbook of Paleoichthyology, vol. 3B*. Gustav Fischer Verlag, Stuttgart, 1–193.

Cappetta H. 2012. *Handbook of Paleoichthyology, Vol. 3E: Chondrichthyes Mesozoic and Cenozoic Elasmobranchii: Teeth*. Verlag Dr. Friedrich Pfeil, 512 pp.

Carlsen AW, Cuny G. 2014. A study of the sharks and rays from the Lillebælt Clay (Early–Middle Eocene) of Denmark, and their palaeoecology. *Bulletin of the Geological Society of Denmark* **62:**39–88.

Carrillo-Briceño J, González-Barba G, Landaeta MF, Nielsen SN. 2013. Condrictios fósiles del Plioceno Superior de la Formación Horcón, Región de Valparaíso, Chile central. *Revista Chilena de Historia Natural* **86:**191–206.

Cecioni G. 1968. *El Terciario de Chile. Zona central*. Santiago: Sociedad Geológica de Chile. Editorial Andrés Bello, 280 p. Santiago.

Chávez–Hoffmeister, MF, Villafaña JA. 2023. The Neogene record of cartilaginous fishes (Chondrichthyes: Holocephali, Elasmobranchii) from northern Chile: A review and identification guide. *Journal of South American Earth Sciences* **124:**104230.

Cione AL, Reguero MA. 1994. New records of the sharks *Isurus* and *Hexanchus* from the Eocene of Seymour Island, Antarctica. *Proceedings of the Geologists Association* **105:**1–14.

Compagno LJV. 1973. Interrelationships of living elasmobranchs. In: Greenwood PH,. Miles RS, Patterson C, eds. *Interrelationships of Fishes*. Supplement I to Zoological Journal of the Linnean Society of London **53:**15–61.

Compagno LJV. 1977. Phyletic relationships of living sharks and rays. *American Zoologist* **17:**303–322.

Compagno LJV. 2001. *Sharks of the World. An Annotated and Illustrated Catalogue of Shark Species Known to Date. Vol. 2, Bullhead, Mackerel, and Carpet Sharks (Heterodontiformes, Lamniformes and Orectolobiformes)*. FAO Species Catalogue for Fishery Purposes 1. Rome, FAO, 269 p.

Cunningham SB. 2000. A comparison of isolated teeth of early Eocene *Striatolamia macrota* (Chondrichthyes, Lamniformes), with those of a Recent sand shark, *Carcharias taurus*. *Tertiary Research* **20:**17–31.

Darwin C. 1846. *Geological observations on South America. Being the third part of the geology of the voyage of the Beagle, under the command of Capt. Fitzroy, R.N. during the years 1832 to 1836*. Smith Elder and Co, 279 p. London.

de Blainville HMD. 1816. Prodrome d'une nouvelle distribution systematique du regne animal. *Bulletin de la Société Philomatique de Paris* **8:**105–124.

de Buen F. 1926. *Catalogo ictiologico del Mediterraneo Espanol y de Marruecos, recopilando lo publicado sobre peces de las costas mediterraneas y proximas del Atlántico (Mar de España). Resultados de las ampafias Realizadas por Acuerdos Internacionales, 2*. Instituto Español de Oceanografía, 1–221.

Dutheil DB. 1991. A checklist of Neoselachii (Pisces, Chondrichthyes) from the Palaeogene of the Paris Basin, France. *Tertiary Research* **13:**27–36.

Ehret DJ, Macfadden BJ, Jones DS, deVries TJ, Foster DA, Salas-Gismondi R. 2012. Origin of the white shark *Carcharodon* (Lamniformes: Lamnidae) based on recalibration of the upper Neogene Pisco Formation of Peru. *Palaeontology* **55:**1139–1153.

Engelbrecht A, Mörs T, Reguero MA, Kriwet J. 2017. Eocene squalomorph sharks (Chondrichthyes, Elasmobranchii) from Antarctica. *Journal of South American Earth Sciences* **78:**175–189.

Fernández-Jiménez R, Otero RA, Soto-Acuña S, Flores G, Bonilla R, González A, Quinzio A. 2016. New records of Paleogene Elasmobranchii from the coast of Coliumo, Biobío Province, Chile. *V Simposio de Paleontología de Chile, Libro de Resúmenes,* p. 85. Concepción.

Fierstine H, Monsch K. 2002. Redescription and phylogenetic relationships of the family Blochiidae (Perciformes: Scombroidei), middle Eocene, Monte Bolca, Italy. *Miscellanea Paleontologia, Studi e Richerche sui Giacimenti Terziari de Bolca, Museo Civico di Storia Naturale di Verona* **9:**121–163.

García F. 1968. Estratigrafía del Terciario de Chile central. In: Cecioni G, ed. *El Terciario de Chile*. Editorial Andrés Bello (Santiago), 280 p.

Glikman LS. 1964. ~~Sharks of Paleogene~~ and their stratigraphic significance. *Nauka Press*. 229 p.

Glikman LS, Zhelezko VI. 1985. Paleogene sharks of the Mangyshlak Peninsula and the Eocene/Oligocene boundary. *Bjulleten' Moskovskogo obshhestva ispytatelej prirody. Otdel geologicheskij* **60:**86–99. [In Russian].

Goldner A, Herold N, Huber M. 2014. Antarctic glaciation caused ocean circulation changes at the Eocene–Oligocene transition. *Nature* **511:**574–577.

Grande L, Chatterjee S. 1987. New Cretaceous fish fossils from Seymour Island. *Palaeontology.* **30:**829–837.

Gray JE. 1851. *List of the specimens of fish in the collection of the British Museum.Part I. Condropterygii*. British Museum of Natural History, 160 p. London.

Groz C, Palma-Heldt S. 2013. *Contribution of fossil record of elasmobranchs to the knowledge of the K/P limit in the Biobio Region, Chile*. Geosur 2013, Abstracts. Viña del Mar (Chile), p. 234.

Gurr, PR. 1962. A new fishfauna from the Woolwich Bottom Beds (Sparnacian) of Herne Bay, Kent. *Proceedings of the Geologists' Association* **73:**419–447.

Herman J. 1982. Die Selachier-Zähne aus der Maastricht Stufe von Hemmoor, Niederelbe (NW-Deutschland). *Geologisches Jahrbuch, Reihe A* **61:**129–159.

Huxley TH. 1880. On the application of the laws of evolution to the arrangement of the Vertebrata, and more particularly of the Mammalia. *Proceedings of the Zoological Society of London* **43:**649–661.

Kennedy AT, Farnsworth A, Lunt DJ, Lear CH, Markwick PJ. 2015. Atmospheric and oceanic impacts of Antarctic glaciation across the Eocene–Oligocene transition. *Philosophical Transactions of the Royal Society A* **373:20140419**, 18 p.

Kriwet J. 2005. Additions to the Eocene Selachian fauna of Antarctica with comments on Antarctic selachian diversity. *Journal of Vertebrate Paleontology* **25:**1–7.

Kriwet J, Lirio JM, Nuñez H, Puceat E, Lecuyer C. 2006. Late Cretaceous Antarctic fish diversity. In: Francis JE, Pirrie D, Crame JA, eds. *Cretaceous–Tertiary High-latitude Palaeoenvironments: James Ross Basin, Antarctica*. Geological Society of London, Special Publications **258:** 83–100.

Kriwet J, Engelbrecht A, Mörs T, Reguero M, Pfaff C. 2016. Ultimate Eocene (Priabonian) chondrichthyans (Holocephali, Elasmobranchii) of Antarctica. *Journal of Vertebrate Paleontology* **36:** e1160911. 19 p.

Lawver LA, Gahagan LM, 2003. Evolution of Cenozoic seaways in the circumAntarctic region. Palaeogeography, Palaeoclimatology, Palaeoecology **198:**11–37.

Le Hon H. 1871. *Préliminaires d'un mémoire sur les poissons tertiaires de Belgique*. Brussels, 15 p.

Le Roux JP, Nielsen S, Henríquez Á. 2008. Depositional environment of *Stelloglyphus llicoensis* isp. nov.: a new radial trace fossil from the Neogene Ranquil Formation, south-central Chile. *Revista Geológica de Chile* **35:**307–319.

Leriche M. 1905. Les poissons éocènes de la Belgique. *Mémoires du Musée Royal d'Histoire Naturelle de Belgique* **3:**49–228.

Long DJ. 1992. Sharks from the La Meseta Formation (Eocene), Seymour Island, Antarctic Peninsula. *Journal of Vertebrate Paleontology* **12:**11–32.

Long DJ. 1993. Late Miocene and early Pliocene fish assemblages from the north central coast of Chile. *Tertiary Research* **14**:117–126.

Mannering AA, Hiller N. 2008. An Early Cenozoic neoselachian shark fauna from the Southwest Pacific. *Palaeontology* **51:**1341–1365.

Müller J, Henle F. 1838. On the generic characters of cartilaginous fishes, with descriptions of new genera. *Magazine of Natural History* **2:**33–37

Muñoz-Cristi J. 1946. Estado actual del conocimiento sobre la geología de la provincia de Arauco. *Anales Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile* **3:**30–63.

Muñoz-Cristi J. 1968. Contribución al conocimiento geológico de la región situada al sur de Arauco y participación del material volcánico en los sedimentos eocenos. In: Cecioni G, ed. *El Terciario de Chile. Zona central*. Santiago: Sociedad Geológica de Chile. Editorial Andrés Bello, 63–93.

Muñoz-Cristi J. 1973. *Geología de Chile.* Editorial Andrés Bello, Santiago. 209 p.

Muñoz-Ramírez CP, Zambrano P, Montoya G, Moyano H. 2007. Dientes de tiburones y rayas (Chondrichthyes, Elasmobranchii) de la Formacion Quiriquina aflorante en Talcahuano, Chile Central. *Boletín de la Sociedad de Biología de Concepción* **78:**7–22.

Nielsen S, Bandel K, Kröger B. 2006. Aturia cubaensis *(Lea, 1841) (Cephalopoda, Nautiloidea) in the Miocene of Chile: Paleobiogeography, taphonomy and mode of life*. Congreso Geológico Chileno N°9, Actas N° 2, Análisis de Cuencas, p. 89–92.

Nolf D. 1988. *Fossiles de Belgique. Dents de Requins et de Raies du Tertiaire de la Belgique*. Institut royal des Sciences naturelles de Belgique, 184 pp.

Oliver-Schneider C. 1936. El *Odontaspis elegans* (Agassiz) en el Terciario Eoceno de Chile. *Comunicaciones del Museo de Concepcion* **4:**77–78.

Otero RA. 2015. *Síntesis preliminar del registro fósil de vertebrados en Faro Carranza (Región del Maule) y su aporte al conocimiento geológico del área*. XIV Congreso Geológico de Chile (La Serena). 4 p.

Otero RA. 2019. *Loancorhynchus catrillancai* gen. et sp. nov., a new swordfish (Xiphioidei, Blochiidae) from the Middle Eocene of central Chile. *PeerJ* **e6671:**21 p

Otero RA. 2024. Review of two marine vertebrate assemblages from the Arauco Basin (central Chile) reveals diversity changes throughout the Maastrichtian. Cretaceous Research **166:105996**, 34 p.

Otero RA, Soto-Acuña S. 2015. New chondrichthyans from Bartonian-Priabonian levels of Río de Las Minas and Sierra Dorotea, Magallanes Basin, Chilean Patagonia. *Andean Geology* **42:**268–283.

Otero RA, Torres T, Le Roux JP, Hervé F, Fanning CM, Yury,-Yañez R, Rubilar-Rogers D. 2012. A late Eocene age proposal for the Loreto Formation, (Brunswick Peninsula, southernmost Chile), based on fossil cartilaginous fishes, paleobotany and radiometric evidence. Paleontological Note. *Andean Geology* **39:**180–200.

Otero RA, Oyarzún JL, Soto-Acuña S, Yury-Yáñez R, Gutierrez N, Le Roux J, Torres T, Hervé F. 2013. Neoselachians and Chimaeriformes (Chondrichthyes) from the Upper Cretaceous-Paleogene of Sierra Baguales, southernmost Chile. Chronostratigraphic, paleobiogeographic and paleoenvironmental implications. *Journal of South American Earth Sciences* **48:**13–30.

Philippi RA. 1887. *Los Fosiles Terciarios i Cuartarios de Chile.* F.A. Brockhaus printing, 236 pp. Leipzig.

Pineda V. 1983. *Evolución paleogeográfica de la Península de Arauco durante el Cretácico Superior-Terciario.* Degree Geologist Memoir, Universidad de Chile, Departamento de Geología (Inédito): 268 pp. Santiago.

Reguero, MA, Marenssi SA, Santillana SN. 2012. Weddellian marine/coastal vertebrates diversity from a basal horizon (Ypresian, Eocene) of the Cucullaea I Allomember, La Meseta Formation, Seymour (Marambio) Island, Antarctica. *Revista Peruana de Biología* **19:**275–284.

Reguero MA, Goin F, Acosta Hospitaleche C, Dutra T, Marenssi S. 2013. *Late Cretaceous/Paleogene West Antarctica terrestrial biota and its intercontinental affinities*. Geological Society (London) Special Publications, SpringerBriefs in Earth System Sciences, 120 p. London.

Reguero MA, Gasparini Z, Olivero EB, Coria RA, Fernández MS, O'Gorman JP, Gouiric-Cavalli S, Acosta Hospitaleche C, Bona P, Iglesias A, Gelfo JN, Raffi ME, Moly JJ,

Santillana SN, Cárdenas M. 2022. Late Campanian-Early Maastrichtian Vertebrates from the James Ross Basin, West Antarctica: updated synthesis, biostratigraphy, and paleobiogeography. *Annals of the Brazilian Academy of Sciences* **94(Suppl. 1):**e20211142, 35 p.

Richter M, Ward DJ. 1990. Fish remains from the Santa Marta Formation (Late Cretaceous) of James Ross Island, Antarctica. *Antarctic Science* **2:**67–76.

Rodriguez D, Ward DJ, Quezada JA. 2023. Paleontology and stratigraphic implications of a late Paleocene elasmobranch assemblage in Talcahuano, southcentral Chile. Andean Geology **50:**217–247.

Schweitzer CE, Feldmann RM. 2002. New Eocene decapods (Thalassinidea and Brachyura) from Southern California. *Journal of Crustacean Biology* **22:**938–967.

Schweitzer CE, Feldmann RM, Garassino A, Karasawa H, Schweigert G. 2010. Systematic list of fossil decapod crustacean species. *Crustaceana Monographs* **10:**1–222.

Suárez ME. 2015. Tiburones, Rayas y Quimeras (Chondrichthyes) Fosiles de Chile. In: Rubilar-Rogers D, Otero RA, Vargas AO, Sallaberry M., eds. *Vertebrados Fósiles de Chile*. Publicacion Ocasional del Museo Nacional de Historia Natural (Chile) **63:**17–33.

Suárez ME, Marquardt C. 2003. *Revision preliminar de las faunas de peces elasmobranquios del Mesozoico y Cenozoico de Chile*. Congreso Geológico Chileno n° 10 (Concepción), Sesion temática 3, Paleontología. Actas, CD-ROM. Universidad de Concepcion, 9 pp.

Suárez ME, Otero RA. 2008. *Nuevos hallazgos de vertebrados marinos en el Campaniano–Maastrichtiano de Loanco, VII Region.* Actas del I Simposio de Paleontología en Chile (Santiago), 78–82.

Suárez ME, Otero RA. 2010. *Primer registro de restos asociados de Isurolamna Cappetta, 1976 (Chondrichthyes, Elasmobranchii) en el Paleógeno de Loanco, Región del Maule*. Segundo Simposio Paleontología en Chile (Concepción), Libro de Actas, p. 15.

Suárez ME, Quinzio LA, Fritis O, Bonilla R. 2003. *Aportes al conocimiento de los vertebrados marinos de la Formación Quiriquina.* Congreso Geológico Chileno n° 10 (Concepción), Sesión temática 3, Paleontología. Actas: 7 pp.

Tavera J. 1942. Contribución al estudio de la estratigrafía y paleontología del Terciario de Arauco. *Congreso Panamericano de Ingeniería de Minas y Geología 1 (Santiago), Anales Parte 1*, **2:** 580–632.

Tavera J. 1980. *Cretáceo y Terciario de la localidad de Algarrobo*. Imprentas Gráficas Conchalí, 45 pp. Santiago.

Valdés C. 2019. *Cenozoico de Loanco y análisis de la Cuenca de Chanco (35°27'-35°42'), Región del Maule, Chile central*. Geologist degree Thesis, Facultad de Ingeniería, Geología, Universidad Andrés Bello, 103 p. Santiago.

Winkler TC. 1874. Mémoire sur des dents de poissons du terrain bruxellien. *Archives du Musée Teyler* **3:**295–304.

Winkler TC. 1880. Note sur quelques dents de poissons fossiles de l'Oligocène inférieur et moyen du Limbourg. *Archives du Musée Teyler* **5:**73–84.

Zhelezko VI, Kozlov V. 1999. Elasmobranchii i biostratigraphia paleogena Zauralia i Srednei Asii. *Materialy po Stratigrafii i Paleontologii Urala* **3:**324 pp. Ekaterinburg.

Zinsmeister WJ. 1979. Biogeographic significance of the Late Mesozoic and early Tertiary molluscan faunas of Seymour Island (Antarctic Peninsula) to the final break-up of Gondwanaland. In: Gray J, Boucot AJ., eds. *Historical Biogeography, Plate Tectonics and the Changing Environment*. Oregon State University Press, Corvallis, OR, pp. 349–355.

Table 1(on next page)

Summary of the Paleogene chondrichthyan record from central Chile.

Available publications, identified taxa and provenance, ordered from older to younger chronostratigraphic occurrences, and comments on their updated status.

Table 1: Summary of the available publications, identified taxa and provenance of the Paleogene chondrichthyan record from central Chile, ordered from older to younger chronostratigraphic occurrences, and comments on their updated status.

original reference	**identified taxa**	**Age**	**horizon**	**locality**	**Repository**	**updated status**
Muñoz-Ramirez et al., 2007	*Squalus* sp.~~,~~ *Squatina* sp., *Cretorectolobus* sp., *Carcharias* sp., *Palaeohypotodus* sp., *Scapanorhynchus* sp., *Palaeogaleus* sp., *Galeorhinus* sp., *Paraorthacodus* sp., *Dasyatis* sp., *Rhinoptera* sp., ?Dasyatidae indet.	Paleocene	Cosmito Formation	Talcahuano, Región del Biobio	Museo Lajos Biró (Q.)	—
Groz and Palma-Heldt, 2013	*Squalus* sp., *Squatina* sp., *Carcharias* sp., *Palaeohypotodus* sp., *Scapanorhynchus* sp., *Paraorthacodus* sp., *Rhinoptera* sp., *Cretorectolobus* sp., *Palaeogaleus* sp., *Galeorhinus* sp., *Dasyatis* sp.	Paleocene	Cosmito Formation	Talcahuano, Región del Biobio	not indicated. Likely, Museo Lajos Biró (Q.)	review and stratigraphic assessment of samples described by Miñoz-Ramirez et al. (2007)
Rodriguez et al., 2023	*Paraorthacodus clarkii*, *Squalus minor*, *Squalus orpiensis*, *Centrophorus* sp., *Squatina prima*, *Anomotodon novus*, *Striatolamia striata*, *Carcharias* spp., *Sylvestrilamia teretidens*, *Odontaspis winkleri*, *Palaeohypotodus speyeri*, *Palaeohypotodus rutoti*, *Isurolamna inflata*, *Premontreia gilberti*, *Physogaleus secundus*, *Palaeogaleus vincenti*, *Hypolophodon sylvestris*.	late Paleocene	Pilpilco Formation	Puente Perales and Cerro San Martín, Región del Biobio	Museo Lajos Biró (Q.)	Review needed. This study suggest keeping under open nomenclature the following taxa due to dubious adscription based on a single sample: *Paraorthacodus* sp., *Squalus* sp., *Centrophorus* sp., *Squatina* sp., *Anomotodon* sp. *Carcharias* spp., *Sylvestrilamia teretidens*, *Odontaspis winkleri*, *Palaeohypotodus speyeri*, *Palaeohypotodus rutoti* and *Isurolamna inflata*. On the other hand, *Premontreia gilberti*, *Physogaleus secundus*, *Palaeogaleus vincenti are easily distinguishable based on a single tooth; finally Striatolamia striata* and *Hypolophodon sylvestris* are based in several samples .
~~Fernández~~ et al., 2016	*Carcharias “hopei”*, *Carcharias* sp., *Striatolamia macrota*, *Myliobatis* sp.	Eocene (undifferentiated)	Cosmito Formation	Coliumo, Región del Biobio	Museo Lajos Biró (Q.)	—
Oliver-Schneider, 1936a, b	*Odontaspis elegans*	Eocene (undifferentiated)	Lebu Group, without further resolution	Lota and Lebu river, Región del Biobio	unknown	Inverifiable
Oliver-Schneider, 1936b	*Odontaspis contortidens*	Eocene (undifferentiated)	Lebu Group, without further resolution	Lebu	unknown	Inverifiable

Suárez and Marquardt, 2003	*Myliobatis* sp.	Eocene (undifferentiated)	Estratos de Algarrobo	Algarrobo, Región de Valparaíso	unknown	unknown repository; at least two genera of Myliobatoidea occur in Algarrobo (Otero, 2024)
Suárez and Otero, 2010	'*Isurolamna*' sp.	middle-upper Eocene	Millongue Formation	Loanco, Región del Maule	MNHN (SGO.PV.6635)	*Lethenia carranzaensis* sp. nov.; this study
Otero, 2015	'*Isurolamna*' sp., *Macrorhizodus praecursor*	middle-upper Eocene	Millongue Formation	Loanco, Región del Maule	not indicated then (MNHN; SGO.PV.6633)	not changed. Described by first time in this study

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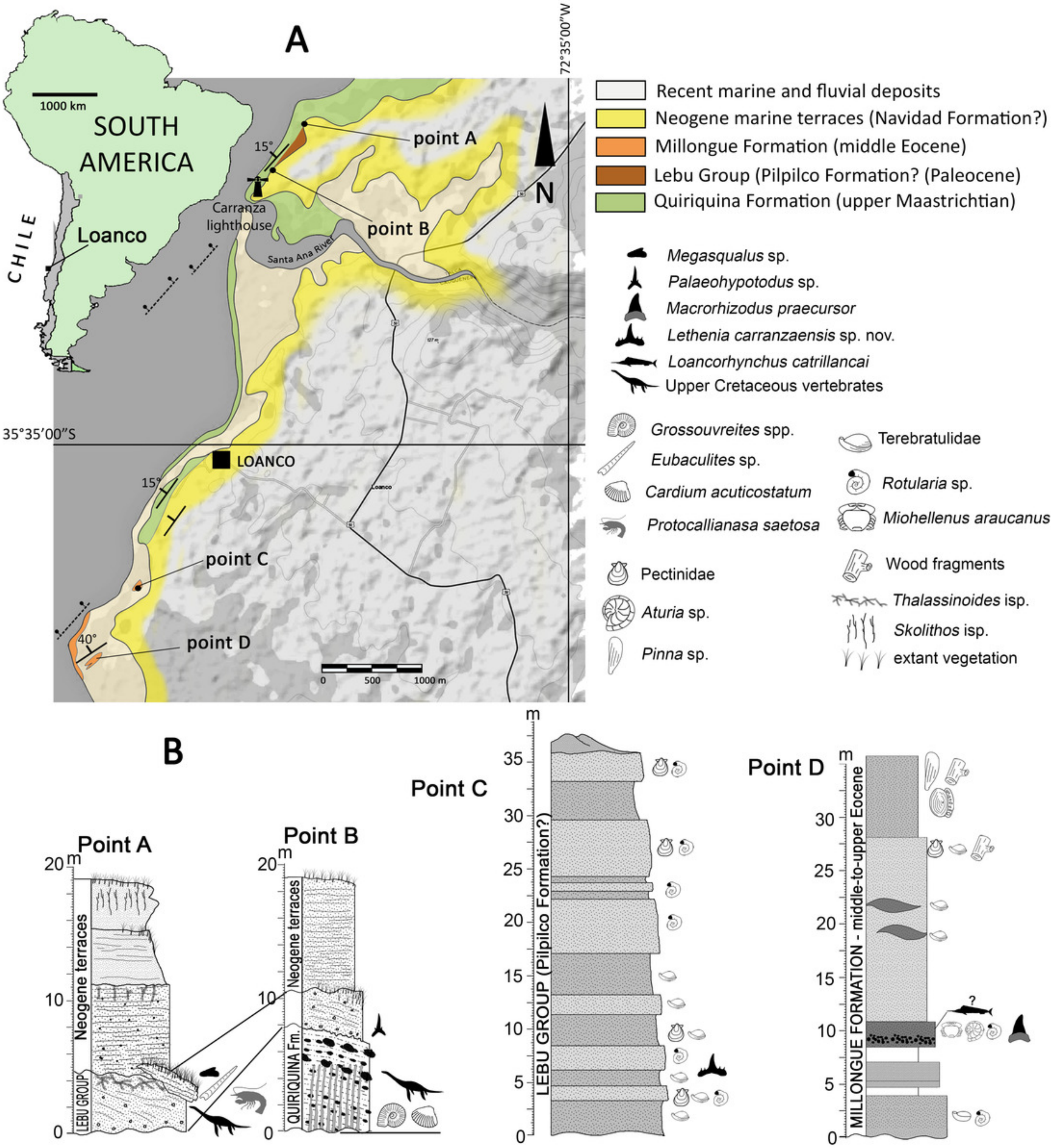
Figure 1

Locality and stratigraphic sections.

(A) map indicating the locality of Loanco, in central Chile. Geologic scheme of the outcrops exposed along the coast and cliffs in Loanco. Modified from Otero (2024). (B) Studied stratigraphic sections. Each point is marked on the geologic scheme in (A). Point A and B columns, modified from Otero (2024).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point A
point B
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Carranza lighthouse
Santa Ana River
LOANCO
15°
15°
40°
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0 500 1000 m
Recent marine and fluvial deposits
Neogene marine terraces (Navidad Formation?)
Millongue Formation (middle Eocene)
Lebu Group (Pilpilco Formation? (Paleocene)
Quiriquina Formation (upper Maastrichtian)
Megasqualus sp.
Palaeohypotodus sp.
Macrorhizodus praecursor
Lethenia carranzaensis sp. nov.
Loancorhynchus catrillancai
Upper Cretaceous vertebrates
Grossouvreites spp.
Eubaculites sp.
Cardium acuticostatum
Protocallianasa saetosa
Pectinidae
Aturia sp.
Pinna sp.
Terebratulidae
Rotularia sp.
Miohellenus araucanus
Wood fragments
Thalassinoides isp.
Skolithos isp.
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Neogene terraces
LEBU GROUP
QUIRIQUINA Fm.
LEBU GROUP (Pilpilco Formation?)
MILLONGUE FORMATION - middle-to-upper Eocene
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Figure 2

Chondrichthyans from Loanco, central Chile.

(A) *Megasqualus* sp. (SGO.PV.6625), isolated lateral tooth in labial view. (B) same in lingual view. (C) Hexanchidae indet. (SGO.PV.6626) isolated main crown in lingual view. (D) *Palaeohypotodus* sp. (SGO.PV.6780), single posterior tooth. Pilpilco Formation, upper Paleocene-lower Eocene. (F) *Macrorhizodus praecursor* (Leriche, 1905) (SGO.PV.6633a, referred) upper inferior tooth in labial view. (G) same in lingual view. (H) *Macrorhizodus praecursor* (Leriche, 1905) (SGO.PV.6633b, referred), incomplete tooth in labial view. (I) same in lingual view. Millongue Formation, upper Eocene-lower Oligocene. Scale bar equals 10 mm in both cases.

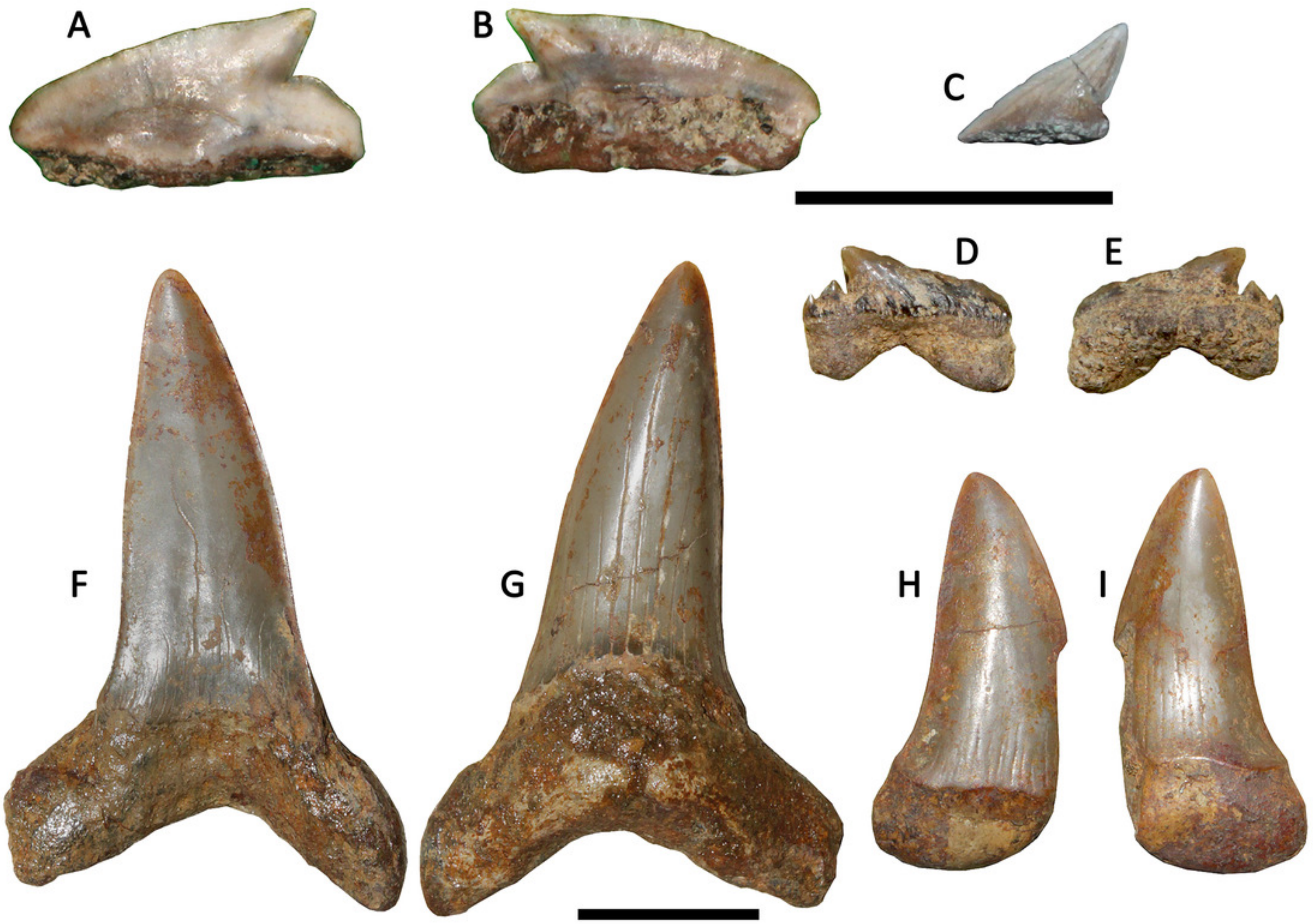
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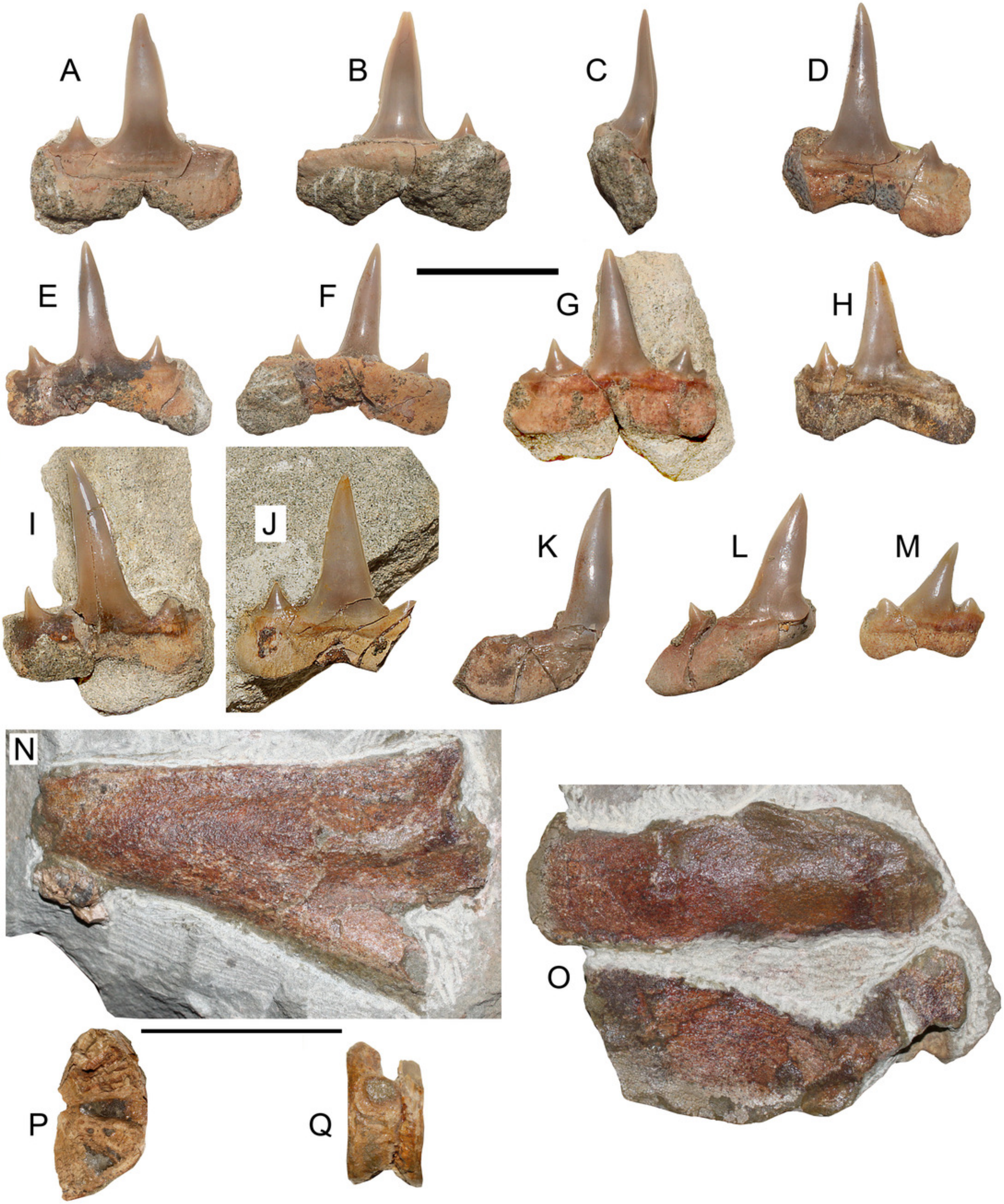
Figure 3

Lethenia carranzaensis sp. nov. (SGO.PV.6635, holotype).

Preserved teeth. (A) anterior tooth in labial view. (B) same in lingual view. (C) profile view. (D) incomplete anterior tooth. (E) anterolateral tooth in labial view. (F) same in lingual view. (G) anterior tooth in labial view. (H) anterolateral tooth in labial view. (I) posterolateral tooth in labial view. (J) anterior tooth in labial view. (K, L, M) Different posterolateral teeth. (N, O) Cartilaginous fragments of the jaw. (P) associated vertebra in articular view. (Q) same in lateral view. Scale bars equals 10 mm, except N-Q, 50 mm.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