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NEW CHONDRICHTHYANS FROM THE UPPER CRETACEOUS (CAMPANIAN–MAASTRICHTIAN) OF SEYMOUR AND JAMES ROSS ISLANDS, ANTARCTICA

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ABSTRACT—We present new records of chondrichthyans recovered from strata of Maastrichtian age of the López de Bertodano Formation, Seymour (=Marambio) Island, and from levels of latest Campanian age of the Santa Marta Formation, James Ross Island, both located in the eastern Antarctic Peninsula. The material from Marambio Island comprises an associated assemblage with the first records of an indeterminate odontaspidid different from *Odontaspis*, as well as the genera *Pristiophorus*, *Squatina*, *Paraorthacodus*, and the species *Chlamydoselachus tatere* from the López de Bertodano Formation. Also, the studied section provides a well-constrained age for several taxa already recognized in the López de Bertodano Formation only by scattered samples of Maastrichtian age for the first time. The assemblage from Marambio Island is representative of one of the latest environmental conditions during the end of the Cretaceous in the coastal seas of the Larsen Basin before major changes that began after the K/P boundary. In addition, the finds from James Ross Island comprise the southernmost records of the neoselachians *Cretalamna* sp., *Centrophoroides* sp., as well as the holocephalans *Callorhinchus* sp. and an indeterminate rhinochimaerid, extending the occurrence of some of these taxa into the late Campanian, being their oldest record of the Weddellian Biogeographic Province.

INTRODUCTION

UPPER CRETACEOUS cartilaginous fishes (Chondrichthyes) from Antarctica have been described since the early twentieth century. Records of chondrichthyans from late Maastrichtian beds of the López de Bertodano Formation exposed on the Seymour (=Marambio) Island, west of Antarctic Peninsula, started with Woodward (1906) who indicated the presence of large vertebral centra referred with doubts to *Ptychodus* Agassiz 1835, discarded later by Welton and Zinsmeister (1980) and then referred to as Lamniformes indet. by Kriwet et al. (2006). Additional finds from Seymour Island include remains of the genus *Isurus* Rafinesque, 1810 (Grande and Eastman, 1986), emended by Richter and Ward (1990), who referred this to the genus *Sphenodus* Agassiz, 1843. Also, the hexanchid *Notidanodon dentatus* (Woodward, 1886) was reported (Cione and Medina, 1987; Grande and Chatterjee, 1987; Martin and Crame, 2006). Odontaspidid sharks were previously recognized by Martin and Crame (2006) who identified the genus *Odontaspis* Agassiz (1838) and cf. *Odontaspis* sp. In addition, callorhynchid fishes (Elasmobranchii, Holocephali, Chimaeriformes) from late Maastrichtian beds of Seymour Island include the presence of endemic elements such *Chimaera zangerli* Stahl and Chatterjee, 1999 and *Callorhinchus torresi* Otero et al., 2013, as well as other taxa within the group with widespread geographic and stratigraphic distributions such as *Ischyodus dolloi* Leriche 1902 (Stahl and Chatterjee, 2002), and the genus *Callorhinchus* Lacépède, 1798 (Martin and Crame, 2006). Most of these previous records have been identified through scattered samples and their general age was regarded unspecifically as Maastrichtian (Kriwet et al., 2006). The best age-constrained materials were described by Martin and Crame (2006) with two taxa (particularly, *Callorhinchus* sp. and *N. dentatus*) from the López de Bertodano Formation, recovered near the well-dated K/P boundary, thus, having a latest Maastrichtian age.

In addition to these records from Seymour Island, late Campanian beds of the Santa Marta Formation exposed on James Ross Island, Antarctica, have yielded specimens referable to the species *Chimaera zangerli* Stahl and Chatterjee, 1999, *Notidanodon dentatus*, *Chlamydoselachus thompsoni* Richter and Ward, 1990, the genera *Sphenodus* Agassiz, 1843, *Paraorthacodus* Glikman,1957, *Squatina* Dúmeril, 1906, *Scapanorhynchus* Davis, 1887, as well as indeterminate Lamniformes (Cione and Medina, 1987; Grande and Eastman, 1986; Kriwet et al., 2006; Richter and Ward, 1990; Stahl and Chatterjee, 1999; Woodward, 1906).

The present paper describes two sets of findings. The first set belongs to remains of different chondrichthyan taxa found directly associated, which occurred all together in a single section of the López de Bertodano Formation on Seymour Island. These are significant by providing an assemblage with a well-constrained age, representing a relatively rich diversity that can be compared with possibly contemporary findings previously described from lower latitudes of the Weddellian Biogeographic Province (WBP) (Zinsmeister, 1979). The assemblage from Seymour Island allows us to recognize the first records of an indeterminate odontaspidid different from the genus *Odontaspis*, as well as the genera *Pristiophorus* Müller and Henle, 1837, *Squatina*, *Paraorthacodus*, and *Chlamydoselachus* in upper levels of the López de Bertodano Formation exposed on Seymour Island. The second set includes new additions to the fossil diversity of chondrichthyans from the late Campanian of the Santa Marta Formation of James Ross Island, all consisting of isolated materials. Among these, there is the first record of the species *Cretalamna* sp. Agassiz, 1843 and the

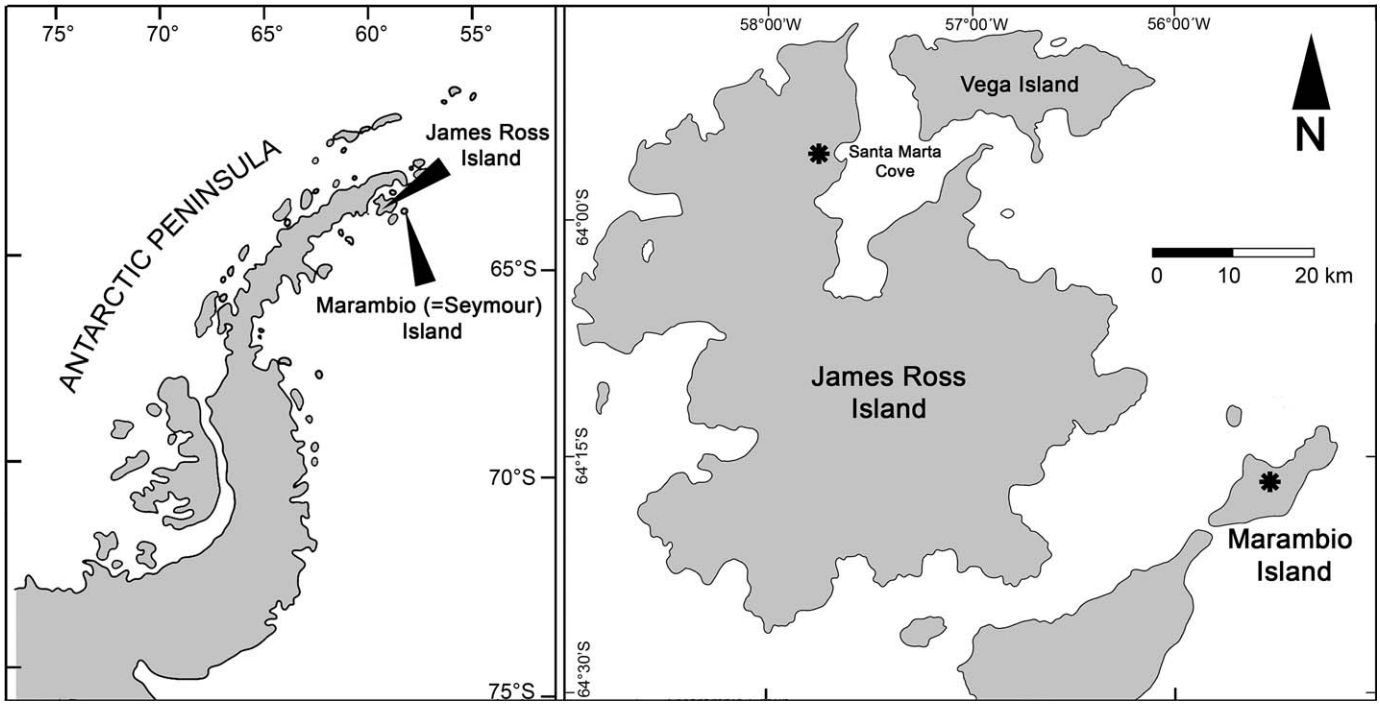

FIGURE 1—Schematic map of the Antarctic Peninsula, indicating the Marambio and James Ross islands. The star indicates the localities where the studied materials were recovered.

genus *Centrophoroides* Davis, 1887 in Antarctica. Also, the first records of the holocephalans *Callorhinchus* sp. and an indeterminate rhinochimaerid from the Santa Marta Formation are reported here.

LOCALITY AND GEOLOGIC SETTING

The two studied localities are situated in the western part of the Antarctic Peninsula (Fig. 1). The materials recovered from Seymour Island (S 64°16′05″, W 56°42′38.8″) were collected in January 2011 by CSG, DRR, RAO, and RYY. The single fossil-bearing bed is part of the López de Bertodano Formation (Rinaldi et al., 1978). The materials from James Ross Island were recovered in February 2012 by a second team (AVM, DRR, RAO, RYY) from siltstone beds consistent with the upper part of the Gamma Member (Lithofacies Association E, sensu Scasso et al., 1991) of the Santa Marta Formation (Olivero et al., 1986), and represent a shallow marine environment.

The López de Bertodano Formation (Rinaldi et al., 1978) is exposed on the southwestern half of the Seymour Island. It comprises a monotonous lithology, mainly friable sandy siltstones of yellow to gray color, variable in hardness, but relatively constant in grain size and mud percentage. It is characterized by an upward increase in glauconite and a volcanic component of the sand fraction (Macellari, 1988). The age of this formation was assigned to the Maastrichtian–Paleocene (Macellari, 1988), based on mollusks (Zinsmeister, 1979, 1982), microfossils (Huber, 1988) and palynomorphs (Askin, 1989). Later, most of the levels of this formation were constrained to the latest Maastrichtian based on different stratigraphic criteria (Crame et al., 2004). The López de Bertodano Formation is overlaid by an unconformity with the Sobral Formation (Rinaldi, 1982; Macellari, 1984) and also the La Meseta Formation (Elliot and Trautman, 1982). Its base is in contact with the Snow Hill Island Formation (Pirrie et al., 1997) through an unconformity contact. Following Macellari (1984, 1988) the López de Bertodano Formation is divided into 10 informal units, named from base to top as Klb1 to Klb9, and the uppermost KTplb10, the six lower units being characterized by the presence of distinctive beds with annelids (namely *Rotularia* units of Macellari, 1984). The upper units 7 to 10 (molluscan units) are characterized by abundant, well-preserved fossils of ammonoids, bivalves, less frequent decapods and vertebrates (Macellari, 1984). The materials were recovered from a single siltstone level placed few meters below the boundary between the Klb9 and KTplb10 units.

The single horizon where the studied material was collected is placed few meters under distinctive levels of glauconite which includes abundant fragments of disarticulated bony fishes near its base. Such lithology, together with the kind of fossils and preservation, was considered indicative of the K/T boundary (Zinsmeister, 1998).

The studied section on James Ross Island is exposed near the Santa Marta Cove, in the southeastern part of the island. The geology consists of Cretaceous marine sediments assigned to the Gustav Group and Marambio Group, part of the Larsen Basin (Scasso et al., 1991; Hathway, 2000) intruded by the James Ross Island Volcanic Group, a Neogene alkali volcanic sequence composed mainly of lava-fed deltas of hyaloclastic breccias and minor mantle xenoliths (Smellie, 1987; Bastías et al., 2012). The material was recovered from siltstone beds consistent with the upper part of the Gamma Member (Lithofacies Association E, sensu Scasso et al., 1991) of the Santa Marta Formation, which is the lower unit of the Marambio Group, and which is interpreted as a shallow marine environment (Olivero et al., 1986). Fossil vertebrates are represented by teeth of ichthyodectiforms, as well as remains of plesiosaurs and occasional remains of dinosaurs (Salgado and Gasparini, 2006; Cerda et al., 2012). Invertebrates are frequent and represented by gastropods (turritelids) and bivalves (mostly trigoniids). Driftwood remains are also abundant. The age of the Santa Marta Formation was assigned to the Santonian–Campanian based on fossil invertebrates and stratigraphic correlations (Olivero et al., 1986) while

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the Gamma Member was constrained to the late Campanian based on ammonoids (Olivero, 1992).

MATERIALS AND METHODS

Nearly 100 samples referable to vertebrate remains were obtained from the studied strata on Seymour Island. These were collected by direct picking over the fossil-bearing level. Sieving was avoided because of the high humidity as well as frozen mud that made very difficult the usage of this technique. The recovered material includes frequent but non-informative bone fragments of marine reptiles, elasmosaur teeth, mosasaur teeth of at least four different morphotypes, as well as the assemblage here studied. On the other hand, the material from James Ross Island is comprised exclusively by specimens collected on surface and was likely transported.

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

SYSTEMATIC PALEONTOLOGY

Class CHONDRICHTHYES Huxley, 1880
Subcohort NEOSELACHII Compagno, 1977
Order PRISTIOPHORIFORMES Berg, 1958
Family PRISTIOPHORIDAE Bleeker, 1859
Genus PRISTIOPHORUS Müller and Henle, 1837

Type species.—*Pristis cirratus* (Latham, 1793), Recent.

PRISTIOPHORUS sp.
Figure 2.1–2.5

Description.—The preserved teeth include two large and fragmentary crowns with part of its peduncle and one isolated peduncle, well preserved. Both preserved crowns display a flattened shape, with both anterior and posterior margins having smooth cutting edges. The enamel has profuse cracks. The preserved peduncles display the typical convex shape of the basal face (Cappetta, 1987), with abundant peripheral grooves and a deep, central nutritive foramen in the middle of the base of the root.

Material.—SGO.PV.6656, three incomplete rostral teeth. Seymour Island, Antarctica. López de Bertodano Formation, klb9 unit, late Maastrichtian.

Remarks.—Teeth of the genus *Pristiophorus* can be distinguished by their rostral spines with sharp, slender crown without serration, and their respective peduncles with a strongly concave basal surface (Latham, 1793). Also, despite the general similitude of the studied material with the genus *Ganopristis* Arambourg, 1935, the presence of a deep central nutritive groove in the first is a feature not observed in sclerorhynchids which usually have an antero-posterior groove on the base. Because no complete crowns were recovered, it is not possible to know the length of these rostral teeth, thus being impossible to identify them to species level. The new record of *Pristiophorus* represents its oldest record in the Seymour Island. Previous records in the Eocene of La Meseta Formation (Grande and Eastman, 1986) have been referred to the species *P. lanceolatus* (Kriwet, 2005).

Order LAMNIFORMES Berg, 1958
Family ODONTASPIDIDAE Müller and Henle, 1839
ODONTASPIDIDAE indeterminate
Figure 2.6–2.17

Description.—Odontaspidid teeth with high and slender crown with sigmoidal profile. Anterior teeth have a single lateral cusplet, inferred by the basal section that can be observed in most of the samples (e.g., Fig. 2.6), although the cusplet itself is absent. One lateral tooth preserves one of the cusplets, which is broad and short (Fig. 2.12). The lingual and labial face of the enameloid is smooth, without folds or any ornamentation. Roots have a lingual shelf, especially prominent in anterior teeth.

Material.—SGO.PV.6660, eight incomplete teeth. Seymour Island, Antarctica. López de Bertodano Formation, klb9 unit, late Maastrichtian.

Remarks.—Odontaspidid sharks have proven to be the most abundant taxon present in shallow-water assemblages from the Maastrichtian of the eastern Pacific (Cione et al., 2007; Suárez et al., 2003; Otero and Suárez, 2009). Among them, teeth of *Carcharias* can be recognized by having crowns with complete cutting edges or else, edges that reach close to the root, a flat labial face, absence of striations in the lingual surface, and presence of one or two lateral cusplets (Capetta, 1987; Compagno, 2001). Considering the record of the genus *Odontaspis* (Martin and Crame, 2006) from the late Maastrichtian of Seymour Island, the studied samples differs from the latter in having a more sigmoidal crown which is also less slender and not highly triangular in outline. The lack of complete specimens prevents any identification to genus level.

Superorder SQUATINOMORPHII Compagno, 1973
Order SQUATINIFORMES de Buen, 1926
Family SQUATINIDAE Bonaparte 1838
Genus SQUATINA Dúmeril, 1906

Type species.—‘*Squalus’* (*Squatina*) *squatina* (Linnaeus, 1758), Recent.

SQUATINA sp.
Figure 2.18–2.20

Description.—Isolated tooth lacking one lateral end. It has a complete cusp with smooth folds near the base. A bulk is noted over the lingual projection of the root, while its basal face has several nutritious foramina.

Material.—SGO.PV.6657, one isolated tooth. Seymour Island, Antarctica. López de Bertodano Formation, klb9 unit, late Maastrichtian.

Remarks.—Teeth of *Squatina* can be distinguished by their small size, with a sharp crown with lateral heels and a smooth, complete cutting edge, the presence of an apron in the base of the crown, and a root with a prominent lingual bulk (Cappetta, 1987). Previous occurrences from the Larsen Basin are known from the Gamma member of the Santa Marta Formation (Olivero et al., 1986), assigned to the late Campanian–?early Maastrichtian (Kriwet et al., 2006). The genus is also known from the Eocene of La Meseta Formation of Seymour Island (Welton and Zinsmeister, 1980; Grande and Eastman, 1986; Kriwet, 2005). The studied material verifies the presence of the genus in the latest Maastrichtian of Seymour Island, but does not allow a more specific identification.

Order HEXANCHIFORMES de Buen, 1926
Suborder CHLAMYDOSELACHOIDEI Berg, 1958
Family CHLAMYDOSELACHIDAE Garman, 1884
Genus CHLAMYDOSELACHUS Garman, 1884
CHLAMYDOSELACHUS TATERE Consoli, 2008
Figure 2.21–2.23

Type species.—*Chlamydoselachus tatere* Consoli, 2008, Danian of New Zealand.

Description.—The material preserves only one of the three cusps, which has a relatively thick and conical shape, not very high, with some foldings near its base and soft striations. The root is flat and broad, labiolingually short, having a notch over its occlusal surface, surrounded by two small ridges. The tooth lacks the prominent projections in lingual direction that are present in the extant species *C. anguineus*, and no accessory intermediate cusplets were present in the tooth, neither basal marks for them

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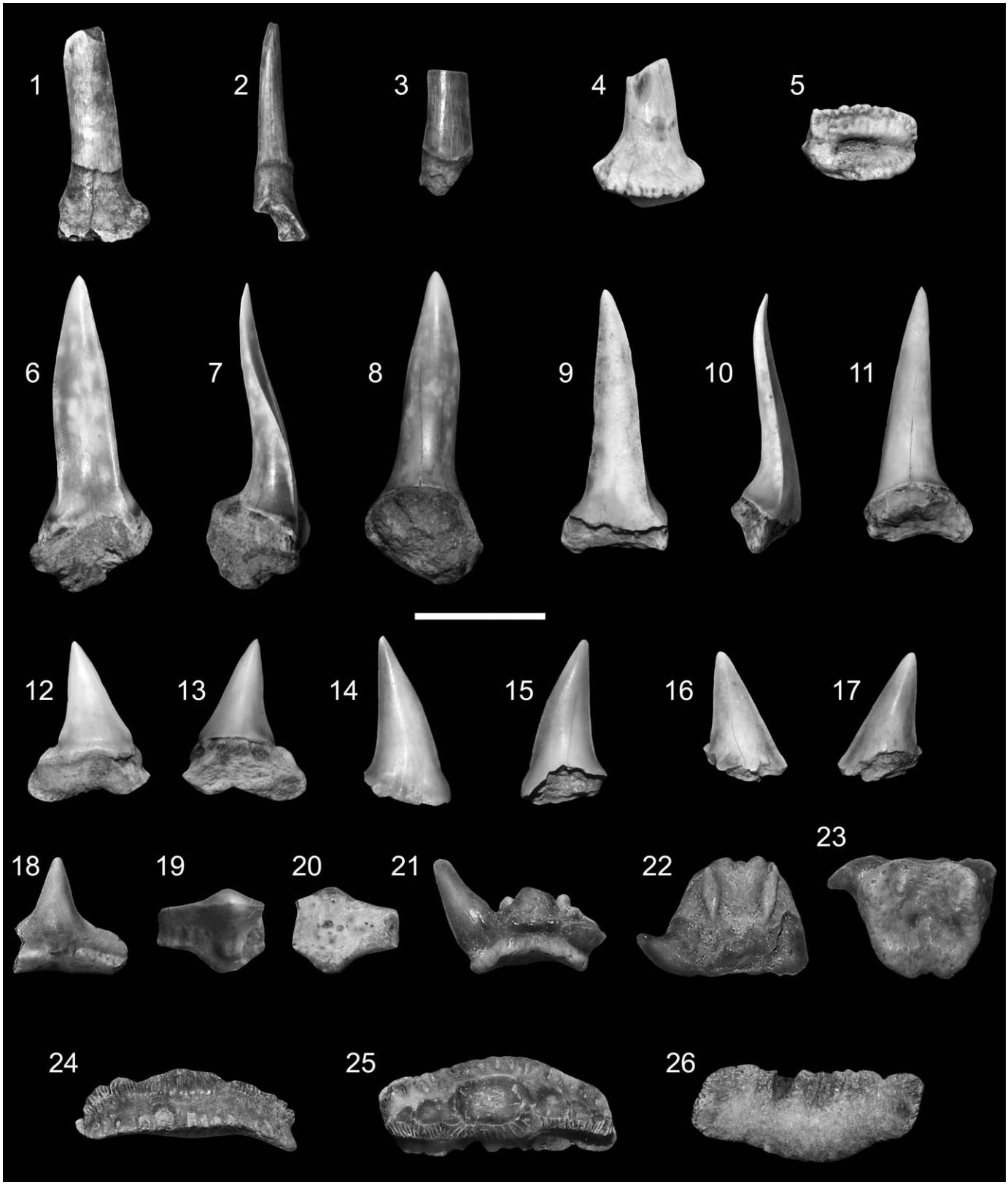

FIGURE 2—New chondrichthyans from late Maastrichtian levels of the López de Bertodano Formation, klb9 unit, on Seymour Island, Antarctica. *1–5*, SGO.PV.6656, *Pristiophorus* sp.: *1*, isolated rostral tooth lacking the top of the crown in dorsoventral view; *2*, same in anterior view; *3*, fragmentary rostral spine in dorsoventral view; *4*, isolated peduncle of a rostral spine in dorsoventral view; *5*, same in basal view; *6–17*, SGO.PV.6660, Odontaspididae indet., anterior teeth: *6*, *9*, labial views; *7*, *10*, profile views; *8*, *11*, lingual views; lateral teeth: *12*, *14*, *16*, labial views; *13*, *15*, *17*, lingual views; *18–20*, SGO. PV.6657, *Squatina* sp., isolated lateral tooth: *18*, labial view; *19*, occlusal view; *20*, basal view; *21–23*, SGO.PV.6658, *Chlamydoselachus tatere* Consoli, 2008, isolated lateral tooth: *21*, labial view; *22*, occlusal view; *23*, basal view; 24–26, SGO.PV.6659, *Paraorthacodus* sp., isolated lateral tooth: *24*, labial view; *25*, occlusal view; *26*, basal view. Scale bar=10 mm.

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that could indicate their presence and posterior absence because of the preservation.

Material.—SGO.PV.6658, one isolated tooth. Seymour Island, Antarctica. López de Bertodano Formation, klb9 unit, late Maastrichtian.

Remarks.—The morphologic features of the single tooth here studied matches with the diagnostic characters of the species *C. tatere* from Danian levels of New Zealand (Consoli, 2008). The new record of *Chlamydoselachus* in the López de Bertodano Formation is the first from the late Maastrichtian, and the third record from the Larsen Basin. The first record of the genus in Antarctica (*C. thompsoni*) is an endemic species recovered from Campanian levels (?Beta Member) of the Santa Marta Formation, on James Ross Island (Richter and Ward, 1990). Additional material from older levels of the same formation (early–late Campanian) were referred to the same species by Kriwet et al. (2006). This new record of *C. tatere* extends the distribution of the species into Antarctica as well as its stratigraphic occurrence into the late Maastrichtian.

Order Synechodontiformes Duffin and Ward, 1993
Family Palaeospinacidae Regan, 1906
Genus Paraorthacodus Glikman, 1957

Type species.—'*Sphenodus*' (*Paraorthacodus*) *recurvus* Trautschold, 1877, Cenomanian of Russia.

Paraorthacodus sp.
Figure 2.24–2.26

Description.—Tooth preserving the complete root and the base of the crown, which is massive and has several nutritive foramina on the labial surface and several nutritive grooves on the base. The crown only preserves its base and has several lateral cusplets on each side. In the recovered specimen, one very small cusplet remained on position on each side, having a total of four cusplets on each flange. The enameloid folds are particularly strong, covering all the preserved part of the crown. The root preserves the typical nutritious grooves and flat base of the genus. The isolated sample and its partial preservation do not allow identifying it at species level.

Material.—SGO.PV.6659, one isolated tooth. Seymour Island, Antarctica. López de Bertodano Formation, klb9 unit, late Maastrichtian.

Remarks.—The genus *Paraorthacodus* is a distinctive taxon having teeth with a massive, almost square root and a slender main crown with several lateral cusplets (Siverson, 1992; Duffin and Ward, 1993). The genus had a widespread distribution along the WBP. It was reported in the Upper Cretaceous of Argentina, and the species *P. patagonicus* (Ameghino, 1893), *P. sulcatus* (Davis, 1888), and *P. validus* (Chapman, 1918) were mentioned from the Upper Cretaceous of the Hamuri Bluff, New Zealand. All these species need to be reviewed; nevertheless, their generic determination appears to be reliable. The genus was also reported in the Maastrichtian and the Paleocene of Chile (Muñoz-Ramirez et al., 2007; Suárez et al., 2003). It is recorded in Antarctica since the early Upper Cretaceous (Klug et al., 2008), while younger records are reported from the Beta Member of the Santa Marta Formation, James Ross Island (Kriwet et al., 2006), assigned to the early to late Campanian based on biostratigraphy and radiometric dating (Olivero et al., 1992; Olivero and Medina, 2000). Klug et al. (2008) introduced the species *P. antarcticus*, confined exclusively to the Santonian–early Maastrichtian of the Santa Marta Formation. The present find is the first in the latest Maastrichtian of the López de Bertodano Formation and the youngest record of the genus in the Larsen Basin. Regretfully, the incompleteness of the studied specimen as well as the absence of additional samples avoid identify it to species-level.

Family Otodontidae Glikman 1964
Genus Cretalamna Glickman, 1958

Type species.—'*Lamna*' (*Cretalamna*) *appendiculata* Agassiz, 1843, Turonian of England.

Cretalamna sp.
Figure 3.1–3.3

Description.—Tooth with high and triangular crown, labiolingually compressed, with complete cutting edges. One lateral cusplet on each side of the crown, having a triangular shape, a complete cutting edge, and also being labiolingually compressed. The root has a medial constriction with squared and robust branches. The anterior branch is missing.

Material.—SGO.PV.6661, one isolated lateral tooth. James Ross Island, Antarctica. Santa Marta Formation, Beta member, middle to late Campanian.

Remarks.—Teeth of *Cretalamna* are up to 3 cm high, with a triangular crown broader in its base, one to three triangular lateral cusplets, complete soft cutting edges, and a smooth enamel (Cappetta, 1987). Southernmost records of the species *Cretalamna* are known from Upper Cretaceous strata of Argentina (Ameghino, 1906; Arratia and Cione, 1996; Bogan and Agnolin, 2010). The present find in late Campanian levels of the James Ross Island is the oldest record along the WBP and the southernmost known record of the species.

Order Squaliformes Goodrich, 1909
Family Squalidae Bonaparte, 1834
Genus Centrophoroides Davis, 1887

Type species.—*Centrophoroides latidens* Davis, 1887, Santonian of Lebanon.

Centrophoroides sp.
Figure 3.4

Description.—Cast preserving the labial surface of a small tooth that is broader than high, having short crowns recurved backwards, with complete cutting edges along the cusp and the distal margin of the crown. The mesial portion of the cutting edge bears irregular serrations. The labial face presents a broken apron. The root is short, and narrower than the crown, having several nutritious foramina.

Material.—SGO.PV.6662, one isolated tooth cast. James Ross Island, Antarctica. Santa Marta Formation, Gamma member, late Campanian.

Remarks.—*Centrophoroides* possesses teeth smaller than 7 mm with a low, posteriorly recurved crown with an irregularly serrated cutting edge, a low posterior heel with a smooth cutting edge, a basal, apron-like small projection of the labial face of the crown, and a root with two deep grooves (Cappetta, 1987). Previous records of the genus *Centrophoroides* in the WBP includes its occurrence in early Maastrichtian beds of central Chile (Suárez et al., 2003) as well as in late Maastrichtian strata of south-central Chile (Suárez et al., 2003). Also, it was recorded in Maastrichtian levels of southernmost Chile (Otero and Suárez, 2009). The present finding in late Campanian beds of the James Ross Island in Antarctica comprises its oldest record in the WBP and southernmost known record of the genus.

Superorder Holocephali Bonaparte, 1832
Order Chimaeriformes Obruchev, 1953
Family Rhinochimaeridae Garman, 1901
Rhinochimaeridae indeterminate
Figure 3.5–3.8

Description.—Incomplete right palatine that preserves most of its anterior portion, only lacking a small fragment of its anterior midline. The plate is very thin and compressed dorsoventrally,

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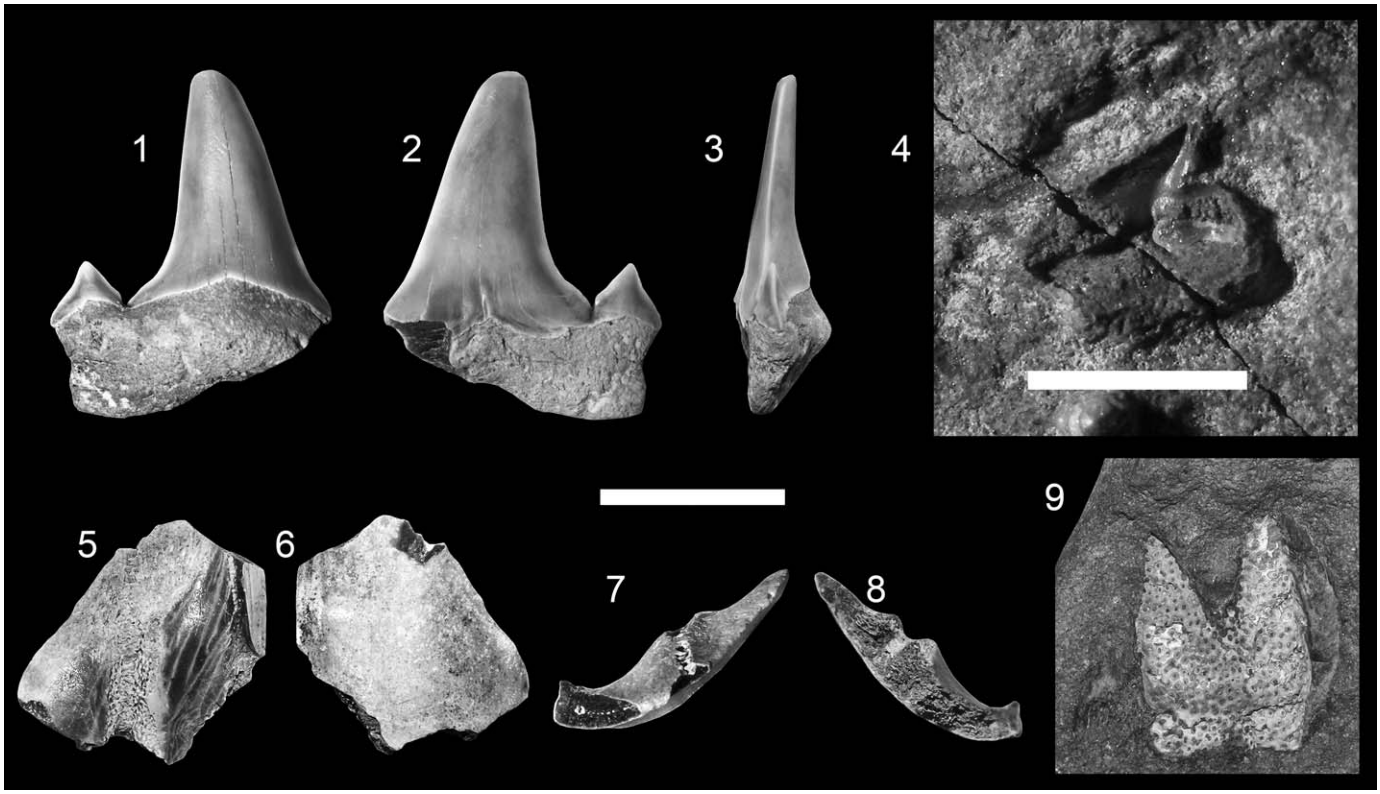

FIGURE 3—New chondrichthyans from late Campanian levels of the Santa Marta Formation, Gamma Member, on James Ross Island, Antarctica. *1–3*, SGO.PV.6661, *Cretalamna* sp. (Agassiz): *1*, lateral tooth in labial view; *2*, same in lingual view; *3*, profile view; *4*, SGO.PV.6662, *Centrophoroides* sp., cast of a lateral tooth showing its lingual surface; *5–8*, SGO.PV.6665, Rhinochimaeridae indet.: *5*, right palatine in occlusal view; *6*, same in basal view; *7*, anterior view; *8*, posterior view; *9*, SGO.PV.6664, *Chimaera zangerli* Stahl and Chatterjee, right palatine in occlusal view; 10, SGO.PV.6663, *Callorhinchus* sp., right palatine in occlusal view. Scale bar=10 mm, except in *4* (5 mm).

being labiolingually recurved and having only two parallel tritors, the medial one being larger and fading anteriorly, while the second tritor is disposed almost in the midline. The symphyseal margin is preserved by a small portion which is straight. In basal view, no descending lamina is present, while the surface is smooth and convex, without any line or ornamentation.

Material.—SGO.PV.6665, one incomplete right palatine. James Ross Island, Antarctica. Santa Marta Formation, Gamma member, late Campanian.

Remarks.—The absence of descending lamina allows discarding the material as belonging to any callorhynchid (Stahl, 1999), while the thin plate differs from the typically massive plates of the Edaphodontinae (Stahl, 1999). Thin palatines without a descending lamina are considered by Stahl (1999) as diagnostic of the Rhinochimaeridae. The presence of only two parallel tritors with one of them in the midline is similar to that described for the rhinochimaerid genus *Lebediodon* from the Upper Cretaceous of Russia (Nessov and Averianov, 1996; Stahl, 1999). The fragmentary nature of the single specimen does not allow any generic determination, although it represents the first Upper Cretaceous rhinochimaerid from Antarctica and the southernmost known occurrence of the family.

Family CALLORHYNCHIDAE Garman, 1901
Subfamily CALLORHYNCHINAE Stahl, 1999
Genus CALLORHINCHUS Lacépède, 1798

Type species.—*Callorhinchus callorhynchus* Linnaeus, 1758, extant species of the Southern Hemisphere.

CALLORHINCHUS sp.
Figure 3.9

Description.—Incomplete palatine preserving most of the tritor and part of the labial margin of the plate. The tritor has a distinctive bifid shape towards the anterolabial margin.

Material.—SGO.PV.6663, an incomplete right palatine. James Ross Island, Antarctica. Santa Marta Formation, Gamma member, late Campanian.

Remarks.—The bifid tritor of the palatine is considered diagnostic of the genus *Callorhinchus* (Kriwet and Gaździcki, 2003; Stahl, 1999). The recovered specimen has a palatine with two massive branches that are very similar in outline. The outline of the palatine appears intermediate between that of *C. hectori* from the Cenomanian of New Zealand (Newton, 1876) and that of *C. torresi* from the late Maastrichtian of Seymour Island, Antarctica (Otero et al., 2013), suggesting an intermediate form between both, which is consistent with its late Campanian age. Due to the fragmentary nature of the material, no specific determinations can be proposed. The present record is the oldest record of the genus *Callorhinchus* in Antarctica.

DISCUSSION

Stratigraphic distribution of Upper Cretaceous condrichthyans from Antarctica.—The synthesis of Upper Cretaceous Antarctic diversity of chondrichtyans (Table 1) shows that several taxa present continuity through the Campanian–Maastrichtian. The genera *Chlamydoselachus* and *Paraorthacodus* are represented in the late Campanian, remaining unreported in lower units of the López de Bertodano Formation, and reappearing in the klb9, near the K/P boundary. The only record from other locality of the WBP comprise material recovered from Danian levels at Chatham Islands, New Zealand (Consoli, 2008). The taxa *Squatina*, *Callorhinchus*, and *Chimaera zangerli* are known in the late Campanian (Beta Member) and in the klb9. All these

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TABLE 1—Stratigraphic distribution of Upper Cretaceous chondrichthyans from Antarctica. Letters indicate the source of information as following: K=Kriwet et al., 2006; M=Martin and Crame, 2006; O=Otero et al., 2013; S=Stahl and Chatterjee, 1999; SC=Stahl and Chatterjee, 2002; T=this study.

	James Ross Island		Marambio Island		
	Santa Marta Formation		López de Bertodano Formation		
taxa	Beta Member	Gamma Member	undifferentiated	klb6	klb9
Chalmydoselachus thompsoni	K	K			
Chlamydoselachus tatere					T
Notidanodon dentatus	K	K	K		M, T
Sphenodus sp.	K	K	K		
Paraorthacodus sp.	K	K			T
Squatina sp.		K			T
Scapanorhynchus sp.		K			
Odontaspis sp.			M		
Ischyodus dolloi				SC	
Callorhinchus torresi					O
Chimaera zangerli		K, T	K		S
Chimaeridae indet.			M		
Callorhinchus sp.		T			M
Pristiophorus sp.					T
Carcharias sp.					T
Cretalamna appendiculata		T			
Centrophoroides sp.		T			
Rhinochimaeridae indet.		T			

genera are probably present along the lower and middle levels of the López de Bertodano Formation. In addition, *Notidanodon dentatus* is one of the most abundant chondrichtyans and at the moment seems to be the taxon with the most complete stratigraphic distribution in the Campanian–Maastrichtian.

Several taxa remain exclusively known from the late Campanian of the Santa Marta Formation, particularly, the species *Cretalamna appendiculata*, the genera *Centrophoroides*, *Scapanorhynchus*, and the present record of an indeterminate rhinochimaerid. On the other hand, taxa exclusively constrained to the late Maastrichtian of the López de Bertodano Formation include the genera *Odontaspis*, *Pristiophorus*, as well as the species *Ischyodus dolloi* and *Callorhinchus torresi*. Finally, the genus *Sphenodus* seems to be present in both members of the Santa Marta Formation and in undifferentiated levels of the López de Bertodano Formation, although no records are known in the upper units such as the klb9.

Associated vertebrates found in Seymour Island.—The assemblage from Seymour Island includes teeth of *Notidanodon dentatus*, previously reported from the Maastrichtian of the López de Bertodano Formation (Cione and Medina, 1987; Grande and Chatterjee, 1987) and from the Beta and Gamma members of the Santa Marta Formation, in the early Campanian–?early Maastrichtian range (Richter and Ward, 1990). It was also reported from the Maastrichtian of Argentinean Patagonia (Novas et al., 2011). Additionally, remains of bony fishes are abundant in the same levels, represented by frequent teeth of ichthyodectiformes, and less frequent indeterminate vertebrae. Identical teeth have been recovered in late Maastrichtian beds of the López de Bertodano Formation on Seymour Island, and from the early Campanian–?early Maastrichtian of the Santa Marta Formation (Kriwet et al., 2006), proving to be abundant in the Upper Cretaceous of the Larsen Basin. On the other hand, remains of marine reptiles were recovered from the same stratigraphic level and are represented by isolated teeth of elasmosaurid plesiosaurs, which are the most frequent group of reptiles recognized in the Maastricthtian of the WBP (Gasparini and Goñi, 1985). Also, recovered mosasauroids are represented by at least four different dental morphotypes, all of them small-sized.

Paleoenvironment of the assemblage from Seymour Island.—The recovered taxa were compared with closely related extant representatives. Based on Didier (2002) and Compagno (2001), the taxa included in the studied assemblage are consistent with a continental shelf environment and temperate to tropical waters (Table 2). The presence of small teeth of four different morphotypes of mosasauroids strongly suggests co-inhabitance with juvenile individuals. Jacobs et al. (2005) indicate that they inhabited a range of environments from intertidal to shallow marine waters, having tolerance of brackish as well as normal marine salinities. Also, juvenile mosasauroids have been found associated with shallow-water chondrichthyan assemblages in other Upper Cretaceous localities of the WBP (Otero et al., 2012a).

Associated vertebrates on James Ross Island.—In this locality, associated vertebrates found during recent fieldwork (2011, 2012) include isolated but relatively frequent teeth of *N. dentatus*, *Sphenodus* sp., indeterminate ichthyodectiform fishes, a single tooth of *Squatina* sp., and a right palatine of *Chimaera zangerli*, all of them previously reported from the Santa Marta Formation (Kriwet et al., 2006 and references therein). In addition, marine reptiles found in the same levels are represented by associated postcranial remains of plesiosaurs (currently under study by the authors) and isolated vertebrae of mosasauroids. Also, the northern part of the Santa Marta Cove has yielded the type material of the mosasaurid *Taniwhasaurus antarcticus* (Novas et al., 2002; Fernández and Martin, 2009). Records of continental vertebrates, particularly dinosaurs, have been found in the Santa Marta Cove and nearby, in strata also belonging to the Santa Marta Formation. These finds comprise the ankylosaurid dinosaur *Antarctopelta oliveroi* (Salgado and Gasparini, 2006), an vertebra of an indeterminate titanosaurian sauropod (Cerda et al., 2012) and most recently an ornithopod dinosaur (Coria et al., in press).

Paleoenvironment of the taxa recovered from James Ross Island.—Although the studied taxa from James Ross Island do not represent an associated assemblage, all of them are consistent with an environment of temperate to cool, deep waters up to 1000 m deep (Table 2) based on extant representatives (Compagno, 2001; Didier, 2002). This is especially interesting since the lithofacies of the Santa Marta Formation include planar cross-bedding, wavy-planar lamination, bioturbation, and fossils of ammonoids and bivalves as well as driftwood. Such sequences are usually interpreted as representing deposition in shallow marine shelf settings (Pirrie, 1990). Nevertheless, high energy currents, turbidity currents and sedimentary structures associated to storm-generated flow processes (Olivero et al., 1986; Pirrie, 1990) provide a possible explanation for faunal elements of deeper facies occurring in units characterized by a shallow-water environment with inputs of continental fauna (dinosaurs) and flora (driftwood).

Taphonomic aspects of the recovered material.—Although the

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TABLE 2—List of the taxa recovered on each stratigraphic unit, with detail of the number of samples, paleoenvironment interpretation based on close extant representatives, taphonomic mode of preservation, and taphonomic interpretation of provenance.

Taxa	Number of samples	Paleoenvironment interpretation	Taphonomic mode	Taphonomic interpretation	References
López de Bertodano Formation, Klb9					
Chlamydoselachus spp.	1	deep water, tropical to cool-temperate	in situ, broken by weathering	autochthonous	Compagno, 2001
Notidanodon dentatus	3	unknown	in situ, broken by weathering	autochthonous	
Paraorthacodus sp.	1	continental shelf	in situ, broken by weathering	autochthonous	Compagno, 2001
Squatina sp.	1	continental shelf, warm-temperate to tropical	in situ, broken by weathering	autochthonous	Compagno, 2001
Pristiophorus sp.	2	benthic, continental shelf, tropical	in situ, broken by weathering	autochthonous	Compagno, 2001
Odontaspididae	8	continental shelf, tropical to cool-temperate	in situ, broken by weathering	autochthonous	Compagno, 2001
Santa Marta Formation, Gamma Member					
Chimaera zangerli	1	depths around 100 to 1000 m, tempertate to cool	transported in concretion	alochthonous	Didier, 2002
Callorhinchus sp.	1	deep to shallow waters, temperate to cool	transported in concretion	alochthonous	Didier, 1995
Rhinochimaeridae indet.	1	depths around 1000 to 2000 m, temperate to cool	transported in concretion	alochthonous	Didier, 2002
Cretalamna sp.	1	littoral and epipelagic, depths until 1200 m, tropical to temperate	scarce transport, well preserved	parautochthonous	Didier, 2002
Centrophoroides sp.	1	depths around 500 to 1000 m, outer continental shelf, tropical	cast in situ	authochtonous	Compagno, 2001

assemblage from Seymour Island comprises broken teeth, these do not reflect effects of transportation. The cutting edges of the crowns are well preserved, as is the enameloid that only bears stains due to their exposure to humid conditions. Also, all the broken surfaces have sharp edges, indicating that the fragmentation occurred recently and the material was not largely transported (Cook, 1995). Lost fragments were removed by effect of their exposure to the extreme climate conditions that causes fractures on the exposed portions.

Regarding the materials from James Ross Island, several samples were recovered inside concretionary nodules that helped to preserve them, but also allowed the possibility of transportation of the sample without suffering destructive effects. In this sense, the most reliable samples are the in situ cast of *Centrophoroides* (SGO.PV.6662) and the isolated tooth of *C. appendiculata* (SGO.PV:6661) which are well preserved. Consistently, both specimens represent tropical taxa that could inhabit shallower waters.

Paleobiogeography.—The genera *Chlamydoselachus* and *Sphenodus* are only known from Upper Cretaceous of Antarctica, remaining unreported in contemporary levels exposed in lower latitudes of the WBP. Also, *Scapanorhynchus*, *Pristiophorus*, and *Ischyodus dolloi* are not known from northern Upper Cretaceous units, although all of them have been recovered from Paleogene levels of the WBP. Particularly, *Pristiophorus* and *Ischyodus dolloi* are known in the Eocene of the La Meseta Formation at Seymour Island (Kriwet, 2005) and in the late Eocene of southernmost Chile (Otero et al., 2012b), while *Scapanorhynchus* was reported in probable Paleocene levels in central Chile (Muñoz-Ramirez et al., 2007). The taxa *Odontaspis*, *Centrophoroides*, *Squatina*, and *Paraorthacodus* are also relatively common elements in the Maastrichtian of the Quiriquina Basin in central Chile (Suárez et al., 2003). The three first taxa have been also recorded in Maastrichtian beds of southernmost Chile (Otero and Suárez, 2009), indicating a widespread distribution in the WBP during the Upper Cretaceous.

Holocephalans seems to be the most diverse chondrichthyans in the WBP, with several endemic species from different localities. Among these are *Edaphodon kawai* from the Maastrichtian of New Zealand (Consoli, 2006), and the Antarctic taxa *Chimaera zangerli* Stahl and Chatterjee (1999) and *Callorhinchus torresi* Otero et al. (2013) from the late Maastrichtian of Seymour Island. Such diversity pattern suggests that Upper Cretaceous records from South America are susceptible to endemism.

CONCLUSIONS

The new finds comprise the first associated occurrence of an odontaspidid different from *Odontaspis*, as well as the genera *Pristiophorus*, *Squatina*, *Paraorthacodus*, and the species *Chlamydoselachus tatere* in Seymour Island, Antarctica. The fossil-bearing strata are part of the klb9 unit of the López de Bertodano Formation, thus having a latest Maastrichtian age representing one of the youngest known Mesozoic assemblages of cartilaginous fishes that inhabited temperate to tropical shallow waters during the end of the Cretaceous in the coastal seas of the Larsen Basin, before major changes that began after the K/P boundary. In addition, the studied section provides a better constraint for the age of several taxa previously recognized in the López de Bertodano Formation only by scattered samples in different units.

The materials recovered from James Ross Island include the first records of the neoselachians *Cretalamna* sp. and *Centrophoroides* sp. in Antarctica. New holocephalans recovered are represented by an indeterminate rhinochimaerid, and the first record of *Callorhinchus* sp. in the Gamma Member of the Santa Marta Formation of the James Ross Island, extending the occurrence of these taxa to the late Campanian and being their older records along the WBP. Although these taxa do not comprise an associated assemblage, they are indicative for deeper facies than those typically described from the Santa Marta Formation, adding evidence to previous proposals on the existence of high energy events and storm-generated flows.

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REFERENCES

Agassiz, L. 1833–1844. Recherches sur les poissons fossiles. 5 vols. Neuchâtel, Switzerland, 1420 p.

Ameghino, F. 1893. Sobre la presencia de vertebrados de aspecto Mesozoico, en la formación Santacruceña de la Patagonia austral. Revista del Jardín Zoológico de Buenos Aires, 1:76–84.

Ameghino, F. 1906. Les formations sédimentaires du Crétacé et du Tertiare de Patagonie, avec un paralèlle entre leurs faunes mammalogiques et celles de l'ancien continent. Anales del Museo Nacional de Historia Natural, Serie 3, 15:1–568.

Arambourg, C. 1935. Note préliminaire sur les vertébrés fossiles des phosphates du Maroc. Bulletin de la Société géologique de France, 5: 413–439.

Arratia, G. and L.A. Cione. 1996. The record of fossil fishes of southern South America, p. 9–72. *In* G. Arratia (ed.), Contribution of southern South America to Vertebrate Paleontology. Münchner Geowissenschaft Abhanlungen, 30.

Askin, R. A. 1989. Endemism and heterochroneity in the Late Cretaceous (Campanian) to Paleocene palynofloras of Marambio Island, Antarctica: implications for origins, dispersal and paleoclimates of southern floras, p. 107–119. *In* J. A. Crame (ed.), Origins and Evolution of the Antarctic Biota. Geological Society (London) Special Publication 47.

Bastías, J., F. Hervé, F. Fuentes, M. Schilling, A. Poiron, F. Gutierrez, and C. Ramirez. 2012. Mantle xenoliths found at Santa Martha Cove, James Ross Island, Antarctica. XIII Congreso Geológico Chileno, T-3:359–360.

Berg, L. S. 1958. System der rezenten und fossilen Fischartigen und Fische. Deustch Verlag der Wissenschaften, Berlin, 310 p.

Bleeker, P. 1859. Enumeratio specierum piscium hucusque in Archipelago indico observatarum, adjectis habitationibus citationibusque, ubi descriptiones earum recentiores reperiuntur, nec non speciebus Musei Bleekeriani Bengalensibus, Japonicis, Capensibus Tasmanicisque. Acta Societatis Scientiarum Indo-Neerlandae, 6:1–276.

Bogan, S. and F. L. Agnolin. 2010. Primera ictiofauna marina del Cretácico Superior (Formación Jaguel, Maastrichtiano) de la Provincia de Río Negro, Argentina. Papéis Avulsos de Zoologia, Museu de Zoologia da Universidade de São Paulo, 50:175–188.

Bonaparte, C. L. 1838. Selachorum tabula analytica. Nuovi Annali della Science Naturali, Bologna, 1:195–214.

Bonaparte, C. L. 1832. Selachorum Tabula Analytica. Nuovi Annali di Scienze Naturali, Bologna, 1:195–214.

Bonaparte, C. L. 1832–1841. Iconografia della Fauna Italica. Roma. Tomo III, Pesci, 75 puntate, 30 fasciculi.

Cappetta, H. 1987. Handbook of Paleoichthyology. Volume 3b: Chondrichthyes II. Mesozoic and Cenozoic Elasmobranchii. H.-P. Schultze (ed.), Gustav Fischer Verlag, Stuttgart–New York, 193 p.

Cerda, I. A., A. P. Carabajal, L. Salgado, R. A. Coria, M. A. Reguero, C. P. Tambussi, and J. J. Moly. 2012. The first record of a sauropod dinosaur from Antarctica. Naturwissenschaften, 99:83–87.

Chapman, F. 1918. Description and revision of the Cretaceous and Tertiary fish remains of New Zealand. Palaeontological Bulletin, 7:1–46.

Cione, A. L., J. A. Mennucci, F. Santalucita, and C. Acosta-Hospitaleche. 2007. Local extinction of sharks of genus *Carcharias* Rafinesque, 1810 (Elasmobranchii, Odontaspididae) in the eastern Pacific Ocean. Paleontological Note, Revista Geológica de Chile, 34:139–145.

Cione, L. A. and F. A. Medina. 1987. A record of *Notidanodon pectinatus* (Chondrichthyes, Hexanchiformes) in the Upper Cretaceous of the Antarctic Peninsula. Mesozoic Research, 1:79–88.

Compagno, L. J. V. 1973. Interrelationships of living elasmobranchs, p. 15–61. *In* P. H. Greenwood, R. S. Miles, and C. Patterson (eds.), Interrelationships of Fishes. Supplement I to Zoological Journal of the Linnean Society of London, 53.

Compagno, L. J. V. 1977. Phyletic relationships of living sharks and rays. American Zoologist, 17:303–322.

Compagno, L. J. V. 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. Roma, FAO, 269 p.

Consoli, C. P. 2006. *Edaphodon kawai*, sp. nov. (Chondrichthyes: Holocephali): a Late Cretaceous chimaeroid from the Chatham Islands, southwest Pacific. Journal of Vertebrate Paleontology, 26:801–805.

Consoli, C. P. 2008. A rare Danian (early Paleocene) *Chlamydoselachus* (Chondrichthyes: Elasmobranchii) from the Takatika Grit, Chatham Islands, New Zealand. Journal of Vertebrate Paleontology, 28:285–290.

Cook, E. 1995. Taphonomy of two non-marine Lower Cretaceous bone accumulations from south-eastern England. Palaeogeography, Palaeoclimatology, Palaeoecology, 116:263–270.

Coria, R. A., J. J. Moly, M. Reguero, S. Santillana, and S. Marenssi. In press. A new ornithopod (Dinosauria; Ornithischia) from Antarctica. Cretaceous Research.

Crame, J. A., J. E. Francis, D. J. Cantrill, and D. Pirrie. 2004. Maastrichtian stratigraphy of Antarctica. Cretaceous Research, 25:411–423.

Davis, J. W. 1887. The fossil fishes of the chalk of Mount Lebanon, in Syria. Scientific Transactions of the Royal Dublin Society, 2:457–636.

Davis, J. W. 1888. On the fossil fish-remains from the Tertiary and Cretaceous–Tertiary formations of New Zealand. Scientific Transactions of the Royal Dublin Society, 4:1–62.

de Buen, F. 1926. Catálogo ictiológico del Mediterráneo español y de Marruecos recopilando lo publicado sobre peces de las costas mediterráneas y próximas del Atlántico (Mar de España). Commission Internationale pour l'exploration scientifique de la mer Méderiterranée, Madrid, 221 p.

Didier, D. 2002. Chimaeras, p. 591–599. *In* K. E. Carpenter (ed.), The Living Marine Resources of the Western Central Atlantic. Volume 1: Introduction, Molluscs, Crustaceans, Hagfishes, Sharks, Batoid Fishes and Chimaeras. FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists, Special Publication 5.

Duffin, C. J. and D. J. Ward. 1993. The Early Jurassic Palaeospinacid sharks of Lyme Regis, southern England. Belgian Geological Survey, Professional Paper, 264:53–102.

Duméril, A. M. 1906. Zoologie analytique ou méthode naturelle de classification des animaux, rendu plus facile à l'aide de tableaux synoptiques. Paris, 344 p.

Elliot, D. H. and T. A. Trautman. 1982. Lower Tertiary strata on Marambio Island, Antarctic Peninusla, p. 287–297. *In* C. Craddock (ed.), Antarctic Geoscience. University of Wisconsin Press, Madison.

Fernández, M. and J. E. Martin. 2009. Description and phylogenetic relationships of *Taniwhasaurus antarcticus* (Mosasauridae, Tylosaurinae) from the upper Campanian (Cretaceous) of Antarctica. Cretaceous Research, 30:717–726.

Garman, S. 1884. An extraordinary shark (*Chlamydoselachus anguineus*). Bulletin of the Essex Institute, 16:47–55.

Garman, S. 1901. Genera and families of the Chimaeroids. Proceedings of the New England Zoological Club, 2:75–77.

Gasparini, Z. and R. Goñi. 1985. Los plesiosaurios cretácicos de América del Sur y del continente antártico. In Congresso Brasileiro de Paleontología, No. 8 (Río de Janeiro), Coletanea de Trabalhos Paleontológicos, Serie Geologie, 27:55–63.

Glikman, L. S. 1957. On the relationships between the families Lamnidae and Odontaspidae and on new lamnid genera from the Late Cretaceous. Akademia Nauk SSSR, Trudy Geologischeskogo Muzeja "A. P. Karpinskogo", 1:110–117. (In Russian)

Glikman, L. S. 1958. O tempakh evolyutsii lamnoidnykh akul. Doklady Akademii Nauk SSSR, 123:568–672.

Glikman, L. S. 1964. Akuly paleogena i ikh stratigrafiches koe znachenie. Akademii Nauk Soyuza Sovetskikh Sotsialisticheskikh Respublik. Moscow, 228 p.

Goodrich, E. S. 1909. Vertebrata Craniata (First fascicle: Cyclostomes and Fishes), p. 1–518. *In* R. Lankester (ed.), A Treatise on Zoology. Adam and Charles Black, London, 9.

Grande, L. and J. T. Eastman. 1986. A review of Antarctic ichthyofaunas in the light of new fossil discoveries. Paleontology, 29:113–137.

Grande, L. and S. Chatterjee. 1987. New Cretaceous fish fossils from Marambio Island, Antarctic Peninsula. Paleontology, 30:829–837.

Hathway, B. 2000. Continental rift to back-arc basin: Jurassic–Cretaceous stratigraphical and structural evolution of the Larsen Basin, Antarctic Peninsula. Journal of the Geological Society of London, 157:417–432.

Huber, B. T. 1988. Upper Campanian–Paleocene foraminifera from the James Ross Island region (Antarctic Peninsula), p. 163–252. *In* R. M. Feldmann and M. O. Woodburne (eds.), Geology and Paleontology of Seymour Island, Antarctic Peninsula, Geological Society of America Memoir 169.

Huxley, T. H. 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.

Klug, S., J. Kriwet, J. M. Lirio, and H. J. Nuñez. 2008. Synechodontiform sharks (Chondrichthyes, Neoselachii) from the Upper Cretaceous of Antarctica, p. 455–467. *In* G. Arratia, H.-P. Schultze, and M. V. H. Wilson (eds.), Mesozoic Fishes 4—Homology and Phylogeny. Verlag, Dr. Friedrich Pfeil, München, Germany.

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. AND A. GAŹDZICKI. 2003. New Eocene Antarctic chimeroid fish (Holocephali, Chimaeriformes). Polish Polar Research, 24:29–51.

KRIWET, J., J. M. LIRIO, H. J. NUÑEZ, E. PUCEAT, AND C. LÉCUYER. 2006. Late Cretaceous Antarctic fish diversity, p. 83–100. *In* J. E. Francis and J. A. Crame (eds.), Cretaceous–Tertiary High-Latitude Palaeoenvironments, James Ross Basin, Antarctica. Geological Society of London Special Publication 258.

LACÉPÈDE, B. G. E. 1798. Histoire naturelle de poissons (vol. I) par le citoyen La Cépède, membre de l'Institut National, et professeur du Muséum d'Histoire naturelle, Tome I, Paris, 400 p.

LATHAM, J. 1793. An essay on the various species of sawfish. Benjamin White and Son, London, p. 273–282.

LERICHE, M. 1902. Les poissons tertiaires de la Belgique I. Les poissons paléocènes. Mémoires du Musée Royale du Historie Naturelle du Belgique 2, 48 p.

LINNAEUS, C. 1758. Systema Naturae, (Systema naturae per regna Tria naturae, secundum classes, ordines, genera, species, cum characteribus, Differentiis, synonymis, locis. Tomus i. Editio decima, reformata.) Holmiae. Systema Naturae, tenth edition, i–ii+824 p.

MACELLARI, C. E. 1984. Revision of the serpulids of the genus *Rotularia* (Annelida) at Marambio Island (Antarctic Peninsula) and their value in stratigraphy. Journal of Paleontology, 58:1,098–1,116.

MACELLARI, C. E. 1988. Stratigraphy, sedimentology and paleoecology of Upper Cretaceous/Paleocene shelf–deltaic sediments of Marambio Island (Antarctic Peninsula), p. 25–53. *In* R. M. Feldmann and M. O. Woodburne (eds.), Geology and Palaeontology of Marambio Island, Antarctic Peninsula. Geological Society of America Memoir 169.

MARTIN, J. E. AND J. A. CRAME. 2006. Palaeobiological significance of high-latitude Late Cretaceous vertebrate fossils from the James Ross Basin, Antarctica, p. 109–124. *In* J. E. Francis, D. Pirrie, and J. A. Crame (eds.), Cretaceous–Tertiary High-Latitude Paleoenvironments, James Ross Basin, Antarctica. Geological Society of London Special Publication 258.

MÜLLER, J. AND F. HENLE. 1837. Ueber die Gattungen der Plagiostomen. Archiv für Naturgeschichte, 3:394–401.

MÜLLER, J. AND F. HENLE. 1838–1841. Systematische Beschreibung der Plagiostomen. Berlín. Plagiostomen: i–xxii+200 p., 60 pls.

MUÑOZ-RAMIREZ, C. P., P. ZAMBRANO, G. MONTOYA, AND H. MOYANO. 2007. Dientes de tiburones y rayas (Chondrichthyes, Elasmobranchii) de la Formación Quiriquina aflorante en Talcahuano, Chile Central. Boletín de la Sociedad de Biología de Concepción, 78:7–22.

NESSOV, L. A. AND A. O. AVERIANOV. 1996. Early Chimaeriformes of Russia, Ukraine, Kazakhstan and middle Asia. II. Description of new taxa. Vestnik Sankt–Petersburgskogo Universitita, 7:3–10. (In Russian)

NEWTON, E. T. 1876. On two chimeroid jaws from the Lower Greensand of New Zealand. Quarterly Journal of the Geological Society of London, 32: 326–331.

NOVAS, F. E., M. P. ISASI, J. S. D'ANGELO, F. BUSKER, M. DAMATO, S. BOGAN, L. IBIRICU, AND K. LACOVARA. 2011. Hallazgo de un esqueleto de plesiosaurio asociado con dientes de selaceos en la Formación El Calafate (Cretácico Superior) De La Provincia de Santa Cruz. Ameghiniana, 48, abstracts of the IV Congreso Latinoamericano de Paleontología de Vertebrados, San Juan, Argentina, p. R247.

NOVAS, F. E., M. FERNÁNDEZ, Z. GASPARINI, J. M. LIRIO, H. J. NUÑEZ, AND P. PUERTA. 2002. *Lakumasaurus antarcticus*, n. gen. et sp., a new mosasaur (Reptilia, Squamata) from the Upper Cretaceous of Antarctica. Ameghiniana, 39:245–249.

OBRUCHEV, D. V. 1953. Studies on edestids ad the works of A. P. Karpinski. U.S.S.R Academy of Sciences, Works on Palaeontological Institute Publication, 45:1–86.

OLIVERO, E. B. 1992. Asociaciones de amonites de la Formación Santa Marta (Cretácico tardío), Isla James Ross, p. 47–76. *In* C. A. Rinaldi (ed.), Geología de la Isla James Ross. Dirección Nacional del Antártico, Buenos Aires.

OLIVERO, E. B. AND F. A. MEDINA. 2000. Patterns of Late Cretaceous ammonite biogeography in southern high latitudes: the family Kossmaticeratidae in Antarctica. Cretaceous Research, 21:269–279.

OLIVERO, E. B., D. R. MARTINIONI, AND F. J. MUSSEL. 1992. Upper Cretaceous sedimentology and biostratigraphy of Western Cape Lamb (Vega Island, Antarctica). Implications on sedimentary cycles and evolution of the basin, p. 147–166. *In* C.A. Rinaldi (ed.), Geología de la Isla James Ross. Instituto Antártico Argentino, Buenos Aires.

OLIVERO, E. B., R. A. SCASSO, AND C. A. RINALDI. 1986. Revision del Grupo Marambio en la Isla James Ross, Antártida. Instituto Antártico Argentino, Contribución, 331:1–29.

OTERO, R. A. AND M. E. SUÁREZ. 2009. Nuevos hallazgos de peces cartilaginosos (Chondrichthyes: Elasmobranchii) del Cretácico Tardío de Magallanes y su relación con los registros previos de Chile central durante el Maastrichtiano. Congreso Geológico Chileno N° 12, Simposio 12, Relaciones Geológicas y Paleontológicas entre Antártica y Patagonia, 4 p.

OTERO, R. A., D. RUBILAR-ROGERS, R. E. YURY-YAÑEZ, A. O. VARGAS, C. S. GUTSTEIN, F. A. MOURGUES, AND E. ROBERT. 2013. A new species of chimaeriform (Chondrichthyes, Holocephali) from the uppermost Cretaceous of the López de Bertodano Formation, Isla Marambio (Seymour Island), Antarctica. Antarctic Science, 25:99–106.

OTERO, R. A., J. F. PARHAM, S. SOTO-ACUÑA, P. JIMENEZ-HUIDOBRO, AND D. RUBILAR-ROGERS. 2012a. Marine reptiles from the Late Cretaceous (early Maastrichtian) deposits in Algarrobo, central Chile. Cretaceous Research, 35:124–132.

OTERO, R. A., T. TORRES, J. P. LE ROUX, F. HERVÉ, C. M. FANNING, R. E. YURY-YÁÑEZ, AND D. RUBILAR-ROGERS. 2012b. A late Eocene age proposal for the Loreto Formation (Brunswick Peninsula, southernmost Chile), based on fossil cartilaginous fishes, paleobotany and radiometric evidence. Andean Geology, 39:180–200.

PIRRIE, D. 1990. A new sedimentological interpretation for part of the Santa Marta Formation, James Ross Island. Short note, Antarctic Science, 2:77–78.

PIRRIE, D., J. A. CRAME, S. A. LOMAS, AND J. B. RIDING. 1997. Late Cretaceous stratigraphy of the Admiralty Sound region, James Ross Basin, Antarctica. Cretaceous Research, 18:109–137.

RAFINESQUE, C. S. 1810. Caratteri di alcuni nuovi generi e nuove specie di animali e pinate della Sicilia, con varie osservazioni sopra i medisimi. Palermo, p. 3–69.

REGAN, T. 1906. A classification of the selachian fishes. Proceedings of the Zoological Society of London, 2:722–758.

RICHTER, M. AND D. WARD. 1990. Fish remains from the Santa Marta Formation (Late Cretaceous) of James Ross Island, Antarctica. Antarctic Science, 2:67–76.

RINALDI, C. A. 1982. The Upper Cretaceous in the James Ross Island Group, p. 281–286. *In* C. Craddock (ed.), Antarctic Geoscience, University of Wisconsin Press, Madison, Wisconsin.

RINALDI, C. A., A. MASSABIE, J. MORELLI, H. L. ROSENMAN., AND R. DEL VALLE. 1978. Geología de la Isla Vicecomodoro Marambio. Contribución del Instituto Antártico Argentino, 217:1–37.

SALGADO, L., AND Z. GASPARINI. 2006. Reappraisal of an ankylosaurian dinosaur from the Upper Cretaceous of James Ross Island (Antarctica). Geodiversitas, 28:119–135.

SCASSO, R. A., E. B. OLIVERO, AND L. A. BUATOIS. 1991. Lithofacies, biofacies, and ichnoassemblage evolution of a shallow submarine volcaniclastic fan-shelf depositional system (Upper Cretaceous, James Ross Island, Antarctica). Journal of South American Earth Sciences, 4:239–260.

SIVERSON, M. 1992. Late Cretaceous *Paraorthacodus* (Palaeospinacidae, Neoselachii) from Sweden. Journal of Paleontology, 66:994–1,001.

SMELLIE, J. L. 1987. Geochemistry and tectonic setting of alkaline volcanic rocks in the Antarctic Peninsula: a review. Journal of Volcanology and Geothermal Research, 32:269–285.

STAHL, B. J. 1999. Handbook of Paleoichthyology, Volume 4: Holocephali. Verlag, Dr. Friedrich Pfeil, München, Germany, 164 p.

STAHL, B. J. AND S. CHATTERJEE. 1999. A Late Cretaceous chimaerid (Chondrichthyes, Holocephali) from Marambio Island, Antarctica. Paleontology, 42:979–989.

STAHL, B. J. AND S. CHATTERJEE. 2002. A Late Cretaceous Callorhynchid (Chondrichthyes, Holocephali) from Marambio Island, Antarctica. Journal of Vertebrate Paleontology, 22:848–850.

SUÁREZ, M. E., L. QUINZIO, O. FRITIS, AND R. BONILLA. 2003. Aportes al conocimiento de los vertebrados marinos de la Formación Quiriquina. Congreso Geológico Chileno No. 10, Resúmenes, Concepción, 7 p.

TRAUTSCHOLD, H. 1877. Über Kreidefossilien Russlands. Bulletin de la Societe des Naturalistes de Moscou, 11:332–349.

WELTON, B. J. AND W. ZINSMEISTER. 1980. Eocene Neoselachians from La Meseta Formation, Marambio Island, Antarctic Peninsula. Contributions in Science of the Natural History Museum of Los Angeles County, 329:1–10.

WOODWARD, A. S. 1886. On the palaeontology of the selachian genus *Notidanus,* Cuvier. Geological Magazine*,* 3:205–217, 253–259.

WOODWARD, A. S. 1906. On fossil fish remains from Snow Hill and Marambio Island. Swedish Sudpolar Expedition 1901–1903, 3:1–4.

ZINSMEISTER, W. J. 1979. Biogeographic significance of the late Mesozoic and early Tertiary molluscan faunas of Marambio Island (Antarctic Peninsula) to the final break-up of Gondwanaland, p. 349–355. *In* J. Gray and A. J. Boucot (eds.), Historical Biogeography, Plate Tectonics and the Changing Environment. Oregon State University Press, Corvallis.

ZINSMEISTER, W. J. 1982. Review of the Upper Cretaceous–lower Tertiary sequence on Marambio Island, Antarctica. Journal of the Geological Society of London, 139:779–786.

ZINSMEISTER, W. J. 1998. Discovery of fish mortality horizon at the K–T boundary on Seymour Island: re-evaluation of events at the end of the Cretaceous. Journal of Paleontology, 72:556–571.

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