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Early Miocene Sr-geochronology of Patagoniense marine units from southern Argentina: implications for molluscan assemblages and interbasinal correlation.

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Abstract:	First geological investigations in southern South America addressed the Oligocene-Miocene Patagoniense deposits, a fossiliferous marine succession distributed in several basins that have been flooded by three transgressions. Chronological calibration and correlation of these transgressive events, lithological units and fossil assemblages through the Patagonian basins still need further definitions in some areas. To tackle this problem, new Sr-isotope ages of pectinid shells from four early Miocene key sections were obtained to improve correlations among the Magallanes-Austral (MAB), San Jorge (SJB) and Mazarredo (MB) basins. The Punta Guanacos section (MAB) was dated in a mean age of 19.8 Ma and correlates with the lower section of the Monte Leon Formation. In the SJB, the lowermost bed of the Chenque Formation at Punta Borja has a mean age of 19.6 Ma, while the boundary between Sequence 1 and 2 of this unit is settled in 17.7 Ma at Punta Delgada. Patagoniense deposits exposed in the cliffs of the southern San Jorge Gulf (MB), lying on the continental Sarmiento Formation, are recognized herein as the Mazarredo Beds with a mean age of 20.9 Ma at Canadón El Lobo. They are younger than the San Julián Formation and correlate with the lower part of the Monte León Formation from Playa La Mina (MAB). This age is of outstanding importance since Mazarredo area constitutes a geographic link between the MAB and SJB and precludes the presence of the "Juliense" transgression in central Patagonia as had been proposed, supporting the early Miocene age previously provided by the authors for the Jorgechlamys centralis – Reticulochlamys borjasiensis Molluscan Assemblage. This assemblage is recorded in the Mazarredo Beds and in the lower section of the Chenque Formation (SJB). Moreover, faunal similarity with the Monte León Formation allows the identification of the Reticulochlamys zinsmeisteri - Struthiolarella patagoniensis - Pleuromeris cruzensis Assemblage at Punta Guanacos in the northeastern sector of the MAB.
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This papers attempt to contribute with the accuracy of the age of one of the most extensive sea incursions of the Southwestern Atlantic Ocean occurred during the early Miocene in the Magallanes-Austral, San Jorge and Mazarredo basins of Patagonia.

The four new Sr-isotope ages presently obtained, allow the correlation among the mentioned basins. During more than one century the fossiliferous horizons exposed in the Mazarredo Basin, herein proposed to be named "Mazarredo Beds", had been considered by numerous authors as deposited by the "Juliense transgression", but palynomorphs and molluscan assemblages had questioned that asseveration.

One of the outstanding conclusions is that the analysis presently carried out releases an early Miocene age (Burdigalian; (20.9 Ma) for the Mazarredo Beds, precluding the presence of the "Juliense transgression" in central Patagonia. These isotopic data support the relative age proposed by the flora and fauna twenty years ago and enable a reappraisal of the timming of the molluscan faunas that inhabited all those basins.

Moreover, a similarity cluster analysis shows that the Punta Guanacos faunas belongs in the *Reticulochlamys zinsmeisteri - Struthiolarella patagoniensis - Pleuromeris cruzensis* Assemblage (RSP), recognized in the southern sector of the Magallanes-Austral Basin (Monte León Formation) in coincidence with the correlation between exposures of that unit and the Punta Guanacos rocks as demonstrated in the present paper.

Sincerely,

Claudia Julia del Río

HIGHLIGHTS

Four new Sr-ages for early Miocene marine beds of central Patagonia are calculated

Marine rocks exposed at southern San Jorge Gulf are named Mazarredo Beds (MB)

The MB are dated in 20,9 Ma, precluding the *Juliense* sea in central Patagonia

The JR Assemblage lasted from 21.1 Ma to 17.6 Ma in the San Jorge and Mazarredo basins

Early Miocene Sr-geochronology of *Patagoniense* marine units from southern Argentina: implications for molluscan assemblages and interbasinal correlation.

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Abstract

Early geological investigations in southern South America addressed the Oligocene-Miocene *Patagoniense* deposits, a fossiliferous marine succession distributed in several basins that had been flooded by three transgressions. Chronological calibration and correlation of these transgressive events, lithological units and fossil assemblages through the Patagonian basins still need further definitions in some areas. To tackle this problem, new Sr-isotope ages of pectinid shells from four early Miocene key sections were obtained to improve correlations among the Magallanes-Austral (MAB), San Jorge (SJB) and Mazarredo (MB) basins. A bed in the middle part of the Punta Guanacos section (MAB) was dated in a mean age of 19.8 Ma and correlates with the lower section of the Monte Leon Formation. In the SJB, the lowermost bed of the Chenque Formation at Punta Borja has an age of 19.6 Ma, while the boundary between Sequence 1 and 2 of this unit has an age of 17.7 Ma at Punta Delgada. *Patagoniense* deposits exposed in the cliffs of the southern San Jorge Gulf (MB), lying on the continental Sarmiento Formation, are recognized herein as the Mazarredo Beds with a mean age of 20.9 Ma at Canadón El Lobo. They are younger than the San Julián Formation and correlate with the lower part of the Monte León Formation from Playa La Mina (MAB). The radiometric date of the Mazarredo Beds is of outstanding importance since Mazarredo area constitutes a geographic link between the MAB and SJB and precludes the presence of the "Juliense" transgression in central Patagonia as had been proposed, supporting the early Miocene age previously provided by the authors for the *Jorgechlamys centralis* –*Reticulochlamys borjasiensis* Molluscan Assemblage. This assemblage is recorded in the Mazarredo Beds and in the lower section of the Chenque Formation (SJB). Moreover, faunal similarity with the Monte León Formation allows the identification of the *Reticulochlamys zinsmeisteri - Struthiolarella patagoniensis - Pleuromeris cruzensis* Assemblage at Punta Guanacos in the northeastern sector of the MAB.

Keywords: Sr-isotope; early Miocene; Patagonia; molluscs; Chenque Formation, Mazarredo Beds

1- Introduction

The extensive middle Cenozoic marine succession in the southern part of South America was firstly recognized and named by Ch. Darwin (1846) as the *Great Patagonian Tertiary Formation*. These fossiliferous deposits, later known as *Patagoniense*, filled several basins along more than 1500 km during different transgressive episodes around the Paleogene-Neogene boundary.

Since the first collections of Neogene molluscs of Patagonia were made by Carlos Ameghino at the end of the 19th century, researchers discovered their importance as stratigraphic tools, and stratigraphic relationships among Patagonian basins soon became matter of discussions, as have been summarized by Feruglio (1949) and Camacho (1995; and bibliography therein). The pioneer stratigraphic works were carried out by F. Ameghino (1894, 1898, 1906), who created informal chronostratigraphic stages based on molluscan faunas that were rejected by Hatcher (1900). Later, Bertels (1977; 1980) and Bellosi (1990) formalized Ameghino's units creating the San Julián and Monte Léon formations for the Magallanes-Austral Basin (MAB) and the Chenque Formation for the San Jorge Basin (SJB). However, the highly fossiliferous marine rocks exposed between both basins, in the southern littoral of the San Jorge Gulf remained unstudied, its relationships with the MAB and SJB are still unknown, and have been referred to the Ameghino's stages or indistinctly considered equivalent to the San Julián, Monte León or Chenque formations. Subsequent detailed stratigraphic works (Parras and Cuitiño, 2021 and bibliography therein) and systematic revisions of the palynomorph (Barreda and Palamarczuk, 2000 a, b) and molluscan assemblages (del Río, 2004) from the MAB and SJB, helped to a better understanding of the biostratigraphic framework. In this sense, del Río (2004) defined five molluscan assemblages and concluded that the fauna preserved in the southern littoral of the San Jorge Gulf and in the lowermost section of the Chenque Formation are partially coeval with that yielded in the Monte León Formation at its type area in the MAB, all being of a relative early Miocene age.

Despite the large amount of paleontological and sedimentological information obtained during the last years, some aspects dealing with the biostratigraphic correlation and geochronological calibration of all these deposits remain yet unresolved. To address this issue, particularly in the early Miocene interval, and to the light of isotopic dates obtained during the last decade (Parras *et al*., 2012; Cuitino, *et* *al*., 2015), the goals of the present contribution are to provide new Sr-isotopic ages from molluscan shells for the *Patagoniense* beds exposed in the San Jorge Gulf and in the northeastern sector of the MAB, and to build a more accurate chronostratigraphic scheme in order to correlate these marine beds with those exposed in southern MAB and in the SJB already dated by other authors. Moreover, it is the purpose of this research to corroborate the identity of the Mazarredo Basin (MB) proposed by Bellosi (1995) and to characterize the fossiliferous beds exposed in the southern littoral of the San Jorge Gulf.

2. Geological Setting and previous works

Middle Cenozoic marine transgressions of southern South America flooded different Patagonian basins connected to the Atlantic Ocean. They are the MAB in southern Patagonia and Isla Grande de Tierra del Fuego, the SJB in central Patagonia, and the Rawson-Valdés and Colorado basins in northern Patagonia (Bellosi, 1995). In the northeastern region of the Santa Cruz Province, Bellosi (1990, 1995) delimited the Mazarredo Basin (MB), which was also considered part of the MAB (Bellosi, 1990; Malumián, 2011) or part of the SJB (Parras and Cuitiño, 2021) (Fig. 1). Fossiliferous sections studied in the present paper are located in the MAB (Punta Guanacos), in the MB (Cañadón El Lobo) and in the SJB (Punta Delgada and Punta Borja). (Fig. 2).

Darwin (1846) included all these marine rocks in his *Great Patagonian Formation*, and since then were subject of stratigraphic and paleontological research arising great stratigraphic controversies among Ameghino (1898, 1906), Hatcher (1897, 1900), Feruglio (1949), Riggi (1979) and Camacho (1980, 1984, 1985, 1995).

A first step to outline the stratigraphic relationships of these strata was defined through the study of palynomorph (Barreda and Palamarkzuk, 2000 a, b) and molluscan assemblages (del Río, 2004). Thus, del Río (2004) grouped the molluscs contained in the San Julián, Monte León and Chenque formations into five informal zones (shown in Fig. 4). Three of them belong to the MAB, being from the oldest to the youngest, the PP Assemblage (Oligocene) recorded in the San Julián Formation at the Gran Bajo de San Julián, and the RSP and PA Assemblages (early Miocene) recorded in the Monte León Formation at the mouth of the Santa Cruz river, southwards to the Las Cuevas-Monte Observación area. The two remaining assemblages correspond to those faunas of the SJB: the early Miocene JR Assemblage and the youngest middle Miocene NVG Assemblage.

2.1. Magallanes-Austral Basin

Ameghino created the *Piso Patagonico,* the *Patagonian Formation* (1889, 1894) or the *Formation Patagoniene* (1898) and, based on its molluscan content, subdivided it into chronostratigraphic informal units named *Juliense, Leonense* and *Superpatagoniense* (*Julien, Leonien, Superpatagonien*) Stages (Ameghino 1898, 1906). Other stratigraphic terms proliferated along the 20th century (*e.g.* Patagonia Formation, Patagónica Formation Ameghino 1894 as used by Russo and Flores, 1972; Di Paola and Marchese, 1973; Riggi, 1979), until Bertels (1977, 1980) proposed the formal names San Julián and Monte León formations. Both units are well exposed in their type areas at the Gran Bajo de San Julián (San Julián Formation) and at the mouth of the Santa Cruz River, southwards to Monte Observación-Las Cuevas's area, along the littoral of the Atlantic Ocean (Monte León Formation). In the Gran Bajo de San Julián and surrounding of the Puerto San Julián, the Monte Léon is probably unconformably overlying on the San Julián Formation (Parras *et al*., 2012).

Molluscan faunas of the Monte León Formation were focus of numerous systematic works (del Río, 2021 and references herein) and biostratigraphic analyses. Del Río (2004) defined the *Reticulochlamys zinsmeisteri - Struthiolarella patagoniensis - Pleuromeris cruzensis* (RSP) Assemblage, recognized at the mouth of the Santa Cruz River and proposed a relative early Miocene age in coincidence with the Aquitanian to early Burdigalian age assigned to the spore-pollen assemblages by Barreda and Palamarczuk (2000a).

Parras *et al.* (2012) performed the first Sr-isotope analysis for the Monte León Formation and obtained numerical ages that range from ~22 Ma to 17.9 Ma. The age of the base of the unit at the Puerto San Julián was estimated in 22.12 Ma, those beds exposed at the mouth of the Santa Cruz River expand the interval 19.36 -18.81 Ma, and the upper section of the unit in the area of Las Cuevas-Monte Observación was calculated in 17.91 Ma, supporting the early Miocene age provided by palynomorphs and molluscan assemblages.

Punta Guanacos, one of the sections dated in this research, is a fossiliferous site in the northeastern sector of the MAB, southwards from the mouth of the Río Deseado (Figure 2-D). It is among the first Patagonian Tertiary marine localities visited by Ch. Darwin during the trip of the HMS Beagle in 1833, but its stratigraphic relationships remained unstudied until recent times when were included in the *Patagoniense* beds (Giacosa *et al*., 1998) without any discussion. Later, Casadío and Griffin (2009) based on stratigraphic and lithostratigraphic considerations, correlated the Punta Guanacos section with the Monte León Formation.

2.2. San Jorge Basin

The middle Cenozoic marine deposits of this basin exhibit their maximum thickness (450 - 500 m) near Comodoro Rivadavia (Fig. 2B), where Frenguelli (1929) and Feruglio (1949) initially recognized the "Juliense", "Leonense" and "Superpatagoniense" Stages of Ameghino, but with different boundaries from those established by Ameghino (1898; 1906). Later, Camacho (1974) rejected the presence of the "Leonense" and "Superpatagoniense" in this area and defined the "*Monophoraster* and *Venericor* Beds" that would lay upon the "Juliense" strata. Instead, Riggi (1979) identified the "Monte León Member" (Patagonia Formation) for those strata. Based on outcrops and subsurface well logs, Bellosi (1987, 1990) considered that the whole shallow marine succession (*Patagoniense* beds) of the SJB constituted a single and distinct unit that called the Chenque Formation, formed by five shallowing-upward depositional sequences. The lower three record the sedimentation from muddy inner- shelf to sandy shoreface and subtidal environments, while the upper two sequences represent upper shoreface to more restricted, tidal-estuarine settings. In the eastern region of the basin, the Chenque Formation lies upon the middle Eocene section ("Casamayoran") of the continental Sarmiento Formation, but in the western region it lies upon the early Miocene section ("Colhuehuapian") (Bellosi, 2010). The upper contact is transitional with the continental Escalante Formation, formerly known as the Santa Cruz Formation (Sosa *et al*., 2021). Accumulation in central Patagonia foreland and progradation from the west of these siliciclastic, fluvio-eolian deposits resulted by the growth of Patagonian Andes since ~14 Ma (Guillaume *et al*., 2009; Rodríguez Tribaldos *et al*., 2017), a time later than the Santa Cruz Formation in the MAB.

The samples from the SJB dated herein comes from the lowermost beds of the unit exposed at Punta Borja (Sequence 1), and from Punta Delgada where the Sequence 1 and the lower part of the Sequence 2 are recognized (Fig. 2B). The first palynological survey (spore-pollen and dynocysts) provided a late Oligocene - early Miocene age for most of the unit (Barreda, 1996; Bellosi and Barreda, 1993), while the upper section was assigned to the middle Miocene (Bellosi, 1990, 1995). Subsequently, Barreda and Palamarczuk (2000 b) restricted the base of the unit to the early Miocene, which is in coincidence with the relative age of the *Jorgechlamys centralis-Reticulochlamys borjasiensis* Assemblage (JR) defined by del Río (2004) for the lower section of the Chenque Formation exposed at Astra and Cerro Chenque.

More recently, Cuitiño *et al*. (2015) obtained $^{87}Sr/^{86}Sr$ ages from oyster shells that encompass the interval between 19.69 Ma and 15.37 Ma for Sequences 1 to 3 at Caleta Córdova (near Astra) and Comodoro Rivadavia areas. Considering the thickness of the undated upper section (~230 m), the top of the Chenque Formation would be around 14 Ma.

2.3. *Mazarredo Basin*

The upper part of the cliffs that shape the southern littoral of the San Jorge Gulf, extending along the Mazarredo and Sanguineto bays (Fig. 2C), encompass a 40 m thick, coarsening-upward marine succession of fine to medium, yellowish and ochreous, highly fossiliferous sandstones, which are glauconitic in the lower section, and tuffaceous in the upper part. It lies over the middle Eocene (“Casamayoran”) and late Oligocene (“Deseadan”) sections of the Sarmiento Formation (Tornöuer, 1903; Pérez *et al*., 2012).

Pioneer studies of those *Patagoniense* beds were carried on by Tornöuer (1903) who mentioned a long list of the invertebrate species. Ameghino (1906) included them into the *Juliense*, and along with the fossiliferous strata exposed at Punta Borja, placed them in the “*Neoinoceramus* Bed”. Subsequent works by middle of the 20th century referred those rocks to the *Juliense* Stage (Frenguelli, 1929; Feruglio, 1949), and later, were indistinctly considered equivalent to the San Julián Formation (Zinsmeister, 1981; Camacho, 1984; 1995; Parma *et al*., 1990), to the Monte León Formation (Martínez *et al*., 2020) or Chenque Formation (Parras and Cuitiño, 2021). Del Río (2004) identified the JR Molluscan assemblage in the marine strata of Bahía Mazarredo, and suggested an early Miocene age. The occurrence of that assemblage also in the lower section of the Chenque Formation dismisses their temporal equivalence with the San Julián Formation in the type area, where the Oligocene *Panopea sierrana–Parinomya patagonensis* Assemblage (PP) is recorded. Moreover, the JR assemblage was considered partially coeval with the RSP assemblage at the mouth of the Santa Cruz River (Monte León Formation) in the MAB.

3. Studied sections

The surveyed fossiliferous localities are Punta Borja and Punta Delgada (Chenque Formation) from the SJB, Cañadón El Lobo (Mazarredo Beds) from the MB and Punta Guanacos (Monte León Formation) from the MAB (Fig. 2).

3.1. Punta Borja

This section corresponds to the lowermost part of the Chenque Formation, exposed at the abrasion platform of the coast in the city of Comodoro Rivadavia (45° 52' 20.56'' S 67° 28' 58.94'' W) (Fig. 2B). It lies over a flat unconformity considered a co-planar surface that separates the Chenque Formation (Sequence 1) from the underlying continental tuffs of the middle Eocene Sarmiento Formation (Fig.3 A). This discontinuity surface, representing the lowstand erosion and the subsequent transgressive ravinement, is a highly burrowed omission (firmground) surface assigned to the *Glossifungites* Ichnofacies, composed of *Gastrochaenolites ornatus* containing the body fossil of their bivalve producers in life-position (Pholadinae) along with *Thalassinoides* isp. (Carmona *et al*., 2006; 2007).

The dated molluscan samples correspond to the lowermost fossiliferous bed, a dark grayish green, fine to medium-grained, tuffaceous and glauconitic sandstone, 2.7 m thick, with dispersed tuffaceous and volcanic clasts. It shows poorly defined horizontal or cross bedding, intense background bioturbation along with some discrete trace fossils, and includes abundant invertebrate and vertebrate fossils. This basal glauconitic deposit, is considered the transgressive lag of the first sequence of the

Chenque Formation. The shelly fauna is dominated by pectinids and oysters represented by abundant articulated or disarticulated valves of *Reticulochlamys borjasiensis, Zygochlamys jorgensis, Jorgechlamys juliana, J. centralis*, bunches of oysters (vertical living-position), rare *Pixiechlamys quemadensis*, articulated *Ameghinomya argentina, A. darwini, Cucullaea* sp., *Pholadidea patagonica* and the gastropods *Valdesia collaris, "V."dalli, Perissodonta ameghinoi, Cirsotrema rugulosa,Trophon santacruzensis* and *Ficus carolina.*

3.2. Punta Delgada

Patagoniense beds exposed at Punta Delgada belongs to the lower part of the Chenque Formation. This 40 m thick section, located 17 km SW of Comodoro Rivadavia (45°59'10.16"S; 67°35'20.18"W) (Fig. 2B), comprises very fine to fine-grained silty sandstones, along with some heterolithic deposits, lenticular shell beds and a tabular white tuff with long and vertical burrows in the upper part (Fig. 3 B). Most sandstones are massive due to high to complete bioturbation and include entire and fragmented invertebrate fossils. The remaining sandstones, showing tractive structures, occur in the upper part of the studied section, and exhibit horizontal lamination, ripples or medium-scale through cross bedding. Heterolithic deposits display wavy or lenticular stratification. Lenses of shell beds or coquinas are generally finning-upward, cross-bedded or massive and sometimes include intraformational clasts.

The studied material comes from a cross-bedded shel -bed with a strong erosive lower contact, interpreted as the transgressive lag deposit of the second sequence of the Chenque Formation (Bellosi, 1987; Buatois *et al*., 2003). The fauna of this shell-bed is not diverse and is mainly represented by the pectinids *Zygochlamys jorgensis, Pixiechlamys quemadensis* and *Swiftopecten iheringii*, and scarce representatives of the gastropods *Glossaulax secundum, Turritella ambulacrum* and *Valdesia collaris*.

3.3. Cañadón El Lobo

This locality is situated in the Bahía Mazarredo, 29.5 km to the northeastern of Fitz Roy and 125 km southeastern of Comodoro Rivadavia (46º 57' S; 66º 52' W) (Fig. 2C). The complete section consists of continental tuffaceous sequence belonging to the Koluel Kaike Formation (23 m thick) at the lower part, followed by the Sarmiento Formation (65 m thick) and capped by the *Patagoniense* beds (37,5 m thick). These marine strata are composed by a lower section (30 m thick) of light green and green-yellowish fossiliferous sandstones and an upper section (10 m thick) of light grey - yellowish poorly fossiliferous tuffaceous sandstones.

The samples studied herein comes from the lower section (Fig. 3 C) and consist from base to top of massive, medium to fine-grained sandstones devoid of fossil remains (10 m thick), followed by a medium-grained, cross - and horizontal-bedded sandstones showing high bioturbation and gypsum veins at the top (9 m thick). Capping these strata, there is a highly fossiliferous succession of shell-beds (7 and 12 m thick), composed by an intercalation of two distinct accumulation types. Type 1 consists of shell-beds up to 40 cm thick, with erosive lower contacts and planar upper ones, grading upwards from a shell-supported to a matrix-supported fabric. They include single event accumulations of a census assemblage of oysters that varies laterally to multi-event of parautochthonous accumulations of oysters and *Zygochlamys jorgensis, Jorgechlamys juliania* and *J. centralis* where the new dated material comes from. The Type 2 fossiliferous accumulation is constituted by multi-event, time-averaged, amalgamated shell-beds with erosive lower bases and sharp non- erosive upper contacts, showing a shell-supported fabric and numerous internal discontinuities that are usually well-developed. They yield parautochthonous accumulations of oysters and pectinids (*Chokekenia nicolasi, Pixiechlamys quemadensis, Swiftopecten iheringii, Zygochlamys jorgensis, Jorgechlamys juliania, J. centralis*) and internal molds of articulated veneroids.

3.4. Punta Guanacos

This section constitutes an 8,5 m thick, small outcrop on the beach situated 3,5 km southeast from Estancia Santa Elena, and 5 km southwards from Puerto Deseado

(47º 48' 38" S 62 º 52' 32" W). (Fig. 2D). The fossiliferous basal bed is a hard massive fine tuffaceous sandstone with clumps of osyters with both valves articulated, in life-position, surrounded by patches of turritellids and brachiopods (Fig. 3 D). Following, there is a tuffaceous bed (8 m thick) with two oysters horizons intercalated with disarticulated specimens lying concave up. Between oyster beds there are abundant, small fossil accumulations, sometimes grouped in lenses that are floating in the matrix, where fossils are randomly oriented and are represented by mostly articulated specimens. Dated samples comes from these lenses and identified species include *Neilo ornata, Cuccullaea alta, Limopsis insolita, Glycymerita cuevensis, Pteromyrtea crucialis, Darwinicardia patagonica,* disarticulated valves of *Spisatella lyelli, Crassatella kokeni*, mostly monospecific accumulations of *Turritella* sp, and lenses constituted by a highly diverse fauna of pectinids such as *Reticulochlamys proxima, Jorgechlamys juliana, J. centralis, Swiftopecten iheringii, Zygochlamys sebastiani, Z. jorgensis* and *Chokekenia nicolasi* and the gastropods *Polinices santacrucensis, Glossaulux vidali, Cirsotrema rugulosa, Urosalpinx dautzembergi, Xymene cossmanni, Neoimbricaria patagonica* and *Antimelatoma quemadensis*.

4. Material and Methods

4.1. Isotopic analysis of pectinid shells

The used material consists of entire and well preserved valves and its stratigraphic provenance is displayed in figure 3.

The hinge areas of the valves were prepared for analysis as this part of the shell usually is thickest and so resists alteration best. Shells were physical cleaned with a steel scalpel, then fragmented in a pestle-and-morter. The fragments were chemically cleaned by brief immersion in dilute nitric acid, washed with ultra-pure water (18MΩ) and dried in a clean environment. Under the microscope, about 5 mg of clean flakes of subsample were picked for analysis. Picked fragments were translucent calcite that was free from staining by Fe or Mn. To the picked samples were added 3 drops of concentrated HNO_3. The samples were then evaporated to dryness to oxidise organic matter, the residue dissolved in 8M HNO_3, and the Sr separated by ion-exchange chromatography using Eichrom Sr-spec resin.

Measurements of $^{87}Sr/^{86}Sr$ were made on a Phoenix Isotopx magnetic-sector thermal-ionization mass-spectrometer using Re filaments. Values of $^{87}Sr/^{86}Sr$ were normalized to an $^{87}Sr/^{86}Sr$ value of 0.1194 using exponential correction for fractionation. Corrections for ^{87}Rb were made by monitoring ^{85}Rb and using the natural isotopic abundance of Rb. Data are normalized to a value of 0.709 174 for EN-1 (modern marine Sr), which is equivalent to a value of 0.710 248 for NIST (SRM) 987 (McArthur et al., 2020). Numerical ages were derived from $^{87}Sr/^{86}Sr$ ratios using the LOWESS 6C calibration curve of $^{87}Sr/^{86}Sr$ against time described in McArthur *et al.* (2020). The uncertainties on the numerical ages are derived by compounding the 2s.e. of measurement with the 95% CI of the LOWESS calibration line.

4.2. Cluster analysis of molluscan species

In order to study the faunal affinities among Punta Guanacos and the RSP and JR Molluscan Assemblages previously recognized in the MAB, MB and SJB (del Río, 2004), a Q-mode cluster analysis (UPGMA linking) was performed using the PAST 3.23 program (Hammer and Harper, 2001). It incorporates a total of 132 species, including 34 species recognized at Punta Guanacos, 110 species from the RSP Assemblage recorded in the Monte León Formation (mouth of the Santa Cruz River), 42 from the Mazarredo Beds, 12 species from Punta Delgada and 24 species from Punta Borja (JR Assemblage) (Suplementary Data S1). A presence-absence matrix was performed and assemblages of each locality were compared using the Simpson (1960) association coefficient, that is calculated as M/Nmin, where Nmin is the number of taxa in the smaller sample and M is the number of shared taxa. The Simpson coefficient is appropriate when there are large differences in the number of taxa between the samples, as it is our case. The cophenetic correlation coefficient (Sokal and Rohlf, 1962) was calculated to measure the fidelity of the dendrogram to the similarity matrix, obtaining a very good result (0.7597).

5. Results and Discussion

The four new $^{87}Sr/^{86}Sr$ ages obtained in the present paper are shown in Table 1. These data enable the refinement of the age and correlation among the early Miocene *Patagoniense* marine deposits exposed in the MAB, MB and SJB (Fig. 4).

5.1. Isotopic dates and correlations

The Punta Guanacos beds are dated by the first time in a mean age of 19.8 Ma (min 19.3 Ma; max 20.3 Ma), allowing its correlation with the Monte León Formation from the mouth of the Santa Cruz River (Fig. 4), as previously suggested by Casadío and Griffin (2009) on the base of lithological features. A further age for the lowermost beds of the Chenque Formation was obtained at Punta Borja, and the mean age of 19.6 Ma (min 19.4 Ma; max 19.8 Ma) calculated for those beds is in concordance with the date provided by Cuitiño *et al*. (2015) from the lowermost strata exposed at Caleta Córdova (19.69 Ma). A $^{87}Sr/^{86}Sr$ mean age of 17.7 Ma (min 17.6 Ma; max 17.8 Ma) dates the boundary of the sequences 1 and 2 at Punta Delgada (Chenque Formation), which is in agreement with similar ages proposed by Cuitiño *et al*. (2015) at cerro Chenque (Fig. 4).

Samples dated from Cañadón El Lobo in the Mazarredo Basin provide a new $^{87}Sr/^{86}Sr$ age of 20.9 Ma (min 20.8 Ma; max 21.1 Ma), being 1.4 – 1.3 Ma older than the lower section of the Chenque Formation at Punta Borja, and correlate with the lower section of the Monte León Formation exposed at Playa La Mina (Puerto San Julián). Similar lithology of Mazarredo Beds with the San Julián Formation at its type area (southern MAB), and the assumption that their molluscan assemblages were the same, led previous authors to correlate both units (Zinsmeister, 1981; Parma *et al*.,1990; Camacho, 1995). However, the presence of the PP Assemblage in the San Julián Formation (del Río, 2004), dated in the 25.32 Ma - 22.77 Ma interval (Parras *et al*., 2012), the development of the JR Assemblage in the *Patagoniense* strata of the Bahía Mazarredo and its mean age of 20.9 Ma calculated herein, precludes their correlation (Fig. 4). In this way, along with previous biostratigraphic analyses, the obtained Sr-ages in the Chenque Formation finish defining that the late Oligocene “Juliense” transgression is not recorded in the San Jorge Basin, as it was proposed (Feruglio, 1949; Camacho, 1995).

Although the marine beds from the Mazarredo and Sanguineto bays contain molluscs from the JR Assemblage, their lithology and facies association do not allow to be considered part of the tuffaceous Chenque Formation. In this way, combination of lithological features, fossil content and age, provide to these highly fossiliferous strata a unique identity that separate them from other *Patagoniense* units and are herein proposed to be named as Mazarredo Beds (Fig. 4). They crop out in the southern littoral of the San Jorge Gulf, NE of the Santa Cruz province and extend from Punta Casamayor eastwards to Punta Nava and Bahía Sanguineto, and from the Atlantic coast southwards to the old Mazarredo Post office and surroundings of the estancias Floradora, and Los Alamos (47º 06' S- 66º46') (Fig. 2C). The region where these marine sediments accumulated is a small depocenter interposed between the SJB and MAB that Bellosi (1995) distinguished as the Mazarredo Basin (Bellosi, 1995). As sated above, other authors have considered it a part of the MAB (Bellosi, 1990; Malumián, 2011) or part of the SJB (Parras and Cuitiño, 2021). The boundary between San Jorge and Mazarredo basins in the extra-Andean region was positioned at 47º S (Bellosi, 1995), a latitude coincident with the limit of two major Cenozoic segments of the Patagonian Cordillera with distinct evolution (Encinas *et al*., 2019). Thus, the San Jorge - Mazarredo basin boundary was probably conditioned by such tectonic feature.

5.2. Molluscan Assemblages: age calibration

In reference to the identity of the molluscan fauna recorded at Punta Guanacos (MAB), the cluster analysis demonstrates that two groups appear clearly defined (Table 2, Fig. 5). Localities where the JR Assemblage is recorded (Cañadón El Lobo-Punta Nava, Punta Delgada and Punta Borja) are strongly separated from the group formed by the fauna of the Monte León Formation at the mouth of the Santa Cruz River (RSP Assemblage), and that of Punta Guanacos. These results indicate that molluscs of Punta Guanacos belong to the RSP Assemblage of the MAB not being related to the JR Assemblage of the MB and SJB. This is the northernmost occurrence of the RSP Assemblage in the MAB, an assemblage that, according to the age of the Monte León Formation at the mouth of the Santa Cruz River (Parras *et al.,* 2012) and data obtained in the present paper, would embraced the interval 20.3 - 18.8 Ma.

The obtained cluster also reasserts the presence of the JR Assemblage in the MB and SJB as previously proposed (del Río, 2004), and the new $^{87}Sr/^{86}Sr$ ages for the Chenque Formation furnish a more accurate timing for that assemblage. It is recognized in the Mazarredo Beds, in the strata exposed from Las Cuevas-Punta Delgada area northwards to Comodoro Rivadavia, where it is identified in the lower 80 m of the Chenque Formation at the Cerro Chenque, and in the lowermost 40 m exposed at Astra (see del Rio, 2004). The upper boundary of the JR Assemblage in the Comodoro Rivadavia area was arbitrarily placed by del Río (2004) in an interval preserving only oysters**,** that is situated immediately below the *Turritella* 2 bed in the Cerro Chenque. Since this bed upwards in the section, any representatives of this fauna were recorded. According to present age results, along with those performed by Cuitiño *et al.* (2015) in Cerro Chenque, the JR Assemblage ranges from a maximum age of 21.1 Ma (Mazarredo Beds) to at least a minimum age of 17.6 Ma in the boundary of sequences 1 and 2 at Punta Delgada (Fig. 4). Whether this assemblage could be even younger is not possible to deduce, because this molluscan assemblage has not yet been recorded in other sections above the Punta Delgada dated beds. The correlation of the JR Assemblage with the RSP Assemblage from the Monte León Formation at the mouth of the Santa Cruz River (del Río, 2004) has been supported by the first isotopic dates reported by Parras *et al*. (2012) and Cuitiño *et al*. (2015), and those presently carried out herein.

Recent fossil collections make now available a more accurate internal setting of the JR Assemblage. It is possible to distinguish a closer affinity between the faunas of Punta Delgada and Punta Borja (SJB) than with the older fauna yielded in the Mazarredo Beds (MB) (Fig. 5). However, this grouping could also reflect disconnection between both basins rather than age differences. This is demonstrated by the restriction of some species to the MB, such as *Limaria (Platilimaria?) patagonica*, *Limatula (?Stabilima) cossmanni*, *Limea (?Gemellima) pisum*, *Pododesmus paucisquamatus*, *Chione casa* and *Fusus stromeri.* Moreover, the geographic location of the MB between the SJB and the MAB seems to have propitiated the occurrence of some species shared with the RSP Assemblage of the southern MAB rather than with those of the SJB, without losing the identity of the JR Assemblage. Some of the common species among MAB and MB, and absent from the SJB, are *Glycymerita cuevensis*, *Neilo ornata*, *Bathytormus longior*, *Iheringicardium ameghinoi, Chokekenia nicolasi*, *Retrotapes scutatus*, *Sassia bicegoi (= Austrosaccia aff. A.*

mathewi; = Siphonalia nodosocincta) and *Valdesia aequistriata*. Such differences could have responded to coastal configuration or marine currents direction.

6. Conclusions

Numerical dating by Sr-isotope stratigraphy provides a more accurate correlation of the marine *Patagoniense* strata exposed in several basins of Central and Southern Patagonia. Values obtained for beds from Punta Guanacos (northeastern Magallanes-Austral Basin, MAB) dates this section as 19.8 Ma (min 19.3 Ma; max 20.3 Ma), being correlated with the Monte León Formation at its type area (southern MAB). Sr-age of lowermost beds of the Chenque Formation at Punta Borja gives an age of 19.6 Ma (min 19.4 Ma; max 19.8 Ma) and the boundary between Sequence 1 and Sequence 2 of the Chenque Formation of 17.7 Ma (min 17.6; max 17.8), corroborating the Sr-ages proposed by Cuitiño *et al*. (2015). A $^{87}Sr/^{86}Sr$ age of 20.9 Ma (min 20.8 Ma; max 21.1 Ma) was obtained for the Mazarredo Beds at Cañadón El Lobo, being 1.3 – 1.4 ma. older than the lower section of the Chenque Formation at Punta Borja. This age allows its correlation with the base of the Monte León Formation exposed at Playa La Mina (southern sector of MAB) and precludes the development of the “Juliense” transgressive event in Central Patagonia. Lithology, age and the occurrence of the JR Assemblage justify its recognition as Mazarredo Beds.

The JR Assemblage persisted from 21.1 Ma until 17.6 Ma in the San Jorge and Mazarredo basins, in central Patagonia, and was contemporaneous with the RSP Assemblage of the MAB which embraced the interval 20.3 Ma - 18.8 Ma. Comparison using the Simpson Similarity Index among the JR Molluscan Assemblage yielded in the Mazarredo Beds and in the Chenque Formation (Punta Borja and Punta Delgada), the RSP Assemblage represented in the Monte León Formation (southern sector of MAB) and the fauna of Punta Guanacos, shows that the last one should be included in RSP Molluscan Assemblage, being this the northernmost occurrence of it.

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LEGENDS

Figure 1- Early - middle Miocene (18-15 Ma) paleogeography of Patagonia (southern Argentina) showing basins flooded by the *Patagoniense* sea in the maximum transgression.

Figure 2 A- Geographic location of measured sections where the dated early Miocene material comes from; 1- Punta Borja (Chenque Formation); 2- Punta Delgada (Chenque Formation); 3- Cañadón El Lobo (Mazarredo Beds); 4- Punta Guanacos (Monte León Formation). **B-** Enlargement of surroundings of Comodoro Rivadavia´ area. **C-** Enlargement of the area of Bahía Mazarredo. D- Enlargement of the Puerto Deseado´ region.

Figure 3- Studied sections showing stratigraphic position of dated samples (red star). A- Punta Borja, at Comodoro Rivadavia; B- Punta Delgada section, south of Comodoro Rivadavia; C- Cañadón El Lobo section, west of Fitz Roy; D- Punta Guanacos section, south of Puerto Deseado (modified from Casadio and Griffin, 2009).

Figure 4 – Chronostratigraphic chart for the lower- middle Miocene *Patagoniense* marine units, and related continental successions, from San Jorge basin (Chenque Formation, orange), Mazarredo basin (Mazarredo Beds, purple) and Magallanes-Austral basin (Monte Leon Formation, green). Mean Sr ages calculated in this paper in red. Molluscan assemblages proposed by del Río (2004); ***** Cuitiño *et al*. (2015), ◆ Gianni *et al*. (2007), ✦Re *et al*. (2010), ☆Parras *et al*. (2012). Molluscan Assemblages modified from del Río (2004) in blue.

Figure 5- Dendrogram displaying results of cluster analysis (UPGMA) using Simpson Similarity Index. Mazarredo Beds includes all the species recorded in the rocks exposed between Cañadón El Lobo and Punta Nava.

Table 1- Values of $^{87}Sr/^{86}Sr$ for four samples of *Zygochlamys jorgensis*. Data normalized to 0.709174 for EN-1. Numerical ages from LOWESS 6C of McArthur *et al*. (2020)

Table 2- Simpson coefficient for molluscan faunas at the studied sections

Supplementary data S1- Stratigraphic distribution of the recognized early Miocene molluscan species of the Monte León Formation al the mouth of the Santa Cruz River and Punta Guanacos, Mazarredo Beds at Cañadón El Lobo and Chenque Formation at Punta Delgada and Punta Borja.

FIGURE 1

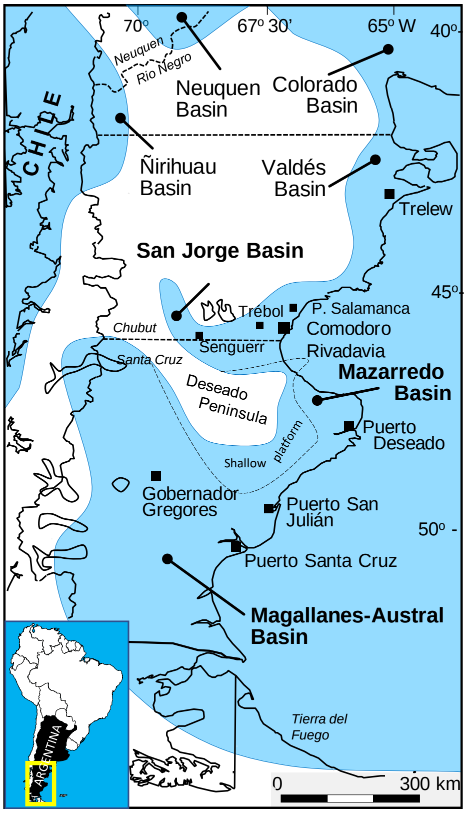

70°
67° 30'
65° W
40°
45°
50°
CHILE
Neuquen
Rio Negro
Neuquen Basin
Colorado Basin
Ñirihuau Basin
Valdés Basin
Trelew
San Jorge Basin
Trébol
P. Salamanca
Comodoro Rivadavia
Chubut
Senguerr
Santa Cruz
Deseado Peninsula
Mazarredo Basin
Puerto Deseado
Shallow
platform
Gobernador Gregores
Puerto San Julián
Puerto Santa Cruz
Magallanes-Austral Basin
Tierra del Fuego
ARGENTINA
0
300 km

FIGURE 2

Click here to access/download;Figure;FIGURE 2 .jpg

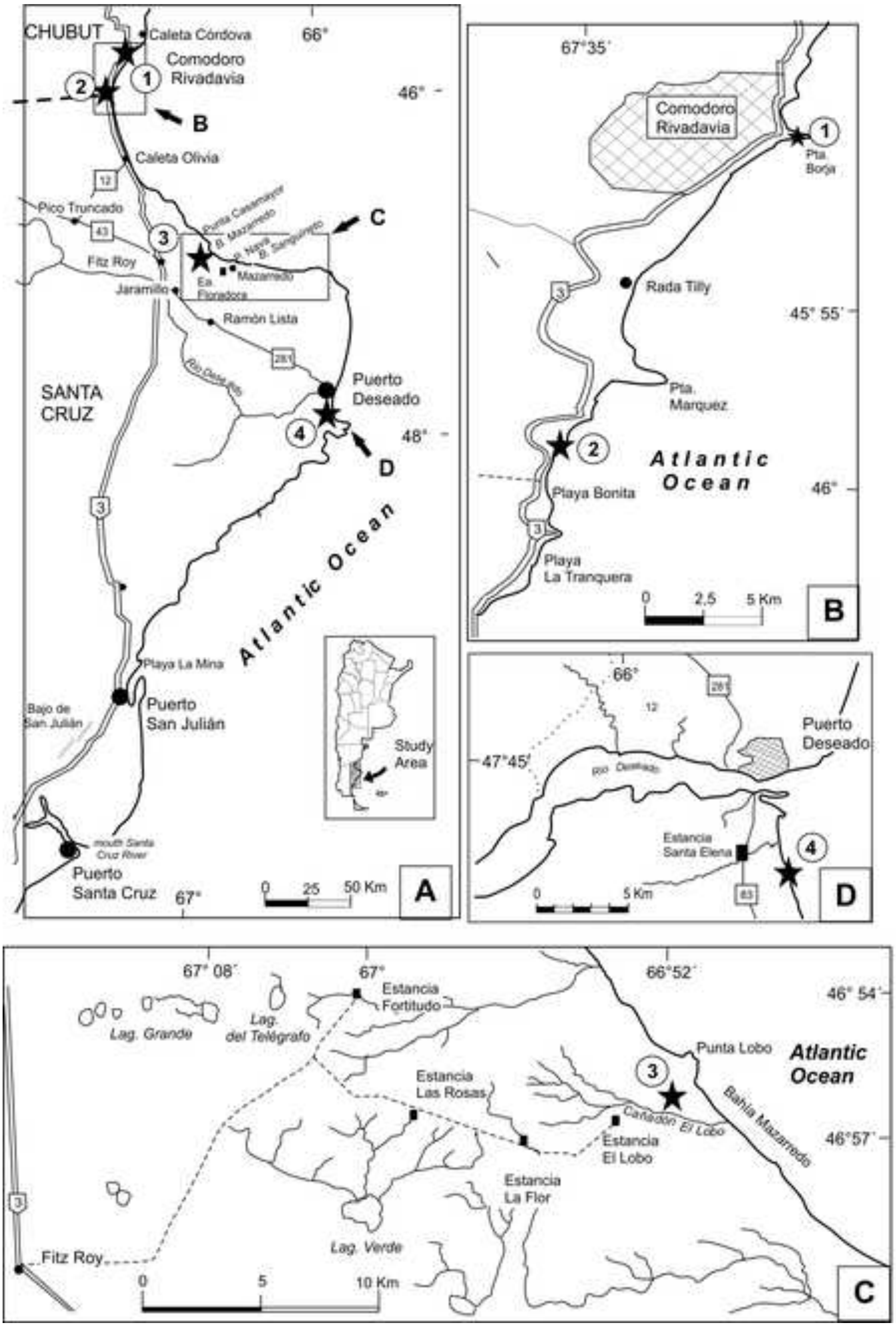


FIGURE 3

Click here to access/download;Figure;FIGURE 3.pdf

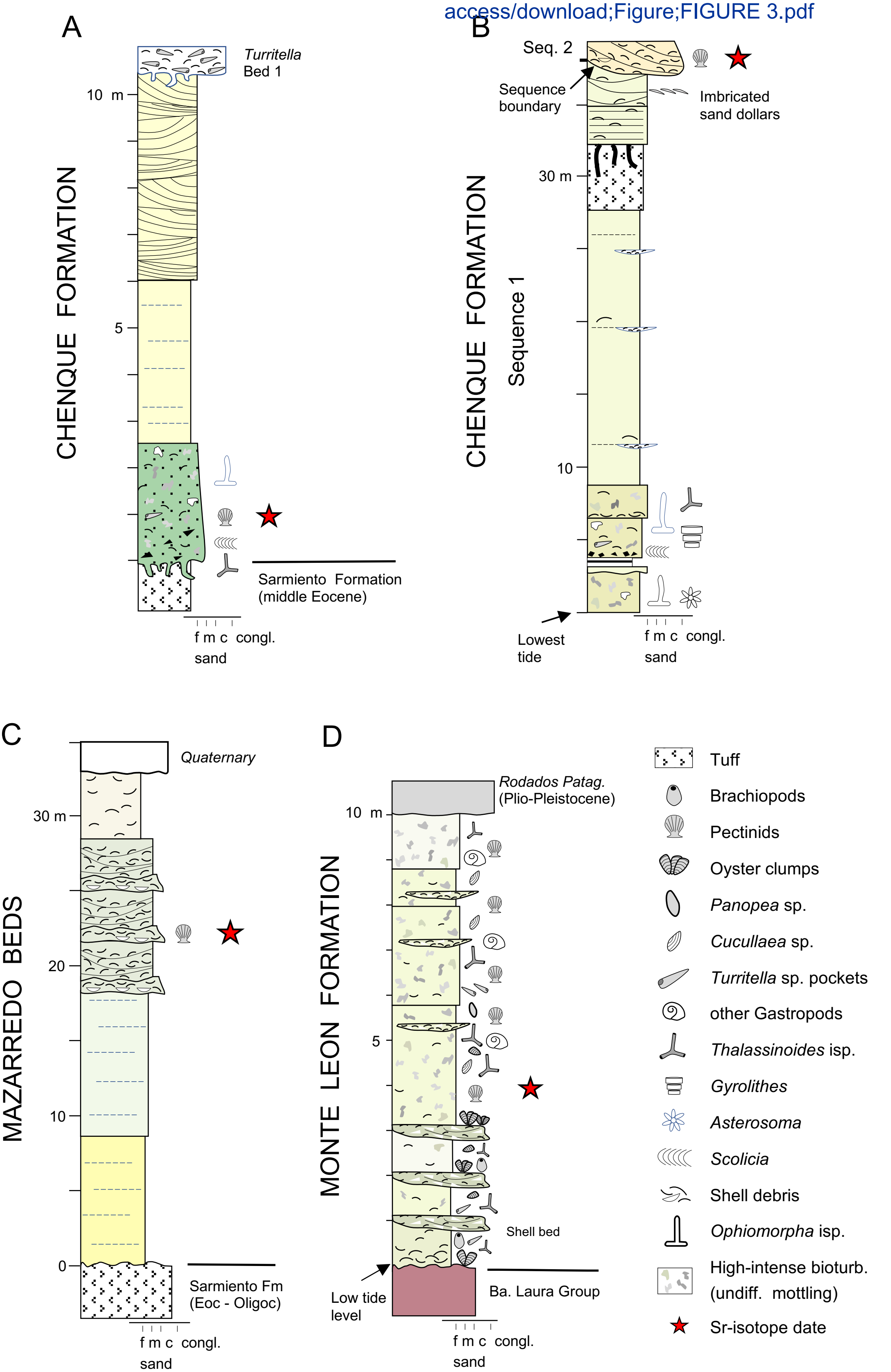
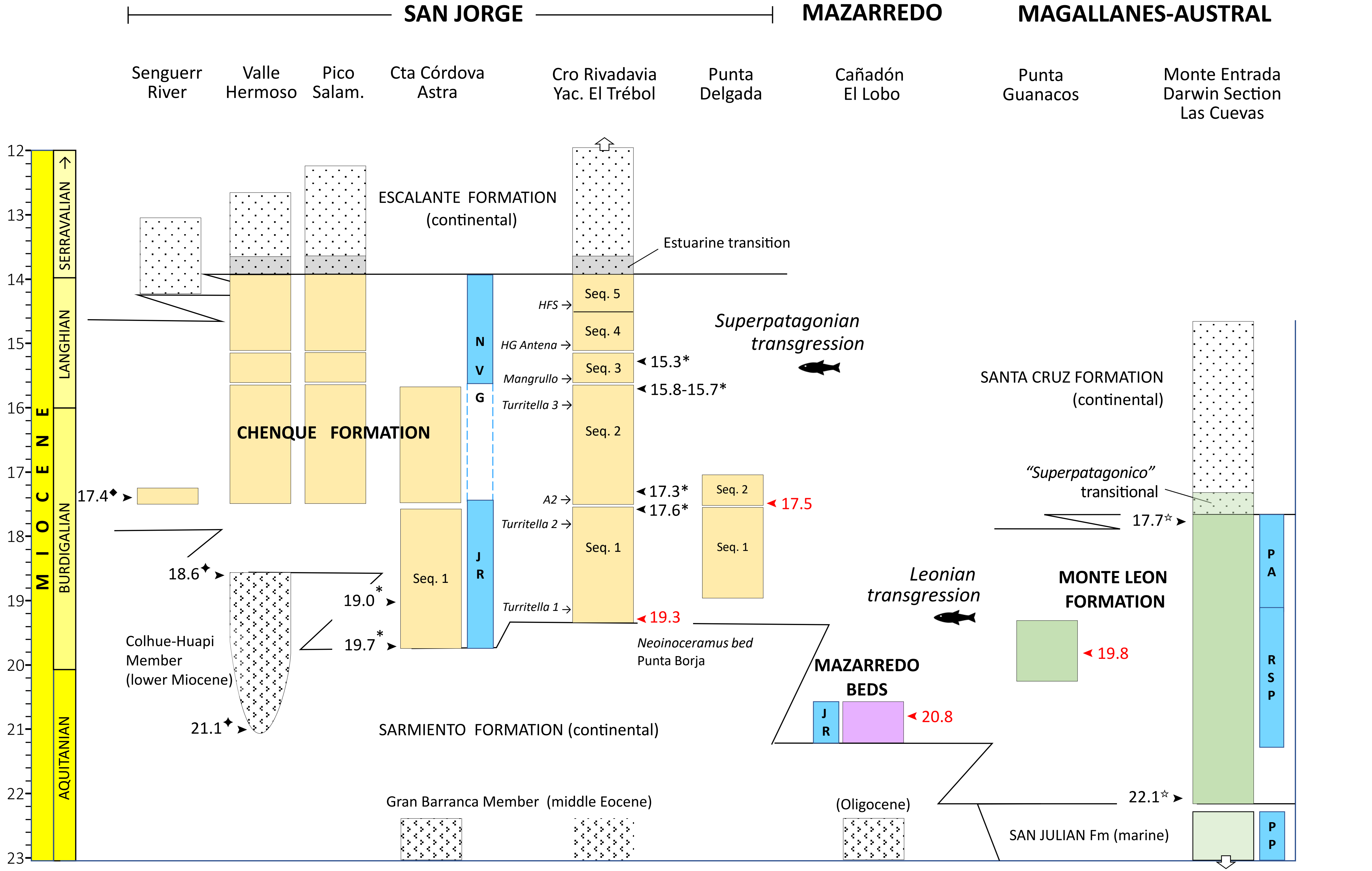
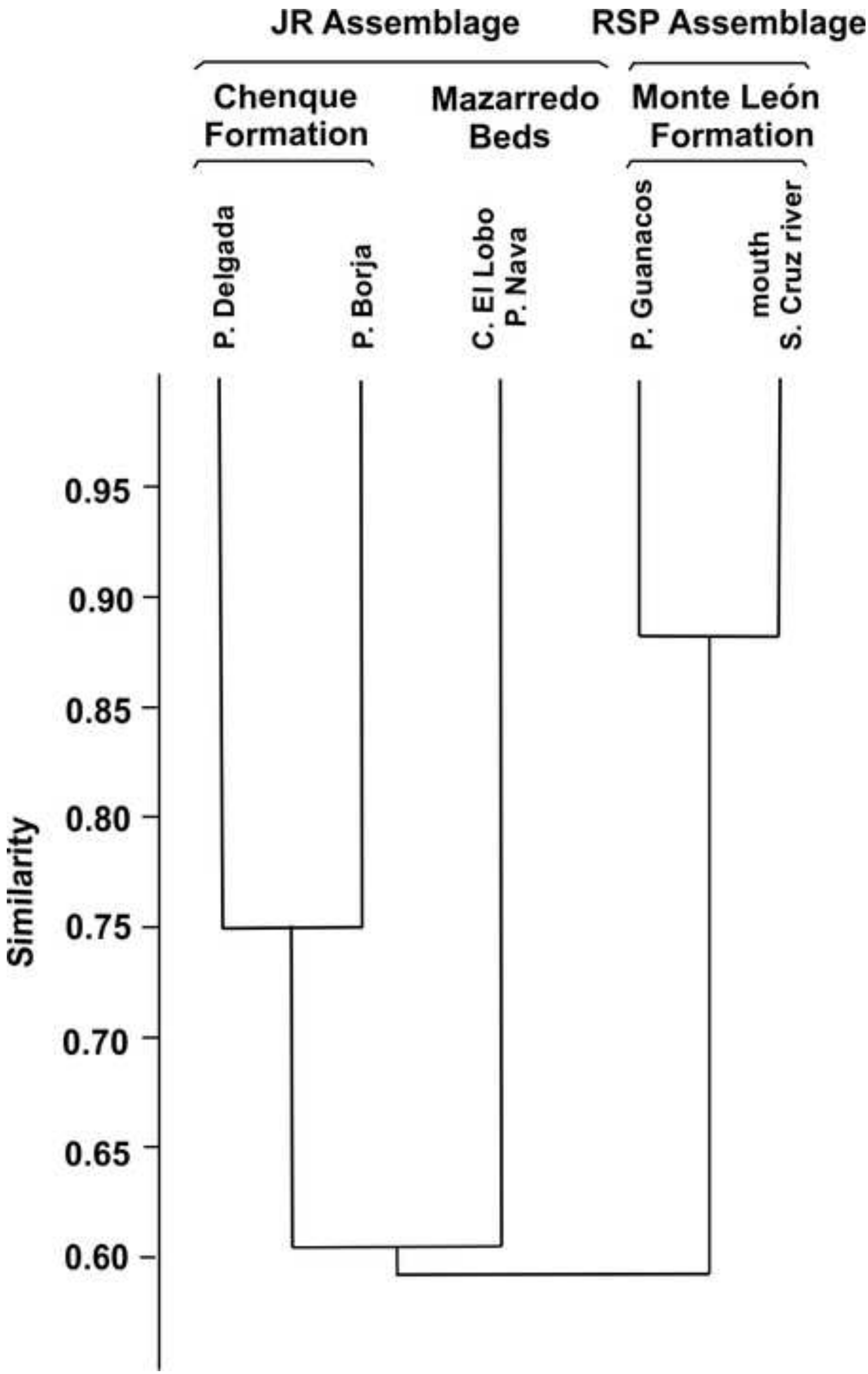


FIGURE 4



SAN JORGE
MAZARREDO
MAGALLANES-AUSTRAL
Senguerr River
Valle Hermoso
Pico Salam.
Cta Córdova Astra
Cro Rivadavia Yac. El Trébol
Punta Delgada
Cañadón El Lobo
Punta Guanacos
Monte Entrada Darwin Section Las Cuevas
MIOCENE
SERRAVALIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
ESCALANTE FORMATION (continental)
Estuarine transition
CHENQUE FORMATION
Seq. 5
Seq. 4
Seq. 3
Seq. 2
Seq. 1
HFS
HG Antena
Mangrullo
Turritella 3
A2
Turritella 2
Turritella 1
NVG
JR
15.3*
15.8-15.7*
17.3*
17.6*
19.3
17.5
17.4
18.6
19.0*
19.7*
21.1
Superpatagonian transgression
SANTA CRUZ FORMATION (continental)
"Superpatagonico" transitional
17.7
Leonian transgression
MONTE LEON FORMATION
19.8
Neoinoceramus bed Punta Borja
MAZARREDO BEDS
20.8
Colhue-Huapi Member (lower Miocene)
SARMIENTO FORMATION (continental)
Gran Barranca Member (middle Eocene)
(Oligocene)
22.1
SAN JULIAN Fm (marine)
PA
RSP
PP

FIGURE 5


JR Assemblage
RSP Assemblage
Chenque Formation
Mazarredo Beds
Monte León Formation
P. Delgada
P. Borja
C. El Lobo P. Nava
P. Guanacos
mouth S. Cruz river
Similarity
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60

LOCALITY	FORMATION	$^{87}Sr/^{86}Sr$	± 2.s.e x 10^6	LOWESS AGES 6C		
				Min	Mean	Max
Punta Guanacos	Monte León	0,708432	13	19,3	19,8	20,3
Punta Delgada	Chenque	0,708619	6	17,6	17,7	17,7
Punta Borja	Chenque	0,708475	12	19,4	19,6	19,8
Cañadón El Lobo	Mazarredo Beds	0,708383	11	20,8	20,9	21,1

Numerical ages from LOWESS 6C of McArthur *et al.* (2020)

	Mouth Santa Cruz River	C. El Lobo - P. Nava	P. Guanacos	P. Delgada	P. Borja
Mouth Santa Cruz River	1	0,64285714	0,88235294	0,66666667	0,70833333
C. El Lobo - P. Nava	0,64285714	1	0,52941176	0,66666667	0,54166667
P. Guanacos	0,88235294	0,52941176	1	0,58333333	0,41666667
P. Delgada	0,66666667	0,66666667	0,58333333	1	0,75
P. Borja	0,70833333	0,54166667	0,41666667	0,75	1

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

SUPPLEMENTARY DATA

	Mouth Santa Cruz Rive	Punta Guanacos	Mazarredo Beds	Punta Delgada	Punta Borja
Iheringinucula crassirugata del Río & Camacho, 1996	1	0	0	0	0
Lamellinucula lunulae del Río & Camacho, 1998	1	1	0	0	0
Scaeoleda? ortmanni (Ihering, 1907)	1	0	0	0	0
Saccella pueyrredona (Ihering, 1907)	1	0	0	0	0
Neilo ornata Sowerby, 1846	1	1	1	0	0
Modiolomytilus? pseudochorus (Doello Jurado, 1922)	1	0	0	0	0
Lithophaga dalli (Ihering, 1907)	0	0	0	1	0
Arca patagonica (Ihering, 1897)	1	0	0	0	0
Cuccullaria darwini (Philippi, 1887)	1	0	1	0	0
Cucullaea marshalli Zinsmeister, 1981	0	0	1	0	0
Cucullaea alta (Sowerby, 1846)	1	0	0	0	0
Glycymerita cuevensis (Ihering, 1897)	1	1	1	0	0
Limopsis insolita (Sowerby, 1846)	1	1	1	0	0
Neopanis quadrisulcata (Ihering, 1897)	1	0	0	0	0
Atrina magellanica (Ihering, 1899)	1	1	1	1	0
"Ostrea" orbignyi Ihering, 1897	1	0	0	0	0
Crassostrea hatcheri (Ortmann, 1897)	1	1	1	1	1
Reticulochlamys borjasiensis del Río, 2004	0	0	0	0	1
Reticulochlamys proxima (Ihering, 1897)	1	0	0	0	0
Reticulochlamys zinsmeisteri del Río, 2004	1	0	0	0	0
Jorgechlamys juliana (Ihering, 1907)	1	1	1	0	1
Jorgechlamys centralis (Sowerby, 1846)	0	1	1	0	1
Swiftopecten iheringii del Río, 1995	0	1	1	1	0
Zygochlamys sebastiani Morra, 1985	1	1	0	0	0
Zygochlamys jorgensis Ihering, 1907	0	1	1	1	1
Chokekenia nicolasi (Morra, 1985)	1	1	1	0	0
Pixiechlamys quemadensis (Ihering, 1897)	0	0	1	1	1
"Myochlamys" patagonensis puntana Ihering, 1907	0	0	1	0	1
Limaria (?Platilimaria) patagonica (Ihering, 1907)	0	0	1	0	0
Limatula (?Stabilima) cossmanni (Ihering, 1907)	0	0	1	0	0
Limea (?Gemellima) pisum (Ihering, 1907)	0	0	1	0	0
Neoinoceramus ameghinoi Ihering, 1902	0	0	1	0	1
Pteromyrtea crucialis (Ihering, 1907)	1	1	1	0	0
Pleuromeris sulcolunularis (Ihering, 1907)	1	1	1	0	0
Darwinicardia patagonica (Sowerby, 1846)	1	1	1	0	0
Osterheldia dalek (Perez & del Río, 2017)	1	0	0	0	0
Osterheldia cannada (Ihering, 1907)	1	0	0	0	0
Bathytormus longior (Ihering, 1897)	1	0	1	0	0
Talabrica elotroyoae Santelli & del Río, 2014	1	0	0	0	0
Spissatella lyelli (Sowerby, 1846)	1	1	0	0	0
Crassatella kokeni Ihering, 1899	1	1	1	0	0
Trachycardium pisum (Philippi, 1887)	1	0	0	0	0
? Hedecardium puelchum (Sowerby, 1846)	1	0	1	0	0
Iheringicardium ameghinoi (Ihering, 1907)	1	0	1	0	0
Patagonicardium philippi (Ihering, 1897)	1	0	0	0	0

Lahillia patagonica Ihering, 1907	1	0	0	0	0
Mactra garreti Ortmann, 1900	1	0	0	0	0
Serratina jeguaensis (Ihering, 1897)	1	0	0	0	0
Macoma ? santacruzensis ((Ihering, 1899)	1	0	0	0	0
Austrocallista iheringii (Cossmann, 1898)	1	0	0	0	0
Ameghinomya meridionalis (Sowerby, 1846)	1	0	0	0	0
Ameghinomya argentina Ihering, 1907	1	0	0	0	1
Ameghinomya darwini (Philippi, 1887)	1	1	0	0	1
Dosinia meridionalis Ihering, 1897	1	0	1	0	0
Retrotapes striatolamellata (Ihering, 1897)	1	0	0	0	0
Retrotapes scutatus (Ihering, 1907)	0	0	1	0	0
Caryocorbula hatcheri (Ortmann, 1900)	1	0	0	0	0
Barnea paucispina (Ihering, 1897)	0	0	0	0	0
Pholadidea patagonica (Philippi, 1887)	1	0	0	1	1
Panopea bagualesia Ihering, 1907 (=sierrana)	1	0	0	0	0
Panopea regularis Ortmann, 1900	1	0	0	0	0
Panopea quemadensis Ihering, 1897	1	1	0	0	0
Solen (Eosolen) crucis (Ihering, 1907)	0	0	0	0	1
Valdesia collaris (Sowerby, 1846)	1	0	0	1	1
Valdesia cuevensis (Ihering, 1897)	1	0	0	0	0
Valdesia aequistriata (Ihering, 1907)	0	0	1	0	0
Fagnanoa dubiosa (Ihering, 1907)	1	0	0	0	0
"Gibbula" dalli (Ihering, 1897)	1	1	0	0	1
"G." ("Phorcus") margaritoides (Cossmann, 1899)	1	0	0	0	0
Solariella dautzenbergi (Cossmann, 1899)	1	1	0	0	0
Calliostoma garreti Ortmann, 1900	1	0	1	0	1
Calliostoma peraratum Cossmann , 1899	1	0	0	0	0
Calliostoma santacruzense Cossmann, 1899	1	1	0	0	0
Homalopoma phillippii (Ihering, 1907)	1	0	0	0	0
Tegula abavus (Ihering, 1907)	0	0	1	0	0
Tegula princeps (Ihering, 1907)	0	0	1	0	0
"Turritella" ambulacrum Sowerby, 1846	1	1	1	1	1
"Turritella" ambulacrum steinmanni Ihering, 1897	0	0	1	0	0
"Turritella" patagonica Sowerby, 1846	1	1	0	0	0
"Turritella" iheringii Cossmann, 1898 (=breant)	1	0	1	0	0
Crepidula gregaria Sowerby, 1846 (=corrugatum, peleus)	1	0	0	0	1
Trochita eleata (Ortmann, 1900) (	1	0	0	0	0
Trochita pileolus (d 'Orbigny, 1841)	1	0	0	0	0
Sigapatella americana Ortmann, 1900	1	0	0	0	0
Cerithioderma patagonica (Cossmann, 1899)	1	0	1	0	0
Ficus carolina (d'Orbigny, 1847)	1	0	1	0	1
Polinices santacrucensis Ihering, 1907	1	1	0	0	0
"Polinices" ortmanni Ihering, 1907	1	0	0	0	0
Glossaulax secundun (Rochebrune & Mabille, 1885)	1	0	0	1	1
Euspira patagonica (Philippi, 1845)	1	0	0	0	0
Struthiochenopus santacruzensis (Ihering, 1907)	1	0	0	0	0
Perissodonta ameghinoi (Ihering, 1897)	1	0	1	0	1
Perissodonta ornata (Sowerby, 1846)	1	0	0	0	0
Sassia bicegoi (Ihering, 1897)	1	0	1	0	0
Cirsotrema rugulosum (Sowerby, 1846)	1	1	1	1	1
Penion subrecta (Ihering, 1899)	1	0	0	0	0
"Cominella" anae (Ortmann, 1900)	1	0	0	0	0

"Fusus" pilsbry Ortmann, 1900	1	0	0	0	0
Urosalpinx dautzenbergi (Ihering, 1897)	1	1	0	0	1
"Urosalpinx" ortmanni Ihering, 1907	0	0	0	0	0
Xymene elegans (Ortmann, 1900)	1	1	0	0	0
Crassilabrum hatcheri (Ortmann, 1902)	1	1	1	0	0
"Ocenebra" *noachina* (Sowerby, 1846)	1	0	0	0	1
"Ocenebra" iheringi (Steinmann & Wilckens, 1908)	1	1	0	0	0
Peonza torquata Olivera, Zinsmeister & Parma, 1994	1	0	0	0	0
Trophon santacruzensis Ihering, 1897	1	1	1	1	1
Dentimargo deuterolivella (Ihering, 1907)	1	0	0	0	0
Austroimbricaria quemadensis (Ihering, 1897)	1	1	0	0	0
Miomelon petersoni (Ortmann, 1900)	1	0	0	0	0
M. dorbignyniana (Phiippi, 1887)	1	0	0	0	0
M. gracilior (Ihering, 1896)	1	0	0	0	0
Adelomelon pilsbryi (Ihering, 1899)	1	0	0	0	0
Neoimbricaria patagonica (Ihering, 1897)	1	1	0	0	0
Splendrillia santacruzensis (Ortmann, 1900)	1	0	0	0	0
Zeacuminia santacruzensis (Ihering, 1897)	1	0	0	0	0
Zeacuminia quemadensis (Ihering, 1897)	1	0	0	0	0
Austrotoma cuevensis (Ihering, 1897)	1	0	0	0	0
Fusiguraleus iheringii (Cossmann, 1899)	1	0	0	0	0
Eoturris santacrucensis (Ihering, 1907)	1	0	0	0	0
Antimelatoma quemadensis (Ihering, 1907)	0	1	0	0	0
Oamaruia? gracilis (Ihering, 1897)	1	0	0	0	0
Zeadmete cruzialis (Ihering, 1907)	1	0	0	0	0
Zeadmete ameghinoi (Ihering, 1897)	1	0	0	0	0
Semiacteon argentinus (Ihering, 1907)	1	0	0	0	0
Turbonilla cuevensis Ihering, 1897	1	0	0	0	0
Turbonilla observatonis Ihering, 1907	1	0	0	0	0
"Odontostomia" euryope Cossmann, 1899	1	0	0	0	0
Odostomia synarthrota Cossmann, 1899	1	0	0	0	0
Odostomia suturalis Ihering, 1897	1	0	0	0	0
Cylichna juliana (Ihering, 1907)	1	0	0	0	0
Kaitoa patagonica (Ihering, 1897)	1	0	0	0	0