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Evidence for early Pliocene and late Miocene transgressions in southern Patagonia (Argentina): $^{87}Sr/^{86}Sr$ ages of the pectinid *"Chlamys" actinodes* (Sowerby)

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ABSTRACT

Numerical ages based on $^{87}Sr/^{86}Sr$ dating of calcitic shells belonging to the pectinid "*Chlamys*" *actinodes* (Sowerby) document the only late Miocene (Tortonian) sea flooding event in the Austral Basin at Cabo Buentiempo (8.95 ± 0.82 Ma, 2 s.e.), and provide evidence of the first documented early Pliocene (Zanclean) transgression in Argentina recorded at Cañadón Darwin (5.15 ± 0.18 Ma, 2 s.e., Austral Basin) and at Terraces of Cerro Laciar (5.10 ± 0.21 Ma, 2 s.e.), southern San Jorge Basin). The sedimentary rocks deposited during the Tortonian are correlated with the youngest beds deposited by the "Entrerriense Sea" that covered northern Patagonia. The Zanclean marine episode is correlated with the long-term cycle represented in the Southern Hemisphere by the flooding events recorded in Cockburn and James Ross Islands (Antarctica) and in North-Central Chile.

1. Introduction

Patagonia (Southern Argentina) was repeatedly flooded by the sea during the Cenozoic, and well-documented lithostratigraphic units are recognized in the Austral, San Jorge, Valdés and Colorado Basins, ranging in age from Paleocene to late Miocene (Fig. 1). Overlying the early-middle Miocene continental and marine rocks in the Santa Cruz Province, there are isolated, widely dispersed fossiliferous marine exposures comprising sandy gravel beds. These are overlain either by continental Quaternary strata (the Patagonian Shingle Formation of Darwin, 1846) or by Pleistocene–Holocene marine terraces (Feruglio, 1933). Some of these exposures, previously mentioned in the geological literature (Hatcher, 1897; Ameghino, 1896), are Cabo Buentiempo, Cañadón Darwin (Austral Basin) and the Terrace of Cerro Laciar (San Jorge Basin; Fig. 2). The age of these marine fossiliferous beds has been controversial. Assigned biostratigraphic ages have ranged from Miocene (Ameghino, 1896) to Pliocene (Hatcher, 1897, 1900; Feruglio, 1950), but on scant evidence. In order to resolve the difficulties involved with determining the age of the fossiliferous gravel beds exposed at the localities mentioned above, we have dated shells of the pectinid *"Chlamys" actinodes* (Sowerby) using Sr-isotope stratigraphy, a method used previously to date beds containing pectinids in Argentina and other southern latitude locations (Dingle et al., 1997; Dingle and Lavelle, 1998; Scasso et al., 2001; Le Roux et al., 2005; Smellie et al., 2006; McArthur et al., 2006; Nielsen and Glodny, 2009; Pirrie et al., 2011).

2. Previous works

Pioneer discoveries in 1895 by the Argentinean explorer Carlos Ameghino in Santa Cruz Province revealed marine fossiliferous strata overlying the marine and continental Miocene sequences of Patagonia. His brother, Florentino Ameghino, reported the existence of these pre-Quaternary deposits (Ameghino, 1896). Although at that time he did not specify the exact geographic location of the deposits. Later, Ihering von (1897), when describing the fauna collected by Carlos Ameghino, stated that the localities of Florentino were Bajo La Pava and Punta Rasa (=Punta Rosa = Estancia Santa Rosa; Fig. 2). Ihering von (1897, 1907) dated

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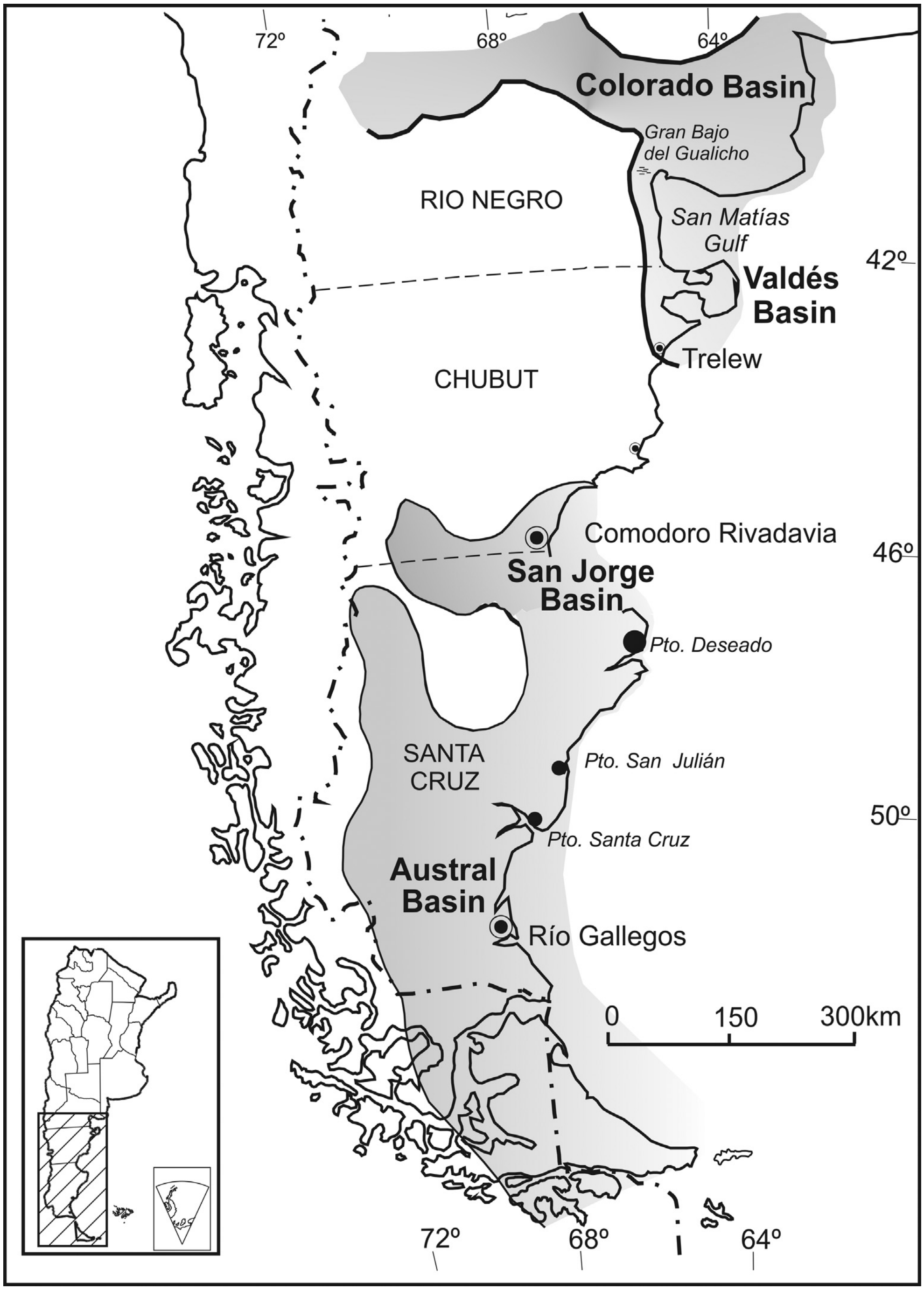

Fig. 1. Areal distribution of marine Miocene deposits in the Patagonian basins. Valdés and Colorado basins (late Miocene) after del Río and Martínez (1998); San Jorge Basin (early–middle Miocene) after Bellosi (1995); Austral Basin (early Miocene) modified from Malumián (1999).

them as late Miocene based on the percentage of living taxa in the assemblages of fossil mollusk recovered.

Hatcher (1897), who in 1896 conducted the Princeton University Expedition to Patagonia, described marine beds unconformably overlying the early Miocene continental Santa Cruz Formation. These beds are exposed at Cabo Buentiempo (mouth of the Río Gallegos) and were named "Cape Fairweather Beds" by Hatcher (op. cit.). Pilsbry (1897) and Ortmann (1902), also based on the number of the living taxa, considered the assemblage to be of Pliocene age.

Ameghino (1902) published a detailed summary of the geographic location of the fossiliferous beds discovered by Carlos. He discussed their stratigraphic relationships and included them in the base of the Tehuelche Formation. Later, Ameghino (1906) stated that these beds represented three stages, that from oldest to youngest were *Rosaense Stage* (Miocene), well exposed south of Puerto San Julián (Estancia Santa Rosa) and in Bajo La Pava; *Laziarense Stage* (Miocene), with its type locality in the surroundings of Cerro Laciar and also exposed at Monte Espejo; and the *Fairweatherense Stage* (Pliocene) exposed at Cabo Buentiempo (Fig. 3). The mollusk assemblages contained in all these deposits were revised by Ihering von (1907), who considered them late Miocene in age, rather than Pliocene.

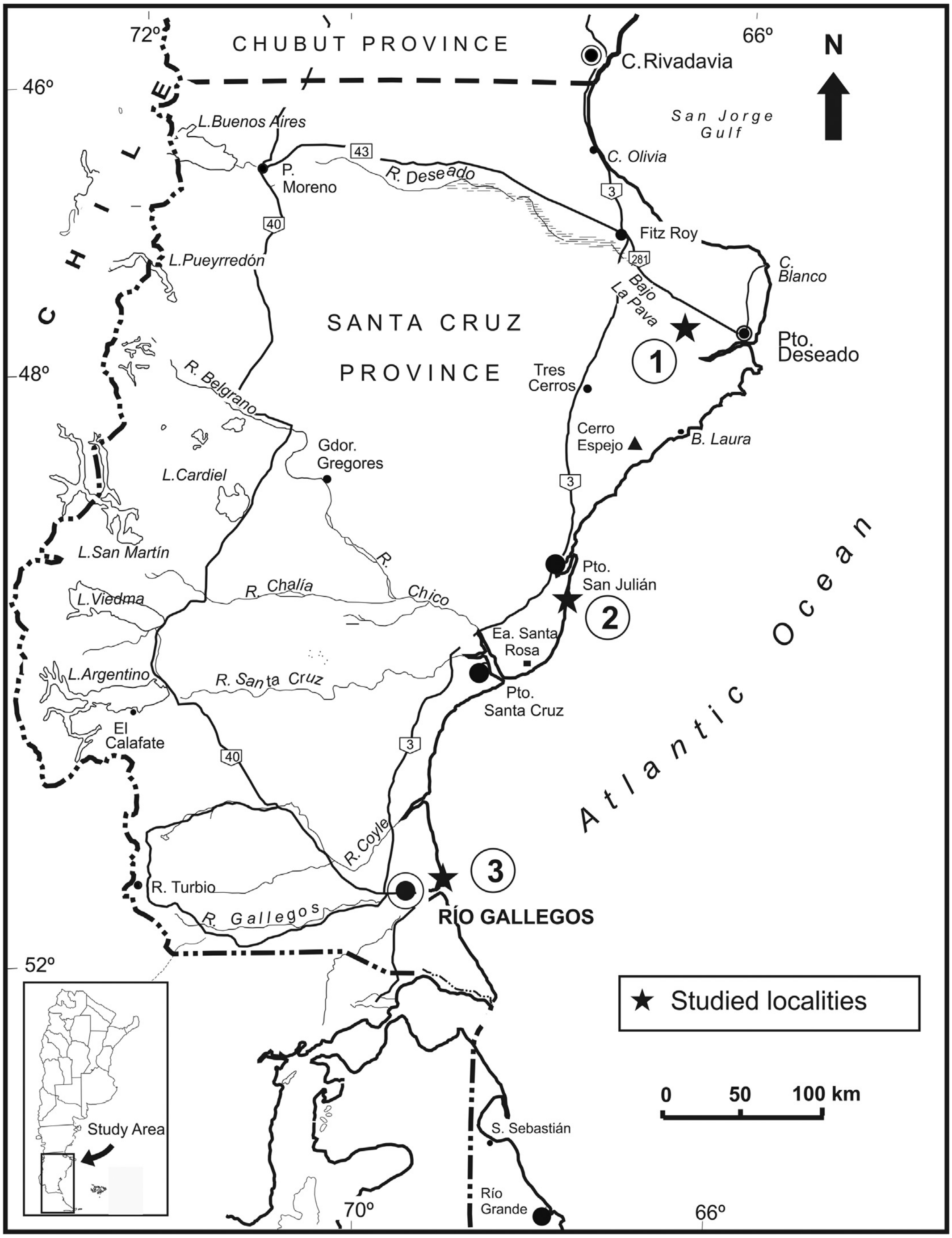

Fig. 2. Geographic placement of studied localities in Santa Cruz Province. 1 – Terrace of Cerro Laciar; 2 – Cañadón Darwin; 3 – Cabo Buentiempo.

Feruglio (1933) carefully described many new post-Miocene marine fossiliferous localities, and grouped them into six "Terrace systems" well exposed along the littoral of Chubut and Santa Cruz Provinces, overlying Neogene marine and continental units. With no further support other than the altitude, the similarity to older Miocene units of the region and the percentage of living species in the fossils assemblages, he placed System I in the late Pliocene–early Pleistocene, Systems II, III, IV in the Pleistocene and Systems V and VI in the Holocene. Later, Feruglio (1950, 1954) summarized the knowledge of the Terrace Systems and updated the composition of the mollusk assemblages, recognizing 52 mollusk species for System I and 14 for System II. He also moved the Cabo Buentiempo beds from System II to System I, and included the new fossil locality Cañadón Darwin in System II. He assigned a late Pliocene age to System I and stated that the age of System II would deserve a detailed discussion, but that it was probably Pliocene or Pleistocene. Disagreeing with Ameghino (1906), he considered the Cabo Buentiempo beds older than, or as old as, those exposed at the surroundings of Cerro Laciar. He based such an assumption on the presence in them of a higher number of Miocene species in the southernmost beds than in the Terrace of Cerro Laciar.

Modern studies assigned the gravel beds at Cañadón Darwin to System II of Feruglio (1933), and placed them in the late Pleistocene–Holocene (Panza and Irigoyen, 1994), and those of Terrace of

	AMEGHINO 1906		FERUGLIO 1933		FERUGLIO 1950		THIS PAPER
	STAGES	LOCALITIES	SYSTEM TERRACES	LOCALITIES	SYSTEM TERRACES	LOCALITIES	
HOLOCENE			VI	Comodoro Rivadavia	VI	Comodoro Rivadavia	not considered
HOLOCENE			V	Puerto Mazarredo	V	Puerto Mazarredo	not considered
PLEISTOCENE			IV	Pto. Deseado-B. Sanguinetti	IV	Pto. Deseado - B. Sanguinetti	not considered
PLEISTOCENE			III	Camarones	III	Camarones	not considered
PLEISTOCENE			II	Ea. Sta Rosa; M. Espejo; C. Tres Puntas; C. Buentiempo	II?	Ea. Darwin; Ea. Sta Rosa M. Espejo; C. Tres Puntas	
PLEISTOCENE			I	Terrace of Cerro Laciar			
PLIOCENE LATE					I	Terrace of Cerro Laciar Cabo Buentiempo	Terrace of Cerro Laciar Cañadón Darwin
PLIOCENE EARLY	"FAIRWEATHERENSE"	Cabo Buentiempo					
MIOCENE	"LAZIARENSE"	Cerro Laciar Monte Espejo					Cabo Buentiempo
MIOCENE	"ROSAENSE"	Ea. Santa Rosa; Bajo La Pava					

Fig. 3. Stratigraphy of the Miocene–Pliocene Stages of Ameghino (1906), the Neogene–Quaternary System Terraces of Feruglio (1933, 1950) and that proposed herein.

Cerro Laciar were considered of late Pliocene age by Giacosa et al. (1998), who stated that in the area situated 68 km south of Bajo La Pava, they are overlain by the La Angelita Basalt, which was dated at 1.96 ± 0.16 Ma by Gorring et al. (1997).

The existence of marine Pliocene horizons was also reported for the Colorado Basin (Río Negro Province), about 800 km north of Puerto Deseado. In this area, exposed along the northern coast of San Matías Gulf, there are marine fossiliferous beds intercalated in the base of the eastern exposures of the continental Rio Negro Formation. These strata are known as Facies Balneario La Lobería Angulo and Casamiquela, 1982 and have been indistinctively assigned to the late Miocene, to the Pliocene or to the late Miocene–early Pliocene depending on the mammal age assignment of the contemporaneous Río Negro Formation. On one hand, Angulo and Casamiquela (1982), proposed a Montehermosan age for the Río Negro Formation, considered by then as Pliocene, but today proved to be late Miocene to early Pliocene (Flynn and Swischer, 1995; Pascual et al., 1996; Cione et al., 2005). A Pliocene age was also accepted by Farinati et al. (1981), Franchi et al. (1984) and Echevarría (1988). On the base of a fission track age of 4.41 Ma calculated by Bigazzi et al. (1995), the beds of the Río Negro Formation overlying the Facies Balneario La Lobería are considered of early Pliocene age (Alberdi et al., 1997). On the other hand, Pascual et al. (1984) and Pascual y Bondesio (1985), recognized in the

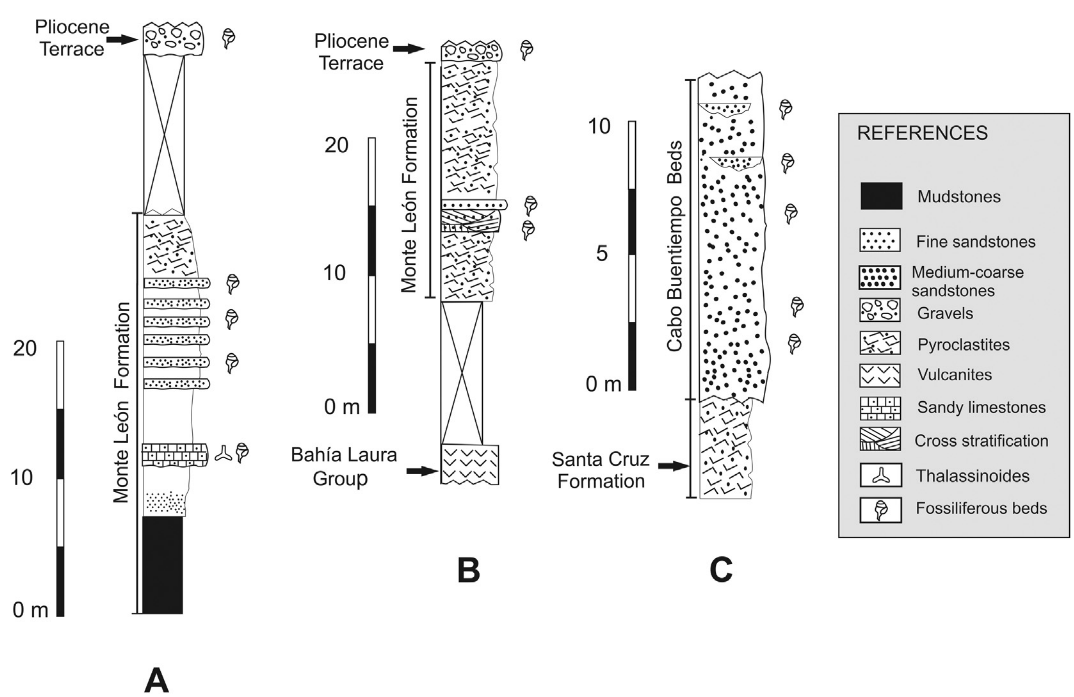

Fig. 4. Lithological sections at A – Cañadón Darwin; B – Terraces of Cerro Laciar; C – Cabo Buentiempo.

eastern exposures of the Río Negro Formation (San Matías Gulf), an assemblage of Huayquerian age, that according to Cione et al. (2005) encompasses the middle and late part of the Tortonian and probably the base of the Messinian (late Miocene).

Dealing with the marine intercalation itself, del Río (1988, 1990, 2000) recognized the late Miocene *Aequipecten paranensis* Biozone in the Facies Balneario La Lobería and correlated it with the Puerto Madryn Formation (Valdés Basin, northern Chubut Province) and with the upper part of the Gran Bajo del Gualicho Formation (Colorado Basin). The presence of typical late Miocene mollusk species such as *A. paranensis* (d'Orbigny), *Amusium paris* del Río, *Pododesmus camachoi* del Río and Martínez and the echinoid *Monophoraster darwini* Desor, all taxa that became extinct at the end of the Miocene, support a Miocene rather than a Pliocene age for the Facies Balneario La Lobería, an age accepted by Farinati and Zavala (2005).

3. Geological setting

Fossiliferous beds are exposed at Cabo Buentiempo, at the mouth of Cañadón Darwin and at the Terrace of Cerro Laciar, all localities in Santa Cruz Province. Lithostratigraphic sections and panoramic views of the fossiliferous sites are illustrated in Figs. 4 and 5.

The Cabo Buentiempo Beds are located at 8.63 km east of the Estancia Cabo Buentiempo and exposed at the top of the cliff along the shore at Cabo Buentiempo, at 131 m–138 m above sea level (51° 32′ 55″ S–68° 56′ 55″ W). They overlie the early Miocene continental, mammal-bearing Santa Cruz Formation, spanning the interval 18 Ma–16 Ma in the Atlantic coastal plain (Perkins et al., 2012) (see Perkins et al., op. cit. and Fleagle et al., 2012, and references therein, for discussion of age of the Santa Cruz Formation over the time). The Cabo Buentiempo Beds measure a variable thickness of up to 10 m and appear to infill channels cut into the underlying unit. The deposit consists of dark brownish medium- to coarse-grained loose sandstone, carrying a within-habitat accumulation constituted by numerous specimens of randomly oriented disarticulated valves of "*Chlamys*" *actinodes* (Sowerby, 1846). Shells are very well preserved, show low size-sorting and exterior and interior surfaces of some valves show a high degree of infestation by boring and encrusting epibionts (serpulids, barnacles and juvenile oyster), suggesting a long period of post-mortem residence

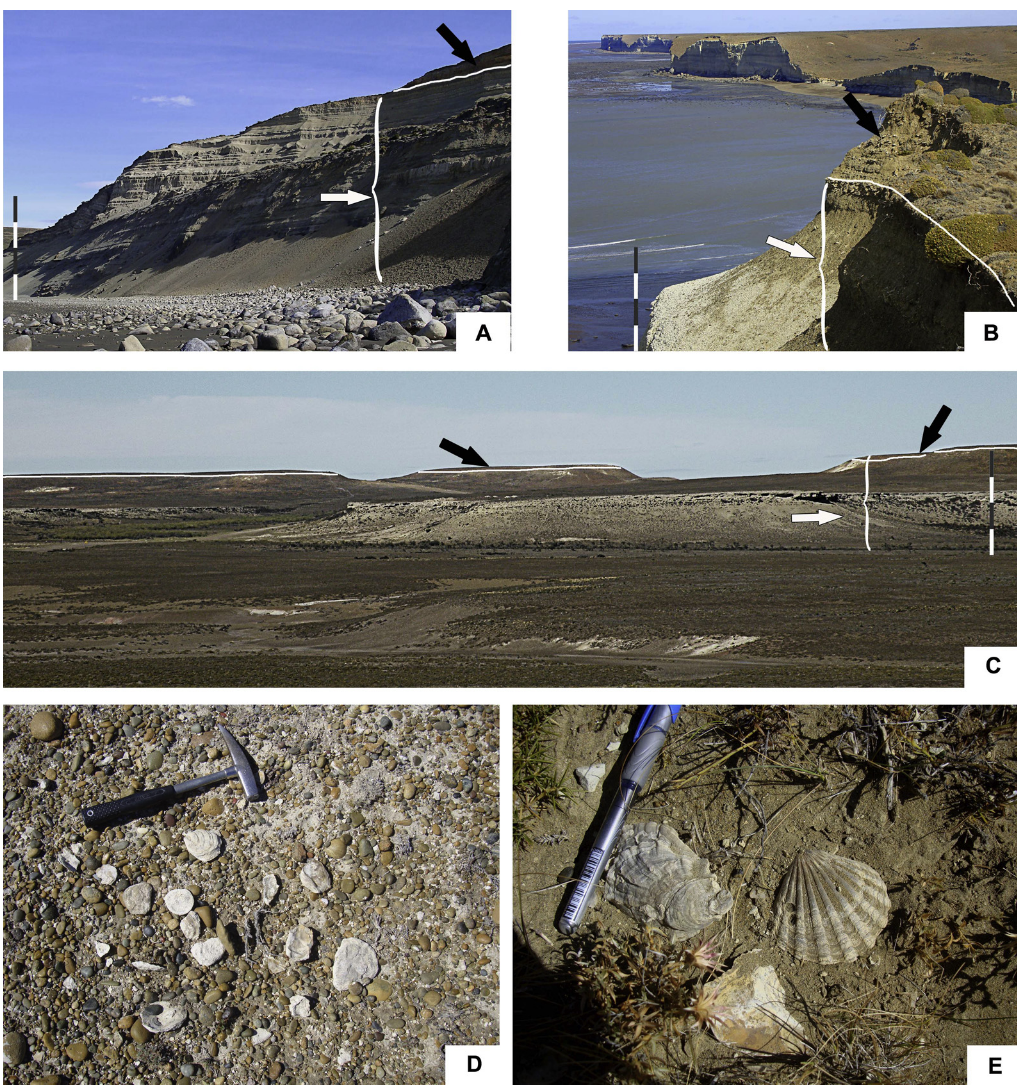

Fig. 5. Panoramic views of the fossil localities at A – Cabo Buentiempo, the white line indicates boundary between the Santa Cruz Formation (white arrow) and Cabo Buentiempo Beds (black arrow); scale: 60 m; B – Cañadón Darwin, the white line indicates boundary between the Monte León Formation (white arrow) and the Pliocene terrace (black arrow), scale = 6 m; C – Terrace of Cerro Laciar, the white line indicates boundary between the Monte León Formation (white arrow) and Pliocene beds (black arrow); scale = 60 m; D – detailed view of molluskan assemblage at Terrace of Cerro Laciar; E – detailed view of molluskan assemblage at Cañadón Darwin.

on the sea floor. Associated with the pectinids appear *Trophon fairus* (Ihering) and balanids. At the top there are two intercalated lens-like oyster beds about 0.5–1 m thick. The oysters belong in "*Ostrea*" *faira* Ihering, are articulated, forming nearly vertical bunches and represent a census assemblages. Together with the oysters there are well preserved shells of *T. fairus* Ihering, *Magellania gigantea* (Ortmann), and balanids.

The fossiliferous locality of Cañadón Darwin (49° 37′ 40″ S, 67° 42′ 53″ W) is located at the mouth of a gully on the Atlantic coast, 6.6 km east of Estancia Makenke (ex-Estancia Darwin). The fossiliferous beds lie at the top of the cliffs, i.e., 65–75 m above sea level, and overlie the highly fossiliferous Miocene marine Monte León Formation. Exposures consists of up to 3 m thick yellowish to grayish medium- to coarse-grained loose sandstones and gravels that contain widely dispersed and chaotically arranged, sometimes fragmented specimens of *Ostrea faira* Ihering, *"Chlamys" actinodes* (Sowerby), *"Chlamys" deseadensis* (Ihering), *T. fairus* (Ihering), *Pachycymbiola feruglioi* (Doello Jurado) and *Pododesmus* sp.

The Terrace of the Cerro Laciar is placed about 50 km west of Puerto Deseado, stretching between 4 and 18 km south of Highway 281 along the southern cliffs of Bajo la Pava, situated west from the reddish rhyolitic dome known as Cerro Laciar (47° 37′ 45″ S–66° 23′ 30″ W; Fig. 6). This terrace is at 170–185 m above sea level and the best exposures are located east of Highway 66. In this area, at least two of the three fossil localities of Feruglio were recognized (47° 34′ 11″S, 66° 29 25″ W and 47° 35′ 21″S, 66° 27′ 22″ W; located 6.8 km and 3.4 km southeast of Estancia Aurora respectively) and a new one was identified at 47° 37′ 11″ S–66° 32′ 11″ W (14.7 km south of Estación Biedma), along Highway 66. Exposures are isolated, overlying the marine early Miocene Monte León Formation and consist of loose gravel with a sandy — sometimes calcareous — matrix, altogether similar to the Pleistocene and Holocene terraces exposed nearby, albeit at considerably lower heights (110 m). Among the most conspicuous fossils are *Ostrea ferrarisi* d'Orbigny, *"Trophon" varians* (d'Orbigny), *"Chlamys" actinodes* (Sowerby), *Chlamys laziarina* (Ihering), *Venericardia dalli* (Ihering) and *P. feruglioi* (Doello Jurado). Fossils are represented by highly eroded and fragmented shells chaotically dispersed, probably reworked by the Quaternary fluvial systems originating the Shingle Formation, responsible for leaching the hosting Pliocene sediments but leaving the Pliocene shells.

4. Material and methods

We used Sr-isotope stratigraphy to date valves of *"Chlamys" actinodes* (Sowerby) from Cabo Buentiempo (three samples), the Terrace of Cerro Laciar (four samples), and Cañadón Darwin (three samples). Several specimens from each deposit were analysed in order to reduce analytical uncertainty on the derived numerical age. The samples were cleaned of adhering matrix by physical abrasion, then broken into sub-cm-sized pieces. The pieces were cleaned by brief immersion in 1% hydrochloric acid, then washed under ultra-pure water, and finally were dried in a clean environment.

From the pieces, the best preserved were gently broken into mm-sized pieces and these were hand-picked under the microscope to select 10 mg of thin, sheet-like, fragments that were the best preserved. The diagnostic features of good preservation are fragmentation along the original layering, clear calcite as fragments, and an absence of Fe or Mn stain. The picked samples were dissolved in nitric acid, evaporated to dryness, and Sr was separated from the residue using standard methods of column chromatography. External precision of ±0.000015 on $^{87}Sr/^{86}Sr$ was measured by running multiple replicates of NIST987 before, during and after the isotopic measurements were made. All analyses are adjusted to NIST987 value of 0.710248.

Numerical ages were derived from $^{87}Sr/^{86}Sr$ ratios using the LOWESS calibration curve of McArthur et al. (2012). The uncertainties on the numerical ages are derived by compounding the uncertainty of measurement with the uncertainty on the calibration line, and are shown in Fig. 7 as standard errors of the mean values.

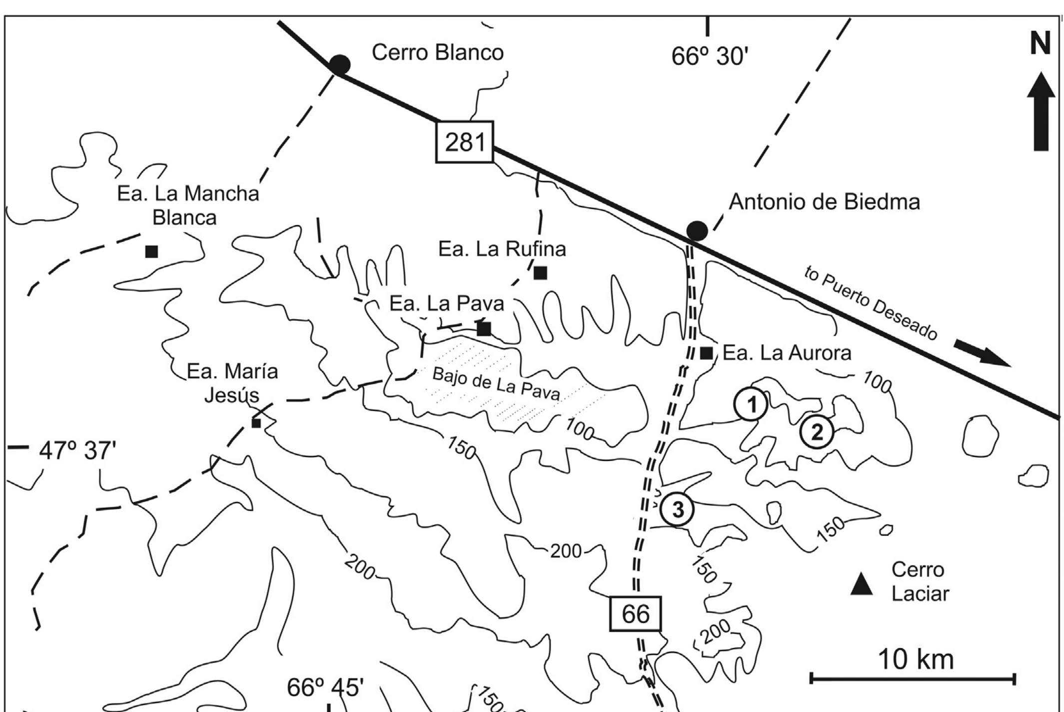

Fig. 6. Geographic location of the Terrace of Cerro Laciar. 1 and 2, fossil locality of Feruglio (1933); 3, fossil locality site studied herein.

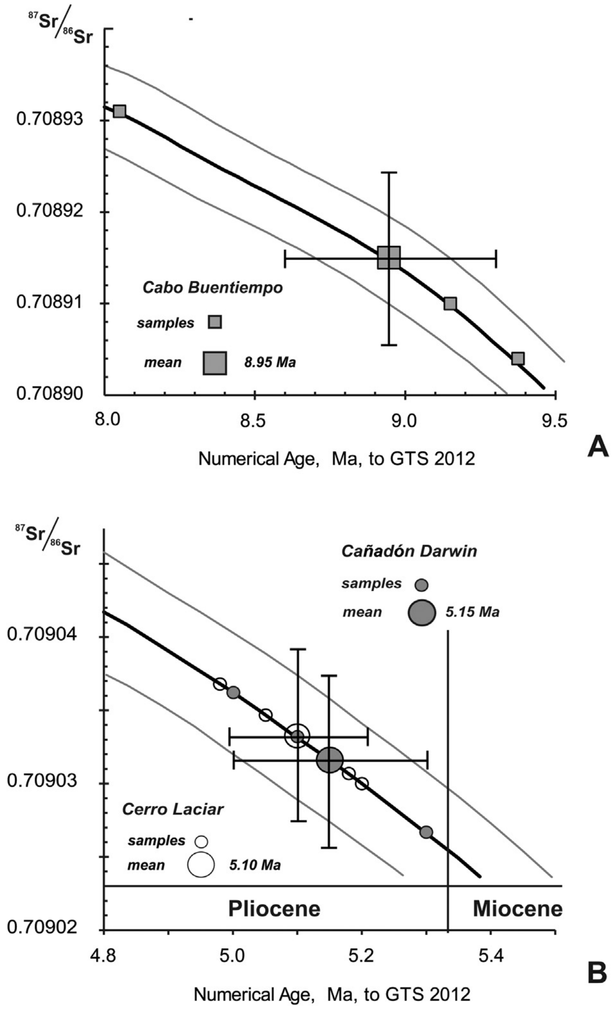

Fig. 7. Sr-isotope calibration of McArthur et al. (2012) and $^{87}Sr/^{86}Sr$ values of samples analysed here for a – late Miocene (Tortonian), b – Miocene–Pliocene boundary. Upper and lower feint curved lines are uncertainty envelopes at 95% confidence intervals on the mean line, which is the middle black line. Uncertainty bars drawn for standard errors of the mean values from Table 1.

Table 1
Values of $^{87}Sr/^{86}Sr$ in ten samples of pectinids (Sowerby) from Santa Cruz Province. Uncertainty on mean age from combining standard errors on the LOWESS fit with the standard error on mean $^{87}Sr/^{86}Sr$ adjusted to value 0.710248 for NIST987.

Locality	$^{87}Sr/^{86}Sr$	±	LOWESS	Dates	Ma	
			Min	Mean	Max	
Cabo	0.708931	10	7.50	8.05	8.60	Late Miocene
Buentiempo	0.708904	11	8.80	9.38	10.00	Late Miocene
	0.708910	11	8.55	9.15	9.75	Late Miocene
Mean	***0.708915***	***6***	***8.60***	***8.95***	***9.30***	***Late Miocene***
Cerro Laciar	0.709035	12	4.40	5.05	5.70	Earliest Pliocene
	0.709030	9	4.70	5.20	5.70	Earliest Pliocene
	0.709037	11	4.40	4.98	5.60	Earliest Pliocene
	0.709031	14	4.45	5.18	5.95	Earliest Pliocene
Mean	***0.709033***	***6***	***4.80***	***5.10***	***5.40***	***Earliest Pliocene***
Cañadón	0.709036	9	4.35	5.00	5.50	Earliest Pliocene
Darwin	0.709033	12	4.45	5.10	5.75	Earliest Pliocene
	0.709027	10	4.75	5.30	5.85	Earliest Pliocene
Mean	***0.709032***	***6***	***4.80***	***5.15***	***5.50***	***Earliest Pliocene***

5. Results and discussion

Data provided in Table 1 and illustrated in Fig. 7 shows that the mean numerical age for the samples from Cabo Buentiempo is 8.95 ± 0.82 Ma, 2 s.e. (Austral Basin), 5.10 ± 0.21 Ma, 2 s.e. for those from Terrace of Cerro Laciar, and 5.15 ± 0.18 Ma, 2 s.e. for those from Cañadón Darwin (San Jorge and Austral Basin respectively). Thus, two different Neogene transgressive marine events are herein documented and will be discussed below:

5.1. Late Miocene flooding

Exposures of the Austral Basin along the southwestern Atlantic littoral, record a marine transgression represented by the San Julián Formation, spanning 25–23 Ma (late Oligocene, Chattian) and a younger flooding episode represented by the sediments that constitutes the Monte León Formation deposited between 22 and 18 Ma (early Miocene, Aquitanian–early Burdigalian) (Parras et al., 2012) (Fig. 8). Following this second transgression, a regressive event and the ensuing continental environment led to the deposition of the mammal-bearing beds of the Santa Cruz Formation. The Cabo Buentiempo strata presently studied overlie the Santa Cruz Formation and the stratigraphic age of the samples analysed herein (8.95 ± 0.82 Ma) point to a late Miocene age (Tortonian). This result indicates a new Neogene flooding event in the southernmost sector of Patagonia. A Tortonian flooding event — known as “Entrerriense transgression” — covered the Valdes Basin (Chubut Province) and is represented by the Puerto Madryn Formation. The transgressive and highstand system tracts of the mentioned unit were dated in 10 ± 0.3 Ma (Scasso et al., 2001) while the uppermost beds of the regressive system tract was dated 9.4 Ma (Zinsmeister et al., 1981). Thus, the transgressive event in Cabo Buentiempo is correlated with the youngest flooding episodes represented in the Puerto Madryn Formation, constituting the first documented record of the southernmost extension of the “Entrerriense Sea” during the late Miocene.

A preliminary comparison of the mollusk faunas contained in the Puerto Madryn Formation (del Río, 1992, 1994) and those in the Cabo Buentiempo Beds (Feruglio’s collections and material recently collected under study), indicates that the assemblages from these two localities are substantially different, suggesting an important latitudinal dispersal control of the late Miocene species, as already proven by del Río (2000) and Martínez and del Río (2002). While the “Entrerriense” mollusks from northern Patagonia show strong affinities with warm and warm-temperate assemblages (del Río, 1988, 1990, 2000), and are part of the Valdesian Province (Martínez and del Río, 2002), those contained in the Cabo Buentiempo represent a poorly diverse cold-temperate assemblage. To further improve our understanding of the taxonomic composition and biostratigraphic relationships of these localities, the late Miocene fauna at Cabo Buentiempo and the earliest Pliocene assemblage at Cañadón Darwin and Terrace of Cerro Laciar deserve a close systematic analysis in order to assess their taxonomic composition and biostratigraphic relationships.

5.2. Early Pliocene flooding

Stratigraphic age of samples from the Terrace of Cerro Laciar (5.10 ± 0.21 Ma, 2 s.e.; southern sector of San Jorge Basin) and from Cañadón Darwin (5.15 ± 0.18 Ma, 2 s.e., Austral Basin) overlap and are not statistically different, pointing to an earliest Pliocene age (Zanclean). These results are the first documented mention of a $^{87}Sr/^{86}Sr$ early Pliocene age in the Atlantic platform of the Patagonian region, proving the existence of a marine transgression of that age in the area. According to the eustatic curve of Hardenbol et al. (1998) (recalibrated from Haq et al., 1988), this flooding event is correlated with the early Pliocene prominent transgressive cycle culminating between 5.1 Ma and 4.9 Ma, the C3 Polarity chronozone

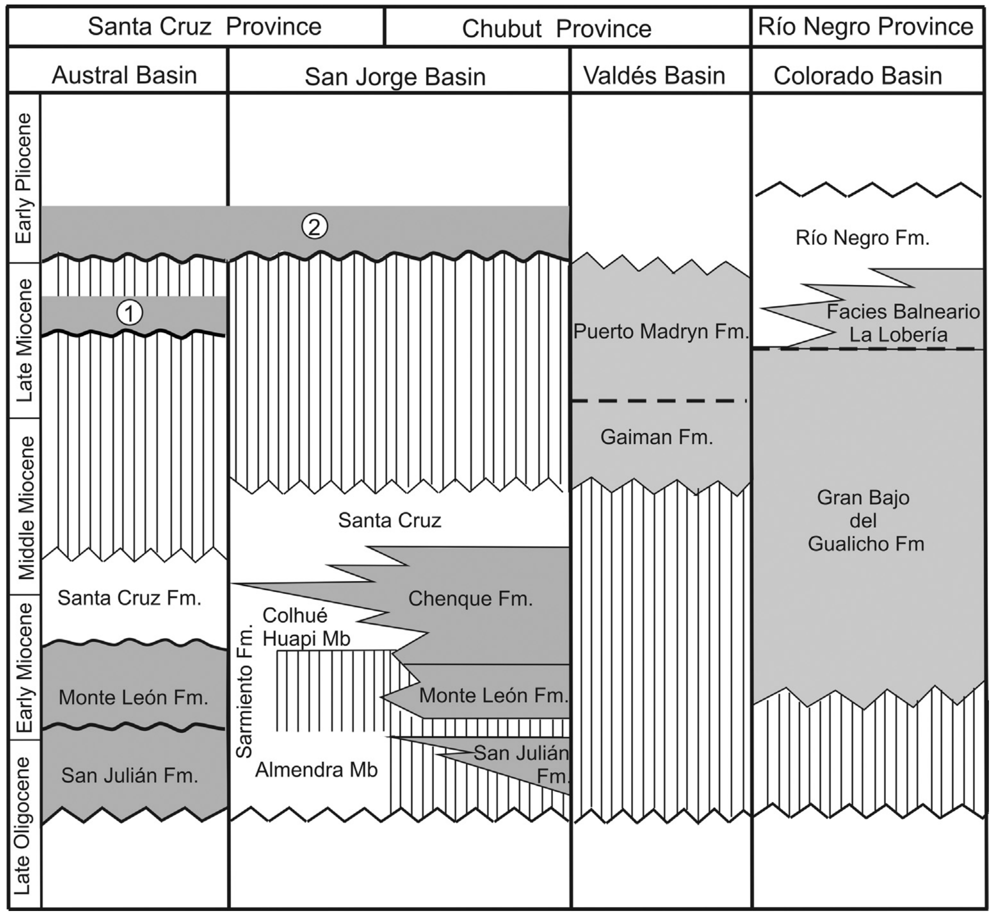

Fig. 8. Proposed correlation of Southwestern Atlantic Patagonian Neogene lithostratigraphic units. 1 – late Miocene transgression recorded at Cabo Buentiempo; 2 – early Pliocene flooding at Cañadón Darwin (Austral Basin) and Terrace of Cerro Laciar (San Jorge Basin). Stratigraphy of San Jorge Basin after Bellosi (2010).

of Cande and Kent (1992, 1995), the PL1 Planktonic Zone of Berggren et al. (1995), and the NN13 Calcareous Nannofossils Zone of Martini (1971). It is also locally correlated with at least two other early Pliocene marine transgressions recently recorded in the Southern Hemisphere. The Patagonian event is slightly older than the marine highstand during the Zanclean (4.9 Ma) recorded at the base of Unit 9 in the Coquimbo Formation in North-Central Chile (Le Roux et al., 2005). Also slightly younger than the Patagonian event are the interglacial event recognized at 5.03 Ma–4.22 Ma in the Jame Ross Island region and at 5.01–4.05 in Cockburn Island (Antarctica) (Smellie et al., 2006; McArthur et al., 2006).

6. Conclusions

The results obtained through Sr-isotope stratigraphy on *C. actinodes*, provide evidences of the existence of two Neogene local sea level changes that had not been recorded before in the Austral and southern sector of the San Jorge basins. Fossiliferous beds overlying the Santa Cruz Formation exposed at the top of the cliffs of Cabo Buentiempo, record a local marine flooding in the Austral Basin during the late Miocene 8.95 + 0.82 Ma, 2 s.e. This is the youngest transgressive event documented in outcrops of the southernmost tip of the Santa Cruz Province and is correlated with the Tortonian flooding ("Entrerriense Sea") recognized in the uppermost sector of the Puerto Madryn Formation (Valdes Basin) dated in 9.4 Ma by Zinsmeister et al. (1981).

Samples of *C. actinodes* from Cañadon Darwin (Austral Basin) and Terrace of Cerro Laciar (San Jorge Basin) were dated in 5.15 + 0.18 Ma, 2 s.e. and 5.10 + 0.21 Ma, 2 s.e., respectively. This information demonstrates the first documented Pliocene (Zanclean) flooding in Patagonia that is correlated to the long-term cycle that encompass 5.33 Ma–4.2 Ma (Hardenbol et al., 1998), and is represented in the Southern Hemisphere by the transgressive events registered in the Cockburn (5.01 Ma–4.05 Ma) and James Ross Islands (5.03 Ma–4.22 Ma) (Antarctica), and in North-Central Chile (4.9 Ma).

Current knowledge of the assemblage presently dated as Pliocene will contribute to fill in the gap in the paleontological information on Cenozoic sequences of Patagonia. It should also contribute to clarify more accurately the biogeographic pattern of Neogene faunas of the region, leading to a better understanding of the origin of the Quaternary and Recent biotas in the Southwestern Atlantic Ocean. The deposits containing the dated Pliocene fauna are not always possible to correlate biostratigraphically because of their highly similar faunal composition and widely separate exposures. Application of Sr-isotope stratigraphy to further date and correlate these deposits seems likely, on present evidence, to be successful.

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