

SEDIMENTOLOGY AND PALEONTOLOGY OF A MIOCENE MARINE SUCCESSION FIRST NOTICED BY DARWIN AT PUERTO DESEADO (PORT DESIRE)

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ABSTRACT

Rocks exposed just south of Puerto Deseado (Port Desire), Santa Cruz Province, were surveyed by Darwin during his journey on board HMS Beagle. The fossil mollusks collected there were studied later by Sowerby, who described four species based on the material from "Port Desire". Sedimentological and stratigraphical observations suggest that the marine rocks cropping out at Darwin's locality should be assigned to the Monte León Formation (early Miocene). The rocks were deposited in subtidal environments, most precisely in an offshore environment near fair weather wave base at the bottom to a lower shoreface at the top of the section.

Keywords: *Darwin, Early Miocene, Monte León Formation, Sedimentology, Paleontology.*

RESUMEN: *Sedimentología y paleontología de una sucesión marina miocena citada por primera vez por Darwin en Puerto Deseado.* Las rocas expuestas al sur de Puerto Deseado, provincia de Santa Cruz, fueron relevadas por Darwin durante su viaje a bordo del HMS Beagle. Los moluscos fósiles que coleccionó fueron estudiados por Sowerby quien describió cuatro especies basadas en ejemplares procedentes de Puerto Deseado. Las observaciones sedimentológicas y estratigráficas sugieren que estos depósitos marinos, estudiados originalmente por Darwin, son asignables a la Formación Monte León (Mioceno temprano). En general, las rocas representan ambientes submareales que en el tramo inferior de la sucesión corresponden a un costa afuera, próximo al nivel de base de olas de buen tiempo, mientras que hacia el techo pasan a un *shoreface* inferior.

Palabras clave: *Darwin, Mioceno temprano, Formación Monte León, Sedimentología, Paleontología.*

INTRODUCTION

The Cenozoic marine deposits of Patagonia have been known since the early 19th century and have been studied ever since d'Orbigny (1842) first described his *Tertiaire Patagonien*. This author also described the fossils that he collected during his explorations in southern South America. All of the specimens he described came from the marine rocks exposed in northern Patagonia - in the vicinity of the mouth of the Río Negro, and in the area surrounding the present city of Paraná, in northeastern Argentina. Likewise, he did mention the presence of a large oyster similar to *Crassostrea patagonica* (d'Orbigny 1842) in Puerto San Julián, which had been given to him by a sailor. However, he never actually visited the coast further south of Río Negro. During his journey to Chile, Bolivia and Peru around Cape Horn, he must have seen from afar the cliffs rising along the

coast, as he included all these exposed rocks in his *Tertiaire Patagonien*.

A few years later, HMS Beagle sailed along the coast of Patagonia, and on this occasion the geology of the region was studied by Charles Darwin, who published his observations (Darwin 1846) together with descriptions of the fossil taxa he collected during this trip (Sowerby 1846). In addition to the localities already mentioned by d'Orbigny, Darwin visited four other places that became classic fossiliferous localities over the years, and that were crucial in establishing the basis of Patagonian Cenozoic stratigraphy. These four localities are San José, Puerto Deseado, Puerto San Julián, and Santa Cruz. San José lies on the northern coast of Península Valdés in Chubut (northern Patagonia). The other three localities lie much further south along the coast of the present province of Santa Cruz. Darwin included all the rocks with marine fossils from these localities, and from

Paraná and Uruguay, in what he called the Great Patagonian Formation. Although this appears to be roughly equivalent to d'Orbigny's *Tertiaire Patagonien*, Darwin was aware that this succession included two distinct units, the lower one marine, and the second one, continental with land vertebrate remains. Nowadays, the four localities visited by Darwin include different formal units, deposited in different basins and environments. For example, the marine deposits at San José locality belong to the Puerto Madryn Formation (late Miocene). The marine rocks and fossils mentioned by Darwin at San Julián belong either to the late Oligocene San Julián Formation (Bertels 1970), or to the early Miocene Monte León Formation (Bertels 1970). At the mouth of the Río Santa Cruz, the rocks described by Darwin belong to the Monte León Formation.

Darwin's observations and fossil collections drew the interest of later explorers,

geologists and paleontologists alike, especially during the second half of the 19th century and early decades of the 20th century. During this period, Ameghino (1896, 1898, 1900-1902) established the earliest stratigraphic subdivision of the Cenozoic rocks of Patagonia. This subdivision was mostly based on the fossil content of these richly fossiliferous beds. However, since Ameghino's subdivision, there has been a lot of controversies, not only because of the age of the rocks, but also because of the stratigraphic relationships and correlations of several outcrops that lie spread over a huge area in Patagonia, and that were attributed to the "Patagonian beds". Most of the rocks exposed there are now included in different formal units, although the exact relationships among them are still partially unresolved (Parras *et al.* 2008). Detailed history of these controversies can be found in Camacho (1974, 1979), Zinsmeister (1981), Legarreta and Uliana (1994), and Malumián (1999, 2002). Many of the rich faunas contained in the marine and continental Cenozoic rocks are crucial in the reconstruction of the evolutionary history of the South American biota. Therefore, a clear understanding of the stratigraphic relationships - especially for those type localities of taxa that are used with biostratigraphic and/or paleobiogeographic purposes - is prerequisite to any further inference involving these rocks and the fossils that they contained.

During its voyage around the world, the HMS Beagle anchored in the Río Deseado mouth. There, Darwin had the opportunity to explore the riverbanks upstream and to provide detailed descriptions of the rocks he encountered. The northern bank of the river - where the modern town of Puerto Deseado (Fig. 1) lies and along where the road and railroad run - is mainly composed of Jurassic volcanic rocks for at least 30 km upstream. These rocks were well recorded by Darwin, who was aware of their lack of fossils. However, a few kilometers further upstream of "Darwin's Rock", the

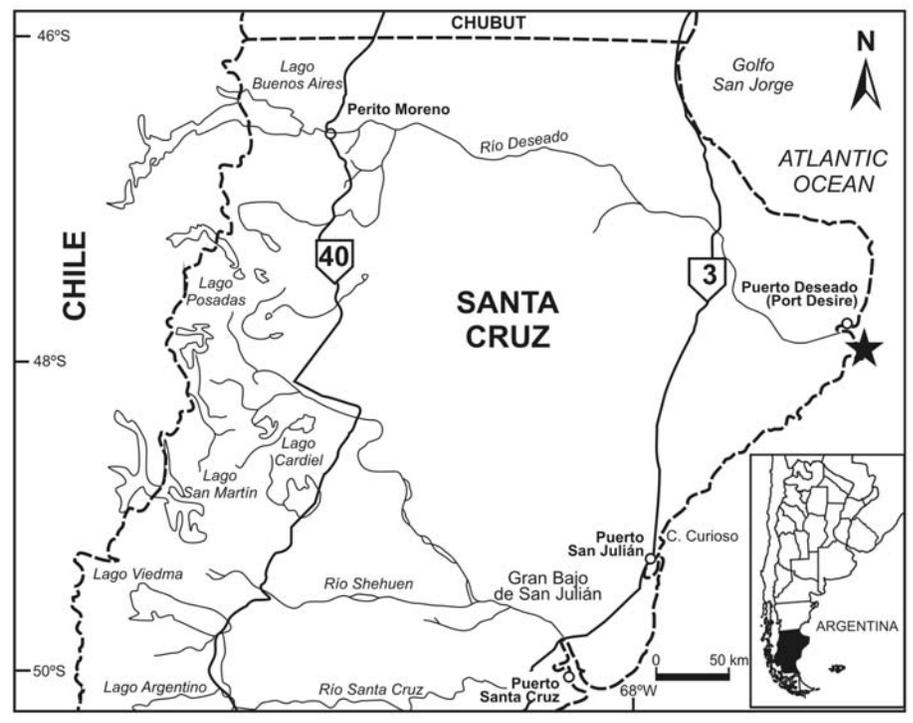


Figure 1: Location map, showing Darwin's locality at Port Desire.

furthest upstream point reached by him, marine Cenozoic rocks rich in fossils become exposed.

These rocks remained unknown to Darwin. Nevertheless, among the fossils collected by him and described by Sowerby (1846), there are several that come from "Port Desire". Darwin mentioned as the fossiliferous locality, the cliffs lying a few miles south of the river mouth. This locality comprises two very small outcrops that ever since remained almost unexplored by geologists or paleontologists, as they are in a relatively inaccessible area and are not visible from the town. Four of the species of mollusks described by Sowerby come from this locality. Despite the fact that it is a type locality of taxa later used in biostratigraphic and paleobiogeographic reconstructions, it has remained obscure and little known ever since Darwin discovered it.

The late Oligocene - early Miocene marine beds exposed along the Atlantic coast of Patagonia are presently included in the San Julián (late Oligocene - early Miocene) and Monte León (early Miocene) formations (in the Austral Basin),

and in the Chenque Formation (in the San Jorge Basin). These rocks were deposited during Atlantic transgressions that covered large portions of Patagonia.

The Monte León Formation was formally described by Bertels (1970), and it includes those deposits at the mouth of the Río Santa Cruz, which are characterized by their abundant and well preserved fauna. These rocks and faunas were extensively studied throughout the years (Ihering 1897, 1899, 1907, 1914, Ortman 1902, Feruglio 1949, Di Paola and Marchese 1973, Bertels 1980, Nández 1988, del Río 2004, del Río and Camacho 1998, Crawford *et al.* 2008, and references therein), but most of these studies were carried out on the exposures found around the mouth of the Río Santa Cruz and in the San Julián area. In contrast, outcrops with similar rocks in the Puerto Deseado area received far less attention (Frenguelli 1931, Feruglio 1949, del Río 2004, Giacosa *et al.* 1998). In this area, the Neogene marine rocks overlie Jurassic volcanic rocks of the Bahía Laura Group, and are reduced to patchy thin exposures isolated one another. Giacosa

et al. (1998) used the informal name "Patagoniano" to designate these outcrops and suggested that these were equivalent to the San Julián and Monte León formations. However, del Río (2004) included them in the Chenque Formation, a unit formally described for rocks exposed about 150 km to the northwest, in the vicinity of Comodoro Rivadavia city. Sedimentological and stratigraphical observations suggest that the Neogene marine rocks at Darwin's locality near Puerto Deseado should be assigned to the Monte León Formation. In this study we present a detailed description of these rocks and comments on its paleontological content.

Institutional abbreviations used in this work are as follows: NHM-L (The Natural History Museum, London, Department of Palaeontology); GHUNLPam (Colección Paleontológica del Departamento de Ciencias Naturales de la Universidad Nacional de La Pampa).

GEOLOGICAL SETTING

South of Puerto Deseado, the Monte León Formation (early Miocene) is exposed between Punta Guanacos and Punta Norte. The lowermost portion of the section is exposed during low tide along the coast, with the remainder of the formation outcropping along the base of cliffs. At the studied locality (47°48'37"S; 65°52'32"W, see Fig. 1), the Monte León Formation is 10 m thick (Fig. 2) and unconformably overlies Jurassic volcanic rocks of the Bahía Laura Group. The contact between the two units is only visible during low tide. The Monte León Formation is unconformably overlain by Quaternary conglomerates (Fig. 3a).

Facies associations (FA)

FA1: This association includes fine bioturbated sandstone and mudstone, intercalated with lenticular shell concentrations (less than one meter wide and 0.4 m thick) with trough-cross stratification, dominated by "*Turritella*" *patagonica* (Fig.

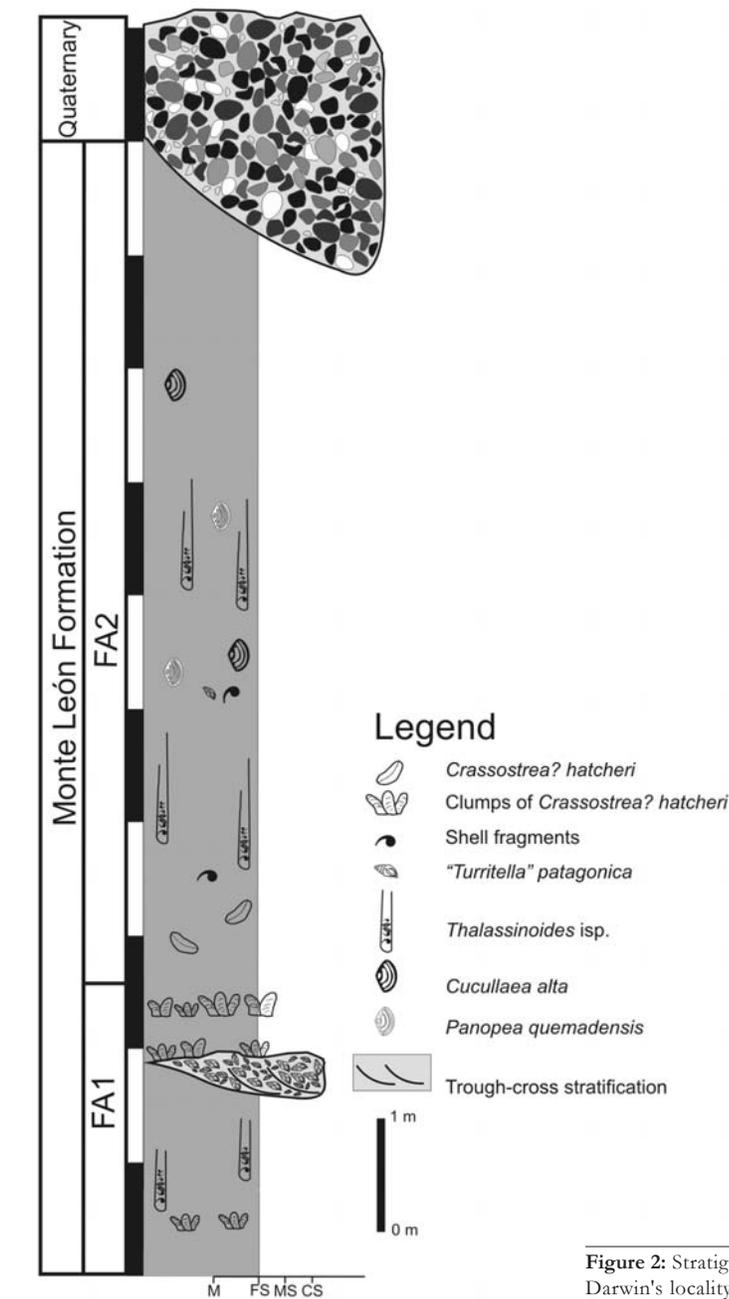


Figure 2: Stratigraphic section at Darwin's locality.

3b). At the top of these concentrations there are specimens - mainly articulated - of *Crassostrea? hatcheri* (Fig. 3c). Specimens of *Crassostrea? hatcheri* in life position are also abundant. They are mainly obvious during low tide on the wide abrasion platform, where some specimens are found forming clumps. Commonly, the valves of this oyster are bioeroded by sponge (*Entobia* isp.), polychaetes (*Maeandropolydora* isp.) and *Pholadidea patagonica* (*Gastrochaenolites*

isp.). Large burrow systems, with horizontal and vertical components are frequent in this facies association. These excavations are 5 cm in average diameter, and are assigned to *Thalassinoides* isp. The fill of these structures consists of alternating sandy and muddy laminae (Fig. 3d).

Interpretation

FA1 represents an environment lying above storm wave base and below nor-

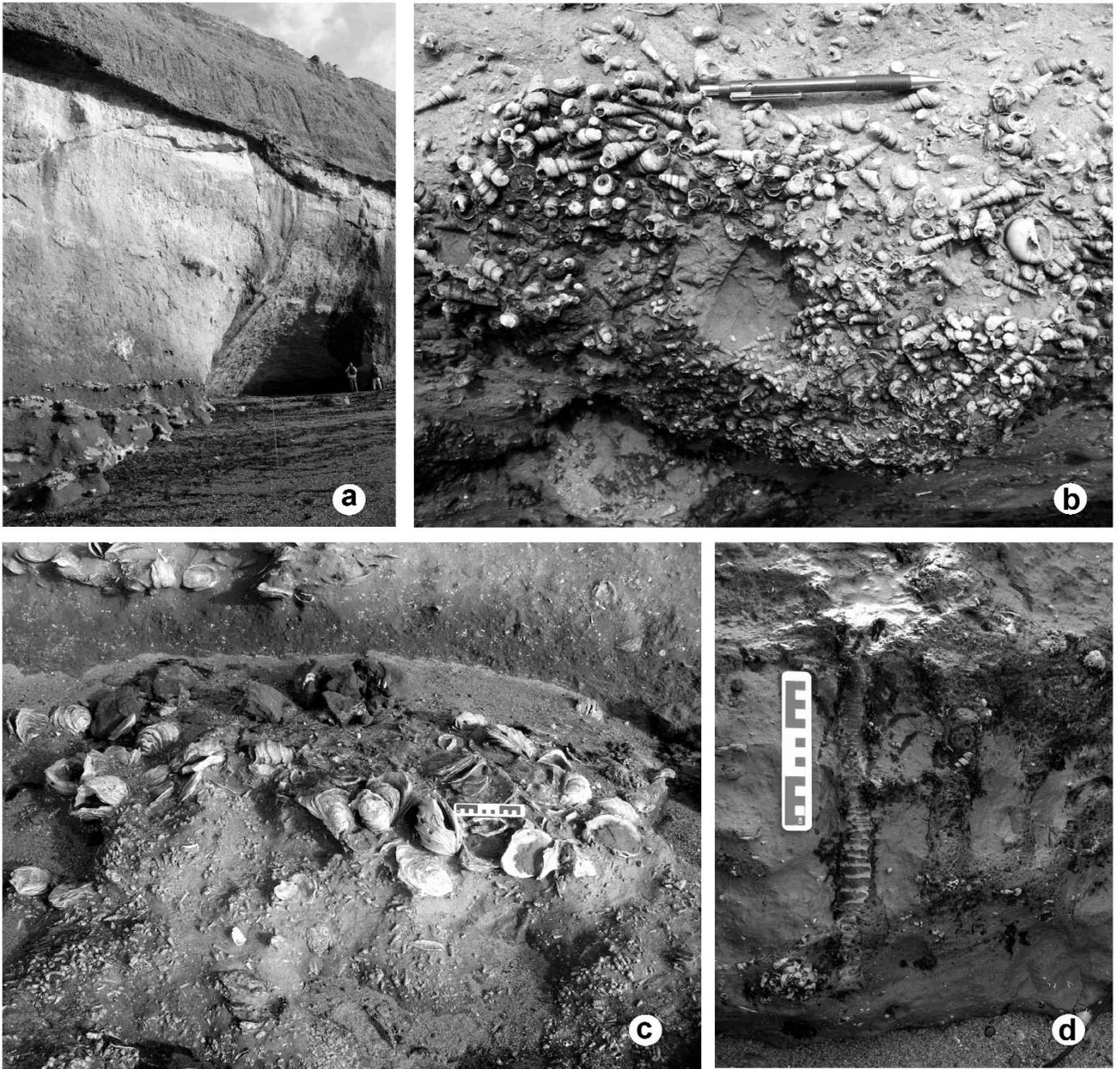


Figure 3: a) Puerto Deseado section. The Monte León Formation is unconformably overlain by Quaternary conglomerates; b) Lenticular shell concentrations dominated by "*Turritella*" *patagonica*; c) Specimens - mostly articulated - of *Crassostrea?* *hatcheri*; d) *Thalassinoides* isp. Filled with alternating sandy and muddy laminae.

mal wave base. The alternating sandy and muddy laminae filling the *Thalassinoides* burrows probably indicate tidal cyclicity. The abundance of *Thalassinoides* isp. suggests that the benthos was well-oxygenated during deposition (Bottjer *et al.* 1986, Bromley 1990) and the substrate was probably firm. However, the abundance of "*Turritella*" *patagonica* - member of a

very shallow infaunal group - suggests that the surface sediments were most likely poorly consolidated. The concentrations of "*Turritella*" *patagonica* may represent the infilling of small tidal channels. The beds with articulated and highly bored oyster clusters point towards periods of lower sedimentation rates.

EA2: comprises mainly fine- to medium-

grained massive tuffaceous sandstones. Bioturbation completely obliterated the sedimentary structures. There are large burrow systems mainly with vertical components, with an average diameter of 5 cm, and more than 1.5 m long, branching points not observed, precluding ichnospecific identification and therefore referred to *Thalassinoides* isp. The fill of

these burrows is mainly composed by sand and abundant fragments of "*Turritella*" *patagonica*. Most of the fossils are disarticulate and the degree of fragmentation is low. In addition to semi-infaunal and epifaunal taxa such as *Atrina magellanica*, *Neopanis quadrisulcata*, *Swiftopecten nodosoplicatus*, *Zygochlamys geminata*, *Zygochlamys quemadensis*, *Reticulochlamys proxima*, *Jorgechlamys centralis* among others, specimens of the deep burrowing bivalve *Panopea quemadensis* and shallow infaunal *Cucullaea alta* and *Labillia patagonica* were found articulated and in life position.

Interpretation

FA2 represents a lower shoreface. Bio-turbation was reported for mixed sediments to a depth of as much as 1 m in shallow marine environments (Smith and Nelson 2003) resulting in a homogenized, poorly-sorted layer (Fürsich and Pandey 2003). Mollusks suggest that background sedimentation rate was low. Most of the taxa found in FA2 represent either very shallow infaunal (e.g. arcoids, cardiids) or epifaunal forms (e.g. pectinids, muricids), indicating that the substrate was stable for extended periods.

In general, the rocks exposed at Darwin's locality represent subtidal facies from an

offshore environment near the fair weather wave base at the bottom, to a lower shoreface at the top of the section.

PALEONTOLOGY

The most conspicuous feature of the rocks described here is the rich and well preserved fauna of mollusks contained in them. This fauna lies almost entirely within FA 2 and amongst the most abundant elements are *Nucula* (*Lamellinucula*) *reticularis*, *Neilo ornata*, *Cucullaea alta*, *Limopsis insolita*, *Glycymeris cuevensis*, *Neopanis quadrisulcata*, *Swiftopecten nodosoplicatus*, *Zygochlamys geminata*, *Zygochlamys quemadensis*, *Reticulochlamys proxima*, *Jorgechlamys centralis*, *Crassostrea? hatcheri*, *Pteromyrtea crucialis*, *Pleuromeris cruzensis*, *Fasciculocardia patagonica*, *Spissatella hyelli*, *Spissatella kokeni*, *Hedecardium? puelchum*, *Cardium patagonicum*, *Labillia patagonica*, *Dosinia laeviuscula*, *Ameghinomya darwini*, *Panopea quemadensis*, *Valdesia dalli*, *Solariella dautzenbergi*, *Calliostoma santacruzense*, "*Turritella*" *ambulacrum*, "*Turritella*" *patagonica*, *Polinices santacruzensis*, *Glossaulax vidali*, *Cirsotrema rugulosum*, *Trophon santacruzensis*, *Xymenella dautzenbergi*, *Xymene cossmanni*, *Entbacanthus monoceros*, *Crassilabrum hatcheri*, cf. *Ocenebra iberingi*, *Urosalpinx archipatagonica*, *Neoimbricaria pa-*

tagonica, *Antimelatoma quemadensis*, and *Dentalium* sp. All these taxa are also found in the Punta Entrada Member of the Monte León Formation, at the mouth of the Río Santa Cruz, the only difference is the relative abundance of taxa in the two areas. They are far less numerous at Puerto Deseado, but this can be due to the fact that the exposures are also very much reduced there. Darwin's specimens were described by Sowerby and four of the species described by him were based on material from "Port Desire". Three of these were bivalves and one is a gastropod. The latter is the most conspicuous fossil at both localities:

***Neilo ornata* (Sowerby, 1846)** (Fig. 4a). It is not strange that Sowerby had only "fragments" (see Griffin and Nielsen 2008), as most of the specimens of this species, although complete in the rock, are very easily broken when collected, possibly as a result of the shell structure in this group. The species is quite common in Puerto Deseado, but it also occurs in the Santa Cruz area (*sensu* Darwin, *i.e.*, just upstream from the mouth of the river in the Atlantic Ocean), where it is generally found at the base of the section. Other species of *Neilo* are known from Paleogene and Neogene rocks ex-

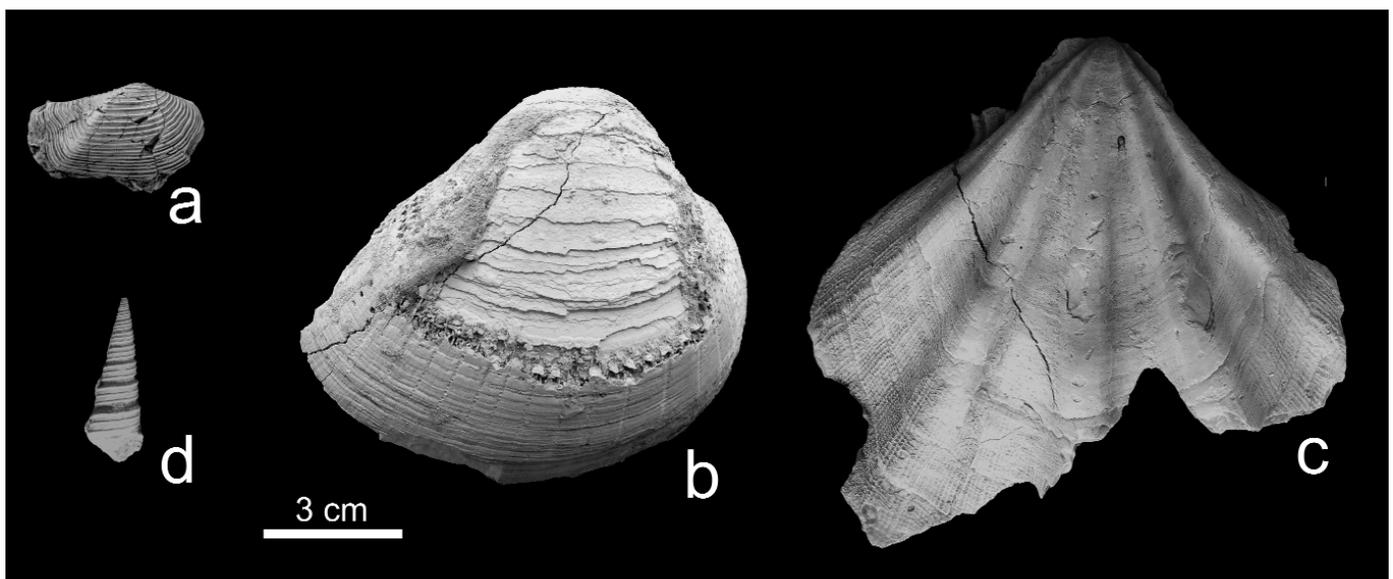


Figure 4: a) *Neilo ornata* (Sowerby, 1846). Lectotype, NHM-L 27974; b) *Cucullaea alta* Sowerby, 1846, GHUNLPam 16859, external view; c) *Jorgechlamys centralis* (Sowerby, 1846), GHUNLPam 16860, left valve; d) "*Turritella*" *patagonica* Sowerby, 1846, GHUNLPam 16861.

posed in different areas of Patagonia and Tierra del Fuego, but the relationships among them remain rather obscure, as in most cases the material consists of fragmentary molds.

***Cucullaea alta* Sowerby, 1846** (Fig. 4b). Also common at Monte León, this species appears sparsely in FA2, and is less abundant than at the localities further south. Darwin's original material - *i.e.*, Sowerby's syntypes - included three specimens, one of them a juvenile from "Santa Cruz", and the other two (possibly the two separate valves of the same specimen) are from "Port Desire". One of the latter is a large well preserved specimen, similar to those found by us at this locality. One of Darwin's specimens from Puerto Deseado is an adult, but the two are fairly well preserved. This species also appears at other Patagonian localities in which rocks of similar age are exposed, although it is never quite as abundant as it is at the exposures at the mouth of the Río Santa Cruz and environs.

***Jorgechlamys centralis* (Sowerby, 1846)** (Fig. 4c). This large pectinid is known from rocks belonging to the Monte León Formation, or to its equivalents such as the Centinela and Chenque Formations. The type material comes from "Santa Cruz" and "Port Desire", but lectotype designation by Griffin and Nielsen (2008) has restricted the type locality to Puerto Deseado. It is an important species as it has been used in biostratigraphic zonations of Patagonian Cenozoic units (del Río 2004).

"*Turritella*" *patagonica* Sowerby, 1846 (Fig. 4d). This species is the most common mollusk in the Monte León Formation. It appears in great numbers and constitutes a significant part of the deposits in which it occurs. The exact generic placement of this species remains as yet uncertain, as pointed out by Griffin and Nielsen (2008). This taxon occurs in many other localities where marine rocks of this age are exposed. It is very common in the Chenque, Centinela, and Carmen Silva formations, al-

beit in none of these it reaches the abundance showed in the Monte León Formation.

CONCLUSIONS

South of Puerto Deseado the rocks exposed along the cliffs show a lithological composition that is not distinguishable from those of the Monte León Formation at its type locality further south. The succession exposed in the Puerto Deseado area contains subtidal facies from an offshore environment near fair weather wave base at the bottom to a lower shoreface at the top of the section. The type specimens of *Neilo ornata*, *Cucullaea alta*, *Jorgechlamys centralis* and "*Turritella*" *patagonica* described by Sowerby (1846) come - in all cases - from the cliffs south of Puerto Deseado. The mollusks collected by us from FA2 are also found in the Punta Entrada Member of the Monte León Formation at the mouth of the Río Santa Cruz suggesting an early Miocene age for Darwin's Port Desire locality.

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WORK CITED IN THE TEXT

- Ameghino, F. 1896. Notas sobre cuestiones de geología y paleontología argentina. Boletín del Instituto Geográfico Argentino 17: 87-119.
 Ameghino, F. 1898. Sinopsis Geológico-Paleontológica. Segundo Censo de la República Argentina 1: 111-225.
 Ameghino, F. 1900-1902. L'age des formations

sédimentaires de Patagonie. Anales de la Sociedad Científica Argentina 50: 109-130, 145-165, 209-229 (1900); 51: 20-39, 65-91 (1901); 52: 189-197, 244-250 (1901); 54: 161-180, 220-249, 283-342 (1902).

- Bertels, A. 1970. Sobre el "Piso Patagoniano" y la representación de la época del Oligoceno en Patagonia austral, República Argentina. Revista de la Asociación Geológica Argentina 25: 495-501.
 Bertels, A. 1980. Estratigrafía y foraminíferos (Protozoa) bentónicos de la Formación Monte León (Oligoceno) en su área tipo, provincia de Santa Cruz, República Argentina. 2º Congreso Argentino de Paleontología y Bioestratigrafía y 1º Congreso Latinoamericano de Paleontología (Buenos Aires, 1978), Actas 2: 213-273.
 Bottjer, D.J., Arthur, M.A., Dean, W.E., Hattin, D.E. and Savrda, C.E. 1986. Rhythmic bedding produced in Cretaceous pelagic carbonate environments: sensitive recorders of climatic cycles. Paleogeography 1: 467-481.
 Bromley, R.G. 1990. Trace Fossils. Unwin Hyman, 280 p., London.
 Camacho, H.H. 1974. Bioestratigrafía de las formaciones marinas del Eoceno y Oligoceno de la Patagonia. Anales de la Academia de Ciencias Exactas, Físicas y Naturales 26: 39-57, Buenos Aires.
 Camacho, H.H. 1979. Significados y usos de "Patagoniano", "Patagoniense", "Formación Patagonica", "Formación Patagonia" y otros términos de la estratigrafía del Terciario marino argentino. Revista de la Asociación Geológica Argentina 34: 235-242.
 Crawford, R.S., Casadío, S., Feldmann, R.M., Griffin, M., Parras, A. and Schweitzer, C. 2008. Mass mortality of fossil decapods within the Monte León Formation (Early Miocene), Southern Argentina: Victims of Andean volcanism. Annals of the Carnegie Museum of Natural History 77: 259-287.
 Darwin, Ch. 1846. Geological observations on South America. Being the third part of the geology of the voyage of the Beagle, under the command of Capt. Fitzroy, R. N. during the years 1832 to 1836. Smith, Elder and Co., 279 p., London.
 del Río, C.J. 2004. Tertiary marine molluscan assemblages of eastern Patagonia (Argentina): a biostratigraphic analysis. Journal of Pa-

- leontology 78: 1097-1122.
- del Río, C.J. and Camacho, H.H. 1998. Tertiary nuculoids and arcoids of eastern Patagonia (Argentina). *Palaeontographica Abt. A* 250: 47-88.
- Di Paola, E.C. and Marchese, H.G. 1973. Litoestratigrafía de la Formación Patagonia en el área tipo (Bajo de San Julián-desembocadura del río Santa Cruz). Provincia de Santa Cruz. República Argentina. 5° Congreso Geológico Argentino, Actas 3: 207-222.
- Feruglio, E. 1949. Descripción Geológica de La Patagonia. Ministerio de Industria y Comercio de La Nación, Dirección General de Yacimientos Petrolíferos Fiscales 2: 1-349.
- Frenguelli, J. 1931. Observaciones estratigráficas en Bahía Sanguinetti (Santa Cruz, Patagonia). *Anales de la Sociedad Científica de Santa Fe* 3: 237-283.
- Fürsich, F.T. and Pandey, D.K. 2003. Sequence stratigraphic significance of sedimentary cycles and shell concentrations in the Upper Jurassic and Lower Cretaceous of Kachchh, western India. *Palaeogeography, Palaeoclimatology, Palaeoecology* 193:285-309.
- Giacosa, R.E., Césari, O. and Genini, A. 1998. Hoja Geológica 4766-II y IV Puerto Deseado. Servicio Geológico Minero Argentino, Boletín 240, 72 p., Buenos Aires.
- Griffin, M. and Nielsen, S.N. 2008. A revision of the type specimens of Tertiary molluscs from Chile and Argentina described by d'Orbigny (1842), Sowerby (1846) and Hupé (1854). *Journal of Systematic Palaeontology* 6: 251-316.
- Ihering von, H. 1897. Os Molluscos dos terrenos terciarios da Patagonia. *Revista del Museo Paulista* 2: 217-382.
- Ihering von, H. 1899. Die Conchylien der pataognischen Formation. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie* 1899: 1-46.
- Ihering von, H. 1907. Les mollusques fossiles du Tertiaire et du Crétacé supérieur de l'Argentine. *Anales del Museo Nacional de Buenos Aires, serie 3*: 1-611.
- Ihering von, H., 1914. Catalogo de molluscos Cretáceos e terciarios da collecção do auctor. *Notas do Museu Paulista* 1: 1-113.
- Legarreta, L. and Uliana, M.A. 1994. Asociaciones de fósiles y hiatus en el Supracretácico-Neógeno de Patagonia: una perspectiva estratigráfico-secuencial. *Ameghiniana* 31: 257-281.
- Malumián, N. 1999. La sedimentación y el volcanismo terciarios en la Patagonia extraandina. In Caminos, R. (ed.) *Geología Argentina, Anales del Instituto de Geología y Recursos Minerales* 29(18): 557-612.
- Malumián, N. 2002. El Terciario marino. Sus relaciones con el eustatismo. In Haller, M.J. (ed.) *Geología y Recursos Naturales de Santa Cruz, Relatorio 15° Congreso Geológico Argentino I-15*: 237-244.
- Náñez, C. 1988. Foraminíferos y bioestratigrafía del Terciario Medio de Santa Cruz oriental. *Revista de la Asociación Geológica Argentina* 43: 493-517.
- Orbigny, A. d'. 1834-1847. *Voyage dans l'Amérique méridionale (le Brésil, la République orientale de l'Uruguay, la République Argentine, la Patagonie, la République du Chili, la République de Bolivia, la République du Pérou), exécuté pendant les années 1826, 1827, 1828, 1829, 1830, 1831, 1832 et 1833*, 5 (3): Mollusques: i-xliii, 1-758, láms. 1-85, vol. 3, part. 3, 290 p., P. Bertrand. Paris, V. Levrault, Strasbourg.
- Ortmann, A.E. 1902. Tertiary Invertebrates. In Scott, W.B. (ed.) *Reports of the Princeton University Expedition to Patagonia 1896-1899*, J. Pierpoint Morgan Publishing Foundation, volume 4, Paleontology I, Part 2: 45-332, Princeton.
- Parras, A., Griffin, M., Feldmann, R., Casadío, S., Schweitzer, C. and Marensi, S. 2008. Correlation of marine beds based on Sr- and Ar-date determinations and faunal affinities across the Paleogene/Neogene boundary in southern Patagonia, Argentina. *Journal of South American Earth Sciences* 26: 204-216.
- Smith, A.M. and Nelson, C.S. 2003. Effects of early sea-floor processes on the taphonomy of shelf skeletal carbonate deposits. *Earth Science Reviews* 63:1-31.
- Sowerby, G.B. 1846. Descriptions of the Tertiary fossil shells from South America. In: Darwin, Ch. *Geological observations on South America. Being the third part of the geology of the voyage of the Beagle, under the command of Capt. Fitzroy, R. N. during the years 1832 to 1836*. Smith, Elder and Co., Appendix: 249-264, London.
- Zinsmeister, W.J. 1981. Middle to late Eocene invertebrate fauna from the San Julián Formation at Punta Casamayor, Santa Cruz province, Southern Argentina. *Journal of Paleontology* 55: 1083-1102.

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