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Maastrichtian-Danian Northpatagonian rocky shore, Argentina

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ABSTRACT

The Atlantic Maastrichtian-Danian (K/P) transgression over northern-central extra-Andean Patagonia (Argentina) covered both Mesozoic sedimentary basins and the Northpatagonian Massif (NPM). The flooding of the NPM resulted in a regional unconformity/nonconformity (70.000 km^2) between the pre-Cretaceous basement (Jurassic Chon Aike Silicic Large Igneous Province and igneous-metamorphic Paleozoic basement) and the K/P marine transgressive record, constituting the widest known ancient rocky shore of South America (Northpatagonian rocky shore).

The transgressive stratigraphic record over the basement is mainly composed of isolated carbonate bioclastic deposits up to 40 m thick with predomination of bivalves, echinoderms, bryozoan, coralline red algae, and foraminifera skeletal remains; we interpreted these bioclastic near-shore deposits as rocky shore associations. The hard substrate, irregular seacoast and low accommodation space over the NPM provided a preferential ecological niche for encrusting biota (i.e., Oyster reefs) during the K/P epicontinental flooding. The colonization of "engineer ecosystems" organisms over thousands of square kilometers probably enhanced the coastal biodiversity. The K/P Northpatagonian rocky shore favored the conformation of a short-lived, transgressive, cool-water carbonate factory in the south-eastern extreme of South America.

1. Introduction

Coastal marine environments have been profusely studied because they represent a dynamic interplay between physic/biological and continental/marine processes. Although >70 % of the world's coastlines are rocky shores (Nyberg and Howell, 2016), ancient examples of this environment have been somewhat neglected by paleontologists and geologists until the 90s (Johnson, 1988a, 1988b, 1992). Geomorphologically, rocky shores often contain coastal cliffs, sea caves, bays, boulder shores and islands (i.e., Semeniuk and Johnson, 1985; Johnson et al., 1996; de Gibert et al., 1998; Betzler et al., 2000; Moura et al., 2006; Andriani and Walsh, 2007; among others). Geologically, ancient rocky shores are unconformities or nonconformities between hard-substrates and shallow marine deposits (i.e., Surlyk and Christensen, 1974; Johnson, 1988a, 1988b, 1992; Johnson and McKerrow, 1995; Johnson et al., 1996; Surlyk, 1997; Johnson and Baarli, 1999, 2012; Felton, 2002; Desrochers, 2006; Surlyk and Sørensen, 2010; Sørensen and Surlyk, 2010, 2011, 2013, 2015; Sørensen et al., 2011, 2012; Schrøder et al., 2019; Puig López et al., 2023; among others). Biologically, rocky shores are very well-studied dynamic marine ecosystems where the substrate provides varied habitats for encrusting biota (i.e., Lewis, 1964, 1986; Dayton, 1975; Paine, 1994; Johnson and Baarli, 1999; Cebrián et al., 2000; Reise, 2001; Spencer and Viles, 2002; Johnson, 2006; Buatois and Encinas, 2011; Chappuis et al., 2014; Pineda-Salgado et al., 2015; McAfee et al., 2017, 2022, and cites therein). In this way, rocky shores and bioclastic deposits are a very frequent configuration during transgressive events because combine shallow marine conditions and hard-substrate (i.e., Webb, 1994; Jia-yu and Johnson, 1996; Sanders, 1998; de Gibert et al., 1998, 2012; Betzler et al., 2000; Larsen et al., 2003; D'Alessandro et al., 2004; Shepard, 2006; Felton et al., 2006; Buatois and Encinas, 2011; Bover-Arnal et al., 2011; Brlek et al., 2018; Sanders et al., 2019).

The worldwide cartography of marine shores for the last 250 Ma (Smith et al., 1994; Johnson, 2006; Johnson and Baarli, 2012) shows a maximum during Paleocene times with major seaways that deeply penetrated the North America, South America, Africa, and Europe (Fig. 1). In South America, the Upper Cretaceous sequences display progressive overstepping of older terranes during the epeiric flooding (i.e., Biddle

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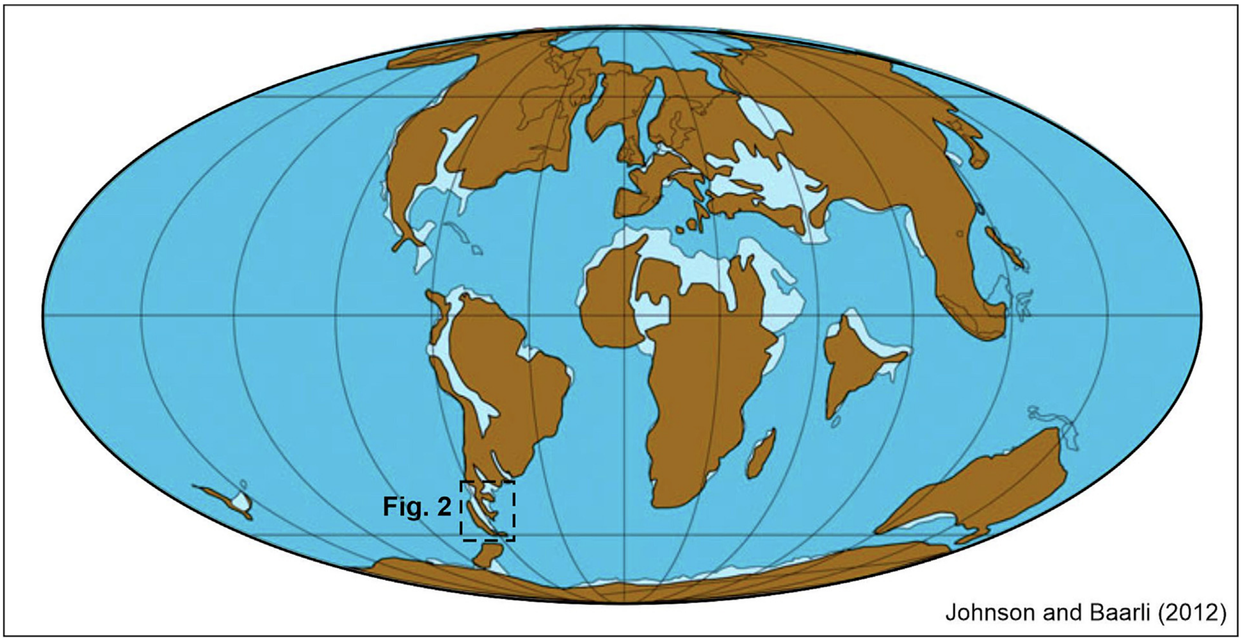


Fig. 1. Global Early Paleocene paleogeographic configuration displaying major seaways penetrating most of the continents during a higher stand in sea level (taken from Johnson and Baarli, 2012, based on Smith et al., 1994). Location of Fig. 2 in the southern extreme of South America.

et al., 1986; Uliana and Biddle, 1988), producing a spectacular increase in the size of areas under marine influence of Argentina (i.e., Malumián et al., 1983; Uliana and Biddle, 1988).

This first Atlantic transgression widely flooded Andean and extra-Andean regions of Patagonia (southern Argentina) during the Maastrichtian-Danian (Fig. 2), representing the widest Cenozoic continental flooding in this region (Malumián and Caramés, 1995). Most of the regional contributions about the Maastrichtian-Danian transgression over central-northern Patagonia were dedicated to lithological/paleoenvironmental characterizations (i.e., Feruglio, 1949; Spalletti et al., 1993; Malumián, 1999), paleontologic/biostratigraphic studies (i.e., Burckhardt, 1901; Feruglio, 1936, 1949; Bertels, 1973, 1975, 1995; Camacho, 1992; Casadío, 1998; del Río, 2004, 2021; Guler et al., 2019; Brezina et al., 2021), paleobiogeographic/paleogeographic reconstructions (i.e., Malumián et al., 1983; Malumián and Náñez, 2011; Aguirre-Urreta et al., 2011), diagenetic studies (Matheos and Tunik, 1998; Matheos et al., 2003) or subsidence analysis (i.e., Gianni et al., 2018a, 2018b; Dávila et al., 2019). Although the K/P transgressive record was described as lying over Jurassic volcanic rocks in the NPM (i.e., Feruglio, 1936, 1949; Simpson, 1941; Camacho, 1992; Aragón et al., 2014; Aguilera et al., 2014, among others) conforming a carbonate platform (Spalletti et al., 1993), just locally was interpreted as a rocky shore (Foix et al., 2015).

This work aims to characterize the K/P transgressive rocky shore and their associated deposits over the NPM, to estimate their areal extension, to approximate the main control factors in its development and contributing to understand the stratigraphic evolution of the extra-Andean Patagonia (Argentina).

2. Geological and paleontological framework

The break-up of Gondwana resulted in different Mesozoic volcanic provinces developed over pre-Mesozoic basements in South America, including the Chon Aike SLIP in Patagonia (Kay et al., 1989; Pankhurst et al., 1998; Bryan and Ernst, 2008; Bryan et al., 2010; Bryan and Ferrari, 2013; Lovecchio et al., 2020; Navarrete, 2021; Navarrete et al., 2021; among others). This SLIP covers 675.000 km^2 (Pankhurst et al., 1998), constituting one of the most important geologic features of the region (Fig. 2A) with several lithostratigraphic units in different geological settings. This regional volcanic record also constitutes the synrift stage in several Jurassic-Cretaceous Patagonian sedimentary basins (i.e., Uliana et al., 1990; Franzese et al., 2003; Lovecchio et al., 2020) such as Golfo San Jorge (Clavijo, 1986; Fitzgerald et al., 1990; Figari et al., 1999; Sylwan, 2001; Figari and Hechem, 2021), Cañadón Asfalto (Figari and Courtade, 1993; Figari et al., 2015; Figari and Hechem, 2021), Austral-Magallanes (Franzese et al., 2003; Fildani et al., 2008; Sachse et al., 2016), Valdés (Continanzia et al., 2011) and San Julián (Homovc and Constantini, 2001).

Simplified, the basement of the NPM is mainly characterized by three groups of rocks: 1) Paleozoic igneous-metamorphic rocks such as Mina Gonzalito Complex, Yaminué Complex, Nahuel Niyeu Formation, El Jagüelito Formation and Punta Sierra Plutonic Complex (i.e., González et al., 2018, 2020), 2) Triassic volcanic/volcaniclastic suites represented by Los Menucos Complex (Cucchi et al., 2001; Labudía and Bjerg, 2001; Lema et al., 2008), and 3) extensive outcrops of the Jurassic Chon Aike SLIP represented by the Marifil Volcanic Complex (MVC), mainly composed of rhyolites, ignimbrites, and breccias (Pankhurst et al., 1998; Márquez et al., 2010; Strazzere et al., 2022). The NPM was strongly eroded from the Middle Jurassic to the Late Cretaceous, conforming a regional planation surface (Aragón et al., 2010, 2014; Aguilera et al., 2014). Fig. 2A displays a simplified pre-K/P distribution of pre-Jurassic basement, Jurassic volcanic rocks (Chon Aike SLIP), and Cretaceous sedimentary basins in Patagonia.

The first K/P Atlantic transgression covered a significant part of Patagonia (i.e., Feruglio, 1949; Camacho, 1967, 1992; Yrigoyen, 1969; Spalletti et al., 1993; Malumián and Caramés, 1995; Malumián, 1999, 2002; Náñez and Malumián, 2008; Aguirre-Urreta et al., 2011; Scasso et al., 2012; Foix et al., 2021); paleogeographic estimations from foraminifera record indicate that about 500.000 km^2 of the current emerged area was flooded by the K/P sea (Fig. 2B), exceeding any other Cenozoic transgression in Patagonia (Malumián and Caramés, 1995).

Most complete marine stratigraphic records took place over Mesozoic sedimentary basins (i.e., Malumián and Caramés, 1995; Malumián, 1999; Náñez and Malumián, 2008), but the continental flooding also covered the NPM (Feruglio, 1949; Camacho, 1992; Spalletti et al., 1993; Malumián and Caramés, 1995; Aragón et al., 2010, 2014; Scasso et al.,

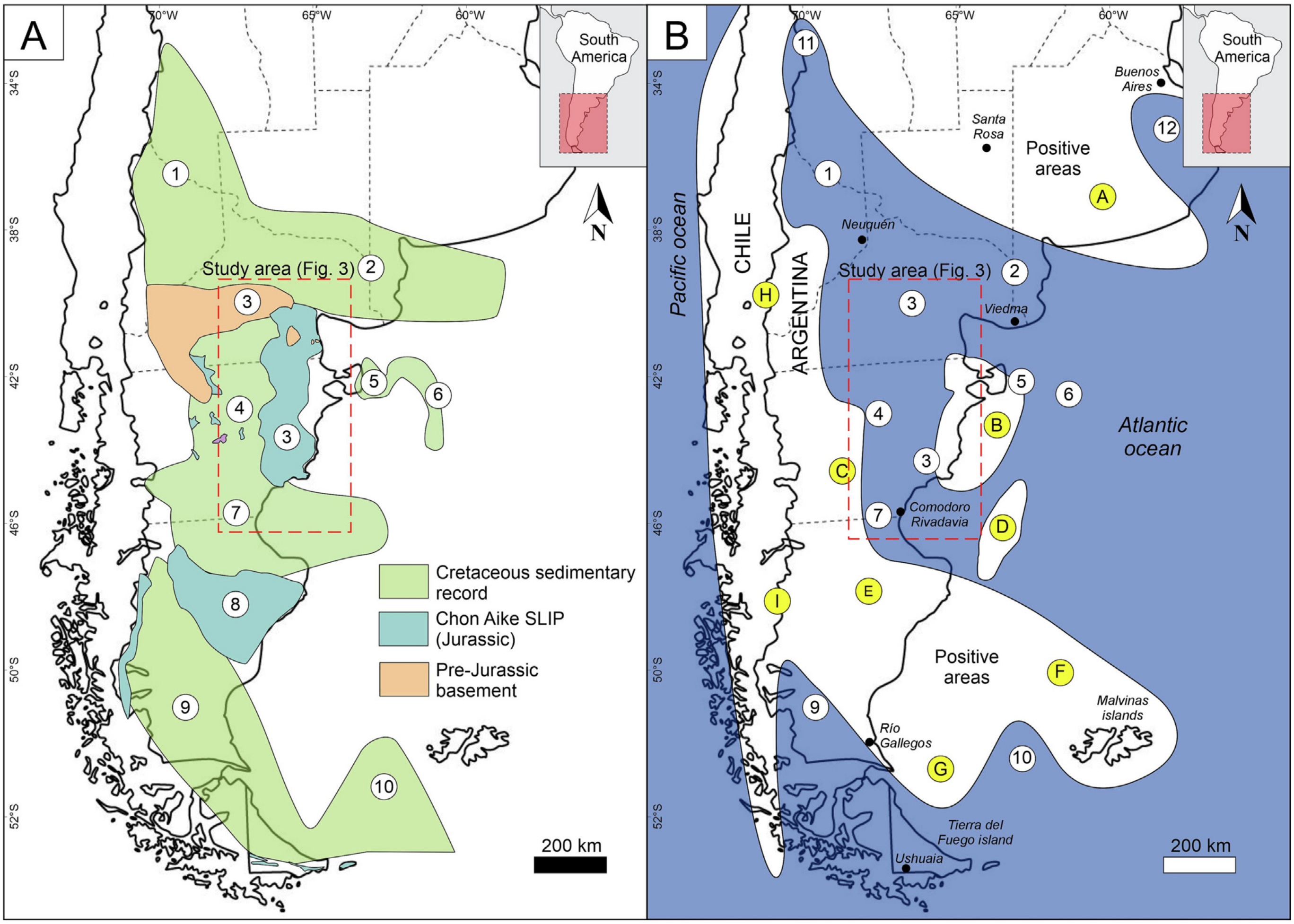


Fig. 2. A) Simplified geologic configuration before the K/P transgression in Patagonia. Location of the study area. B) Paleogeography of the Maastrichtian transgression (taken from Náñez and Malumián, 2008) with flooded and emerged areas. References: 1) Neuquén basin, 2) Salado basin, 3) Northpatagonian Massif, 4) Cañadón Asfalto basin, 5) Valdés basin, 6) Rawson basin, 7) Golfo San Jorge basin, 8) Deseado Region, 9) Austral-Magallanes basin, 10) Malvinas basin, 11) High Andes (Tunik et al., 2004) and 12) Colorado basin. A) Tandilia High (taken from Lovecchio et al., 2018), B) Camarones High, C) San Bernardo Fold-Belt, D) Eastern Patagonian High, E) Deseado High, F) Malvinas High, G) Dungeness High, H) Northern Patagonian Andes and I) Southern Patagonian Andes. Location of the study area on the Northpatagonian Massif.

2012; Foix et al., 2021). Roughly, the K/P marine stratigraphic record in the sedimentary basins is a 200–300 m thick, siliciclastic tidally-dominated succession overlying Cretaceous continental units, mainly characterized by quartz-glauconitic, transgressive/regressive sandstones (few tens meters thick), inner shelf mudstones (up to 150–200 m thick) and scarce bioclastic deposits (Legarreta et al., 1990; Legarreta and Uliana, 1994; Malumián, 1999; Foix et al., 2021; and cites therein). The K/P marine flooding in the NPM mainly took place over a Middle Jurassic to the Late Cretaceous erosive planation surface (Aragón et al., 2010, 2014; Aguilera et al., 2014). Gianni et al. (2018a, 2018b) suggested that a Late Cretaceous-Paleocene regional subduction-related subsidence (flexural + dynamic) drove this marine flooding over Patagonia during a large flat-slab event.

Several equivalent lithostratigraphic units have been defined for the K/P marine flooding over extra-Andean Patagonia (Feruglio, 1949; Camacho, 1967, 1992; Yrigoyen, 1969; Spalletti et al., 1993; Malumián and Caramés, 1995; Malumián, 1999, 2002; Náñez and Malumián, 2008; Scasso et al., 2012; Foix et al., 2021), such as Salamanca Formation (Golfo San Jorge basin), Roca Formation (Neuquén basin-NPM), Arroyo Salado and El Fuerte formations (central-eastern NPM), Bustamante formation (southern NPM), La Colonia formation (Cañadón Asfalto basin), among others. K/P near-shore carbonate deposits over the NPM mainly comprise bioclastic rocks and were included in the “Northpatagonian platform” (Spalletti et al., 1993). Offshore epiclastic deposits usually cover this carbonate record during the transgression deepening (Feruglio, 1949; Andreis et al., 1975; Spalletti et al., 1993; Ardolino et al., 2003; Foix et al., 2015).

The K/P transgression contains an abundant paleontologic record in the central-northern Patagonia (Table 1). Particularly, the molluscan Danian assemblage in Patagonia incorporates 35 genera of gastropods and 31 genera of bivalves, but Oysters constitute the dominant molluscan group throughout almost all basins (del Río, 2021). Also, these Oyster communities support a wide variety of boring and encrusting biota, including sponges, polychaetes, bivalves, fungi, algae, barnacles, and bryozoans (Brezina et al., 2014, 2017).

Maastrichtian and Danian foraminiferal assemblages were recognized in the marine record (i.e., Kaasschieter, 1963; Méndez, 1966; Chebli and Serraiotto, 1974; Malumián and Caramés, 1995; Náñez and Malumián, 2008; Malumián and Náñez, 2011; Simeoni, 2014) (see Table 2). Most of Maastrichtian endemic calcareous foraminiferal species disappear during the K/P transition (Malumián and Náñez, 2011). Later, Danian cosmopolitan Midway type foraminiferal assemblages of Patagonia include at least 234 benthic endemic species (Malumián and Caramés, 1995).

3. Material and methods

We present a regional dataset constituted by both previous works and own information. This contribution includes a regional stratigraphical, lithological, and paleontological characterization of initial transgressive

Table 1
Main K/P marine paleontologic record in central-northern Patagonia.

Fossil record	References
Bivalves	Burckhardt (1901), von Ihering (1903), Celeste (1940), Feruglio (1936, 1949), Petersen (1946), Camacho (1992), Spalletti et al. (1993), Griffin and Hünicken (1994), Casadío (1998), del Río (2004, 2012, 2021), Griffin et al. (2005, 2008), del Río et al. (2011), Scasso et al. (2012), del Río and Martínez (2015)
Gastropods	Feruglio (1949), Camacho (1992), Griffin and Hünicken (1994), del Río (2012)
Brachiopods	Feruglio (1949), Chebli and Serraiotto (1974), Spalletti et al. (1993)
Echinoderms	Feruglio (1949), Parma (1989), Spalletti et al. (1993) Parma and Casadío (2005), Martínez et al. (2011), Foix et al. (2015)
Barnacles	Brezina et al. (2014, 2017)
Briozoans	Brezina et al. (2014, 2021)
Coral reefs and stromatolites	Baron-Szabo et al. (2003), Kiessling et al. (2005), Aguirre-Urreta et al. (2011), Scasso et al. (2012), Carrera and Casadío (2016)
Boring polychaetes	Brezina et al. (2014)
Nannofossils, foraminifera, palynomorphs and dinoflagellates	Méndez (1966), Bertels (1969, 1973, 1974, 1975, 1979, 1995), Archangelsky (1973, 1976), Chebli and Serraiotto (1974), Malumián et al. (1983), Concheyro and Náñez (1994), Malumián (1999, 2002), Palamarczuk et al. (2002), Náñez and Malumián (2008), Malumián and Náñez (2011), del Río et al. (2011), Simeoni (2014), Vellekoop et al. (2017), Guler et al. (2014, 2019)

K/P marine sedimentary rocks and their substrate in the NPM. Freely accessible satellite images were used to characterize some stratigraphic relationships. The regional cartography of the studied rocks was made using a free Geographic Information System (QGIS). Complementary, thin sections were used for qualitative petrographic characterizations.

4. Results

We analyzed the basal K/P transgressive stratigraphic record over 70.000 km^2 in the NPM, central-northern extra-Andean Patagonia (Argentina). 64 localities were described/compilated in the Chubut and Río Negro provinces (Fig. 3), mainly conformed by isolated outcrops. The substrate of K/P marine deposits is constituted by Jurassic volcanic rocks (83 % = 53 localities), Cambrian metamorphic rocks (12 % = 8 localities), Triassic volcanic rocks (3 % = 2 localities) and Ordovician plutonic rocks (2 % = 1 locality).

4.1. Chubut province

In the south-eastern extreme of the NPM (Fig. 3), near the Atlantic seacoast, the K/P bioclastic record was named Rocanense by Feruglio (1936, 1949), Bustamante Formation (Simpson, 1941; Ardolino et al., 2003) or Bustamante Member/Salamanca Fm (Andreis et al., 1975; Sciutto et al., 2000; Foix et al., 2015). We described this bioclastic unit in two carbonate quarries: Cantera El Tablón (locality 4) and Tetas de Pineda (locality 1). At El Tablón quarry, the bioclastic deposits overlie the MVC (Fig. 4A, B), even preserving mollusc shells (oysters?) on the unconformity (Fig. 4C, D). In this locality, the carbonate record reaches up to 10 m in thickness (Ardolino et al., 2003) being characterized by bioclasts ranging between 0.1 and 10 cm in large (Fig. 5A) with some volcanic clasts (1–4 cm) near the basal contact (Fig. 5B). The bioclastic deposits display meter-scale low-angle cross-bedding and reactivation surfaces dipping away from the Jurassic outcrops, interpreted as foreshore deposits over paleo-islands (Fig. 5C). Bivalves with minor bryozoan and echinoderms are the most abundant marine fossil remains in the bioclastic deposits (Fig. 6). Overlying the basal bioclastic interval, the stratigraphic succession continues with inner shelf mudstones deposited during the marine deepening.

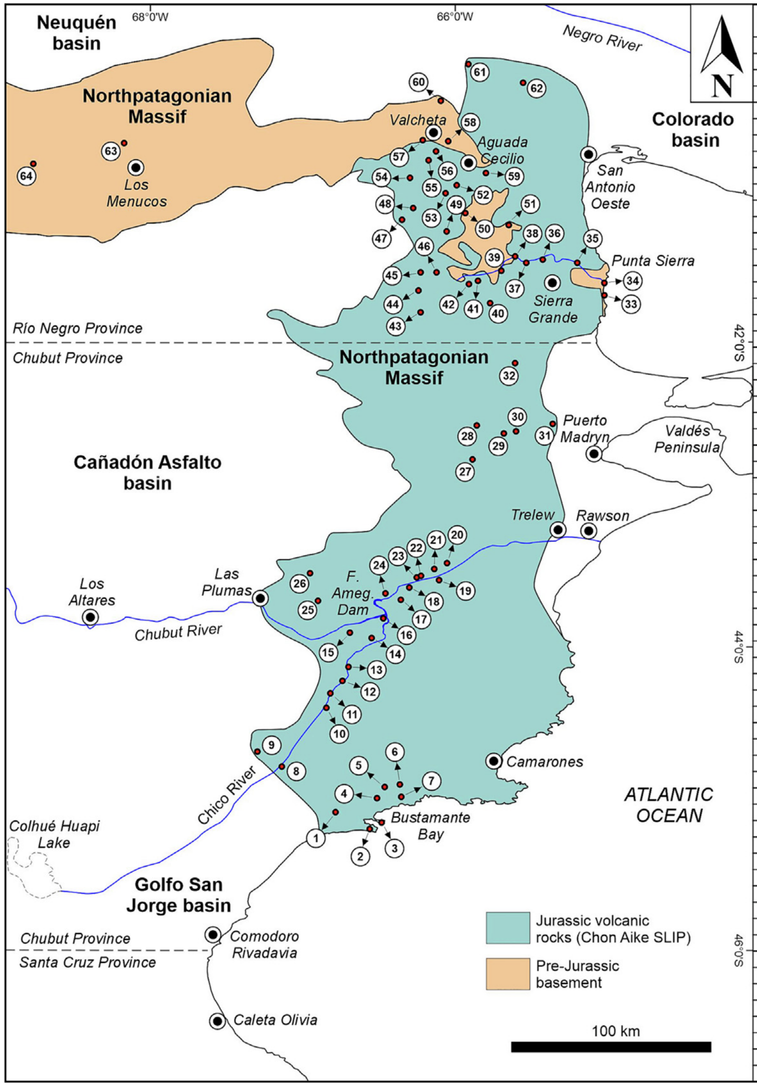
At Tetas de Pineda (locality 1), the Salamanca Formation also overlies the MVC with a 15–20 m thick, parallel stratified, basal bioclastic stratigraphic interval that surrounds the local paleohighs (Fig. 7A, B). Oyster remains are frequent and some volcanic clasts up to 3–4 cm in diameter were described (Fig. 7C). Petrographic analysis of thin sections shows skeletal packstones mainly constituted by bivalve remains with felsitic volcanic lithoclasts (Fig. 8A, B). Also, echinoderm plates (Fig. 8C) and spines (Fig. 8D, E), coralline red alage (Fig. 8D), bryozoan (Fig. 8E) and benthic foraminifera (Fig. 8F) were recognized.

Other nearby quarries, such as Bahía Bustamante (locality 5) and La Esther (locality 7), contain bioclastic deposits about 4 m and 9 m in thickness respectively (Ardolino et al., 2003). The stratigraphic relationship between MVC/bioclastic deposits was also described at the Aristizábal (locality 2) and Gravina (locality 3) peninsulas (Feruglio, 1949; Ardolino et al., 2003), with bioclastic deposits ranging 4–5 m in thickness (Ardolino et al., 2003).

On the banks of both lower Chico and Chubut rivers (Fig. 3), the K/P bioclastic deposits also overlie Jurassic volcanic rocks (Feruglio, 1949;

Table 2
K/P foraminifera record in central-northern Patagonia.

Age	Benthic foraminifera	Planktonic foraminifera	References
Maastrich.	*Discorbis correcta*		
	Bulliminella isabelleana		Náñez and Malumián (2008)
	Charltonina acutimarginata		
	Angulogavelinella? sp.		
Danian	*Bulliminella isabelleana*		
	Lagenoglandulina neuquensis		
	Favolagena atilai		
	Ammoelphidiella? sp.		Malumián and Caramés (1995)
	Discorbinella castellaroae		
	Guttulina luisae		
	Lagena archangelsky		
	Lenticulina wichmanni		
	Migros hanseni		
	Palmula budensis rocanense		
		Globigerina pseudobulloides	
		Globigerina triloculinoides	Kaasschieter (1963)
		Globigerina compressa	
		Globigerina daubjergensis	
		Chiloguembelina midwayensis	
		Globoconusa daubjergensis	Chebli and Serraiotto (1974)



N°	LOCALITY	PROVINCE	K/P MARINE UNIT	CARB. THICK.	BASEMENT			REFERENCES
			UNIT		UNIT	LITHOLOGY	AGE	
1	Tetas de Pineda	Chubut	Bustamante Fm.	15 m	Marifil Volcanic Complex	Volcanic	Jurassic	Andreis et al. (1975), Foix et al. (2015), this work
2	Península Aristizábal	Chubut	Bustamante Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Feruglio (1949)
3	Península Gravina	Chubut	Bustamante Fm.	5 m	Marifil Volcanic Complex	Volcanic	Jurassic	Feruglio (1949), Ardolino et al. (2003)
4	Cantera El Tablón	Chubut	Bustamante Fm.	15 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003), this work
5	Cantera Bustamante	Chubut	Bustamante Fm.	4 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
6	Estancia La Herminia	Chubut	Bustamante Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
7	Cantera La Esther	Chubut	Bustamante Fm.	9 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
8	Paso Arroqui	Chubut	Salamanca Fm.	20 m	Marifil Volcanic Complex	Volcanic	Jurassic	Yláñes (1979), Ardolino et al. (2003)
9	Laguna Colorada	Chubut	Salamanca Fm.	1-6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
10	Puesto Álvarez	Chubut	Salamanca Fm.	3 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003), this work
11	Estancia Josefina	Chubut	Salamanca Fm.	1-6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
12	Estancia Piedra Blanca	Chubut	Salamanca Fm.	1-6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
13	Estancia La Mimosa	Chubut	Salamanca Fm.	1-6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ardolino et al. (2003)
14	Cerro La Cueva	Chubut	Salamanca Fm.	2-10 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
15	Cerro Dos Puntas	Chubut	Salamanca Fm.	2-10 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
16	Cerro La Junta	Chubut	Salamanca Fm.	2-10 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
17	Dique F. Ameghino	Chubut	Salamanca Fm.	2-10 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007), this work
18	Estancia La Leonetta	Chubut	Salamanca Fm.	12 m	Marifil Volcanic Complex	Volcanic	Jurassic	Panza et al. (2002), Sacomani et al. (2007)
19	Estancia Villegas	Chubut	Salamanca Fm.	2-10 m	Marifil Volcanic Complex	Volcanic	Jurassic	Panza et al. (2002), Sacomani et al. (2007)
20	Cantera La Alicia	Chubut	Salamanca Fm.	2 m	Marifil Volcanic Complex	Volcanic	Jurassic	Panza et al. (2002), Sacomani et al. (2007)
21	Cantera Don Pedro	Chubut	Salamanca Fm.	3 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
22	Cañadón Iglesias	Chubut	Salamanca Fm.	15 m	Marifil Volcanic Complex	Volcanic	Jurassic	Celeste (1940), Panza et al. (2002), Sacomani et al. (2007)
23	Cantera La Esperanza	Chubut	Salamanca Fm.	5 m	Marifil Volcanic Complex	Volcanic	Jurassic	Panza et al. (2002), Sacomani et al. (2007)
24	Cantera San Benito	Chubut	Salamanca Fm.	6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
25	Estancia Laguna Grande	Chubut	Salamanca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
26	Estancia Las Mesetas	Chubut	Salamanca Fm.	10 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sacomani et al. (2007)
27	Sierra Chata	Chubut	La Colonia Fm.	7 m	Marifil Volcanic Complex	Volcanic	Jurassic	Haller et al. (2005)
28	Cerro de la Pava	Chubut	La Colonia Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Haller et al. (2005)
29	Lomas Azules	Chubut	La Colonia Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Haller et al. (2005)
30	Laguna de la Tacuara	Chubut	La Colonia Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Haller et al. (2005)
31	Estancia Santa Lucía	Chubut	La Colonia Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Haller et al. (2005)
32	Puesto La Picada	Chubut	La Colonia Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Cortés (1980), Haller et al. (2005)
33	Punta Colorada	Río Negro	El Fuerte Fm.	5 m	El Jagüelito Fm.	Metamorphic	Cambrian	Spalletti et al. (1993), Busteros et al. (1998), this work
34	Playas Doradas	Río Negro	El Fuerte Fm.	4 m	Punta Sierra Plutonic Complex	Plutonic	Ordovician	Busteros et al. (1998), this work
35	Cantera Pazos	Río Negro	Arroyo Salado Fm.	No data	El Jagüelito	Metamorphic	Cambrian	Busteros et al. (1998)
36	Ruta N°3	Río Negro	Arroyo Salado Fm.	6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Weber (1983), Busteros et al. (1998)
37	Cantera Morón	Río Negro	Arroyo Salado Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Busteros et al. (1998)
38	Estancia Santa Rosa	Río Negro	Arroyo Salado Fm.	No data	Mina Gonzalito Complex	Metamorphic	Cambrian	Busteros et al. (1998)
39	Arroyo Salado	Río Negro	Arroyo Salado Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Busteros et al. (1998)
40	Laguna El Salitral Grande	Río Negro	Arroyo Salado Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Busteros et al. (1998)
41	Aguada Las Chilcas	Río Negro	Arroyo Salado Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Busteros et al. (1998)
42	Mesada Blanca	Río Negro	Arroyo Salado Fm.	6 m	Marifil Volcanic Complex	Volcanic	Jurassic	Busteros et al. (1998)
43	Puesto Molina	Río Negro	Roca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Franchi et al. (2001)
44	Arroyo de la Ventana	Río Negro	Roca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Franchi et al. (2001)
45	Sierra Campana Mahuida	Río Negro	Roca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Franchi et al. (2001)
46	Puesto Durazno	Río Negro	Roca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Franchi et al. (2001)
47	El Tembrao	Río Negro	Roca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Espejo (1999), Franchi et al. (2001)
48	Cantera Cayuqueo	Río Negro	Roca Fm.	40 m	Marifil Volcanic Complex	Volcanic	Jurassic	Ravazzioli (1982), Espejo (1999), Franchi et al. (2001)
49	Corral Chico	Río Negro	Roca Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Franchi et al. (2001)
50	Cerro Lisera	Río Negro	Arroyo Salado Fm.	7 m	El Jagüelito	Metamorphic	Cambrian	Busteros et al. (1998)
51	Mina Gonzalito	Río Negro	Arroyo Salado Fm.	7 m	Mina Gonzalito Complex	Metamorphic	Cambrian	Busteros et al. (1998)
52	Puesto Llanqueleo	Río Negro	Arroyo Barbudo Fm.	7 m	Marifil Volcanic Complex	Volcanic	Jurassic	Busteros et al. (1998), Martínez et al. (2001)
53	Cantera Galván	Río Negro	Roca Fm.	<1 m	Marifil Volcanic Complex	Volcanic	Jurassic	Franchi et al. (2001)
54	Arroyo Pajalta	Río Negro	Arroyo Barbudo Fm.	30 m	Marifil Volcanic Complex	Volcanic	Jurassic	Spalletti et al. (1993), Espejo (1999), Caminos (2001)
55	Estancia Santana	Río Negro	Arroyo Barbudo Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Caminos (2001)
56	Cantera Lucero	Río Negro	Arroyo Barbudo Fm.	2 m	Marifil Volcanic Complex	Volcanic	Jurassic	Espejo (1999), Caminos (2001)
57	Cantera Sin Nombre	Río Negro	Roca Fm.	2 m	Nahuel Niyeu Fm.	Metamorphic	Cambrian	Espejo (1999)
58	Cantera Gisela	Río Negro	Roca Fm.	2 m	Nahuel Niyeu Fm.	Metamorphic	Cambrian	Espejo (1999), Caminos (2001)
59	Cantera La Calera	Río Negro	Roca Fm.	5 m	Marifil Volcanic Complex	Volcanic	Jurassic	Spalletti et al. (1993), Martínez et al. (2001), this work
60	Laguna del Indio Muerto	Río Negro	Arroyo Barbudo Fm.	No data	Nahuel Niyeu Fm.	Metamorphic	Cambrian	Caminos (2001)
61	Puesto A. Medina	Río Negro	Arroyo Barbudo Fm.	2 m	Marifil Volcanic Complex	Volcanic	Jurassic	Sepúlveda (1983), Espejo (1999)
62	Bajo del Gualicho	Río Negro	Arroyo Barbudo Fm.	No data	Marifil Volcanic Complex	Volcanic	Jurassic	Martínez et al. (2001)
63	Sierra de Queupuniyeu	Río Negro	Roca Fm.	No data	Los Menucos Complex	Volcanic	Triassic	Cucchi et al. (2001)
64	Meseta de Colitoro	Río Negro	Roca Fm.	9 m	Los Menucos Complex	Volcanic	Triassic	Spalletti et al. (1993), Cucchi et al. (2001)

Fig. 3. Study area and distribution of localities where the K/P marine record overlies Jurassic (Chon Aike SLIP) or pre-Jurassic basement in the NPM.

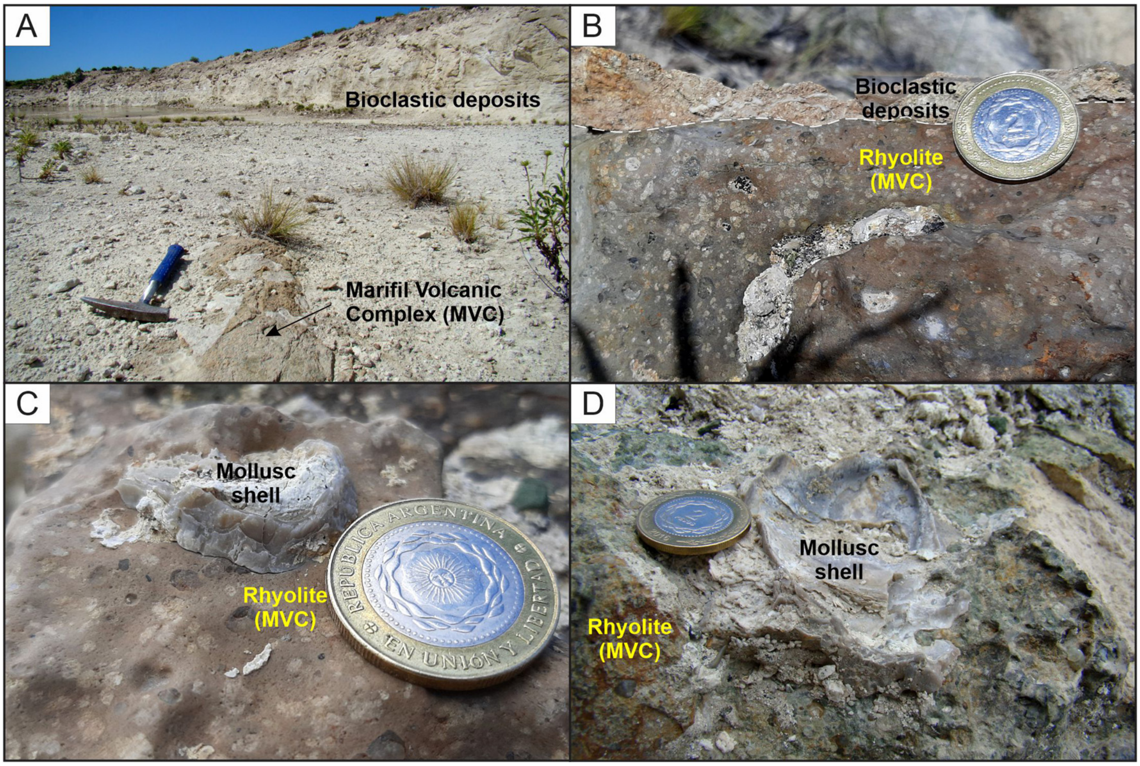


Fig. 4. Unconformity between Jurassic volcanic rocks (VMC) and K/P bioclastic deposits, El Tablón quarry (Chubut). A, B) The bioclastic carbonates over the Jurassic rhyolitic rocks (VMC). C, D) Mollusc shells (Oysters) over the Jurassic volcanic rocks (VMC). The coin is 2.3 cm in diameter.

Ylláñez, 1979; Panza et al., 2002; Ardolino et al., 2003; Sacomani et al., 2007). At the Paso Arroqui (locality 8), bioclastic deposits up to 20 m thick are interbedded with sandstone (Ylláñez, 1979 in Sacomani et al., 2007). At the Puesto Álvarez (locality 10), the basal sedimentary record is composed of a 3 m thick bioclastic sandstones with large-scale cross-stratification (Fig. 9A). In this case, the substrate (MVC) seems to preserve a 0.5 m thick altered profile with volcanic boulders (Fig. 9B). In the lower Chubut River valley, downstream of the Florentino Ameghino dam, several carbonate quarries have been exploited with carbonate thickness ranging 2–6 m (Panza et al., 2002; Sacomani et al., 2007): Cantera La Alicia (locality 20), Cantera Don Pedro (locality 21), Cantera La Esperanza (locality 23), Cantera San

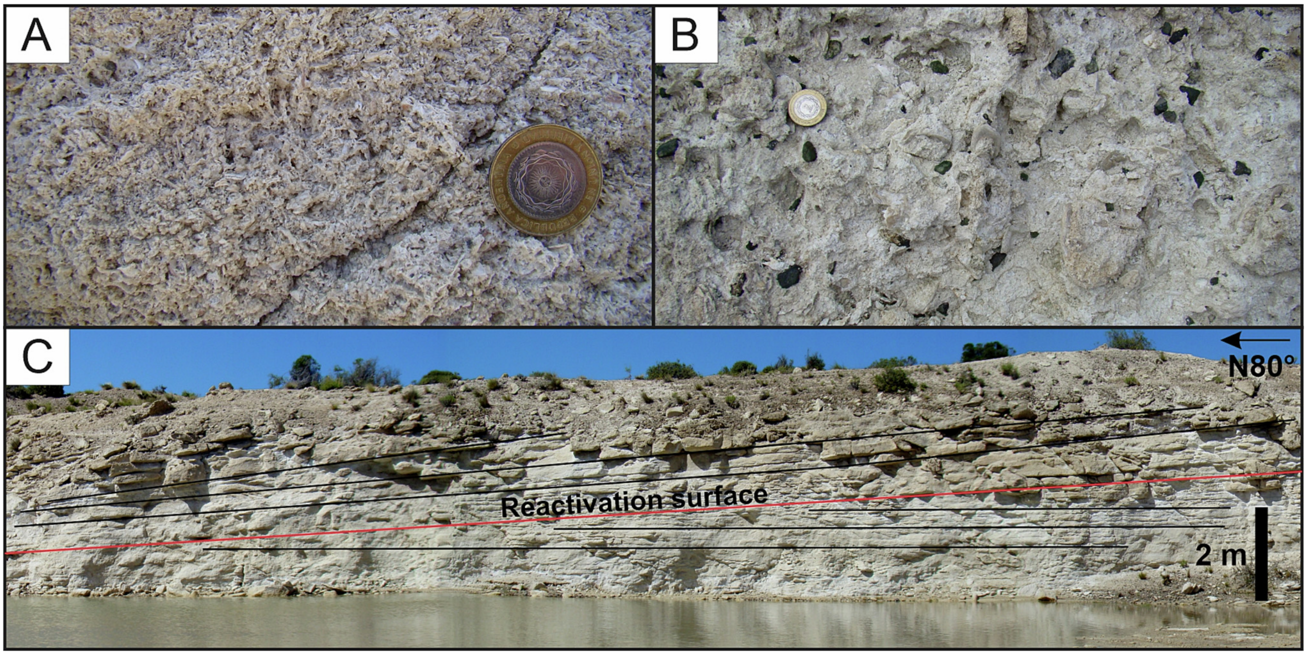


Fig. 5. Basal bioclastic deposits at El Tablón quarry. A) Very fragmented bioclastic carbonates. B) Frequent volcanic clasts near the basal contact with de MVC. C) Meter-scale low-angle cross-bedding and reactivation surface interpreted as foreshore deposits. The coin is 2.3 cm in diameter.

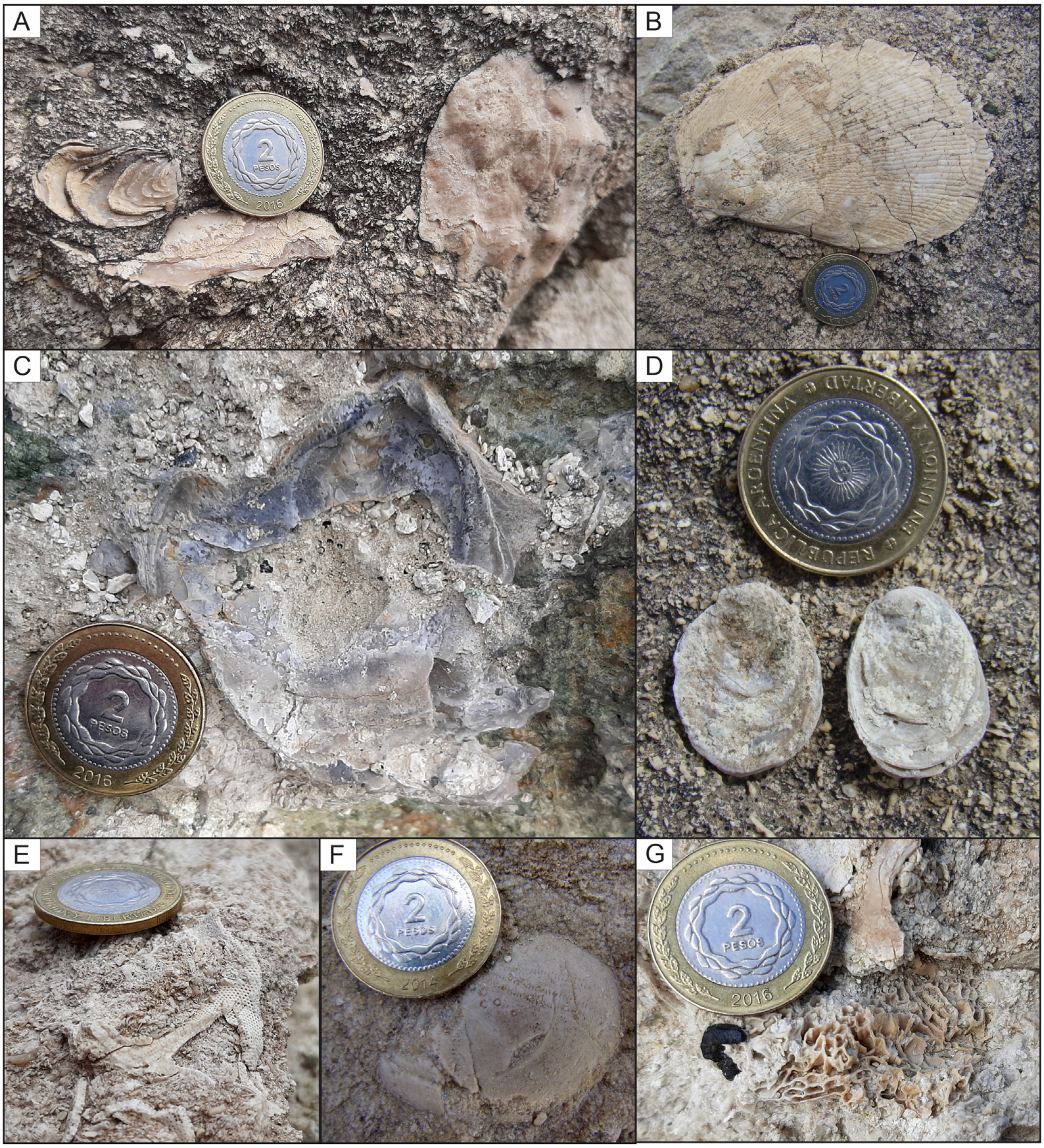


Fig. 6. Invertebrate fauna in K/P bioclastic deposits (El Tablón quarry). A–D) Bivalve remains, including Oysters. E) Bryozoan. F) Echinoderms (*Linthia*?). G) Corals? remains. The coin is 2.3 cm in diameter.

Benito (locality 24). At the Cañadón Iglesias outcrops (Feruglio, 1949; Lapido and Page, 1979; Lapido, 1981), Celeste (1940) described a bioclastic record up to 15 m in thickness (locality 22).

Tabular outcrops of the K/P bioclastic deposits often conform structural terraces over the MVC, such as at Dique Florentino Ameghino (locality 17, Fig. 10A) or near Estancia Las Mesetas (locality 26, Fig. 10B) with 10 m in thickness (Sacomani et al., 2007).

Westward of Puerto Madryn city (Fig. 3), the K/P marine deposits were described as Puesto La Picada (Cortés, 1980) or La Colonia Formation (Haller, 1981; Haller et al., 2005) (locality 32). Near Sierra Chata (locality 27), Haller et al. (2005) described the unconformity between the marine sedimentary and the Jurassic VMC, where the transgressive record includes mudstones and silicified carbonates up to 7 m thick.

Feruglio (1949) resumed the marine paleontological record of this carbonate interval over the Chubut province, including bivalves (i.e., *Pectunculus feruglioi*, *Trigonia wilckensi*, *Venericardia palaeopatagonica*, *Patagocardia peterseni*, *Phacoides* sp., *Lucina* sp., *Meretrix rothi*, *Solecurtus* sp., *Panopea* sp., *Lima* sp., *Pecten* sp., *Ostrea ameghinoi*, *Gryphaea rostrigera*, *Exogyra mendozana*, *Modiola aprilis*), schaphopods (i.e., *Dentalium* sp.), grastropods (i.e., *Natica* sp., *Ampullospira dubia*, *Calyptraea* sp., *Scalaria* sp., *Turritella malaspina*, *Melania ameghiniana*, *Arrhoges gregaria*, *Perissoptera* sp., *Triton* sp., *Cominella praecursor*, *Retusa sculata*, *Cinulia pauper*) and echonoids (i.e., *Linthia joannis-böhmi*).

4.2. Río Negro province

In the northeastern NPM, the K/P transgression conformed a widely distributed carbonate platform composed of skeletal fragments (Spalletti et al., 1993), including Roca, Arroyo Barbudo, El Fuerte and Arroyo Salado formations (Fig. 3). Along the Salado creek, northward of Sierra Grande city, the Arroyo Salado Formation shows several carbonate outcrops overlying both Paleozoic igneous-metamorphic

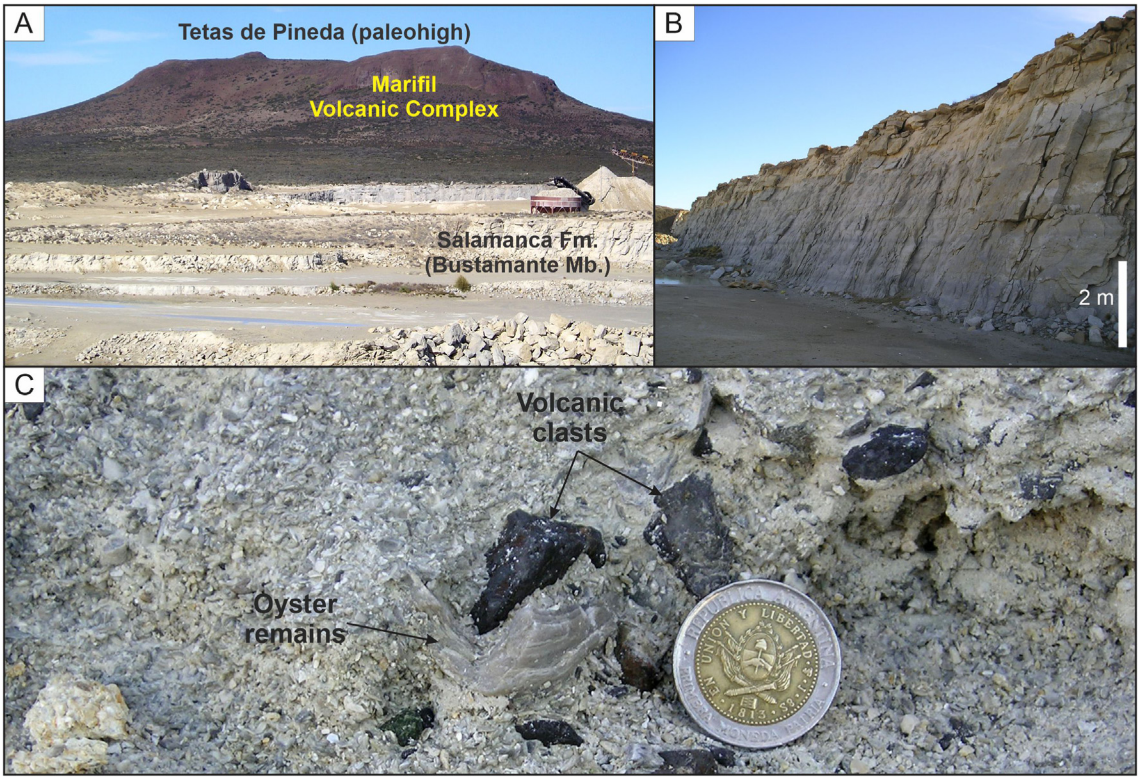


Fig. 7. Basal bioclastic deposits of the Bustamante Formation/Member (Salamanca Fm.) over the MVC (Tetas de Pineda quarry), Chubut (modified from Foix et al., 2015). A) Tetas de Pineda quarry. B) Tabular strata of bioclastic carbonates. C) Domain of bioclasts of bivalve molluscs (Oysters?) with the presence of volcanic clasts (substrate). The coin is 2.3 cm in diameter.

basement and the MVC (Busteros et al., 1998) (Fig. 3). The unconformity over Cambrian high-grade metamorphic rocks (locality 38) and Jurassic volcanic rocks (locality 32) can be observed on satellite images (Fig. 11A, B).

Nearly Valcheta city (Fig. 3), the Arroyo Barbudo/Roca Formation usually overlies metamorphic rocks of the Nahuel Niyeu Formation (localities 57, 58 and 60) or the MVC (localities 53, 56 and 59), often used as carbonate exploitations (Espejo, 1999; Caminos, 2001). The Cantera La Calera (locality 59) is a carbonate quarry that contains massive, silicified carbonates up to 5 m thick (Fig. 12). The Arroyo Barbudo Formation contains a bioclastic basal record up to 30 m thick over the MVC (Espejo, 1999; Caminos, 2001) at the upper Pajalta Creek (locality 54), with equivalents in the Gran Bajo del Gualicho (localities 61 and 62) (Sepúlveda, 1983; Martínez et al., 2001). This relationship also occurs in isolated outcrops of the Roca/Arroyo Barbudo Formation surrounding the Somouncurá basalts, such as Ventana creek (locality 44), Sierra Campana Mahuida (locality 45), Puesto Durazo (locality 46), El Tembrao (locality 47), Corral Chico (locality 49) (Franchi et al., 2001; Caminos, 2001). At Cantera Cayuqueo (locality 48), Ravazzoli (1982) describes 40 m of carbonate sandstones overlying the MVC.

The El Fuerte Formation outcrops on the Atlantic seacoast between San Antonio Oeste city and Punta Colorada with carbonate sandstones ranging about 4–6 m in thickness (Rodríguez, 1990; Busteros et al., 1998), but reaching up to 9 m few kilometers northward of Punta Sierra (Weber, 1983). At the mouth of Salado Creek and Playas Doradas (locality 34), the El Fuerte Formation overlies El Salado pluton (Fig. 13A, B), an intrusive body that integrates the Ordovician Punta Sierra Plutonic Complex (Busteros et al., 1998). At the Punta Colorada (locality 33) is outcropped the unconformity between low-angle cross-bedded bioclastic sandstones (El Fuerte Formation) and the Cambrian, low-grade metamorphic rocks of the El Jagüelito Formation (Fig. 13C).

In the central-western MNP, the Roca Formation overlies volcanic/volcaniclastic rocks of the Los Menucos Complex (Fig. 3) and contains up to 9 m of bioclastic deposits (Spalletti et al., 1993; Cucchi et al., 2001) at the Meseta de Colitoro (locality 64).

In this region of the NPM, Spalletti et al. (1993) described a variable paleontological record, including *Gryphaea* sp., *Gryphaea rothi*, *Odontogryphaea*, *Exogyra* sp., *Ostrea clarae*, *Ostrea rionegrensis*, *Venericardia* sp., *Leda*, pectinids and terebratulid brachiopods.

4.3. Summary and interpretations

The work includes 64 localities where the K/P bioclastic marine record overlies volcanic (MVC - Chon Aike SLIP) or igneous-metamorphic rocks over ~70.000 km^2. These results show a regional rocky shore occurred during a major transgressive event over rocky reliefs, the right paleoenvironmental scenario for their formation (i.e., Surlyk and Christensen, 1974; Bromley and Asgaard, 1993; Webb, 1994; Jia-yu and Johnson, 1996; Sanders, 1998; de Gibert et al., 1998, 2012; Betzler et al., 2000; Larsen et al., 2003; D'Alessandro et al., 2004; Shepard, 2006; Felton et al., 2006; Surlyk and Sørensen, 2010; Buatois and Encinas, 2011; Bover-Arnal et al., 2011; Brlek et al., 2018; Sanders et al., 2019). This extra-Andean ancient rocky shore is the widest known in South America, and here is named as "Northpatagonian rocky shore" (Fig. 14).

The sedimentary record of rocky shores usually contains bioclastic deposits because they constitute a favorable environment for benthic carbonate production (cf. Surlyk and Christensen, 1974; Surlyk, 1997; Libbey and Johnson, 1997; de Gibert et al., 1998, 2012; Sanders, 1998; Betzler et al., 2000; Cebrián et al., 2000; Johnson and Baarli, 1999, 2012; Taylor and Wilson, 2003; D'Alessandro et al., 2004; Surlyk and Sørensen, 2010; Sørensen and Surlyk, 2013, 2015; Sanders et al., 2019), as we have described in the K/P studied example. We suppose that the molluscan death assemblage has a high environmental fidelity to the rocky shore life assemblage, but the low representation of gastropods can also result from differential taphonomic loss (Sørensen and Surlyk, 2015).

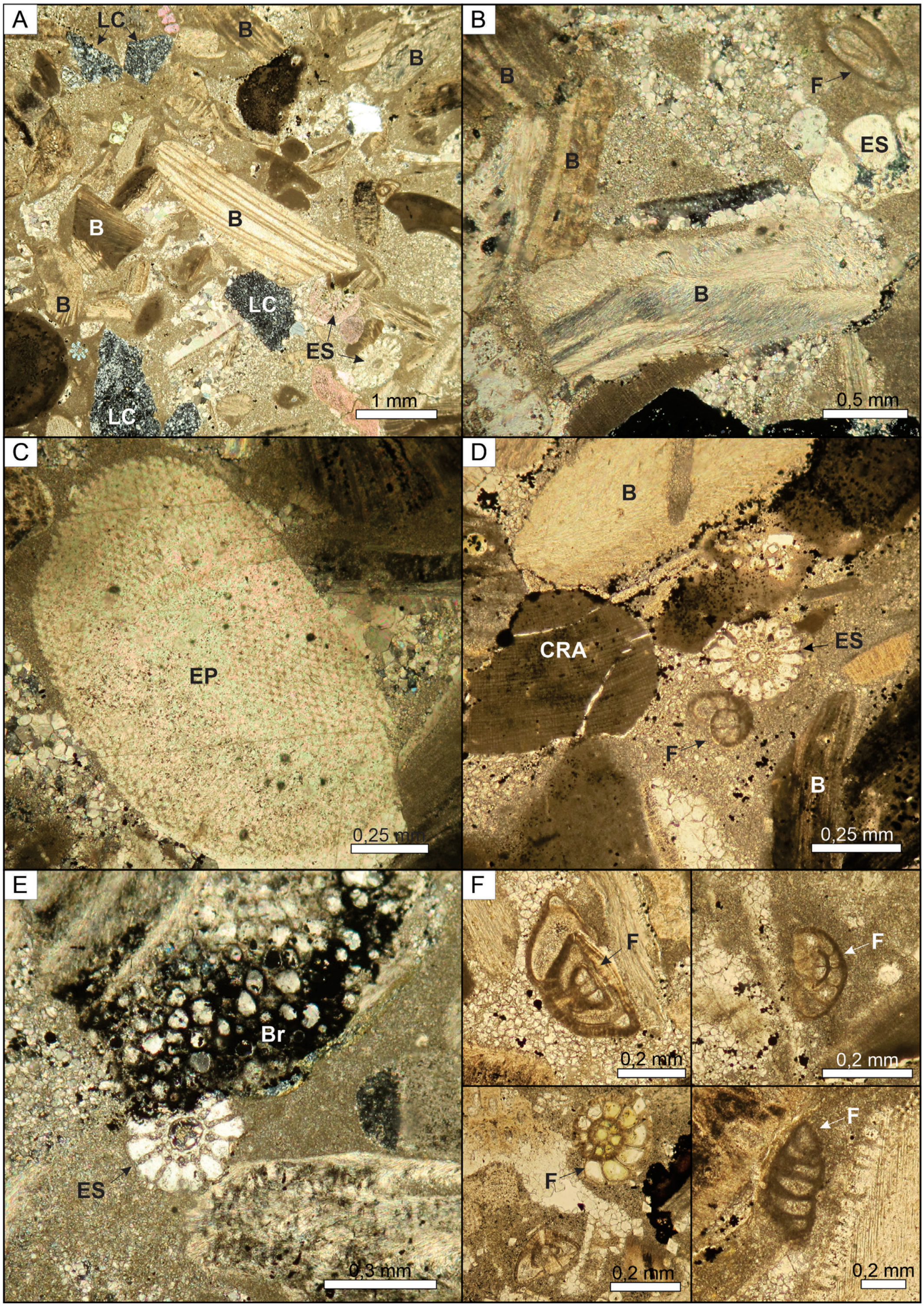


Fig. 8. Thin-section photomicrographs of bioclastic deposits (locality 1, Tetas de Pineda). A) Skeletal packstone mainly constituted by bivalve remains (B), with presence of felsitic volcanic lithoclasts (LC). Sparry calcite cement. Crossed nicols. B) Foliated structure of bivalve shell (B), benthic foraminifera (F) and fragment of echinoderm spine (ES). Sparry calcite cement. Crossed nicols. C) Fragment of echinoderm plate (EP) with uniform "honeycomb" microtexture. Crossed nicols. D) Coralline red algal grain (CRA) showing a fine-scale reticulate structure. Transverse section of an echinoderm spine with single-crystal optical behavior. Parallel nicols. E) Tangential section of bryozoan fragment (Br) with a regular box-like arrangement (note sparry carbonate infilling the porous). A transverse section of echinoderm spine is also observed. Crossed nicols. F) Multicamerate benthic foraminifera (F). Parallel nicols.

Most of encrusting communities are restricted to shallow marine environments, colonizing subtidal and intertidal zones (cf. Bromley and Asgaard, 1993; Libbey and Johnson, 1997; Cruz-Motta et al., 2010; Santos et al., 2011; Bover-Arnal et al., 2011; Brlek et al., 2018). In this way, the dominant macrobiota of K/P bioclastic deposits allows us to interpret intertidal and shallow subtidal paleoenvironmental conditions during the basement flooding over a very wide area of the extra-Andean Patagonia. Considering a tabular thickness of about 2–4 m covering only half of the Northpatagonian rocky shore (35.000 km^2), the volume of K/P bioclastic carbonate deposits could be about 70–140 km^3.

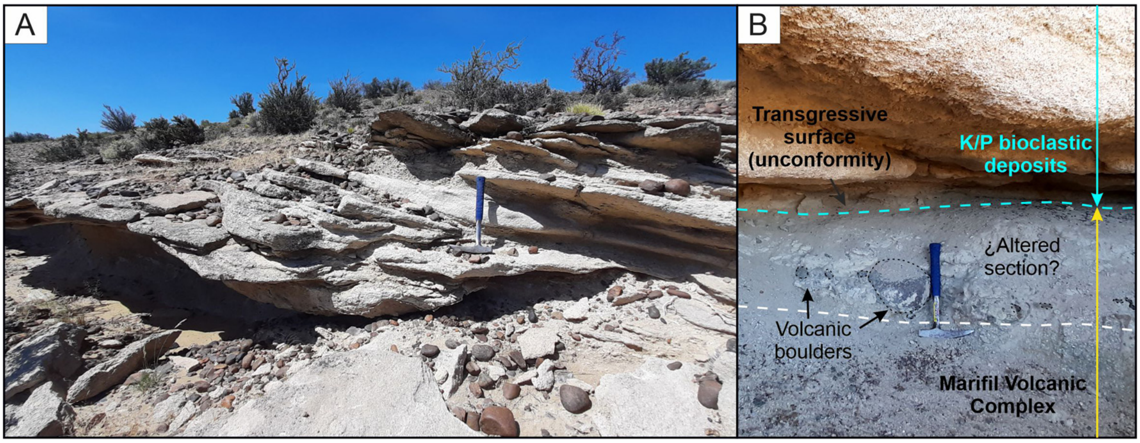


Fig. 9. A) Large-scale cross-bedded bioclastic sandstones, Puesto Álvarez locality (Chico River). B) Transgressive surface over acid volcanic rocks (MCV), which seems to preserve a 0.5 m thick altered profile, Puesto Álvarez locality (Chico River). B).

5. Discussion

Long-term continental flooding episodes are mainly controlled by sea-level rise (i.e., Hays and Pitman, 1973; Vail et al., 1977; Haq et al., 1987, 1988), regional subsidence (i.e., Gurnis, 1991, 1993; Müller et al., 2008, 2018) or a combination of both (Miller et al., 2005; Spasojevic and Gurnis, 2012; Haq, 2014; Dávila et al., 2018, 2019; Cao et al., 2019). Highest frequency of rocky shore occurs on volcanic islands, active orogenic wedges and convergent-plate margins (Johnson, 1988a), with very well documented examples (Johnson et al., 1996; Sanders, 1998; Felton, 2002; Spencer and Viles, 2002; D'Alessandro et al., 2004; Felton et al., 2006; Andriani and Walsh, 2007; Bover-Arnal et al., 2011; Buatois and Encinas, 2011; de Gibert et al., 2012; Brlek et al., 2018; Sanders et al., 2019). However, epicontinental flooding usually covers both sedimentary basins and basement rocks, where the basement-onlapping shallow marine successions constitute rocky shores (i.e., Surlyk and Christensen, 1974; Johnson, 1988a, 1988b, 1992; Johnson et al., 1996; Surlyk, 1997; Johnson and Baarli, 1999, 2012; Domènech et al., 2001; Desrochers, 2006; Surlyk and Sørensen, 2010; Sørensen and Surlyk, 2010, 2011, 2013, 2015; Sørensen et al., 2011, 2012; Puig López et al., 2023).

The K/P transgressive marine record over central-northern extra-Andean Patagonia has been studied for over a century. However, most contributions are local studies or monodisciplinary methodological

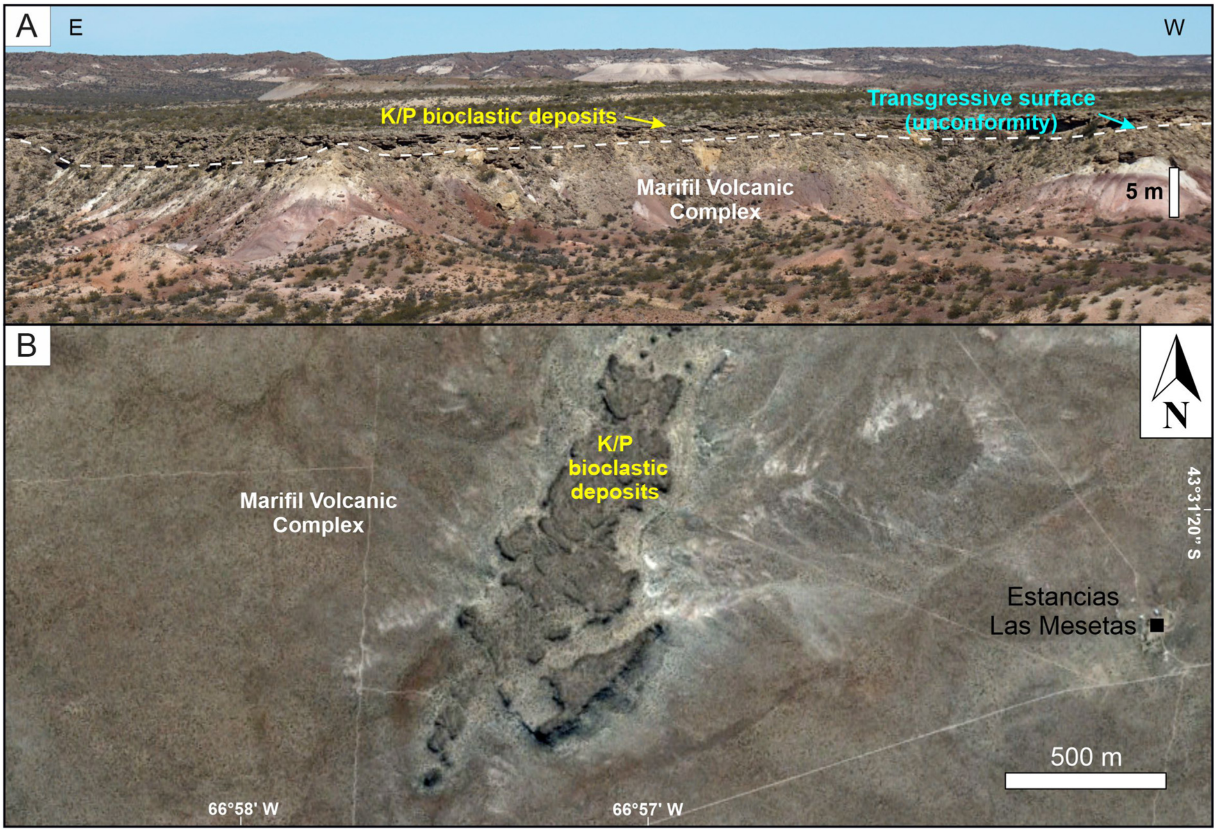


Fig. 10. A) K/P bioclastic deposits overlying the MVC (unconformity), Lower Chubut River (downstream of Florentino Ameghino Dam). Picture courtesy of Juan Manuel Turra. B) Tabular relictic outcrops of K/P marine deposits over the MVC, Estancia Las Mesetas (Chubut).

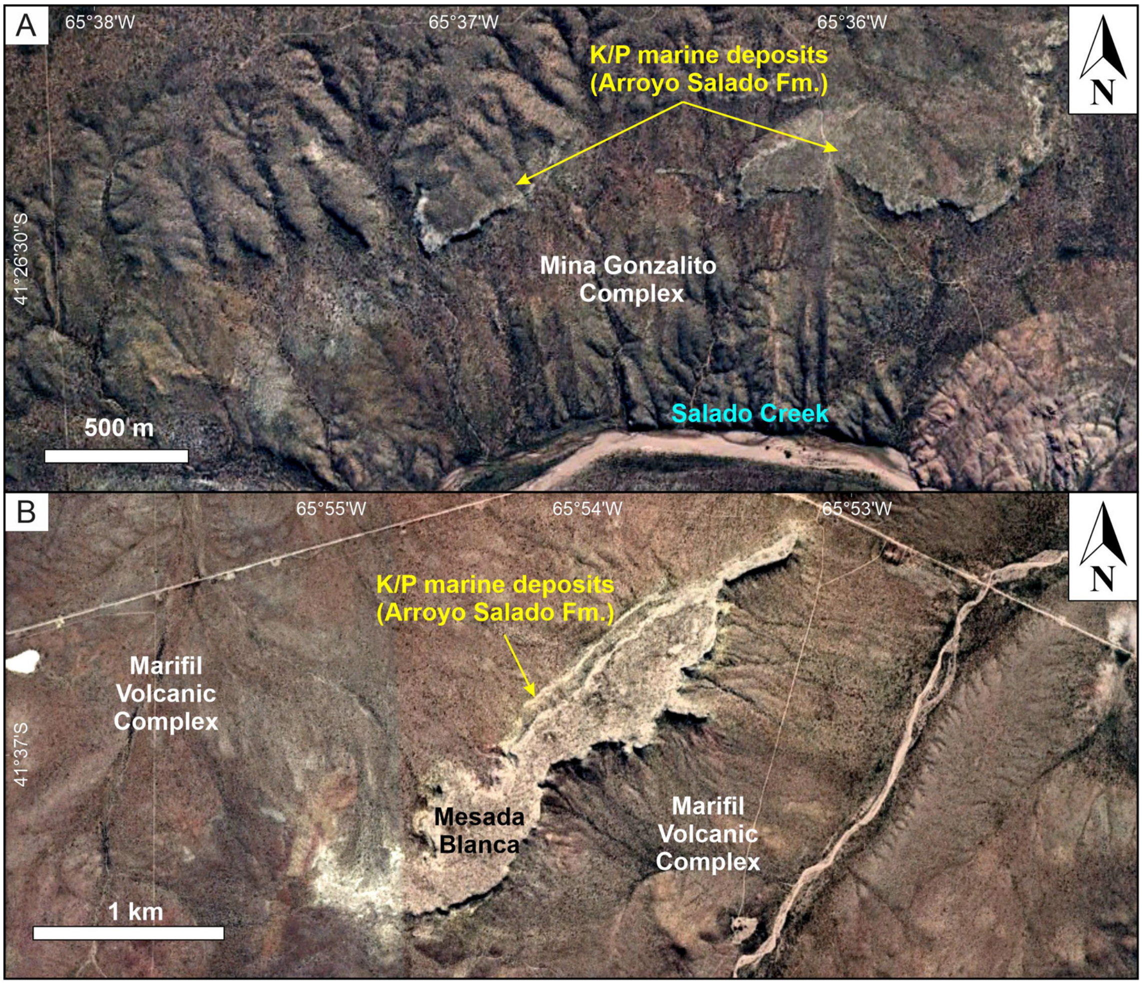


Fig. 11. Google Earth satellite images of K/P marine outcrops (Arroyo Salado Fm.) in the NPM, Río Negro Province. A) Unconformity over Paleozoic high-grade metamorphic rocks (Mina Gonzalito Complex), nearly Estancia Santa Rosa. B) Unconformity over Jurassic volcanic rocks (Chon Aike SLIP), Mesada Blanca locality.

approaches. Although this K/P marine record disposed over the Jurassic and Paleozoic basement probably conforms to the widest outcropped unconformity/nonconformity has not yet been interpreted as a regional rocky shore. This local scenario reinforces the global idea that rocky shores have received insufficient attention from stratigraphers (Johnson, 1988a, 1988b, 1992) and their deposits might be more common in the geological record than previously thought (Puig López et al., 2023). We discussed the main control factors for the K/P Northpatagonian rocky shore, including geological, paleogeographical, and paleoecological implications (Fig. 15).

5.1. Geology

The pre-K/P extra-Andean Patagonian geology is a first-order factor on the regional substrate distribution during the continental flooding (Fig. 14). The Chon Aike SLIP constituted the widest substrate for the K/P Northpatagonian rocky shore, with more restricted Paleozoic igneous-metamorphic examples. The basement rocks were flooded by the K/P sea where there was no previous Cretaceous sedimentary record, or where it was eroded (Aragón et al., 2010, 2014; Aguilera et al., 2014). The rapid sea level rise during the advance of

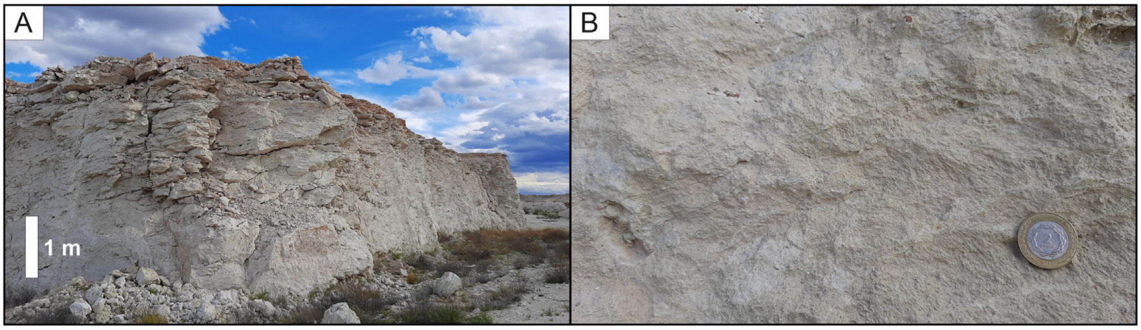


Fig. 12. A) The Arroyo Barbudo/Roca Formation at Cantera La Calera, nearly Aguada Cecilio locality. B) Detail of massive, silicified carbonates. The coin is 2.3 cm in diameter.

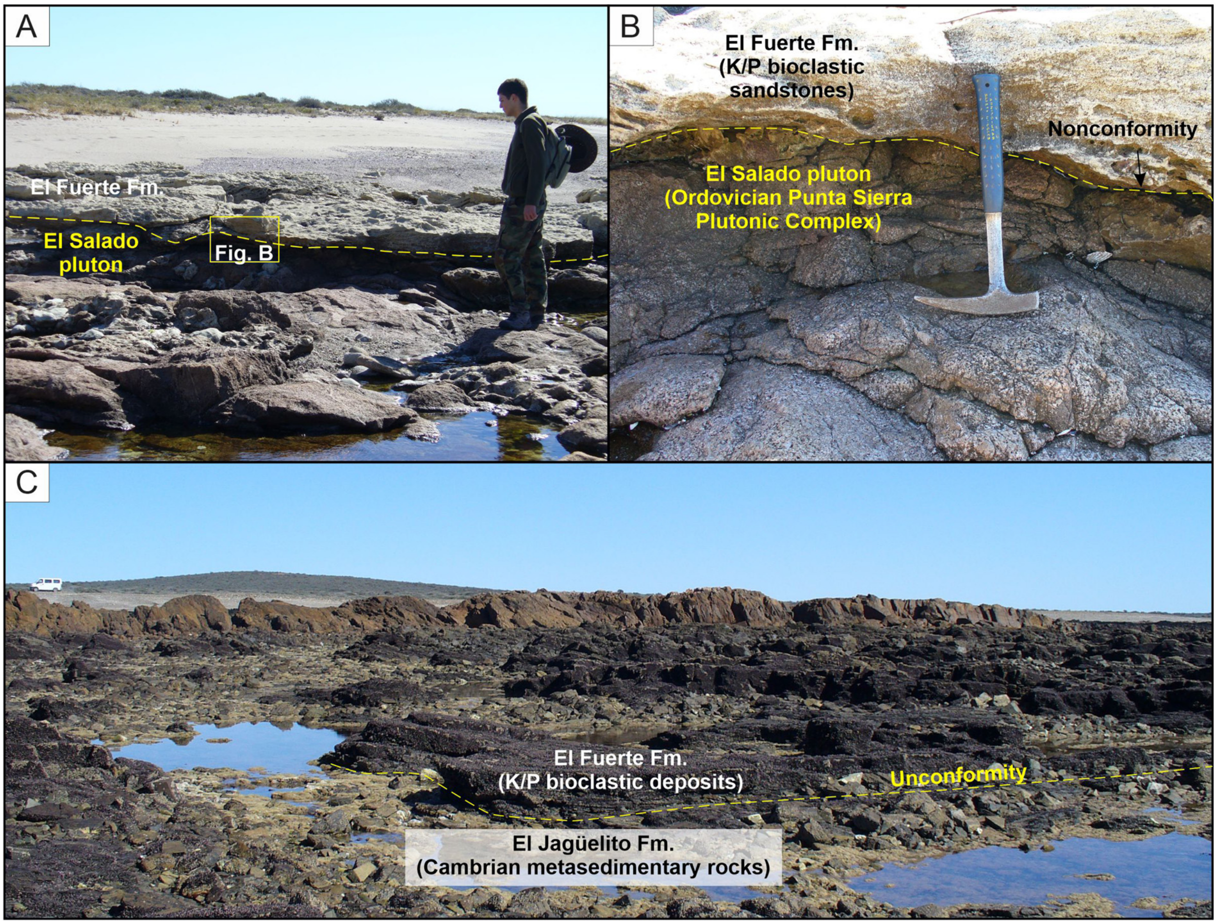


Fig. 13. A) Nonconformity between El Salado pluton (Ordovician Punta Sierra Plutonic Complex) and El Fuerte Formation (K/P bioclastic sandstones), Playas Doradas locality. Location of panel B. B) Detail of the nonconformity between Ordovician igneous basement and bioclastic marine deposits. C) Unconformity between Cambrian, low-grade metamorphic rocks (El Jagüelito Fm.) and the El Fuerte Formation, Punta Colorada locality.

the transgression probably inhibited the development of more encrusting invertebrates, reducing the biodiversity and community net production (i.e., Rilov et al., 2021) and favoring the preservation of rocky shores (Manikam et al., 2022; Puig López et al., 2023). In addition to providing less favorable substrates to encrusting biota, sedimentary basins (Golfo San Jorge, Cañadón Asfalto, Valdés-Rawson,

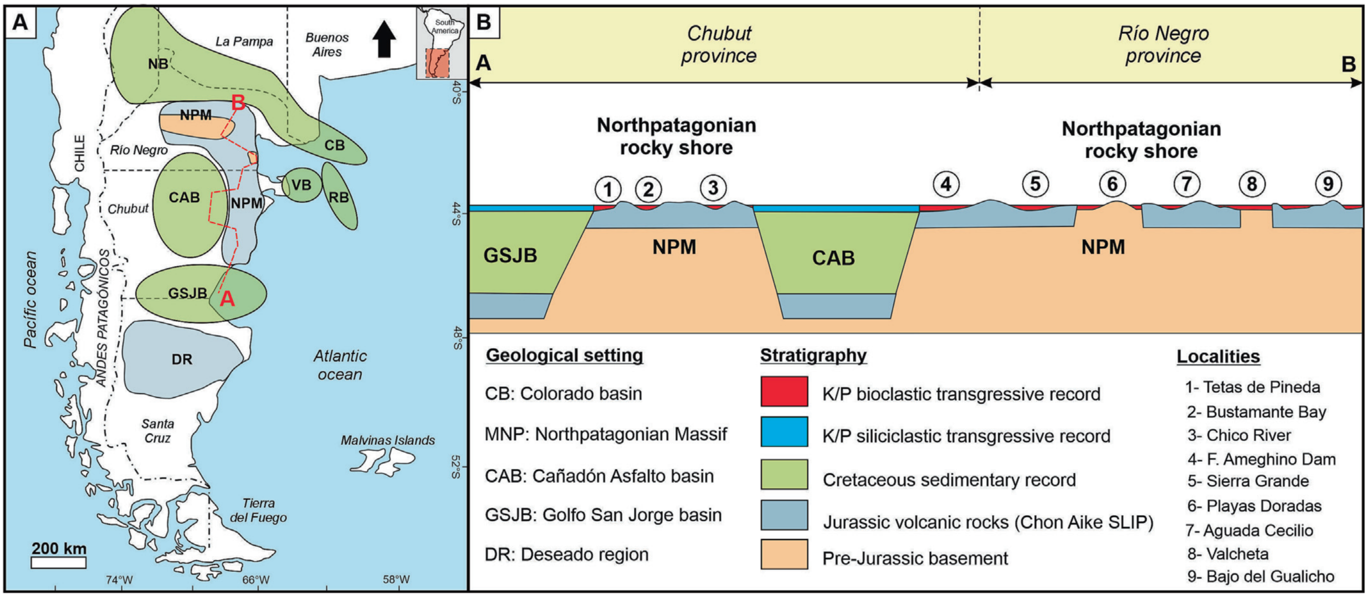
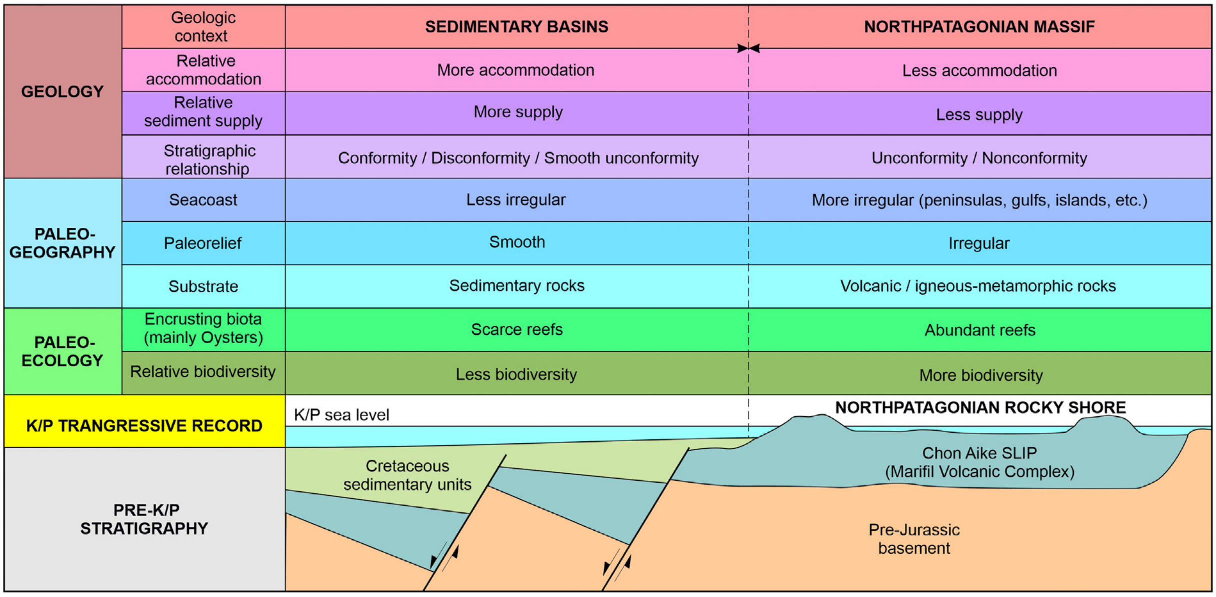


Fig. 14. A) Simplified distribution of main extra-Andean Mesozoic geological settings, Patagonia (Argentina). Location of A and B sections. B) Regional distribution of K/P transgressive deposits over sedimentary basins and the Northpatagonian Massif (A–B section is about 1000 km in length, without vertical scale). The Northpatagonian rocky shore included at least 70.000 km^2 in the Northpatagonian Massif.



	Geologic context	SEDIMENTARY BASINS	NORTHPATAGONIAN MASSIF
GEOLOGY	Relative accommodation	More accommodation	Less accommodation
	Relative sediment supply	More supply	Less supply
	Stratigraphic relationship	Conformity / Disconformity / Smooth unconformity	Unconformity / Nonconformity
PALEO-GEOGRAPHY	Seacoast	Less irregular	More irregular (peninsulas, gulfs, islands, etc.)
	Paleorelief	Smooth	Irregular
	Substrate	Sedimentary rocks	Volcanic / igneous-metamorphic rocks
PALEO-ECOLOGY	Encrusting biota (mainly Oysters)	Scarce reefs	Abundant reefs
	Relative biodiversity	Less biodiversity	More biodiversity

Fig. 15. Main control factors on the K/P transgressive deposits over Mesozoic sedimentary basins and the Northpatagonian Massif, Patagonia (Argentina).

Colorado, Neuquén) had relatively high subsidence rates and sediment supply than the NPM (Fig. 15).

5.2. Paleogeography

The type of substrate partially determines the type of biota that may occur. For example, suspension feeders prefer a hard substrate (i.e., Bromley and Asgaard, 1993; de Gibert et al., 2012; Bayne, 2017; Reijmer, 2021). The NPM, and particularly the Chon Aike SLIP, provided a continental-scale hard substrate for the conformation of K/P encrusting rocky shore biota. The pre-K/P relief included a regional erosive planation surface with large, rounded landforms (whaleback type) and isolated inselbergs (Aguilera et al., 2014). The initial K/P marine inundation probably turned the inselbergs into islands, the negative landforms into gulfs/bays and the positive rounded landforms into peninsulas/barriers. Thus, the irregular seacoast configuration (Feruglio, 1949; Foix et al., 2015) would have increased/controlled the ecological niches for encrusting invertebrates (cf. Betzler et al., 2000) and related bioclastic deposits (Fig. 15). A K/P archipelago of volcanic rocks is a very probable paleogeographic scenario for de NPM during the initial transgression because positive landforms have no bioclastic record (i.e., Tetas de Pineda). Though geographic distribution suggests that the world's rocky shores are segregated along tectonically active as opposed to passive coasts (Johnson, 1988a), the Northpatagonian rocky shore represents an example of a flooded divergent margin.

5.3. Paleoecology

Most of the data presented here reveals that the K/P transgressive bioclastic deposits are mainly composed of skeletal fragments of Oysters (Feruglio, 1936, 1949; Spalletti et al., 1993). In addition, oysters are the dominant molluscan group throughout almost all Patagonian basins for this time (del Río, 2021) and support a wide variety of boring and encrusting biota, including sponges, polychaetes, bivalves, fungi, algae, barnacles and bryozoans (Brezina et al., 2014, 2017). Though oysters colonized both hard and soft substrates (Seilacher et al., 1985; Machalski, 1998; Kidwell and Brenchley, 1994; Anderson et al., 2004), they are typically encrusting fauna of rocky shores from the Mesozoic (i.e., Johnson, 1988a; Zítt and Nekvasilova, 1996; de Gibert et al., 1998, 2012; Johnson and Baarli, 1999, 2012; Betzler et al., 2000; D'Alessandro et al., 2004; Sørensen and Surlyk, 2008; Bover-Arnal et al., 2011; among others), even present in K/P rocky shore successions (i.e., Sanders, 1998). In this sense, Late Cretaceous carbonate platforms reached high latitudes in the northern and southern hemispheres (Kiessling et al., 2003), with benthic carbonate factories dominated by bivalves (oysters), echinoids, bryozoan, brachiopods, and red algae (i.e., Surlyk and Christensen, 1974; Surlyk, 1997). Oysters are considered as habitat-forming species or ecosystem engineers that enhance the biodiversity from attenuation wave energy, improvement of water quality by biofiltered, creation of habitats for fish species, and support of a wide diversity of epibenthic invertebrates (Newell, 1988; Coen et al., 2007; Grabowski and Peterson, 2007; Parras and Casadío, 2006; Padilla, 2010; Gutiérrez et al., 2011; Bayne, 2017; Coen and Humphries, 2017; McAfee et al., 2017). Therefore, the Northpatagonian rocky shore provided a regional ecological niche for oyster reefs and probably enhanced the K/P coastal biodiversity (Fig. 15).

The interplay of local/regional factors (substrate, paleorelief, subsidence) and external controls (sea level rise) favored the conformation of a K/P, short-lived, transgressive, cool-water carbonate factory (*sensu* Surlyk, 1997; Schlager, 2000, 2003; Reijmer, 2021) or heterozoan factory (*sensu* Michel et al., 2018, 2019) over the NPM. This example is partially synchronous (Late Cretaceous-Danian) with one of the largest and longest-lived cool-water carbonate platforms occurred in the Baltic Shield (Surlyk, 1997), mainly conformed by oyster bank communities along the rocky shorelines. The inclusion of the K/P cool water carbonate sedimentation over Patagonia in the worldwide carbonate platform reconstructions (i.e., Kiessling et al., 2000, 2003) will extend its distribution to higher latitudes and would increase the global carbonate production (70–140 km^3).

6. Conclusions

- We recognized the K/P Northpatagonian rocky shore over 70.000 km^2 in central-northern extra-Andean Patagonia (Argentina), the widest known ancient rocky shore of South America. The substrate is mainly composed of Jurassic volcanic rocks (Chon Aike SLIP), with more restricted Triassic volcanic rocks and Paleozoic igneous-metamorphic complexes.

- The initial K/P rocky shore transgressive record is mainly composed of bioclastic deposits up to 40 m in thickness. The hard substrate, the irregular seacoast configuration, and the relatively low accommodation settings over the NPM provided the conditions for developing of oyster reefs and related marine biota.
- The interplay of geological, paleogeographical, and paleoecological conditions favored the conformation of a K/P, short-lived, transgressive, cool-water carbonate factory in the south-eastern extreme of South America.

Data availability

Data will be made available on request.

Declaration of competing interest

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.

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References

Aguilera, E.Y., Rabassa, J., Aragón, E., 2014. Paleo-landscapes of the Northern Patagonian Massif, Argentina. In: Rabassa, J., Ollier, C. (Eds.), Gondwana Landscapes in Southern South America. Springer, pp. 423–445 https://doi.org/10.1007/978-94-007-7702-6_15.

Aguirre-Urreta, B., Tunik, M., Naipauer, M., Pazos, P., Ottone, E., Fanning, M., Ramos, V.A., 2011. Malargüe Group (Maastrichtian-Danian) deposits in the Neuquén Andes, Argentina: implications for the onset of the first Atlantic transgression related to Western Gondwana breakup. Gondwana Research 19, 482–494. https://doi.org/10.1016/j.gr.2010.06.008.

Anderson, J., Hedgecock, D., Berrigan, M., Criddle, K., Dewey, W., Ford, S., Goulletquer, P., Hildreth, R., Paolisso, M., Targett, N., Whitlatch, R., 2004. Nonnative Oyster in the Chesapeake Bay. The National Academies Press, Washington, DC (344 pp.).

Andreis, R.R., Mazzoni, M., Spalletti, L.A., 1975. Estudio estratigráfico y paleoambiental de las sedimentitas terciarias entre Pico Salamanca y Bahía Bustamante, Provincia del Chubut, República Argentina. Revista de la Asociación Geológica Argentina 30, 85–103.

Andriani, G.F., Walsh, N., 2007. Rocky coast geomorphology and erosional processes: a case study along the Murgia coastline South of Bari, Apulia - SE Italy. Geomorphology 87, 224–238. https://doi.org/10.1016/j.geomorph.2006.03.033.

Aragón, E., Aguilera, E.Y., Cavarozzi, C., Ribot, A., 2010. The North Patagonian Altiplano and the Somón Cura basaltic plateau. Geociências 29 (4), 527–532.

Aragón, E., Aguilera, E.Y., Cavarozzi, C.E., Ribot, A., 2014. The exhumation of the Northern Patagonian Massif Gondwana planation surface due to uprising during the Oligocene. In: Rabassa, J., Ollier, C. (Eds.), Gondwana Landscapes in Southern South America. Springer, pp. 517–525 https://doi.org/10.1007/978-94-007-7702-6_19.

Archangelsky, S., 1973. Palinología del Paleoceno de Chubut. I: descripciones sistemáticas. Ameghiniana 10, 199–339.

Archangelsky, S., 1976. Palinología del Paleoceno de Chubut. II. Diagramas polínicos. Ameghiniana 13, 43–55.

Ardolino, A., Panza, J.L., Ylláñez, E., Parisi, C., 2003. Hoja Geológica 4566-I, Garayalde, Provincia del Chubut. Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino, Boletín264 (84 pp., Buenos Aires).

Baron-Szabo, R.C., Casadío, S., Parras, A., 2003. First shallow water scleractinian coral reef from the danian, northern Patagonia, Argentina. Ameghiniana, Suplemento Resúmenes 40, 79R.

Bayne, B.L., 2017. Biology of Oysters. Developments in Aquaculture and Fisheries Science. 41. Elsevier Science & Technology, London (844 pp.).

Bertels, A., 1969. Estratigrafía del límite Cretácico-Terciario en Patagonia septentrional. Revista de la Asociación Geológica Argentina 24 (1), 41–54 (Buenos Aires).

Bertels, A., 1973. Ostracodes of the type localiy of the Lower Tertiary (lower Danian) Rocanian Stage and Roca Formation (Argentina). Micropaleontology 19 (3), 308–340.

Bertels, A., 1974. Upper Cretaceous (lower Maastrichtian?) ostracodes from Argentina. Micropaleontology 20 (4), 385–397.

Bertels, A., 1975. Upper Cretaceous (middle Maastrichtian) ostracodes of Argentina. Micropaleontology 21 (1), 97–130.

Bertels, A., 1979. Paleobiogeografía de los foraminíferos del Cretácico superior y Cenozoico de América del Sur. Ameghiniana 16 (3–4), 273–356.

Bertels, A., 1995. The Cretaceous-Tertiary boundary in Argentina and its ostracodes. In: Ríha, J. (Ed.), Ostracoda and Biostratigraphy, Balkema, Rotterdam, Brookfield. 1994. Proceedings of the Twelfth International Symposium on Ostracoda, Praga, pp. 163–170.

Betzler, C., Martín, J.M., Braga, J.C., 2000. Non-tropical carbonates related to rocky submarine cliffs (Miocene, Almería, southern Spain). Sedimentary Geology 131, 51–65. https://doi.org/10.1016/S0037-0738(99)00125-6.

Biddle, K.T., Uliana, M.A., Mitchum, R.M., Fitzgerald, M.G., Wright, R.C., 1986. The stratigraphic and structural evolution of the central and eastern Magallanes Basin, Southern South America. In: Allen, P.A., Homewood, P. (Eds.), Foreland Basins. International Association of Sedimentologist, Special Publication8, pp. 41–61.

Bover-Arnal, T., Jaramillo-Vogel, D., Showani, A., Strasser, A., 2011. Late Eocene transgressive sedimentation in the western Swiss Alps: records of autochthonous and quasi-autochthonous biofacies on a karstic rocky shore. Palaeogeography, Palaeoclimatology, Palaeoecology 312, 24–39. https://doi.org/10.1016/j.palaeo.2011.08.006.

Brezina, S.S., Romero, M.V., Casadío, S., Bremec, C., 2014. Boring polychaetes associated with Pycnodonte (Phygraea) vesicularis (Lamarck) from the Upper Cretaceous of Patagonia. A case of commensalism? Ameghiniana 52, 129–140. https://doi.org/10.5710/AMGH.04.12.2013.1266.

Brezina, S.S., Romero, M.V., Casadío, S., 2017. Encrusting and boring barnacles through the Cretaceous/Paleogene boundary in Northern Patagonia (Argentina). Ameghiniana 54, 107–123. https://doi.org/10.5710/AMGH.11.10.2016.2969.

Brezina, S.S., Taylor, P.D., Romero, M.V., Palópolo, E.E., Casadío, S., 2021. Upper Maastrichtian and Danian bryozoans from Northern Patagonia, Argentina. Cretaceous Research 125, 104845. https://doi.org/10.1016/j.cretres.2021.104845.

Brlek, M., Iveša, L., Brčić, V., Santos, A., Ćorić, S., Milošević, M., Avanić, R., Devescovi, M., Pezelj, D., Mišur, I., Miknić, M., 2018. Rocky-shore unconformities marking the base of Badenian (Middle Miocene) transgressions on Mt. Medvednica basement (North Croatian Basin, Central Paratethys). Facies 64, 25. https://doi.org/10.1007/s10347-018-0537-0.

Bromley, R.G., Asgaard, U., 1993. Endolithic community replacement on a Pliocene rocky coast. Ichnos 2, 93–116. https://doi.org/10.1080/10420949309380081.

Bryan, S.E., Ernst, R.E., 2008. Revised definition of large igneous provinces (LIPs). Earth-Science Reviews 86, 175–202. https://doi.org/10.1016/j.earscirev.2007.08.008.

Bryan, S.E., Ferrari, L., 2013. Large igneous provinces and silicic large igneous provinces: progress in our understanding over the last 25 years. Geological Society of America Bulletin 125 (7–8), 1053–1078. https://doi.org/10.1130/B30820.1.

Bryan, S.E., Ukstins-Peate, I., Peate, D.W., Self, S., Jerram, D.A., Mawby, M.R., Marsh, J.S., Miller, J.A., 2010. The largest volcanic eruptions on Earth. Earth-Science Reviews 102, 207–229. https://doi.org/10.1016/j.earscirev.2010.07.001.

Buatois, L.A., Encinas, A., 2011. Ichnology, sequence stratigraphy and depositional evolution of an Upper Cretaceous rocky shoreline in Central Chile: Bioerosion structures in a transgressed metamorphic basement. Cretaceous Research 32, 203–212. https://doi.org/10.1016/j.cretres.2010.12.003.

Burckhardt, C., 1901. Le gisement supracrétacique de Roca (Río Negro). Revista del Museo de La Plata 10, 207–223.

Busteros, A., Giacosa, R., Lema, H., Zubia, M., 1998. Hoja Geológica 4166-IV Sierra Grande. Provincia de Río Negro. Programa Nacional de Cartas Geológicas de la República Argentina 1:250.000. Boletín241 (85 pp.).

Camacho, H.H., 1967. Las transgresiones del Cretácico superior y Terciario de la Argentina. Revista de la Asociación Geológica Argentina 22 (4), 253–280.

Camacho, H.H., 1992. Algunas consideraciones acerca de la transgresión marina paleocena en la Argentina. Miscelanea de la Academia Nacional de Ciencias 85, 1–41 Córdoba.

Caminos, R., 2001. Hoja Geológica 4166-1 Valcheta, Provincia de Río Negro. Instituto de geología y Recursos Minerales, Servicio Geológico Minero Argentino, Boletín310 (71 pp.).

Cao, W., Flament, N., Zahirovic, S., Williams, S., Müller, R.D., 2019. The interplay of dynamic topography and eustasy on continental flooding in the late Paleozoic. Tectonophysics 761, 108–121. https://doi.org/10.1016/j.tecto.2019.04.018.

Carrera, M.G., Casadío, S., 2016. Solenoporacean red algae from Lower Danian (Paleogene) coral reefs of northern Patagonia, La Pampa, Argentina. Ameghiniana 53, 623–628. https://doi.org/10.5710/AMGH.10.02.2016.2956.

Casadío, S., 1998. Las ostras del límite Cretácico-Paleógeno de la Cuenca Neuquina (Argentina). Su importancia bioestratigráfica y paleobiogeográfica. Ameghiniana 35, 449–471.

Cebrián, E., Ballesteros, E., Canals, M., 2000. Shallow rocky bottom benthic assemblages as calcium carbonate producers in the Alboran Sea (southwestern Mediterranean). Oceanologica Acta 23 (3), 311–322. https://doi.org/10.1016/S0399-1784(00)00131-6.

Celeste, R., 1940. Relaciones entre el Rocaneano el Salamanqueano en la Zona Comprendida Entre Mamelones de Pineda y V. Mena y A. Nay en el valle del río Chico, territorio del Chubut. Tesisn° 26. Inédita.

Chappuis, E., Terradas, M., Cefalì, M.E., Mariani, S., Ballesteros, E., 2014. Vertical zonation is the main distribution pattern of littoral assemblages on rocky shores at a regional scale. Estuarine, Coastal and Shelf Science 147, 113–122. https://doi.org/10.1016/j.ecss.2014.05.031.

Chebli, G., Serraiotto, A., 1974. Nuevas localidades del Paleoceno marino en la región central de la provincia del Chubut. Revista de la Asociación Geológica Argentina 29, 311–318.

Clavijo, R., 1986. Estratigrafía del Cretácico inferior en el sector occidental de la Cuenca del Golfo San Jorge. Boletín de Informaciones Petroleras 9, 15–32.

Coen, L.D., Humphries, A., 2017. Oyster-generated marine habitats: their services, enhancement, restoration, and monitoring. In: Murphy, S., Allison, S. (Eds.), Routledge Handbook of Ecological and Environmental Restoration. Taylor & Francis Group, Routledge, Cambridge, U.K, pp. 275–295 https://doi.org/10.4324/9781315685977.

Coen, L.D., Brumbaugh, R.D., Bushek, D., Grizzle, R., Luckenbach, M.W., Posey, M.H., Powers, S.P., Tolley, S.G., 2007. Ecosystem services related to oyster restoration. Marine Ecology Progress Series 341, 303–307. https://doi.org/10.3354/meps341303.

Concheyro, A., Náñez, C., 1994. Microfossils and biostratigraphy of the Jagüel and Roca formations (Maestrichtian-Danian), province of Neuquén. Ameghiniana 31, 397–398.

Continanzia, J., Manceda, R., Covellone, G.M., y Gavarrino, A.S., 2011. Cuenca de Rawson-Valdés: Síntesis del Conocimiento Exploratorio - Visión Actual. VIII Congreso Exploración y Desarrollo de Hidrocarburos (Simposio Cuencas Argentinas: Visión Actual). Actas, Mar del Plata, pp. 47–63.

Cortés, J.M., 1980. Senoniano marino en el flanco oriental del Macizo Nordpatagónico. Revista de la Asociación Geológica Argentina 35 (3), 438–439.

Cruz-Motta, J.J., Miloslavich, P., Palomo, G., Iken, K., Konar, B., Pohle, G., Trott, T., Benedetti-Cecchi, L., Herrera, C., Hernandez, A., Sardi, A., Bueno, A., Castillo, J., Klein, E., Guerra-Castro, E., Gobin, J., Gomez, D.I., Riosmena-Rodriguez, R., Mead, A., Bigatti, G., Knowlton, A., Shirayama, Y., 2010. Patterns of spatial variation of assemblages associated with intertidal rocky shores: a global perspective. PLoS One 5, e14354. https://doi.org/10.1371/journal.pone.0014354.

Cucchi, R., Busteros, A., Lema, H., 2001. Hoja Geológica 4169-II, Los Menucos, Provincia de Río Negro. IGRM-SEGEMAR, Boletín265 p. 105 (Buenos Aires).

D'Alessandro, A., Massari, F., Davaud, E., Ghibaudo, G., 2004. Pliocene-Pleistocene sequences bounded by subaerial unconformities within foramol ramp calcarenites and mixed deposits (Salento, SE Italy). Sedimentary Geology 166, 89–144. https://doi.org/10.1016/j.sedgeo.2003.11.017.

Dávila, F., Lithgow-Bertelloni, C., Martina, F., Ávila, P., Nóbile, J., Collo, G., Ezpeleta, M., Canelo, H., Sánchez, F., 2018. Mantle influence on andean and pre-andean topography. In: Folguera, A., et al. (Eds.), The Evolution of the Chilean-Argentinean Andes. Springer, pp. 363–385 https://doi.org/10.1007/978-3-319-67774-3_15.

Dávila, F.M., Ávila, P., Martina, F., 2019. Relative contributions of tectonics and dynamic topography to the Mesozoic-Cenozoic subsidence of southern Patagonia. Journal of South American Earth Sciences 93, 412–423. https://doi.org/10.1016/j.jsames.2019.05.010.

Dayton, P.K., 1975. Experimental evaluation of ecological dominance in a rocky intertidal algal community. Ecological Monographs 45, 137–159.

de Gibert, J.M., Martinell, J., Domènech, R., 1998. Entobia ichnofacies in fossil rocky shores, Lower Pliocene, Northwestern Mediterranean. Palaios 13, 476–487.

de Gibert, J.M., Domènech, R., Martinell, J., 2012. Chapter 15. Rocky shorelines. In: Knaust, D., Bromley, R.G. (Eds.), Trace Fossils as Indicators of Sedimentary Environments, Developments in Sedimentology. 64. Elsevier, Amsterdam, pp. 441–462.

del Río, C.J., 2004. Tertiary marine molluscan assemblages of Eastern Patagonia (Argentina): a biostratigraphic analysis. Journal of Paleontology 78 (6), 1097–1122. https://doi.org/10.1666/0022-3360(2004)078<1097:TMMAOE>2.0.CO;2.

del Río, C.J., 2012. A new early Danian gastropod assemblage from northern Patagonia (Río Negro province, Argentina). Journal of Paleontology 86, 1002–1016. https://doi.org/10.2307/23353786.

del Río, C.J., 2021. Paleoclimate and changing composition of the Paleogene-Neogene shallow molluscan assemblages of Patagonia. Journal of South American Earth Sciences 108, 103209. https://doi.org/10.1016/j.jsames.2021.103209.

del Río, C.J., Martínez, S.A., 2015. Paleobiogeography of the Danian molluscan assemblages of Patagonia (Argentina). Palaeogeography, Palaeoecology, Palaeoclimatology 417, 274–292. https://doi.org/10.1016/j.palaeo.2014.10.006.

del Río, C.J., Concheyro, A., Martínez, S., 2011. The Maastrichtian-Danian at General Roca: a reappraisal of the chronostratigraphy and biostratigraphy of a type locality (Patagonia, Argentina). Neues Jahrbuch für Geologie und Paläontologie 259, 129–156. https://doi.org/10.1127/0077-7749/2011/0103.

Desrochers, A., 2006. Rocky shoreline deposits in the lower Silurian (upper Llandovery, Telychian) Chicotte formation, Anticosti island, Quebec. Canadian Journal of Earth Sciences 43, 1205–1214. https://doi.org/10.1139/e06-054.

Domènech, R., de Gibert, J.M., Martinell, J., 2001. Ichnological features of a marine transgression: Middle Miocene rocky shore of Tarragona, Spain. Geobios 34, 99–107. https://doi.org/10.1016/S0016-6995(01)80051-6.

Espejo, P., 1999. Calizas y dolomías del departamento Valcheta, Río Negro. In: Zappettini, E.O. (Ed.), Recursos Minerales de la República Argentina. Instituto de Geología y Recursos Minerales (SEGEMAR), Anales35, pp. 1407–1419.

Felton, E.A., 2002. Sedimentology of rocky shorelines: 1. A review of the problem, with analytical methods, and insights gained from the Hulopoe Gravel and the modern rocky shoreline of Lanai, Hawaii. Sedimentary Geology 152, 221–245. https://doi.org/10.1016/S0037-0738(02)00070-2.

Felton, E.A., Crook, K.A.W., Keating, B.H., Kay, E.A., 2006. Sedimentology of rocky shorelines: 4. Coarse gravel lithofacies, molluscan biofacies, and the stratigraphic and eustatic records in the type area of the Pleistocene Hulopoe Gravel, Lanai, Hawaii. Sedimentary Geology 184, 1–76. https://doi.org/10.1016/j.sedgeo.2005.08.005.

Feruglio, E., 1936. Nuevas especies de moluscos supracretácicos y terciarios de la Patagonia. Boletín de Informaciones Petroleras 139, 121–136.

Feruglio, E., 1949. Descripción Geológica de la Patagonia. Vol. 1. Yacimientos Petrolíferos Fiscales, Buenos Aires (334 pp.).

Figari, E.G., Courtade, S.F., 1993. Evolución tectosedimentaria de la cuenca de Cañadón Asfalto, Chubut, Argentina. 12° Congreso Geológico Argentino1. Actas, pp. 66–77.

Figari, E.G., Hechem, J.J., 2021. Cuencas volcano-sedimentarias del Mesozoico. In: Giacosa, R.E. (Ed.), Relatorio de Geología y Recursos Naturales de la Provincia de Chubut, pp. 129–141.

Figari, E.G., Strelkov, E., Laffife, G., Cid de la Paz, M., Courtade, S., Celaya, J., Vottero, A., Lafourcade, S., Martinez, R., Villar, H., 1999. Los Sistemas Petroleros de la Cuenca del Golfo San Jorge: Síntesis Estructural, Estratigráfica y Geoquímica. 4° Congreso de Exploración y Desarrollo de Hidrocarburos. Actas, Buenos Aires, pp. 197–237.

Figari, E.G., Scasso, R.A., Cúneo, R.N., Escapa, I., 2015. Estratigrafía y evolución geológica de la cuenca de Cañadón Asfalto, Provincia del Chubut, Argentina. Latin American Journal 22 (2), 135–169.

Fildani, A., Romans, B.W., Fosdick, J.C., Crane, W.H., Hubbard, S.M., 2008. Orogenesis of the Patagonian Andes as reflected by basin evolution in southernmost South America. In: Spencer, J.E., Titley, S.R. (Eds.), Ores and Orogenesis: Circum-Pacific Tectonics, Geologic Evolution, and Ore Deposits. 22. Arizona Geological Society Digest, pp. 259–268.

Fitzgerald, M.G., Mitchum, R.M., Uliana, M.A., Biddle, K.T., 1990. Evolution of the San Jorge Basin, Argentina. American Association of Petroleum Geologists Bulletin 74 (6), 879–920 Tulsa.

Foix, N., Paredes, J.M., Giacosa, R.E., Allard, J.O., 2015. Arquitectura estratigráfica del Paleoceno en el flanco norte de la cuenca del Golfo San Jorge, Patagonia central. Revista de la Asociación Geológica Argentina 72 (1), 96–106.

Foix, N., Krause, J.M., Bellosi, E., Raigenborn, M.S., 2021. Sedimentitas paleógenas y neógenas del margen atlántico. In: Giacosa, R.E. (Ed.), Relatorio de Geología y Recursos Naturales de la Provincia de Chubut, pp. 489–521.

Franchi, M., Ardolino, A., Remesal, M., Caba, R., Dalponte, M., Lizuain, A., 2001. Hoja Geológica 4166-III, Cona Niyeu. Provincia de Río Negro. Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino. Boletín262 (87 pp., Buenos Aires).

Franzese, J.R., Spalletti, L., Gómez Pérez, I., Macdonald, D., 2003. Tectonic and paleoenvironmental evolution of Mesozoic sedimentary basins along the Andes foothills of Argentina (32°-54°S). Journal of South American Earth Sciences 16, 81–90. https://doi.org/10.1016/S0895-9811(03)00020-8.

Gianni, G.M., Dávila, F.M., Echaurren, A., Fennell, L., Tobal, J., Navarrete, C., Giménez, M., 2018a. A geodynamic model linking Cretaceous orogeny, arc migration, foreland dynamic subsidence and marine ingression in southern South America. Earth Sciences Review 185, 26–462. https://doi.org/10.1016/j.earscirev.2018.06.016.

Gianni, G.M., Echaurren, A., Fennell, L., Navarrete, C.R., Quezada, P., Tobal, J., Giménez, M., Dávila, F.M., Folguera, A., 2018b. Cretaceous orogeny and marine transgression in the southern central and northern Patagonian Andes: aftermath of a large-scale flat-subduction event? In: Folguera, A., et al. (Eds.), The Evolution of the Chilean-Argentinean Andes. Springer, pp. 291–328 https://doi.org/10.1007/978-3-319-67774-3_12

González, P.D., Sato, A.M., Naipauer, M., Varela, R., Basei, M., Sato, K., Llambías, E.J., Chemale, F., Castro Dorado, A., 2018. Patagonia-Antarctica Early Paleozoic conjugate margins: Cambrian synsedimentary silicic magmatism, U-Pb dating of K-bentonites, and related volcanogenic rocks. Gondwana Research 63, 186–225. https://doi.org/10.1016/j.gr.2018.05.015.

González, P.D., Naipauer, M., Sato, A.M., Varela, R., Basei, M.A.S., Cábana, M.C., Vlach, S.R.F., Arce, M., Parada, M., 2020. Early Paleozoic structural and metamorphic evolution of the Transpatagonian Orogen related to Gondwana assembly. International Journal of Earth Sciences 110, 81–111. https://doi.org/10.1007/s00531-020-01939-0.

Grabowski, J.H., Peterson, C.H., 2007. Restoring oyster reefs to recover ecosystem services. Ecosystem Engineers: Plants to Protists. 4, pp. 281–298.

Griffin, M., Hünicken, M.A., 1994. Late Cretaceous-early Tertiary gastropods from southeastern Patagonia, Argentina. Journal of Paleontology 68, 257–274.

Griffin, M., Casadío, S., Parras, A., 2005. Maastrichtian and Danian Species of Turkostreini (Ostreidae, Crassostreinae) from the Neuquén Basin, Argentina. Ameghiniana 42, 257–276.

Griffin, M., Parras, A., Casadío, S., 2008. Maastrichtian-Danian mytilids and pinnids (molluska: Bivalvia) from northern Patagonia, Argentina. Ameghiniana 45, 139–152.

Guler, M.V., Borel, C.M., Brinkhuis, H., Navarro, E., Astini, R., 2014. Brackish to freshwater dinoflagellate cyst assemblages from the La Colonia Formation (Paleocene?), Northeastern Patagonia, Argentina. Ameghiniana 51, 141–153. https://doi.org/10.5710/AMGH.15.02.2014.949.

Guler, M.V., González Estebenet, M.S., Navarro, E.L., Astini, R.A., Pérez Panera, J.P., Ottone, E.G., Pieroni, D., Paolillo, M.A., 2019. Maastrichtian to Danian Atlantic transgression in the north of Patagonia: a dinoflagellate cyst approach. Journal of South American Earth Sciences 92, 552–564. https://doi.org/10.1016/j.jsames.2019.04.002.

Gurnis, M., 1991. Continental flooding and mantle-lithosphere dynamics. In: Sabadini, R., Lambeck, K., Boschi, E. (Eds.), Glacial Isostasy, Sea-Level, and Mantle Rheology. Kluwer Academic Publishers, Dordrect, pp. 445–492.

Gurnis, M., 1993. Phanerozoic marine inundation of continents driven by dynamic topography above subducting slabs. Nature 364, 754–756.

Gutiérrez, J.L., Jones, C.G., Byers, J.E., Arkema, K.K., Berkenbusch, K., Commito, J.A., Duarte, C.M., Hacker, S.D., Lambrinos, J.G., Hendriks, I.E., Hogarth, P.J., Palomo, M.G., Wild, C., 2011. Physical ecosystem engineers and the functioning of estuaries and coasts. In: Wolanski, E., McLusky, D.S. (Eds.), Treatise on Estuarine and Coastal Science. vol. 7. Academic Press, Waltham, pp. 53–81.

Haller, M.J., 1981. Descripción Geológica de la Hoja 43h, Puerto Madryn, provincia del Chubut. Servicio Geológico Nacional. Boletín184 (41 pp., Buenos Aires).

Haller, J., Meister, C.M., Monti, A.J., Weiler, N., 2005. Hoja Geológica 4366-II, Puerto Madryn. Provincia del Chubut. Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino. Boletín289 (39 pp., Buenos Aires).

Haq, B.U., 2014. Cretaceous eustasy revisited. Global and Planetary Change 113, 44–58. https://doi.org/10.1016/j.gloplacha.2013.12.007.

Haq, B.U., Hardenbol, J., Vail, P.R., 1987. Chronology of fluctuating sea levels since the Triassic (250 million years ago to present). Science 235, 1156–1166.

Haq, B.U., Hardenbol, J., Vail, P.R., 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. Society of Economic Paleontologists and Mineralogists 42, 71–108.

Hays, J.D., Pitman, W.C., 1973. Lithospheric plate motion, sea level changes and climatic and ecological consequences. Nature 246, 18–22.

Homovc, J., Constantini, L., 2001. Hydrocarbon exploration potential within intraplate shear related depocenters: Deseado and San Julián basins, southern Argentina. American Association of Petroleum Geologists Bulletin 85 (10), 1795–1816.

Jia-yu, R., Johnson, M.E., 1996. A stepped karst unconformity as an Early Silurian rocky shoreline in Guizhou Province (South China). Palaeogeography, Palaeoclimatology, Palaeoecology 121, 115–129. https://doi.org/10.1016/0031-0182(95)00082-8.

Johnson, M.E., 1988a. Why are ancient rocky shores so uncommon? Journal of Geology 96, 469–480.

Johnson, M.E., 1988b. Hunting for ancient rocky shores. Journal of Geological Education 36, 147–154.

Johnson, M.E., 1992. Ancient rocky shores: a brief history and annotated bibliography. Journal of Coastal Research 8 (4), 797–812.

Johnson, M.E., 2006. Uniformitarianism as a guide to rocky-shore ecosystems in the geological record. Canadian Journal of Earth Sciences 43, 1119–1147.

Johnson, M.E., Baarli, B.G., 1999. Diversification of rocky shore biotas thought geologic time. Geobios 32, 257–273.

Johnson, M.E., Baarli, B.G., 2012. Development of intertidal biotas through Phanerozoic time. In: Talent, J.A. (Ed.), Earth and Life; Global Biodiversity, Extinction Intervals and Biogeographic Pertubations Through Time. Springer, pp. 63–128 https://doi.org/10.1007/978-90-481-3428-1_5.

Johnson, M.E., McKerrow, W.S., 1995. The Sutton Stone - an early Jurassic rocky shore deposit in South Wales. Palaeontology 38, 529–541.

Johnson, M.E., Ledesma-Vasouez, J., Clark, H.C., Zwiebel, J.A., 1996. Coastal evolution of Late Cretaceous and Pleistocene rocky shores: Pacific rim of northern Baja California, Mexico. Geological Society of America Bulletin 108, 708–721. https://doi.org/10.1130/0016-7606(1996)108<0708:CEOLCA>2.3.CO;2.

Kaasschieter, J.P.H., 1963. Geology of the Colorado Basin. Tulsa Geological Society Digest31 pp. 177–187.

Kay, S.M., Ramos, V., Mpodozis, C., Sruoga, P., 1989. Late Paleozoic to Jurassic silicic magmatism at the Gondwana margin: analogy to the middle Proterozoic in North America? Geology 17, 324–328.

Kidwell, S.M., Brenchley, P.J., 1994. Patterns in bioclastic accumulation through the Phanerozoic: changes in input or in destruction? Geology 22 1139–11.

Kiessling, W., Flügel, E., Golonka, J., 2000. Fluctuations in the carbonate production of Phanerozoic reefs. In: Insalaco, E., Skelton, E.W., Palmer, R.J. (Eds.), Carbonate Platform Systems: Components and Interactions. Geological Society, London, Special Publicationsvol. 178, pp. 191–215.

Kiessling, W., Flügel, E., Golonka, J., 2003. Patterns of Phanerozoic carbonate platform sedimentation. Lethaia 36, 195–226. https://doi.org/10.1080/00241160310004648.

Kiessling, W., Aragón, E., Scasso, R., Aberhan, M., Kriwet, J., Medina, F., Fracchia, D., 2005. Massive corals in Paleocene siliciclastic sediments of Chubut (Argentina). Facies 51, 233–241. https://doi.org/10.1007/s10347-005-0023-3.

Labudía, C.H., Bjerg, E.A., 2001. El Grupo Los Menucos: redefinición estratigráfica del Triásico superior del Macizo Nordpatagónico. Revista de la Asociación Geológica Argentina 56, 404–407.

Lapido, O., 1981. Descripción Geológica de la Hoja 44g, Cañadón Iglesias, Provincia del Chubut. Servicio Geológico Nacional, Boletín185 pp. 1–50 (Buenos Aires).

Lapido, O., Page, R., 1979. Relaciones Estratigráficas y Estructura del Bajo de la Tierra Colorada (Provincia del Chubut). 7° Congreso Geológico Argentino1 pp. 299–313 (Buenos Aires).

Larsen, M., Piasecki, S., Surlyk, F., 2003. Stratigraphy and sedimentology of a basement-onlapping shallow marine sandstone succession, the Charcot Bugt Formation, Middle–Upper Jurassic, East Greenland. In: Ineson, J.R., Surlyk, F. (Eds.), The Jurassic of Denmark and Greenland. Geological Survey of Denmark and Greenland Bulletinvol. 1, pp. 893–930.

Legarreta, L., Uliana, M.A., 1994. Asociaciones de fósiles y hiatos en el Supracretácico Neógeno de la Patagonia: una perspectiva estratigráfico-secuencial. Ameghiniana 31, 257–281.

Legarreta, L., Uliana, M.A., Torres, M., 1990. Secuencias Deposicionales Cenozoicas de Patagonia Central: Sus Relaciones con las Asociaciones de Mamíferos Terrestres y Episodios Marinos Epicontinentales. 3° Simposio del Terciario de Chile, Actas. Sociedad Geológica de Chile, Concepción, pp. 135–176.

Lema, H., Busteros, A., Giacosa, R., Cucchi, R., 2008. Geología del Complejo Volcánico Los Menucos en el área tipo Rio Negro. Revista de la Asociación Geológica Argentina 63, 3–13.

Lewis, J.R., 1964. The Ecology of Rocky Shores. English Universities Press, London.

Lewis, J.R., 1986. Latitudinal trends in reproduction, recruitment and population characteristics of some rocky littoral molluscs and cirripedes. Hydrobiologia 142, 1–13.

Libbey, L.K., Johnson, M.E., 1997. Upper Pleistocene rocky shores and intertidal biotas at Playa La Palmita (Baja California Sur, Mexico). Journal of Coastal Research 13, 216–225.

Lovecchio, J.P., Rohais, S., Joseph, P., Bolatti, N.D., Kress, P.R., Gerster, R., Ramos, V.A., 2018. Multistage rifting evolution of the Colorado basin (offshore Argentina): evidence for extensional settings prior to the South Atlantic opening. Terra Nova 30, 359–368. https://doi.org/10.1111/ter.12351.

Lovecchio, J.P., Rohais, S., Joseph, P., Bolatti, N.D., Ramos, V.A., 2020. Mesozoic rifting evolution of SW Gondwana: a poly-phased, subduction-related, extensional history responsible for basin formation along the Argentinean Atlantic margin. Earth-Science Reviews 203, 103138. https://doi.org/10.1016/j.earscirev.2020.103138.

Machalski, M., 1998. Oyster life positions and shell beds from the Upper Jurassic of Poland. Acta Palaeontologica Polonica 43, 609–634.

Malumián, N., 1999. La sedimentación en la Patagonia Extraandina. In: Caminos, R. (Ed.), Geología Argentina. Instituto de GEOLOGÍA y Recursos Naturales, Anales29 (18), pp. 557–612.

Malumián, N., 2002. El Terciario marino: sus relaciones con el eustatismo. Geología y Recursos Naturales de Santa Cruz. I-15. Relatorio del XV Congreso Geológico Argentino, El Calafate, pp. 237–244 (Buenos Aires).

Malumián, N., Caramés, A., 1995. El daniano marino de Patagonia (Argentina): paleobiogeografía de los foraminíferos bentónicos. In: Náñez, C. (Ed.), Paleógeno de América del Sur. 3. Publicación especial de la Asociación Paleontológica Argentina, Buenos Aires, pp. 83–105.

Malumián, N., Náñez, C., 2011. The Late Cretaceous-Cenozoic transgressions in Patagonia and the Fuegian Andes: foraminifera, palaeoecology, and palaeogeography. Biological Journal of the Linnean Society 103, 269–288. https://doi.org/10.1111/j.1095-8312.2011.01649.x.

Malumián, N., Nullo, F.E., Ramos, V.A., 1983. The cretaceous of Argentina, Chile, Paraguay and Uruguay. The Phanerozoic of the World II, The Mesozoic B pp. 265–303.

Manikam, S.L., Green, A.N., Cooper, A., Deacon, G., Flemming, B., 2022. Development and preservation of transgressive sandy versus rocky shorelines: observations from the SE African shelf. Geomorphology 419, 108485. https://doi.org/10.1016/j.geomorph.2022.108485.

Márquez, M.J., Massaferro, G.I., Fernández, M.I., 2010. El volcanismo del Complejo Marifil en Arroyo Verde, vertiente suroriental del Macizo de Somún Cura, Chubut. Revista de la Asociación Geológica Argentina 66 (3), 314–324.

Martínez, H., Náñez, C., Lizuain, A., Dal Molin, C., Turel, A., 2001. Hoja Geológica 4166-II, San Antonio Oeste. Provincia de Río Negro. Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino. Boletín254 (32 pp.).

Martínez, S., del Río, C.L., Concheyro, A., 2011. Danian (Early Paleocene) Echinoids From the Roca Formation, northern Patagonia, Argentina. N. lb. Oeol. Paliiont. Abh261 pp. 165–176.

Matheos, S., Tunik, M.A., 1998. Rasgos Diagenéticos en Calizas del Maastrichtiano-Daniano, Noreste del Macizo Nordpatagónico, Provincia de Río Negro. VII Reunión Argentina de Sedimentología pp. 88–89 (Salta).

Matheos, S.D., Brea, M., Lourenco, F., Beilinson, E., 2003. Composition and Diagenesis of Limestones From Salamanca Formation, Lower Tertiary, Southeast of Patagonia, Argentina. 3rd Latin-American Congress of Sedimentology, Abstracts41 (Belem, Brazil).

McAfee, D., O'Connor, W.A., Bishop, M.J., 2017. Fast-growing oysters show reduced capacity to provide a thermal refuge to intertidal biodiversity at high temperatures. Journal of Animal Ecology 86, 1352–1362. https://doi.org/10.1111/1365-2656.12757.

McAfee, D., Bishop, M.J., Williams, G.A., 2022. Temperature-buffering by oyster habitat provides temporal stability for rocky shore communities. Marine Environmental Research 173, 105536. https://doi.org/10.1016/j.marenvres.2021.105536.

Méndez, I.A., 1966. Foraminíferos, edad y correlación estratigráfica del Salamanquense de Punta Peligro (45° 30′; 67° 11′) Provincia del Chubut. Revista de la Asociación Geológica Argentina 21 (2), 127–157.

Michel, J., Borgomano, J., Reijmer, J.J.G., 2018. Heterozoan carbonates: when, where and why? A synthesis on parameters controlling carbonate production and occurrences. Earth-Science Reviews 182, 50–67. https://doi.org/10.1016/j.earscirev.2018.05.003.

Michel, J., Laugié, M., Pohl, A., Lanteaume, C., Masse, J.-P., Donnadieu, Y., Borgomano, J., 2019. Marine carbonate factories: a global model of carbonate platform distribution. International Journal of Earth Sciences 108, 1773–1792. https://doi.org/10.1007/s00531-019-01742-6.

Miller, K.G., Kominz, M.A., Browning, J.V., Wright, J.D., Mountain, G.S., Katz, M.E., Sugarman, P.J., Cramer, B.S., Christie-Blick, N., Pekar, S.F., 2005. The Phanerozoic Record of Global Sea-Level Change. Science 310, 1293–1298. https://doi.org/10.1126/science.1116412.

Moura, D., Albardeiro, L., Veiga-Pires, C., Boski, T., Tigano, E., 2006. Morphological features and processes in the Central Algarve rocky coast (South Portugal). Geomorphology 81, 345–360. https://doi.org/10.1016/j.geomorph.2006.04.014.

Müller, R.D., Sdrolias, M., Gaina, C., Steinberger, B., Heine, C., 2008. Long-term sea-level fluctuations driven by ocean basin dynamics. Science 319 (5868), 1357–1362. https://doi.org/10.1126/science.1151540.

Müller, R.D., Hassan, R., Gurnis, M., Flament, N., Williams, S.E., 2018. Dynamic topography of passive continental margins and their hinterlands since the Cretaceous. Gondwana Research 53, 225–251. https://doi.org/10.1016/j.gr.2017.04.028.

Náñez, C., Malumián, N., 2008. Paleobiogeografía y paleogeografía del Maastrichtiano marino de Patagonia, Tierra del Fuego y de la Plataforma Continental Argentina basada en foraminíferos bentónicos. Revista Espanola de Paleontologia 23, 273–300.

Navarrete, C., 2021. The volcanism of the Jurassic Chon Aike Silicic LIP influenced by Paleozoic inherited crustal structures in the northeastern Deseado Massif, Patagonia. Journal of South American Earth Sciences 112, 103611. https://doi.org/10.1016/j.jsames.2021.103611.

Navarrete, C., Hurley, M., Butler, K., Liendo, I., Litvak, V., Folguera, A., 2021. Jurassic volcanism of the Chon Aike Silicic LIP in the northeastern Deseado Massif. Journal of South American Earth Sciences 107, 102886. https://doi.org/10.1016/j.jsames.2020.102886.

Newell, R.I., 1988. Ecological Changes in Chesapeake Bay: Are They the Result of Overharvesting the American Oyster, Crassostrea Virginica. Understanding the Estuary: Advances in Chesapeake Bay Research129. Chesapeake Research Consortium Publication, pp. 536–546.

Nyberg, B., Howell, J., 2016. Global distribution of modern shallow marine shorelines. Implications for exploration and reservoir analogue studies. Marine and Petroleum Geology 71, 83–104. https://doi.org/10.1016/j.marpetgeo.2015.11.025.

Padilla, D.K., 2010. Context-dependent impacts of a non-native ecosystem engineer, the Pacific oyster Crassostrea gigas. Integrative and Comparative Biology 50 (2), 213–225. https://doi.org/10.1093/icb/icq080.

Paine, R.T., 1994. Marine rocky shores and community ecology: an experimentalist's perspective. In: Kinne, O. (Ed.), Excellence in Ecology. Ecology Institute, Oldendorf/Luhe, Germany, p. 152.

Palamarczuk, S., Habib, D., Olsson, R.K., Hemming, S., 2002. The Cretaceous-Paleogene Boundary in Argentina: New Evidence From Dinoflagellate, Foraminiferal and Radiometric Dating. Geological Society of America. Abstracts p. 34.

Pankhurst, R., Leat, P., Sruoga, P., Rapela, C., Márquez, M., Storey, B., Riley, T., 1998. The Chon Aike province of Patagonia and related rocks in West Antarctica: a silicic large igneous province. Journal of Volcanology and Geothermal Research 81, 113–136. https://doi.org/10.1016/S0377-0273(97)00070-X.

Panza, J.L., Sacomani, L.E., Parisi, C., Rodríguez, M.F., Aragón, E., 2002. Hoja Geológica 4366-27, Campamento Villegas, Provincia del Chubut. Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino. Boletín330 (156 pp.).

Parma, S.G., 1989. Los Primeros Cassidulidae (Echinodermata: Cassiduloida) de la Formacion Roca (Paleoceno), Casa de Piedra (Límite Entre las Provincias de Rio Negro y La Pampa), Rep. Argentina. IV Congreso Argentino de Paleontologiá y Bioestratigrafia4. Actas, Mendoza, pp. 93–98.

Parma, S.G., Casadío, S., 2005. Upper Cretaceous-Paleocene echinoids from northern Patagonia, Argentina. Journal of Paleontology 79, 1072–1087. https://doi.org/10.1666/0022-3360(2005)079[1072:UCEFNP]2.0.CO;2.

Parras, A., Casadío, A., 2006. The oyster Crassostrea? Hatchery (Ortmann, 1897), a physical ecosystem engineer from the upper Oligocene-lower Miocene of Patagonia, Southern Argentina. Palaios 21, 168–186. https://doi.org/10.2110/palo.2005.p05-48.

Petersen, C.S., 1946. Estudios Geológicos en la Región del río Chubut Medio. Boletín de la Dirección General de Minas y Geología59 pp. 1–137.

Pineda-Salgado, G., Quiroz-Barroso, S.A., Sour-Tovar, F., 2015. Analysis of bioerosion in clasts from a Miocene rocky-shore, Concepción Formation, Veracruz, México. Palaeogeography, Palaeoclimatology, Palaeoecology 439, 50–62. https://doi.org/10.1016/j.palaeo.2015.06.010.

Puig López, J.M., Howell, J., Roetzel, R., Poyatos-Moré, M., 2023. Transgressive rocky coasts in the geological record: Insights from Miocene granitic rocky shorelines and modern examples. Sedimentary Geology 446, 106344. https://doi.org/10.1016/j.sedgeo.2023.106344.

Ravazzoli, I.A., 1982. Descripción Geológica de la Hoja 40 h, Cerro Corona. Provincia de Río Negro. Carta Geológico-Económica de la República Argentina. Escala 1:200.000. Boletín190. Servicio Geológico Nacional, Buenos Aires (39 pp.).

Reijmer, J.J.G., 2021. Marine carbonate factories: review and update. Sedimentology 68, 1729–1796. https://doi.org/10.1111/sed.12878.

Reise, K., 2001. Ecological Comparisons of Sedimentary Shores. Ecological Studies15. Springer-Verlag, Berlin Heidelberg (344 pp.).

Rilov, G., David, N., Guy-Haima, T., Golomba, D., Arav, R., Filin, S., 2021. Sea level rise can severely reduce biodiversity and community net production on rocky shores. Science of the Total Environment 791, 148377. https://doi.org/10.1016/j.scitotenv.2021.148377.

Rodríguez, M.F., 1990. Bioestratigrafía de los Sedimentos Terciarios Aflorantes en la Región de Sierra Grande, Provincia de Río Negro. Tesis de Licenciatura. Universidad Nacional de Buenos Aires (inédito) (85 pp.).

Sachse, V.F., Strozyk, F., Anka, Z., Rodriguez, J.F., di Primio, R., 2016. The tectono-stratigraphic evolution of the Austral Basin and adjacent areas against the background of Andean tectonics, southern Argentina, South America. Basin Research 28, 462–482. https://doi.org/10.1111/bre.12118.

Sacomani, L., Panza, J., Parisi, C., Pezzuchi, H., 2007. Hoja Geológica 4366-III (Las Plumas), Provincia del Chubut. Servicio Geológico Minero Argentino, Boletín291 (74 pp., Buenos Aires).

Sanders, D., 1998. Tectonically controlled Late Cretaceous terrestrial to neritic deposition, Gosau Group, Northern Calcareous Alps (Tyrol, Austria). Facies 39, 139–178. https://doi.org/10.1007/BF02537015.

Sanders, D., Keller, G., Schlagintweit, F., Studeny, M., 2019. Cretaceous-Paleocene transition along a rocky carbonate shore: implications for the Cretaceous-Paleocene boundary event in shallow platform environments and correlation to the deep sea. In: Adatte, T., Bond, D.P.G., Keller, G. (Eds.), Mass Extinctions, Volcanism, and Impacts: New Developments. Geological Society of America Special Papervol. 544, pp. 137–163. https://doi.org/10.1130/2019.2544(06).

Santos, A., Mayoral, E., Bromley, R.G., 2011. Bioerosive structures from Miocene marine mobile-substrate communities in southern Spain, and description of a new sponge boring. Palaeontology 54, 535–545. https://doi.org/10.1111/j.1475-4983.2011.01040.x.

Scasso, R.A., Aberhan, M., Rui, L., Weidemeyer, S., Medina, F.A., Kiessling, W., 2012. Integrated bio-and lithofacies analysis of coarse-grained, tide-dominated deltaic environments across the Cretaceous/Paleogene boundary in Patagonia, Argentina. Cretaceous Research 36, 37–57. https://doi.org/10.1016/j.cretres.2012.02.002.

Schlager, W., 2000. Sedimentation rates and growth potential of tropical, cool-water and mud-mound carbonate systems. In: Insalaco, E., Skelton, P., Palmer, T.J. (Eds.), Carbonate Platform Systems: Components and Interactions. vol. 178. Geological Society of London, London, pp. 217–227. https://doi.org/10.1144/GSL.SP.2000.178.01.14.

Schlager, W., 2003. Benthic carbonate factories of the Phanerozoic. International Journal of Earth Sciences 92, 445–464. https://doi.org/10.1007/s00531-003-0327-x.

Schrøder, A.E., Sørensen, A.M., Surlyk, F., 2019. Morphological adaptations of the brachiopods from a Late Cretaceous rocky shore, Ivö Klack, southern Sweden. Palaeogeography, Palaeoclimatology, Palaeoecology 514, 785–799. https://doi.org/10.1016/j.palaeo.2018.09.019.

Sciutto, J.C., Césari, O., Escribano, V., Pezucchi, H., 2000. Hoja Geológica 4566-III, Comodoro Rivadavia, provincia del Chubut. Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino, Boletín351 (60 pp.).

Seilacher, A., Matyja, B.A., Wierzbowski, A., 1985. Oyster beds: morphologic response to changing substrate conditions. In: Bayerand, U., Seilacher, A. (Eds.), Sedimentary and Evolutionary Cycles. Springer-Verlag, Berlin, pp. 412–435.

Semeniuk, V., Johnson, D.P., 1985. Modern and Pleistocene rocky shore sequences along carbonate coastlines, Southwestern Australia. Sedimentary Geology 44, 225–261. https://doi.org/10.1016/0037-0738(85)90015-6.

Sepúlveda, E.G., 1983. Descripción Geológica de la Hoja 38 i, Gran Bajo del Gualicho. Provincia de Río Negro. Carta Geológico-Económica de la República Argentina. Escala 1:200.000. Boletín194. Servicio Geológico Nacional, Buenos Aires (64 pp.).

Shepard, T.H., 2006. Sequence architecture of ancient rocky shorelines and their response to sea-level change: an Early Jurassic example from South Wales, UK. Journal of the Geological Society, London 163, 595–606. https://doi.org/10.1144/0016-764920-015.

Simeoni, M., 2014. Nannofossils and foraminifera from the Salamanca Formation (Paleocene) in Punta Peligro Norte (Chubut, Argentina). Carnets de Géologie Notebooks on Geology 14, 343–349.

Simpson, G.G., 1941. The Eogene of Patagonia. American Museum Novitates 1120, 1–15 (New York).

Smith, A.G., Smith, D.G., Funnell, B.M., 1994. Atlas of Mesozoic and Cenozoic Coastlines. University of Cambridge Press, Cambridge, UK. Cambridge University Press, Cambridge (99 pp.).

Sørensen, A.M., Surlyk, F., 2008. A brachiopod boring (*Podichnus*) in a Late Cretaceous oyster from a mangrove-like environment. 41. Lethaia, Skåne, Sweden, pp. 295–298.

Sørensen, A.M., Surlyk, F., 2010. Palaeoecology of tube-dwelling polychaetes on a Late Cretaceous rocky shore, Ivö Klack (Skåne, southern Sweden). Cretaceous Research 31, 553–566. https://doi.org/10.1016/j.cretres.2010.07.005.

Sørensen, A.M., Surlyk, F., 2011. Taphonomy and palaeoecology of the gastropod fauna from a Late Cretaceous rocky shore, Sweden. Cretaceous Research 32, 472–479. https://doi.org/10.1016/j.cretres.2011.03.003.

Sørensen, A.M., Surlyk, F., 2013. Mollusc life and death assemblages on a tropical rocky shore as proxies for the taphonomic loss in a fossil counterpart. Palaeogeography, Palaeoclimatology, Palaeoecology 377, 1–12. https://doi.org/10.1016/j.palaeo.2013.02.024.

Sørensen, A.M., Surlyk, F., 2015. Rocky shore taphonomy - A comparative study of modern and Late Cretaceous analogues. Palaeogeography, Palaeoclimatology, Palaeoecology 423, 44–52. https://doi.org/10.1016/j.palaeo.2015.01.026.

Sørensen, A.M., Floris, S., Surlyk, F., 2011. Late Cretaceous scleractinian corals from the rocky shore of Ivö Klack, southern Sweden, including some of the northernmost zooxanthellate corals. Cretaceous Research 32, 259–263. https://doi.org/10.1016/j.cretres.2010.12.005.

Sørensen, A.M., Surlyk, F., Jagt, J.W.M., 2012. Adaptive morphologies and guild structure in a high-diversity bivalve fauna from an early Campanian rocky shore, Ivö Klack (Sweden). Cretaceous Research 33, 21–41. https://doi.org/10.1016/j.cretres.2011.07.004.

Spalletti, L., Matheos, S., Merodio, J., 1993. Sedimentitas carbonáticas Cretácico-Terciarias de la Plataforma Norpatagónica. XII Congreso Geológico Argentino y II de Exploración de Hidrocarburosvol. I. Actas, Buenos Aires 249–245.

Spasojevic, S., Gurnis, M., 2012. Sea level and vertical motion of continents from dynamic earth models since the Late Cretaceous. AAPG Bulletin 96, 2037–2064. https://doi.org/10.1306/03261211121.

Spencer, T., Viles, H., 2002. Bioconstruction, bioerosion and disturbance on tropical coasts: coral reefs and rocky limestone shores. Geomorphology 48, 23–50. https://doi.org/10.1016/S0169-555X(02)00174-5.

Strazzere, L., Pavón Pivetta, C., Gregori, D.A., Benedini, L., Geraldes, M.C., Barros, M.V., 2022. The Marifil Volcanic Complex at Sierra de Pailemán: implications for the Early Jurassic magmatic evolution of the Eastern North Patagonian Region. International Geology Review 64 (6), 844–866. https://doi.org/10.1080/00206814.2021.1884996.

Surlyk, F., 1997. A cool-water carbonate ramp with bryozoan mounds: Late Cretaceous-Danian of the Danish Basin. In: James, N.P., Clarke, J.A.D. (Eds.), Cool Water Carbonates. SEPM Special Publicationvol. 56, pp. 293–307. https://doi.org/10.2110/pec.97.56.0293.

Surlyk, F., Christensen, W.K., 1974. Epifaunal zonation on an Upper Cretaceous rocky coast. Geology 2, 529–534. https://doi.org/10.1130/0091-7613(1974)2<529:EZOAUC>2.0.CO;2.

Surlyk, F., Sørensen, A.M., 2010. An early Campanian rocky shore at Ivö Klack, southern Sweden. Cretaceous Research 31, 567–576. https://doi.org/10.1016/j.cretres.2010.07.006.

Sylwan, C.A., 2001. Geology of the Golfo San Jorge basin, Argentina. Journal of Iberian Geology 27, 123–157.

Taylor, P.D., Wilson, M.A., 2003. Palaeoecology and evolution of marine hard substrate communities. Earth-Science Reviews 62, 1–103. https://doi.org/10.1016/S0012-8252(02)00131-9.

Tunik, M.A., Concheyro, A., Ottone, E.G., Aguirre-Urreta, B., 2004. Paleontología de la Formación Saldeño (Maastrichtiano), Alta Cordillera de Mendoza, Argentina. Ameghiniana 41 (2), 143–160.

Uliana, A., Biddle, K.T., 1988. Mesozoic-Cenozoic paleogeographic and geodynamic evolution of southern South America. Revista Brasileira de Geociencias 18 (2), 172–190.

Uliana, M.A., Biddle, K.T., Cerdan, J., 1990. Mesozoic extension and the formation of Argentine sedimentary basins. In: Tankard, A.J., Blackwill, H.R. (Eds.), Extensional Tectonics and Stratigraphy of the North Atlantic Margins. American Association of Petroleum Geologist, Memoirvol. 46, pp. 599–614. https://doi.org/10.1306/M46497C39.

Vail, P.R., Mitchum Jr., R.M., Thompson III, S., 1977. Seismic stratigraphy and global changes of sea level, part 3: relative changes of sea level from coastal onlap. In: Payton, C.E. (Ed.), Seismic Stratigraphy - Applications to Hydrocarbon Exploration. Memoir. vol. 26. American Association of Petroleum Geologists, pp. 63–81. https://doi.org/10.1306/M26490C5.

Vellekoop, J., Holwerda, F., Prámparo, M.B., Willmott, V., Schouten, S., Cúneo, N.R., Scasso, R.A., Brinkhuis, H., 2017. Climate and sea-level changes across a shallow marine

Cretaceous-Palaeogene boundary succession in Patagonia, Argentina. Palaeontology 60, 519–534. https://doi.org/10.1111/pala.12297.

von Ihering, H., 1903. Les mollusques des terrains crétaciques supérieurs de l'argentine orientale. Anales del Museo Nacional de Buenos Aires, serie 3 9 (2), 193–229.

Webb, G.E., 1994. Paleokarst, paleosol, and rocky-shore deposits at the Mississippian-Pennsylvanian unconformity, northwestern Arkansas. Geological Society of America Bulletin 106 (5), 634–648. https://doi.org/10.1130/0016-7606(1994)106<0634:PPARSD>2.3.CO;2.

Weber, E.I., 1983. Descripción Geológica de la Hoja 40 j, Cerro el Fuerte, Provincia de Río Negro. Carta Geológico-Económica de la República Argentina. Escala 1:200.000. Boletín196. Servicio Geológico Nacional, Buenos Aires.

Ylláñez, E., 1979. Descripción geológica de la Hoja 46f, Uzcudúm. Servicio Geólogico Nacional, provincia del Chubut. Informe inédito.

Yrigoyen, M.R., 1969. Problemas estratigráficos del Terciario de Argentina. Ameghiniana 6, 315–329.

Zítt, J., Nekvasilova, O., 1996. Epibionts, their hard-rock substrates, and phosphogenesis during the Cenomanian-Turonian boundary interval (Bohemian Cretaceous Basin, Czech Republic). Cretaceous Research 17, 715–739. https://doi.org/10.1006/cres.1996.0038.