



The Maastrichtian – Danian at General Roca (Patagonia, Argentina): a reappraisal of the chronostratigraphy and biostratigraphy of a type locality

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With 12 figures and 6 tables

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Abstract: The Late Cretaceous – Early Paleogene succession exposed in the type area of the Roca Formation (General Roca, Río Negro Province), has been sampled in detail. Analyses of the calcareous nannofossil assemblages indicate the Late Maastrichtian – Early Danian interval (CC26-NP4 zones; MARTINI 1971), which is the first proved evidence of the Late Maastrichtian in the mentioned type area. Moreover, the “Rocanense” invertebrate fauna has been placed in a high resolution biostratigraphic scheme based on the nannofossil zones, and three assemblages have been recognized.

Key words: Biostratigraphy, Roca Formation, Jagüel Formation, Late Maastrichtian, Danian, nannofossils, mollusks, echinoderms.

1. Introduction

The marine sediments of the Maastrichtian – Danian interval cover a wide area of Patagonia and yield well documented assemblages of planktic and benthic foraminifera, ostracods, palynomorphs and calcareous nannofossils, which are useful tools in dating these marine sedimentary horizons, providing information of the faunal transition and recovery after the terminal Cretaceous mass extinction event. After decades of being almost ignored, and because of the world aroused interest in the Cretaceous/Paleogene (K/Pg) boundary, the attention of many paleontologists was directed towards the Patagonian biota of this interval (BERTELS 1980 and bibliography therein; CONCHEYRO 1995; NAÑEZ & CONCHEYRO 1997, among others). However, the different criteria in defining units (bio-/chronostratigraphic vs. lithostratigraphic criteria), the still incomplete chronostratigraphic data, and the fact that

many studies focused on partial sections dated without detailed sampling, resulted in different views about age and units identity. These factors, along with the partial knowledge of accurate stratigraphic location of some invertebrate groups, have led to confuse the biochron of some species, as it happened in the type area of the Roca Formation, where some biostratigraphic conclusions dealing with decapods, oysters, echinoderms were built upon on partial data (FELDMANN et al. 1995; FELDMANN & SCHWEITZER 2006 and bibliography therein; CASADÍO 1998; PARMA & CASADÍO 2005).

The aim of this paper is to re-evaluate the age of the Jagüel and Roca formations in the type area of the latter unit considering the calcareous nannofossil content for the first time. The biostratigraphic and chronostratigraphic results will be compared with those obtained by BERTELS (1970a, 1973), who carried out the pioneer studies in this area based on foraminifera and ostracods. It will also be attempted

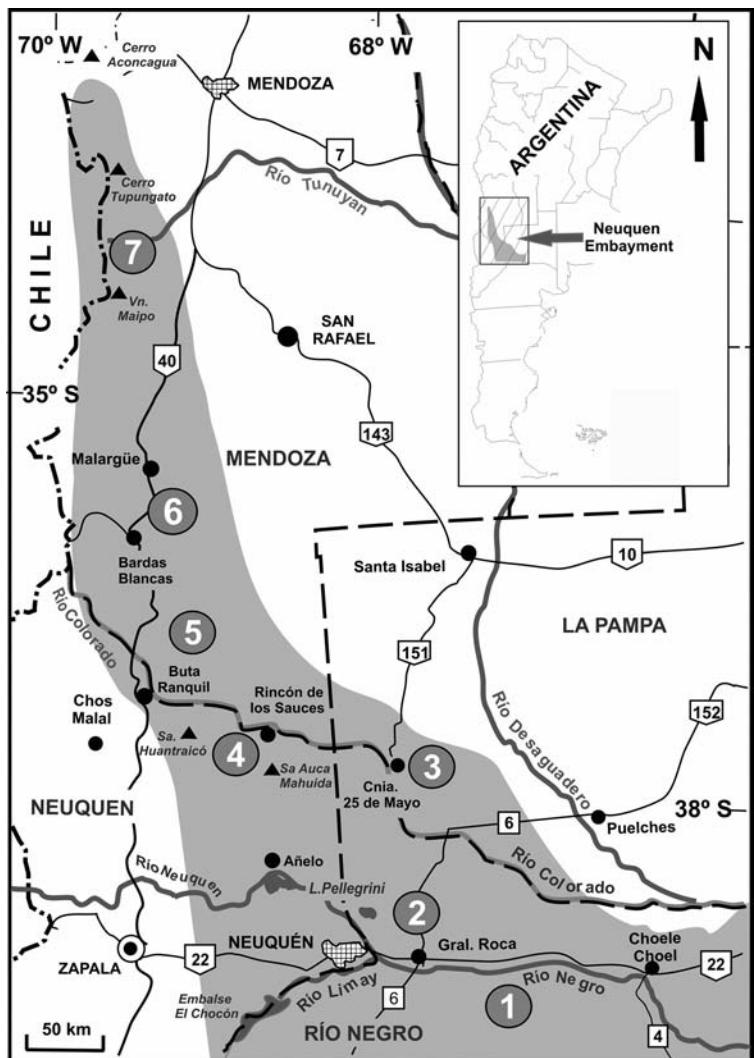


Fig. 1. Geographic location of main regions with exposures of the Maastrichtian – Danian marine sediments in the Neuquén Embayment (gray area; modified from Scasso et al. 2005) as explained in the text: 1 – Matuasto section; 2 – Lago Pellegrini - General Roca (enlargement in Figure 3); 3 – SW La Pampa Province; 4 – Sierra Huantraicó - Sierra Auca Mahuida; 5 – Lui Malal section; 6 – Malargüe-Bardas Blancas; 7 – Western Cordillera.

to provide the detailed geographic location and chronostratigraphic placement of the “Rocanense” faunas recently collected, as well as that of the material recovered previously by S. ROTH, W. SCHILLER and A. ROMERO. This contribution seeks to improve the knowledge on the age of the Maastrichtian – Danian rocks in the study area, providing new information which could be helpful in future biostratigraphic and biotic interpretations.

2. The Maastrichtian – Danian sediments in the Neuquén Embayment: A summary

Geographic distribution. – Marine sedimentary rocks deposited during Maastrichtian – Danian times are extensively distributed in Patagonia varying lithostratigraphic nomenclature in the different basins: Arroyo Barbudo and Pedro Luro formations (Colorado Basin), Lefipán and Salamanca formations (San Jorge Basin) and Cerro Cazador, Cerro Dorotea, Policarpio and Río Claro formations (Austral Basin). In the Neuquén Basin, sediments from this interval are known as Jagüel, Huantraicó, Roca, and Saldeño formations, and the uppermost part of the Loncoche Formation. After being discovered in the surroundings of the city of General Roca (Río Negro Province) by RHODE (in DÖRING 1882), subsequent authors, such as BODENBENDER (1892), GERTH (1913, 1925), WINDHAUSEN (1914), WICHMANN (1924) and WEAVER (1927, 1931), among others, expanded the area where Maastrichtian and Danian sediments were found, to the western and northern sectors of the Neuquén Embayment. Outcrops are recognized

in at least seven regions: 1 - Matuasto section; 2 - Lago Pellegrini – General Roca (Northern Río Negro Province), 3 - Southwestern La Pampa Province; 4 - Sierras de Auca Mahuida and Huantraicó (North-eastern Neuquén Province); 5 - Lui Malal section; 6 - Malargüe-Bardas Blancas; and 7 - Western Cordillera (Mendoza Province) (Fig. 1).

Sequence stratigraphy analyses involving these sediments were carried out by ULIANA (1975), ULIANA & DEL LAPÉ (1981), LEGARRETA & GULISANO (1989), LEGARRETA et al. (1989) and BARRIO (1990), who included them in the upper part of the Malargüe Group, stating that these deposits would represent the final Atlantic transgressive-regressive phase of the sea that flooded the Eastern sector of the Neuquén Basin during Late Cretaceous – Paleogene times. The regressive phase is represented by the Roca Formation WEAVER 1927, which comprises marls and bioclastic limestones with abundant skeletal fragments, and by the Jagüel Formation (BERTELS 1969a), Huantraicó Formation (BERTELS 1969a) and the uppermost part of the Loncoche Formation (GROEBER 1946), which consists of marls, mudstones, claystones and siltstones. The Roca Formation is recognized in all of the mentioned regions, whereas the Jagüel Formation is known in the Río Negro and La Pampa Provinces and in the Auca Mahuida area. The Huantraicó Formation and the marine section of the Lonconche Formation are restricted to the south of Malargüe (BERTELS 1969 a; BARRIO 1990; PARRAS et al. 1998).

Lithology. – The Roca and Jagüel formations show lithological variations depending on their palaeogeographic locations in the basin, during the Maastrichtian – Danian interval. In the case of the Jagüel Formation, variations are mostly restricted to characteristics of the carbonate deposition, which changes from mudstones and bioclastic limestone beds in the Auca Mahuida and Huantraicó areas, to an intercalation of marls and coquinas towards the Eastern sector of the embayment. In turn, variations in the Roca Formation are stronger than those recorded in the Jagüel Formation, and are related to thickness and facies changes. The thickness of carbonate deposits varies from 25 m in the eastern-most sections to 150 m in the Huantraicó area. In the surroundings of General Roca- Lago Pellegrini the outcrops are dominated by intercalations of calcareous sandstones, mudstones and limestones yielding abundant skeletal fragments with scarce matrix. Westwards, in the Huantraicó and Auca

Mahuída regions, bioclastic sedimentation is represented by bioruditic limestones, packstones and grainstones, interbedded with sandy calcarenites and calcareous mudstones (BARRIO 1990). Calcareous mudstones have lenticular geometry and represent tidal channels (LANES, pers. comm.) or bioherm bodies (LEANZA et al. 1985).

Age. – BERTELS (1964, 1968a, b, 1969a, b, 1970a, b, 1972, 1973, 1974, 1975a, b, 1980) provided the first detailed descriptions of numerous sections widespread in the Neuquén Embayment. Based on their microfaunal assemblages (foraminifera and ostracods) the Jagüel and the Huantraicó formations were distinguished from the Roca Formation. While this latter unit was placed in the Danian, the Jagüel and the Huantraicó formations were considered to be of Early? – Middle Maastrichtian age.

During the last decades the knowledge on these sedimentary deposits has been enhanced (see CAMACHO 1992 for a synthesis), many other sections were studied in the Neuquén Embayment, and new chronostratigraphic information has been provided by calcareous nannofossils. The pioneer analyses based on this group were carried out by MALUMIÁN (1969) and MALUMIÁN et al (1984) who placed the Jagüel Formation from General Roca and Allen's well in the Middle Maastrichtian. ANGELOZZI (1987) gave a Danian age to the Jagüel and Roca formations exposed in Lomas Blancas (Auca Mahuida region). A Late Maastrichtian age was first proposed by A. CONCHEYRO for the Cretaceous marine deposits in Bajada del Jagüel and Opaso sections (Auca Mahuida region) and Cerros Bayos (CASADÍO & CONCHEYRO 1992; CONCHEYRO 1995; DEL RÍO et al. 2004, 2007). CONCHEYRO & VILLA (1996) demonstrated that the Jagüel Formation exposed in the Lui Malal section is part of the Late Maastrichtian – Danian interval. Integrated studies based on foraminifera, calcareous nannofossils and palynomorphs corroborated a Late Maastrichtian - Danian age for all the sections mentioned above (CONCHEYRO & NAÑEZ 1994; NAÑEZ & CONCHEYRO 1997; PAPU et al. 1999).

More recently, the accuracy obtained near the K/Pg in the Neuquén Basin has been improved, varying the precision of sampling intervals between one meter to two centimetres, depending on rock features and location of sections in the basin. Examples of this are the Matuasto and Bajada del Jagüel sections, where the K/Pg interval has been accurately identified on the base of foraminifera and



Fig. 2. Panoramic view of exposures of the Jagüel and Roca formations to the north of General Roca.

calcareous nannofossils (CONCHEYRO et al. 2002; SCASSO et al. 2005; KELLER et al. 2007).

In reference to the age of the Roca Formation, BERTELS (1969), CONCHEYRO & VILLA (1996), NAÑEZ & CONCHEYRO (1997) and KELLER et al (2007) gave a Danian age to exposures of this unit in the Bajada del Jagüel, Huantraicó and Lui Malal localities. CASADÍO & CONCHEYRO (1992), and DEL Río et al. (2004, 2007) placed the Roca Formation of Cerros Bayos (Southwestern La Pampa Province) in the Danian. The Saldeño Formation, correlated with the Roca and Pircala formations, was placed in the Late Maastrichtian by TUNIK et al. (2004), and KIESSLING et al (2006) assigned this unit exposed in Huantraicó to the Early – Late Maastrichtian.

3. The Jagüel and Roca formations in the study area: General Roca (Río Negro Province)

Previous works. – The sedimentary sequence exposed in the yellow cliffs that run in west-east direction, and to the north of General Roca (region 2 in Fig. 1), consists of the lacustrine Allen Formation at the bottom, the marine Jagüel and Roca formations in the middle, and the lacustrine Carrizo Formation at the top (Fig. 2).

The first recognition of the fossiliferous beds of the Roca Formation was made by G. ROHDE (mentioned in DÖRING 1882), but it was ROTH (1899) who published preliminary data providing a very simple

stratigraphic regional scheme for this sequence. WINDHAUSEN (1914) was the pioneer author in describing these sediments, and SCHILLER (1922) sampled a section along the Zanjón Roca, from the city of General Roca northwards to the “Horno de Cal continuo” (Permanent lime kiln). He proposed the lime kiln as the “classic area” and considered the cliffs westwards from the lime kiln, as the “model area” of these beds (Fig. 3).

WEBER (1964) described two sections close to the “classic area” of SCHILLER (1922), naming them as NCW (Cuchillas Noroeste de Roca) and NR (Roca Norte), and BERTELS (1964, 1970) included material from a third locality (RS = Río Seco). Probably in accordance with the region proposed by SCHILLER (1922) as the “classic” area, BERTELS (1969a, 1970a), chose the NR section as the type locality of the Roca Formation (HC in Fig. 3).

According to BERTELS (1970a), the NR type section consists of 14 m of basal marls that are overlain by 22 m of intercalated marls and fossiliferous limestones that show a gradual upward increase in thickness and culminate in a hard massive limestone devoid of fossils. In the RS and NWC sections, she recognized the Roca and Jagüel formations, and distinguished them under biostratigraphic criteria only. Based on the foraminifera and ostracod content, the complete type section of the Roca Formation was placed in the Danian, and the Jagüel Formation in the Middle Maastrichtian or in the Lower? – Middle Maastrichtian (BERTELS 1964, 1970a, 1972, 1973, 1975a). BERTELS (1970a) argued that the absence

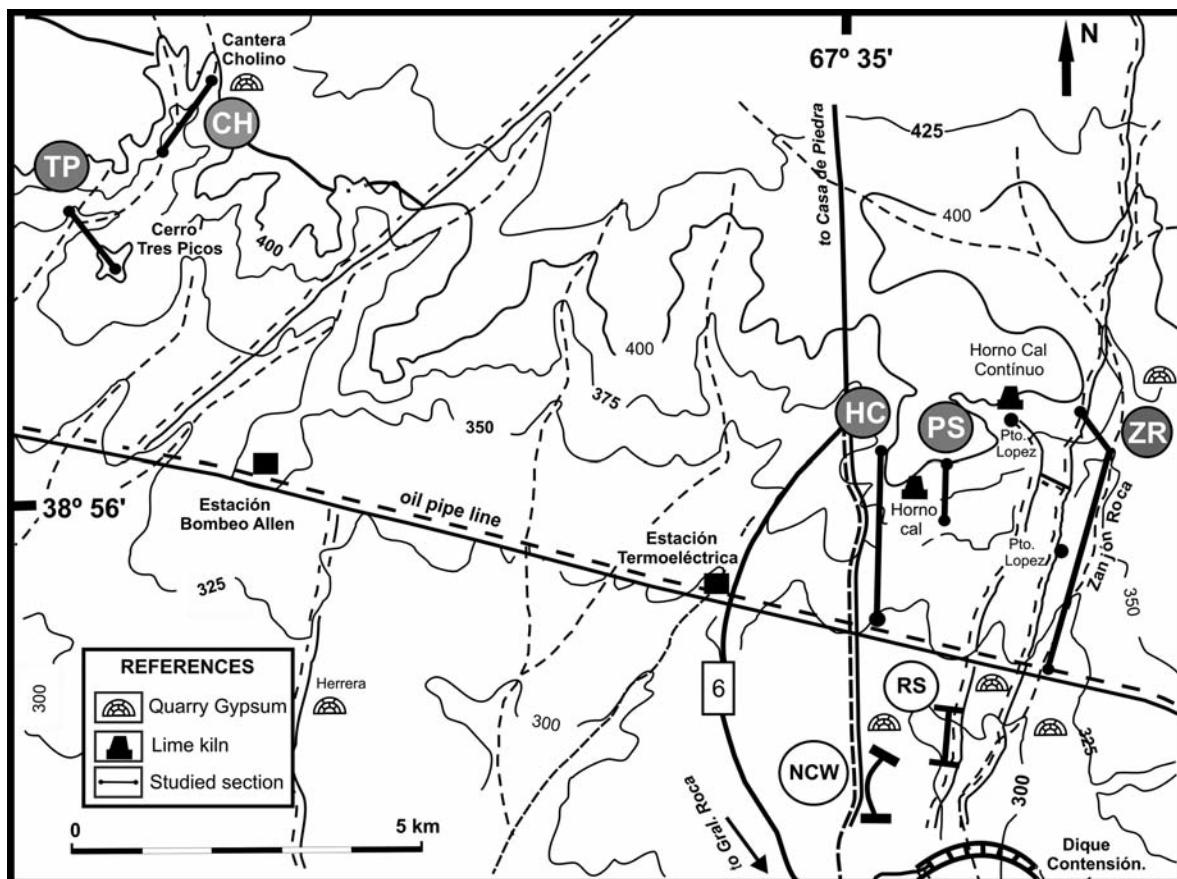


Fig. 3. Topographic map showing measured sections placed to the north of the city of General Roca (region 2 in Fig. 1). ZR = Zanjón Roca; PS = Picada Sísmica; HC = Horno de Cal (Type section of the Roca Formation = NR section of BERTELS, 1969a); CH = Cantera Cholino; TP = Cerro Tres Picos. (NCW and RS correspond to localities described by WEBER (1964) and BERTELS (1970a).

of Late Maastrichtian rocks in the area, and in the whole of the Neuquén Basin, was due to a biostratigraphic hiatus.

Later, ULIANA & DEL LAPÉ (1981) proposed a lithostratigraphic criterion to separate the Jagüel and Roca formations. In this way, they included the basal greenish calcareous muddy strata of the type section of the Roca Formation (as defined by BERTELS 1969a; 1970a) in the upper part of the Jagüel Formation, and used the first occurrence of a fossiliferous limestone to delimit the base of the Roca Formation.

The Roca Formation contains a diverse and abundant fauna of invertebrates, mainly dominated by mollusks, followed by decapods, echinoderms, bryozoans and corals. Fossils were first studied by

BURCKHARDT (1901) and OPPENHEIM (in BÖHM 1903) who described and illustrated 11 species of mollusks and two species of echinoderms. Knowledge of this fauna was substantially increased by IHERING (1902, 1903, 1904, 1907) with the description of other 28 taxa, 24 of which were new species. IHERING (1907) differentiated it from the youngest Tertiary Patagonian assemblages including it in the “Rocanense Stage”. Since then, this assemblage has been always referred to as “Rocanense fauna” in geological literature. With the exception of the description of a reduced number of species from the type area, that involve to carditids (FOSSA-MANCINI 1938), oysters (CASADÍO 1998), nautiloids (CASADÍO et al. 1999), mytilids (GRIFFIN et al. 2008) and pectinoideans (DEL RÍO et al. 2008) the “Roca-

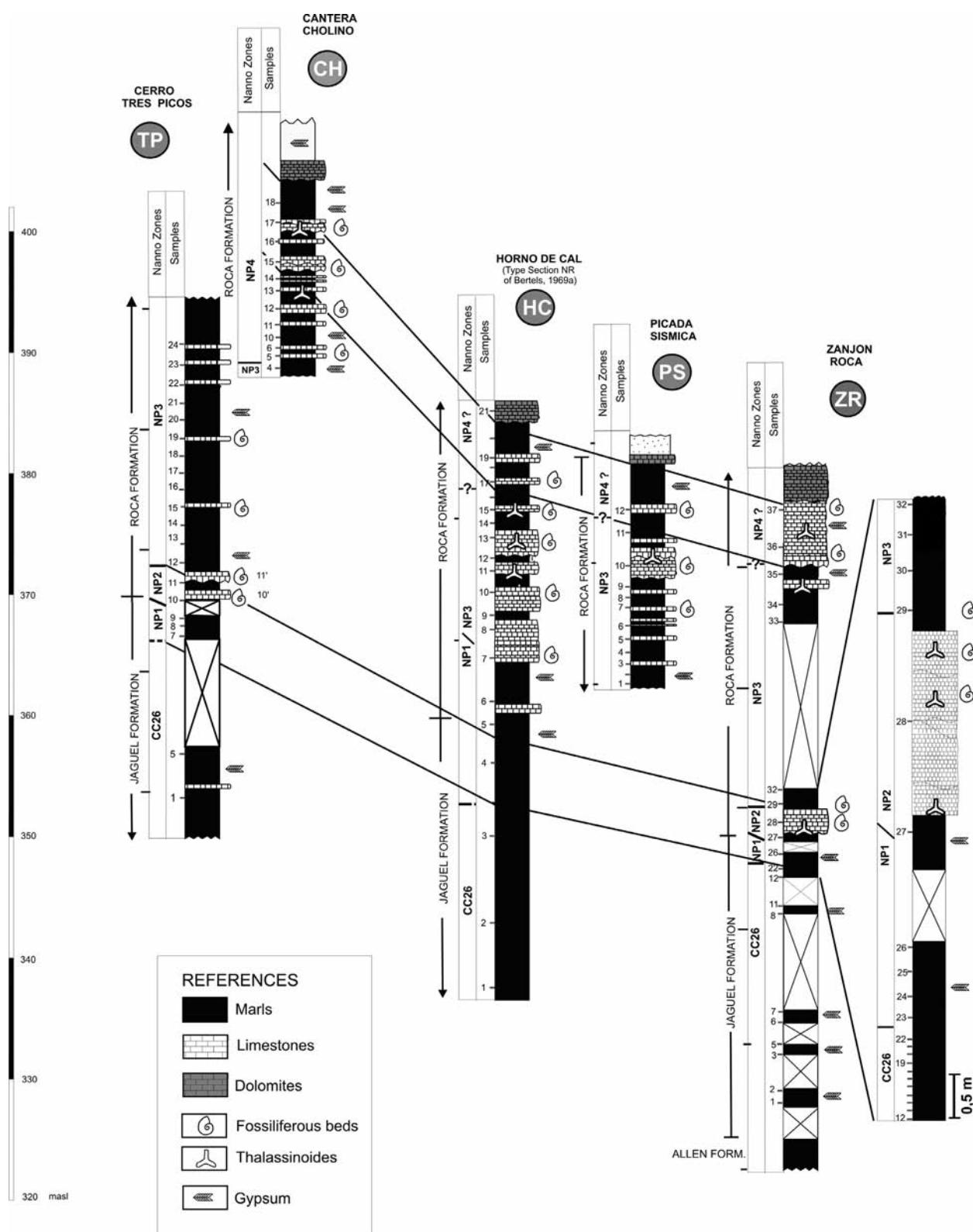


Fig. 4. Lithology and correlation of the studied sections. (NR = Roca Norte section of BERTELS (1970a); masl = meters above sea level).



Fig. 5. Maastrichtian beds of the Jagüel Formation exposed at the base of Cerro Tres Picos.

nense” fauna has remained almost unknown since IHERING’s times.

Minor groups such as decapods and echinoids also received little attention. After first mentioned by BÖHM (1901), decapods were studied by FELDMANN et al. (1995) and later revised by SCHWEITZER (2005), SCHWEITZER et al. (2000, 2004), and KARASAWA & SCHWEITZER (2004) (see FELDMANN & SCHWEITZER 2006 for the listed bibliography). Echinoids were revised by PARMA & CASADÍO (2005) who included the description of two species recorded in the type area.

4. Material and methods

Most of the exposures in the area have been highly eroded or partially destroyed by mining activity, which resulted in the mixing of fossils from different stratigraphic horizons. However, some very good exposures are located along gullies such as the Zanjón Roca or along the creek that runs from the Cantera Cholino (Cholino’s Quarry) down to the base of the Cerro Tres Picos. The type section of the Roca Formation as defined by BERTELS (1969a, 1970a) was recognized, sampled, and named HC

(Horno de Cal, $38^{\circ} 56' S - 67^{\circ} 35' W$). Moreover, four new complementary sections named Cantera Cholino ($38^{\circ} 53' S - 67^{\circ} 40' W$), Cerro Tres Picos ($38^{\circ} 54' S - 67^{\circ} 40' W$), Picada Sísmica and Zanjón Roca ($38^{\circ} 55' S - 67^{\circ} 32' W$) (CH, TP, PS and ZR acronyms respectively in Fig. 3) were measured at 1:100 scale, where samples for microfossil studies were collected, in some cases, every 10 cm interval (Fig. 4).

Calcareous nannofossils were analyzed through simple smear-slides (EDWARDS 1963; BOWN & YOUNG 1998) and standard light-microscope techniques using a Leica DMLP at 1000 X magnification. Samples were semi-quantitatively logged and slides were observed for at least 30 min, in most cases much longer, covering at least two transverse transects along the major axis of the slide. Abundance and preservation categories are given in the range charts (Tables 1-5) where species presence is indicated with an “X”. Samples for SEM observations were prepared using ultrasonic and successive decantation methods, centrifugation, and concentration in a cellulose nitrate filter. Estimation of preservation is based on the scheme of ROTH & THIERSTEIN (1972) as follows: P = poor, severe dissolution, fragmentation, and/or overgrowth have occurred; most primary features have been destroyed and many speci-

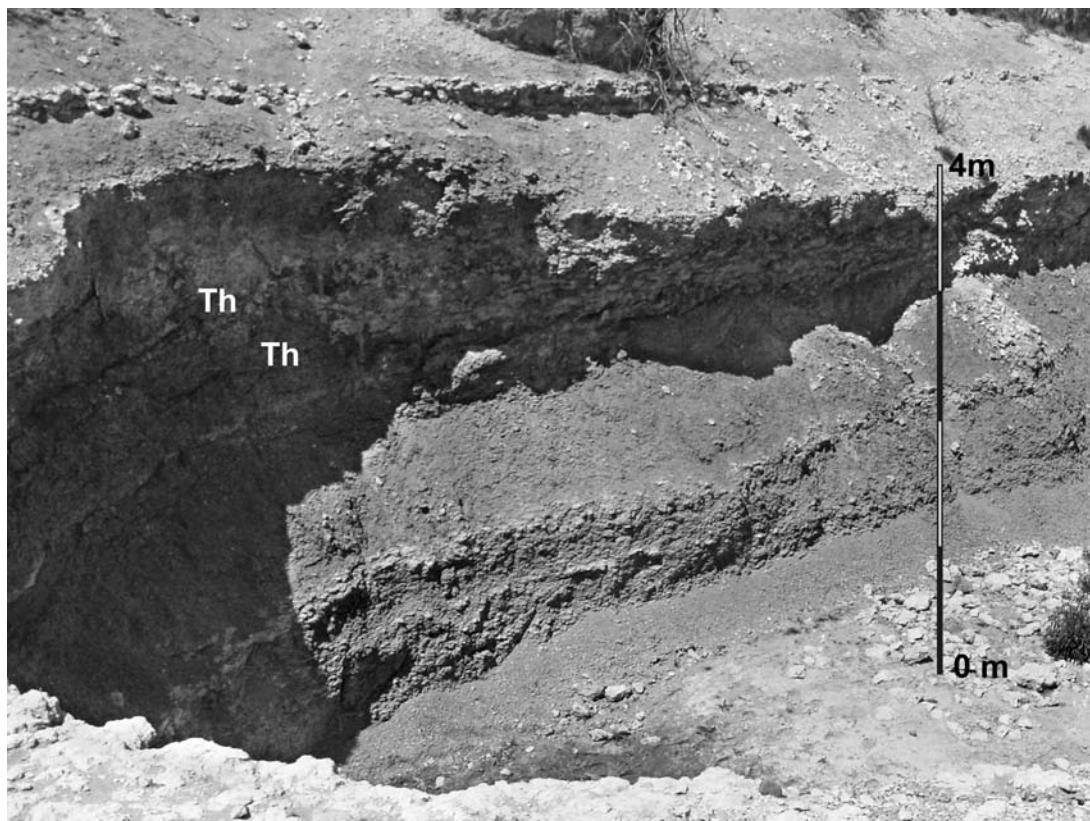


Fig. 6 – Intercalation of marlstones and shell-beds with *Thalassinoides* horizons in the uppermost section of the Roca Formation at Cantera Cholino

mens cannot be identified at the specific level; M = moderate, dissolution and/or overgrowth are evident; a significant proportion (up to 25 %) of the specimens cannot be identified to species level with absolute certainty; G = good, little dissolution and/or overgrowth is seen; diagnostic characteristics are preserved and all specimens can be identified. E = excellent, no dissolution and/or overgrowth is observed; all specimens can be identified. Taxa considered herein are listed in Appendix where they are arranged alphabetically by generic epithets.

The mollusk fauna considered in this study includes the earliest collections made in the area by S. ROTH between 1895 and 1896 and A. ROMERO, who sent his collection to the Museo Argentino de Ciencias Naturales B. RIVADAVIA (MACN) in 1903. Only a small number of specimens (mainly holotypes) described by H. v. IHERING between 1902 and 1907 were incorporated into the collections of the MACN, while the rest of the material was lost until recently identified by the curators of the Paleo-invertebrate Division. Moreover, it is considered the

Fig. 7. 1 – Panoramic view of the Maastrichtian nannoflora, **2-4** – *Eiffellithus turriseiffelii* (DEFLANDRE) REINHARDT, BAFC-NP 3047, 2. distal view partially overgrowth, 3. lateral view, **5-6** – *Eiffellithus gorkae* VEKSHINA, BAFC-NP 3047, 5. distal view, 6. proximal view, **7** – *Eiffellithus parallelus* PERCH-NIELSEN, BAFC-NP 3047, distal view. **8** – *Prediscosphaera stoveri* (PERCH-NIELSEN) SHAFIK & STRADNER, BAFC-NP 3047, proximal views, **9** – *Manivitella pemmatoidea* (DEFLANDRE) THIERSTEIN, BAFC-NP 3047, distal view, **10** – *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) GARTNER, BAFC-NP 3047, distal view, **11** – *Ahmuelllerella octoradiata* (GARTNER) REINHARDT, BAFC-NP 3047, distal view, **12** – *Watznaueria barnesiae* (BLACK) PERCH-NIELSEN, BAFC-NP 3047, distal view, **13-15** – *Arkhangelskiella cymbiformis* VEKSHINA, BAFC-NP 3047, 13. distal view, 14. proximal view, 15. distal view. The white bar indicates 2 μ m.

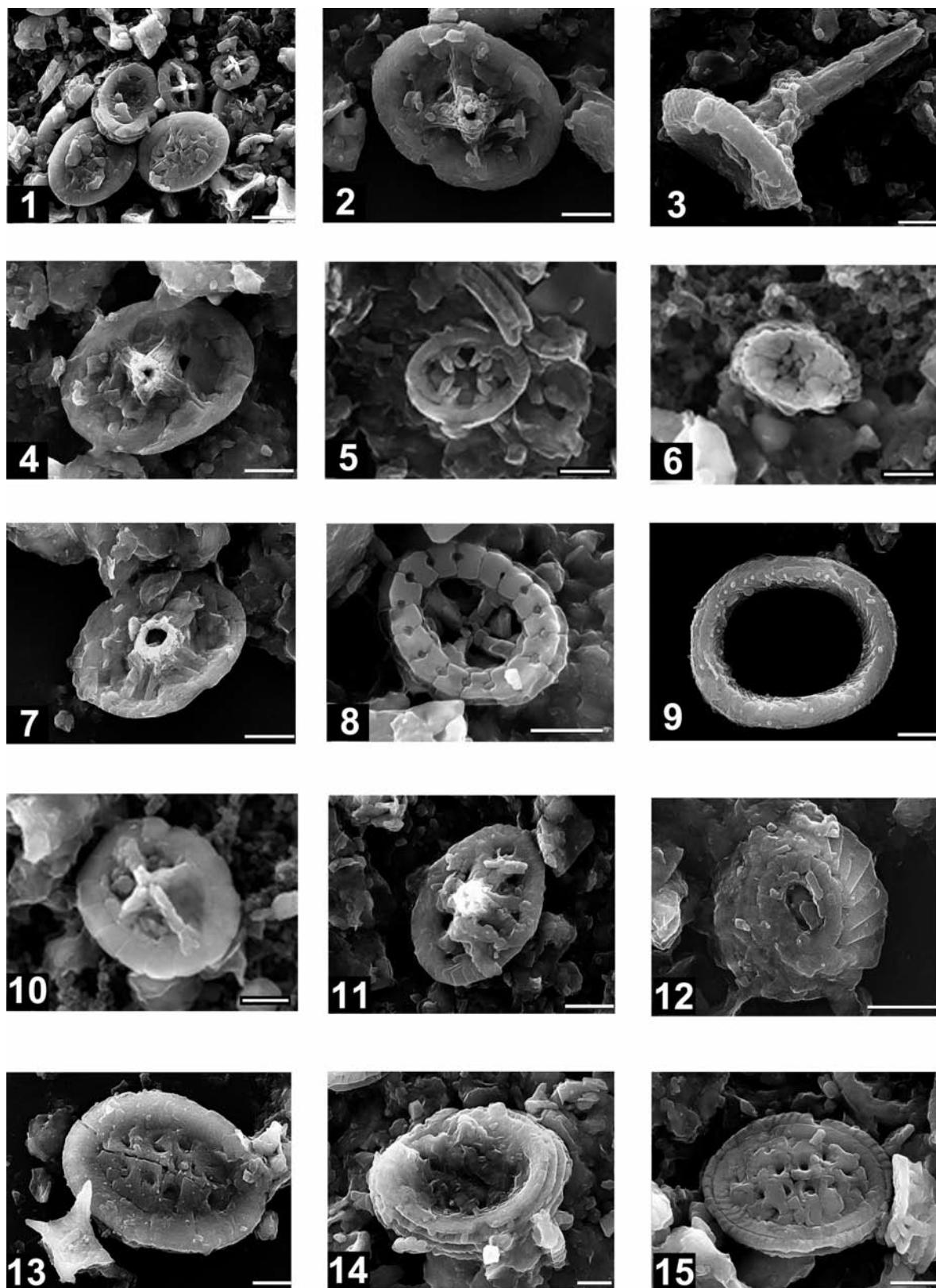


Fig. 7 (Legend see p. 136)

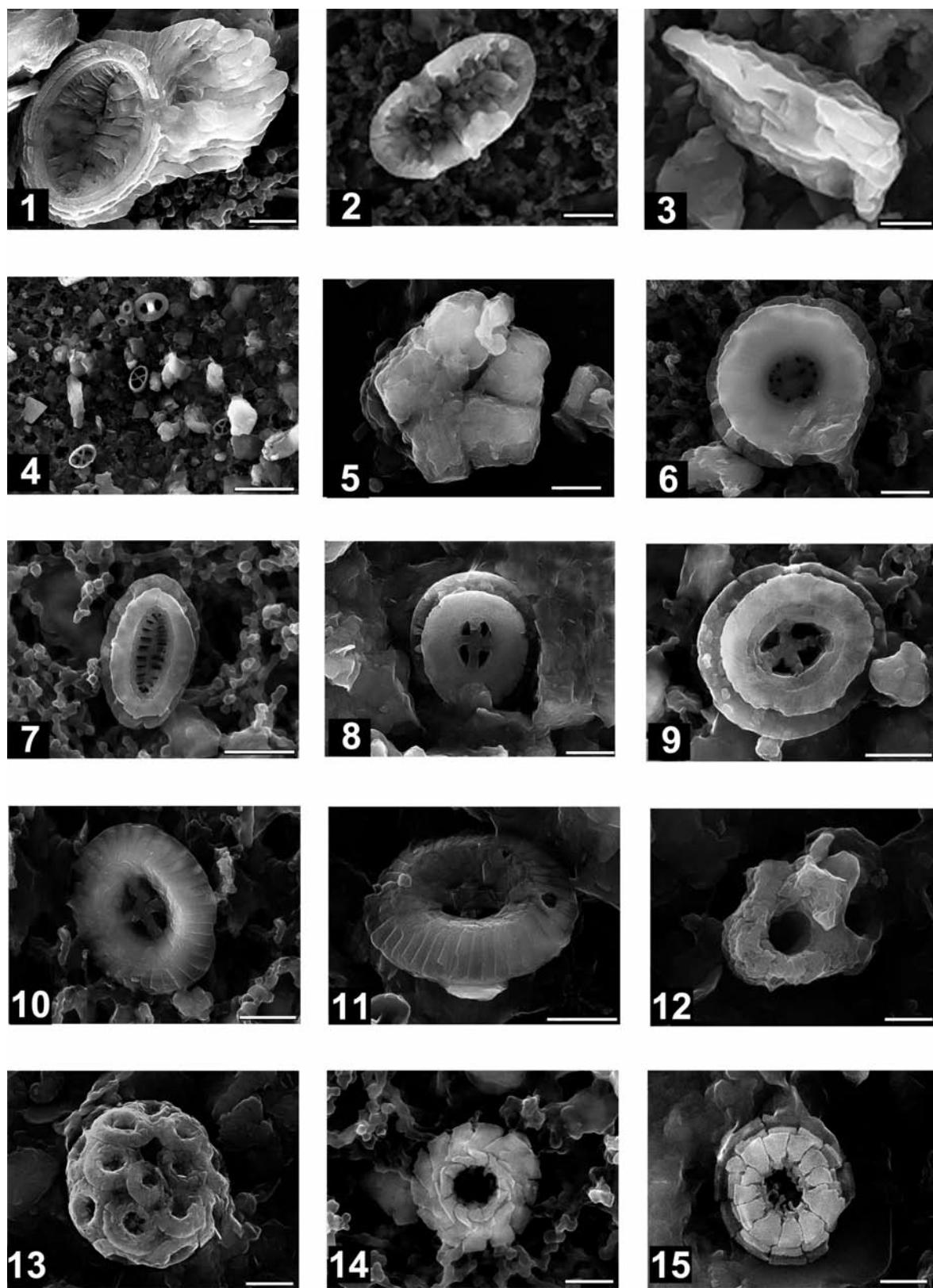


Fig. 8 (Legend see p. 139)

material recently collected by the authors, which includes the already known taxa, and new species of echinoids (holasteroids and spatangoids), bivalves (malletids, nuculanids and pterioids) and gastropods of the Families Epitonidae, Trochidae, Tediidae, Pseudolividae, Fasciolaridae, Ficidae and Tediidae.

5. Stratigraphic sections

In the present analyses the lithostratigraphic scheme proposed by ULIANA & DELLAPÉ (1981) when describing the lithology of sections is followed (Fig. 4). Both the Jagüel and the Roca formations were recognized, comprising a sedimentary sequence that dips less than 1° to the east. The Jagüel Formation is composed of a 25 m thick homogenous succession of laminated greenish to yellowish marls, interbedded with numerous thin gypsum layers and crossed by veins of secondary gypsum (Fig. 5). Fossils are restricted to scarcely spread, minute and unidentified molds of micro-mollusks and contain an abundant, rich and exceptionally well preserved nannofossil assemblage. The contact with the underlying Allen Formation is difficult to distinguish in the field because of the strong lithological similarity between both units. The base of the Jagüel Formation can only be recognized by the occurrence of the first marine microfossil assemblage. The Roca Formation consists of a basal carbonate section and of an upper section characterized by deposition of thick gypsum beds. The carbonate sector is 25-28 m thick and is composed of intercalated greenish marls, fossiliferous limestones and abundant thin gypsum layers. Marls are almost indistinguishable from those of the underlying Jagüel Formation, and usually yield rare minute molds of unidentified mollusks. The frequency of limestones intercalations shows a gradual upward increase. The lowermost coquinas are very thin (not more than 10 cm thick), massive, lenticular bodies, with planar or erosive lower contacts, that usually cannot be traced laterally for more than a few

meters. In many cases these basal coquinas cannot be recognized because they have been eroded and fossils from different stratigraphic intervals are intermixed. Nonetheless, they are very well exposed in our studied sections. An exceptional thick basal limestone is that exposed in Zanjón Roca section (sample 28 in Fig. 4) where a hard, 2.5 m thick amalgamated, lenticular and highly fossiliferous bed constitutes the base of the Roca Formation. The uppermost limestone of this carbonate section corresponds to 2 m thick, amalgamated, tabular coquinas. Together with the overlying dolomite bed, this limestone constitutes a pronounced topographic step placed around 400 m above sea level which can be observed in the area for over 50 km. This last coquina exhibits highly erosive internal surfaces and beds with *Thalassinoides* that in some cases stretch laterally for up 5 km (Fig. 6).

The described carbonate deposits are superimposed by up to 25 m thick whitish and grayish gypsum beds that constitute the top of the Roca Formation and cause the second and the uppermost topographic step of the cliffs.

6. Analysis of the calcareous nannofossils

The recovered nannoflora is one of the best preserved in Argentina and comprises two different associations of Maastrichtian and Danian ages as will be described below with special focus on some relevant taxa (Figs. 7-9; Tables 1-5).

Maastrichtian association. – The main representative species of the Maastrichtian association are *Cribrosphaerella daniae* PERCH-NIELSEN, *Cribrosphaerella ehrenbergii* (ARKHANGELSKY) DEFLANDRE in PIVETEAU, *Micula decussata* VEKSHINA, *Micula concava* (STRADNER in MARTINI & STRADNER) VERBEEK, *Lithraphidites quadratus* BRAMLETTE & MARTINI, *Nephrolithus frequens* GÓRKA, *Kamptnerius magnificus* DEFLANDRE, *Arkhangelskiella*

Fig. 8. 1 – *Kamptnerius magnificus* DEFLANDRE, BAFC-NP 3047, proximal view, **2** – *Rhagodiscus angustus* (STRADNER) REINHARDT, BAFC-NP 30474, distal view, **3** – *Acuturris scotus* (RISATTI) WIND & WISE in WISE & WIND, AFC-NP 3047, lateral view, **4** – Panoramic view of the Danian nannoflora, **5** – *Braarudosphaera bigelowi* (GRAN & BRAARUD) DEFLANDRE, BAFC-NP 3075, distal view, **6** – *Markalius inversus* (DEFLANDRE) BRAMLETTE & MARTINI, BAFC-NP 3075, proximal view, **7** – *Hornibrookina edwardsii* PERCH-NIELSEN, BAFC-NP 3075, proximal view, **8-11** – *Cruciplacolithus primus* PERCH-NIELSEN, BAFC-NP 3075, **12** – *Lanternithus duocavus* LOCKER, BAFC-NP 3075, distal view, **13-15** – *Toweius africanus* (PERCH-NIELSEN) PERCH-NIELSEN, BAFC-NP 3003. 13. coccospaere, 14. distal view, 15. proximal view. The white bar indicates 2 µm.

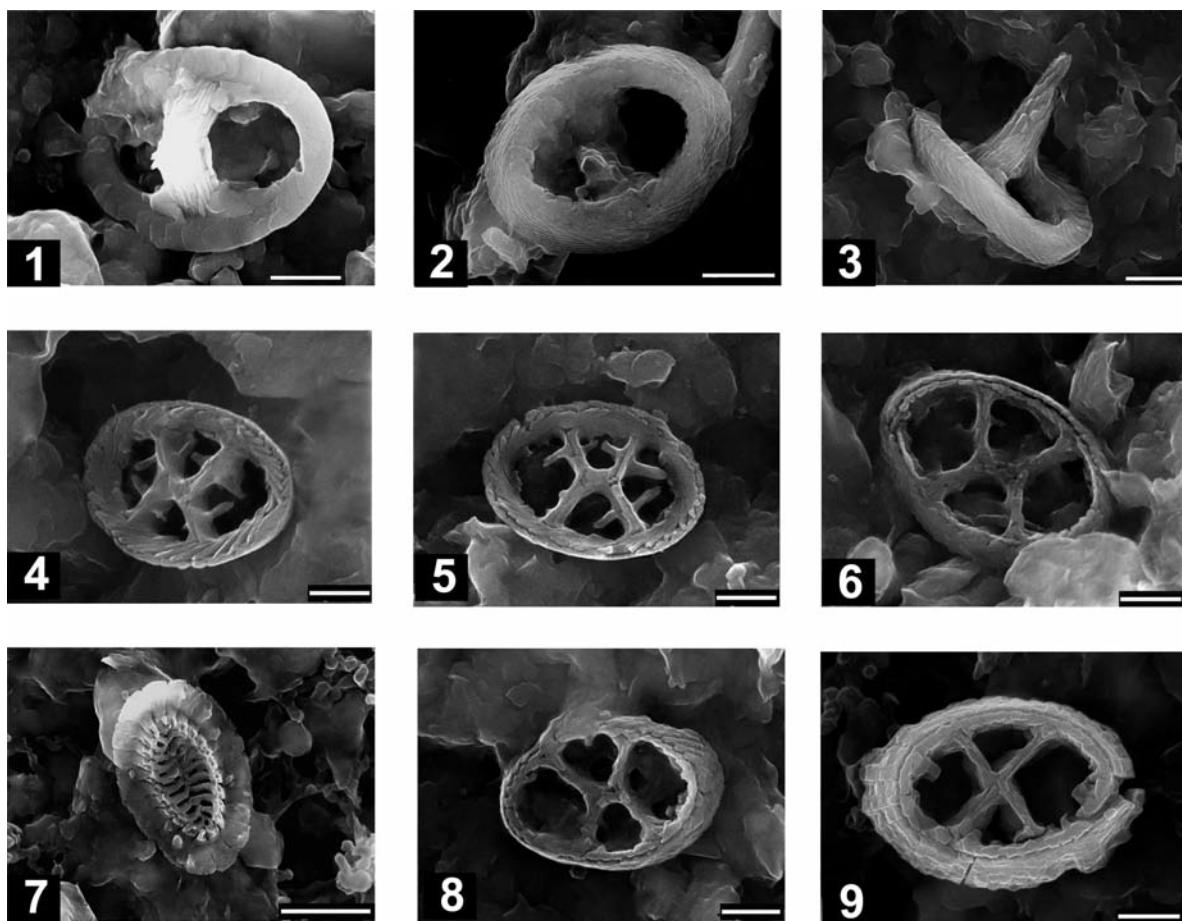


Fig. 9. 1-3 – *Placozygus sigmoides* BRAMLETTE & SULLIVAN, BAFC-NP 3003, 1. distal view, 2. proximal view, 3. lateral view, **4-5 –** *Neochiastozygus primitivus* PERCH-NIELSEN, BAFC-NP 3003, distal views, **6 –** *Neochiastozygus modestus* PERCH-NIELSEN, BAFC-NP 3003, proximal view, **7 –** *Hornibrookina teurensis* EDWARDS, BAFC-NP 3003, distal view, **8-9 –** *Neochiastozygus modestus* PERCH-NIELSEN, BAFC-NP 3003, distal views. The white bar indicates 2 µm.

cymbiformis VEKSHINA, *Ahmuellerella octoradiata* (GÓRKA) REINHARDT, *Gartnerago segmentatum* (STOVER) THIERSTEIN, *Prediscosphaera stoveri* (PERCH-NIELSEN) SHAFIK & STRADNER, *Eiffellithus turriseiffelii* (DEFLANDRE in DEFLANDRE & FERT) REINHARDT, and *Eiffellithus gorkae* REINHARDT. These taxa constitute part of a well diversified, frequent to abundant nannoflora with a moderate to good species preservation, without major overgrowth effects.

Micula decussata, *Arkhangelskiella cymbiformis* and *Eiffellithus turriseiffelii* predominate as the most frequent species in every Maastrichtian samples probably due to their high resistance to dissolution (THIERSTEIN 1980) or to palaeoecological requirements (LADNER & WISE 1999; THIBAULT & GARDIN 2006).

The presence of *Nephrolithus frequens* and *Cribrosphaerella danae* confirms a Late Maastrichtian age for the interval, particularly CC26 Zone (PERCH-NIELSEN 1985a), in agreement with the age established for the Jagüel Formation in other localities of the Neuquén Embayment (CONCHEYRO 1995, 2001; CONCHEYRO & NÁÑEZ 1994; CONCHEYRO & VILLA 1996; NÁÑEZ & CONCHEYRO 1997; PAPU et al. 1999).

Nephrolithus frequens is a taxon from cool waters with a geographic distribution that ranges from high to medium latitudes being considered an important marker for high latitudes (WIND & WISE 1976; WIND 1979). It displays a diachronous biochron in the Maastrichtian and, along with *Cribrosphaerella danae*, has been used to indicate the Late Maastrichtian in absence of other Maastrichtian markers.

With the exception of *M. decussata*, the remaining Maastrichtian species are also known as cool water taxa (THIBAULT & GARDIN 2006), and their persistence through all Maastrichtian samples reflect cool conditions or a considerable input of austral species to the Neuquén Basin, as was pointed out by CONCHEYRO & VILLA (1996) and later mentioned by CASADÍO et al (2004).

The cosmopolitan taxon *Micula decussata* is dominant in all Maastrichtian samples and many discussions have been built upon its high abundance, which could be due to differential preservation or to any particular paleoecological requirement (LADNER & WISE 1999; OVECHKINA & ALEKSSEV 2005), as it was also suggested by KELLER et al. (2007) in Barranca del Jagüel. Its high abundance could suggest low productivity and high-stress conditions close to the K/Pg boundary (THIBAULT & GARDIN 2006). This situation has been clearly observed throughout the Neuquén Basin and has also been detected in the type area of the Roca Formation, where it is commonly recorded in all samples placed immediately below the K/Pg boundary.

Danian association. – Its richness and abundance are low; the preservation varies from poor, with commonly fragmented specimens near the K/Pg boundary, to moderate and good upwards in the section. Among the most abundant and common fossils are *Biantholithus sparsus* BRAMLETTE & MARTINI, *Thoracosphaera operculata* BRAMLETTE & MARTINI, *Thoracosphaera saxeae* STRADNER, *Micrantholithus pinguis* BRAMLETTE & SULLIVAN, *Micrantholithus vesper* DEFLANDRE in DEFLANDRE & FERT, *Braarudosphaera bigelowi* (GRAN & BRAARUD) DEFLANDRE, *Markalius inversus* (DEFLANDRE in DEFLANDRE & FERT) BRAMLETTE & MARTINI, *Markalius apertus* PERCH-NIELSEN, *Cyclagelosphaera reinhardtii* (PERCH-NIELSEN) ROMEIN, *Chiastozygus ultimus* PERCH-NIELSEN, and *Neochiastozygus primitivus* PERCH-NIELSEN. Following PERCH-NIELSEN et al. (1982) and BURNETT (1998) among others, the Danian association is constituted by four different categories of nannofossils which are identified as “Cretaceous species”, “Cretaceous survivor species”, “incoming Paleogene species”, and “reworked species”.

Among the “Cretaceous species” there must be mentioned: *Nephrolithus frequens*, *Micula decussata*, *Arkhangelskiella cymbiformis*, *Cribrosphaerella daniae*, *Eiffellithus turriseiffelii*, *Watznaueria barnesiae* (BLACK) PERCH-NIELSEN, *Watznaueria*

ovata BUKRY, and *Cyclagelosphaera margerelii* NÖEL which remain as rare taxa in almost all Danian samples, and show a general trend of decreasing abundance.

The “Cretaceous survivor species” such as *Placozygus sigmoides* (BRAMLETTE & SULLIVAN) ROMEIN, *Micrantholithus pinguis* BRAMLETTE & SULLIVAN, *Micrantholithus vesper*, *Braarudosphaera bigelowi*, *Thoracosphaera operculata* and *Thoracosphaera saxeae* have a bloom at the base of the Danian allowing them to be considered in the literature as one of the earliest Danian associations (BURNETT 1998; MAI et al. 1994; KELLER et al. 2007). *Braarudosphaera bigelowi* has been considered as an opportunistic species (KONNO et al. 2007) and its presence in the study area constituting real chalks confirms that hypothesis. Moreover, its physical association in the chalks with *M. pinguis* and *M. vesper* led us to the conclusion that these pentalithids should have had the same behaviour. Thoracosphaerids and pentalithids blooms are mentioned in the literature for the Early Danian and the species *Thoracosphaera saxeae*, *T. operculata* (both consistently present in the complete Danian sequence in the studied area) along with *Micrantholithus pinguis*, *Micrantholithus vesper*, and *Braarudosphaera bigelowi* confirm the K/Pg transition in many regions (JIANG & GARTNER 1986; PERCH-NIELSEN 1985b; POSPICHAL & WISE 1990; ROMEIN et al. 1996; GARDIN 2002), being all of them characteristic inhabitants of shallow waters.

The “Incoming Paleogene species” are characterized by the common presence of *Biantholithus sparsus* BRAMLETTE & MARTINI, *Hornbrookina edwardsii* PERCH-NIELSEN, *Hornbrookina teuriensis* EDWARDS, *Cruciplacolithus primus* PERCH-NIELSEN, *Cruciplacolithus tenuis* (STRADNER) HAY & MOHLER, and *Chiasmolithus danicus* (BROTZEN) HAY & MOHLER, a clear Danian marker (PERCH-NIELSEN 1985b; VAROL 1998). *Hornbrookina edwardsii* is common to abundant in many samples and it has been mentioned as a basal Danian species and *Hornbrookina teuriensis*, a taxon larger than *H. edwardsii* is usually well preserved, being a frequent to abundant species in the uppermost part of the measured sections. Small specimens of *Cruciplacolithus primus* have been identified in most Danian samples throughout the studied area and its first common occurrence confirms the base of the Danian. However, MAI et al. (2003) mentioned its first occurrence just in the Late Maastrichtian, where it is

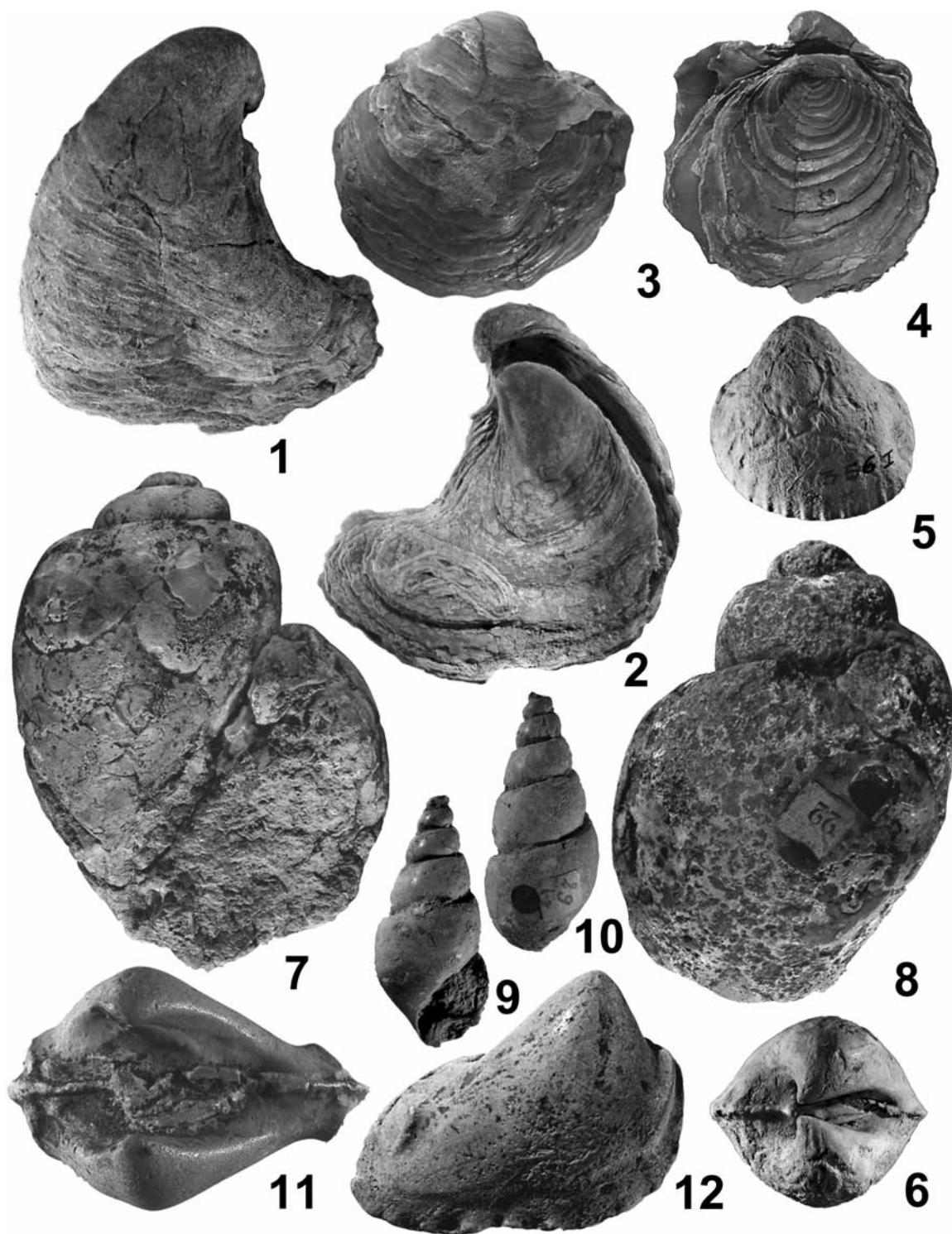


Fig. 10. 1-2 – *Pycnodonte burckhardti* IHERING MACN -Pi 5219; 3-4 – *Gryphaostrea callophylla* (IHERING), holotype, MACN-Pi 138; 5-6 – “*Venericardia*” *iheringii* var. *burckhardtii* IHERING, holotype, MACN-Pi 356 I; 7-8 – *Pseudostylostoma romeroi* IHERING, holotype, MACN-Pi 693a; 9-10 – “*Rostellaria*” *rothi* IHERING, holotype, MACN-Pi 759; 11-12 – *Arca ameghinorum* (IHERING), holotype, MACN-Pi 340. All specimens in natural size.

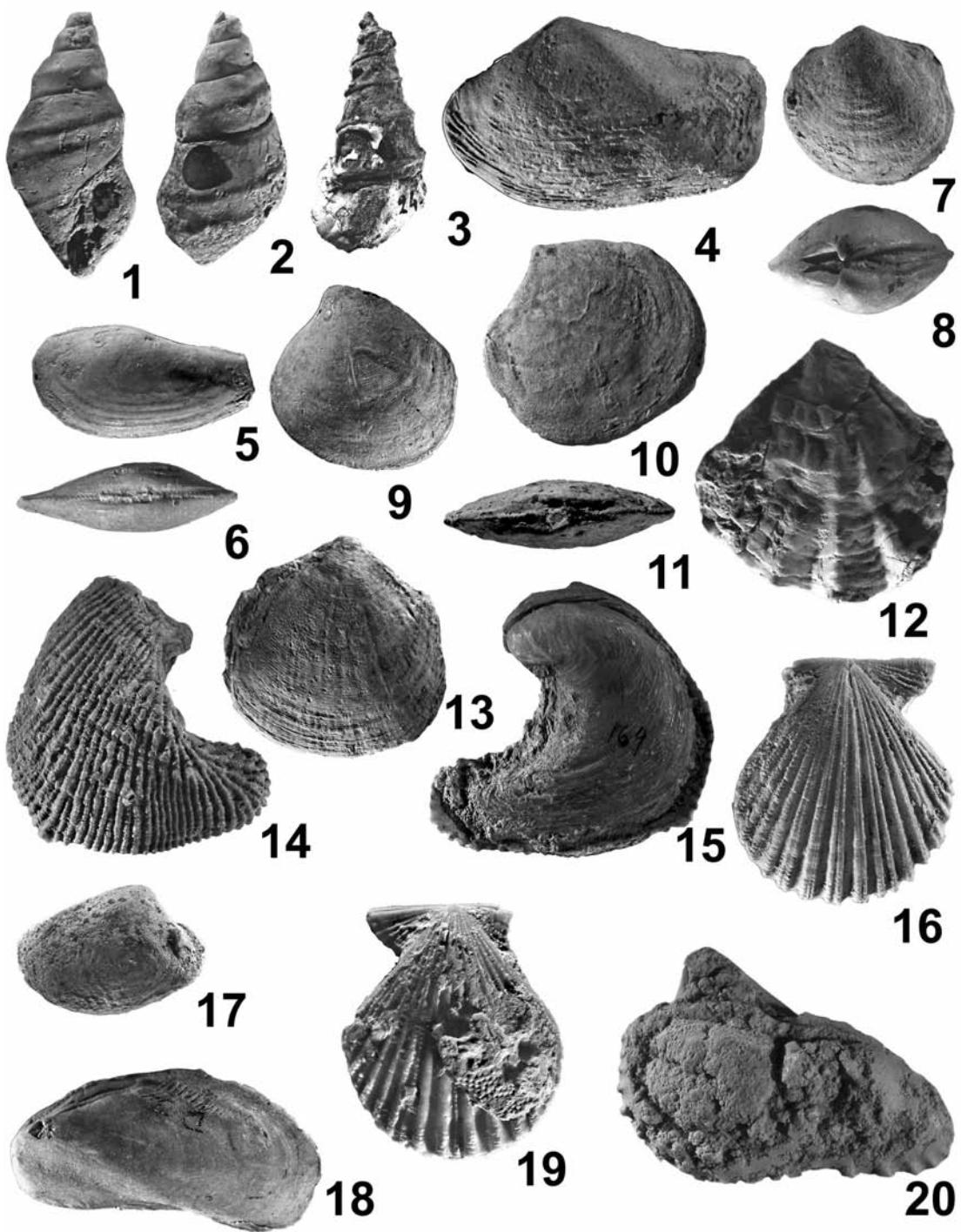


Fig. 11. 1-2 – *Strutiochenopus patagonensis* (IHERING), holotype, MACN-Pi 759 (x1.5); 3 – *Turritella burckhardti* IHERING, holotype, MACN-Pi 5218 (x1); 4 – *Neilo* sp. MACN-Pi 5223 (x2) (= *Malletia ornata* SOWERBY, in IHERING 1907); 5-6 – “*Leda*” cf. “*Leda*” *perdita* FERUGLIO, MACN-Pi 5220 (x2); 7-8 – “*Phacoides*” *rocana* IHERING, holotype, MACN-Pi 5217 (x1); 9 – “*Dosinia*” *burckhardti* IHERING, holotype, MACN-Pi 415 (x1); 10-11, 13 – “*Tellina*” *burmeisteri* IHERING, 10-11: holotype, MACN-Pi 5216 (x1); 13: MLP 5527 (x1); 12 – *Plicatula* sp., MACN-Pi 5222 (x2); 14-15 – *Cubistostrea ameghinoi* (IHERING), holotype, MACN-Pi 167 (x1); 16, 19 – “*Chlamys*” *salamanca* (IHERING), MACN-Pi 5212 (x2); 17 – *Leionucula dynastes* (IHERING), holotype, MACN-Pi 5215 (x1); 18 – *Gregariella amara* GRIFFIN et al., MACN-Pi 5221 (x2); 20 – *Arca ameghinorum* (IHERING), MACN – Pi 5213 (x1).

CALCAREOUS NANNOFOSSILS ZONES			INVERTEBRATE TAXA
NP1- NP2	NP3	NP4	
			<i>Calyptrea cf. pileolus</i>
			<i>Pectiniidae</i> indet.
			corals
			<i>Gryphaostrea callophyla</i>
			Trochidae indet.
			<i>Delectopecten neuquensis</i>
			<i>Chlamys salamanca</i>
			" <i>Venericardia</i> " <i>iheringi</i> var. <i>burckhardti</i>
			<i>Pycnodonte burckhardti</i>
			bryozoans
			<i>Modiola rionegrensis</i>
			<i>Gregariella amara</i>
			" <i>Tellina</i> " <i>burmeisteri</i>
			" <i>Leda</i> " cf. " <i>L.</i> " <i>perdita</i>
			Pseudolividae indet.
			<i>Hemaster</i> sp.
			<i>Holasteroida</i> indet.
			<i>Plesiaster</i> sp.
			<i>Linthia?</i> <i>joannisboehmi</i>
			<i>Linthia</i> sp.
			Naticidae indet.
			Epitoniidae indet.
			Fasciolariidae indet.
			Ficiidae indet.
			Tudiclidiae indet.
			<i>Turnitella burckhardti</i>
			crabs
			<i>Leionucula dynastes</i>
			<i>Neilo</i> sp.
			" <i>Phacoides</i> " <i>rocana</i>
			" <i>Dosinia</i> " <i>burckhardti</i>
			<i>Arca ameghinorum</i>
			<i>Cubistostrea ameghinoi</i>
			<i>Nuculanidae</i> indet.
			<i>Parvamussium bayoense</i>
			Limidae indet.
			<i>Plicatula</i> sp.
			<i>Struthiochenopodus patagonensis</i>
			<i>Pseudotylostoma romeroi</i>
			Scaphandridae indetp.
			" <i>Rostellaria</i> " <i>rothi</i>
			<i>Hercoglossa romeroi</i>

Fig. 12. Biostratigraphic distribution of the Danian "Rocanense" invertebrates in the type area of the Roca Formation related to calcareous nannofossil zones.

normally overlooked due to its small size. In the basal Danian, where its first common occurrence is recorded, the taxa show an increment in size and can be easily recognized.

Biantholithus sparsus is another interesting nannofossil with 7-9 simple calcitic triangular to rounded elements (MAI et al. 1994). Although sometimes considered as a "Cretaceous survivor species", occurring in Maastrichtian assemblages (VAN HECK

& PRINS 1987; MAI et al. 2003), it has extensively been used to indicate the base of the Danian (BRAMLETT & MARTINI 1964; PERCH-NIELSEN 1979; PERCH-NIELSEN 1985b; VAN HECK & PRINS 1987; POSPICHAL & WISE 1990; VAROL 1998). The acceptance in the present study of the first occurrence (FO) of *B. sparsus* as "incoming Paleogene species" and as Early Danian marker is in accordance with observations carried out in the Austral Ocean by

POSPICHAL & WISE (1990), as well as with those studies made by A. CONCHEYRO in other regions of the Neuquén Embayment (CONCHEYRO 1995; CONCHEYRO et al. 2002).

“Reworked species” such as *Micrantholithus hoschulzii* (REINHARDT) THIERSTEIN, *Micrantholithus obtusus* STRADNER, *Nannoconus circularis* DERES & ACHERITÉGUY, *Nannoconus steinmanni* KAMPTNER, and *Zeugrhabdotus embergerii* (NÖEL) PERCH-NIELSEN, have also been observed in the typical assemblages that characterize the Vaca Muerta and Agrio formations (Tithonian to Valanginian-Upper Hauterivian in age) (BOWN & CONCHEYRO 2004). Their presence in the studied sections indicates important reworking. This situation had been previously recognized in the southern area of Mendoza Province (CONCHEYRO & VILLA 1996) and it could be explained either by variations in the regional subsidence or eustatic oscillations, which would have favoured the erosion of older sediments from the western flank, as the result of the latest Maastrichtian-earliest Danian Laramide tectonic phase (onset of the Andean Orogeny), or as the combination of both factors.

7. Biostratigraphy

The Maastrichtian association is assigned to the CC26 Zone due to the presence of *Nephrolithus frequens* and *Cribrosphaerella daniae* (PERCH-NIELSEN 1985a; BURNETT 1998; POSPICHAL & WISE 1990; CONCHEYRO 1995), being the first confirmed record of the Late Maastrichtian in the type area and type section of the Roca Formation. The blooms of *Placozygus sigmoides*, *Thoracosphaera operculata*, *T. saxeae*, *Biantholithus sparsus* and *pentalithids* suggest the presence of the Early Danian NP1 Zone (MARTINI 1971) (OKADA & BUKRY 1980; GARDIN 2002). The permanent presence of some “Cretaceous survivor species” indicates a most refined biostratigraphic event. According to VAROL (1998), the NP1 in the North Sea can be subdivided into two zones and three subzones (NNTp1a - NNTp1b - NNTp2), using the successive FO of *Biantholithus sparsus*, *Cyclagelosphaera alta*, *Placozygus sigmoides* and *Cruciplacolithus primus*, respectively. The recognition of these bioevents in the study area led us to allocate the nannoflora in the lowest Danian.

Although an association assigned to the NP2 Zone is recognized in the sequence, no markers such as the FO of *Cruciplacolithus intermedius* VAN HECK

& PRINS and of *Coccolithus pelagicus* (WALLICH) SCHILLER have been detected. For this reason, the boundary between NP1 and NP2 cannot be accurately defined by their lithological continuity.

The NP3 Zone is determined by the FO of *Chiasmolithus danicus* and *Neochiastozygus modestus*, the presences of *Hornibrookina edwardsii* and *Hornibrookina teuriensis*, and the bloom of *Toweius africanus* (PERCH-NIELSEN) PERCH-NIELSEN which displays excellent preserved coccospores.

The NP4 Zone is recognized by the FO of *Neochiastozygus perfectus* PERCH-NIELSEN, only found in the Cantera Cholino section. This species has been used as a zonal marker by VAN HECK & PRINS (1987).

8. The Danian “Rocanense” invertebrate assemblages

With the exception of the oysters *Gryphaostrea callophylla* (IHERING), *Cubistostrea ameghinoi* (IHERING) and *Pycnodonte (Phygraea) burckhardti* (IHERING), that have been mentioned in other sectors of the basin (CASADÍO 1998; DEL RÍO et al. 2007), references to the “Rocanense” assemblage are usually restricted to the type area of the Roca Formation. This fauna is mainly represented by oysters, carditids, veneroids and the gastropods “*Rostellaria*” *rothi* (IHERING) and “*Turritella*” *burckhardti* (IHERING) (Table 6; Figs. 10-11). Because most of the species named by IHERING (1903, 1907) were defined on internal or composite molds of articulated specimens, it is not possible to make any revision at the generic level, but the material is easily recognized at the species level. Just in a few cases, minor modifications to IHERING’s generic assignments must be introduced. IHERING (1907) placed molds of malletids into *Malletia ornata* SOWERBY, an Oligocene-Miocene species of Patagonia actually belonging to the genus *Neilo*. New findings of material that have parts of the shell preserved have allowed to distinguish it from *N. ornata*, since the “Rocanense” shells have a much thinner and densely spaced commarginal ridges than *N. ornata*, which probably places it in a different species (Fig. 11.4). Also, preserved internal characters such as adductor and pallial blood vessel scars of specimens of *Tellina burmeisteri* IHERING indicate that this species corresponds to some lucinoidean genus (Figs. 11.10-11, 11.13). The hinge of a poorly preserved mold of a right valve of *Venericardia ameghinorum* IHERING from Cantera

Cholino confirms that this taxa belongs to *Arca* (Fig. 11.20).

The only biostratigraphic study dealing with this fauna corresponds to that provided by ROSSI DE GARGÍA & LEVY (1984) who, based on a compiled section, probably from the type area, proposed four roughly defined “zones”. From base to top, these “zones” are: *Gryphaostrea callophylla* Zone, *Cubistostrea ameghinoi* Zone, *Venericardia* sp. Zone and *Odontogryphaea* Zone.

In this study, three Danian assemblages associated with the nannofossil zones are locally distinguished (Fig. 12). The oldest assemblage is associated with the NP1-NP2 zones recorded at the base of Cerro Tres Picos and Zanjón Roca sections. At Cerro Tres Picos (samples 10' and 11') the assemblage is yielded in the extremely thin lenticular basal calcareous bodies, and is represented by a poorly diversified fauna constituted by *Gryphaostrea callophylla*, *Pycnodonte burckhardti*, “*Chlamys*” *salamanca* (IHERING) and “*Venericardia iheringi* var. *burckhardti*” IHERING, associated to bryozoans and scarce corals. At Zanjón Roca, this assemblage is contained in the thick multi-event shell bed (sample 28) present at the base of the Roca Formation where, apart from the mentioned taxa, *Delectopecten neuquensis* DEL RÍO et al., new pectinids, trochids and *Calyptarea* cf. *pileolus* have been recorded.

The second association is contained in the NP3 Zone and is represented in the Cerro Tres Picos (sample 23), Picada Sísmica (samples 7 and 10), Horne de Cal (samples 7, 10 and 13) and Zanjón Roca (sample 29) sections. It is recognized by the first occurrences of *Cubitostrea ameghinoi* (IHERING), *Turritella burckhardti* (IHERING), numerous gastropods of the Families Fasciolariidae, Ficiidae, Tuditidae and Pseudolividae, and soft-bottom dwellers such as *Leionucula dynastes* (IHERING), *Neilo* sp., “*Phacoides*” *rocana* (IHERING), “*Dosinia*” *burckhardti* (IHERING), “*Tellina*” *burmeisteri* (IHERING), Holasteroidea indet. *Linthia* sp., *Hemimaster* sp., *Plesiaster* sp., and *Linthia?* *joannisboehmi* (OPPENHEIM in BÖHM, 1903, MARTINEZ et al. 2011), among the most abundant taxa. In strata belonging to sample 7 in the Picada Sísmica section, this assemblage is contained in uni-event shell-beds that laterally vary from a concentration of *Leionucula dynastes* and “*Phacoides*” *rocana* to accumulations of “*Dosinia*” *burckhardti* and “*Tellina*” *burmeisteri*. In Cerro Tres Picos (sample 23) this assemblage is replaced by a well diversified soft-bottom dweller assemblage represented by abundant still undetermined nuculanids.

The third and youngest association is contained in the uppermost shell-beds of the Roca Formation that underlies the dolomite bed. It is much more diverse than the others and is well recorded in Cantera Cholino (samples 5-17) where it is associated with the NP4 Zone, in Horne de Cal (samples 15 and 17), Picada Sísmica (sample 12) and Zanjón Roca (samples 36-37). The taxa restricted to this assemblage are *Pseudotylostoma romeroi* (IHERING), “*Struthiochenopus*” *patagonensis* (IHERING), “*Rostellaria*” *rothi* (IHERING), *Parvamussium bayoense* DEL RÍO et al., *Plicatula* sp., *Hercoglossa romeroi* (IHERING), and still undetermined species of the Limidae, Nuculanidae and Scaphandridae. This assemblage is usually contained in shell-supported multi-event beds, with horizons almost exclusively represented by *Cubistostrea ameghinoi*, *Pycnodonte burckhardti*, “*Rostellaria*” *rothi* and “*Turritella*” *burckhardti*. These beds frequently vary laterally to monospecific uni – event concentrations of *Cubistostrea ameghinoi* to accumulations of *Pycnodonte burckhardti* and “*Rostellaria*” *rothi*.

With the exception of the abundance of *Gryphaostrea callophylla* at the base of the sections and of *Pyconodonte burckhardti* at the top (which is same that *Odontogryphaea burckhardti*) no agreement has been found with the “zones” proposed by ROSSI DE GARGÍA & LEVY (1984).

9. Discussion and conclusions

The Jagüel Formation (BERTELS 1969a) and the Roca Formation (WEAVER 1927) were studied in the type area of the Roca Formation in the surroundings of General Roca. BERTELS (1970 a) stated the absence of Late Maastrichtian sediments in the type area of the Roca Formation and did not recognize deposits older than the Danian at the base of the type section of this unit. However, *Nephrolithus frequens*, *Cribrosphaerealla daniae*, *Arkhangelskiella cymbiformis*, and *Predicosphaera stover* were recovered from the 20 m thick marls (Jagüel Formation) that separate the base of the Roca Formation (as defined by BERTELS 1969a) from the Allen Formation. This finding documents the presence of Late Maastrichtian sediments (CC26 Zone) for the first time in this area, proving that the biostratigraphic hiatus proposed by BERTELS (1970a), which would have extended from the Middle Maastrichtian to the Danian, does not exist.

The sampling and dating of the studied sections allowed the correlation proposed in Fig. 4 which has

been based on the calcareous nannofossil zones yielded in the marlstones, the uppermost bioclastic accumulations and the overlying dolomite bed. The Jagüel Formation contains two calcareous nannofossil assemblages: one of Late Maastrichtian age (CC26 Zone) and another one of Danian age (NP1-NP2 Zone). The sampling interval does not allow to distinguish the K/Pg transition, but the presence of both assemblages are clearly identified in Zanjón Roca and Cerro Tres Picos, consequently allowing the correlation of the basal sedimentites of the section. The transition between the NP1 and NP2 zones is not recognized because of the absence of *Cruciplacolithus intermedius* due to the poor diversity of the assemblage. In the Roca Formation three Danian calcareous nannofossil assemblages are distinguished. The oldest one belongs to the NP1-NP2 zones and is contained in the 20-30 cm thick marlstones that overlay the first coquinas of the unit. Upwards, the NP3 Zone is identified and its transition with the NP1-NP2 Zone has been recognized in Cerro Tres Picos and Zanjón Roca which led to the correlation of the middle part of the study sections. Finally, an assemblage assigned to the NP4 Zone has been only identified in Cantera Cholino with the first occurrence of *Neochiastozygus perfectus*. Bioclastic beds contained in the NP4 Zone in Cantera Cholino consist of accumulations of *Cubistostrea ameghinoi*, *Pycnodonte burckhardti*, “*Rostellaria*” *rothi* and *Hercoglossa* sp., associated with *Thalassinoides* horizons. These fossiliferous concentrations are recognized in the Horne de Cal, Picada Sísimica and Zanjón Roca where the interbedded marlstones are devoid of calcareous nannofossils. Along with the overlying dolomite bed, these fossiliferous strata make possible the correlation of the uppermost strata of the fossiliferous sector of the Roca Formation, all these horizons being probably correlated with the NP4 Zone.

As a result of the correlation that was carried out among sections, a detailed stratigraphic location of the “Rocanense” fauna was obtained, placing it in the NP1-NP4 zones and allowing the recognition of three associations related to the nannofossils zones. According to this biostratigraphic distribution, and similar to what happen with other Danian sections (i.e. Cerros Bayos, DEL RÍO et al. 2007), in the type area of the Roca Formation an upwards increase in the number of recorded species is also observed going from 10 species in the NP1-NP2 zones to 29 species in the NP4 Zone, showing a gradual recovery during the Danian.

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References

- ANGELOZZI, G. N. (1987): Nanofósiles paleocenos del Noreste de la Cuenca Neuquina, República Argentina. – Ameghiniana, **24** (3-4): 299-307.
- BARRIO, C. A. (1990): Late Cretaceous – Early Tertiary sedimentation in a semi-arid foreland basin (Neuquén Basin, western Argentina). – Sedimentary Geology, **66**: 255-275.
- BERTELS, A. (1964): Micropaleontología del Paleoceno de General Roca. – Revista del Museo de La Plata (nueva serie) 4, Paleontología, **23**: 125-184.
- (1968a): *Huantraiconella* n.gen. (Ostracoda, Buntoniinae) del Terciario Inferior (Daniano) de Argentina. – Ameghiniana, **5** (7): 252 -256
- (1968b): Micropaleontología y estratigrafía del límite Cretácico-Terciario en Huantrai-co (provincia de Neuquén). Ostracoda. Parte 1. – Ameghiniana, **5** (8): 279-278.
- (1969a): Estratigrafía del Límite Cretácico-Terciario en Patagonia Septentrional. – Revista de la Asociación Geológica Argentina, **24** (1): 41-54.
- (1969b): Micropaleontología y estratigrafía del límite Cretácico-Terciario en Huantrai-co (provincia de Neuquén). Ostracoda. Parte 2. – Ameghiniana, **6** (4): 253-290.
- (1970a): Los foraminíferos planctónicos de la Cuenca Cretácico-Terciaria en Patagonia septentrional (Argentina) con consideraciones sobre la estratigrafía de Fortín General Roca (Provincia de Río Negro). – Ameghiniana, **7** (1): 1-56.
- (1970b): *Hiltermannia* n. gen (Foraminiferida) del Cretácico Superior (Maastrichtiano) de Argentina. – Ameghiniana, **7** (12): 167-172.
- (1972): Buliminacea y Cassidulinacea (Foraminiferida) guías del Cretácico superior (Maastrichtiano medio) y Terciario inferior (Daniano inferior) de la República Argentina. – Revista Española de Micropaleontología, **4** (3): 327-353.
- (1973): Ostracodes of the type locality of Lower Tertiary (lower Danian) Ropian Stage and Roca Formation of Argentina. – Micropaleontology, **19** (3): 308-340.
- (1974): Upper Cretaceous (lower Maastrichtian?) ostracods from Argentina. – Micropaleontology, **20** (4): 385-397.
- (1975a) *Harringtonia* gen. nov. (Ostracoda, Crustacea) y nuevas especies del Terciario de la República Argentina. – Ameghiniana, **12** (3): 259-279.

- (1975b): Upper Cretaceous (middle Maastrichtian) ostracods from Argentina. – *Micropaleontology*, **21** (1): 97-130.
- (1980): Estratigrafía y Foraminíferos (Protozoa) bentónicos del límite Cretácico-Terciario en el área tipo de la Formación Jagüel, Provincia de Neuquén, República Argentina. – *Actas 2º Congreso Argentino de Paleontología y Bioestratigrafía y 1º Congreso Latinoamericano de Paleontología*. (Buenos Aires, 1978), **2**: 47-91.
- BODENBENDER, G. (1892): Sobre el terreno Jurásico y Cretáceo en los Andes argentinos, entre el río Diamante y el río Limay. *Boletín de la Academia Nacional de Ciencias de Córdoba*, **13**: 1-44.
- BÖHM, J. (1903): Über Ostreeen von General Roca am Río Negro. – *Zeitschrift der Deutschen Geologischen Gesellschaft*, **63**: 37-41.
- BOWN, P. (1998): Calcareous Nannofossil Biostratigraphy. – British Micropalaeontological Society Publication Series, 314 pp.; London (Chapman & Hall).
- BOWN, P. R. & YOUNG, J. R. (1998): Techniques. – In: Bown, P. R. (Ed.): *Calcareous Nannofossil Biostratigraphy*, 16-28; Dordrecht (Kluwer Academic Press).
- BOWN, P. R. & CONCHEYRO, A. (2004): Lower Cretaceous Calcareous Nannoplankton from the Neuquén Basin, Argentina. – *Marine Micropaleontology*, **52**: 51-84.
- BRAMLETTE, M. N. & MARTINI, E. (1964): The great change in calcareous nannoplankton fossils between the Maastrichtian and Danian. – *Micropaleontology*, **10** (3): 291-322.
- BURCKHARDT, C. (1901): Le gisement supracrétacique de Roca (Río Negro). – *Revista del Museo de La Plata*, **10**: 207-223.
- BURNETT, J. A. (1998): Upper Cretaceous. – In: BOWN, P. (Ed.): *Calcareous Nannofossil Biostratigraphy*. – British Micropalaeontological Society Publications Series, 132-199; London (Chapman & Hall).
- CAMACHO, H. H. (1992): Algunas consideraciones acerca de la transgresión marina paleocena en la Argentina. – *Miscelánea de la Academia Nacional de Ciencias* **85**: 1-41.
- CASADÍO, S. (1998): Las ostras del límite Cretácico-Paleógeno de la Cuenca Neuquina (Argentina). Su importancia bioestratigráfica y paleobiogeográfica. – *Ameghiniana*, **35**: 449-471.
- CASADÍO, S. & CONCHEYRO, A. (1992): Facies y ambientes de sedimentación en el límite Cretácico-Terciario de La Pampa, Argentina. – *Actas 3º Congreso Geológico de España y 8º Congreso Latinoamericano de Geología*, **4**: 30-34.
- CASADÍO, S., GRIFFIN, M., PARRAS, A., CONCHEYRO, A., FELDMANN, R., GASPARINI, Z. & PARMA, G. (2004): Biotic and Environmental changes across the K/P boundary in Patagonia. 10º Reunión de Sedimentología, Simposio límite K/T de Argentina. San Luís. Acta de Resúmenes: 187-188.
- CASADÍO, S., RODRIGUEZ, M. F., REICHLER, V. A. & CAMACHO, H. H. (1999): Tertiary Nautiloids from Patagonia, Southern Argentina. – *Ameghiniana*, **36**: 189-202.
- CONCHEYRO, A. (1995): Nanofósiles calcáreos del Cretácico Superior y Paleógeno de Patagonia, Argentina. – Tesis de Doctorado, Universidad de Buenos Aires (unpublished).
- (2001): Nanofósiles calcáreos del límite Cretácico-Paleógeno de la Cuenca Neuquina, Occidente de Argentina. – *4º Congreso de Geología y Minería de la Sociedad Cubana de Geología*. (digital version).
- CONCHEYRO, G. A. & NAÑEZ, C. (1994): Microfossils and biostratigraphy of the Jagüel and Roca formations (Maastrichtian-Danian), Province of Neuquén. – *Ameghiniana*, **31** (4): 397-398.
- CONCHEYRO, G. A., NAÑEZ, C. & CASADÍO, S. (2002): El límite Cretácico-Paleógeno en Trapalco, Provincia de Río Negro, Argentina. Una localidad clave en América del Sur? – *Actas 15º Congreso Geológico Argentino (El Calafate)*, **1**: 590-595.
- CONCHEYRO, G. A. & VILLA, G. (1996): Calcareous Nannofossils across the Maastrichtian – Danian of Liu Malal Section, Northern Patagonia, Argentina. – *Paleopelagos*, **6**: 281-297.
- DEL RÍO, C. J., BEU, A. & MARTÍNEZ, S. A. (2008): The Pectinoidean genera *Delectopecten* STEWART, 1930 and *Parvamussum* SACCO, 1897 in the Danian of Patagonia (Argentina). – *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **249**: 281-295.
- DEL RÍO, C. J., CONCHEYRO, A., MARTÍNEZ, S. & STILWELL, J. (2004): Macro y nanofósiles de Cerros Bayos (Daniano), Cuenca Neuquina, Provincia de La Pampa, Argentina. 10º Reunión de Sedimentología, Simposio límite K/T de Argentina. San Luís. Acta de Resúmenes: 190.
- DEL RÍO, C. J., STILWELL, J. D., CONCHEYRO, A. & MARTÍNEZ, S. A. (2007): Paleontology of the Danian Cerros Bayos section (La Pampa Province, Argentina). – *Alcheringa*, **31** (3): 241-269.
- DÖRING, A. (1882): Geología. Informe oficial de la Comisión científica agregada al Estado Mayor General de la expedición al Río Negro (Patagonia) realizada en los meses de abril, mayo y junio de 1879, bajo las órdenes del General Julio A. Roca. Buenos Aires, 1881. Entrega 3, parte 3. Buenos Aires, 295-530.
- EDWARDS, A. (1963): A preparation technique for calcareous nannoplankton. – *Micropaleontology*, **9**: 103-104.
- FELDMANN, R. M., CASADÍO, S., CHIRINO-GALVEZ, L. & AGUIRRE URRETA, M. B. (1995): Fossil Decapod crustaceans from the Jagüel and Roca formations (Maastrichtian-Danian) of the Neuquén Basin Argentina. – *The Paleontological Society, Memoirs*, **43**: 22 pp.
- FELDMANN, R. M. & SCHWEITZER, C. R. (2006): Paleobiogeography of Southern Hemisphere decapod Crustacea. – *Journal of Paleontology*, **80**: 83-103.
- FOSA-MANCINI, E. (1938): La “*Cardita beaumonti*” y la “*Cardita morganiana*” en la literatura geológica argentina. – *Notas del Museo de La Plata* 3, *Paleontología*, **14**: 205-230.
- GARDIN, S. (2002): Late Maastrichtian to Early Danian calcareous nannofossils at Elles (Northwest Tunisia). A tale of one million years across the K-T boundary. – *Palaeogeography, Palaeoclimatology, Palaeoecology*, **178**: 211-231.

- GERTH, E. (1913): Stratigraphie und Bau der argentinischen Kordillere zwischen dem Río Grande und Río Diamante. – Zeitschrift der Deutschen Geologischen Gesellschaft, **65**: 568-575.
- (1925): Estratigrafía y distribución de los sedimentos mesozoicos en los Andes argentinos. – Actas de la Academia Nacional de Ciencias, **9** (1): 11-55.
- GRiffin, M., PARRAS, A. & CASADÍO, S. (2008): Maastrichtian – Danian Mytilids and Pinnids (Mollusca: Bivalvia) from Northern Patagonia, Argentina. – *Ameghiniana*, **45** (1): 139-152.
- GROEBER, P. (1946): Observaciones geológicas a lo largo del meridiano 70°. I-Hoja de Chos Malal. – Revista de la Sociedad Geológica Argentina, 177-208.
- IHERING, H. v. (1902): Historia de las ostras argentinas. – Anales del Museo Nacional de Buenos Aires, **7**: 109-123
- (1903): Les Mollusques des Terrains Crétaciques Supérieurs de l'Argentine Orientale. – Anales del Museo Nacional de Buenos Aires 9 (serie 3), **2**: 193-229.
 - (1904): Nuevas observaciones sobre moluscos cretácicos y terciarios de Patagonia. – Revista del Museo de La Plata, **11**: 229-243.
 - (1907): Les Mollusques fossiles du Tertiaire et du Cretacé Supérieur de l'Argentine. – Anales del Museo Nacional de Buenos Aires, serie 3, **14** (7): 1-611.
- JIANG, M. & GARTNER, S. (1986): Calcareous nannofossil succession across the Cretaceous-Tertiary boundary in east-central Texas. – *Micropaleontology*, **32**: 232-255.
- KELLER, G., ADATTE, T., TANTAWY, A. A., BERNER, Z. & STUEBEN, D. (2007): High stress Late Cretaceous to Early Danian paleoenvironment in the Neuquén Basin, Argentina. – *Cretaceous Research*, **28**: 939-960.
- KISSLING, W., SCASSO, R., ABERHAN, M., RUIZ, L. & WEIDEMEYER, S. (2006): A Maastrichtian microbial reef and associated limestones in the Roca Formation of Patagonia (Neuquén Province, Argentina). – *Fossil Record*, **9** (2): 183-197.
- KONNO, S., HARADA, N., NARITA, H. & JORDAN, R. (2007): Living *Braarudosphaera bigelowii* (GRAN & BRAARUD) DEFLANDRE in the Bering Sea. – *Journal of Nannoplankton Research*, **29** (2) : 78-87.
- LADNER, B. & WISE, S. (1989): Calcareous nannofossil biostratigraphy of Upper Cretaceous to Paleocene sediments from Leg 173, Iberia Abyssal plain, Sites 1067-1069. – Proceedings of the Ocean Drilling Program, Scientific Results, **173**: 1-50.
- LEANZA, H. A. & HUGO, C. A. (1985): Los biohermas ostreros de la Formación Roca (Paleoceno) en el sudeste de la provincia de La Pampa, Argentina. – *Ameghiniana*, **2**: 143-149.
- LEGARRETA, L. & GULISANO C. A. (1989): Análisis estratigráfico secuencial de la Cuenca Neuquina (Triásico superior – Terciario inferior). – In : CHEBLI, G. & SPALLETTI, A. (Eds.): *Cuencas Sedimentarias Argentinas*, 221-243.
- LEGARRETA, L., KOKOGIAN, D. A. & BOGGETTI, D. A. (1989): Depositional sequences of the Malargüe Group (Upper Cretaceous-Lower Tertiary), Neuquén Basin, Argentina. – *Cretaceous Research*, **10**: 337-356.
- MAI, H., ROMEIN, A. J. T. & WILLEMS, H. (1994): Coccospheres of a rare nannofossil species; *Biantholithus sparsus* BRAMLETTE & MARTINI 1964. – *Marine Micropaleontology*, **24**: 1-2.
- MAI, H., SPEIJER, R. & SCHULTE, P. (2003): Calcareous index nannofossils (coccoliths) of the lowermost Paleocene originated in the Late Maastrichtian. – *Micropaleontology*, **49** (2): 189-195.
- MALUMIÁN, N. (1969): First report on fossil nannoplankton from Neuquén, Argentina. – *Verhandlungen der Geologischen Bundesanstalt, Sonderband*, **3**: 93.
- MALUMIÁN, N., ECHEVARRÍA, A., MARTÍNEZ MACCHIAVELLO, J. & NÁÑEZ, C. (1984): Los microfósiles. – *Actas 9º Congreso Geológico Argentino (S.C. de Bariloche)*, Relatorio, **2**: 485-526.
- MARTÍNEZ, S., DEL RÍO, C.J. & CONCHEYRO, A. (2011): Danian (Early Paleocene) echinoids from the Roca Formation, northern Patagonia, Argentina. – *Neues Jahrbuch für Geologie und Paläontologie*. (in press)
- MARTINI, E. (1971): Standard Tertiary and Quaternary calcareous nannoplankton zonation. – In: FARINACCI, A. (Ed.): *Proceedings of the 2nd Planktonic Conference*, 739-785; Rome (Tecnoscienza).
- NAÑEZ, C. & CONCHEYRO, A. (1997): El límite Cretácico-Paleógeno. – In: *Geología y Recursos Minerales del Departamento de Añelo. Provincia de Neuquén, República Argentina*. Escala 1:200.000. Proyecto Nacional de Cartas Geológicas de la Republica Argentina. Anales, **25**: 129-150.
- OKADA, H. & BUKRY, D. (1980): Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation. – *Marine Micropaleontology*, **5**: 321-325.
- OVECHKINA, M. & ALEKSSEV, A. (2005): Quantitative changes of calcareous nannoflora in the Saratov region (Russian Platform) during the late Maastrichtian warming event. – *Journal of the Iberian Geology*, **31** (1): 149-165.
- PAPU, O. H., PRÁMPARO, M. B., NAÑEZ, C. & CONCHEYRO, A. (1999): Palinología y micropaleontología de la Formación Jagüel (Maastrichtiano-Daniano), perfil Opaso, Cuenca Neuquina, Argentina. – *Actas del Simposio Paleógeno de América del Sur (Buenos Aires, 1996)*. – Anales del Servicio Geológico y Minero, **33**: 17-31
- PARMA, S. G. & CASADÍO, S. (2005): Upper Cretaceous-Paleocene echinoids from Northern Patagonia, Argentina. – *Journal of Paleontology*, **79**: 1072-1087.
- PARRAS, A. M., CASADÍO, S. & PIRES, M. (1998): Secuencias depositacionales del Grupo Malargüe y el límite Cretácico-Paleógeno, en el sur de la provincia de Mendoza, Argentina. Simposio del Paleógeno de América del Sur y de la península Antártica. – Asociación Paleontológica Argentina, Publicación Especial, **5**: 61-69.
- PERCH-NIELSEN, K. (1979): Calcareous nannofossils zonation at the Cretaceous-Tertiary boundary in Denmark. – In: CHRISTENSEN W. K. & BIRKELUND, T. (Eds.): *Cretaceous Tertiary Boundary Events*, **1**: 115-135; Copenhagen (University of Copenhagen).
- (1985a): Mesozoic calcareous nannofossils. – In: BOLLI, H. H., SAUNDERS, J. B & PERCH-NIELSEN, K. (Eds.): *Plankton Stratigraphy*, 329-426; Cambridge (Cambridge University Press).

- (1985b): Cenozoic Calcareous nannofossils. – In: BOLLI, H. H., SAUNDERS, J. B & PERCH-NIELSEN, K (Eds.): Plankton Stratigraphy, 427-554; Cambridge (Cambridge University Press).
- PERCH-NIELSEN, K., MCKENZIE, J. A. & HE, Q. (1982): Biostratigraphy and isotope stratigraphy and the “catastrophic” extinction of calcareous nannoplankton at the Cretaceous/Tertiary boundary. – Geological Society of America, Special Paper, **190**: 353-371.
- POSPICHAL J. & WISE, S. (1990): Maestrichtian calcareous nannofossils biostratigraphy of Mand Rise ODP Leg 113 Sits 689 and 690. Weddell Sea. – Proceeding of the Ocean Drilling Program, Scientific Results, **113**: 465-487.
- ROMEIN, A. J. T., WILLEMS, H., & MAI, H. (1996): Calcareous nannoplankton of the Geulhemmerberg K/T boundary section, Maastrichtian type area, the Netherlands. – *Geologie en Mijnbouw*, **75**: 231-238.
- ROSSI DE GARCIA, E. & LEVY, R. (1984): Megafaunas de invertebrados terciarios. 9º Congreso Geológico Argentino. Relatorio **2** (6): 467-484.
- ROTH, S. (1899): Apuntes sobre la geología y la paleontología de los territorios del Río Negro y Neuquén. Reconocimiento de la región andina de la República Argentina. – *Revista del Museo de La Plata*, **9**: 141-197.
- ROTH, P. H. & THIERSTEIN, H. (1972): Calcareous nannoplankton: Leg 14 of the Deep Sea Drilling Project, **14**: 421-485.
- SCHILLER, W. (1922): Los sedimentos marinos del límite entre el Cretáceo y Terciario de Roca en la Patagonia septentrional. – *Revista del Museo de La Plata*, 26 (serie 3), **2**: 256-280.
- SCASSO, R., CONCHEYRO, A., KISSLING, W., ABERHAM, M., HECHT, L., MEDINA, F. & TAGLE, R. (2005): A tsunami deposit at the Cretaceous-Tertiary boundary in the Neuquén Basin of Argentina. – *Cretaceous Research*, **26**: 283-297.
- THIBAULT, N. & GARDIN, S. (2006): Maastrichtian calcareous nannofossil biostratigraphy and paleoecology in the Equatorial Atlantic (Demerara Rise, ODP Leg 207 Hole 1258A). – *Revue de Micropaléontologie*, **49**: 199-214.
- THIERSTEIN, H. (1980): Selective dissolution of Late Cretaceous and Earliest Tertiary nannofossils: Experimental evidence. – *Cretaceous Research*, **2**: 165-179.
- 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, M. (1975): Geología de la región comprendida entre los ríos Colorado y Negro, Provincias de Neuquén y Río Negro. – Tesis Doctoral. Universidad Nacional de La Plata (unpublished).
- ULIANA, M. & DEL LAPÉ, D. (1981): Estratigrafía y Evolución paleoambiental de la sucesión Maestrichtiano-Eoterciaria del Engolfamiento Neuquino (Patagonia Septentrional). – Actas 8º Congreso Geológico Argentino, **3**: 673-711.
- VAN HECK, S. E. & PRINS, B. (1987): A refined nannoplankton zonation for the Danian of the Central North Sea. – *Abhandlungen der Geologischen Bundesanstalt*, **39**: 285-303.
- VAROL, O. (1998): Paleogene. – In: BOWN, P. R. (Ed.): *Calcareous Nannofossil Biostratigraphy*, 200-224; Dordrecht (Kluwer Academic Press).
- WEAVER, C. E. (1927): The Roca Formation in Argentina. – *American Journal of Science*, series **5**, **12**: 417-434.
- (1931): Paleontology of the Jurassic and Cretaceous of West Central Argentine. – *University of Washington, Memoirs*, **1**: 82-89.
- WEBER, E. I. (1964): Estudio geológico de General Roca. Tesis de Doctorado en Ciencias Naturales. Universidad de Buenos Aires. – 149 pp. (unpublished).
- WICHMANN, R. (1924): Nuevas observaciones geológicas en la parte oriental del Neuquén y en el territorio del Río Negro. – *Publicación de la Dirección General de Minas, Geología e Hidrología*, **2** (Geología): 3-22.
- WIND, F. H. (1979): Maastrichtian-Campanian nannofloral provinces of the southern Atlantic and Indian Oceans. – In: TALWANI, M., HAY, W. W. & RYAN, W. B. F. (Eds.): *Results of Deep Drilling in the Atlantic Oceans: Continental margins and paleoenvironments*. – American Geophysical Union, Maurice Ewing series **3**: 123-137.
- WIND, F. H. & WISE, S. (1976): Jurassic to Holocene calcareous nannofossils from the Falkland (Malvinas) Plateau. – *Antarctic Journal of United States*, **11** (3): 169-171.
- WINDHAUSSEN, A. (1914): Contribución al conocimiento geológico de los territorios del Río Negro y Neuquén. – *Anales del Ministerio de Agricultura, Sección Geología, Mineralogía y Minería*, **10** (1): 9-60.

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Table 1. Cantera Cholino – Calcareous nannofossil range chart.

Table 2. Picada Sísmica – Calcareous nannofossil range chart.

Table 3. Cerro Tres Picos – Calcareous nannofossil range chart.

MAASTRICHTIAN	STAGE			CALCAREOUS NANNOFOSSIL ZONES			STAGE	CALCAREOUS NANNOFOSSIL ZONES		
	CC 26	NP1-NP2	NP 3	FORMATION	SAMPLES	FORMATION		CRETACEOUS SPECIES		
TP 25										
TP 24										
TP 23	P	VR								
TP 22	P	VR								
TP 21	P	VR								
TP 20	P	VR								
TP 19	P	R								
TP 18	P	R								
TP 17	G	A								
TP 16	G	A								
TP 15	M	F								
TP 14	M	F								
TP 13	M	F								
TP 12	M	F								
TP 11	P	A								
TP 10	P	A								
TP 9	M	F								
TP 8	M	F								
TP 7	M	F								
TP 6	G	A	X	X	X					
TP 5	P	F			X	X				
TP 4	P	F	X	X	X	X				
TP 3	P	F			X					
TP 2	M	F	X	X			X	X		
TP 1	P	F	X	X			X	X		

Table 4. Hornero de Cal (Type section of the Roca Formation) – Calcareous nannofossil range chart.

MAAS	STAGE			CALCAREOUS NANNOFOSSIL ZONES			STAGE	CALCAREOUS NANNOFOSSIL ZONES		
	DANIAN	NP1-NP3	ROCA	FORMATION	SAMPLES	FORMATION		CRETACEOUS SPECIES		
CC26										
JAGÜEL										
HC 9	M	F								
HC 8	P	R								
HC 7	P	R								
HC 6	P	R								
HC 5										
HC 4	M	F								
HC 3	G	A	X	X	X	X				
HC 2	P	R	X	X						

Table 3. Cerro Tres Picos – Calcareous nannofossil range chart. Cont.

Table 4. Horro de Cal (Type section of the Roca Formation) – Calcareous nannofossil range chart. Cont.

Table 5. Zanjón Roca – Calcareous nannofossil range chart.

MAASTRICHTIAN	STAGE	CALCAREOUS NANNOFossil ZONES			PRESERVATION	ABUNDANCE	CRETACEOUS SPECIES																				
		FORMATION																									
		SAMPLES																									
ZR 38					<i>Actinocyclus regularis</i>																						
ZR37					<i>Acuturris scotus</i>																						
ZR 36					<i>Ahmuellerella octoradiata</i>																						
ZR 35 M	DANIAN	NP 3			<i>Arkhangelskiella cymbiformis</i>																						
ZR34 P					<i>Arkhangelskiella maastrichtiana</i>																						
ZR 33 P	ROCA			R		X																					
ZR 32 P				R																							
ZR 31 P				R																							
ZR 30 P				F																							
ZR 29 M				F																							
ZR 28																											
ZR 27 M	JAGÜEL	CC 26	NP1- NP2																								
ZR 26 G				F																							
ZR 25 M				F		X																					
ZR 24 M				F			X	X																			
ZR 23 G				F				X																			
ZR 22 G				F		X	X	X	X								X	X	X	X	X	X	X	X	X		
ZR 21 M				F		X		X	X								X	X	X	X	X	X	X	X	X		
ZR 20 M				F			X	X									X	X	X	X	X	X	X	X	X		
ZR 19 M				F		X		X	X								X	X	X	X	X	X	X	X	X		
ZR 18 M				F		X	X	X									X		X	X	X	X	X	X	X		
ZR 17 G				F		X	X	X									X	X	X	X	X	X	X	X	X		
ZR 16 G				F		X	X	X									X	X	X	X	X	X	X	X	X		
ZR 15 G				F		X	X	X	X								X	X	X	X	X	X	X	X	X		
ZR 14 M				F		X		X	X								X	X	X	X	X	X	X	X	X		
ZR 13 M				F		X		X									X	X	X	X	X	X	X	X	X		
ZR 12 M				A		X	X										X	X	X	X	X	X	X	X	X		
ZR 11 G				A		X	X										X	X	X	X	X	X	X	X	X		
ZR 10 M				F		X	X										X	X	X	X	X	X	X	X	X		
ZR 9 G				A		X	X	X	X								X	X	X	X	X	X	X	X	X		
ZR 8 M				F		X		X									X	X	X	X	X	X	X	X	X		
ZR 7 G				A		X	X	X									X	X	X	X	X	X	X	X	X		
ZR 6 M				F																							
ZR 5 M				A		X	X	X	X								X	X	X	X	X	X	X	X	X		
ZR 4 M				A		X	X	X	X								X	X	X	X	X	X	X	X	X		
ZR 3 M				A		X	X										X		X	X	X	X	X	X	X		
ZR 2' M				A		X	X	X	X	X							X	X	X	X	X	X	X	X	X		
ZR 2 M				A		X											X	X	X	X	X	X	X	X	X		
ZR 1 P				R													X	X	X	X	X	X	X	X	X		

Appendix

Taxonomic list. A full list of all taxa cited in the range charts. Most bibliographic references can be found in PERCH-NIELSEN (1985a, b) and BOWN (1998).

Ahmuellerella octoradiata (GÓRKA 1957) REINHARDT 1966
Acuturris scotus (RISATTI, 1973) WIND & WISE in WISE & WIND (1977)
Ahmuellerella regularis (GÓRKA 1957) REINHARDT & GÓRKA 1967
Arkhangelskiella cymbiformis VEKSHINA, 1959
Arkhangelskiella maastrichtiana BURNETT 1997a
Biantholithus sparsus BRAMLETTE & MARTINI 1964
Biscutum constans (GORKA 1957) BLACK in BLACK & BARNEs (1959)
Biscutum melaniae (GÓRKA 1957) BURNETT 1997
Biscutum notaculum WIND & WISE in WISE & WIND 1977
Braarudosphaera bigelowii (GRAN & BRAARUD 1935) DEFLANDRE 1947

Chiasmolithus danicus (BROTZEN 1959) HAY & MOHLER 1967

Chiastozygus garissoinii BUKRY 1969

Chiastozygus ultimus PERCH-NIELSEN 1981

Coccolithus pelagicus (WALLICH 1871) SCHILLER 1930

Cretarhabdus conicus BRAMLETTE & MARTINI (1964)

Cribrosphealerella danaiae PERCH-NIELSEN (1973)

Cribrosphealerella ehrenbergii (ARKHANGELSKY 1912) DEFlandRE in PIVETEAU (1952)

Cruciplacolithus primus PERCH-NIELSEN 1977

Cruciplacolithus tenuis STRADNER 1961) HAY & MOHLER in HAY et al. 1967

Cyclagelosphaera margerelii NOËL (1965)

Cyclagelosphaera reinhardtii (PERCH-NIELSEN 1968) ROMEIN 1977

Eiffellithus gorkae REINHARDT 1965

Eiffellithus parallelus PERCH-NIELSEN 1973

Eiffellithus turriseiffelii (DEFlandRE in DEFlandRE & FERT 1954) REINHARDT (1965)

Gartnerago segmentatum (STOVER 1966) THIERSTEIN 1974

Table 5. Zanjón Roca – Calcareous nannofossil range chart. Cont.

		CRETACEOUS SURVIVORS SPECIES												INCOMING PALEOGENE SPECIES			
Prediscosphaera stoveri																	
Refecapsa crenulata																	
Rhagodiscus angustus																	
Rhagodiscus reniformis																	
Rhagodiscus splendens																	
Staurolithites melincensis																	
Vagajilla barchena																	
Watnaueria barnesiae																	
Watnaueria fossacincta																	
Watnaueria ovala																	
Zeugihabdus embergeri																	
Zygodiscus spiralis																	
Acanthica sp.																	
Bianolithus sp.																	
Bianolithus sparsus																	
Brauniosphaera alita																	
Brauniosphaera bigelowi																	
Chiastozygus ultimus																	
Cyclocladosphaera reinhardtii																	
Lanthemithus duocavus																	
Markalius apertus																	
Markalius inversus																	
Micrantholithus pinguis																	
Micrantholithus vesper																	
Neochiastozygus primitivus																	
Neocrepidolithus cruciatus																	
Placozygus sigmoides																	
Thracosphaera crassa																	
Thracosphaera operculata																	
Thracosphaera saxeae																	
Chiasmolithus donicus																	
Coccilithus pelagicus																	
Cruciplacolithus primus																	
Cruciplacolithus tenuis																	
Hornbrookina edwardsii																	
Hornbrookina teuriensis																	
Neochiastozygus modestus																	
Neocrepidolithus dirimus																	
Toveius officianus																	

Appendix Cont.

Hornbrookina edwardsii PERCH-NIELSEN 1977
Hornbrookina teuriensis EDWARDS 1973
Kamptnerius magnificus DEFLANDRE 1959
Lanternithus duocavus LOCKER 1967
Lithraphidites carniolensis DEFLANDRE 1963
Lithraphidites quadratus BRAMLETTE & MARTINI 1964
Lucianorhabdus cayeuxii DEFLANDRE (1959)
Manivitella pemmatoides (DEFLANDRE in MANIVIT 1965)
 THIERSTEIN 1971
Markalius apertus PERCH-NIELSEN (1979b)
Markalius inversus (DEFLANDRE in DEFLANDRE & FERT 1954) BRAMLETTE & MARTINI 1964
Micrantholithus pinguis BRAMLETTE & SULLIVAN 1961
Micrantholithus vesper DEFLANDRE in DEFLANDRE & FERT 1954
Microrhabdulus decoratus DEFLANDRE 1959
Micula concava (STRADNER in MARTINI & STRADNER 1960) VERBEEK 1976
Micula decussata VEKSINA (1959)

Micula murus (MARTINI 1961) BUKRY 1973
Micula swastica STRADNER & STEINMETZ 1984
Nannoconus circularis DÉRES & ACHERITÉGUY 1980
Neochiastozygus modestus PERCH-NIELSEN 1971
Neochiastozygus perfectus PERCH-NIELSEN 1971
Neochiastozygus primitivus PERCH-NIELSEN 1981
Neocrepidolithus cruciatus (PERCH-NIELSEN 1979)
 PERCH-NIELSEN 1981
Neocrepidolithus dirimus (PERCH-NIELSEN 1979)
 PERCH-NIELSEN 1981
Nephrolithus frequens GÓRKA 1957
Nodosella elegans PERCH-NIELSEN 1981
Octolithus multiplus (PERCH-NIELSEN 1973) ROMEIN 1979
Placozygus sigmoides (BRAMLETTE & SULLIVAN 1961)
 ROMEIN 1979
Prediscosphaera cretacea (ARKHANGELSKY 1912) GARTNER 1968
Prediscosphaera spinosa (BRAMLETTE & MARTINI, 1964)
 GARTNER, 1968
Prediscosphaera stoveri (PERCH-NIELSEN 1968) SHAFIK & STRADNER 1971

Table 6. Stratigraphic distribution of recorded “Rocanense” fauna in the studied sections of the Roca Formation in the type area. (* taxa described by IHERING (1902, 1903, 1907) and recognized in the present analysis).

LITHOLOGICAL SECTIONS	ZANJÓN ROCA				PICADA SISMICA			HORNO CAL (Type Section NR of Bertels, 1969a)					CERRO PICOS			TRES			CANTERA CHOLINO							
	28	29	36	37	7	10	12	7	10	13	15	17	10'	11'	15	19	23	5	6	12	13	14	15	17		
FOSSILIFEROUS BEDS																										
* <i>Leionucula dynastes</i> Ihering			x		x							x													x	
* <i>Neilo</i> sp.			x		x							x										x				
Nuculanidae indet.												x									x					
“ <i>Leda</i> ” cf. “ <i>L.</i> ” <i>perdita</i> Feruglio					x																					
* “ <i>Modiola rionegrensis</i> Ihering			x																							
<i>Gregariella amara</i> Griffin et al.			x																							
Limidae indet.		x										x														
<i>Plicatula</i> sp.												x														
* <i>Pycnodonte burckhardti</i> (Böhm)			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
* <i>Gryphaostrea callophyla</i> (Ihering)	x					x							x	x												
* <i>Cubitostrea ameghinoi</i> (Ihering)		x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
“ <i>Chlamys</i> ” <i>salamanca</i> Ihering	x			x	x				x				x	x	x	x	x	x	x	x	x	x	x	x	x	
Pectinidae indet.	x																									
<i>Deflectopecten neuquensis</i> del Río et al.	x																		x	x						
<i>Parvamussium bayoense</i> del Río et al.																		x	x	x	x	x	x	x	x	
* <i>Arca ameghinorum</i> (Ihering)		x	x															x	x	x	x	x	x	x	x	
* “ <i>Venericardia</i> ” <i>iheringii</i> var. <i>burckhardtii</i> Ih.		x	x				x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
* “ <i>Phacoides</i> ” <i>rocanica</i> Ihering			x																		x					
* “ <i>Dosinia</i> ” <i>burckhardtii</i> Ihering		x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
* “ <i>Tellina</i> ” <i>burmeisteri</i> Ihering			x																							
Trochidae indet.	x			x																						
* “ <i>Struthiochenopus</i> ” <i>patagonensis</i> (Ihering)				x														x	x							
* <i>Rostellaria</i> “ <i>rothi</i> ” Ihering			x		x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
<i>Calyptraea</i> cf. <i>pileolus</i> d’Orbigny	x																									
Epitoniidae indet.				x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Naticidae indet.			x					x												x						
* <i>Turritella burckhardtii</i> Ihering		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
* <i>Pseudodystoma romeroi</i> Ihering		x										x								x	x	x	x	x	x	x
Ficidae indet.	x		x									x								x	x	x	x	x	x	x
Fasciolariidae indet.	x		x									x								x				x		
Tudicidae indet.	x		x									x														
Pseudolividae indet.		x																								
Scaphandridae indet.		x																								
<i>Hercoglossa romeroi</i> (Ihering)		x							x													x				
<i>Hemister</i> sp.	x																									
<i>Linthia</i> sp.	x			x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
<i>Linthia?</i> <i>joannisboehmi</i>	x			x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Holasteroida indet.	x																									
<i>Plesiaster</i> sp.	x																									
crabs		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
corals	x							x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
bryozoans	x							x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	

Appendix Cont.

Retecapsa crenulata (BRAMLETTE & MARTINI 1964) GRÜN in GRÜN & ALLEMANN 1975
Retecapsa surirella (DEFLANDRE & FERT 1954) GRÜN in GRÜN & ALLEMANN 1975
Rhagodiscus angustus (STRADNER 1963) REINHARDT 1971
Rhagodiscus reniformis PERCH-NIELSEN 1973
Rhagodiscus splendens (DEFLANDRE 1953) VERBEEK 1977
Staurolithites mielnicensis (GORKA 1957) PERCH-NIELSEN (1968) sensu CRUX in LORD (1982)
Thoracosphaera operculata BRAMLETTE & MARTINI 1964
Thoracosphaera saxeana STRADNER 1961
Toweius africanus (PERCH-NIELSEN 1981) PERCH-NIELSEN 1984

Watznaueria barnesiae (BLACK 1959) PERCH-NIELSEN 1968
Watznaueria biporta BUKRY 1969
Watznaueria britannica (STRADNER 1963) REINHARDT 1964
Watznaueria fossacincta (BLACK 1971) BOWN in BOWN & COOPER 1989
Watznaueria ovata BUKRY 1969
Zeugrhabdotus diplogrammus (DEFLANDRE in DEFLANDRE & FERT 1954) BURNETT in GALE et al. 1996
Zeugrhabdotus embergeri (NOËL 1958) PERCH-NIELSEN 1984
Zygodiscus spiralis BRAMLETTE & MARTINI 1964