Antarctic Science 17 (2), 267–280 (2005) © Antarctic Science Ltd Printed in the UK DOI: 10.1017/S0954102005002671

Nautilids from the Upper Cretaceous of the James Ross Basin, Antarctic Peninsula

MARCELA CICHOWOLSKI[1,2]*, ALFREDO AMBROSIO[1,3] and ANDREA CONCHEYRO[1,2,4]

[1]*Departamento de Ciencias Geológicas, Universidad de Buenos Aires. Ciudad Universitaria, Pabellón II (C1428EGA), Buenos Aires, Argentina*
[2] *(CONICET) Consejo Nacional de Investigaciones Científicas y Técnicas. Rivadavia 1917 C1033AAJ, Buenos Aires, Argentina*
[3]*Laboratorio de Anatomía Comparada y Evolución de los Vertebrados. Museo Argentino de Ciencias Naturales Bernardino Rivadavia. Ángel Gallardo 470 (C1405DJR), Buenos Aires, Argentina*
[4] *Instituto Antártico Argentino. Cerrito 1248, C1010AAZ Buenos Aires, Argentina*
**mcicho@gl.fcen.uba.ar*

Abstract: To date, Cretaceous nautilids from the Antarctic Peninsula have received little attention and only a single species had been reported, *Eutrephoceras simile* Spath, from Seymour, Snow Hill, and James Ross islands. Currently, it is considered a synonym of *Eutrephoceras subplicatum* (Steinmann), which has also been described from the Upper Cretaceous of central Chile, southern Argentina and Angola. Here, we report and describe *E. subplicatum* in detail, based on specimens from the Lower Campanian–Maastrichtian of Vega, Seymour and James Ross islands, presenting, for the first time, embryonic conch features related to the palaeoecology of these organisms. The nauta of this species had a diameter of approximately 30 mm with 5–6 septa. In addition, we describe a new species, *Eutrephoceras antarcticum*, and one specimen assigned to the same genus in open nomenclature, both recovered from the Lower Campanian beds of James Ross Island.

Received 2 September 2004, accepted 11 January 2005

Key words: Campanian, embryonic conch, *Eutrephoceras*, Maastrichtian, palaeoecology, Seymour Group

Introduction

Nautilid records from the Upper Cretaceous of the James Ross Basin start with Kilian & Reboul (1909), who described Antarctic material under the name *Nautilus blanfordianus.* They used this name for two specimens found in Lower Maastrichtian strata of Snow Hill and Seymour Islands and for some others found in India, which had already been described by Blanford & Stoliczka (1865) as *Nautilus bouchardianus* D'Orbigny, 1840. Spath (1953) described *Eutrephoceras simile* from twenty Early Maastrichtian specimens from The Naze and Dagger Peak (James Ross Island) and considered the Antarctic specimens of Kilian & Reboul to belong to the same species. According to Spath (1953), the name *N. blanfordianus* was given by Kilian & Reboul to the Indian forms figured by Blanford (1861, in Blanford & Stoliczka 1865), and he preferred to use a new name for the Antarctic specimens (see Spath (1953) for a more detailed description of the nomenclatorial situation). Del Valle *et al*. (1982) listed *E. simile* from the Upper Cretaceous of The Naze and Cape Lamb (James Ross and Vega islands) and Marenssi *et al*. (1992) cited *Eutrephoceras simile* from Cape Hamilton and Ekelöf Point (James Ross Island).

Steinmann (1895) described *Nautilus subplicatus*, from the Upper Cretaceous of Quiriquina Island (central Chile). Stinnesbeck (1986) revised this material, and also studied other Maastrichtian nautilids from the same region, considering them to belong to the same species, *Eutrephoceras subplicatum*. Stinnesbeck (1986) also pointed that differences in dimensions between *E. subplicatum* and *E. simile* noted by Spath (1953), were due to some illustrations in the work of Steinmann (1895) that had not been made maintaining the real proportions. Therefore, this author concluded that *E. simile* is a junior subjective synonym of *Eutrephoceras subplicatum* (Steinmann), this latter being the older and valid name for the species according to the principle of priority of the International Code of Zoological Nomenclature.

Systematic works on post-Triassic nautilids are very controversial; the major discussion pivots around the family level. The great morphological homogeneity of this group, in addition to the scarcity of features that can be described (due in part to poor preservation, which makes it difficult to observe more characteristics), make systematic and phylogenetic study an unprofitable task (Cichowolski 2003). Several classification schemes exist, which differ considerably in the number and identity of the groups that conform to them. Regarding phylogeny of the post-Triassic nautilids, the only attempt has been that of Engeser (1999), who published a summary of the results of a cladistic analysis in which about half of the existing post-Triassic nautilid genera were included. However, this was just an abstract, without a published dataset on which to analyse the proposed phylogeny. Consequently, the controversies about the relationships between the different genera of this group of nautilids continue.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

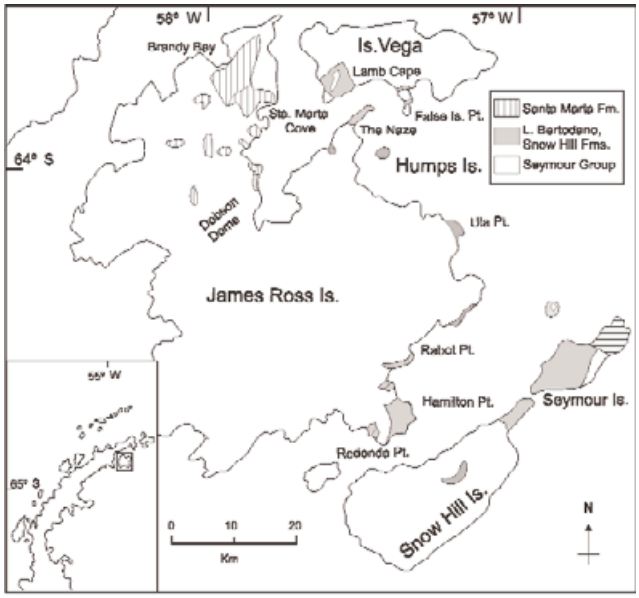

Fig. 1. Map showing the basin location, fossil localities and Upper Cretaceous outcrops of the James Ross Basin, Antarctica.

Geological setting

Centred on the James Ross Island group, in the north-west region of the Weddell Sea, the James Ross Basin (Fig. 1) represents the principal Late Mesozoic–Early Cenozoic back-arc basin exposed within the Antarctic Peninsula–Scotia arc region (Crame *et al*. 1996). The exposed basin-fill comprises an extensive succession of Lower Cretaceous–Lower Tertiary marine sedimentary strata, which is known to be in excess of 6 km thick (Crame *et al*. 1991). However, the thickest part of the basin fill, estimated by geophysical methods, reaches up to 12 km (Ghidella & Labrecque 1992). Arc-derived volcaniclastic sedimentary rocks form the basin-fill and constitute a regressive megasequence, starting with the Barremian–Santonian Gustav Group (Medina *et al*. 1992, Crame *et al*. 1996). This group consists of approximately 2500 m of deep-water sediments comprising, from base to top, the Lagrelius Point, Kotick Point, Whisky Bay, and Hidden Lake formations (Ineson 1986, Medina *et al*. 1992) (Figs 2 & 3). The overlying Marambio Group

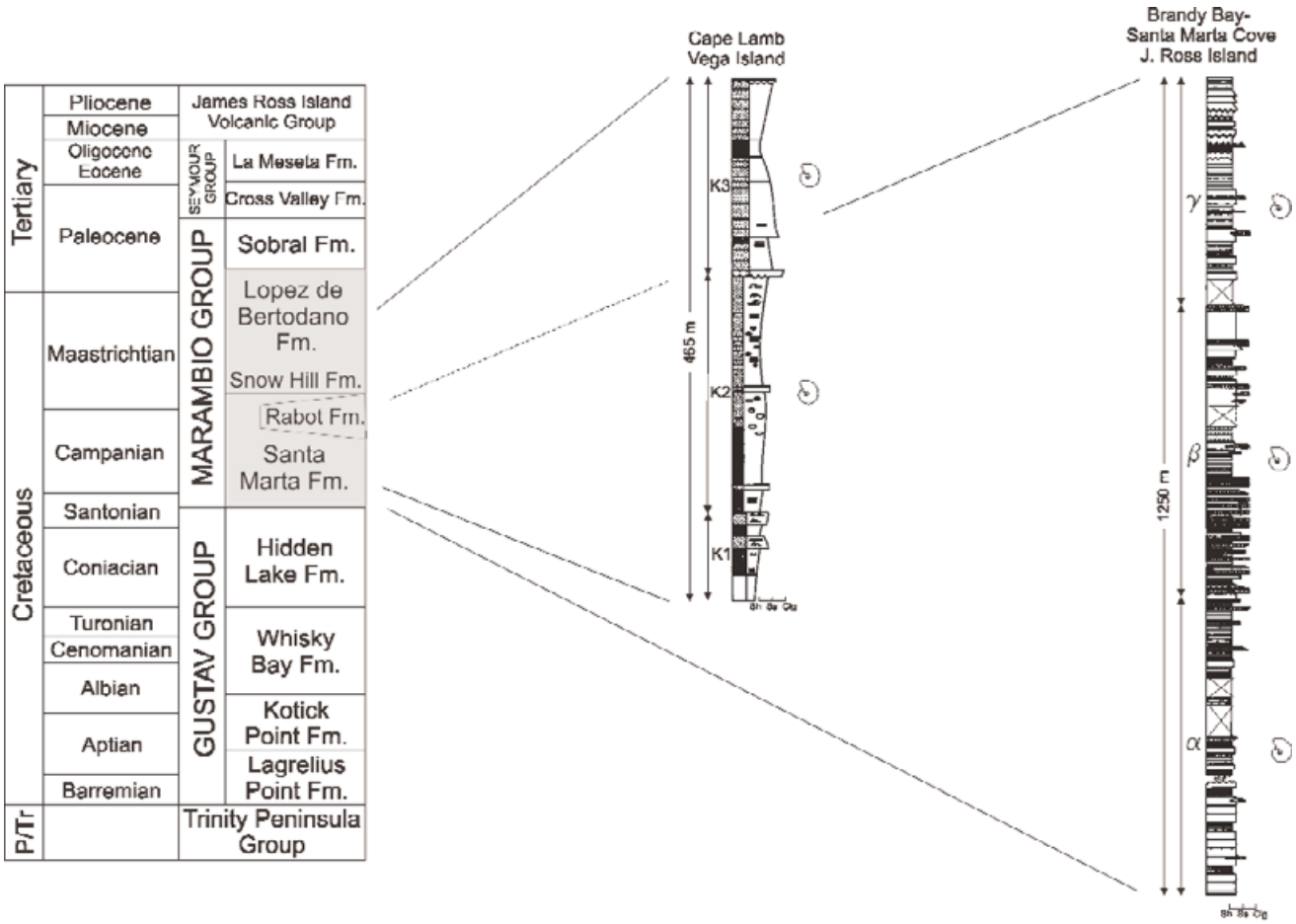

Fig. 2. Idealized stratigraphic columns of the James Ross Basin, showing the schematic sedimentary profiles of the Santa Marta, Snow Hill Island and López de Bertodano formations at Brandy Bay–Santa Marta Cove (James Ross Island) and Cape Lamb (Vega Island), respectively. Taken from Olivero *et al*. (1986) and Marenssi *et al*. (2001).

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

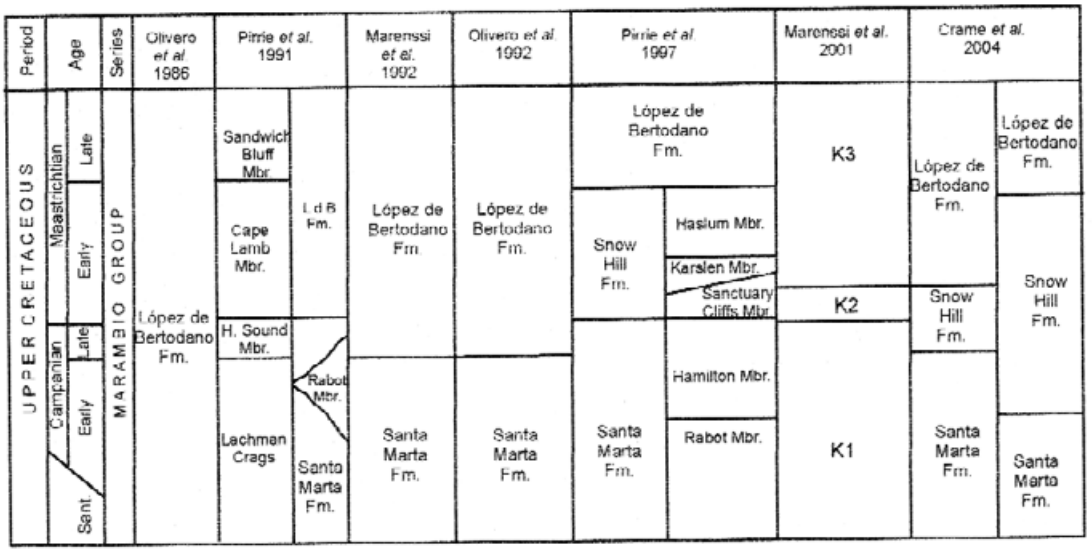

Fig. 3. Comparative scheme showing different stratigraphic subdivisions of the Marambio Group.

(Santonian–Paleocene) comprises almost 3000 m of shallow marine sediments. This group includes the Santa Marta, Rabot, Snow Hill, López de Bertodano, and Sobral Formations (Rinaldi 1982, Olivero *et al*. 1986, 1992, Lirio *et al.* 1989, Marenssi *et al*. 1992, Pirrie *et al*. 1997) (Figs 2 & 3). The Seymour Island Group (Paleocene–Oligocene?) comprises nearly 900 m of marine shallow water and deltaic sediments cropping out in the Seymour Island (Elliot *et al*. 1975, Marenssi *et al*. 1998).

The studied specimens were collected at Brandy Bay–Santa Marta Cove (James Ross Island), in the Santa Marta Formation, and in the Snow Hill Island and López de Bertodano formations, mainly at Cape Lamb (Vega Island) (Fig. 1).

The Santonian–Upper Campanian Santa Marta Formation consists of approximately 1200 m of marine volcaniclastic and siliciclastic shelf deposits (Fig. 2). It is divided into three members: Alpha, Beta and Gamma (Olivero *et al*. 1986). According to Pirrie (1989), this shallow marine sequence was deposited at an active margin, and sedimentation was affected by background shelf and arc-related volcaniclastic processes. The Alpha Member (Santonian–Lower Campanian), about 500 m thick, includes a lower succession of tuffaceous mudstones followed by fine-grained, tuffaceous turbidites (Olivero *et al*. 2004). In this member *Eutrephoceras* sp. was found. The Beta Member (Lower Campanian–lowermost Upper Campanian), about 500 m thick, includes a lower succession composed of channelled debris flows and interbedded turbidites, followed by silty, fine sandstones, which are covered by coarse–medium sandstones and coquinas (Olivero *et al*. 2004). *Eutrephoceras antarcticum* sp. nov. and one specimen of *E. subplicatum* were found in this member. The Gamma Member (Late Campanian–Early Maastrichtian), about 200 m thick, includes mostly fine-grained, well sorted sandstones interbedded with black carbonaceous mudstones, scarce conglomerates, and pebbly sandstones (Scasso *et al*. 1991). Most specimens of *E. subplicatum* from the Santa Marta Formation were found in the Gamma Member (Fig. 2).

Several specimens of *Eutrephoceras subplicatum* were found in the Snow Hill Island and López de Bertodano formations (Rinaldi *et al*. 1978, Pirrie *et al.* 1997), most of them at Cape Lamb in Vega Island. These outcrops were studied in detail by Olivero *et al*. (1992), Pirrie *et al*. (1991), and Marenssi *et al*. (2001). These last authors divided the sequence in three informal members, denominating them K_1, K_2, and K_3 (Figs 2 & 3). The K_1 member, about 52 m thick, includes mudrocks, sandy mudrocks and very fine

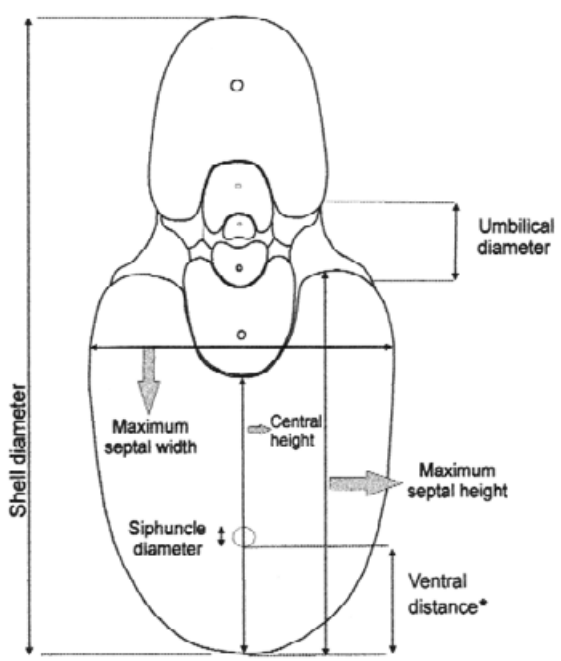

Fig. 4. Scheme showing the parameters measured in the nautilid shells. *Ventral distance is the distance from the ventral border of the siphuncle to the ventral border of the septum.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

sandstones, and was interpreted as deposited in a shallow muddy shelf, near to an estuarine or a deltaic outlet (Pirrie *et al.* 1991). The K_2 member, about 217 m thick, includes muddy sandstones, very fine, fossiliferous sandstones, and fine, moderate fossiliferous sandstones with hummocky cross stratification. It reflects a shallowing-up trend (Olivero *et al.* 1992), from an off-shore environment towards a storm-dominated shoreface environment. The K_1 and K_2 members conform a whole transgressive–regressive cycle (Marenssi *et al*. 2001). The K_3 member, about 170 m thick, includes a conglomerate with inverse grading at the base, very fine, muddy sandstones, sandy shales with ripple lamination, very fine to fine sandstones and fine conglomerates. K_3 was interpreted as deposited in a marine shelf environment and represents a complete transgressive–regressive cycle that ends with subaereal

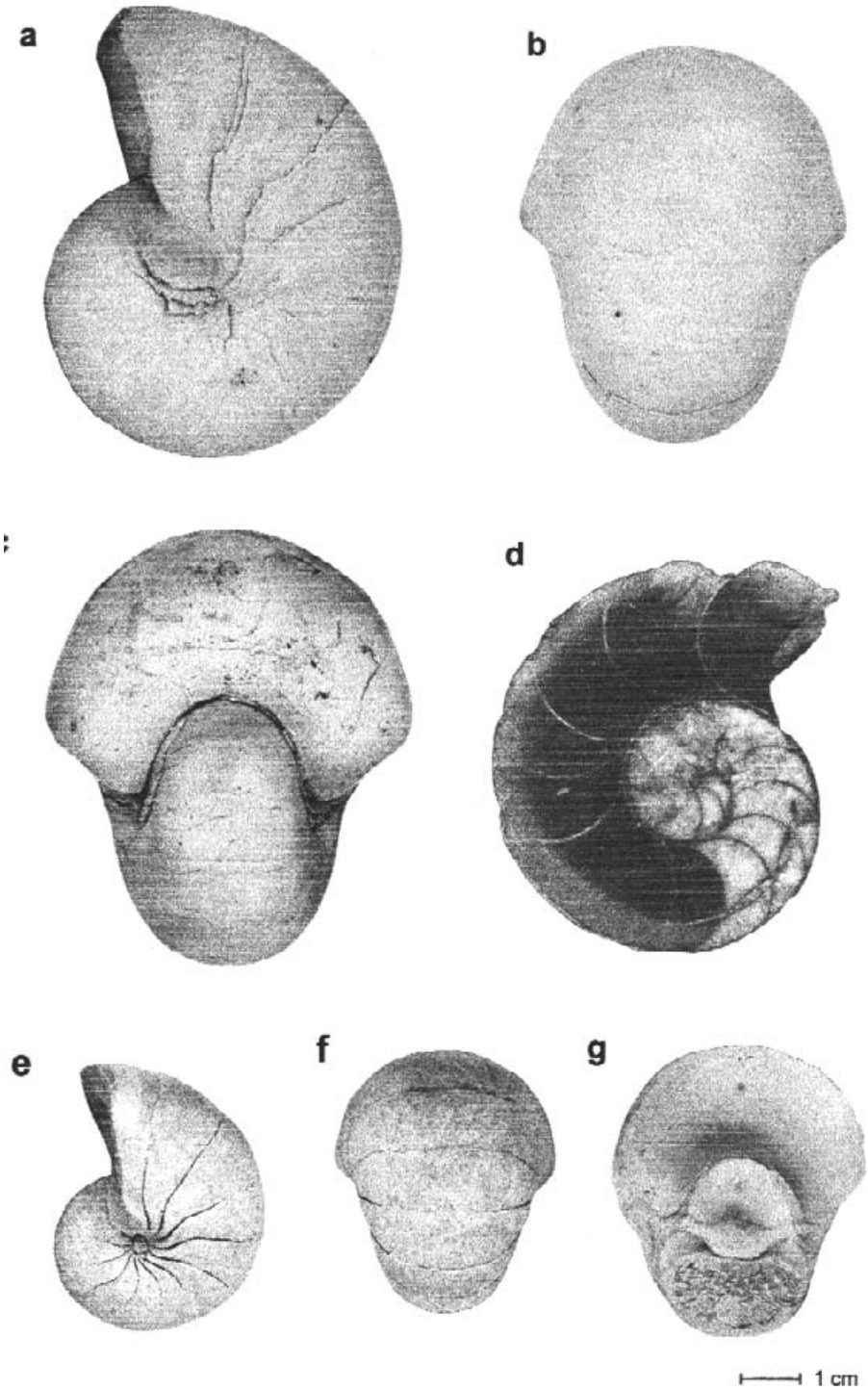

Fig. 5. *Eutrephoceras subplicatum* (Steinmann). **a–c.** CPBA 20043.1 in lateral, ventral and apertural view. **d.** CPBA 20036.6, in sagital cut. **e–f.** CPBA 20041.1 in lateral and ventral views. **g.** CPBA 20043.2 in apertural view.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

exposure (Pirrie *et al*. 1991, Marenssi *et al*. 2001). *Eutrephoceras subplicatum* was found only in members K_2 and K_3 (Fig. 2).

Systematic palaeontology

The genus *Eutrephoceras* was erected by Hyatt (1894) based on the species *Nautilus dekayi* Morton. Most authors have included it in the family Nautilidae (Spath 1927, Kummel 1956, 1964, Shimansky 1975, Tintant & Kabamba 1983), but Miller (1951) placed it in a separate monogeneric family, Eutrephoceratidae, which Matsumoto *et al*. (1984) regarded as a subfamily of Nautilidae. Later, Engeser (1999) placed *Eutrephoceras* in the family Aturiidae. In this paper, *Eutrephoceras* is provisionally considered to belong to Nautilidae, following the most common assumption.

The nautilid material described here is stored at the Palaeontological Collections of the University of Buenos Aires (CPBA). Dimensions of specimens are indicated as follows: U = umbilical diameter, D = shell diameter, W = maximum septal width, H = maximum septal height, Si = siphonal index (ratio between the distance from the ventral border of the siphuncle to the ventral border of the septum and the central height of the septum) (Fig. 4).

Class: Cephalopoda Cuvier 1797
Order: Nautilida Agassiz 1847
Family: Nautilidae De Blainville 1825
Genus *Eutrephoceras* Hyatt 1894

Type species: *Nautilus dekayi* Morton, 1834, from the Campanian of North America, by original designation.

Diagnosis: The conch is nautiliconic and typically subglobular; the whorls are reniform in cross section, broadly rounded ventrally and laterally, and moderately deeply impressed dorsally. The umbilicus is small and inconspicuous, sometimes occluded; the umbilical shoulders are low and rounded. The surface of the conch is generally smooth, sometimes sculptured. The septa are moderately convex apicad; the sutures of typical forms are slightly sinuous, but at least the external sutures of some forms are essentially straight. An annular lobe is present in some species but not in the type species. The siphuncle is small, circular in cross section, and orthochoanitic in structure; its position varies considerably in different species, but in no case it is marginal. (Modified from Miller 1947).

Age: Late Jurassic–Miocene (Kummel 1956).

Eutrephoceras subplicatum (Steinmann) (Figs 5, 6 & 7)

1895 *Nautilus subplicatus* Philippi; Steinmann, pl. 4, figs 1–3, p. 65.
1909 *Nautilus blanfordianus*; Kilian & Reboul, pl. 1, figs 1–2, p. 8.
1953 *Eutrephoceras simile*; Spath, p. 40, pl. 12, figs 1–5.
1955 *Nautilus blanfordianus* Kilian & Reboul; Hünicken, p. 32, 61, 98 & 101.
1955 *Eutrephoceras simile* Spath; Cecioni, p. 143.
1965 *Eutrephoceras simile* Spath; Hünicken, pl. 1, figs. 1–4, pl. 7, fig. 5, p. 50.
1980 *Eutrephoceras simile* Spath; Blasco de Nullo *et al.* pl. 5, figs. 11–13.
1982 *Eutrephoceras simile* Spath; del Valle *et al*., listed in table 30.3, p. 278.
1986 *Eutrephoceras subplicatum* (Steinmann); Stinnesbeck, pl. 6, figs. 1–3, p. 187–188.
1992 *Eutrephoceras simile* Spath; Marenssi *et al*., listed on p. 95.

Lectotype: Specimen described and illustrated by Steinmann (1895, p. 65, fig. 4.2a–c), from the Maastrichtian of Quiriquina Island, Chile.

Material examined: Sixty five specimens: 41 from Vega Island (Cape Lamb) (CPBA 20034.1–4, 20035.1–4, 20036.1–15, 20037.1–4, 20038.1, 20040.1–7, 20041.1–4, 20043.1–2), 15 from James Ross Island (Brandy Bay–Santa Marta Cove) (CPBA 20039.1–3, 20044.1–2, 20045.1, 20048.1, 20051.1–8), 6 from Seymour Island (CPBA 20047.1–6), 1 from Robertson Island (Cape Marsh) (CPBA 20052.1), and 2 from undetermined localities (CPBA 20050.1–2). Santa Marta Formation (Beta and Gamma members) and Snow Hill Island and López de Bertodano formations (K_2 and K_3 members), Early Campanian–Late Maastrichtian.

Description: Medium to large adult forms, with maximum diameter about 170 mm. Nautiliconic, involute nautilid, globular to subglobular in shape (Fig. 5a, b, d–f). The living chamber occupies about half a whorl. The umbilicus is very small in the internal mould (U/D about 0.05) (Fig. 5e), and is covered by a callus if the shelly material is preserved (Fig. 5a). The whorl section is semilunate; the ventral side is rounded and the dorsum impressed (Fig. 5c & g). This impression becomes deeper with ontogeny (Fig. 5g). There is a very small dorsal furrow in the middle part of the dorsum, which is observable only in early ontogenetic stages of some specimens (Fig. 5g), being completely absent in others. The flanks are rounded, and the maximum whorl width is at the dorsal third. The septal width is always larger than the septal height (average W/H: 1.38). The average W/D is 0.84, whereas that of H/D is 0.61. (Table I). The siphuncle is orthochoanitic in structure (Fig. 5d), and its position is between the centre and the venter of the septum (average Si: 0.38) (Fig. 5c & g); there is occasionally a slight tendency to shift the siphuncle to a more ventral position during growth. The diameter of the siphuncle is relatively small (3–4% of the shell diameter). The suture line is very slightly sinuous. It is almost straight

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

Table I. Measurements in *Eutrephoceras subplicatum* shells.

Specimen	Shell diameter	Max. septal width	Max. septal height	Central height	Ventral distance*	Siphuncle diameter	Si	W/H	W/D	H/D
20035.1	49	41.5	-	-	-	-	-	-	0.85	-
20035.1	-	17.3	10.8	9.4	4	1	0.42	1.6	-	-
20035.1	-	21	14	10.8	4	1.3	0.37	1.5	-	-
20035.2	68.4	61	-	-	-	2.6	-	-	0.89	-
20035.2	81	71	-	-	-	3	-	-	0.87	-
20035.2	59	51.7	-	-	-	1.4	-	-	0.87	-
20035.2	-	21.7	16.4	12	5	0.5	0.42	1.32	-	-
20041.2	35	29	22	15	5	1.4	0.33	1.32	0.83	0.63
20041.2	-	85	67	42	12.5	3.5	0.29	1.27	-	-
20041.2	-	24	18	13	5.5	1.5	0.42	1.33	-	-
20041.2	-	45	33	23.6	12	1.6	0.5	1.36	-	-
20034.1	48	42	27	20	11	2	0.55	1.55	0.87	0.6
20034.1	28	24.6	19.6	14	5.8	1.6	0.41	1.25	0.87	0.7
17185.b	59	46	-	-		3	-	-	0.78	-
17185.b	-	35	23	16	4.6	2.5	0.28	1.52	-	-
20041.1	44.6	32	26	18.6	-	-	-	1.23	0.72	0.58
20034.4	60	51	34	23	8	2.5	0.35	1.5	0.85	0.56
20041.4	31	27	19	13.6	5	1	0.37	1.42	0.87	0.61
20036.7	40	32	23	16.5	6	2.3	0.26	1.39	0.8	0.57
20043.2	46.5	39.4	28	18.7	6.6	1.6	0.35	1.41	0.85	0.6
20043.2	16.5	15	10.4	9	4.4	1	0.48	1.44	0.9	0.63
20043.2	-	82.3	62	41	16	4	0.39	1.33	-	-
20043.2	28.3	24.8	16	12	3.4	1	0.28	1.55	0.86	0.56
20043.1	76.5	61.4	47	31	12	3	0.38	1.3	0.8	0.61
20043.1	82	66.6	52.6	31.7	11.5	3	0.36	1.26	0.81	0.64
20043.1	90	72.7	58	34.5	14	2.6	0.4	1.25	0.8	0.64
20043.1	97.5	78	61	37.5	14.2	3.3	0.38	1.28	0.8	0.62
20043.1	117.2	90	77	48	19	3.7	0.39	1.16	0.77	0.65
17185 c	65	52	35	24	-	-	-	1.48	0.8	0.53
17185 c	46	36	27	18	-	-	-	1.33	0.78	0.58
17185 c	-	22.6	17	13	5	1.5	0.38	1.33	-	-
17185 c	-	19	14	10.8	4	1.4	0.37	1.36	-	-
17185 a	30.5	25	18	13	4	1.4	0.31	1.38	0.82	0.59
20036.6	64	58	39	25.4	7.5	2.7	0.29	1.48	0.9	0.61
20036.6	58.6	54.4	34.7	23	7.4	2.4	0.32	1.56	0.92	0.59
20036.6	40.7	34.6	25.4	16	5.6	1.7	0.35	1.36	0.85	0.62
20050.2	52	42	31	18.5	7.4	-	0.4	1.35	0.8	0.59
20050.2	21	18	12	10	-	-	-	1.5	0.85	0.57
20044.1	21	17.6	14	9	3.7	1.3	0.41	1.26	0.83	0.66
20039.1	61	52	-	-	-	2.8	-	-	0.85	-
20044.2	47	45	32	19	-	-	-	1.4	0.95	0.68
20046.7	-	19.7	13.7	10.7	4	1.4	0.37	1.43	-	-
20037.1	55	47	-	-	-	2.6	-	-	0.85	-
20037.1	-	61	-	-	-	2.7	-	-	-	-
20037.1	-	43.6	-	-	-	2.3	-	-	-	-
20037.1	-	79	58	38.5	12	4	0.31	1.36	-	-
20040.3	-	50	-	-	-	2.6	-	-	-	-
20040.3	-	39	-	-	-	2	-	-	-	-
20036.3	28	20	17	13	6	1.7	0.46	1.17	0.71	0.6
20036.3	35	30	22	14.6	6.6	1.7	0.45	1.36	0.85	0.63
20036.3	40	35	25	16.4	7	2	0.42	1.4	0.87	0.62
20036.3	50	43	29	18.4	7	2	0.38	1.48	0.86	0.58
20036.3	71	67	45	28	11	2.7	0.39	1.48	0.94	0.63
20036.3	86	86	59	37	16	3	0.43	1.45	1	0.68
20036.4	-	65.5	45.9	28.6	10.3	2.4	0.36	1.4	-	-
20036.4	-	59.6	42.3	27	10.5	2.4	0.38	1.41	-	-
20036.4	-	55.9	39.3	25.4	9.7	2.6	0.38	1.42	-	-
20036.4	-	81.5	60	38.4	13.3	3.5	0.34	1.35	-	-
20036.5	44.1	36.5	26.3	19.1	6.9	1.3	0.36	1.38	0.82	0.59
20036.5	-	71.7	50.1	31.6	13.2	2.4	0.42	1.43	-	-

*Ventral distance refers to the distance from the ventral border of the siphuncle to the ventral border of the septum.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

Table I. (continued)Measurements in *Eutrephoceras subplicatum* shells.

Specimen	Shell diameter	Max. septal width	Max. septal height	Central height	Ventral distance*	Siphuncle diameter	Si	W/H	W/D	H/D
20036.5	-	76.9	53.6	34.5	13.1	2.8	0.38	1.43	-	-
20036.5	-	39.8	27.6	18.4	6.2	1.6	0.34	1.44	-	-
20036.5	-	43.3	29.9	20	6.9	1.6	0.34	1.45	-	-
20036.5	-	22.6	17.2	13.3	4.6	1	0.34	1.31	-	-
20036.2	-	82	60.5	38.7	13.7	3.7	0.35	1.35	-	-
20036.2	-	65.2	46.2	29	9.9	2.3	0.34	1.41	-	-
20036.2	-	75.3	53.4	35.3	12	3.4	0.34	1.41	-	-
20036.2	-	59.8	44.6	28.1	10	3	0.35	1.34	-	-
20036.2	-	55.6	39	25	9.6	2.4	0.38	1.42	-	-
20036.1	86	86	56	36	15	3.5	0.41	1.53	1	0.65
20036.1	41	35.4	24.7	16.3	6	1.2	0.37	1.43	0.86	0.6
20036.1	-	66.6	45.4	27.7	10.2	2.3	0.37	1.47	-	-
20036.1	-	30.6	21.7	14.4	6	1.5	0.42	1.41	-	-
20036.1	27.4	24.6	16.1	11.8	5.4	0.8	0.46	1.53	0.9	0.59
20036.1	-	20.5	12.5	10.1	4.5	0.7	0.44	1.32	-	-
20047.1	48.6	42.8	29.9	19.8	5.2	1.1	0.26	1.43	0.88	0.61

*Ventral distance refers to the distance from the ventral border of the siphuncle to the ventral border of the septum.

on the venter and flanks, and turned adorally on the umbilical shoulder, forming a small saddle of pointed angle (Fig. 5a, b, d–f). It develops a small lobe, half on the umbilical wall and half on the dorsal side. This is followed by a wide and rounded lateral saddle that ends in a wide dorsal lobe, in the middle of which a very small annular lobe may exist in some specimens in early ontogenetic stages (Fig. 5c & g). The first whorl has about seven chambers, whereas the second has about 14 (Fig. 5d). The embryonic conch has a diameter of approximately 32 mm, and is recognizable because of the presence of the nepionic constriction (Fig. 6a & b). It contains about 5 or 6 septa, as indicated by the position of the septal approximation (a decrease in the septal angle, which occurs between the last

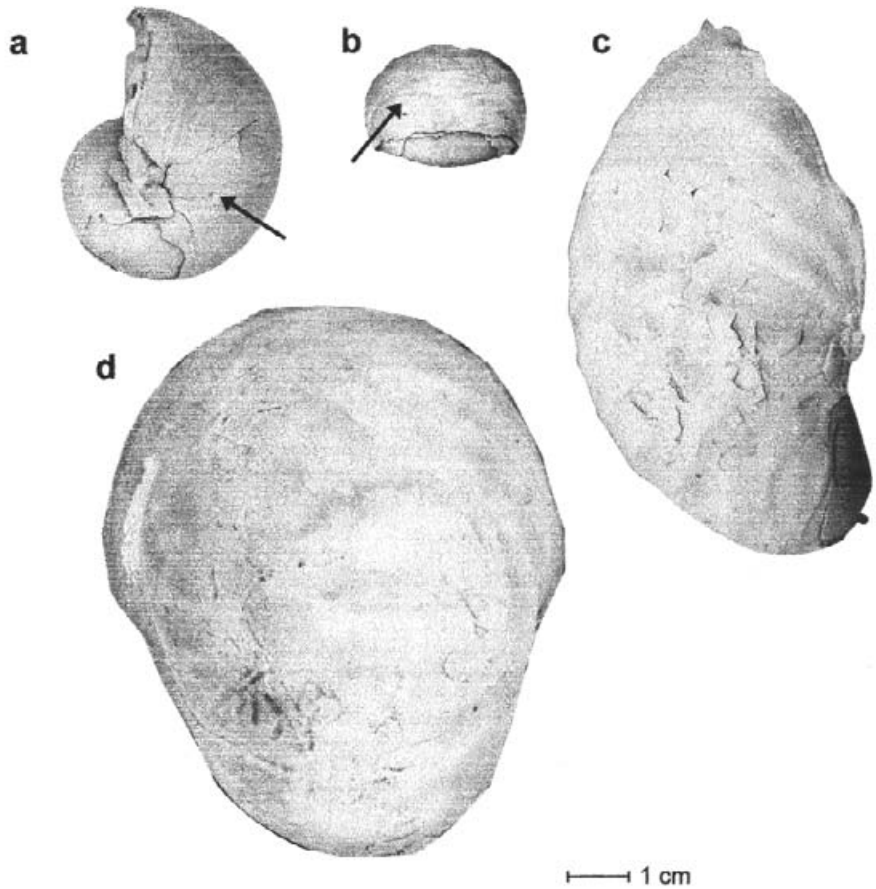

Fig. 6. *Eutrephoceras subplicatum* (Steinmann). **a–b.** CPBA 20041.3 in lateral and ventral views. The arrows show the nepionic constriction. **c–d.** CPBA 20037.4 in lateral and ventral views showing the ornamentation pattern.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

embryonic septum and the first post-embryonic one) (Fig. 7). The umbilical perforation is relatively small due to a rather tight initial coiling (Fig. 5d). The shell ornamentation is variable through the ontogenetic development, and also between different specimens. The embryonic conch is characterized by a fine reticulate pattern, formed by a set of radial and longitudinal ridges (Fig. 6a & b). After that, the ornamentation may consist of growth lines or rounded ribs (Fig. 6c & d); the latter leave their impressions on the internal mould. Their breadth is about 3.5 mm; the interspaces are slightly narrower. The ribs describe a broad adorally convex curve on the flank and cross the venter in an adorally concave sinus.

Remarks: Before Stinnesbeck (1986) considered *E. simile* Spath as a synonym of *E. subplicatum* (Steinmann), Kilian & Reboul (1909) had already noted the similarities between both forms. Recently, the first author revised the nautilid collections from Quiriquina Island (Chile) and Austral Basin (Argentina), and it could be confirmed that these samples were co-specific with the Antarctic material.

Howarth (1965) revized, but not illustrated, Upper Cretaceous nautilids of Angola, previously assigned to *Eutrephoceras egitoense* (Miller & Carpenter 1956), and concluded that they corresponded to *E. simile* Spath (= *E. subplicatum*). Unfortunately, we have only had access to the illustrations from Miller & Carpenter (1956) and therefore, we cannot confirm the validity of Howarth's (1965) taxonomic conclusions. Considering some palaeoecological characteristics of this group of nautilids, and the palaeogeographic configuration at the end of the Cretaceous, the presence of the same species at both sides of the Atlantic Ocean is doubtful (see below).

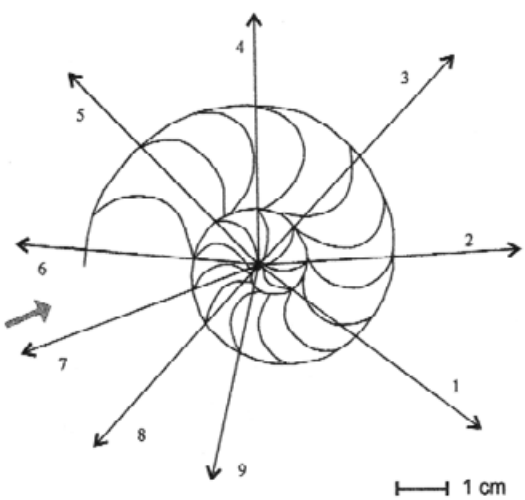

Fig. 7. Scheme showing the septal approximation in *Eutrephoceras subplicatum* (Steinmann), based on a photograph of a sagital cut. The arrows with numbers mark the septum number. The small arrow indicates the approximation between septa 6 and 7.

Some features of *Eutrephoceras subplicatum* are easily recognizable as specific characters, for example the almost straight external suture line with a small and acute saddle on the umbilical shoulder, and the semilunate cross section of the whorls. However, there is some variability within the species, regarding characters as the ornamentation in adults, and the presence of an annular lobe in early ontogenetic stages. The annular lobe is a very small lobe in the middle of the dorsal side of the suture, which corresponds with the dorsal furrow in the septum. It is only present in early ontogenetic stages, whereas it is not visible in later septa. Generally, in species of *Cymatoceras* [e.g. *Cymatoceras perstriatum* (Steuer, 1897) and *C. patagonicum* Cichowolski, 2003, from the Cretaceous of Argentina], this character is constant and conspicuous (Cichowolski 2003). However, in *Eutrephoceras subplicatum* it seems to be an inconspicuous feature. Despite the fact that Spath (1953) did not observe the annular lobe in the Antarctic material, it is present in some specimens of our collection and also in those from the Quiriquina Island. In the Austral basin (Argentina), Hünicken (1965) also noted the presence of that furrow. Since, to our knowledge, the function of this structure is unknown, it is impossible to evaluate its adaptive significance and the potential cause of the variability observed.

Regarding the ornamentation pattern of adult forms, the heterogeneity implies some controversy about the characters commonly used to classify the Post-Triassic nautilids. *Eutrephoceras*, in its original definition (Hyatt 1894), is supposedly a smooth genus. It means that the shell of representatives of this genus is ornamented only with growth lines. Nevertheless, Miller (1947) had noted that some species often have ribs or folds as a variable character within individuals. A known case is *E. bouchardianum* (D'Orbigny, 1840). As mentioned above, specimens of *Eutrephoceras subplicatum* may show rounded ribs on the external surface of the shell, even on the phragmocone, but it is not a constant feature. Following the classification of Spath (1927), every species with ribs should be considered to belong to the family Cymatoceratidae Spath, which was erected to unite genera with ribbed shells. However, it is known that most of these genera have many differences regarding other characters, such as the suture line, the conch and septa shape, etc. Therefore, it is not surprising that the validity of this family has long been questioned (Wiedmann 1960, Shimansky 1975, Tintant & Kabamba 1983, Tintant 1993). The present classification bears some identification problems, given the high morphological homogeneity present in this group of nautilids. As already stated by Kummel (1956), the conch shape and the suture line of many cymatoceratid species are nearly the same as that found in many non-cymatoceratid species. As long as there is no phylogenetic analysis that can resolve the evolutionary relationships of this group of nautilids, the controversy about the systematics will continue.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

Regarding the embryonic conch features, here we report for the first time the size and the number of septa of early post-hatching *E. subplicatum*. The diameter of about 30 mm estimated here corresponds with the reticulate ornamentation pattern described by previous authors (Spath 1953, Hünicken 1965). This pattern is typical of the embryonic stage (Chirat 2001). In our samples, the nepionic constriction appears at approximately this diameter, in addition to the disappearance of the fine reticulate pattern on the shell surface. This size of the embryonic conch is three times larger than that of the type species, *Eutrephoceras dekayi*. Apparently, the latter species has the smallest embryonic conch within Post-Triassic nautilids, with 9–10 mm (Landman *et al*. 1983). According to Engeser (1999), *Eutrephoceras* and *Aturia* have as synapomorphic character an embryonic conch with a maximum diameter of 10 mm. However, Chirat & Rioult (1998) and Chirat (2001) have suggested that the embryonic conch size is a polymorphic character within a genus. Since Engeser (1999) did not show his data matrix (see introductory section), there is no reason to believe that all species belonging to the same genus have the same early ontogenetic features.

Eutrephoceras subplicatum is similar to *E. sphaericum* (Forbes, 1846), from the Upper Cretaceous of India (Wiedmann 1960), in the umbilical callus and the suture line, but they differ in the conch shape (less inflated in the Antarctic species) and the position of the siphuncle (more

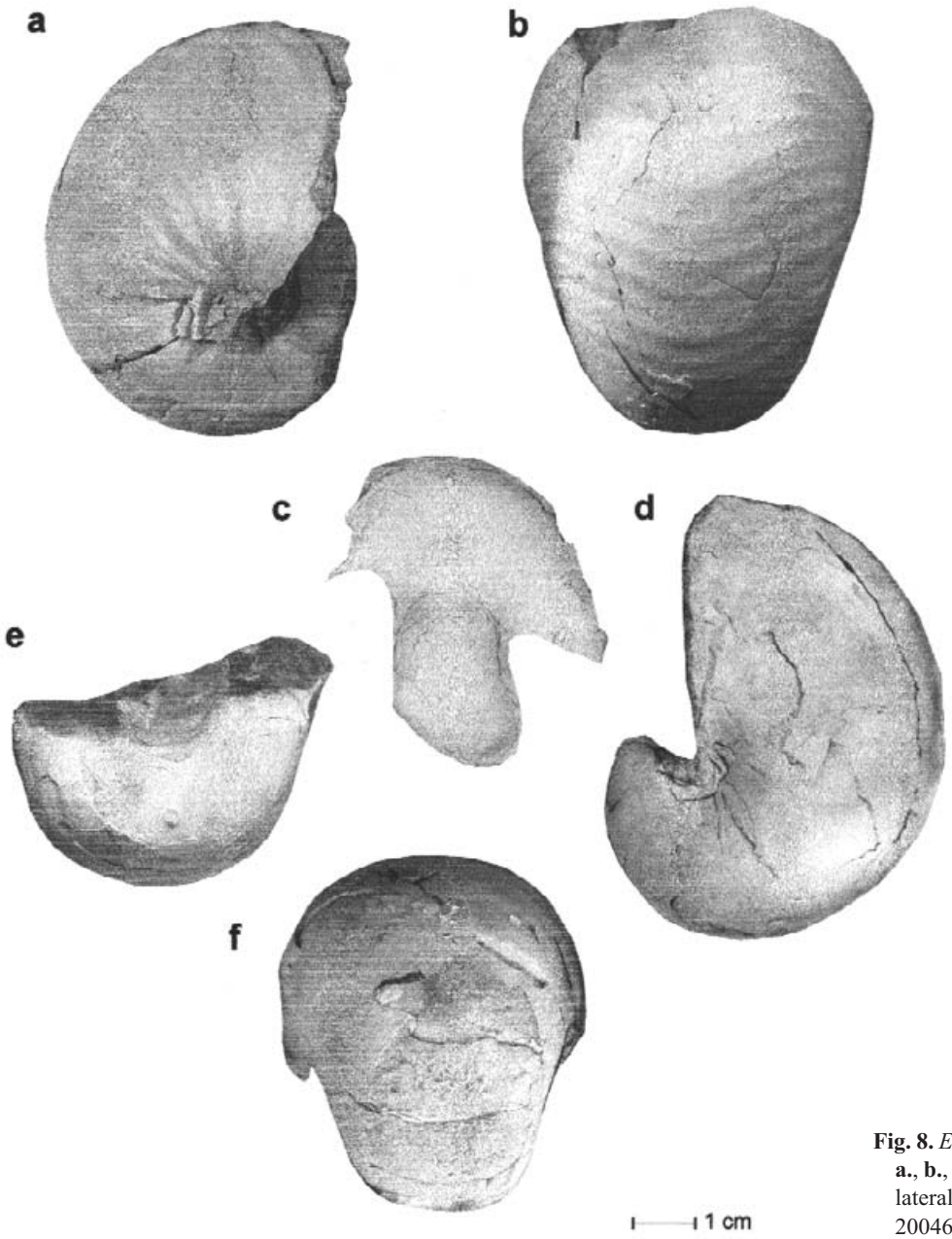

Fig. 8. *Eutrephoceras antarcticum* sp. nov. **a.**, **b.**, **d.** & **f.** CPBA 20046.1 in both lateral and ventral views. **c.** & **e.** CPBA 20046.2 in apertural views.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

ventral in *E. subplicatum*).

Eutrephoceras subplicatum resembles the type, *E. dekayi* from the Campanian of North America (Spengler 1910), in the general conch shape, the suture line and the early reticulate ornamentation, but they are different in the position of the siphuncle (in *E. dekayi* is subdorsal), the ornamentation in adults (*E. dekayi* lacks ribs), and the size of the embryonic conch.

Steinmann's species is similar to *Eutrephoceras bouchardianum* from the Upper Cretaceous from India and Madagascar (Kabamba 1983) in the general conch shape and the presence of ribs in adult forms, but they differ in the suture line. Furthermore, *E. bouchardianum* has a ventral depression on the last whorl.

Eutrephoceras antarcticum sp. nov. (Fig. 8)

Derivation of name: from the Antarctic region.

Material: CPBA 20046.1–3. Two almost complete specimens and one incomplete phragmocone.

Syntypes: CPBA 20046.1–2.

Paratype: CPBA 20046.3.

Horizon and locality: Santa Marta Formation, Beta Member (Fig. 2), N Sequence of Olivero & Medina (2000), upper Lower Campanian. Brandy Bay–Santa Marta Cove, James Ross Island (Figs 1 & 2).

Diagnosis: Nautiliconic, subglobular nautilid with a small umbilicus and a rounded umbilical shoulder. Whorl section reniform. Ventral part of the body chamber slightly impressed. Siphuncle between centrum and venter. Suture line with a low and wide ventral saddle (with a shallow lobe in the middle), a rounded lateral lobe, a small umbilical saddle and a narrow lobe on the umbilical wall. Phragmocone with about 14 chambers per whorl. The ornamentation in latter ontogenetic stages may consist of rounded ribs on the body chamber.

Description: CPBA 20046.1–2 are small specimens (D: 76.2 and 52 mm) with part of the body chamber preserved. Nautiliconic, subglobular conch, with a small umbilicus (U/D about 0.1) on the internal mould (Fig. 8d). The whorl cross section is reniform in outline; the flanks are rounded and the dorsum impressed (Fig. 8c & e). On the body chamber, the ventral part is slightly impressed (Fig. 8b). The septal proportions in CPBA 20046.1 are W/D: 0.86, H/D: 0.67, and W/H: 1.28, whereas in CPBA 20046.2 are W/D: 0.78, H/D: 0.61, W/H: 1.27. The siphuncle is narrow and it is located between the centre and the venter (Si: 0.2) (Fig. 8c & e). The suture line is slightly sinuous with a low and wide ventral saddle with a central shallow lobe in the middle part, followed by a rounded lateral lobe, a small saddle near the umbilical shoulder which ends in a narrow lobe on the umbilical wall (Fig. 8a, d & f). The dorsal part of the suture is not visible. There are about 14 septa in a whorl. In CPBA 20046.1, the ornamentation consists of rounded ribs, with a width between 2.9 and 3.3 mm and interspaces of between 1.3 and 2 mm (Fig. 8a & b). The trajectory of the ribs describes a rounded ventral sinus, an adorally convex curve on the flanks and a small adapically convex curve on the umbilical shoulder.

Remarks: The small and delicate siphuncle, the reniform whorl section and the inconspicuous umbilicus allowed us to assign these specimens to Eutrephoceras Hyatt.

They do not belong to *Kummelonautilus* Matsumoto (1983) because species belonging to that genus have the whorls higher than wide, with ovoid section. Furthermore, the conch is smooth and the suture line lacks the medial lobe in the central part of the ventral saddle. Unfortunately, only three specimens of the new material are available, and because of their poor preservation state, the characteristics to be described are limited. However, we consider that they are enough to be compared with other species and, thus, the erection of a new species is justified.

Eutrephoceras antarcticum is similar to *E. bouchardianum*, from the Upper Cretaceous of India and Madagascar (Kabamba 1983), regarding the presence of a slight ventral depression and rounded ribs on the body chamber, in adult forms. They mainly differ in the sinuosity of the suture line, which is more pronounced in the austral species.

The new species mainly differs from *E. subplicatum* in the suture line (which is straighter in this last species), and in the general conch shape (more inflated and without the ventral depression in *E. subplicatum*). Furthermore, *E. antarcticum* is probably smaller in whole size.

Eutrephoceras antarcticum is different from the type species, *E. dekayi*, from the Campanian of North America, mainly in the position of the siphuncle (subdorsal in the type), and the suture line (straighter in *E. dekayi*) (Shimer & Shrock 1959). Furthermore, *E. dekayi* lacks ribs.

Eutrephoceras antarcticum and *E. azraqensis* Al-Harithi & Ibrahim, 1992, from the Maastrichtian of Jordan, differ mainly in the suture line (more sinuous in *E. antarcticum*).

The new species is very similar to *Anglonautilus japonicus* Matsumoto & Takahashi, 1982, from the Lower Cenomanian of Japan (Matsumoto *et al*. 1984), in the external suture line. Furthermore, they share the ventral shallow depression; they differ however, in the ornamentation (the Japanese species has more conspicuous folds), and in the position of the siphuncle (it is more dorsal in *A. japonicus*). In addition, *A. japonicus* has a deviation from the normal spiral coiling in adult forms.

Eutrephoceras antarcticum differs from *E. indicum* (D'Orbigny, 1850) from the Upper Cretaceous of India (Wiedmann 1960) in the suture line (the Indian form lacks the medial lobe in the middle part of the ventral saddle), and

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

in the whorl cross section shape that is less depressed in the latter species.

The Antarctic species differs from *Eutrephoceras vastum* (Kner, 1848) from the Upper Cretaceous of Europe, in the general conch shape (more globose in *E. vastum*), and in the whorl section (more depressed in *E. vastum*) (Wiedmann 1960).

The new form is different from *Eutrephoceras nodai* Matsumoto, 1983, from the Lower Turonian of Japan, in the conch shape (more compressed in the Japanese species). Furthermore, *E. nodai* lacks the medial lobe in the ventral part of the suture and the rounded ribs.

Eutrephoceras antarcticum differs from *E. soyaense* Matsumoto & Miyauchi, 1983, from the Campanian of Japan, in the suture line (more sinuous in the occidental species), in the ornamentation (the conch is smooth in the oriental form), the position of the siphuncle (more ventral in our species), and in the septal density (lower in *E. antarcticum*).

Eutrephoceras sp. (Fig. 9)

Material examined: CPBA 20042.1. One specimen from Brandy Bay–Santa Marta Cove, James Ross Island (Fig. 1). Santa Marta Formation, Alfa Member (Fig. 2), Lower Campanian (Olivero & Medina 2000).

Description: Incomplete small phragmocone (D: 37.3 mm). Nautiliconic, subglobular conch with the umbilicus closed by a small callus (Fig. 9a). The whorl section shape is not visible but the venter and flanks are rounded (Fig. 9b & c). The whorl proportions are W/D: 0.79, H/D: 0.66, and W/H: 1.2. The siphuncle is not visible. The external part of the suture line is straight (Fig. 9b & c). The embryonic conch has a diameter of approximately 28.2 mm, and is recognizable because of the presence of the nepionic constriction (Fig. 9a). The ornamentation of the embryonic conch consists of a very fine reticulate spiral and radial lirae. Adorally, the ornamentation is composed of growth lines (Fig. 9a).

Remarks: Based on the smooth conch and the straight external suture line, this specimen is assigned to *Eutrephoceras* Hyatt. However, the impossibility to determine such characters as the position of the siphuncle and the whorl section shape do not allow identifying it at a specific level. In particular, the siphuncle position is an important feature at this taxonomic status.

This specimen is similar to *Eutrephoceras dekayi*, in the suture line and the general conch shape, but they differ in the diameter of the embryonic conch, being nearly three times bigger in the Antarctic form.

Eutrephoceras sp. differs from *E. subplicatum* in the conch shape (more inflated in the latter species), and in the suture line (straighter in *Eutrephoceras* sp). They cannot be compared regarding the ornamentation in adults, given the young stage of the single specimen available.

This form differs from *E. antarcticum* sp. nov. mainly in the suture line, which is more sinuous in the latter species.

Discussion

Although the three different taxa described in this paper are recorded from Lower Campanian strata of the James Ross Basin, *Eutrephoceras subplicatum* is represented only by one sample of this age. Furthermore, *Eutrephoceras* sp. was found in the Alpha Member of the Santa Marta Formation, whereas *Eutrephoceras antarcticum* sp. nov. and the single Early Campanian sample of *E. subplicatum* was found in the Beta Member. Even though, the coeval existence of these two species cannot be confirmed, but if the present scenario of the different Indo-Pacific *Nautilus* species is considered (Saunders & Ward 1987), a similar situation could have been possible for some species of *Eutrephoceras* in the James Ross Basin by Late Cretaceous times. Unfortunately, the newly described material is too poor to allow us to make more precise inference about the communities or populations at those times.

Despite *E. subplicatum* had already been described for the James Ross Basin, the knowledge about embryonic conch characteristics contribute to the understanding of the palaeoecology and palaeobiogeography of this species, since it has relation to the reproductive ecology and dispersal of these organisms. The size and number of septa

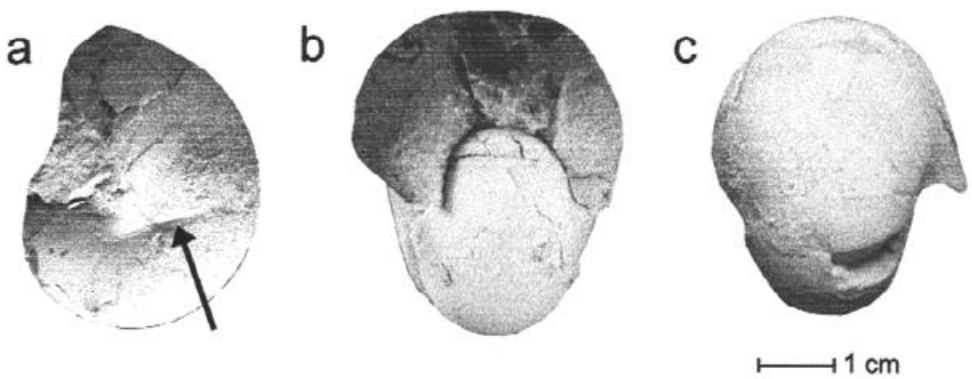

Fig. 9. *Eutrephoceras* sp. **a–c.** CPBA 20042.1 in lateral, apertural, and ventral views. The arrow indicates the nepionic constriction.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

Fig. 10. Palaeogeographic reconstruction and southern hemisphere surface circulation inferred for the Late Campanian and Early Maastrichtian (taken from Huber & Watkins 1992), with the location of the published records of *Eutrephoceras subplicatum*.

in the nauta (embryonic conch) corresponding to this taxon are similar to that of *Nautilus* nauta, and therefore its mode of life could have been similar, too. This could mean that *E. subplicatum*, as probably all post-Triassic nautilids, could have had a nektobenthic life habit through all the life cycle. Because *Eutrephoceras* (like Recent *Nautilus*) was possibly a nektobenthic scavenger (Ward *et al*. 1980), limited to depths less than approximately 800 m, due to implosion of the phragmocone (Westermann 1973), it is improbable that these animals could have crossed wide and deep oceans.

Following this reasoning, it is worth noting that many genera of post-Triassic nautilids are distributed world-wide (e.g. *Cymatoceras* and *Eutrephoceras*), although at specific level, provincial differences seem to rule. This contrasts markedly to that of certain species of ammonoids, which had a really world-wide distribution (Matsumoto *et al*. 1984). This difference may be attributed to the fact that ammonoids, in contrast to nautiloids, had a planktonic stage after hatching (Landman *et al*. 1983, 1996, Jacobs & Landman 1993) and could therefore be widely distributed by oceanic currents at this ontogenetic stage. Therefore, it is worth discussing the palaeogeographical distribution of *E. subplicatum*, since it has been reported, as mentioned above, not only from Antarctica, Chile, and Argentina, but from Angola (west-central Africa) as well (Fig. 9). The Antarctic Peninsula, the Austral Basin in southern Argentina, and the Quiriquina Island in central Chile, were located along the Pacific margin by the Late Cretaceous. The geometry of the Patagonia/Antarctica cusp is problematical, but, probably, there was not a great marine distance between both regions (Zinsmeister 1987, Vaughan & Storey 2000, Macdonald *et al*. 2003). Hence, the nautilids could have migrated at this margin between the different regions (Fig. 10). Taking into account the palaeocurrent pattern of the Late Cretaceous (Huber & Watkins 1992) and the available data of the host strata ages (Early Campanian–Maastrichtian in Antarctica, Late Campanian–Maastrichtian in Argentina, and Maastrichtian in Chile) (Cecioni 1955, Stinnesbeck 1986), we suggest that *E. subplicatum* migrated from the Antarctic Peninsula northward, to southern Argentina and central Chile. The existence of a shallow marine route from South America/Antarctica to Angola is more complicated to propose and certify by these times, considering the most accepted palaeogeographical configurations that locate these regions separated by a wide and deep Atlantic Ocean. For the case that the African specimens are true *E. subplicatum*, it could be explained by the Mabesoone & Stinnesbeck's (1993) hypothesis, which implies that the last link between South America and Africa, in the Pernambuco–Paraiba area, rifted at the end of the Cretaceous, and that the new continuous Atlantic seaway remained narrow, probably up to the Eocene. The absence of *E. subplicatum* records along the Atlantic margin of South America could be due a fossil record bias.

Acknowledgements

The authors are very grateful to Markus Wilmsen (Institut für Paläontologie, Würzburg), Neil Landman (American Museum of Natural History, New York), and Alan Vaughan (British Antarctic Survey, Cambridge), for their constructive and helpful reviews of this paper. We also thank very specially Eduardo Olivero (CADIC, Ushuaia) and Francisco Medina (University of Buenos Aires) for providing many of the fossil specimens studied here, and for the assistance with some literature. We are grateful to Wolfgang Stinnesbeck (Universität Karlsruhe, Germany) for the fruitful discussions via e-mail, and his reprints. We acknowledge Christian Salazar (Universidad de Concepción, Chile) and Fernanda Rodríguez (SEGEMAR, Buenos Aires, Argentina) for access to fossils under their care, and Axel Bachmann (Universidad de Buenos Aires) for translating some German literature. We thank Rubén Somoza (Universidad de Buenos Aires) for the given useful information, and Beatriz Aguirre-Urreta and Andrés Folguera (Universidad de Buenos Aires) for their help in revising the manuscript. This research was partially supported by the Instituto Antártico Argentino (A. Concheyro) and the Paleontological Research Institution Award (to M. Cichowolski).

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

References

Agassiz, L. 1847. *An introduction to the study of natural history.* New York: Greeley & McElrath, 58 pp.

Al-Harithi, T. & Ibrahim, K. 1992. Some Cephalopoda from Maastrichtian outcrops of Wadi Usaykhim, Al Azraq area in East Jordan. *Senckenbergiana Lethaea*, **71**, 427–437.

Blanford, H.F. & Stoliczka, F. 1865. Fossil Cephalopoda, Cretaceous rocks, Southern India. *Memoirs of the Geological Survey of India. Palaeontologia Indica*, **1**, 1–40.

Blasco De Nullo, G., Nullo, F. & Proserpio, C. 1980. Santoniano–Campaniano: Estratigrafía y contenido ammonitifero. Cuenca Austral. *Revista de la Asociación Geológica Argentina*, **35**, 467–493.

Cecioni, G. 1955. Distribuzione verticale di alcune Kossmaticeratidae nella Patagonia Cilena. *Bolletino della Societá Geologica Italiana*, **74**, 141–149.

Chirat, R. 2001. Anomalies of embryonic shell growth in post-Triassic Nautilida. *Paleobiology*, **27**, 485–499.

Chirat, R. & Rioult, M. 1998. Occurrence of early post-hatching Jurassic Nautilida in Normandy, France: palaeobiologic, palaeoecologic and palaeobiogeographic implications. *Lethaia*, **31**, 137–148.

Cichowolski, M. 2003. The nautiloid genus *Cymatoceras* from the Cretaceous of the Neuquén and Austral basins, Argentina. *Cretaceous Research*, **24**, 375–390.

Crame, J.A., Pirrie, D., Riding, J.B. & Thomson, M.R.A. 1991. Campanian–Maastrichtian (Cretaceous) stratigraphy of the James Ross Island area, Antarctica. *Journal of the Geological Society*, *London*, **148**, 1125–1140.

Crame, J.A., Lomas, S.A., Pirrie, D. & Luther, A. 1996. Late Cretaceous extinction patterns in Antarctica. *Journal of the Geological Society*, *London*, **153**, 503–506.

Crame, J.A., Francis, J.E., Cantrill, D.J. & Pirrie, D. 2004. Maastrichtian stratigraphy of Antarctica. *Cretaceous Research*, **25**, 411–423.

Cuvier, G. 1797. *Tableau élementaire de l´histoire naturelle des animaux*. Paris: Baudouin, 710 pp.

De Blainville, H.M.D. 1825. *Manuel de malacologie et de conchyliologie*. Paris: F.G. Levrault, 664 pp.

Del Valle, R.A., Fourcade, N.H. & Medina, F.A. 1982. The stratigraphy of Cape Lamb and The Naze, Vega and James Ross islands, Antarctica. *In* Craddock, C., *ed. Antarctic geoscience.* Madison: University of Wisconsin Press, 275–280.

Elliot, D.H., Rinaldi, C.A., Zinsmeister, W.J., Trautman, T.A., Bryant, W.A. & Del Valle, R.A. 1975. Geological investigations on Seymour Island, Antarctic Peninsula. *Antarctic Journal of the United States*, **10**, 182–186.

Engeser, T. 1999. Phylogeny of the "Post-Triassic" nautiloids. *Fifth International Symposium. Cephalopods - Present and Past* (*Vienna*), *Abstracts*, 36.

Forbes, E. 1846. Report on the fossil invertebrata from Southern India, collected by Mr. Kaye and Mr. Cunliffe. *Transactions of the Royal Geological Society of London*, **2**, 97–174, pls. 7–19.

Ghidella, M.E. & Labrecque, J.L. 1992. Anomalías magnéticas sobre la Isla James Ross y terrenos circundantes. *In* Rinaldi, C.A., *ed. Geología de la Isla James Ross*. Buenos Aires: Instituto Antártico Argentino. Dirección Nacional del Antártico, 299–313.

Howarth, M.K. 1965. Cretaceous ammonites and nautiloids from Angola. *Bulletin of the British Museum* (*Natural History*). *Geology Series*, **10**, 335–412.

Huber, B.T. & Watkins, D.K. 1992. Biogeography of Campanian–Maastrichtian calcareous plankton in the Region of the Southern Ocean: paleogeographic and paleoclimatic implications. *Antarctic Research Series*, **56**, 31–60.

Hünicken. M. 1955. Depósitos neocretácicos y terciarios del extremo SSW de Santa Cruz (Cuenca Carbonífera de Río Turbio). *Revista del Instituto Nacional de Investigación de las Ciencias Naturales. Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"*, **4**, 1–164.

Hünicken, M. 1965. Algunos cefalópodos supracretácicos del Río Turbio (Santa Cruz). *Revista de la Facultad de Ciencias Exactas Físicas y Naturales de la Universidad de Córdoba. Serie Ciencias Naturales*, **52**, 47–80.

Hyatt, A. 1894. Phylogeny of an acquired characteristic. *Proceedings of the American Philosophical Society*, **41**, 349–647.

Ineson, J.R. 1986. Proximal deep-water sedimentation in a Cretaceous back-arc basin, Antarctica. *Abstracts of the XII International Sedimentological Congress*, *Canberra*, *Australia*, *August 24–30*, *1986*, 152.

Jacobs, D.K. & Landman, N.H. 1993. *Nautilus* – a poor model for the function and behavior of ammonoids? *Lethaia*, **26**, 101–111.

Kabamba, M. 1983. *Les nautiles du Crétacé supérieur de Madagascar; contribution à l´étude de l´évolution des Nautiloïdes du Crétacé; systématique*, *phylogenie*, *biostraigraphie*, *paléoécologie*, *évolution.* Thèse de 3ème cycle, Géologie, Université Dijon, 136 pp, 7 pls. [Unpublished]

Kilian, W. & Reboul, P. 1909. Des céphalopodes néocrétacés des Iles Seymour et Snow Hill. *Wissenschaftliche Ergebnisse der Schwedisch-en Südpolar-Expedition (1901–1903)*, **3**(6), 1–75.

Kner, R. 1848. Versteinerungen des Kreidemergels von Lemberg und seiner Umgebung. *Haidingers Naturwissenschatliche Abhandlungen*, **3**(2), 1–42, pls. 1–5.

Kummel, B. 1956. Post-Triassic Nautiloid Genera. *Bulletin of Museum of Comparative Zoology at Harvard College*, **114**, 324–494.

Kummel, B. 1964. Nautiloidea-Nautilida. *In* Moore, R.C., *ed. Treatise on Invertebrate Paleontology*, K, Mollusca 3. Lawrence: Geological Society of America and University of Kansas Press, K383–K457.

Landman, N.H., Rye, D.M. & Shelton, K.L. 1983. Early ontogeny of *Eutrephoceras* compared to Recent *Nautilus* and Mesozoic ammonites: evidence from shell morphology and light stable isotopes. *Paleobiology*, **9**, 269–279.

Landman, N.H., Tanabe, K. & Shigeta, Y. 1996. Ammonoid embryonic development. *In* Landman, N.H., Tanabe, K. & Davis, R.A., *eds*. *Ammonoid paleobiology*. New York: Plenum Press, 343–405.

Lirio, J.M., Marenssi, S.A. Marshall, P.A., Santillana, S.N. & Rinaldi, C.A. 1989. Marambio Group at the southeastern part of James Ross Island, Antarctica. *Instituto Antártico Argentino. Contribución*, **371**, 46 pp.

Mabesoone, J.M. & Stinnesbeck, W. 1993. Did South American elements of the Messel fauna migrate via Africa? *Darmstädter Beiträge zur Naturgeschichte*, **3**, 257–262.

Macdonald, D., Gomez-Pereza, I., Franzese, J., Spalletti, L., Lawverc, L., Gahagan, L., Dalziel, I., Thomas, C., Trewin, N., Hole, M. & Paton, D. Mesozoic break-up of SW Gondwana: implications for regional hydrocarbon potential of the southern South Atlantic. *Marine and Petroleum Geology*, **20**, 287–308.

Marenssi, S.A., Santillana, S.N. & Rinaldi, C.A. 1998. Stratigraphy of La Meseta Formation (Eocene), Marambio Island, Antarctica. *In* Casadío, S., *ed*. *Paleógeno de América del Sur y de la Península Antártica*. *Revista de la Asociación Paleontológica Argentina*, *Publicación Especial*, **5**, 137–146

Marenssi, S.A., Salani, F.M. & Santillana, S.N. 2001. Geología del Cabo Lamb, Isla Vega, Península Antártica. *Instituto Antártico Argentino*, *Contribución*, **530**, 1–43.

Marenssi, S.A., Lirio, J.M., Santillana, D.R. & Palamarczuk, S. 1992. El Cretácico Superior de la Isla James Ross, Antártida. *In* Rinaldi, C.A., *ed. Geología de la Isla James Ross*. Buenos Aires: Instituto Antártico Argentino. Dirección Nacional del Antártico, 77–85.

Matsumoto, T. 1983. Cretaceous nautiloids from Hokkaido I. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, **129**, 9–25.

CAMBRIDGE JOURNALS

http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16

Matsumoto, T. & Miyauchi, T. 1983. Cretaceous nautiloids from Hokkaido III. Some nautiloids from the Campanian of Soya, Northern Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, **132**, 220–229.

Matsumoto, T. & Takahashi, T. 1982. A new nautiloid species from the Cretaceous of Hokkaido. *Proceedings of the Japanese Academy of Science*, **58B**, 259–298.

Matsumoto, T., Takahashi, T., Obata, I. & Futakami, M. 1984. Cretaceous nautiloids from Hokkaido – IV. An interesting nautiloid species from the Cenomanian of Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, **133**, 288–299.

Medina, F.A., Buatois, L. & López Angriman, A. 1992. Estratigrafía del Grupo Gustav en la isla James Ross, Antártida. *In* Rinaldi, C.A., *ed*. *Geología de la isla James Ross*. Buenos Aires: Instituto Antártico Argentino, Dirección Nacional del Instituto Antártico, 167–192.

Miller, A.K. 1947. Tertiary nautiloids of the Americas. *Memoir of the Geological Society of America*, **23**, 1–234.

Miller, A.K. 1951. Tertiary nautiloids of West-coastal Africa. *Annales du Musée du Congo Belge*, *Sciences Géologiques*, **8**, 1–88.

Miller, A.K. & Carpenter, L.B. 1956. Cretaceous and Tertiary nautiloids from Angola. *Estudos*, *Ensayos e Documentos*, **21**, 1–48. Lisbon.

Morton, S.G. 1834. *Synopsis of the organic remains of the Cretaceous group of the United States*. Philadelphia: Key and Biddle, 1–88, pls. 1–19.

Olivero. E.B. & Medina, F.A. 2000. Patterns of Late Cretaceous ammonite biogeography in southern high latitudes: the family Kossmaticeratidae in Antarctica. *Cretaceous Research*, **21**, 269–279.

Olivero, E.B., Scasso, R.A. & Rinaldi, C.A. 1986. Revisión del Grupo Marambio en la isla James Ross, Antártida. *Instituto Antártico Argentino*, *Contribución*, **331**, 1–29.

Olivero, E.B., Martinioni, D.R. & Mussel, F.J. 1992. Upper Cretaceous sedimentology and biostratigraphy of western Cape Lamb (Vega Island, Antarctica). Implications on sedimentary cycles and evolution of the basin. *In* Rinaldi, C.A., *ed*. *Geología de la isla James Ross*. Buenos Aires: Instituto Antártico Argentino, Dirección Nacional del Instituto Antártico, 147–166.

Olivero, E.B., Buatois, L.A. & Scasso, R.A. 2004. *Paradictyiodora antarctica*: a new complex vertical spreite trace fossil from the Upper Cretaceous–Paleogene of Antarctica and Tierra del fuego, Argentina. *Journal of Paleontology* **78**(4), 783–789.

D'Orbigny, A. 1840–1842. *Paléontologie Française. Terrains Crétacé I*, *Céphalopodes.* Paris: Victor Masson. 662 pp, 151 pls (1–120, 1840; 121–430, 1841, 431–662, 1842).

D'Orbigny, A. 1850. *Prodrome de Paléontologie stratigraphique universelle des animaux mollusques et rayonnés*. II. Paris: Victor Masson, 427 pp.

Pirrie, D. 1989. Shallow marine sedimentation within an active margin basin, James Ross Island, Antarctica. *Sedimentary Geology*, **63**, 61–82.

Pirrie, D., Crame, J.A. & Riding, J.B. 1991. Late Cretaceous stratigraphy and sedimentology of Cape Lamb, Vega Island, Antarctica. *Cretaceous Research*, **12**, 227–258.

Pirrie, D., Crame, J.A., Lomas, S.A. & Riding, J.B. 1997. Late Cretaceous stratigraphy of the Admiralty Sound region, James Ross Basin, Antarctica. *Cretaceous Research*, **18**, 109–137.

Rinaldi, C.A. 1982. The Upper Cretaceous in the James Ross Island Group. *In* Craddock, C., *ed. Antarctic geoscience.* Madison: University of Wisconsin Press, 281–286.

Rinaldi, C.A., Massabie, A., Morelli, J. Rosenman, H.L. & Del Valle, R. 1978. Geología de la isla Vicecomodoro Marambio. Buenos Aires: *Instituto Antártico Argentino*, *Contribución*, **217**, 1–37.

Saunders, B.W. & Ward, P.D. 1987. Ecology, distribution, and population characteristics of *Nautilus*. *In* Saunders, B.W. & Landman, N.L., *eds. Nautilus. The biology and paleobiology of a living fossil.* New York: Plenum Press, 137–161.

Scasso, R.A., Olivero, E.B. & Buatois, L.A. 1991. Lithofacies, biofacies, and ichnoassemblage evolution of a shallow submarine volcaniclastic fan-shelf depositional system (Upper Cretaceous, James Ross Island, Antarctica). *Journal of South American Earth Sciences*, **4**, 239–260.

Shimansky, V.N. 1975. *Melovye Nautiloidei*. Academy of Sciences of the URSS, Transactions of the Palaeontological Insitute **150**, Moscow, 208 pp. (In Russian).

Shimer, H.W. & Shrock, R.R. 1959. *Index fossils of North America*. New York: John Wiley & Sons, 837 pp.

Spath, L.F. 1927. Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch). *Memoirs of the Geological Survey of India*, *Palaeontolgia Indica*, *New Series*, **9**, 1–71.

Spath, L.F. 1953. The Upper Cretaceous cephalopod fauna of Graham Land. *Falkland Islands Dependencies Survey*, *Scientific Reports*, No. 3, 2–58.

Spengler, E. 1910. Untersuchungen über die südindische Kreideformation. 4. Die Nautiliden und Belemniten des Trichinopoly districts. *Beiträge für Pälaontologie und Geologie Osterreich–Ungarns und des Orients*, **23**, 125–157.

Steinmann, G. 1895. Die Cephalopoden der Quiriquina-Schichten. *Neues Jahrbuch für Mineralogie*, *Geologie und Paläontologie*, **10**, 64–68.

Steuer, A. 1897. Argentinische Jura-Ablagerungen. Ein Beitrag zur Kenntniss der Geologie und Paläeontologie der argentinischen Anden. *Palaeontologische Abhandlungen* **7**, *Neue Folge*, **3**, 222 pp.

Stinnesbeck, W. 1986. Zu den faunistischen und palökologischen Verhältnissen in der Quiriquina Formation (Maastrichtium) Zentral-Chiles. *Palaentographica Abteilung A*, **194**, 99–237.

Tintant, H. 1993. L´évolution itérative des nautiles post-Triasiques. *Geobios*, *Memoire Special*, **15**, 359–372.

Tintant, H. & Kabamba, M. 1983. Le Nautile, fossile vivant ou forme cryptogene? Essai sur l'évolution et la classification des nautilacés. *Bulletin de la Société Zoologique de la France*, **108**, 569–579.

Vaughan, A.P.M. & Storey, B.C. 2000. The eastern Palmer Land shear zone: a new terrane accretion model for the Mesozoic development of the Antarctic Peninsula. *Journal of the Geological Society*, *London*, **157**, 1243–1256.

Ward, P.D., Greenwald, L. & Rougerie, F. 1980. Shell implosion depth for living *Nautilus macromphalus* and shell strength of extinct cephalopods. *Lethaia*, **13**, 182.

Westermann, G.E.G. 1973. Strength of concave septa and depth limits of fossil cephalopods. *Lethaia*, **6**, 383–403.

Wiedmann, J. 1960. Zur Systematik Jungmesozoischer Nautiliden. *Palaeontographica Abteilung A*, **115**, 144–206.

Zinsmeister, W.J. 1987. Cretaceous paleogeography of Antarctica. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, **59**, 197–206.

CAMBRIDGE JOURNALS
http://journals.cambridge.org Downloaded: 19 May 2013 IP address: 54.234.42.16