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MARINE CRETACEOUS ORGANIC-WALLED DINOFLAGELLATE CYSTS FROM THE AUSTRAL-MAGALLANES BASIN

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ABSTRACT

Cretaceous marine sedimentary rocks from the Austral-Magallanes Basin have provided a valuable organic-walled dinoflagellate cyst record as a useful tool for biostratigraphical interpretations and paleo-oceanographical reconstructions. This paper contains a revision of the main dinoflagellate cyst information previously published in southwest Patagonia and the Continental Platform, encompassing two time intervals, the Late Hauterivian to Early Cenomanian and the Campanian to Maastrichtian. We present for the first time a sequence of Cretaceous diagnostic dinoflagellate cyst events identified at surface and subsurface sections throughout the Austral-Magallanes Basin. In ascending order, nineteen primary bioevents of first occurrence (FO), last occurrence (LO) and acme were recognized. Eleven biovents were identified in the Early Cretaceous: LO of *Senoniasphaera tabulata*, LO of *Kleithriaphaeridium fasciatum*, FO of *Prolixosphaeridium parvispinum*, LO of *Phoberocysta neocomica*, FO of *Herendeenia postprojecta*, FO of *Odontochitina operculata*, LO of *Cassiculosphaeridia magna* and the LO of *Kaiwaradinium scrutillinum*, *Ovoidinium* sp. Acme, LO of *Dingodinium cerviculum* and LO of *Muderongia tetracantha*. Nine bioevents were identified in the Late Cretaceous: FO of *Odontochitina porifera*, FO of *Palaeohystrichophora infusorioides*, FO of *Nelsoniella aceras*, FO of *Nelsoniella tuberculata*, FO of *Xenikoon australis,* LO *Nelsoniella aceras,* LO of *Odontochitina spinosa*, FO of *Manumiella druggii* and FO of *Eisenackia circumtabulata*. In general, the Austral-Magallanes Basin assemblages compare well with those coeval from the middle to high Southern Hemisphere latitudes sites, suggesting paleo-oceanographical connections between the southernmost tip of South America, Antarctica, New Zealand and Australia during the Cretaceous.

INTRODUCTION

Dinoflagellates are eukaryotic unicellular organisms occupying most aquatic environments, from freshwater bodies to the open ocean. Along with diatoms, free-living dinoflagellates are the main component of marine phytoplankton and represent an important part of primary productivity in aquatic ecosystems. During their life cycle, some dinoflagellates produce preservable non-motile organic-walled resting cysts while others calcareous and siliceous cysts (mainly vegetative). The usefulness and applications of dinoflagellates from a paleontological point of view derive from the preservation potential of the resting cysts in the fossil record. Their specific diversification and the substitution of taxa over time, define them as excellent biostratigraphic markers. Several dinoflagellate cyst-based biostratigraphical frameworks offer valuable biostratigraphic information for Cretaceous marine sequences in the Northern (*e.g.,* Prössl, 1990; Williams *et al*., 1990; Harding, 1990; Nør-Hansen, 1993; Leereveld, 1997a, b; Torricelli, 2000; Pestchevitskaya, 2008; Pestchevitskaya *et al*., 2011), as well as in the Southern Hemisphere (*e.g.*, Wilson, 1984; Helby *et al.,* 1987; Marshall, 1990; Schiøler and Wilson, 1998; Roncaglia *et al*., 1999; Riding and Crame 2002; Oosting *et al.,* 2006; Bowman *et al.,* 2012). In southern South America, the marine sedimentary rocks of the Austral-Magallanes Basin present a rich dinoflagellate cyst record that have contributed to elucidate biostratigraphic and palaeobiogeographic aspects in the Cretaceous marine succesions (*e.g.,* Pöthe de Baldis and Ramos, 1983*;* Pöthe de Baldis, 1986; Palamarczuk *et al*., 2000 a, b; Guler *et al*., 2003; Marenssi *et al*., 2004; Guler *et al.,* 2005; Guler and Archangelsky, 2006; Povilauskas and Guler, 2008; Guler *et al*., 2015; Gonzalez Estebenet *et al*., 2017).

The aim of this work is to document the main organic-walled dinoflagellate cyst records from the Cretaceous sedimentary sequences of the Austral-Magallanes basin published to date. Also, we present for the first time a sequence of a selected significative biostratigraphical diagnostic taxa events of first (FO) and last (LO) occurrences, identified throughout the Cretaceous in the Austral-Magallanes Basin. The sequence of bioevents was compared with other biostratigraphical frameworks of middle to high latitudes sites (*e.g.,* Morgan, 1980; Helby *et al*., 1987; Bowman *et al*., 2012). The global spatial differentiation of dinoflagellate cyst assemblages (i.e., provincialism) depends on physicochemical characteristics of the water masses and the ancient surface water circulation patterns (*e.g.*, Sluijs e*t al*., 2005; Pross and Brinkhuis, 2005). Comparison with other Cretaceous assemblages from elsewhere allowed inferring biogeographical affinities and their implication in the oceanographical circulation in the southernmost tip of South America.

GEOLOGICAL SETTING

The Austral-Magallanes Basin is located in the southernmost region of South America (Fig. 1) and is limited by the Southern Patagonian Andes to the west, the Deseado Massif to the northeast and the Río Chico High to the east (Biddle *et al*., 1986; Robbiano *et al*., 1996; Galeazzi, 1998). The geological and sedimentary history of the Austral-Magallanes Basin is related to three main tectonic stages (Biddle *et al*., 1986; Robbiano *et al*., 1996; Ramos, 2002; Rodríguez and Miller, 2005). The initial rift stage took place during Middle to Late Jurassic and correlates with the break-up of Gondwana (*e.g.*, Pankhurst *et al.*, 2000). During this extensional episode grabens and half-grabens were filled with lacustrine, volcaniclastic and alluvial sediments of the "Serie Tobífera"/El Quemado (*e.g.*, Arbe and Fernández Bell Fano, 2002) related with the development of a marginal basin in the southwest area of the basin (the Rocas Verdes Basin) associated to the opening of the Wedell Sea (Dalziel, 1981; Biddle *et al*., 1986). Subsequently, during the subsidence episode, the sedimentary infilling is represented by fluvial, estuarine and marine deposits of the transgressive sequences of the Springhill Formation (Fig. 2) Robbiano *et al*., 1996; Arbe, 2002; Schwarz *et al*., 2011). In turn, the Springhill Formation is overlaid by a thick deep-marine succession, characterized by alternating black mudstones and marls of the Río Mayer Formation, which extends to the Albian (Fig. 2) (Biddle *et al*., 1986; Arbe, 1989, 2002; Rodriguez and Miller, 2005; Richiano *et al.,* 2012, 2013). Towards the end of this cycle (Lower Aptian-Albian) in the North and East sector of the basin, a large deltaic system resulted in the deposition of the Piedra Clavada Formation (Poiré *et al*., 2004; Richiano *et al*., 2012) and its equivalent Kachaike Formation in the Lago San Martín area (Fig. 2). The last foreland basin stage initiate in the "mid"-Cretaceous and is characterized by a regional change from an extensive to a compressive phase and the onset of a retroarc fold-thrust belt (Ramos *et al*., 1982; Biddle *et al*., 1986; Wilson, 1991; Fildani *et al*., 2003; Fildani and Hessler, 2005). The Cenomanian to ?Santonian continental to marginal marine Mata Amarilla Formation is a key unit in the development of the basin, as it marks the beginning of this foreland stage of the Basin (Fig. 2) (Arbe, 1989; Varela and Poiré, 2008; Varela, 2009, 2011, 2015; Varela *et al*., 2012). The Alta Vista Formation of a late Santonian-late Campanian age, also represents one of the first marine deposits accumulated during the foreland basin stage (Arbe and Hechem, 1984; Kraemer and Riccardi, 1997). This unit overlies conformably the Cerro Toro Formation and it is conformably covered by the Anita Formation (Fig. 2). Finally, the youngest Late Cretaceous marine succession includes the

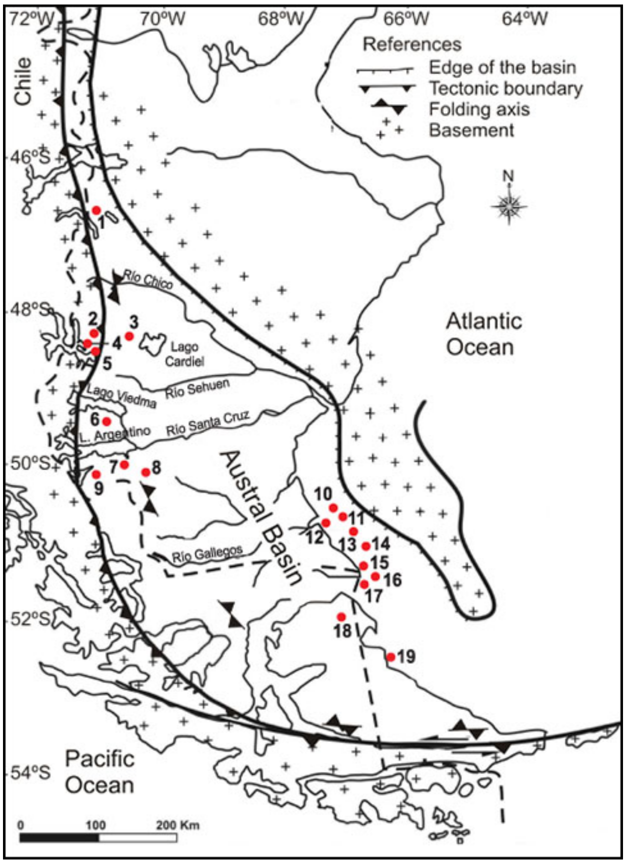

Figure 1. Location map of the Austral Basin, southernmost part of South America, indicating the sites mentioned in the text: 1) Springhill Formation, El Salitral farm (Ottone and Aguirre Urreta, 2000). 2) Río Mayer Formation, Fósiles River (Pöthe de Baldis and Ramos, 1983, 1988). 3-5) Río Mayer/Piedra Clavada Formation, Lago Cardiel (Medina *et al.*, 2008). 3) Guler and Archangelsky (2006). 4) Baldoni *et al.* (2001). 5) Guler and Archangelsky (2006). 6) Río Guanaco Formation, South of Lago Viedma (Pöthe de Baldis, 1986). 7) Calafate Formation, South of Lago Argentino (Marenssi *et al.*, 2004; Guler *et al.*, 2005). 8) Cerro Cazador Formation, South of Lago Argentino (Povilauskas and Guler, 2008). 9) Alta Vista Formation, South of Lago Argentino (González Estebenet *et al.*, 2017). 10) GHF2x-1 well (Guler *et al.*, 2003). 11) GIA5x-1 well (Guler *et al.*, 2003). 12) GGHGx-1 well (Guler *et al.*, 2003). 13) GHJ10x-1 well (Guler *et al.*, 2003). 14) GOC5x-1 well (Guler *et al.*, 2003). 15) GSJ2x-1 well (Guler *et al.*, 2003). 16) MLD3x-1 well, Springhill Formation (Palamarczuk *et al.*, 2000a; Guler *et al.*, 2015). 17) MLD4x-1 well, Springhill Formation (Guler *et al.*, 2015). 18) Calafate 87, 5 and 78; Zorzal 1; Cullen 40, 133 and 49; Lynch 11 and Lynch Sur 1 wells; Springhill and Pampa Rincon Formations (Quattrocchio *et al.*, 2006). 19) MFJ8 well (Palamarczuk *et al.*, 2000b). Modified from Nullo *et al.* (1999).

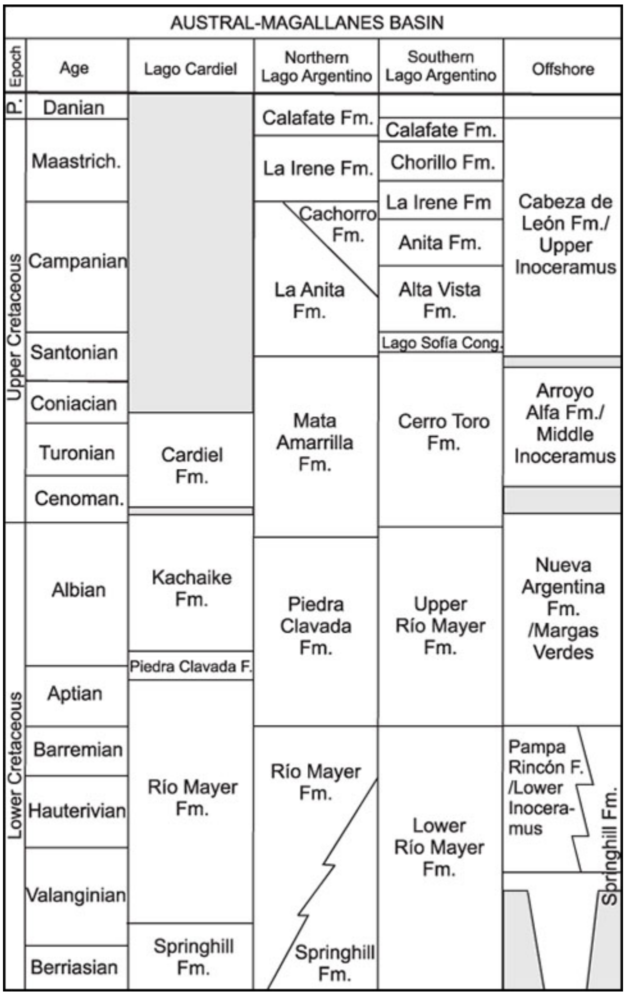

Figure 2. Comparative litostratigraphic chart of the Cretaceous units mentioned in the text. Lago Cardiel area after: Nullo *et al.* (1999); Medina *et al.* (2008). Northern Lago Argentino area after: Varela *et al.* (2012; 2016). Southern Lago Argentino area after: Nullo *et al.* (1999), Arbe (2002); Richiano *et al.* (2012); Marenssi *et al.* (2004); González Estebenet *et al.* (2017). Plataform area after: Robbiano *et al.*, (1996); Peroni *et al.* (2002); Arbe and Fernández Bell Fano, (2002); Rodríguez and Cagnolatti (2008); Schwarz *et al.* (2011).

sandstones and mudstone beds of the Maastrichtian Calafate Formation (Feruglio, 1949; Marenssi *et al.*, 2004).

SIGNIFICANT CRETACEOUS MARINE ORGANIC-WALLED DINOFLAGELLATE CYSTS RECORDS FROM THE AUSTRAL-MAGALLANES BASIN

Early Cretaceous dinoflagellate cysts

Early Cretaceous dinoflagellate cysts in the Austral-Magallanes Basin mostly come from the Springhill Formation and its distal lateral equivalent Lower Rio Mayer Formation and the informal subsurface Palermo Aike or Lower Inoceramus units, and from the Upper Río Mayer, Piedra Clavada and

Kachaike Formation and their equivalent subsurface Margas Verdes or Nueva Argentina units (Fig. 1, 2). Marine shales of these stratigraphical units compose the source rocks of the most important petroleum systems of the Basin. Cornú (1986) described the palynoflora from offshore wells located eastern Tierra del Fuego province and indicated four informal dinoflagellate cyst Zones of Late Hauterivian age, for the marine Springhill and Lower Inoceramus formations. Ottone and Aguirre Urreta (2000) suggested a probable late early Hauterivian to early Barremian age for the Springhill Formation at southwestern Santa Cruz Province based on ammonites and dinoflagellate cysts. Quattrocchio *et al.* (2006) recorded Early Cretaceous dinoflagellate cyst assemblages, offshore northeastern Tierra del Fuego province, mainly composed by *Circulodinium distinctum, Cometodinium* cf. *C. comatum*, *Cribroperidinium confossum*, *Cyclonephelium vannophorum* and *Oligosphaeridium complex,* and other brackish assemblages dominated by *Aptea* spp. and prasinophycean algae. In the Continental platform, eight wells located offshore Santa Cruz province provided diverse and well preserved dinoflagellate cyst assemblages from the Springhill Formation (Fig. 1). The taxa *Oligosphaeridium* mainly *O. complex*, *Kleithriasphaeridium fasciatum, Circulodinium distintinctum, Cribroperidinium/Apteodinium group* and Ceratiacean morphotypes, well represented by *Muderongia australis*, dominate many of the assemblages along the sedimentary successions. Ceratiacean dinoflagellates comprise a conspicuous group of cornucavate morphotypes and with the exception of the extant genus *Ceratium*, all their representatives disappeared in the Cretaceous. *Muderongia* is the oldest known ceratioid genus, emerges during the late Jurassic, and become more diverse in the Early Cretaceous. The genus *Muderongia* together with other ceratiacean relatives like *Phoberocysta*, *Pseudoceratium*, *Endoceratium* and *Odontochitina*, include several age-diagnostic taxa, useful for the Cretaceous dinoflagellate cysts biostratigraphy (*e.g.*, Morgan, 1980; Helby *et al.,* 1987; Leereveld, 1997a, b; Oosting *et al.,* 2006). The presence of other Early Cretaceous conspicuous taxa like *Cassiculosphaeridia magna*, *Batioladinium micropodum* and *Dingodinium cerviculum* is common and frequent throughout the sections. In the Austral-Magallanes Basin, dinoflagellate cyst offered a valuable tool for correlation among neritic sections of the Springhill Formation within the eastern margin of the basin (Fig. 2) (Palamarczuk *et al*., 2000a, b; Guler *et al*., 2003, 2015). Specifically, the same sequence of diagnostic dinocyst events of first occurrences (FOs) and last occurrence (LOs), can be found at most of the sites, and the stratigraphic order of the eight bioevents is close similar to that documented from independently well-dated Australian locations (*e.g.*, Oosting *et al*., 2006). The dinoflagellate cyst biostratigraphy constrained the age of these subsurface intervals between the early Barremian to the early Aptian. In ascending order, the bioevents identified in the Springhill Formation are: the LO of *Senoniasphaera tabulata,* the LO of *Kleithriasphaeridium fasciatum*, the FO of *Prolixosphaeridium parvispinum,* the LO of *Phoberocysta neocomica*, the FO of *Herendeenia postprojecta,* the FO of *Odontochitina operculata*, the LO of *Cassiculosphaeridia magna* and the LO of *Kaiwaradinium scrutillinum* (Fig. 3). Notably, peak abundance of *Ovoidinium* sp., a presumably southeastern Atlantic Ocean endemic palaeoperidiniod taxa (Guler *et al.,* 2015) was consistently recorded at the top of the successions in most of the analyzed sites (Guler *et al.,* 2003, 2015). Furthermore, it was recognized in the upper part of the *Muderongia australis* Zones of Helby *et al.* (1987), which extend to the early Aptian (Oosting *et al.,* 2006). An acme of *Ovoidinium cinctum* marks the O. (as *Ascodinium*) *cinctum* Subzone (Helby *et al.,* 1987, 2004) at the uppermost part of the *M. australis* Zone when it is present (Helby *et al.,* 1987), indicating the boundary between the *M. australis* and *O. operculata* zones. The boundary between both zones in the Austral-Magallanes Basin might be marked by the consistent and high proportions of *Ovoidiniun* sp., as equivalent to the *O. cinctum* acme event of Australia. According to Oosting *et al*. (2006) the *M. australis* and *O. operculata* Zone boundary and the *O. cinctum* acme event, when exist offshore eastern Australia, correlate with the onset and extent of the Oceanic Anoxic Event 1b or Selli Event that occur in the Early Aptian. These records from the eastern margin of the basin characterize the presumably youngest deposits of the Springhill Formation, in accordance with the diachronism of these transgressive deposits (Fig. 2). The unit exhibits a strong diachronism, being younger to the east and north of the basin (*e.g.,* Robbiano *et al*., 1996; Pittion and Arbe, 1999; Arbe, 2002; Schwarz *et al*., 2011).

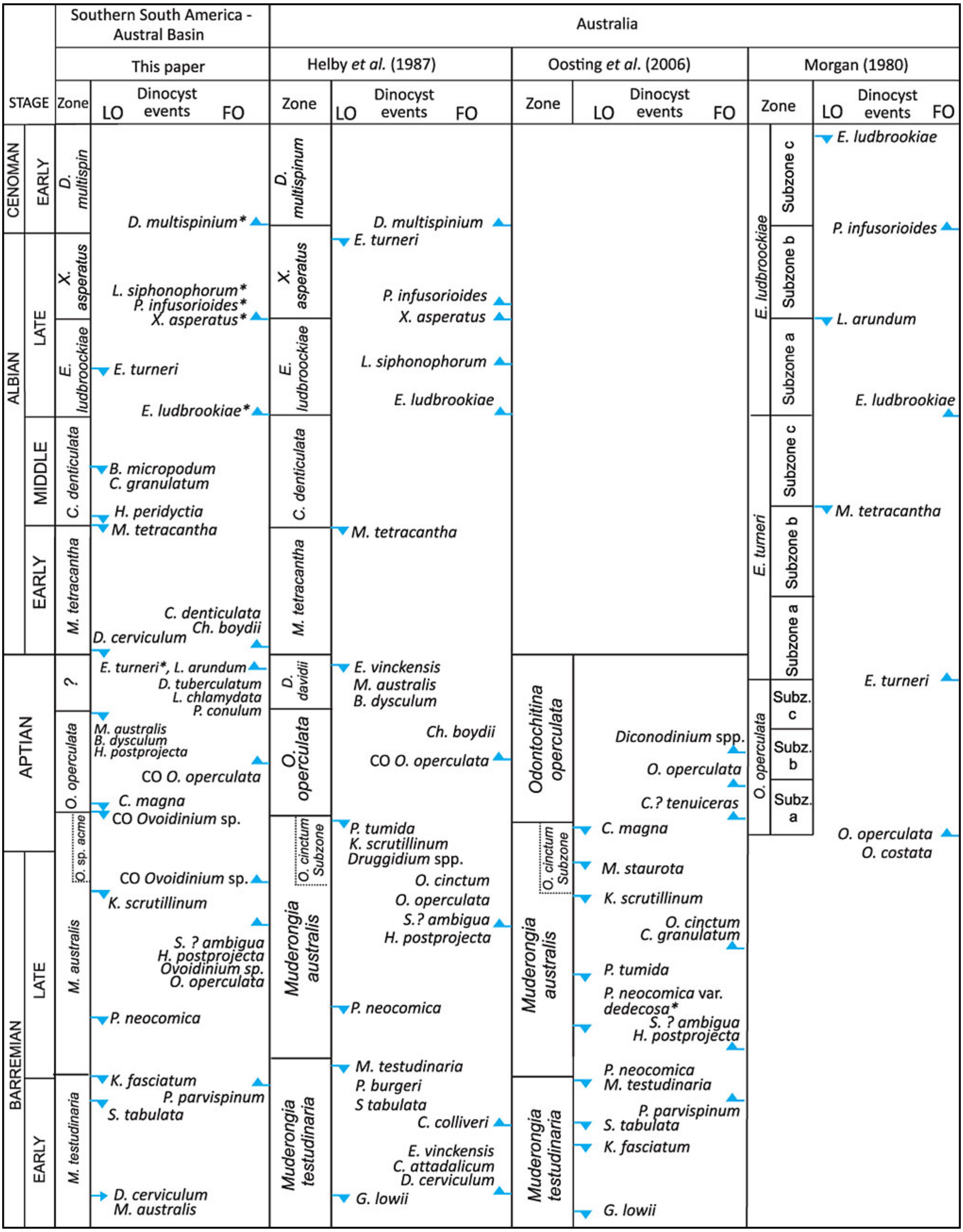

Figure 3. Biostratigraphical events of First Occurrences (FOs), Last Occurrences (LOs), Common Occurrence (CO) and Acme of selected dinoflagellate cyst species for the Early Cretaceous of the Austral Basin. (*) Asterisk indicate that the FO data come from cutting samples from wells, which might be subjected to a possible distortion by downhole contamination. Comparison with other bioevents sequences and zonation schemes from Australia (Helby *et al*., 1987; Oosting *et al*., 2006; Marshall, 1990).

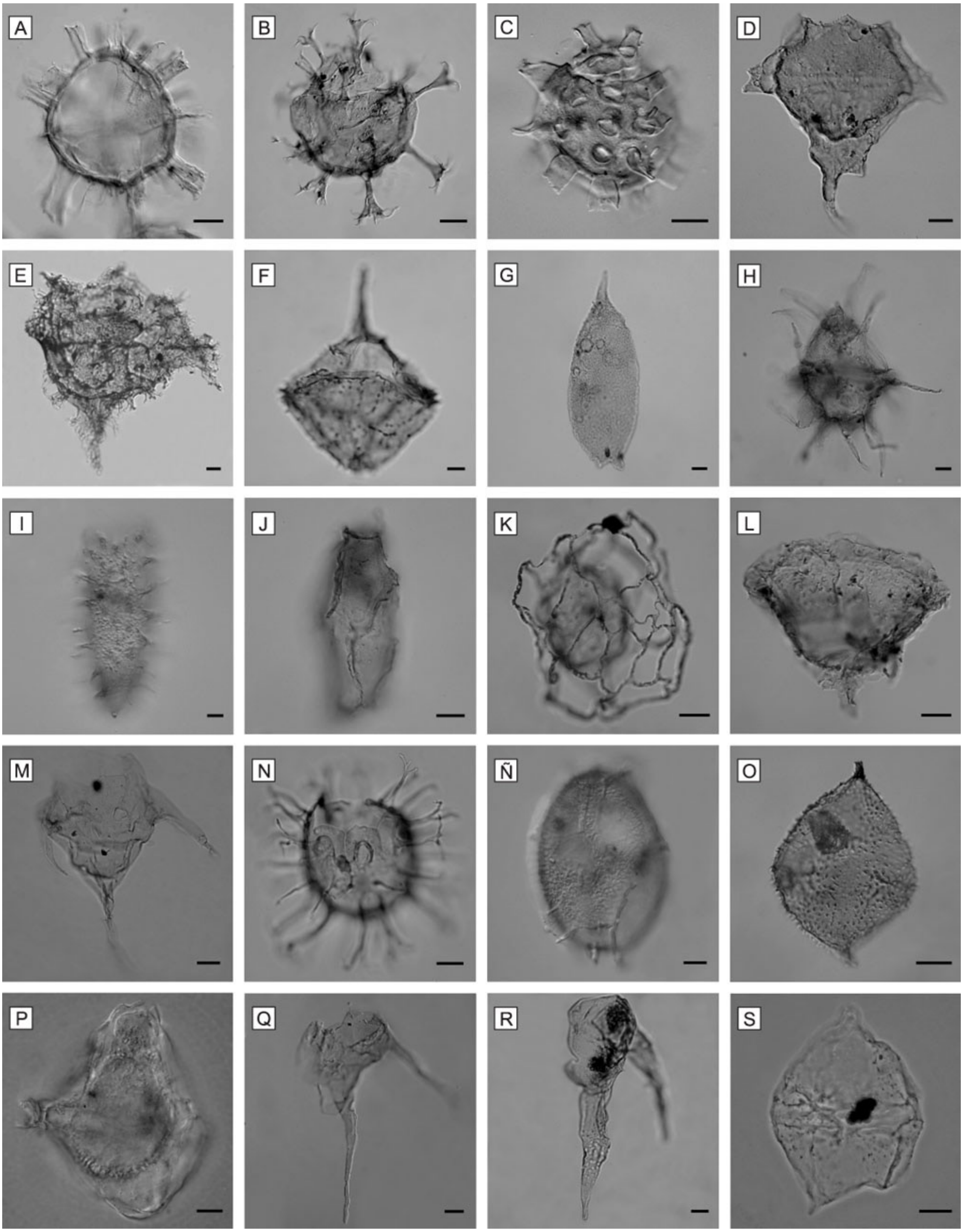

Figure 4. Early Cretaceous dinoflagellate cysts from the Austral Basin. Scale bar= 10 μm. a) ***Kleithriasphaeridium fasciatum***. Springhill Formation, oblique right lateral view, low focus. b) ***Oligosphaeridium complex***. Springhill Formation, dorsal view, high focus. c) ***Lithosphaeridium arundum***. Kachaike Formation, dorsal view, high focus. d) ***Muderongia australis***. Springhill Formation, dorsal view, optical section. e) ***Endoceratium turneri***. Margas Verdes Formation, dorsal view, high

Late Aptian to early Albian dinoflagellate cyst assemblages were recorded at the uppermost Río Mayer Formation, Piedra Clavada Formation (Medina *et al*., 2008) and the coeval lower Kachaike Formation (Baldoni *et al.,* 2001; Guler and Archangelsky, 2006) where the Albian is well represented (Baldoni *et al.,* 2001). The uppermost part of the Río Mayer Formation contains rich fossil invertebrate fauna including ammonoids of the Aptian/Albian transition whereas the Piedra Clavada Formation is dated as early Albian based on ammonoids of the genus *Beudanticeras* (Medina *et al.,* 2008). *Litosphaeridium arundum*, *Chichaouadinium boydii*, *Prolixosphaeridum conulum, Dinopterygium tuberculatum* and *Muderongia tetracantha* constitute key biostratigraphic taxa for these stratigraphical units in the southwestern Patagonia (Pöthe de Baldis and Ramos, 1983, 1988; Baldoni *et al.*, 2001; Guler and Archangelsky, 2006; Medina *et al.,* 2008). The presence of *Dingodinium cerviculum* in these "Mid" Cretaceous units associated with the Aptian/Albian transition ammonite fauna represents the LO of the species in the Austral-Magallanes Basin. It is in accordance with the top range of the species in the early Albian of Australia (Partridge, 2006) where *D. cerviculum* disappear in more than hundreds of wells in the lower part of the *Muderongia tetracantha* Zone (Medina *et al.,* 2008). Among other typical Albian taxa, it is common the presence of *Muderongia tetracantha* (*sensu* Morgan, 1980), which LO is an early Albian bioevent that mark the top of the Subzone b of *Endoceratium turneri* Zone of Morgan (1980) and the coeval *Muderongia teracantha* interval Zone of Helby *et al*. (1987). Offshore Austral-Magallanes Basin assemblages exhibit an Albian dinoflagellate cyst events sequence (Palamarczuk *et al.,* 2000a, b; Guler, Pers. Obs). The continuous and common occurrence of *Hapsocysta peridictya* constituted a consistent Early Albian age marker. Its stratigraphic range extends from the top of the Subzone a to the top of the Subzone b of the *Pseudoceratium turneri* Zone of Morgan (1980). In Australia, the LO of *H. peridictya* and *M. tetracantha* are simultaneous in the early Albian (Morgan, 1980). Notably, in the Austral-Magallanes Basin *M. tetracantha* is absent in distal successions, presumably due to environmental preferences. In general, Albian assemblages are characterized by the common presence of *Diconodinium* spp., *Odontochitina* (mostly *O. costata*) and *Canninginopsis denticulata*, and high proportions of the typical oceanic taxa *Impagidinium, Pterodinium* and chorate cysts like *Oligosphaeridium pulcherrimum*, *O. complex, Nematosphaeropsis densiradiata* and *Hapsocysta peridictya*. At the upper part of the succession there were inferred the middle Albian *C. denticulata*, the late Albian *E. ludbroockiae*, latest Albian *X. asperatus* and the early Cenomanian *D. multispinum* Zones of Helby *et al.* (1987) and the equivalent subzones of the *E. turneri* and *E. ludbrookiae* Zones of Morgan (1980). The Early Cretaceous dinoflagellate cyst species identified in the Austral-Magallanes Basin are listed in table 1 and some of them are illustrated in figure 4.

Late Cretaceous dinoflagellate cysts

The Late Cretaceous dinoflagellate cyst assemblages records described so far in the Austral-Magallanes Basin are confined to the southwestern Santa Cruz Province (Pöthe de Baldis, 1986; Marenssi *et al.*, 2004; Guler *et al.*, 2005; Guerstein *et al.,* 2005; Povilauskas and Guler, 2008; González Estebenet *et al.,* 2017) (Fig. 1). Pöthe the Baldis (1986) documented dinoflagellate cyst assemblages from the Río Guanaco Formation (upper Santonian to lower Campanian *sensu* Blasco *et al.* 1980), at the south of Lago Viedma (Fig. 1). The assemblages are dominated

focus. f) ***Cribroperidinium muderongense***. Springhill Formation, ventral view, low focus. g) ***Batioladinium micropodum***. Springhill Formation, right lateral view. h) ***Hystrichodinium pulchrum***. Springhill Formation, right lateral view. i) ***Prolixosphaeridium parvispinum***. Piedra Clavada Formation, ventral view, intermediate focus. j) ***Carpodinium granulatum***. Piedra Clavada Formation, ventral view, high focus. k) ***Hapsocysta peridictya***. Margas Verdes Formation, oblique ventral view. l) ***Dinopterygium tuberculatum***. Piedra Clavada/Margas Verdes Formations, dorsal view, low focus, hipocyst. m) ***Muderongia tetracantha***. Piedra Clavada Formation, dorsal view, high focus. n) ***Systematophora areolata***. Springhill Formation, dorsal view, intermediate focus. ñ) ***Herendeenia postprojecta***. Springhill Formation, ventral view, high focus. o) ***Diconodinium multispinum***. Margas verdes, ventral view, high focus. p) ***Dingodinium cerviculum***. Springhill Formation, right lateral view. q) ***Odontochitina operculata***. Springhill Formation, ventral view, low focus. r) ***Odontochitina costata***. Margas Verdes Formation, general view s) ***Ovoidinium* sp.** Springhill Formation, dorsal view, high focus.

by *Hystrichodinium* cf. *H. isodiametricum*, *Hystricho sphaeropsis ovum*, and *Chlamydophorella nyei* with fewer proportions of *Isabelidinium*? *acuminatum*, *Odontochitina operculata* and *Palaeohystrichophora infusorioides*. Additionally, it was described the new species *Surculosphaeridium*? *argentinense* (as *Areosphaeridium argentinense*). González Estebenet *et al*. (2017) documented dinoflagellate cyst assemblages from the Alta Vista Formation, southeast of the Lago Argentino (Fig. 1), mainly composed by *Alterbidinium acutulum*, *Coronifera oceanica*, *Dinopterygium* sp., *Oligosphaeridium* sp., *Palaeocystodinium* sp., *Sepispinula ancorifera* and *Systematophora* sp. and species of *Chatangiella*, *Cribroperidinium*, *Exochosphaeridium*, *Impagidinium*, *Isabelidinium, Spinidinium* and *Spiniferites* (Table 1). The age of the unit relies on the five age-diagnostic taxa *Odontochitina porifera*, *Palaeohystrichophora infusorioides*, *Nelsoniella aceras*, *Nelsoniella tuberculata* and *Xenikoon australis* (Fig. 5). The three latter are conspicuous taxa from the Southern Hemisphere. The co-occurrence of this age-marker taxa suggested an early to "mid" Campanian age, in agreement with the independent age control given by invertebrate remains (Riccardi and Rolleri, 1980; Riccardi 1983; Kraemer and Riccardi, 1997; Arbe, 2002). Also, it was identified the *Nelsoniella aceras* Interval Zone (late Santonian to early Campanian, Helby *et al*., 1987) and the *Xenikoon australis* Interval Zone (early Campanian, Helby *et al*., 1987). Povilauskas and Guler (2008) analyzed late Campanian to early Maastrichtian marine dinoflagellate cysts from the Cerro Cazador Formation at northwestern Santa Cruz Province. The assemblages are dominated by peridiniacean dinoflagellate cysts as *Cerodinium* sp., *Diconodinium* sp., *Isabelidinium* sp. cf. *I. pellucidum*, *Isabelidinium* spp., ?*Nelsoniella* sp., *Odontochitina spinosa, Odontochitina* spp., *Palaeocystodinium australinum*, *Palaeocystodinium granulatum*, *Palaeocystodinium lidiae* and *Spinidinium* sp. The Gonyaulacales taxa such as *Exochosphaeridinum* sp. and *Spiniferites ramosus* are represented in low proportions. Marenssi *et al.* (2004) studied the dinoflagellate cyst assemblages from the Calafate Formation at the south of Lago Argentino (Fig. 1). The assemblages are characterized by the presence of *Manumiella druggii*, *Manumiella* spp., *Isabelidinium*? *cretaceum* (as *M.* ?*cretacea*), *Isabelidinium* spp., *Alterbidinium acutulum*, *Palaeocystodinum lidiae*, *Alisocysta circumtabulata* (as *Eisenackia circumtabulata*), *Hafniasphaera* cf. *fluens*, *Impagidinium* sp., among others (Table 1). The age-markers *Manumiella druggii* and *Eisenackia circumtabulata* indicated an age no older than Maastrichtian (?late Maastrichtian) for this unit (Fig. 5). Moreover, the LO of *Manumiella druggii* would mark the base of the Australian Late Maastrichtian to earliest Danian *Manumiella druggii* Interval Zone of Helby *et al*. (1987). This zone was also recognized in New Zealand (Wilson, 1984; Schiøler and Wilson, 1998; Roncaglia *et al*., 1999) and Antarctic Peninsula (Bowman *et al*., 2012). Nevertheless, in the locality of Cerro Calafate (south of Lago Argentino), the Eocene Man Aike Formation unconformably overlies the late Cretaceous Calafate Formation and the Cretaceous/Palaeogene boundary deposits would not have been represented (Marenssi *et al*., 2002, 2004). Guler *et al*. (2005) described four new dinoflagellate cyst taxa from the Calafate Formation including *Andalusiella spinosa*, *Palaeocystodinium pilosum*, *Caligodinium perforatum* and *Hafniasphaera australis*. Additionally, Guerstein *et al*. (2005) described the new taxa *Diconodinium lurense*, based on records from the Austral, Colorado and Punta del Este (offshore Uruguay) basins. Table 1 contains the Late Cretaceous dinoflagellate cyst species identified in the Austral-Magallanes Basin and figure 6 illustrated some of the specimens.

PALEOBIOGEOGRAPHICAL IMPLICATIONS

In general, the Cretaceous dinoflagellate cyst assemblages recorded in the Austral-Magallanes Basin reflect close similarity with the marine palynofloras throughout the mid to high Southern Hemisphere latitudes, including the Antarctic region, New Zealand and Australia, denoting a marked austral provincialism. Also, the applicability of the Cretaceous dinoflagellate cysts zonal schemes defined for Southern Hemisphere sequences (*e.g.*, Morgan, 1980; Helby *et al*., 1987; Mao and Mohr, 1992; Schiøler and Wilson, 1998; Roncaglia *et al.*, 1999; Bowman *et al.*, 2012) proved the strong paleobiogeographical affinities between the Austral-Magallanes Basin assemblages and those from the Austral Realm. It is known that provincialism depends on the physico-chemical characteristics of the watermasses as well as the surface water circulation patterns. Thus, dinoflagellate cyst provincialism in the fossil record can be used

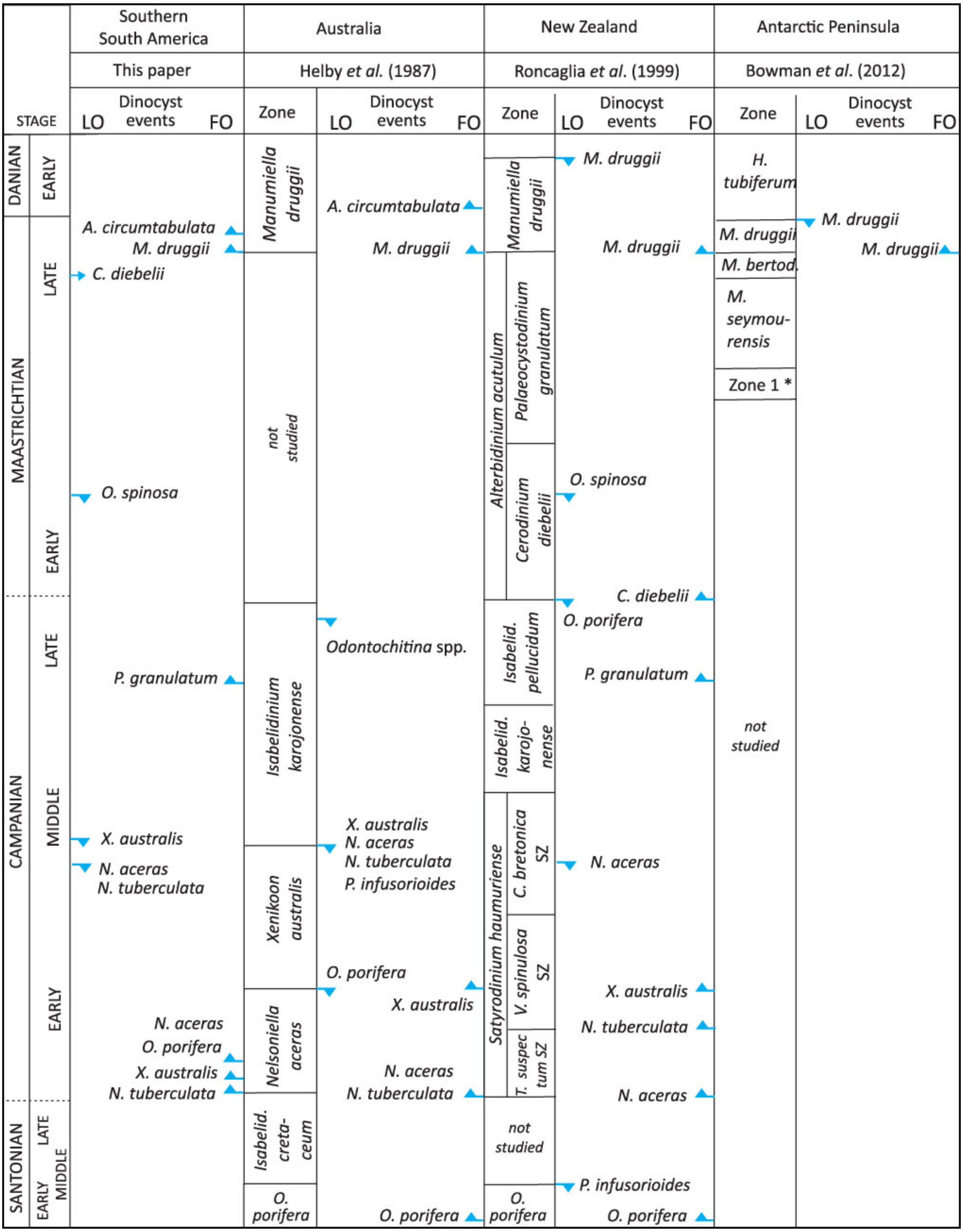

Figure 5. Biostratigraphical events of First Occurrences (FOs) and Last Occurrences (LOs) of selected dinoflagellate cyst species for the Late Cretaceous of the Austral Basin. Comparison with other bioevents sequences and zonation schemes from Australia (Helby *et al*., 1987; 2004), New Zealand (Roncaglia *et al*., 1999) and Bowman *et al*. (2012).

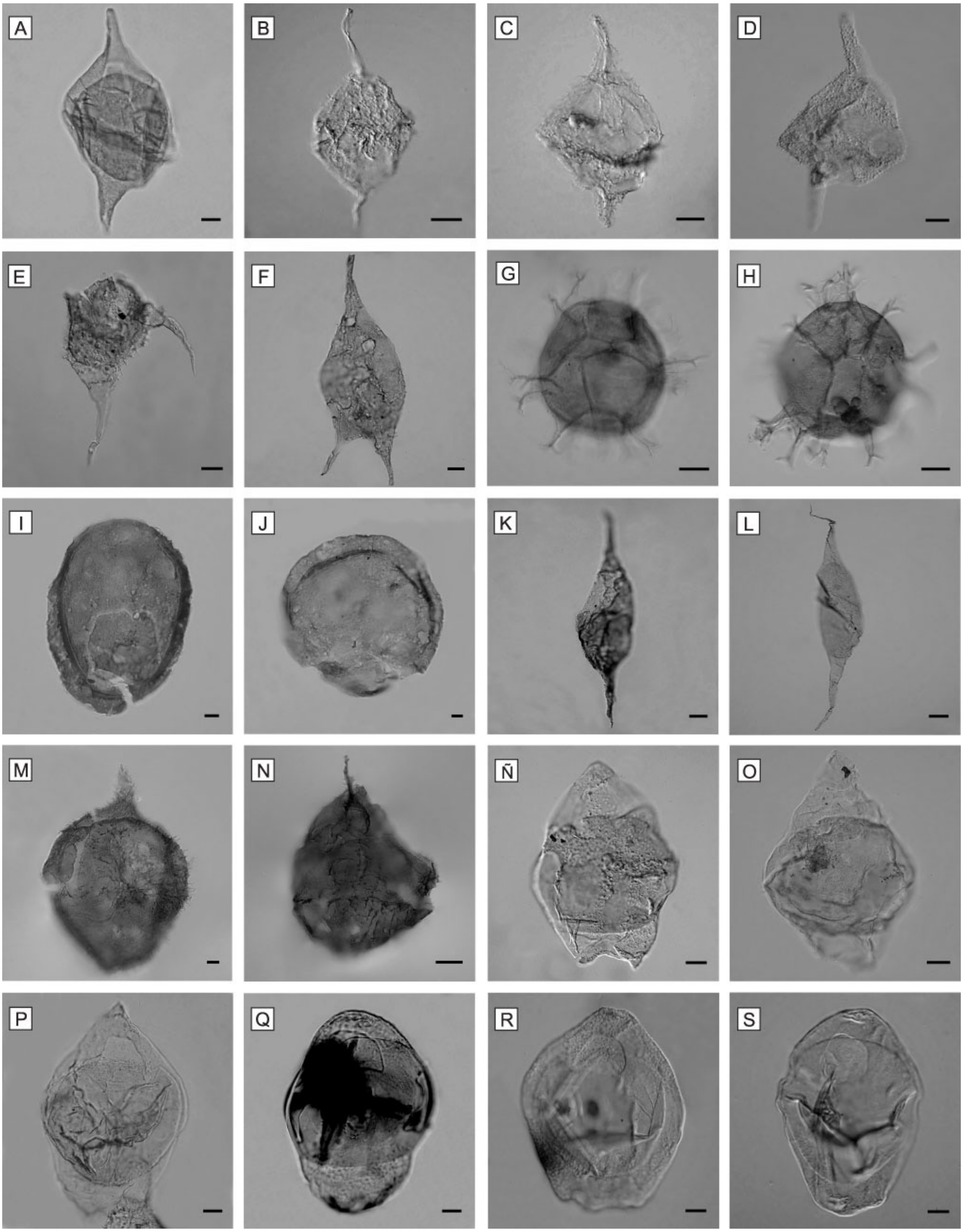

Figure 6. Late Cretaceous dinoflagellate cysts from the Austral Basin. Scale bar= 10μm. a) ***Alterbidinium acutulum***. Calafate formation, ventral view, low focus. b), c) ***Andalusiella spinosa***. Calafate Formation, general view. d) ***Diconodinium lurense***. Calafate Formation, general view. e) ***Odontochitina spinosa***. Cerro Cazador Formation, ventral view, low focus. f) ***Cerodinium*** sp. Calafate Formation, general view. g), h) ***Hafniasphaera australis***. Calafate Formation, g) oblique dorsal view, high focus h)

to infer oceanographical connections in the past (Norris, 1965; Lentin and Williams, 1980; Wrenn and Beckman, 1982; Sluijs *et al*., 2005; Slimani *et al*., 2010; Bowman *et al*., 2012).

Particularly, the late Hauterivian to early Aptian dinoflagellate cyst assemblages from the offshore Austral-Magallanes Basin (*e.g.*, Palamarczuk *et al*., 2000a, b; Guler *et al*., 2003, 2015) exhibit strong affinities with those from offshore west and northwest Australia (Helby *et al*., 1987; Oosting *et al.,* 2006) (Fig. 7). However, the dinoflagellates cyst assemblages from the Austral-Magallanes Basin do not reflect palaeobiogeographic affinities with the Neuquén Basin (Paolillo *et al*., 2015, 2018) despite the close palaeogeographical position of both basins (Fig. 7); presumably due to paleotemperatures differences and/or absence of marine connections, as it was visualized with the fossil invertebrate fauna (*e.g.,* Aguirre Urreta *et al*., 2008). This is in agreement with the global palaeogeography and palaeoceanographic current context and is closely related to the geodynamic evolution of the two basins. During the Berriasian to Early Barremian times, the Neuquén Basin was connected to the Pacific Ocean (Uliana and Biddle, 1988) through a volcanic arc in the western margin, allowing the exchange of marine biota from warm lower- latitudes (*e.g.*, Aguirre Urreta *et al*., 2008; Paolillo *et al*., 2018). Several ceratiacean species proved to be biostratrigraphically useful through the Early Cretaceous worldwide (*e.g.*, Duxbury, 1977; Helby *et al*., 1987; Backhouse 1987; Leereveld, 1997b; Monteil, 1992). Noteworthy, typical austral *Muderongia* species as *Muderongia australis*, *Muderongia testudinaria,* among others, are index taxa for the Australian zonations (Helby *et al*., 1987; 2004; Backhouse, 1987) and they were not recorded in the Neuquén Basin. Instead, in the Hauterivian of the Neuquén Basin, *Muderongia staurota*, *M. pariata*, *M.* cf. *M. siciliana,* and closely related *Muderongia* morphotypes resemble those recorded in the Northern Hemisphere. The taxa are conspicuous of the Hauterivian Boreal and Tethyan cyst assemblages (*e.g.*, Duxbury, 1977; Leereveld, 1997b; Torricelli, 2000, 2001, 2006) and are absent in the high-latitude Southern Hemisphere sites, including the Austral-Magallanes Basin. Furthermore, the Early Cretaceous assemblages from the Austral-Magallanes Basin show the common presence of *Batioladinium jaegeri*, *B. micropodum*, *Carpodinium granulatum*, *Cassiculosphaeridia magna*, *Dingodinium cerviculum* (large forms with relatively thick walls) and species of *Aprobolocysta*, which have been associated with relatively cool waters (de Renéville and Raynaud, 1981; Habib and Drugg, 1987; Leereveld, 1995) indicating low-temperature-water environment conditions. Likewise, in the Austral-Magallanes Basin, the assemblages are characterized by the common presence of large thick-walled and coarse ornamented specimens of *Dingodiniun cerviculum*, whereas thin-walled forms recorded in the Neuquén Basin (Paolillo *et al*., 2017) have been related to relatively warm environments (Leereveld, 1995; Torricelli 2000, 2001, 2006; Oosting *et al*., 2006).

The late Aptian - early Albian assemblages (*e.g.*, Guler and Archangelsky, 2006a; Medina *et al*., 2008) compare well with those from well-dated sequences of the James Ross Basin, exposed at the northeastern tip of Antarctic Peninsula (Riding and Crame, 2002), one of the thickest and complete Cretaceous sedimentary succession, that provide reference dinoflagellate cyst biostratigraphy patterns for the Southern Hemisphere. The Albian to early Cenomanian assemblages (Palamarczuk *et al.* 2000a, b; Guler and Archangelsky, 2006b) are markedly similar to those from Australia (*e.g.,* Morgan, 1980; Helby *et al*., 1987; Backhouse, 2006) and New Zealand (*e.g.,* Wilson, 1984) (Fig. 8). Thus, the palaeobiogeographical affinities between those late Early Cretaceous dinoflagellate cyst assemblages reflect exchange of taxa among the Austral-Magallanes Basin and those from Antarctica Peninsula, Australia and New Zealand suggesting oceanic connections among the southernmost tip of South America and those high-

apical view, high focus. i), j) ***Caligodinium perforatum***. Calafate Formation, i) oblique antapical view, high focus, j) lateral view, high focus. k) ***Palaeocystodinium*** sp. Calafate Formation, right lateral view, high focus. l) ***Palaeocystodinium pilosum***. Calafate Formation, general view. m) ***Apteodinium*** sp. Calafate Formation, right lateral view, high focus. n) ***Cribroperidinium*** sp. Calafate Formation, left lateral view. ñ), o), p) ***Isabelidinium*** spp. Calafate Formation, ñ) dorsal view, high focus, o) dorsal view, high focus, p) ventral view, low focus. q) ***Isabelidinium cretaceum***. Calafate Formation, ventral view, low focus. r) ***Manumiella druggii***. Calafate Formation, dorsal view high focus. s) ***Manumiella*** sp. Calafate Formation, ventral view, low focus.

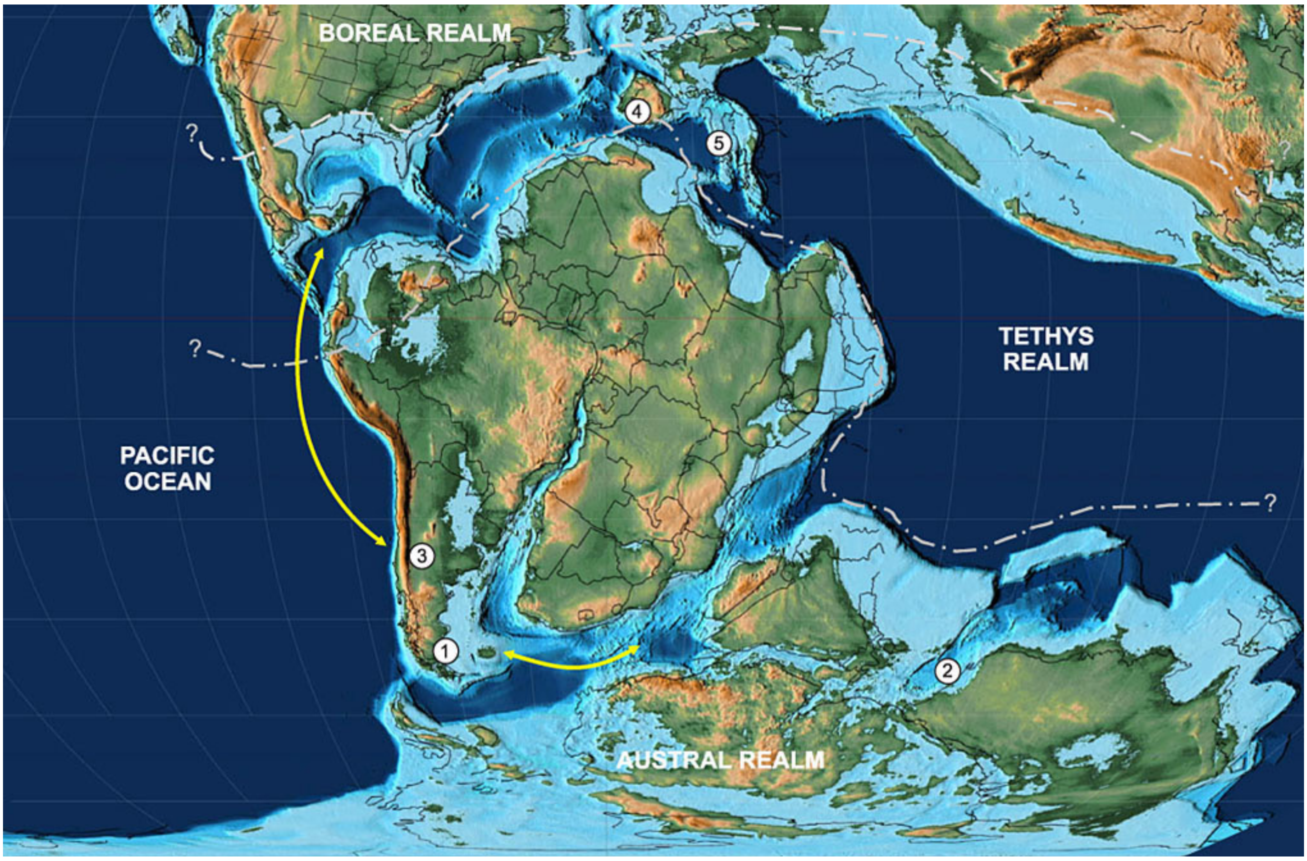

Figure 7. Paleogeographic map during the Early Cretaceous (Barremian base map by Scotese 2014, PaleOMaP). 1) Austral Basin (Palamarczuk *et al.*, 2000a, b; Guler *et al.*, 2003; 2015; 2016). 2) West and northwest Australia (Helby *et al.*, 1987; Oosting *et al.,* 2006). 3) Neuquén Basin (*e.g.*, Paolillo *et al.*, 2015; 2018). 4) 5) Tethyan regions (Leereveld, 1997; Torricelli, 2000; 2001; 2006). Yellow arrows indicate the probable oceanic connections during the Early Cretaceous.

latitude South Hemisphere sites.

For the Late Cretaceous, Lentin and Williams (1980) defined three Provinces based on the latitudinal distribution of Campanian peridinialean dinoflagellate cysts: the Malloy suite or tropical-subtropical province, characterized by species of *Andalusiella*, *Cerodinium*, *Phelodinium* and *Senegalinium*; the Williams suite or warm-temperate North Atlantic Province, represented by *Alterbidinium*, *Chatangiella* (small taxa), *Isabelidinium*, *Spinidinium* and *Trithyrodinium*; and the McIntyre suite or boreal province, that consist mostly of *Laciniadinium* and *Chatangiella* (large taxa). Lentin and Williams (1980) noted that the Williams suite might occur in the South Atlantic Ocean (Uruguay, Argentina and Australasia), with some southern taxa as *Amphidiadema* and *Nelsoniella*, named the South Atlantic Province. Later, Mao and Mohr (1992) proposed for the Indian Ocean a Campanian to Maastrichtian dinoflagellate cool temperate South Indian province or Helby suite. This province is characterized by the genera *Isabelidinium*, *Chatangiella*, *Nelsoniella*, *Amphidiadema* and *Xenikoon*. More recently, Bowman *et al*. (2012) propose the dinoflagellate cyst South Polar Province for the late Maastrichtian to earliest Paleocene (early Danian) that encompasses the entire Antarctic Margin, southern Australia, the East Tasman Plateau, Southern India Ocean (Kerguelen Plateau), New Zealand and the western tip of Southern South America, that is, the Austral-Magallanes Basin (Fig. 9).

Late Cretaceous dinoflagellate cyst assemblages from the Austral-Magallanes Basin (Marenssi *et al.*, 2004; Guler *et al.*, 2005; Povilauskas and Guler, 2008; González Estebenet *et al.,* 2017) exhibit a marked similarity with those from the Antartic region (Askin, 1988; Thorn *et al*., 2009; Bowman *et al*., 2012), New Zealand (Wilson, 1984; Roncaglia *et al*., 1999; Willumsen, 2004, 2006, 2011), Australia

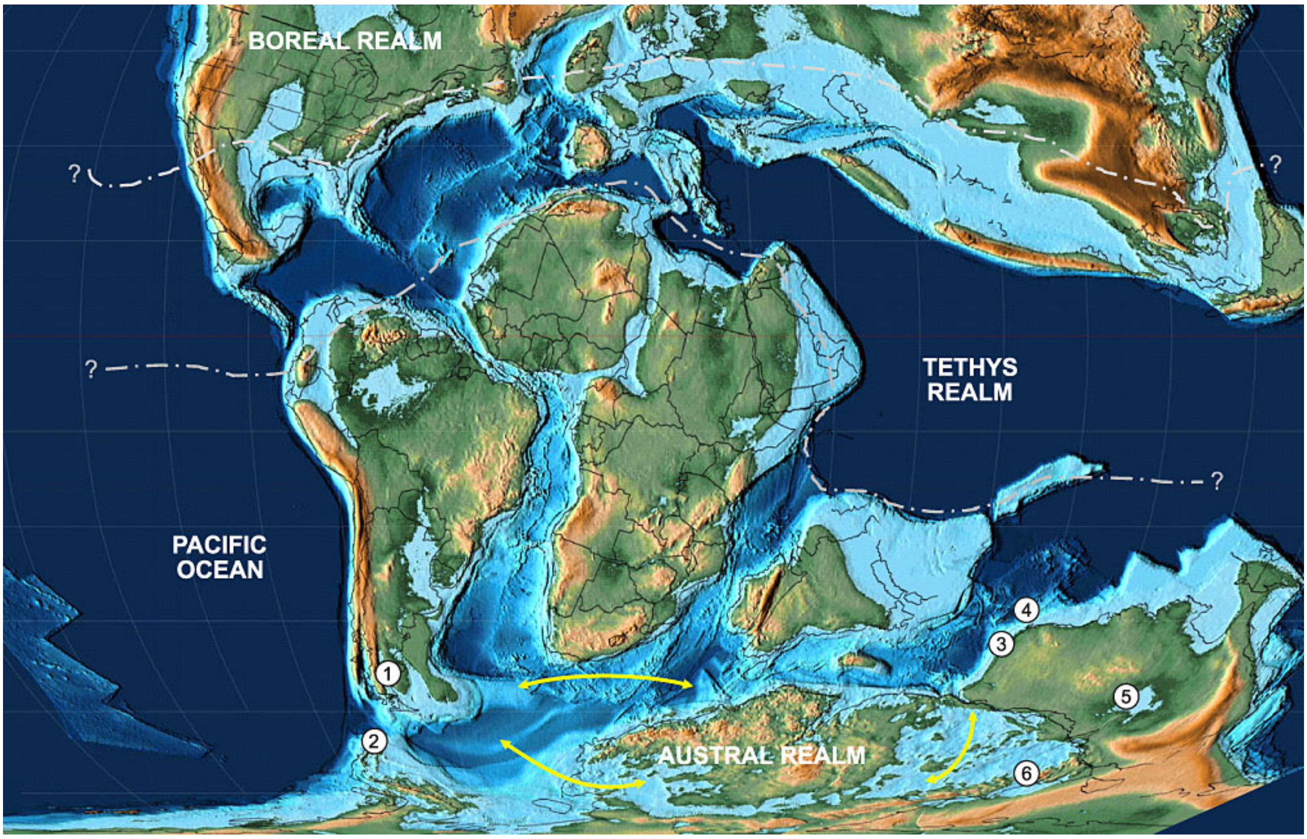

Figure 8. Paleogeographic map during the late Early Cretaceous (Albian base map by Scotese 2014, PaleOMaP). 1) Austral Basin (Palamarczuk *et al*. 2000a, b; Guler and Archangelsky, 2006a, b; Medina *et al*., 2008). 2) James Ross Basin, Antarctic Peninsula (Riding and Crame, 2002). 3) Western Australia (Backhouse, 2006). 4) Western Australia (Helby *et al*., 1987). 5) Central Australia (Morgan, 1980). 6) New Zealand (Wilson, 1984). Yellow arrows indicate the probable oceanic connections during the late Early Cretaceous.

(Helby *et al.,* 1987; Marshall, 1990); Southern Indian Ocean (Mao and Mohr, 1992) and the East Tasman Plateau (Brinkhuis *et al*., 2003; Williams *et al*., 2004). Accurately, the early to middle Campanian Alta Vista Formation (González Estebenet *et al*., 2017) and late Campanian to early Maastrichtian Cerro Cazador Formation (Povilauskas and Guler, 2008) show high representation of mid to high-southern latitude taxa (*e.g.,*Helby *et al*., 1987; Mao and Mohr, 1992; Roncaglia *et al*., 1999). Furthermore, the Late Cretaceous assemblages from the Austral-Magallanes Basin contain species that characterize both, the Campanian Williams suite of Lentin and Williams (1980) and the Campanian to Maastrichtian Helby suite of Mao and Mohr (1992). Moreover, with the exception of *Amphidiadema*, the assemblages of the Alta Vista Formation contain the totality of taxa that characterizes the Helby suite. These assemblages resemble those coeval associations recognized from offshore Colorado Basin (*e.g.*, Gamerro and Archangelsky, 1981; Ottone, 2015) and Pelotas Basin (*e.g.,* Arai *et al*., 2000; Menezes *et al*., 2016; Premaor *et al*., 2017), since the latter two basins contain dinoflagellate cyst assemblages with Austral components.

The late Maastrichtian dinoflagellate cyst assemblages from the Calafate Formation (Marenssi *et al*., 2004; Guler *et al*., 2005) show a turnover in the Peridiniales taxa, resulting in *Alterbidinium acutulum*, *Cerodinium diebelii*, *Andalusiella*, *Palaeocystodinium* and the first record of the genus *Manumiella.* Several studies based on the taxonomy and distribution of the *Manumiella* species have showed their value as global biostratigraphic markers for the Late Maastrichtian and the Cretaceous/Paleogene boundary (*e.g.*, Helby *et al.,* 1987; Askin, 1988; Roncaglia *et al.,* 1999; Habib and Saeedi, 2007; Thorn *et al*., 2009; Bowman *et al*., 2012). Based on the biogeographic affinities between the Austral-Magallanes Basin assemblages (Calafate Formation)

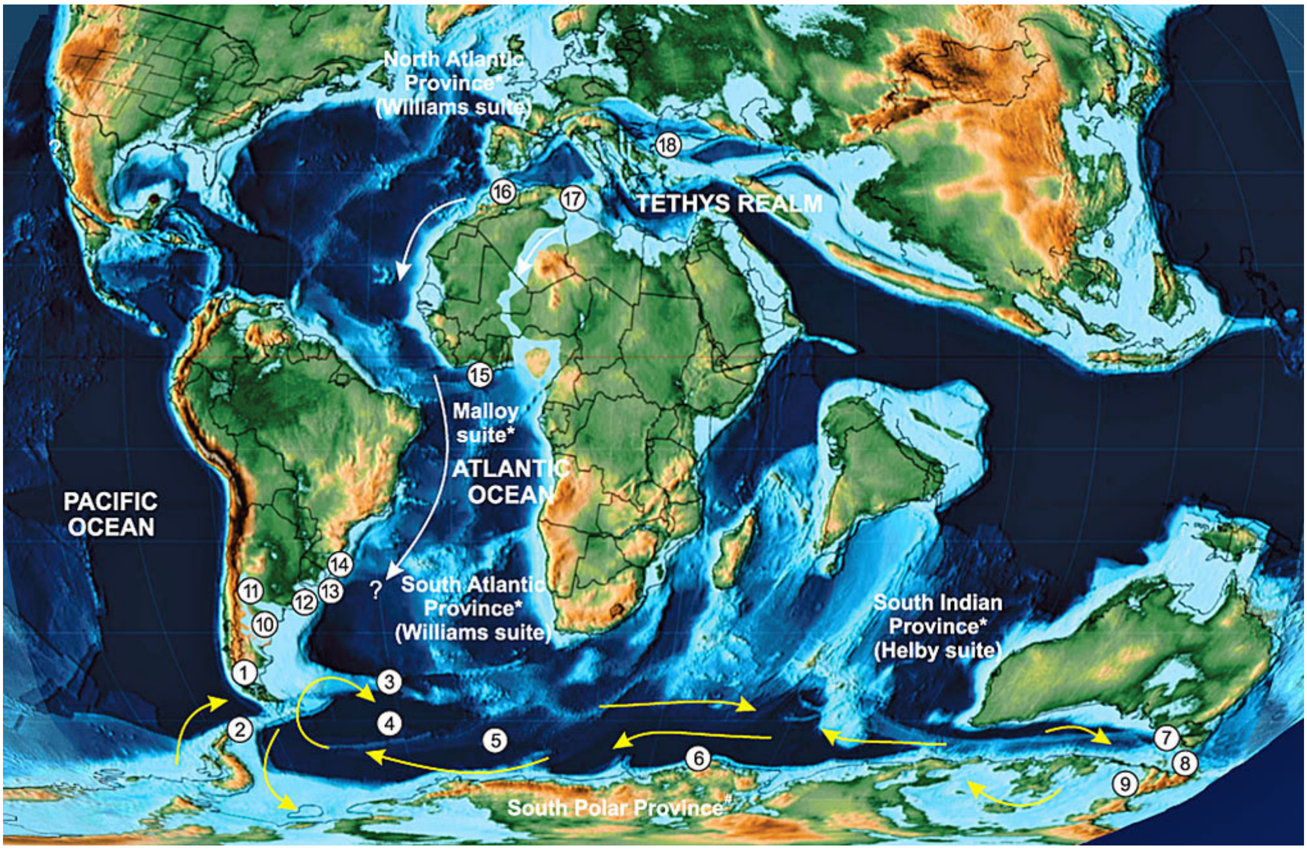

Figure 9. Paleogeographic map during the Late Cretaceous (modified from the Maastrichtian base map by Scotese 2014, PaleOMaP and Denham and Scotese, 1987). 1) Austral Basin (Povilauskas and Guler, 2008; Marenssi *et al.*, 2004; Guler *et al.*, 2005; González Estebenet *et al.*, 2017). 2) Antarctic Peninsula (*e.g.*, Askin 1988; 1999; Riding *et al.*, 1992; Thorn *et al.*, 2007; 2009; Bowman *et al.*, 2012). 3) DSDP site 327 (Harris, 1977). 4) South Georgia Basin (ODP Leg 114, site 698; Mohr and Mao, 1997). 5) Maud Rise (ODP Leg 113; Mohr and Mao, 1997). 6) ODP site 738 (Tocher, 1991) and ODP site 748 (Mao and Mohr, 1992), Kerguelen Plateau, Southern Indian Ocean. 7) Southeast Australia (Helby, 1987). 8) East Tasman Plate (Brinkhuis *et al.*, 2003; Williams *et al.*, 2004). 9) New Zealand (Wilson, 1984; 1987; Roncaglia *et al.*, 1999); Willumsen, 2004; 2006; 2011; Bowman *et al.*, 2012). 10-11) North of Patagonia, 10) Somuncurá-Cañadón Asfalto Basin (Vellekoop *et al.*, 2017a). 11) Neuquén Basin (Palamarczuk and Habib, 2001; Palamarczuk *et al.*, 2002; 2006; Woelders *et al.*, 2017). 12) Colorado Basin (Gamerro and Archangelsky, 1981; Guerstein and Junciel, 2001; 2003). 13) Punta del Este Basin (Daners and Guerstein, 2004; Daners *et al.*, 2004). 14) Pelotas Basin (Arai *et al.*, 2000; Menezes *et al.*, 2016; Premaor *et al.*, 2017). 15) Ivory Coast- Ghana (Oboh-Ikuenobe *et al.*, 1998). 16) Morocco (Rauscher and Doubinger, 1982; Slimani *et al.*, 2010). 17) Tunisia (Brinkhuis and Zachariasse, 1988; Brinkhuis *et al.*, 1998; M'hamdi *et al.*, 2015; Vellekoop *et al.*, 2015). 18) Turkey (Vellekoop *et al.*, 2017b; Açikalin *et al.*, 2015). (*) Asterisk differentiate Campanian dinoflagellate cysts provinces from the Maastrichtian Danian ones indicated by (#) numeral.

and those from the Southern Hemisphere middle to high-latitudes sites, Bowman *et al*. (2012) considered the southernmost tip South America within the Late Maastrichtian to Early Danian South Polar Province (Fig. 9). Based on models of ocean currents, these authors suggested shallow marine connections through an archipielago across Antarctica between southern South America and the Tasman Sea. Worth mentioning that a circumpolar flow through an open and deep Drake Passage and Tasman Gateway was recorded just in the earliest Oligocene.

Any attempt to analyze biogeographic affinities between the late Maastrichtian dinoflagellate cyst assemblages from the Austral-Magallanes Basin (Calafate Formation) with those from the north of Patagonia and other adjacent southwest Atlantic basins is limited by the lack of coeval intervals. The assemblages from the north of Patagonia are mostly confined to the Maastrichtian to Danian boundary (Gamerro and Archangelsky, 1981; Guerstein and Junciel, 2001; Palamarczuk and Habib, 2001; Palamarczuk *et al*., 2002; Daners and Guerstein, 2004; Daners *et al.*, 2004; Prámparo *et al.*, 2006; Guler *et al.*, 2014; Vellekoop *et al.*, 2017a; Woelders *et al.*, 2017; Guler *et al.*, 2018). Furthermore, Guler *et al.* (2019) indicated that these assemblages from north of Patagonia and adjacent basins compare well with those coevals from northern Africa and Tethyan areas (Brinkhuis and Zachariasse 1988; Slimani *et al.*, 2010; Açikalin *et al.*, 2015; M'hamdi *et al.* 2015; Vellekoop *et al.*, 2015; Vellekoop *et al.*, 2017b; Guler *et al.*, 2018). In agreement, Maastrichtian invertebrates in northern Patagonia showed Austral affinities, while around the K-Pg boundary and most accentuated in the Danian, the fauna show clear affinities with those warm-waters low-latitudes coeval associations from northern Brazil, Caribe and north of Africa (Olivero *et al.*, 1990; Medina and Olivero, 1994; Feldmann *et al.*, 1995; Casadío, 1998; Casadío *et al.*, 1999; 2005). Likewise, Maastrichtian calcareous foraminiferal benthic assemblages from northern Patagonia contain endemic species, whose most of them disappear in the Maastrichtian/ Danian transition and were replaced by the midway assemblages (Náñez and Malumián, 2008; Malumián and Náñez, 2011).

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	1	2	3	4	5	6	Fig.
Achomosphaera neptunii (Eisenack, 1958) Davey and Williams, 1966	*						
Aptea sp. cf. A. *polymorpha* Eisenack, 1958a emend. Dörhöfer and Davies, 1980	*						
Alisocysta circumtabulata Drugg, 1967						*	
Alterbidinium acutulum (Wilson, 1967) Lentin and Williams, 1985 emend. Khowaja-Ateequzzaman *et al.*, 1991				*		*	5.a
Andalusiella spinosa Guler *et al.*, 2005						*	5b,c
Andalusiella sp.						*	
Aprobolocysta sp.	*						
Aprobolocysta sp. cf. *A. alata* Backhouse, 1987	*						
Apteodinium granulatum (Eisenack, 1958) Lucas-Clark, 1987	*	*					
Apteodinium maculatum Eisenack and Cookson, 1960	*						
Apteodinium spp.	*	*		*		*	5.m
Batiacasphaera asperata Backhouse, 1987	*						
Batiacasphaera sp. cf. *B. kekerengensis* Schiøler and Wilson, 1998						*	
Batiacasphaera sp. cf. *B. granulosa* Cookson and Eisenack, 1974		*					
Batiacasphaera sp.	*						
Batioladinium jaegeri (Alberti, 1961) Brideaux, 1975 emend. Below, 1990	*						
Batioladinium micropodum (Eisenack and Cookson, 1960) Brideaux, 1975 emend. Below, 1990	*						4.f
Batioladinium sp. cf. *B. subtilis* Stover and Helby, 1987	*						
Batioladinium spp.	*						
Belodinium dysculum Cookson and Eisenack, 1960 emend. Stover and Helby, 1987	*						
Caligodinium perforatum Guler *et al.*, 2005						*	5.i,j
Caligodinium sp.						*	
Callaiosphaeridium asymmetricum (Deflandre and Courteville, 1939) Davey and Williams, 1966 emend. Clarke and Verdier, 1967	*		*				
Canninginopsis denticulata Cookson and Eisenack, 1962	*						
Canninginopsis sp.	*						
Carpodinium granulatum Cookson and Eisenack, 1962 emend. Leffingwell and Morgan, 1977	*	*					4.j
Cassiculosphaeridia delicata Stover and Helby, 1987	*						
Cassiculosphaeridia magna Davey, 1974	*						
Cassiculosphaeridia pygmaeus Stevens, 1987	*						
Cassiculosphaeridia reticulata Davey, 1969	*						
Cassiculosphaeridia sp.	*						
Cerbia tabulata (Davey and Verdier, 1974) Below, 1981	*						
Cernicysta helby (Morgan, 1980) Stover and Helby, 1987	*						
Cernicysta sp.	*						
Cerodinium diebelii (Alberti, 1959) Lentin and Williams, 1987						*	
Cerodinium spp.					*	*	5.f
Chatangiella spp.				*			
Chichauoadininium boydii (Morgan, 1975) Bujak and Davies, 1983	*	*					
Chlamydophorella ambigua (Deflandre, 1937) Stover and Helby, 1987	*	*					
Chlamydophorella nyei Cookson and Eisenack, 1958		*	*				
Circulodinium brevispinosum (Pocock, 1962) Jansonius, 1986	*						
Circulodinium sp. cf. *C. distinctum* (Deflandre and Cookson, 1955) Jansonius, 1986			*				
Circulodinium colliveri (Cookson and Eisenack, 1960) Helby, 1987	*						
Circulodinium distinctum (Deflandre and Cookson, 1955) Jansonius, 1986	*	*					

	1	2	3	4	5	6	Fig.
Circulodinium sp.	*			*			
Cometodinium sp.	*						
Coronifera oceanica Cookson and Eisenack, 1958	*	*		*			
Cribroperidinium ?muderongense (Cookson and Eisenack, 1958) Davey, 1969	*						4.f
Cribroperidinium edwardsii (Cookson and Eisenack, 1958) Davey, 1969	*						
Cribroperidinium orthoceras (Eisenack, 1958) Davey, 1969		*					
Cribroperidinium spp.	*	*		*		*	5.n
Cribroperidinium? muderongense (Cookson and Eisenack, 1958) Davey, 1969	*						
Cyclonephelium compactum Deflandre and Cookson, 1955			*				
Dapsilidinium warenii (Habib, 1976) Lentin and Williams, 1981	*						
Diconodinium cristatum Cookson and Eisenack, 1974 emend. Morgan, 1977	*						
Diconodinium davidii Morgan, 1975	*						
Diconodinium lurense Guerstein *et al.*, 2005						*	5.d
Diconodinium multispinum (Deflandre and Cookson, 1955) Eisenack and Cookson, 1960	*						4.o
Diconodinium pusillum Singh, 1971	*						
Diconodinium sp.	*				*	*	
Dingodinium cerviculum Cookson and Eisenack, 1958 emend. Khowaja-Ateequzzaman, 1990	*	*					4.p
Dingodinium sanmartinoi Pöthe de Baldis and Ramos, 1983	*						
Dinopterygium cladoides (Eisenack and Cookson 1960) Stover and Evitt, 1978		*					
Dinopterygium tuberculatum (Eisenack and Cookson, 1960) Stover and Evitt, 1978	*						4.l
Dinopterygium sp.				*			
Disphaeria macropyla Cookson and Eisenack, 1960emend. Norvick, 1976	*						
Dissiliodinium globulus Drugg, 1978	*						
Downiesphaeridium cf. *armatum* (Deflandre, 1937) Islam, 1993 emend. Davey, 1969			*				
Eisenackia circumtabulata Drugg, 1967						*	
Endoceratium exquisitum Morgan, 1980	*						
Endoceratium ludbrookiae (Cookson and Eisenack, 1958) Loeblich Jr. and Loeblich III, 1966 emend. Morgan, 1980	*						
Endoceratium turneri (Cookson and Eisenack, 1958) Stover and Evitt, 1978	*						4.e
Exochosphaeridinum sp.					*		
Exochosphaeridium bifidum (Clarke and Verdier, 1967) Clarke *et al.*, 1968 emend. Davey, 1969						*	
Exochosphaeridium phragmites Davey *et al.*, 1966	*	*					
Exochosphaeridium robustum Blackhouse, 1988	*						
Exochosphaeridium spp.	*			*			
Florentinia cf. *deanei* (Davey and Williams, 1966) Davey and Verdier, 1973			*				
Florentinia laciniata Davey and Verdier, 1973		*	*				
Florentinia mantellii (Davey and Williams, 1966) Davey and Verdier, 1973		*					
Florentinia spp.	*	*		*			
Gonyaulacysta spp.	*	*					
Hafniasphaera australis Guler *et al.*, 2005						*	5.g,h
Hafniasphaera sp. cf. *H. fluens* Hansen, 1977						*	
Hapsocysta peridictya (Eisenack and Cookson, 1960) Davey, 1979 emend. Davey, 1979	*						4.k
Herendeenia postprojecta Stover and Helby, 1987	*						4.ñ
Heslertonia heslertonensis (Neale and Sarjeant, 1962) Sarjeant, 1966			*				
Homotryblium sp. cf. *H. tenuispinosum* Davey and Williams, 1966			*				
Hystrichodinium sp. cf. *H. isodiametricum* (Cookson and Eisenack, 1958) Stover and Evitt, 1978			*				

	1	2	3	4	5	6	Fig.
Hystrichodinium pulchrum Deflandre, 1935	*	*	*				4.h
Hystrichodinium sp.	*						
Hystrichosphaeridium tubiferum (Ehrenberg, 1837) Deflandre, 1937. emend. Davey and Williams, 1966			*				
Hystrichosphaeropsis ovum Deflandre, 1935			*				
Impagidinium spp.	*			*		*	
Impletosphaeridium sp.	*						
Isabelidinium cretaceum (Cookson, 1956) Lentin and Williams, 1977						*	5.q
Isabelidinium cf. *pellucidum* (Deflandre and Cookson, 1955) Lentin and Williams, 1977					*		
Isabelidinium spp.				*	*	*	5.ñ,o,p
Isabelidinium? acuminatum (Cookson and Eisenack, 1958) Stover and Evitt, 1978			*				
Kaiwaradinium scrutillinum Backhouse, 1987	*						
Kiokansium unituberculatum (Tasch en Tasch *et al.*, 1964) Stover and Evitt, 1978	*	*					
Kleithriasphaeridium fasciatum (Davey *et al.*, 1966) Davey, 1974	*						4.a
Leberidocysta chlamydata (Cookson and Eisenack, 1962) Stover and Evitt, 1978	*	*					
Litosphaeridium arundum (Eisenack and Cookson, 1960) Davey, 1979 emend. Lucas-Clark, 1984	*						4.c
Litosphaeridium siphoniphorum (Cookson and Eisenack, 1958) Davey and Williams, 1966 emend. Lucas-Clark, 1984	*						
Manumiella complex						*	
Manumiella druggii (Stover, 1974) Bujak and Davies, 1983						*	5.r
Manumiella lata (Cookson and Eisenack, 1968) Bujak and Davies, 1983			*				
Meiourogonyaulax sp.	*						
Meiourogonyaulax stoveri Millioud, 1969	*						
Membranilarnacia angustivela (Deflandre and Cookson, 1955) McMinn, 1988						*	
Microdinium ornatum Cookson and Eisenack, 1960	*						
Microdinium reticulatum Vozzhennikova, 1967	*						
Muderongia australis Helby, 1987	*						4.d
Muderongia sp. cf. M. staurota Sarjeant, 1966 emend. Monteil, 1991	*						
Muderongia spp. (Cookson and Eisenak) Stover and Evitt, 1978	*						
Muderongia tetracantha (Gocht, 1957) Alberti,1961 emend. Monteil, 1991.	*	*					4.m
Nelsoniella aceras Cookson and Eisenack, 1960				*			
Nelsoniella tuberculata Cookson and Eisenack, 1960				*			
?Nelsoniella sp.					*		
Nematosphaeropsis densiradiata (Cookson and Eisenack, 1962) Stover and Evitt, 1978	*						
Nematosphaeropsis sp.						*	
Odontochitina costata Alberti, 1961 emend. Clarke and Verdier, 1967	*	*					4.r
Odontochitina imparilis (Duxbury, 1980) Bint, 1986	*						
Odontochitina operculata (Wetzel, 1933) Deflandre and Cookson, 1955	*	*	*				4.q
Odontochitina porifera Cookson, 1956				*			
Odontochitina shinghii Morgan, 1980		*					
Odontochitina spinosa Wilson, 1984					*		5.e
Odontochitina spp.		*			*		
Oligosphaeridium complex (White, 1842) Davey and Williams, 1966	*	*				*	4.b
Oligosphaeridium poculum Jain, 1977	*						
Oligosphaeridium pulcherrimun (Deflandre and Cookson, 1955) Davey and Williams, 1966		*				*	
Oligosphaeridium sp. cf. *O. dividuum* Williams, 1978	*						

	1	2	3	4	5	6	Fig.
Oligosphaeridium sp. cf. *O. pulcherrimun* (Deflandre and Cookson, 1955) Davey and Williams, 1966	*						
Oligosphaeridium spp.	*	*		*			
Oligosphaeridium pulcherrimun (Deflandre and Cookson, 1955) Davey and Williams, 1966	*						
Operculodinium centrocarpum (Deflandre and Cookson, 1955) Wall, 1967			*			*	
Operculodinium cf. *radiculatum* Smith, 1992						*	
Ovoidinium sp.	*	*					4.s
Palaeocystodinium australinum (Cookson, 1965) Lentin and Williams, 1976 emend. Malloy, 1972					*		
Palaeocystodinium granulatum (Wilson, 1967) Lentin and Williams, 1976					*		
Palaeocystodinium lidiae (Górka, 1963) Davey, 1969					*	*	
Palaeocystodinium pilosum Guler *et al.*, 2005							5.l
Palaeocystodinium sp.				*		*	5.k
Palaeohystrichophora infusorioides Deflandre, 1935	*			*			
Palaeoperidinium cretaceum (Pocock, 1962 ex Davey, 1970) Lentin and Williams, 1976 emend. Harding, 1990	*						
Pareodinia spp.	*						
Phoberocysta neocomica (Gocht, 1957) Millioud, 1969	*						
Phoberocysta sp.	*						
Pilosidinium aptiense (Burger, 1980) Courtinat en Fauconnier and Masure, 2004		*					
Prolixosphaeridium conulum Davey, 1969	*	*					
Prolixosphaeridium parvispinium (Deflandre, 1937b) Davey *et al.*, 1969		*					4.i
Prolixosphaeridium parvispinum (Deflandre, 1937) Davey *et al.*, 1969	*						
Prolixosphaeridium sp.	*						
Psaligonyaulax deflandrei Sarjeant, 1966 emend. Sarjeant, 1982	*						
Pterodinium sp.				*			
Saeptodinium? sp.			*				
Senoniasphaera tabulata Backhouse and Helby, in Helby, 1987	*						
Sepispinula ?ambigua (Deflandre, 1937) Masure, in Fauconnier and Masure, 2004	*						
Sepispinula ancorifera (Cookson and Eisenack, 1960) Islam, 1993 emend. Cookson and Eisenack, 1968		*		*			
Spinidinium spp.				*	*		
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854	*	*	*		*	*	
Spiniferites spp.	*	*		*			
Spongodinium reticulatum Hultberg, 1985						*	
Spongodinium sp.						*	
Stephodinium australicum Cookson and Eisenack, 1962	*						
Stephodinium sp.		*					
Stiphrosphaeridium cf. *anthophorum* (Cookson and Eisenack, 1958) Lentin and Williams, 1985			*				
Surculosphaeridium? argentinense (Pöthe de Baldis, 1986) Stover and Williams, 1995			*				
Systematophora areolata Davey, 1979	*						4.n
Systematophora cretacea Davey, 1979		*					
Systematophora sp.				*			
Tanyosphaeridinium sp. cf. *T. isocalamus* (Deflandre and Cookson, 1955) Davey and Williams, 1969		*					
Tanyosphaeridium sp. cf. *T. salpnix* Norvick, 1976	*						
Tanyosphaeridium spp.	*						
Tanyosphaeridium variecalamum Davey and Williams, 1966	*		*				

	1	2	3	4	5	6	Fig.
Tanyosphaeridium xanthiopyxides (Wetzel, 1933 ex Deflandre, 1937) Stover and Evitt, 1978						*	
Tectatodinium rugulatum (Hansen, 1977) McMinn, 1988						*	
Tehamadinium coummia (Below, 1981) Jan du Chêne *et al.*, 1986 emend. Jan du Chêne *et al.*, 1986	*						
Tehamadinium sp. cf. *T. sousense* (Below, 1981) Jan du Chêne *et al.*, 1986		*					
Tehamadinium spp. (3, 4)	*						
Tenua hystrix Eisenack, 1958 emend. Sarjeant, 1985	*						
Trichodinium castanea Deflandre, 1935		*					
Valensiella sp.		*					
Wrevittia cassidata (Eisenack and Cookson, 1960) Helenes and Lucas-Clark, 1997 emend. Sarjeant, 1966	*						
Xenascus asperatus Stover and Helby, 1987	*						
Xenikoon australis Cookson and Eisenack, 1960				*			

Table 1. Taxonomic list of dinoflagellate cyst species identified in the Cretaceous of the Austral-Magallanes Basin. References of taxa follow Fensome and Williams (2004) and Williams *et al*. (2017, DINOFLAJ3). Presence of taxa in different stratigrafical units is indicated: **1)** Springhill Formation (Palamarczuk *et al*., 2000a, b; Guler *et al*., 2003; Guler *et al*., 2015). **2)** Upper Río Mayer/ Piedra Clavada/Kachaike formations (Guler and Archangelsky, 2006a, b; Medina *et al*., 2008). **3)** Río Guanaco Formation (Pöthe de Baldis, 1986). **4)** Alta Vista Formation (González Estebenet *et al*., 2017). **5)** Cerro Cazador (Povilauskas and Guler, 2008). **6)** Calafate Formation (Marenssi *et al*., 2004; Guler *et al*., 2005; Guerstein *et al*., 2005). Reference to figures in right column.