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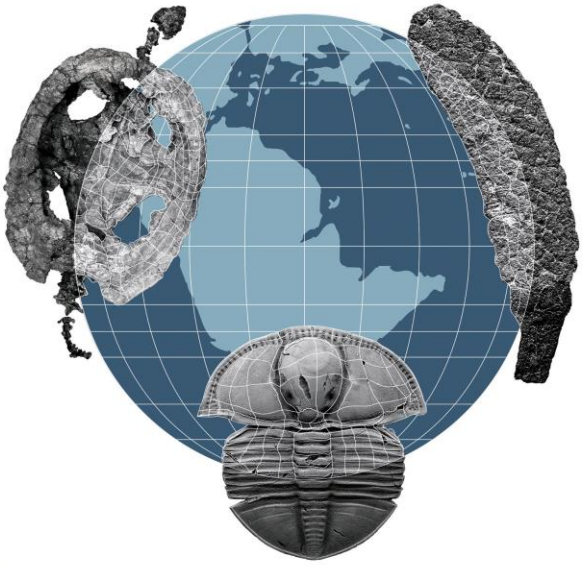

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LATE CRETACEOUS ORGANIC-WALLED DINOFLAGELLATE CYSTS FROM THE ALTA VISTA FORMATION, AUSTRAL BASIN, ARGENTINA

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Abstract. The Alta Vista Formation represents one of the first Late Cretaceous marine deposits accumulated during the foreland stage of the Austral Basin, Patagonia. All the analyzed samples contain dinoflagellate cysts, denoting marine conditions throughout the unit, and despite the extremely poor preservation of the assemblages, diagnostic species were identified. The age of the Alta Vista Formation was assigned between the late Santonian and the late Campanian on the base of the invertebrate remains. Nevertheless, the age is still debatable and a detailed biostratigraphy have not been proposed for the unit so far. As in other Late Cretaceous Southern Hemisphere middle to high latitudes successions, the dinoflagellate cysts from the Alta Vista Formation are useful for biostratigraphic interpretations. The co-occurrence of *Odontochitina porifera*, *Palaeohystrichophora infusorioides*, *Nelsoniella aceras*, *Nelsoniella tuberculata* and *Xenikoon australis* is consistent with a Campanian age, in agreement with the age indicated by the invertebrates recorded in other localities where the unit crop-outs. In particular, the occurrence of *Xenikoon australis* and *Nelsoniella tuberculata* constrains the age to the early–middle Campanian. Since the basal levels of the Alta Vista Formation were not identified in the studied sections, the age suggested herein corresponds to the upper part of the unit.

Keywords. Paleomicroplankton. Biostratigraphy. Campanian. Patagonia. South America.

Resumen. QUISTES DE DINOFLAGELADOS DEL CRETÁCICO TARDÍO DE LA FORMACIÓN ALTA VISTA, CUENCA AUSTRAL, ARGENTINA. La Formación Alta Vista representa uno de los primeros depósitos marinos del Cretácico Superior acumulados durante la etapa de antepaís de la Cuenca Austral, Patagonia. Todas las muestras analizadas contienen quistes de dinoflagelados, denotando condiciones marinas a lo largo de la secuencia y, a pesar de la pobre preservación de

las asociaciones, se identificaron especies diagnósticas. La edad de la formación fue asignada al Santoniano tardío-Campaniano tardío sobre la base de invertebrados fósiles. Sin embargo, la edad es aún motivo de debate y una bioestratigrafía ajustadapara la unidad no ha sido propuesta hasta el momento.Al igual que en otras sucesiones de latitudes medias a altas del Cretácico Superior del Hemisferio Sur, los quistes dinoflagelados de la Formación Alta Vista son útiles para interpretaciones bioestratigráficas. La co-ocurrencia de *Odontochitina porifera*, *Palaeohystrichophora infusorioides*, *Nelsoniella aceras*, *Nelsoniella tuberculata* and *Xenikoon australis* es consistente con una edad campaniana, en concordancia con la edad indicada por los invertebrados registrados en otras localidades donde la unidad aflora. En particular, la presencia de *Xenikoon australis* y *Nelsoniella tuberculata* limita la edad al Campaniano temprano-medio. Dado que los niveles basales de la Formación Alta Vista no fueron identificados en la sección estudiada, la edad aquí sugerida podría corresponder a la parte superior de la unidad.

Palabras clave. Paleomicroplancton. Bioestratigrafía. Campaniano. Patagonia. América del Sur.

THE organic-walled dinoflagellate cysts are a valuable tool for biostratigraphic interpretations in Upper Cretaceous sequences worldwide (e.g. Wilson, 1984; Helby *et al.*, 1987; Askin, 1988; Marshall, 1990; Mao and Mohr, 1992; Mohr and Mao, 1997; Schiøler and Wilson, 1998; Roncaglia *et al.*, 1999; Brinkhuis *et al.*, 2003; Fensome *et al.*, 2008; Bowman *et al.*, 2012). Diverse stratigraphic frameworks based on diagnostic dinoflagellate cyst events in the middle to high latitudes of the Southern Hemisphere have been performed in the Antarctic Peninsula (Askin, 1988; Askin and Jacobson, 1996; Thorn *et al.*, 2009; Bowman *et al.*, 2012), New Zealand (Wilson, 1984; Roncaglia *et al.*, 1999); Australia (Helby *et al.*, 1987; McMinn, 1988; Marshall, 1990); Southern Indian Ocean (Mao and Mohr, 1992) and the Tasman Shelf (Brinkhuis *et al.*, 2003). However, the southernmost part of South America (Patagonia, Argentina) lacks a refined Late Cretaceous dinoflagellate cysts biostratigraphy and the scarce records described so far are confined to the southwest of the Santa Cruz Province (Pöthe de Baldis, 1986; Marenssi *et al.*, 2004; Guler *et al.*, 2005; Povilauskas and Guler, 2008). Furthermore, erratic records and the endemism observed in these assemblages have hampered a biostratigraphic correlation with other Upper Cretaceous middle to high-latitudes austral successions.

In the Austral Basin, the Alta Vista Formation (Furque 1973; *nom. transl.* Arbe and Hechem, 1984) represents one of the first marine deposits accumulated during the foreland basin stage (Arbe and Hechem, 1984; Kraemer and Riccardi, 1997). Originally, the sedimentology and the paleontological characteristics of the unit were analyzed by Furque (1973), Arbe and Hechem (1984), Riccardi and Rolleri (1980), Riccardi (1983), Kraemer and Riccardi (1997), Arbe (2002). In turn, the age of the Alta Vista Formation has been assigned between the late Santonian and the late Campanian on the base of the invertebrate remains, mainly ammonites and bivalves (Riccardi and Rolleri, 1980; Riccardi 1983; Kraemer and Riccardi, 1997; Arbe, 2002). Nevertheless, the age

of the Alta Vista Formation is still debatable and its resolution is important since it constitutes one of the key stratigraphical units for the understanding of the evolution of the Austral basin during the Late Cretaceous. The aim of the present paper is to propose the age of the Alta Vista Formation in the south of the Lago Argentino (Santa Cruz Province, Argentina) based on diagnostic dinoflagellate cyst taxa, and to discuss with other biostratigraphic data previously indicated by other authors.

GEOLOGICAL SETTING

The Austral Basin (Magallanes Basin in Chile) extends through a wide area (approximately 230.000 Km^2) in the southwestern portion of the South American Plate encompassing the southernmost part of Chile, Argentina and the adjacent Continental Platform (Fig 1; Nullo *et al*., 1999). It comprises about 160.000 m^2, its shape is elongated in a NNW-SSE direction and it is bounded by the Scotia Plate to the south, the Patagonian – Fueguian Andes to the west, and the Deseado Massif and the Río Chico High to the northeast (Fig. 1). The geological development of the Austral Basin is associated with three main tectonic stages. The first one is the rift stage during the Jurassic, associated with the breakup of Gondwana and the early opening of the South Atlantic Ocean (Pankhurst *et al*., 2000). The fill of this stage consist of volcaniclastic syn-rift deposits and marine transgressive sequences (Dalziel, 1981; Biddle *et al*., 1986). Subsequently, a thermal subsidence stage developed in the Early Cretaceous, and the third one corresponds to the foreland stage from the "mid" Cretaceous to the Neogene (Arbe, 1989, 2002; Biddle *et al*., 1986). During the "mid" Cretaceous a change in the tectonic context took place due to the beginning of subduction along the western margin of South America which generated the uplift of the Andean

belt and a retroforeland subsidence to the east (Biddle *et al*., 1986; Ramos, 1989; Wilson, 1991; Fildani and Hessler, 2005; Spalletti and Franzese, 2007; Varela, 2011; Varela *et al*., 2012).

The Alta Vista Formation is related with the beginning of the foreland stage of the Austral Basin (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. The Alta Vista Formation crop-outs in theAnita and Alta Vista farms, in the southeastern of the Lago Argentino (Fig. 1) and consists of a 345 meter-thick succession of very fine dark-grey sediments, rarely interbedded with yellow sandstone bodies (Fig. 2). The thick fine sediment intervals (15 - 85 m) are composed by very thin beds of structureless mudstones, structureless very fine sandstones, and thinly laminated sandstones. These deposits contain abundant plant debris and a low grade of bioturbation. The rare yellow sandstone bodies are sigmoidal-shape strata internally composed by structureless fine-sandstones, laminated sandstone and sandstone with ondulitic lamination. To a lesser extent, these sandstones intervals are characterized by heterolithic and mudstones facies. As in the mud-rich intervals, these sandstone bodies exhibit abundant plant debris and a higher bioturbation grade.

MATERIALS AND METHODS

A total of 42 samples from the lower and middle part of the Alta Vista Formation from the Anita and Alta Vista farms were processed for palynological analysis (Fig. 2). The chemical treatment of the samples included the removal of carbonates and silicates with hydrochloric and hydrofluoric acids, respectively. Organic residues were sieved at 10 and 20 μm, stained with Bismarck C and mounted in glycerin–jelly. Light microscopy observation was at 600× and 1000×

magnifications using a Nikon Eclipse 600 and Leica DM 2500. The nomenclature of dinoflagellate cysts mentioned in the text follows Fensome and Williams (2004) and Fensome *et al.* (2008). Images were taken with a Nikon Coolpix 950 digital camera. The sample number followed by the England Finder (EF) references are provided for each illustrated specimen. Slides containing the illustrated specimens are stored in the Colección Palinológica, Laboratorio de Palinología,INGEOSUR-Universidad Nacional del Sur, Bahía Blanca, Argentina.

DINOFLAGELLATE CYST ASSEMBLAGES COMPOSITION

Palynomorph assemblages from the 42 productive samples analyzed from the Alta Vista Formation contain dinoflagellate cysts, pollen grains, spores, freshwater green algae and foraminiferal linings; only one sample was barren of dinoflagellate cysts (AV25, Fig. 2). The presence of dinoflagellate cysts in all the samples indicate marine conditions throughout the unit. The extremely poor preservation of the palynological assemblages has hampered the taxonomical identification of the dinoflagellate cyst specimens and hence, most of them were placed as indeterminate. The dinoflagellate cysts taxa identified were listed in Table 1 and their stratigraphic distribution is shown in Table 2. Selected specimens were illustrated in Figure 3.

BIOSTRATIGRAPHICALLY SIGNIFICANT DINOFLAGELLATE CYSTS

The relative dating of the Alta Vista Formation relies on a few dinoflagellate cyst species with well-known lowest occurrences (LOs) and highest occurrences (HOs), among them: *Odontochitina porifera*, *Palaeohystrichophora infusorioides*, *Nelsoniella aceras*, *Nelsoniela tuberculata* and *Xenikoon australis*; the last three ones are South Hemisphere mid to high latitude conspicuous taxa (e.g. Lentin and Williams, 1980; Mao and Mohr, 1992; Helby *et al*., 1987). Figure 4 shows the main Late Cretaceous Australian and New Zealand dinoflagellate cysts Zones

which are reference biostratigrafic frameworks for the South Hemisphere and the biostratigraphical ranges of the diagnostic species which are considered reference.

The LO of ***Odontochitinia porifera*** marks the base of the early Santonian Australian *Odontochitina porifera* 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). Williams *et al.* (2004) indicated the LO of *Odontochitina porifera* between ca. 85 Ma (Southern Hemisphere mid-latitudes) and 84 Ma (Northern Hemisphere mid-latitudes). The HO of *Odontochitina porifera* has been previously recorded from the lower-middle Campanian of Australia (Marshall, 1985; Helby *et al.*, 1987) and the upper Campanian of the James Ross Island Group, Antarctica (Dettmann and Thomson, 1987; Askin, 1988; Askin *et al.*, 1991; Duane *et al.*, 1992). However, these dinoflagellate assemblages from the James Ross Island region of Antarctica were assigned to a late Campanian to early Maastrichtian age (Pirrie and Riding, 1988; Crame *et al.*, 1991; Pirrie *et al.*, 1997). Likewise, the HO of the species marks the top of the *Odontochitina porifera* Range Zone of Wilson (1984) (=*Odontochitina porifera* Range Superzone Schiøler and Wilson, 1998) of Campanian – Maastrichtian age and marks the base of the late Maastrichtian *Alterbidinium acutulum* Interval Zone of Wilson (1984, New Zealand). Mohr and Mao (1997) recorded the HO of *Odontochitina porifera* in the lower Maastrichtian (Southern Ocean). Williams *et al.* (2004) indicated the HOs between ca. 71 Ma and 70.5 Ma in the Northern and Southern Hemisphere mid-latitudes, respectively.

Palaeohystrichophora infusorioides is recorded since the early Late Cretaceous (Schiøler and Wilson, 1998; McMinn, 1988) and its HO is within the Subzone C-l of Mao and Mohr (1992) of late Campanian age (Mohr and Mao, 1997). In agreement, Fensome *et al.* (2009) recorded the HO of *Palaeohystrichophora infusorioides* at 73 Ma (late Campanian) in the Northern Hemisphere

(Scotian Margin, Canada). It is worth mentioning that Pöthe de Baldis (1986) recorded this species in Santonian-Campanian deposit from the south of the Lago Viedma, Santa Cruz Province.

The LO of ***Nelsoniella aceras*** marks the base of the Australian *Nelsoniella aceras* Interval Zone of Evans (1971) of late Santonian-early Campanian age (Helby *et al*., 1987; McMinn, 1988). This zone was also recognized in New Zealand (Schiøler and Wilson, 1998) and Kerguelen Plateau, southern Indian Ocean (Mao and Mohr, 1992). The HO of *Nelsoniella aceras* extends to the top of the *Xenikoon australis* Interval Zone (Helby *et al.*, 1987) of early Campanian age, which is partly synchronous with the lower-middle Campanian *Satyrodinium haumuriense* Interval Zone of Marshall (1990) (Schiøler and Wilson, 1998; Roncaglia *et al.*, 1999). In northeastern Antarctic Peninsula, Askin (1988), Askin *et al.* (1991) and Duane *et al.* (1992) recorded the HO of *Nelsoniella aceras* in sediments of middle Campanian age. These records indicate that the stratigraphical range of *Nelsoniella aceras* spans from late Santonian to middle Campanian, though Mao and Mohr (1992) recorded the HO of this species in the upper Maastrichtian from the Southern Indian Ocean (Hole 748C).

According to Helby *et al.* (1987) ***Nelsoniella tuberculata*** occurs with and have concurrent range with *Nelsoniella aceras*, which extends from the late Santonian to the early Campanian, spanning the *Nelsoniella aceras* Interval Zone and the *Xenikoon australis* Interval Zone (Fig. 4). Marshall (1990; Australia) and Roncaglia *et al.* (1999; New Zealand) stated that the stratigraphic range of *Nelsoniella tuberculata* is confined to early - middle Campanian *Satyrodinium haumuriense* Interval Zone (Marshall, 1990); specifically confined to the *Vozzhennikovia spinulosa* Interval Subzone of Roncaglia and Schiøler (1997). Therefore, the stratigraphic range of *Nelsoniella tuberculata* extends from late Santonian to middle Campanian.

The LO of ***Xenikoon australis*** marks the base of the Australian *Xenikoon australis* Interval Zone of early Campanian age (Helby *et al.*, 1987). In the southern Indian Ocean (ODP, Hole 748C) this species has the LO in the late Campanian (Subzone B-3; Mao and Mohr, 1992) and in New Zealand is recorded in the early Campanian *Satyrodinium haumuriense* Zone, within the *Vozzhennikovia spinulosa* Interval Subzone (Roncaglia and Schiøler, 1997; Roncaglia *et al.*, 1999). According to Helby *et al.* (1987). The HO of *Xenikoon australis* marks the top of the *Xenikoon australis* Zone (early Campanian, Helby *et al.*, 1987) and moreover, the youngest occurrences of *Xenikoon australis* and *Nelsoniella* spp. are more or less coincident in Australia (Helby *et al.*, 1987). The HO of *Xenikoon australis* is recorded in the Maastrichtian from sediments of Southern Indian Ocean (Mao and Mohr, 1992), New Zealand (Roncaglia *et al.*, 1999) and only two records come from the Nothern Hemisphere (Benson, 1976; Firth, 1987). Thus, the stratigraphic range of *Xenikoon australis* extends from early Campanian to Maastrichtian.

DISCUSSION AND CONCLUSIONS

As it was previously mentioned, the Alta Vista Formation in the Lago Argentino area conformably overlies the Cerro Toro Formation and in turn, it is conformably overlain by the Anita Formation (Furque, 1973; Riccardi and Rolleri, 1980; Arbe and Hechem, 1984; Cereceda, 2016; Fig. 5). The Cerro Toro Formation has been assigned to an early Cenomanian - early Campanian age, based on inoceramids and ammonites (Feruglio, 1945; Leanza, 1967; Furque, 1973; Ricardi and Rolleri, 1980; Arbe and Hechem, 1984; Kraemer and Riccardi, 1997). Furthermore, U/Pb detrital zircons analysis in Chile, indicated a maximum depositional Cenomanian - Santonian interval for the Cerro Toro Formation (Berndhardt *et al.*, 2012). The Anita Formation has been assigned to the Campanian - ?early Maastrichtian based on their fossil invertebrate remains

(Feruglio, 1945, 1949; Furque, 1973; Riccardi and Rolleri, 1980; Riccardi, 1983; Arbe and Hechem, 1984; Kraemer and Riccardi, 1997).

The age of the Alta Vista Formation has been largely discussed (Fig. 5). Furque (1973) recognized sediments of Late Cretaceous age in the Lago Argentino area and defined the Las Hayas Formation, composed of the Horqueta and the Alta Vista members. The bivalve *Inoceramus* and a complete specimen of *Eupachydiscus* in the base would have indicated a the late Santonian – early Campanian age for the Las Layas Formation (Leanza, 1967). In the South of the Viedma Lake, Riccardi and Rolleri (1980) and Riccardi (1983) defined early Campanian kossmaticeratid ammonites-bearing levels at the upper part of the Cerro Toro Formation that would correspond to the Alta Vista Member according to these authors. Arbe and Hechem (1984) elevated the Alta Vista Member (*sensu* Furque 1973) to the rank of formation and divided it into two members. In the Lower Member of the Alta Vista Formation Kraemer and Riccardi (1997) recorded fragments of re-transported bivalves and Arbe (2002) recognized specimens belonging to the *Anapachydiscus steinmanii* Zone of Kraemer and Riccardi (1997) of Santonian-Campanian age. In the Upper Member the invertebrate fauna (Kraemer and Riccardi, 1997) and the fossils kossmaticeratids indicated an early Campanian age (Riccardi, 1983). Nevertheless, according to Arbe and Hechem (1984) and Arbe (2002) (in figure 1 and 6), the Upper Member would extend into the late Campanian.

Palynomorph assemblages from the Alta Vista Formation here analyzed show a poor preservation, presumably subjectedto high temperatures and pressure; compressive processes related to tectonic deformation of the orogenic front would have affected the studied area during the "mid"-Cretaceous-Neogene (Ramos *et al*., 1982; Biddle *et al*., 1986). Although a small number of dinoflagellate cysts could be taxonomically identified, the presence of age-diagnostic taxa

provided significative bioestratigraphic data. . The co-occurrence of *Odontochitina porifera*, *Palaeohystrichophora infusorioides Nelsoniella aceras*, *Nelsoniella tuberculata* and *Xenikoon australis* is consistent with a Campanian age. Furthermore, the LO of *Xenikoon australis* and the HO of *Nelsoniela tuberculata* suggest an age no older than early Campanian and no younger than middle Campanian.

Since the basal levels of the unit were not identified in the studied sections (Cereceda, 2016) the age suggested by the dinoflagellate cysts might correspond to the upper part of the Formation, in agreement with the early-middle Campanian age indicated by the invertebrate fauna recorded in other localities (Riccardi, 1983; Kraemer and Riccardi, 1997; Arbe, 2002).

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CAPTIONS

Figure 1.1. Location map of the study area, southwestern Patagonia, Argentina. **2,** Detail of the location of the study section of the Alta Vista Formation in the hills of the Anita and Alta Vista farms (50°29'20.51" S - 72°34'34.00" W).

Figure 2. Stratigraphic section of the Alta Vista Formation indicating location of the palinological samples analyzed.

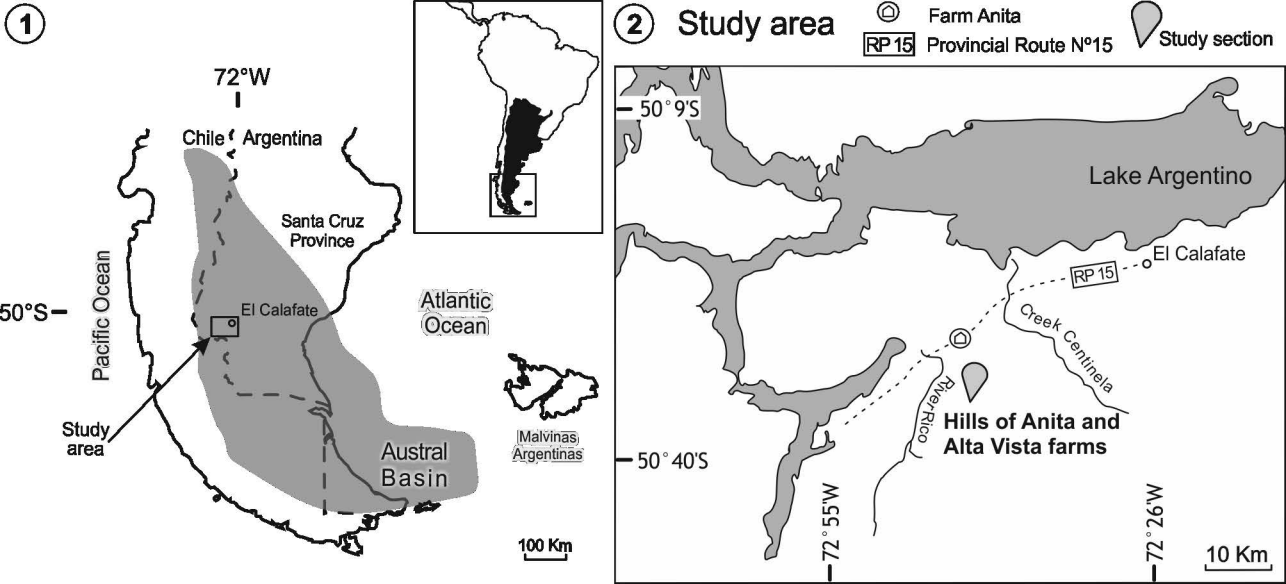
Table 1. Taxonomic list of genera and species of dinoflagellate cysts identified in the Alta Vista Formation.

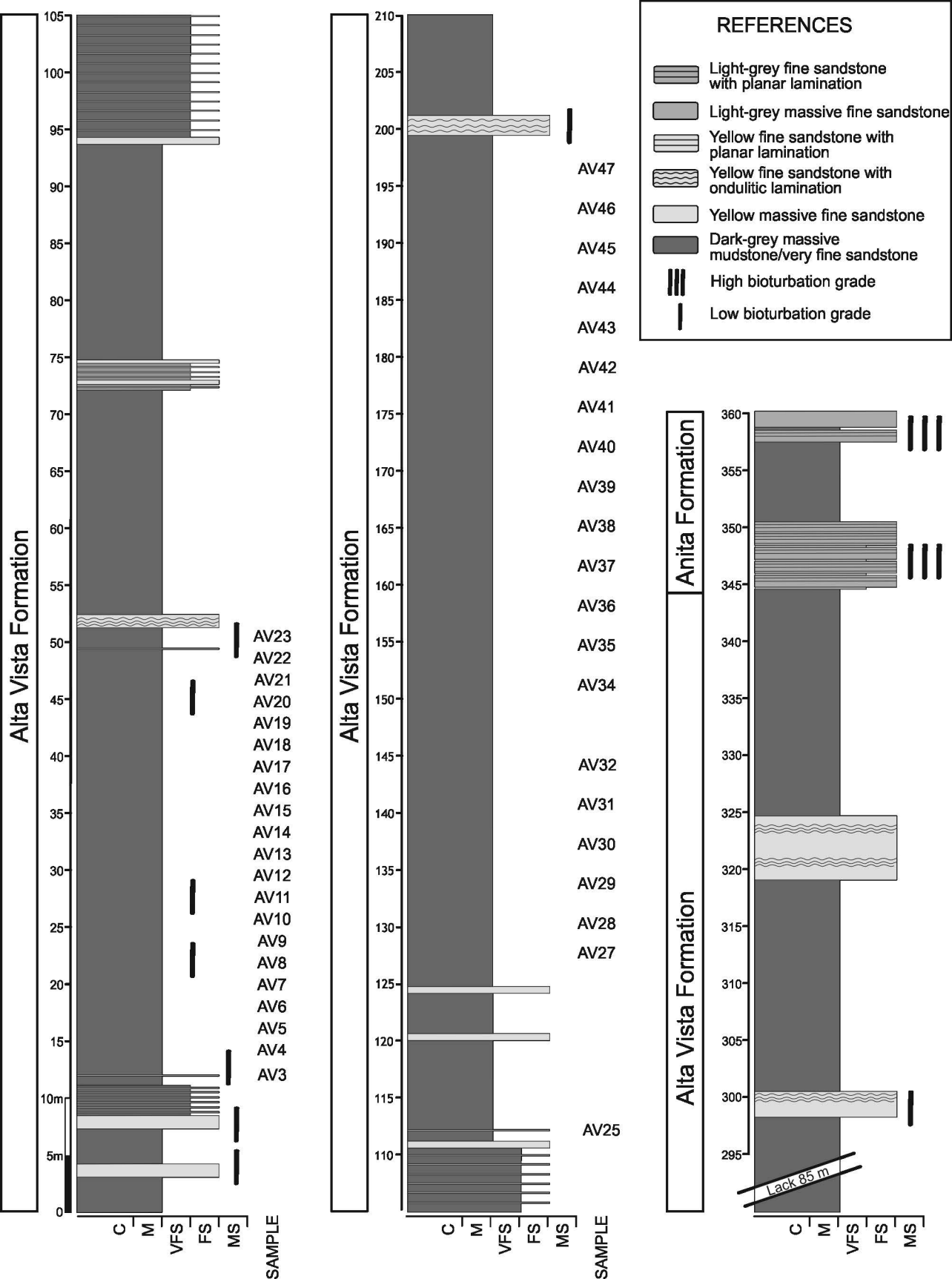
Figure 3. Dinoflagellate cysts from the Alta Vista Formation. Specimens are identified by sample number/England Finder references. Scale bar = 20 μm. **1, *Nelsoniella aceras*** Cookson and Eisenack, 1960, AV13/J40-3; **2, *Xenikoon australis*** Cookson and Eisenack, 1960, AV17/X29; **3, *Cribroperidinium*** sp. AV19/E28-1; **4, *Nelsoniella tuberculata*** Cookson and Eisenack, 1960 AV14/J38-3; **5, *Exochosphaeridium*** sp. AV14/A47-2; **6, *Cribroperidinium*** sp. AV23/P22; **7, *Sepispinula ancorifera*** AV17/P54-4; **8, *Dinopterygium*** sp. AV13/N52-2; **9, *Palaeohystrichophora infusorioides*** Deflandre, 1935 AV34/N58; **10, *Chatangiella*** sp., AV12/V31-4 **11, cf. *Chatangiella*** sp. AV19/N42-1; **12, *Odontochitina porifera*** Cookson, 1956, AV10/Z27-4.

Table 2. Stratigraphic distribution of the dinoflagellate cyst taxa identified in the studied sections of the Alta Vista Formation, ordered following the lowest occurrences. Species with biostratigraphic importance are highlighted in grey.

Figure 4. Dinoflagellate cyst zones of Australia (Helby *et al*., 1987) and New Zealand (Schiøler and Wilson, 1998; Roncaglia *et al.*, 1999), showing LO datums and HO datums of selected key dinoflagellate cyst species.

Figure 5. Stratigraphic chart of the Upper Cretaceous units of the Austral Basin in Lago Argentino region. It shows the different stratigraphic proposals for the Alta Vista Formation considered in this study.


1
72°W
Chile
Argentina
Santa Cruz
Province
Pacific Ocean
50°S
El Calafate
Study
area
Atlantic
Ocean
Austral
Basin
Malvinas
Argentinas
100 Km
2
Study area
Farm Anita
RP 15
Provincial Route Nº15
Study section
50° 9'S
Lake Argentino
El Calafate
RP 15
Creek Centinela
R. Rico
Hills of Anita and
Alta Vista farms
50° 40'S
72° 55'W
72° 26'W
10 Km


REFERENCES
Light-grey fine sandstone with planar lamination
Light-grey massive fine sandstone
Yellow fine sandstone with planar lamination
Yellow fine sandstone with ondulitic lamination
Yellow massive fine sandstone
Dark-grey massive mudstone/very fine sandstone
High bioturbation grade
Low bioturbation grade
Alta Vista Formation
Anita Formation
Alta Vista Formation
Alta Vista Formation
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10m
5m
0
AV23
AV22
AV21
AV20
AV19
AV18
AV17
AV16
AV15
AV14
AV13
AV12
AV11
AV10
AV9
AV8
AV7
AV6
AV5
AV4
AV3
C
M
VFS
FS
MS
SAMPLE
210
205
200
195
190
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145
140
135
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120
115
110
AV47
AV46
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AV32
AV31
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AV25
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SAMPLE
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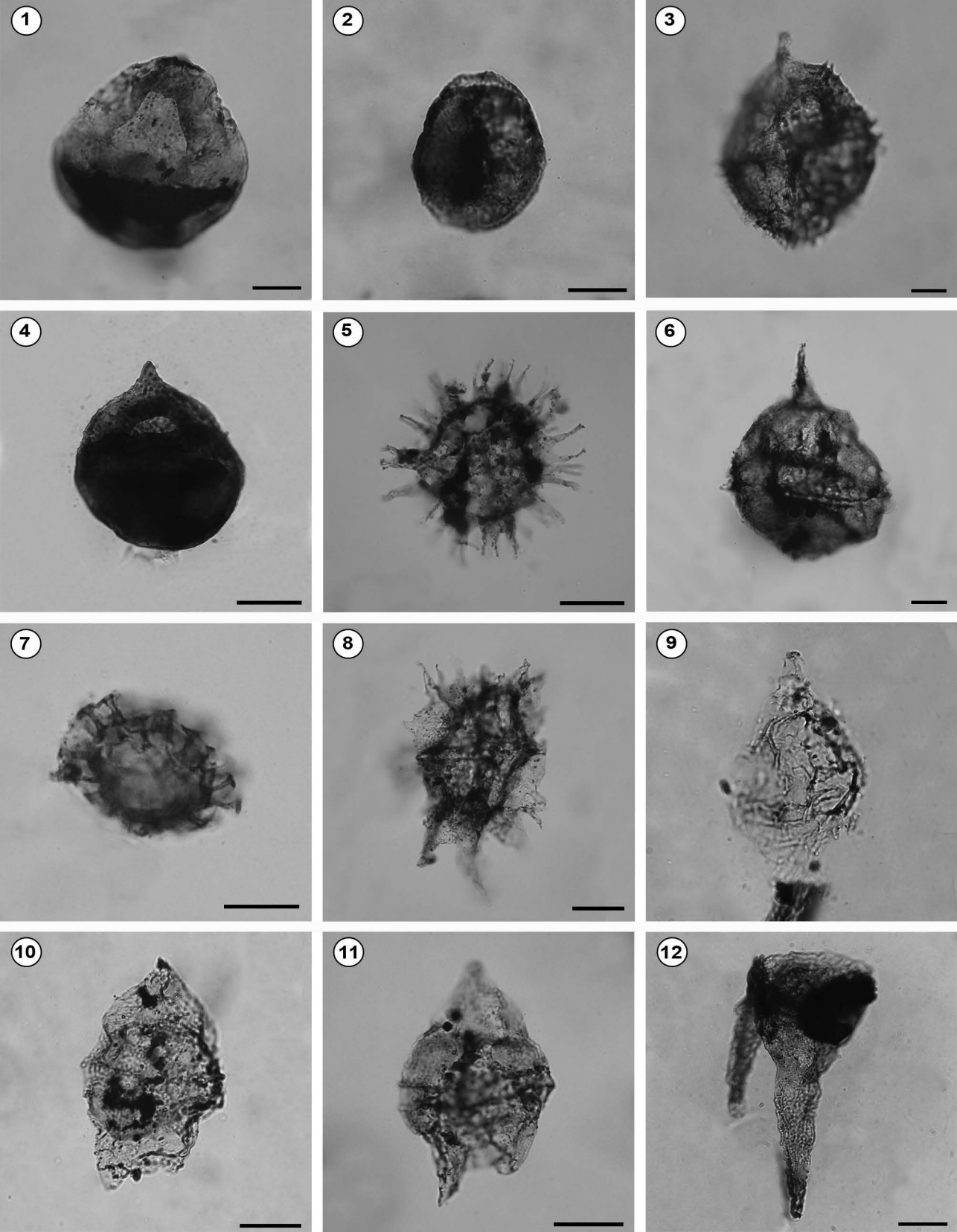
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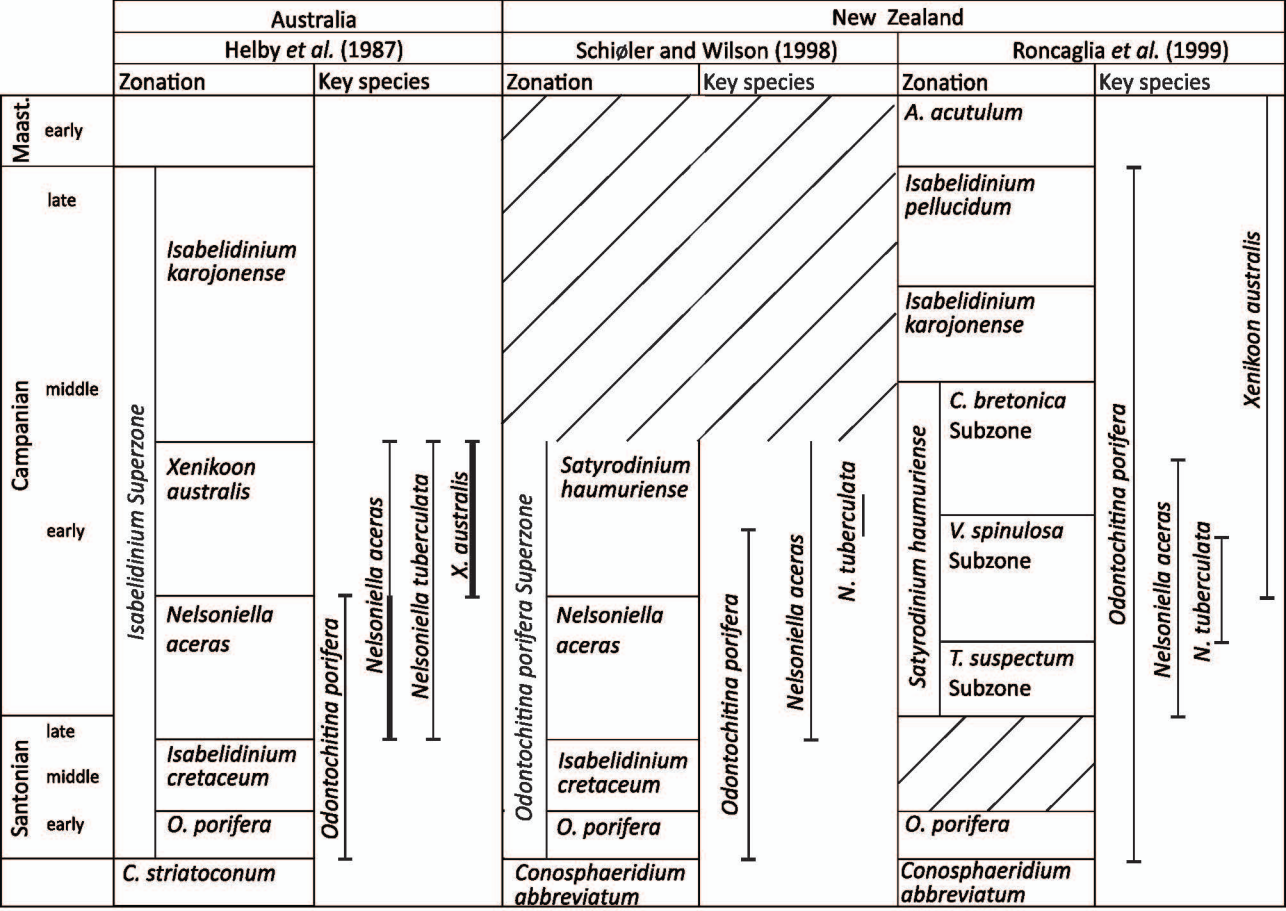
Australia
New Zealand
Helby et al. (1987)
Schiøler and Wilson (1998)
Roncaglia et al. (1999)
Zonation
Key species
Zonation
Key species
Zonation
Key species
Maast.
early
late
Campanian
middle
early
Santonian
late
middle
early
Isabelidinium Superzone
Isabelidinium karojonense
Xenikoon australis
Nelsoniella aceras
Isabelidinium cretaceum
O. porifera
C. striatoconum
Odontochitina porifera
Nelsoniella aceras
Nelsoniella tuberculata
X. australis
Odontochitina porifera Superzone
Satyrodinium haumuriense
Nelsoniella aceras
Isabelidinium cretaceum
O. porifera
Conosphaeridium abbreviatum
Odontochitina porifera
Nelsoniella aceras
N. tuberculata
A. acutulum
Isabelidinium pellucidum
Isabelidinium karojonense
Satyrodinium haumuriense
C. bretonica Subzone
V. spinulosa Subzone
T. suspectum Subzone
O. porifera
Conosphaeridium abbreviatum
Odontochitina porifera
Nelsoniella aceras
N. tuberculata
Xenikoon australis
References:
Lowest occurrence
Highest occurrence
Presence
Abundance

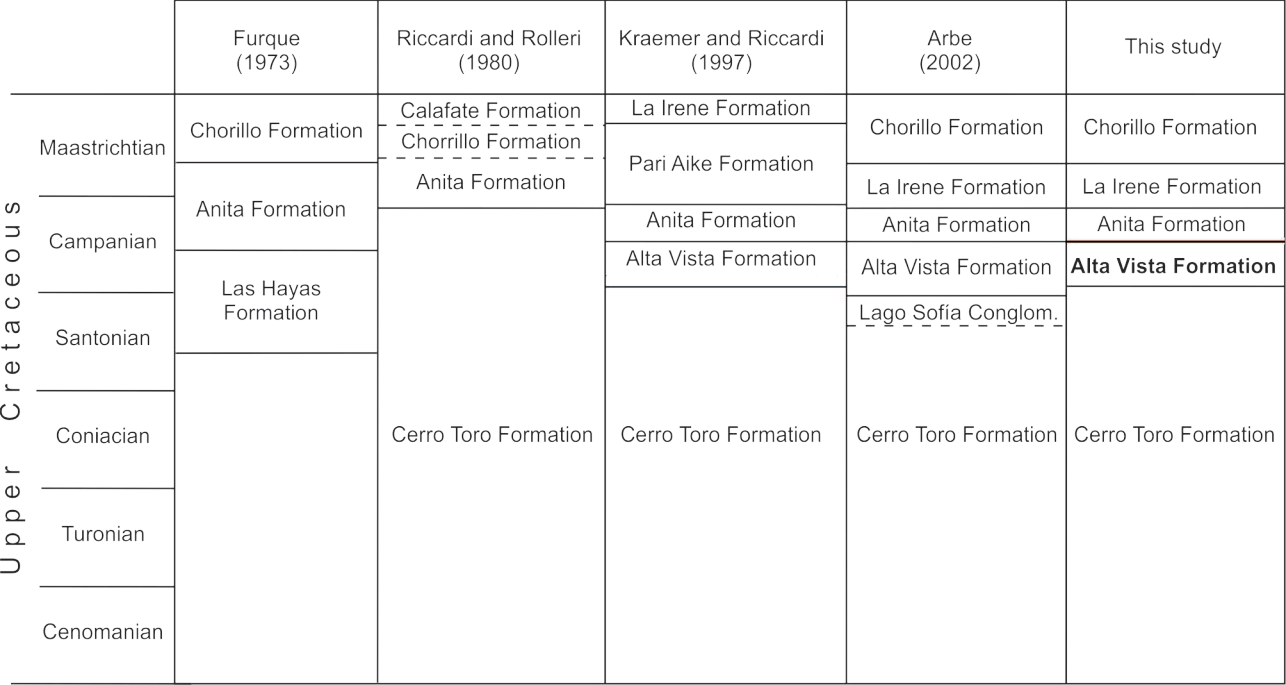
Furque (1973)
Riccardi and Rolleri (1980)
Kraemer and Riccardi (1997)
Arbe (2002)
This study
Upper Cretaceous
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Chorillo Formation
Anita Formation
Las Hayas Formation
Calafate Formation
Chorrillo Formation
Anita Formation
Cerro Toro Formation
La Irene Formation
Pari Aike Formation
Anita Formation
Alta Vista Formation
Cerro Toro Formation
Chorillo Formation
La Irene Formation
Anita Formation
Alta Vista Formation
Lago Sofía Conglom.
Cerro Toro Formation
Chorillo Formation
La Irene Formation
Anita Formation
Alta Vista Formation
Cerro Toro Formation

TABLE 1. Taxonomic list of species of dinoflagellate cysts present in the Alta Vista Formation.

Alterbidinium acutulum *(Wilson, 1967) Lentin and Williams, 1985 emend. Khowaja-Ateequzzaman* et al.*, 1991*
Apteodinium *sp.*
cf. Florentinia *Davey and Verdier, 1973 emend. Duxbury, 1980*
Chatangiella *spp.*
Circulodinium *sp.*
Coronifera oceanica *Cookson and Eisenack, 1958 emend. May, 1980*
Cribroperidinium *spp.*
Dinopterygium *sp.*
Exochosphaeridium *spp.*
Impagidinium *spp.*
Isabelidinium *spp.*
Nelsoniella aceras *Cookson and Eisenack, 1960*
Nelsoniella tuberculata *Cookson and Eisenack, 1960*
Odontochitina porifera *Cookson, 1956*
Oligosphaeridium *sp.*
Palaeocystodinium *sp.*
Palaeohystrichophora infusorioides *Deflandre, 1935*
Pterodinium *sp.*
Sepispinula ancorifera *(Cookson and Eisenack, 1960) Islam, 1993 emend. Cookson and Eisenack, 1968*
Spinidinium *spp.*
Spiniferites *spp.*
Systematophora *sp.*
Xenikoon australis *Cookson and Eisenack, 1960*

TABLE 2. Stratigraphical distribution of the dinoflagellate cyst taxa identified in the Alta Vista Formation, ordered following the lowest occurrences. Species with biostratigraphic importance are highlighted in grey.

Samples	**dinoflagellate cysts indet.**	**Nelsoniella tuberculata**	**Xenikoon australis**	**Cribroperidinium** *spp.*	**Dinopterygium** *sp.*	**Isabelidinium** *spp.*	**Nelsoniella aceras**	**Odontochitina porifera**	*cf.* **Florentinia**	**Pterodinium** *sp.*	**Spiniferites** *spp.*	**Chatangiella** *spp.*	**Sepispinula ancorifera**	**Spinidinium** *spp.*	**Exochosphaeridium** *spp.*	**Systemalophora** *sp.*	**Impagidinium** *spp.*	**Alterbidinium acutulum**	**Coronifera oceanica**	**Palaeohystrichophora infusorioides**	**Circulodinium** *sp.*	**Apteodinium** *sp.*	**Oligosphaeridium** *sp.*	**Palaeocystodinium** *sp.*
AV47	●																							
AV46	●							●																
AV45	●							●																
AV44	●		●			●		●			●													
AV43	●	●	●				●	●						●	●								●	●
AV42	●			●				●																
AV41	●							●							●							●		
AV40	●		●				●																	
AV39	●																							
AV38	●			●				●																
AV37	●																							
AV36	●																							
AV35	●	●		●			●	●																
AV34	●	●		●			●								●					●	●			
AV32	●	●																						
AV31	●																							
AV30	●			●																				
AV29	●																							
AV28	●			●				●																
AV27	●																							
AV23	●			●				●																
AV22	●	●																						
AV21	●	●																						
AV20	●	●	●			●		●																
AV19	●	●	●	●		●	●	●				●						●	●					
AV18	●	●	●			●	●																	
AV17	●	●	●		●	●	●					●	●					●						
AV16	●	●	●	●	●	●	●	●							●									
AV15	●	●	●	●			●	●			●			●			●							
AV14	●	●	●				●							●	●	●								
AV13	●	●	●	●	●	●	●	●			●		●	●										
AV12	●	●	●	●		●	●	●				●												
AV11	●	●	●	●	●	●	●	●				●												
AV10	●	●	●			●	●	●			●	●												
AV9	●	●	●	●	●	●	●	●		●	●													
AV8	●	●	●	●																				
AV7	●		●		●			●																
AV6	●		●				●		●															
AV5	●	●	●	●	●	●	●	●																
AV4	●	●	●																					
AV3	●	●																						