The austral palaeobiogeography of an Early Cretaceous (Albian) trigoniid bivalve assemblage from the upper part of the Fossil Bluff Group, Alexander Island, Antarctica

by

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Abstract

An Early Cretaceous (Late Albian) assemblage of trigoniid bivalves occurs in a single bed of the Mars Glacier Formation, in the upper part of the Fossil Bluff Group in eastern Alexander Island, Antarctica. It comprises: *Eselaevitrigonia* sp. nov., *Nototrigonia (Nototrigonia) ponticula* SKWARKO, *Nototrigonia (Nototrigonia) spedeni* FLEMING, *Nototrigonia (Callitrigonia)* sp. nov., *Pacitrigonia* sp. nov. and *Pisotrigonia capricornia* SKWARKO, all new records for Antarctica. The assemblage most resembles Australasian faunas, rather than South American ones, and provides an example of a distinct Austral palaeobiogeographic distribution. The surface flow of the southern margin of the Pacific Ocean was eastwards, bringing larval spat from Australasia towards the west coast of the Antarctic Peninsula. Larval spat from Alexander Island appear to have been denied access to the Austral Basin of South America. Possible reasons for this include palaeogeographic barriers and Pacific Ocean current circulation.

Introduction

This article assesses the palaeobiogeographic significance of newly discovered Late Albian trigoniids of Alexander Island (Fig. 1). The fauna compares most closely those from Australia (e.g. SKWARKO 1963; 1981a–d) and New Zealand (FLEMING 1987), and provides a marked contrast to the more proximal faunas from the Austral Basin in southern South America (MEDINA 1987). Trigoniids are not recognised in the Neuquen (Andean) Basin further north (PERÉZ and REYES 1978; 1979). This article examines the faunal discrepancy between the areas.

The trigoniid fauna is common in a single bed of the Mars Glacier Member of the Neptune Glacier Formation in the upper part the Fossil Bluff Group (Fig. 2). Hitherto, trigoniid bivalves from this group have been described only from Jurassic-Cretaceous boundary strata (WILLEY 1975). The new locality is on the north side of Offset Ridge (KG.4203), 7 km W of Triton Point (Fig. 3). It is the southernmost Cretaceous trigoniid locality known (68°23' W, 71°40' S). However, originally it would have been situated at about 70 °S, based on the Atlas 3 palaeogeographic reconstruction for the Albian at 105 Ma (Cambridge Paleomap Services 1992).

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The Albian trigoniid fauna, which is completely new to the Early Cretaceous of Antarctica, is being prepared for formal systematic description elsewhere (KELLY in prep.). It comprises six taxa, mainly nototrigoniids (Fig. 4):

> *Eselaevitrigonia* aff. *meridiana* WOODS
> *Nototrigonia (Nototrigonia) ponticula* SKWARKO
> *Nototrigonia (Nototrigonia) spedeni* FLEMING
> *Nototrigonia (Callitrigonia)* sp. nov.
> *Pacitrigonia* sp. nov.
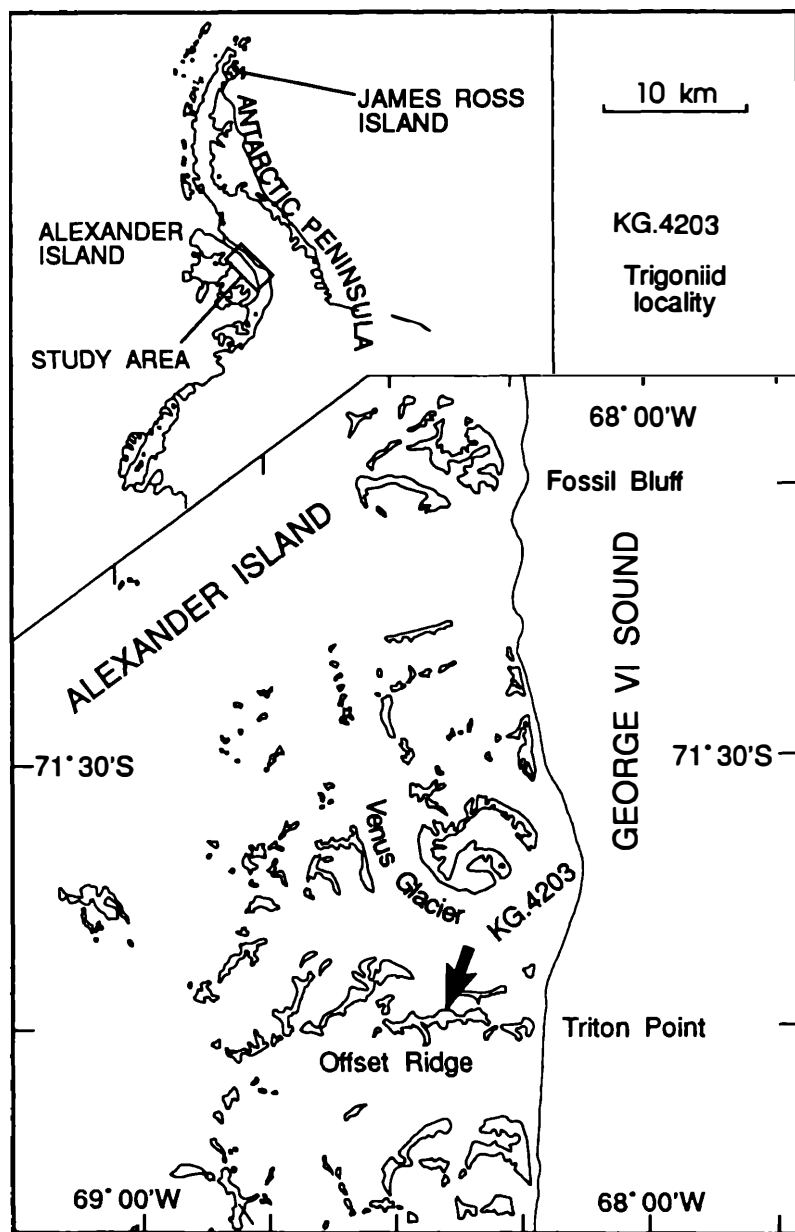> *Pisotrigonia capricornia* SKWARKO

Fig. 1: Location of Albian trigoniid locality on Offset Ridge, Alexander Island.

The associated fauna includes: an indeterminate ammonite, belemnites, including *Dimitobelus diptychus* (M'COY); bivalves, including arcids, pinnids, heterodonts and myoids; gastropods and serpulids. Higher in the same section occur inoceramid bivalves of the *I. carsoni-I. sutherlandi* M'COY group, both characteristic of the Late Albian in Queensland, Australia and, higher still, *Aucellina* cf. *euglypha* WOODS, a species characteristic of the Late Albian of New Zealand. Stratigraphically lower, in a nearby section, the ammonite *Lechites gaudini* (BRONGNIART) occurs. All these associated faunas indicate a Late Albian age for the trigoniids (KELLY and MONCRIEFF, 1992).

In southern South America most of the Albian trigoniids, described hitherto, come from the Austral Basin, which certainly opens into the South Atlantic (RICCARDI 1988), but may also have extended to the Pacific Ocean. The fauna, originally described by PIATNITZKY (1938), contains trigoniids, which were revised by MEDINA (1987), including:

> *Iotrigonia rolli* (PIATNITZKY)
> *Iotrigonia feruglioi* MEDINA
> *Megatrigonia piatnitzkyi* MEDINA
> *Pisotriogonia ferugloi* PIATNITZKY
> *Austrotrigonia? palaeopatagonica* (PIATNITZKY)

This fauna shows considerable affinity with southern African forms, especially with the species, described by VAN HOEPEN (1929), of the genera *Iotrigonia* and *Megatrigonia*. In the more northerly Neuquen Basin, trigoniid-bearing facies do not appear to have existed in Albian time.

Trigoniids no longer live in the Antarctic or South American waters. In Mesozoic time they were pandemic, but, in Cenozoic and Recent times, they are restricted to Australasian waters (DARRAGH 1986). They did not form part of the Southern Ocean fauna, discussed by CLARKE and CRAME (1989), after Cretaceous times.

Palaeoenvironment

The Fossil Bluff Group of Alexander Island represents the infill of a Mesozoic fore-arc basin. The sedimentary deposits are primarily volcaniclastic, derived from the active island-arc to the east. Environments from afforested terrestrial, through marginal marine to offshore marine shelf are represented (Kelly in press).

The Offset Ridge trigoniid bed occurs in a Late Albian transgressive sequence. At the base of the sequence lie the fossil forest levels of the Triton Point Member (MONCRIEFF and KELLY 1993) from which standing trees, mainly gymnosperms, have been preserved (JEFFERSON 1982). Overlying sandstones, lacking in situ plant remains, are current-bedded and bear trace fossils. The trigoniid bed, 1.15 m thick, is about 150 m above the base of the Mars Glacier Member (Fig. 3), and is the first level at which molluscan remains appear. It is a poorly sorted medium-grained sandstone, grey when fresh, weathering dark brown and showing low-angle eastward-dipping foresets. The fauna is almost entirely a thanatocoenosis, dominated by isolated valves in current-stable orientation, but fragmentary material is also present. Deep-burrowing *Panopea* are found occasionally in situ, but other benthic fauna comprises mainly byssate or shallow burrowing forms and shows signs of having been transported a short distance. About 50 cm above the trigoniid bed large inoceramids become abundant in sandstone. Higher still, inoceramids continue in mudstone lithology, until eventually they are replaced by abundant *Aucellina* cf. *euglypha*. KELLY (in

press) used this biotic succession to show a sequence of deepening and quietening environments, demonstrating transgression, the trigoniids representing one of the shallowest marine biofacies.

Palaeobiogeography

Cretaceous climates have been regarded by many palaeontologists as very equable (e.g. HALLAM 1985), and Crame (in press) recognised the Late Albian as the acme of the Cretaceous greenhouse state. However, there is growing evidence for limited polar ice. FRAKES & KRASSAY (1992) argued that Aptian dropstones in Queensland, Australia, indicated ice-rafting rather than transport by tree-roots or vegetation. Although similar exotic clasts were discovered in Aptian strata of the Fossil Bluff Group during the present study, I believe a tree-root dropstone origin is an adequate source. The palaeobiogeographic distribution of the trigoniids of the Mars Glacier Member (Fig. 5) shows strong austral

AGE	STAGE		GROUP	FORMATION	MEMBER / BED
Early Cretaceous	Albian	Late	Fossil Bluff	Neptune Glacier 2200m	Mars Glacier >900m / Triton Point 0-600m * / Delmos Ridge 800-1050m
	Aptian			Pluto Glacier 1400m	
	Barremian				
	Hauterivian			Spartan Glacier 1000m	
	Valanginian				
	Berriasian			Himalia Ridge (including Ablation Point) >2650m	*
Late Jurassic	Tithonian				*
	Kimmeridgian				

Fig. 2:
Stratigraphy of the Fossil Bluff Group (after BUTTERWORTH et al. 1988 and MONCRIEFF and KELLY 1993).
Trigoniid occurrences are marked *

provinciality. (cf. KAUFFMAN 1973). This pattern is also shown in other faunas, e.g. the dimitobelid belemnite faunas in Albian/Cenomanian time (DOYLE and HOWLETT 1989). *Dimitobelus,* although nektic, is not recorded in southern Africa or India, and is restricted to the southern borders of the Pacific Ocean.

Nototrigonia. The first reliable appearance of *Nototrigonia* was in the Hauterivian/Barremian of Australia (SKWARKO 1963, 1981c, d), where it continued into the Late Cenomanian. In New Guinea it occurred with *Iotrigonia (Zaletrigonia)* (SKWARKO 1981b) and, although believed to be of late 'Neocomian' age, may even be latest Jurassic, but the stratigraphy of this occurence cannot be relied on. The subgenus *N. (Callitrigonia)* (COX 1964) occurred in the Aptian and Albian of Australia. In New Zealand the Hauterivian/Barremian interval is not represented in marine strata and *Nototrigonia* s. s. did not appear there until Late Albian. However, the subgenus *Kupenga* appeared in latest Albian and Cenomanian (FLEMING 1987). The Alexander Island specimens indicate that by Late Albian time both *Nototrigonia* s.s. (Figs 4c, e) and *N. (Callitrigonia)* (Fig. 4f) had reached Antarctica. Although the nototrigoniids *Sphenotrigonia* and *Pleurotrigonia* are well known in southern Africa, unpublished records of *Nototrigonia* now exist (M.R. COOPER pers. comm. 1992). However, there are no records of the genus in South America, despite a large trigoniid literature.

Eselaevitrigonia. The first appearance of *Eselaevitrigonia* was in the Umia Group, *Trigonia* beds, of Kutch, India (COX 1952), and is of undifferentiated 'Neocomian' age. A New Guinea occurence (SKWARKO 1981a) was described as probable Late Jurassic age, but is uncertain and a Neocomian age is not
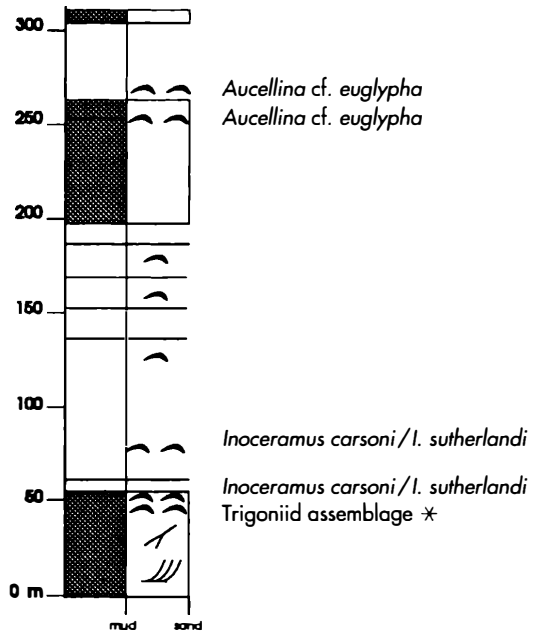

Fig. 3:
Stratigraphic log of KG.4203, entirely within the Mars Glacier Member of the Neptune Glacier Formation. The trigoniid level is marked *

KG.4203

⌒⌒ shell bed

⌁ trace fossils

⫽⫽ cross bedding

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precluded. Late Albian occurences are known from New Zealand (FLEMING 1987) and Alexander Island (Fig. 5b). Only in the Campanian and Maastrichtian did the genus reach Chile (PERÉZ and REYES 1978) and the adjacent northern tip of the Antarctic Peninsula (James Ross Island) (MEDINA 1980; ZINSMEISTER and MACELLARI 1988). The pattern of this migration during the Cretaceous is a very regular progression from western India, via Australasia and West Antarctica, towards Chile. The slowness of this migration suggests that it is not just larval transport that is significant for the dispersal, but that it may have been gradual success in competition against other taxa which eventually made the migration possible.

Pacitrigonia. This occurence of *Pacitrigonia* (Fig. 5a) is important because it is, globally, the first appearance of the genus. There are no further records until the Campanian and Maastrichtian of Chile (PERÉZ and REYES 1978) and New Zealand (FLEMING 1987) and the Campanian of New Caledonia (FRENEIX 1981) where the *P. hanetiana* (D'ORBIGNY) group appears as a characteristic element. Thus, in the Albian *Pacitrigonia* is endemic to Alexander Island while, by latest Cretaceous, it was endemic to the southern Pacific. It is important as an example of an invertebrate genus having a polar origin (CRAME 1986).

SKWARKO (1981d) indicated that *Pacitrigonia* was probably derived from *Nototrigonia* via, what was to be described later, as *Kupenga* (FLEMING 1987), in the Cenomanian of New Zealand. The evidence here is that *Nototrigonia* and *Pacitrigonia* already co-existed in the Late Albian. If *Pacitrigonia* is to be derived from *Nototrigonia,* then it must be from earlier stock than SKWARKO suggested.

Pisotrigonia. Although pterotrigoniids are cosmopolitan throughout the Cretaceous, having appeared in the Late Jurassic, *Pisotrigonia* is Gondwanic (COOPER 1989). *Pisotrogonia capricornia* (SKWARKO 1963) was first described
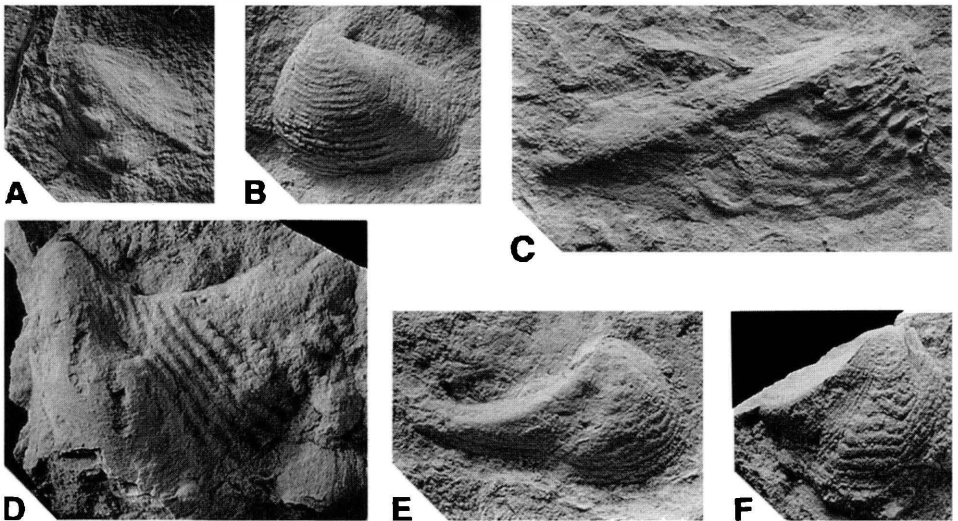

Fig. 4: The trigoniid fauna: a, *Pacitrigonia* sp. nov., KG.4203.173; b, *Eselaevitrigonia* aff. *meridiana* (WOODS) KG.4203.227; c, *Nototrigonia (N.) ponticula* SKWARKO, KG.4203.175; d, *Pisotrigonia capricornia* SKWARKO, KG.4203.283; e, *Nototrigonia (N.) spedeni* FLEMING, KG.4203.157; f, *Nototrigonia (Callitrigonia)* sp. KG.4203.313; a–c, latex casts; d–f natural composite moulds; a, b, e, f × 1.5; c, e × 1. Mars Glacier Member of the Neptune Glacier Formation, Offset Ridge, Alexander Island, Antarctica.

from the late Neocomian to Aptian of the Northern Territory, Australia. It is possible that the Late Valanginian *P. kraussi* (KITCHIN) (COOPER 1991) may be the same taxon. *P. capricornia* is characterised by relativey few rows of coarsely tuberculate costae below the umbones. Generically the Alexander Island record (Fig. 5d) is not of great significance, however, the specific identity relates it to Australia and similar forms are not recorded from South America.

Larval development

The prodissoconch of trigoniids such as *Neotrigonia* is approximately 0.2–0.3 mm in length (from figures of DARRAGH 1986). This is within the 0.2–0.6 mm range given for the prodissoconch II in planktotrophic larvae, but spans the upper limit, 0.135–0.230 mm, for prodissoconch I in nonplanktotropic
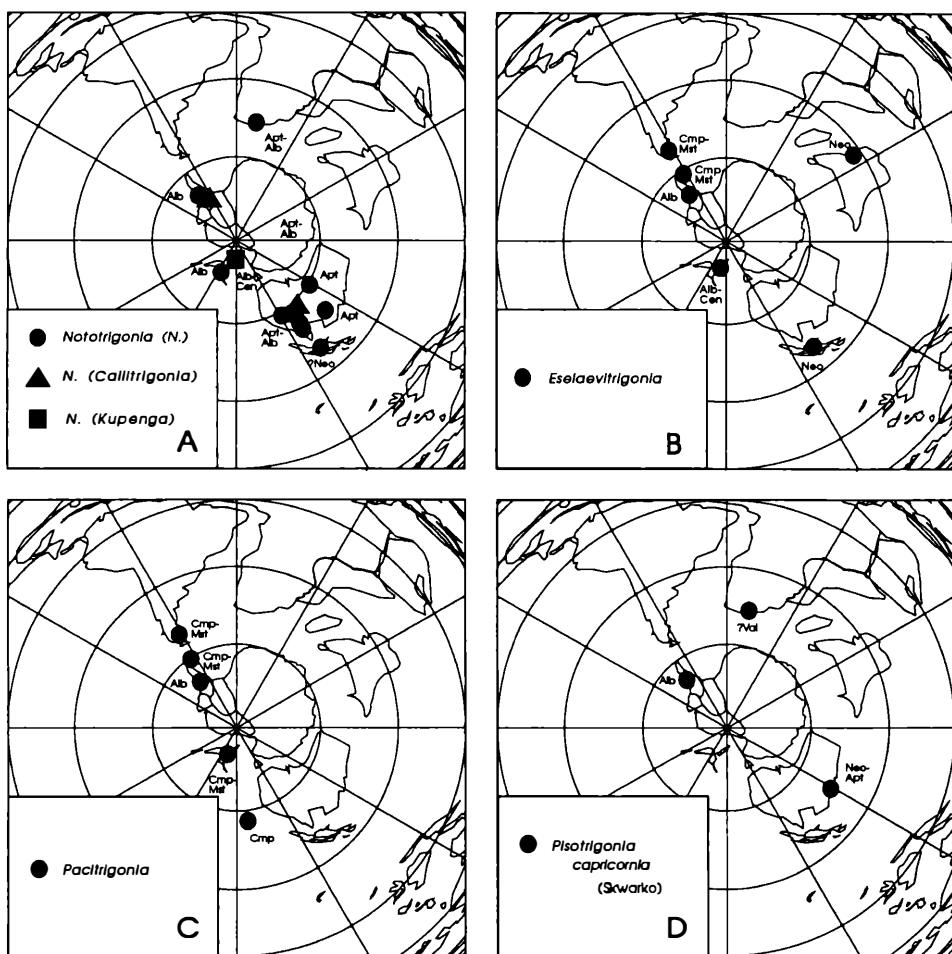
Fig. 5: Trigoniid palaeobiogeographic distributions: a, *Nototrigonia;* b, *Eselaevitrigonia;* c, *Pacitrigonia;* d, *Pisotrigonia capricornia* (SKWARKO) (After author's data, COX 1952, FLEMING 1987, FRENEIX 1981, MEDINA 1980, PERÉZ and REYES 1978, SKWARKO 1981a-d, and ZINSMEISTER and MACELLARI 1988). Map based on Cambridge Paleomap Services (1992), azimuthal equal area (LAMBERT) projection for 105 ma, courtesy of A. G. SMITH.

larvae. The predominance of planktotrophy in shallow marine benthos suggests that the trigoniids may be planktotrophic and, therefore, are capable, of considerable dispersal through oceanic circulation (JABLONSKI and LUTZ 1983). Such larvae my survive 6 months in the tropics, but only 2–6 weeks in temperate water. Trigoniid larvae will only develop into adults if they reach a sufficiently shallow-water environment.

Constraints on faunal movement

The theoretical mid-Cretaceous oceanic circulation model of BARRON and PETERSON (1990) is modified here, mainly by moving southward the Subtropical Convergence, after discussion with W HAY for the Albian (Fig. 6). They proposed a broadly anti-clockwise gyre for the South Pacific. Along the south coast of the Pacific, from Australasia to the coast of West Antarctica, the main surface current would have been easterly, with minor clockwise gyres in the embayments. This current explains the great similarity of the Alexander Island and Australasian faunas.

The tectonic history in the Scotia Arc area is complex (BARKER, DALZIEL and STORY 1991), but the barriers between the southeast Pacific Ocean and the South Atlantic started to subside during the late Early Cretaceous (e.g. CEPEK et al. 1985). However, deep-water circulation probably did not commence until 23 Ma (BARKER and BURRELL 1977), although CEPEK et al. (1985) favoured an earlier date of 80–65 Ma. The contrasting benthic fauna between the Austral Basin and that of Alexander Island suggest that shallow marine breakthrough did not exist during this part of the Albian. Although, had the Drake Passage been breached already, it is possible that there was a strong faunal gradient between the areas without overlap of taxa.
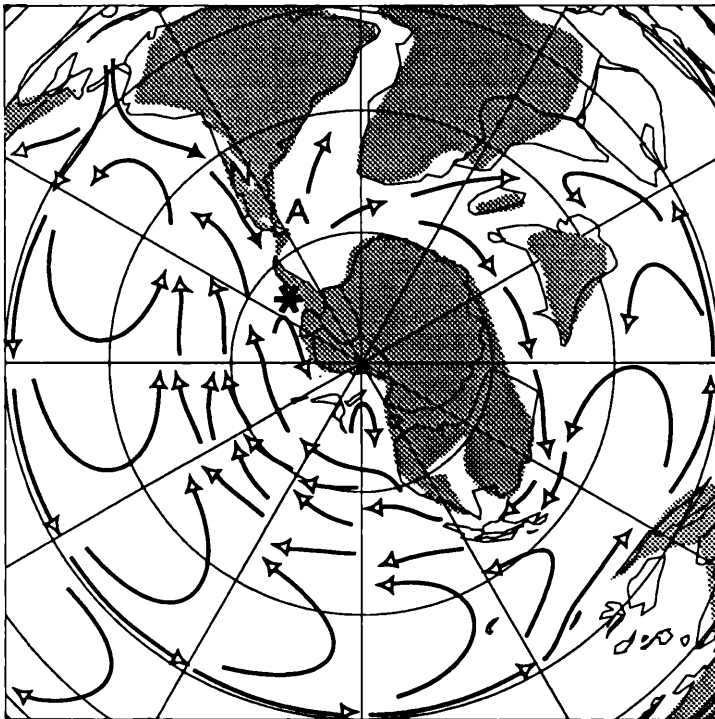

Fig. 6:
Reconstruction of southern hemisphere during the late Early Cretaceous (Albian), as in Figure 5. Approximate land areas stippled. Oceanic surface-currents modified from BARRON and PETERSON (1990).

* = Alexander Island; N = Neuquen Basin; A = Austral Basin.

If the South American Austral basin was open to the Pacific, then it is likely that Alexander Island forms could have reached there by current transport. However, ZINSMEISTER (1982) believed that there was an Equatorial Counter Current reaching the South American coast before being deflected southwards close to the coast. The model of BARRON and PETERSON did not show an Equatorial Counter Current, and the origin of the South American coastal current may be related to currents in the Central American region which was flooded in mid-Cretaceous time. If there was a warm coastal current moving south (a continuation of the current moving along the northern part of the South American coast), it may have deflected the cold northward current away from the shore and thus denied the trigoniid larvae access to the shallow water environment that they needed to develop.

The similarity of Late Cretaceous trigoniids in Campanian-Maastrichtian of James Ross Island and the Austral Basin is because both are situated in comparable positions in the back-arc basin of the Antarctic Peninsula/Andean volcanic arc.

Conclusions

The Albian trigoniid faunas of Alexander Island, dominated by nototrigoniids, and Australasia contain elements in common, which contrast to those of the Austral Basin of South America in which *Nototrigonia* is absent. The South American fauna, including *Iotrigonia* and *Megatrigonia,* is closer to that of South Africa. Whilst latitudinal contral may have been significant, the physical barrier of the Antarctic Peninsula/Andean volcanic arc may have prevented faunal mixing between the fore-arc and back-arc regions. However, if the Austral Basin of South America was open to the Pacific, perhaps a warm southward moving coastal current was preventing the access for the larvae in the cold Pacific current, coming from the Antarctic, to the shallow marine conditions in which they could reach maturity. The larvae died off before they found a suitable substrate on which to develop.

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