

Late Triassic-Early Jurassic Calcareous Nannofossils of the Queen Charlotte Islands, British Columbia

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ABSTRACT

Sediments of the Kunga and Maude groups (Early Norian-Aalenian) from the Queen Charlotte Islands, British Columbia, have yielded the first records of early Mesozoic calcareous nannofossils in North America. These occurrences are the only record of Triassic nannofossils away from the recent discoveries in the Tethyan area (Austria, Indonesia, and the northwestern Australian margin). The nannofossil assemblages from the Queen Charlotte Islands are generally poor to moderately preserved, with species diversities typical for this time interval (2-10 species). The assemblages are comparable to those from northwest Europe, for the Lower Jurassic, and to those from Austria, Indonesia, and the Australian margin, for the Upper Triassic. They show compatible stratigraphical ranges, allowing the application of existing biostratigraphical zonations. Palaeobiogeographical interpretations are inconclusive and fail to positively confirm a low latitude (Tethyan) position for the Queen Charlotte Islands, as indicated by macrofossil data. However, Triassic nannofossil assemblages have yet to be described from high palaeolatitude locations. In addition, certain features of the Lower Jurassic assemblages may indicate Tethyan affinities but also distinguish these assemblages from those which have been previously documented. These features include the absence of *Schizosphaerella punctulata*, which occurs abundantly in the circum-Mediterranean region and was previously thought to be "cosmopolitan" in distribution; and the absence of *Mitrolithus jansae* which characterizes "Tethyan" assemblages in the circum-Mediterranean area. The Queen Charlotte Islands results are compared with new nannofossil data from Argentina, Timor and North America. *J. Micropalaeontol.*, 11 (2): 177-188, December 1992.

INTRODUCTION

Calcareous nannofossils are relatively well studied for much of the Late Cretaceous to Recent interval and provide valuable biostratigraphical and palaeoenvironmental information. From their first appearance in the Late Triassic and through their initial evolutionary diversification during the Jurassic, they are less well known and data are geographically restricted, primarily to the northwest European region. Although advances have been made in biostratigraphical resolution for this time interval, our knowledge of their palaeobiogeography is still rudimentary. At present it is possible to recognise significant differences between northern European (Boreal) and circum-Mediterranean/proto-Atlantic (Tethyan) assemblages, but data from the remainder of Tethys and the Pacific region are extremely rare (Bown, 1987). The discovery of calcareous nannofossils in the Upper Triassic and Lower Jurassic of British Columbia is therefore of interest in terms of testing biostratigraphical schemes established in the European area, and also for determining palaeobiogeographical patterns in a region of the early Mesozoic ocean unstudied by nannofossil workers.

GEOLOGY OF THE QUEEN CHARLOTTE ISLANDS

The Queen Charlotte Islands are part of the Insular Belt of the Canadian Cordillera, situated at the western edge of the North American continent and separated from the Pacific Ocean floor by the Queen Charlotte Transform Fault. To the east lies

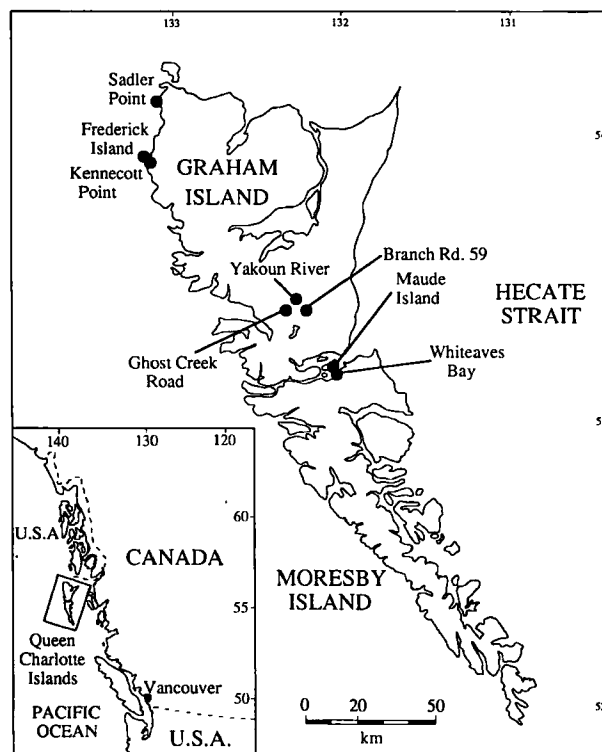


Fig.1. Queen Charlotte Islands location map.

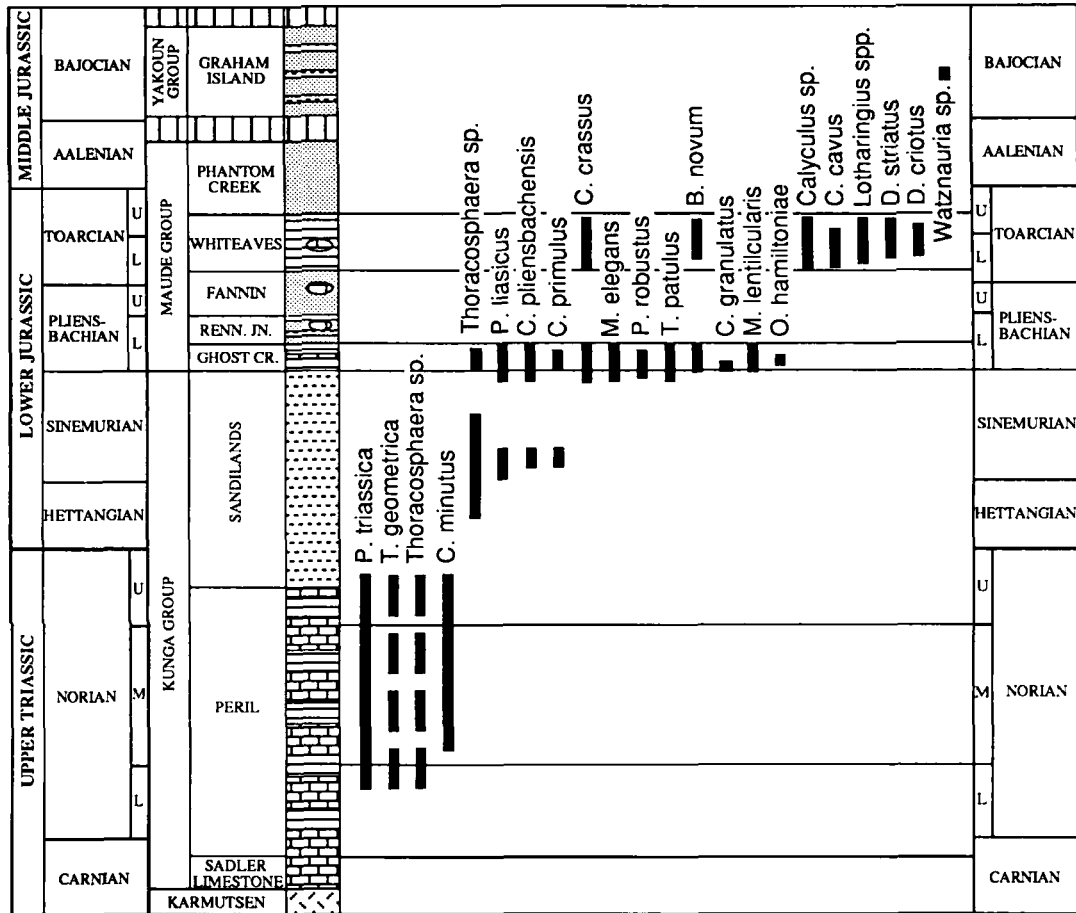


Fig. 2. Composite stratigraphy and nannofossil distribution of lower Mesozoic sequences, Queen Charlotte Islands. Stratigraphy from Carter *et al.* (1989) and Tipper *et al.* (1991).

the shallow shelf region of Hecate Strait; to the south, Queen Charlotte Sound and Vancouver Island; and to the north, Dixon Entrance and the Alexander Archipelago of southeast Alaska (Fig. 1). The islands are composed of a varied assemblage of Mesozoic and Cenozoic plutonic, volcanic, metamorphic, and sedimentary rocks (Sutherland Brown *et al.*, 1983). Basement is formed by the Upper Triassic Karmutsen Formation which is predominantly composed of volcanic rocks. There is, however, recent evidence of older, Palaeozoic rocks (Carboniferous-Permian), below the Karmutsen Formation (Hesthammer *et al.*, 1991). Overlying the basement is a relatively complete early Mesozoic sedimentary sequence which ranges from Carnian (Upper Triassic) to Aalenian (Middle Jurassic) and is for the most part only moderately tectonised and of low metamorphic grade (Fig. 2). All units are relatively well dated by integrated ammonite, conodont, and radiolarian studies (e.g. Carter *et al.*, 1989; Tipper *et al.*, 1991). The lowest unit is the Kunga Group which is Late Triassic to Early Jurassic (Carnian-Sinemurian) in age and divided into three formations: the Sadler Limestone Formation (thickly-bedded, dark limestone); the Peril Formation (thinly-bedded dark limestone with subordinate dark shales and siltstone; common *Halobia* and *Monotis* bivalves), and the Sandilands

Formation (thinly-bedded and banded, hard, dark siliceous siltstone with interbedded tuff, fine to medium grained sandstone, and shale). The Triassic/Jurassic boundary interval falls within the Sandilands Formation.

Conformably overlying the Kunga Group is the Maude Group, of Early to early Mid Jurassic age (Sinemurian-Aalenian). This unit is divided into five formations: the Ghost Creek Formation (dark grey shale and silty shale, with pale limestone interbeds and lenses); Rennell Junction Formation (fine grained sandstone, argillaceous siltstone, grey shale, and limestone interbeds and lenses); Fannin Formation (sandstone, minor siltstone, and rare tuffaceous shales); Whiteaves Formation (glauconitic, greenish-grey silty shale with minor sandstone interbeds, limestone nodules, and bentonitic ash beds); and Phantom Creek Formation (brown, fine to coarse grained sandstones). The Mid to Late Jurassic succession which includes the Yakoun and Moresby groups is dominated by pyroclastic lithologies, along with conglomerate, shale, and siltstone.

This early Mesozoic sequence is at the western edge of an allochthonous tectonostratigraphic terrane known as Wrangellia. The lithological units can be related to those within the Wrangellia Terrane on Vancouver Island and in

KENNECOTT POINT - SECTION KP-M

MID - LATE NORIAN	AGE		SPECIES
	PERIL	FORMATION	
	SAND- ISLANDS		
		10448	Prinsiosphaera triassica
		KP-9	Thoracosphaera sp. indet.
		10447	Crucirhabdus minutus
		KP-8	Thoracosphaera geometrica
		KP-7	Crucirhabdus primulus
		KP-6	
		KP-5	
		10444	
		10446	
		KP-4	
		KP-3	
		10445	
		KP-2	
		KP-1	

FREDERICK ISLAND - SECTION C

EARLY NORIAN	AGE
PERIL	FORMATION
FI-8 FI-7 10431 FI-6 FI-5 10438 10437 FI-3 FI-4	SAMPLE NO. / SPECIES
	Prinsiosphaera triassica
C	Thoracosphaera geometrica
C	Thoracosphaera sp. indet.
C	Thoracosphaera sp.1
	Thoracosphaera sp.2

KEY

R = Rare (0-2 counts)
F = Few (3-5 counts)
C = Common (6-100 counts)
A = Abundant (101-1000 counts)
VA = Very abundant (>1001 counts)
? = Questionably present
. = Not present

FREDERICK ISLAND - SECTION E

MID-LATE NORIAN	AGE	FORMATION	SAMPLE NO.	SPECIES
10443				<i>Prinosphaera triassica</i>
10442				<i>Thoracosphaera geometrica</i>
10441				<i>Thoracosphaera</i> sp. Indet.
FI-13				<i>Crucirhabdus minutus</i>

FREDERICK ISLAND - SECTION D

EARLY-MID NORIAN	AGE
PERIL	FORMATION
	SAMPLE NO. / SPECIES
10436	Thoracosphaera sp.1
10435	Thoracosphaera sp.2
10434	Thoracosphaera sp. indet.
10433	Prinslosphaera triassica
10432	
FI-1	

KENNECOTT POINT - SECTION X

LATE NORIAN		AGE	
SANDILANDS		FORMATION	
		SAMPLE NO.	SPECIES
KP-15			<i>Crucirhabdus minutus</i>
KP-14			<i>Prinosphaera triassica</i>
KP-10			<i>Thoracosphaera geometrica</i>
KP-11			
KP-13			
KP-12			

Fig.3. Stratigraphical distribution of nannofossils from Upper Triassic sections of the Queen Charlotte Islands.

MAUDE ISLAND

EARLY PLIENSCHACHIAN	AGE		L. PLIENSCHACHIAN E. TOAR.	FANNIN	FORMATION	SPECIES
	GHOST CREEK	RENNELL JUNCTION				
MI-1	F					<i>Biscutum novum</i>
MI-2	R					<i>Crepidolithus crassus</i>
MI-3	R					<i>Crepidolithus granulatus</i>
MI-4	R					<i>Mitrolithus elegans</i>
MI-5	R					<i>Mitrolithus lenticularis</i>
MI-6	R					<i>Parahadolithus liasicus</i>
MI-7	R					<i>Parahadolithus robustus</i>
MI-8	R					<i>Tubirhabdus patulus</i>
MI-9	R					<i>Crucirhabdus primulus</i>
MI-10	R					<i>Orthogonoides hamiltoniae</i>
MI-11	R					<i>Crepidolithus plienschachianus</i>
MI-12	R					<i>Thoracosphaera</i> sp. indet.
MI-13	R					
MI-14						
MI-15						
MI-16						
MI-17						
MI-18						
MI-19						
MI-20						
MI-22						
MI-24						
MI-26						

MORESBY ISLAND - WHITEAVES BAY

E. PLENSBACHIAN	GHOST CREEK	RENNELL JUN.-FANNIN	WHITEAVES	TOARCIAN	AGE	SPECIES	
						SAMPLE NO.	FORMATION
WB-15	F	F				Crepidolithus crassus	
WB-16	A	F				Mitrolithus elegans	
WB-17	C	F				Bisutum novum	
WB-18	C	F				Crepidolithus pliensbachensis	
WB-19	C	F				Crucirhabdus primulus	
WB-20						Parnabdoolithus liasicus	
WB-21						Parnabdoolithus robustus	
WB-22						Tubirhabdus patulus	
WB-23						Mitrolithus lenticularis	
WB-24						Thoracosphaera sp. indet.	
WB-25						Crepidolithus granulatus	
WB-26							
WB-27							
WB-28							
WB-29							
WB-30							
WB-31							
WB-32							
WB-33							
WB-34							
WB-35							

GRAHAM ISLAND - YAKOUN RIVER

EARLY TOARCIAN		LATE TOARCIAN		AGE	
WHITEAVES		FORMATION		SPECIES	
"HARPOCERAS"	"PHYM."	"GRAMM."	LEV	AMMONITE ZONE	SAMPLE NO.
YR-1	.	.	YR-23		<i>Crepidolithus crassus</i>
YR-2	.	.	YR-22		<i>Calyculus</i> sp. indet.
YR-3	.	.	YR-21	.	<i>Crepidolithus cavus</i>
YR-4	.	.	YR-20	.	<i>Lotharingius</i> sp. indet.
YR-5	.	.	YR-19	.	<i>Biscutum novum</i>
YR-6	.	.	YR-18	.	<i>Lotharingius sigillatus</i>
YR-7	.	.	YR-17	.	<i>Discorhabdus</i> sp. indet.
YR-8	.	.	YR-16	.	<i>Discorhabdus striatus</i>
YR-9	.	.	YR-15	.	<i>Lotharingius barozii</i>
YR-10	.	.	YR-14	.	<i>Lotharingius hauffii</i>
YR-11	.	.	YR-13	.	<i>Discorhabdus criotus</i>
YR-12	.	.	YR-12	.	<i>Axopodorhabdus atavus</i>
YR-13	.	.	YR-11	.	<i>Lotharingius contractus</i>
YR-14	.	.	YR-10	.	<i>Lotharingius cruceicentralis</i>
YR-15	.	.	YR-9	.	<i>Lotharingius velatus</i>
YR-16	.	.	YR-8	.	<i>Retecapsa incompta</i>
YR-17	.	.	YR-7	.	<i>Watznaeria bitannica</i>
YR-18	.	.	YR-6	.	
YR-19	.	.	YR-5	.	
YR-20	.	.	YR-4	.	
YR-21	.	.	YR-3	.	
YR-22	.	.	YR-2	.	
YR-23	.	.	YR-1	.	

**GRAHAM ISLAND -
GHOST CREEK ROAD**

LATE SINE. I SAND I LANDS	EARLY PLIEN. GHOST CREEK	AGE	SPECIES
		FORMATION	SAMPLE NO.
GCR-6			<i>Crepidolithus crassus</i>
GCR-5			<i>Crepidolithus plienbachensis</i>
GCR-4			<i>Mitrolithus elegans</i>
GCR-3			<i>Parhabdolithus liasicus</i>
GCR-2			<i>Parhabdolithus robustus</i>
GCR-1			<i>Tubirhabdus patulus</i>

KEY

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Fig. 4. Stratigraphical distribution of nannofossils from Jurassic sections of the Queen Charlotte Islands.

mainland British Columbia. The palaeogeographical setting is thought to be that of a back-arc basin adjacent to the North American craton. The sediments were deposited in a marine basin of fluctuating water depth which was periodically euxinic, and received variable amounts of volcanic detritus. Vulcanism was sporadic through the Late Triassic and Early Jurassic but became more persistent in the Mid Jurassic (Cameron and Tipper, 1985). Macropalaeontological, stratigraphical, and palaeomagnetic evidence suggest that the Wrangellia terrane has undergone post-Pliensbachian latitudinal displacement of around 2400 km, moving north from a more "equatorial" position in the northern hemisphere, eastern Pacific (Smith and Tipper, 1989).

NANNOFOSSIL RESULTS

1. Calcareous nannofossils from the Queen Charlotte Islands

A total of 200 samples were collected from the Kunga and Maude groups (Upper Triassic to Middle Jurassic) during the 1990 field season. 75 of these, from throughout the stratigraphical interval, yielded calcareous nannofossils. The nannofossil assemblages are generally poorly preserved and of low abundance and diversity. The best preservation was observed in the Peril (Norian) and Ghost Creek (Lower Pliensbachian) formations; poor preservation and patchy occurrence was observed in the Sandilands (Norian-Sinemurian) and Whiteaves (Toarcian) formations. The Rennell Junction, Fannin, and Phantom Creek formations were barren. A summary of the stratigraphical distribution of nannofossils is given in Fig. 2 and individual sections in Figs. 3, 4 and 5.

Norian. Sections of the Peril Formation and Sandilands Formation on Frederick Island, and at Kennecott Point on Graham Island (Fig. 1), yielded rare to abundant Upper Triassic nannofossil assemblages. The assemblages are dominated by *Prinsiosphaera triassica* together with rarer *Thoracosphaera geometrica*, *Thoracosphaera* spp. and *Crucirhabdus minutus*. The lower Peril Formation (Early Norian) sampled at Sadler Point (Graham Island) was barren. The highest productive Triassic sediments were from the lower Sandilands Formation at Kennecott Point of Late Norian age. The Sandilands sediments spanning the Triassic/Jurassic boundary were barren.

These assemblages are comparable to previously reported Late Triassic assemblages from Tethys, but are lacking *Eoconusphaera zlamachensis* (which is common in the Northern Calcareous Alps, Austria), and contain a slightly more diverse *Thoracosphaera* assemblage.

Hettangian. At Kennecott Point, the Hettangian Sandilands sediments yielded only fragments of *Thoracosphaera* sp. indet. Thoracospheres have not been previously reported from rocks of Early Jurassic age.

Sinemurian. Sandilands sediments of Sinemurian age were sampled at Kennecott Point and yielded fragments of *Thoracosphaera* sp. indet. with rare and poorly preserved coccoliths, such as *Crepidolithus pliensbachensis*, *Crucirhabdus primulus* and *Parhabdololithus liasicus* (Fig. 5).

AGE	STAGE	AMMONITE ZONE	FORMATION	SPECIES				
				SAMPLE NO.				
					Thoracosphere fragments	Thoracosphaera sp. indet.	Parhabdololithus liasicus	Crepidolithus pliensbachensis
LATE TRIASSIC	LATE NORIAN		SANDILANDS	KP-45	.	C	R	R
				KP-44	.	.	.	.
				KP-43	.	.	.	.
				KP-39	.	R	R	.
				10455	.	.	.	.
				KP-38	.	.	.	.
				KP-37	?	.	.	.
				KP-36	.	.	.	.
				KP-35	A	F	.	.
				KP-34	.	.	.	.
				KP-33	C	F	.	.
				10454	A	.	.	.
				KP-32	.	.	.	.
				KP-31	?	.	.	.
				KP-30	.	.	.	.
				KP-29	?	.	.	.
				10453	.	.	.	.
				KP-28	.	.	.	.
				KP-27	.	.	.	.
				10452	.	.	.	.
LATE TRIASSIC	LATE NORIAN		SANDILANDS	KP-26	.	.	.	.
				KP-24	.	.	.	.
				KP-23	.	.	.	.
				KP-22	.	.	.	.
				KP-21	.	.	.	.
				10451	.	.	.	.
				10450	.	.	.	.
				KP-20	.	.	.	.
				KP-19	.	.	.	.
				10449	.	.	.	.
LATE TRIASSIC	LATE NORIAN		SANDILANDS	KP-18	.	.	.	.
				KP-17	.	.	.	.

Fig. 5. Stratigraphical distribution of nannofossils from Kennecott Point, Queen Charlotte Islands.

These coccolith assemblages are dated as NJ2 *Parhabdololithus liasicus* Nannofossil Zone (bucklandi Ammonite Zone-obtusum Ammonite Zone) (Bown *et al.*, 1988) which is stratigraphically compatible, i.e. time equivalent, with the Canadensis Ammonite Zone-Arnioceras assemblage "Zone" given by ammonites (Tipper *et al.*, 1991). (Nannofossil zones will be indicated in the text by a number and the prefix NJ, and refer to the biozonation scheme of Bown *et al.* (1988). Ammonite zones will be indicated by the abbreviation Am.). The occurrence of *C. pliensbachensis* in the topmost Canadensis Am. Zone and Arnioceras assemblage "Zone" samples is compatible with the *Semicostatum* Am. Zone first occurrence in northwest Europe (Fig. 6). The subzonal marker species *Parhabdololithus marthae* is not present, possibly due to preservation.

The uppermost Sandilands Formation of Late Sinemurian age was sampled on Ghost Creek Road in central Graham Island and yielded relatively abundant, moderately well

AGE		EUROPEAN AMMONITE ZONES	NANNOFOSSIL ZONES		Q.C.I. AMMONITE ZONES
			ZONES	SUBZONES	
EARLY JURASSIC	TOARCIC	Levesquei	B. intermed. ^{NJ8}	R. incompta	"Levesquei"
		Thouarsense	Discorhabdus striatus		Grammoceras
		Variabilis			unamed
		Bifrons			"Phym."
		Falciferum	C. superbus ^{NJ6}		"Harpoceras"
		Tenuicostatum	Lotharingius hauffii	Crepidolithus cavus	Carlottense
	PLIENSCHACHIAN	Spinatum		B. finchii	Kuenae
		Margaritatus	Biscutum novum	Crepidolithus granulatus	Freeboldi
		Davoei		C. pliensbach.	Whiteavesi
		Ibex			Imlayi
	SINEMURIAN	Jamesoni	Crepidolithus crassus		unzoned at present
		Raricostatum			
		Oxynotum	Parhabdolithus liasicus	Mitrolithus elegans	"Arnioceras"
		Obtusum			
		Turneri		Parhabdolithus marthae	Canadensis
		Semicostatum			
	HETT.	Bucklandi	Schizo-sphaerella punctulata		unzoned at present
		Angulata			
		Liassicus			
LATE TRIASSIC	RAET.	Planorbis	Prinsiosphaera triassica	Eoconusphaera zambachensis	Crickmayi
		Marshi			Am.-Cordiller.
	NORIAN	Suessi		Thoracosphaera geometrica	Columbianus
		Macer			Rutherfordi
		Hogarti			Magnus
		Bicrenatus			Dawsoni
	EARLY				Kerri
		Paulkei			
		Jandianus			

Fig. 6. Stratigraphy and biostratigraphy of the lower Mesozoic sequences of the Queen Charlotte Islands. Nannofossil zones are from Bown *et al.* (1988) (Lower Jurassic) and Bralower *et al.* (1991) (Upper Triassic). Queen Charlotte Island ammonite zones are based upon field observation summarised in Carter *et al.* (1989) (Upper Triassic) and Tipper *et al.* (1991) (Lower Jurassic). Shaded nannofossil zones have been identified in the Queen Charlotte Islands.

preserved nannofossil assemblages, consisting of *Crepidolithus crassus*, *Crepidolithus pliensbachensis*, *Mitrolithus elegans*, *Parhabdolithus liasicus*, *P. robustus*, and *Tubirhabdus patulus*. The assemblages are dated as NJ3 *Crepidolithus crassus* Zone (Oxynotum-Jamesoni Am. Zone).

Pliensbachian. Pliensbachian sediments of the Ghost Creek, Rennell Junction, and Fannin formations were sampled on Maude Island (stratigraphical section no. 8 of Cameron and Tipper, 1985) and at Whiteaves Bay on Moresby Island

(stratigraphical section no. 7 of Cameron and Tipper, 1985). The Ghost Creek Formation (earliest Pliensbachian) consistently yielded relatively abundant nannofossil assemblages of variable preservation. The assemblages are generally dominated by *Crepidolithus crassus* and *Mitrolithus elegans* together with rarer *Biscutum novum*, *Crucirhabdus primulus*, *Crepidolithus crassus*, *C. granulatus*, *C. pliensbachensis*, *Mitrolithus lenticularis*, *Orthogonoides hamiltoniae*, *Parhabdolithus liasicus*, *P. robustus*, and *Tubirhabdus patulus* (Fig. 4). The assemblages are dated as NJ4 *Biscutum novum* Zone (Jamesoni-Margaritatus Am. Zone). *Biscutum* has a first occurrence within the Jamesoni Am. Zone in northwest Europe and its occurrence in these Ghost Creek Formation samples but not in the Ghost Creek Road samples indicates a first occurrence in the Imlayi Am. Zone in the Queen Charlotte Islands. The Imlayi Am. Zone is stratigraphically equivalent to the Jamesoni Ammonite Zone in northwest Europe (Fig. 6).

The late Early Pliensbachian and Late Pliensbachian Rennell Junction and Fannin formations were barren of nannofossils.

Toarcian. The Toarcian Whiteaves and Phantom Creek formations were sampled on the Yakoun River in central Graham Island (stratigraphical section no. 15 of Cameron and Tipper, 1985) and at Whiteaves Bay on Moresby Island (stratigraphical section no. 7 of Cameron and Tipper, 1985). The Whiteaves Formation was barren at Whiteaves Bay, but sporadically productive from the Yakoun River. The Whiteaves Formation shales were essentially barren of fine fraction calcite and assemblages were extremely rare and poorly preserved (etched). Assemblages were predominantly composed of *Crepidolithus cavus*, *C. crassus*, *Lotharingius* spp., *Biscutum novum*, and *Discorhabdus striatus*. Samples containing *Lotharingius* spp. are dated as NJ5 *Lotharingius hauffii* Zone (Margaritatus-Tenuicostatum Am. Zone) (Bown *et al.*, 1988) or younger; and those containing *D. striatus* are dated as NJ7 *Discorhabdus striatus* Zone

(Falciferum-Levesquei Am. Zone). The assemblages and biostratigraphy are comparable to that of northwest Europe, although the poor preservation makes any firm comparison difficult. The presence of questionable *Lotharingius contractus* and *Watznaueria britannica* in the upper samples dated as Grammoceras Am. "Zone" (G. Jacobs pers comm., 1990) (Thouarsense Am. Zone equivalent) suggests a first occurrence of these forms considerably earlier than those seen in northwest Europe (Aalenian and Lower Bajocian respectively).

Samples from the Phantom Creek Formation (latest Toarcian-Aalenian) were barren.

Bajocian. The Graham Island Formation is of Early Bajocian age and consists of tuffaceous sandstone with rare shale interbeds. The formation was sampled on Branch Road 59, central Graham Island (stratigraphical section 13 of Cameron and Tipper, 1985). One sample yielded the dissolution resistant genus *Watznaueria*, which has a first occurrence in the Lower Bajocian in northwest Europe; the remaining samples were barren.

2. Calcareous nannofossils from other early Mesozoic American sections

Oregon. A small number of samples were taken from early Mesozoic sequences in the John Day inlier of central-east Oregon. The sequence was deposited within an island arc setting related to subduction along the continental margin (Dickinson and Thayer, 1978). A generalised stratigraphy is given in Figure 7. Lithologies include calcareous sandstone (Suplee Fm.); black shales (Nicely Fm.); volcanoclastic turbidites (Hyde Fm.); and conglomerates, siltstones, sandstones, and volcanoclastics (Snowshoe Fm.).

Most of the samples studied were barren of nannofossils: one sample from the Caps Creek Formation yielded rare *Parhabdololithus liasicus*; one sample from the Warm Springs Member yielded rare *Lotharingius* cf *L. crucicentralis*.

Mowich Group	Lonesome Fm.	BATHONIAN
	Snowshoe Fm	AAL-BAJ
	Hyde Fm.	TOARCIAN
	Nicely Fm.	UPPER PLIENSBACH.
	Suplee Fm	
	Caps Creek Fm	SINEMURIAN

Fig. 7. Generalised stratigraphy of the John Day Inlier, Oregon (Dickinson and Thayer, 1978).

New York Canyon, Nevada. The Triassic/Jurassic boundary interval was sampled in the New York Canyon region of west-central Nevada. This section has been proposed as the stratotype for the Triassic-Jurassic system boundary as it provides a record of nearly continuous sedimentation across the boundary interval and yields one of the most complete ammonite successions. The sequence is composed of alternating hard siltstone and limestone of Norian (including Rhaetian) to Pliensbachian age, and is divided into two formations and eight members (Taylor *et al.*, 1983) (Fig. 8).

The sediments are thought to have been deposited in an autochthonous cratonal basin, the Sonomia Basin, in basinal to shallow marine water depths. The New York Canyon strata were deposited in the shallowest marine area of the basin but contain good ammonite successions along with other macrofossils, e.g. bivalves, brachiopods and gastropods. Currently no microfossils have been recorded from the section and all samples prepared for nannofossil study were barren. Nannofossil absence is probably due to dissolution although their original absence cannot be discounted.

VOLCANO PEAK GP.	SUNRISE FORMATION	Mona Peak	Pliensbachian	JURASSIC	
		Joker Peak			
		New York Canyon	Sinemurian		
		Five Card Draw			
		Ferguson Hill	Hettangian		
	GABBS FORM'N	Muller Canyon	Norian		TRIASSIC
		Mount Hyatt			
		Nun Mine			

Fig. 8. Stratigraphy of the Triassic/Jurassic boundary sequence, New York Canyon, Nevada (Smith *et al.*, 1983).

Nequen Basin, Argentina. Samples of Jurassic (Pliensbachian-Aalenian) age from the Nequen Basin were provided by Dr. Kielbowicz (YPF, Buenos Aires) and come from Picun Leufu Province in the Principal Cordillera of Argentina. The Nequen Basin was one of two narrow basins which formed at the end of the Triassic along the western margin of the South American sub-continent. Early Jurassic sedimentation was generally restricted to narrow and small basins which were marginal to the eastern Pacific Ocean.

Five samples yielded nannofossil assemblages (Fig. 9) which are most closely comparable with "Tethyan" assemblages from Portugal (Bown, 1987). Tethyan affinities are indicated by the presence of common *Biscutum finchii* and *B. grande* in the Pliensbachian-Toarcian, and *Carinolithus magharensis* and *Triscutum* sp. in the Late Toarcian-Aalenian. No other records of early Mesozoic nannofossils from South America have been published.

3. Calcareous nannofossils from Timor

Samples from the Upper Triassic and Lower Jurassic Aitutu and Wai-Luli formations from West Timor were collected by Simon Barkham (Royal Holloway and Bedford New College). These formations form part of an autochthonous sedimentary sequence which was deposited in a relatively deep continental shelf sea at the northern edge of Australian Gondwanaland, the southern margin of eastern Tethys. Two sections were studied for nannofossils, from the River Anin and the River Meto (Kristan-Tollman *et al.*, 1987).

Upper Triassic sediments from the River Anin section contain nannofossil assemblages consisting of *Prinsiosphaera triassica*, *Eoconusphaera zlambachensis* and *Crucirhabdus minutus*, which are closely comparable with Upper Norian (Rhaetian) assemblages from the Northern Calcareous Alps.

Lower Jurassic sediments from the River Meto section yielded nannofossil assemblages which indicate a Sinemurian-Lower Toarcian age range including the NJ3, NJ4 and NJ5 nannofossil zones (Figure 10). A number of features of these assemblages are unique to Timor or indicate affinities with other Tethyan and low latitude areas. These are summarised as follows:

a. The abundance of *Mitrolithus elegans* in many of the samples is not typical of northwest European assemblages but is comparable with results from Eiberg, Austria (Bown and Lord, 1990) and the Queen Charlotte Islands assemblages

AGE	NANNOFOSSIL ZONE	SPECIES	
		SAMPLE NO.	
LATE TOAR- EALENIAN	R.incompta NJ8a	69	Biscutum novum
		68	Crepidolithus crassus
		60	Parhabdololithus llasticus
		59	Tubirhabdus patulus
		57	Biscutum cf. B. grande
		56	Calculus sp. indet.
		55	Crepidolithus granulatus
		53	Crucirhabdus primulus
		51	Lotharingius barozii
		49	Lotharingius primigenius
		48	Mitrolithus lenticularis
		47	Axopodorhabdus atavus
		46	Biscutum finchii
		45	Biscutum grande
		44	Crepidolithus cavus
LATE PLIENS.- EARLY TOARCIAN	L. hauffii NJ5	69	Orthogonoides hamiltoniae
		68	Sollasites sp. indet.
		60	Bussonius prinsii
		59	Lotharingius hauffii
		57	Schizosphaerella punctulata
		56	Biscutum depravatus
		55	Biscutum dubium
		53	Biscutum intermedium
		51	Bussonius leufuensis
		49	Carinolithus magharensis
		48	Diductius constans
		47	Discorhabdus criotus
		46	Discorhabdus striatus
		45	Ethmorhabdus gallicus
		44	Lotharingius cf. L. contractus
PL.	NJ4	69	Lotharingius crucicentralis
		68	Lotharingius sigillatus
		60	Retecapsa incompta
		59	Triscutum sp. indet.
		57	Zeughrhabdus erectus
		56	
		55	
		53	
		51	
		49	
		48	
		47	
		46	
		45	
		44	

Fig. 9. Stratigraphical distribution of nannofossils from Picun Leufu, Nequen Basin, Argentina.

described here. In addition, specimens of *M. elegans* which have distinctive distal extensions of the spine (*M. elegans* var.1 in range chart) are observed in both the Timor and Eiberg assemblages (see Bown, 1987; p.27; Pl. 3, figs. 14-15).

b. The common occurrence of *Crepidolithus timorensis*, particularly in the Sinemurian, is observed in both the Timor and Eiberg sections.

c. *Mitrolithus jansae*, *M. lenticularis*, *Parhabdololithus robustus*, *Biscutum finchii* and *B. grande* are common in the Timor sections and these taxa are characteristic of Early Jurassic assemblages from western Tethys (Portugal, Italy, Tunisia). However, *M. jansae* is found more abundantly in assemblages of western Tethys. The taxa listed above are rare or absent in northwest Europe.

d. The presence of *Mazaganella pulla* and *M. protensa* has only previously been recorded from Timor and DSDP Site 547 (offshore Morocco) (Bown, 1987, p. 113). *Timorella cypella* has been recorded from Timor only (Bown, 1987, p. 35).

DISCUSSION

The lack of early Mesozoic nannofossil data from the American continent is due to a number of factors, including unfavourable palaeogeography, post-depositional tectonism and metamorphism, and a general lack of carbonate-rich argillaceous marine sediments. The occurrence of calcareous nannofossils in the early Mesozoic sequences of the Queen Charlotte Islands represents the first record of this fossil group

from Triassic and Lower Jurassic rocks of North America. The nannofossil assemblages from the Queen Charlotte Islands and from the Nequen Basin, provide the first evidence of nannofossil presence in the large Mesozoic Pacific Ocean to the west of Tethys. Their existence in marginal basins of the eastern Pacific suggests that nanoplankton had colonized the entire marine environment by the Early Jurassic. The lack of Triassic nannofossil records from high latitude regions may reflect more restricted distribution at this time but this is in need of further examination as research has only been carried out in northwest Europe, where favourable lithologies are rare. The overriding conclusion from the results presented here is that both Triassic and Early Jurassic nannofloras were for the most part cosmopolitan in distribution with only a small proportion of the total number of species displaying restricted distributions. The nannofossil results from the Queen Charlotte Islands, Timor and Argentina confirm a sequence of successive evolutionary appearances of taxa which can be recognised over a wide geographical area but also show features of provincialism which allow biogeographical subdivision. The only disappointing aspect of the results is the poor preservation of the nannofossils from the Queen Charlotte Islands which is almost certainly reflected in lowered diversities and possible distortion of stratigraphical ranges. Despite this, a number of conclusions may be drawn concerning palaeobiogeography and biostratigraphy.

NORIAN - RHAETIAN	LATE SINEMURIAN		EARLY PLIEN.	L.P.E.T.	AGE
	C. crassus NJ3	B. novum NJ4	NJ5		NANNOFOSSIL ZONE
P. triassica	WAI-LULI			FORMATION	
AITUTU				SAMPLE NO.	SPECIES
				212	Prinsiosphaera triassica
				200	Crepidolithus crassus
				201	Crepidolithus pliensbachensis
				202	Crepidolithus timorensis
				203	Mitrolithus elegans
				210C	Mitrolithus elegans (var.1)
				201D	Parhabdolithus ilasicus dist.
				210F	Tubirhabdus patulus
				206	Schizosphaerella punctulata
				207	Crucirhabdus primulus
				208	Parhabdolithus cf. P. robustus
				208A	Parhabdolithus ilasicus lias.
				208B	Mitrolithus lenticularis
				208C	Mitrolithus jansae
				208D	Parhabdolithus robustus
				208E	Calyculus sp. indet.
				208F	Mazaganella protensa
				205A	Biscutum novum
				220	Mazaganella pulla
				221	Axopodorhabdus atavus
				226	Biscutum finchii
					Biscutum grande
					Crepidolithus cavus
					Lotharingius hauffii
					Lotharingius sigillatus

Fig. 10. Stratigraphical distribution of nannofossils from the River Meto section, Timor.

Triassic calcareous nannofossil biogeography

The Triassic nannofossil assemblages from the Queen Charlotte Islands compare well with those described from the Northern Calcareous Alps (Moshkovitz, 1982; Jafar, 1983; Bown and Lord, 1990), Timor (this paper), and the northwest Australian shelf (Bralower *et al.*, 1991). In all cases the assemblages are abundant and of low species diversity, dominated by the spherical nannolith, *Prinsiosphaera triassica*, together with rarer *Thoracosphaera* spp., and the small coccolith *Crucirhabdus minutus*. The only major discrepancy between the assemblages observed is the absence of *Eoconusphaera zlambschensis* in the Queen Charlotte Islands. In the Northern Calcareous Alps, *E. zlambschensis* is commonly a significant assemblage contributor. It is found more rarely in material from Timor and northwest Australia (Fig. 11). It has a stratigraphical range through the Middle and Upper Norian, which is well represented in the Queen Charlotte Islands. From an albeit rather restricted data set its distribution appears to display an abundance gradient from western to eastern Tethys (becoming rarer to the east) and a complete absence in the eastern Pacific. This distribution pattern is also shown by *Mitrolithus jansae* in the Early Jurassic.

Although the widespread distribution of Late Triassic nannofloras is steadily being demonstrated, their biostratigraphical utility is limited by low species diversity. However, abundant *Prinsiosphaera* is confirmed as a good marker of the Norian (and "Rhaetian") as is the extinction of

these forms at or very near to the Triassic/Jurassic boundary level.

Early Jurassic nannofossil biogeography

As for the Late Triassic, our understanding of Early Jurassic nannofossil biogeography is limited by the geographical restriction of the data. The only productive sections known from the immense Eastern Tethys-Pacific oceanic area are from Timor, Argentina (Nequen Basin) and the Queen Charlotte Islands.

In the European/Western Tethys/proto-Atlantic region the nannofloras broadly delineate a northern (high latitude), Boreal province and a southern (low latitude), Tethyan province. The provincialism is shown by limited endemism (mainly endemic Tethyan taxa) and differences in species dominance. The most striking Tethyan marker is *Mitrolithus jansae* which often dominates assemblages throughout its Sinemurian to Early Toarcian range (Bown, 1987). Other taxa which are only found commonly in the Tethyan province include *Biscutum grande*, *Mitrolithus lenticularis* and *Mazaganella pulla*.

Tethyan nannofossil assemblages have been reported from Italy (e.g. Young *et al.*, 1986; Reale, 1989; Cobianchi, 1990), Portugal (Bown, 1987), Tunisia (Bown, 1987), and offshore Morocco (DSDP Site 547) (Bown, 1987). The assemblages from Timor and Argentina also display features indicating Tethyan affinities, as described above, however, *M. jansae* is rare in Timor and absent in Argentina. Boreal assemblages are known from the northern hemisphere only, e.g. Britain, France, Germany and Holland.

The Early Jurassic nannofossil assemblages from the Queen Charlotte Islands are broadly comparable with those of northern Europe in terms of both assemblage components and stratigraphical ranges. The biozonation scheme of Bown *et al.* (1988), which was developed in northwest Europe, was applied successfully. The Tethyan marker, *M. jansae*, is absent from the material and only the rare occurrence of *M. lenticularis*, points to speculative Tethyan affinities. The most interesting feature of the assemblages is the absence of *S. punctulata*, an *incertae sedis* taxon, which is a common-abundant component of nannofossil assemblages in both Boreal and Tethyan provinces in the European region. *S. punctulata* is present in Pliensbachian material from Timor but absent in Argentina (although it is abundant in Toarcian material from Argentina) (Fig. 11). Its absence in the Queen Charlotte Islands is surprising considering its abundance in both the European epicontinental sea and the Tethys Ocean. Similarly, the absence of *M. jansae* is unexpected, particularly as it appears to characterise Tethyan

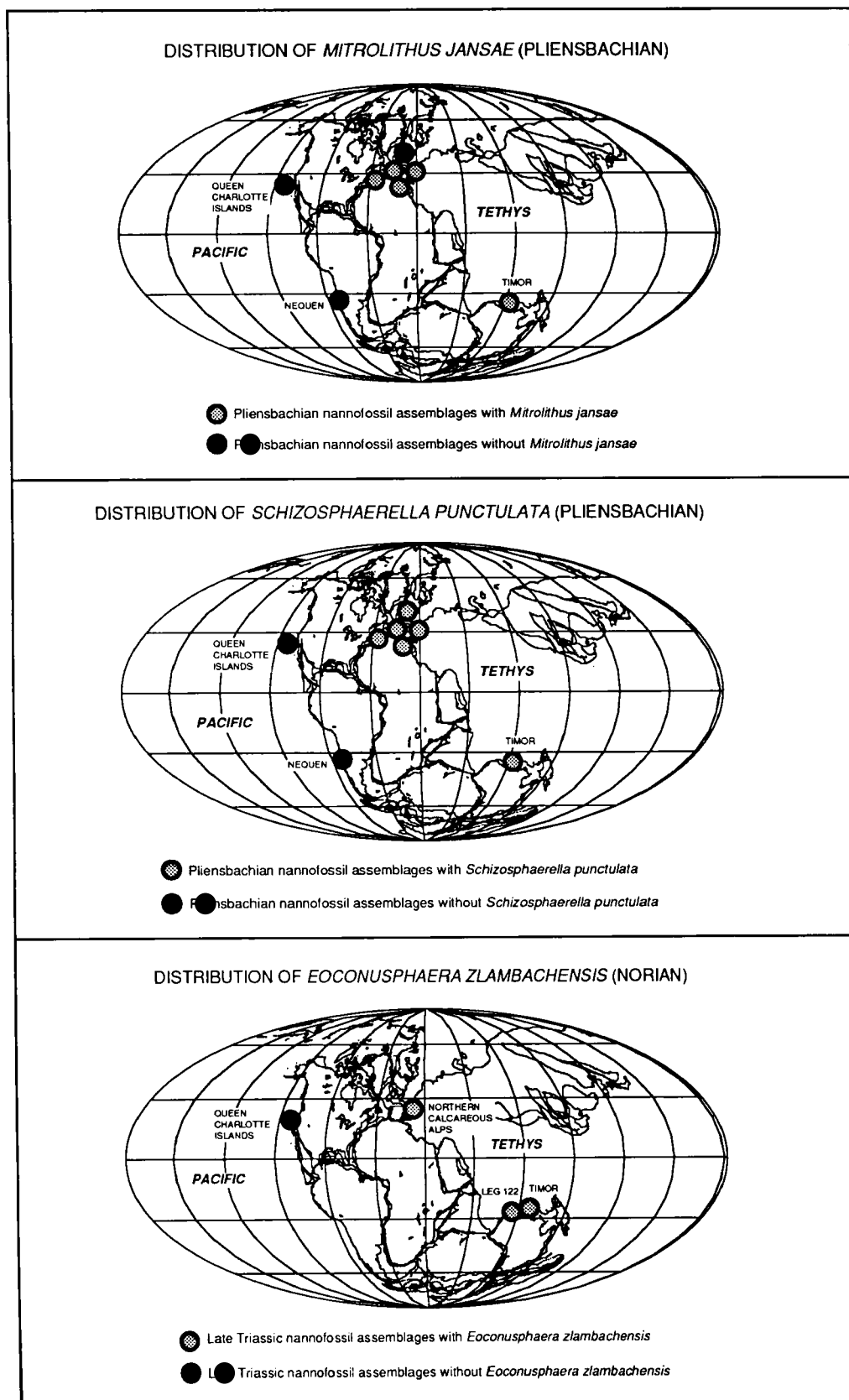


Fig. 11. Palaeobiogeography of *Eoconusphaera zambachensis* (Upper Triassic), *Schizosphaerella punctulata* (Pliensbachian) and *Mitrolithus jansae* (Pliensbachian). Reconstruction from Terra Mobilis.

assemblages, being present both in western and eastern Tethys (although it is rarer in eastern Tethys) (Fig. 11).

Although data are still too scarce to draw firm conclusions concerning global distribution patterns for this time interval, it appears probable that certain species were present in the Tethys/proto-Atlantic and in certain cases further north, but did not colonise the Pacific Ocean (or at least the eastern Pacific margins) at all, or not until a later date. This kind of distribution pattern appears to be displayed by *E. zlambachensis* in the Late Triassic and by *S. punctulata* and *M. jansae* in the Pliensbachian. Comparable distribution patterns are also observed for certain younger Mesozoic nannofossil taxa, e.g. *Nannoconus* and *Conusphaera* in the Late Jurassic, both of which had evolutionary appearances in the western Tethys/proto-Atlantic and remained abundant but restricted in distribution.

A number of explanations for this kind of distribution may be offered:

1. Temperature - latitudinally zoned provinces controlled primarily by differing temperatures are thought to account for the broad patterns of living and fossil nannoplankton distribution. The Queen Charlotte Islands are thought to have occupied a low latitude position at this time but nannofossil assemblages do not include Tethyan taxa such as *M. jansae* or supposedly cosmopolitan taxa, such as *S. punctulata*. Straightforward temperature control can not, therefore, account for these distributions.

2. Preservation - the missing species are all robust, particularly *S. punctulata*, thus dissolution can not account for their absence in assemblages which retain more delicate forms.

3. Water depth - all the missing taxa have been found across a wide range of non-oceanic water depths, however, no early Mesozoic oceanic assemblages have as yet been reported. The presence of many of the early Mesozoic taxa around both Tethyan and Pacific margins suggests that the open ocean was not a significant physical or ecological barrier to distribution. However, those taxa which are essentially restricted to Europe, the proto-Atlantic and Tethys may have been ecologically limited to the ocean margins (the limiting factor being possibly related to nutrient availability) and were thus unable to cross the Pacific during Triassic and earliest Jurassic time. The presence of *S. punctulata* in the Argentinian section in the Toarcian may indicate that a route to the eastern Pacific had opened up by this time, most likely via the Central American Seaway/Hispanic Corridor.

CONCLUSIONS

1. The majority of Early Jurassic nannoplankton were cosmopolitan in distribution. However, a small number of endemic species and differences in species abundances allow the recognition of Boreal and Tethyan provinces.

2. Upper Triassic nannoplankton have now been reported from low latitude sites in both the Tethys and Pacific oceans, suggesting at least global equatorial distribution at this time.

3. Certain taxa are limited in distribution to Europe, the proto-Atlantic, and Tethys, and may have been prevented from colonising the Eastern Pacific due to ecological factors related to water depth. This barrier would have been removed once the Central American Seaway opened.

4. The Bown *et al.* (1988) nannofossil zonation scheme for the Lower Jurassic was successfully applied to the Queen Charlotte Islands material.

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