MESOZOIC CALCAREOUS NANNOFOSSILS FROM MASIRAH ISLAND (SULTANATE OF OMAN)

Katharina von Salis, Geologisches Institut ETHZ, CH-8092 Zürich, Switzerland & Adrian Immenhauser, Mineralogisch-Petrographisches Institut der Universität Bern, Baltzerstrasse 1, CH-3012 Bern, Switzerland. Present address: Vrije Universiteit, Faculty of Earth Sciences, De Boelelaan 1085, NL-1081HV Amsterdam, The Netherlands

Abstract: Calcareous nannofossils were studied in support of the geological mapping and structural interpretation of Masirah Island in Oman. The assemblages found include Middle Triassic(?), Early Jurassic (Late Pliensbachian), and Early as well as Late Cretaceous assemblages from a little-known region between the western Tethys and the Pacific Realm.

Introduction

Masirah Island is one of the less well-known fragments of ocean floor occurring at the southeastern coast of Oman (Figure 1). The island extends over roughly 700km^2 and is formed by two well-exposed ophiolite nappes (Marquer *et al.*, 1995) presently under study by a group of earth scientists at the University of Berne and Neuchatel (Peters *et al.*, 1995).

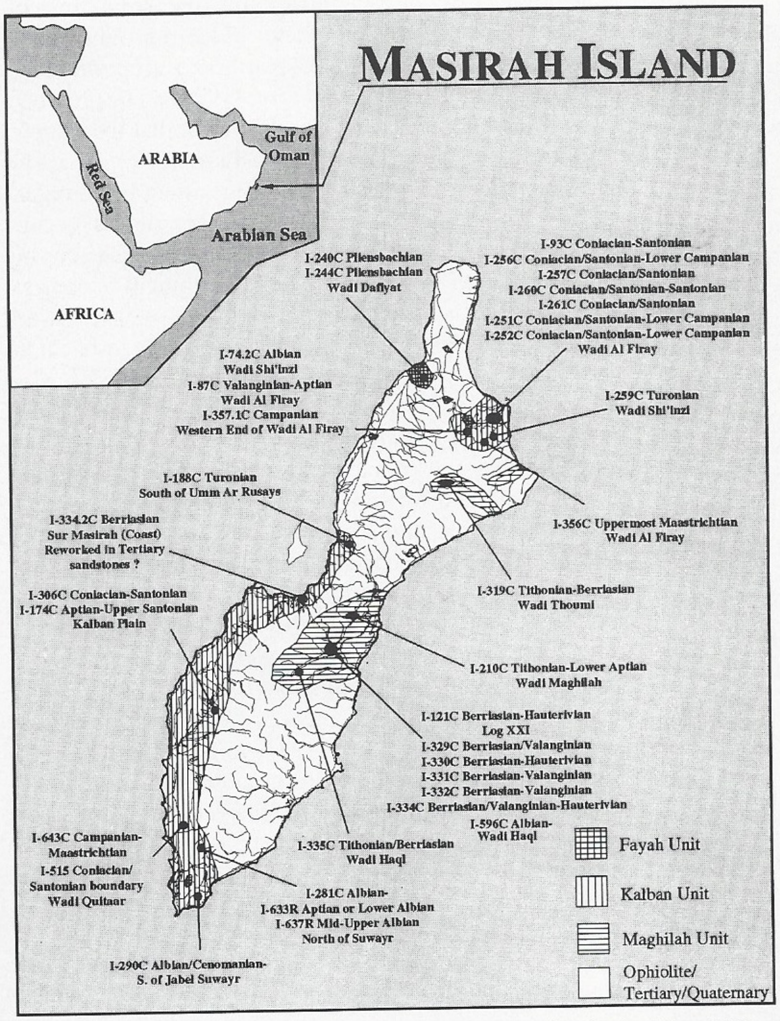


Figure 1: Map of Masirah Island, Sultanate of Oman, showing the localities yielding useful calcareous nannofossil assemblages.

The Masirah Ophiolite was formed about 150Ma (Figure 2) during the Late Jurassic/Early Cretaceous at a latitude of 38°±12°S (Gnos & Perrin, 1996; Immenhauser, 1995, 1996). It belongs to the oldest-preserved oceanic crust of the evolving proto-Indian Ocean which opened in the Late Jurassic between West and East Gondwanaland (*e.g.* Salman & Abdulah, 1995). Masirah became part of the northward drifting Indian Transit Plate (including Pakistan and the Seychelles), when this plate separated from Africa/Madagascar after 84Ma (Immenhauser *et al.*, 1997). The ophiolite was obducted in its present position onto the continental margin of SE Arabia at Cretaceous/Tertiary boundary times, around 65Ma. The obduction is thought to be related to oblique, hot-spot (Deccan Traps)-induced rifting between India/Pakistan and the Seychelles Microcontinent at 65Ma (Plummer & Belle, 1995; Immenhauser *et al.*, 1997).

The autochthonous sedimentary cover of the lower of the two ophiolite nappes on Masirah provides an unbroken stratigraphic record from 150Ma to 65Ma (Immenhauser, 1995). The dating of samples of the highly tectonised sediments was achieved by calcareous nannofossils, foraminifera and radiolaria (Dumitrica *et al.*, 1997). Much to the surprise of the authors, also the Middle Triassic yielded questionable calcareous nannofossils, and Lower Jurassic calcareous nannofossil assemblages were found besides the expected Lower and Upper Cretaceous ones. Since the knowledge about Triassic and Lower Jurassic calcareous nannofossils from the southeastern part of the Tethys is small, we decided to present the new findings in order to complement the present palaeogeographic distribution picture.

Since reports about calcareous nannofossils from other time periods of this part of the world are scarce too, we also present the results of the nannofossil analyses from later time periods and discuss the problems encountered in the age assignment of the various sediment packages.

Material and methods

Spot-samples for age determination by coccoliths were collected from pelagic sediments and were mainly taken in the shaley partings and interbeds of radiolarian micrites

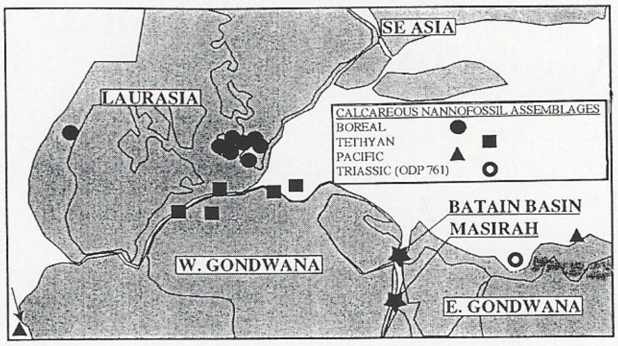


Figure 2: Palaeotectonic map of the Toarcian, modified after Ricou (1994), with position of Masirah Island and Lower Jurassic calcareous nannofossil occurrences after de Kaenel & Bergen (1993), Bown (1987), Erba *et al.* (1992) and Kristan-Tollmann (1988). Triassic occurrence after Bralower *et al.* (1991).

Figure 3: Distribution of Upper Pliensbachian calcareous nannofossils from Masirah Island

SAMPLE	ABUNDANCE	PRESERVATION	*Biscutum profundum*	*Calcivascularis jansae*	*Calyculus ? sp.*	*Crepidolithus crassus*	*Crepidolithus granulatus*	*Lotharingius sp.*	*Mitrolithus elegans*	*Mitrolithus lenticularis*	*Mitrolithus sp.*	*Orthogonoides hamiltoniae*	*Parhabdolithus robustus*	*Schizosphaerella punctulata*	*Similiscutum avitum*	*Similiscutum cruciulus*	*Tubirhabdus patulus*	*Zeugrhabdotus erectus*
240	R	P	+	+	+	+	+	+	+	+	+	+	+	+			+	+
243	vR	P	+												+	+		
244	vR	vP	+	+			+							+				

and even from ribbon-bedded cherts. Upper Cretaceous flysch-type sediments were best dated with samples taken in shaley interbeds. Simple smear-slides were prepared from the samples and embedded in Canada balsam. The study was undertaken at a magnification of x1000 with a light microscope (LM) equipped with polarisers and a gypsum plate. Approximately 250 smear-slides were prepared of which some 20% yielded more or less datable coccolith floras. A few samples were also studied by scanning electron microscope (SEM), the preparation following the usual techniques as described in Perch-Nielsen (1985).

Middle Triassic

Sample I-620, which yielded Middle Triassic radiolaria also included forms which - with doubt - may possibly be assigned to the calcareous nannofossil genus *Calyculus*. This genus was described by Noël (1973) from the Toarcian (Lower Jurassic) of France and consists of subvertical elements surrounding a relatively wide central area. According to Erba *et al.* (1992), "*Calyculus* has not been reported from older than Toarcian sediments so far". While the organic origin of the specimens illustrated in Plate 1, Figures 1-3 seems likely, their generic assignment must remain speculative. No other calcareous nannofossils were found by SEM nor LM in sample I-620, which yielded the following age-indicative radiolaria: *Tritortis balatonica* Kozur and *Tritortis kretaensis subcylindrica* Kozur (Upper Langobardian or Lower Cordevolian; Dumitrica *et al.*, 1997).

Lower Jurassic

The age assignment of Early Jurassic was essential in proving the presence of exotic sediment blocks older than the formational age of the ophiolite on which they were found. Exotic sediment blocks on Masirah Island form part of the Upper Cretaceous Fayah Unit and were shed in the latest Maastrichtian (see below).

Three samples (I-240, I-243 and I-244; Figure 3) were found to include the very rare to rare, poorly to moderately well-preserved calcareous nannofossils listed in Figure 4. Sample I-243 was only studied by SEM. The illustrations are shown on Plate 1. The fact that the assemblages are different is probably due to the different technique used for their study in the case of I-240 and I-243, and by the very poor state of preservation of the coccoliths in sample I-244. For LM illustrations see Crux (1987) and de Kaenel & Bergen (1993), who also present SEM pictures.

Age

Only sample I-240 can be used for an age determination. The presence of *Lotharingius* sp., the first, small form of that genus, suggests an age not older than late Early Pliensbachian (*davoei* Zone of Northern Europe and Portugal, according to de Kaenel *et al.* (1996)). The presence of *Biscutum profundum* means, however, that the sample is of even younger, Late Pliensbachian age (*margaritus* Zone). At the same time, the sample cannot be younger, since it includes *Parhabdolithus robustus*, the last occurrence (LO) of which has been reported in the same zone by de Kaenel *et al.* (1996). This age assignment is contradicted by the distributions reported by Bown (1996) who reported the LO of *P. robustus* in the Lower Pliensbachian *ibex* Zone.

Palaeogeography

The assemblage in sample I-240 is as rich as coeval assemblages from the western and eastern Tethys or from Northern Europe, and no forms restricted to Oman were found. From the palaeogeographic map (Figure 2), it follows that the Lower Jurassic coccolith assemblage reported here was deposited about mid-way between the Italian Jurassic assemblages which were classified as 'tethyan' and those labelled 'pacific' in Timor by Bown (1987). While one Masirah assemblage includes *Mitrolithus jansae*, which was found by Bown (1987) to be restricted to an equatorial/sub-equatorial belt and absent in the Pacific samples from Argentina and the Queen Charlotte Islands (Bown, 1992), none includes *Mazaganella pulla* or *Mazaganella protensa* that were reported by the same author from the southern edge of the Tethys. The sample also lacks *Crucirhabdulus primulus* and *Parhabdolithus liasicus*, two species usually found in Pliensbachian assemblages.

Cretaceous

A synthetic composite section of the autochthonous Cretaceous sediments on the lower nappe of the Masirah Ophiolite, as reconstructed from observations in the field and the ages derived from coccolith, foraminiferal and radiolarian dating, can be found in Immenhauser (1995).

Figure 4: Distribution of Lower Cretaceous calcareous nannofossils from Masirah Island

SAMPLE	ABUNDANCE	PRESERVATION	*Assipetra infracretacea*	*Biscutum* sp.	*Braarudosphaera* sp.	*Calcicalathina oblongata*	*Crepidolithus* sp.	*Cruciellipsis cuvillieri*	*Cyclagelosphaera margerelii*	*Cyclagelosphaera deflandrei*	*Cyclagelosphaera* sp.	*Diazomatolithus lehmannii*	*Discorhabdus* sp.	*Eiffellithus windii*	*Ellipsagelosphaera frequens*	*Ellipsagelosphaera* sp.	*Eprolithus floralis*	*Eprolithus* sp.	*Glaukolithus diplogrammus*	*Haqius circumradiatus*	*Hexalithus hexalithus*	*Kokia ?* sp.	*Lithraphidites carniolensis*	*Lithraphidites morayfirthensis*	*Loxolithus* sp.	*Manivitella* sp.	*Micrantholithus* sp.	*Microstaurus chiastius*	*Nannoconus globulus*	*Nannoconus steinmannii*	*Nannoconus* (top-views)	*Nannoconus* sp.	*Palaeomicula maltica*	*Palaeomicula variabilis*	*Podorhabdus* sp.	*Polycostella beckmannii*	*Polycostella senaria*	*Polycostella* sp.	*Prediscosphaera columnata*	*Prediscosphaera* sp.	*Quadrum ?* sp.	*Reinhardtites* cf. *R. anthophorus*	*Rhagodiscus* cf. *R. asper*	*Rucinolithus hayi*	*Rucinolithus irregularis*	*Rucinolithus wisei*	*Rucinolithus* sp.	*Stradneria crenulata*	*Triquetrorhabdulus ? shetlandensis*	*Tubodiscus jurapelagicus*	*Watznaueria barnesae*	*Zeugrhabdotus embergeri*	*Zeugrabdotus erectus*	*Zeugrhabdotus* sp.	CC ZONES Sissingh (1977)	STAGE
24.1	Fc	Pm						?				+			+		+						+	?		+		?																?	+						F	+			7b	AP
74.2	R	P			+											+	+	+								+		?											+									+			R				8a	AP
87	R	P	+								+			?			+	+								+					+																	+			R				7?	AP?
95	R	P					?							?					?					?	+	+																					+	+			R				7??	AP?
121	R	vP						+		+		+	+										+	?				?			+																				R	+			2–4	
174	+	vP															+	+					+																						+			+			+				7?	AP?
280	+	vP																									+		+	+												+				+						+	+			7?	AP?
281	+	vP																+																																	+	+		+	7?	AP?
310	R	vP					?									+			+																+	?															R			+	1?	BE?
319	+	vP																																						+											+	+			8?	AL?
329	+	P								+																																						+			+	+			?	
330	Rf	P						+	+	+		+				+					+	+	+									?	+				+	+								+		+			R	+			2–4	
331	+	P						?		+																												+													+	+			2–4?	
332	R	P						+	+	+		+				+							+					?				+						+								+		+			R	+			2–4	
334	+	P	?						+	+		+				+							+		+			+						+														+			R	+			2–5	
335	R	P	?					+	+	+		+											+											+				+								+	+	+		+	R				2–4	
344	R	P	+																				+					+						+				R						+						?		R	+	?		1?	BE?
344	+	P																																														+			+				?	
355	+	P																										+	?	+		+																			+				1–7	
511	R	P	?													+																				?															+	+			1?	
542	+	P						?			+																																				+	+			+	+			2–4	
546	+	P			+			+			+																				+																	+			+				2–4	
551	+	P																										+																							+				?	
563	vR	vP														+																															?				+	+			?	
596	vR	P															+	+																							+										+	+			7?	AP?
597	vR	P						+				+						?				?	+																		+				+			+			+	+			2–4	
605	R	vP				?	?					+																																							+				3–5	
637	F	vP		+														+		+			+																				+				+	+	+			F				?	

C=common; F=few; R=rare; +=present
P=poor; M=moderate; v=very; ?=uncertain, questionable
AL=Albian; AP=Aptian; BE=Berriasian

Four groups of Cretaceous assemblages could easily be distinguished on the basis of their calcareous nannofossil content (Figures 4, 5). They are dated, where possible, according to the zonation proposed by Sissingh (1977), taking into account also the findings of Perch-Nielsen (1985) and Bralower *et al.* (1989).

The sediments that were assigned an Early Cretaceous age include only poorly- to very poorly-preserved coccoliths. Their distribution in some samples is presented in Figure 4. The age assignment of many samples was difficult and often represents an educated guess rather than a firm statement. Nevertheless, the presence of forms generally used for the biostratigraphic subdivision of the Lower Cretaceous of the Tethyan Realm allows for an approximate age determination of a dozen or so samples. The knowledge of the presence of these species in this part of the Tethys may prove useful in future studies. Classical markers used in the Tethyan Realm for zonation found herein are: *Calcicalathina* sp.(?), *Cruciellipsis cuvillieri, Eprolithus floralis, Microstaurus chiastius, Polycostella beckmannii, P. senaria*(?), *Prediscosphaera columnata, Rucinolithus irregularis* and various species of *Nannoconus*. Forms known mainly from the Boreal Realm include *Kokia* sp.(?) and *Lithraphidites moray firthensis*(?). The poor preservation does not allow for an unequivocal determination of the forms indicated by '(?)'.

Three major Upper Cretaceous assemblages were found (Figure 5): the Coniacian/Santonian is characterised by the presence of *Marthasterites furcatus* (which, however, ranges from the Late Turonian through the earliest Campanian, but is most common in the Coniacian and Santonian). The Campanian is approximated by the presence of *Broinsonia parca parca* and the Upper Maastrichtian by the presence of *Micula murus*, the marker-species for the uppermost Maastrichtian. Other Upper Cretaceous marker-species include *Arkhangelskiella cymbiformis, Eiffellithus eximius, Helicolithus trabeculatus, Lithastrinus septenarius, Lithraphidites quadratus, Prediscosphaera stoveri, Reinhardtites anthophorus* and *Tranolithus orionatus*.

Upper Cretaceous sediments from Oman were the object of a special study on the evolutionary trends in the family Arkhangelskiellaceae by Lauer (1974). In our material, specimens of this family were not common and thus were not restudied especially. An intensive search in the field for samples above those that include *Micula murus*, in order to find sediments including *Micula prinsii*, the marker of the terminal Cretaceous, or even a Cretaceous/Tertiary boundary section, was not successful. The contact with the se diments overlying those including *M. murus* is tectonic.

Tertiary

Very rare Tertiary coccoliths were found in several samples. They include *Coccolithus pelagicus* and small Prinsiaceae, such as are found from the Paleocene through the Recent, and *Chiasmolithus solitus* (Eocene). It has not been possible to ascertain that these occurrences are actually dating the sample in question. Since many samples included no coccoliths at all, contamination in the laboratory seems, however, unlikely.

Systematic remarks

Systematic information and illustrations of the calcareous nannofossil species listed, mentioned and illustrated can be found in Perch-Nielsen (1985), Bown (1987) and de Kaenel & Bergen (1993).

Figure 5: Distribution of Upper Cretaceous calcareous nannofossils from Masirah Island (RW) = reworked

643	593	517	357	356	306	261	260	259	257	256	252	251	249	188	93	18	SAMPLE
+	+	F	+	Ca	+	Ct	Ct	vR	Fc	vR	R	R	R	vR	Fc	R	ABUNDANCE
P	P	Pm	P	M	P	Mp	Mp	Pm	Mp	Pm	P	vP	P	vP	Mp	vP	PRESERVATION
				+													*Arkhangelskiella cymbiformis*
				+													*Arkhangelskiella specillata*
											?						*Assipetra infracretacea* (RW)
			+	+									+		+		*Biscutum* sp.
															+		*Braarudosphaera bigelowii*
				+		+			+		+		+				*Broinsonia enormis*
	?																*Broinsonia parca s.a.*
				+													*Bukrylithus ambiguus*
				+											+		*Ceratolithoides aculeus*
			?	+		+	+		+		+						*Chiastozygus amphipons*
+							+	+	+		+					+	*Chiastozygus fessus*
							+										*Conusphaera* sp. (RW)
						+			+								*Corollithion ? madagaskarensis*
							+										*Corollithion signum*
							+										*Crepidolithus ?* sp.
							+										*Cretarhabdus conicus*
		+	+	+		+	+		+		+		+		R		*Cribrosphaerella ehrenbergii*
	?																*Cruciellipsis cuvillieri* (RW)
						+	+										*Cyclagelosphaera deflandrei*
						+							+				*Cyclagelosphaera margerellii*
		+		+		+	+		+		+				+		*Cylindralithus* sp.
				+													*Diazomatolithus lehmannii* (RW)
+		+				+	+		+	+	+	+			+	?	*Eiffellithus eximius*
				+													*Eiffellithus parallelus*
+			+	+	+	+	+		+	+		?	+	+	+	+	*Eiffellithus turriseiffelii*
		+		+						+							*Eiffellithus* sp.
						+	+	+									*Ellipsolithus communis* (RW)
						+											*Eprolithus floralis*
									+								*Gartnerago obliquum*
+				+			+				+				+		*Glaukolithus compactus*
		+				+	+		+		+						*Glaukolithus diplogrammus*
				?			?										*Grantarhabdus coronadventis*
						+											*Helicolithus trabeculatus*
			+	?			+								+		Holococcolith
				+													*Kamptnerius magnificus*
						+											*Lithastrinus grillii*
															+		*Lithastrinus septenarius*
						+	+		+	+				+			*Lithastrinus* sp.
				+													*Lithraphidites quadratus*
				+			+		+						+		*Lithraphidites* sp.
			+	+			+								+		*Loxolithus* sp.
				+													*Lucianorhabdus* sp.
			+	+		+	+					+		+	+		*Manivitella pemmatoidea*
						+	+		+	+	+						*Marthasterites furcatus*
						+											*Micrantholithus obtusus* (RW)
				+			+								+		*Microrhabdulus attenuatus*
													+				*Microrhabdulus decoratus*
				+													*Microrhabdulus undosus*
+	?	+	+	+	+	+			+		+	+	+	+		+	*Micula decussata*
				+													*Micula murus*
				+													*Micula praemurus*
		+		+													*Micula swastica*
						+			+		+				+		*Nannoconus* sp. (RW?)
				+													*Petrarhabdus copulatus*
				+		+	+		+								*Placozygus fibuliformis*
				?		+					+						*Placozygus* cf. *P. sigmoides*
+			+	+		+	+	+	+						+		*Prediscosphaera cretacea*
		+	+	+		+					+	+	+		R	+	*Prediscosphaera* sp.
				+													*Prediscosphaera spinosa*
				+													*Prediscosphaera stoveri*
							+										*Prolatipatella multicarinata*
		+															*Quadrum gartneri*
			+	+	+									+	+	+	*Quadrum* sp.1
							+								+		*Quadrum* sp.2
				+											+		*Reinhardtites mirabilis*
					?		+								+		*Reinhardtites anthophorus*
							?										*Rhagodiscus asper* (RW)
						+											*Rhagodiscus elongatus*
						+											*Rhagodiscus reniformis*
				+			+										*Rhagodiscus splendens*
				+													*Rotelapillus munitus*
															+		*Rucinolithus* sp.
											+						*Sollasites* sp.
+		+	+	+	+	+	+		+		+		+			+	*Stradneria crenulata*
							+										*Tegumentum stradneri* (RW)
				+			+										*Tetrapodorhabdus decorus*
				+													*Thoracosphaera* sp.
							+								+		*Tranolithus gabalus*
				+											+		*Tranolithus minimus*
		+	+	?		+	+	+	+		+	+			+	+	*Tranolithus phacelosus/orionatus*
		+	+														*Uniplanarius gothicus*
				+													*Uniplanarius trifidus*
+	+	+		Fc	+	Fc	Fc	R	F	R	R	R		+	Fc	R	*Watznaueria barnesae*
		+		+			+		+		+		+	+		+	*Zeugrhabdotus embergeri*
			+														*Zeugrhabdotus erectus*
				+			+			+			?				*Zeugrhabdotus pseudanthophorus*
14–20?	18–23?	20–22	22–23	25/26	15–20	14	15–17	13–18?	14–17	13	14–16	14–22?	14–22?	14–22?	15	14–23?	**CC ZONES Sissingh (1977)**

Discussion and conclusion

What had started out as a routine biostratigraphic investigation of samples collected by a geologist in the field in order to help him with the interpretation of the complicated geology, turned out to actually change the previous geological picture considerably. In addition, it provided an interesting surprise in the form of enigmatic Middle Triassic nannofossils and an Early Jurassic calcareous nannofossil assemblage from an area from which none was previously described. This assemblage could be shown to correspond broadly to those found in the western part of the Tethys.

According to Bown (1987), the relatively common presence of *Calcivascularis jansae* "reveals the tethyan affinities of a nannofossil assemblage immediately". At the same time, it seems that some of the species usually present in the tethyan Pliensbachian, such as *Crucirhabdus primulus* and *Parhabdolithus liasicus*, are missing in the samples studied.

The often relatively poor state of preservation of the Lower Cretaceous calcareous nannofossil assemblages prevented the assignment of most samples to a specific zone. Nevertheless, a more broad age assignment was possible in many cases and sometimes supported by radiolarian stratigraphy. Also, the Upper Cretaceous assemblages were rarely well enough preserved to allow for a clear zonal assignment.

Acknowledgements

This research was supported by the Swiss National Science Foundation (project No. 22-33559.92). Work on Masirah Island was possible due to the help of the Ministry of Petroleum and Minerals of Oman, especially Mohammed Bin Hussein Bin Kassim, Director General of Minerals, and Dr. Hilal Al Azri, Director of the Geological Surveys, who provided logistical help and support. Dr. E. de Kaenel (Neuchatel) verified the determinations of the Jurassic coccoliths. F. Zweili provided valuable technical help with the SEM. Dr. J.A. Burnett and Dr. P.R. Bown reviewed the manuscript.

References

Bown, P.R. 1987. Taxonomy, evolution, and biostratigraphy of Late Triassic-Early Jurassic calcareous nannofossils. *Special Papers in Palaeontology*, **18**: 1-118.

Bown, P.R. 1992. Late Triassic-Early Jurassic calcareous nannofossils of the Queen Charlotte Islands, British Columbia. *Journal of Micropalaeontology*, **11**(2):177-188.

Bown, P.R. 1996. Recent advances in Jurassic calcareous nannofossil research. *In*: A.C. Riccardi (Ed.). *Advances in Jurassic Research. GeoResearch Forum*, **1-2**: 55-66.

Bralower, T.J., Bown, P.R. & Siesser, W.G. 1991. Significance of Upper Triassic nannofossils from the Southern Hemisphere (ODP Leg 122, Wombat Plateau, N.W. Australia). *Marine Micropaleontology*, **17**: 119-154.

Bralower, T.J., Monechi, S. & Thierstein, H.R. 1989. Calcareous Nannofossil Zonation of the Jurassic-Cretaceous Boundary Interval and Correlation with the Geomagnetic Polarity Timescale. *Marine Micropaleontology*, **14**: 153-235.

Crux, J.A. 1987. Early Jurassic calcareous nannofossil biostratigraphic events. *Newsletters on Stratigraphy*, **17**(2): 79-100.

Dumitrica, P., Immenhauser, A. & Dumitrica-Jud, R. 1997. Mesozoic radiolarian biostratigraphy from the Masirah Ophiolite (Sultanate of Oman). Part I: Middle Triassic, Uppermost Jurassic and Lower Cretaceous Spumellarians and multisegmented Nassellarians. *Bulletin of the National Museum of Natural Science, Taichung, Taiwan*, **9**: 1-106.

Erba, E., Castradori, D. & Cobianchi, M. 1992. Compilation of Upper Triassic and Jurassic calcareous nannofossil ranges. *In*: F. Proto Decima, S. Monechi & D. Rio (Eds). *Proceedings of the INA Conference, Firenze. Memorie di Scienze Geologiche*, **43**: 27-40.

Gnos, E. & Perrin, M. 1996. Formation and evolution of the Masirah Ophiolite constrained by paleomagnetic study of volcanic rocks. *Tectonophysics*, **253**: 53-64.

Immenhauser, A. 1995. The autochthonous Mesozoic sediment record on the Masirah Island ophiolite (Sultanate of Oman). Dissertation, University of Berne.

Immenhauser, A. 1996. Cretaceous sediments on the Masirah Island Ophiolite (Sultanate of Oman): Evidence for an unusual bathymetric history. *Journal of the Geological Society, London*, **153**: 539-551.

Immenhauser, A., Gnos, E. & Peters, Tj. 1997. Late Cretaceous/Early Tertiary convergence between the Indian and Arabian plates recorded in ophiolites and related sediments. *Tectonophysics*, **271**: 1-19.

de Kaenel, E. & Bergen, J.A. 1993. New Early and Middle Jurassic coccolith taxa and biostratigraphy from the eastern proto-Atlantic (Morocco, Portugal and DSDP Site 547B). *Eclogae Geologicae Helvetiae*, **86**(3): 861-907.

de Kaenel, E., Bergen, J.A. & von Salis Perch-Nielsen, K. 1996. Jurassic calcareous nannofossils stratigraphy of western Europe: Compilation of recent studies and calibration of bioevents. *Bulletin de la Société Géologique de France, 1996*, **167**(1): 15-28.

Kristan-Tollmann, E. 1988. Coccolithen aus den Älteren Allgäuschichten (Alpiner Lias, Sinemur) von Timor, Indonesian. *Geol. Paläontol. Mitt. Innsbruck*, **15**: 71-83.

Lauer, G. 1974. Evolutionary trends in the Arkhangelskiellaceae (calcareous nannoplankton) of the Upper Cretaceous of Central Oman, SE Arabia. *Archives de Science, Genève*, 28(2): 259-262.

Marquer, D., Peters, Tj. & Gnos, E. 1995. A new structural interpretation for the emplacement of the Masirah Ophiolites (Oman): A main Paleocene intra-oceanic thrust. *Geodynamica Acta*, **8**: 13-19.

Noël, D. 1973. Nannofossiles calcaires de sédiments jurassiques finement laminés. *Bulletin de la Muséum National d'Histoire Naturelle, 3e série*, **75**: 95-155.

Perch-Nielsen, K. 1985. Mesozoic calcareous nannofossils. *In*: H.M. Bolli, J.B. Saunders & K Perch-Nielsen (Eds). *Plankton Stratigraphy*: 329-426. Cambridge University Press.

Peters, Tj. (coord.), Immenhauser, A., Mercolli, I. & Meyer, J. 1995. Geological map of Masirah North and Masirah South with explanatory notes. Sheet K768-North and Sheet K768-South, Scale 1:50 000. Directorate General of Minerals, Oman Ministry of Petroleum and Minerals.

Plummer, P.S. & Belle, E.R. 1995. Mesozoic tectono-stratigraphic evolution of the Seychelles micro-continent. *Sedimentary Geology*, **96**: 73-91.

Ricou, L.-E. 1994. Tethys reconstructed: Plates, Continental fragments and their Boundaries since 260Ma from central America to Southeast Asia. *Geodynamica Acta*, **7**: 169-218.

Salman, G. & Abdulah, I. 1995. Development of the Mozambique and Ruvuma sedimentary basins, offshore Mozambique. *Sedimentary Geology*, **96**: 7-41.

Sissingh, W. 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, **56**: 37-65.

PLATE 1

Figs 1, 2: Coccoliths or inorganic calcite grains? Sample I-620 of Middle Triassic age based on radiolaria (Dumitrica *et al.*, 1997). Magnifications: x7000 & x11350.

Fig.3: *Mitrolithus*? sp.. Sample I-243, Pliensbachian, x7000.

Fig.4: *Biscutum profundum* de Kaenel & Bergen (1993). Sample I-241, Pliensbachian, x5000.

Fig.5: *Similiscutum cruciulus* de Kaenel & Bergen (1993). Sample I-241, Pliensbachian, x6000.

Fig.6: *Similiscutum avitum* de Kaenel & Bergen (1993). Sample I-243, Pliensbachian, x8000.

Fig.7: *Lithraphidites carniolensis* Deflandre (1963). Sample I-356, Upper Maastrichtian, x5000.

Fig.8: *Lithastrinus grillii* ? Stradner (1962). Sample I-257, Coniacian/Santonian, x7600.

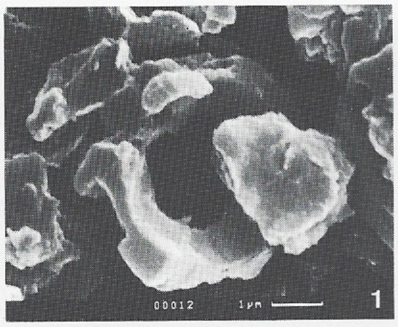
Fig.9: *Micula swastica* Stradner & Steinmetz (1984). Sample I-356, Upper Maastrichtian, x6300.

Fig.10: *Helicolithus trabeculatus* (Górka, 1957) Verbeek (1977). Sample I-261, ±Coniacian/Santonian, x6000.

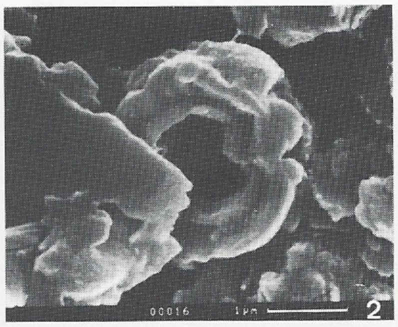
Fig.11: *Marthasterites furcatus* (Deflandre *in* Deflandre & Fert, 1954) Deflandre 1959. Sample I-257, ±Coniacian/ Santonian, x6250.

Fig.12: *Prediscosphaera cretacea* (Arkhangelsky, 1912) Gartner (1968). Sample I-261, ±Coniacian/Santonian, x6500.

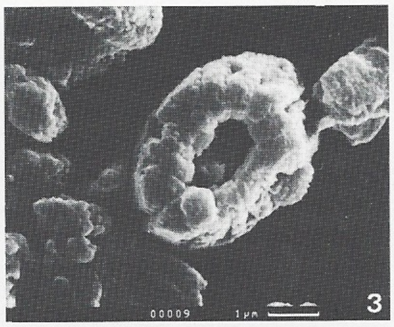
PLATE 1



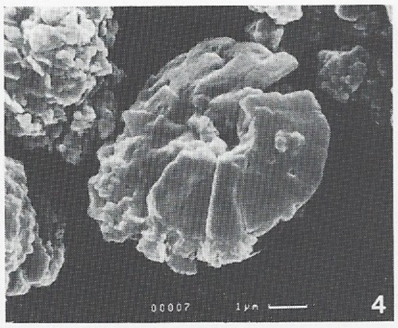
Coccolith?



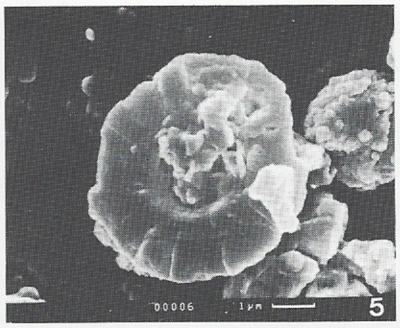
Coccolith?



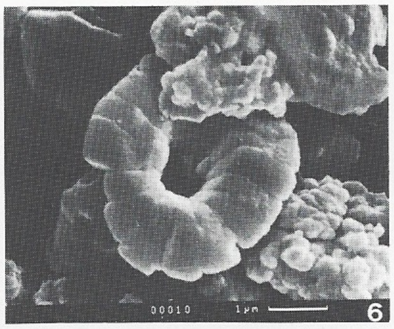
Mitrolithus? sp.



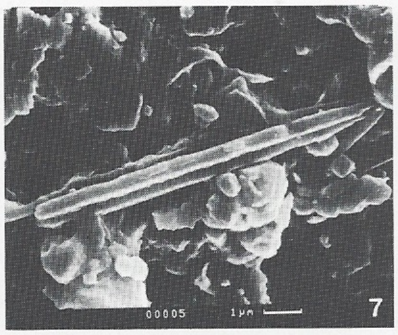
Biscutum profundum



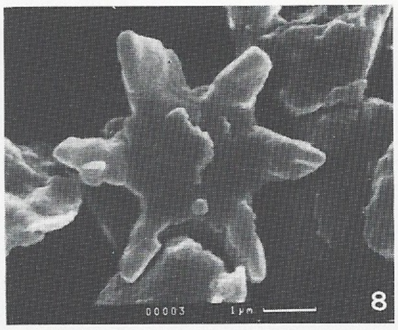
Similiscutum cruciulus



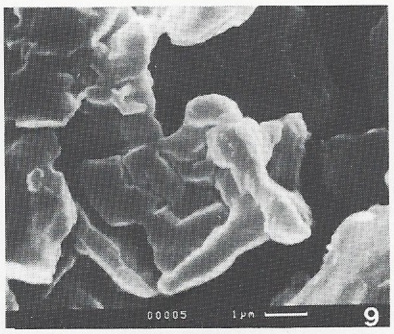
Similiscutum avitum



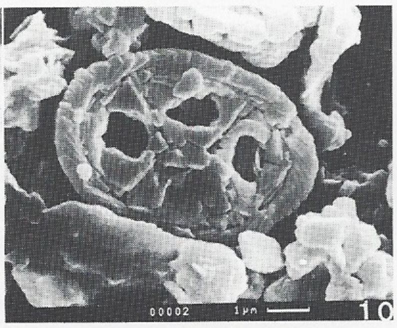
Lithraphidites carniolensis



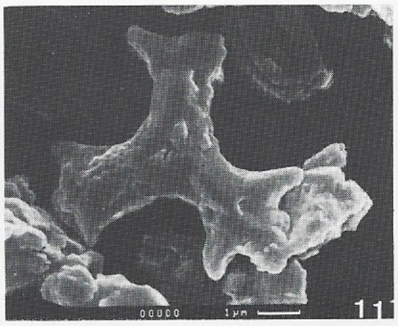
***Lithastrinus grillii* (?)**



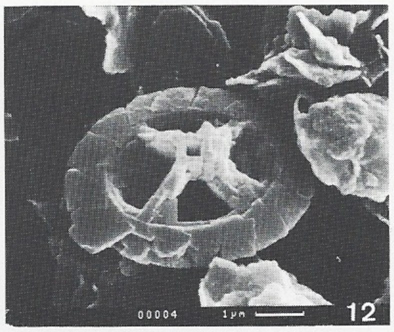
Micula swastica



Helicolithus trabeculatus



Marthasterites furcatus



Prediscosphaera cretacea