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CRETACEOUS COCCOLITH CORRELATION FOR POINT LOMA FORMATION OUTFALL TEST WELL, SAN DIEGO, CALIFORNIA

BY

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ABSTRACT

A 632' (192.6 m) section of the Upper Cretaceous Point Loma Formation was cored on Pt. Loma Peninsula in 1991, just north of the type section. Coccolith floras from 40 samples are late Campanian from Subzone CC22a, CC22b, and CC23a, with *Quadrum trifidum* throughout. Previous paleomagnetic studies of outcrop samples at the same locality indicate the entire cored section is in Chron 33 and that Chron 32r occurs just above the cored section. The estimated ages for the cored section, which includes most of the Point Loma Formation, are less than 75.5 Ma at the base and more than 74.5 Ma at the top.

INTRODUCTION

The type section of the Upper Cretaceous Point Loma Formation was established along the sea cliff at the southern end of the Point Loma Peninsula in San Diego (83 m exposed). This Campanian and Maestrichtian thin-bedded marine sandstone and siltstone unit was also identified to the north at La Jolla and Carlsbad in San Diego County (Kennedy and Moore, 1971). The Point Loma Formation is significant because of the presence of well preserved ammonites, gastropods, pelecypods, and some dinosaur and shark remains (Deméré, 1988; Bannon and others, 1989). Foraminifer and coccolith remains are also present adding to the fossil diversity for correlation (Sliter, 1968, Bukry and Kennedy, 1969). Recently, paleomagnetic studies at both Point Loma and La Jolla established the presence of early Maestrichtian paleomagnetic Chron 32r in cliff outcrops at both localities (Bannon and others, 1989).

This study of a new deep core (DH-1) at Point Loma is intended to establish the coccolith stratigraphic zonation in a thicker section at the San Diego Water Treatment Plant, just north of the type section. Core DH-1 was drilled for the City of San Diego by Woodward-Clyde Consultants to analyze the lithologic characteristics of the Point Loma Formation for potential tunneling of a new wastewater outfall. Drilling occurred from December 16-19, 1991, using a diamond-impregnated bit and wireline core barrel taking 5' core lengths. The coring location is approximately 65' (19.8 m) south of the U. S. Navy property line and 165' (50.3 m) east of the sea cliff top, at the northern end of the plant (lat. 32° 40' 50" N, long. 117° 14' 45" W). The borehole spudded-in at elevation 101' (30.8 m), encountered the Point Loma Formation at 41' (12.5 m), and terminated at 675' (205.7 m), or 574' (175 m) below sea level still in the Point Loma Formation. The interval 0 to 43' (13.1 m) was logged only from cuttings of a sand unit with basal gravel. Casing was set to 43' (13.1 m) to begin core recovery. According to Kennedy and Moore (1971) the estimated thickness of the Point Loma Formation is up to 400 m. The DH-1 core sampled at least half of the entire formation and provides the opportunity to examine 574' (175 m) of unexposed strata from sea level to the total depth. Using projected dip and offshore exposures, Kennedy (1975) had postulated that 623.4' (190 m) of the Point Loma Formation might occur below sea level.

METHODS AND MATERIALS

A total of 40 coccolith samples were taken from core DH-1. Sampling was directed to non-sandy siltstone units at about a 10' to 20' interval, using the detailed lithologic core log provided by Woodward-Clyde Consultants. Samples were stored in plastic bags and prepared as coccolith smear slides using the procedure of Bukry and Kennedy (1969) for study by light microscope. Checklist occurrences are based on 10-minute searches for biostratigraphic key species at magnification 500X.

Preservation of coccoliths is generally good to poor. Most intervals show etching and fragmentation. Flora abundances (ACFRB) are relative estimates of whole specimens (Abundant ~15 per microscope field; Common ~6 per field; Few ~2 per field) plus the concentration of specimen fragments that form a background hash.

Coccolith biostratigraphic zonation is based on Perch-Nielsen (1985), stage correlation and paleomagnetic stratigraphy is based on Bannon and others (1989), Burnett and others (1992), and Manivit (1971), and age estimates are based on Kent and Gradstein (1985).

COCCOLITH RESULTS

A checklist of key stratigraphic coccolith species was prepared (Figure 1) to determine the boundaries between biostratigraphic units, and to relate these to the international stages, paleomagnetic units, and time scales for the Late Cretaceous. The key coccolith characteristic of the cored section is the persistent occurrence of *Quadrum trifidum* throughout; this species defines the original late Campanian to early Maestrichtian *Quadrum trifidum* Zone (Bukry and Bramlette, 1970). The interval from the first *Q. trifidum* to the last *Q. trifidum* is now identified as Zone CC22 and Zone CC23 (see Perch-Nielsen, 1985), with CC23 containing the Campanian-Maestrichtian (C-M) boundary.

Because *Q. trifidum* occurs in the lowest sample, 674.4' (205.6 m), the flora is no older than Zone CC22. These are the deepest fossils yet dated from the Point Loma Peninsula and they are late Campanian in age. The deepest occurrence of *Reinhardtites levis* is recorded in sample 597.1' (182.1 m) and marks the boundary between Subzone CC22a below and CC22b above. The top of Subzone CC22b is the last *R. anthophorus* which is noted in sample 103' (31.4 m). Samples 96.7' (29.5 m) through 49.8' (15.2 m), the topmost sample examined, lack *R. anthophorus* but contain *Broinsonia parca*, *Ceratolithoides aculeus*, *Q. trifidum* and *R. levis*, and are assigned to basal Zone CC23 (Subzone CC23a).

The coccolith floras contain etched and fragmented specimens with resistant species predominant. For example, the most persistently occurring taxa are *Ceratolithoides aculeus*, *Micula decussata*, *Quadrum trifidum* and *Watznaueria barnesae*. Large durable taxa, such as *Arkhangelskiella cymbiformis* and

Subzone	Sample	Abundance	*A. cymbiformis*	*B. parca*	*C. aculeus*	*C. crenulatus*	*C. ehrenbergii*	*E. turriseiffeli*	*M. decussata*	*P. cretacea*	*Q. gartneri*	*Q. sissinghii*	*Q. trifidum*	*R. anthophorus*	*R. levis*	*W. barnesae*	*Zygodiscus* spp.
CC23a	49.8	A	√	√	√	√	√	√	√			√	√		√	√	√
	65.8	C	√	√	√				√	√		√	√			√	
	74	B															
	80	F		√	√		√		√				√			√	
	88	R							√			√	√		√	√	
	96.7	C	√	√				√	√			√	√		√	√	
CC22b	103	A	√	√	√			√	√	√		√	√	√	√	√	
	112	R			√		√	√	√			√	√			√	
	124.5	R							√			√	√			√	
	143	F		?					√			√	√			√	
	156	C		√	√		√		√	√	√		√	√	√	√	
	173	C	?	√	√	√			√	√		√	√	√		√	
	186.3	R							√			√	√			√	
	204.5	F		√	√	√		√	√				√		√	√	
	218	F						√	√				√			√	√
	238.3	F		√	√				√			√	√			√	√
	257	F	√	√	√				√		√	√	√			√	
	278	A	√	√	√		√		√	√		√	√			√	√
	299	A		√	√	√		√	√	√		√	√			√	
	313	R							√			√	√			√	
	328	A	√	√	√	√	√	√	√	√		√	√	√	√	√	√
	348	C			√		√	√	√	√	√	√	√	√		√	
	366.4	C		√	√		√		√			√	√			√	
	388	F			?		√		√				√	√		√	
	401.5	F			√				√				√	√		√	
	420	C	√	√	√	√	√	√	√	√		√	√		√	√	
	441.7	R	√	√	√				√				√			√	
	459.3	R		√		√	√		√				√			√	
	480.7	F	√	√					√	√		√	√	√		√	√
	500	F	√	√	√		√		√	√	√	√	√	√	√	√	√
	514	B															
	534.7	F	√	√	√			√	√		√	√	√	√		√	√
	555	B															
	580.5	B															
	597.3	A	√	√	√	√	√	√	√			√	√	√	√	√	√
CC22a	614.3	F							√			√	√	√		√	
	640.5	C	√	√	√	√	√	√	√		√	√	√	√		√	√
	656.3	C	√	√	√		√	√	√	√	√		√	√		√	√
	667.2	F	√		√		√	√	√							√	√
	674.4	R							√				√	√		√	√

Figure 1. Checklist of selected coccoliths in Point Loma corehole DH-1. Zonation from Perch-Nielsen (1985). Sample identification is also depth (feet) in corehole. Note that *C. obscurus*, *K. magnificus*, *L. cayeuxii*, and *T. phacelosus* were scanned for with the other taxa, but were not found.

Broinsonia parca are also typical members of these floras. Concentration of these robust forms and a background of fragmented coccoliths, together with the lithology of graded beds and interbedded sandstone and siltstone, and submarine slides described by Kennedy and Moore (1971), indicates that significant downslope sediment transport has occurred. The best coccolith abundance is in dark grey siltstone with minimum sand content.

STAGE CORRELATION

Most of the Point Loma Formation cored in DH-1 is assigned to late Campanian Zone CC22, identified between 103' (31.4 m) and 674.4' (205.6 m). This Campanian stage correlation is supported by the data presented in Perch-Nielsen (1985) and Burnett and others (1992). These authors placed the C-M boundary either within CC23a or at the top of CC23a, with the CC23a/23b boundary marked by the last *B. parca*.

Burnett and others (1992) evaluated the biostratigraphy of both coccoliths and megafossils at a group of European reference sections and determined that if the preferred megafossil -- *Belemnella lanceolata* (first occurrence) -- is used for the C-M boundary, then the boundary is within coccolith Subzone CC23a. Therefore, the C-M boundary in DH-1 would be above 103' (31.4 m) if it is in this section. Furthermore, paleomagnetic evidence indicates the C-M boundary is above the cored interval.

PALEOMAGNETIC CORRELATION

One of the goals of this study was to relate the paleomagnetic stratigraphy previously done for the Point Loma Formation at La Jolla and Point Loma (Bannon and others, 1989) to new coccolith biostratigraphy (Figure 2). According to Bannon and others, the identification of paleomagnetic Chron 32r at Point Loma and La Jolla with early Maestrichtian Pacific region molluscs provides a useful guide to improved correlation of Pacific Slope strata. By adding the transoceanic coccolith

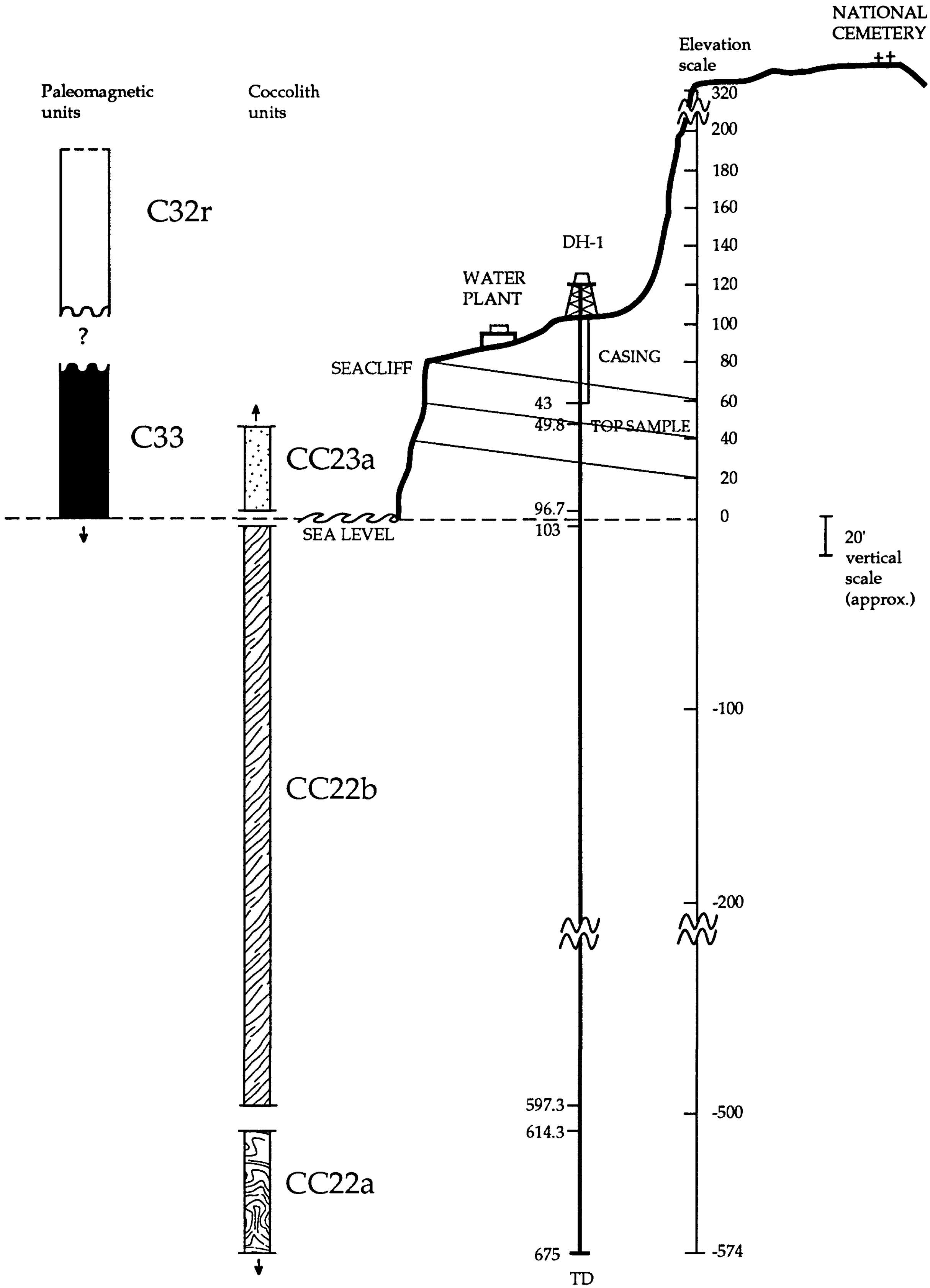

Figure 2. Sketch section of western shore of Point Loma Peninsula at Water Treatment Plant (looking north). Relation of corehole to seacliff is shown with previously reported paleomagnetic units from outcrop (Bannon and others, 1989) and coccolith units reported herein. Local dip of Point Loma Formation is about 8° E. (Kennedy and Moore, 1971).

biostratigraphy to this magnetic designation it is possible to indicate good concordance between European and Pacific molluscs in addition to identification of the magnetic reversal scale.

At the Point Loma Peninsula, Bannon and others (1989) noted the sea cliff part of the Point Loma Formation has normal magnetic polarity and that the reversed Chron 32r was found in the cliff behind the Water Treatment Plant (no elevation given), but partly covered except at the top. A geologic map of Point Loma (Kennedy, 1975) shows the Point Loma Formation outcrop extends up to elevation 200' (61 m) in the cliff at the north end of the plant. The U. S. Geological Survey 7 1/2-minute quadrangle map for Point Loma shows the sea cliff at the Plant is 80' (24.4 m) high; the DH-1 core hole started at elevation 101' (30.2 m), behind the plant. Projecting the 8° E dip measured at the western shore of Point Loma, the entire section of DH-1 core samples should be within the normal-polarity upper part of Chron 33.

TIME SCALE

The *Quadrum trifidum* Zone (Bukry and Bramlette, 1970) is shown to bracket the C-M boundary (74.5 Ma) by Kent and Gradstein (1985) and the age ranges from 75.5 Ma at the base of the zone to 73.0 Ma at the top. Paleomagnetic Chron 32r is shown immediately above the C-M boundary between 74.2 Ma and 73.5 Ma, with an upper and lower reversed-polarity segment separated by a normal segment (Figure 3). The estimated duration of each segment would be less than 233 kyr.

At San Diego the normal segment within C32r was noted in only a single sample, so the entire C32r (700 kyr) may be present, or an erosionally reduced chron may be present in the 30 to 50 m of section (see Bannon and others, 1989). The average sedimentation rate for the whole reversed-polarity thickness would be 43 to 71 m/m.y.

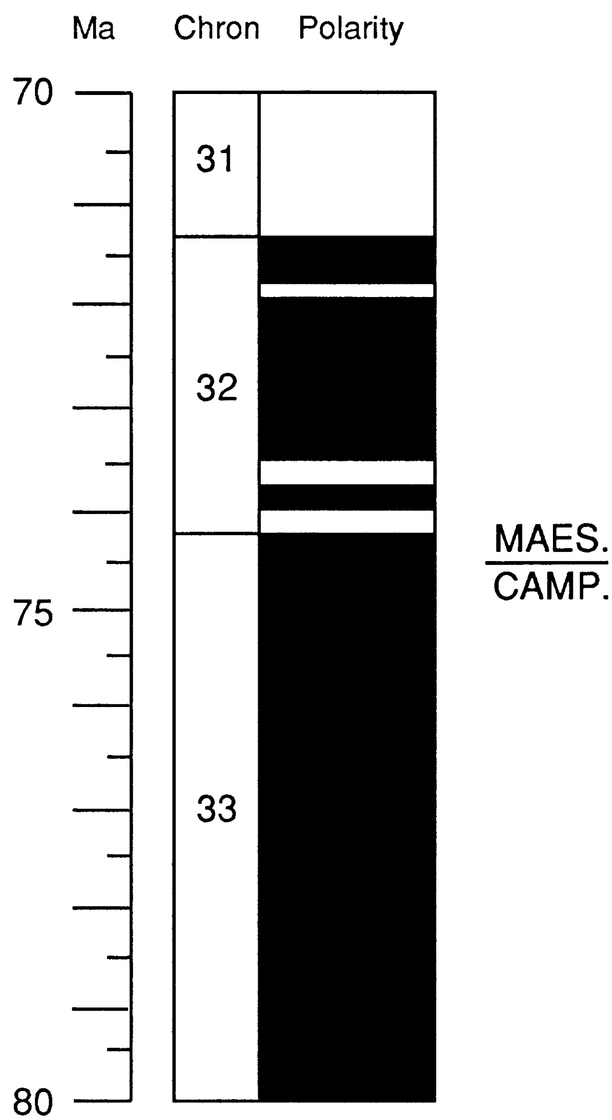

Figure 3. Paleomagnetic units with polarity, ages, and Campanian-Maestrichtian boundary (after Kent and Gradstein, 1985).

A duration for the strata cored at DH-1 can be determined by the presence of *Q. trifidum* throughout and identification of Chron 32r just above the cored section. The cored interval represents less than 1.3 m.y. (first *Q. trifidum* at 75.5 Ma, base of C32r at 74.2 Ma). Therefore, the whole 190.4 m cored section represents a minimum sedimentation rate of, at least, 146.5 m/m.y.

CONCLUSIONS

The study shows the presence of the late Campanian *Quadrum trifidum* Zone (CC22) through the lower 571' (174.0 m) of core hole DH-1 in the Point Loma Formation at the Point Loma Water Treatment Plant. A short upper interval of 47' (14.3 m) is assigned to the Campanian part of the *Tranolithus phacelosus* Zone (CC23). Prior paleomagnetic results for the Point Loma outcrops, also at the Water Treatment Plant site (Bannon and others, 1989), show normal polarity of Chron 33 for the sea cliff section (80' [24.4 m] at this location). The early Maestrichtian Chron 32r was described from the cliff behind the plant (above the core site). The age estimate for the base of Chron 32r (from Kent and Gradstein, 1985), above DH-1, is 74.2 Ma, for the C-M boundary is 74.5 Ma, and for the first *Q. trifidum* (an event below the bottom of DH-1) is 75.5 Ma. Therefore, the sampled interval of DH-1 from 49.8' (15.2 m) to 674.4' (205.6 m) is within the late Campanian and was deposited during a time interval slightly less than 1 m.y., between 75.5 Ma and 74.5 Ma, yielding an average sedimentation rate over 190 m/m.y.

Preliminary correlation to the coccolith stratigraphy for the La Jolla Cove section of the Point Loma Formation (Bukry, in prep.) supports the results for the Point Loma Peninsula (DH-1). The La Jolla section has a short interval of Subzone CC22b at the base in Chron 33, but the major part of the La Jolla section is in Subzone CC23a and also contains the full Chron 32r with top and bottom exposed in the sea cliff. Again, coccolith zonation, paleomagnetic stratigraphy and regional megafossil stratigraphy place the C-M boundary within a short interval in coccolith

Subzone CC23a between the last *R. anthophorus* and the base of Chron 32r. The study of coccoliths from the San Diego Cretaceous sections has provided helpful correlation of paleomagnetic and megafossil results to studies of European and Atlantic Coastal Plain microfossil and megafossil sections (Burnett and others, 1992; Bukry, 1990). The designation of *B. lanceolata* and coccolith Subzone CC23a as guides to the C-M boundary in Europe (Burnett and others, 1992) is supported by the paleomagnetics and Pacific megafossil stratigraphy of the Point Loma Formation of San Diego, as shown through the new coccolith zonation described here.

In consideration of the close proximity of several acceptable microfossil and megafossil criteria for the C-M boundary to the base of Chron 32r, the C-M boundary could be effectively designated as the base of Chron 32r. Designation of a paleomagnetic event for stage boundaries would permit close correlation of marine and terrestrial strata, and prevent proliferation of paleomagnetic stage names. The main body of international stratigraphic stages could be retained with emended boundaries, adjusted to proximal paleomagnetic events. If there will always be a place for larger hierarchical units (stages, series) in geology, then the boundaries of these units should be made as global as possible.

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List of Coccolith Taxa Considered

Arkhangelskiella cymbiformis Vekshina

Broinsonia parca (Stradner)

Calculites obscurus (Deflandre)

Ceratolithoides aculeus (Stradner)

Cretarhabdus crenulatus (Bramlette and Martini)

Cribrosphaera ehrenbergii Arkhangelsky

Eiffellithus turriseiffeli (Deflandre)

Kamptnerius magnificus Deflandre

Lucianorhabdus cayeuxii Deflandre

Micula decussata Vekshina

Prediscosphaera cretacea (Arkhangelsky)

Quadrum gartneri Prins and Perch-Nielsen

Q. sissinghii Perch-Nielsen

Q. trifidum (Stradner)

Reinhardtites anthophorus (Deflandre)

R. levis Prins and Sissingh

Tranolithus phacelosus Stover

Watznaueria barnesae (Black)

Zygodiscus spp.

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