21. CENOZOIC RADIOLARIANS FROM THE BARBADOS RIDGE, LESSER ANTILLES SUBDUCTION COMPLEX, DEEP SEA DRILLING PROJECT LEG 78A¹

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ABSTRACT

Radiolarians occur at two Leg 78A sites. The Barbados Ridge Site 541, 3 km arcward of the deformation front, includes a short radiolarian sequence at the bottom of the hole, with assemblages ranging from the lower Miocene Stichocorys delmontensis Zone through the Calocycletta costata Zone. The oceanic reference Site 543, 3 km seaward of the deformation front, includes a longer sequence from the middle Eocene Thecocystis cryptocephala Zone to the middle Miocene Dorcadospirys alata Zone. These sites are compared to other Deep Sea Drilling Project sites in the Caribbean and Gulf of Mexico and also to a land-based section at Bath Cliff, Barbados. Because this is the first time we have been able to document the nature of a subduction zone complex by drilling, a major objective of this chapter is a comparison of the radiolarian sequence in the deformation zone with the corresponding sequence at the oceanic reference site. The part of the section with radiolarians does not show any stratigraphic inversion, such as is documented by calcareous nannofossils higher in the hole. By comparing varying evolutionary morphologies of three unrelated taxa, a correlation is made within the Calocycletta costata Zone. This correlation, and others made in the most general manner, suggest variations in the environment or in the rate of deposition, uneven core recovery, or perhaps the tilting of beds with the down-going crust.

INTRODUCTION

Radiolarians were recovered at two sites of DSDP Leg 78A on the Barbados Ridge Complex. Site 541 is 3 km arcward of the deformation front and includes sediments scraped off the down-going plate. Oceanic reference Site 543 is 3 km west of this front (Fig. 1). The localities and water depths of these sites are:

<table>
<thead>
<tr>
<th>Hole</th>
<th>Water depth (m)</th>
<th>Position</th>
<th>Recovery (m)</th>
<th>No. of cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>541</td>
<td>4961</td>
<td>15°31.2'N, 58°43.7'W</td>
<td>459.0</td>
<td>50</td>
</tr>
<tr>
<td>543</td>
<td>5643</td>
<td>15°42.7'N, 58°39.2'W</td>
<td>228.4</td>
<td>34</td>
</tr>
<tr>
<td>543A</td>
<td>5643</td>
<td>15°42.7'N, 58°39.2'W</td>
<td>69.4</td>
<td>16</td>
</tr>
</tbody>
</table>

A Recent assemblage occurs in the top core at Site 541. Early Miocene radiolarian assemblages occur in the three lowest cores. Drilling was terminated when the hole collapsed at 460 m sub-bottom depth. At Site 543, a sparse Recent assemblage occurs at the top. Midhole, a long radiolarian sequence was recovered, with assemblages ranging from middle Eocene to middle Miocene. Below this sequence are occasional sparse, partially dissolved assemblages.

Figure 2 is a summary of the radiolarian zones represented in Leg 78A. Figure 3 is a correlation of the two sites. Tables 1, 2, and 3 summarize the occurrences and abundances of species found in Holes 541, 543, and 543A, respectively.

PROCEDURES

Samples were taken at least every section, and as closely spaced as three per section, in order to describe and compare the sites adequately. Sediments were washed and sieved at 44 μm. Four types of strewn slides in three size fractions (>149 μm, 63-149 μm, 44-63 μm, and >44 μm) were permanently mounted.

Relative abundances of species are recorded in five categories (defined in Table 1). These categories indicate the percentage that a taxon represents of the total assemblage on the >44-μm slide. The density of radiolarians on a slide was calculated by counting eight random grids on the whole slide and extrapolating the average number to the whole slide. The abundance of a taxon was calculated from its numbers in 20 random grids and extrapolated to the whole slide. Near the evolutionary transition of a species, both the ancestral and the descendant taxa were counted on the whole slide to ascertain which predominates.

The radiolarian zones used in this paper are the chronozones defined by Riedel and Sanfilippo (1978), with the Thyrsocrinites bromia Zone emended by Maurrasse and Glass (1976) and Saunders et al. (in press).

SITE 541

Hole 541 in the deformation zone was drilled with the hope of penetrating the down-going oceanic crust, an objective not previously achieved at any convergent margin. The hole collapsed at 460 m sub-bottom depth, and drilling was terminated.

In Core 1 (Sections 541-1-1 and 541-1, CC), sponge spicules are few and broken. Recent radiolarians are very rare, with thin-walled skeletons.

Cores 2 through 46 consist of calcareous units overlying a hemipelagic mud. Siliceous microfossils are absent.

In Section 541-47, CC, very few and very badly preserved, unidentifiable radiolarians occur. In Cores 48 through 50, radiolarians are very rare to abundant, moderately well to poorly preserved (Table 1). Orospheerid fragments are common. These early Miocene assemblages range from the Calocycletta costata Zone to the Stichocorys delmontensis Zone.

Samples 541-48-5, 105-107 cm through 541-50-1, 120-122 cm are assigned to the Calocycletta costata Zone and contain radiolarians in two different preservation states. Radiolarians are, in general, moderately

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well preserved, the exception being from Samples 541-49-1, 10-12 cm to 541-49-3, 35-37 cm where skeletons are quite poorly preserved. Specimens of Cystocapsella cornuta, Liriospyris stauropora, Calocycleta costata, C. virgini, Stichocorys delmontensis, S. wolffii, and Dorcadospyris dentata are most frequent. No specimens of Dorcadospyris alata occur, indicating that the sequence does not approach the evolutionary boundary of D. dentata/D. alata. Also, because of the poor recovery of Core 50 (39%) and the resulting hiatus between Sections 1 and 3, the lower limit of the zone is not located.

The Stichocorys wolffii Zone is missing. Sample 541-50-3, 12-14 cm through Section 541-50,CC are assigned to the Stichocorys delmontensis Zone due to the appearance of Lychnocanoma elongata and Dorcadospyris ateuchus and to the disappearance of Calocycleta costata and S. wolffii. Thelocyrtis annosasa is absent. The assemblage is dominated by Didymocyrtis tubaria, Dorcadospyris ateuchus, Cystocapsella cornuta, C. tetrapera, L. elongata, Cyclamptierium leptetrum, and S. delmontensis. Specimens of S. delmontensis appear almost identical with specimens of S. wolffii encountered slightly higher in the hole, differing only in a slightly more porous thorax (more than 6 pores/visible half).

SITE 543

Two holes (543 and 543A) were drilled at this site, in 5643 m of water. This oceanic reference site is 3 km seaward of the deformation front. Basement was reached in Hole 543A. Radiolarians in varying abundances and states of preservation were recovered from both holes. The most significant recovery is a Cenozoic sequence that ranges from middle Eocene to middle Miocene in Hole 543.

Hole 543

A sparse, Recent assemblage of radiolarians showing strong dissolution occurs in Section 543-1,CC. Cores 2 through 16 are barren. Radiolarians occur again in Section 543-17-1 and continue through the last core (34,CC).

At the top of this long sequence (Sample 543-17-1, 10-12 cm) are a few fragments, one of which is identi-
fied as Calocycletta costata, dating the sample as no younger than the middle Miocene Dorcadospyris alata Zone. The assemblages in Samples 543-17-2, 10-12 cm through 543-18-1, 30-32 cm show increasing abundances and better states of preservation, and are assigned to the Dorcadospyris alata Zone. The following species dominate: Dorcadospyris alata, Cyrtocapsella cornuta, Liriospyris parkerae, Calocycletta costata, Cy-
Table 1. Radiolarians at Site 541.

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Radiolarian Zones</th>
<th>Sample (interval in cm)</th>
<th>Radiolarian density (taxonomic index)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Preservation (taxonomic index)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calocycletta costata</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calocycletta serrata</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cyclampterium leptetrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Didymocyrtis violina</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Didymocyrtis tubaria</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lithocyrtis annosa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stichocorys delmontensis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Theocyrtis tuberosa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thryocorys graciilis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thyrsocyrtis tetracantha</td>
</tr>
</tbody>
</table>

Note: Present but less than 0.01% = +; 0.01%-0.1% = r (very rare); 0.1%-1% = R (rare); 1-10% = F (few); >10% = C (common); looked for, but absent = —; blank space indicates species not looked for.

cyclampterium leptetrum, Stichocorys delmontensis, and S. wolffii.

In Samples 543-18-2, 31-33 cm through 543-20-1, 70-72 cm, Dorcadospyris dentata is consistently more abundant than its descendant, D. alata. This fact, along with the continuing occurrence of Calocycletta costata and C. virginis, the morphotypic top of Siphistochyrtus corona and Didymocyrtis violina, and the evolutionary top of Liriospyris stauropora, places these samples in the lower Miocene Calocycletta costata Zone. The upper radiolarian sequence at Site 541 (Section 541-48-5) correlates with the bottom third of this zone (Fig. 3).

Sample 543-20-2, 70-72 cm through Section 543-20,CC are assigned to the Stichocorys wolffii Zone. S. wolffii, S. delmontensis, Eucyrtis prismatica, Cyclampterium leptetrum, Carpoconopsis cingulata, C. bramlettei, and Cyclampterium corinna dominate; the evolutionary top of Didymocyrtis marina occurs; Calocycletta costata is absent. Radiolarians are very abundant, occurring in highly diverse assemblages of moderate preservation.

There was no recovery from Core 21. What little was recovered from Core 22 (Section 543-22-1, top—approximately 25 cm) is assigned to the Stichocorys delmontensis Zone (see Table 2). S. delmontensis, Didymocyrtis prismatica, Cyclampterium corinna, C. tetrapera, Calocycletta serrata, Dorcadospyris ateuchus, and Eucyrtis diaplanes dominate the assemblage. S. wolffii and Theocyrtis annosa are notably absent. Specimens are very abundant and very well preserved.

Samples 543-23-1, 145-147 cm through 543-24-1, 2-4 cm (again, see Table 2) have common to abundant radiolarians, and the quality of preservation remains moderately good. This sequence is placed in the Lichnocanoma elongata Zone. L. elongata, D. ateuchus and T. annosa (both morphotypic tops), Cyclampterium pegerrum (evolutionary top), and Didymocyrtis prismatica dominate the assemblage. Calocycletta serrata and Cyclampterium tetrapera are absent. C. cornuta occurs in only the first two samples. This assignment indicates that the Cyclampterium tetrapera Zone may have occurred in the lost Core 22.

Samples 543-24-2, 40-42 cm through 543-26-1, 64-66 cm show a rapid decline in the quality of preservation and a great variability in abundance. The assemblages have very low diversities, being dominated by Dorcadospyris ateuchus and occasionally by Cyclampterium pegerrum. L. elongata is absent and the evolutionary top of Tristylospyris triceros has not been reached, placing these samples in the Dorcadospyris ateuchus Zone. The Oligocene/Miocene boundary occurs within this interval.

The Theocyrtis tuberosa Zone is represented by Samples 543-26-2, 43-45 cm through 543-27-2, 126-128 cm. The following species appear: Artophormis gracilis, Lithocyrtis angusta, T. tuberosa, C. pegerrum, C. milowi, and Tristylospyris triceros. Abundances and the quality of preservation improve. T. triceros is dominant, and the Lithocyrtis aristotelis group has not yet appeared.

Two samples, 543-27-3, 53-55 cm and 543-27-4, 78-80 cm, are assigned to the Cryptopyrora ornata Zone (Saunders et al., in press). Thyrsocytis tetracantha goes to extinction just below these samples; specimens of the L. aristotelis group occur with great frequency; and L. angusta drops out—all in accordance with the definition of this interval-chronozone. The assemblage includes Tristylospyris triceros, Theocyrtis tuberosa, Lichnocanoma bajunensis, and the latest occurrences of Lipoocyrtis jacchia and Lichnocanoma amphitheir. The Eocene/Oligocene boundary is not yet firmly established.
Table 2A. Radiolarians in Hole 543: early Miocene to middle Miocene.

in radiolarian stratigraphy and can therefore not be placed more precisely than between Samples 543-27-2, 126–128 cm and 543-27-5, 104–106 cm.

The assemblages in Samples 543-27-5, 104–106 cm through 543-28-3, 73–75 cm belong to the Calocyclas bandyca Zone (Saunders et al., in press) and include Tristylolipysris triceros, Lithocyclos aristotilis group, Lophocyclos jaccia, L. amphihrirte, Dictyopora mongolfieri, and the latest occurrences of Thyrsocyrtis bromia, T. tetracantha, Eusyringium fistuligerum, Lychnocanoma bajunensis, P. chalara, and Thyrosocyrtis triacantha dominate the assemblage. Radiolarians are abundant and moderately well preserved.

Samples 543-29-3, 6–8 cm through 543-30-1, 10–12 cm are assigned to the Podocycris mitra Zone. P. chalara appears sporadically and continuously decreases in abundance until it disappears in the middle of the sequence, whereas P. mitra is present continuously but with fluctuating abundance. P. sinuosa occurs only at the bottom of the sequence. Section 543-29, CC contains a displaced component from the top of the Podocycris mitra Zone. Radiolarians are abundant and moderately well preserved.

Samples 543-30-1, 38–40 cm through 543-30-3, 7–9 cm belong to the Podocycris ampla Zone. P. sinuosa is consistently more abundant than P. mitra, which disappears in the middle of the zone. P. ampla is present throughout; P. phyxois occurs very rarely at the bottom of the zone. Other dominant taxa include C. hispida, D. mongolfieri, L. bajunensis, P. papalis, and T. triacantha. Radiolarians are abundant and moderately well preserved.

Samples 543-30-3, 132–134 cm through 543-30-5, 129–131 cm are assigned to the Thyrosocyrtis triacantha Zone. P. phyxois and E. fistuligerum are absent, whereas...
Theocotyle venezuelensis appears with increasing abundance. Specimens of D. mongolfieri, Thysocyrtis triacantha, C. hispida, Rhadalithis pipa, P. sinuosa, and L. bajunensis predominate. Radiolarians are common and moderately well preserved.

Sample 543-30-6, 60–62 cm through Section 543-31,CC are assigned to the Dictyopora mongolfieri Zone due to the presence of D. mongolfieri in considerable numbers and to the absence of Eusyringium lagena. P. sinuosa, L. bajunensis, C. hispida, and T. hirsuta occur frequently. Radiolarians are abundant and moderately well preserved.

The top of the sequence from Samples 543-32-1, 37–39 cm through 543-32-5, 68–70 cm has very abundant and very well preserved specimens. Both abundance and preservation decline to the point that skeletons at the bottom are rare and dissolved almost beyond recognition. The assemblage is dominated by Theocotylissa fícus, C. hispida, and P. sinuosa. Specimens superficially similar to D. mongolfieri are common, but they lack strict longitudinal pore alignment and ribs. Calocyclus ma castum and Periphaena delta appear with increasing abundance. This sequence is assigned to the Theocotyle cryptocephala Zone in accord with its definition, although specimens of T. cryptocephala occur rarely and sporadically.

Sections 543-32,CC through 543-34,CC are unzoned because assemblages are sparse and very poorly preserved. Specimens of C. castum, Calocycloidea ampla, Dictyopora mongolfieri, and Theocotylissa fícus occur rarely and cannot be used with confidence for zonation. Species of the genera Amphicraspedum and Spongodiscus dominate the assemblages.

**Hole 543A**

During offset drilling we recovered one core from the surface, washed down to 332 m, and continuously cored to 411 m at basement and 44 m into basalt.

Sections 543A-1–3 and 543A-1,CC contain a Recent radiolarian assemblage of low to moderate diversity, showing breakage and signs of dissolution. Sample 543A-H1-1 is barren.

After voids in the recovery, samples 543A-H1-4, 95–97 cm through 543A-2-1, 95–97 cm contain common to few radiolarians in moderate to poor states of preservation (Table 3). Sample 543A-H1-4, 95–97 cm contains specimens of Podocyrtis mitra, P. trachodes, and Sethocyrtis triconiscus, placing it in the Podocyrtis mitra Zone. This assignment correlates best with samples from Section 543-29-7.

Rare specimens of Eusyringium fistuligerum and P. dorus, and the common occurrence of P. sinuosa, place
### Table 3. Radiolarians in Hole 543A.

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Zonal Assignment</th>
<th>Sample (interval in cm)</th>
<th>Radiolarian Density (millimeter cube)</th>
<th>Preservation (very poor, poor, moderate)</th>
<th>E. affinis</th>
<th>B. affinis</th>
<th>C. costata</th>
<th>T. castum</th>
<th>T. cryptocephala</th>
<th>D. alata</th>
<th>D. mongolfieri</th>
<th>P. mitra</th>
<th>P. ampla</th>
<th>T. trian受灾</th>
</tr>
</thead>
<tbody>
<tr>
<td>middle Eocene</td>
<td></td>
<td>H1-4, 95-97</td>
<td>9.52</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>H1-5, 85-87</td>
<td>28.77</td>
<td>r</td>
<td>F + r + F</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unzoned</td>
<td></td>
<td>H1-6, 64-66</td>
<td>0.63</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>r + r + r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. mongolfieri</td>
<td></td>
<td>H1, CC</td>
<td>9.73</td>
<td>r</td>
<td>F + r + F</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T. cryptocephala</td>
<td></td>
<td>2-1, 95-97</td>
<td>1.96</td>
<td>VP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Unzoned</td>
<td></td>
<td>2-2, 56-58</td>
<td>&lt;0.1</td>
<td>VP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>r + r + r</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>2-CC</td>
<td>1.96</td>
<td>VP</td>
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<td></td>
<td></td>
<td>+</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: See Table 1 for an explanation of symbol.

Sample 543A-H1-5, 85–87 cm at the boundary between the Podocyrtis ampla and Thysocoris trian受灾 Zones. This assignment correlates closest with Section 543-30-3. Radiolarians are abundant and moderately well preserved.

Sample 543A-H1-6, 64–66 cm contains no diagnostic species. Specimens are few and very poorly preserved. *P. sinuosa* and *Rhabdolithis pipa* are dominant.

Section 543A-H1, CC contains specimens of both Theocorys anacelata and Dictyopora mongolfieri, placing it in the Dictyopora mongolfieri Zone. Specimens of *T. trian受灾* are rare in comparison to those of *T. tensa*. *Periplaena delta* is absent. This information places the sample near the middle of the zone, which correlates best with Section 543-31-1.

Sample 543A-2-1, 95–97 cm contains an abundant, highly diverse assemblage, very poorly preserved. *Calocyrtis costata*, *Theocotyle cryptocephala*, and *Theocotylissa ficus* are present. This sample is assigned to the Theocotyle cryptocephala Zone, and correlates best with Section 543-32-4.

Sections 543A-2-2 and 543A-2, CC contain radiolarians in moderate abundance but very poorly preserved. Several specimens of *C. castum* and *Buryella clinata* occur.

Cores 3, 4, and 5 contain radiolarians in varying abundances, but so poorly preserved that specimens are unrecognizable. Cores 6 to basement are barren.

**DISCUSSION**

The pattern of radiolarian occurrences from the Barbados Ridge follows that described from land-based studies and from DSDP Legs 4, 7, 10, 15, and 68, which have shown that radiolarians, and siliceous microfossils in general, do not occur in Tertiary sediments younger than middle Miocene in the Gulf of Mexico and the Caribbean (Sanfilippo and Riedel, 1973, 1976; Riedel and Sanfilippo, 1970, 1971, 1973; Riedel and Westberg, in press). At Site 541 within the deformation zone, radiolarians were found only in the top core (a Recent assemblage showing signs of dissolution) and bottom four cores (*Calocyrtis costata* Zone and Stichocorys delmontensis Zone of the upper lower Miocene). Even as far east as the oceanic reference Site 543, radiolarians occur again in the top core, disappear, and then reappear in a long, continuous sequence from Cores 17 through 34 at the bottom of the hole (*Dorcadospyris alata* Zone of the middle Miocene to *Theocotyle cryptocephala* Zone of the middle Eocene).

Site 543 can be compared also with the results of a land-based study by Saunders et al. (in press) on the Eocene to lower Oligocene section at Bath Cliff, Barbados. Noted differences are the rare and intermittent occurrence of "Carpocanistrum" azyx at Site 543, and the absence of the "Carpocanistrum" azyx and *Podocyrtis goetheana* Zones (see Table 2). Radiolarian events in the two sections are summarized in Table 4.

As for the intracomparison of the Miocene portions at Sites 541 and 543, there are several questions to be asked. What has happened to the radiolarians in the deformation zone? Can one measure the integrity of the section? Can the amount of compaction be quantified? Why is the *Dorcadospyris alata* Zone missing from Site 541? To answer these questions, one must first determine what part of the *Calocyrtis costata* Zone in Site 541 is represented in Site 541.

With this objective, the evolution of morphological traits in three taxa was measured and plotted. (1) The first trait is the width and height of the thorax in *Cyclampterus lepetitrum*. These proportions are known to change through the time represented by the *Calocyrtis costata* Zone and thus offer promise for fine-scale correlation. (2) Second is the volume of the cephalis of *Dorcadospyris dentata*. Both the evolutionary top and the morphotypic bottom of *D. dentata* occur in Site 543. At the top of the zone there is great similarity in the cephalis between *D. dentata* and its descendant *D. alata*. Measuring the evolutionary change in the cephalis down the zone would help correlate the location of Site 541 within the zone. (3) Last is the width of the cos-
The study of the cephalic development of *Dorcadospyris dentata* at Site 543 shows again two sets of values for the changing volume (height × width). The “lower” numbers occur higher in the zone, whereas the “higher” values appear in the lower third. Without knowing the correlation for sample spacing at Site 541, I simply compared the quotient values to the Site 543 graph (Fig. 4). The highest and lowest values are marked on the graph and show that all the Site 541 values “fit” in the lower third of the zone. Even the trend of values for both sites are quite similar in the bottom 5 m.

The study of the cephalic development on the thorax of *Calocycletta costata* shows a different trend. Early in its evolution from *C. virginis*, the thoracic ridges are less prominent, as they are at the end of the lineage. The most robust ridges occur toward the middle of its development. Thus the results here show three sets of numbers—low at the top half of the zone, high at the third quarter, and low again in the bottom quarter. The calculated values for Site 541 could “fit” either low set for Site 543 but coordinates best with the lowest quarter when compared with the two studies discussed. Here the trends in values are less easy to compare and appear to be similar only in their variability.

The results of these three studies show that the approximately 10 m of sediment in the *Calocycletta costata* Zone of Site 541 correlate to the lower portion (4–8 m) of the same zone in Site 543. It would be nice to be able to compare each assemblage according to the frequencies of individual taxa, which could perhaps indicate the degree of compaction in the down-going section. But to do this the beds would have to be relatively flat or at least at comparable degrees of tilt. The greater apparent thickness of the lower third of the *Calocycletta costata* Zone at Site 541 may result from tilting of these beds as they are being downthrust. This may be supported by comparing a zone of radiolarian dissolution (between Samples 541-49-1, 10–12 cm and 541-49-3, 35–37 cm) at Site 541 and its probable corresponding level at Site 543, which is simply a decrease in radiolarian abundance in Sample 543-19-4, 30–32 cm. On the other hand, if it is hypothesized that the *Stichocorys wolffi* Zone occurs in the void core Section 541-50-2, then that part of the section is thinner at Site 541 than at Site 543.

In general, the radiolarians occur in a more competent underlying section, which shows greater density and strength than the overlying hemipelagic deposits. The section resists off-scraping, maintaining its integrity, and appears to be subducted with the underlying oceanic crust.

As to the question raised by the absence of the middle Miocene radiolarians at Site 541, the absence could be due to a hiatus or to tectonic thinning, but the evidence available is insufficient at this time to speculate further.

### SPECIES LIST

This list provides bibliographic references to the species in this chapter. Only references to the original description and to the present concept of the species (indicated by —), if different from the original, are given.

- *Artophormis gracilis* Riedel
- *Artophormis gracilis* Riedel, 1959, p. 300, pl. 2, figs. 12, 13.
- *Buryella clinata* Foreman
- *Buryella clinata* Foreman, 1973, p. 433, pl. 8, figs. 1–3; pl. 9, fig. 19.
- *Calocycletta costata* (Mato and Theyer)—Sanfilippo and Riedel, in Saunders et al., in press.
- *Calocyclas bandyca* (Mato and Theyer)—Sanfilippo and Riedel, in Saunders et al., in press.
- *Calocyclas hispida* (Ehrenberg)
- *Anthocyrtis hispida* Ehrenberg, 1873, p. 216.
- *Calocycletta costata* (Riedel)
- *Calocycletta costata* Riedel, 1959, p. 296, pl. 2, fig. 9.
- *Calocycletta costata* (Riedel)—Riedel and Sanfilippo, 1978, p. 66, pl. 3, fig. 9.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Height/width</th>
<th>Standard deviation</th>
</tr>
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<tbody>
<tr>
<td>48-5, 108–107 cm</td>
<td>0.9734</td>
<td>± 0.5968</td>
</tr>
<tr>
<td>48-6, 87–89 cm</td>
<td>0.9583</td>
<td>± 0.5960</td>
</tr>
<tr>
<td>48-4, 40–42 cm</td>
<td>0.7001</td>
<td>± 0.0603</td>
</tr>
<tr>
<td>49-4, 108–107 cm</td>
<td>0.5990</td>
<td>± 0.0428</td>
</tr>
<tr>
<td>49-5, 90–92 cm</td>
<td>0.7798</td>
<td>± 0.0304</td>
</tr>
<tr>
<td>50-1, 20–22 cm</td>
<td>0.8672</td>
<td>± 0.1222</td>
</tr>
</tbody>
</table>

Figure 4. Thorax development of Cyclamptesium leptetrum within the Calocycletta costata Zone at Site 543. (Depth in meters from top of C. costata Zone is indicated. Cores and sections are given in brackets.)

Calocycletta serrata Moore

Calocycletta virginis Haeckel
Calocycletta virginis Haeckel, 1887, p. 1381, pl. 74, fig. 4.


Calocyrella ampulla (Ehrenberg)
Eucyrtidium ampulla Ehrenberg, 1854, pl. 36, fig. 15; 1873, p. 225.

Calocyrella ampulla (Ehrenberg)—Riedel and Sanfilippo, 1970, p. 524, pl. 6, fig. 1; Riedel and Sanfilippo, 1978, p. 66.

Calocyrella casta (Haeckel)
Calocyrella casta Haeckel, 1887, p. 1384, pl. 73, fig. 10.

Calocyrella casta (Haeckel)—Foreman, 1973, p. 434, pl. 1, figs. 7, 9, 10; Riedel and Sanfilippo, 1978, p. 66, pl. 1, fig. 9; pl. 3, fig. 15.

“Carpocanistrum” azyx Sanfilippo and Riedel
Carpocanistrum(?) azyx Sanfilippo and Riedel, 1973, p. 530, pl. 35, fig. 9.

“Carpocanistrum” azyx Sanfilippo and Riedel, in Saunders et al., in press.

Carpocanopsis brevilegii Riedel and Sanfilippo
Carpocanopsis brevilegii Riedel and Sanfilippo, 1971, p. 1597, pl. 2C, figs. 8–14; pl. 8, fig. 7; 1978, p. 67, pl. 4, fig. 6.
Figure 5. Cephalis development of *Dorcadospyris dentata* within the *Calocyctetta costata* Zone at Site 543. (Depth in meters from top of *C. costata* Zone is indicated. Cores and sections are given in brackets.)

*Carpocanopsis cingulata* Riedel and Sanfilippo.
*Carpocanopsis cingulata* Riedel and Sanfilippo, 1971, p. 1597, pl. 2G, figs. 17-21; pl. 8, fig. 8; 1978, p. 67, pl. 4, fig. 4.

*Cryptoprora ornata* Ehrenberg
*Cryptoprora ornata* Ehrenberg, 1873, p. 222; 1875, pl. 5, fig. 8; Sanfilippo and Riedel, in Saunders et al., in press.

*Cyclamptrium leptetrum* Sanfilippo and Riedel
*Cyclamptrium leptetrum* Sanfilippo and Riedel, 1970, p. 456, pl. 2, figs. 11, 12.

*Cyclamptrium milowi* Riedel and Sanfilippo
*Cyclamptrium milowi* Riedel and Sanfilippo, 1971, p. 1593, pl. 3B, fig. 3; pl. 7, figs. 8-9; Riedel and Sanfilippo, 1978, p. 67, pl. 4, fig. 14.
Cyclamptium pegetrum Sanfilippo and Riedel
Cyclamptium pegetrum Sanfilippo and Riedel, 1970, p. 456, pl. 2, figs. 8–10; Riedel and Sanfilippo, 1978, p. 68, pl. 4, fig. 16.
Cyclocapsella cornuta Haeckel
Cyclocapsella (Cyclocapsella) cornuta Haeckel, 1887, p. 1513, pl. 78, fig. 9.
Cyclocapsella cornuta Haeckel—Riedel and Sanfilippo, 1978, p. 68, pl. 4, fig. 17.
Cyclocapsella tetrapera Haeckel
Cyclocapsella (Cyclocapsella) tetrapera Haeckel, 1887, p. 1512, pl. 78, fig. 5.
Cyclocapsella tetrapera Haeckel—Riedel and Sanfilippo, 1978, p. 68, pl. 4, fig. 18.

Dictyophimus craticula Ehrenberg
Dictyophimus craticula Ehrenberg, 1873, p. 223; Riedel and Sanfilippo, 1978, p. 68, pl. 4, fig. 19.

Dictyopora armadillo (Ehrenberg) group
Eucyrtidium armadillo Ehrenberg, 1873, p. 225; 1875, pl. 9, fig. 10.
Dictyopora armadillo (Ehrenberg) group—Nigrini, 1977, p. 250, pl. 4, fig. 4.

Dictyopora mongolfieri (Ehrenberg)
Eucyrtidium mongolfieri Ehrenberg, 1854, pl. 36, fig. 18B, lower.
Dictyopora mongolfieri (Ehrenberg)—Nigrini, 1977, p. 250, pl. 4, fig. 7.
Lithocyclia angusta (Haeckel)
Lophocyrtis jacchia
Moore
Lithocyclia aristotelis (Ehrenberg)
Lithochytris vespertilio (Ehrenberg)
Liriospyris stauropora (Haeckel)
Liriospyris parkerae
Riedel and Sanfilippo
Lamptonium fabaeforme fabaeforme (Krasheninnikov)
Lamptonium fabaeforme constrictum (Riedel and Sanfilippo)
Lamptonium fabaeforme chaunothorax (Riedel and Sanfilippo)
Lamptonium (Podocyrtis) fasciolata
Lamptonium (Lampterium) mitra (Haeckel)

Lithocyclia angusta (Haeckel), Sanfilippo and Riedel, 1980, p. 1010, text fig. 1c.

Lithocyclia tubaria (Haeckel)

Podocyrtis (Lampterium) mitra (Haeckel), Riedel and Sanfilippo, 1978, p. 68, pl. 5, fig. 2.

Didymocyrtis violina (Haeckel)

Lithocyclia aristotelis

Podocyrtis (Podocyrtis) ampla

Lychnocanoma amphitrite Foreman
Lychnocanoma amphitrite Foreman, 1973, p. 437, pl. 11, fig. 10; Riedel, Sanfilippo, and Westberg, in Boili et al., in press.

Lychnocanoma bajunensis n. sp.
(Plate 1, Figs. 4–6)

Description. Spherical cephalis has a few very small pores and a slight apical spine or thorn. The thorax is rounded-conical with small, round, wide-set pores quincuncially arranged in vertical rows. Three thin to moderately robust, bladed, solid legs arise from the lower thorax above a short, smooth peristome. Legs are quite long, flared, slightly curved to angular proximally, with convexity outward.

Measurements. Based on 20 specimens from Samples 543-27-3, 53-55 cm; 543-29-4, 73-75 cm; 543-29-5, 14-16 cm; and 543-30-4, 60-62 cm. Length of cephalis plus thorax: mean (x) = 84.8 µm, range: 74.9-95.8 µm. Maximum breadth of thorax: x = 85.0 µm, range: 79.0-99.8 µm. Length of legs (on a straight measure from lower thorax to toe): x = 289.4 µm, range: 208.0-403.5 µm. Maximum distance between legs: x = 284.5 µm, range: 199.7-328.6 µm. Diameter of peristome: x = 43.7 µm, range: 33.3-58.2 µm.

Distinctions from other species. This species differs from a number of Lychnocanoma species (including Ehrenberg's 1875 Lychnocanoma tripodium, L. trichopus, and L. carinatum; and others not yet described) in having the following combination of characters: longer, less robust legs, a regular pore arrangement over the entire thorax (not poreless proximally), and a more rounded-conical thorax without ribs.

Remarks. This species ranges from the bottom of the Dictyopora mongolfieri Zone of the middle Eocene to the top of the Cryptophora ornata Zone near the Eocene/Oligocene boundary. At the end of its range, specimens have a larger thorax, wider mouth, and more prominent apical horn. The legs appear to arise lower on the thorax and tend to be shorter and more robust.

The specific name bajunensis is derived from the colloquial adjective “bajun” meaning “of Barbados!”

Lychnocanoma elongata (Vinassa)

Lychnocanoma bajunensis n. sp.

PERIPHAEHA DELTA

Lychnocanoma bajunensis n. sp.

Podocyrtis (Podocyrtis) ampla

Lychnocanoma bajunensis n. sp.

Spherical cephalis has a few very small pores and a slight apical spine or thorn. The thorax is rounded-conical with small, round, wide-set pores quincuncially arranged in vertical rows. Three thin to moderately robust, bladed, solid legs arise from the lower thorax above a short, smooth peristome. Legs are quite long, flared, slightly curved to angular proximally, with convexity outward.

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Lychnocanoma bajunensis n. sp.
Acknowledgments

I would like to thank sincerely W. R. Riedel and Annika Sanfilippo for their initiation and unending support of this research.

References


Plate 1. 1-3. Cyclampterium leptetrum Sanfilippo and Riedel, (1) Sample 541-49-4, 105-107 cm, C2; × 135, (2) Sample 543-19-6, 113-115 cm, C2; × 135, (3) Sample 543-18-3, 31-33 cm, C1; × 135. 4-6. Lychnocanoma bajunensis n. sp. (4) holotype; Sample 543-29-5, 14-16 cm, C1, J/42-1; × 135, (5) specimen showing 3 legs; Sample 543-29-5, 125-127 cm, C2, K/15-0; × 135, (6) close-up of leg structure; arrows indicate 3 silica arches making up a bladed leg and surrounding a pore; Sample 543-29-5, 14-16 cm, C1, O/27-4; × 860. 7,8. Dorcadospyris dentata Haeckel, (7) Sample 543-18-2, 31-33 cm, C1, × 135, (8) Section 543-19,CC, C1, × 135. 9. Calocycletta costata (Riedel); Section 543-19,CC, C1, V/39-0; × 550, arrow indicates width of ridge.