INTRODUCTION

During Leg 33 of the Deep Sea Drilling Project five sites (314 to 318) were occupied and eight holes drilled between Hawaii and Tahiti in the Central Pacific Ocean. Material from two sites (315 and 316) yielded silicoflagellates and diatoms sufficient for detailed investigation, whereas the recovered sediments from Sites 314, 317, and 318 are barren of silicoflagellates.

Increased interest in silicoflagellate biostratigraphy and systematics in the last few years is indicated by a large number of papers dealing with this subject, most of them based on material recovered by the Deep Sea Drilling Project. Since the first investigation of continuous deep-sea sequences (Martini, 1971a, b), the knowledge of the distribution and diversity of silicoflagellate assemblies has been considerably broadened, especially through the studies of Bukry (1973a-d, 1974a, b); Dumitrica (1973a, b); and Ling (1970, 1972, 1973) on the basis of deep-sea material, and Bachmann (1970, 1971a, b) and Martini (1972a, b, 1974) on the basis of land sections and localities. The systematics of silicoflagellates, on the other hand, shows little improvement. This is indicated by the use of a variety of names for the same taxa as a result of badly figured species, overemphasis of aberrant forms, and unknown or insufficient data on localities and their stratigraphic position. Fortunately, the Ehrenberg collection, which encompasses a large number of silicoflagellates, survived the last war and is now housed in the Museum für Naturkunde der Humboldt-Universität in Berlin. An investigation and documentation of the type material have been completed and will be published in the near future by Locker. It is hoped that the paper by Locker will clear up many of the misinterpretations and uncertainties in the silicoflagellate field.

LOCALITIES AND ASSEMBLAGES RECOVERED

Geographical positions of the DSDP sites drilled during Leg 33 are as follows (see also Figure 1):

- Site 314: lat 15°54.76'N, long 168°28.07'W, water depth 5213 meters
- Holes 315, 315A: lat 4°10.26'N, long 158°31.52'W, and 158°31.54'W, water depth 4152 meters
- Site 316: lat 0°05.44'N, long 157°07.71'W, water depth 4451 meters
- Holes 317, 317A, 317B: lat 11°00.09'S, long 162°15.78'W, water depth 2598 meters
- Site 318: lat 14°49.63'S, long 146°51.51'W, water depth 2641 meters

As noted above, only the equatorial Sites 315 and 316 yielded silicoflagellates in the upper part of the drilled sections.

In Hole 315 silicoflagellates occur in varying numbers in all cores, indicating the presence of the Dictyocha aculeata Zone (Core 1), Mesocena quadrangula Zone (Cores 2 and 3), and Dictyocha fibula Zone (Core 4). In Hole 315A silicoflagellates were encountered down to Core 5, with the Dictyocha fibula Zone present in Cores 1 and 2, the Dictyocha rhombica Zone in Core 3 and possibly in Core 4, and the Dictyocha triacantha Zone (?) in Core 5. With the decrease of the diatom population in Core 4 and below Core 5, silicoflagellates become extremely rare or disappear. The population in samples from Core 5 is rather small and monotonous, and the tentative placement in the Dictyocha triacantha Zone is deduced from the nannoplankton Zone NN 5 (Sphenolithus heteromorphus Zone), which is present at this interval.

At Site 316 silicoflagellates occur commonly only in Cores 1 to 3, and as usual, are associated with diatoms (Plate 2, Figures 7, 8). The assemblages are of low diversity owing to the equatorial position of Site 316. The Dictyocha aculeata Zone and Mesocena quadrangula Zone are present in Core 1, and the Dictyocha rhombica Zone has been identified in Core 2 and the upper part of Core 3. In Core 3 an unconformity with several nannoplankton zones missing marks the lowest common occurrence of silicoflagellates. Below, only a single specimen of Dictyocha cf. rhombica was found in Core 3, Section 2 at 30-31 cm, and probably belongs in the Dictyocha triacantha Zone as indicated by the nannoplankton of this particular sample. Correlation of Sites 315 and 316 and silicoflagellates identified in samples from these sites are shown in Figure 2 and Tables 1 and 2.

NEOGENE AND QUATERNARY SILICOFLAGELLATE ZONATION
AND COMPARISON WITH ZONATIONS OF OTHER FOSSIL GROUPS IN THE PRESENT MATERIAL

The silicoflagellate zonation used during Leg 33 has been described in detail by Martini (1971a, b, 1972a, b) with the additional Dictyocha aculeata Zone described by Dumitrica, 1973, and includes the following zones from top to bottom:

- Dictyocha aculeata Zone (base = last M. quadrangula)
- Mesocena quadrangula Zone (base = first M. quadrangula)
- Dictyocha fibula Zone (base = change in frequency of D. rhombica and D. fibula, D.f. > D.r.)
- Dictyocha rhombica Zone (base = last D. triacantha)
- Dictyocha triacantha Zone (base = last N. quadrata)

As shown in Figure 3, a number of silicoflagellate zonations have been applied in different areas by various authors, indicating somewhat better time resolution in the Northern Pacific (Ling, 1973) and Eastern

Erlend Martini, Geologisch-Paläontologisches Institut der Universität Frankfurt a. M., Germany
Pacific (Bukry and Foster, 1973) than in the Central Pacific (Martini, 1971a, b, present paper) or Europe (Sanfilippo et al., 1973). However, all silicoflagellate zonations show a surprisingly low resolution in the upper Miocene, as does the nannoplankton zonation, in which the Discoaster quinqueramus Zone (NN 11) encompasses a time interval of approximately 4.5 m.y., and in which only recently some additional species suitable for a further subdivision have been found in certain areas. Also, the reported occurrences of some species (e.g., D. pseudofibulà) in deep-sea cores lead to the suspicion that they have a wedge-shaped occurrence in a time/space model.

Although the silicoflagellate occurrences at Sites 315 and 316 cover only the late Miocene to Quaternary interval, and cores are irregularly spaced, some correlations with other fossil groups are possible in the present material. According to revised shipboard identifications and Schrader (this volume), the base of the Dictyocha aculeata Zone is in the higher part of Zone NN 19 (Pseudoemiliania lacunosa Zone) of the standard nannoplankton zonation (Martini, 1971a, b) and in the upper part of the diatom Nitzschia reinholdii Zone (Burckle, 1972). The base of the Mesocena quadrangula Zone is within an uncored interval, and no correlations are available. The base of the Dictyocha fibula Zone (D. rhombica/D. fibula datum) was found to be within standard nannoplankton Zone NN 11 (Discoaster quinqueramus Zone), within the foraminiferal Globorotalia acostaensis Zone (N16), within the radiolarian Onmiarticctus antepenultimus Zone, and in the lower part of the diatom Nitzschia porteri Zone. Earlier correlation of the base of the D. fibula Zone (Martini, 1971a, b) to the nannoplankton zonation was based on samples from the Swedish Deep Sea Expedition Station 76. However, reexamination of Sample 509-509.5 cm revealed rare specimens of Discoaster quinqueramus and early forms of Ceratolithus tricorniculatus, indicating that this sample belongs in Zone NN 11 (Discoaster quinqueramus Zone) rather than Zone NN 10 (Discoaster calcaris Zone). Therefore, the old correlations have to be corrected inasmuch as the base of the Dictyocha fibula Zone is in the lower part of nannoplankton Zone NN 11 (Discoaster quinqueramus Zone). The base of the Dictyocha rhombica Zone in Hole 315A is within an uncored interval and at Site 316 is obscured by an unconformity with several nannoplankton zones missing.

SILICOFLAGELLATE SURFACE ORNAMENTATION

Surface ornamentation of Neogene and Quaternary silicoflagellates has been described by several authors...
Neogene and Quaternary Silicoflagellates

D. aculeata Zone
M. quadrangula Zone
D. fibula Zone
D. rhombica Zone
D. triacantha Zone

TABLE 1
Distribution of Silicoflagellates at Site 315

Note: Numbers refer to specimens found in 10 rows of approximately 30mm length on a routine smear slide viewed with an ocular 12.5X and an objective 25X.

SYSTEMATIC PALEONTOLOGY

The systematic paleontology of silicoflagellates is in a rather chaotic state, as there is considerable confusion about species names owing to poor illustration and description by early authors as well as to insufficient data on the stratigraphic position of samples from which silicoflagellates were described. Fortunately the famous Ehrenberg collection survived the war. Most of Ehrenberg’s silicoflagellate species are recognizable and are photographed, redrawn, and redescribed by Locker (personal communication). It seems that species names are often used without reference to the original illustrations. To avoid further confusion, species names and concepts...
Dictyocha ausonia Deflandre

Remarks: A single specimen showing eight short secondary spines pointing outwards instead of four on the basal ring was found in Sample 316-1-4, 5-6 cm (D. aculeata Zone). It represents most likely an aberrant specimen of D. aculeata.

Dictyocha ausonia Deflandre (Plate 1, Figures 15-18)

**Table 2** Distribution of Silicoflagellates at Site 316

<table>
<thead>
<tr>
<th>Sample (Interval in cm)</th>
<th>Dictyocha aculeata</th>
<th>Dictyocha ausonia</th>
<th>Dictyocha crux</th>
<th>Dictyocha medusa</th>
<th>Dictyocha medusa var.</th>
<th>Dictyocha medusoides</th>
<th>Dictyocha quadraangularis</th>
<th>Dictyocha tricentrales</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1, 120-121</td>
<td>48</td>
<td>3</td>
<td>5</td>
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<tr>
<td>1-2, 33-34</td>
<td>34</td>
<td>1</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-4, 5-6</td>
<td>25 1</td>
<td>7</td>
<td>34</td>
<td></td>
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<tr>
<td>1-4, 70-71</td>
<td>13</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-6, 75-76</td>
<td>30</td>
<td>2</td>
<td>21</td>
<td></td>
<td></td>
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<td>4</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-1, 70-71</td>
<td>3</td>
<td>14</td>
<td>2</td>
<td>93</td>
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<td>47</td>
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<td>2-2, 125-126</td>
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<td>34</td>
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</tr>
<tr>
<td>2, CC</td>
<td>3</td>
<td>2</td>
<td>115</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-1, 120-121</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3-2, 30-31</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: See footnote in Table 1 for explanation of numbers.

used in this paper (e.g., D. fibula, D. rhombica) are the same as those in Martini, 1971, but some will probably have to be changed after the redesignation of the Ehrenberg material is available.

References to the original descriptions and possible synonyms, or to more recent descriptions or illustrations of particular species are limited to a minimum, and only some remarks or short discussions are given.

**Genus DICTYOCHA Ehrenberg, 1839**

**Dictyocha aculeata** (Lemmermann)

(Plate 1, Figure 2; Plate 2, Figures 3a, b)

**Remarks:** Aberrant specimen of D. aculeata. It represents most likely a mesocena, CC (M. Zone) and is tentatively included here.

**Dictyocha cf. ausonia Deflandre**

(Plate 1, Figures 19-20)

**Remarks:** Navicular forms which are within the range of D. ausonia and D. mutabilis according to Deflandre (1950) were found in two specimens in the D. fibula Zone of Hole 315A, but are not associated with good D. ausonia specimens, the last of which was found some 50 meters below the occurrences of the navicular forms (Table 2 and Figure 2).

**Dictyocha fibula Ehrenberg**

(Plate 1, Figure 7)

**Remarks:** In Sample 316-2-2, 125-126 cm a single specimen similar to D. crux was encountered in a population which is dominated by Dictyocha rhombica. The apical ring is extremely small, the outline of the basal ring and length of spines are identical with that of D. rhombica specimens present in the same sample; this specimen is only tentatively included in D. crux.

**Dictyocha cf. crux Ehrenberg**

(Plate 1, Figure 4)

**Remarks:** In Sample 316-2-2, 125-126 cm a single specimen similar to D. crux was encountered in a population which is dominated by Dictyocha rhombica. The apical ring is extremely small, the outline of the basal ring and length of spines are identical with that of D. rhombica specimens present in the same sample; this specimen is only tentatively included in D. crux.

**Dictyocha fibula Ehrenberg**

(Plate 1, Figures 9, 10, 12; Plate 2, Figures 1, 4)

**Remarks:** In Sample 316-2-2, 125-126 cm a single specimen similar to D. fibula was encountered in a population which is dominated by Dictyocha rhombica. The apical ring is extremely small, the outline of the basal ring and length of spines are identical with that of D. rhombica specimens present in the same sample; this specimen is only tentatively included in D. crux.

**Dictyocha medusa Haeckel**

(Plate 1, Figures 5, 6)

**Remarks:** Rare specimens corresponding to that figured on Plate 1, Figure 6 occur in the D. rhombica Zone at Hole 315A and Site 316, but were also found in the lower part of the D. fibula Zone and in the D. triacantha Zone (7) of Hole 315A. The cf-specimen (Plate 1, Figure 5) from Sample 316-2-2, 30-31 cm (D. rhombica Zone) has a more rectangular outline and the supporting spines on the basal ring are more prominent than in the common form.
Figure 3. Correlation of silicoflagellate zonations used in different parts of the Pacific Ocean and in Europe, and indication of equivalent nannoplankton zones.

Dictyocha messanensis Haeckel

(Plate 1, Figure 9; Plate 2, Figures 2a, b)

Dictyocha messanensis Haeckel in Peters, 1860, p. 799 (pl. 12, fig. 3-6 in Haeckel, 1862, fide Loeblich et al., 1968).

Dictyocha fibula var. messanensis (Haeckel), in Ling, 1972, p. 161, pi. 25, fig. 18, 19.

Remarks: A single specimen was found during scanning electron microscope examination of Sample 316-1-4, 5-6 cm (M. aculeata Zone), showing the broken base of a spine on the apical bar (Plate 2, Figures 2a, b). As mentioned under D. fibula, most specimens in the M. quadrangula Zone and D. aculeata Zone differ from D. fibula in having a more quadrate basal ring and radial spines of equal length (Plate 1, Figure 9), and are included here, although only in a very few specimens a spine on the apical bar seemed to be present when studied with the light microscope.

Dictyocha rhombica (Schulz)

(Plate 1, Figures 11, 13, 14; Plate 2, Figure 6)

Dictyocha rhombica (Schulz), in Deflandre, 1941, p. 101, fig. 1-7. Dictyocha rhombica (Schulz), in Martini, 1971b, p. 1696, pl. 1, fig. 8.

Remarks: Although common in the D. rhombica Zone and also present to a lesser extent in the D. triacantha Zone and D. fibula Zone, this species with a horizontal apical bar is among the most disputed forms, and it seems to be identical with D. aspera of some authors. Data from the original material of the Ehrenberg collection even indicate that the type of D. fibula has a horizontal bar and not a vertical bar as commonly accepted (Locker, personal communication). In the present paper specimens with a horizontal apical bar approximately equivalent in length to the lateral rods are included in “D. rhombica.” Specimens encountered in Hole 315A, Core 5 (D. triacantha Zone?) are generally larger than those from the D. rhombica Zone. A single aberrant specimen (Plate 1, Figure 11) similar to D. triacantha Ehrenberg was found among 93 counted specimens on a smear slide of Sample 316-2-1, 70-71 cm.

Dictyocha speculum Ehrenberg

(Plate 1, Figure 8)

Dictyocha speculum Ehrenberg, 1839, p. 129, pl. 4, fig. Xn. Dictyocha speculum Ehrenberg, in Martini, 1971b, p. 1696, pl. 1, fig. 13, 14. Distephanus speculum (Ehrenberg), in Ling, 1972, p. 166, pl. 26, fig. 23, 24, pl. 27, fig. 1, 2.

Remarks: Specimens found in small numbers in the D. rhombica Zone of Hole 315A and Site 316 and in the D. fibula Zone of Hole 315A show a relatively large apical ring and two opposite basal spines much longer than the remaining ones.

Genus MESOCENA Ehrenberg 1843

Mesocena quadrangula Haeckel

(Plate 1, Figure 1; Plate 2, Figures 5a, b)

E. MARTINI

Northern Pacific
(Ling 1973)

Southwestern Pacific
(Dumitrica 1973)

Central Pacific
(Martini 1975)

Quat.

M111
M110
MN9
MN8
MN7
MN6
MN5
MN4
MN3
MN2
MN1

D. octangulatus Zone
D. australis Zone
D. subarctia Zone

N. quadrangula Zone

D. australis Zone

M. cf. elliptica Zone

D. perlaevis Zone

M. cf. elliptica Zone

D. fibula Zone

E. antiqua Zone

D. f. perlaevis Zone

C. hemisphaericus Zone

D. f. aspera Zone

C. hemisphaericus Zone

D. f. rhabdias Zone

D. speculum pentag. Zone

D. australis Zone

D. f. perlaevis Zone

Mesocena circulus opulenta Zone

D. f. rhabdias Zone

D. subarctia Zone

M. cf. elliptica Zone

Mesocena circulus opulenta Zone

D. subarctia Zone

References


Figure 3. (Continued).

“Mesocena” cf. elliptica Ehrenberg, in Dumitrica, 1973b, p. 850, pl. 6, fig. 1.

Remarks: The “Mesocena elliptica complex” of various authors obviously contains quite different forms and needs further study and proper differentiation. Specimens considered here show a rounded to quadrate ring with irregularly scattered knots on the surface (Plate 2, Figures 5a, b) clearly seen in the light microscope, and four prominent spines of equal length, arranged along the long and short axis. Further, it seems to be a stratigraphically useful species with a range restricted to the late Pliocene and most of the Pleistocene. Its last occurrence seems to be in the upper part of standard nannoplankton Zone NN19 (Pseudoemiliania lacunosa Zone) and in the upper part of the diatom Nitzschia reinholdii Zone in the Central Pacific. It was also noted by Dumitrica (1973b) in the early Pleistocene of the southwest Pacific and is present in the Western Indian Ocean (DSDP 241) in the basal Gephyrocapsa oceanica Zone (NN 20).


NEOGENE AND QUATERNARY SILICOFLAGELLATES


PLATE 1
All specimens approximately ×450

Figure 1  
*Mesocena quadrangula* Haeckel.  
Sample 315-3, CC, *M. quadrangula* Zone.

Figure 2  
*Dictyocha aculeata* (Lemmermann).  
Sample 316-1-4, 70-71 cm, *D. aculeata* Zone.

Figure 3  
*Dictyocha cf. aculeata* (Lemmermann).  
Sample 316-1-4, 5-6 cm, *D. aculeata* Zone.

Figure 4  
*Dictyocha cf. crux* Ehrenberg.  
Sample 316-2-2, 125-126 cm, *D. rhombica* Zone.

Figure 5  
*Dictyocha cf. medusa* Haeckel.  
Sample 316-2-2, 30-31 cm, *D. rhombica* Zone.

Figure 6  
*Dictyocha medusa* Haeckel.  
Sample 316-2-1, 70-71 cm, *D. rhombica* Zone.

Figure 7  
*Dictyocha crux* Ehrenberg.  
Sample 315A-5-1, 45-46 cm, *D. triacantha* Zone (?)

Figure 8  
*Dictyocha speculum* Ehrenberg.  
Sample 316-2-1, 135-136 cm, *D. rhombica* Zone.

Figure 9  
*Dictyocha messanensis* Haeckel.  
Sample 316-1-4, 5-6 cm, *D. aculeata* Zone.

Figure 10  
*Dictyocha fibula* Ehrenberg.  
Sample 315A-2, CC, *D. fibula* Zone.

Figure 11  
*Dictyocha rhombica* (Schulz), aberrant specimen.  
Sample 316-2-1, 70-71 cm, *D. rhombica* Zone.

Figure 12  
*Dictyocha fibula* Ehrenberg, large form.  
Sample 315-3, CC, *M. quadrangula* Zone.

Figures 13, 14  
*Dictyocha rhombica* (Schulz).  

Figures 15-18  
*Dictyocha ausonia* Deflandre.  
15. Sample 316-1, CC, *M. quadrangula* Zone.  
17, 18. Sample 315A-5-1, 45-46 cm, *D. triacantha* Zone (?)

Figures 19, 20  
*Dictyocha cf. ausonia* Deflandre.  
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Sample Location</th>
<th>Zone</th>
<th>Magnification</th>
<th>SEM Magnification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td><em>Dictyocha fibula</em> Ehrenberg.</td>
<td>315A-2-1, 80-81 cm</td>
<td><em>D. fibula</em> Zone</td>
<td>1300×</td>
<td>3250×</td>
</tr>
<tr>
<td>Figure 2</td>
<td><em>Dictyocha messanensis</em> Haeckel.</td>
<td>316-1-4, 5-6 cm</td>
<td><em>D. aculeata</em> Zone</td>
<td>1300×</td>
<td>6500×</td>
</tr>
<tr>
<td>Figure 3</td>
<td><em>Dictyocha aculeata</em> (Lemmermann).</td>
<td>316-1-4, 5-6 cm</td>
<td><em>D. aculeata</em> Zone</td>
<td>1300×</td>
<td>6500×</td>
</tr>
<tr>
<td>Figure 4</td>
<td><em>Dictyocha fibula</em> Ehrenberg.</td>
<td>316-1-4, 5-6 cm</td>
<td><em>D. aculeata</em> Zone</td>
<td>1300×</td>
<td></td>
</tr>
<tr>
<td>Figure 5</td>
<td><em>Mesocena quadrangula</em> Haeckel.</td>
<td>66-A1-2, top</td>
<td><em>M. quadrangula</em> Zone</td>
<td>1300×</td>
<td>3250×</td>
</tr>
<tr>
<td>Figure 6</td>
<td><em>Dictyocha rhombica</em> (Schulz).</td>
<td>66-2-2, 140-141 cm</td>
<td><em>D. rhombica</em> Zone</td>
<td>1200×</td>
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<tr>
<td>Figure 7</td>
<td><em>Coscinodiscus</em> sp.</td>
<td>315A-2-1, 80-81 cm</td>
<td><em>D. fibula</em> Zone</td>
<td>1080×</td>
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</tr>
<tr>
<td>Figure 8</td>
<td><em>Roperia tesselata</em> (Roper)</td>
<td>316-1-4, 5-6 cm</td>
<td><em>D. aculeata</em> Zone</td>
<td>650×</td>
<td></td>
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