

20. NEOGENE AND PLEISTOCENE RADIOLARIANS FROM DEEP SEA DRILLING PROJECT LEG 79 IN THE REGION OF THE MAZAGAN PLATEAU, OFF CENTRAL MOROCCO¹

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ABSTRACT

At Sites 545 and 547, samples of middle and early Miocene age yielded a sufficient number of identifiable radiolarians to allow zonal age determinations and comparison with the previously established zonation in tropical latitudes. The Miocene evolution of paleoenvironments along the Northwest African continental margin is considered.

INTRODUCTION

Relatively few Neogene and Pleistocene cores off central Morocco from DSDP Leg 79 contained siliceous remains (diatoms and radiolarians). Only two of the holes (545 and 547A) recovered layers of radiolarian-bearing sediments. Miocene sequences of well-preserved radiolarian assemblages were sampled at Site 545 at 33°39.9'N, 9°21.9'W, water depth ~3150 m. At Site 547, at 33°46.8'N, 9°21.0'W, water depth ~3940 m, rather poorer radiolarian assemblages have been found. The Quaternary period is marked by a scarcity of radiolarians. Radiolarian specimens have been detected only within a short interval at Site 545. Miocene sedimentation was punctuated by episodes containing older, reworked faunal elements.

PROCEDURES

The primary objective of this study was to carry out a biostratigraphic investigation of Miocene sediments off central Morocco in an area that lies in the subtropical belt.

After the first analysis of core-catcher samples was made aboard ship, five to six samples were taken from each core containing radiolarians. Sampling, when core catchers did not reveal any radiolarians, was widely spaced. A total of 140 samples was examined to determine the core intervals bearing siliceous organisms.

The core samples were prepared according to the standard technique described by Riedel and Sanfilippo (1977). After sieving at 45 μ m, permanent strew slides of the coarse fraction (three for each sample) were studied. The total abundance of radiolarians and relative abundance of species was estimated. The radiolarian species selected for this paper were chosen because of their well-established stratigraphic usefulness (Riedel and Sanfilippo, 1971, 1978). Moreover, additional radiolarian specimens have been noted with a view toward a better understanding of the paleogeographic environmental question.

RADIOLARIANS AT EACH SITE

The information on the presence of Miocene radiolarians is summarized in Tables 1 and 2 for those cores in which significant radiolarian assemblages have been identified. The relative abundance of radiolarians and

the relative proportion of the total radiolarian assemblage in each sample is indicated as follows: abundant (A), common (C), few (F), or rare (R). A dash (—) indicates that no specimens were detected (Table 2). Preservation of the specimens is indicated as good (G), moderate (M), or poor (P).

These same terms are used to indicate in a semiquantitative fashion the proportion of the diatom assemblage associated with the radiolarian assemblage in the coarse fraction (see Table 1).

Site 545

Radiolarians occur in the upper Pleistocene (depth = 9–18 m). Significant quantities of radiolarians were identified in the lower-middle Miocene (depth = 217–251 m).

Pleistocene

Core 545-2 contains rare to common radiolarians, poorly preserved, of Pleistocene age. The more abundant assemblage appears within sections 6 and 7 (545-2-6, 103–106 cm; 545-2-7, 20–24 cm). It includes *Amphirhopalum ypsilon*, *Eucyrtidium acuminatum*, *Lamprocyclus maritimalis*, *Theocorythium trachelium*, and other species belonging to the genera *Stylodictya* and *Polysolenia*. All species are considered warm temperate water elements and have been found in Recent sediments at middle latitudes of the Atlantic Ocean (Labracherie, 1978). Typical tropical species are virtually absent (e.g., *Euchitonia elegans*, *Pterocanium praetextum praetextum*, *Spongaster tetras tetras*). *Stylatractus universus* is missing from this relatively well-preserved assemblage. The globally synchronous extinction of *S. universus*, detected near the isotope Stage 11–12 boundary, is a good biostratigraphic indicator (Hays and Shackleton, 1976). Whereas the transition between Stages 12 and 11 has been estimated at 440,000 yr. ago (Shackleton and Opdyke, 1976) it is assumed that the radiolarian assemblage from Core 545-2 is younger than 440,000 yr.

Radiolarians are absent in samples from Core 545-3 through Core 545-23. Sample 545-23-7, 12–15 cm yielded some highly corroded, unidentifiable radiolarian fragments.

¹ Hinz, K., Winterer, E. L., et al., *Init. Repts. DSDP, 79*: Washington (U.S. Govt. Printing Office).

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ence of upwelling processes (high proportions of diatoms) and nutrient-richer intermediate depth water masses that have a southern origin (abundance of some radiolarians) (Labracherie et al., in press).

Off central Morocco numerous well-preserved radiolarians are associated with rich diatom assemblages (coarse fraction) during the early Miocene (*S. delmontensis* Zone and lower part of the *S. wolffii* Zone) (Table 1). Such an assemblage may reflect upwelling influence in a coastal area. Miocene upwelling could then be compared with the highly productive coastal upwelling of the glacial regimes during the late Pleistocene (Labracherie, 1980b). During the late early Miocene (*C. costata* Zone) rare diatoms are evident in the coarse biosiliceous fraction which is itself less well preserved. This change may support the idea of a weaker upwelling at this time. During the following phase (boundary early-middle Miocene and the lower part of the *D. alata* Zone), the radiolarian association suggests warmer coastal waters. Both this increase of surface temperatures and the absence of diatoms could be correlated to a migration of the upwelling center in relation to one of the highest Tertiary sea levels (von Rad and Wissmann, 1982). Such a situation could tentatively be compared to that described off Northwest Africa during the last transition from a Quaternary glacial to an interglacial mode featuring a shifting of upwelling center from the lower to upper continental slope (Diester-Haass, 1977). Moreover, as far as the Quaternary distribution of siliceous organisms in the same region is concerned, both diatoms and radiolarians were detected in sediments underlying very fertile areas (upwelling center) whereas only radiolarians were found offshore (Labracherie, 1980b).

Finally, the biogenic silica accumulation (radiolarian-bearing sediments) during the Miocene from *S. delmontensis* Zone to *C. costata* Zone is rather uniform along the Northwest African continental margin, between 20° and 33°N. A highly productive upwelling correlated with nutrient-rich waters and reflected by diversified and well-preserved radiolarian assemblages characterizes the nearest sites of the adjacent continent (Sites 140, 369, 415, and 545) (Fig. 1). At more oceanic sites, productivity is less important (Sites 138, 141, 368, and 416).

At the end of middle Miocene the absence of radiolarians, except at Holes 139 and 369A (Fig. 1) may suggest that upwelling influence was less extensive and possibly concentrated between 23° and 26°N. Paleopositions of these sites at middle Miocene coincide with the highest fertility area for modern upwelling. Such an evolution has been correlated to a southward shift in wind regimes (Sarnthein et al., 1982).

The absence of radiolarians from sediments above the middle Miocene off Northwest Africa could indicate surface and subsurface waters were nutrient poor and suggest a calmer surface water circulation.

CONCLUSIONS AND SUMMARY

At Sites 545 and 547, samples yielded a sufficient number of identifiable radiolarians to allow zonal age determinations and comparisons with the previously established zonations in tropical latitudes.

During the early Miocene, high biogenous opal contents in sediments off Morocco signal an enhanced fertility induced by upwelling. Radiolarian assemblages suggest warming of coastal waters at the beginning of the middle Miocene and at the same time a weaker and vari-

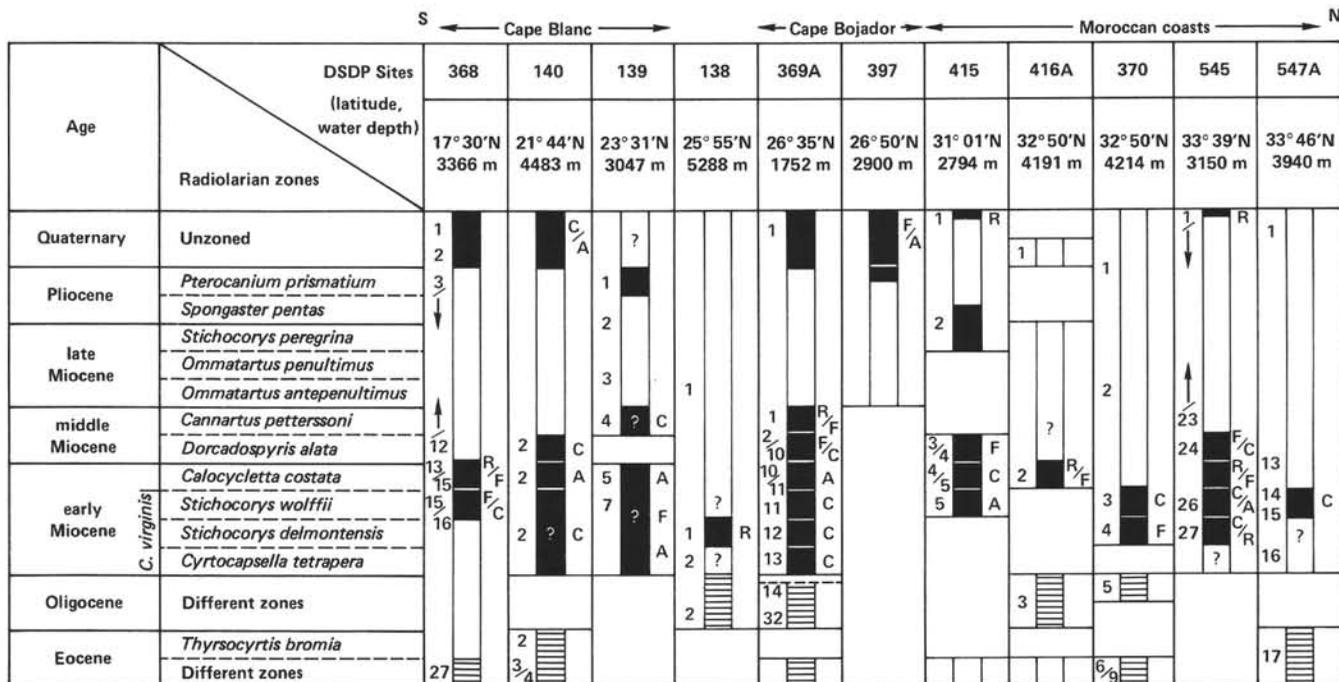


Figure 1. DSDP Sites drilled along the African margin (Legs 14, 41, 50, 79) with cores containing Miocene radiolarians (black squares) or Paleogene radiolarians (hatched squares) and approximate correlations (see Petrushevskaya and Kozlova, 1972; Johnson, 1977; Westberg et al., 1980; and this report). Core numbers on left and estimated abundance on right. At the Leg 14 sites, age assignment is uncertain because of the zonation used at that time (the *C. virginis* zone without subdivision). Abundance is described as A, abundant; C, common; F, few; R, rare.

able upwelling. The disappearance of biogenic silica in sediments above the middle Miocene off the Northwest African continental margin is correlated to a calmer surface water circulation.

ACKNOWLEDGMENTS

The samples for this study were kindly provided by Peter Baumgartner, DSDP Staff Scientist for Leg 79. The analytical part of this work was performed with the financial support of the Centre National de la Recherche Scientifique, through L.A. 197 at the Université de Bordeaux I, and the Institut de Géologie du Bassin d'Aquitaine, in Bordeaux. I am very grateful to Dora Morel, Bordeaux, for carefully correcting the English language in an earlier version of this paper. This paper was also improved by the critical reviews of D. A. Johnson, Woods Hole Oceanographic Institution, Woods Hole, MA (U.S.A.) and W. R. Riedel, Scripps Institution of Oceanography, La Jolla, CA (U.S.A.).

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Date of Initial Receipt: November 2, 1982

Date of Acceptance: May 20, 1983

APPENDIX Species List

- Amphirhopalum ypsilon* Haeckel. *Amphirhopalum ypsilon* Haeckel, 1887, p. 522; Nigrini, 1967, p. 35, pl. 3, figs. 3a-d.
- Anthocyrtdium* spp. Sanfilippo and Riedel. *Anthocyrtdium* spp. Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 224, pl. 6, fig. 9.
- Calocycletta costata* (Riedel). *Calocycletta costata* Riedel, 1959, p. 296, pl. 2, fig. 9. *Calocycletta costata* (Riedel) Riedel and Sanfilippo, 1970, p. 535, pl. 14, fig. 12; Moore, 1972, p. 147, pl. 1, fig. 8; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 226, pl. 6, fig. 10.
- Calocycletta robusta* Moore group. *Calocycletta robusta* Moore, 1971, p. 743, pl. 10, fig. 5, 6. *Calocycletta caepa* Moore, 1972, p. 150, pl. 2, fig. 4, 7. *Calocycletta robusta* Moore group, Riedel and Sanfilippo, 1978, p. 66, fig. 3, figs. 10-11.
- Calocycletta serrata* Moore. *Calocycletta serrata* Moore, 1972, p. 148, pl. 2, fig. 1-3.
- Calocycletta virginis* (Haeckel). *Calocycletta virginis* Haeckel, 1887, p. 1381, pl. 74, fig. 4. *Calocycletta virginis* Haeckel, Riedel, 1959, p. 295, pl. 2, fig. 8; Riedel and Sanfilippo, 1970, p. 535, pl. 14, fig. 10; Moore, 1972, p. 147, pl. 1, fig. 7.
- Cannartus bassanii* (Carnevale). *Cannartus bassanii* (Carnevale) Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 216, pl. 1, figs. 1-3.

- Cannartus mammifer* (Haeckel). *Cannartidium mammiferum* Haeckel, 1887, p. 375, pl. 39, fig. 16; *Cannartus mammiferus* (Haeckel), Riedel, 1959, p. 291, pl. 1, fig. 4.
- Cannartus prismaticus* (Haeckel). *Pipettella prismatica* Haeckel, 1887, p. 305, pl. 39, fig. 6. *Cannartus prismaticus* (Haeckel), Riedel and Sanfilippo, 1970, p. 520, pl. 15, fig. 1; Riedel and Sanfilippo, 1971, p. 1588, pl. 2C, figs. 11–13.
- Cannartus tubarius* (Haeckel). *Pipettaria tubaria* Haeckel, 1887, p. 339, pl. 39, fig. 15. *Cannartus tubarius* (Haeckel), Riedel, 1959, p. 289, pl. 1, fig. 2; Riedel and Sanfilippo, 1970, p. 520, pl. 15, fig. 2; Riedel and Sanfilippo, 1978, p. 67, pl. 4, fig. 3.
- Cannartus violina* Haeckel. *Cannartus violina* Haeckel, 1887, p. 358, pl. 39, fig. 10; Riedel, 1959, p. 290, pl. 1, fig. 3; Moore, 1971, pl. 12, fig. 4; Riedel and Sanfilippo, 1978, p. 67, pl. 4, fig. 4.
- Carpocanopsis bramlettei* Riedel and Sanfilippo. *Carpocanopsis bramlettei* Riedel and Sanfilippo, 1971, p. 1597, pl. 2G, figs. 8–14; pl. 8, fig. 7; Riedel and Sanfilippo, 1978, p. 67, pl. 4, fig. 6.
- Carpocanopsis cingulata* Riedel and Sanfilippo. *Carpocanopsis cingulata* Riedel and Sanfilippo, 1971, p. 1597, pl. 2G, figs. 17–21; pl. 8, fig. 8; Riedel and Sanfilippo, 1978, p. 67, pl. 4, fig. 7.
- Carpocanopsis favosa* (Haeckel). *Cycladophora favosa* Haeckel, 1887, p. 1380, pl. 62, figs. 5, 6. *Carpocanopsis favosum* (Haeckel), Riedel and Sanfilippo, 1971, p. 1597, pl. 2G, figs. 15, 16; pl. 8, figs. 9–11.
- Collosphaera*(?) Riedel and Sanfilippo. *Collosphaera*(?) Riedel and Sanfilippo, 1971, p. 1586, pl. 2A, fig. 3.
- Cyclampterium leptetrum* Sanfilippo and Riedel. *Cyclampterium leptetrum* Sanfilippo and Riedel, 1970, p. 456, pl. 2, figs. 11–12; Sanfilippo and Riedel, 1971, pl. 20, figs. 9–12; Riedel and Sanfilippo, 1978, p. 67, pl. 4, figs. 12–13.
- Cyrtocapsella cornuta* (Haeckel). *Cyrtocapsa* (*Cyrtocapsella*) *cornuta* Haeckel 1887, p. 1512, pl. 78, fig. 5. *Cyrtocapsella cornuta* (Haeckel) Sanfilippo and Riedel, 1970, p. 453, pl. 1, figs. 19–20; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 220, pl. 5, figs. 1–2; Riedel and Sanfilippo, 1978, p. 68, pl. 4, fig. 17.
- Cyrtocapsella japonica* (Nakaseko). *Cyrtocapsella japonica* (Nakaseko), Sanfilippo and Riedel, 1970, p. 452, pl. 1, figs. 13–15; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 5, figs. 4–6.
- Cyrtocapsella tetrapera* (Haeckel). *Cyrtocapsa* (*Cyrtocapsella*) *tetrapera* Haeckel, 1887, p. 1512, pl. 78, fig. 5. *Cyrtocapsella tetrapera* (Haeckel) Sanfilippo and Riedel, 1970, p. 453, pl. 1, fig. 16–18; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 5, figs. 4–6; Riedel and Sanfilippo, 1978, p. 68, pl. 4, fig. 18.
- Dendrosphyris bursa* Sanfilippo and Riedel. *Dendrosphyris bursa* Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 217, pl. 2, figs. 9–13.
- Dicolocapsa microcephala* Haeckel. *Dicolocapsa microcephala* Haeckel, 1887, p. 1312; Sanfilippo and Riedel, 1970, pl. 1, fig. 7.
- Dorcadospyrus alata* (Riedel). *Brachiosphyris alata* Riedel, 1959, p. 293, pl. 1, figs. 11–12. *Dorcadospyrus alata* (Riedel), Riedel and Sanfilippo, 1970, p. 523, pl. 15, fig. 5; Riedel and Sanfilippo, 1971, p. 1590, pl. 2D, fig. 1; Moore, 1971, pl. 11, figs. 3–4; Riedel and Sanfilippo, 1978, p. 68, pl. 5, fig. 2.
- Dorcadospyrus atechus* (Ehrenberg). *Dorcadospyrus atechus* (Ehrenberg), Riedel and Sanfilippo, 1970, p. 523, pl. 15, fig. 4; Riedel and Sanfilippo, 1971, pl. 2D, fig. 6, pl. 3A, figs. 9–10; Riedel and Sanfilippo, 1978, p. 68, pl. 5, fig. 3.
- Dorcadospyrus dentata* Haeckel. *Dorcadospyrus dentata* Haeckel, 1887, p. 1040, pl. 85, fig. 6; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 218, pl. 3, figs. 2–3.
- Dorcadospyrus forcipata* (Haeckel). *Diposphyris forcipata* Haeckel, 1887, p. 1037, pl. 85, fig. 1. *Dorcadospyrus forcipata* (Haeckel), Riedel and Sanfilippo, 1971, p. 1590, pl. 2D, figs. 2–3; Moore, 1971, p. 740, pl. 10, figs. 1–2.
- Dorcadospyrus simplex* (Riedel). *Dorcadospyrus simplex* (Riedel), Riedel and Sanfilippo, 1970, pl. 15, fig. 6.
- Dorcadospyrus tricerus* (Ehrenberg). *Dorcadospyrus tricerus* (Ehrenberg), Moore, 1971, p. 739, pl. 6, figs. 1–3.
- Eucyrtidium acuminatum* (Ehrenberg). *Eucyrtidium acuminatum* (Ehrenberg), Nigrini, 1967, p. 81, pl. 8, figs. 3a–b.
- Eucyrtidium cienkowskii* Haeckel. *Eucyrtidium cienkowskii* Haeckel, 1887, p. 1493; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 221, pl. 5, figs. 7–11.
- Eucyrtidium diaphanes* Sanfilippo and Riedel. *Eucyrtidium diaphanes* Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 221, pl. 5, figs. 12–14; Riedel and Sanfilippo, 1978, p. 68, pl. 5, fig. 5.
- Histiastrium martinianum* Carnevale group. *Histiastrium martinianum* Carnevale group, Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 217, pl. 2, figs. 7–8.
- Lamprocyclus maritialis* Haeckel *maritialis* Nigrini. *Lamprocyclus maritialis* Haeckel *maritialis* Nigrini, 1967, p. 74, pl. 7, fig. 5.
- Lamprocyclus* sp. Different species belonging to the genus *Lamprocyclus*.
- Liriospyris parkerae* Riedel and Sanfilippo. *Liriospyris parkerae* Riedel and Sanfilippo, 1971, p. 1590, pl. 2C, fig. 15; pl. 5, fig. 4; Riedel and Sanfilippo, 1978, p. 69, pl. 5, fig. 15.
- Liriospyris stauropora* (Haeckel). *Trissocyclus stauropora* Haeckel, 1887, p. 987, pl. 83, fig. 5. *Liriospyris stauropora* (Haeckel), Goll, 1968, p. 1431, p. 175, figs. 1–3, 7; Riedel and Sanfilippo, 1978, p. 69, pl. 5, fig. 16.
- Lithopera renzae* Sanfilippo and Riedel. *Lithopera renzae* Sanfilippo and Riedel, 1970, p. 454, pl. 1, figs. 21–23, 27; Riedel and Sanfilippo, 1978, p. 70, pl. 6, fig. 11.
- Lophocyrtis jacchia* (Ehrenberg). *Lophocyrtis jacchia* (Ehrenberg), Riedel and Sanfilippo, 1971, p. 1594, pl. 3C, figs. 4–5; pl. 7, fig. 16; Riedel and Sanfilippo, 1978, p. 70, pl. 7, fig. 1.
- Lychnocanoma bellum* (Clark and Campbell). *Lychnocanoma bellum* (Clark and Campbell), Riedel and Sanfilippo, 1971, p. 1595; Riedel and Sanfilippo, 1977, pl. 10, fig. 10.
- Lychnocanoma elongata* (Vinassa). *Lychnocanoma elongata* (Vinassa), Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 221, pl. 5, figs. 19–20; Riedel and Sanfilippo, 1978, p. 70, pl. 7, fig. 4.
- Phormostichoartus corona* (Haeckel). *Cyrtophormis* (*Acanthocyrtis*) *corona* Haeckel, 1887, p. 1462, pl. 77, fig. 15. *Phormostichoartus corona* (Haeckel), Riedel and Sanfilippo, 1971, p. 1600, pl. 11, figs. 13–15; pl. 2J, figs. 1–5; Riedel and Sanfilippo, 1978, p. 71, pl. 7, fig. 12.
- Podocyrtis chalara* Riedel and Sanfilippo. *Podocyrtis chalara* Riedel and Sanfilippo, 1970, p. 535, pl. 12, figs. 2–3; Riedel and Sanfilippo, 1978, p. 71, pl. 12, figs. 2–3.
- Podocyrtis diamesa* Riedel and Sanfilippo, emend. Sanfilippo and Riedel. *Podocyrtis diamesa* Riedel and Sanfilippo, 1970, p. 53, pl. 12, fig. 4; Sanfilippo and Riedel, 1973, p. 531, pl. 20, figs. 9–10; pl. 35, figs. 10–11; Riedel and Sanfilippo, 1978, p. 72, pl. 8, fig. 4.
- Polysolenia* spp. Riedel and Sanfilippo. *Polysolenia* spp. Riedel and Sanfilippo, 1971, p. 1586, pl. 1B, figs. 13–14; pl. 2A, figs. 11–14.
- Solenosphaera* spp. Riedel and Sanfilippo. *Solenosphaera* spp. Riedel and Sanfilippo, 1971, p. 1586, pl. 1A, figs. 19–22; pl. 2A, figs. 4–10.
- Stichocorys armata* (Haeckel). *Cyrtophormis armata* Haeckel, 1887, p. 1460, p. 78, fig. 17. *Stichocorys armata* (Haeckel), Riedel and Sanfilippo, 1971, p. 1595, pl. 2E, figs. 13–15; Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 222, pl. 6, figs. 1–2.
- Stichocorys delmontensis* (Campbell and Clark). *Stichocorys delmontensis* (Campbell and Clark), Sanfilippo and Riedel, 1970, p. 451, pl. 1, fig. 9; Riedel and Sanfilippo, 1971, p. 1595, pl. 1F, figs. 5–7; pl. 2E, figs. 10–11; Riedel and Sanfilippo, 1978, p. 74, pl. 9, fig. 10.
- Stichocorys diploconus* (Haeckel). *Stichocorys diploconus* (Haeckel), Sanfilippo and Riedel, 1970, p. 451, pl. 1, figs. 31–32.
- Stichocorys wolffii* Haeckel. *Stichocorys wolffii* Haeckel, 1887, p. 1479, pl. 80, fig. 10; Riedel and Sanfilippo, 1971, pl. 2E, figs. 8–9; Riedel and Sanfilippo, 1978, p. 74, pl. 9, fig. 12.
- Theocorythium trachelium* (Ehrenberg) *dianae* (Haeckel). *Theocorythium trachelium* (Ehrenberg) *dianae* (Haeckel), Nigrini, 1967, pl. 8, figs. 1a–b; pl. 9, figs. 1a–b.
- Theocyrtis annosa* (Riedel). *Phormocyrtis annosa* Riedel, 1959, p. 295, pl. 2, fig. 7. *Theocyrtis annosa* (Riedel), Riedel and Sanfilippo, 1970, p. 535, pl. 15, fig. 9; Riedel and Sanfilippo, 1978, p. 78, pl. 10, fig. 3.
- Thyrsocyrtis bromia* Ehrenberg. *Thyrsocyrtis bromia* Ehrenberg, Riedel and Sanfilippo, 1971, p. 1596, pl. 8, fig. 6; Moore, 1971, pl. 5, figs. 1–3; Riedel and Sanfilippo, 1978, p. 78, pl. 10, figs. 4–5.
- Thyrsocyrtis tetracantha* (Ehrenberg). *Thyrsocyrtis tetracantha* (Ehrenberg), Riedel and Sanfilippo, 1970, p. 527; Moore, 1971, pl. 4, fig. 3; Riedel and Sanfilippo, 1978, p. 80, pl. 10, figs. 8–9.
- Zygospyris brevispina* Carnevale group. *Zygospyris brevispina* Carnevale group, Sanfilippo and Riedel in Sanfilippo et al., 1973, p. 219, pl. 3, figs. 17–19.