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Radiolaria from eastern tropical Pacific sediments

ABSTRACT

Ten species of Radiolaria, six of them new, are described from Quaternary sediments of the eastern tropical Pacific. Their distributions in Recent sediments from 26 localities are shown to correspond to near-surface current patterns, and complementary patterns are shown for some well-known tropical species. Distributions to depth in five cores are presented. Foraminiferal studies indicate that each of these cores contains a horizon representing the last glacial stage. Changes in the radiolarian assemblage are recognized, but they are not always consistent with the foraminiferal biostratigraphy.

INTRODUCTION

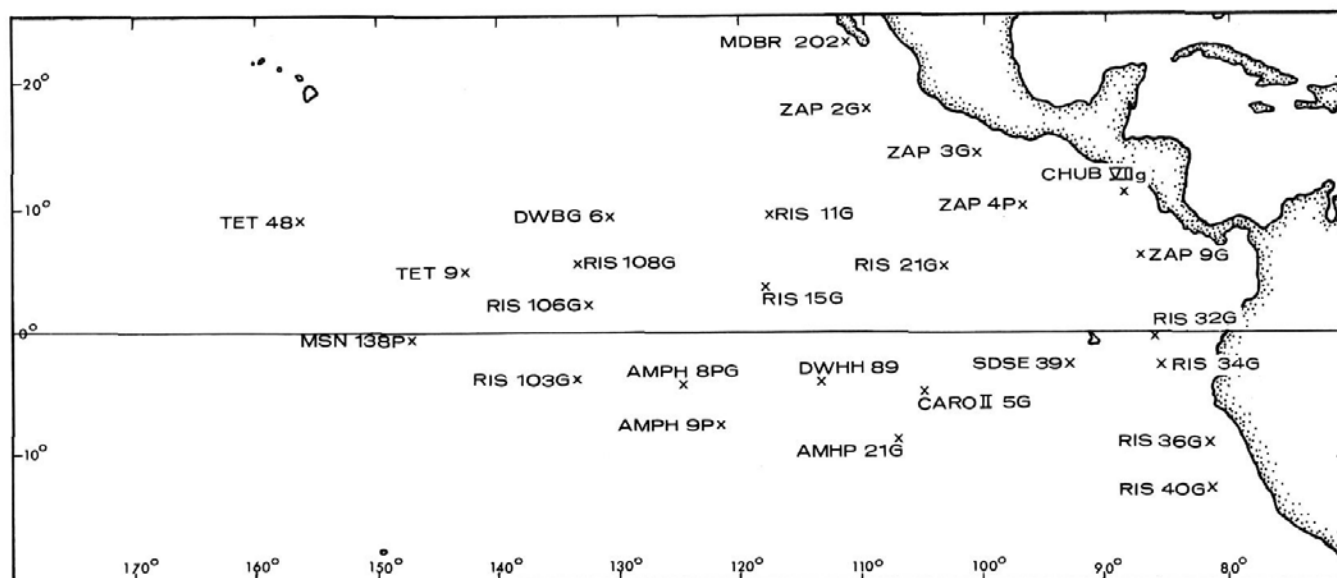
A number of studies (Bieri, MS.; Bradshaw, 1959; Brinton, 1962) of living planktonic organisms in the Pacific Ocean have revealed distinct faunal regions characterized by certain species or assemblages of chaetognaths, foraminifera and euphausiids. These regions are often sharply delineated and appear to be closely related to the surface water masses. Similar geographic zonation, based on tests of planktonic foraminifera (Parker, personal communication) may be seen in Recent sediments from the southeast Pacific, and, on a gross scale, there is a zonation of the skeletal remains of Radiolaria into high, middle and low latitude assemblages (Riedel, 1958; Hays, 1965; Nigrini, MS. in press (essentially the same manuscript as Clark, MS.)).

The present study was designed to test for smaller-scale geographic zonation of Radiolaria and to investigate the sharpness of boundaries between such assemblage zones. For this purpose samples of Recent sediments (text-figure 1) were selected from the eastern tropical Pacific in the region of the Peru Current, the South and North Equatorial Currents, and the Equatorial Countercurrent (Sverdrup, Johnson and Fleming, 1942, p. 708). These represent an area from 23°N to 13°S and westward to 156°W. Since near-surface samples (usually within 10 cm. of the tops of cores) were used, it is probable that all of the sediments examined are, in fact, Recent rather than Pleistocene. It is, nevertheless, possible that *in situ* or reworked Pleistocene assemblages are included in the material studied. Nine species of Radiolaria were described, and their distribution in Recent sediments examined along with five previously described species (Nigrini, MS. in press). In addition, five gravity cores from this region were examined to depth to determine whether or not changes in oceanic conditions corresponding to glacial stages are reflected by the radiolarian fauna. In this connection, one additional radiolarian species (*Plectacantha cremastoplegma*) was described.

SAMPLING AND COUNTS

Sediment samples were taken from within the top 10 cm. of 26 cores, except in two instances where the upper parts of the cores are not available, in the collections of the Scripps Institution of Oceanography, La Jolla (text-figure 1 and table 1). Both smear and strewn slides were prepared in the usual way (Nigrini, MS. in press).

Distributional data are based on counts to 350 individuals of 15 species. Initially, the numbers obtained were expressed as percentages. However, percentage counts of this type are statistically unsound because of the interdependence of the derived values. Ideally, counts should be made



TEXT-FIGURE 1
Locations of samples.

relative to some independent value, such as the amount of sediment accumulated per unit period of time. Nevertheless, percentages are of some use to the investigator as a numerical representation of qualitative visual impressions gained while working with the material over a long period of time. In order that conclusions might not be drawn from individual numbers, the percentage data were combined in the following way: a species contributing 2% or less of the counted individuals is "rare"; 3–10%, "few"; 11–25% "several"; 26–40%, "common"; and greater than 40%, "abundant".

Counted species include those described herein and the following previously described species (Nigrini, MS. in press):

Panartus tetrathalamus Haeckel
Amphirhopalum ypsilon Haeckel
Euchitonia spp. (*E. elegans*, *E. mülleri* and indeterminate form)
Spongaster tetras tetras Ehrenberg
Theocorythium trachelium trachelium (Ehrenberg)

SYSTEMATIC DESCRIPTIONS

In the following descriptions the synonymies include only changes of name, and no suprageneric classification has been attempted. Dimensions are, in all cases, based on at least 20 measured specimens. Occurrences, other than the present findings, are those recorded in references included in the synonymy and those recorded in Benson (MS.). Photographed specimens are located according to sample number, slide letter (in the case of more than one slide from a particular location), and England finder co-ordinates

(Riedel and Foreman, 1961). Type and figured specimens will be deposited in the U. S. National Museum, Washington, D. C., and the USNM numbers used herein are from their Cenozoic Catalogue No. 132.

Genus POLYSOLENIA Ehrenberg, 1872; emend. Nigrini (in press)

Polysolenia murrayana (Haeckel)

Plate 1, figure 1 a–b

Choenicosphaera murrayana HAECKEL, 1887, p. 102, pl. 8, fig. 6.
Trypanosphaera brachysiphon CLEVE, 1900, p. 13, pl. 6, fig. 3.
Acrosphaera murrayana (Haeckel). — POPOFSKY, 1917, p. 259, text-figs. 22–23.

Description: Shell thin-walled, smooth, usually spherical but sometimes ellipsoidal, with numerous irregularly scattered, subcircular pores of variable size, their diameter up to 1/6 of shell diameter. Seven to ten pores on a half-equator. Most pores bear a corona of 2–6 (usually 3) short, pointed spines. No spines between pores.

Dimensions: Diameter of shell 127–184 μ . Length of spines up to 22 μ .

Occurrence: Faeroe Channel (Haeckel, 1887); 56° N, 17° W and 41° N, 66° W (Cleve, 1900); Atlantic Ocean (Sargasso Sea) and southern Indian Ocean (Popofsky, 1917); Gulf of California (*Choenicosphaera murrayana* in Benson, MS.).

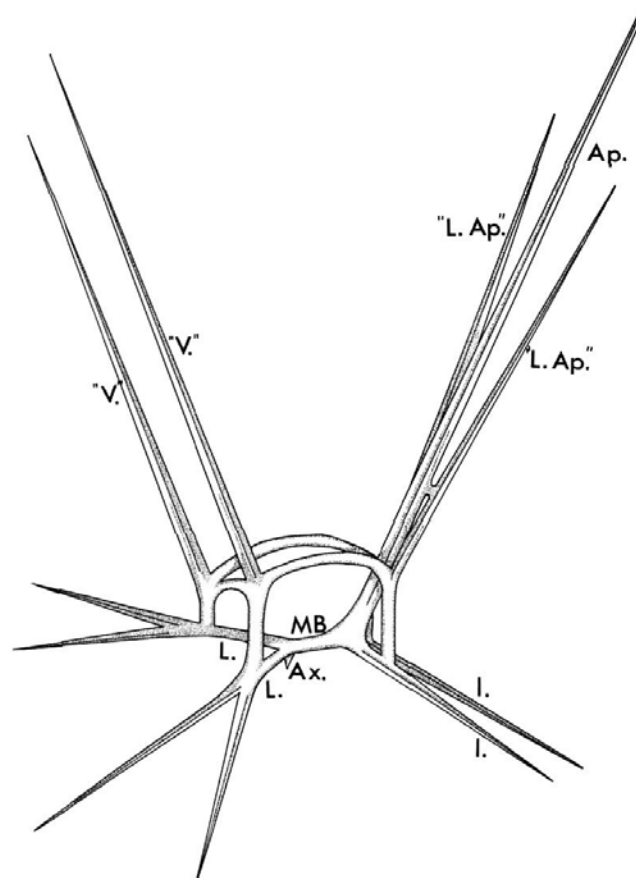
Abundant to few in the regions of the North and South Equatorial and Peru Currents, but rare or absent in the region of the Equatorial Countercurrent (text-figure 3).

TABLE 1
Eastern Tropical Pacific Samples

Expedition abbr. and core number	Latitude	Longitude	Water depth (m.)	Depth of sample in core (cm.)
AMPH 8PG*	4°20'S	125°29'W	4300	13-15
AMPH 9Pt	7°31'S	121°56'W	4410	0-2
AMPH 21G**	8°29'S	107°26'W	3120	2-5
CARO II 5G	4°45'S	104°53'W	3254	6-8
CHUB VIIg	11°30'N	88°04'W	5065-5120	7-10
DWBG 6	9°36'N	130°41'W	5003	0-2
DWHH 89	4°02'S	113°18'W	4140	0-3
MDBR 202	23°45'N	111°31'W	442	20-21
MSN 138P	0°15'S	147°34'W	4410	0-2
RIS 11G	9°45'N	117°37'W	4370	0-4
RIS 15G	3°57'N	118°03'W	4100	0-2
RIS 21G	5°32'N	103°09'W	3330	3-5
RIS 32PG	0°09'S	85°59'W	2770	2-5
RIS 34G	2°46'S	85°28'W	3210	2-5
RIS 36G	9°07'S	81°32'W	4810	4-7
RIS 40G	12°58'S	81°31'W	4840	0-3
RIS 103G	4°07'S	133°58'W	4400	3-6
RIS 106G	2°04'N	132°32'W	4310	3-6
RIS 108G	5°38'N	133°26'W	4410	0-3
SDSE 39	2°44'S	92°45'W	3600	8-10
TET 9	4°57'N	142°55'W	4882	0-3
TET 48	9°10'N	156°25'W	5285	0-2
ZAP 2G	17°51.5'N	109°31'W	3640	0-2
ZAP 3G	14°14'N	100°32'W	3450	0-2
ZAP 4P	10°24'N	96°41.5'W	4020	0-2
ZAP 9G	6°38'N	86°39'W	2860	0-2

*gravity core, both piston and gravity cores obtained.
†piston core

**gravity core, gravity core only obtained



TEXT-FIGURE 2

Basic skeletal elements of *Plectacantha cremastoplegma*. Ap, apical spine; "L. Ap.", "lateral apical" spine; "V.", vertically directed spine; L, primary lateral; I, secondary lateral; MB, median bar; Ax, axial rod.

Figured specimen from RIS 36G, 4-7 cm., USNM No. 650022.

Remarks: This species is distinguished from *Poly-solenia flammabunda* (Haeckel) by the smoothness of the shell wall between pores. It is identified and described by Benson (MS.) as *Choenicosphaera murrayana* Haeckel.

Genus CYPASSIS Haeckel, 1887

***Cypassis irregularis* Nigrini, n. sp.**

Plate 1, figure 2a-c

?*Spongoliva* sp. — HOLLANDE and ENJUMET, 1960, pl. 63.

Description: Cortical twin shell spiny, slightly constricted equatorially, with subcircular to subangular pores having no definite arrangement; pores variable in size, tending to be smaller equatorially. Poles of twin shell not closed by a definite lattice, always spiny. In some specimens these spines support an irregular, usually incomplete, spongy meshwork. When complete, this meshwork forms an ellipsoidal shell around the cortical shell. Polar caps have not been observed.

Outer medullary shell ellipsoidal, connected to an inner, spherical medullary shell by radial beams;

numerous radial beams also connect outer medullary shell to cortical twin shell at the equatorial constriction.

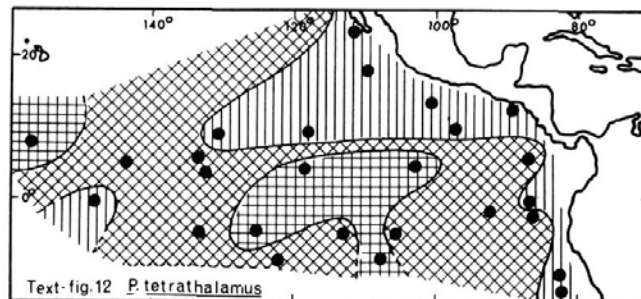
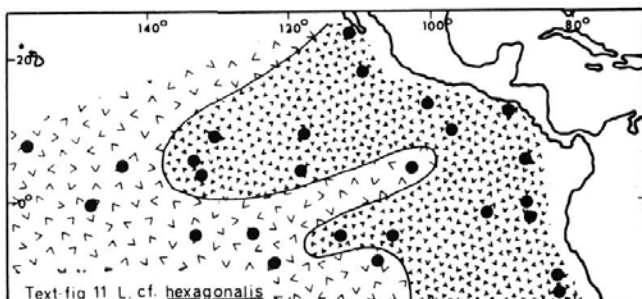
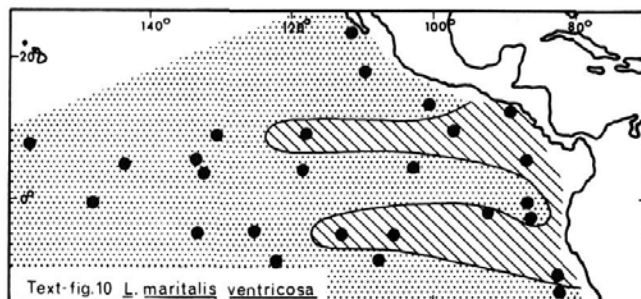
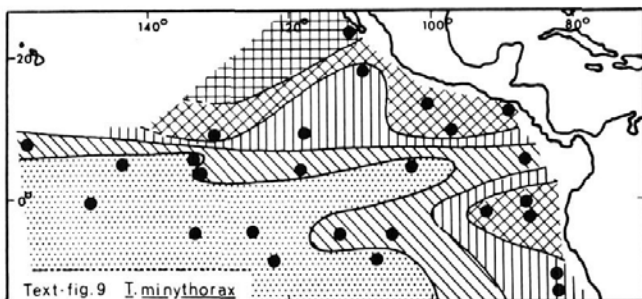
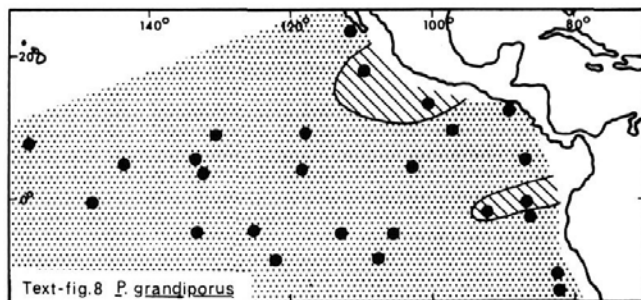
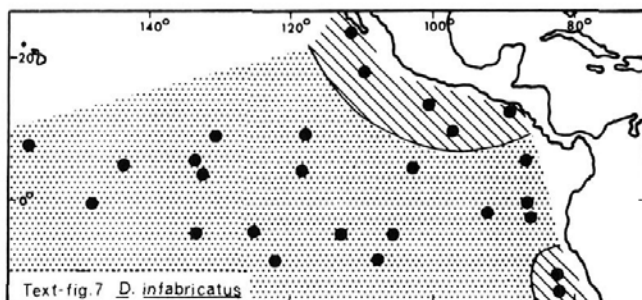
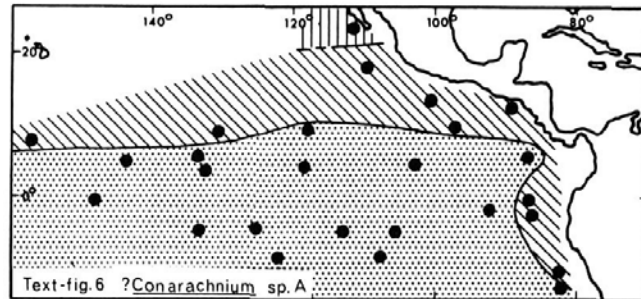
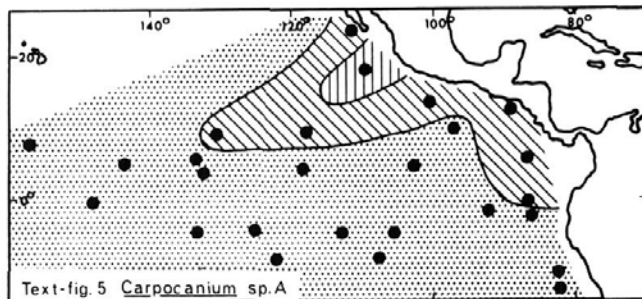
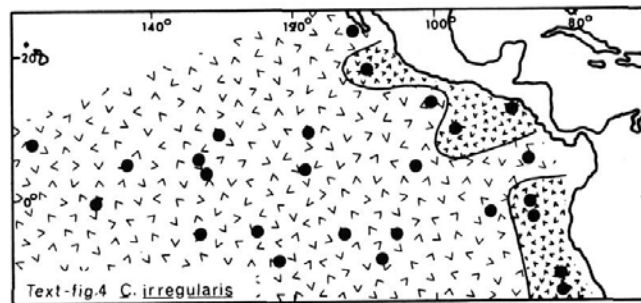
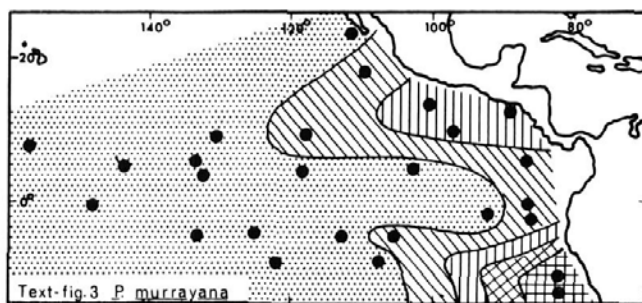
Dimensions: Length of cortical twin shell 118-184 μ . Maximum breadth of cortical twin shell 63-99 μ .

Occurrence: Gulf of California (?*Spongoliva* cf. *ellipsoides* Popofsky, in Benson, MS.).

Rare in samples from along the coast of Central and South America; absent from all other samples examined (text-figure 4).

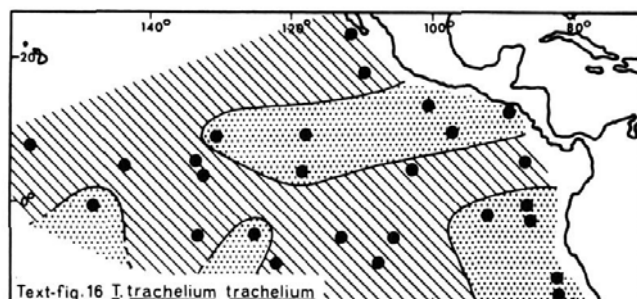
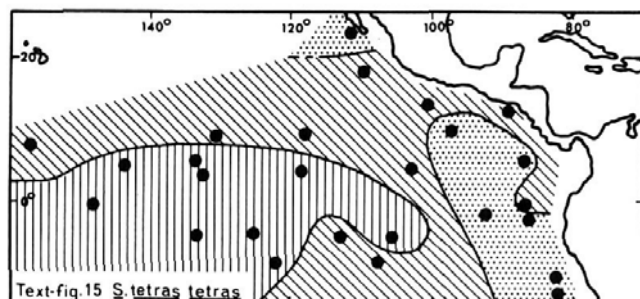
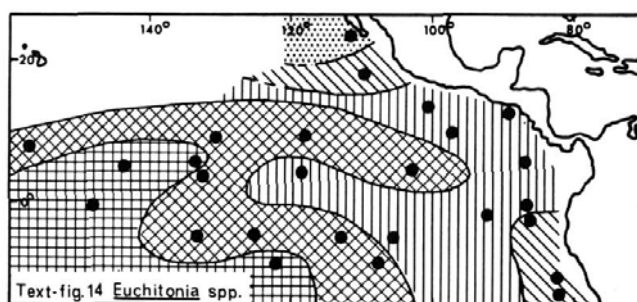
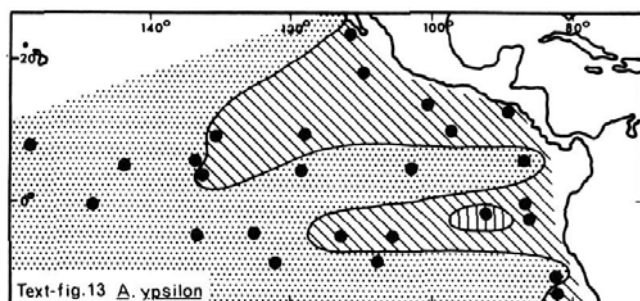
Figured specimens from RIS 34 G, 42-45 cm., USNM No. 650023 (holotype, plate 1, figure 2a-b) and USNM No. 650024 (paratype, plate 1, figure 2c).

Remarks: This species was named *irregularis* because of the irregular nature of its cortical and extracortical shells.



TEXT-FIGURES 3-12

Species distribution maps. Dots, rare or absent (0-2% of the counted individuals); diagonal lines, few (3-10%); vertical lines, several (11-25%); diagonal cross-hatching, common (26-40%); vertical-horizontal cross-hatching, abundant (>40%); large V's, absent; small v's, rare (<2%).



TEXT-FIGURES 13-16

Species distribution maps. Dots, rare or absent (0-2% of the counted individuals); diagonal lines, few (3-10%); vertical lines, several (11-25%); diagonal cross-hatching, common (26-40%); vertical-horizontal cross-hatching, abundant (>40%).

Genus PLECTACANTHA Joergensen, 1905

***Plectacantha cremastoplegma* Nigrini, n. sp.**

Plate 1, figure 3a-c; text-figure 2

Description: One-segmented shell consisting of a basic spine structure connected distally by a thin, smooth, irregular lattice of straight bars and subangular to subcircular pores of varying size. Primary and secondary laterals, median bar, thorn-like axial rod, and apical spine present in the usual (*Plagiocarpa*, Popofsky, 1913, text-figure 2d) configuration. Primary laterals both fork distally, each forming 2 (sometimes 3) stout, 3-bladed spines. Secondary laterals strongly developed into stout, 3-bladed spines. Similar spines ("lateral apical") flank the apical spine, one on each side of it. Strong arches extend between the primary laterals, and from each primary lateral to its corresponding "lateral apical" spine and secondary lateral. Two, vertically directed, stout, 3-bladed spines originate at the points of bifurcation of the primary laterals, initially forming part of the arch structure.

Dimensions: Length of cephalis (excluding spines) 72-113 μ . Maximum breadth of cephalis (excluding spines) 81-108 μ .

Occurrence: Absent from all near-surface samples examined.

Figured specimens from RIS 34G, 132-135 cm., USNM No. 650025 (holotype, plate 1, figure 3a);

from RIS 34G, 52-55 cm., USNM No. 650026 (paratype, plate 1, figure 3b); and from RIS 34G, 72-75 cm., USNM No. 650027 (paratype, plate 1, figure 3c).

Remarks: The specific name *cremastoplegma* is derived from the hanging or draped meshwork over the basic skeletal elements.

Genus CARPOCANIUM Ehrenberg, 1847

***Carpocanium* sp. A**

Plate 1, figure 4

Description: Shell elongate, subcylindrical, smooth, with completely hidden spherical cephalis. Primary lateral and dorsal spines extend to the thoracic wall and draw it inwards, thus making the upper part of the shell trilobate.

Thoracic pores subcircular to circular, approximately equal in size over most of the segment but smaller over the cephalic end, usually arranged in longitudinal rows, 9-13 in a vertical series, 7-10 on a half-equator. Mouth slightly constricted and sometimes surrounded by a well-developed, poreless, hyaline peristome. Terminal teeth, up to 14 on well-developed individuals, flat, usually truncate, parallel, as broad as, or broader than, the intervening spaces. Peristome may be smoothly terminated, or absent and termination ragged.

Dimensions: Length of thorax 81–137 μ ; of peristome and terminal teeth up to 45 μ (usually up to 18 μ). Maximum breadth of thorax 63–81 μ .

Occurrence: Gulf of California (*Carpocanium* sp., in Benson, MS.).

Few in the region of the North Equatorial Current and in one equatorial sample near the coast of South America, most abundant in the northern part of the study area, rare or absent in all other samples examined (text-figure 5).

Figured specimen from RIS 11G, 0–4 cm., USNM No. 650028.

Remarks: This species differs from previously figured members of the genus *Carpocanium* by its elongate, subcylindrical thorax. It is also described by Benson (MS.).

Genus CONARACHNIUM Haeckel, 1881

***Conarachnium* ? sp. A**

Plate 1, figure 5a–b

Description: Shell inflated conical, smooth, thin-walled. Cephalis trilocular, with numerous small subcircular pores and a well-developed, 3-bladed apical horn 1–2 times cephalic length. Usually a short, conical vertical horn may also be seen. In some specimens the cephalis is open apically, the opening surrounded by a corona of small spines. Primary lateral and dorsal spines continue as weakly developed ribs in the thoracic wall for about 1/3 of its length but have not been observed to form wings. Collar stricture not pronounced.

Thorax inflated conical with slight terminal constriction on complete specimens, but termination usually ragged. Pores subcircular to polygonal, much larger than the intervening bars, aligned longitudinally and increasing in size distally, 5–8 in a vertical series, 5–8 on a half-equator. Peristome not differentiated; numerous (up to 16) short, acute terminal teeth projecting from the thorax at irregular intervals.

Dimensions: Length of apical horn 18–45 μ (usually 18–27 μ), of cephalis 27–36 μ , of thorax (including terminal teeth) 63–146 μ . Maximum breadth of cephalis 18–27 μ , of thorax 72–117 μ .

Occurrence: Gulf of California (*Conarachnium* ? sp., in Benson, MS.).

Few along the coast of Central and South America, and to the west in the region of the North Equatorial Current; most abundant in the northernmost sample in the study area; rare or absent in all other samples examined (text-figure 6).

Figured specimens from RIS 36G, 4–7 cm., USNM No. 650029 (plate 1, figure 5a) and USNM No. 650030 (plate 1, figure 5b).

Remarks: This species is also described by Benson (MS.). Its generic position is questionable because the illustrated specimen of the type species of *Conarachnium* (*Eucyrtidium trochus* Ehrenberg, 1872) appears to be broken and is probably a 3-segmented form. However, the verbal description of the genus is compatible with the species here described.

Genus *Dictyophimus* Ehrenberg, 1847; **emend.** Nigrini (in press and herein)

The type species of the genus *Dictyophimus* is *D. crisiæ* Ehrenberg, 1854. It is a 3-segmented form, and therefore the genus was regarded by Nigrini (in press) as tricyrtid. The dicyrtid *D. infabricatus*, described herein, is clearly closely related to *D. crisiæ*, and the definition of the genus should be emended to include also this 2-segmented form.

***Dictyophimus infabricatus* Nigrini, n. sp.**

Plate 1, figure 6

Description: Shell thin-walled, smooth, conical to inflated conical. Cephalis simple, spherical, with numerous small subcircular pores. Apical horn usually 1 to 2 times the cephalic length (rarely longer), either 3-bladed or cylindrical; vertical horn present, usually shorter than apical horn, but sometimes equally developed. Both apical and vertical spines free of shell wall. Thin by-spines present on cephalis and upper thorax. Collar stricture distinct.

Thorax tetrahedral with 3 strong, 3-bladed or cylindrical ribs, corresponding to primary lateral and dorsal spines; ribs either divergent or bowed, tapering distally, and extending beyond the thoracic lattice, which is usually attached to the ribs for its entire length. Pores subcircular to subangular, aligned longitudinally and increasing in size distally. Termination invariably ragged.

Dimensions: Length of cephalis 14–27 μ , of thorax 72–156 μ , of ribs 127–230 μ . Maximum breadth of cephalis 18–27 μ , of thorax 72–156 μ .

Occurrence: Few along the coast of Central and South America, except from 0° to 10°N; rare or absent in all other samples examined (text-figure 7).

Figured specimen (holotype) from RIS 36G, 4–7 cm., USNM No. 650031.

Remarks: This species, as its name suggests, is distinguished by its ragged thoracic termination.

Genus PTEROCANIUM Ehrenberg, 1847

***Pterocanium grandiporus* Nigrini, n. sp.**

Plate 1, figure 7

Description: Similar in size and shape to *P. trilobum* Nigrini (in press), but shell may be heavier and rougher, cephalic pores better defined, and apical horn usually longer. Thoracic pores larger than those of *P. trilobum*, 9–11 across the widest part of the segment.

Abdomen often quite well developed and attached to the feet for at least most of its length. Pores large, subcircular, having no definite arrangement; those adjacent to the feet larger than the others. Termination always ragged.

Dimensions: Length of apical horn 45–81 μ , of cephalis 14–27 μ , of thorax 63–90 μ , of feet 108–240 μ . Maximum breadth of cephalis 23–27 μ , of thorax 90–127 μ .

Occurrence: Few in 2 samples near the coast of Central America and in 2 equatorial samples near the coast of South America, rare or absent in all other samples examined (text-figure 8).

Figured specimen (holotype) from RIS 11G, 0–4 cm., USNM No. 650032.

Remarks: This species is distinguished from other members of the genus *Pterocanium* by its large thoracic and abdominal pores, and for that reason is named *grandiporus*.

Genus THEOCONUS Haeckel, 1887

***Theoconus minythorax* Nigrini, n. sp.**

Plate 1, figure 8

Description: Shell conical, rather thick-walled, smooth. Cephalis trilocular with relatively large subcircular pores and a short, 3-bladed apical horn, usually about 1/2 of the cephalic length. Primary lateral and dorsal spines continue as ribs in the thoracic wall for more than 1/2 of its length and may project to form small, thornlike wings. Collar stricture not pronounced.

Thorax small, campanulate; pores subcircular, 8–10 on a half-equator, aligned longitudinally with very narrow intervening bars. Lumbar stricture distinct.

Abdomen slightly flared, up to 3 times as long as thorax. Pores similar to those on thorax, 9–10 on a half-equator. Termination always ragged; mouth wide open.

Dimensions: Length of cephalis 27–36 μ , of thorax 36–45 μ , of abdomen 63–127 μ . Maximum breadth of cephalis 18–27 μ , of thorax 63–72 μ , of abdomen 90–118 μ .

Occurrence: Gulf of California (*Theoconus zancleus* Müller, in Benson, MS., *partim*).

Few to abundant in the regions of the North and South Equatorial and Peru Currents, but rare or absent in the region of the Equatorial Countercurrent (text-figure 9).

Figured specimen (holotype) from RIS 36G, 4–7 cm., USNM No. 650033.

Remarks: This species differs from other members of the genus *Theoconus* by its small thorax, relative to the size of its abdomen, and by its large pores. It was identified and described by Benson (MS.) as *Theoconus zancleus* Müller, but *T. zancleus* is apparently not synonymous with the species here described. Also, it is thought that Benson's description encompasses 2 species; the specimen shown in plate 33, figure 5, appears to be the same as *T. minythorax*, but the one in plate 33, figure 4 is not.

The name *minythorax* refers to the relatively small thorax of this species.

Genus LAMPROCYCLAS Haeckel, 1881, emend. Nigrini (in press)

***Lamprocyclas maritalis* Haeckel *ventricosa* Nigrini, n. subsp.**

Plate 1, figure 9

Description: Shell campanulate, rather thick-walled, rough. Cephalis trilocular with numerous small subcircular pores and a stout 3-bladed apical horn, 1 to 2 times the cephalic length. Primary lateral and dorsal spines continue as ribs in the thoracic wall and may become external, forming small wings. Collar stricture not pronounced.

Thorax inflated conical with hexagonally framed, circular to subcircular pores, aligned longitudinally, 11–14 across the widest part of the segment. Lumbar stricture distinct.

Abdomen inflated cylindrical, much larger than the thorax. Pores hexagonally framed, circular to subcircular, larger than thoracic pores, arranged in longitudinal rows, 3–9 (usually 5–9) in a vertical series, 11–14 on a half-equator.

Peristome often small, but clearly differentiated, poreless, with numerous acute, sometimes forked teeth arising from its lower edge; sometimes teeth are rudimentary or absent. Subterminal teeth, on the abdomen just above the peristome, are divergent, small and thornlike.

Dimensions: Length of apical horn 54–81 μ , of cephalis 36–45 μ , of thorax 54–63 μ , of abdomen (excluding peristome and terminal teeth) 72–127 μ .

Maximum breadth of cephalis 36–45 μ , of thorax 108–127 μ , of abdomen 156–193 μ .

Occurrence: Few along the coast of Central America (south of 11°N) and South America, and extending westward in the regions of the North and South Equatorial Currents; rare or absent in all other samples examined (text-figure 10).

Figured specimens (holotype) from RIS 36G, 4–7 cm., USNM No. 650034.

Remarks: This subspecies is distinguished from *Lamprocyclas maritilis maritilis* Haeckel and *Lamprocyclas maritilis maritilis* Haeckel *polypora* Nigrini by its larger abdomen. At the lower limit of its abdominal dimensions, it grades into *L. maritilis polypora*, hence an arbitrary minimum abdominal breadth of 150 μ has been selected for *L. maritilis ventricosa*. In Indian Ocean material, Nigrini (in press) found that the average abdominal breadth of *L. maritilis polypora* is 123 μ (range 119–136 μ).

The distribution shown in text-figure 10 roughly corresponds to a plot of average abdominal size, based on 10 measured specimens of *Lamprocyclas maritilis* from each sample. In the area of few *L. maritilis ventricosa* the average abdominal breadth is > 150 μ , whereas it is < 150 μ in the area of rare or absent *L. maritilis ventricosa*.

Genus LITHOSTROBUS Bütschli, 1882

***Lithostrobos* sp. cf. *L. hexagonalis* Haeckel**
Plate 1, figure 10

Cf. *Lithostrobos hexagonalis* HAECKEL, 1887, p. 1475, pl. 79, fig. 20.

Description: Shell conical, quite thin-walled, smooth, with 5–7 or more segments. Cephalis cap-shaped with numerous subcircular pores and several horns: 1) an apical horn, 3-bladed, usually as long as the cephalis; 2) a vertical horn, shorter, conical; and 3) two or more short conical horns, not connected to internal structure. Both apical and vertical spines are free of the shell wall; primary lateral and dorsal spines continue as ribs in the thoracic wall to the break in its contour. Collar pores large; collar stricture not pronounced.

Thorax conical for most of its length, but indents sharply to the lumbar stricture. Thoracic and post-thoracic pores circular to subcircular, regularly arranged in transverse rows.

Each of the 3–5 post-thoracic segments has the same general shape, dilating from the preceding stricture for about half its length, then exhibiting a sharp break

in contour from which the shell narrows to the next stricture. The segments increase in diameter distally. Short by-spines project from the break in the contour of each segment. In rare, more complete specimens, the thoracic ribs project to form long, cylindrical, external spines (probably 3, but only 2 have been observed) which connect the by-spines, and there is a long, curved, cylindrical apical horn. Termination usually ragged; mouth wide open.

Dimensions: Total shell length (excluding apical horn) 108–271 μ (usually 108–231 μ). Length of cephalis 18–27 μ . Maximum breadth of cephalis 18–27 μ ; of shell 108–212 μ (usually 108–175 μ).

Occurrence: Tropical Central Pacific, Challenger Station 272 (3° 48' S, 152° 56' W, 2600 fm.) (Haeckel, 1887); Gulf of California (*Lithostrobos* cf. *hexagonalis* Haeckel, in Benson, MS.).

Rare in the regions of the North and South Equatorial and Peru Currents; absent from the western and southwestern parts of the study area (text-figure 11).

Figured specimen from RIS 36G, 4–7 cm., USNM No. 650035.

Discussion: This species is also described by Benson (MS.). It differs from Haeckel's (1887) illustration of *L. hexagonalis* by the absence of a distinct transverse ridge on each segment.

DISTRIBUTION IN RECENT SEDIMENTS OF PREVIOUSLY DESCRIBED SPECIES

Panartus tetrathalamus Haeckel (text-figure 12)

Common to abundant throughout most of the equatorial region of the study area, decreasing in abundance to the north in the region of the North Equatorial Current and also in the 2 southernmost samples examined.

Amphirhopalum ypsilon Haeckel (text-figure 13)

Few in the regions of the North and South Equatorial Currents, but decreasing in abundance westward and in the region of the Equatorial Countercurrent; distribution similar to that of species described herein.

Euchitonia spp. (text-figure 14)

Rare in the northernmost sample examined, few in the region of the Peru Current, generally several along the coast of Central America and in the region of the South Equatorial Current, common to abundant in the western part of the study area.

Spongaster tetras tetras Ehrenberg (text-figure 15)

Absent from the northernmost sample examined, rare or absent in the region of the Peru Current, few in the

TABLE 2

Distribution of selected radiolarian species in five gravity cores

	Depth Sampled (cm.)	<i>Polysolenia</i> <i>murrayana</i>	<i>Cypassis</i> <i>irregularis</i>	<i>Plectacantha</i> <i>crenastoplegma</i>	<i>Carpocanium</i> sp. A	<i>Conarachnium</i> ? sp. A	<i>Dictyophimus</i> <i>infabricatus</i>	<i>Pterocanium</i> <i>grandiporus</i>	<i>Theoconus</i> <i>minythorax</i>	<i>Lamprocyclus</i> <i>maritilis ventricosa</i>	<i>Lithostrobilus</i> sp. cf. <i>L. hexagonalis</i>	<i>Panartus</i> <i>tetrathalamus</i>	<i>Amphirhopalum</i> <i>ypsilon</i>	<i>Euchitonina</i> spp.	<i>Spongaster</i> tetras tetras	<i>Theocorythium</i> <i>trachelium trachelium</i>
AMPH 21G	2-5	R	—	—	—	R	—	—	R	R	—	A	R	C	F	F
	12-5	R	—	—	—	—	—	—	R	R	—	A	R	C	F	F
	22-5	R	—	—	R	R	—	—	R	—	—	A	R	C	F	R
	32-5	F	—	—	R	—	R	—	R	R	—	A	R	C	F	F
	42-5	F	—	—	—	—	—	R	R	R	—	A	R	C	F	F
	52-5	R	—	—	R	—	—	—	F	R	—	A	R	S	F	R
CARO II 5G	62-5	R	—	—	R	R	—	—	F	R	—	A	R	S	F	F
	6-8	F	—	—	R	R	R	R	F	F	R	C	F	S	S	F
	15-7	F	—	—	F	F	R	R	S	R	F	C	F	S	F	F
	25-7	F	R	—	F	F	R	R	S	F	F	C	F	S	F	R
	34-6	F	R	—	F	R	R	R	S	F	R	C	F	S	F	R
	43-5	F	R	—	F	F	R	R	S	F	R	C	R	S	F	—
	55-7	F	R	—	F	F	R	R	S	F	R	C	R	S	F	—
	63-5	F	R	—	F	F	R	R	S	F	F	C	R	F	F	R
	74-6	F	R	—	F	F	R	R	C	F	R	S	R	S	F	—
	84-7	F	R	—	F	F	R	R	C	R	R	C	R	F	F	R
	99-101	R	R	—	F	F	R	R	A	R	R	C	R	F	R	R
	110-2	R	R	—	F	F	R	R	S	F	—	A	R	F	F	R
RIS 32 PG	121-4	R	R	—	R	F	R	F	C	F	F	C	F	F	R	R
	2-5	F	R	—	F	F	R	F	C	R	R	S	F	S	F	R
	10-5	F	—	—	R	F	R	F	S	F	R	C	F	S	F	R
	20-5	R	R	—	F	F	F	F	S	R	R	C	F	S	F	R
	32-5	F	R	—	R	F	R	F	S	R	R	C	F	S	F	—
	42-5	F	R	R	R	F	R	F	S	F	F	A	F	S	R	R
	52-5	F	R	R	R	S	R	F	S	F	F	S	F	S	F	R
	62-5	F	R	R	F	S	R	F	S	F	—	C	R	S	F	—
	72-5	F	R	—	R	S	R	F	S	R	R	C	F	S	R	R
	82-5	F	R	—	R	S	R	F	S	F	R	C	F	S	R	—
	92-5	F	R	R	F	S	R	F	S	R	F	S	R	S	R	R
	102-5	F	R	R	R	S	R	F	C	R	F	S	R	S	R	—
RIS 34 G	112-5	F	R	R	R	F	R	F	S	R	R	C	R	S	R	—
	2-5	F	R	—	R	F	F	F	C	F	R	C	F	S	R	—
	12-5	S	R	—	F	F	F	F	C	F	R	C	F	S	F	—
	22-5	F	R	—	F	F	R	F	S	F	R	C	F	C	R	R
	32-5	F	R	—	R	F	R	F	S	S	R	C	F	A	S	R
	42-5	F	R	—	F	F	F	S	S	S	R	C	F	S	F	—
	52-5	F	F	R	—	S	F	S	C	F	R	S	F	S	F	—
	62-5	S	R	R	R	S	F	C	C	F	F	F	R	S	—	—
	72-5	F	R	R	F	S	F	F	C	S	F	S	R	S	F	—
	82-5	F	R	F	R	S	R	S	C	S	F	S	R	S	F	—
	92-5	S	F	R	F	F	F	F	C	S	R	S	R	F	F	—
	102-5	S	R	R	F	F	F	F	C	C	R	S	R	S	F	—
SDSE 39	112-5	F	R	F	F	S	R	F	A	C	R	S	R	F	R	—
	122-5	R	R	F	F	S	F	F	A	F	F	F	F	R	—	—
	132-5	R	R	F	F	S	F	F	A	S	F	S	R	S	R	—
	142-5	F	R	F	F	S	F	S	A	F	F	S	R	F	F	—
	152-5	R	R	F	F	S	F	F	A	F	F	S	R	R	R	—
	8-10	R	—	—	R	R	R	F	C	F	R	C	S	F	R	—
	17-9	R	—	—	F	F	R	F	C	F	R	C	S	F	F	—
	28-30	F	—	—	F	F	R	R	C	F	F	C	S	F	R	—
	41-3	F	R	R	R	F	R	R	S	F	R	C	F	F	F	R
	51-3	S	R	R	R	S	R	F	C	F	R	S	R	F	R	R
	61-3	F	R	R	R	S	F	F	C	F	R	S	R	F	R	—
	73-5	F	R	R	R	F	R	F	A	F	R	S	R	F	R	—
	92-4	F	R	R	R	F	R	F	A	F	R	S	R	F	F	R
	100-2	R	R	R	F	S	R	R	A	R	R	S	R	F	—	—
	111-3	R	R	R	F	F	F	R	A	R	R	S	R	F	R	—
	121-3	R	R	R	F	F	F	F	A	F	R	S	R	F	R	R

Lines subdividing the cores correspond with the foraminiferal changes observed by Blackman.

A=abundant, C=common, S=several, F=few, R=rare, —=absent.

regions of the North and part of the South Equatorial Currents, common in a broad region which includes the Equatorial Countercurrent and part of the South Equatorial Current.

Theocorythium trachelium trachelium (Ehrenberg) (text-figure 16)

Rare or absent in the regions of the Peru Current and the North Equatorial Current (except for few in the 2 northernmost samples examined), few throughout most of the regions of the South Equatorial Current and the Equatorial Countercurrent.

SUMMARY OF DISTRIBUTIONS OF COUNTED SPECIES

The work of Brinton (1962) and others has revealed a distinctive distributional pattern for living planktonic organisms, apparently related to oceanographic water masses, in the eastern tropical Pacific. This pattern consists of two areas extending westward from the Central and South American coasts in the regions of the North and South Equatorial Currents; these areas are divided by a tongue corresponding to the Equatorial Countercurrent.

The radiolarian species described and counted during the present study were selected because a qualitative inspection suggested similar distributions of these forms in Recent sediments. This has now proved to be the case for at least some of the species. In particular, *Polysolenia murrayana* (text-figure 3), *Theoconus*

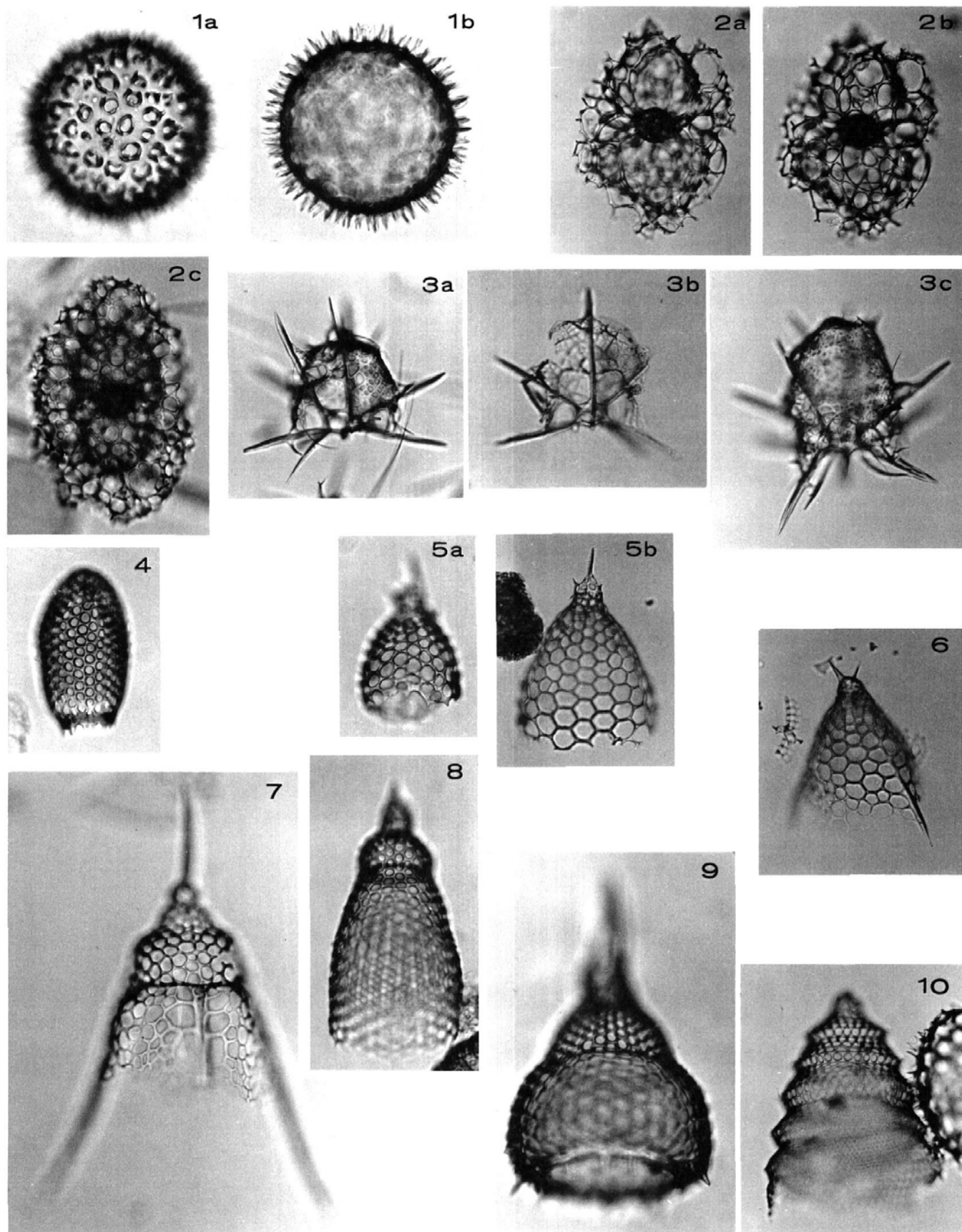
minyathorax (text-figure 9) and *Lamprocyclas maritima ventricosa* (text-figure 10) are relatively common in the region of the Peru Current and along the Central American Coast. They are apparently carried oceanwards by the North and South Equatorial Currents and decrease in abundance to the west, but within the tongue of the Equatorial Countercurrent they are rare or absent. A similar, but less well-defined distributional pattern was found for *Conarachnium*? sp. A (text-figure 6). *Carpocanium* sp. A (text-figure 5) also has a similar distribution, but north of the equator only. *Pterocanium grandiporus* (text-figure 8) and *Dictyophimus infabricatus* (text-figure 7) appear to prefer coastal regions and are not carried oceanward in significant numbers. *Lithostrobos* sp. cf. *L. hexagonalis* (text-figure 11) and *Cypassis irregularis* (text-figure 4) are not sufficiently abundant to provide meaningful distributions. *Plectacantha cremastoplegma* was not found in near-surface sediments.

A complementary distributional pattern was found for some well-known tropical forms, in particular *Spongaster tetras tetras* (text-figure 15). This species is abundant in the Equatorial Countercurrent tongue, but decreases in abundance in the regions of the North and South Equatorial Currents and along the coasts of Central and South America. *Panartus tetrathalamus* (text-figure 12) decreases in abundance in the regions of the Peru and North Equatorial Currents, but is quite abundant in the regions of both the South Equatorial

PLATE 1

All figures $\times 225$

- 1 *Polysolenia murrayana* (Haeckel)
RIS 36G; 4–7 cm., slide A–G27/2, USNM No. 650022; a, focused on surface; b, focused on perimeter.
- 2 *Cypassis irregularis* Nigrini, n. sp.
RIS 34G, 42–45 cm.; a–b, holotype, slide B–H23/3, USNM No. 650023; a, focused on medullary shells; b, focused on extra-cortical meshwork; c, paratype, with complete extra-cortical meshwork; slide A–P42/0, USNM No. 650024.
- 3 *Plectacantha cremastoplegma* Nigrini, n. sp.
RIS 34G; a, holotype, 132–135 cm., M28/1; USNM No. 650025; b, paratype, chosen to show apical and "lateral apical" spines; 52–55 cm., D25/0, USNM No. 650026; c, paratype, with subcircular pores; 72–75 cm., T55/3, USNM No. 650027.
- 4 *Carpocanium* sp. A.
RIS 11G, 0–4 cm., slide B–R46/3, USNM No. 650028.
- 5 *Conarachnium*? sp. A.
RIS 36G, 4–7 cm.; a, slide A–047/4, USNM No. 650029; b, slide C–047/4; USNM No. 650030.
- 6 *Dictyophimus infabricatus* Nigrini, n. sp.
Holotype, RIS 36G, 4–7 cm., slide B–E41/0, USNM No. 650031.
- 7 *Pterocanium grandiporus* Nigrini, n. sp.
Holotype, RIS 11G, 0–4 cm., slide A–J34/4, USNM No. 650032.
- 8 *Theoconus minyathorax* Nigrini, n. sp.
Holotype, RIS 36G, 4–7 cm., slide A–T37/3, USNM No. 650033.
- 9 *Lamprocyclas maritima ventricosa* Nigrini, n. subsp.
Holotype, RIS 36G, 4–7 cm., slide A–E45/1, USNM No. 650034.
- 10 *Lithostrobos* sp. cf. *L. hexagonalis* Haeckel
RIS 36G, 4–7 cm., slide C–C37/1, USNM No. 650035.



Current and the Equatorial Countercurrent. *Euchitonia* spp. (text-figure 14) are least abundant near the coasts of Central and South America, particularly at the northern and southern limits of the study area; they increase in abundance towards the open ocean. *Amphirhopalum ypsilon* (text-figure 13) was formerly described as a tropical form, but its distribution pattern resembles more closely the patterns obtained for those species described herein. The meaning of the distributional pattern for *Theocorythium trachelium trachelium* (text-figure 16) is not clear at the present time.

EXAMINATION TO DEPTH OF FIVE GRAVITY CORES

In conjunction with this study of Recent sediments from the eastern tropical Pacific, investigations were extended to depth in a number of cores. Working with foraminifera, Blackman (personal communication) has been able to define the last glacial stage in cores from the southeast Pacific. Unfortunately, in this area Radiolaria are usually poor or absent in those cores which contain the best foraminiferal assemblages, and *vice versa*. However, 5 of the cores studied by Blackman do contain a sufficiently good radiolarian fauna to permit a meaningful examination. Counts (table 2), similar to those made on Recent samples, were made at 10 cm. intervals down each of these 5 cores.

AMPH 21 G (core length 79 cm.)

Blackman found in this core a poorly defined high-latitude foraminiferal fauna between 25 cm. and 55 cm.

The radiolarian fauna is mainly tropical, and forms common in the Peru Current are sparsely distributed. There is an increase in the abundance of *Polysolenia murrayana* within Blackman's glacial zone. Below the zone there is an increase in *Theoconus minyathorax* and a decrease in *Euchitonia* spp.

CARO II 5 G (core length 140 cm.)

According to Blackman, a high-latitude foraminiferal fauna lies between 45 cm. and 90 cm. in this core.

Observable changes in the radiolarian fauna occur at various levels in the core, but do not correlate particularly well with Blackman's glacial zone. Below 45 cm. there is a decrease in abundance of *Amphirhopalum ypsilon*, below 76 cm. *Theoconus minyathorax* increases, below 87 cm. *Euchitonia* spp. decreases, and below 101 cm. *Polysolenia murrayana* decreases. *Cypassis irregularis* is absent near the top of the core, but at depth it is consistently present in small numbers.

RIS 32 PG (core length 119 cm.)

In this core Blackman found a tropical fauna down to 45 cm. and a high-latitude one down the remainder of the core.

No really convincing faunal changes were observed in the radiolarian fauna. *Plectacantha cremastoplegma* is absent above 45 cm., and there is a slight increase in the abundance of *Conarachnium?* sp. A at 55 cm. and below.

RIS 34 G (core length 160 cm.)

In this core Blackman found a high-latitude foraminiferal fauna between 45 cm. and 115 cm.

The following changes in the radiolarian fauna were observed: A decrease in abundance of *Panartus tetrathalamus* below 45 cm. and corresponding increases in *Theoconus minyathorax* and *Conarachnium?* sp. A. *Amphirhopalum ypsilon* decreases in abundance below 55 cm. *Plectacantha cremastoplegma* is absent down to 45 cm., but is consistently present in small numbers down the remainder of the core. These changes coincide with the top of Blackman's glacial zone, and corresponding changes at the bottom of the zone would be expected. However, the only convincing faunal changes below 115 cm. are a further increase in *T. minyathorax* and a slight increase in *P. cremastoplegma*.

SDSE 39 (core length 528 cm., examined down to 123 cm.)

According to Blackman, in this core a high-latitude foraminiferal fauna lies between approximately 25 cm. and approximately 95 cm.

There is an increase in abundance of *Polysolenia murrayana* within Blackman's glacial zone. Just below the top of this zone *Cypassis irregularis* and *Plectacantha cremastoplegma* appear and are present in small numbers down the remainder of the core examined. At the same level *Amphirhopalum ypsilon* decreases in abundance. There is a decrease in *Panartus tetrathalamus* below 53 cm. and an increase in *Theoconus minyathorax* below 75 cm. These two changes are apparently unrelated to Blackman's glacial zone.

SUMMARY

In the eastern tropical Pacific, distribution patterns of selected radiolarian species in Recent sediments are in good agreement with those patterns previously presented for other planktonic groups. Changes in abundance are more dramatic for some species than for others, but, on the whole, boundaries are relatively sharp. *Polysolenia murrayana* and *Theoconus minyathorax* appear to give the sharpest patterns. The distributions presented herein certainly show that there is a recognizable small-scale geographic zonation of Radiolaria in Recent sediments.

Variations down the 5 cores examined are less well-defined. The most convincing changes are those found at the top of Blackman's glacial zone (45–115 cm.) in RIS 34 G. However, the changes in the opposite sense expected at the bottom of this zone could not be detected. The most consistent variations are 1) an increase in the abundance of *Theoconus minythora* at the lower boundary, 2) an increase in *Polysolenia murrayana* at the upper boundary and a decrease at the lower one, 3) a decrease in *Amphirhopalum ypsilon* at the upper boundary, and 4) the absence of *Plectacantha cremastoplegma* above the upper boundary.

Assuming that Blackman's interpretation of the observed foraminiferal zonation is correct, the observed changes in the radiolarian fauna are not as marked as one might wish. However, there is just enough correlation to suggest a potential use for Radiolaria in Quaternary stratigraphy and to encourage further investigation.

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BIBLIOGRAPHY

- BENSON, R. N.
MS. *Recent Radiolaria from the Gulf of California*. Minnesota, Univ., Ph. D. thesis (1966).
- BIERI, R.
MS. *Distribution of the planktonic Chaetognatha in the water masses of the Pacific*. California, Univ., Scripps Inst. Oceanogr., Ph. D. thesis (1957).
- BRADSHAW, J. S.
1959 *Ecology of living planktonic foraminifera in the North and equatorial Pacific Ocean*. Cushman Found. Foramin. Res., Contr., vol. 10, pt. 2, pp. 25–64, pls. 6–8, text-figs. 1–43.
- BRINTON, E.
1962 *The distribution of Pacific euphausiids*. Scripps Inst. Oceanogr., Bull., vol. 8, no. 2, pp. 51–270, text-figs. 1–126.
- CLARK, CATHERINE A.
MS. *Radiolaria in Recent pelagic sediments from the Indian and Atlantic Oceans*. Cambridge Univ., Ph. D. dissertation (1965).
- CLEVE, P. T.
1900 *Notes on some Atlantic plankton-organisms*. K. Svenska Vetensk.-Akad., Handl., vol. 34, no. 1, pp. 1–22, pls. 1–8.
- EHRENBERG, C. G.
1872a *Mikrogeologische Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss*. K. Preuss. Akad. Wiss., Monatsber., Jahrg., 1872, pp. 265–322.
1872b *Mikrogeologische Studien ueber das kleinste Leben der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss*. K. Akad. Wiss. Berlin, Abh., Jahrg., 1872, pp. 131–399, pls. 1–12.
- HAECKEL, E.
1887 *Report on the Radiolaria collected by H. M. S. Challenger during the years 1873–1876*. Rept. Voy. Challenger, Zool., vol. 18, pp. i–clxxxviii+1–1803, pls. 1–140.
- HAYS, J. D.
1965 *Radiolaria and Late Tertiary and Quaternary history of Antarctic seas*. Amer. Geophys. Union, Antarctic Research, ser. 5, Biol. Antarctic Seas, vol. 2, pp. 125–184, pls. 1–3.
- HOLLANDE, A., and ENJUMET, MONIQUE
1960 *Cytologie, évolution et systématique des Sphaeroïdés (Radiolaires)*. Mus. Natl. Hist. Nat., Arch., ser. 7, vol. 7, pp. 1–134, pls. 1–64.
- JØRGENSEN, E.
1905 *The protist plankton and the diatoms in bottom samples*. Bergens Mus., Skr., ser. 1, no. 7, pp. 49–151, 195–225, pls. 6–18.
- NIGRINI, CATHERINE A.
MS. *Radiolaria in pelagic sediments from the Indian and Atlantic Oceans*. Scripps Inst. Oceanogr., Bull., in press.
- POPOFSKY, A.
1913 *Die Nassellarien des Warmwassergebietes*. Deutsche Südpolar-Exped. 1901–1903, vol. 14 (Zool., vol. 6), pp. 217–416, pls. 28–38.
1917 *Die Collosphaeriden, mit Nachtrag zu den Spumellarien und Nassellarien*. Deutsche Südpolar-Exped. 1901–1903, vol. 16 (Zool., vol. 8), no. 3, pp. 235–278, pls. 13–17.
- RIEDEL, W. R.
1958 *Radiolaria in Antarctic sediments*. B. A. N. Z. Antarctic Res. Exped., Repts., ser. B, vol. 6, pt. 10, pp. 217–255, pls. 1–4.
- RIEDEL, W. R., and FOREMAN, HELEN P.
1961 *Type specimens of North American Paleozoic Radiolaria*. Jour. Pal., vol. 35, no. 3, pp. 628–632, text-figs. 1–7.
- SVERDRUP, H. U., JOHNSON, M. W., and FLEMING, R. H.
1942 *The oceans. Their physics, chemistry, and general biology*. New York: Prentice Hall, pp. 1–1087, text-figs. 1–265.