ABSTRACT

The radiolarian species, Protocystis thomsoni *(Murray), is reported for the first time from the northeast Pacific Ocean. A detailed study indicated that this species shows considerable variation in the shape of the shell, as well as in the peristome and its teeth. Statistical treatment indicated that the shape of the shell has no taxonomic significance. The local distribution of the species and its position within the water column are discussed and compared with those of specimens from other parts of the world.*

The radiolarian Protocystis thomsoni (Murray) in the northeast Pacific Ocean

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INTRODUCTION

Radiolaria have long been recognized in the oceans of the world. Several monographic works, such as Haeckel (1887), *Challenger* Expedition; Borgert (1904–1913), Plankton Expedition; Haecker (1904–1908), Tiefsee Expedition; and Popofsky (1904–1926), Plankton and Südpolar Expeditions, indicate that the Radiolaria have a wide distribution and an enormous number of varieties and specimens.

A quick glance at the history of studies on modern Radiolaria presents an interesting phenomenon. A fine start, mainly by European scientists late in the last century, reached a culmination in the early part of this century, resulting in the many monographic works listed above. This momentum was suddenly lost all over the world, and consequently no additional major taxonomic contributions concerning the modern Radiolaria have been made, at least within the last two decades.

Radiolarian skeletons are one of the chief biological constituents of the surface sediments of the present-day sea bottom. This is particularly true in the Pacific Ocean. Riedel (1959) mapped a wide area of part of the eastern Pacific Ocean bottom as Radiolaria ooze. In the northeast Pacific Ocean, Nayudu and Enbysk (MS. in press) found that, in approximately half of the area between 40° and 65° N. lat. and between 124° and 170° W. long., the surface sediment was "Radiolaria-rich" sediment or "clays with Radiolaria", in which all other biologic elements were scarce. In the "Diatom-rich" area to the north, Radiolaria were also frequently found.

Modern Radiolaria in the northeast Pacific Ocean, north of 40° N. lat. and east of 180° W. long., have not been studied in detail. To obtain some knowledge of these Radiolaria, to provide the initial step for an understanding of their local distribution pattern, and to contribute to the compilation of their world-wide distribution, the writer is currently engaged in their study. The first report of the results of this continuing investigation is this detailed study of a phaeodarian Radiolaria species, *Protocystis thomsoni* (Murray), from plankton samples, including its taxonomic history, infraspecific variation, and distribution in the area.

ACKNOWLEDGEMENTS

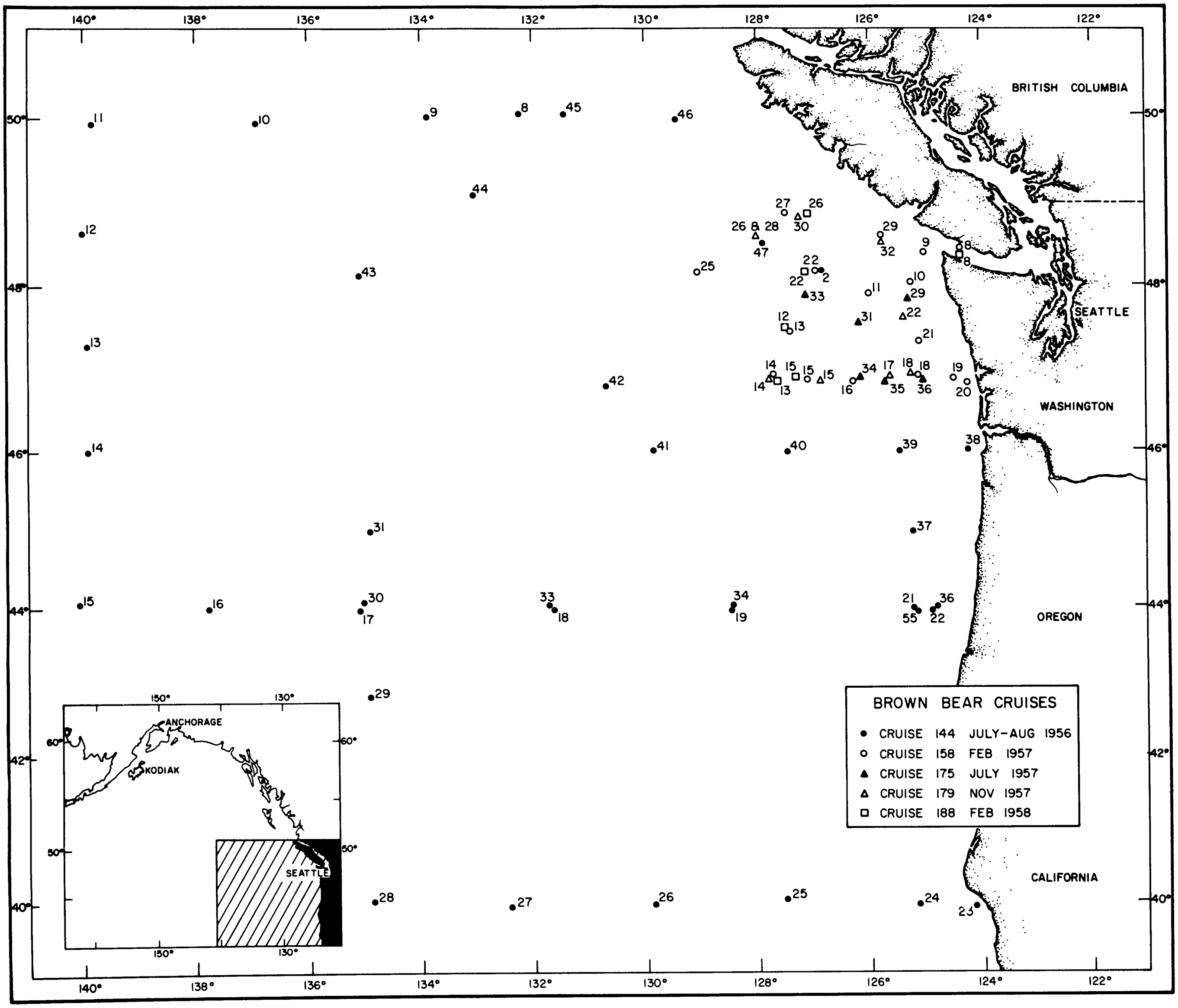
Grateful acknowledgement is extended to Betty J. Enbysk and Dean A. McManus, Department of Oceanography, University of Washington, for their helpful suggestions and critical reading of the manuscript. The writer is also indebted to Donald Doyle for preparing the illustrations and to Shirley J. Patterson for typing the manuscript.

This work is jointly supported by the Atomic Energy Commission Contract No. AT(45-1)-1725, and the Office of Naval Research Contracts Nonr-477(10) and Nonr-477(37), Project No. NR 083 012.

This paper is Contribution no. 340 from the Department of Oceanography, University of Washington, Seattle, Washington.

SAMPLES AND METHODS OF STUDY

During five cruises from 1956 to 1958, 102 plankton samples from 75 stations were collected aboard the research vessel, M. V. *Brown Bear*, of the Department of Oceanography, University of Washington. These stations are scattered in the area between 39° and 51° N. lat. and from the west coast of North America westward to 141° W. long. The area and the sample stations are shown in text-figure 1. The physico-chemical nature of the water mass of the area has already been presented by Smith (1963) in connection with his planktonic foraminiferal investigation of the same area.



TEXT-FIGURE 1

Stations of northeast Pacific Ocean samples collected on cruises of the *Brown Bear*.

A Clarke-Bumpus sampler (Clarke and Bumpus, 1950) with a 74-mesh nylon net of aperture size 0.239 mm. or a half-meter net of the same mesh size were used for the collection of the samples.

A portion of each sample was examined under a binocular microscope, and radiolarian specimens were picked out with a micropipette. Samples in which *Protocystis thompsoni* (Murray) were observed (Table 1) were further examined to recover more specimens for statistical study purposes.

All of the specimen and assemblage slides will be deposited permanently in the Micropaleontology Collections of the Department of Oceanography, University of Washington.

TAXONOMIC NOTES

Wallich (1869), in his article "On some undescribed Testaceous Rhizopods from the North Atlantic Deposits", noted a siliceous-shelled protozoan in the samples, named it *Protocystis*, and described it as a new genus. The generic characteristics were: "Shell siliceous, entire, hyaline; subglobular; surface of shell fitted with minute circular depressions." Among five species and varieties established by Wallich, only *P. aurita* was both described and illustrated (*loc. cit.*, p. 110, pl. 3, figs. 15–17). Wallich did not directly designate the type species of the genus, but in the explanation of figure 15 he used the notation "*Protocystis aurita* (nov. gen.)." On this basis, one can conclude that Wallich intended to name this species as the type species of the genus. This

TABLE 1

LIST OF THE REPORTED OCCURRENCES OF *Protocystis thomsoni* (Murray)

Station		Latitude	Longitude	Depth of occurrence	Remarks
Challenger (Haeckel, 1887)	289	39°41′S	131°23′W	4663m.	(*Ch. trifida* Haeckel) South Pacific Ocean (between New Zealand and Valparaiso)
	318	42°32′S	56°29′W	3721m.	
	319	41°54′S	54°48′W	4435m.	
	323	35°39′S	50°47′W	3475m.	
	324	36°09′S	48°22′W	5121m.	South Atlantic Ocean
	325	36°44′S	46°16′W	4846m.	
	326	37°03′S	44°17′W	5075m.	
	327	36°48′S	42°45′W	5303m.	
	328	37°38′S	39°36′W	5303m.	
	329	37°31′S	36°07′W	4892m.	
	330	37°45′S	33°00′W	4462m.	
Valdivia (Haecker 1906, 1908; Borgert 1911)	48	0°09′N	8°30′W	2400–2700m.	South Equatorial Current
	120	42°18′S	14°01′E	450–600m.	West Wind Drift
	121	43°52′S	13°06′E	350–500m.	
				50–300m.	
	132	55°21′S	5°16′E	1900–2500m.	Antarctic Drift
	136	55°57′S	16°15′E	900–1500m.	
	169	34°14′S	80°31′E	300–400m.	South Indian Ocean
	228	2°39′S	65°59′E	150–220m.	North Indian Ocean
Brown Bear Cruise 144	15	44°05′N	140°04′W	200–400m.	
	31	44°59′N	134°57′W	,, ,,	
	44	49°05′N	133°04′W	,, ,,	N. E. Pacific Ocean
	47	49°59′N	129°28′W	,, ,,	
	47	48°32′N	127°57′W	,, ,,	
*	*	*	*	0–50m.[1]	Kurile-Kamchatka Trough, N. W. Pacific Ocean

* Data unknown. Approximate location of Kurile-Kamchatka Trough from Udincev, G. B. (1954).
[1] Data from Reshetnyak (1955).

interpretation makes the designation an "original designation" of the type species, following Article 68 (a) (i) of the International Code of Zoological Nomenclature (1961).

In his preliminary report on the *Challenger* Collection to Professor Thomson, Murray (1876) separated these microorganisms from Radiolaria and discussed them under "Deep-Sea Rhizopods". Apparently, at this time he was unaware of Wallich's work, for he mentioned:

"Many other Rhizopods, with more or less flask-shaped or bivalved siliceous shells, which are undescribed, so far as is known.

"Mr. Wild has figured six of these last in Plate 24; for the sake of convenience we have been accustomed to call the organisms Challengeridae. This provisional name will be retained if it be found that these organisms are new to science and universally distributed in deep water."

Neither generic nor specific names were assigned to these organisms by Murray, nor was a description given for any of the six figured specimens. Only two of the figured six are now regarded as belonging to the family Challengeriidae. From the remarks quoted above it is not clear to the present writer whether Murray actually had in mind at that time using the provisional name "Challengeridae" in the sense of family rank or merely as a means of indicating the presence of more than one form. In any case, this provisional name could be presumed valid as a family name by Article 17 (8) of the International Code, but, at the same time, according to Article 11 (e) it is not valid because it is not "based on the name then valid for a contained genus...".

Haeckel (1879) classified the siliceous shells as Radiolaria and defined the family Challengeriidae. Obviously, Wallich's work was again ignored, because the generic name *Challengeria*, together with five other generic names, was included in this family. No definitions, illustrations, or specific names were given for these genera. Furthermore, some of the genera were later excluded from the family by Haeckel.

Murray (1885) figured 14 different named species under the generic name *Challengeria* and also recognized them as Radiolaria. He again did not present any description of these species; however, by illustrating them, he validated the generic name *Challengeria* for the first time, in accordance with Article 16 (a), and consequently the family name Challengeriidae also became valid. The generic name *Challengeria* is a junior synonym and will be replaced by *Protocystis* (see the later part of the paper). Nevertheless, the family name Challengeriidae must still be retained as valid, according to Article 40 of the International Code.

In his *Challenger* Report, Haeckel (1887) restricted the family Challengeriidae from his previous article and also subdivided it into two subfamilies and six genera. For one of the genera the name *Challengeria* was retained. Haeckel was still unaware of Wallich's work.

Borgert (1901, 1904), who first called attention to Wallich's article, reintroduced the name *Protocystis* to replace the name *Challengeria*, which he regarded as a junior synonym. Haecker (1906, 1908) acknowledged Wallich's contribution, but at the same time tried to retain the name *Challengeria* by restricting it to a narrower sense. He defined *Challengeria* Murray, emend. Haecker (*s. str.*) as: "Peristom einzähnig. Randstacheln fehlen"; and *Protocystis* Wallich as: "Peristom zwei- bis dreizähnig. Höchstens zwei Randstacheln." Borgert (1911) reviewed Haecker's classification and expressed the opinion that for practical purposes he was still in favor of retaining Haeckel's scheme with the modification of restoring the older name *Protocystis* to replace *Challengeria*. The genus *Protocystis* Wallich is defined by Borgert as: "Challengeriden ohne pharynx, mit einem oder mehreren Zähnen an der Schalenmündung, aber ohne Randstacheln." The writer follows Borgert's definition in the present paper because of the fact that the number of teeth is quite variable within the species discussed below and is therefore not suitable as a generic criterion.

It should be noted here that, in Campbell's paper on Radiolaria in the "Treatise on Invertebrate Paleontology" (1954), both of the generic names *Challengeria* and *Protocystis* are retained, although the criteria of absence of marginal spines and presence of oral teeth are common to both.

SYSTEMATIC DESCRIPTION

In the present paper, Campbell's classification scheme (1954) is generally followed with the modification of 1) recognizing *Protocystis* as the generic name, because it has priority over its synonym *Challengeria*, and 2) dropping all the subgeneric names based on the numbers of oral teeth.

Class Actinopoda Calkins, 1909
Subclass Radiolaria Müller, 1858
Order Osculosida Haeckel, 1887
Suborder Phaeodarina Haeckel, 1879
Superfamily Challengeriicae Murray, 1885
Family Challengeriidae Murray, 1885
Subfamily Challengeriinae Murray, 1885
Genus Protocystis Wallich, 1869

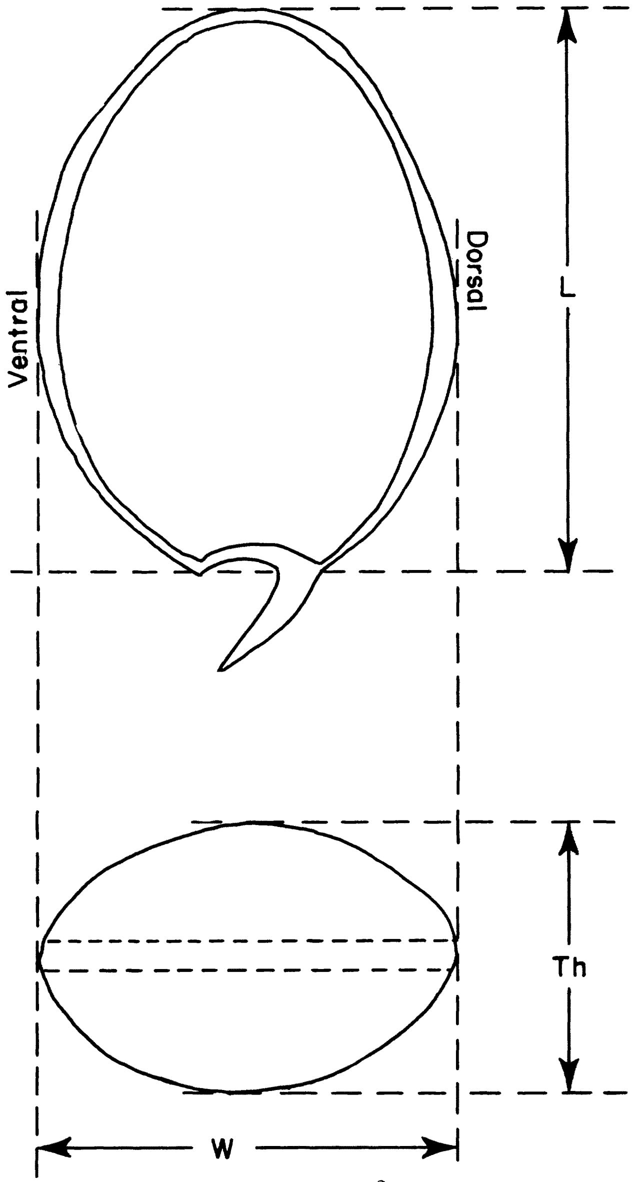
Protocystis thomsoni (Murray)
Plate 1, figures 1–11; plate 2, figures 1–7

Challengeria thomsoni Murray, 1885, Rept. Voy. *Challenger*, Narrative, vol. 1, pt. 1, p. 226 (pl. expl.), pl. A, fig. 2.
Challengeria (Challengeretta) thomsoni Murray. – Haeckel, 1887, Rept. Voy. *Challenger*, Zool., vol. 18, pt. 2, p. 1650.
Protocystis thomsoni (Murray). – Haecker, 1906, Archiv Protistenk., vol. 7, no. 2, pp. 291–292, text-fig. Fb. – Haecker, 1908, Deutsch. Tiefsee-Exped., Wiss. Ergebn., vol. 14, pp. 261–262, pl. 49, figs. 388–389; text-fig. 29b. – Borgert, 1911, Plankton-Exped., Ergebn., vol. 3, pt. 11, pp. 440–441, text-figs. 7a–b. – Reshetnyak, 1955, Akad. Nauk SSSR, Zool. Inst., Trudy, vol. 21, p. 98, fig. 2 (in plate).
?*Challengeria (Challengerilla) trifida* Haeckel, 1887, Rept. Voy. *Challenger*, Zool., vol. 18, pt. 2, p. 1652.
Not *Challengeria thomsoni* (Murray). – Hensen, 1887, Komm. wiss. Unters. deutsch. Meere in Kiel, 1882–1886, Ber., no. 5, p. 79, pl. 6, figs. 70–72. – Möbius, 1887, *ibid.*, p. 121.

Orientation: A few words should be inserted here concerning the orientation of the *Protocystis* shell. The shell is oriented in such a way that its dorsal side is indicated by the location of the peristome process and the ventral side by the location of the center of the free oral margin (see text-figure 2), as mentioned by Haeckel (1887) and followed later by Haecker (1906, 1908) and Borgert (1901, 1904, 1911).

However, no evidence as to the living position of the microorganism is available. In the illustrations of Wallich (1869), Murray (1876, 1885), Haeckel (1887), and Borgert (1901, 1904, 1911), the oral part of the shell is shown as the upper pole. Haecker (1904, 1906, 1908), considering the static condition, as well as knowledge of the other forms of Tripylea, particularly the Tuscaroridae, suggested that the oral pole pointed downward. In the present investigation, although the oral end is considered to point downward, as shown in text-figure 2, in plates 1 and 2 this orientation is intentionally reversed for convenience of observation and illustration of the details of the variable features.

Description: Shell oval to circular in outline in side view, moderately compressed laterally, bilaterally symmetrical; mouth oval to circular in shape; peristome process semicircular at base, extending obliquely, covering over a part of the mouth; proximal half of the peristome process an open half-cylinder, distal



TEXT-FIGURE 2

Diagrammatic sketches to illustrate the measurements of *Protocystis thomsoni* (Murray). L = length of shell, W = width of shell, Th = thickness of shell.

half forked, with two parallel to subparallel, thin pointed teeth in most cases; sometimes with a small third tooth developed on the dorsal side and situated between the other two teeth in oral view.

Dimensions: Length of the shell 349 (304–384) μ, width 280 (256–320) μ, thickness 190 (176–208) μ. Length of the peristome process, plus teeth, 64–100 μ.

WALL STRUCTURE

The delicate wall structure, the "Diatomeenstruktur" of Borgert (1901, 1911), Haecker (1906, 1908), and Schröder (1913), of challengeriids was noted even before the group was included in the Radiolaria. Murray (1876) described the structure in these words: "the shells of all have an exceedingly beautiful tracery, a fenestrated appearance often, which was at first supposed to be due to perforations of the shell, but which a closer examination shows to be caused by pit-like depressions..." Later (1885, pl. A, fig. 2a), he illustrated the vertical cross section of the shell wall of *Protocystis thomsoni* (Murray). He also recognized that the pore and cavity structures are different in different species. Haeckel (1887), Haecker (1906, 1908), and Schröder (1913) studied the wall structure of other species of the genus, but none of them made a detailed investigation of the present species.

In order to study the wall structure in detail, two specimens of *Protocystis thomsoni* (Murray) from the northeast Pacific Ocean were intentionally broken, after measurement of the shell and study of the oral area were completed. Several pieces of the shells were then mounted in various orientations on glass slides for microscopic examination. The fragments on the slides were examined under transmitted light and under phase contrast, as well as under dark field illumination, with magnification up to 1600 times.

The following conclusions resulted from these observations. In the external surface view, the shell wall is actually penetrated by numerous tiny openings in the outer margin of the shell wall (plate 1, figure 1). On lowering the plane of focus, the expanding openings become circular, and hexagonal meshes (similar to the areolae of diatoms) formed by the walls between the cavities become apparent (plate 1, figure 2). As the focus is further lowered, the hexagonal meshwork becomes clearer (plate 1, figure 3), and finally, as the plane of focus reaches the innermost part of the shell wall, the tiny openings reappear (plate 1, figures 4–5). These openings are interpreted as the openings in the inner margin of the shell wall.

In vertical cross section, the outer margin of the shell wall is smooth, and each cavity, the "intraparietal cavity" of Haeckel (1887) and "Kämmerchen" of Haecker (1906, 1908), is a cylindrical canal with nearly uniform width throughout, and narrow openings at both the outer and the inner margin of the shell wall (plate 1, figure 6).

The above observations and their interpretation indicate a wall structure that differs from the structure portrayed by Murray (1885). His vertical cross section of the shell wall is refigured here (plate 1, figure 7) from his original illustration (*loc. cit.*, plate A, figure 2a) for comparative purposes. It is clear that, in Murray's drawing, the opening of each cavity at the outer margin of the shell is considerably larger than that at the inner one and shows a circular depression on the outer margin of the shell. He also depicted the cavity as spindleshaped, constricted at about $\frac{2}{3}$ of the distance from the outer margin, then sharply expanded to the original width, and finally narrowed again at the innermost part, which penetrates the inner margin of the shell and forms a tiny pitlike opening. There seems to be no doubt that Murray's specimen (*loc. cit.*, plate A, figure 2) belongs to the present species, *Protocystis thomsoni* (Murray). The above differences in opinion may have resulted from the different methods of observation used and the subsequent interpretation of the structure, or the shape of the cavities themselves may be quite variable within this single species, as well as among separate species.

VARIATION

Variable features exhibiting wide ranges have been observed in the specimens of *Protocystis thomsoni* (Murray) from the northeast Pacific Ocean. These are the shape of the shell, the character of the peristome and its teeth, and the thickness of the shell wall.

Shape of shell

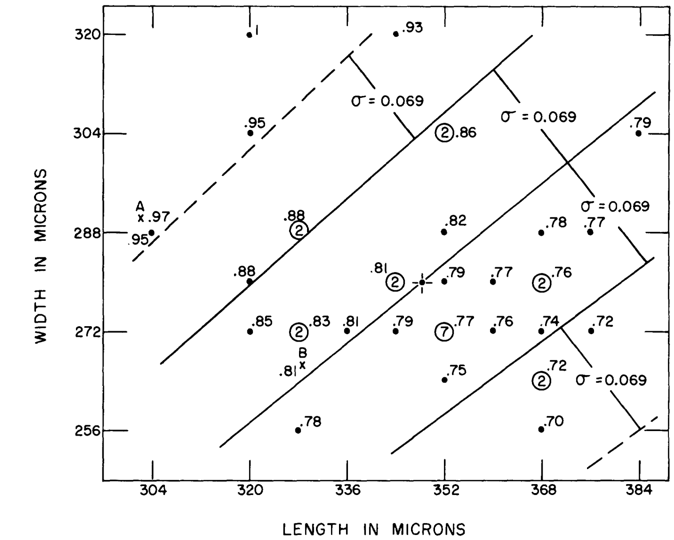
The shape of the shell of the species varies considerably. Haecker (1906) noticed this variation and designated the oval forms as var. *ovalis* and the round forms as var. *circularis*. At the same time, he also noticed that the shell is thicker for the former than the latter and interpreted this as due to some ecological factors, but failed to mention the occurrence of intermediate forms between the two. Borgert (1911), while confirming the existence of the above two different forms, recognized the presence of intermediate forms between the two varieties in his samples from the Plankton Expedition.

The two above-mentioned variations, as well as the intermediate forms, were recovered from the present northeast Pacific Ocean samples. Although most of the specimens are oval, like the specimen figured by Murray, gradational variations are present from true oval to almost completely circular. Because of the diversity of forms, a statistical evaluation was made of these shape variations.

The two varieties, *ovalis* and *circularis*, are based on the shape of the shell in lateral view. Thickness of the shell was not considered in the analysis, as it varies only slightly, from 186 to 208 microns, and does not directly affect the outline of the shell.

All specimens recovered from the samples studied were measured as shown in text-figure 2, and measurements of the width and length of the shell and the ratio of width to length were then plotted in a scatter diagram (see text-figure 3). In the diagram, the measurements and the width to length ratio of var. *circularis* and var. *ovalis* from Haecker's original figures (1908, plate 49, figures 388–389) were also plotted for comparison.

It can easily be seen from text-figure 3 that the ratio of width to length varies continuously without any appreciable break and that only one population appears to be present instead of two. The two varieties, *circularis* and *ovalis*, of *Protocystis thomsoni* (Murray) are names only of the extreme forms or the end members of a continuous series of variation of the species.



TEXT-FIGURE 3

Scatter diagram of the ratio of width to length plotted in length-width graph of *Protocystis thomsoni* (Murray) from the northeast Pacific Ocean.

② = number of specimens which have the same dimensions.

-¦- = mean measurements of the population: $\bar{L} = 348.5\mu$; $\bar{W} = 280.2\mu$; $\frac{W}{L} = 0.804$. The diagonal line passing through this point is the line of the mean value of the ratio of width to length.

A × = measurements of *Protocystis thomsoni* var. *circularis* (from Haecker, 1908, pl. 49, fig. 388).

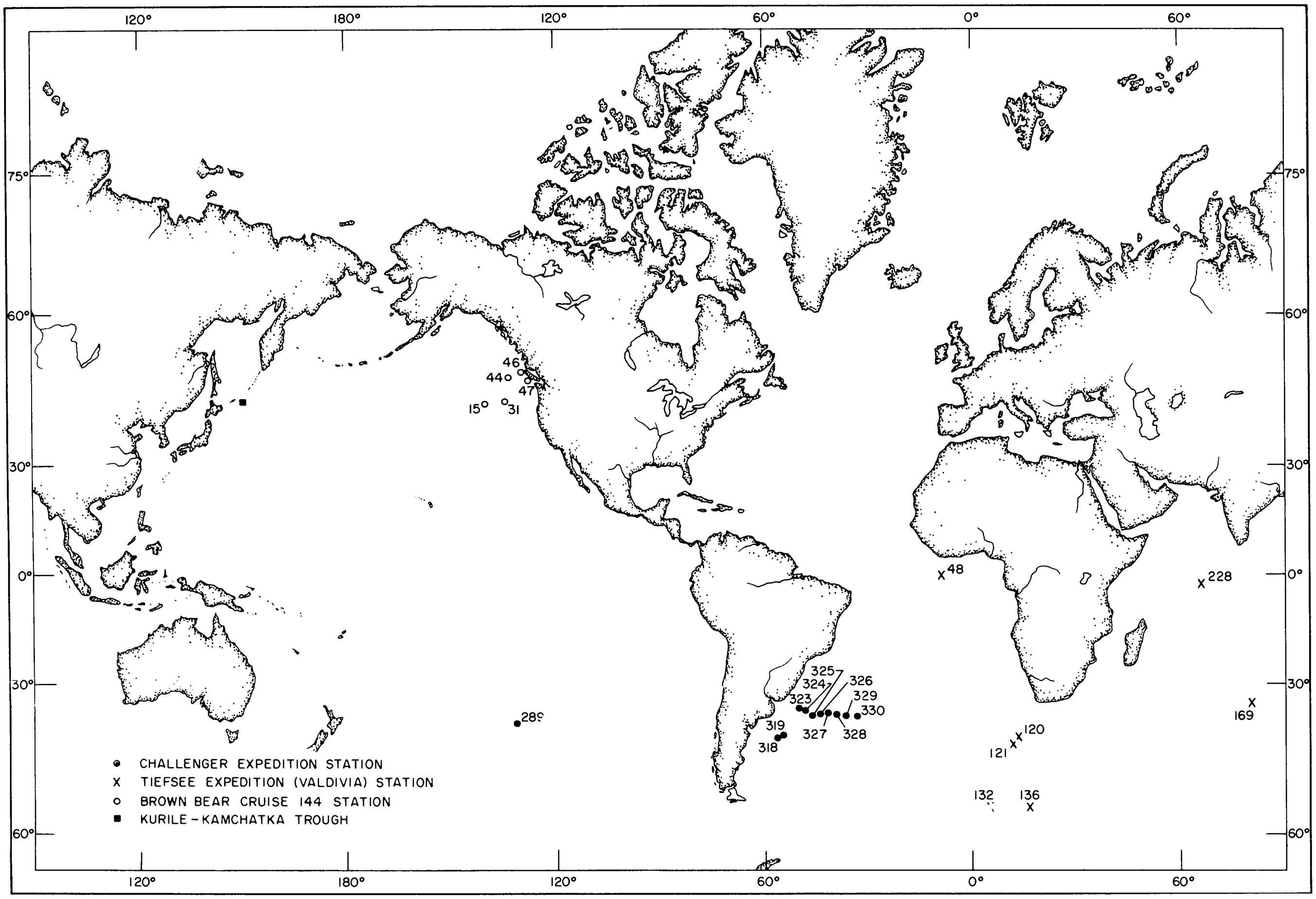
B × = measurements of *Protocystis thomsoni* var. *ovalis* (from Haecker, 1908, pl. 49, fig. 389).

σ = standard deviation of the ratio of width to length.

Peristome process and teeth

There are considerable variations in the direction of the peristome process and teeth in side view. If the oral margin is considered as horizontal, as shown in text-figure 2, the angle of the direction of the peristome process varies from a high angle (plate 2, figures 1a, 2a, 6a, 7a) to a very low angle (plate 2, figure 4a). The direction of the teeth also shows gradation from a high angle (figures 1a, 2a, 6a, 7a) to intermediate angles (figures 3a, 4a) to almost horizontal (figure 5a). The direction of the teeth and that of the peristome process vary from almost the same (figures 1a, 2a, 6a, 7a) to considerably different (figure 5a).

In oral view, the tooth directions also show different patterns, nearly parallel (figures 2d, 6d, 7d), distinctly divergent (figure 4d), and tending to converge (figures 1d, 3d) with, in the extreme case, both teeth touching (figure 5d).



TEXT-FIGURE 4

Map of the world showing the distribution pattern of the reported occurrences of *Protocystis thomsoni* (Murray).

The length of the teeth is also highly variable, ranging from quite long to very short.

The third tooth on the dorsal side, if present, is generally short, pointed and straight. The direction may coincide with that of the peristome process and the other teeth (figure 6a) or be slightly divergent (figure 7a).

Thus it is almost impossible to state which pattern of the teeth and peristome process should be considered the most characteristic of the species. These variations, therefore, cannot be considered of any taxonomic value.

Thickness of shell wall

The variation in the thickness of the shell wall of the species and its relationship to vertical distribution of the microorganism should also be considered here. Generally, in tripylean Radiolaria, the thicker, larger shell is found at the greater depths, while the thinner, smaller form is found near the surface or at shallower depths. Also it has been noticed that the circular specimens have thinner shell walls than those of the oval or nearly oval specimens (Haecker, 1906, 1908). The latter trend is also found in the specimens recovered from the northeast Pacific Ocean (plate 1, figures 8, 11).

However, within the present species, the thickness of the shell wall varies considerably in each specimen, depending on the place where the measurement is made, and this is particularly true in the oval and related forms, as shown in plate 1, figures 8–10. In this respect, the circular form (figure 11) is less variable throughout the specimen. Unless some agreement is reached as to where the thickness of the shell wall is to be measured, it is difficult to make any meaningful comparison.

Furthermore, in the present study, as well as in that of Haecker (1906), the thin-walled circular form and the thick-walled oval form were both found in the same plankton samples. Therefore, the thickness of the shell wall is highly variable, and no conclusion can be drawn on its relationship to depth.

HORIZONTAL DISTRIBUTION

This paper constitutes the first reported occurrence of *Protocystis thomsoni* in the northeast Pacific. As stated earlier, only 5 out of over 100 samples from the area contained the species. Therefore, there are too few occurrences to give any definite conclusion concerning the horizontal distributional pattern or to detect any relationship between the distribution of the species and the physico-chemical environment of the water mass. Future study of plankton samples from the North Pacific Ocean may provide this information.

The occurrences of the species in other parts of the world, as reported by Haeckel (1887), Haecker (1906), and Reshetnyak (1955), are listed in Table 1, and the distribution of these authors' sample stations is mapped in text-figure 4.

Haecker (1906), relying on Haeckel's data from the *Challenger* Expedition and his own samples from the Plankton Expedition, considered that *Protocystis thomsoni* has a "unipolar" distribution. The present findings of the species on the American side and Reshetnyak's discovery in the Kurile-Kamchatka trough on the Asiatic side of the North Pacific Ocean indicate that the species has instead a wide geographical distribution.

VERTICAL DISTRIBUTION

Although *Protocystis thomsoni* (Murray) is considered to be one of the characteristic forms of deep water, Haecker (1906) found that most deep-water tripylean Radiolaria can also occur at shallower depths. He reported this species in the 500 to 350 m. and 300 to 50 m. samples from *Valdivia* Station 121. Proceeding to the north and entering the warmer waters of the South Atlantic, he found the same species in abundance at 1000 or 1500 m. to 4000 or 5000 m. in depth. From these facts, Haecker termed the present species a "submergent" species.

The known vertical distribution of *Protocystis thomsoni* (Murray) in the northeast Pacific Ocean is not conclusive because the species occurs at only a few stations and because the maximum sampled depth was only 400 m. All of the specimens found in the present study were from samples taken from 400 to 200 m. in depth. No specimens were found at these same stations in the samples between 200 m. and the surface.

The recent findings of Reshetnyak (1955) are important. He reported that *Protocystis thomsoni* (Murray) is one of the stenobathyal index forms of "surface Radiolaria" (0 to 50 m. depth horizons) in the Kurile-Kamchatka trough. The "surface Radiolaria" characterize a surface water mass of a mean temperature of 2.6° C and a salinity of $33.0^{0}/_{00}$ (Orlov *et al.*, 1959).

The following explanation might account for these distributions. This is a cold-water species, and its distribution is controlled by the temperature of the water mass. The shallower occurrence reported by Reshetnyak is probably due to the northerly trend of isotherms in the North Pacific Ocean from west to east (Fleming, 1955). Haecker's (1906) discovery of this species in deep water in warm regions and its shallower occurrence in the colder area can be explained by the progressive submergence of cold water in the temperate and tropical zones. If these interpretations are further substantiated, then *Protocystis thomsoni* (Murray) will become a useful index form for the distribution of a cold water mass. Samples from the northeast Pacific Ocean from below depths of 400 m. are still needed to ascertain the vertical distribution of the species from this area.

CONCLUSIONS

1) The presence of the radiolarian species *Protocystis thomsoni* (Murray) is reported within the area between 39° and 51° N. lat. and from the west coast of North America westward to 141° W. long.

2) The shape of the shell, the pattern of the teeth, the direction of the peristome process and teeth, and the thickness of the shell wall are highly variable within the species and, therefore, can not be considered to be of any taxonomic value.

3) The details of the wall structure are discussed and illustrated. The interpretation of the wall structure indicated that the parietal cavities are more or less cylindrical and that their structure is, therefore, slightly different from that figured in a previous study made by Murray (1885).

PLATE 1

1–11 *Protocystis thomsoni* (Murray)

All specimens from the northeast Pacific Ocean.

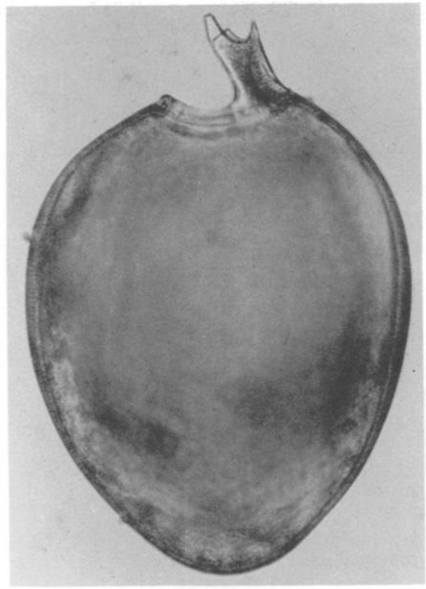
1–5, detailed shell wall structure at 5 inwardly different focus levels, × 1600.

6, diagrammatic illustration of the vertical cross section of the shell wall.

7, diagrammatic illustration of the vertical cross section of the shell wall by Murray (1885, pl. A, fig. 2a).

8–11, specimens from *Brown Bear* Cruise 144, Station 46, showing the shape variation from oval to circular forms, × 200.


8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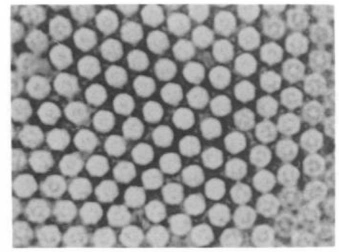
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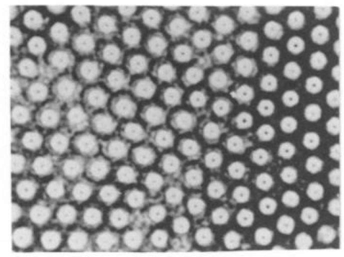
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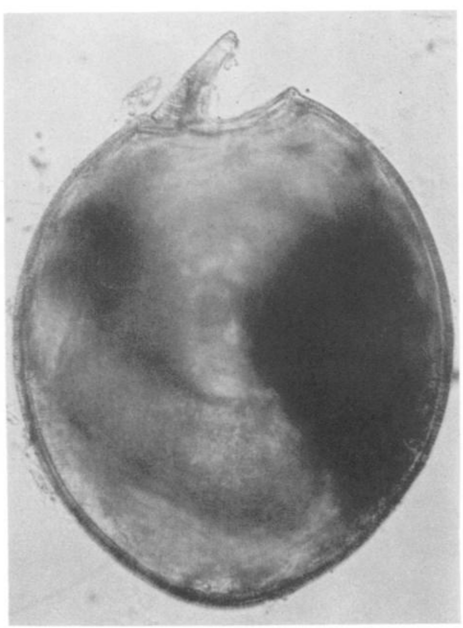
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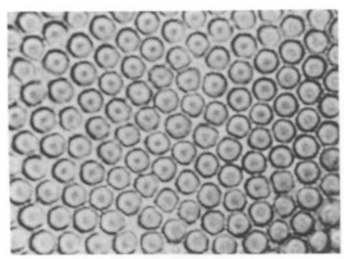
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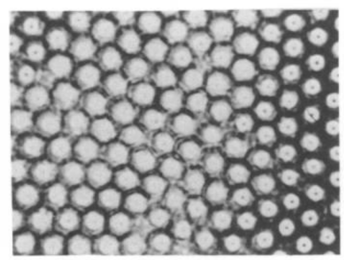
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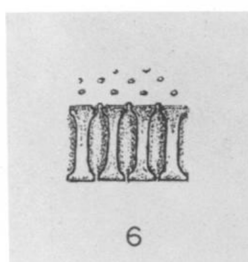
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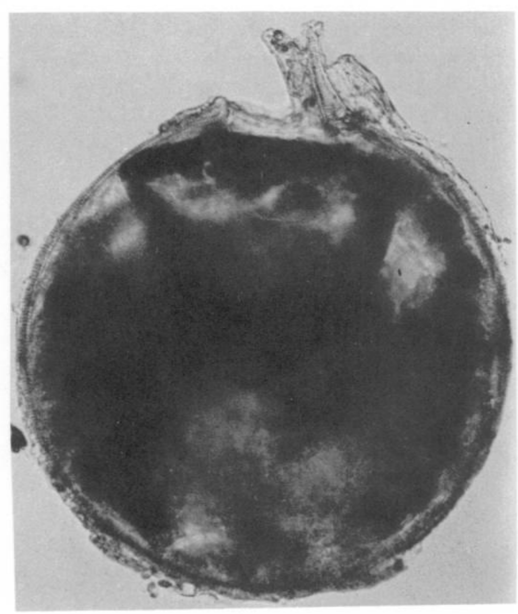
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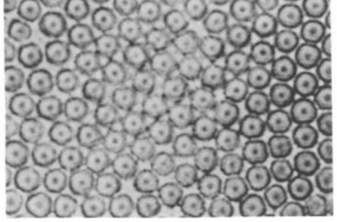
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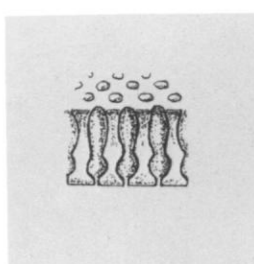
7

4) Although no distributional pattern is suggested from the present study, the presence of the species on the Asiatic and on the American side of the North Pacific Ocean, as well as in the South Atlantic, indicates that the species has a wide geographical distribution in both hemispheres and is not one of the unipolar distributional forms as assumed by Haecker (1906, 1908).

5) Vertical distribution of the species in the northeastern Pacific samples available at present is between depths of 400 and 200 m.

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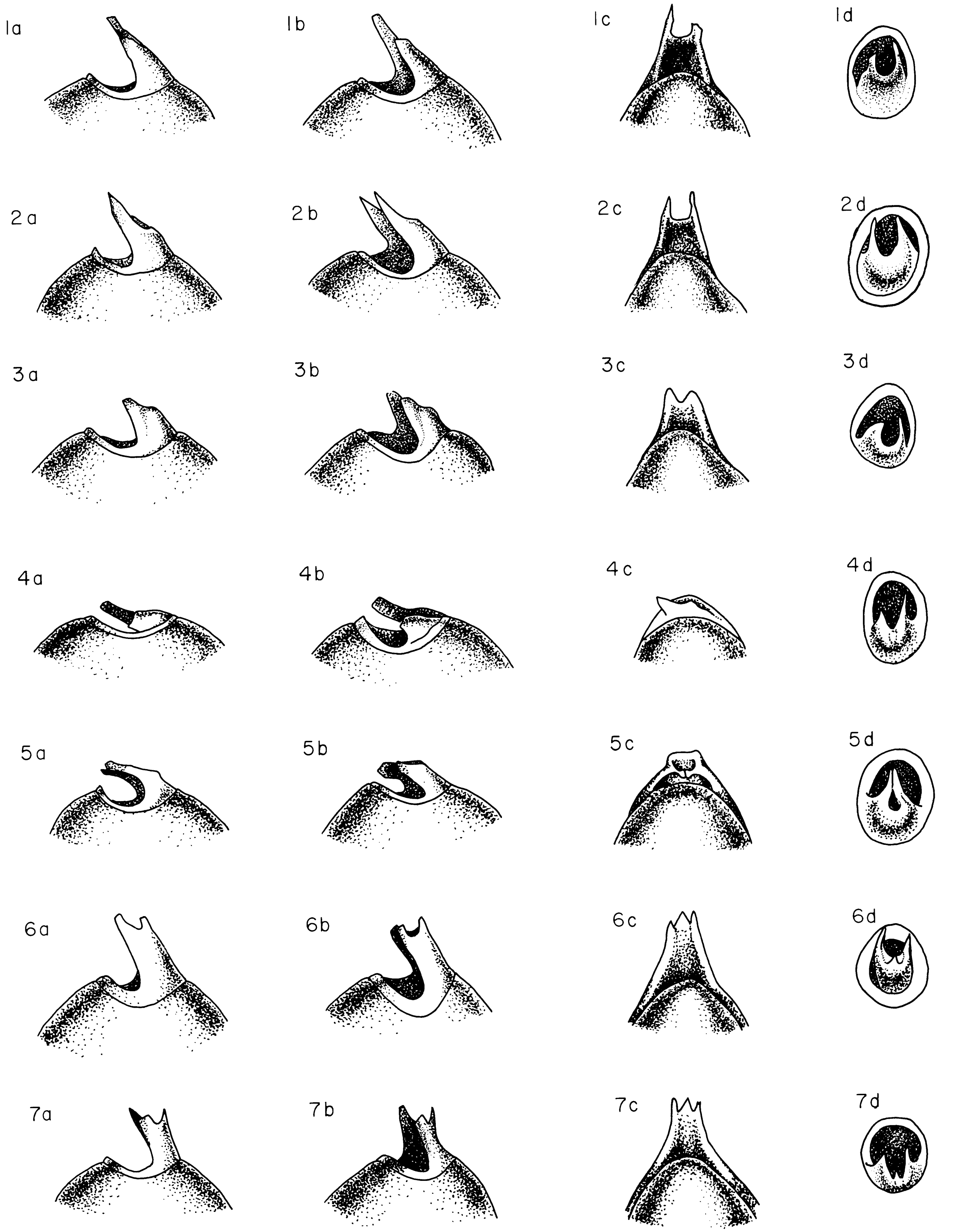
PLATE 2

1–7 *Protocystis thomsoni* (Murray)

All specimens from the northeast Pacific Ocean; observed variation patterns of oral structure, × 150; a, side view; b, oblique side view; c, ventral view; d, oral view.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