G. Arthur Cooper

Homeomorphy in Recent Deep-Sea Brachiopods

SMITHSONIAN CONTRIBUTIONS TO PALEOBIOLOGY NUMBER 11

SERIAL PUBLICATIONS OF THE SMITHSONIAN INSTITUTION

The emphasis upon publications as a means of diffusing knowledge was expressed by the first Secretary of the Smithsonian Institution. In his formal plan for the Institution, Joseph Henry articulated a program that included the following statement: "It is proposed to publish a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge." This keynote of basic research has been adhered to over the years in the issuance of thousands of titles in serial publications under the Smithsonian imprint, commencing with *Smithsonian Contributions to Knowledge* in 1848 and continuing with the following active series:

Smithsonian Annals of Flight
Smithsonian Contributions to Anthropology
Smithsonian Contributions to Astrophysics
Smithsonian Contributions to Botany
Smithsonian Contributions to the Earth Sciences
Smithsonian Contributions to Paleobiology
Smithsonian Contributions to Zoology
Smithsonian Studies in History and Technology

In these series, the Institution publishes original articles and monographs dealing with the research and collections of its several museums and offices and of professional colleagues at other institutions of learning. These papers report newly acquired facts, synoptic interpretations of data, or original theory in specialized fields. These publications are distributed by mailing lists to libraries, laboratories, and other interested institutions and specialists throughout the world. Individual copies may be obtained from the Smithsonian Institution Press as long as stocks are available.

S. DILLON RIPLEY
Secretary
Smithsonian Institution

SMITHSONIAN CONTRIBUTIONS TO
PALEOBIOLOGY

NUMBER 11

G. Arthur Cooper

Homeomorphy in Recent Deep-Sea Brachiopods

SMITHSONIAN INSTITUTION PRESS
CITY OF WASHINGTON
1972

ABSTRACT

G. Arthur Cooper. Homeomorphy in Recent Deep-Sea Brachiopods. *Smithsonian Contributions to Paleobiology,* number 11, 25 pages, 5 figures, 4 plates. 1972.—A collection of brachiopods from the Baja California Abyssal Plain forms a deep-sea assemblage unusual in that it contains three genera that are unrelated but externally almost identical; i.e., they are homeomorphs. One is *Neorhynchia,* an impunctate rhynchonellid; the second, a punctate terebratulid with short loop, is called *Abyssothyris;* and the third is referred to a new genus, *Notorygmia,* related to *Macandrevia.* A discussion of homeomorphy is followed by the systematics of the genera and species involved.

Official publication date is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, Smithsonian Year.

UNITED STATES GOVERNMENT PRINTING OFFICE
WASHINGTON : 1972

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 50 cents (paper cover)

Contents

G. Arthur Cooper

Homeomorphy in Recent Deep-Sea Brachiopods

Introduction

The collection that forms the subject of this paper was sent to me by Mr. Spencer R. Luke of the Aquarium Museum, Scripps Institution of Oceanography, La Jolla, California. Most of the material was collected by Professor Carl Hubbs and collaborators of the Scripps Institution whose work was supported by NSF Grants Nos. GBS 13319 and GS 1300. Permission to describe the material was kindly granted by Dr. William A. Newman. I am grateful to all of these men for their generosity in permitting this study and for permitting retention of the type specimens and study set in the national collection. These specimens and those retained by Scripps constitute the finest collection of abyssal brachiopods yet made.

Thanks are given to Dr. Helen McCammon, Field Museum of Natural History, Chicago, and to Dr. Richard E. Grant for critically reviewing this paper. Their suggestions proved helpful and valuable. Thanks are also due to Mr. Lawrence B. Isham, visual information specialist at the National Museum of Natural History for his fine drawings of the lophophore of *Neorhynchia* and *Abyssothyris*.

Homeomorphy

Homeomorphy, or convergence of exterior form, in Recent brachiopods occurs in three unrelated genera inhabiting the Baja California Abyssal Plain off the coast of California. Association of these genera is not confined to the Baja California Abyssal Plain but has been identified in the Pacific south of California to the Antarctic. The associated genera are *Abyssothyris, Neorhynchia,* and *Notorygmia* (a new genus for the species hitherto identified as *Macandrevia diamantina* Dall). The homeomorphy exhibited by *Abyssothyris* and *Neorhynchia* was described by Muir-Wood (1960). The example from the Baja California Abyssal Plain is more remarkable because it involves three genera having almost identical external form and representing two orders and three superfamilies of brachiopods. So precise is the homeomorphy that the first two genera were mistaken and described under the name *Terebratula wyvillii* by Thomas Davidson (1878), a usually astute observer and the most widely informed brachiopod worker of the last century.

Homeomorphy is common among the brachiopods and has attracted considerable attention. Examples from the Paleozoic Era have been described by Cooper (1930), Ulrich and Cooper (1936), and Bell (1938); and from the Mesozoic by Cloud (1941) and Buckman (1901, 1906). Cooper (1970, p. 238) indicated homeomorphy in Tertiary and Recent brachiopods. Mimicry of external form in the brachiopods often is so deceptive that it has led to difficult problems in classification and identification. The confusion created by homeomorphy is nowhere better shown than that revealed by Muir-Wood in *Abyssothyris* and *Neorhynchia.* Although this astute worker was aware of the pitfalls of homeomorphy, the third member of the trio mentioned above escaped her.

Abyssothyris was proposed by Thomson (1927, p. 190) for the deep-sea species *Terebratula wyvillii* Davidson (1878) taken from collections made by the *Challenger* Expedition. Specimens were taken from depths ranging from more than 6,000 feet (1,830 m) to deeper than 17,000 feet (5,183 m). The species was named after Wyville Thomson, and the name was later corrected to *T. wyvillei* (Thom-

G. Arthur Cooper, Department of Paleobiology, Smithsonian Institution, Washington, D. C. 20560.

son, 1927, p. 199). In studying Davidson's described and figured specimens in the British Museum (Natural History), Muir-Wood discovered that another species, *Neorhynchia strebeli* (Dall), was misidentified by Davidson as *T wyvillei.* Davidson's specimens all came from the Southern Hemisphere off Australia, the Falkland Islands, and Chile.

Neorhynchia also was named by Thomson (1915, p. 388), who selected *Hemithyris strebeli* Dall from the mid-Pacific as the type species. These two brachiopods, *A. wyvillei* and *N. strebeli,* share a feature—their sulcate anterior commissure—that makes them similar in appearance and has caused the confusion between the genera. These brachiopods are anteriorly folded toward the ventral side; thus, the ventral valve has a marked median fold, and the dorsal valve has a median sulcus of varying depth.

In a survey of the brachiopods in the National Museum, Dall (1920) designated type localities for each of the species. This was done in ignorance of the generic composition of the lots taken from some of the named localities. In the case of *Terebratula (Abyssothyris) wyvillei,* Dall (1920, p. 321) stated: "As Davidson appears to have selected no special locality among those he enumerates in the Challenger Report, I choose station 299, off Valparaiso, Chile in 2160 fathoms [12,960 feet], gray mud, bottom temperature 34°F." Not realizing the role that homeomorphy can play in such matters, Dall inadvertently selected a locality where specimens of *Neorhynchia* misidentified by Davidson as *Abyssothyris* occur. Also taken at this station was another brachiopod, *Waldheimia wyvillii* Davidson, which will be referred to later.

Muir-Wood (1960, p. 523) states:

> Unfortunately the only specimens preserved from here [Challenger station 299] are both *Neorhynchia,* one of which was figured by Davidson in 1880 (pl. 2, figs. 8, 8a), also in 1886 (pl. 2, fig. 9), no. ZB 1161 as *T.* [*Terebratula,* the generic name used by Davidson] *wyvillei* [Muir-Wood overlooked the occurrence of *Waldheimia wyvillii* at the same station]. If Dall's selection is to be accepted then the type specimen of *Terebratula wyvillei* is a rhynchonellid and *Abyssothyris* would have to be replaced and become a synonym of *Neorhynchia. Abyssothyris wyvillei* would become *Neorhynchia wyvillei.* The terebratulid *Abyssothyris* sens. str. would be left without either a generic or specific name and would have to be renamed.

Muir-Wood further points out that the question of inclusion of a type locality in the description of a new species was not embodied in the new International Code of Zoological Nomenclature. She also indicates that inasmuch as "Dall's selection was made in 1920 and that the rules of that date did not provide for the definition of a nominal species by reference to a type locality, the selection can be set aside, and a lectotype chosen from another Challenger Station." This recommendation was followed by the designation of specimen ZB 1160 (from *Challenger* station 160 at 2,600 fathoms) as the lectotype.[1] The type thus fixed is wider than long and has a narrow, deep fold on the ventral valve and a narrow, deep sulcus on the dorsal valve. The lectotype measurements, in millimeters (taken from Muir-Wood, 1960, pl. 7, figs. 5a-c), are as follows: length 12.5, width 14.5, and thickness about 8.0. A second specimen (Muir-Wood, 1960, pl. 7, figs. 3a-c) has the following measurements: length 12.7, width 12.7, and thickness 8.0. Thus, the specimens are slightly wider than long or are equal in length and width, quite unlike those from the Baja California Abyssal Plain that are described below. An immature specimen illustrated by Muir-Wood (1960, pl. 7, fig. 1) is slightly longer than wide: length 10.5 mm and width 9.5 mm.

Specimens of *Neorhynchia* misidentified by Davidson as *Terebratula wyvillii* were taken by the *Challenger* at station 184 south of New Guinea at 1,400 fathoms and at station 299 off Valparaiso, Chile, at 2,160 fathoms. A specimen from the former locality is 15 mm long by 16.5 mm wide, representing a shell with width greater than the length. The sulcus is broad and shallow and the fold low.

Study of the specimens submitted by Scripps Institution complicates matters still further. Comparison of the types of *Terebratula wyvillii, Hemithyris (Neorhynchia) strebeli* Dall, and *Macandrevia (Notorygmia) diamantina* with the specimens from the Baja California Abyssal Plain indicates that the latter are not the same as Davidson's and Dall's species. When plotted with the large collection of *Neorhynchia* from the Baja California Abyssal Plain, the specimen of *N. strebeli* falls entirely outside the range of variation of the largest California specimens. Examples of *Macandrevia diamantina* from off Cocos Island, west of Panama, the type locality,

[1] Article 16(b) of the 1961 edition of the International Code of Zoological Nomenclature adopted by the XV International Congress of Zoology specifically rules out mention of a type locality as an "indication" in establishing a type species.

are yellow, flat, and expanded, whereas specimens from the Baja California Abyssal Plain are translucent white, very deep, and elongated. Other specimens of this sulcate type of *Macandrevia* from locations farther south and in Antarctic seas are similar to the California specimens rather than to those from off Cocos Island. *Abyssothyris wyvillei,* primarily a southern species, is deeply sulcate and wider than long. Dall's specimens identified as *A. wyvillei* from southwest of the Galápagos are not like Davidson's specimens, nor are they close to those from the Baja California Abyssal Plain. We do not have collections large enough from Dall's localities or other areas yielding these three genera to discover the relationship of these species to those from the Baja California Abyssal Plain. All of the scattered specimens of these three genera are more like those of the Baja California Abyssal Plain than they are like Dall's and Davidson's type specimens.

Sulcation

The majority of articulate brachiopods (class Articulata) have a median fold—a device thought to facilitate filter feeding—separating the incoming streams with food from the excurrents bearing body waste. So many brachiopods are folded toward the dorsal side in the adult condition that this is regarded as normal for articulate brachiopods. Folding in the opposite direction—toward the ventral side, the ventral valve having a fold and the dorsal valve an opposing sulcus—is rare in the adult condition of the articulate brachiopod. Among early brachiopods many are ventrally folded in the young, but folding direction reverses in growth, and the more usual condition of uniplication, the dorsal valve with fold, is established in the adult. Heterochronous homeomorphs of *Abyssothyris* and *Neorhynchia* have existed since Silurian time. Of impunctate brachiopods, *Brachymimulus,* a member of the *Triplesiacea,* has a form almost identical to that of *Neorhynchia,* but it has a long, forked cardinal process and entirely different ventral beak structures. In the Mississippian the rhynchonellid *Sanjuania* is similar in shape to *Neorhynchia,* as is *Paranorella* of the Permian. *Camarophorina* is a smooth, sulcate stenoscismatacean from the Permian identical in form to *Neorhynchia, Brachymimulus,* and *Sanjuania. Norella* is a sulcate rhychonellid of the Triassic. Thus, homeomorphs of *Neorhynchia* have existed since the Silurian.

A similar series of heterochronous homeomorphs exists among the punctate brachiopods and duplicate the exterior form of *Abyssothyris* and *Notorygmia.* In the Permian, *Cryptacanthia* and *Glossothyropsis* are almost identical homeomorphs of the two modern genera. The loop of *Glossothyropsis* is like that of *Notorygmia* but it does not have a septal pillar in the initial stages of its development. *Nucleata, Nucleatula,* and *Dinarella* are short-looped punctate forms from the Mesozoic that ape *Abyssothyris.* In the Pliocene of the Mediterranean region *"Terebratula" meneghiniana* Seguenza, because of its sulcate commissure, has been referred to *Abyssothyris* (Muir-Wood, 1960, p. 524; Thomson, 1927, p. 201) even though its interior has not been analyzed.

Of some interest in the Permian is an association like that of *Abyssothyris* and *Neorhynchia.* In the black shale and limestone of the South Wells Member of the Cherry Canyon Formation, *Paranorella,* a sulcate rhynchonellid, occurs with *Glossothyropsis,* a long-looped terebratulid.

The fact that the homeomorphs of the Baja California Abyssal Plain are deep-water dwellers and that these genera are in deep water wherever found suggests that sulcation may be a phenomenon of deep water. This suggestion might also hold for the association of the homeomorphs *Paranorella* and *Glossothyropsis* in the Permian. The South Wells Member, in which this association occurs, is regarded in some quarters as of deep-water origin, but not abyssal as in the modern examples under discussion. Unfortunately for this idea, sulcation is not confined in modern brachiopods to the abyss or even to moderately deep waters. Shallow-water, sulcate genera are fairly common: *Terebratella, Magellania, Terebratalia,* and *Waltonia* to name the most conspicuous ones. Some of these, such as the last two, actually may live in the tidal zone. Among the fossil forms noted above, none save possibly *Paranorella* and *Glossothyropsis* can be connected with a deep-water environment. *Glossothyropsis* is fairly common in some normal marine environments that definitely can be identified as shallow water. This is true also of the Silurian and Mesozoic homeomorphs mentioned above whose associates and paleogeography indicate shallow-water environment. Whatever the evolutional pressure toward sulcation, it apparently is not great depth of water.

Locality data

Baja California Abyssal Plain

Locality S 1070–22.—Latitude, 31°19.7′ N to 31°08.2′ N; longitude, 119°39.2′ W to 119°35.5′ W. Depth, 3,601 to 3,687 m; 25-foot otter trawl. R/V *Melville.* Collectors: C. Hubbs, R. Wisner, S. Luke; December 18, 1969.

The material from this collection, received in early 1970, consisted of 147 specimens of *Abyssothyris elongata,* 108 of *Neorhynchia profunda,* 8 of *Notorygmia,* and 4 of *Pelagodiscus.* The percentage relationship of the homeomorphs—*Abyssothyris,* 55 percent; *Neorhynchia,* 42 percent; and *Notorygmia,* 3 percent—compares favorably to the associations seen at localities Mv 70–III–6 and Mv 70–III–8 but not with the collection from west-southwest of Cortes Bank. This is the only sample with a fair supply of young specimens of *Abyssothyris* and *Neorhynchia.*

Locality Mv 70–III–3.—Latitude, 31°24.0′ N to 31°28.8′ N; longitude, 120°14.5′ W to 120°10.3′ W. Depth, 3,880 m; 25-foot otter trawl. R/V *Melville.* Collectors: R. Wisner, F. Rokop, and S. Luke; March 21, 1970.

This collection, the smallest studied, numbers only 15 specimens: 4 of *Abyssothyris,* 1 of *Notorygmia,* 7 of *Neorhynchia,* and 3 of *Pelagodiscus.* The latter are attached to rock and soft tarry material (Emery, 1960, p. 322). This is the only locality in which *Neorhynchia* outnumbered *Abyssothyris.*

Locality Mv 70–III–6.—Latitude, 31°36.0′ N to 31°14.4′ N; longitude, 120°07.4′ W to 120°09.6′ W. Depth, 3,706–3,806 m; 25-foot otter trawl. R/V *Melville.* Collectors: R. Wisner, F. Rokop, and S. Luke; March 23, 1970.

A total of 314 specimens were taken here: 188 of *Abyssothyris,* 120 of *Neorhynchia,* 3 of *Notorygmia,* and 3 of *Pelagodiscus.* The percentage relationship of the homeomorphs—60 percent *Abyssothyris,* 39 percent *Neorhynchia,* and 1 percent *Notorygmia*—is like that of localities S 1070–22 and Mv 70–III–8. Some of the specimens were attached to soft, tarry "pebbles."

Locality Mv 70–III–8.—Latitude, 31°47.5′ N to 32°00′ N; longitude, 120°19.0′ W to 120°18.0′ W.

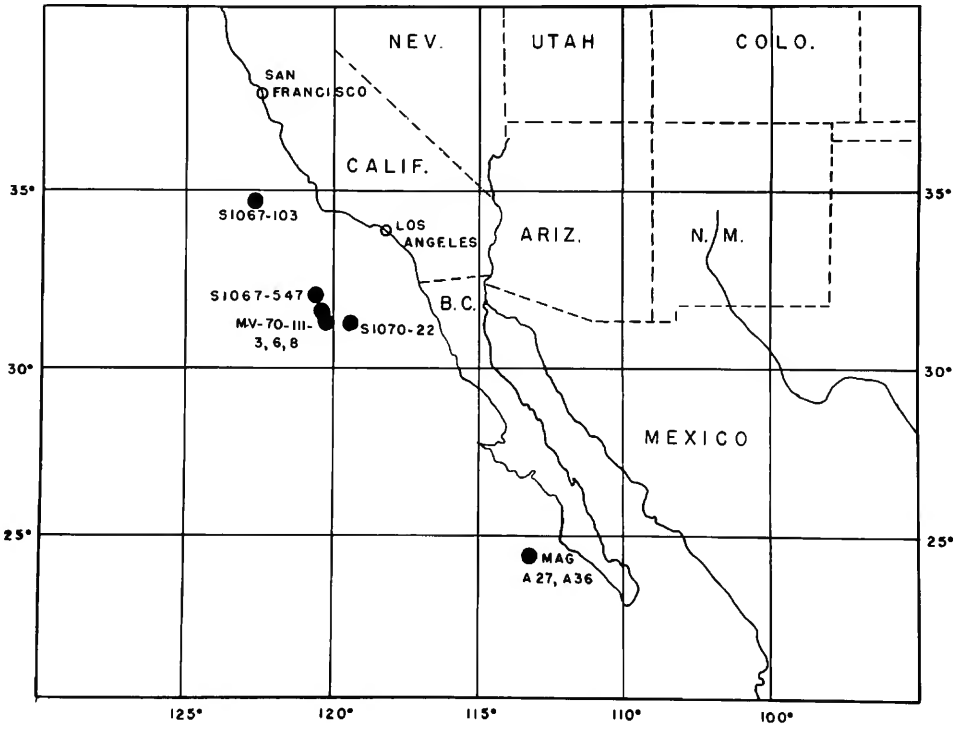


Figure 1.—Locations from which the collections were taken.

Depth, 3,916 m; 25-foot otter trawl. R/V *Melville.* Collectors: R. Wisner, F. Rokop, and S. Luke; March 23, 1970.

Specimens were abundant at this locality, 270 in all: 150 of *Abyssothyris,* 109 of *Neorhynchia,* 1 of *Notorygmia,* and 10 of *Pelagodiscus.* The percentage relationship of the homeomorphs—58 percent *Abyssothyris,* 41.6 percent *Neorhynchia,* and 0.4 percent *Notorygmia*—is like that of localities S 1070–22 and Mv 70–III–6. One *Pelagodiscus* is attached to a *Neorhynchia,* but all of the others are attached to tarry "pebbles" or small rock pebbles.

West-Southwest of Cortes Bank

Locality S 1067–547.—Latitude, 32°05′ N to 32°03′ N; longitude, 120°29.4′ W to 120°30′ W. Depth, 3,777–3,792 m; 40-foot otter trawl. Collectors: C. Hubbs, R. Wisner, and D. Perkins.

This locality produced 335 specimens: 295 of *Abyssothyris,* 38 of *Neorhynchia,* and 2 of *Notorygmia,* showing an association unlike that of the above localities except in the small number of *Notorygmia.* The relationship percentages are: 88 percent *Abyssothyris,* 11 percent *Neorhynchia,* and 1 percent *Notorygmia.* Although black, the pebbles to which some of the specimens are attached are not soft or tarry.

Off Central California, South of Davidson's Seamount

Locality S 1067–103.—Latitude, 34°51′ N to 35°05′ N; longitude, 122°49′ W. Depth, 3,878–3,972 m. June 10, 1967. No other data.

Only one *Neorhynchia* was taken at this locality. It was attached to a blackened pebble.

Off Baja California

Locality Mag Bay Exped. Sta. A–27.—Latitude, 24°30.5′ N to 24°37.3′ N; longitude, 113°28.7′ W to 113°08.8′ W. Depth, 3,564–3,574 m. Collector: H. Lowenstam.

This collection consists of a single specimen each of *Abyssothyris elongata, Neorhynchia abyssa,* and *Notorygmia,* indicating the same grouping of homeomorphs as occur farther to the north.

Locality Mag Bay Exped. Sta. A–36.—Latitude, 24°45.2′ N to 24°21.3′ N; longitude, 113°25′ W to 113°16.8′ W. Depth, 3,039 m. Collector and donor: H. Lowenstam.

This collection consisted of one specimen of each homeomorph: *Neorhynchia, Abyssothyris,* and *Notorygmia.*

Antarctica

Locality Eltanin Cruise 25 Sta. 364.—Latitude, 56°17′ S to 56°19′ S; longitude, 156°13′ W to 156°18′ W, South Pacific Ocean.

The collection consisted of two specimens of *Notorygmia*: a large, nearly complete one (USNM 550406) 23 mm long, 19 mm wide, and about 13 mm thick, and a single smaller ventral valve. The larger specimen conforms to *Notorygmia abyssa,* new species, rather than to *N. diamantina* (Dall).

Systematics

The literature is replete with complaints against "unjustified" splitting. Many synonymies indicate the difference of opinion among authors as to the setting up of species. The problem of establishing species in connection with the homeomorphs from the Baja California Abyssal Plain is an excellent example of the difficulties faced by taxonomists. In this case the three species from the Baja California Abyssal Plain do not conform with the type species of the genera involved. None of the type species is represented by samples adequate to establish a species without question. Each of these lots of type species is represented by a few specimens only: *Neorhynchia,* 4; *Notorygmia,* 2; and *Abyssothyris,* 4 (three from *Challenger* Station 160 and another paratype from *Challenger* Station 302). Establishing species on these inadequate lots was fully justified at the time because these few specimens were all that were known.

The deep-sea brachiopods from Baja California constitute adequate lots on which to base new species of *Neorhynchia* and *Abyssothyris* because each is represented by many specimens. In the case of *Notorygmia,* on the other hand, the total of all lots is not a good supply of specimens although it represents a much larger sample than that of the type species—*Macandrevia diamantina.* The lots of *Abyssothyris* and *Neorhynchia* from the Baja California Abyssal Plain, although showing some variation in many characters, are uniform in their general expression, i.e., elongation of the shell. In this they are entirely unlike the

type species of their respective genera and thus deserve another name.

It will take a great deal of exploration of the deeps to collect material sufficient to demonstrate that these three genera really are each represented by a single species. This exploration may rather show that a number of races or subspecies are localized in the deeps. What localization seems apparent now is of one species of *Neorhynchia* off the Galápagos, one of *Abyssothyris* in the Northern Hemisphere, and another of *Abyssothyris* in the Southern Hemisphere. *Notorygmia diamantina* may be restricted because the isolated examples of this species outside the Baja California Abyssal Plain and off Cocos Island are most like *Notorygmia* from off California. In view of the above remarks there seems to be no choice other than to designate new species on the present adequate material rather than to include them in the hypodigm of the type species, thus distorting the conception of those species.

Order RHYNCHONELLIDA Kuhn, 1949

Superfamily RHYNCHONELLACEA Gray, 1848

Family BASILIOLIDAE Cooper, 1959

Subfamily BASILIOLINAE Cooper, 1959

Genus *Neorhynchia* Thomson, 1915

Neorhynchia strebeli (Dall)

PLATE 1: FIGURES 1-11

Hemithyris strebeli Dall, 1908, p. 441.
Neorhynchia strebeli (Dall).—Dall, 1920, p. 290.—Thomson, 1927, p. 149.—Hertlein and Grant, 1944, p. 57.—Cooper, 1959, p. 35.—Ager, in Williams et al., 1965, p. H622.—Muir-Wood, 1960, p. 524, pl. 7, figs. 7, 8a-d.

Hitherto, this species and genus have been poorly known. Dall (1908) had four specimens: a large adult, the lectotype; a fragmentary paralectotype, partially broken; and two immature specimens. The holotype is wider than long but has a fairly strongly marked fold and sulcus. This specimen is one of the largest individuals of the genus yet seen, and its greater width than length set it strongly apart from the specimens from the Baja California Abyssal Plain. Dimensions of the type specimen when plotted on the same scatter diagram as those of the California specimen fall far away from the widest and largest individuals (see Figure 2).

The specimen figured by Muir-Wood (1960, p. 524, pl. 7, figures 8a-d) likewise is wider than long but is more nearly equidimensional than the holotype. It is possible that specimens of *Neorhynchia* from the southern Pacific may belong to a third species. They are not elongated like the California species but they are much more broadly sulcate. Too few specimens are known at present to make a decision.

Measurements in millimeters:

USNM specimen	*Length*	*Brachial valve length*	*Width*	*Thickness*	*Apical angle*
110741a (lectotype)	17.4	15.4	19.2	10.5	104°

LOCALITY.—At 2.084 fathoms (3,801 m) in *Globigerina* ooze, latitude 8°7′30″ S, longitude 104°10′ W, southwest of the Galápagos Islands.

TYPES.—Lectotype: USNM 110741. Figured paralectotype: USNM 110741a.

Neorhynchia profunda, new species

FIGURE 3*a,b;* PLATE 1: FIGURES 12-51; PLATE 2: FIGURES 1–22.

DESCRIPTION.—Medium size, outline elongate subtriangular; profile sublenticular; valves unequal, the ventral valve having the greater depth. Widest at or slightly anterior to midvalve. Sides rounded; anterior margin varying from truncated to subnasute; posterolateral margins forming an angle varying from 85° to 102° Beak nearly straight to suberect; foramen small, hypothyridid; deltidial plates small, disjunct. Pedicle usually very short, just protruding from the foramen but in rare examples moderately long (up to 3 mm). Shell very thin, translucent to transparent (especially when wet), pale brownish gray, glossy when dry; impunctate.

Ventral valve gently convex in lateral profile, with the umbonal region the most convex; anterior profile strongly convex and with long, steeply sloping sides. Umbonal and median regions swollen, the swelling continuing anteriorly to form a fold at the front margin varying from broad to narrowly rounded and fairly convex in subnasute forms.

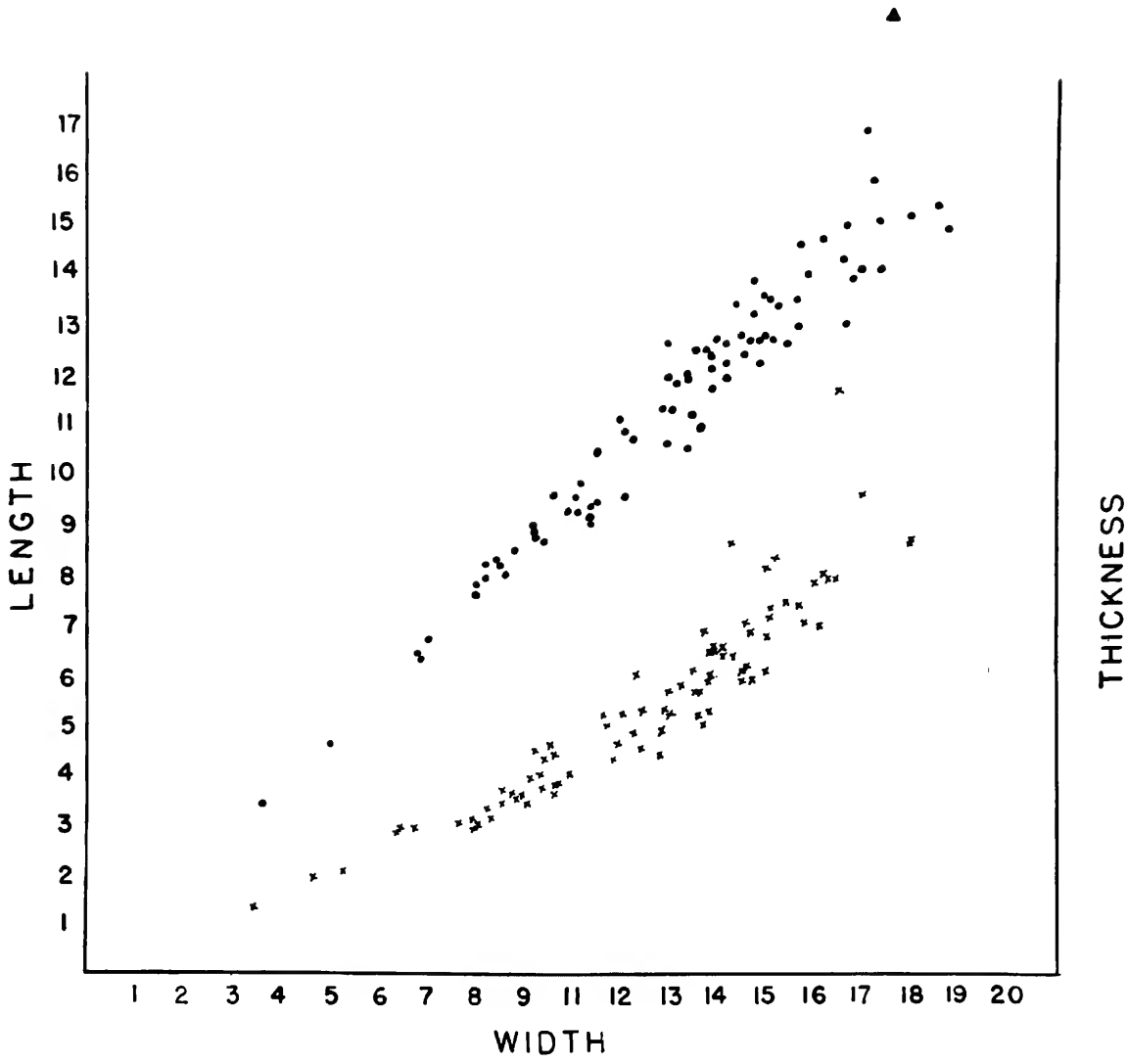


FIGURE 2.—Scatter diagram showing the length/width (dots) and thickness/width (crosses) relationships of *Neorhynchia profunda,* new species, from loc. S 1070–22. Triangle at top represents length/width of the lectotype, *N. strebeli.*

Dorsal valve moderately convex in lateral profile and with the greatest convexity in the posterior half; anterior profile flatly convex and with the median part gently concave. Umbonal region moderately swollen; sulcus originating on the umbonal region, deepening and widening to the anterior margin where it occupies more than half the width. Flanks bounding sulcus swollen. Tongue moderately long and rounded.

Ventral valve interior with strong narrow teeth bounding narrow transverse slits; teeth supported by stout dental plates; apical plate restricting foramen usually short when present; muscle area short, narrow, anteriorly truncated.

Dorsal valve interior with strong socket ridges bounding deep corrugated sockets; outer hinge plates concave, moderately broad and margined by narrow, slightly elevated crural bases; inner hinge plates lacking. Median ridge low, separating two elongate adductor marks. Crura short, falcifer type. Brachium a loose spirolophe, partially uncoiled in many specimens (Figure 3*a,b*).

Measurements in millimeters:

USNM specimen	*Length*	*Dorsal valve length*	*Width*	*Thickness*	*Apical angle*
550391a	17.0	15.3	15.6	8.8	108°
550391c	16.5	14.4	13.5	8.5	90°
550391d	19.2	17.1	17.0	12.1	111°
550392d (holotype)	17.7	15.9	16.9	9.4	91°
550392e	17.7	16.0	14.3	10.6	89°
550392g	15.2	14.0	12.4	7.2	90°
550393a	12.5	11.0	10.9	5.4	104°
550393f	17.0	15.3	15.2	9.0	108°
550394h	16.7	15.3	13.3	11.5	88°
550394o	14.6	13.3	14.3	7.6	98°
550394s	13.4	12.2	12.8	7.0	100°

DIAGNOSIS.—*Neorhynchia* with length consistently greater than the width.

TYPES.—Holotype: USNM 550392d. Figured paratypes: USNM 55039li,j,m; 550392e,i; 550393e,m-s; 550394b,g,h,t; 550409; 550433–5. Unfigured paratypes: USNM 550391a-h,k,l,n,o; 550392a-c,f-h; 550393a-d,f-l; 550394a,c-f,i-s,u.

LOCALITIES.— S 1070–22; Mv 70–III–3; Mv 70–III–6; Mv 70–III–8; S 1066–547; S 1070–22; Mag Bay Exped. Sta. A–27; Mag Bay Exped. Sta. 36.

VARIATION.—*Neorhynchia profunda* is variable in outline and thickness but it maintains well its elongate form. Out of 179 specimens measured, only 11 have a length/width ratio of one or less, indicating equal length and width or greater width than length. The range observed in the L/W ratio is from 0.92 to 1.35. The 39 specimens from locality Mv 70–III–6 included only one specimen wider than long. Localities Mv 70–III–8 and S 1066–547 had none wider than long. Locality S 1070–22 contained ten specimens that were wider than long but only three of these were immature specimens below 10 mm in length. The others ranged from 10.5 mm to 16.1 mm in length. This locality is the only one from which a fair number of specimens below 10 mm in length were taken, but the large majority of these young specimens (L/W ratio, 1.04) are longer than wide and average the same L/W ratio as the 58 percent of this sample measuring 10–15 mm. All of these specimens contrast strongly with the type specimen of *N. strebeli,* which is wider than long, more so than any specimen from the Baja California Abyssal Plain. The lectotype has L/W ratio of 0.90. It is also a remarkably thin shell for one of its size: length 17.4 mm, width 19.2 mm, and thickness 10.5 mm. The width of the lectotype nearly equals the length of the longest specimen of *N. profunda* from the Baja California Abyssal Plain. That specimen is 19.4 mm long but its width is only 15.6 mm.

Most rhynchonellids, like most brachiopods, are variable in thickness. *Neorhynchia* is like most of its relatives in initially starting with a flattened shell and after a certain stage, depending on the kind of rhynchonellid, growing more rapidly at the anterior to enlarge the body region. The thickness/width ratio of *Neorhynchia* is fairly uniform in all localities. At locality S 1070–22 it averages 0.47, which includes about 20 percent of specimens below 10 mm. It averages 0.57 at localities S 1066–547 and Mv 70–III–6 but 0.61 at locality Mv 70–III–8. The specimens from these three localities are mostly adults. The thicker specimens usually are more strongly folded at the anterior.

Like in its homeomorph *Abyssothyris,* the variation in the folding of the anterior commissure in *Neorhynchia* is evident to a marked degree. Most of the shells, after becoming adult, have a broad and gentle wave of the anterior margin, as USNM 550392d (Plate 2: figures 1–4), but ten (or about 5 percent are nasute like USNM 550394g (Plate 1: figures 17–19). Only four of the youngest specimens from locality S 1070–22 proved to be rectimarginate.

COMPARISON.—When the type specimen of *N. strebeli* is compared with most specimens of *N. profunda* the differences are apparent. As mentioned above, *N. strebeli* is wider than long, whereas *N. profunda* is much longer than wide. Only a very small percentage (6 percent) of specimens of *N. profunda* proved to have length or width equal, or the width greater than the length. The sulcus of the majority of the specimens of *N. profunda* appears shallower and broader than that of the type specimen, although none of them attains the great width of the type.

DISCUSSION.—Prior to the collecting of the specimens on which the above description is based, *Neorhynchia* was a very rare genus known only from the types and a few other individuals such as those misidentified as *Abyssothyris* (Muir-Wood, 1960).

Order TEREBRATULIDA Waagen, 1883

Suborder TEREBRATULIDINA Waagen, 1883

Superfamily TEREBRATULACEA Gray, 1840

Family TEREBRATULIDAE Gray, 1840

Genus *Abyssothyris* Thomson, 1927

Abyssothyris elongata, new species

FIGURES 3*c-e,* 4; PLATE 2: FIGURE 39; PLATE 3: FIGURES 20–41; PLATE 4: FIGURES 1–52.

DESCRIPTION.—Large for the genus; white to translucent but with traces of a thin brown epidermis; outline variable, ranging from elongate-oval to roundly elliptical; strongly inequivalve, the ventral valve deeper, widest midvalve; sides broadly rounded; anterior narrowly rounded to subnasute; anterior commissure faintly to strongly sulcate; beak suberect, obliquely truncated. Apical angle varying from 70° to 95°. Foramen fairly large, moderately to slightly labiate, permesothyridid. Surface marked by concentric lines and varices of growth. Symphytium thick, concave. Pedicle variable from restricted to the beak to at least 5 mm, the distal end tufted and frayed into fibers. Punctae averaging about 69/mm^2.

Ventral valve strongly but unevenly convex in lateral profile, the greatest convexity posterior to midvalve; anterior profile strongly and narrowly convex with steep and nearly vertical sides. Beak narrowly swollen; umbonal region swollen and narrow, the swelling continuing anteriorly to the front margin, there forming a moderate to deep fold to receive the tongue of the dorsal valve.

Dorsal valve moderately and fairly evenly convex in lateral profile, with the maximum convexity at about midvalve; anterior profile varying from gently to flatly convex to very gently concave, the sides short and steep. Umbonal region moderately swollen, the swelling extending to midvalve, rarely to the anterior margin, but usually flattening at midvalve and becoming slightly to moderately concave at the front margin; tongue moderately long and usually narrowly rounded. Flanks bounding sulcus inconspicuous, rounded and with short, steep slopes.

Ventral valve interior with small teeth unsupported or with slight anterior thickening; pedicle collar short, thick; muscle scars lightly impressed.

Dorsal valve interior with strong, elevated socket ridges, short sockets, outer hinge plates broad and slightly concave; no inner hinge plates; crural base not elevated; loop short with length about equal to width and equal to less than one-fourth the shell length; crural processes short and blunt, originating immediately anterior to the anterior end of the outer hinge plate; transverse ribbon variable, fairly broad and with a low median angularity; anterolateral extremities of the loop rounded and without anterior projections.

Muscles. The diductors form the anteriormost pair; posterolateral to them are the adjustor muscles attached to the pedicle. The accessory diductor has an elongate attachment, very narrow, and extends posterodorsally to attach to a flat band of muscle tissue that ties the adductors together and attaches to the cardinal process. This broad band is attached on the whole surface of the cardinal process. All of the above muscles are brown in color. The adductors are white and situated between and just posterior to the diductors. The adductors divide about one-third their length toward the dorsal valve to form four muscles in that valve. The anterior pair is the larger.

Lophophore. This is short and of the plectolophous type with two lobes on each side and two smaller ones in the middle. The larger lobe is attached to the anterior and concave lateral parts of the loop. The smaller lobe is recessed in a direction dorsal to the larger and is suspended from the anterior part of the crural process. The posterior part of the lophophore is suspended across the gap between the crural processes. The filaments are about 3.5 mm long at the largest part of the lophophore (Figures 3*c–e,* 4).

Measurements in millimeters:

USNM specimen	*Length*	*Dorsal valve length*	*Width*	*Thickness*	*Apical angle*
550550	19.4	17.7	14.8	12.0	84°
550395d	18.7	16.5	14.0	11.2	67°
550397e	17.8	16.8	15.5	11.1	93°
550397h	17.1	14.8	14.0	9.6	84°
500397j	16.7	15.3	12.6	10.0	81°
550397m (holotype)	18.6	17.1	15.0	12.0	98°
550398p	19.7	17.1	14.5	11.7	75°
550398q	17.8	16.5	11.7	11.2	77°
550398t	16.8	15.6	12.6	11.1	84°
550398w	19.0	16.8	13.7	11.9	72°
550400a	18.9	17.2	12.3	12.6	74°
550400c	19.3	17.8	16.4	12.3	92°

TYPES.—Holotype: USNM 550397m. Figured paratypes: USNM 550397e,h,n,o,p; 550398i,n,p-s,v-y; 550400a,b; 550401a,b; 550436; 550437a-c. Unfigured paratypes: USNM 550397a-d,f,g,i-m,p,q; 550398a-h, j-m,o,t,u.

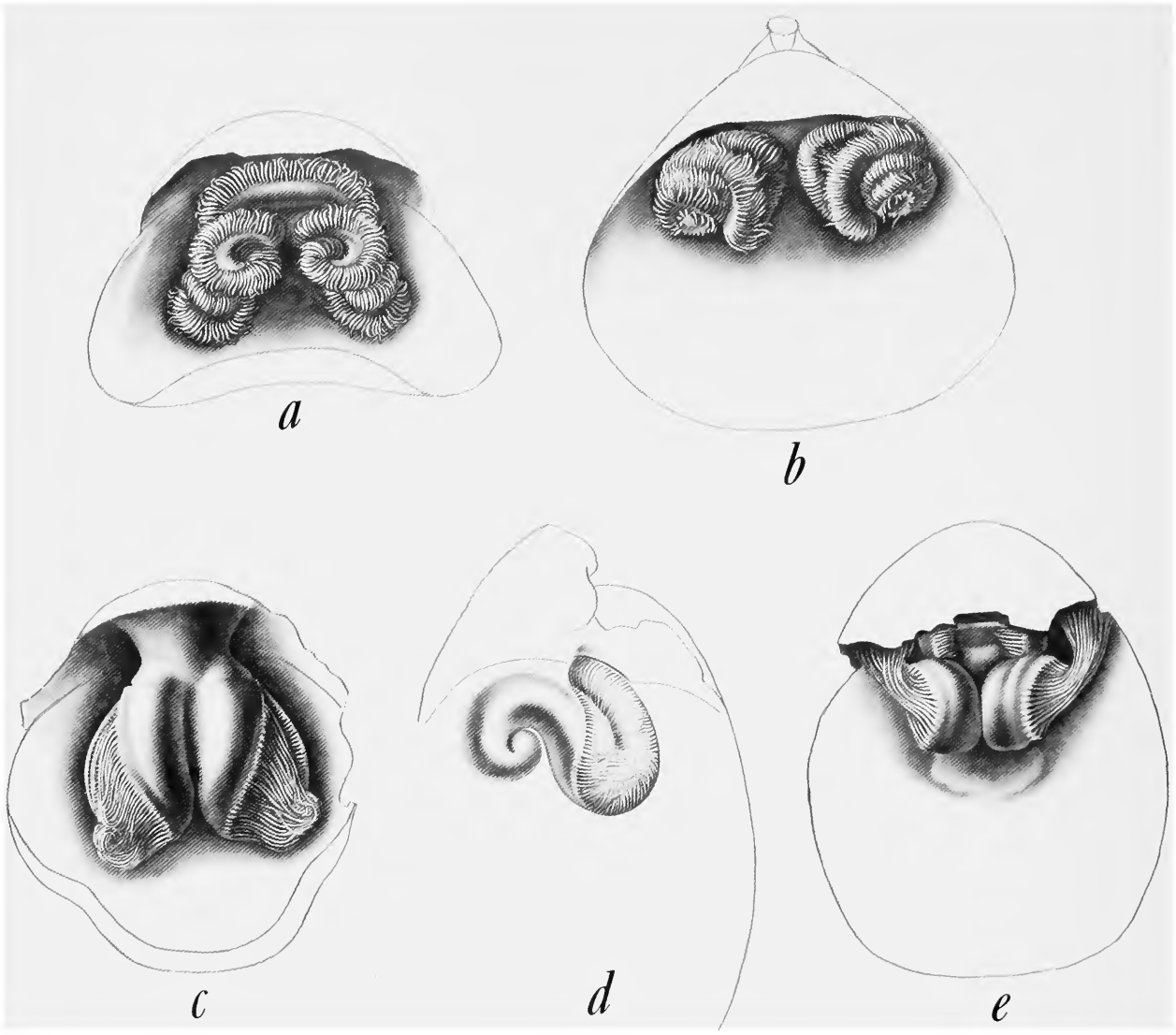


FIGURE 3.—Lophophores (× 4) of *Neorhynchia* and *Abyssothyris*. *a, b,* of *Neorhynchia profunda,* new species, from loc. S 1070–22: *a,* dorsal view; *b,* ventral view. *c–e,* of *Abyssothyris elongata,* new species, from loc. S 1056–547: *c,* dorsal view; *d,* lateral view; *e,* ventral view.

COMPARISON.—Specimens of *Abyssothyris* are known from widely scattered localities but an abundance of specimens such as that recorded here has not been taken hitherto. Two species of the genus are known at the present time—a fossil one, *A. fijiensis* Elliott (in Muir-Wood, 1960, p. 526, pl. 7) from the Miocene-Lower Pliocene of Fiji, and a Recent one, *A. wyvillei* (Davidson). The latter is known from off South Australia and northern Queensland, off the west coast of Patagonia, off Valparaiso, Chile, and near the Falkland Islands. All of the Recent specimens are from deep water, 1,893 to 5,305 m.

Abyssothyris elongata differs from *A. fijiensis* in being larger, more elongate, and with much narrower fold. The beak of the Fiji species is more strongly labiate and the loop narrower. The fossil species is more like *A. wyvillei* from the Southern Hemisphere but has strong differences nevertheless.

As described by Davidson (1880, p. 27, pl. 2, figs. 7–9) and Muir-Wood (1960), *A. wyvillei* is pre-

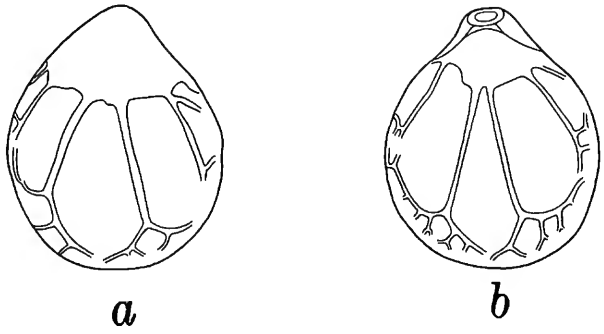


FIGURE 4.—Pallial trunks (× 2) of *Abyssothyris elongata*, new species, from loc. Mv–70–III–6: *a*. ventral view; *b*, dorsal view. (See Plate 3: figures 21–24.)

dominantly nearly equal in length and width and has a fairly strong median fold extending from near the middle of the ventral valve to the anterior margin. This is quite unlike *A. elongata*, which is elongate and does not have so prominent a fold, the folding being indicated by the long dorsal tongue and deep pedicle valve.

The loop of *A. elongata* has strongly rounded anterolateral extremities, whereas the same feature in the type of *A. wyvillei* is more elongated and angular. The Galápagos specimen is like Davidson's species in this respect.

The lophophore is unusual in having the lateral branches tightly coiled and directed inward rather than extending anteriorly to form a "horseshoe" as in many other terebratulids, such as *Liothyrella notorcadensis* Jackson. Helmcke (1940, p. 257, fig. 20) illustrates a short lophophore like this one in *Liothyrella winteri* Blochmann, which has a loop similar to that of *Abyssothyris*. Blockmann's species is not a deep-sea form (depth, 672 m).

Abyssothyris, identified as *A. wyvillei*, coming from the vicinity of the Galápagos Islands (lat. 10°15′ S, long. 95°41′ W), is different from the new species here described and from *A. wyvillei* from more southern waters. The three specimens in the collection of the National Museum of Natural History are smaller than either of those figured by Davidson or those from the Baja California Abyssal Plain. Like Davidson's species, they are equidimensional in length and width, one being 11 mm by 11 mm and the other 13 mm by 13 mm. They are, however, rather compressed and the fold is broad, open, and prominent only at the anterior. This is a possible third species of *Abyssothyris* but much more material is needed to establish this as a fact.

The collection in the National Museum of National History includes a few other specimens of *Abyssothyris* from the Southern Hemisphere but they do not help in clarifying the species problem. Much more exploration of the deeps is needed.

VARIATION.—*Abyssothyris* proves to be variable in some features but is fairly constant in its growth form, the creation of an elongate shell. Of 200 measured specimens from localities S 1070–22 and S 1066–547 only one specimen was wider than long (from S 1070–22) and had an L/W ratio of 0.95. The measured lot from locality S 1070–22 contains numerous immature specimens with lengths less than 10 mm but not one of them is wider than long although their L/W ratios are less than those of the adults. Twenty-one percent of the specimens in this lot measured 10 mm or less and their average L/W index was 1.12. Twenty-seven percent of this lot measured 10 to 15 mm and had an L/W ratio (1.16) slightly greater than the preceding group. Forty-seven percent, measuring between 15.1 mm and 18.9 mm, are still more elongate and have an L/W ratio of 1.28. Only five percent of the specimens measured above 19 mm, and these had an average L/W ratio of 1.37. Three specimens are almost exactly twice as long as wide but they are exceptions. The range of L/W ratio is 0.95 to 1.48 for the above collection.

The lot from locality S 1066–547 consists almost wholly of large adults. Only one specimen was below 10 mm in length and only seven percent of the lot measured between 10 and 15 mm. This group averaged somewhat higher than specimens of the same range of measurements from locality S 1070–22. Seventy-eight percent of lot S 1066–547 consists of specimens from 15.1 mm to 18.9 mm, and their L/W ratios averaged 1.39, which is higher than for the corresponding group above. Fourteen percent measuring above 19 mm have an L/W ratio of 1.45. These specimens represented shells with length averaging nearly twice the width, and four specimens were more than twice as long as wide. The observed range of L/W ratio for specimens from this locality is 1.18 to 1.60. The elongate form of the species is very evident and is in strong contrast to the lectotype of *A. wyvillei* selected by Muir-Wood (1960, pp. 523, 525), which has an L/W ratio of 0.88.

The anterior commissure of *Abyssothyris elongata* is variable from almost rectimarginate to nasute. As a

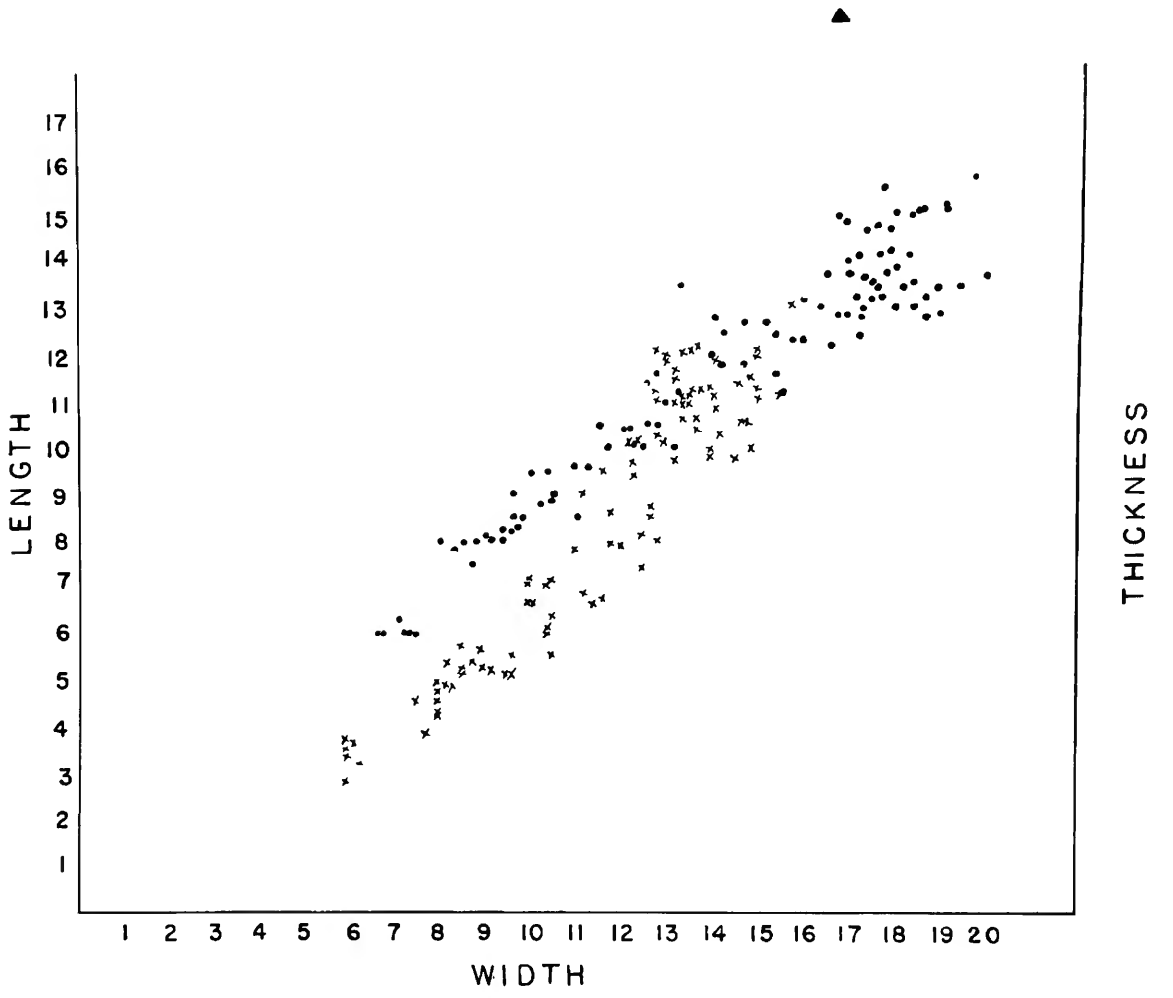


FIGURE 5.—Scatter diagram showing the length/width (dots) and thickness/width (crosses) relationships of *Abyssothyris elongata,* new species, from loc. S 1070–22. Triangle a top indicates length/width of *A. wyvillei.*

general rule the smaller specimens are rectimarginate or nearly so and the larger ones usually are more strongly sulcate. USNM 550398p (Plate 4: figures 24–26) is a large adult with rectimarginate anterior commissure. A strongly nasute, narrow specimen in the same lot is USNM 550398r (Plate 4: figures 15–17). A strongly folded but wide specimen is USNM 550400a (Plate 4: figures 5–8). From locality S 1070–22, specimen 550397o (Plate 4: figures 43–46) is a large rectimarginate individual, but specimens 550397n (Plate 4: figures 38–41) and 550397q (Plate 3: figures 30–33) are narrowly elongate and nasute.

Variation in the loop appears to be a function of age and calcification of the specimens. A few individuals have much wider transverse bands than usual (USNM 550398i) but the loop is remarkably uniform in its characteristic features: shortness, and rounded anterolateral extremities. The median flexure of the transverse band is variable, stronger and sharper in some specimens than others, but always present. The crural processes vary from blunt and rounded to long and acute. Young specimens do not have a readily recognizable cardinal process, but in large, old individuals such as USNM 550398x (Plate 3: figure 25) it is a large boss with ragged edge.

Suborder TEREBRATELLIDINA Muir-Wood, 1955

Superfamily TEREBRATELLACEA King, 1950

Family DALLINIDAE Beecher, 1893

Notorygmia, new genus

Macandrevia Thomson, 1927, p. 239 (part).

DESCRIPTION.—Moderately large, somewhat diamond-shaped to pentagonal in outline; valves unequal in depth, the ventral valve deeper than the dorsal valve; shell usually thin, yellowish or white, and translucent to transparent; beak suberect; foramen large, elongate, but open anteriorly; deltidial plates rudimentary or absent. Surface marked only by concentric growth lines. Punctae very fine but not crowded.

Pedicle valve interior with strong teeth buttressed by short dental plates. Dorsal valve with strong socket ridges and small outer hinge plates. Crural bases supported by short sloping plates (inner hinge plates?) that meet the valve floor to bound a narrow notothyrial cavity. Loop long, free in adults, with short posterior crural processes and narrow descending and ascending branches; anterior junction of branches with short, delicate spines.

TYPE SPECIES.—*Notorygmia abyssa,* new species.

DICUSSION.—Internally, *Notorygmia* is exactly like *Macandrevia* in having plates (inner hinge?) attaching the crural bases to the valve floor. The loop is exactly like that of *Macandrevia,* and its developmental stages are known from two immature specimens of *Macandrevia* [*Notorygmia*] *diamantina* Dall described and figured by Jackson (1912, p. 380). The smallest individual showed the descending branches attached to a septal pillar and the presence of a small hood. The next larger stage revealed remnants of the processes that attached the loop to the septum in the terebrataliform loop stage.

The character that sets this shell apart from other macandrevias is the strong sulcation of the anterior commissure. All other species of *Macandrevia* are rectimarginate or nearly so. A new species from the west coast of Africa actually shows a slight tendency toward sulcation but otherwise most specimens of all other species are rectimarginate. Strong sulcation is the homeomorphic character that confuses this genus with *Abyssothyris* and *Neorhynchia.* The confusion with the former is stronger because both genera are punctate.

Notorygmia is a widely distributed brachiopod, ranging from latitude 31° north, in the Baja California Abyssal Plain south to the Gulf of Panama, and to latitude 56° south and longitude 156° west and finally to a point off Queen Mauds Land, Antarctica (Jackson, 1912). This vast expanse of sea is essentially the same as that in which *Abyssothyris* and *Neorhynchia* range. Throughout this region these genera are usually taken from great deeps.

In any assemblage containing all three homeomorphs, *Notorygmia* is readily distinguished from *Neorhynchia* by its punctate shell and lack of deltidial plates; it differs from *Abyssothyris,* also punctate, in its suppression of deltidial plates and the presence of a long, recurved loop.

The name of this new genus derives from the Greek *notos* (back) and *orygma* (trench).

Notorygmia diamantina (Dall)

PLATE 2: FIGURES 30–38.

Macandrevia diamantina Dall, 1895, p. 723, pl. 30, fig. 5; pl. 32, figs. 3, 6; 1908, p. 455.—Thomson, 1918, p. 34 (part); 1927, p. 240 (part).

Examination of Dall's type specimens of *Macandrevia diamantina* reveals significant differences between them and specimens taken from off Baja California and even south to the Antarctic. Dall's types and two additional specimens from southeast of Cocos Island, Gulf of Panama, and one specimen from off Sechuca Point, Peru, are notable for their slender lateral profile and nearly equal length and width. Compared to specimens of *Notorygmia* from off California and Baja California that are deep and strongly elongated, the differences become striking.

Measurements (in millimeters) of Dall's specimens are as follows:

USNM specimen	*Length*	*Dorsal valve length*	*Maximum width*	*Thickness*	*Apical angle*	*L/W ratio*
122860a (type)	18.1	16.0	17.3	8.1	97°	1.05
122860b (paratype)	16.1	14.5	16.2	6.8	103°	0.99
110743	13.4	11.9	12.4	5.5	105°	1.08
223627	15.6	13.8	14.8?	6.2	100°	1.05

TYPES.—Lectotype: USNM 122860a. Figured paralectotype: USNM 122860b.

DISCUSSION.—It is interesting that two species of *Macandrevia* occur off Cocos Island—*M. craniella*

Dall and *M. americana* Dall. Both occur in deep water, the latter at 1,175 fathoms (2,149 m) and the former at 1,672 fathoms (3,059 m). *Macandrevia craniella* was found with *N. diamantina*. Both *M. craniella* and *M. americana* are rectimarginate and in every way normal for *Macandrevia*. This reiterates the point previously made that sulcation appears not to be confined to brachiopods in abyssal waters. See also discussion (below) of *Waldheimia wyvillei* Davidson.

Notorygmia abyssa, new species

PLATE 2: FIGURES 23-29; PLATE 3: FIGURES 1-19.

Macandrevia diamantina Jackson (not Dall), 1912, p. 379, pl. 2, figs. 15-19.—Thomson, 1927, p. 240 (part).—Hertlein and Grant, 1944, p. 157 (part).
Macandrevia coatsi Jackson.—Helmcke, 1939, p. 251.

DESCRIPTION.—Elongate-oval in outline, with maximum width near midvalve; sides rounded; anterior nasute; posterolateral margins forming angle of 85°. Shell thin, translucent, glossy but with traces of a light brown periostracum. Anterior commissure strongly sulcate, producing an anterior projection of the ventral valve.

Ventral valve with the umbo moderately convex and the anterior half nearly flat in lateral profile; strongly and somewhat narrowly domed in anterior profile, the crest of the dome narrowly rounded; sides sloping steeply. Fold originating posterior to midvalve but broad and gentle, narrowing anteriorly.

Dorsal valve evenly and gently convex in lateral profile but broadly and gently convex in anterior profile and with the median region narrowly sulcate. Sides narrowly rounded, slopes precipitous. Sulcus barely visible at midvalve, but deepening anteriorly to become a moderately deep and narrow groove; tongue long and narrowly rounded.

Measurements in millimeters:

USNM specimen	*Length*	*Dorsal valve length*	*Width*	*Thickness*	*Fold width*	*Apical angle*
550402a	19.6	18.0	16.9	11.6	11.6	85°
550402b	19.8	18.0	16.8	11.0	9.3	88°
550406	22.7	19.7	19.1	12.0	10.4	87°
549762	17.3	15.7	15.8	?	11.2	92°
550404a	19.1	?	16.5	9.1	10.0	86°
550404b	18.4	16.4	15.0	8.8	9.3	90°
550403	12.8	11.3	12.0	5.3	5.8	107°
550405	16.0	14.6	15.0	6.6	7.8	101°
550105	14.7	13.4	13.1	6.4	8.0	105°

DIAGNOSIS.—Elongate, narrow, and deep *Notorygmia* with strong sulcus.

LOCALITIES.—SV 1066–547; S 1070–22; Mv 70–III–6; Mv 70–III–8; Mag Bay Exped. Sta. A27; *Eltanin* Cruise 25 Sta. 364.

TYPES.—Holotype: USNM 550402b. Figured paratypes: USNM 550402a, 550404, 550405.

DISCUSSION.—This species is distinguished by its elongate-oval to pentagonal outline, great depth of the adult, and strong, rather narrow fold. The type specimen of *Macandrevia diamantina* Dall appears to be a fully grown adult specimen. Its length and width are nearly equal and it has a very narrow profile. Its width is greater than most of the specimens of *N. abyssa* recorded above. In order better to compare the specimens of *N. abyssa* with Dall's species a specimen (USNM 550402a) of *M. diamantina* was measured at three stages of its growth as indicated by varices on the shell. At 7 mm of length the width and length were equal; at 12.4 mm of length the width measured 11.5 mm, showing an already lengthening shell. At 16 mm the width was 14.3 mm but the shell had still 3.6 mm more of length to form a strongly elongated adult. *Notorygmia diamantina* is also much more diamond-shaped than *N. abyssa*, which has more rounded sides and is rather pentagonal in outline. The fold and sulcus of *N. abyssa* are far more pronounced than those of Dall's species.

Other minor characters help to distinguish these species. The specimens from off Cocos Island are more opaque than *N. abyssa* and are somewhat yellowish in color. They do not show any traces of the dark brown periostracum similar to that appearing on parts of *N. abyssa*.

Macandrevia coatsi Jackson is a name appearing in Helmcke's list of brachiopods in the Zoological Museum of Berlin. The specimens come from the same locality, but not same depth, as listed by Jackson for *M. diamantina*. It seems likely that Jackson intended to designate a new species for them but later changed his mind in favor of identification with Dall's species. Jackson's name is a nomen nudum.

The validity of the name *Notorygmia abyssa*, new species, will hold unless or until it can be demonstrated that *Waldheimia wyvillei* Davidson, described below, can be proved to be sulcate and to belong to *Notorygmia*. More collecting off Chile will be needed to prove this point.

Waldheimia (=Macandrevia?) wyvillei (Davidson)

Waldheimia wyvillii Davidson, 1878, p. 438; 1880, p. 44, pl. iii, figs. 13a, b; 1886, p. 66, pl. X, figs. 5, 6. The name given by Davidson is *W. wyvillii* but should be spelled *wyvillei* as explained by Thomson (1927, p. 199).

This is a very poorly known species that has been overlooked and its correct genus not established. It was ignored by Thomson. The name is based on a single specimen dredged by the *Challenger* expedition from locality 229 (lat. 33°31′ S, long. 74°33′ W) at 2,160 fathoms off Valparaiso, Chile, the same locality that produced *Neorhynchia* misidentified as *Abyssothyris* (*Terebratula wyvillei*). This specimen proves by its interior details to belong to *Macandrevia* or *Notorygmia.*

Dr. C. Howard Brunton, Keeper of the Recent Brachiopoda at the British Museum (Natural History), kindly examined this specimen for me, and later, in a hurried visit to the British Museum, I had opportunity to study it. Unfortunately, the specimen is badly damaged. Most of the ventral valve is broken away and the anterior margin has been destroyed. This damage has the advantage of giving a view of the interior where the critical characters reside but it obscures vital exterior characters. Dr. Brunton and I concur in our examination that the ventral valve has dental plates and that the long loop is unsupported. These two characters, combined with the open nature of the foramen, clearly indicate the diagnostic characters of *Macandrevia.* But the question is: To what species of *Macandrevia* is *Waldheimia wyvillei* related, or is it the same or related to *Macandrevia diamantina* Dall, now placed in *Notorygmia?*

As figured by Davidson, *Waldheimia wyvillei* seems to have a rectimarginate anterior commissure, and Davidson (1886, p. 67) stated unequivocally that the dorsal valve is "without sinus." Moreover, Davidson remarked that his species suggests a thin or compressed *Macandrevia cranium* (Müller). It is possible that *Waldheimia wyvillei* is a small example of *Macandrevia americana* Dall, which is also known from the coast of Chile (Dall, 1920, p. 357). The fact that *Waldheimia wyvillei* occurs with *Abyssothyris wyvillei* suggests the possibility that it is a species of *Notorygmia* and another example of the homeomorphy that forms the subject of this paper, but Davidson's unequivocal statement that his species is without a sinus rules out that possibility. According to Dall (1920, p. 357), *Macandrevia americana* has a wide bathymetric range, from 122 to 2,222 fathoms; consequently, the species is not out of place at *Challenger* locality 299.

Appendix

Pelagodiscus atlanticus King

PLATE 4: FIGURES 53-56

For an extended synonymy see Helmcke (1940, p. 230).

Although this species has no direct bearing on the problem discussed herein, figures of this interesting and ubiquitous brachiopod are included because it is the commonest deep-sea brachiopod and has been reported more widely than any other. It is shown attached to a specimen of *Neorhynchia profunda* (Plate 4: figures 53–56). Also shown is the ventral side, which usually is not seen. The large pedicle and the two sets of setae are clearly visible.

LOCALITIES.—S 1067–103; S 1070–22; Mv 70–III–3,6,8.

TYPES.—Hypotypes: USNM 550391e (on *Neorhynchia*); USNM 550438.

Literature cited

Bell, W. C.
1938. Homeomorphy in the Brachiopod Genus *Acrotreta. Bulletin of the Geological Society of America,* 49:1909–1910.

Buckman, S. S.
1901. Homeomorphy among Jurassic Brachiopods. *Proceedings of the Cotteswold Naturalists Field Club,* 13:231–290.
1906. Brachiopod Homeomorphy: *Pygope, Antinomia, Pygites. Quarterly Journal of the Geological Society of London,* 62:433–455.

Cloud, P. E., Jr.
1941. Homeomorphy, and a Remarkable Illustration. *American Journal of Science,* 239:899–904.

Cooper, G. A.
1930. The Brachiopod Genus *Pionodema* and Its Homeomorphs. *Journal of Paleontology,* 4(4):369–382, plates 35–37.
1959. Genera of Tertiary and Recent Rhynchonelloid Brachiopods. *Smithsonian Miscellaneous Collections,* 139(5):1–90, 22 plates.
1970. Generic Characters of Brachiopods. *Symposium, North American Paleontological Convention, Field Museum Natural History, September 1969,* pages 194–263, 5 plates.

Dall, W. H.
1895. Scientific Results of Explorations by the U.S. Fish Commission Steamer *Albatross*. No. XXXIV.—Report on Mollusca and Brachiopoda Dredged in Deep Water, Chiefly near the Hawaiian Islands, with Illustrations of Hitherto Unfigured Species from Northwest America. *Proceedings of the United States National Museum,* 17(1032):675–733 plates 23–32. [Brachiopoda, pages 713–729, plates 30–32.]
1908. Reports on the Mollusca and Brachiopods [Albatross Dredging Operations in Western Pacific]. *Bulletin of Museum of Comparative Zoology, Harvard,* 43(6):205–487, 19 plates. [Brachiopods, pages 205–212].
1920. Annotated List of the Recent Brachiopoda in the Collection of the United States National Museum, with Descriptions of Thirty-three New Species. *Proceedings of the United States National Museum,* 57:261–377.

Davidson, Th.
1878. Extract from Report to Professor Sir Wyville Thomson, F.R.S., on the Brachiopoda Dredged by H. M. S. *Challenger. Proceedings of the Royal Society of London,* 27(188):428–439.
1880. Report on the Brachiopoda Dredged by H. M. S. *Challenger* during the years 1873–1876. *Report on the Scientific Results of the Voyage of H. M. S.* Challenger, *Zoology,* 1:1–67, 4 plates.
1886–1888. A Monograph of Recent Brachiopoda. *Transactions of the Linnaean Society of London,* series 2, Zoology, 4:1–248, 30 plates.

Emery, K. O.
1960. *The Sea off Southern California: A Modern Habitat of Petroleum.* xii+366 pages. New York and London: John Wiley and Sons.

Helmcke, J. G.
1940. Die Brachiopoden der Deutschen Tiefsee-Expedition. *Wissenschaftliche Ergebnisse der deutschen Tiefsee-Expedition auf dem Dampfer* Valdivia, *1898–1899,* 24(3): 215–316, 43 figures.

Hertlein, L. G., and U. S. Grant, IV
1944. The Cenozoic Brachiopoda of Western North America. *Publications of the University of California at Los Angeles in Mathematical and Physical Sciences,* 3:1–236, 21 plates.

Jackson, J. W.
1912. The Brachiopoda of the Scottish National Antarctic Expedition (1902 to 1904). *Transactions of the Royal Society of Edinburgh,* 48(2)19:367–390, plates 1 and 2.

Muir-Wood, H. M.
1959. Report on the Brachiopoda of the John Murray Expedition. *The John Murray Expedition, 1933–34, Scientific Reports,* 10(6):283–317, 5 plates.
1960. Homeomorphy in Recent Brachiopoda: *Abyssothyris* and *Neorhynchia.* [With an appendix by G. F. Elliott.] *Annals and Magazine of Natural History,* series 13:521–528, plate 7.

Thomson, J. A.
1915. The Genera of Recent and Tertiary Rhynchonellids. *Geological Magazine,* new series, 6(2):387–392.
1918. Brachiopoda. *Australasian Antarctic Expedition, 1911–14, Scientific Reports,* Series C, 4(3):1–75, 4 plates, map.
1927. Brachiopod Morphology and Genera (Recent and Tertiary). *New Zealand Board of Science and Art, Manual,* 7:1–338, 2 plates.

Ulrich, E. O., and G. A. Cooper
1936. New Silurian Brachiopods of the Family Triplesiidae. *Journal of Paleontology,* 10(5):331–347, plates 48–50.

Williams, A., et al.
1965. In R. C. Moore, editor, *Treatise on Invertebrate Paleontology, Part H, Brachiopoda.* 2 vols., 927 pages, 746 figures. New York: Geological Society of America (and University of Kansas Press).

PLATES

PLATE 1

Neorhynchia strebeli (Dall)

Figures 1–11: 1–4, Anterior, dorsal, lateral, and ventral views (× 1) of the holotype (USNM 110741); 5, dorsal view (× 2) of the holotype; 6, 7, posteriorly tilted and dorsal views (× 4) of the posterior part of the holotype showing the hypothyridid foramen, disjunct deltidial plates and dental plates; 8–10, ventral, posteriorly tilted, and laterally tilted views (× 4) of the cardinalia of the holotype showing the falcifer crura, slight median ridge, strong socket ridges, and outer hinge plates; 11, interior of the dorsal valve (× 4) of a paratype (USNM 110741a), younger than the holotype, showing cardinalia. Both specimens taken at a depth of 3,801 m in *Globigerina* ooze, lat. 8°7′30″S, long. 104°10′W, southwest of the Galápagos Islands.

Neorhynchia profunda, new species

Figures 12–25: 12–15, Anterior, lateral, dorsal, and ventral views (× 1) of a young adult (paratype, USNM 550394b); 16, dorsal view (× 2) of the preceding paratype; 17–19, anterior, lateral, and dorsal views (× 1) of a strongly folded individual (paratype, USNM 550394g); 20–22, anterior, dorsal, and lateral views (× 2) of the preceding paratype showing the growth lines; 23–25, lateral, dorsal, and anterior views (× 2) of another obese, strongly folded individual (paratype, USNM 550394h) showing the small beak and growth lines. All specimens from loc. MV 70–III–6.

Figures 26–46: 26–28, Anterior, dorsal, and lateral views (× 2) of a broadly folded, young adult (paratype, USNM 550393n); 29–32, dorsal, lateral, anterior, and ventral views (× 1) of a young specimen (paratype, USNM 550393e); 33–35, anterior, lateral, and dorsal views (× 3) of an immature specimen (paratype, USNM 550393o); 36–39, anterior, ventral, lateral, and dorsal views (× 1) of a broad specimen (paratype, USNM 550393r); 40–43, anterior, ventral, dorsal, and lateral views (× 1) of a strongly folded paratype (USNM, 550393s); 44, interior view (× 3) of the posterior part of a dorsal valve of a young specimen (paratype, USNM 550393p) showing cardinalia and adductor scars; 45, 46, interior (× 2) of the dorsal and ventral valves of a young specimen (paratype, USNM 550393q) showing cardinalia with short crura, teeth, and deltidial plates forming a hypothyridid foramen. All specimens from loc. S 1070–22.

Figure 47: Interior (× 2) of an obese dorsal valve (paratype, USNM 550139o) showing deeply entrenched adductor scars. Loc. Mv 70–III–8.

Figures 48–51: 48, Interior (× 2) of dorsal valve of an obese specimen (paratype, USNM 550392e) showing cardinalia with slight development of inner hinge plates and deeply inserted muscle scars; 49–51, dorsal, lateral, and anterior views (× 1) of an elongated obese individual (paratype, USNM 550392i). Both specimens from loc. S 1066–547.

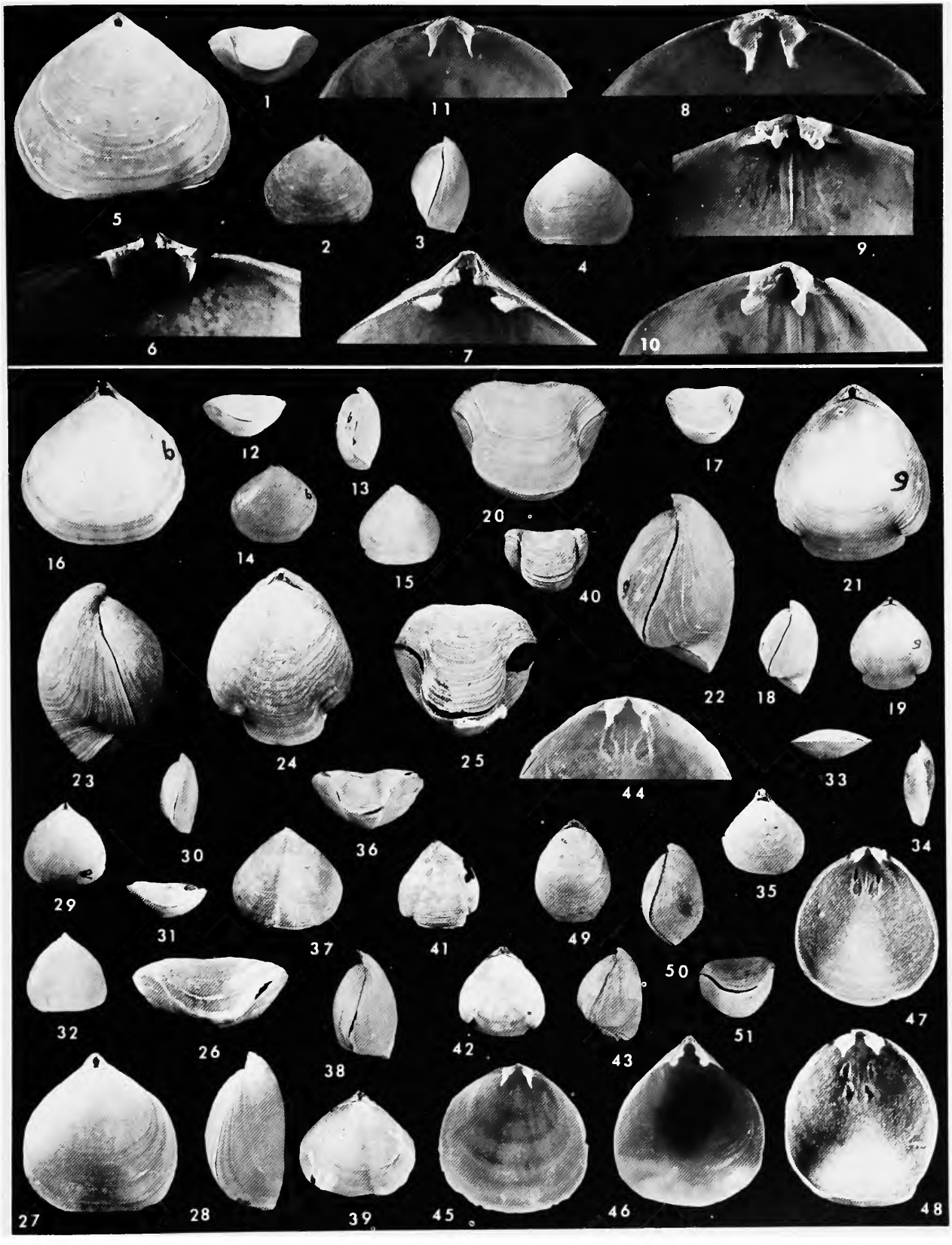

1
11
8
5
2
3
4
9
6
7
10
16
12
13
20
17
14
15
40
21
22
18
19
23
24
25
44
33
34
30
36
29
35
31
37
41
49
50
47
32
26
38
42
43
51
27
28
39
45
46
48

PLATE 2

Neorhynchia profunda Cooper, new species

Figures 1–5: 1–4, Anterior, lateral, ventral, and dorsal views (× 1) of a large, moderately folded individual (paratype, USNM 550392d); 5, dorsal view (× 2) of the same specimen. Loc. S 1066–547.

Figures 6–15: 6–9, Dorsal, lateral, anterior, and ventral views (× 1) of an elongated but not strongly folded individual (paratype, USNM 550391i); 10–13, anterior, lateral, ventral, and dorsal views (× 1) of another elongated, old adult (paratype, USNM 550391j) which is not strongly folded; 14, 15, posterior parts (× 2) of ventral and dorsal valves of an elongated individual (paratype, USNM 550391m) showing teeth, foramen, and cardinalia with a slight development of inner hinge plates. All specimens from loc. Mv–70–III–8.

Figures 16–22: 16, Pebble (× 1) with attached *Neorhynchia* at left and an *Abyssothyris* at right (paratype, USNM 550409); 17, dorsal view (× 3) of a complete specimen (paratype, USNM 550433) in alcohol showing the spirolophous lophophore with left side partly unrolled; 18, interior (× 2) of an adult dorsal valve (paratype, USNM 550394t) showing cardinalia and muscle scars; 19, ventral view (× 2) of a specimen (paratype, USNM 550434) in alcohol with part of the ventral valve removed and showing the spiral lophophore from the ventral side; 20, 21, interior (× 3) of the ventral and dorsal valves of a young adult (paratype, USNM 550393m) showing teeth, hypothyridid foramen, and well-developed, short cardinalia; 22, interior (× 2) of a large adult (paratype, USNM 550435) in alcohol, with part of the dorsal valve removed to show the spirolophe. All specimens from loc. S 1070–22.

Notorygmia abyssa Cooper, new species

Figures 23–29: 23–27, Dorsal, anterior, ventral, posterior, and lateral views (× 1) of a complete specimen (paratype, USNM 549762); 28, 29, laterally tilted and ventral views (× 2) of the dorsal valve interior of the preceding paratype showing the long, unsupported or dalliniform loop. Specimen from Mag Bay Expedition Sta. 27.

Notorygmia diamantina (Dall)

Figures 30–38: 30–33, Side, anterior, dorsal, and ventral views (× 1) of paralectotype (USNM 122860b); 34, dorsal view (× 2) of the preceding specimen showing open delthyrium; 35–37, anterior, dorsal, and lateral views (× 2) of the lectotype (USNM 122860a); 38, interior (× 3) of the dorsal valve of the lectotype showing cardinal process, descending lamellae of the loop, and plates attached to the floor and forming the notothyrial cavity. Both specimens taken at a depth of 2,150 m on mud bottom, lat. 5°56′S, long. 85°10′30″W, southeast of Cocos Island.

Abyssothyris elongata Cooper, new species

Figure 39: Thin section (× 50) showing the punctae taken just anterior to the umbonal region (paratype, USNM 550436). Loc. S 1070–22.

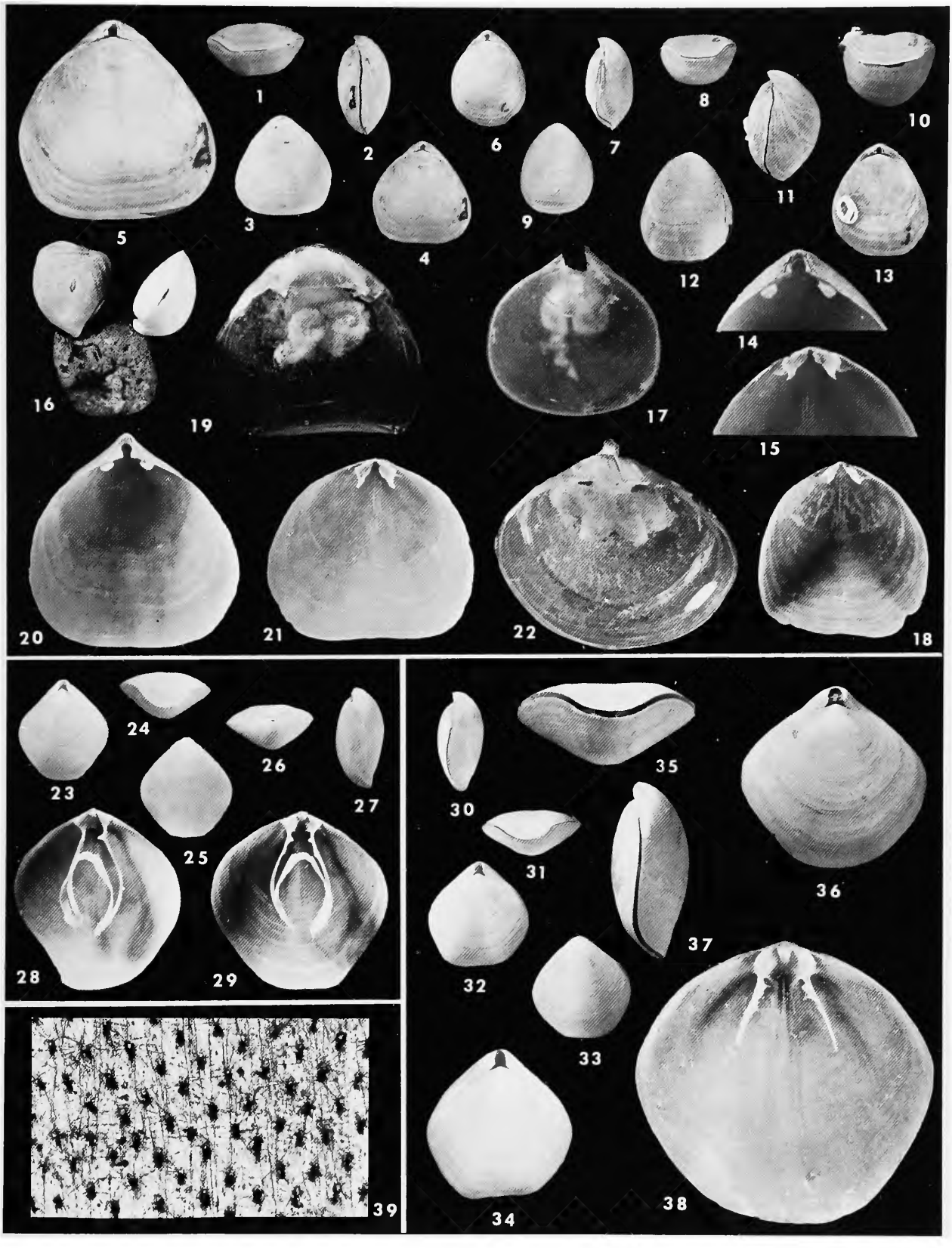

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39

PLATE 3

Notorygmia abyssa Cooper, new species.

Figures 1–6: 1–5, Dorsal, anterior, lateral, ventral, and posterior views (× 1) of a paratype (USNM 550402a); 6, dorsal view (× 2) of a large specimen (paratype, USNM 550404) in alcohol showing open delthyrium, shadow of lophophore, and traces of the periostracum. Both specimens from loc. Mv 70–III–6.

Figures 7–18: 7–11, Ventral, lateral, posterior, anterior, and dorsal views (× 1) of the holotype (USNM 550402b); 12–14, lateral, anterior, and dorsal views (× 2) of the holotype; 15, 16, laterally tilted and ventral views (× 2) of dorsal valve interior of the holotype showing the dalliniform loop and cardinal process; 17, 18, dorsal views (× 2) of two specimens (paratypes, USNM 550402c-d) in alcohol showing the long plectolophe characteristic of this genus. All specimens from loc. S 1070–22.

Figure 19: Ventral view (× 2) of another specimen (paratype, USNM 550405) in alcohol and showing the plectolophe. Loc. S 1066–547.

Abyssothyris elongata Cooper, new species.

Figures 20–24: 20, Pebble (× 1) with two individuals (paratype, USNM 550401) attached, showing living habit; 21–24, ventral, anterior, dorsal, and lateral views (× 2) of a specimen (paratype, USNM 550550) in alcohol and showing the pallial sinuses. Both specimens from loc. Mv–70–III–6.

Figures 25, 26: 25, Posterior of dorsal valve (× 3) of a fully grown specimen (paratype, USNM 550398x) showing the loop and large cardinal process (note the well-rounded anterolateral extremities of the loop); 26, specimen (paratype; USNM 550398n) tilted laterally to show loop in partial profile (× 2). Both specimens from loc. S 1066–547.

Figures 27–41: 27, Interior of a dorsal valve (× 2) with part of the ventral valve adhering, showing the loop of a young adult and absence of dental plates; 28, 29, interior (× 2) of two young dorsal valves (paratypes, USNM 550437b,c) displaying the loop; 30–33, anterior, ventral, lateral, and dorsal views (× 1) of an elongated individual (paratype, USNM 550397q; compare with *Neorhynchia,* Plate 1: figures 49–51); 34–37, anterior, lateral, ventral, and dorsal views (× 1) of a characteristic specimen (paratype, USNM 550397m; compare with *Neorhynchia,* Plate 2: figures 6–9); 38–41, lateral, dorsal, ventral, and anterior views (× 2) of the preceding specimen. All specimens from loc. S 1066–547.

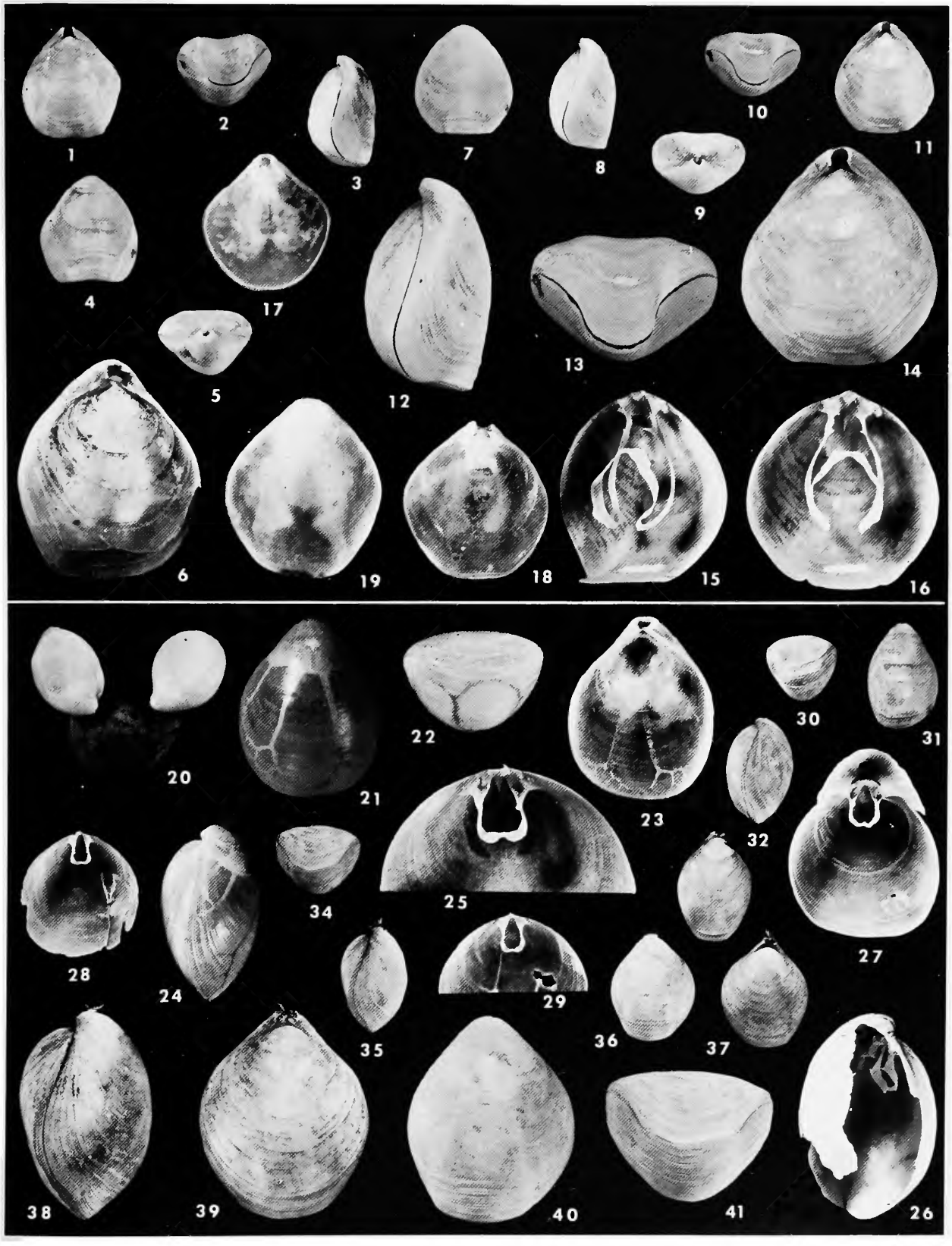

1
2
3
7
8
10
11
4
17
9
5
12
13
14
6
19
18
15
16
20
21
22
23
30
31
32
28
24
34
25
27
29
35
36
37
38
39
40
41
26

PLATE 4

Abyssothyris elongata Cooper, new species.

Figures 1–14: 1–4, Ventral, lateral, dorsal, and anterior views (× 1) of a paratype (USNM 550400b) showing pallial trunks and a very slightly sulcate anterior commissure; 5–8, ventral, anterior, lateral, and dorsal views (× 1) of an elongate, anteriorly tapering individual (paratype, USNM 550400a); 9–11, lateral, dorsal, and anterior views (× 1) of a wide, swollen, and strongly folded specimen (paratype, USNM 550400c); 12–14, dorsal, anterior, and lateral views (× 2) of the preceding specimen. All specimens from loc. Mv 70–III–8.

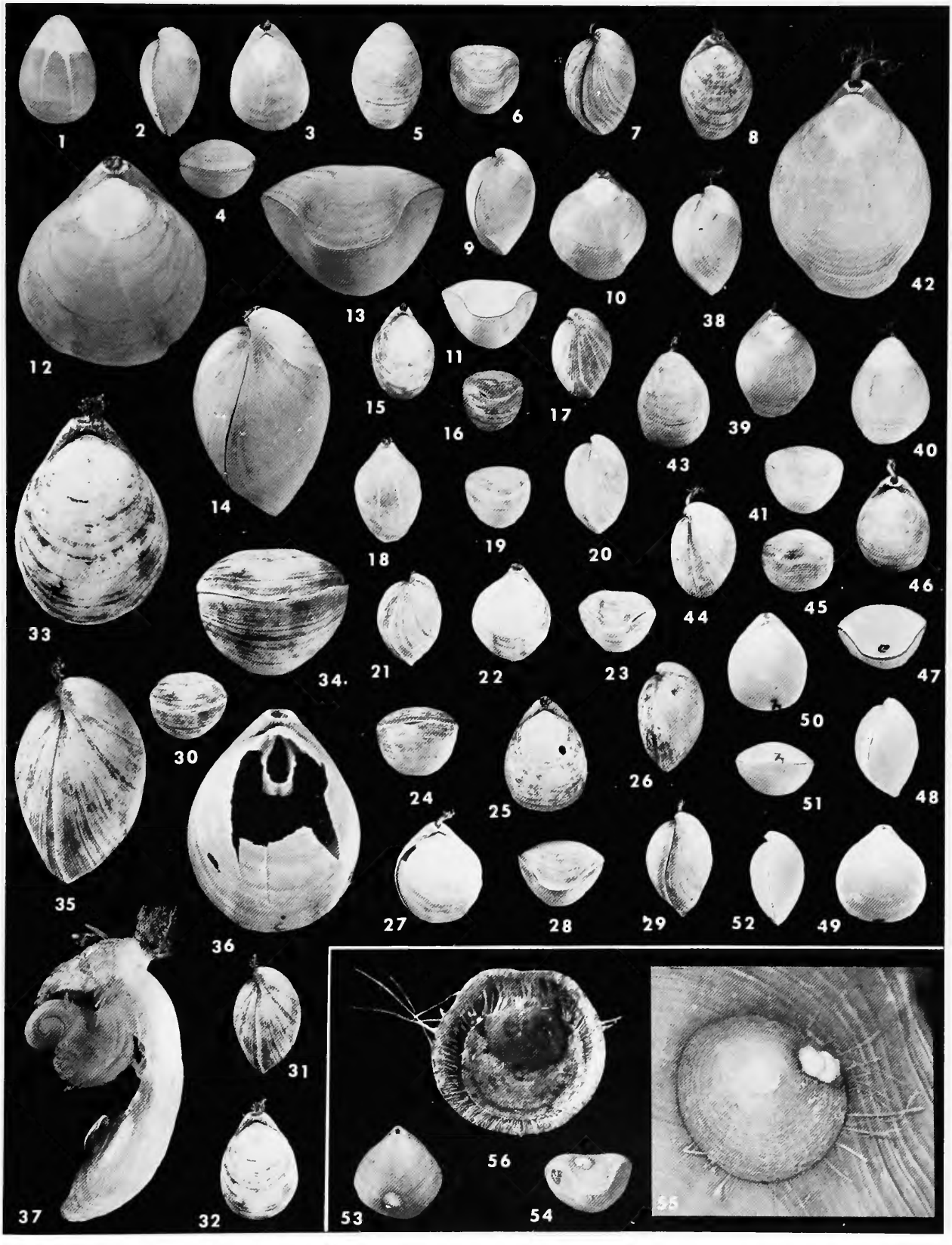
Figures 15–37: 15–17, Dorsal, anterior, and lateral views (× 1) of an anteriorly tapering but weakly folded specimen (paratype, USNM 550398r); 18–20, dorsal, anterior, and lateral views (× 1) of a tapering specimen (paratype, USNM 550398q) preserving the main pallial trunks of the dorsal valve; 21–23, lateral, dorsal, and anterior views (× 1) of a wide but anteriorly narrowly folded individual (paratype, USNM 550398v); 24–26, anterior, dorsal, and lateral views (× 1) of an oval specimen (paratype, USNM 550398p) wide anteriorly and with a nearly rectimarginate anterior commissure; 27–29, dorsal, anterior, and lateral views (× 1) of a wide specimen (paratype, USNM 550398s) with long pedicle and fairly strongly sulcate anterior commissure; 30–32, anterior, lateral, and dorsal views (× 1) of an elongate specimen (paratype, USNM 550398w) having a short, frayed pedicle; 33–35, dorsal, anterior, and lateral views (× 2) of the preceding specimen; 36, dorsal view (× 2) of a specimen (paratype, USNM 550398i) with broken dorsal valve showing the dorsal side of the loop which has an unusually broad transverse band; 37, lateral view (× 2.5) of a specimen (paratype, USNM 550398y) with pedicle valve removed to show the plectolophus lophophore and the short frayed pedicle. All specimens from loc. S 1066–547.

Figures 38–52: 38–41, Lateral, dorsal, ventral, and anterior views (× 1) of a strongly folded specimen (paratype, USNM 550397n) showing traces of the pallial sinuses and a long, frayed pedicle; 42, dorsal view (× 2) of the preceding paratype; 43–46, ventral, lateral, anterior, and dorsal views (× 1) of an oval specimen (paratype, USNM 550397o) having a long pedicle but nearly rectimarginate anterior commissure; 47–49, anterior, lateral, and dorsal views (× 1) of a laterally strongly rounded specimen (paratype, USNM 550397e) with strongly sulcate anterior commissure; 50–52, dorsal, anterior, and lateral views (× 1) of a rectimarginate individual (paratype, USNM 550397h). All specimens from loc. S 1070–22.

Pelagodiscus atlanticus (W. King)

Figures 53–55: 53, 54, Dorsal and anterior views (× 1) of *Neorhynchia* with *Pelagodiscus* (hypotype, USNM 550391e) attached on the sulcate part of the dorsal valve; 55, dorsal view (× 10) of the preceding specimen showing long setae. Loc. Mv 70–III–8.

Figure 56: Ventral view (× 10) of another specimen (hypotype, USNM 550438) showing the round, thick pedicle, the short setae of the ventral valve, and a few of the long dorsal setae. Loc. S 1070–22.



☆ U.S. GOVERNMENT PRINTING OFFICE: 1972 O—484—314/16

Publication in Smithsonian Contributions to Zoology

Manuscripts for serial publications are accepted by the Smithsonian Institution Press, subject to substantive review, only through departments of the various Smithsonian museums. Non-Smithsonian authors should address inquiries to the appropriate department. If submission is invited, the following format requirements of the Press will govern the preparation of copy.

Copy must be typewritten, double-spaced, on one side of standard white bond paper, with 1½" top and left margins, submitted in ribbon copy with a carbon or duplicate, and accompanied by the original artwork. Duplicate copies of all material, including illustrations, should be retained by the author. There may be several paragraphs to a page, but each page should begin with a new paragraph. Number consecutively all pages, including title page, abstract, text, literature cited, legends, and tables. The minimum length is 30 pages, including typescript and illustrations.

The *title* should be complete and clear for easy indexing by abstracting services. Taxonomic titles will carry a final line indicating the higher categories to which the taxon is referable: "(Hymenoptera: Sphecidae)." Include an *abstract* as an introductory part of the text. Identify the *author* on the first page of text with an unnumbered footnote that includes his professional mailing address. A *table of contents* is optional. An *index*, if required, may be supplied by the author when he returns page proof.

Two *headings* are used: (1) text heads (boldface in print) for major sections and chapters and (2) paragraph sideheads (caps and small caps in print) for subdivisions. Further headings may be worked out with the editor.

In *taxonomic keys,* number only the first item of each couplet; if there is only one couplet, omit the number. For easy reference, number also the taxa and their corresponding headings throughout the text; do not incorporate page references in the key.

In *synonymy,* use the short form (taxon, author, date:page) with a full reference at the end of the paper under "Literature Cited." Begin each taxon at the left margin with subsequent lines indented about three spaces. Within an entry, use a period-dash (.—) to separate each reference. Enclose with square brackets any annotation in, or at the end of, the entry. For *references within the text,* use the author-date system: "(Jones 1910)" and "Jones (1910)." If the reference is expanded, abbreviate the data: "Jones (1910:122, pl. 20: fig. 1)."

Simple *tabulations* in the text (e.g., columns of data) may carry headings or not, but they should not contain rules. Formal *tables* must be submitted as pages separate from the text, and each table, no matter how large, should be pasted up as a single sheet of copy.

Use the *metric system* instead of, or in addition to, the English system.

Illustrations (line drawings, maps, photographs, shaded drawings) can be intermixed throughout the printed text. They will be termed *Figures* and should be numbered consecutively; however, if a group of figures is treated as a single figure, the components should be indicated by lowercase italic letters on the illustration, in the legend, and in text references: "Figure 9*b*." If illustrations (usually tone photographs) are printed separately from the text as full pages on a different stock of paper, they will be termed *Plates,* and individual components should be lettered (Plate 9*b*) but may be numbered (Plate 9: figure 2). Never combine the numbering system of text illustrations with that of plate illustrations. Submit all legends on pages separate from the text and not attached to the artwork. An instruction booklet for the preparation of illustrations is available from the Press on request.

In the *bibliography* (usually called "Literature Cited"), spell out book, journal, and article titles, using initial caps with all words except minor terms such as "and, of, the." For capitalization of titles in foreign languages, follow the national practice of each language. Underscore (for italics) book and journal titles. Use the colon-parentheses system for volume, number, and page citations: "10(2):5-9." Spell out such words as "figures," "plates," "pages."

For *free copies* of his own paper, a Smithsonian author should indicate his requirements on "Form 36" (submitted to the Press with the manuscript). A non-Smithsonian author will receive 50 free copies; order forms for quantities above this amount with instructions for payment will be supplied when page proof is forwarded.


SMITHSONIAN INSTITUTION
WASHINGTON, D.C.