SMALL TUBIFORM FOSSILS FROM THE LOWER CRETACEOUS OF ALEXANDER ISLAND

By BRIAN J. TAYLOR

ABSTRACT. Numerous small tubiform fossils occur at one locality near Fossil Bluff, Alexander Island. The concentric layers of collophane composing each tube are separated by calcite which also fills the cores. These loosely laminated tubes, many of which have been considerably modified by diagenesis, are similar structurally to the eunicid *Hyalinoecia* and chaetopterids *Spiochaetopterus* and *Telepsavus*, and may have been built up in a way analogous to that of the two chaetopterids. Three other small tubes, none of which has been identified, are also described.

THE outer margins of several calcareous concretions, which occur at a height of 122 m. in the exposed sedimentary succession of Aptian age at locality F (Fig. 1) in Alexander Island, contain a relatively large number of small, black-shelled and unbranched tubes unlike any other invertebrate shells so far encountered in that area. Unfortunately, these interesting tubes are not well exposed (Fig. 2) nor are they easily removed from the matrix with a fine needle or dilute acid; it has not been possible to examine satisfactorily their morphology and ornamentation, although they appear to lack segmentation and are longitudinally and finely striated.

The tubes, which are orientated parallel to one another, resemble a number of fine needles at least 2 cm. long and not more than 1 mm. wide; the smallest are 57 μm. in diameter. They may taper slightly and some if not all are laminated with the laminae inclined to the tube wall.

INTERNAL MORPHOLOGY

The tubes are perhaps best examined in thin section, which reveals that they are either circular or elliptical in cross-section depending on their orientation. Each tube is composed of up to 11 concentric layers of isotropic collophane interlaminated with calcite and surrounding a core of coarsely crystalline calcite (Fig. 3a and b). The collophane layers, which are isotropic, illustrate graphically the multi-layered construction of the tube and this can be seen in all but the smallest of the specimens. The collophane may have replaced a phosphorus-rich polysaccharide such as onuplin or even chitin.

In some tubes there is a regular concentric arrangement of collophane layers but in others there is considerable disorder, some layers actually lying in a haphazard fashion within the calcite core (Fig. 3c and d) or more widely dispersed like Saturn's rings (Fig. 3b). In these extreme cases, it seems as though an original multi-layered structure had been modified by diagenesis. The layers, which show some splitting and coalescing, are rarely in contact with one another and are separated by matrix or bands of calcite which have possibly replaced the collophane. In some tubes, the thickest layer is innermost, whereas in others it is outermost. Subordinate layers between the calcite core and the outermost bands may be imbricately arranged (Fig. 3e). Although the layers do not appear to be perforated, radial cracks occur at fairly regular intervals and, while individual layers are usually constant in thickness, there are differences between adjacent ones. In longitudinal section, the isotropic layers, some of which appear to exhibit compound lamination, are arranged as a series of concentric cylinders rather than cone-in-cone.

Differences in the number of layers in a tube can be interpreted as indicating the occurrence of several types of tube, growth stages or sections cut at various levels through one organism. The smaller forms with one or two layers could represent the narrower distal end of a tube (Fig. 3f), whereas the multi-layered forms may correspond to the apertural end. In some modern pogonophorans, the tube collapses repeatedly as the worm withdraws into it, thus giving rise to multi-layering at the apertural end.

REMARKS

On the basis of their small size and composition, these tubes can be compared with several species of hydroid, modern and fossil Pogonophora and with certain tubicolous polychaetes.

Fig. 1. Map of Alexander Island showing the localities where the fossil tubes were collected.

However, the differences of opinion of those who have studied many of the illustrations reproduced here only emphasize their problematical nature.

Comparison with hydroids

Some unbranched hydroids such as *Hydractinia* and *Tubularia simplex* are similar in size to the fossil tubes, that of *T. simplex* having been described as "smooth, unbranched, without annulations, generally a little angulated at intervals and tapering towards the bottom" (Hincks, 1868, p. 121). Although the structure of the perisarc (which consists of chitin) varies between different genera, the tube wall of several forms is composed of rings or annuli at different points, but these appear to be related only to the bifurcations (Hyman, 1940, p. 402).

Comparison with coleolids

The tubes from Alexander Island are also similar in size and overall shape to the Coleolidae,* a group of small Palaeozoic conoidal shells of uncertain affinities which are composed of calcium carbonate (Fisher, 1962). Although many coleolids consist of only one thick wall, a multi-layered effect completely unrelated to the shell's morphology is often produced when they become invaginated or "nested". This phenomenon is due to some as yet unknown

* Dr. E. L. Yochelson (personal communication) does not attach any age significance to the *Coleolus* kind of worm tube and he distrusts its stratigraphical value.

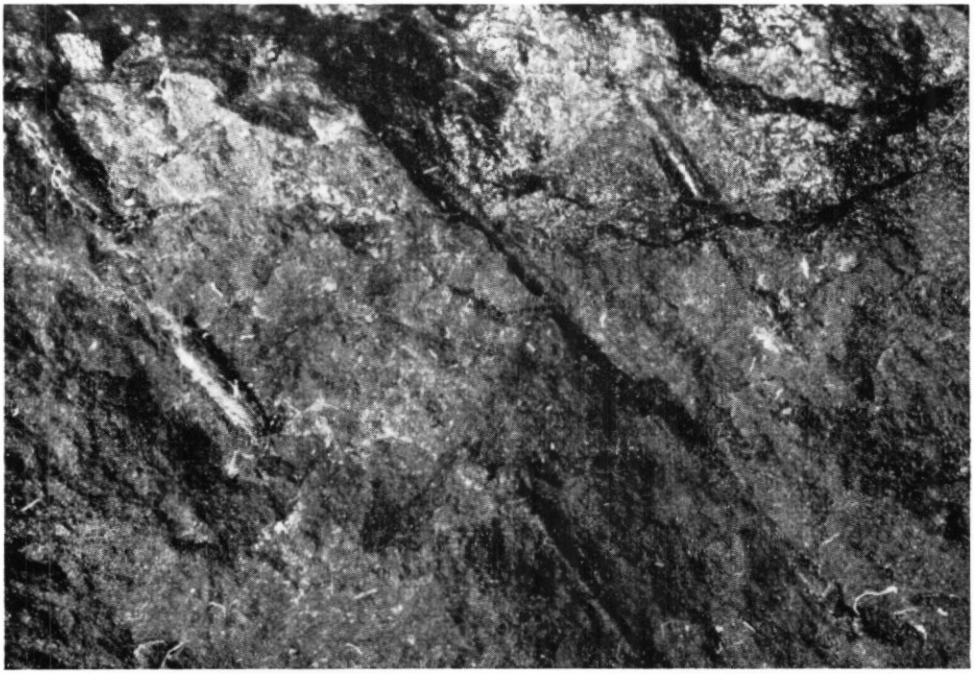

Fig. 2. Several orientated tubes (partly obscured by matrix) near the outer margin of a cement-stone concretion at locality F, south-eastern Alexander Island; ×14 (KG.13.16).

hydrodynamic force (Yochelson, 1968). "Nesting" may have occurred in specimens of *Coleoloides* from the Cambrian of Harts Hill, Nuneaton, up to six calcitic shells often lying eccentrically within a larger one. Alternatively, this apparent layering could represent successive phases of recrystallization.

Some forms of *Coleolus* from the Maquoketa Formation (Upper Ordovician) of Iowa are reputed to be multi-layered and composed of calcium phosphate. Moreover, in overall structure, these shells are thought to be practically identical with those described here (personal communication from E. L. Yochelson). Although these Ordovician specimens undoubtedly appear to be multi-layered in the hand specimen, thin-section studies suggest that invagination had occurred. Furthermore, many of the tubes are composed of a massive form of phosphate containing micro-fossils.

Comparison with annelids (excluding polychaetes)

The so-called "tubicola" serpulids (such as *Longitubus*) from the Cretaceous of New Jersey also have calcareous shells and they are composed of not more than one or two layers (Howell, 1943). The tubes of deep-water annelids collected off the coast of California were found to be formed of as many as four differently orientated major layers, each composed of several bundles of (?) chitin. However, these tubes were segmented and larger (1·0–2·5 mm. in diameter) than the Alexander Island material (personal communication from O. S. Adegoke).

An unidentified multi-layered structure referred to as a sphere but perhaps representing a transverse section through a tube, and thought to be comparable in some respects with several of the transverse thin sections figured here, occurs in the Upper Cretaceous of the Alps (Locker, 1967, pl. II, fig. 13). However, the structure is smaller than the fossil tubes and the eight concentric layers comprising the wall seem to consist of calcium carbonate (personal communication from S. Locker). Moreover, none of the layers is isotropic, even though Locker's figure suggests this is so.

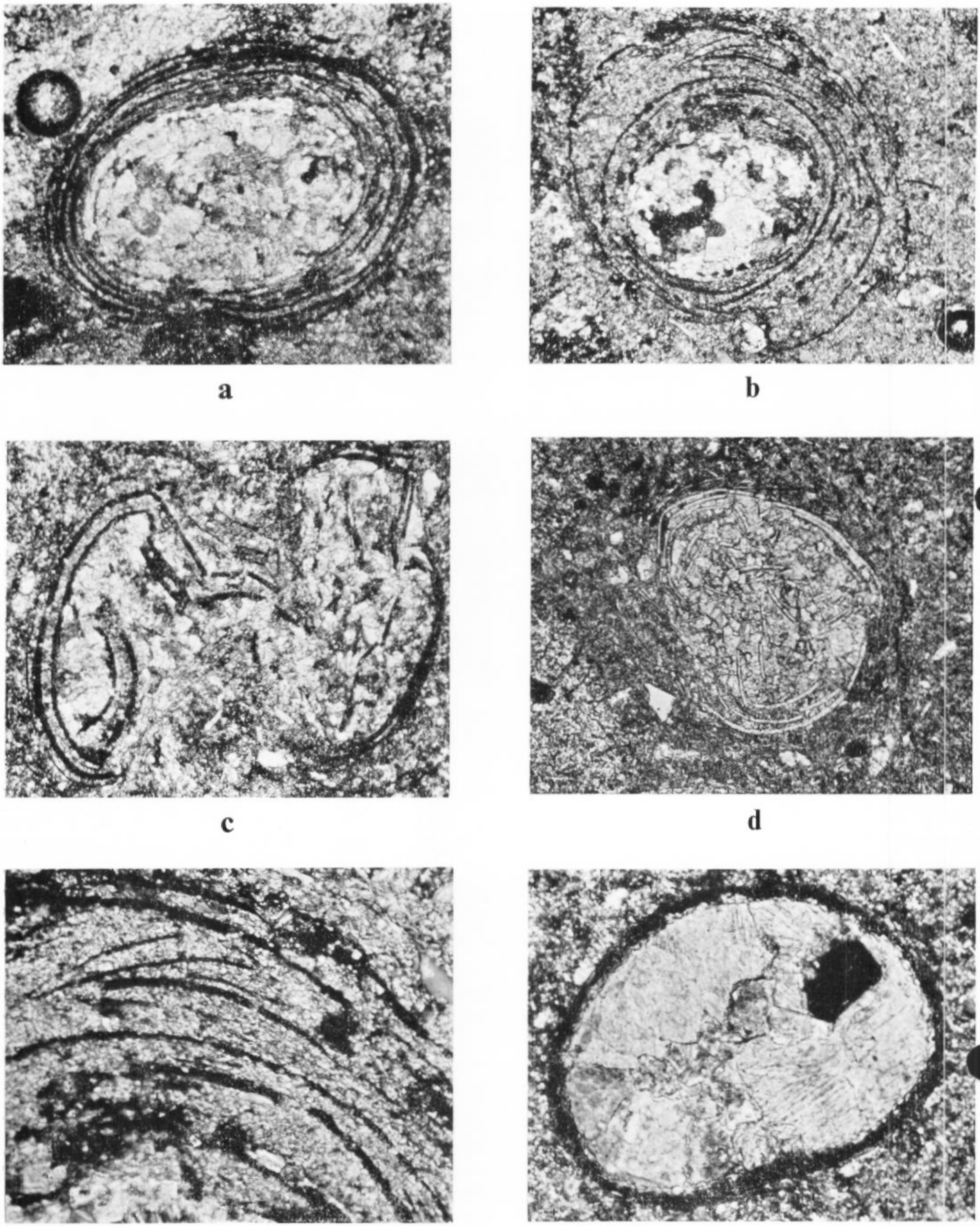

Fig. 3. a. A thin section approximately normal to the tube walls showing a core of coarsely crystalline calcite surrounded concentrically by several layers of isotropic collophane separated from each other by finer-grained calcite; X-nicols; ×112 (KG.13.16c).

b. A more widespread arrangement of collophane layers resembling Saturn's rings probably resulting from diagenesis. Some distortion of the tube is also apparent; X-nicols; ×136 (KG.13.16c).

c. The dislocation of two tubes showing the disorderly arrangement of the fragmented layers of collophane; X-nicols; ×120 (KG.13.16c).

d. Considerable disorder shown by fragmented layers of collophane lying haphazardly within a calcite core; ordinary light; ×88 (KG.13.16c).

e. Enlargement of part of Fig. 3a showing the concentric arrangement of six major collophane laminae and the imbricate arrangement of three thinner laminae; X-nicols; ×270 (KG.13.16c).

f. A thin section normal to a small tube or the distal end of a normal-sized tube showing a single layer of collophane surrounding a core of massive calcite; X-nicols; ×240 (KG.13.16c).

Comparison with pogonophorans

Undoubtedly, the small tubes from Alexander Island are comparable in many respects with the Pogonophora or beard worms, which secrete an unbranched and extremely slender tube often one hundred times longer than the diameter (Fig. 4a). Modern pogonophoran tubes, which are composed of chitin and protein (Ivanov, 1963, p. 122; Foucart and others, 1965) are usually 10–35 cm. long and generally less than 1 mm. wide, although some as wide as 2·8 mm. have been recorded (Hyman, 1959; Ivanov, 1963). Their morphology is somewhat variable. Some are relatively straight and virtually unornamented, whereas others are clearly segmented (*Lamellisabella johanssoni*), are divided into conical segments (*Polybrachia annulata*) (Ivanov, 1963, p. 120, fig. 84) or develop modifications, particularly at their anterior ends.

Several fossils having affinities with the Pogonophora have been recorded: notably *Hyolithellus* from the Cambrian (Poulsen, 1963), and forms from the early Oligocene of Oregon (Adegoke, 1967) and from sideritic and phosphoritic concretions in the Lower Pleistocene near Antwerp (de Heinzelin, 1965; van Tassel, 1965). The thin and apparently single-layered wall structure of the Oligocene tubes and the morphology, ornamentation and segmentation of these and the other specimens suggest that they are most probably pogonophorans.

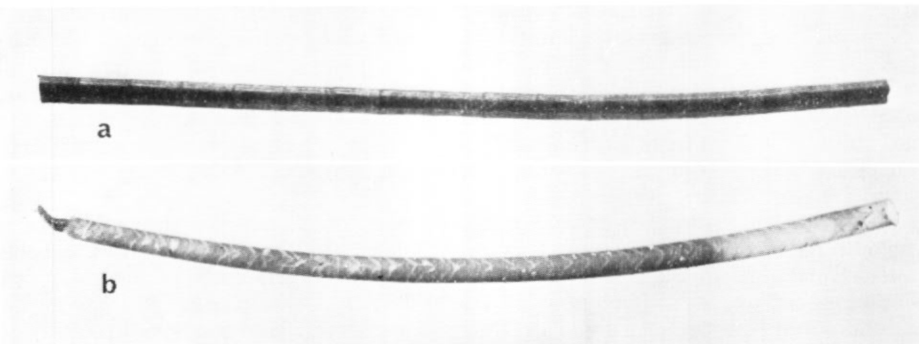

Fig. 4. a. Part of the tube of the pogonophoran *Galathealinum mexicanum* from the central Pacific Ocean showing transverse segmentation; ×2.
b. A tube of *Hyalinoecia tubicola* showing a succession of scars left by the valves which seal off the tube when the polychaete is alarmed. The worm can be seen protruding through the narrower end of the tube; ×1·3.

Several thin sections through the tube of the pogonophore *Galathealinum mexicanum* have not only confirmed the findings of Southward and Southward (1966, p. 598, fig. 13) but have emphasized the difference between the pogonophoran wall structure and that of the specimens from Alexander Island. Whereas the latter are multi-layered (though modified by diagenesis), the modern pogonophoran tube is formed of a single layer of short closely bonded fibres. Furthermore, it is unlikely that the fibres could form separate layers, even assuming that the tube had been disrupted in some way and that the fibres had been interleaved with sediment or a mineral such as calcite. It is therefore improbable that replacement or recrystallization of a pogonophore tube could have caused the disruption illustrated in Fig. 3b.

It is interesting that, when he investigated the structure of *Hyolithellus*, Poulsen found the tubes were broken into fragments and showed a laminated structure. Moreover, when X-ray fluorescence analysis of a pogonophoran tube showed a high calcium content similar to that of *Hyolithellus*, Poulsen (personal communication) thought that both types of tube must be composed of alternating laminae of organic "tissue" and calcium carbonate. However, he has since confirmed the present observations that these laminae of calcite (if they do exist) cannot be resolved optically as such and that the pogonophoran tube is in fact a single-walled laminated unit. The finely laminated structure of *Hyolithellus* described by Lochman (1956) may correspond to the bonded fibrous structure described above.

Dr. D. B. Carlisle (personal communication) has suggested that, as far as he could tell from the present illustrations, the tubes from Alexander Island were "very likely to be pogonophoran in origin". Dr. E. C. Southward, who examined the same photographs, commented that although the size and laminated nature of these tubiform fossils are reminiscent of Pogonophora, the layers of the pogonophoran tube are normally close in contact with one another. Nevertheless, she admitted that decay or recrystallization could possibly have separated them.

Comparison with polychaetes

Dr. Southward is inclined to interpret them as belonging to some form of polychaete which builds tubes with a rather loosely laminated structure of protein and polysaccharide materials. These tubes are often comparable in diameter with those described here but some chaetopterids are annulated with transverse and perforated partitions while others are branched or crooked (Barnes, 1965, p. 223). The annulations are not conspicuous in all forms, and the partitions may not be detectable in fossils (personal communication from R. D. Barnes).

Several polychaetes, notably the eunicid *Hyalinoecia tubicola* (Fig. 4b) and the chaetopterids *Spiochaetopterus* and *Telepsavus* (Barnes, 1964, 1965), secrete fine straw-like tubes practically identical with those from Alexander Island.

H. tubicola, which lives in sand, muddy sand or mud, secretes a smooth and relatively straight tube. The worm is able to carry this over the sea bed by moving half out and anchoring itself before pulling the tube along behind. It is normally open at both ends but when the animal is alarmed the ends are effectively sealed by pairs of internal curved valves. These tubes, which may be up to 5 mm. in diameter, have been described by Fauvel (1959, p. 32) as "chitineau, rigide, transparent", whereas analysis has shown that they contain *no chitin* (personal communication from E. C. Southward). Instead, the material is probably an organic complex composed of onuplin (a phosphorus-rich polysaccharide) and an albuminoid (McIntosh, 1908, p. 423).

Thin sections through both dried and wet specimens of *H. tubicola* show that the tube is distinctly laminated like those from Alexander Island. In these specimens the tube wall, approximately 60 μm. thick, is composed of up to nine layers each of which is distinctly fibrous and evidently easily fragmented. *Spiochaetopterus* also secretes a laminate and loosely bonded tube composed of a cornified or chitin-like material (Barnes, 1964, p. 398) with an internal diameter ranging from 0·7 to 1·2 mm. Sections prepared by Professor Barnes from *Spiochaetopterus* show the same kind of separation of the laminae as in Fig. 3b.

On the basis of the structure of the tube wall and its composition, it is evident that the specimens from Alexander Island are undoubtedly more akin to the polychaetes than to Pogonophora. Although many *Hyalinoecia* tubes appear to be much longer (6–14 cm.) overall than those described here, they are said to range in size from very small ones to larger deep-water forms such as those from the Bay of Biscay which are about 10 mm. in diameter (personal communication from E. C. Southward). The *Spiochaetopterus* tube is generally smaller although its total length may vary with the substratum, but the polychaete is smaller (3–12 cm.) and more abundant in muddy strata (Barnes, 1964, p. 398). Barnes's observations may be applicable to the fossil tubes of Alexander Island, since they are very small and have a high density per unit area at their only locality—certainly more than the 25–35 individuals per 0·1 m.^{2} observed for *Spiochaetopterus* (Barnes, 1964, p. 398).

The present observations and those of most of the individuals who have examined photographs of the material therefore suggest that these fossil tubes represent an aggregation of polychaetes similar to *Hyalinoecia* or *Spiochaetopterus*. Moreover, it seems likely that, although the laminae comprising the tube walls may have been loosely bonded, they were further separated by decay and/or recrystallization. It may therefore be interesting to speculate on how such a multi-layered tube was built up.

Tube construction

Although it has been reported that *Hyalinoecia* can build a tube in a single day (Eisig, 1906, p. 263), the method of construction is imperfectly known. However, *Hyalinoecia* and similar polychaetes (such as the fossil forms described here) could secrete tubes in a way analogous to that of *Spiochaetopterus*; on emerging from its tube it secretes a series of gutter-like half sections from epidermal glands situated on the antero-ventral region of the body, and the joins are reinforced with additional secretions which gradually thicken the wall (Barnes, 1964, p. 402). The tube can be extended at both ends and, like *Hyalinoecia*, construction is rapid; if one of these worms is dislodged from its old tube, it is able to secrete a delicate short one within an hour (Barnes, 1964, p. 404). Like most modern polychaetes, the fossil forms presumably depended on a current of water passing through the tube to bring food (suspended detritus and plankton) and oxygen while at the same time removing excreted and gaseous waste.

So far as the author is aware, neither *Spiochaetopterus* nor *Hyalinoecia* have been previously recorded from the fossil record, although certain families of polychaete are well represented, notably the Serpulidae. *Hyalinoecia tubicola* is virtually cosmopolitan and is normally found with other scavengers on the continental slopes although it has been dredged from 4–1,000 m., whereas *Spiochaetopterus oculatus* is very common along the North American Atlantic coast particularly in the more muddy substrates.

Other Tubiform Fossils

At Fossil Bluff, three other tubiform fossils were recorded. Two were inclined to the bedding and the other was approximately parallel to it. One of the former (KG.1.418) is at least 15 mm. long and tusk-like in appearance, tapering from its widest part (2·5 mm.) to a slightly recurved tip. It appears to have been crushed and much of the shell wall has been haematitized. The other two tubes (KG.1.722, 728), which are 1·5 mm. in diameter and at least 1 cm. long, are similar in size to those from locality F but the composition and structure of the tube wall are different.

The tube parallel to the bedding (KG.1.728) is well preserved but only partly exposed; it appears to taper slightly downwards and has no surface ornament. Even in the hand specimen, it is clear that the tube, which is circular in cross-section, consists of a central core surrounded by a relatively thick wall. The core is composed mainly of calcite which is partly replaced by prehnite, whereas the tube wall is composed of quartz and divided into inner and outer layers. Because of the irregular crystal boundaries, it is probable that the quartz is secondary. As the original composition is therefore not known with certainty and the morphology is incomplete, the specimen cannot be identified satisfactorily. There is, however, a possibility that specimens KG.1.722 and 728 may represent the apices of gastropod digitations, as digitate forms resembling *Anchura* are relatively common in the succession where the tubiform structures occur.

Conclusions

The majority of those who have examined photographs of these multi-layered tubes are agreed that, although they are probably laminated like those of a polychaete, the wide separation of the laminae is a secondary feature. A similar form of separation is evident in sections of the polychaetes, *Hyalinoecia* and *Spiochaetopterus*. The technique by which the fossil tubes were built is thought to be analogous to that of *Spiochaetopterus*. Three other tubiform fossils described here have not yet been identified.

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REFERENCES

ADEGOKE, O. S. 1967. A probable pogonophoran from the early Oligocene of Oregon. *J. Paleont.*, **41**, No. 5, 1090–94.

BARNES, R. D. 1964. Tube-building and feeding in the chaetopterid polychaete, *Spiochaetopterus oculatus*. *Biol. Bull. mar. biol. Lab., Woods Hole*, **127**, No. 3, 397–412.

———. 1965. Tube-building and feeding in chaetopterid polychaetes. *Biol. Bull. mar. biol. Lab., Woods Hole*, **129**, No. 2, 217–33.

EISIG, H. 1906. *Ichthyotomus sanguinarius* eine auf aalen schmarotzende Annelide. *Fauna Flora Golf. Neapel*, 28 monographie, 300 pp.

FAUVEL, P. 1959. Classe des Annélides Polychètes. Annelida Polychaeta (Grube, 1851). (*In* GRASSÉ, P.-P., *ed, Traité de zoologie: anatomie, systématique, biologie. Tome V. Annélides, Myzostomides, Sipunculiens. Echiuriens, Priapuliens, Endoproctes, Phoronidiens.* Fasc. 1, 13–196.)

FISHER, D. W. 1962. Small conoidal shells of uncertain affinities. (*In* MOORE, R. C., *ed. Treatise on invertebrate paleontology. Pt. W. Miscellanea* (*conodonts, conoidal shells of uncertain affinities, worms, trace fossils and problematica*). Lawrence, Kansas, University of Kansas Press and the Geological Society of America, W.98–143.)

FOUCART, M. F., BRICTEUX-GRÉGOIRE, S. *and* C. JEUNIAUX. 1965. Composition chimique du tube d'un pogonophore (*Siboglinum* sp.) et des formations squelettiques de deux ptérobranches. *Sarsia*, No. 20, 35–41.

HEINZELIN, J. DE. 1965. Pogonophores fossiles? *Bull. Soc. belge Géol. Paléont. Hydrol.*, **73** (for 1964), Fasc. 3, 501–10.

HINCKS, T. 1868. *A history of the British hydroid Zoophytes. Vol. II.* London, John Van Voorst.

HOWELL, B. F. 1943. *Hamulus*, "*Falcula*", and other Cretaceous Tubicola of New Jersey. *Proc. Acad. nat. Sci. Philad.*, **95**, 139–66.

HYMAN, L. H. 1940. *The invertebrates: Protozoa through Ctenophora. Vol. 1.* 1st edition. New York and London, McGraw-Hill Book Company, Inc.

———. 1959. *The invertebrates: smaller coelomate groups. Chaetognatha, Hemichordata, Pogonophora, Phoronida, Ectoprocta, Brachipoda, Sipunculida, the coelomate Bilateria. Vol. 5.* New York, London, Toronto, McGraw-Hill Book Company, Inc.

IVANOV, A. V. 1963. *Pogonophora*. London, Academic Press. (Translated from the Russian and edited by D. B. Carlisle. With additional material by Eve C. Southward.)

LOCHMAN, C. 1956. Stratigraphy, paleontology, and paleogeography of the *Elliptocephala asaphoides* strata in Cambridge and Hoosick quadrangles, New York. *Bull. geol. Soc. Am.*, **67**, No. 10, 1331–96.

LOCKER, S. 1967. Die Sphären der Oberkreide und die Sogenannte Orbulinaritfazies. *Geologie*, Jahrg. 16, Ht. 7, 850–59.

MCINTOSH, W. C. 1908. *A monograph of the British annelids. Vol. 2—Part 1. Polychaeta. Nephthydidae to Syllidae.* London, Ray Society.

POULSEN, V. 1963. Notes on *Hyolithellus* Billings, 1871, Class *Pogonophora* Johannson, 1937. *Biol. Meddr*, **23**, Nr. 12, 15 pp.

SOUTHWARD, E. C. *and* A. J. SOUTHWARD. 1966. A preliminary account of the general and enzyme histochemistry of *Siboglinum atlanticum* and other Pogonophora. *J. mar. biol. Ass. U.K.*, **46**, No. 3, 579–616.

TASSEL, R. VAN. 1965. Concrétions tubulées du Merksemien (Pléistocène inférieur), à Anvers. *Bull. Soc. belge Géol. Paléont. Hydrol.*, **73** (for 1964), Fasc. 3, 469–500.

YOCHELSON, E. L. 1968. On the nature of *Polylopia*. *Prof. Pap. U.S. geol. Surv.*, No. 593-F, F1–7.