TUBE ULTRASTRUCTURE OF THE FOSSIL GENUS *ROTULARIA*
DEFRANCE, 1827 (POLYCHAETA, SERPULIDAЕ)

OLEV VINN
Institute of Geology, University of Tartu, Vanemuise 46, 51014 Tartu, Estonia <olev.vinn@ut.ee>

INTRODUCTION

Among polychaete annelids, calcareous tubes occur in Serpulidae, Spionidae, Sabellidae, and Cirratulidae (Perkins, 1991; Fischer et al., 2000). The tubes of most serpulids are completely or partially cemented to the substrate. The fossil genus *Rotularia* has a peculiar unattached, spirally coiled tube, thus well distinguishable from the other known serpulids. Tube records of *Rotularia* are known from Mesozeic (Late Jurassic) (Ball, 1960; Stevens, 1967) to Early Tertiary sediments, becoming very common during the Cretaceous and Eocene (see Savazzi, 1995). It also has a global distribution (Wrigley, 1951; Ball, 1960; Keen, 1961; Regenhardt, 1961; Howell, 1962; Stevens, 1967; Chiplonek and Tapassi, 1973; Ware, 1975; Lommerzheim, 1979; Macellari, 1984; Jäger, 1993).

Owing to the peculiar shape of *Rotularia*, many authors in the past interpreted it as a vermetid gastropod (e.g., Bronn, 1827; Schauert, 1865; Stoliczka, 1868; Whitfield, 1890; Rovereto, 1904; Cossmann, 1912; Doncieux, 1926; Rutsch, 1939; Wenz, 1943). Serpulid identification has been definitively confirmed by recent observations on the tube structures (Accorsi Benini and Ungaro, 1989; Savazzi, 1995). All rotularias were cemented to the substrate during their earliest growth stage, but they became detached shortly after the formation of first whorls (Savazzi, 1995). Their tubes have two layers (Schmidt, 1955; Ball, 1960; Savazzi, 1995), the thin inner layer composed of lamellae sub-parallel to the inner shell surface and the thick outer layer with chevron shaped growth lamellae.

The tube ultrastructure of Recent serpulid polychaetes has been recently studied by various authors (Bubel et al., 1983; ten Hove and Zibrowius, 1986; Zibrowius and ten Hove, 1987; ten Hove and Smith, 1990; Nishi, 1993; Weedon, 1994; Alani et al., 1995; Sanfilippo and Molland, 2000; Sanfilippo, 1996, 1998a, 2001). The ultrastructure of fossil *Rotularia* is known in only a few species (Bandel, 1986; Sanfilippo, 1998a, 1998b, 1999; Zibrowius and ten Hove, 1987; Weedon, 1994; Vinn, 2005). The tubes of most of Recent serpulids are composed of irregularly oriented prismatic crystals of aragonite or calcite, named as fine, complex crossed lamellar structure sensu Carter et al. (1990). Less commonly they have ordered chevron structure sensu Weedon (1994, p. 5, fig. 2), here termed as lamello-fibrillar structure sensu Carter et al. (1990). Also, various simple and spherulitic prismatic structures have been observed in serpulid polychaetes (see below).

The details of tube ultrastructure of *Rotularia* were hitherto undescribed. The aim of this paper is to describe the tube ultrastructure of *Rotularia* and to compare it with that of the Recent serpulids. The ultrastructure of the *Rotularia* tube wall provides taxonomic evidence of serpulid affinities. The value of this approach is evident especially in fossil records, when indeterminable fragments of skeletons are often the sole available remains (see Sanfilippo, 1996, 1998b; Sanfilippo and Molland, 2000). Too, the mode of life of *Rotularia* among serpulids may be reflected in their ultrastructure.

MATERIAL AND METHODS

A well-preserved specimen of the type species *Rotularia spirulaea* Lamarck, 1818, and a specimen of *Rotularia nummularia* Schlotheim, 1820 were selected for a SEM study of tube ultrastructure. *Rotularia spirulaea* comes from the Eocene of Doss Trento (Trento, Northern Italy) and *Rotularia nummularia* from the Eocene of Gomberto (Vicenza, Northern Italy).

*Rotularia* tubes in epoxy resin were ground longitudinally and transversely, polished, and treated with a 1:1 mixture of 25% glutaraldehyde and 1% acetic acid, to which alcin blue was added (GA-solution) for 5 to 45 minutes before SEM study (Schöne et al., 2005). To make comparisons, tubes of the Recent serpulids *Bathyvermilia langerhansi*, *Cucugera websteri*, *Hydroides dianthus*, *Laminatubus alvini*, and *Pomatoceros triquetus* in epoxy resin were also examined, ground longitudinally, polished, and treated with 1% acetic acid for two minutes, then coated with gold and studied with SEM. Fifty Recent serpulid species were selected and their tube ultrastructures were compared with those of *Rotularia* (author’s unpublished database of serpulid tube ultrastructures).

INSTITUTIONAL ABBREVIATIONS

NHMW, Natural History Museum in Vienna, ZMA-V.Pol., University of Amsterdam, Zoological Museum, polychaete collection, and TUG, Museum of Geology, University of Tartu.

RESULTS

**Tube ultrastructure of Rotularia spirulaea** Lamarck, 1818.—The tube is composed of two distinct layers (Fig. 1.1). The outer layer, of variable thickness (1.6 mm dorsally and 0.67 mm laterally, measured at the tube opening), has a homogeneous structure (sensu Carter et al., 1990) and is composed of variably oriented clusters of angular crystals, each crystal 7–30 μm thick (Fig. 2.1–2.3). At the border between the outer and inner layer, sectors of spherulitic prisms were observed reaching into both layers. Some sectors of spherulitic prisms are grown completely inside the inner layer (Fig. 2.3). These spherulitic prisms reveal incremental zonation perpendicular to their longitudinal axis (Fig. 2.3).

The inner layer is 0.18 mm thick (Fig. 1.1) and has a lamello-fibrillar structure (sensu Carter et al., 1990). The term lamello-fibrillar (Carter et al., 1990) is preferred here because the chevron-shaped growth increments are not characteristic of all serpulids with that particular ultrastructure (personal observations). In *Rotularia* the growth lamellae of the lamello-fibrillar inner layer do not have chevron shapes (Savazzi, 1995, p. 77, figs. 13–16). The inner layer is mostly composed of elongate prismatic crystals 5–8 μm long and 1 μm thick, which have a common orientation within the single growth increment and a different orientation in adjacent growth increments (Fig. 2.4). Growth increments are oriented perpendicular to the tube’s growth direction.

**Tube ultrastructure of Rotularia nummularia** Schlotheim, 1820.—The tube is composed of two, and at some places three, distinct ultrastructural layers (Fig. 1.2). The border between the outer and inner layers is somewhat transitional. The outer layer is of variable thickness (1.3 mm dorsally and 0.45 mm laterally, measured at the tube opening). The ultrastructure of the outer layer is composed of variably oriented clusters of angular crystals, each crystal 6–10 μm thick (Fig. 2.6). At some places within the outer tube layer, the structure is similar to an irregular, simple prismatic structure (sensu Carter et al., 1990). The length of the...