INTRODUCTION

Hydrothermal vents and methane seeps sustain unique ecosystems with a highly adapted fauna that largely thrives on chemotrophic endosymbionts. This large biomass attracts not only predators but also parasitic taxa like the recently reported oophagous bivalve *Acesta bullitis* Vokes, 1963 that lives permanently attached to a vestimentiferan tube worm (Järnegren et al., 2005). Here I report large brachiopods of the Early Cretaceous seep-restricted genus *Peregrinella* Oehlert, in Fischer, 1887 that were infested by polychaete tubes inside their shells during their lifetime.

Many Paleozoic and Mesozoic vent and seep communities were dominated by brachiopods, yet their ecologic role in these ecosystems remains elusive (Campbell and Bottjer, 1995b; Campbell and Bottjer, 1995a; Sandy, 1995; Peckmann et al., 2007). Several of these brachiopod taxa appear to be endemic to vents and seeps, and their mass occurrence combined with their often large size makes the analogue to chemosymbiotic bivalves like modern *Calyptogena* Dall, 1891 or *Bathymodiolus* Kenk and Wilson, 1985 an attractive hypothesis. However, chemosymbiosis has never been demonstrated for brachiopods found at Recent vents or seeps (Campbell and Bottjer, 1995a; Barry et al., 1996; Zezina, 2000), thus from a uniformitarian point of view, chemosymbiosis in extinct brachiopods is doubtful.

The dimerelloid rhynchonellid *Peregrinella* is the largest Mesozoic brachiopod, with a diameter exceeding 10 cm, and it has been found exclusively in Early Cretaceous hydrocarbon seep deposits ranging from North America to Europe and Tibet (Campbell and Bottjer, 1995b; Gaspard, 1999; Campbell, 2006). *Peregrinella* often co-occurs with serpulid tubes ("Serpula recta"; see Campbell and Bottjer [1995b] for a compilation), but such tubes have never been described from the interior of the shell. Several authors made serial grindings or thin sections of *Peregrinella* (i.e., Biernat, 1957; Sun, 1986; Posenato and Morsilli, 1999) in which internal tubes surely would have attracted attention, and such tubes have never been reported in the old—often very detailed—descriptions of *Peregrinella* from Europe (i.e., Toulou, 1911).

The worm-infested specimens documented here were collected from a Hauterivian mass occurrence of *Peregrinella multcarinata* Lamarec, 1819 in southeastern Crimea, Ukraine (Sarycheva, 1960; Smirnova, 1972). The specimens reach 90 mm in diameter and occur in an isolated carbonate body within thick-bedded, deepwater clay- and siltstones of the so-called “Planerskoje section” (Smirnova, 1972). The carbonate exudes a petroliferous odor when struck with a hammer and shows cement phases typical for hydrocarbon seep carbonates (Kiel and Peckmann, 2008). The specimens are catalogued in the Paleobiology collection of the Smithsonian Natural History Museum in Washington DC, USA (USNM).

OBSERVATIONS

Twenty-four specimens of *Peregrinella multcarinata* from the Planerskoje section have long tubes inside them. The longest observed tube has a length of 75 mm, is just over 1 mm in diameter at the start, and has a diameter of 3.5 mm at its end (Fig. 1.1). Occasionally the tubes have bulges 5 mm in diameter, but this thickness is achieved by tube wall material; the diameter of the tubes’ interior never exceeds 3.5 mm. The tubes are often curved or undulating, and sometimes make U-turns. These U-turns are usually located in the dorsal third of the shell, are oriented at various angles from parallel to perpendicular to the inner shell wall, and always turn the tubes away from the dorsal side of the shell so that they grow back towards the ventral margin. Only at their starting point are they attached to the brachiopod’s shell (Fig. 1.2) and they remain close to the inner shell wall during their entire length. They were not observed to cross the shells’ interior from one valve to the other. Most of the tubes are associated with the pedicle valve, with only two exceptions where they occurred close to the brachial valve. Multiple occurrences of up to three tubes within a single brachiopod specimen were observed. The tubes are found only in large specimens; among the hundreds of checked individuals, the two smallest with a tube inside were 55 mm wide. Most tubes were found in articulate specimens and they are frequently seen in voids inside the shells, surrounded by large, yellowish calcite crystals that grow radially away from the tube (Fig. 1.3). Light microscopy and SEM imaging shows that the tube wall is composed of two distinct layers. In slightly weathered specimens, the inner layer has a whitish color under the light microscope; the outer layer has same silverish to dark-grey color as *Peregrinella’s* shell. Indeed, SEM observations show that the outer layer is composed of the same calcitic fibrous prisms as the shell of *Peregrinella multcarinata*, with the prisms being oriented parallel to, or spirally around the tube (Fig. 1.4, 1.6). The whitish inner layer consists of sublayers; thin inner and outer layers of acicular prisms more-or-less perpendicular to the tube’s surface and a thick irregular granular layer between them (Fig. 1.5, 1.6). The complete inner layer rarely exceeds 150 μm in thickness, whereas the outer layer usually has multiples of this thickness, especially at the bulges, where it can reach 700 μm or more.

POLYCHAETE PALEOECOLOGY

Several observations indicate that these tubes were built by polychaete worms within the shell of the living brachiopod:

- The inner tube wall consists of acicular microstructure similar to that of other polychaetes with calcareous tubes (ten Hove and Zibrowius, 1986; Beesley et al., 2000; Vinn, 2005), suggesting that the animal living within the tube was a polychaete worm. The prisms of the polychaete’s tube are not arranged in a chevron-like fashion as in serpulids (cf. Weedon, 1994); hence the identity of the polychaete remains uncertain.
- The tubes always occur inside the shell. Had the polychaete lived after the death of the brachiopod, it should have attached itself anywhere on the shell.
- The fact that the outer tube wall has the same microstructure as the shell of *Peregrinella multcarinata* indicates that the brachiopod enclosed this ‘foreign matter’ with its own shell material, like mollusks form pearls around foreign particles inside their shells. This implies that the polychaete built its tube while the brachiopod was alive.
- The tubes avoid the dorsal third of the brachiopod’s interior where most of the soft tissue of the brachiopod is located.
- The tubes tend to stay close to the inner shell wall, suggesting...