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Keck Geology Consortium: Projects 2007-2008
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A FIELD AND LABORATORY STUDY OF THE EDIACARAN FOSSILS OF HEWITT'S COVE: EVIDENCE OF TECTONIC DEFORMATION AND CONSIDERATION OF PALEOBIOLOGY

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INTRODUCTION

Ediacaran fossils have baffled scientists since their original discovery in 1868. As the oldest unambiguously multicellular organisms with tissues, Ediacaran organisms (or simply Ediacarans) represent a key stage in the evolution of life, and understanding their fossil record is essential to understanding the status of life prior to the great radiation of forms seen in the Early Cambrian. However, the bizarre shapes and structures of many Ediacarans have made placing them in phylogenetic context with modern taxa and determining their ecological roles difficult. In this study, the Ediacaran fossils of a roughly 575 Ma argillite bed of the Cambridge Formation, exposed at Hewitt's Cove, Massachusetts (see Fig. 1), were described and considered in relation to current theories on Ediacaran paleobiology.

Figure 1. The inclined surfaces of the argillite bed at Hewitt's Cove, 2007.

THE EDIACARAN *ASPIDELLA*

Despite careful combing of the field site and microscopic examination of numerous thin sections, no evidence of any fossil genus, other than the Ediacaran *Aspidella*, was found. *Aspidella* are mysterious organisms, even by Ediacaran standards. Specimens consist of a fossil structure that superficially resembles a small crater, generally no more than a few centimeters in diameter and a few millimeters in height (see Fig. 2). The name '*Aspidella*' was first used by Elkanah Billings in 1872 to describe ring-shaped fossils from Newfoundland (Billings, 1872). The type specimen of *Aspidella* has been lost (Gehling et al., 2000), leaving the genus vulnerable to nomenclatural uncertainty. *Aspidella* has since be-

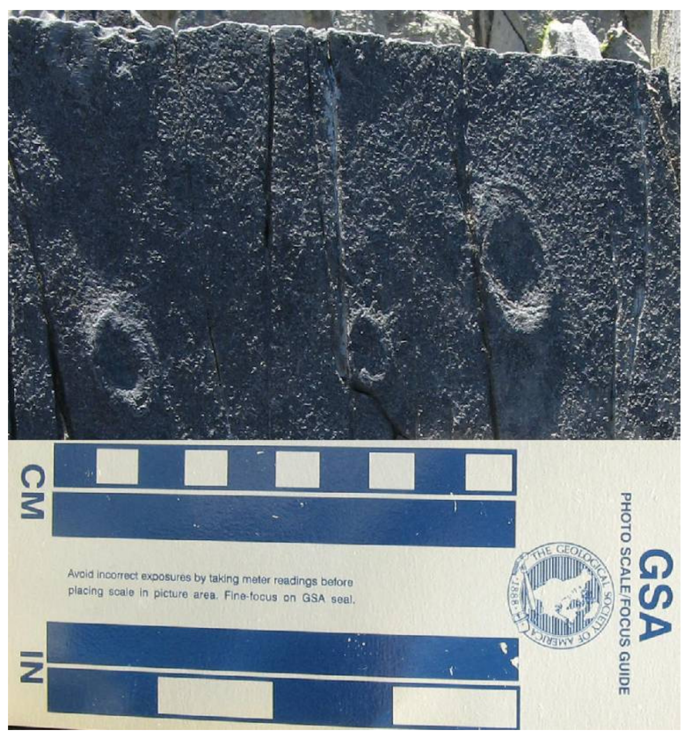

Figure 2. Aspidella in outcrop at Hewitt's Cove.

come somewhat of a junkyard taxon, in which many varieties of ring-shaped fossils with otherwise indeterminate morphologies have been lumped (Gehling et al., (2000).

The original description of *Aspidella* suggests the type specimen actually had multiple ridges radiating from the center of the ring, like the spokes of a bicycle wheel (Gehling et al., 2000). If this is true, the name *Aspidella* is actually more morphologically specific than commonly perceived. However, for the purposes of this study, the name *Aspidella* will be used in the standard way (as a catch-all genus for ring-shaped Ediacarans), with the understanding that the genus is in need of revision.

The nature of *Aspidella* is the subject of much discussion and debate. The general consensus is that they were relatively sessile organisms, similar in appearance, but with perhaps no evolutionary relation, to modern members of the order Pennatulacea (the sea pens). They, and many other Ediacaran taxa, are believed to have each had a soft stalk (the rachis) with a frond-like appendage at one end and a stiff base (the peduncle) at the other (terminology from Laflamme and Narbonne, 2008). This base anchored the *Aspidella* to the sea floor. Only the stiff peduncles of most *Aspidella* are preserved as fossils, but comparison of the bases to those of other fossil organisms gives credence to the notion that stalks and fronds were present in life. In rare instances, *Aspidella* specimens from the Fermeuse Formation have been found with what appear to be impressions of stalks attached to the more clearly preserved peduncles (Gehling et al., 2000).

That no fossils other than those of *Aspidella* were discovered does not imply that only one variety of Ediacaran was present in Precambrian Hewitt's Cove. Given that only a portion of each *Aspidella* was ever found (never any more than the organism's holdfast structure), it would be expected that any Ediacarans with bodies softer than the holdfasts of *Aspidella* might not be preserved. This effectively rules out nearly all other Ediacaran forms. So, while Hewitt's Cove is a location dominated by a single fossil organism, it may well have been an environment of far richer biodiversity. Nevertheless, *Aspidella* were the only Ediacarans found during the 2007 field season, and it is solely on them that interpretations of the location's paleoecology must be based.

THE POSSIBILITY OF TECTONIC STRETCHING

Hewitt's Cove's *Aspidella* fossils all have an elliptical shape, and this is an important characteristic to understand. It distinguishes them from the *Aspidella* of most other locations, including some that are temporally congruent, such as those of the Mistaken Point assemblage (Canfield et al., 2007). Because the long axes of the elliptical fossils all have similar orientations, it has been speculated that these *Aspidella* were shallow-water dwellers that evolved a streamlined shape and aligned themselves with currents or light sources for photosynthesis (McMenamin, personal communication, 2007). However, the planar, normally graded, and fine-grained laminations of the argillites, combined with their observed lack of traction features and storm indicators (e.g., hummocy and swaley laminae), suggest they formed below the storm wave-base, where it is unlikely strong currents were present.

Measurements of the orientation of the *Aspidella* show exceedingly uniform orientations throughout the exposure, not just on a single bedding surface. This raises the possibility of another explanation for both the unusual shape of the *Aspidella* and their shared long-axis orientation: tectonic deformation. Ancient marine fossils are commonly known to become stretched and distorted in a particular direction by the stress/strain of tectonic events (Webster and Hughes, 1999; Underwood, 1992; Cooper, 1990). Assuming that the *Aspidella* bases were actually circular when first fossilized, a tectonic event could have stretched the fossils into elliptical shapes and would be expected to stretch the great majority of fossils throughout the local exposure in the same direction and to the same degree. The *Aspidella* fossils of the Conception and St. Johns' Group of the Avalon Peninsula are also elliptical, and research has indicated that tectonic deformation is responsible for the elliptical shapes in these instances (Gehling et al., 2000).

SIZE DISTRIBUTION OF THE HEWITT'S COVE POPULATION

Given the limited fossil preservation and the inferred tectonic deformation, it is impossible to determine, based on morphology alone, whether all *Aspidella* fossils observed at Hewitt's Cove belong to the same species or the same subspecies (or the same genus, given the suspect nature of the Aspidella taxon). However, the holdfast fossils all have identical morphology and give no reason to assume the presence of different species. Figure 3 shows the relative abundance of *Aspidella* fossils within their measured range of total elliptical surface area. The graph shows a unimodal distribution. Were the population composed of more than one *Aspidella* species, a bimodal distribution in size might be expected . Whether or not the population is composed of a single species remains unproven, but given the unimodal distribution and the identical (though poorly preserved) structure of the holdfast fossils, it is most parsimonious to conclude that the argillites of Hewitt's Cove record only one species of *Aspidella*.

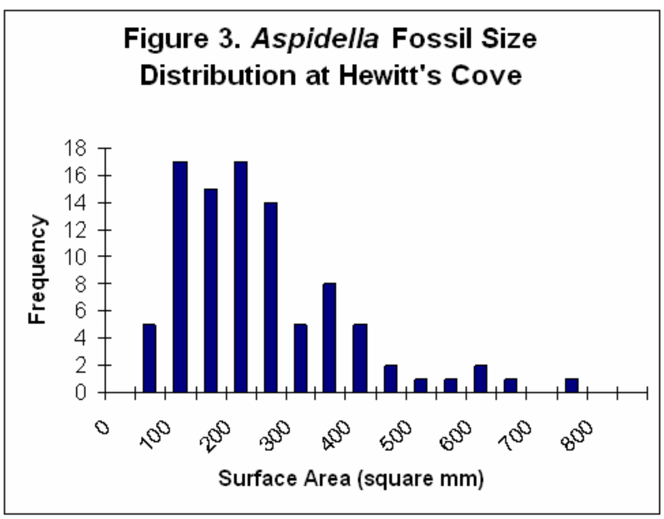

Figure 3. Size distribution of Hewitt's Cove Aspidella population (n=95).

As has been previously observed (Bailey and Ross, 1993), small and large *Aspidella* appear side by side on the same surfaces throughout the Hewitt's Cove exposure, and Aspidella of any given size appear equally common at all elevations. This suggests that variations in taphonomic sorting were minimal throughout the depositional history of the argillites. However, this does not mean that the *Aspidella* population as a whole was not subject to a single consistent sorting bias or to multiple consistent sorting biases. The size distribution graph is decidedly right skewed, and taphonomic bias against large individuals may explain this shape. Alternatively, this shape may indicate a population where the majority of individuals failed to reach maximum size.

As always with Ediacarans, eagerness to extrapolate should be tempered. Virtually nothing is known about the life history of *Aspidella*. Still, the simplest interpretation is that *Aspidella* had only one morphological stage in which they grew, reproduced, and died. Following this interpretation, the Hewitt's Cove size distribution graph may depict a population in which individuals grew larger over time and were characterized with greater mortality early in life than later.

On the whole, the graph contradicts what would be predicted from theories that propose Aspidella to have reproduced by division (Grazhdankin and Gerdes, 2007). If *Aspidella* reproduced simply by splitting themselves in two, the largest individuals should be roughly twice the size of the smallest (assuming perfect one-splits-into-two divisions and that the *Aspidella* consistently split at the first opportunity). Instead, the largest individuals are nearly fifteen times as large as the smallest individuals. If *Aspidella* did reproduce by division, their divisions must have either been unequal or there must have been great variability in the intervening pre-division periods of growth.

EVIDENCE FOR MOVEMENT

Although the argillite beds of the Cambridge Formation record only a limited portion of the *Aspidella* structure, the beds are ideal for answering questions related to *Aspidella* locomotion, because the fossils are embedded in laminated rock. Were the laminations not present, it would be impossible to detect areas of the argillite that had been disturbed; however, with them, movement of the *Aspidella* (especially vertical movement) should be seen as regions where the laminations are blurred and/or disrupted. All examined thin sections showed no signs of lamination disruption (see Fig. 4). This suggests *Aspidella* had a stationary lifestyle, or were only mobile above the sediment-water interface.

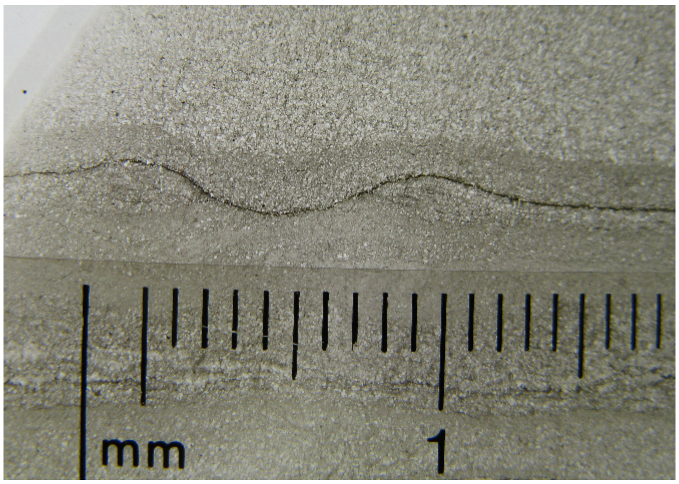

Figure 4. Aspidella in thin section, Hewitt's Cove Section.

The lack of lamination disruption above the *Aspidella* fossils indicates that the organisms anchored themselves to the surface of the sea floor or rested upon it. Had they buried their holdfasts any distance below the top layer of sediment, lamination disturbance above the Aspidella fossils would be expected. This observation contrasts with models that relate *Aspidella* to modern sea pens – many of which do actively bury their bases (Kastendiek, 1976). The lack of horizontal disturbances around the *Aspidella* indicates that the organisms were also incapable of, or at least seldom engaged in, lateral movement. Finally, the lack of any disturbance around all observed *Aspidella* implies that the organisms were buried without a struggle. There is no indication here -- as there is in some instances of turbidite-buried trilobites (Speyer and Brett, 1986) -- that the *Aspidella* were buried suddenly and attempted to escape. Modern sea pens are known to have the ability to extricate themselves after being buried (Kastendiek, 1976). The *Aspidella* were either too immobile to fight through the sediment load or were already dead at the time of burial.

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