



The ins and outs of Ediacaran discs



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ABSTRACT

Abundant discoid fossils referable to *Aspidella* and rarer specimens of *Eoporpita* and *Hiemalora* occur in the Ediacaran “June beds” deposits of the Mackenzie Mountains, Northwest Territories, Canada. Among them are specimens that preserve partial stem imprints, supporting recent interpretations of Ediacaran discs related to *Aspidella* as the basal holdfast structures of fronds. The range and morphological transitions among the June beds specimens accounted for by taphonomy have implications for our recognition and classification of Ediacaran discoidal fossils. We find that *Aspidella* represents the remains of an outer membranous cover of the holdfast structure and that *Eoporpita*, rather than being a distinct biological taxon, represents the remains of its internal contents. Here we reconstruct the internal structure of these holdfasts as a series of laterally-adjacent, hollow, club-like lobes arranged in tiers. This implies that Ediacaran discoid holdfasts may additionally have had structural and/or metabolic functions in addition to their role in anchoring fronds.

1. Introduction

Discs are the most common fossils of the Ediacara biota worldwide, and can occur in densities of hundreds to thousands per square meter (Gehling et al., 2000; Gehling and Droser, 2013; Serezhnikova, 2013). This ubiquity places great import on understanding their structure and function in order to understand and interpret more fully the paleobiology and paleoecology of the earliest benthic multicellular communities. They also have historical significance, as discs were the first documented fossil from what came to be known as the Ediacaran dating back to a time when Precambrian macrofossils were scarcely known and controversial (Billings, 1872; see Gehling et al., 2000). They have undergone several major reinterpretations over the past 150 years including: inorganic pseudofossils (see review in Hofmann, 1971), medusoid cnidarians (Sprigg, 1947, 1949; Glaessner and Wade, 1966; Wade, 1972), bases of polyps (Jenkins, 1985), and microbial colonies (Grazhdankin and Gerdes, 2007), but the current general consensus is that Ediacaran discs ascribable to *Aspidella terranovica* (Billings, 1872) represent the holdfasts of frondose organisms whose petalodia had escaped preservation (Gehling et al., 2000; Tarhan et al., 2015; Burzynski and Narbonne, 2015). This view is bolstered by multiple specimens of fronds attached to holdfasts indistinguishable from what would otherwise be classified as discoid taxa (Ford, 1958; Jenkins and Gehling, 1978; Gehling et al., 2000; Hofmann et al., 2008; Laflamme and Narbonne, 2008; Tarhan et al., 2010, 2015; Laflamme et al., 2011; Serezhnikova, 2010, 2013; Burzynski and Narbonne, 2015).

Though their identity as holdfasts of fronds is now largely resolved,

many important aspects of their anatomy, functional morphology and taphonomy remain uncertain. Is the surface of the structure that we see true to the surface in life? If so, what was their internal morphology? What is the nature of the concentric rings and radial grooves that are common on many specimens? Were they fluid-filled or sand-filled structures? Did these discs have any function beyond anchoring? Until now, taphonomic and other factors have restricted our ability to address these fundamental questions and limited our understanding of the role of discs beyond substrate adhesion for frondose organisms.

Here we present a comprehensive re-evaluation of some of the most common discoidal Ediacaran fossils based on a study of more than 100 slabs containing impressions that were collected from the informally named “June beds” in the Mackenzie Mountains of NW Canada (Fig. 1). All specimens described here are preserved in the Fermeuse-style taphonomic mode (preservation at the base of deeper-water event beds, *sensu* Narbonne, 2005) from deep-sea turbidites (Narbonne and Aitken, 1990; Dalrymple and Narbonne, 1996; Macdonald et al., 2013; Narbonne et al., 2014; Sperling et al., 2016). In contrast with occurrences of deep-water Ediacaran discs in Finnmark (Farmer et al., 1992) and Newfoundland (Gehling et al., 2000; Burzynski and Narbonne, 2015), the June beds lack cleavage, facilitating thin-section studies of the internal anatomy of the discs.

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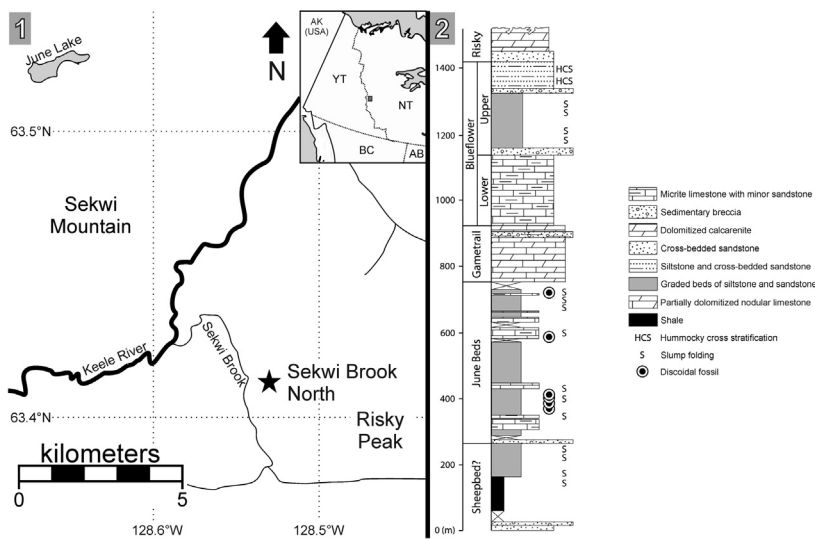


Fig. 1. Location (1) and Ediacaran strata (2) at Sekwi Brook North, Mackenzie Mountains, Northwest Territories, Canada. Stratigraphic section . adapted from Carbone et al. (2015)

2. Geological setting

2.1. Regional geology

Upper Neoproterozoic strata in the Mackenzie Mountains comprise the Windermere Supergroup, a 5–10 km thick succession of Tonian – Ediacaran siliciclastics and carbonates that crops out discontinuously from the Alaska – Yukon border to the Sonoran Desert of Mexico (Ross, 1991). Earliest Windermere strata in the Mackenzie Mountains consist of rift-related deposits concurrent with the opening of the proto-Pacific Ocean that pass upward into deep-water passive margin deposits that contain abundant Ediacara-type fossils (Aitken, 1989; Narbonne and Aitken, 1995; Dalrymple and Narbonne, 1996; MacNaughton et al., 2000; Macdonald et al., 2013; Sperling et al., 2016).

The continuous section at Sekwi Brook North begins above a large thrust fault in the Sheepbed Formation and continues upwards for 1.5 km to the erosional top of the Risky Formation (Fig. 1.2). Aitken (1989) included all of the fine-grained siliciclastic strata below the Gametrail Formation at Sekwi Brook within the Sheepbed Formation, and this was followed by Narbonne and Aitken (1990, 1995), Dalrymple and Narbonne (1996), and Turner et al. (2011). Macdonald et al. (2013) subsequently separated the Sheepbed Formation at Sekwi Brook into a lower unit of dark, pyritic shales similar to those of the type Sheepbed and an unconformably overlying unit of fine-grained turbidites and contourites they dubbed the “June beds”, a designation accepted by subsequent workers (Narbonne, 2004; Carbone et al., 2015; Sperling et al., 2016; Eyster et al., 2017). The June beds are significant in containing the oldest Ediacaran body fossils in the NW Canada (Narbonne and Aitken, 1990; Narbonne, 1994; Narbonne et al., 2014). The Gametrail Formation overlies the June beds, and consists primarily of thin-bedded limestones interbedded with massive carbonate debris flows (Aitken, 1989; Macdonald et al., 2013). The Blueflower Formation gradationally overlies the Gametrail Formation, consisting of a lower carbonate-dominated member and an upper member composed primarily of shales and turbiditic sandstones from a shallower-water setting (MacNaughton et al., 2000; Macdonald et al., 2013). The Blueflower Formation contains the oldest trace fossils in the succession (Hofmann, 1981; Aitken, 1989; Narbonne and Aitken, 1990; Carbone and Narbonne, 2014) along with a sparse assemblage of Ediacaran discs, tubes, and segmented fossils (see review in Carbone et al., 2015). The youngest strata of the Windermere Supergroup, the dolomitic Risky Formation, was deposited between storm- and fair-weather wave base (MacNaughton et al., 2000). The Windermere Supergroup is capped by a major karstic unconformity that corresponds to the base of the Sauk Sequence. The Ediacaran – Cambrian boundary at Sekwi Brook North is

located within this unconformity (Macdonald et al., 2013) but occurs within the overlying Ingta Formation in more distal sections (MacNaughton et al., 2000; Carbone and Narbonne, 2014).

2.2. June beds

The fossils in this study were collected at Sekwi Brook North from the June beds, a 450 m-thick unit dominated by deep-water turbidites (Macdonald et al., 2013; Narbonne et al., 2014; Sperling et al., 2016). The basal contact of the June beds is erosional, and is marked by 10 m deep channels filled with matrix-supported cobble-clast conglomerate with giant ooids (> 2 mm) and medium- to coarse-grained quartz sand with detrital mica (Dalrymple and Narbonne, 1996; Macdonald et al., 2013). Overlying strata of the June beds are dominated by turbiditic sandstone, contourite sandstones, and ribbon-bedded carbonates. The June beds are interpreted as having been deposited on a deep-water, southwest-facing continental slope, based on abundant turbidites showing unidirectional southwest transport, slump scars, slump folds, and poorly sorted debris-flow deposits (Dalrymple and Narbonne, 1996; Narbonne et al., 2014). Shallow-water features, such as desiccation cracks, wave ripples, hummocky cross-stratification, herringbone cross-stratification, or other wave- or tide-generated structures, are absent. Redox geochemistry of the June beds suggests that conditions were predominantly anoxic and ferruginous, with brief episodes of oxygenation (Sperling et al., 2016). Radiometric dates are absent, but considerations of the sequence stratigraphy and chemostratigraphy suggest that the June beds date to approximately 560–580 Ma (Macdonald et al., 2013), roughly coeval with the Ediacaran fossil-rich intervals of Avalonian Newfoundland (Pu et al., 2016).

The June beds are dominated by thin turbidites interspersed with m-scale packages of contourite sandstones and ribbon-bedded lime mudstone (Dalrymple and Narbonne, 1996; Macdonald et al., 2013; Narbonne et al., 2014). Turbidites less than 2 cm thick typically contain only the uppermost part of a typical turbidite succession (T_d - T_e ; turbidite nomenclature after Bouma, 1962); thicker turbidites 3–10 cm-thick typically begin with the T_c division (rarely T_a or T_b). The discs of this study predominantly occur on the soles of 3–10 cm thick fine- to medium-grained T_{c-e} beds.

The Ediacaran discs on the soles of the turbidite beds show Fermeuse-style preservation (*sensu* Narbonne, 2005). The original nomenclature of these discs (Narbonne and Aitken, 1990) followed the names described from Ediacara and the White Sea, but nearly all of these discoid taxa worldwide have now been referred to the Ediacaran form-genus *Aspidella* Billings, 1872, a view with which we concur. Several individuals referable to the lobate form *Eoporpita* Wade, 1972

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