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EDIACARAN FOSSILS FROM THE BONAVISTA PENINSULA (AVALON ZONE), NEWFOUNDLAND: PRELIMINARY DESCRIPTIONS AND IMPLICATIONS FOR REGIONAL CORRELATION

S.J. O'Brien and A.F. King[1]
Regional Mapping Section

ABSTRACT

Exceptionally well-preserved Ediacaran biota that are comparable with the deep-water Mistaken Point and Fermeuse assemblages of soft-bodied sessile and mobile multicellular organisms have been discovered in newly recognized upper Conception Group strata in the Catalina–Port Union area of the Bonavista Peninsula, on the northeast coast of Newfoundland. The diverse fossil assemblage at the new Ediacaran site includes frond-, discoidal- and spindle-shaped biota and other forms. Discoidal fossils include the Spriggia *and* Ediacaria *morphological variants of* Aspidella*, including discoidal holdfast forms attached to fronds. Elsewhere on the eastern Bonavista Peninsula,* Aspidella *fossils have been recovered from stratigraphically higher, black shale-rich facies that are correlatable with much of the St. John's Group of the Avalon Peninsula.*

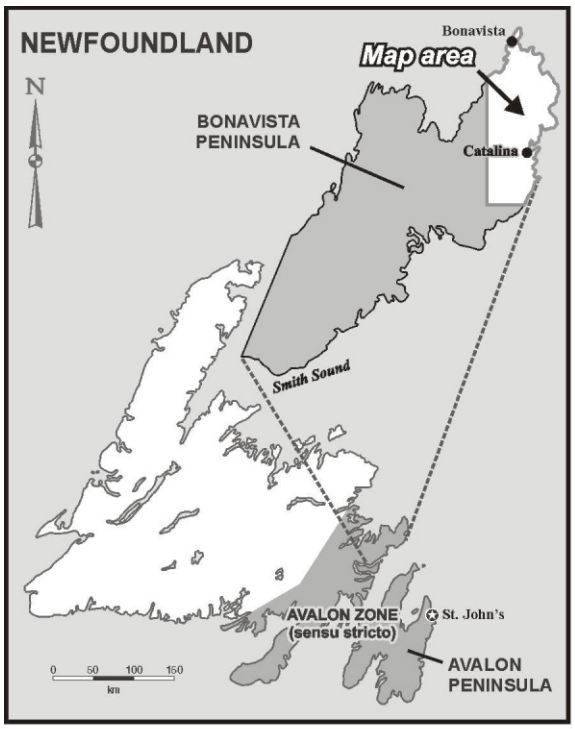
The proposed biostratigraphic correlation of the fossiliferous turbidites around Catalina and Port Union with the Mistaken Point Formation lends firm support to earlier, preliminary findings by the authors, suggesting the Neoproterozoic record for the Appalachian Avalon Zone on the eastern Bonavista Peninsula is a correlative of the Conception and St. John's groups of the Avalon Peninsula. These new data impact on existing correlations and views of lithostratigraphic and biostratigraphic development of Neoproterozoic basin-fills on the Bonavista Peninsula and elsewhere across eastern Newfoundland.

GEOLOGICAL SETTING

Recent mapping of the sub-Cambrian stratified succession of the Appalachian Avalon Zone on the Bonavista Peninsula of Newfoundland (O'Brien and King, 2002 and *this volume*) has identified extensive areas of silicified and non-silicified, deep-marine to deltaic, siliciclastic sedimentary facies comparable with the late Neoproterozoic succession of the Avalon Peninsula. Of particular importance to the following account is a distinctive lithofacies of mainly medium-bedded, variegated siliceous sandstones, siltstones and mudstones, with laminae and thin beds having a tuffaceous aspect, which occupies the core of a broad periclinal fold (Catalina dome) extending from Little Catalina – through Goodland Point, Catalina – to Port Union (Figure 1). This distal turbiditic facies, previously assigned to the unseparated Musgravetown Group by earlier workers, is specifically correlatable with the 400-m-thick, deep-marine siliciclastic strata of the Mistaken Point Formation, the uppermost stratigraphic unit of the latest Neoproterozoic Conception Group of the Avalon Peninsula (Figure 2). At the well-known Mistaken Point locality (the formational type section of Williams and King, 1979) on the southeast Avalon, the Neoproterozoic turbiditic sandstones are profusely fossiliferous and contain frond, spindle, discoidal and other perplexing impressions characteristic of the world's widely scattered Ediacaran fossil assemblages, the oldest known fossil animals on Earth (*see* Misra, 1969, 1971; Williams and King, 1979; Anderson and Conway Morris, 1982; Jenkins and Gehling, 1978; Narbonne *et al*., 2001).

During the 2003 field season, exceptionally well-preserved examples of similar Ediacaran body fossils were discovered at the boundary between siliceous and non-siliceous parts of the turbidite sequence near Catalina, more than 200 km north of Mistaken Point. The hitherto unreported fossiliferous beds occur in a unit dominated by medium-bedded, grey-green sandstones and mudstones – correlated with the uppermost Mistaken Point Formation (i.e., Hibbs Cove Member; King, 1990) – stratigraphically above a medium- to thick-bedded, siliceous sandstone turbidite sequence (T(B)CDE Bouma divisions). The fossil-bearing beds are

[1] Memorial University of Newfoundland, Department of Earth Sciences (retired)



LEGEND

LATE NEOPROTEROZOIC

SIGNAL HILL GROUP

4 Gibbett Hill Formation

ST. JOHN'S GROUP

3 Unseparated Renews Head and Fermeuse formation equivalents

2 Trepassey Formation (may include upper strata of Mistaken Point Formation)

CONCEPTION GROUP

1 Mistaken Point Formation

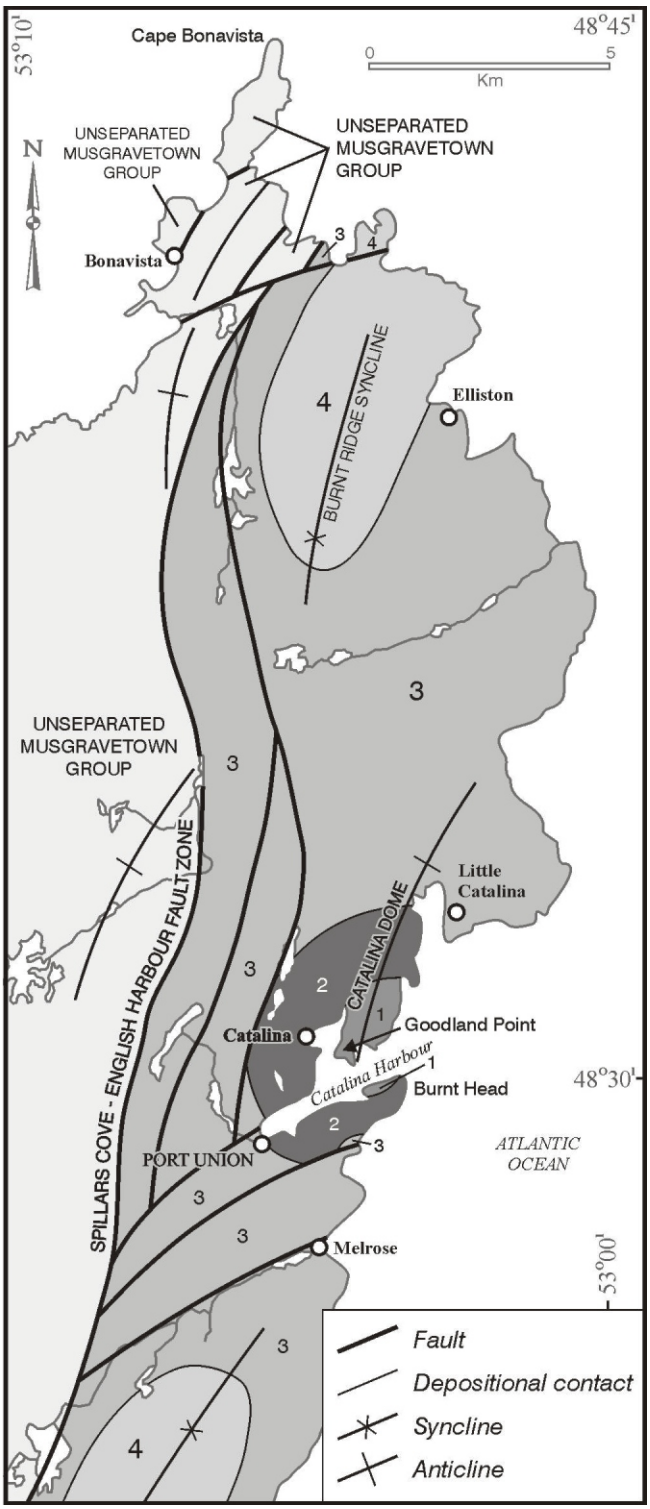


Figure 1. *Simplified geological map of the eastern Bonavista Peninsula.*

overlain by a monotonous succession of grey, very thin- to medium-bedded mudstones, siltstones and sandstones (mainly TDE beds), correlated with the Trepassey Formation of the St. John's Group (*see* O'Brien and King, 2002, *this volume*, and REGIONAL CORRELATION, below). The base of the turbidite sequence at Catalina is unexposed. The absolute age of the Catalina–Port Union area fossil site has not yet been established; tuffs immediately above similar fauna at a comparable stratigraphic position at Mistaken Point have yielded zircons dated by G.R. Dunning at 565 ± 3 Ma (reported by Benus, 1988).

NEOPROTEROZOIC FOSSILS

The Ediacaran fossils occur on the peninsula that extends eastward from Port Union, through Murphy's Cove (or Southeast Cove), to Burnt Head, south of Catalina Harbour. The most prolific site thus far discovered includes nine examples of Ediacaran fronds in an area of approximately 10 m by 1 m on the top surface of a 45-cm-thick bed of internally laminated, fine-grained, greenish-grey sandstone. Above and below the main frond-bearing layer, thin layers and beds (1 cm to 20 cm thick) of light-green to buff sandstone, having a probable tuffaceous component, are interbedded with the darker sandstones (Plate 1), stratigraphically above laminated to medium-bedded siliceous units (Plate 2) that occupy the core of the Catalina Dome. Discoidal impressions occur on the same surface and others 1 to 2 m above and below the frond-bearing bed. Additional loose frond material was discovered approximately 10 m lower in the stratigraphic section from the principal locality; other *Aspidella* and partial frond fossils, together with tentaculate disc-like examples, were discovered approximately 300 m farther east.

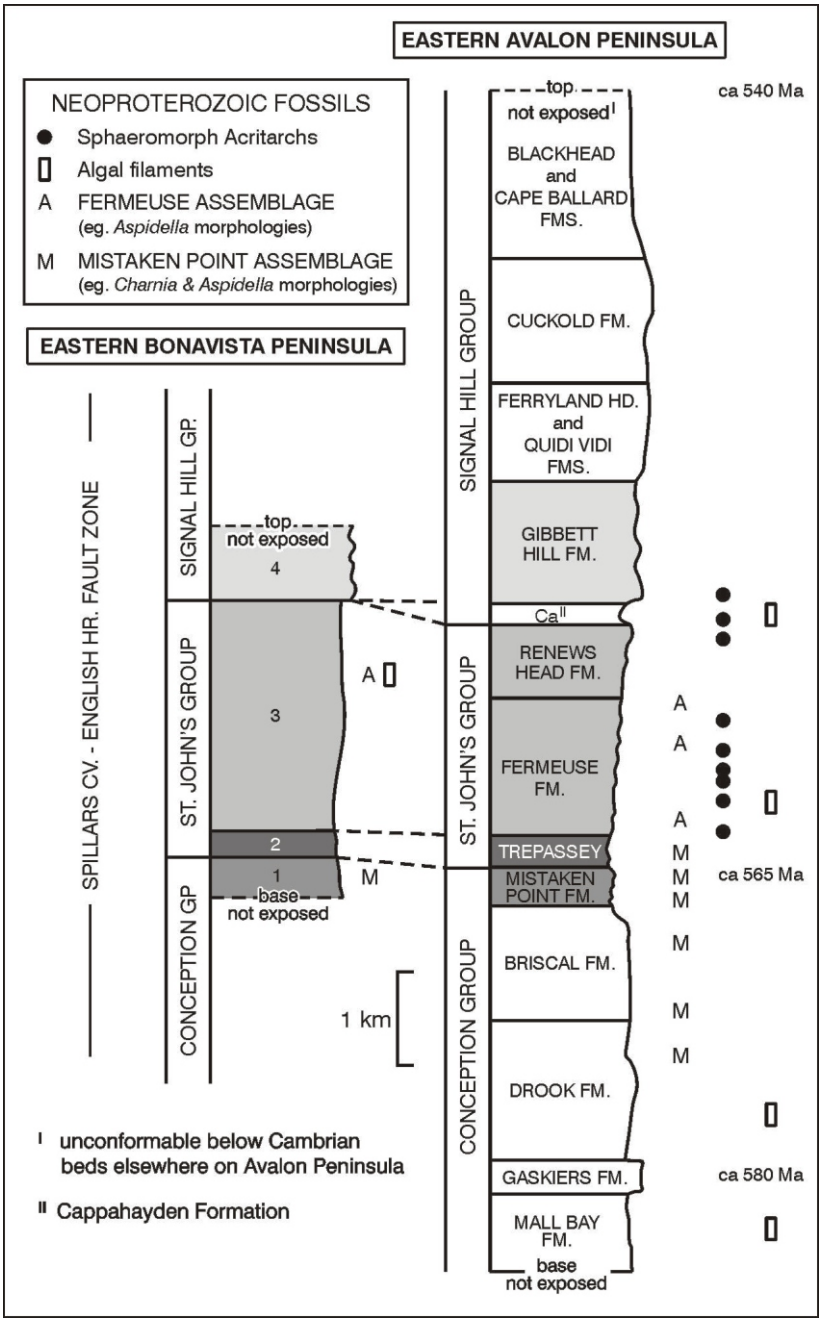


Figure 2. *Correlation between units on the Bonavista and Avalon peninsulas (Avalon Peninsula sections from Williams and King, 1979, and King, 1980, 1988).*

Aspidella occurs not only with other Ediacaran fauna in the turbidites at and near the principal locality south of Catalina Harbour (*see* DISCOIDAL FOSSILS, below), but also in stratigraphically higher rocks elsewhere in the region. The younger *Aspidella*-bearing beds occur within widely developed sequences of dark-grey to black shale and sandstone, included by earlier workers with the Musgravetown Group, but since remapped by the authors and correlated with upper Fermeuse and lower Renews Head formations (St. John's Group) of the Avalon Peninsula (O'Brien and King, 2002, *this volume*; *see below*). On the Bonavista Peninsula, *Aspidella* occurs as far south as the English Harbour area, about 20 km from Catalina. There, oval-shaped discoidal fossils, 0.5 to 2 cm in diameter, showing central invagination with radial grooves and spokes are comparable with the *Aspidella*-type preservation (*see* Gehling *et al*., 2000). They occur in dark shales containing laminae to thin beds of lenticular sandstone like those in the classical *Aspidella terranovica*-bearing facies in the upper Fermeuse Formation (St. John's Group) on the Avalon Peninsula[2]. Poorly preserved microfossils were previously discovered by the

[2] The late Precambrian discoidal fossil *Aspidella terranovica*, first described by E. Billings in 1872 from black shales in the St. John's area (Fermeuse Formation, St. John's Group), is the first named Ediacaran body fossil (Gehling *et al*., 2000).

Plate 1. *Conception Group siliceous sandstones, Catalina–Port Union area.*

second author in the same succession, between Catalina and nearby Melrose. These are compressions of simple, non-septate algal filaments (*Taeniatum* sp), interpreted to be the remains of tubular sheaths of cyanophytes (Hofmann *et al*.,1979).

In the vicinity of the principal fossil site, beds strike subparallel to the coast; gently dipping bedding-plane surfaces are areally restricted within near-vertical, ca. 4- to 5-m-high coastal cliffs. Beds dip away from the relatively sheltered coastline, minimizing erosional effects, resulting in excellent preservation. Similar stratigraphic levels are exposed in other nearby areas, although cleavage development there is more pronounced; the potential for additional discovery, nevertheless, is significant. Further investigations are planned for the upcoming field season and the Ediacaran fossil locality has been designated as a protected "significant fossil site" under the province's Historic Resources Act.

A brief, preliminary description of a representative selection of Ediacaran forms discovered thus far in the Burnt Point section, in the Catalina–Port Union area, is presented below. The forms are illustrated in Figure 3.

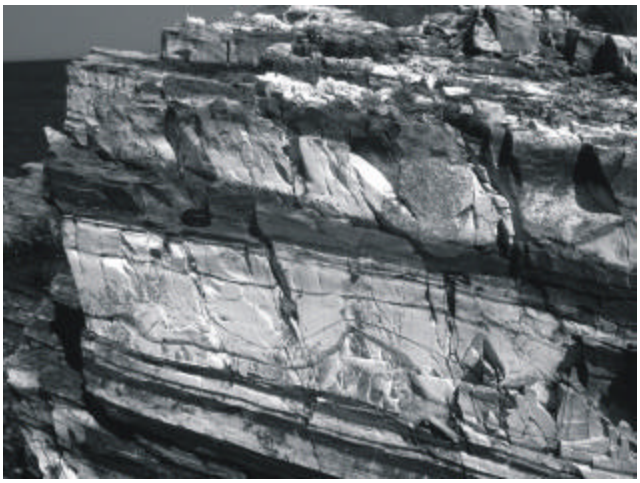


Plate 2. *Fossiliferous sandstones; upper Mistaken Point Formation correlative, Catalina–Port Union area.*

DISCOIDAL FOSSILS

Well-defined oval-shaped discoidal impressions are clearly identifiable with morphological variants of *Aspidella*. This body fossil includes a wide intergradation of preservational morphologies, which can be represented between three end-members: i) *Aspidella*-type preservation, ii) *Spriggia* preservation and iii) *Ediacaria* preservation (*see* Gehling *et al*., 2000). At the newly discovered fossil site, discs showing *Spriggia* preservation are most common (Plate 3a) and can occur on the same bedding surface with fronds, radial forms and tentaculate discs.

For example, flat to low-relief, elongate discs, from 3 cm to 8 cm long by 1 cm to 4 cm wide, are composed of a prominent central boss surrounded by sharp multiple concentric rings with raised ridges. Some large discs have a central boss with saucer-like raised rim (Plate 3b). The discs represent sessile holdfasts with the central boss providing an anchorage site for the once-upright frond. Numerous smaller discs, 0.5 cm to 2 cm in diameter, with convex morphologies, conform mainly to *Ediacaria* preservation and to a lesser extent to *Aspidella*-type preservation. In both of these types, the prominent cup-shaped central boss may contain a small plug or load cast of sand; radial grooves and concentric rings are more typically poorly defined and may be faint to indistinct.

FROND-LIKE FOSSILS

Frond-like fossils with stalks attached to prominent disc-like anchoring structures are the common fauna in the newly discovered fossil site. They are preserved in the plane of the bedding as high positive relief structures with fronds and stalks having a combined length up to 15 cm. The elon-

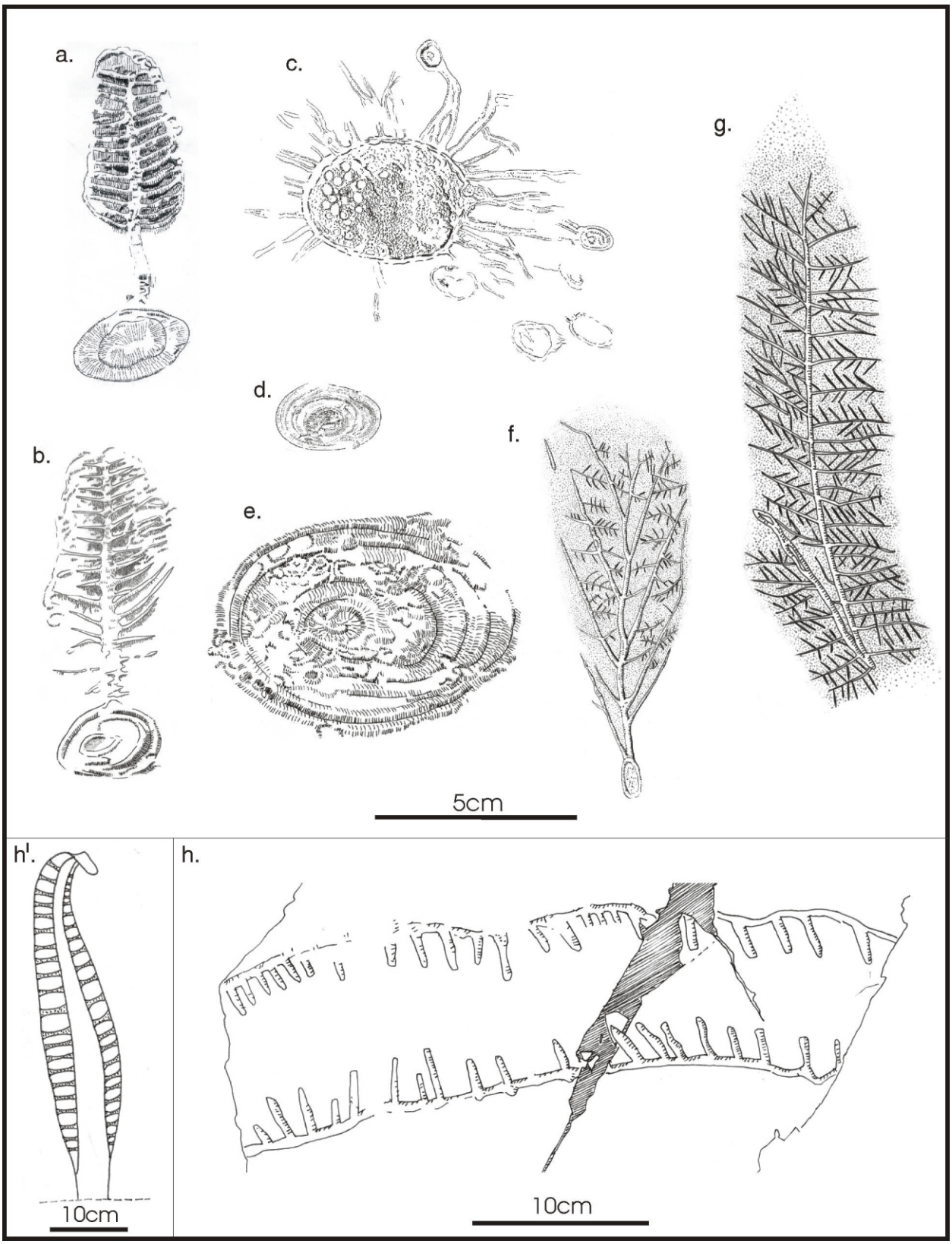


Figure 3. *Sketch of the several Ediacaran forms exposed in the Catalina–Port Union area, eastern Bonavista Peninsula: a, b) variants of frond-like forms; c) tentaculate disc; d, e)variants of discoid forms; f) bush-like form; g) spindle-like form; h) ladder-like form and its possible reconstruction, h' (after Mestel, 1997, page 26).*

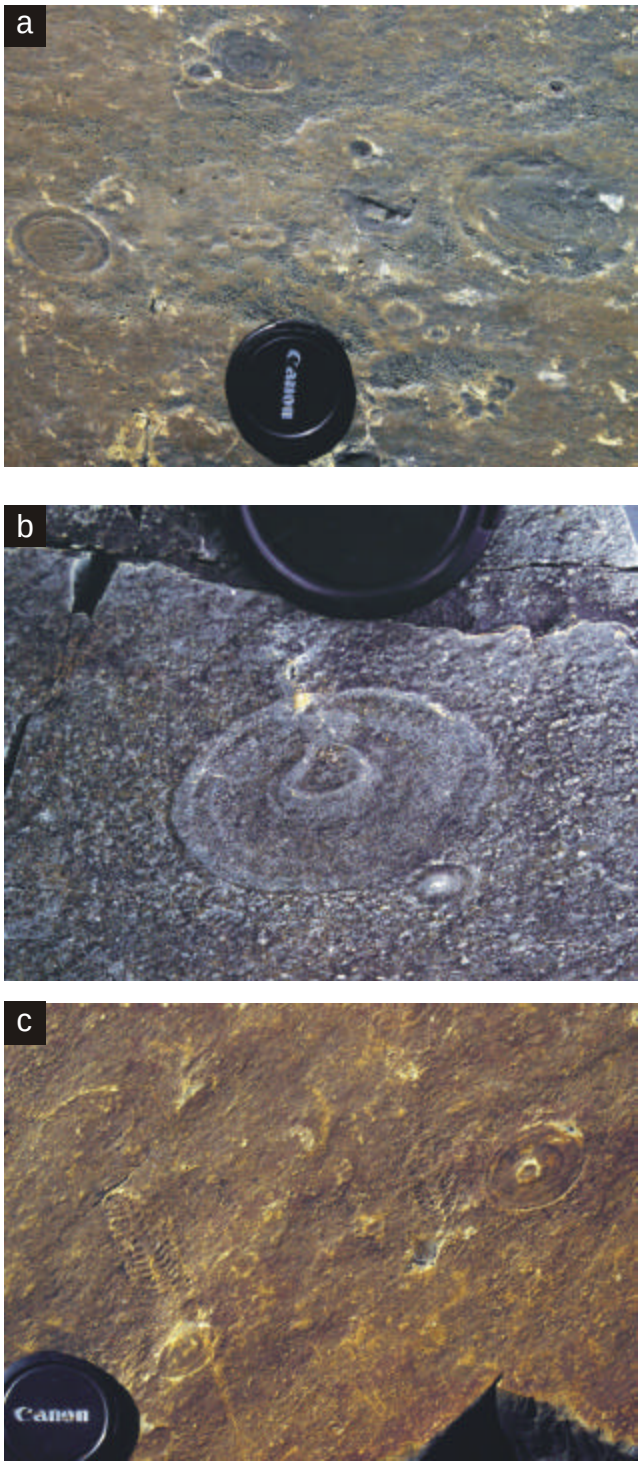


Plate 3. *Examples of principal Ediacaran forms from the Catalina–Port Union area: a)* Spriggia*-morphological variation of* Aspidella*; b) discoidal sessile holdfast to Ediacaran frond; c) frond-like forms with* Spriggia *morphological variation of* Aspidella*, locally as holdfasts.*

gate frond is composed of a narrow median or axial zone from which lateral primary branches or lobes extend symetrically on either side at an angle of 90° relative to the axis. Details of their surface and internal morphology are vague. Some fronds have a well-defined oval outline or margin (e.g., Plate 3c) but other tree-like fronds appear to lack a peripheral boundary surrounding the tips of their branches (e.g., Plate 4a). The axis continues at the base of the frond as a high relief stalk that terminates in a prominent disc showing *Spriggia* or *Ediacaria* preservation. The fronds on the bedding planes are preserved with a unimodal alignment and have a consistent felling direction indicating paleocurrents to the northwest (holdfast to the southeast) The frondose and discoidal remains are referable to *Charniodiscus* Ford, 1958, from the late Neoproterozoic Woodhouse and Bradgate Beds and overlying purple siltstones (Swithland Slate), Charnwood Forest, Leicestershire, England (Ford, 1958, 1963). Comparable frond-like forms with the same taxon have been described from the type locality at Mistaken Point (e.g., Misra, 1969; Anderson and Conway Morris, 1982; Narbonne *et al*., 2001; Narbonne and Gehling, 2003).

One rare member of the assemblage is an incomplete frond-like specimen (40 cm long by 10 cm wide) that may have been more than 1 m long when intact (Plate 4b). This unusual elongate, parallel-sided form resembles a ladder with broken rungs; it has high positive relief with mutually opposed discontinuous branches (each 2 cm to 3 cm long), merging from opposite sides of the main shaft at approximately 90°. Although the long, linear, parallel margins and the length-to-width ratio are comparable with those features present in the newly described frondose *Charnia wardi* of the southeastern Avalon Peninsula (Narbonne and Gehling, 2003), this specimen lacks the alternating pattern of sigmoidal branches about a mid-line. A possible reconstruction of this form is shown in Figure 3h[1].

SPINDLE-SHAPED FOSSILS

Unattached, spindle-shaped biota are relatively uncommon forms in the new fossil site. They were preserved as elongate external moulds representing imprints of the organism in mud at the time of their burial. Individuals vary in length from 10 to 20 cm and in width from 3 to 5 cm. They appear to be bilaterally symmetrical with as many as 20 branches attached to a narrow linear to slightly sinuous median axial region. They also appear to terminate in pointed ends which in large specimens may not be present due to incomplete preservation.

One specimen shows a possible broken stalk and basal bulbous disc superimposed above the branches, which is

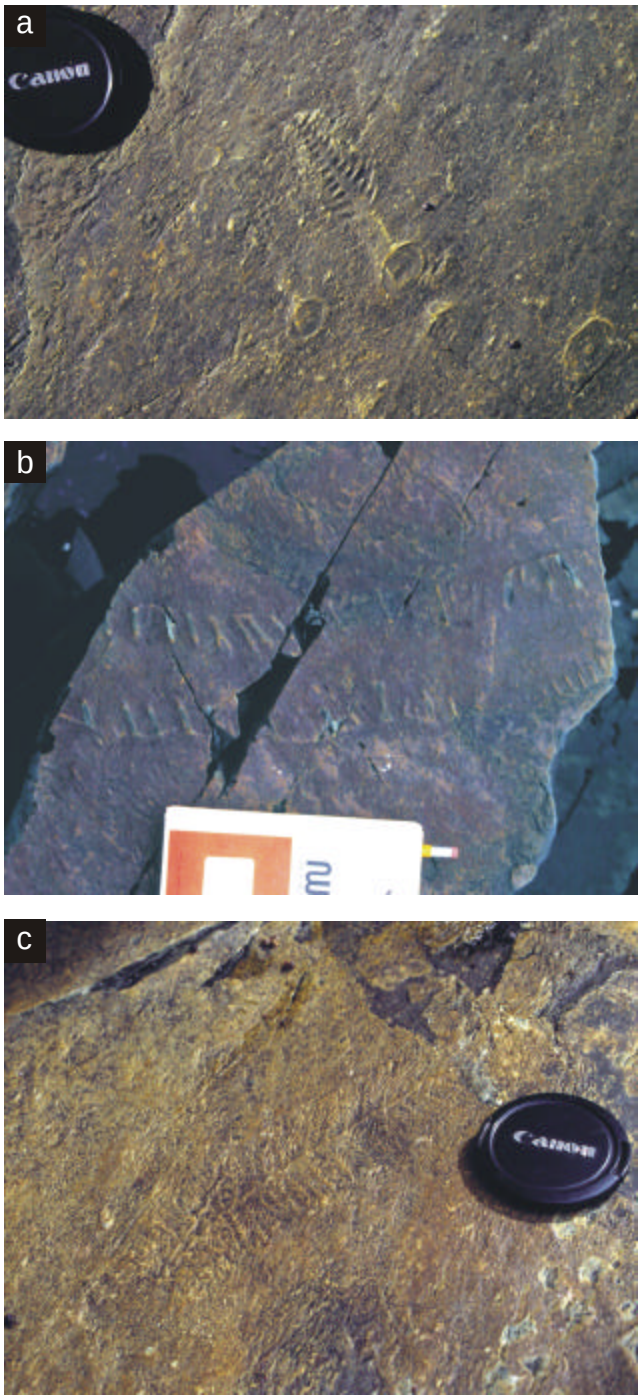


Plate 4. *Examples of principal Ediacaran forms from the Catalina–Port Union area: a) Ediacaran frond-like forms lacking peripheral boundary;* Spriggia *holdfast of frond-like organism with prominent stalk; b) incomplete specimen of "ladder-like" frond; c) spindle-shaped frond of probable* Charnia *affinity.*

presumably part of a much larger organism (Plate 4c). The branches in this specimen are composite structures consisting of a series of short tubes that are connected to one another basally and radiate outwards from the branch. If the stalk and disc were originally part of the organism, the specimen is a possible frond with *Charnia* or *Rangea* affinities.

The systematic placement of these complex spindle-shaped organisms, like those at Mistaken Point and in the Ediacaria assemblage of South Australia (e.g., Jenkins and Gehling, 1978), is problematic. They may show some morphological similarities to *Charnia* or *Rangea*, they may have preservational environmental attributes consistent with sessile forms (e.g., Narbonne *et al*., 2001), or some may have features attributable to planktonic colonial hydrozoans (e.g., Anderson and Conway Morris, 1982).

BUSH-LIKE FOSSILS

The colloquially termed "bush-like" and "leaf-like" forms and "feather dusters" that are described by Narbonne *et al.* (2001) from the Mistaken Point site also occur in this new fossil site, but are rare and have incomplete preservation. They appear to be oval-shaped forms (up to 10 cm long and 3 cm wide) with relatively narrow linear branches that are arranged in alternate positions as they extend outwards from either side of a common stem. Similar bush-shaped forms occur in the Mistaken Point assemblage (e.g., Misra, 1969; Anderson and Conway Morris, 1982) and have been referred by Narbonne *et al*. (2001) to *Bradgatia linfordensis* Boynton and Ford, 1995, from Charnwood Forest, England.

The bush-like specimen (Plate 5a) is interpreted as a sessile organism that was attached to the sea floor by a thick stem and holdfast (not preserved in the specimen). This specimen with incomplete bush-like features, however, shows *Charnia*-like attributes; regularly spaced cross-structures of subparallel secondary divisions between adjacent branches resemble the alternating segmented lobes present in *Charnia masoni* Ford, 1958.

RADIAL FORMS AND TENTACULATE DISCS

Several obscure forms that have positive relief are associated with the discoidal fossils. They consist of a circular body (3 to 5 cm diameter) covered by granules and 0.5-cm-scale knobs of sediment arranged in diffuse bands. The body is surrounded by numerous (20 or more) faint radiating lines resembling either tentacles or rootlets; these projections from the main body may be tubular branches (up to 5 cm long) that have been flattened and broken during their preservation (Plate 5b).The radial forms may have been attached to the sea floor by these projections or alternatively, they may have functioned as tentacles, comparable with those in a sea-anemone or in a jelly fish. Similar morphological forms may occur in the Mistaken Point assemblage where they have been described as "star-shaped forms"

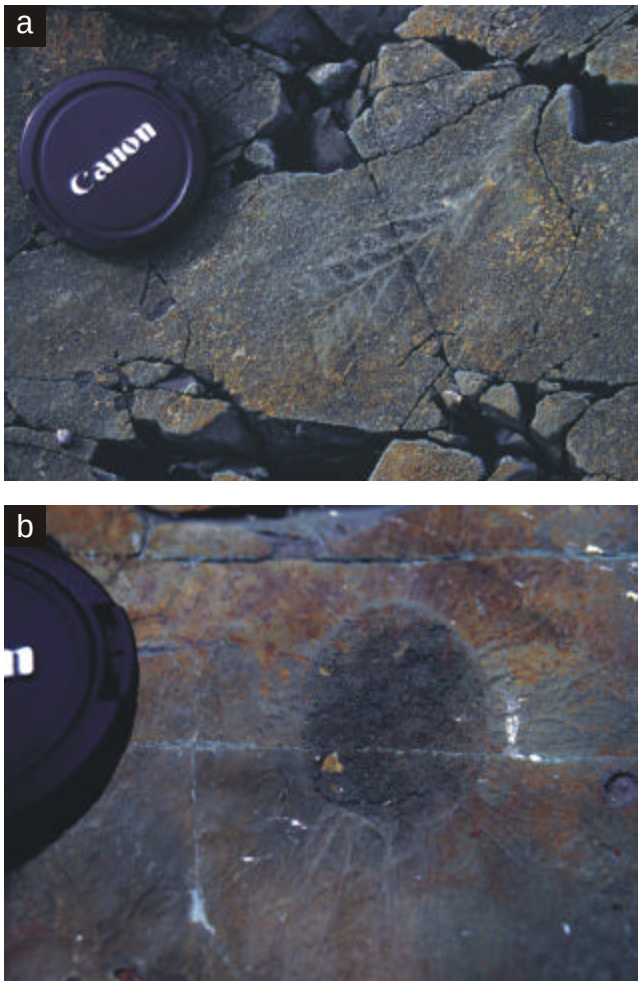


Plate 5. *Examples of principal Ediacaran forms from the Catalina–Port Union area: a) bush-like form, possibly comparable with* Bradgatia *but showing* Charnia*-like attributes; b) well-preserved tentaculated disc style fossil with possible affinities to* Hiemalora *Fedonkin.*

(e.g., Anderson and Conway Morris, 1982) and as tentaculated discs with possible affinities to *Hiemalora* Fedonkin, 1972, from the White Sea region of Russia (Narbonne *et al*., 2001).

REGIONAL CORRELATION

The discovery of Ediacaran fossils in eastern Bonavista Peninsula turbidites, and the biostratigraphic correlation of these fossiliferous beds with the lithologically similar Mistaken Point Formation, provide firm support for earlier, preliminary findings by the authors (O'Brien and King, 2002) that first challenged the long-standing assignment of rocks of this section, and of all sub-Cambrian strata on the Bonavista Peninsula, to the Musgravetown Group (e.g., Christie, 1950; Jenness, 1963). Facies development in the stratigraphic section of the eastern Bonavista Peninsula, east of the Spillars Cove–English Harbour fault zone (*see* O'Brien and King, *this volume*), is atypical of the Neoproterozoic succession west of that structure – a wide area of subaerial volcanic and non-fossiliferous cupriferous shallow-marine and terrestrial redbeds (O'Brien and King, 2002). The marine turbidites and pro-delta facies shales and sandstones show comparable facies and stratigraphic order to the Neoproterozoic succession of the eastern Avalon Peninsula (e.g., Williams and King, 1979; King, 1988, 1990); some specifics of the biostratigraphic and lithologic correlation of these areas is given in Figure 2.

Although the absolute age of the Neoproterozoic section of the eastern Bonavista Peninsula remains unconstrained, correlation with the dated Mistaken Point Formation (*see above*) implies that these rocks were deposited at and after 565 ± 3 Ma. They are, therefore, potentially time-stratigraphic equivalent to the lithologically contrasting Musgravetown siliciclastic rocks widely developed west of the Spillars Cove–English Harbour fault zone, and throughout the western Avalon Zone. The several-kilometre-thick pile of Musgravetown Group strata accumulated coeval with and subsequent to eruption of 570 +5/-3 Ma rhyolite flows located at, and near, the base of the shallow-marine part of the siliciclastic succession (O'Brien *et al*., 1989). The marked facies contrast in similar-age rocks across the fault zone attests to the importance of that structure.

Strata that are time equivalent to the fossiliferous eastern Bonavista succession described are also present in the volcanic-rich Long Harbour Group of northern Fortune Bay. The timing of late Neoproterozoic marine siliciclastic sedimentation in that part of the southwestern Avalon Zone (Andersons Cove Formation; Williams, 1971) is bracketed by 568 ± 3 Ma and 551 ± 6 Ma U–Pb zircon ages of underlying and overlying volcanic formations (O'Brien *et al.*, 1994,1995; O'Brien, 1998). The younger volcanic succession passes up into red beds correlative with upper Musgravetown and upper Signal Hill groups, which are in turn conformably overlain by shallow-marine siliciclastic strata, the Proterozoic–Paleozoic boundary (ca. 543 Ma) stratotype, the Chapel Island Formation.

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