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LITHOSTRATIGRAPHIC AND BIOSTRATIGRAPHIC STUDIES ON THE EASTERN BONAVISTA PENINSULA: AN UPDATE

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ABSTRACT

Recent mapping of well-exposed coastal sections through the Ediacaran succession between Melrose and Maberly, on the northwest coast of Trinity Bay, eastern Newfoundland, has enabled recognition of facies correlatives of the late Neoproterozoic Trepassey, Fermeuse and Renews Head formations of the St. John's Group, and the approximate location of their formational boundaries. Study of this continuous section also reveals that thick, tabular-bedded slumped units, in part diagnostic of the recently defined Back Cove member of the shale-dominant Fermeuse Formation, have much greater vertical stratigraphic extent than previously recognized. Further detailed study of the Renews Head Formation and the gradationally overlying Gibbett Hill Formation of the Signal Hill Group has identified regionally developed facies that are indistinguishable from those diagnostic of the lower part of the adjacent Musgravetown Group, west of the Spillars Cove–English Harbour fault zone. The facies commonality may imply linkage of the Neoproterozoic succession across that structure, and original stratigraphic continuity from the Gibbett Hill Formation (Signal Hill Group) and underlying shale-rich succession in the east, upward into the Rocky Harbour Formation (Musgravetown Group) in the west.

Several significant new Ediacaran fossil discoveries made in 2005 demonstrate that the stratigraphic range of Bradgatia, Charnia, Charniodiscus, Ivesheadia *and spindles is significantly longer than that reported from equivalent rocks on the southeastern Avalon Peninsula. Existing data from the Bonavista region of the Avalon Zone reveal little prominent faunal distinction between the Mistaken Point Formation of the Conception Group and the overlying Trepassey and Fermeuse formations of the St. John's Group. Some rare, newly discovered specimens of* Hiemalora *in both the Mistaken Point and the Fermeuse formations are interpreted as being attached to stems and fronds. This unique preservation suggests that the radial appendages of* Hiemalora *may be root-like structures rather than tentacles.*

INTRODUCTION

The eastern Bonavista Peninsula study is part of a continuing investigation aimed at understanding the Neoproterozoic history of the large, well-preserved Avalonian sedimentary basins of the southeastern Newfoundland Appalachians, and developing a unified tectonostratigraphic framework to serve as a guide for exploration for sediment-hosted base metals. Recent mapping and paleontological field studies on the eastern Bonavista Peninsula (Figure 1) have further refined the stratigraphy of the late Neoproterozoic (Ediacaran) strata east of the Spillars Cove–English Harbour fault zone (see O'Brien and King, 2005), and provided new data on the biotal composition, stratigraphic ranges and geographic distribution of well-preserved Ediacaran taxa in the region (Hofmann *et al*., 2005a, b). The Ediacaran succession there, preserves the transition from deep-water basin and slope (Conception Group) to shallowing-upward basinal, prodelta and delta front (St. John's Group) and ultimately alluvial conditions (Signal Hill Group). The field work reported here, carried out over a three-week period in 2005, has provided new information on facies distribution within the St. John's Group and has identified mappable boundaries for regional subdivisions of formational status that match those defined elsewhere in the Avalon Zone (cf., King, 1990). The study also points to possible depositional linkages across the regionally extensive Spillars Cove–English Harbour fault zone, and strengthens

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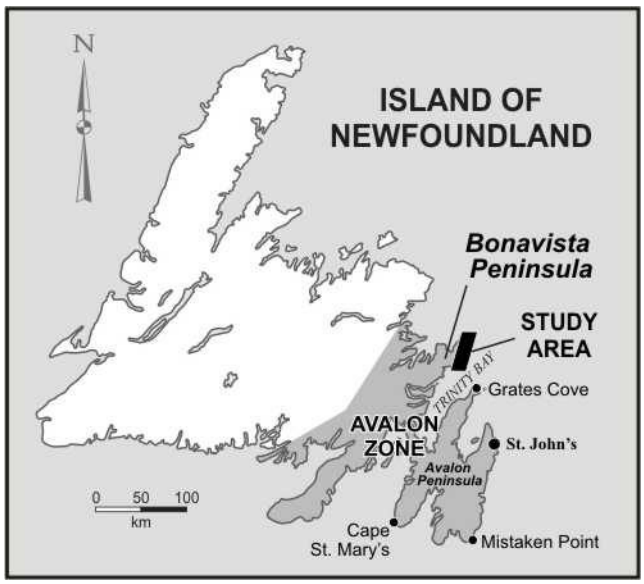

Figure 1. *Location of the study area.*

correlations of the Musgravetown Group in this area with the Signal Hill Group succession and associated Musgravetown Group rocks between Grates Cove and Cape St. Mary's, on the Avalon Peninsula.

NOTES ON LITHOSTRATIGRAPHY AND CORRELATIONS

Earlier reconnaissance study of the Bonavista Peninsula, east of the Spillars Cove–English Harbour fault zone (O'Brien and King, 2002), identified dark-grey shale facies correlative of the Fermeuse and Renews Head formations of the St. John's Group exposed on the Avalon Peninsula (Williams and King, 1979), but did not allow for a regionally mappable distinction between these formations. New mapping of more than 20 km of coastal exposures in the region between Little Catalina and Elliston (Figure 2) has enabled recognition and separation of both formations as extensive mappable units throughout much of the eastern Bonavista Peninsula. There, the Trepassey, Fermeuse and Renews Head formations (in ascending stratigraphic order between Little Catalina and Elliston) are part of a very thick (≥1 km) conformable sequence having gradational contacts. The Fermeuse Formation is the thickest and most areally extensive of the three formations, and is well in excess of 350 m thick. Each of these well-exposed formations on the Bonavista Peninsula shows major coarsening-upward cycles. The St. John's Group here, like its correlative on the Avalon Peninsula, is interpreted as a shallowing-upward marine cyclic sequence formed in a basinal slope environment in response to seaward advances of a large prograding delta (*see* King, 1980, 1990).

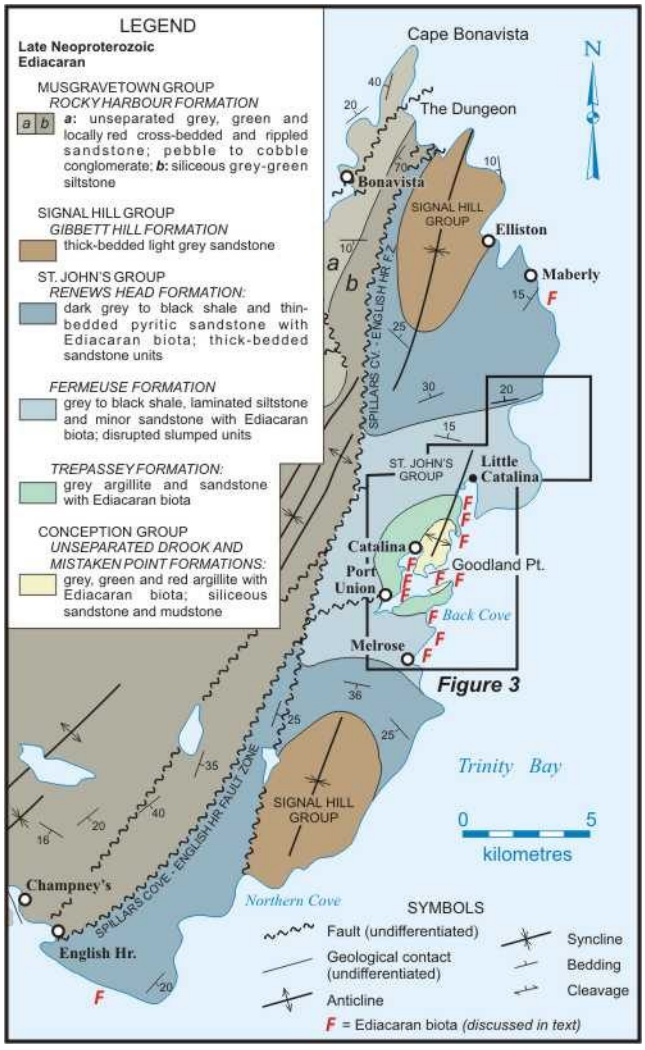

Figure 2. *Simplified geology of the eastern Bonavista Peninsula (modified from O'Brien and King, 2005);* ***F*** *may indicate multiple fossil localities.*

ST. JOHN'S GROUP

Trepassey Formation

The most complete and best exposed section through the Trepassey Formation is located on the west side of Little Catalina Harbour, along the north-plunging axis of the Catalina Dome, where it lies stratigraphically above the Mistaken Point Formation of the Conception Group (Units 2 and 3; Figure 3). Other sections are exposed in Port Union Harbour and the north coast of Back Cove. The formation has been previously divided into a lower, mud- and silt-rich Catalina member (Unit 4; Figure 3) and an upper, sand-rich Port Union member (Unit 5; Figure 3) (O'Brien and King, 2005). For further details, the reader is referred to descriptions given in O'Brien and King (2005).

Fermeuse Formation

The black-shale-dominated Fermeuse Formation (Unit 6; Figure 3) stratigraphically overlies thick-bedded, fine- to medium-grained grey sandstone of the Port Union Member, upper Trepassey Formation, along the northwestern shore of Little Catalina Harbour. An ascending stratigraphic section through at least 50 m of lower Fermeuse Formation is exposed in, and around, Little Catalina Harbour, westward toward the Cuckold Head area (Figure 3). More than 300 m of stratigraphically higher Fermeuse Formation is exposed across a series of open north-trending folds westward to Nova Scotia Head[3] and northeastward, in high coastal cliffs, to North Head, and thence to Jerdan's Brook[3]. Much of the section from North Head to Jerdan's Brook is a gently dipping (10 to 20°) homocline.

The basal contact of the Fermeuse Formation is obscured by beach deposits in the coastal section at Little Catalina Harbour. A sharp, conformable contact with the underlying Port Union member of the Trepassey Formation is exposed in the aforementioned Port Union and Back Cove sections, on the south side of the Catalina Dome (O'Brien and King, 2005). The top of the Fermeuse Formation is tentatively drawn along the south shore of the promontory near Charlie's Cove[3], on the coast of Trinity Bay, approximately 3 km north-northeast of Little Catalina Harbour (Figure 3).

The Fermeuse Formation succession studied to date, in common with its correlative in eastern Avalon Peninsula (see King, 1990), consists primarily of three principal, interbedded lithofacies, which, in mainly ascending order, are A-6, B-6 and C-6. The prominent facies (A-6) seen in the lowermost part of the formation is dark-grey to black shale and mudstone with laminae, and thin to medium interbeds of grey siltstone, fine-grained, brown-weathering grey sandstone and minor tuff. Impoverished current ripples and crosslamination are locally present in this lithofacies but are usually indistinct; rhythmically alternating sand–mud-graded units are common. A second, characteristically remobilized facies (B-6) consists of slumped folds of sandstone and interbedded mudstone, resedimented in a mud matrix. This disrupted facies occurs as discrete metre- to decametre-scale units throughout most of the section from Little Catalina to Charlie's Cove, where it occurs in facies A-6. Available data indicate tuff beds are most common in the lower 300 m or so of section. A third facies (C-6), developed in the upper part of the succession, includes black shales with rare or widely spaced laminae to thin beds of silty sandstone. In general, the proportion of sand increases upward through the succession exposed between North Head and Charlie's Cove. Thin, brown-weathering tuff layers have been identified in the upper half of the Fermeuse Formation but are less common than in the underlying strata.

Good examples of the disrupted facies (B-6) are prominent throughout the black shale succession exposed in low coastal cliffs at the north end of Little Catalina Harbour. The Fermeuse Formation there, contains repetitive and spectacularly preserved, tabular units of syn-sedimentary folds and disrupted beds of sandstone; each unit is commonly several metres thick, and interbedded with black shale and silty sandstone. The slumped units are locally capped by sand-rich sedimentary breccias overlain by shale. Thin beds of ash within the shales preserve a variety of Ediacaran fossils at several stratigraphic levels. The slumped and disrupted units are interpreted to have formed by gravitational sliding of poorly consolidated beds of sand and mud on a sloping paleosurface during normal pelagic sedimentation. The presence of truncated folds of sandstone and coarse breccias at the top of the disrupted unit indicates slumping followed by periods of erosion with intense bottom currents. Superb examples of the same slumped facies occur between Back Cove and Melrose on the south limb of the Catalina Dome, and have been described previously (O'Brien and King, 2005). Thin ash beds are preserved at multiple levels through this succession.

Contrasting lithofacies A-6 and B-6, previously described from the lower part of the Fermeuse Formation and designated Back Cove member by O'Brien and King (2005), together with facies C-6, are now known to have a vertical stratigraphic extent upward from the base much greater than previously envisaged, and occur over a stratigraphic thickness approaching a kilometre.

Renews Head Formation

In the coastal sections studied south of Maberly, the Fermeuse Formation is gradationally and conformably overlain by an estimated 100-m-thick succession (minimum thickness), herein correlated with the Renews Head Formation (Unit 7; Figure 3). This formation at the top of the St. John's Group differs from the Fermeuse Formation by its greater silt and sand content, its pyritic, rusty-weathering lenticular bedding and other sedimentary structures such as impoverished or starved current ripples, pseudo-nodules, water-escape structures and small sand dykes. The Renews Head Formation is divisible into three main lithofacies: black shale with numerous laminae of rusty brown-weathering grey silty sandstone (facies A-7); thin- to medium-bedded lenticular sandstone intercalated with black shale (facies

[3]Local place-name usage, not shown on published topographic maps

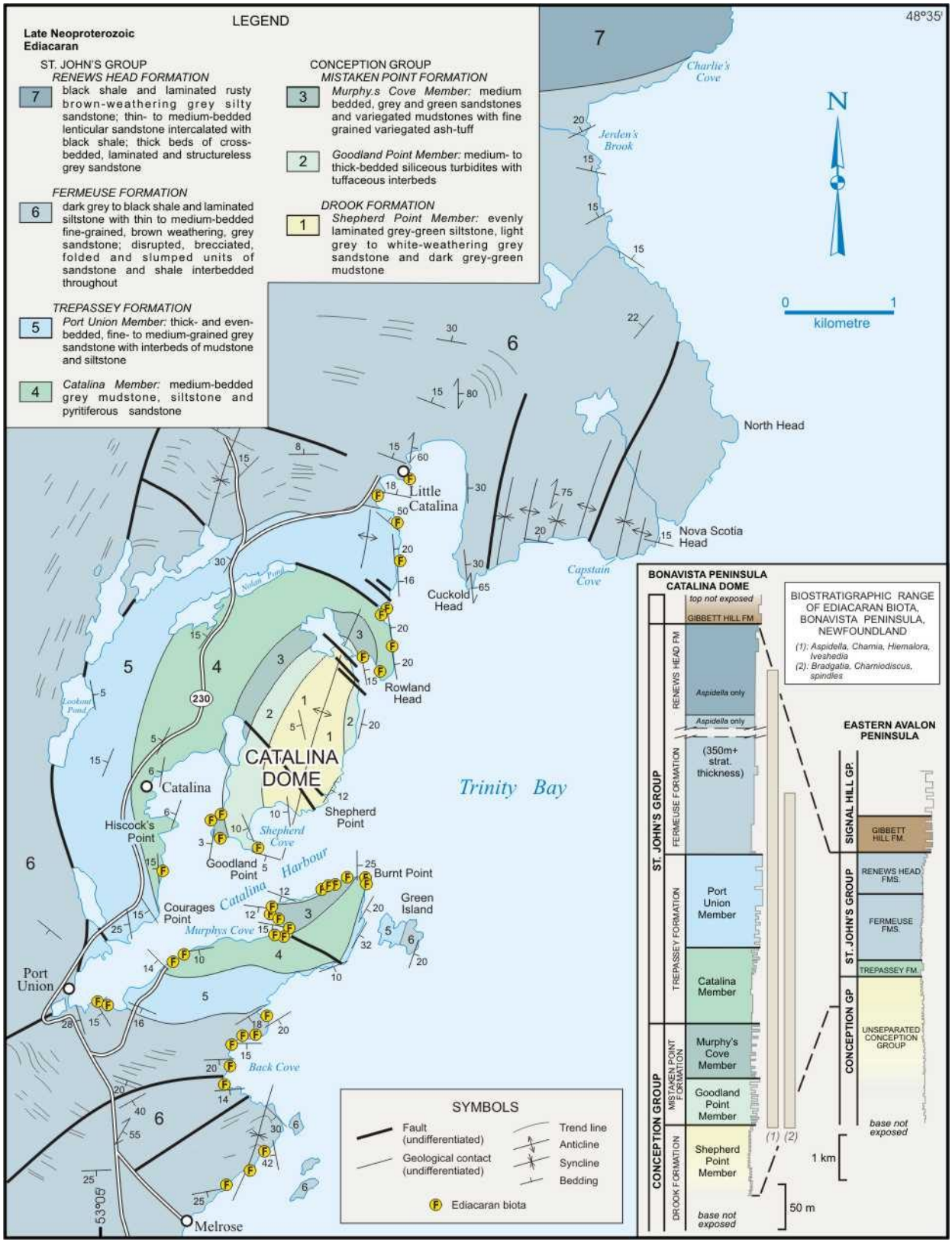

Figure 3. *Geology of the Catalina Dome and adjacent area, northwestern Trinity Bay; inset shows regional stratigraphic correlation of Late Neoproterozoic units and approximate biostratigraphic range of Ediacaran biota (modified from O'Brien and King, 2005).*

B-7); and distinctive, very thick (1 to 3 m) to extremely thick (>3 m) beds of crossbedded, laminated and structureless grey sandstone units interbedded with black shales and thin sandstones (facies C-7). The coarse-grained sandstones are associated with granule and small pebble layers locally. Good examples of facies A-7 and B-7 are exposed in the coastal exposures between Elliston and Maberly. Remains of *Aspidella terranovica*, Billings, 1872, occur as rare oval-shaped discs from 1 to 5 cm diameter in shale-rich facies; good examples are exposed on the coastal exposures approximately 1 km south of Maberly and are comparable to those described in the St. John's area (cf. King, 1990, Plate 23, page 45). Facies C-7 is commonly incised or present in facies A-7 and B-7, and is well exposed in the high coastal cliffs south of Maberly. The third lithofacies is interpreted as major channelized sand lobes and sheets, which are possible delta-front deposits related to delta-top sedimentation recorded in the overlying Gibbett Hill Formation. The thick sandstone units with their large-scale crossbeds and parallel-laminated beds (some of which show primary current lineations) are more abundant and better developed here than in corresponding facies of the Fermeuse Formation on the Avalon Peninsula (*see* King, 1990). The top of the Renews Head Formation is exposed in the community of Elliston, where well laminated sandstone with thin layers of pale green siltstone is overlain by very thick grey sandstone beds having a massive appearance. The Gibbett Hill Formation succession has been described previously in O'Brien and King (2002).

Further study of well-exposed sections of the Renews Head Formation and overlying Gibbett Hill Formation of the Signal Hill Group at Spillars Cove and the coast south of Maberly has revealed additional facies that are characteristic of the adjacent Rocky Harbour Formation of the Musgravetown Group (O'Brien and King, 2002, 2004b) exposed immediately west of the Spillars Cove–English Harbour fault zone. Most notable are: 1) crossbedded sandstones and lenticular-bedded and rippled and diagenetically altered yellow-green sandstones, similar to the Cape Bonavista facies, and 2) dark-grey shales and lenticular sands, characteristic of the Birchy Cove–Newmans Cove facies of the Rocky Harbour Formation (cf. O'Brien and King, 2002). The new observations are consistent with the view that the Rocky Harbour Formation may have once lain in depositional contact above the Signal Hill Group in this area, and that there once was stratigraphic continuity across the fault. Such a relationship is compatible with relationships seen on the east side of Trinity Bay (King, 1988, 1998) where the Gibbett Hill Formation is conformably overlain by Musgravetown Group tuffaceous siltstone and arkoses (cf. Big Head Formation, King, 1988). This places the widely developed sulphide-bearing and shale-rich St. John's Group in the same basin, below the copper-bearing red and grey beds of the Musgravetown Group.

Further study of the St. John's Group succession between English Harbour and Horse Chops, immediately east of the Spillars Cove–English Harbour fault zone demonstrates significant throw along the structure. New mapping in progress (S. O'Brien, unpublished data, 2005) has shown that the succession there can be assigned in its entirety to the Renews Head Formation and that both the Trepassey and Fermeuse formations may have been excised along the fault.

NOTES ON THE BIOSTRATIGRAPHY OF EDIACARAN BIOTA

As previously reported (O'Brien and King, 2004a, 2005; Hofmann *et al*., 2005a, b), the Ediacaran fossil assemblage of the Bonavista Peninsula comprises many forms known from the Mistaken Point area of the Avalon Peninsula (Narbonne *et al*., 2001; Clapham *et al*., 2003; Narbonne, 2005), including *Aspidella*, *Bradgatia*, *Charnia*, *Charniodiscus*, *Hiemalora*, *Ivesheadia*, and, possibly, *Blackbrookia*, and informally named forms referred to as spindles, strings, brush-like fossils, and rare ladder-like bodies. Mapping has thus far identified more than 20 separate Ediacaran fossil localities in the region between Melrose and Maberly, on the northwest coast of Trinity Bay (Figure 2).

The Ediacaran fossils occur abundantly under laminae and thin beds of light-coloured ash, within the turbidites of the Mistaken Point Formation (upper part of the Conception Group) and in the shale- and sand-rich facies of the Trepassey, Fermeuse and Renews Head formations (St. John's Group). The Ediacaran biota occurs in stratigraphic units and lithofacies similar to those elsewhere in the eastern Avalon Zone, southeast of Trinity Bay, including the Mistaken Point area (Narbonne *et al*., 2001; Clapham *et al*., 2003; Narbonne, 2005).

New data collected in 2005 have demonstrated that the stratigraphic ranges of *Bradgatia*, *Charnia*, *Charniodiscus*, *Ivesheadia*, and spindles extend upward at least 300 m (approximated thickness) into the Fermeuse Formation of the St. John's Group. This range is significantly higher than that reported from equivalent rocks on the southeastern Avalon Peninsula (Narbonne *et al*., 2001). These new observations in Ediacaran strata from the Bonavista Peninsula demonstrate that the concept of separate "Mistaken Point" and "Fermeuse" fossil assemblages (cf. Narbonne *et al*., 2001) in the Ediacaran strata, provisionally recognized in correlative rocks on the Avalon Peninsula, is not necessarily

applicable to this part of the Newfoundland Avalon Zone. Some rare, newly discovered specimens of *Hiemalora* in both the Conception Group (Mistaken Point Formation) and the lower St. John's Group (Fermeuse Formation) are attached to stems and fronds. This unique preservation argues that equivocal, tentacle-like appendages of *Hiemalora* may be root-like structures (Hofmann *et al*., 2005b).

In the Elliston to Little Catalina section, *Aspidella* is present throughout the Trepassey and Fermeuse formations; recent discoveries have extended the range through much of the Renews Head Formation. As previously reported, *Aspidella* occurs throughout the underlying Mistaken Point Formation in the Catalina Dome.

GEOCHRONOLOGY

The absolute age of fossiliferous Conception Group strata in eastern Bonavista Peninsula is presumed to be between ca. 575 and 560 Ma, based on correlation with dated upper Conception Group rocks containing Ediacaran biota in southern Avalon Peninsula. Previously, samples were collected on the eastern Bonavista Peninsula to test this correlation by way of U–Pb geochronology; the thickest regionally continuous ash bed in the fossiliferous Conception Group, sampled in 2004, did not contain zircon (G. Dunning, unpublished data, 2005). New samples of thinner ash units within the Mistaken Point Formation of that group were collected by the authors and G. Dunning (Department of Earth Sciences, Memorial University) during the 2005 field season. These have been processed, yielded abundant zircons, and are presently being dated (U–Pb TIMS).

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