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STRATIGRAPHY AND STRUCTURE OF SEDIMENTARY ROCKS IN THE HUMBER ARM ALLOCHTHON, SOUTHWESTERN BAY OF ISLANDS, NEWFOUNDLAND

E. Burden, T. Calon, L. Normore and S. Strowbridge
Department of Earth Sciences, Memorial University of Newfoundland, St John's, NF, A1B 3X5

ABSTRACT

In western Newfoundland, mélange surrounding, and underlying the Little Port and Blow Me Down igneous complexes are stratigraphically resolved into four distinctive rock assemblages. Each is tentatively correlated using lithostratigraphy and tectonostratigraphic characteristics, and palynomorph biostratigraphy, and are provisionally assigned to existing Cambrian and Ordovician formations of the Curling and Northern Head groups.

Significantly, two of the younger (Tremadoc and Arenig) biostratigraphic assemblages examined and mapped in this structurally complex region remain in the oil window.

REGIONAL SETTING, PURPOSE AND SCOPE

The Humber Arm Allochthon (Figure 1) comprises westerly transported thrust slices of lower Paleozoic rocks that represent remnants of the Iapetus Ocean and its flanking Laurentian continental margin (Williams, 1975, 1995). The upper slices contain oceanic crust and mantle of the Bay of Islands Ophiolite Complex (Church and Stevens, 1971), and an island-arc suite of the Little Port Complex (Williams, 1973; Malpas, 1979). Mélanges at the base of these slices have blocks of both igneous complexes, and sedimentary blocks derived from the Humber Arm Supergroup; blocks are embedded in either a serpentinite or shale matrix.

The intermediate and lower thrust slices are dominantly sedimentary rock (Figure 2). The intermediate thrust slice comprises the [1]Blow-Me-Down Brook formation. In early work, this was thought to be a lower to middle Ordovician (Taconic) flysch at the top of the Humber Arm Supergroup. However, fossil evidence now indicates an Early Cambrian age for this unit (Lindholm and Casey, 1990). Several sandstone–shale units originally assigned to the formation have been re-assigned to the Eagle Island formation, which represents the Taconic flysch (Waldron and Palmer, 2000). The Blow Me Down Brook formation is now placed at the base of the Humber Arm Supergroup. It is in structural contact with Companion Mélange consisting of sedimentary blocks in a shale matrix having a thin zone of ophiolite-derived material at the base (Cawood *et al.,* 1988).

The lower slices of the allochthon consist of coherent sedimentary successions of the Humber Arm Supergroup, subdivided into the Curling and Northern Head groups (Waldron and Palmer, 2000). The late Precambrian – Middle Cambrian Curling Group comprises siliciclastic rocks of the Blow Me Down Brook, Summerside, and Irishtown formations. The Middle Cambrian to Early to Middle Ordovician Northern Head group is divided into the Cooks Brook, Middle Arm Point, and the Eagle Island formations. The Cooks Brook formation consists of ribbon limestone interbedded with conglomerate and grey shale; trilobite faunas reported in Cawood *et al.* (1988) and recovered from boulders and nodular limestones indicate that the strata are no older than the late Middle Cambrian. The Middle Arm Point formation contains green and red siliceous mudstone with thin-bedded silty dolostones and limestones; graptolites recovered from the Middle Arm Point formation indicate an Arenig age for these beds (Botsford, 1988). The Eagle Island formation consists of grey and green lithic sandstones interbedded

[1] Blow-Me-Down Brook is hyphenated when used in the sense of Stevens (1965; Bruckner, 1966); elsewhere in Current Research 2001 see Palmer *et al., this volume,* usage follows that suggested by Waldron and Palmer (2000).

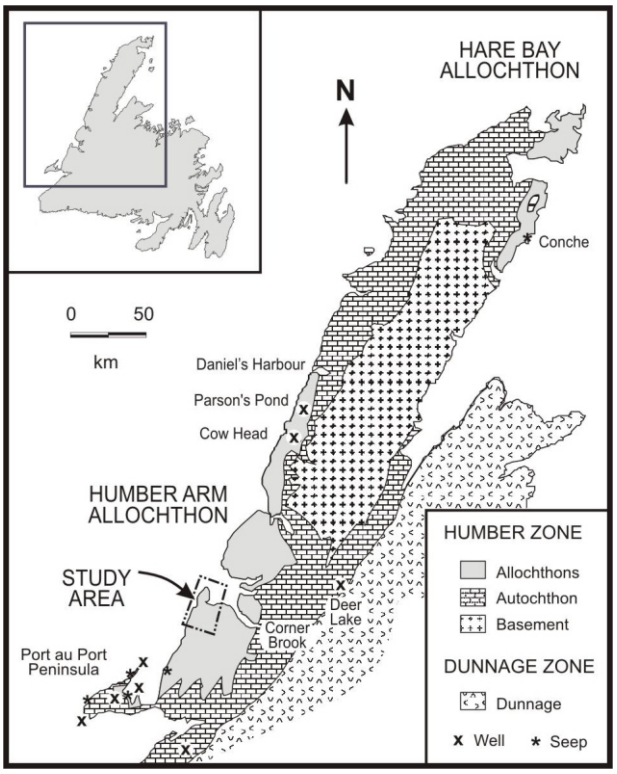

Figure 1. *Regional location map of Humber Zone allochthons and the study area.*

with grey, green and red shales; graptolites reported in Botsford (1988) indicate a middle to late Arenig age.

Regional mapping of this area of western Newfoundland has generated a stratigraphy model and a tectonic assembly that has seen wide acceptance. In recent years, research has turned toward detailed 1:50 000-scale analysis of strata, and to levels that can find application in, amongst other things, mineral and hydrocarbon exploration. The purpose of this NATMAP project is to contribute to the geological understanding of this region by examining in detail the stratigraphy and structure of sedimentary rocks in the upper and intermediate thrust slices of the Humber Arm Allochthon, west and south of the Blow Me Down ophiolite massif (Figure 3).

In early work, the sedimentary rocks lying beneath the ophiolite massif were assigned to the Humber Arm Supergroup (undivided) and described as a mixed unit of sandstone, shale and oolitic limestone, possibly correlative to the Cooks Brook formation (Williams, 1973). In their 1:250 000-summary and synthesis map, Williams and Cawood (1989) treated the rocks as a mélange associated with the upper slice and including slices of Blow Me Down Brook formation. The western mélange is in contact with the Little Port Complex, whereas the Blow Me Down Brook formation, a little farther east, structurally underlies the ophiolite massif. This project will significantly add to our understanding of local strata and structure. On completion, the results will be compiled in a new 1:50 000-scale geological map for the area.

Recent fieldwork concentrated on the complex tectonostratigraphy of the Little Port–Lark Harbour–York Harbour area south of the Bay of Islands (Figure 3). It also included a partial study of a less deformed sedimentary slice at Bear Cove. Detailed sections of coastal outcrops were measured and sketched to establish local lithostratigraphic and structural relationships. Lithological assemblages were extensively sampled for biostratigraphy; more than 100 samples were collected for palynology.

RESULTS

Four distinctive and predominantly sedimentary rock assemblages have been identified. To aid in diagnosis, three assemblages, previously mapped as mélange, are informally named after the locality where they are best exposed, namely Little Port, Bear Cove and Riley's Brook; the fourth lithologic assemblage is the Blow Me Down Brook formation. Based on lithofacies, the three mélange assemblages may, in part, be correlated with existing lithostratigraphic units found elsewhere in the Humber Arm Supergroup. Palynological analysis is in progress; preliminary results are consistent with the suggested correlations.

BLOW ME DOWN BROOK ASSEMBLAGE

The lithostratigraphic assemblage comprising the Blow Me Down Brook formation is best developed in thrust slices that structurally underlie the Blow Me Down ophiolite massif (Figure 3). Other good exposures examined in this study lie on the south shore of Bay of Islands where they extend to York Harbour and on the shores of Governors Island and Seal Island (Figure 3). The Blow Me Down Brook lithostratigraphic assemblage contains green, thick-bedded, coarse-grained arkosic sandstone, having subordinate conglomerate, and local intervals (1 to 6 m thick) of grey and red shale (Plate 1). The diagnostic trace fossil, *Oldhamia curvata* Lindholm and Casey 1990 occurs in abundance in an anomalous thick red shale unit on Governors Island (Plate 2). Lindholm and Casey (1990) discussed uncertainties surrounding the age for *Oldhamia* species, concluding that while some Middle Cambrian and Precambrian reports are in the literature, North American occurrences are primarily in Early Cambrian strata.

A preliminary examination of acritarchs from these islands and from a quarry beneath the ophiolite complex, shows well preserved fossils with an Acritarch Alteration

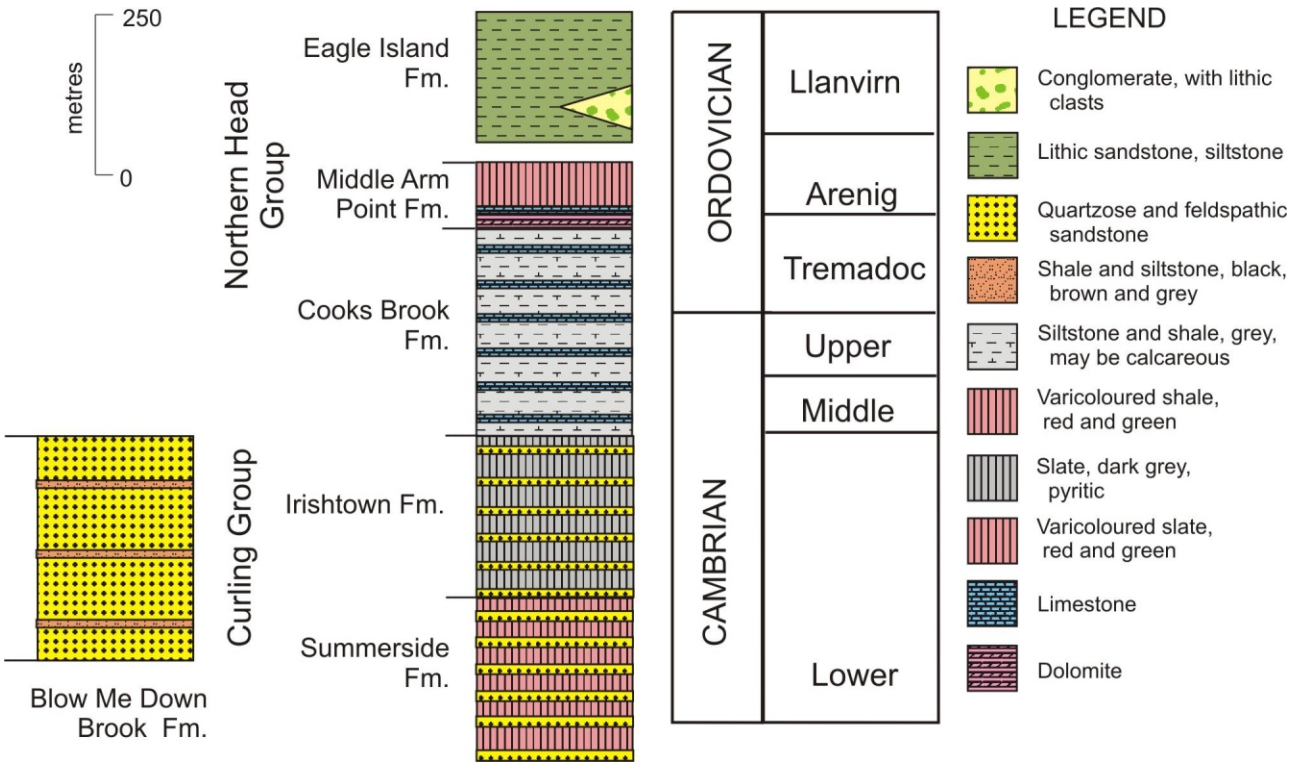

Figure 2. *Sedimentary strata of the Humber Arm Supergroup in the Bay of Islands region.*

Index (AAI) of a little more than 3 on a scale published in Williams *et al.* (1998). This lies just outside the oil window. Fossils are dominantly cyanobacteria filaments with leiospheres, *Annulum squamaceum* (Volkova) Martin *in* Martin and Dean 1983, *?Fimbriaglomerella membranacea* (Kirjanov) Moczydlowska and Vidal, 1988, *Retisphaeridium dichamerum* Staplin *et al.*, 1965, and sphaeromorph clusters. These taxa are found elsewhere in the Bay of Islands in other Blow Me Down Brook formation beds and in the Irishtown formation (Palmer *et al., this volume*). *Fimbriaglomerella membranacea* and *A. squamaceum* are thought to indicate an early Cambrian age (Molyneux *et al.*, 1996).

On Seal Island, the Blow Me Down Brook formation shows a westerly verging fold-and-thrust pattern having gently south–southwest-plunging overturned cleavage folds.

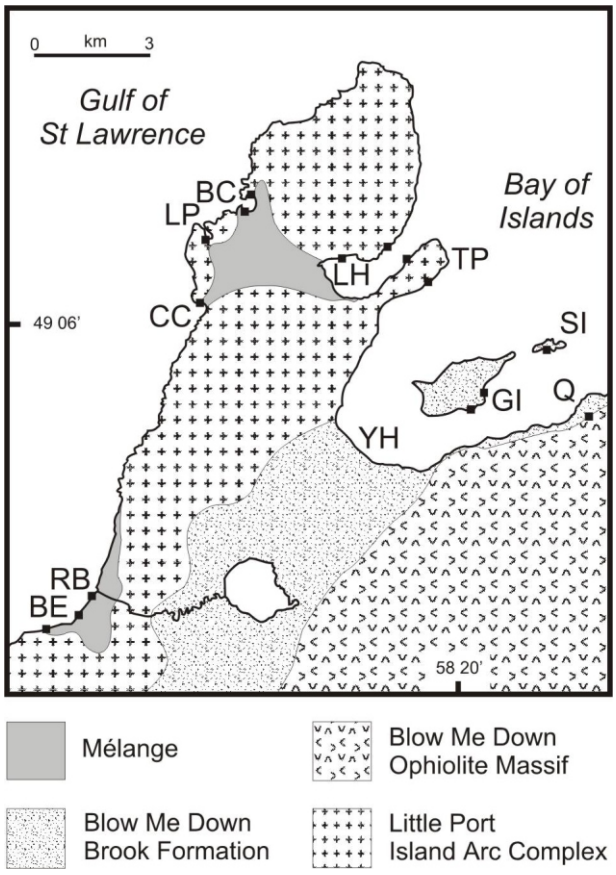

Figure 3. *Location map for outcrops identified in this paper; BE - Bear Cove, RB - Riley's Brook, CC - Caplin Cove, LP - Little Port, BC - Bottle Cove, LH - Lark Harbour, TP - Tortoise Point (Blow Me Down Provincial Park), YH - York Harbour, GI - Governors Island, SI - Seal Island, Q - Quarry, (base-map geology summarized from Williams and Cawood, 1989).*

Plate 1. *Outcrop of Blow Me Down Brook formation from southern Governors Island showing thick-bedded character of graded pebbly sandstones (horizontal rod 1 m).*

Along the shore to the north of the Blow Me Down ophiolite massif, the assemblage is contained in a northerly verging overturned cleavage fold system broken by high-angle reverse faults. Southwest of Tortoise Point in Blow Me Down Provincial Park (Figure 3) sedimentary rock outcrop, at the base of quartz dioritic cliffs, is mainly covered with glacial sediment. One outcrop with lithological characteristics of the Blow Me Down Brook formation structurally overlies, with a moderate northeast-dipping contact, strata conforming to the Bear Cove Assemblage.

LITTLE PORT ASSEMBLAGE

The Little Port Assemblage is apparently an integral part of the Little Port Complex, a 505-Ma (Jenner *et al.*, 1991) island-arc sequence. In outcrop, sediments locally overlie variably altered, red tinged and oxidized, mafic volcanic rocks having an undisturbed unconformable contact. It is a heterogeneous lithologic succession, with the basal strata (up to 20 m thick) consisting of poorly sorted conglomerate with igneous clasts, green medium-bedded coarse sandstone, laminated limestone and limestone breccia associated with red chert (Plate 3). These rocks pass rapidly into an upper unit (minimum 40 m thick) of highly cleaved grey and black siliceous shale interbedded with parallel and cross-laminated sandstone near the base and ribbon limestone at the top (Plate 4). Much of the upper unit displays mesoscopic polyphase fold patterns and is severely imbricated. Typical occurrences outcrop at Little Port, Bottle Cove and Caplin Cove. The Little Port Assemblage is normally observed in steep fault contact with the Bear Cove and Riley's Brook lithologic assemblages. At the south side of Bear Cove, the Little Port sedimentary assemblage is overthrust in a northerly direction, by mafic volcanic rocks of the Little Port Complex along a serpentinite shear zone containing well-developed C–S fabric.

Plate 2. *Trace fossil* Oldhamia curvata *from southern Governors Island.*

To date, the few palynomorph samples that have been processed from rock from this unit have been carbonized and unproductive.

BEAR COVE ASSEMBLAGE

At Bear Cove, the Bear Cove Assemblage consists of several thrust panels repeating sections of grey and black shales, and light-green calcareous shales, interlayered in various proportions with thin- to medium-bedded oolitic grainstone showing turbidite structures, ribbon-laminated grainstone, and limestone conglomerate and breccia. Char-

Plate 3. *Conglomerate of the Little Port sediment assemblage at Little Port.*

acteristic occurrences are identified in thrust-bounded panels at Bear Cove, Little Port, and along the shoreline of Blow Me Down Provincial Park. Stratigraphic thicknesses of some successions reach 50 m (Plate 5), but generally are difficult to establish due to effects of deformation and of covered intervals.

Structurally, the Bear Cove Assemblage appears as a broken formation. It is imbricated on a scale of several tens of metres, and the panels contain polyphase fold patterns consisting of an early generation of rootless isoclinal folds with axial–planar cleavage and a second generation of asymmetric inclined folds with local crenulation cleavage in hinge domains.

On small, rocky shoals (White Rocks), lying off Bear Cove, carbonate conglomerate of the Bear Cove Assemblage contains boulders that have Late Cambrian trilobites (Kindle and Whittington, 1965). Based on crudely similar lithofacies and on limited macrofossil evidence, these occurrences are tentatively correlated with the Cooks Brook formation (Boyce *et al.*, 1992). Williams (1973) reported an Early Ordovician age for a graptolite occurrence in this assemblage at Little Port.

Onshore at Bear Cove and at Blow Me Down Provincial Park, palynomorph residues of shaly strata are very

Plate 4. *Deformed siliceous shale, sandstone and limestone of the Little Port sediment assemblage at Little Port (rod 15 cm).*

organic in composition; furthermore, limestone at Blow Me Down Provincial Park has a distinctive petroliferous odor. In plane light, fossil residues are yellow (AAI ~2.0); under ultra-violet light, fossils fluoresce amber. Hence, given these colour and fluorescence properties as a guide, it must be concluded that the strata of the Bear Cove Assemblage at Bear Cove and at Blow Me Down Provincial Park were never deeply buried and still remain in the oil window. For a preliminary age assessment, the acritarch *Lunulidia* sp. is relatively abundant; *Lunulidia* sp. is thought to be a lower Ordovician (Tremadoc) species (Eisenack, 1958). In addition to acritarchs, part of a graptolite theca was identified. Graptolites evolved in the Late Cambrian but did not become common and abundant until the Early Ordovician. Correlation with the Cooks Brook formation is possible, but the overall lack of significant carbonate development in the entire Bear Cove Assemblage makes this a very tenuous link.

Plate 5. *Approximately 50 m of calcareous shale and siltstone and overlying interbeds of oolitic grainstone and conglomerate. Fault-bound panel of Bear Cove Assemblage at Bear Cove.*

RILEY'S BROOK ASSEMBLAGE

The Riley's Brook Assemblage is a succession of grey, red and brown to black siltstone and shale interlayered with several intervals of thick-bedded, grey to green coarse-grained sandstones having turbidite structures. At Riley's Brook, this unit exceeds 140 m in thickness (Plate 6). Three prominent sandstone beds, separated by distinctively coloured siltstone and shale bands are traceable for several kilometres along this stretch of coastline. Inasmuch as relationships between thrust panels in the section from Riley's Brook to Bear Cove have yet to be fully explained, the base of the Riley's Brook Assemblage may be a gradational contact with the underlying Bear Cove Assemblage. A similar contact may be inferred from outcrops on a largely forested cliff on the northwestern shoreline of Blow Me Down Provincial Park.

Acritarch assemblages collected from near the base of the unit at Riley's Brook contain abundant *Baltisphaeridium longispinosum* (Eisenack) Eisenack 1959 and other presently unidentified acanthomorph taxa; these rocks are Early Ordovician, and probably Arenig in age. Significantly, fossils from Blow Me Down Provincial Park are pale and fluoresce bright yellow; those from Riley's Brook are a little darker in colour. With an AAI between 2 and 3, both localities are in the oil window. Based on lithofacies and very preliminary biostratigraphic evidence, it is possible that the Riley's Brook Assemblage correlates with the Middle Arm Point or Eagle Island formations.

Plate 6. *Interbedded coarse-grained sandstone and red and brown-black siltstone and shale of the Riley's Brook Assemblage at Riley's Brook.*

SUMMARY

In merging paleontology and structural geology significant refinement of "mélange" stratigraphy is possible. Evidence presented here indicates that strata carry diagnostic properties amenable to regional mapping. By putting strata in a proper tectonostratigraphic context and differentiating rocks that still lie within the oil window, significant new insights into petroleum prospects for this area emerge. In understanding fossils, strata and structure, the complex geology of the allochthon and hydrocarbon prospects beneath the Gulf of St. Lawrence may be better understood. So too, with this report, it is now clear that thrust panels lying immediately adjacent to and beneath volcanic rocks in this area are not highly metamorphosed, and may yet remain petroliferous With proper sequencing of source, reservoir and seal, this area may yet contain significant hydrocarbon traps.

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