*Current Research (2001) Newfoundland Department of Mines and Energy Geological Survey, Report 2001-1, pages 105-112*

# STRATIGRAPHY OF THE CURLING GROUP (CAMBRIAN), HUMBER ARM ALLOCHTHON, BAY OF ISLANDS

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## ABSTRACT

*The Curling Group consists of clastic sedimentary rocks within the Humber Arm Allochthon, that are considered approximate correlatives of the contemporary shelf succession of the Labrador Group. The Blow Me Down Brook formation is well exposed on Woods Island, where it is dominated by feldspathic and lithic sandstones. A stratigraphic contact on mafic lavas is exposed in a tectonically separated section. The Summerside formation contains abundant red shales, together with graded and massive quartzose sandstones. The Irishtown formation contains black shales, interbedded with well indurated quartzose sandstones and local conglomerates. All three formations contain sedimentary structures indicative of rapid deposition by episodic turbidity currents or other types of sediment-gravity flow. Four palynomorph assemblages that have been recovered from the Curling Group are comparable with those displayed in the Labrador Group. All of the samples examined were from outside the oil window, but strata in this part of the Humber Arm Allochthon might still remain gas prone.*

## INTRODUCTION

The sedimentary rocks of the Humber Arm Supergroup are deeper water, time-equivalents of the Cambro-Ordovician shelf succession found in the Humber Zone of the western Newfoundland Appalachians. They have been divided into two groups by Botsford (1988). The lower, Curling Group, which consists of interbedded shales and sandstones, has suffered varying degrees of deformation and metamorphism, locally to greenschist facies. The group is equivalent to the Neoproterozoic to Early Cambrian Labrador Group of the shelf succession. The Curling Group has been informally divided into three formations but has not been formally described, nor have the sedimentary environments been interpreted in any detail (Stevens, 1970). The overlying Northern Head group includes ribbon-laminated carbonate, carbonate conglomerate, and shale, time-equivalent to the Port au Port and St. George groups of the shelf succession, and was studied in detail by Botsford (1988).

The area along the shores of the Humber Arm in the Bay of Islands region provides the best exposure of Summerside and Irishtown formation strata (Figure 1). However, both formations are deformed by at least two generations of structures. Earlier, predominantly brittle deformation has resulted in disruption of stratification, local asymmetric folding, and development of broken formation and mélange. Overprinted on these features are more ductile, more upright structures including folds and axial-planar cleavage. The intensity of these D2 structures decreases westward, but unfortunately the earlier D1 structures have disrupted stratigraphic sections more severely in the west, so the location of type sections involves some compromises.

### Blow Me Down Brook Formation

The most continuous and undisturbed section of the Blow Me Down Brook formation is located on the south shore of Woods Island (Figure 2), where it youngs to the east, and is relatively unaffected by D2 structures (Waldron and Palmer, 2000). Neither a top nor a base of the formation is visible in this section. Immediately east, a short section shows the Blow Me Down Brook formation lies in west-dipping stratigraphic contact on several tens of metres of pillowed, massive and brecciated volcanic rocks (Waldron and Palmer, *op. cit.*). This is inferred to represent the original base of the formation, although it is possible that the volcanic rocks could represent a series of flows within the orig-

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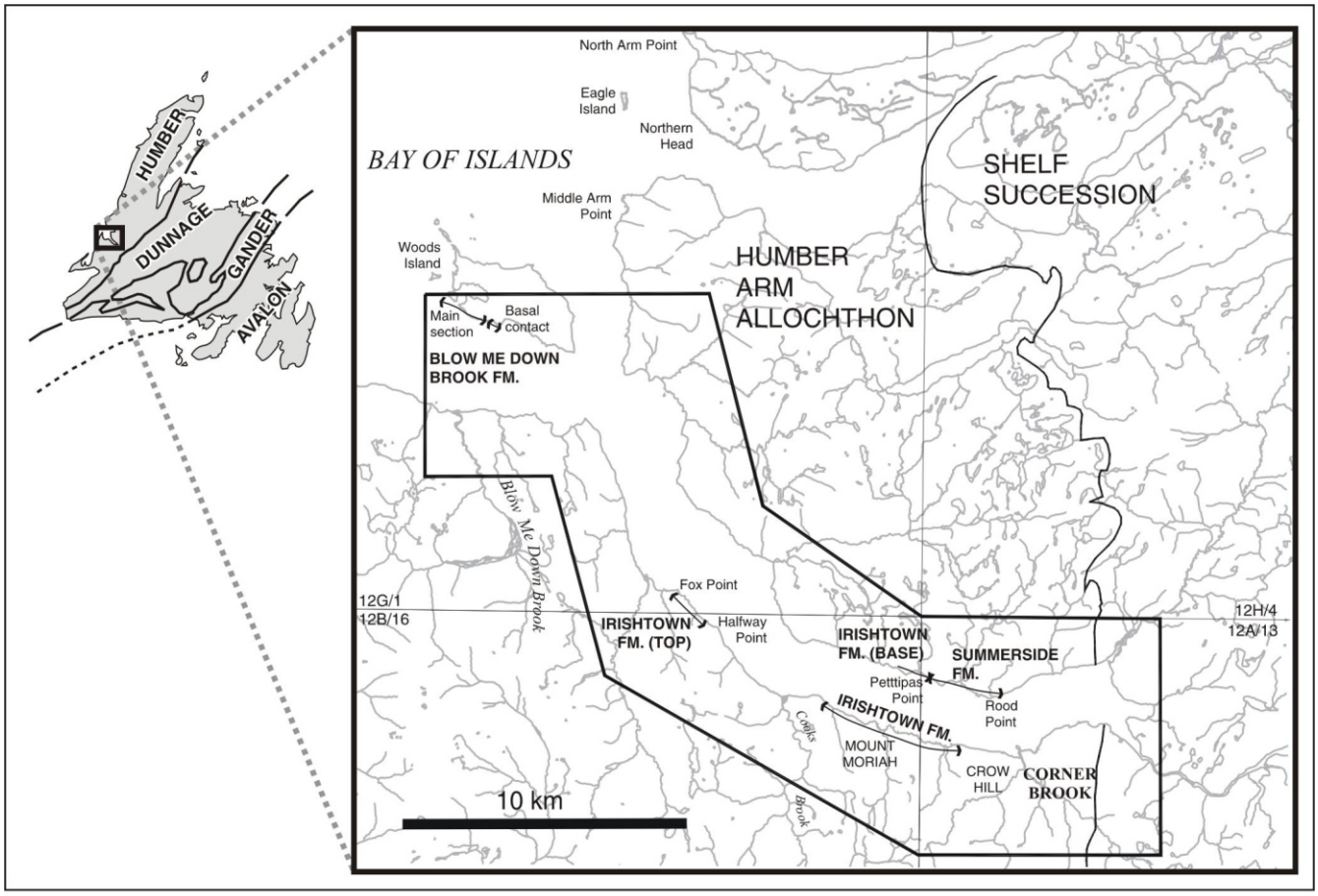


**Figure 1.** *Map showing location of study area within the Humber Zone of insular Newfoundland Appalachians, and sections measured in Curling Group.*

inal formation. The volcanic rocks are, in turn, bounded to the east by a highly sheared contact, where they structurally overlie an interval that includes several disrupted slices of the Blow Me Down Brook formation, which nonetheless display more shaly facies than the main section. These observations (plus other unpublished analyses by E. Burden in the Blow Me Down Brook formation farther west) suggest that the continuous section may have been preserved as an intact slice because of its lack of shaly intervals, and may therefore be atypical of the formation.

The formation is a package of clastic rocks dominated by very thick, graded sandstone units. The thickest, largely undistributed section, of about 372 m was measured on the south coast of Woods Island (Figure 2). Faults are common throughout the main section but most appear to show small offsets, allowing reasonably confident correlation of stratigraphy. Scoured bases and crossbeds indicate that the section is upright (Plate 1a). A basal unit of red mudstone, 10 to 20 cm thick, stratigraphically overlies the mafic volcanic rocks in the fault-bounded short section to the east of the main section.

Generally, the formation (Figure 2) consists of grey-green, beige-weathering, pebbly and granular, very coarse- to medium-grained sandstone in fining-up packages that are 5 to 20 m thick, commonly having scoured bases. Sedimentological features include planar laminations, crossbeds, graded bedding and dewatering structures. Floating pebbles and/or grey-green mudchips are common in the lower units of the graded packages. The mudchips indicate that fine units were initially present but have been removed by scouring. Between 130 and 140 m above the base of the main section is a crossbedded quartzarenite package that stands out due to its pale colour. A 10-cm lens of dark-grey mudstone at 365 m represents the only fine-grained material in the section, apart from the red mudstone.

With the exception of the crossbedded quartzarenites, the sandstones appear texturally and compositionally immature; granule conglomerates include both feldspathic and fine-grained lithic fragments. These beds are typical of high-energy sediment gravity-flow deposits found in deep-sea fans and other deep-marine environments. The quartzarenites are provisionally interpreted as products of reworking

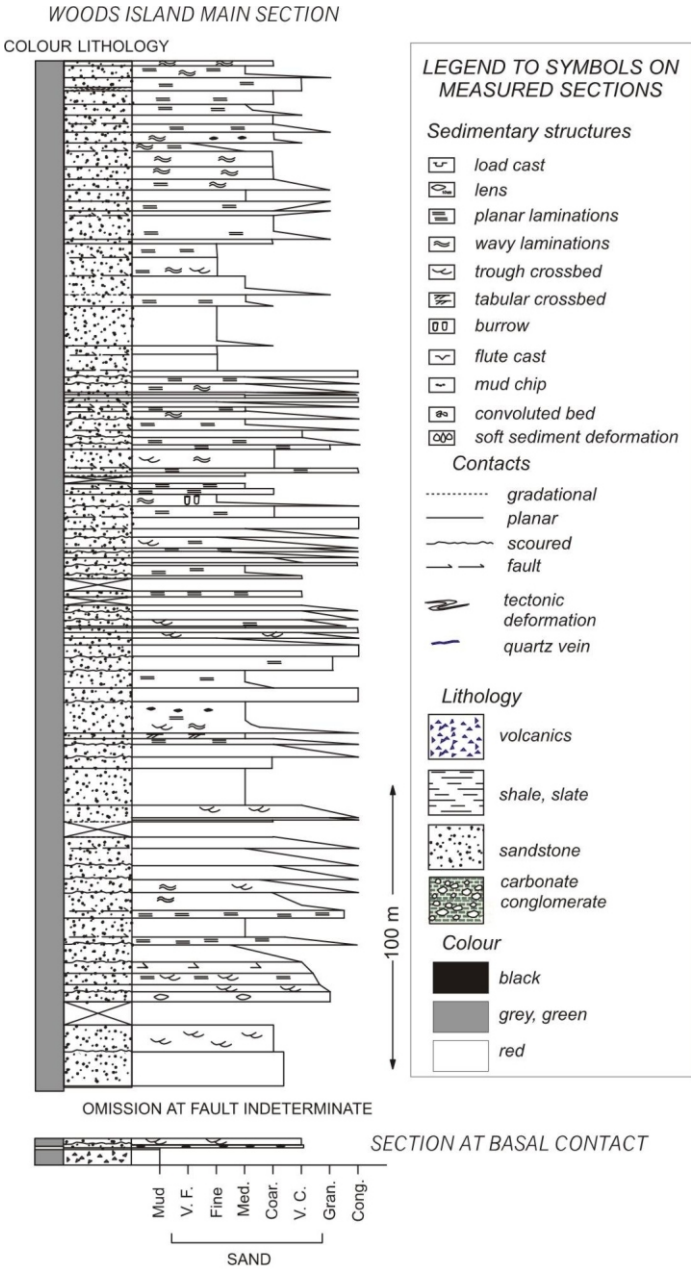


**Figure 2.** *Measured sections in Blow Me Down Brook formation, south coast of Woods Island.*

by strong bottom currents; interestingly, a closely similar facies is present in comparable sediment-gravity-flow deposits of the Meguma Group in Nova Scotia (Waldron and Jensen, 1985).

Isolated tectonic slices of the formation immersed in mélange or broken formation to the east contain a much higher proportion of shale, suggesting that other parts of the formation included more fine-grained facies, and that these units were preferentially tectonized during emplacement of the allochthon. Lindholm and Casey (1989, 1990) recorded the trace fossil *Oldhamia* Forbes, 1848, both from the main section and from the tectonic slices farther east, indicating an Early Cambrian age. (No unequivocal new occurrences were located in this study of the main section.)

**Summerside Formation**

A section of the Summerside formation approximately 700 m thick occurs on the north shore of Humber Arm (Figure 1; *see* Waldron and Palmer, 2000, for location details). The rocks are tectonized and significantly metamorphosed. Original fine-grained sediments are now phyllites, whereas sandstones show strong pressure-solution cleavage; tectonic strains may have significantly modified original thicknesses. In addition, the section includes several folded intervals; overturned sections are indicated by scoured contacts, crosslaminations and crossbeds.

The Summerside section (Plate 1b and Figure 3) consists of 10- to 40-m-thick meta-sandstone packages separated by green and red slate packages ranging from 1 to 20 m thick. The meta-sandstone units are coarse to very coarse grained (sometimes with granule-size grains) quartz-rich arkosic sandstone (Waldron and Palmer, 2000), and display grading, scoured bases, planar laminations, and crosslaminations. They appear similar in composition to the Blow Me Down Brook formation sandstones but contain red mudstone intraclasts that are absent in the latter formation.

Although the Summerside and Blow Me Down Brook formations are inferred to be Early Cambrian and contain generally similar character sandstones, the two units differ markedly in their relative proportion of fine-grained rocks (much greater in the Summerside) and in their oxidation state (predominantly oxidized in the Summerside, predominantly reduced in the Blow Me Down Brook).

**Irishtown Formation**

A section with an estimated thickness of 1140 m was measured on the south shore of Humber Arm (Figures 1 and 4). Exposure is discontinuous and may include some repetitions and/or omissions in areas of poor exposure and tectonic complexity. In the section illustrated, the formation consists mainly of dark-grey to black slates having thin fine-grained sandstone laminations and graded sandstone beds (Plate 1c). Slate intervals represent extremely tectonized shales and reach thicknesses of 100 m or more. These packages are undoubtedly tectonically thickened but contain no marker beds. Large (wavelength >30 m) open folds also

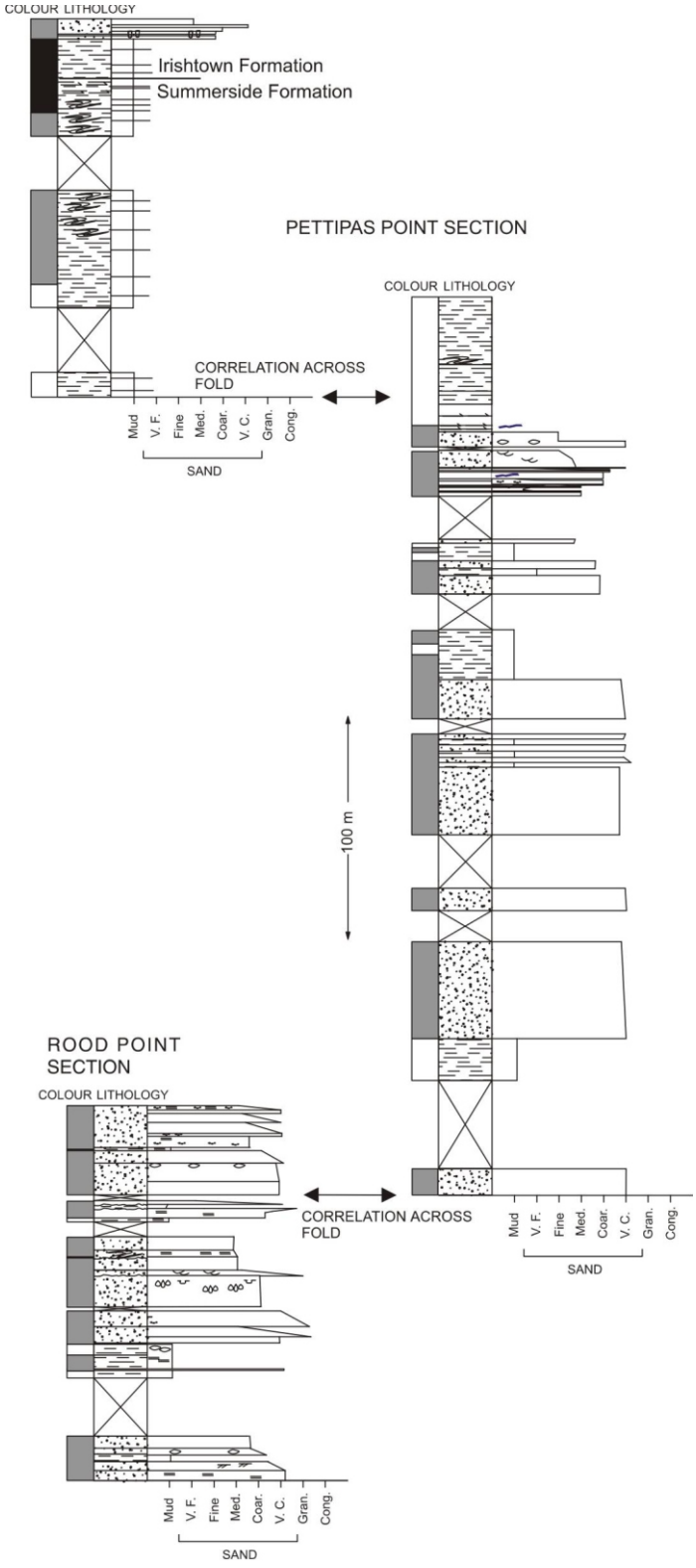


**Figure 3.** *Measured section in Summerside formation at Summerside. Legend to symbols and shadings shown in Figure 2.*

duplicate strata. Five- to ten-metre intervals of fine-grained sandstone to granule conglomerate occur interbedded with slate in the lower 350 m of section. In addition, single <1-m-thick beds of sandstone occur within slate-dominated intervals in the upper parts of the section. Grading, crossbeds and parallel-laminations are common sedimentary features. Flute casts and load structures mark the base of many beds. The more thinly bedded sandstones typically display partial or complete Bouma sequences, indicative of deposition by turbidity currents. More massive sandstones probably also represent sediment-gravity flows, in which other mechanisms of grain support may have operated, in addition to fluid turbulence. A distinctive ribbon-laminated unit of millimetre-scale orange sandstone laminations and thin (<1 cm) black slate interbeds is a marker in the upper part of the section, and indicates that there is no large-scale duplication within the section. Outside the measured sections, intervals of conglomerate occur at a number of locations; because of their absence in the measured section these are probably lenticular, on a regional scale.

Although detailed petrographic work has not been done on either the sandstones and conglomerates, their general composition is consistent with an inferred passive margin environment. The sandstones appear quartz-rich and compositionally, relatively mature; the conglomerates include rounded clasts of vein quartz, carbonate material including micrite and boundstone, and occasional granitoid fragments.

**Palynomorph Assemblages**

A total of 31 samples from Pettipas Point, Mount Moriah, Halfway Point, and Woods Island were processed according to standard palynological techniques and examined for organic debris, alteration index and palynomorph species. In total, only 5 samples from Summerside and Irishtown formation strata at Pettipas Point can be considered barren. All other samples have acritarchs and other organic debris useful for providing an age estimate for these rocks.

Palynology samples from the Bay of Islands follow a predictable pattern of thermal maturation changes from carbonized organic debris in older, more deeply buried

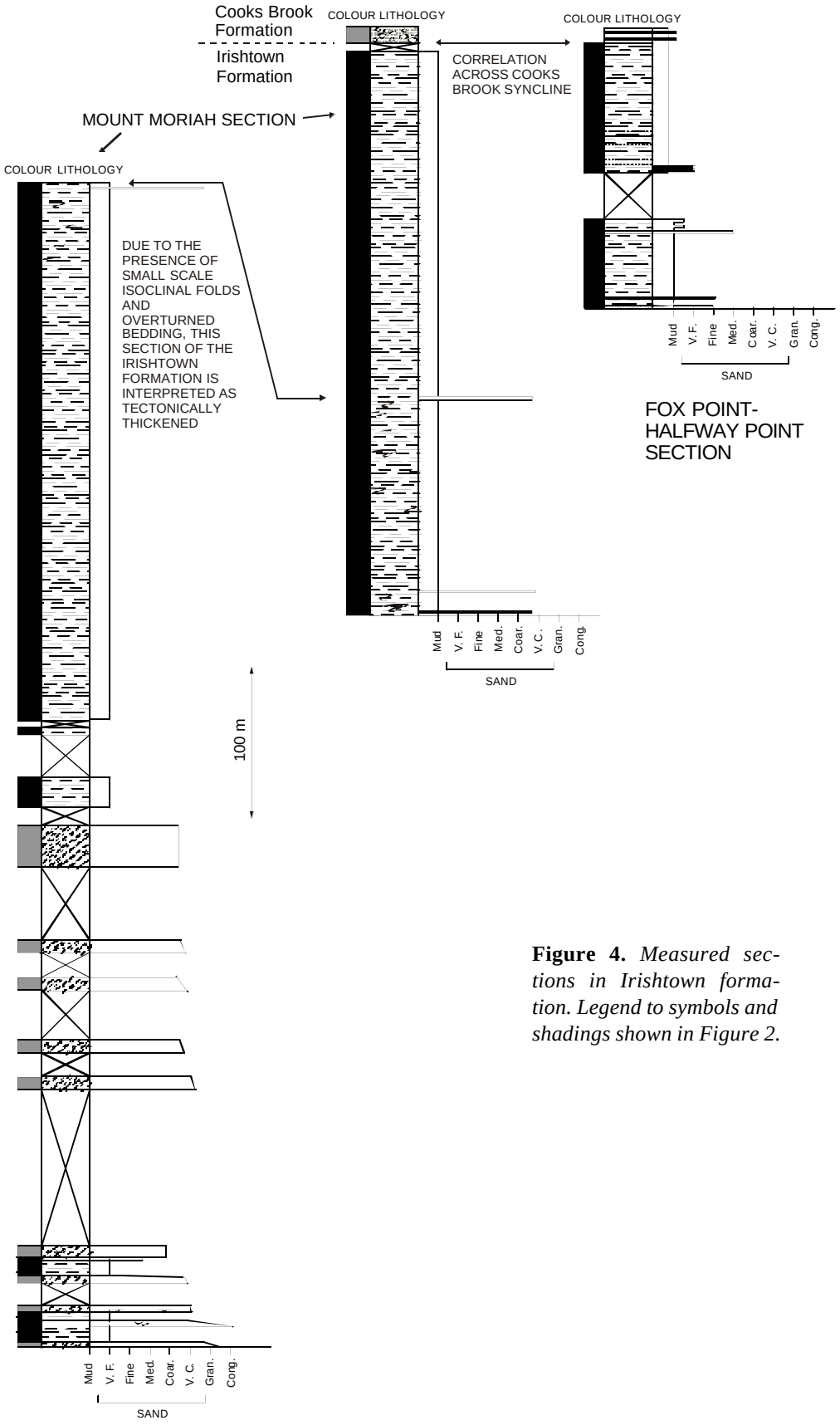


**Figure 4.** *Measured sections in Irishtown formation. Legend to symbols and shadings shown in Figure 2.*

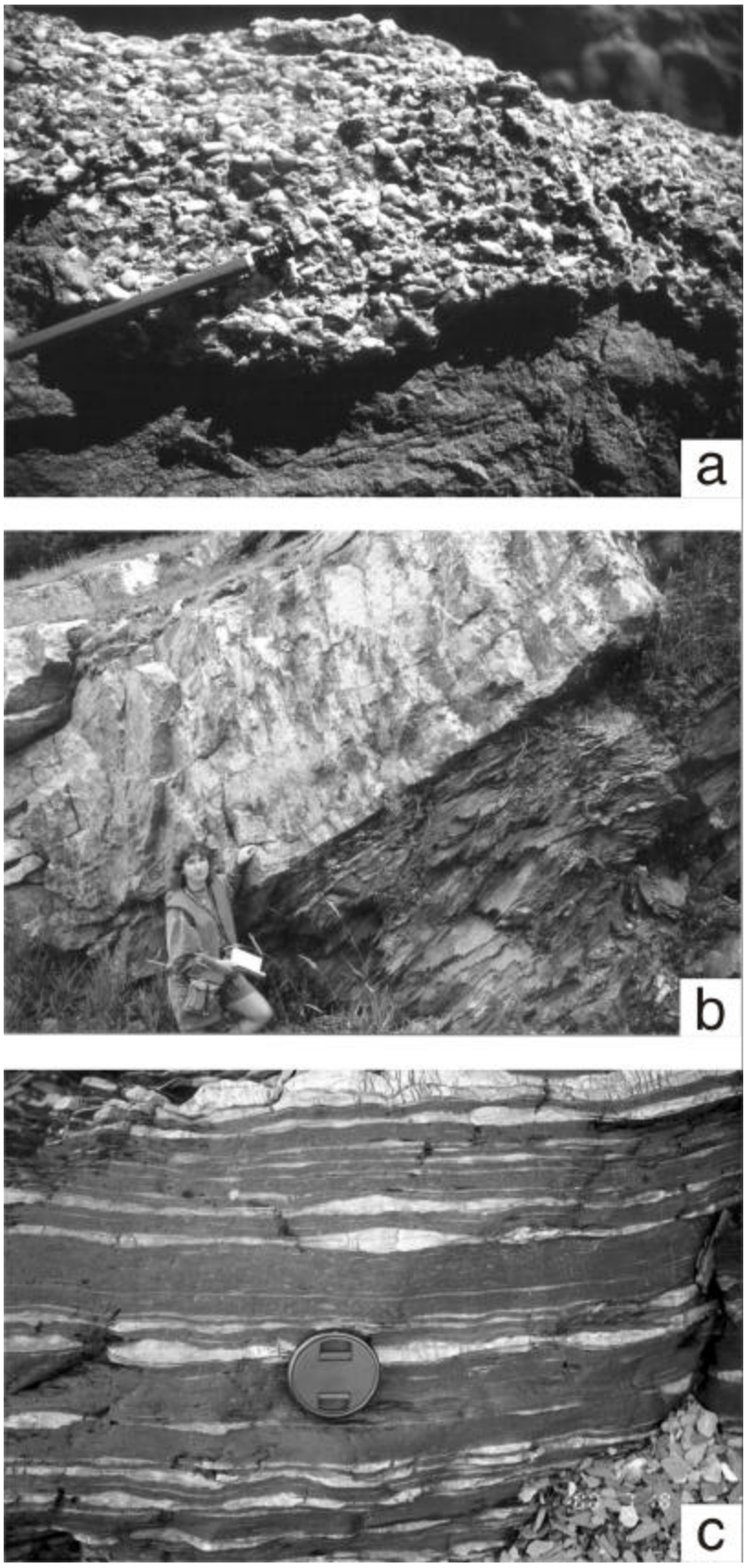


**Plate 1.** *Field photographs illustrating lithological and structural features of Curling Group. a) Blow Me Down Brook formation, south coast of Woods Island, showing erosional scour at base of pebble to granule conglomerate bed. b) Summerside formation, showing massive quartz sandstone overlying red slate. c) Thinly bedded crosslaminated siltstones of Irishtown formation.*

strata near Corner Brook to less metamorphosed and still identifiable fossils in strata near the top of the stratigraphic section, and on Woods Island, near the mouth of the bay. All of the samples examined in this study lie outside the oil window. The least metamorphosed samples from Woods Island are no longer capable of generating oil. Nevertheless, strata in this part of Humber Arm might still remain gas prone.

Four palynomorph assemblages are recognized in samples collected from this transect through the Curling Group. The least complex assemblage comprises sphaeromorphs, which include large (>100 μ) granular forms. This assemblage occurs sporadically in samples from the Summerside formation at Pettipas Point and is common in Irishtown strata at Mount Moriah and Halfway Point. Assemblages with this composition might indicate late Precambrian strata as for instance work by Martin (1993) and Moczydlowska *et al.* (1993). These resilient fossils, however, also occur in younger rock where they may be the last material metamorphosed.

Samples from near the top of the Irishtown formation including the section at Mount Moriah contain tetrads and clusters of small sphaeromorphs, *Annulum squamaceum* (Volkova) Martin *in* Martin and Dean, 1983, *Retisphaeridium dichamerum* Staplin *et al.*, 1965, and possibly a specimen of *Fimbriaglomerella membranacea* (Kirjanov) Moczydlowska and Vidal, 1988. *Annulum squamaceum* and *Fimbriaglomerella membranacea* are key Early Cambrian zone fossils (Molyneux *et al.,* 1996). Their occurrence, near the top of the formation, suggests that a significant hiatus separates the Irishtown for-

mation from overlying middle Middle Cambrian Cooks Brook formation.

The third significant acritarch assemblage is a sample of Blow Me Down Brook formation in melange lying below the Blow Me Down Brook formation at Woods Island. This assemblage contains more than 20 species of acritarchs dominated by several species of the genus Skiagia Downie, 1981, *Comosphaeridium* Staplin *et al.*, 1965, and *Michrystridium* Deflandre, 1937, specimens of *Archaeodiscina umbonulata* Volkova, 1968, *Baltisphaeridium cerinum* Volkova, 1968, *Multiplicisphaeridium waltonii?* Downie, 1981, *Leiovalia* sp., paraconodonts, and arthropod? fragments. Collectively, this assemblage corresponds with fossils of middle and late Early Cambrian rocks (Molyneux *et al.*, 1996). A similar assemblage occurs near the base of the Forteau Formation in the Port au Port #1 well on the Port au Port Peninsula.

The last assemblage, also recovered from the Blow Me Down Brook formation in tectonic slices at the eastern end of Woods Island contains abundant acritarch clusters and tetrads, *Leiovalia* sp., and filaments. Less common are specimens of *Archaeodiscina umbonulata* and *Lophosphaeridium* sp., *Archaeodiscina umbonulata* is considered an important Early Cambrian zone fossil (Molyneux *et al.*, 1996). This assemblage is present at the top of the Forteau Formation in the Port au Port #1 well.

## DISCUSSION AND CONCLUSIONS

Preliminary observations of the primary depositional features of the Curling Group confirm the interpretations of Stevens (1970) that all three formations include deep-water, turbiditic sedimentary facies. Previous descriptions of all three formations have emphasized the well-exposed coarse clastic portions of the successions; however, both the Irishtown and Summerside formations contain significant amounts of mudrocks, which are generally poorly exposed. The Irishtown formation is inferred to contain lenticular conglomerate-filled channels. It probably represents a mud-dominated, highly channelized submarine fan environment comparable to large, river-fed fans identified in modern passive margin environments, characterized by extended narrow channels with large muddy levees. Generally, in lithological character and age it is potentially correlative with shelf deposits of the Hawke Bay Formation, although that formation lacks a source for the conglomeratic material locally found in the Irishtown. The Summerside formation also contains a significant proportion of mud, but is distinctive in the red, oxidized character of much its mudstone. Sulphides of the Summerside formation, however, resemble those of the Irishtown formation. The red sediments are, however, comparable to Early Cambrian deep-water red sediments elsewhere in the Appalachian–Caledonide orogen and suggest that relatively oxidizing conditions may have existed during burial of some Early Cambrian deep-water sediments, possibly because of a low rates of deposition of organic matter.

The Blow Me Down Brook formation is dominated by sandstones which, in character, are similar to deposits of poorly channelized, small, sand-rich submarine fans of tectonically active margins. For this reason, and because the sandstones appear less compositionally mature than those of the Irishtown and Summerside formations, and also because at one location the formation is in depositional contact on volcanic rocks, it might be inferred to originate in a rift environment. However, as yet the palynological results provide no clear age distinction between the three formations, all of which were deposited in the Early Cambrian. Further sampling and refinement of palynological zonation will be necessary before the relative age and stratigraphic relationships of the Blow Me Down Brook formation can be known with certainty.

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