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STRATIGRAPHY AND SEDIMENTOLOGY OF THE PORT AU PORT GROUP (MIDDLE TO UPPER CAMBRIAN), WESTERN NEWFOUNDLAND: PRELIMINARY RESULTS

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ABSTRACT

Preliminary results of detailed stratigraphical and sedimentological analyses of Middle and Upper Cambrian platform strata in western Newfoundland, indicate a possible alternative to current regional correlations. Relative inboard–outboard facies relationships between measured sections, may dictate further revisions in Cambrian platform paleogeographical models, and may also indicate significant tectonic juxtaposition of terrains previously interpreted as autochthonous.

INTRODUCTION

During 1988, a project was initiated to study the stratigraphy and sedimentology of autochthonous platformal Cambrian strata in western Newfoundland. Stratigraphic sections were measured, and sedimentological field relationships were recorded for the carbonates and minor siliciclastics of the March Point, Petit Jardin and Berry Head formations (Middle to Upper Cambrian) in the areas of the Port au Port Peninsula, South East Arm of Bonne Bay, and Goose Arm of Bay of Islands (Figure 1). At these locations, the units are as yet unmapped at the formation level (1:50,000). This study is in its preliminary stages and the results presented are still tentative and subject to re-interpretation, pending further field surveys during the four-year lifetime of the project.

Analyses of data collected will enhance the resolution of regional correlations of the Cambrian carbonate lithostratigraphic units and allow statistical validation of possible stratigraphic bundling (i.e., grouping and correlation of small-scale carbonate cycle bundles) in these rocks. With this data, the paleogeography of the Cambrian platform and nature of the ancient continental margin can be better reconstructed, and, also, will clearly constrain the large-scale tectonic relationships of the autochthonous and allochthonous strata in western Newfoundland. In addition, if the statistical analysis does reveal stratal bundling at more than one scale, then the deciphering of such packaging would provide an efficient correlation tool for base-metal exploration in the western Newfoundland Cambro–Ordovician strata.

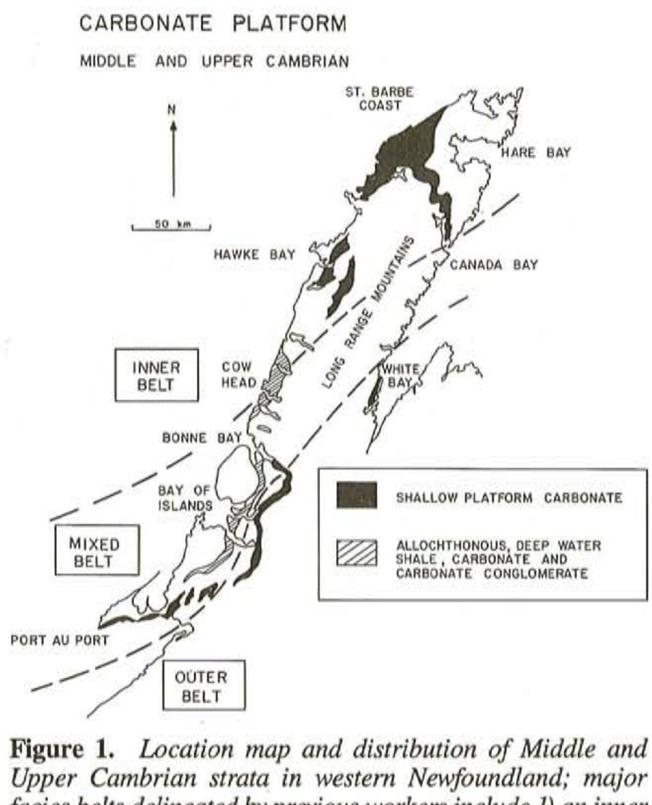

Figure 1. *Location map and distribution of Middle and Upper Cambrian strata in western Newfoundland; major facies belts delineated by previous workers include 1) an inner mixed siliciclastic-carbonate belt, 2) an intermediate belt in which inner facies and oolite are mixed, and 3) an outer belt of stacked oolite sand shoals; (from James et al., 1983).*

GEOLOGICAL SETTING

Autochthonous Cambrian strata of the Labrador and Port au Port groups record sedimentation on the ancestral North American (Laurentian) continental margin, adjacent to the Iapetus Ocean (Williams and Stevens, 1974). This ancient trailing margin, evolved from a rift–drift setting to a thermally stable passive margin in the late Proterozoic to

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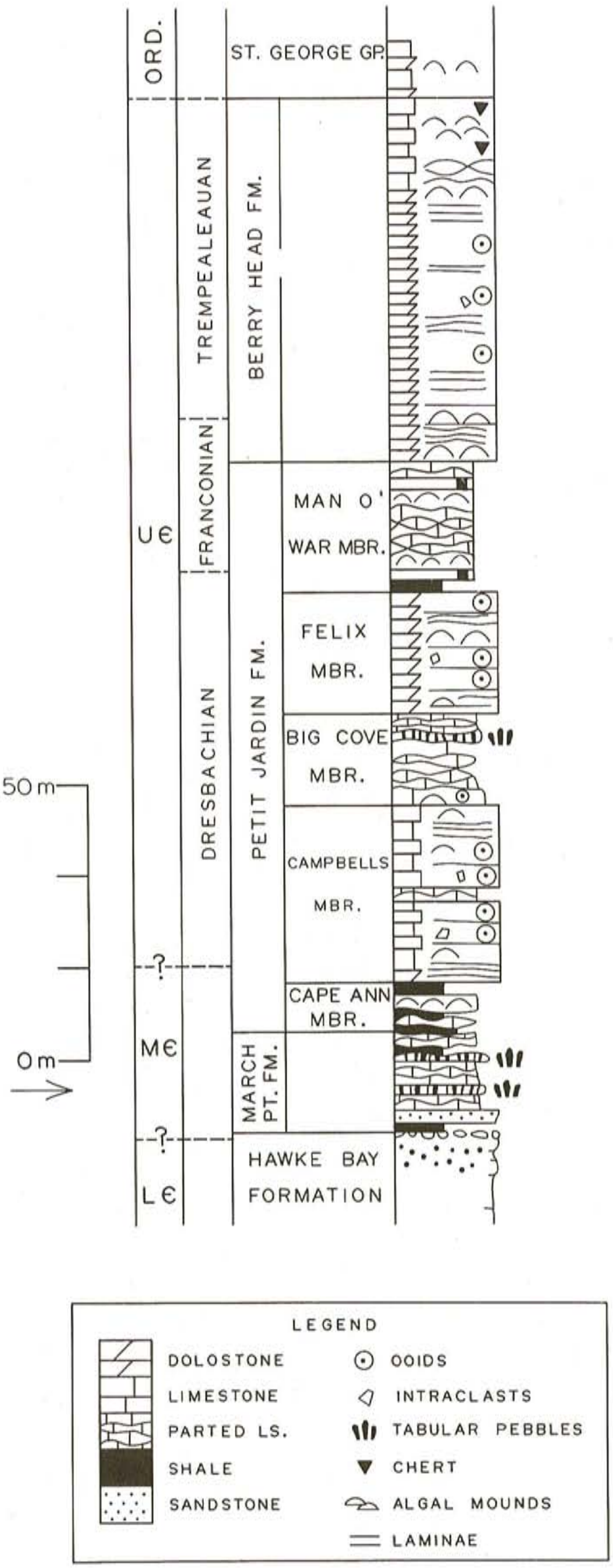

earliest Cambrian (James and Stevens, 1982). Williams and Hiscott (1987) have suggested that the stratigraphic signal of the rift–drift transition occurs possibly within, but probably no later than, the Bradore Formation (lower Labrador Group), and the subsequent Cambrian to Lower Ordovician deposition represents sedimentation on a rigid lithosphere, characteristic of a stable passive margin experiencing a linear subsidence rate (James *et al.*, *in press*).

The Lower Cambrian Forteau Formation (Bonnia-Ollenellus Zone), represents deposition of limestone, shale, siltstone and minor sandstone on a pre-platform, Lower Cambrian mixed siliciclastic–carbonate shelf (James *et al.*, 1988). Terrigenous clastics and minor carbonates of the overlying Hawke Bay Formation (*Bonnia-Olenellus* to *Bathyuriscus-Elrathina* and *Ehmaniella zones;* Knight and Boyce, 1987) represent a possible pan-Iapetus drop in sea-level, and the influx of littoral siliciclastic facies across the Forteau shelf (Palmer and James, 1979). Overlying Middle to Upper Cambrian March Point, Petit Jardin and Berry Head formations consist of limestones, dolostones and minor fine-grained terrigenous siliciclastics (Knight, 1977, 1980; Levesque, 1977) (Figure 2).

Grand Cycles

Stratigraphic superposition of the members of the March Point, Petit Jardin and Berry Head formations have been interpreted by Chow and James (1987a) to constitute at least three Grand Cycles (cf. Aitken, 1966, 1978) in western Newfoundland. Grand Cycles consist of *lower* shaly and *upper* carbonate half cycles (Figure 2). Alternate shale and carbonate half cycles are interpreted to result from lateral shifts in two adjacent sedimentary mega-environments, in response to eustatic sea-level fluctuations. In western Newfoundland, the two mega-environments consist of, 1) a subtidal oolite shoal complex associated with back-shoal intertidal–supratidal flats (carbonate half cycle), which lie relatively outboard of, and adjacent to, 2) a fine-grained, mixed, carbonate–siliciclastic tidal-flat system (shaly half cycle) (Chow, 1986). Repetitive vertical stacking of carbonate and shaly half cycles suggested to Chow and James (1987a) that the paleogeographical character of the Middle to Upper Cambrian carbonate platform was persistent, if not static, through time. They interpreted the present regional distribution of strata as a reflection of the former relative positions of major facies belts on the Cambrian platform (Figures 1 and 3).

Figure 2. *Stratigraphic column of Middle and Upper Cambrian strata in western Newfoundland; from Chow and James (1987a); Grand cycles are expressed as couplets; March Point-Cape Ann/Campbells; Big Cove/Felix; Man O'War/Berry Head.*

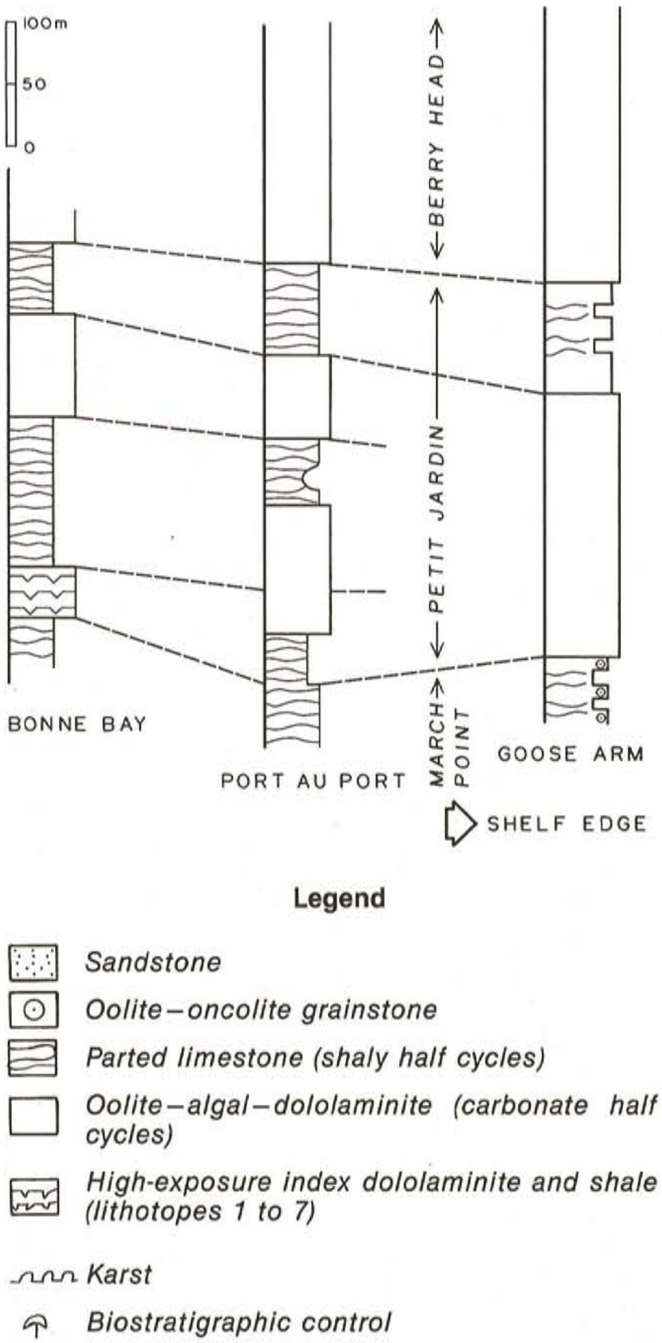

Figure 3. *Previous lithostratigraphic correlations of Middle and Upper Cambrian strata for sections in this investigation; modified from Chow (1986).*

PRELIMINARY RESULTS

During the 1988 survey season, work focussed on describing the Middle and Upper Cambrian strata, specifically the detailed sedimentology and stratigraphy of the Grand Cycles of the March Point, Petit Jardin and Berry Head formations.

Sedimentology

Carbonate Half Cycles. Sediments of the Middle and Upper Cambrian carbonate half cycles (Campbells member, Felix member, and Berry Head formation), are currently categorized into three basic lithotopes: grey oolite (subtidal), brown oolite (intertidal) and dololaminite (supratidal) (Chow and James, 1987b). Metre-scale or smaller algal mounds (e.g., LLH stromatolites or thrombolites) and minor shale, punctuate the oolite–dololaminite sequences. These strata are here subdivided into fourteen basic lithotopes (Table 1). Metre-scale packages of these lithotopes comprise the carbonate half cycles at each locality. However, this is not to imply that metre-scale packages are composed of all fourteen lithotopes, indeed, rarely do more than five or six lithotopes occur in any given package. Composition and internal organization of these metre-scale packages is complex, and a predictive model, which would determine lithotope composition and proportion within a given package, has as yet, not been developed. Similarly, the stacking order of lithotopes is not uniform throughout a given section or from area to area. Further analysis is needed to clearly indicate, whether these lithotopes are organized in statistically predictable packages, and/or whether different lithotopes, as delineated here, can occupy the same stratigraphic position within packages at separate localities or at stratigraphically different positions in a larger scale package.

It appears that deposition occurred above storm wave-base, and possibly above normal wave-base, for each of the carbonate half cycles. This is suggested by the following evidence; predominance of exposure surfaces, lack of large-scale and hummocky bedforms in sediments of the appropriate grain sizes, and the monotonous thickness of the beds (<1 m) and lithotope packages (<2 m).

With the exception of the Goose Arm section, in which several-metre-thick oolite and oncolite beds occur in the March Point Formation, the beds of oolite in carbonate half cycles are <1-m thick, and generally lack large-scale cross-stratification. This does not support Chow's (1986) interpretation, of the grey oolite as a subtidal mobile shoal facies fringed by a back shoal tidal flat and represented by the brown oolite and dololaminite lithotopes. However, if Chow and James' (1987b) interpretation that these oolite beds represent *in situ* sedimentation is accepted, then the thin oolites cannot be explained as washover deposits. Rather, they represent deposits of short-lived, shallow marine environments as suggested by the occurrence of intercalated algal mounds.

These Cambrian sediments have many characteristics in common with algal–oolite shoreface to foreshore environments of Great Salt Lake, Utah, and Shark Bay, Western Australia, including type and distribution of fauna and sediment, and scale of bedforms (Eardley, 1938, 1966; Logan, *et al.*, 1970, 1974). The physical characteristics of

Table 1. *Lithotopes delineated in this investigation for the carbonate half cycles of Cambrian Grand Cycles, western Newfoundland*

LITHOTOPE	DESCRIPTION	RELATIVE EXPOSURE INDEX	OBSERVED IN GRADATIONAL CONTACT WITH
1	Shale, buff to grey, dolomitic, mudcracks common	High	2-7
2	Very argillaceous dolostone, orange to buff, mudcracks common	High	1,3-7
3	Argillaceous dolostone, beige, blocky	High	1,2,4-7
4	Dolostone, minor argillaceous, buff to beige, blocky	High	1-3,5-7
5	Dolostone, buff, argillaceous, laminated, mudcracked	High	1-4,6-8
6	Dolostone, buff, blocky, laminated to massive	High	1-5,7,8,10,11
7	Dolostone, buff, blocky, laminated to massive, very intraclastic	High	1-6,8,10,11
8	Oolite, cross-bedded, minor to abundant dololutite flasers and clasts	Interm	5,6,7,9-12
9	Oolite, clean, grey to buff	Interm	8,10-14
10	Dololutite-parted limestone, grainy (peloidal to oolitic)	Interm	5-9,11
11	Dololutite-parted limestone, syneresis, flaser- to lenticular-bedded	Interm	5-9,10,12
12	Argillaceous dolomite-parted limestone, flaser- to lenticular bedded	Interm	8,9,12,13,14
13	Shale-parted limestone, wave ripples, cruziana ichnofacies	Low	9,12,14
14	Shale, dark grey, fossiliferous calcareous and oolite lenses rare	Low	9,12,13

these modern, shallow, low-gradient, epeiric environments, which have a restricted fauna, may provide a better analogy than do the Bahamian-type oolite environments for the sediments of the Middle and Upper Cambrian in the study area, where the oolite shoals are characterized by large-scale accretionary bedding (Ball, 1967; Halley *et al.*, 1983), lack of small-scale cyclicity and subaerial exposure, and a scarcity of stromatolites.

Shaly Half Cycles. The March Point Formation and Cape Ann, Big Cove, and Man O'War members of the Petit Jardin Formation on the Port au Port Peninsula and Bonne Bay, are characteristically shaly and lack significant oolites. These units consist of shale- and/or dololutite-parted limestones, associated with flaser to lenticular bedding that show small-scale current and wave-ripple cross-stratification. Intraclastic, flat pebble conglomerates are common, and algal bioherms, some stacked up to 3-m high, punctuate these successions. These sediments are interpreted by Chow (1986) as mixed carbonate–siliciclastic tidal-flat deposits, grouped in shallowing-upward flaser- to lenticular-bedded metre-scale packages. This tidal-flat system is envisaged as inboard of the oolite shoal–back-shoal flat system of the carbonate half cycles.

In order to integrate these parted limestone units into the overall stratigraphy, a paleoenvironmental interpretation must be made that is consistent with the interpretation of the depositional environments for the carbonate half cycles. In this report, the shaly half cycle sediments are re-interpreted as mixed, fine-grained (peloidal mud to fine sand) carbonate and siliciclastic sediments deposited below normal, but above storm wave-base. Significantly, the flaser- to lenticular-bedded packages of Chow (1986) could not be delineated in the field, due to the lateral variability and stratigraphically gradational characteristics of the flaser- and lenticular-parted limestones. On the basis of preliminary data presented here, it is apparent that this facies occupied a paleogeographic position outboard to, and gradational with, the algal–oolite shoreface to foreshore environments of the oolitic carbonate half cycles, and inboard to the thick subtidal oolite shoal sequences at Goose Arm. This reconstruction places the flaser- to lenticular-parted limestones in the lee of a subtidal oolite shoal belt of the subtidal to very low intertidal zone (*Cruziana* ichnofacies; Frey and Pemberton, 1984). Further work will determine the efficacy of this preliminary interpretation.

STRATIGRAPHY

Stratigraphic correlations of Middle and Upper Cambrian rocks, in the sections measured, have been previously proposed by Chow and James (1987a). They attributed the generation of Newfoundland Grand Cycles to global sea-level fluctuations, through comparisons made with other North American Cambrian Grand Cycles. However, Grand Cycles, as defined by shaly and carbonate half cycle couplets, are correlated with difficulty throughout the Great Northern Peninsula because the number of couplets expressed at different localities is variable (Figure 3). Chow and James (1987a) attributed this variation to the relative positions of stratigraphic sections with respect to major facies belts on the Cambrian platform.

An alternative stratigraphic framework and approximate gross correlation is presented as a preliminary result of this investigation. Within the constraints of known biostratigraphical control, the thick sequence of shales and mud-cracked dololaminites at Bonne Bay (lithotopes 1 to 7;

Table 1) are possible time-equivalents to the Campbells member of the Petit Jardin Formation on the Port au Port Peninsula (Figure 4). Therefore, it is possible that the Bonne Bay sediments represent significant inboard deposition relative to the sections on the Port au Port Peninsula. In contrast, the Goose Arm section experienced the most outboard depositional conditions, at least during deposition of the March Point Formation as evidenced by the thick beds of oolite and oncolite grainstone, which dominate the sequence. Correlation of strata above and below the Campbells member can be made to maintain this inboard to outboard relationship of the various sections, such that interpreted time-equivalent interval thickness and average bedset thickness increase paleoshoreward. This re-interpretation is preliminary, and at this point in the investigation we do not favour any one interpretation, rather, alternatives are being tested in order to develop an overall stratigraphic model.

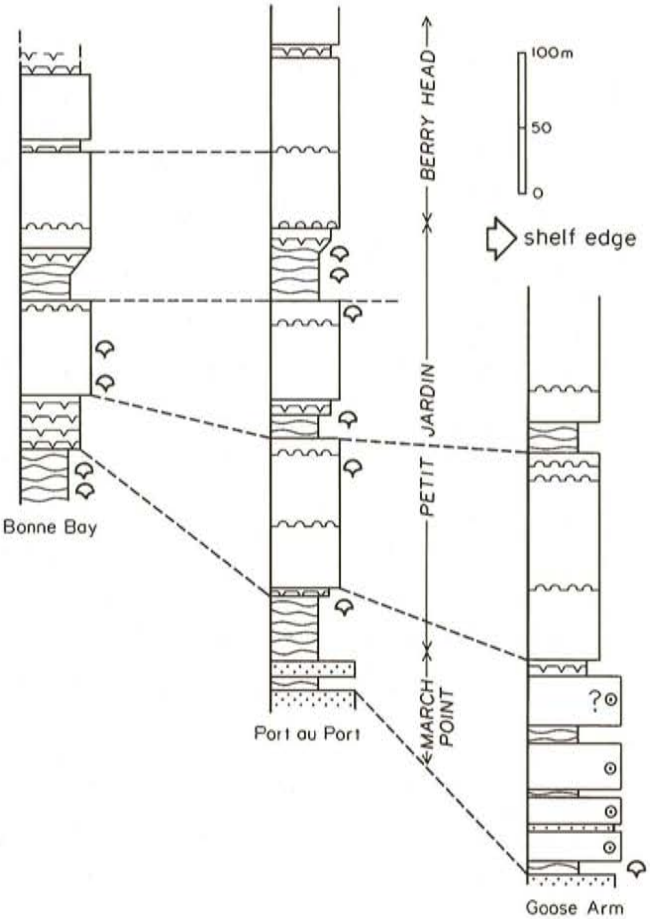

Figure 4. *Lithostratigraphic interpretation of the Middle and Upper Cambrian strata; see Figure 3 for legend.*

Care was taken to correlate gross stratal intervals, bounded above and below, by disconformities, i.e., major karst surfaces. These major surfaces, typically with an overlying quartzose carbonate, occur near the tops of each carbonate half cycle, and are recognized as regional events by Chow (1986). Quartz is patchy in temporal and spatial distribution, and is neither present on every major karst surface nor ubiquitous over the study area for a given correlatable karst surface. In this way, the preliminary correlations are consistent with sequence stratigraphic principles.

Further work, particularly measurement of sections at Little Coney Arm of White Bay and along the St. Barbe Coast, will help clarify these proposed paleogeographic and stratigraphic relationships. Statistical work will reveal if any small-scale rhythms exist in these strata, which would be critical to refining and increasing the resolution of these gross correlations. It is of fundamental importance to understand the relative proximal to distal positioning of these sections because small-scale rhythms would be expressed differently at each location as a result of differences including accommodation, supply of sediment and length and frequency of exposure/nondeposition.

CONCLUSIONS

This report is a preliminary revision of previous stratigraphical, sedimentological and paleogeographical interpretations of the Middle and Upper Cambrian carbonate strata of western Newfoundland. Of primary significance to exploration in Cambro–Ordovician autochthonous strata throughout the study area, is the recognition that Cambrian sections exposed in the areas of study may represent disparate inboard and outboard platform sedimentation. Documentation of paleoenvironmental gradients expressed by such an inboard/outboard disparity, is critical to understanding regional facies distributions, which in turn would control the potential distribution of facies-dependent base-metal mineralization.

Re-interpretation of paleogeographic positions of the major facies belts in the Newfoundland Cambrian Grand Cycles has implications for the models for the generation of Cambrian Grand Cycles in general (Aitken, 1978; Chow and James, 1987a). That is, Grand Cycle superpositioning of carbonate half cycles over shaly half cycles is re-interpreted here as the result of progradation of most proximal over most distal facies, rather than the reverse. Further work is required before the causal mechanism for Grand Cycle development can be determined. It must also be noted that statistical testing of the preliminary interpretation presented here must be sought in the fine-scale organization of stratal packages within the Grand Cycles.

Present distribution of the measured stratigraphic sections has strong implications for tectonism associated with the closing of the Iapetus Ocean. Present geographic arrangement of the most inboard (Bonne Bay section), intermediate (Port au Port) and most outboard (Goose Arm) strata, suggests significant tectonic juxtaposition of these sections may have occurred, and thus revision of paleogeographic models currently in use for Middle and Upper Cambrian rocks may be in order. Further implications as to the amount of transport experienced by imbricate thrust slices in which these strata occur must be evaluated, as well as the possibility of northeast–southwest oriented tectonic telescoping of these terrains.

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