# [PS]Nature and Origin of Dolomitization of the Boat Harbour Formation Carbonates in Northern Peninsula, Western Newfoundland, Canada: Implications for Porosity Controls*

**Babatunde J. Olanipekun[1] and Karem Azmy[1]**

Search and Discovery Article #50533 (2012)
Posted January 9, 2012

[1]Earth Sciences, Memorial University of Newfoundland, St John's, NF, Canada (bjo852@mun.ca)

* Adapted from poster presentation at AAPG International Conference and Exhibition, Milan, Italy, October 23-26, 2011

## Abstract

The Boat Harbour Formation of the lower Ordovician (Tremadocian/Arenigian) St George Group Carbonate on Northern Peninsula is about 140m thick and conformably overlain by the porous Catoche Formation.

In addition to petrographic investigations (transmitted light microscope, cathodoluminiscence and fluid inclusion microthermometry), data from geochemical analyses (major and trace elements-Ca, Mg, Fe, Mn, and Sr-, O-, and C- and Sr-isotopes) were utilized to investigate the origin of dolomites and the results were also compared with their counterparts of the equivalent section in Isthmus Bay at Port au Port Peninsula (about 300km to South).

At least three 3 phases of dolomites were identified from petrographic examination. The earliest phase D1 is dolomicrite with crystals ranging from ~3 to 35 µm. The following phase D2 consists of planar sub-to euhedral crystals ranging from 30 to120µm. The latest phase, D3, is the coarsest and consists of curved, dominantly non-planar crystals ranging from 300 µm to 9mm, exhibit undulose extinction. The dolomite phases generally exhibit dull luminescence except for D3 which exhibits concentric zoning. Microthermometric measurements of the primary two-phase fluid inclusions in D2 (homogenization temperatures up to ~170<o>C and salinity up to ~13% eq. wt% NaCl) and D3 (homogenization temperatures up to ~181<o>C and salinity estimates up to 20.22 eq. wt% NaCl) suggest that they formed under relatively deep burial conditions and from hot saline brine. This is supported by the petrographic evidence and geochemical composition, especially the depleted δ<18>O values (-11.1±1.2‰ VPDB) and low Sr contents (72±8ppm).

Sr composition of the dolomites shows a decreasing trend from oldest (~228ppm-D1) to youngest (72ppm-D3). Also, the low Sr ( 228 ± 28 ppm)

and δ<18>O(-6.0±0.8‰ VPDB) of D1 suggest that it was likely deposited from a relatively Sr-poor fluid such as a mixture of seawater and meteoric water while D2 and D3 were precipitated from diagenetic fluids that were circulated into the heated basin and refluxed back through faults.

In general, the Formation is not pervasively dolomitized compared to its counterpart section on the Port au Port Peninsula and dolomitization is more concentrated in the zones around the chemostratigraphically and petrographically delineated lower Boat Harbour disconformity.

Petrographic exams suggest that the dominant porosity type is intercrystalline and associated with D2 while vuggy porosity is associated with D3. Visual estimates of porosity imply that it varies from <1 to ~8% in an interval of ~3m-thick immediately below the lower Boat Harbour disconformity. Chemostratigraphic correlations with the equivalent Boat Harbour Formation section in the Isthmus Bay (300 km to South) indicate that porous interval is associated with fluctuations in sea-level marked by a negative shift in the δ<13>C profile of both sections.

# NATURE AND ORIGIN OF DOLOMITIZATION OF THE BOAT HARBOUR FORMATION CARBONATES IN NORTHERN PENINSULA, WESTERN NEWFOUNDLAND, CANADA: IMPLICATION FOR POROSITY CONTROLS.

Babatunde J. Olanipekun[1](bjo852@mun.ca); Karem Azmy[1](kazmy@mun.ca).

1. Earth Sciences Dept., Memorial University of Newfoundland, St John's, Canada

## ABSTRACT

The Boat Harbour Formation is about 140m thick on Northern Peninsula and constitutes the upper part of the Lower Ordovician St George Group Carbonates (Fig 1).

Dolomitization is relatively more extensive in the lower 30-40m of the formation and petrographic examinations suggest that the sequence has been affected by three 3 main phases of dolomitization. The earliest phase, D1, grades from micritic to fine crystalline texture (~4-35µm; Fig 3c) and the subsequent phase, D2, consists of coarser planar sub-euhedral crystal (30-200µm; Fig 3d-f). The latest phase of dolomitization, D3 is formed of the coarsest non-planar crystals (150µm to 7mm; Fig 3g-h). The D3 crystals exhibit sweeping-undulose extinction under crossed polars, which is characteristic of saddle dolomite. The earliest dolomite (D1) exhibits dull to no luminescence (CL) but the D2 crystals show concentric CL zoning whereas those of D3 exhibit thin brightly luminescent rim. Microthermometric investigation of the primary two-phase fluid inclusions(Figure 4 and 5) in D3 crystals (homogenization temperatures up to ~181° C and salinity estimates up to 20.22 eq. wt% NaCl) suggests that the dolomites formed under relatively deep-burial conditions and/or from hot saline brine. This is supported by their depleted $\delta^{18}O$ signatures (–11.1±1.2‰ VPDB) and low Sr contents (72±8ppm).

Based on trace element composition, particularly low Sr (~ 227 ppm-D1) and isotopic ($\delta^{13}C$ and $\delta^{18}O$) composition of the dolomites, D1 was likely deposited from early diagenetic fluids that formed from a mixture of meteoric and evaporated seawater. (Figure 8) On the other hand, D2 was likely precipitated from pore fluids that circulated down the heated basin. Similarly, D3 was precipitated from hydrothermal fluids that were circulated at deeper-burial settings (mean Th value ~148±19°C, mean salinity ~24±2 eq.wt% NaCl).

Porous D2 dolomite intervals are generally associated with the lower Boat Harbour disconformity (Figure 2). Intercrystalline porosity occurs dominantly in D2 and visual estimates suggest that porosity varies from <1 to ~8% but vuggy pores are much less common and sometimes associated with D3. The most porous zone (10-15m) is immediately below the disconformity and extends down to the Formation bed boundary.

## MAP OF STUDY LOCATION

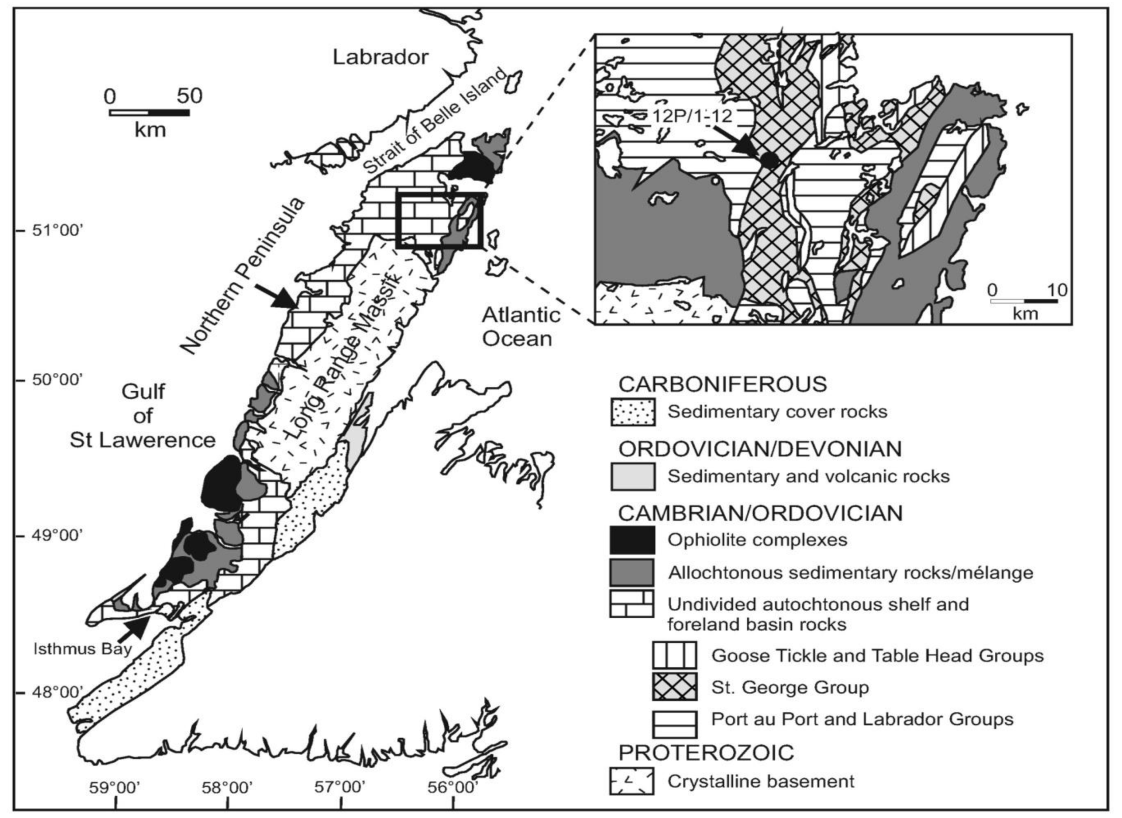


Figure 1.Map of western Newfoundland. The open box and black arrow indicate the approximate location of the current study area (drill hole 12P/1-12) on the Northern Peninsula and the Isthmus Bay outcrop in Port au Port Peninsula respectively (modified from Zhang and Barnes 2004).

## MAIN OBJECTIVES

- Study the petrography of the Boat Harbour dolomites in the Northern Peninsula for correlation with those in Isthmus Bay (300 kms to south),
- Investigate the nature of the dolomitizing fluids and controls on the associated porosity;
- Compare the dolomitization and patterns of porosity distribution with the equivalent sequence in Isthmus bay.

## Stratigraphic framework of the St George Group and Boat Harbour Formation.

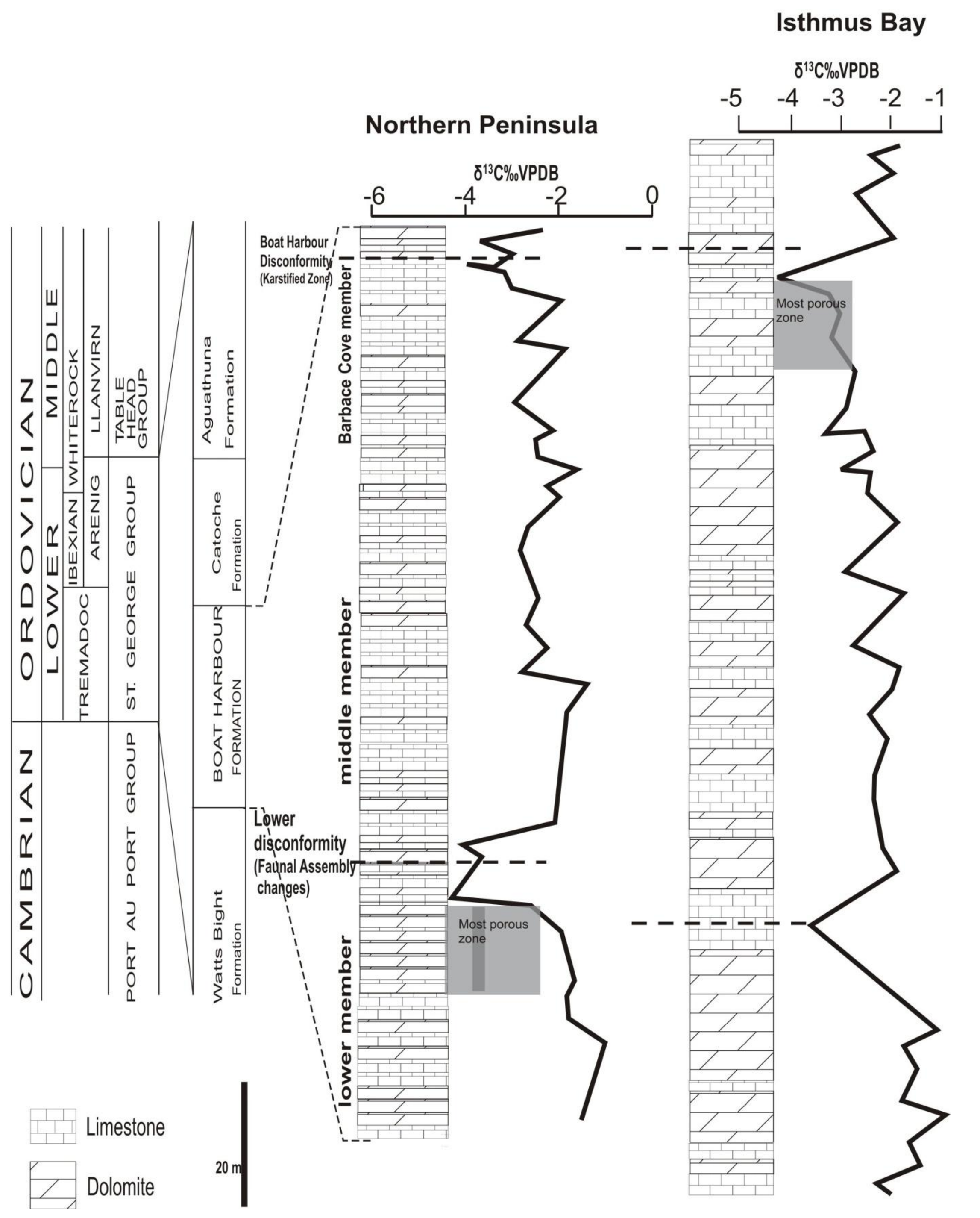


Figure 2 shows the vertical depth profile of the $\delta^{13}C$ of the section in Northern Peninsula and Isthmus Bay.

## PETROGRAPHIC EXAMINATION

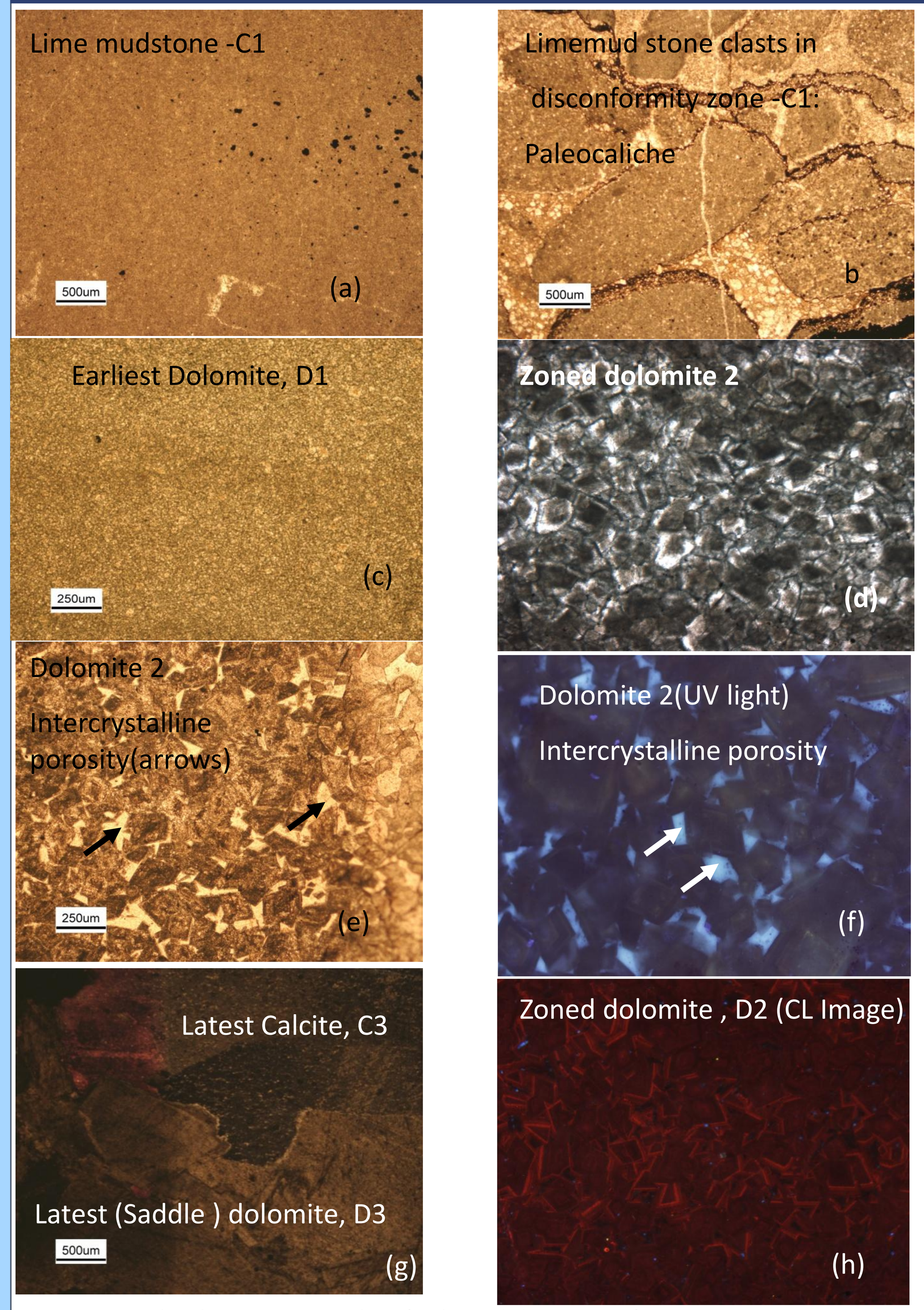


Figure 3 a-h: Photomicrographs of selected diagenetic features in Boat Harbour Formation, Northern Peninsula.

## Microthermometric Analyses

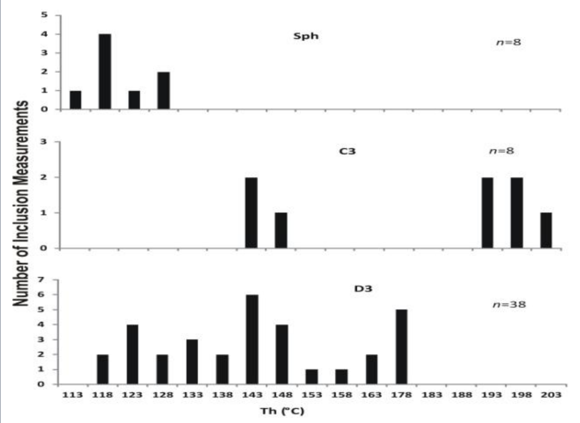


Figure 4. Frequency histogram of homogenization temperatures Th(°C) for fluid inclusion in: Sphalerite (Sph); Latest calcite (C3) and latest dolomite phase (D3).

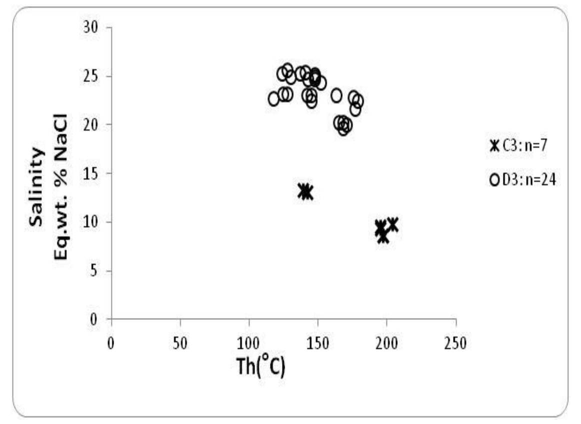


Figure 5.Plot of Salinity (Eq.wt% NaCl) versus homogenization temperatures of D3 and C3.After Bodnar (1992).

## GEOCHEMICAL EXAMINATION

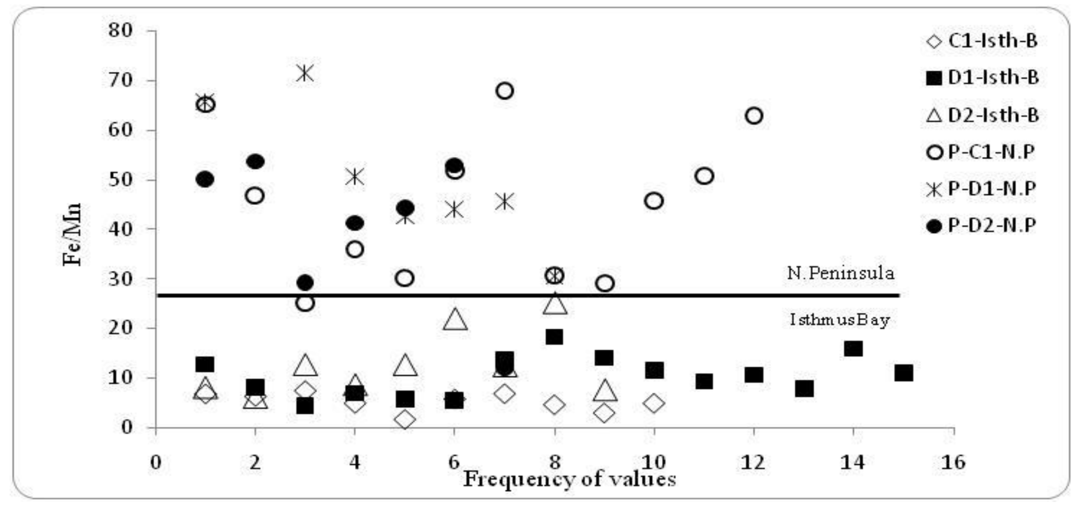


Figure 6.Chart showing comparison of $Fe^{2+}/Mn^{2+}$(ppm) ratio for the major carbonates in Boat Harbour Formation in both Isthmus Bay and Northern Peninsula.

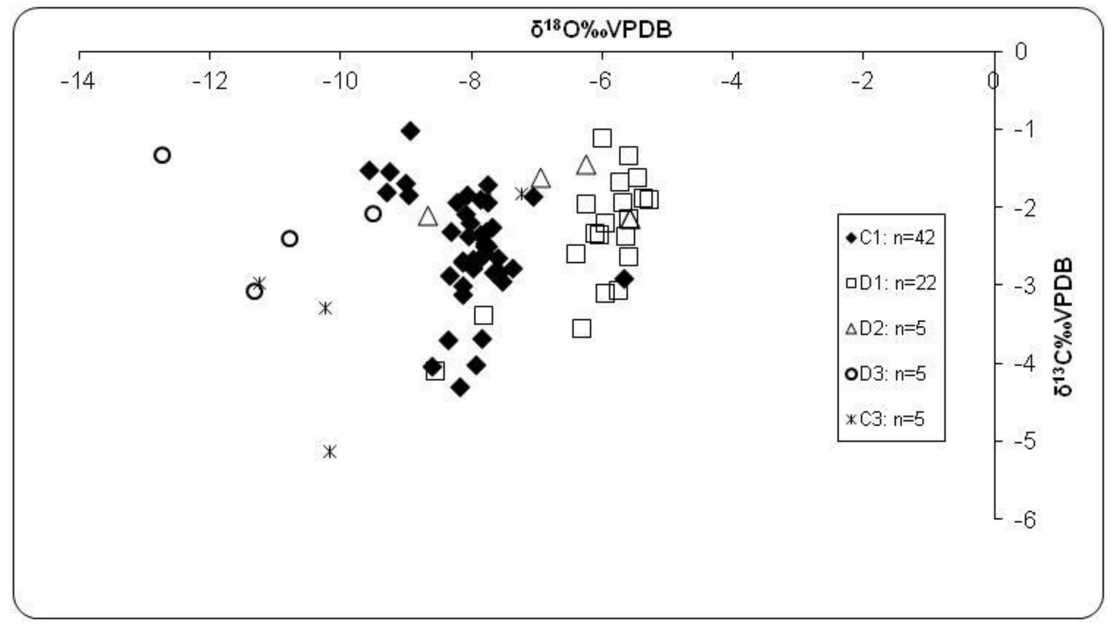


Figure 7. Plot of $\delta^{18}O$‰(VPDB) versus $\delta^{13}C$ ‰9VPDB) in Boat Harbour Formation in Northern Peninsula.

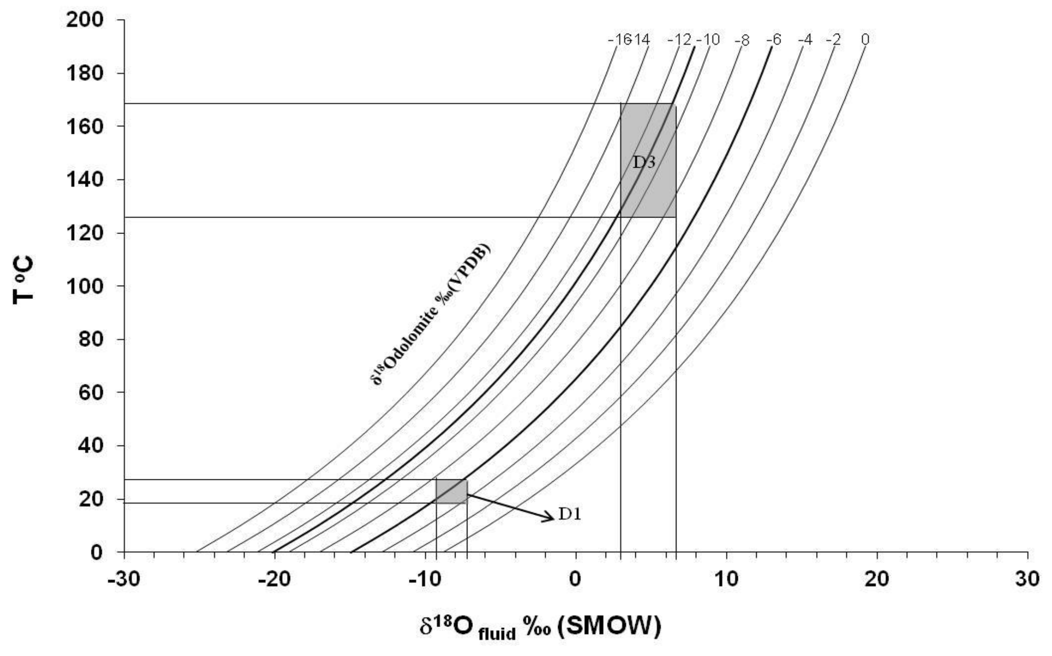


Figure 8. Plot of Temperature vs $\delta^{18}O_{diagenetic\ fluid}$ for various $\delta^{18}O_{dolomite}$ values using equation $10^3 \ln\alpha = 3.2*10^6 T^{-2} - 3.3$(Land 1983).

## CONCLUSIONS

- Limestone facies (C1; Fig 3 a and b) comprises mainly lime-mudstone intercalated with peloidal lamina, micro-breccias, with low Sr and high $Fe^{2+}$ suggesting the section was subtidal and deposited in a restricted setting
- Isthmus bay section relatively richer is skeletal grain clasts, and has low Sr and comparatively low $Fe^{2+}$ hence likely proximal to the rim of the platform.
- Latest calcite spar (C3; 200 µm to 4mm;Fig 3g) with blocky texture is present which is replacive or vug/fracture filling and it is associated with the latest (saddle) dolomite phase (D3).
- The intensity of burial dolomitization (i.e D2 and D3;Fig 2) is associated with the two disconformities.
- Dolomite abundance is lower in the Northern Peninsula section compared to its counterpart in Isthmus bay compared (Figure 2).
- The disconformities enhanced the secondary porosity development, through which more dolomitizing fluid were able to circulate better in the Formation.
- The data for burial dolomites suggest formation under high geothermal temperature . They are relatively more abundant around the disconformity zones which are the zones with dolomitization-related porosity.

## FUTURE WORK

- Determine the Rare Earth Element (REEs) geochemistry of the major carbonate minerals in the Formation using Secondary Ion Mass Spectrometer (SIMS);
- To carry out gas inclusion analyses of the major carbonate minerals.

## REFERENCES

Azmy K., Lavoie D., Knight I., Chi G. (2008). Dolomitization of the lower ordovician aguathuna formation carbonates, port au port peninsula, western newfoundland, canada: Implications for a hydrocarbon reservoir. *Canadian Journal of Earth Sciences, 45*, 795-813. doi:doi:10.1139/E08-020

Azmy, K., & Conliffe, J. (2010). Dolomitization of the lower st. george group on the northern peninsula in western newfoundland: Implications for lateral distribution of porosity. *Bulleting of Canadian Petroleum Geology (Accepted),*

Land, L. S. (1983). The application of stable isotopes to studies of the origin of dolomite and to problems of diagenesis of clastic sediments. in: Stable isotopes in sedimentary geology. M.A. arthur, T.F. anderson, I.R. kaplan, J. veizer and L.S. land (eds.). 10, p. 4-1– 4-22. *SEPM Short Course Notes, 10*(4-1), 4-22.