Karem Azmy

Origin of hydrothermal dolomitization of St. George Group in western Newfoundland: implications for lateral distribution of porosity

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Post-doc fellows

Conliffe, J.,	2010
Blamey, N.,	2012

PhD Students

Olanipekum, B.J.	(in progress)
Bakhit, A.	(in progress)

MSc Students

Greene, M.,	2008.
Schwartz, S.,	2008.
Azomani, E.,	2012.

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Publications

8 published (SG, CBPG, CJES, Geofluids)

2 reports

1 in review (MPG)

3 in reparation (SG, GSA)

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Publications (* = student or post-doc fellow)

* Azomani, E., Azmy, K., Blemey, N., Brand, U., Al-Aasm, I., Origin of Lower Ordovician dolomites in eastern Laurentia: Controls on porosity and implications from geochemistry. Marine and Petroleum Geology (*in review*)

*Conliffe, J., **Azmy, K**., Greene, M., 2012. Hydrothermal Dolomites in the Lower Ordovician Catoche Formation. Marine and Petroleum geology 30: 161-173.

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. Bulletin of Canadian Petroleum Geology 58(4):1-14.

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Publications (cont.)

*Conliffe, J., **Azmy, K.**, Gleeson, S.A., Lavoie, D., 2010. Fluids associated with hydrothermal dolomitization in St. George Group, western Newfoundland, Canada. Geofluids 9:1-16.

Azmy, K., Stouge, S., Christiansen, J.L., Harper, D.A.T., Knight, I., Boyce, D., 2010. Carbon-isotope stratigraphy of the Lower Ordovician succession in Northeast Greenland: implications for correlations with St. George Group in western Newfoundland (Canada) and beyond. Sedimentary Geology, 225: 67-81.

Azmy, K., Lavoie, D. 2009. High-resolution isotope stratigraphy of the Lower Ordovician St. George Group of western Newfoundland, Canada: implications for global correlation. Canadian Journal of Earth Sciences, 46: 1-21.

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Publications (cont.)

Azmy, K., Knight, I., Lavoie, D., Chi, G., 2009. Origin of the Boat Harbour dolomites of St. George Group in western Newfoundland, Canada: implications for porosity controls. Bulletin of Canadian Petroleum Geology, 57: 1-24.

Conliffe, J., **Azmy, K.**, Knight, I., Lavoie, D., 2009. Dolomitization in the Lower Ordovician Watts Bight Formation of the St Georges Group, Western Newfoundland. Canadian Journal of Earth Sciences, 46: 247-261.

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Publications (cont.)

Azmy, K., Lavoie, D., Knight, I., Chi, G., 2008. Dolomitization of the Aguathuna Carbonates in Western Newfoundland, Canada: Implications for a Potential Hydrocarbon Reservoir. Canadian Journal of Earth Sciences, 45 (7): 795-813.

Knight, I., **Azmy, K.**, Boyce, D., Lavoie, D., 2008. Tremadocian carbonates of the lower St. George Group, Port au Port Peninsula, western Newfoundland: Lithostratigraphic setting of diagenetic, isotopic, and geochemistry studies. Current Research Newfoundland and Labrador Department of Natural Resources Geological Survey. Report 08-1: 1-43.

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Publications (cont.)

Knight, I., **Azmy, K.**, *Greene, M., and Lavoie, D. 2007. Lithostratigraphic setting of diagenetic, isotopic, and geochemistry studies of Ibexian and Whiterockian carbonates of the St. George and Table Head groups in western Newfoundland. Current Research Newfoundland and Labrador Department of Natural Resources Geological Survey. Report 07-1: 55-84.

Publications (cont.)

to be submitted

Azmy, K., Blamey, N., Constraints on fluid origins during carbonate diagenesis from fluid inclusion gas analysis. GSA.

* Olanipekun, B.J., Azmy, K., Brand, U., Dolomitization of the Boat Harbour Formation: implications for diagnetic history and porosity control. Sedimentary Geology.

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Multi-technique approach:

Petrography

Cathodoluminescence

UV□luminescence

Microthermometry (T$_h$, salinity estimates)

Gas analysis of flincs

Leach analysis of flincs

C□ & O□isotopes

Major and minor elements

Rare earth elements (REE)

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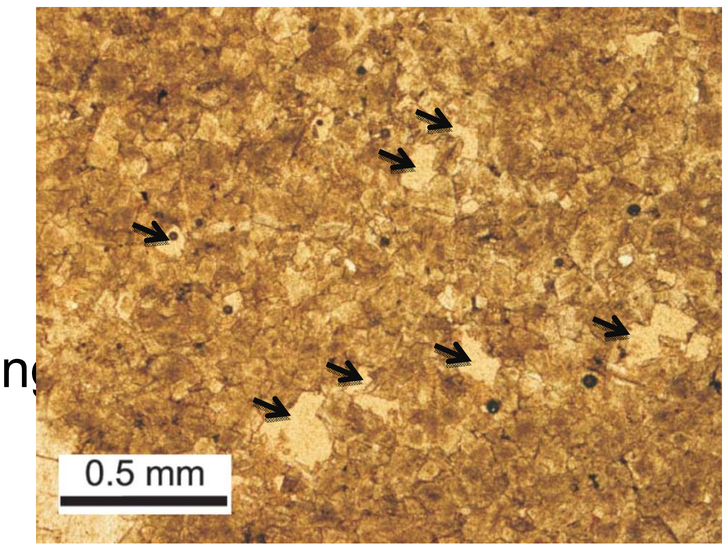
Description: The study of origin and distribution of hydrothermal dolomites and their control on porosity development in carbonates.

Objectives:
Investigate the diagenetic evolution & reservoir characterization of the carbonates.

•study (petrographically & geochemically) the dolomitization phases

•investigate the origin & nature of the dolomitizing fluids to understand the controls on porosity development & distribution.



N
12P/1-12
Port au Choix
12i/6-121
St. John's
Island of Newfoundland
12B/11-44
RND1
Isthmus Bay
Saint Pierre and Miquelon
St Pierre
© 2010 Europa Technologies
Image © 2010 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Tele Atlas
48°38'54.88" N 55°18'37.39" W elev 438 ft
©2009 Google
Eye alt 385.40 mi

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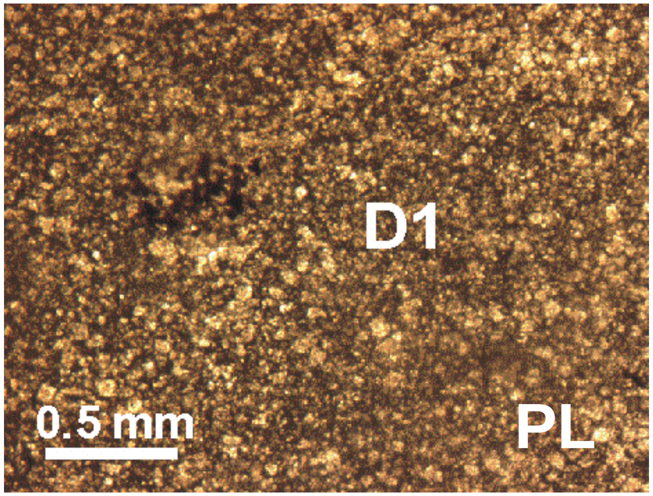
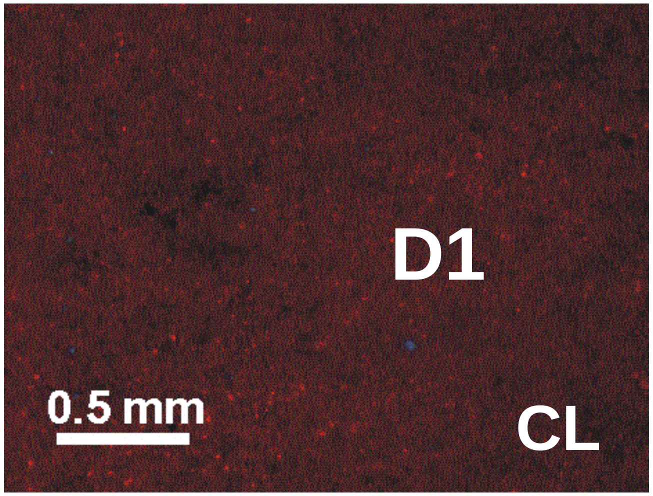
Results / Achievements

Petrography

3 major dolomitization phases:

(D1) Pervasive fabric retentive dolomicrite (4 to 40 μm)





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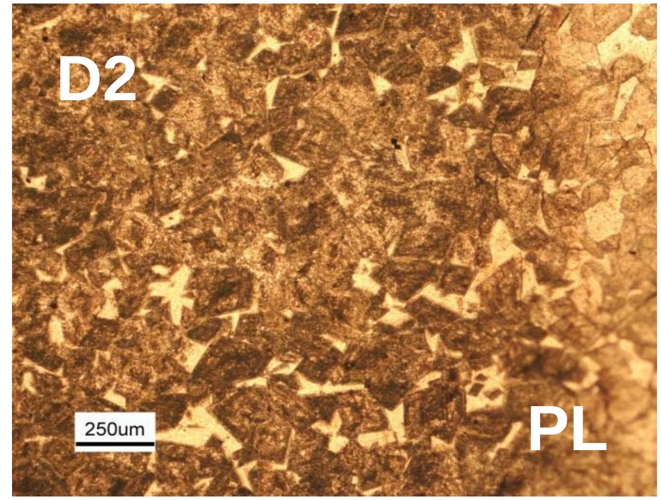
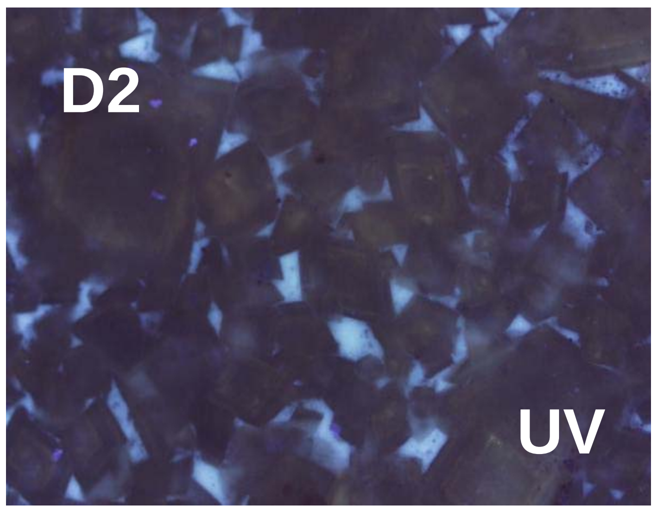
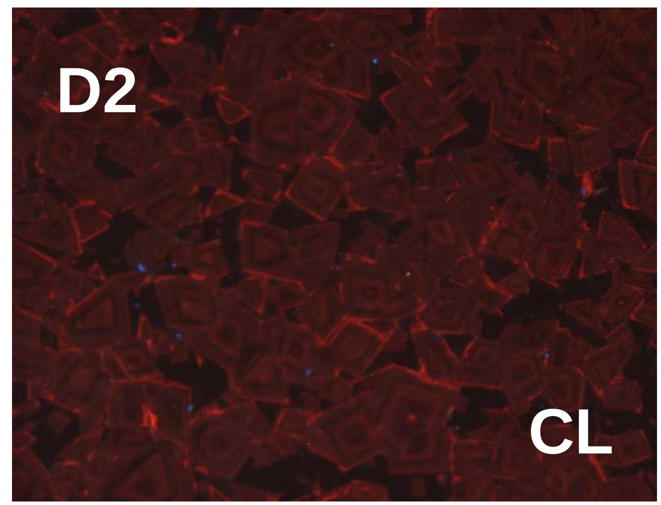
(D2) mid-burial hydrothermal

sub- to euhedral crystals (50□ 250 μm) with high intercrystalline porosity (up to 10% in some horizons).







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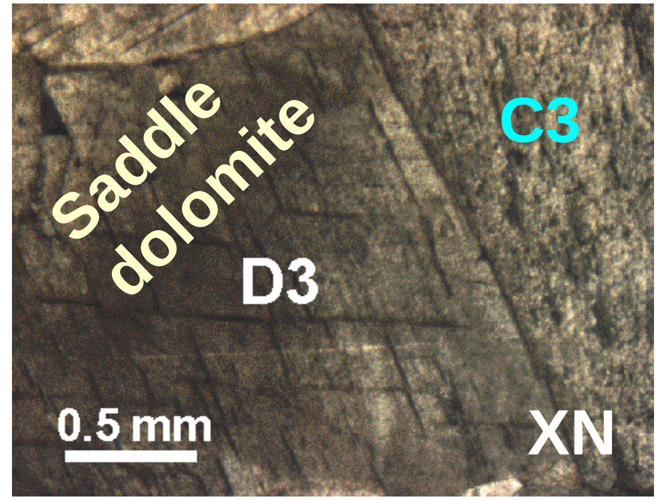
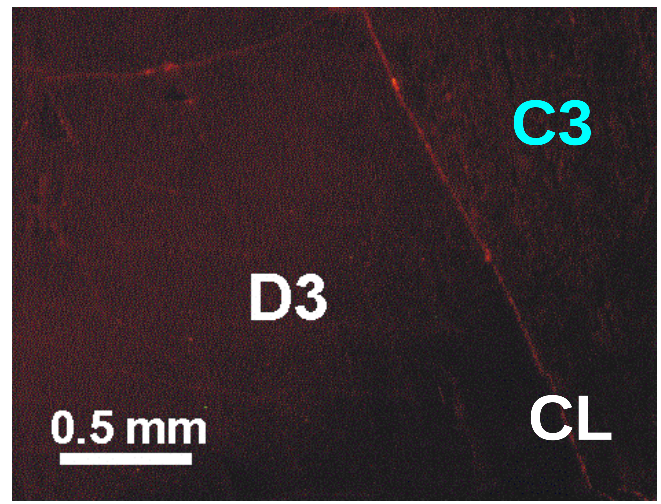
(D3) deep-burial hydrothermal
fracture-filling
sub- to anhedral crystals
(up to 0.5 cm)
milky appearance
undulose extinction

(C3) latest fracture-filling calcite





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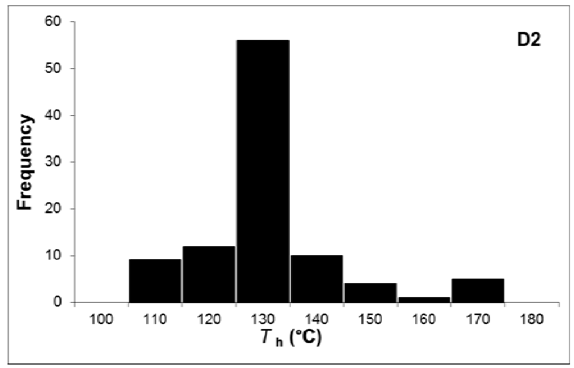
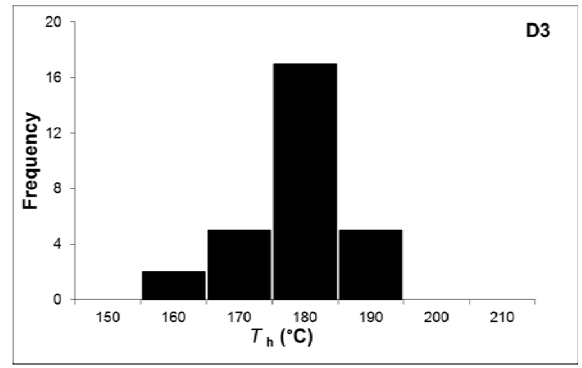
Microthermometry

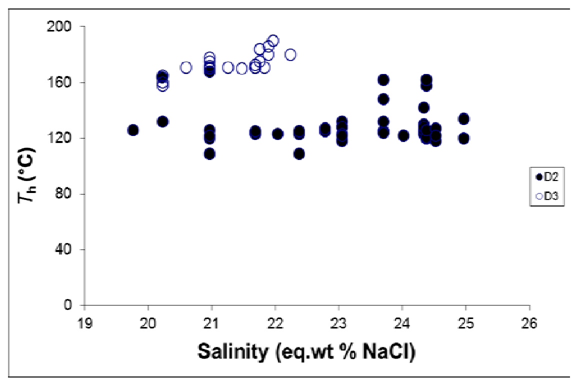
2 phases of hot dolomitizing fluids (D2 & D3)

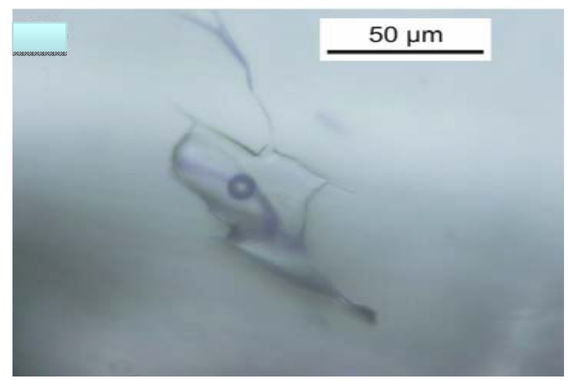
T_h at up to 130^{o}C & 180^{o}C, respectively.

Salinity estimates 22 to 25 eq wt% NaCl









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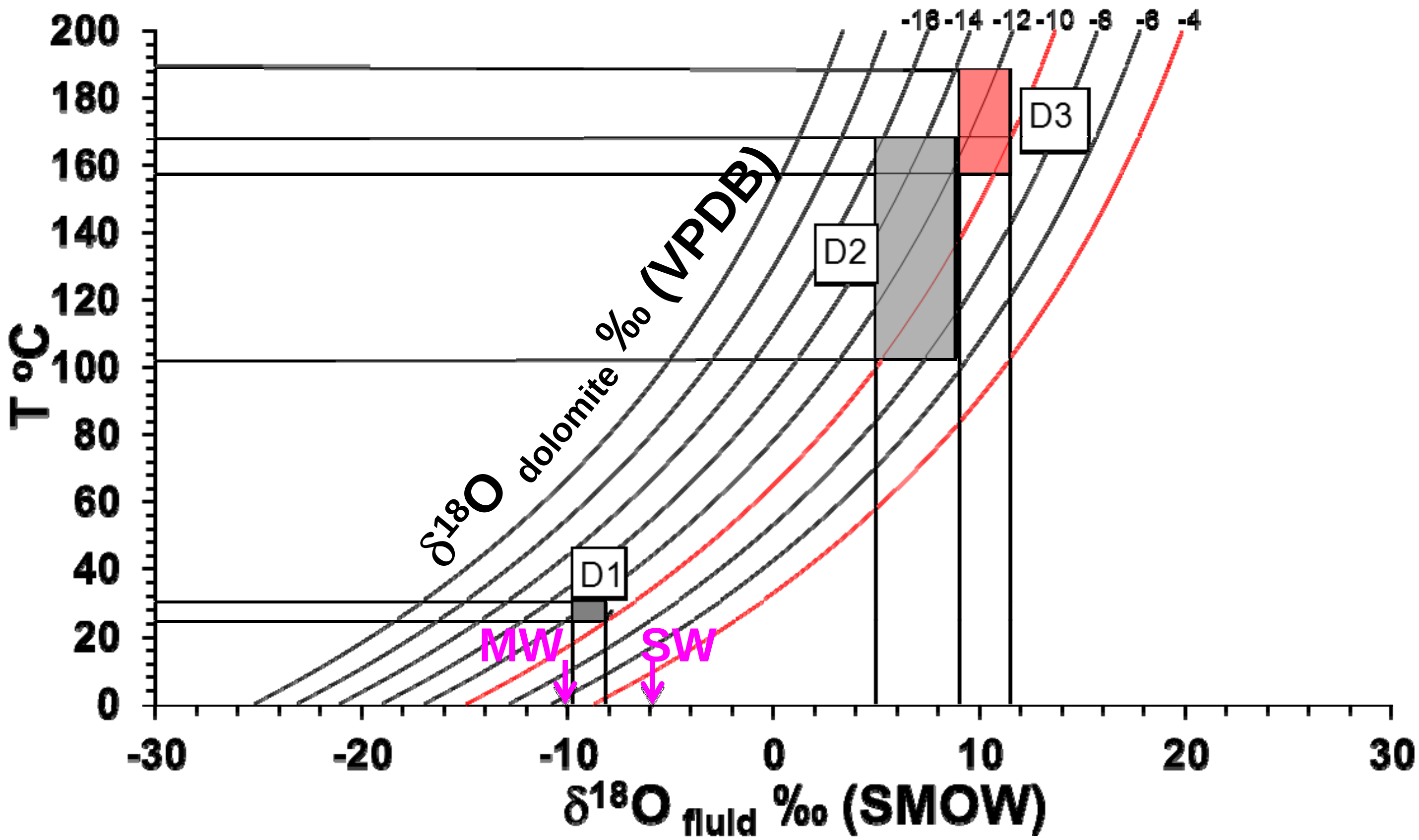
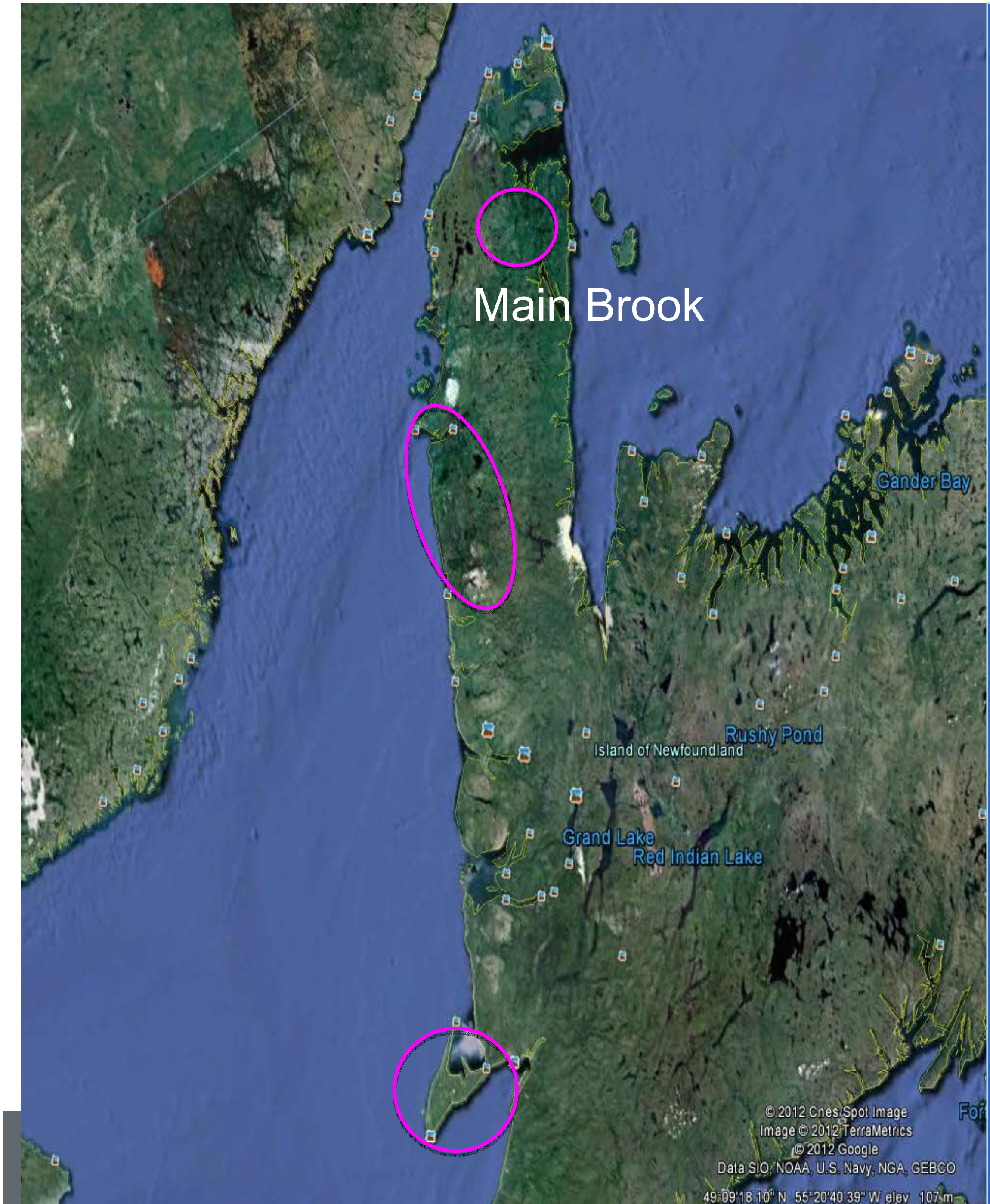
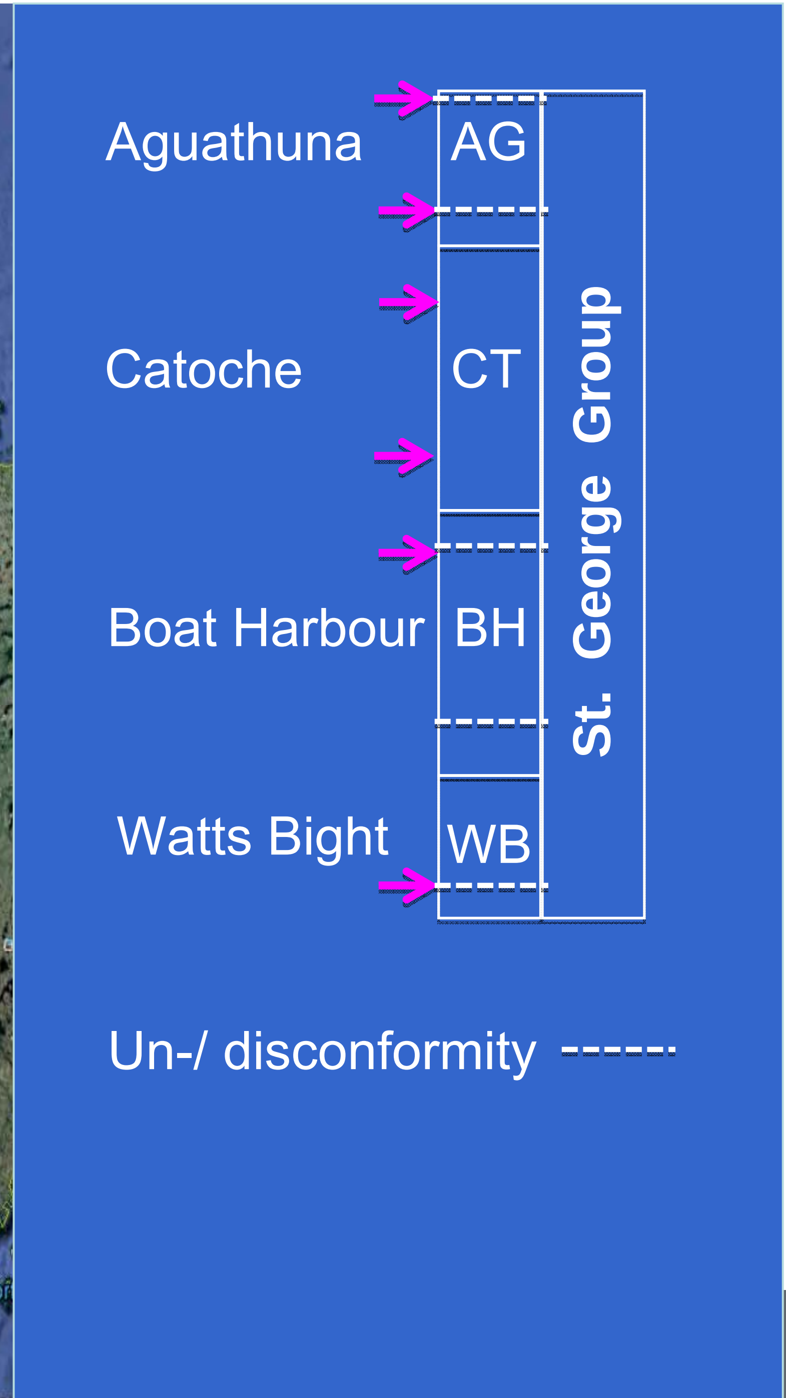
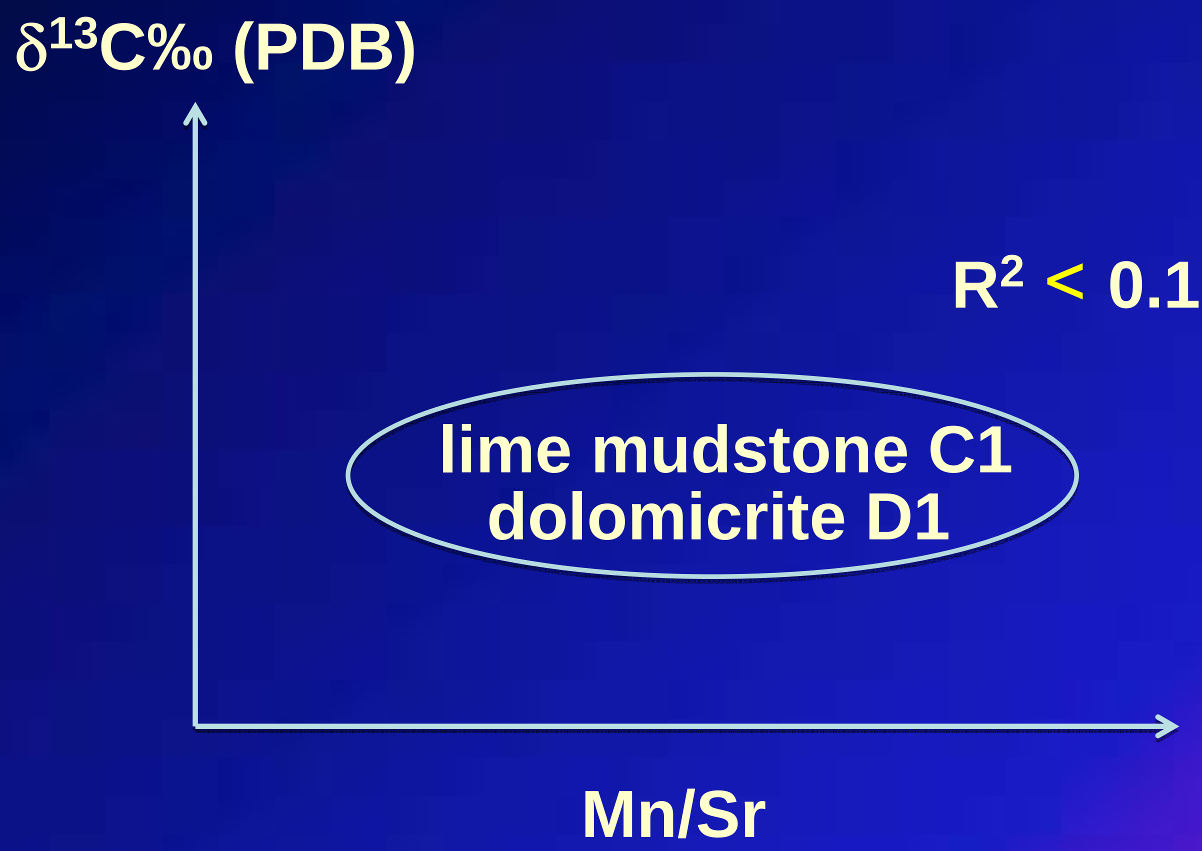
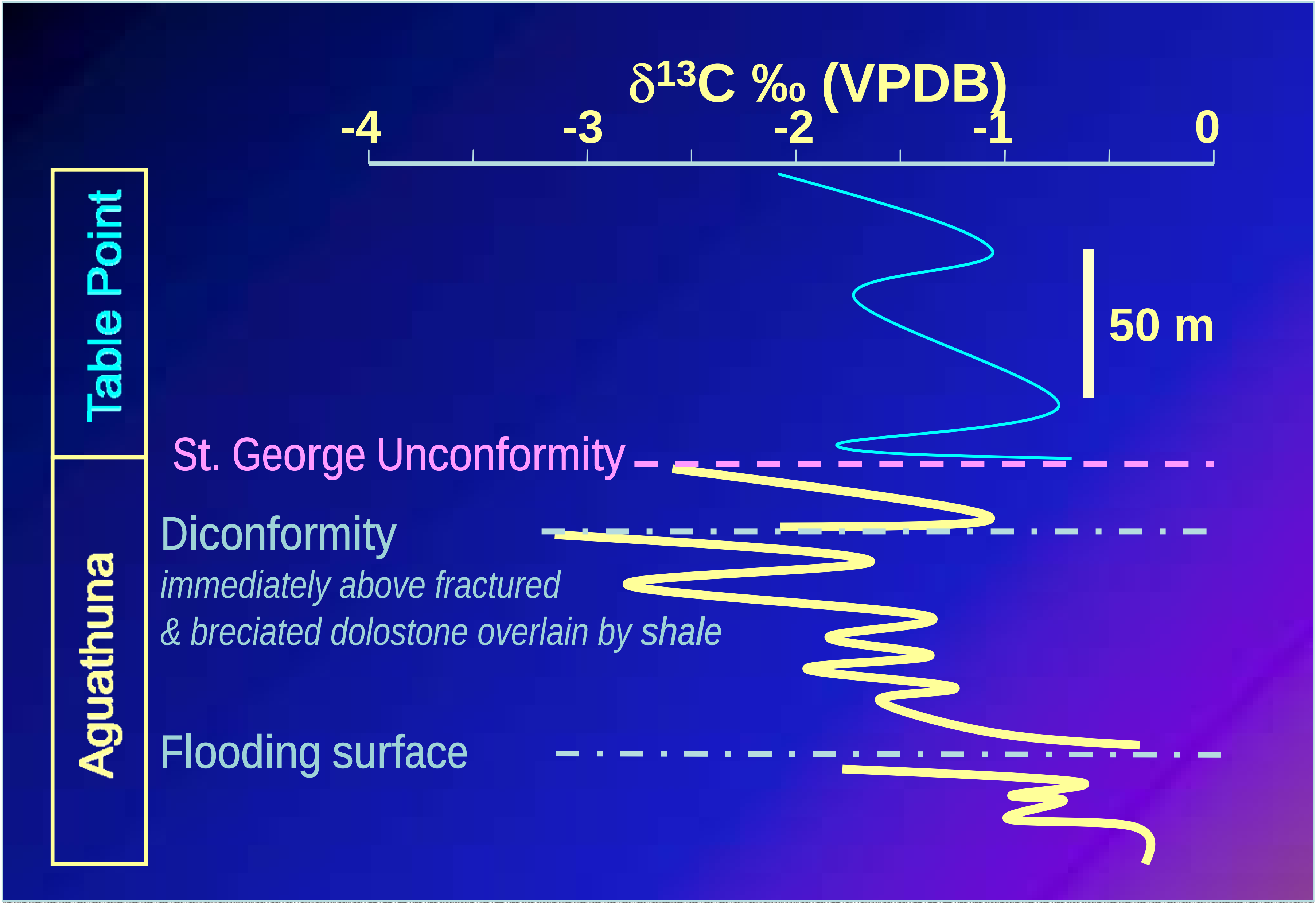
Stable isotopes



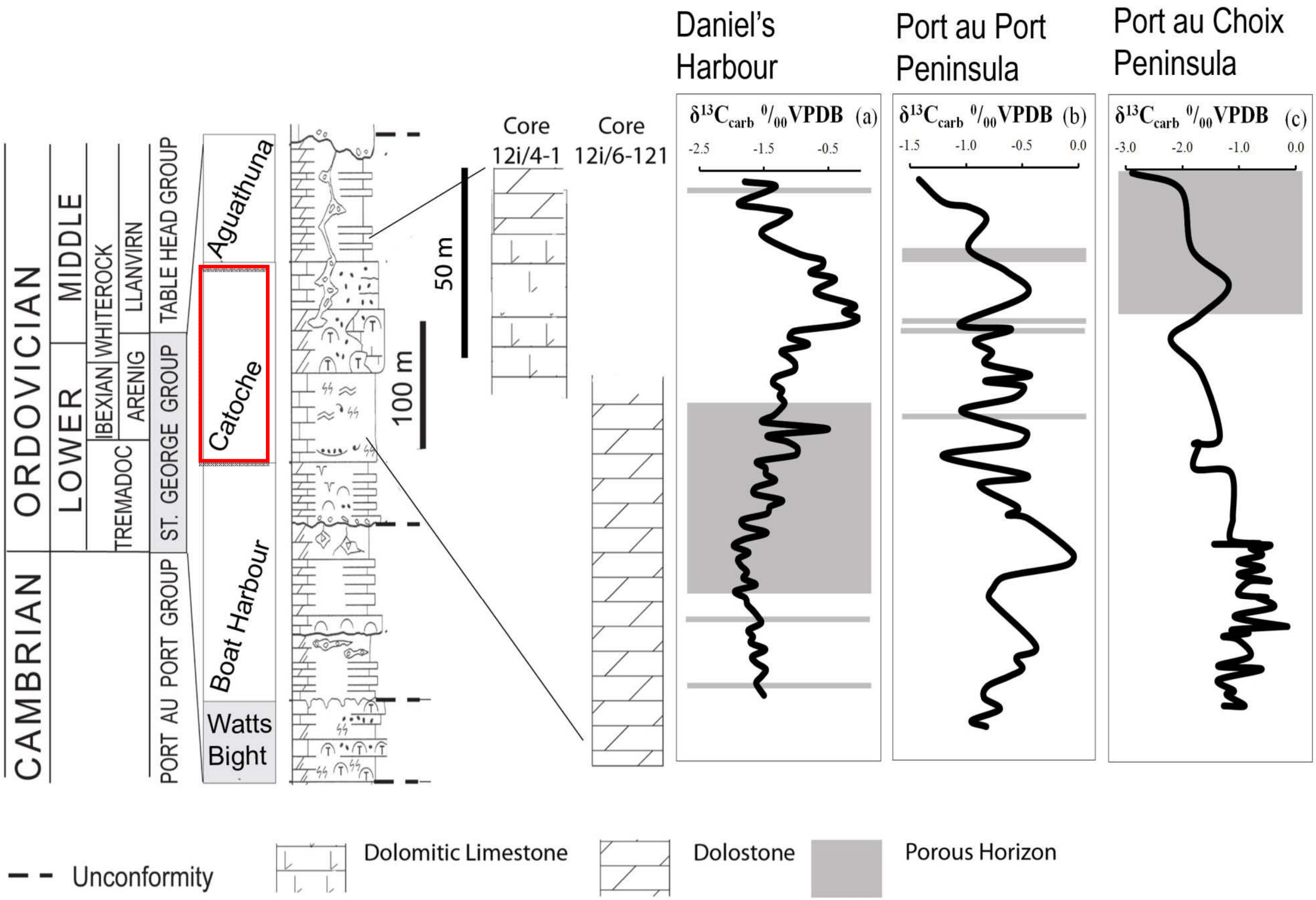

Main Brook
Gander Bay
Rushy Pond
Island of Newfoundland
Grand Lake
Red Indian Lake
© 2012 Cnes/Spot Image
Image © 2012 TerraMetrics
© 2012 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
49°09'18.10" N 55°20'40.39" W elev 107 m

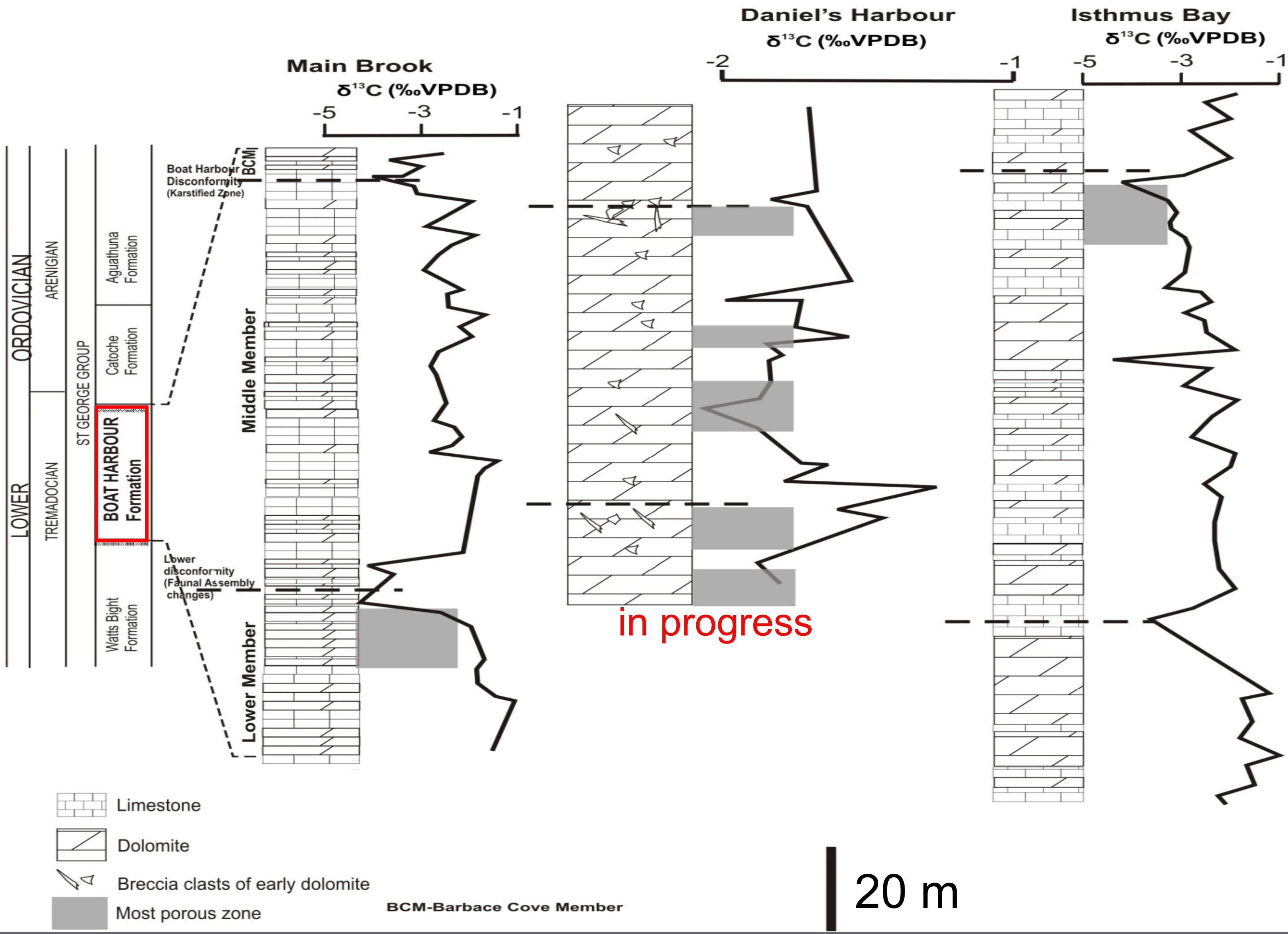

Aguathuna
AG
Catoche
CT
Boat Harbour
BH
Watts Bight
WB
St. George Group
Un-/ disconformity ------


δ13C‰ (PDB)
R2 < 0.1
lime mudstone C1
dolomicrite D1
Mn/Sr



δ13C ‰ (VPDB)
-4
-3
-2
-1
0
Table Point
Aguathuna
50 m
St. George Unconformity
Diconformity
immediately above fractured
& breciated dolostone overlain by shale
Flooding surface


Daniel's Harbour
Port au Port Peninsula
Port au Choix Peninsula
CAMBRIAN
ORDOVICIAN
LOWER
MIDDLE
TREMADOC
IBEXIAN
WHITEROCK
ARENIG
LLANVIRN
PORT AU PORT GROUP
ST. GEORGE GROUP
TABLE HEAD GROUP
Watts Bight
Boat Harbour
Catoche
Aguathuna
100 m
50 m
Core 12i/4-1
Core 12i/6-121
δ13Ccarb ‰VPDB (a)
-2.5 -1.5 -0.5
δ13Ccarb ‰VPDB (b)
-1.5 -1.0 -0.5 0.0
δ13Ccarb ‰VPDB (c)
-3.0 -2.0 -1.0 0.0
Unconformity
Dolomitic Limestone
Dolostone
Porous Horizon



Main Brook
δ13C (‰VPDB)
-5 -3 -1
Daniel's Harbour
δ13C (‰VPDB)
-2 -1
Isthmus Bay
δ13C (‰VPDB)
-5 -3 -1
LOWER
ORDOVICIAN
TREMADOCIAN
ARENIGIAN
ST GEORGE GROUP
Watts Bight Formation
BOAT HARBOUR Formation
Catoche Formation
Aguathuna Formation
BCM
Boat Harbour Disconformity (Karstified Zone)
Middle Member
Lower disconformity (Faunal Assembly changes)
Lower Member
in progress
Limestone
Dolomite
Breccia clasts of early dolomite
Most porous zone
BCM-Barbace Cove Member
20 m

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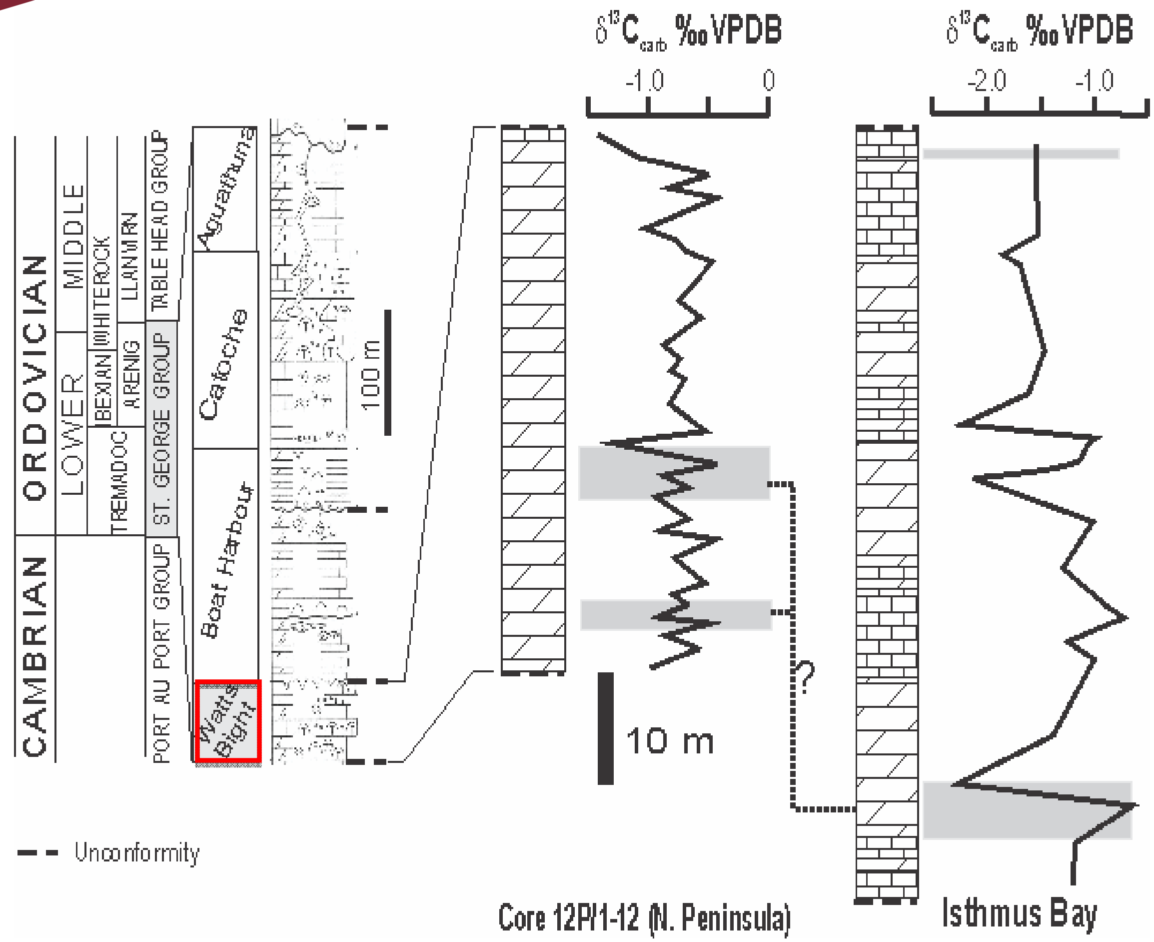
C-isotope profile

unconformity *vs.* porosity

Correlation of sequences across western Newfoundland



Main Brook Port au Port

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Why is intercrystalline porosity in D2 at times associated with –ve $\delta^{13}C$ shifts (un-/disconformity)?

drop of sealevel brings oxygenated water in contact with organic matter in the relatively lower shelf $\Rightarrow$ oxidation and release of light $^{12}CO_2$

also, it allows meteoric water to dissolve marine carbonates and create a preliminary system of conduits that facilitates the circulation of the dolomitizing fluids, which enhances porosity by dolomitization.

Why is intercrystalline porosity in D2 not always associated with un-/disconformity?

Porous D2 horizons have usually higher mean [Ca^{+2}], i.e., developed directly from calcite ($CaCO_3$ □ lime mudstone)

If D2 is formed by recrystallization of D1 (dolomicirite) $\Rightarrow$ no porosity (no molar volume change)

If dolomitization occurs simultaneously with dissolution of calcite $\Rightarrow$ no prosity

If Mg^{+2} is limited (semi-closed / closed conditions) & dissolution continues after dolomitization stops $\Rightarrow$ porosity.

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Isotope Correlation

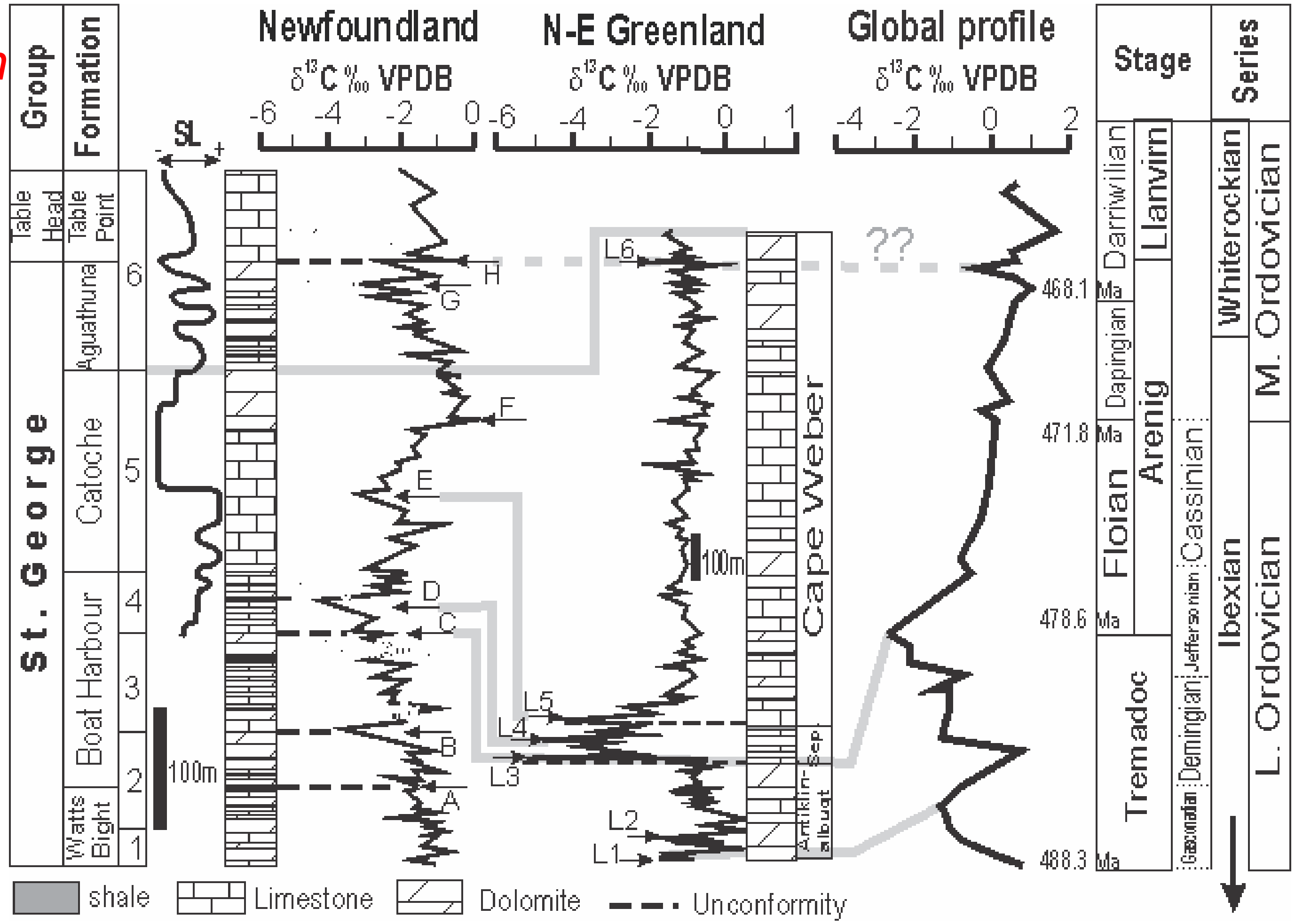
High-resolution global correlations

Western NL

vs

Greenland

Azmy et al 2010 Sed Geol.



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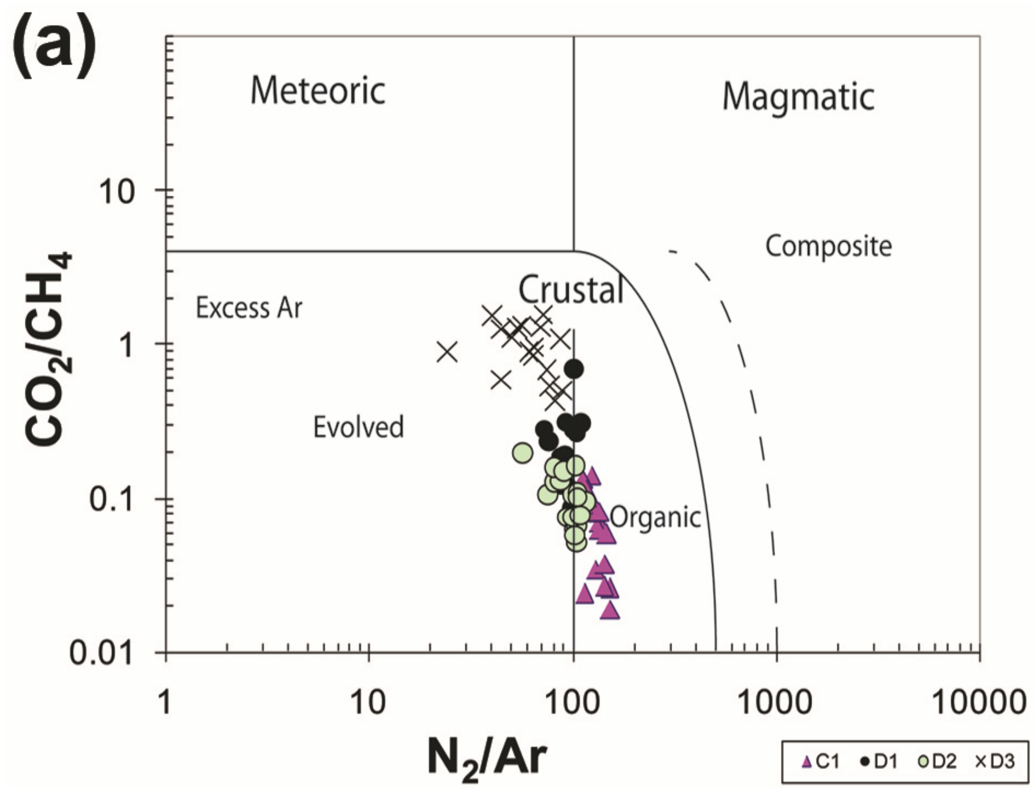
Fluid-inclusion gas ratios

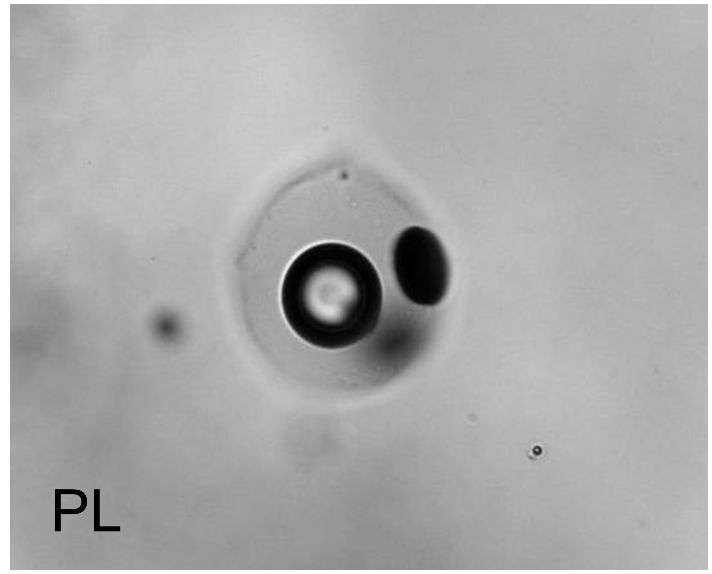
Hydrothermal dolomitizing fluids.

No magmatic inputs.



Gas ratios

Volatiles (CO_2, N_2, $C_{1\text{-}5}$) from gas fields provide information on whether gas was generated by "cooking" an oil play by igneous intrusion, or gas in contact with an oil play not "cooked"



Major, minor

dolomicrite, D1

$^{m}(Sr/Ca)_{dolomite} = Dr_{sr}\ ^{m}(Sr/Ca)_{fluid}$

Comparison with $^{m}(Sr/Ca)_{SW} \Rightarrow$ sabkha *vs.* mxied water origin (diluted SW)

$^{m}(Sr/Ca)_{fluid} > {}^{m}(Sr/Ca)_{SW} \Rightarrow$ sabkha ($Sr \geq 550ppm$)

$^{m}(Sr/Ca)_{fluid} < {}^{m}(Sr/Ca)_{SW} \Rightarrow$ mxied water origin (diluted SW) ($Sr \sim 150ppm$)

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REE

all trivalent (except for Ce^{+4} and Eu^{+2} in certain environments)

similar ionic radii □ chemical characteristics change systematically along the series.

narrow range of partition coefficient

i.e., variations reflect oceanic composition and/or nature of fluids that deposited the carbonates

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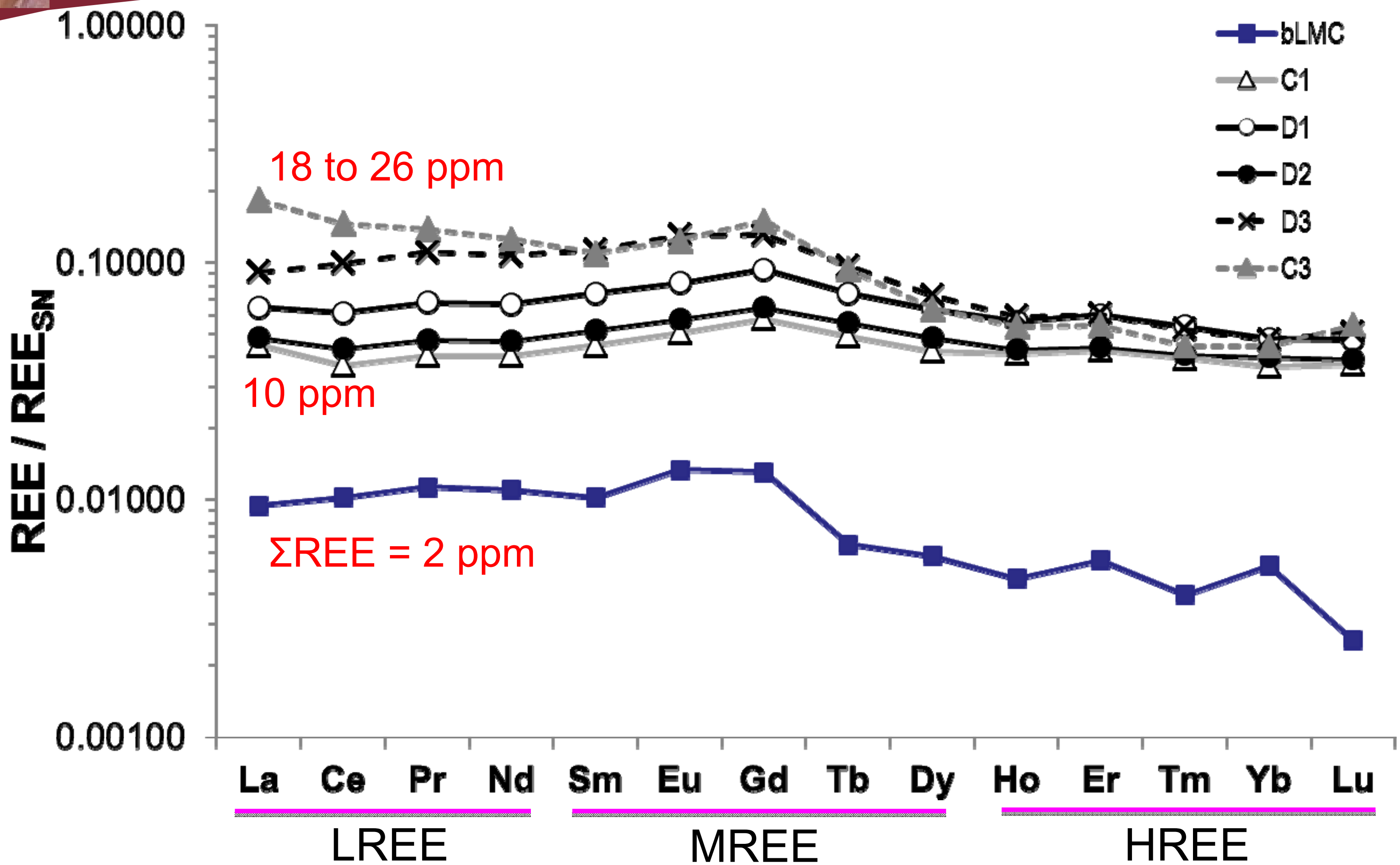

1.00000
0.10000
0.01000
0.00100
REE / REE$_{SN}$
bLMC
C1
D1
D2
D3
C3
18 to 26 ppm
10 ppm
ΣREE = 2 ppm
La
Ce
Pr
Nd
Sm
Eu
Gd
Tb
Dy
Ho
Er
Tm
Yb
Lu
LREE
MREE
HREE

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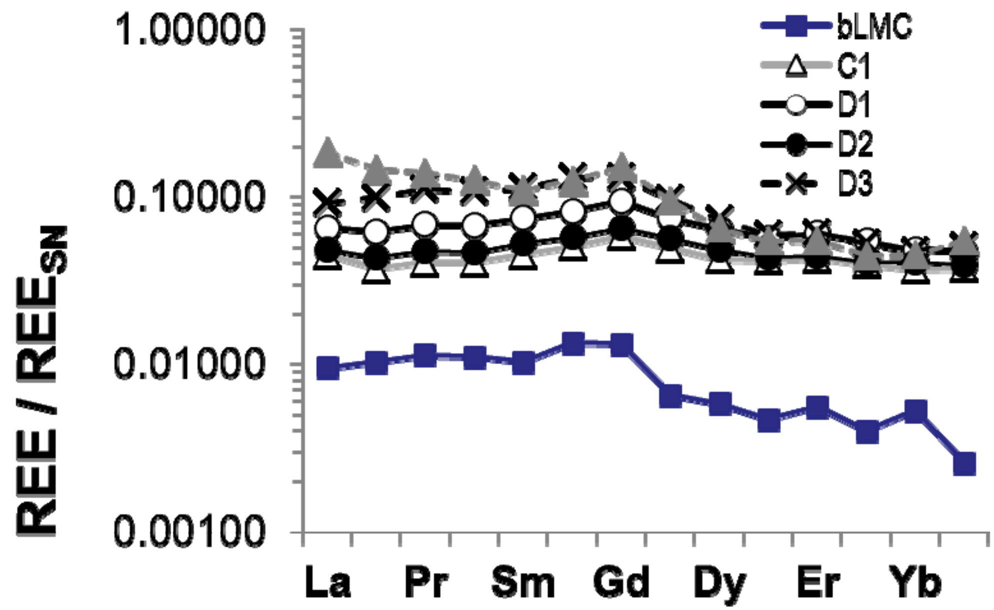
lime mudstones (C1) &
dolomicrites (D1) have:

- similar REE patterns
- near□micritic grain size
- similar mean $\delta^{13}C$ values
- comparable mean ∑REE values



Thus,

C1 is the precursor of D1 that originated from dolomitizing fluids formed from mixture of marine and meteoric water.

D1 is not syngenetic (sabkha) as has been believed

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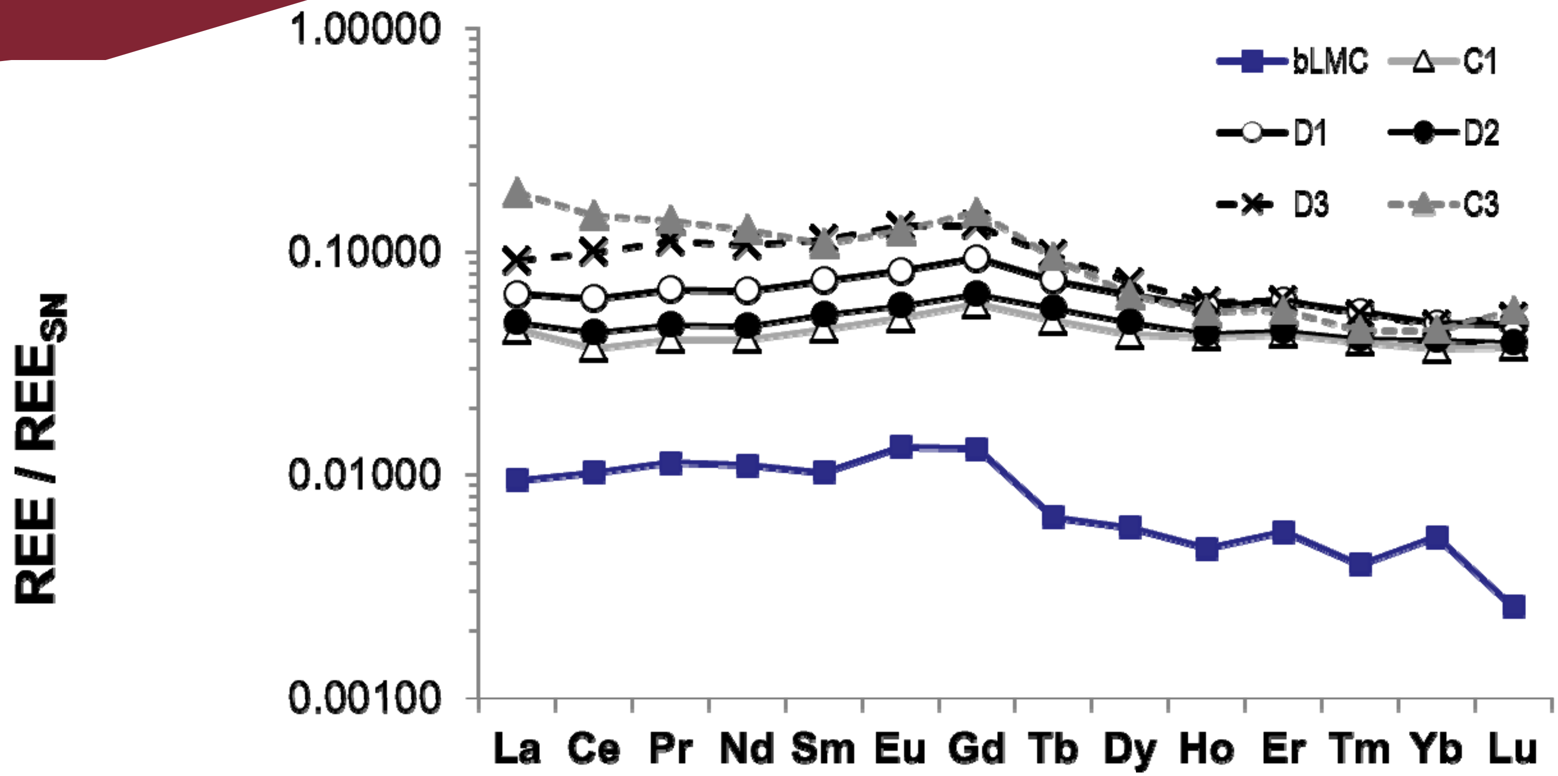

C1 REE$_{SN}$ pattern between those of bLMC & D1 supports the scenario that D1 is an early stage (near-surface) dolomitization.

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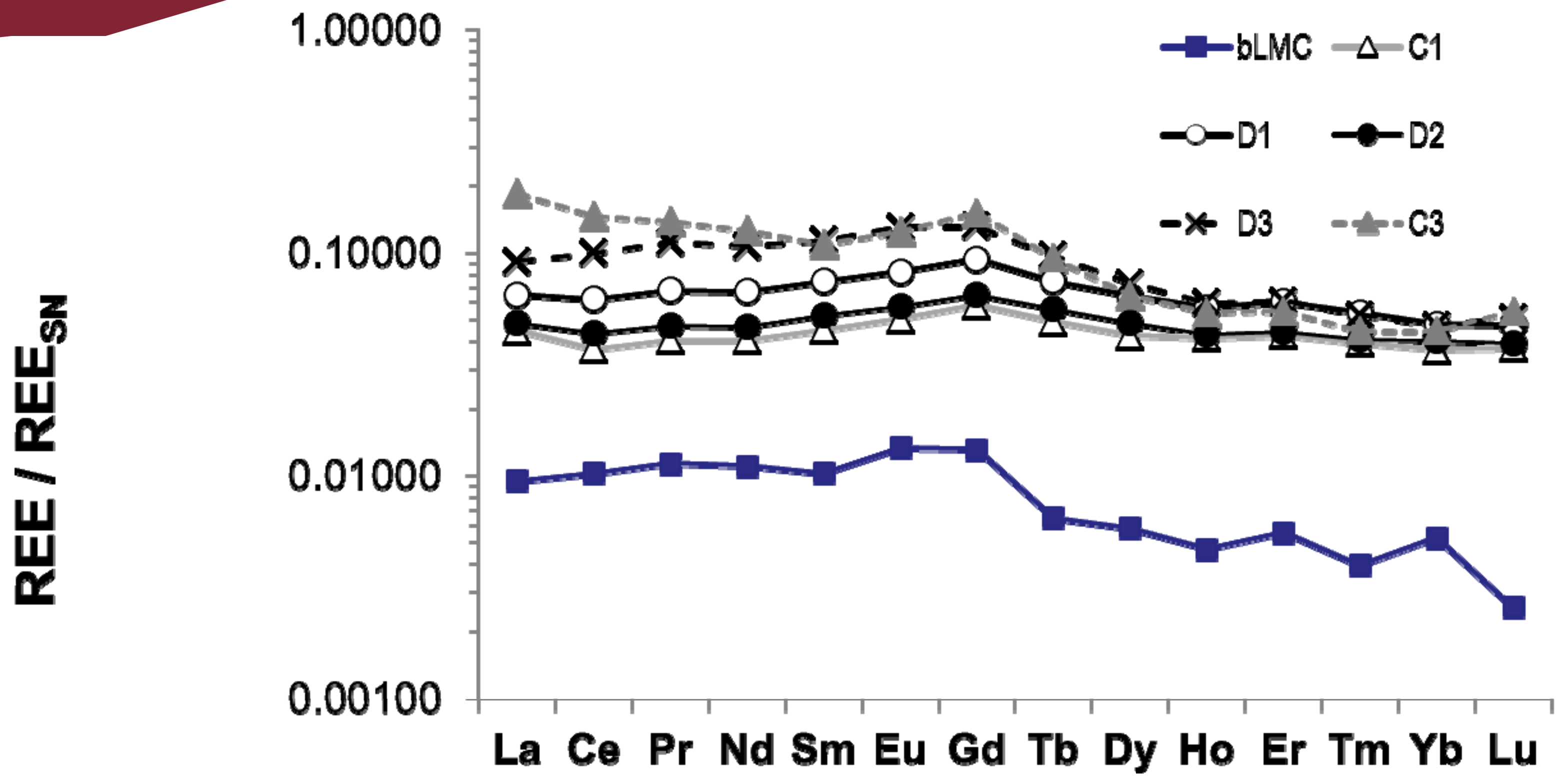

All dolomite phases (D1, D2 & D3) are parallel and almost superimposed around the HREE section, suggesting an origin from similar or same fluids that were circulated in the crust during burial history.

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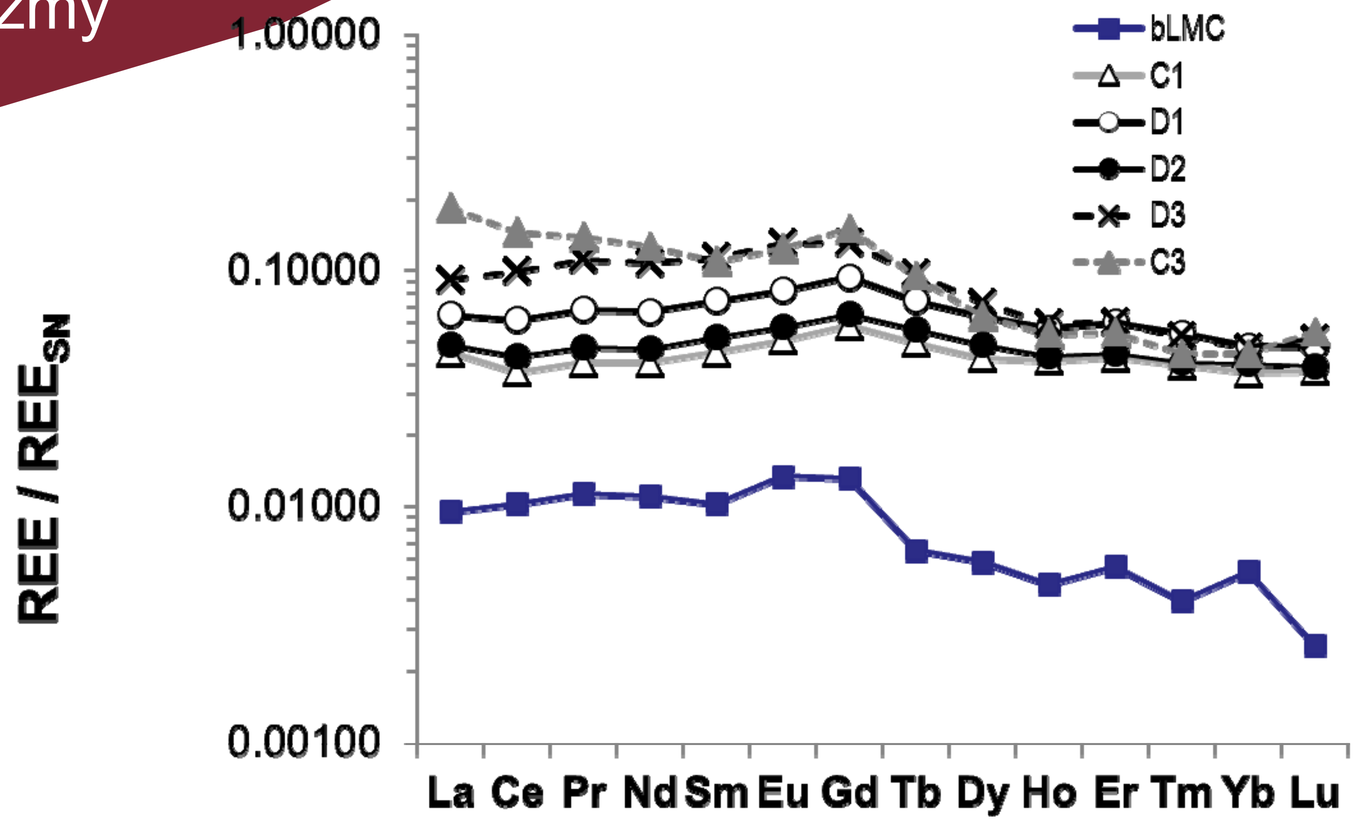

∑REE of D3 and C3 are relatively higher than the other dolomites because they precipitated at the latest stages of burial as fracture□filling but not replacive.

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Proposed Work

- Study of other porous dolomites from different independent systems (different age and location) for comparison with St. George Group dolomites.

This will provide better understanding of controls on patterns of porosity distribution in hydrothermal dolomites

- Study of geochemistry (REE) of carbonates from modern extreme environments and ancient chemosynthetic (hydrocarbon seeps) settings.

Conclusions

❖Intercrystalline porosity is:

- ➢ associated with hydrothermal dolomites of mid burial settings
- ➢ in horizons likely associated with un□ / disconformities

❖Dolomitization was by basinal fluids that were circulated in the crust under semi-closed to closed system conditions.

❖No contribution from magmatic fluids.

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Impact:

❖ Better understanding porosity distribution in onshore sequence:

- ➢ allows predicting/modeling porosity patterns in their equivalent offshore counterparts.
- ➢ will have important implications for hydrocarbon exploration.

❖ The approach can be applied to any carbonate rocks regardless age or location.

Thank you