Massive Dolomitization of a Pinnacle Reef in the Lowermost Devonian West Point Formation (Québec, Canada): An Extreme Case of Hydrothermal Dolomitization through Fault-Controlled Circulation of Magmatic Fluids*

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Abstract

Lower Devonian pinnacle reefs of the West Point Formation in Gaspé Peninsula (Québec, eastern Canada) were built on paleotectonic highs in an Early Devonian foreland basin. These large structures are found along Acadian (Early-Middle Devonian) transpressive faults in northern Gaspé. Of the nine pinnacles known in outcrop, only one is dolomitized and occurs at the junction of two major Acadian faults.

The petrography of the dolomitized facies has revealed the presence of three dolomite and one late calcite phases. A first dolomite phase of small crystals is minor; the following dolomite dominates and consists of large (cm-sized) replacive saddle dolomite crystals that carry fluid inclusions with homogenization temperatures ranging between 301 to 382°C. The third dolomite consists of large (mm to cm-sized) saddle dolomite crystals that fill fractures that cut through the previous dolomite, this phase is characterized by lower temperature fluid inclusions (159 to 171°C). A lower temperature calcite phase (107-123°C) fills some void space. Fluid inclusions in these phases are all saline (8.7 to 13.3 wt% NaCl equiv.). The dolomite and calcite phases are characterized by very negative $\delta^{18}O_{VPDB}$ values (between -19‰ to -14‰) and negative $\delta^{13}C_{VPDB}$ values (between -1‰ to -8‰). The main dolomite phase originated from a fluid that had very positive $\delta^{18}O_{SMOW}$ values (+8‰); the following dolomite and calcite precipitated from fluids with lower $\delta^{18}O_{SMOW}$ values (+3.4‰ and +4.5‰). It is proposed that fault-controlled circulation of magmatic fluids are responsible for the very high temperature massive dolomite replacement of the calcite host. This is backed by $^{87}Sr/^{86}Sr$ ratios of the replacement high temperature dolomite that are consistent with fluids derived from A-type magma. High temperature burial fluids later used fractures to circulate in the dolomitized host to precipitate late dolomite and calcite. Regionally, hydrocarbon migration is recognized at the time of late calcite cementation.

This very high temperature dolomitization is not reported in the hydrocarbon literature and provides a link with process recognized in the mining literature.

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Outline

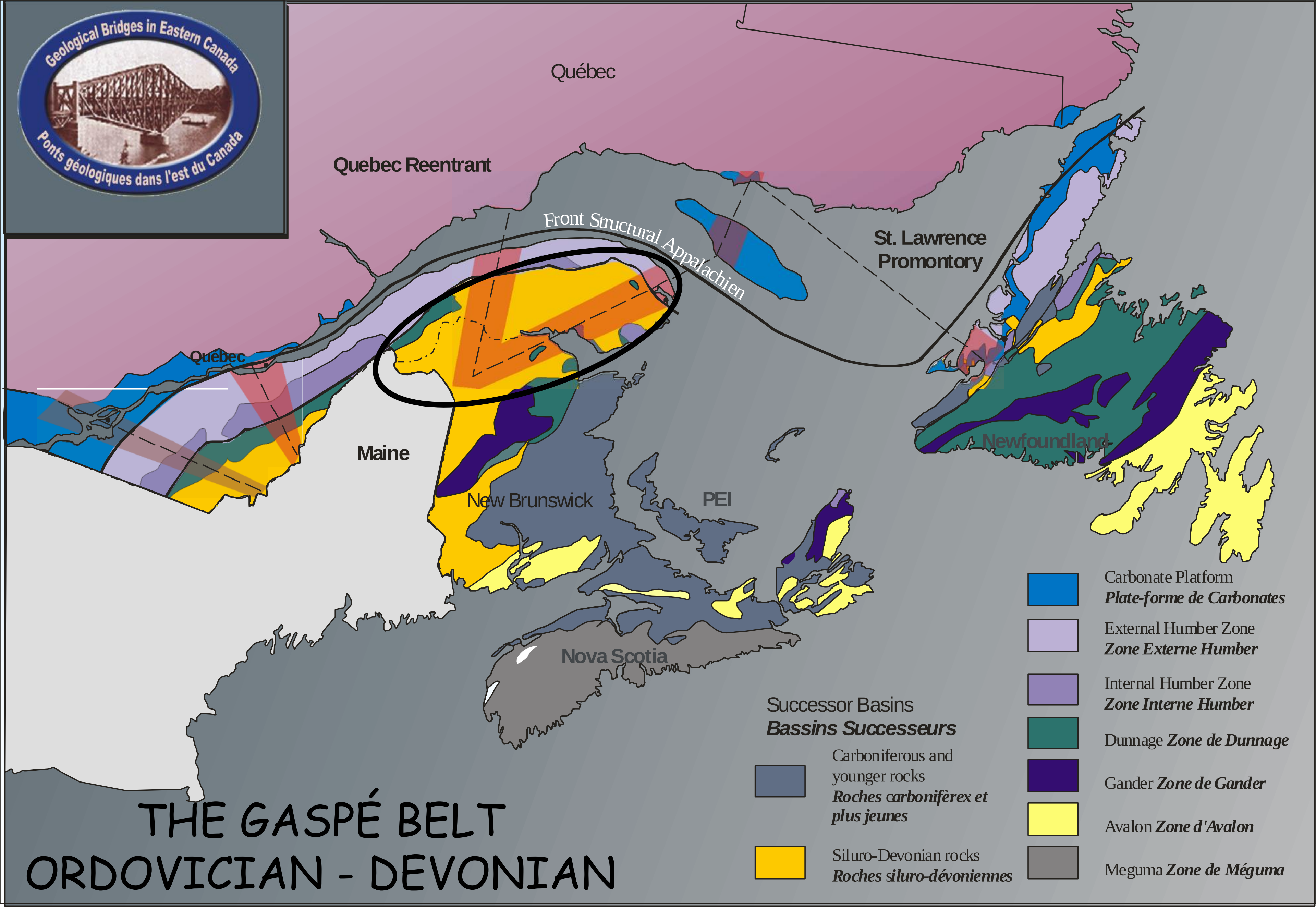
Overview of the Silurian-Devonian geological architecture in eastern Canada

Lower Devonian reef framework

Field, petrography and isotope (O, C, Sr, Mg) evidence for fault-controlled hydrothermal alteration

Model and significance for hydrocarbon exploration

THE GASPÉ BELT
ORDOVICIAN - DEVONIAN



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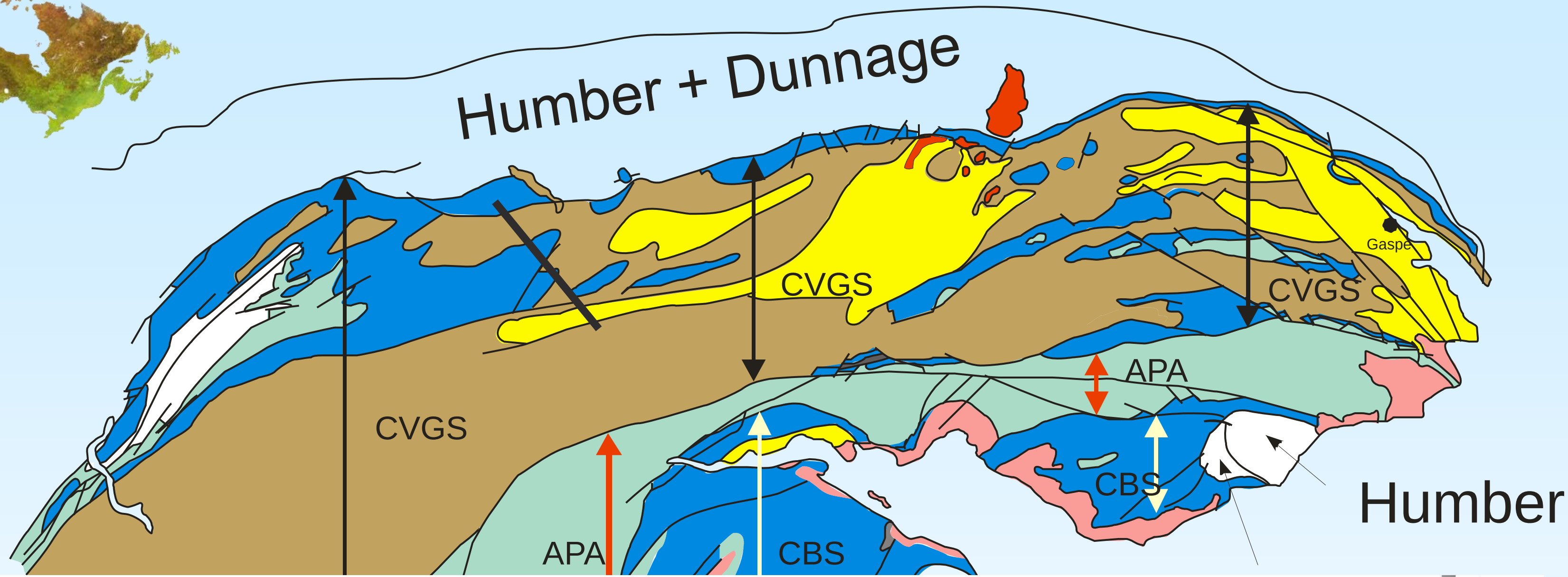
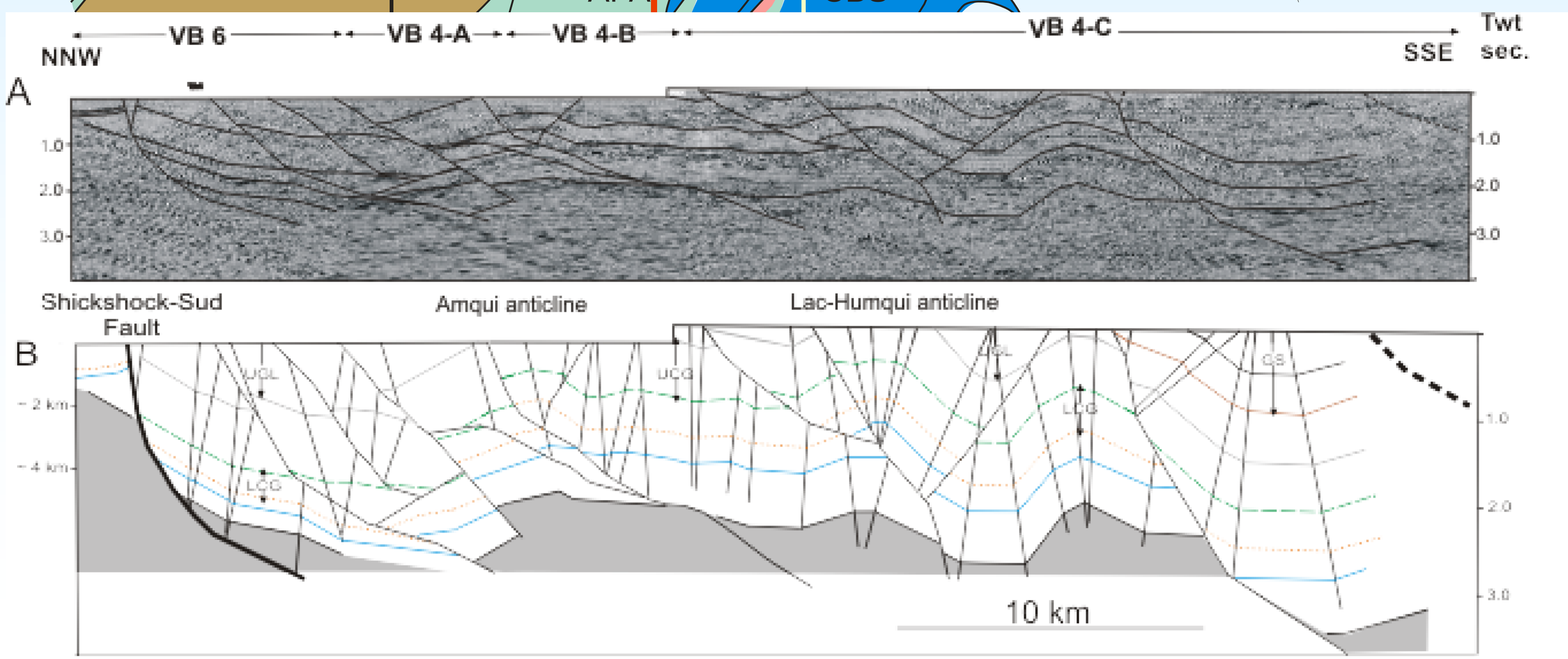
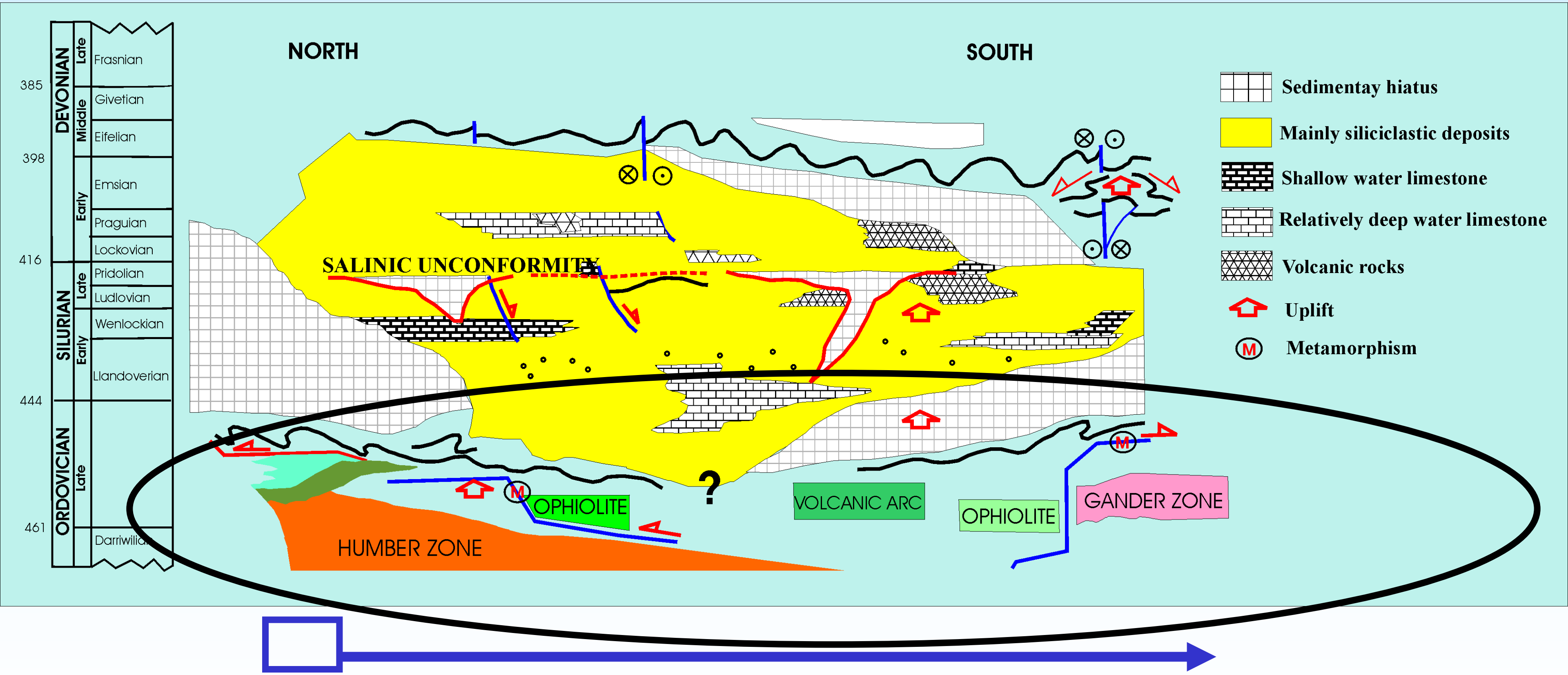
The Gaspé Belt: Upper Ordovician – Middle Devonian



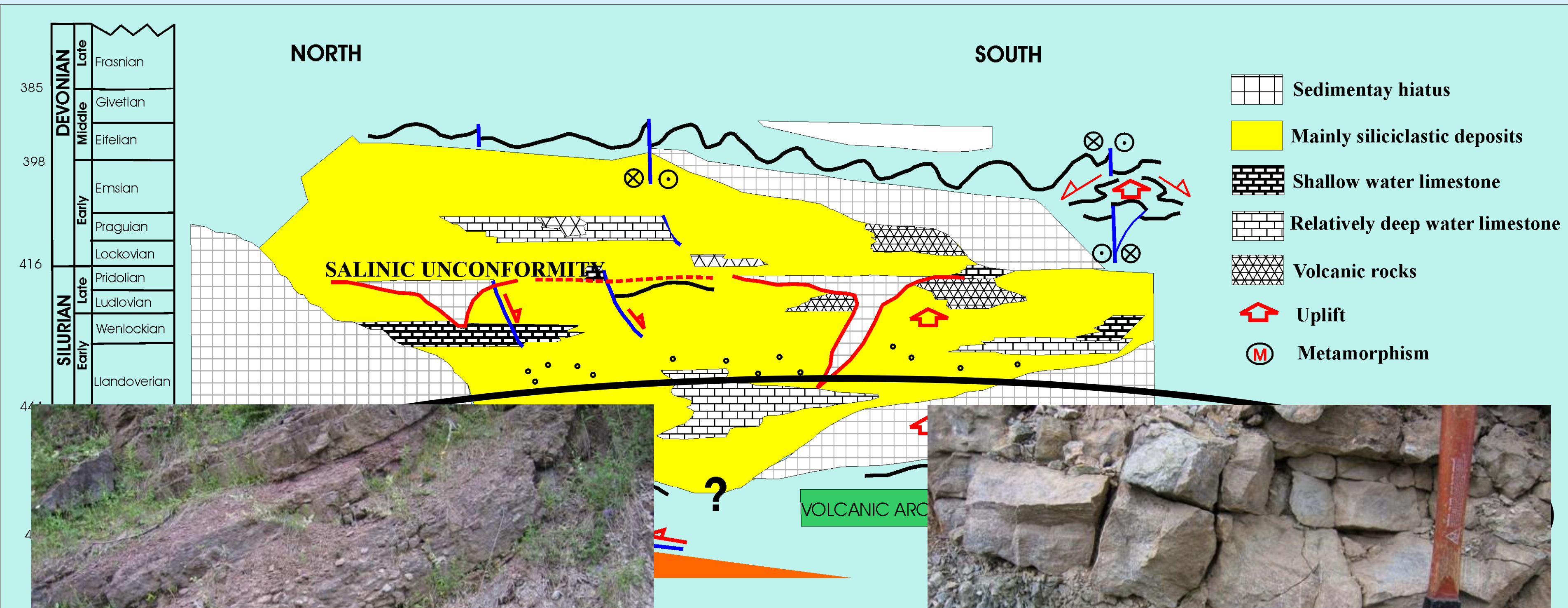


Substratum of the Gaspé belt

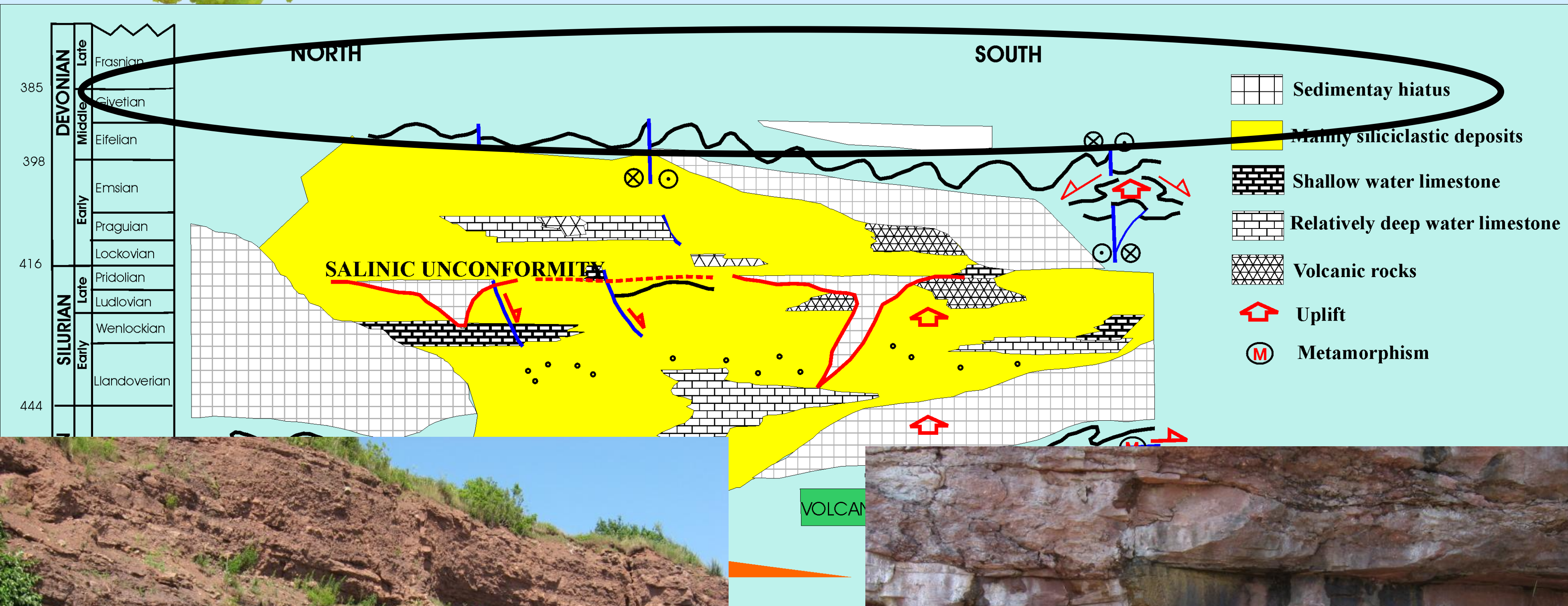


Pinet et al. (2005)

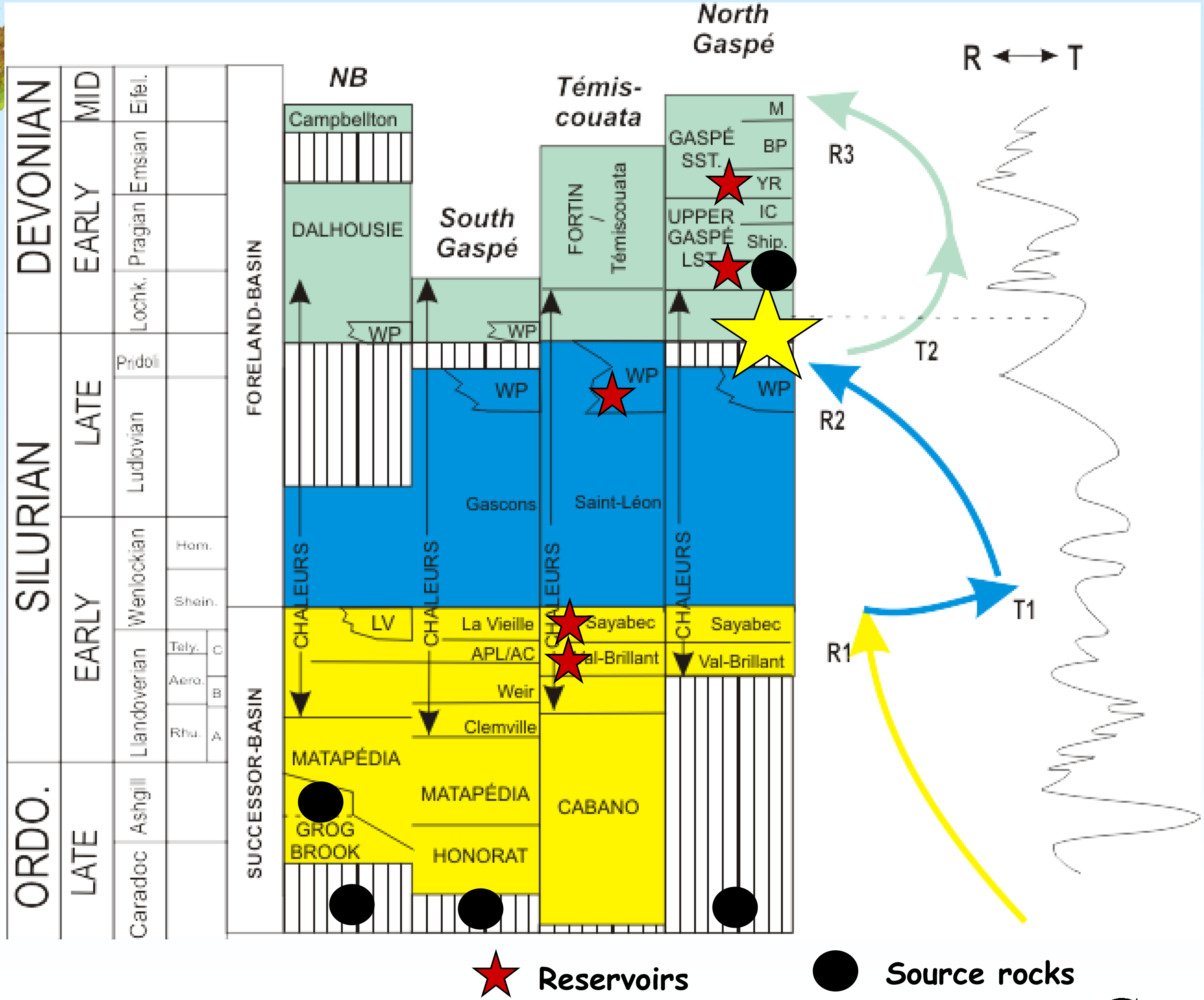
Substratum of the Gaspé belt



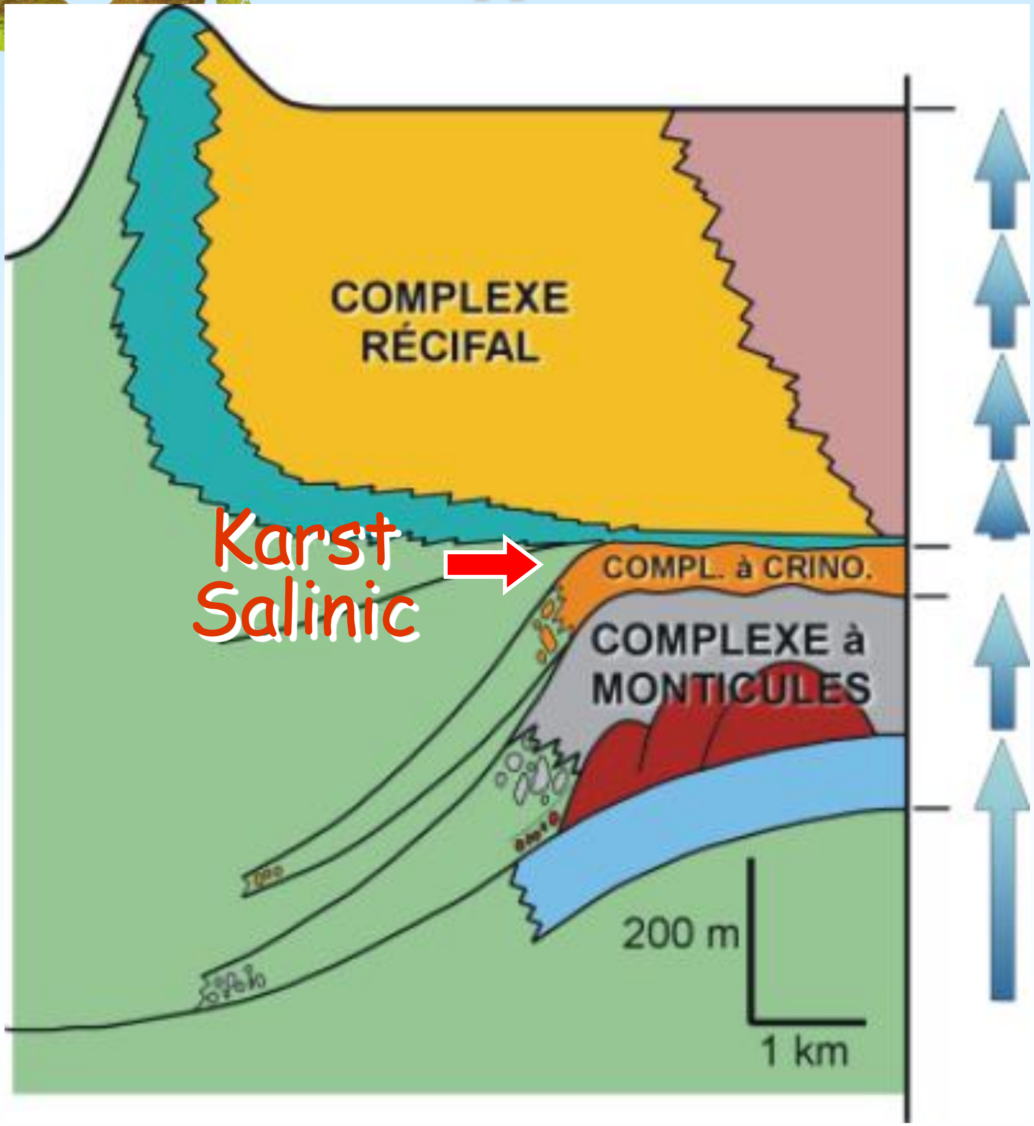
The Carboniferous unconformity



Stratigraphy of the Gaspé Belt



The carbonate response to a slow sea level fall
The Upper Silurian West Point reef complexes



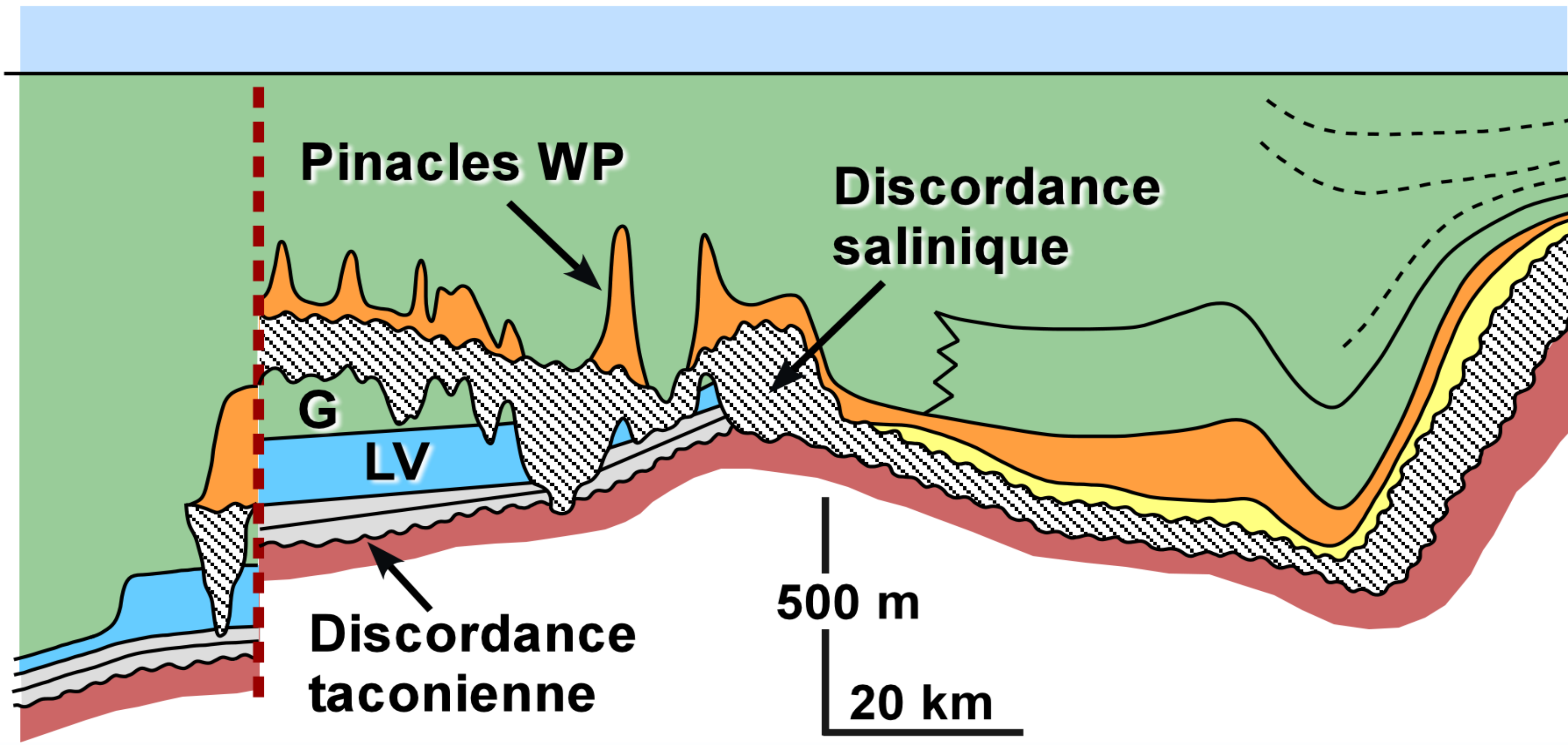
4 «shallowing» sequences

6 shallowing sequences

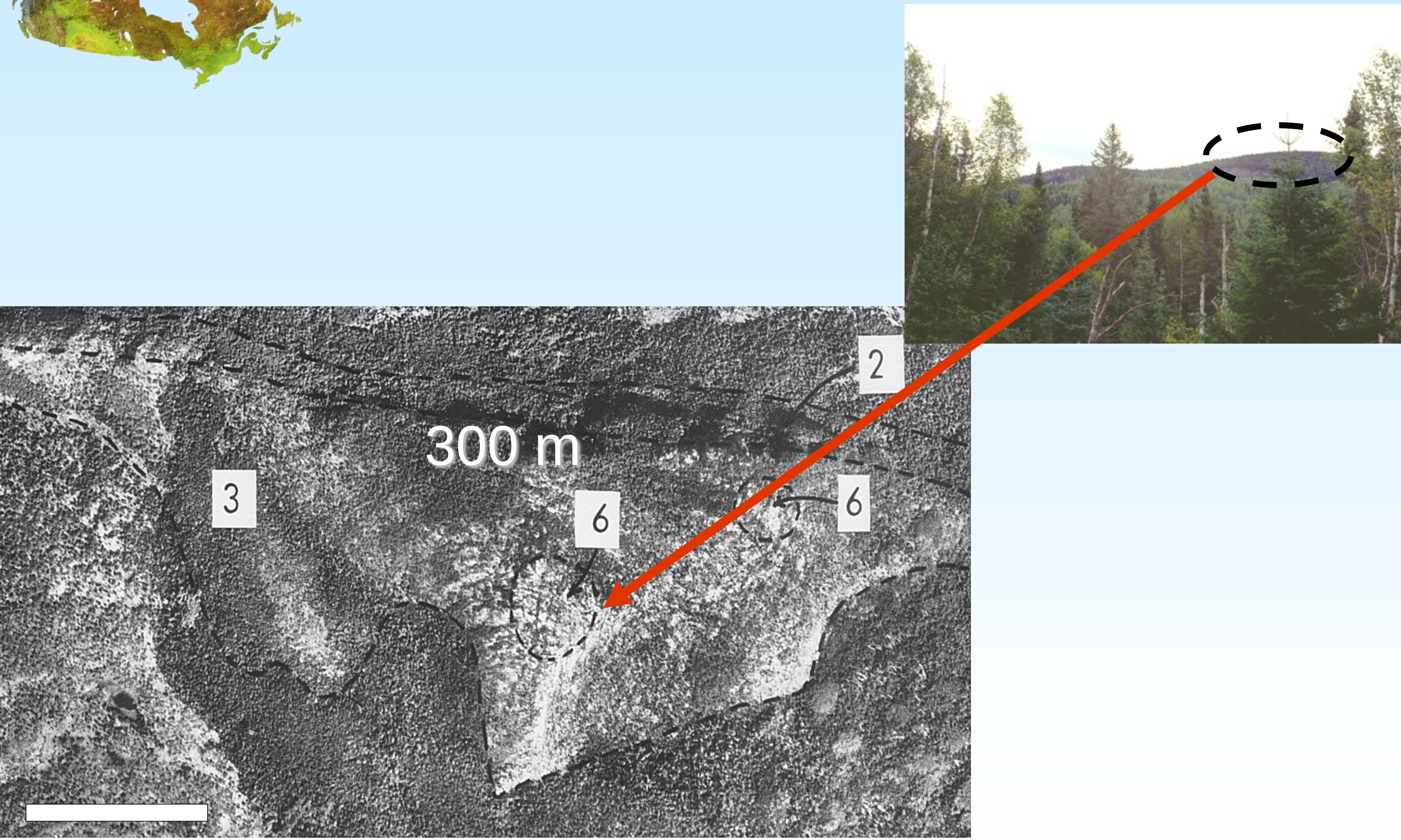
2 shallowing sequences

Bourque (2001)

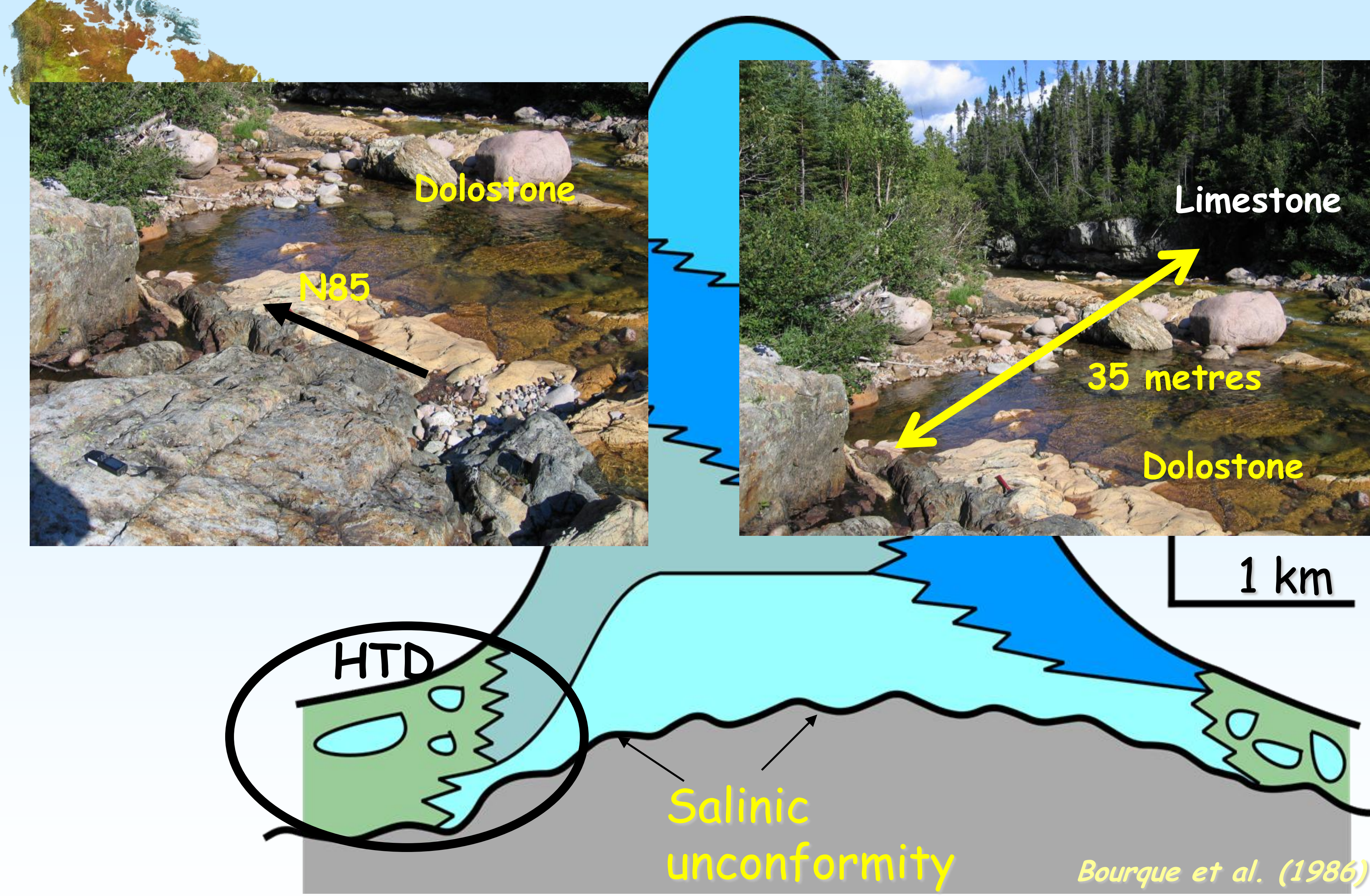
A RAPID (TECTONICALLY-DRIVEN) SEA LEVEL RISE – T3 EVENT SEDIMENTARY RESPONSE: PINNACLE REEFS



Pinnacle reef of the Madeleine river area

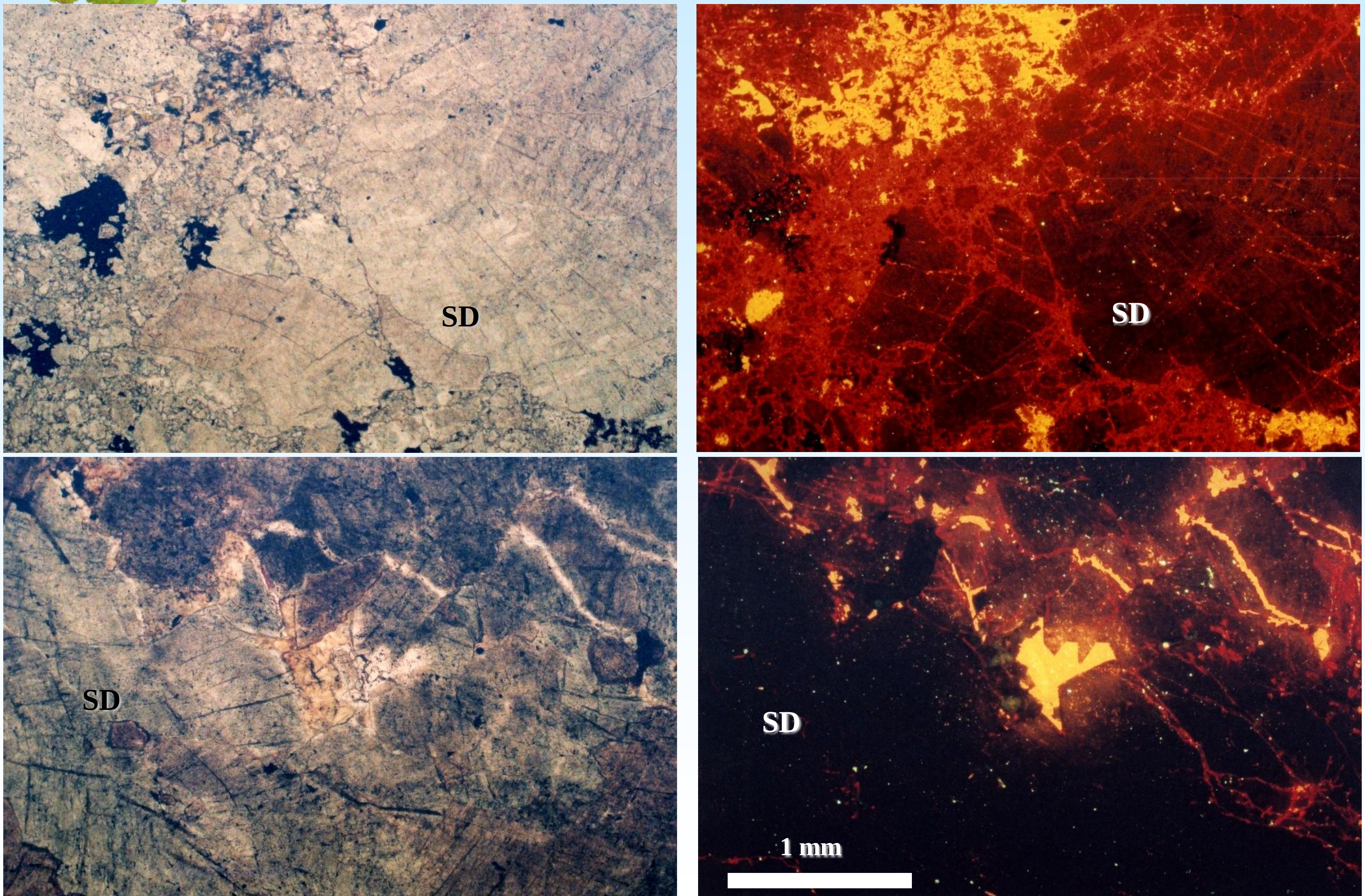


Lowermost Devonian pinnacle buildups – HTD in northern Gaspé

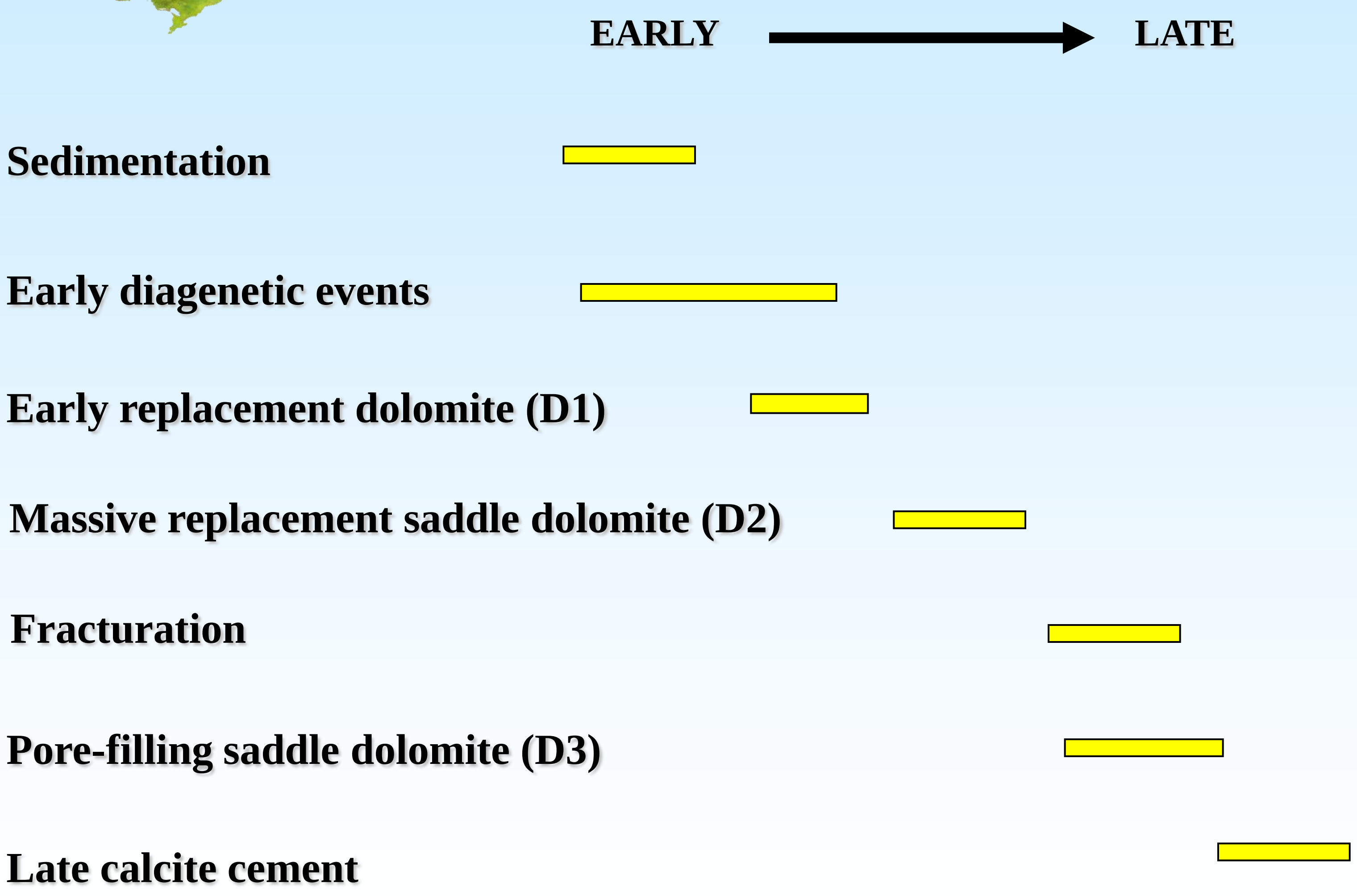


HTD IN LOWER DEVONIAN ASSOCIATED WITH STRIKE-SLIP

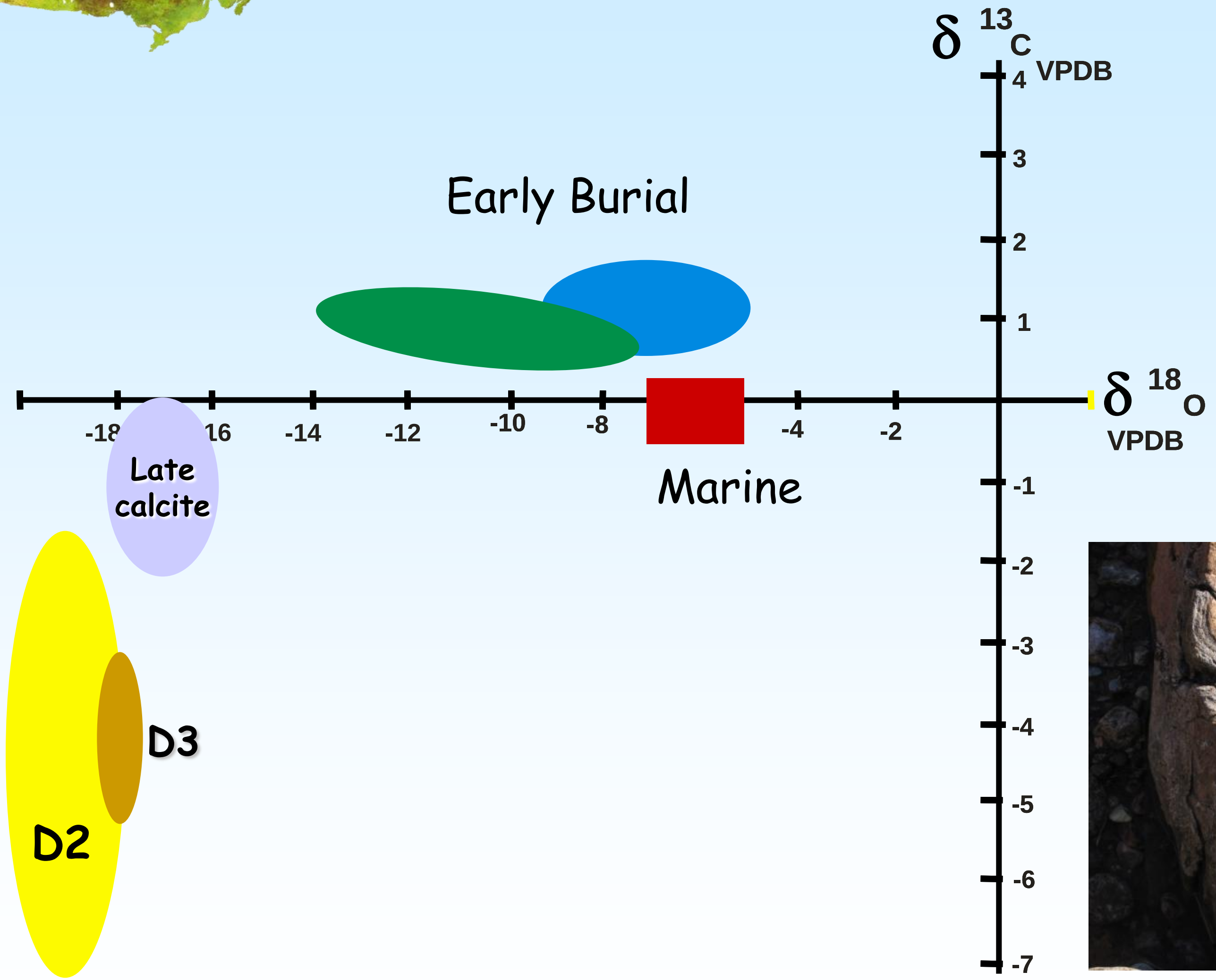
Early and late saddle dolomite – intense brecciation and High temperature calcite cementation / alteration



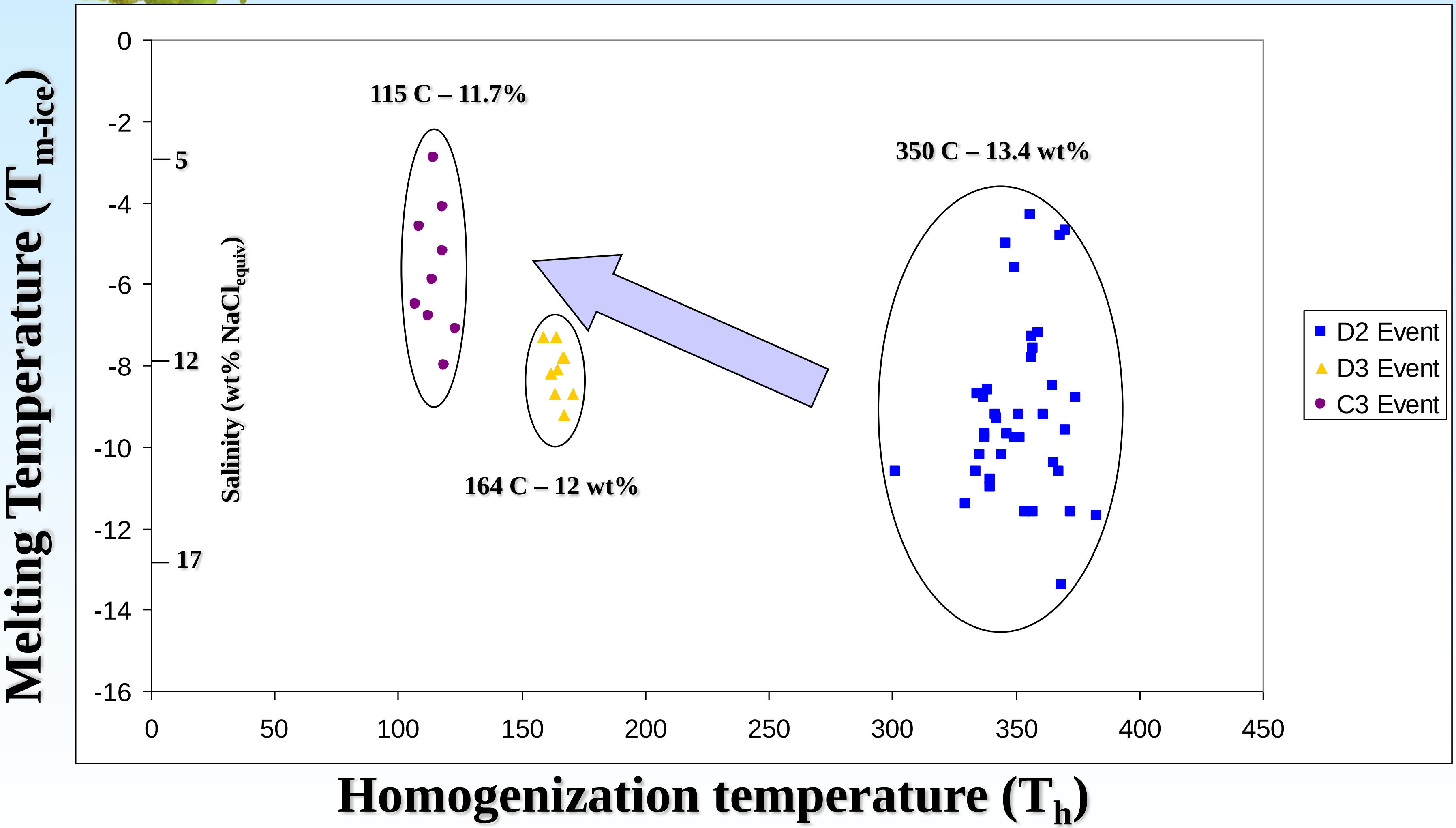
PARAGENETIC SUCCESSION OF EVENTS



STABLE ISOTOPES
WEST POINT PINNACLE REEFS

FLUID INCLUSIONS
WEST POINT PINNACLE REEFS



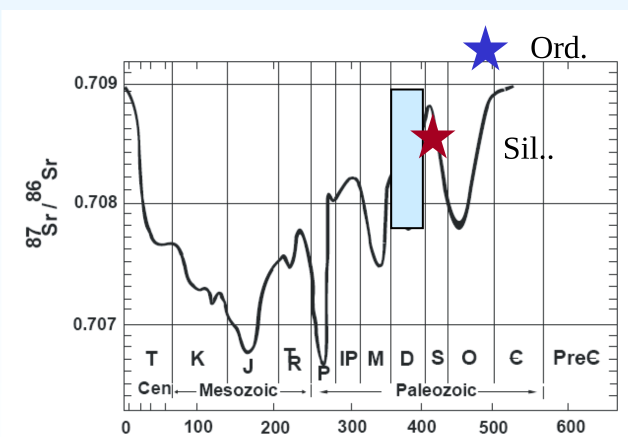
$\delta^{18}O_{smow}$ of the dolomitizing fluids

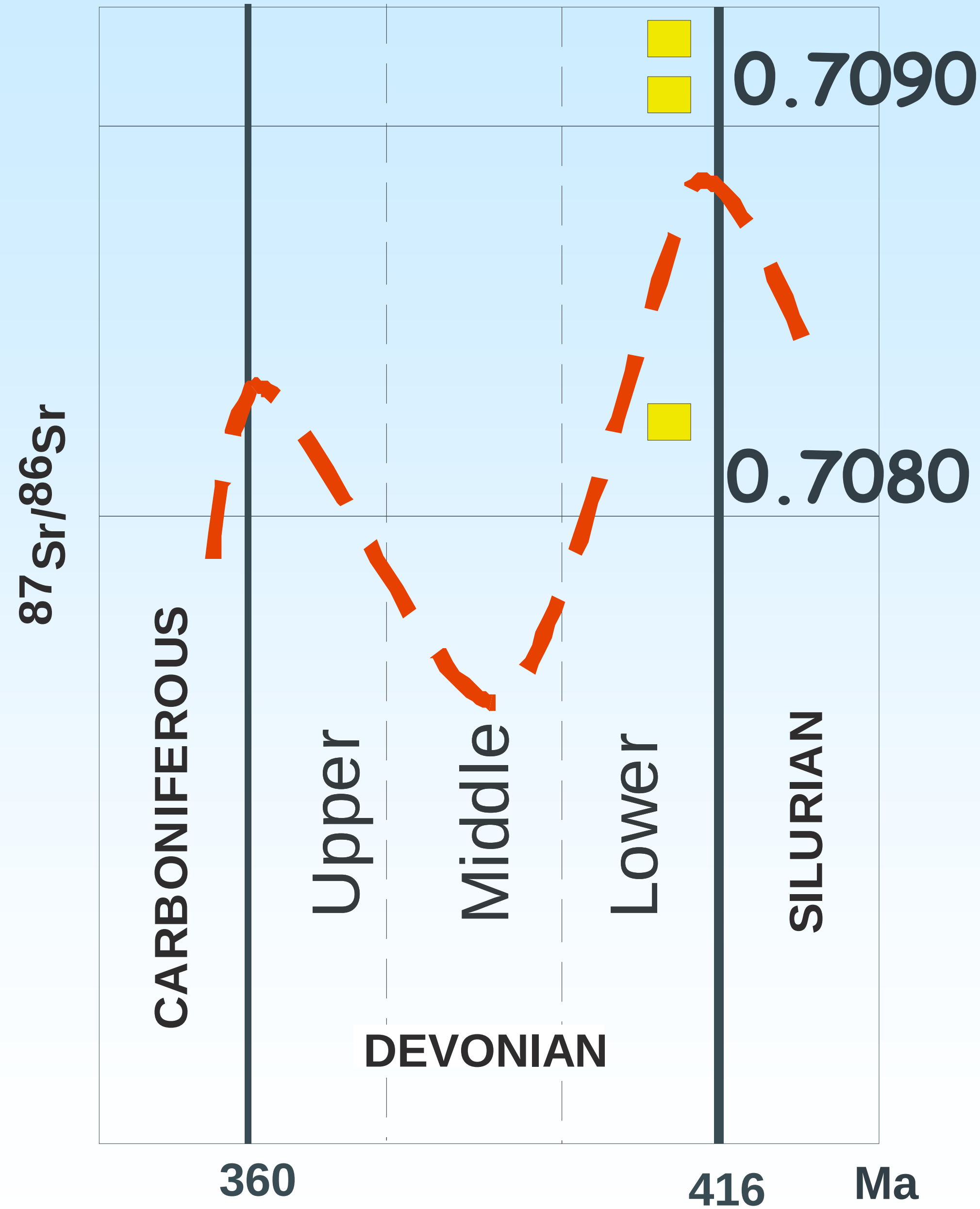
Cement Stratigraphy	Homogenization Temperature	δ18O Mineral (PDB)	Isotopic Composition of Diagenetic Fluid ‰ (SMOW)	Average ‰ (SMOW)
D2	356.5	-19.1	6.58	**8.27**
	340.1	-17.06	8.24	
	361.1	-15.8	9.98	
D3	164.8	-16.6	3.38	**3.38**
C3	115.1	-14.1	4.50	**4.50**

ORIGIN OF THE DOLOMITIZING FLUIDS

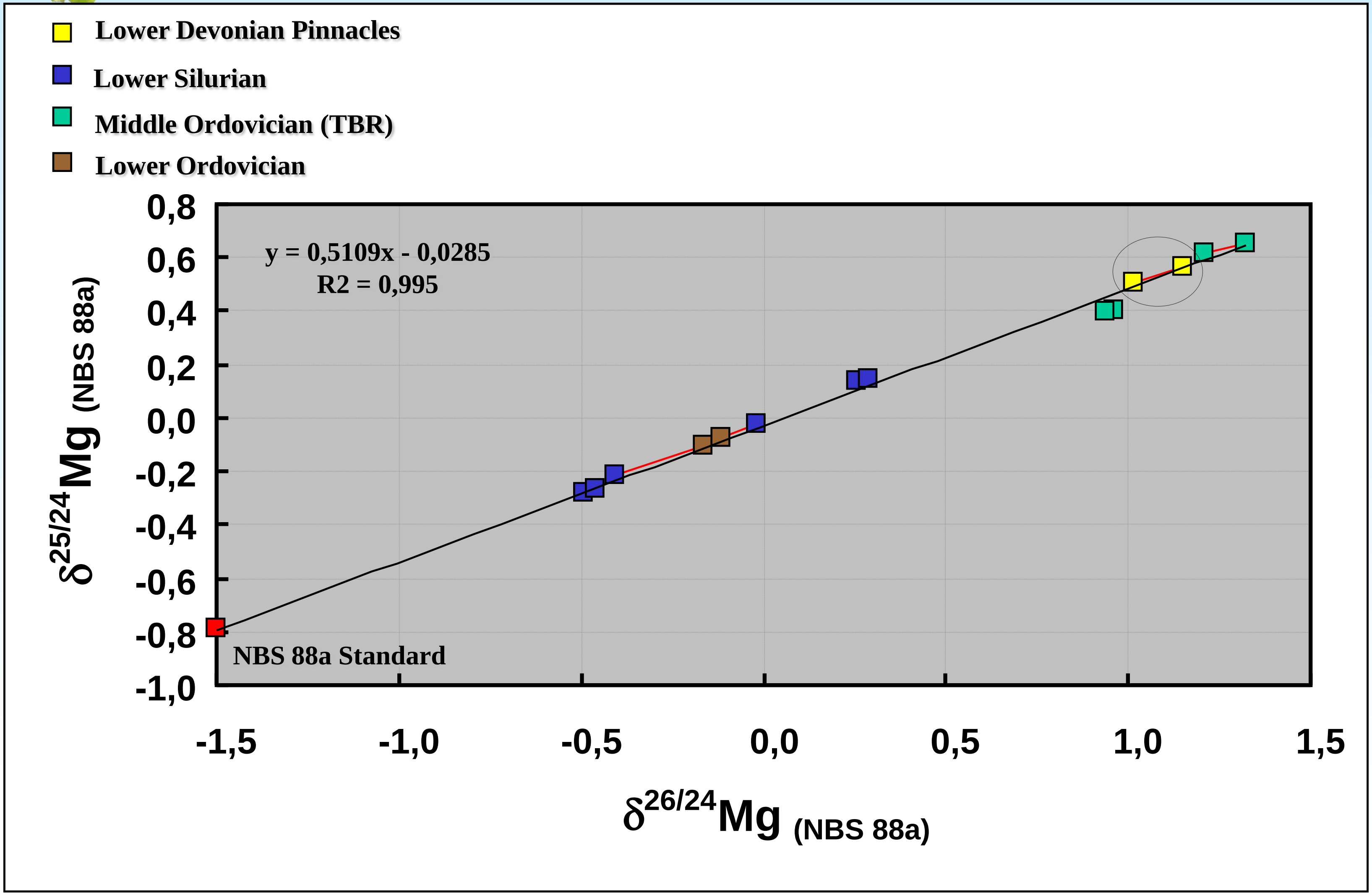
The 87Sr/86Sr data

Pinacles – Northern Gaspé

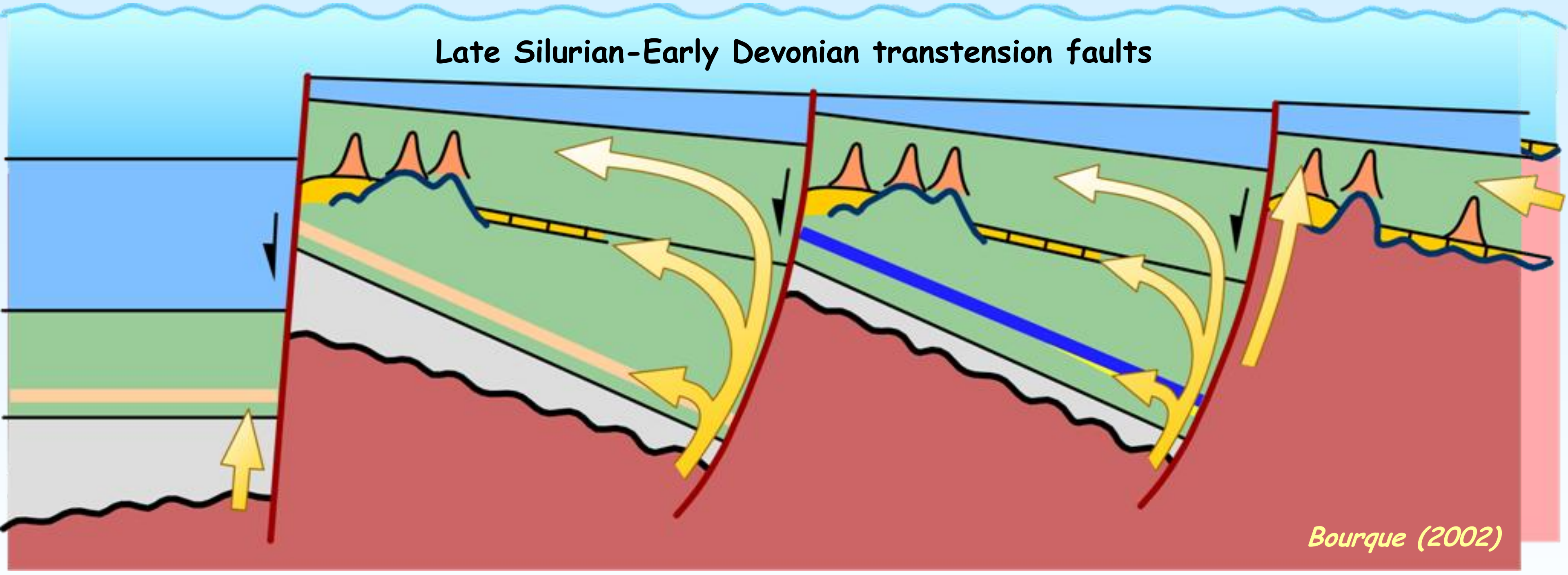




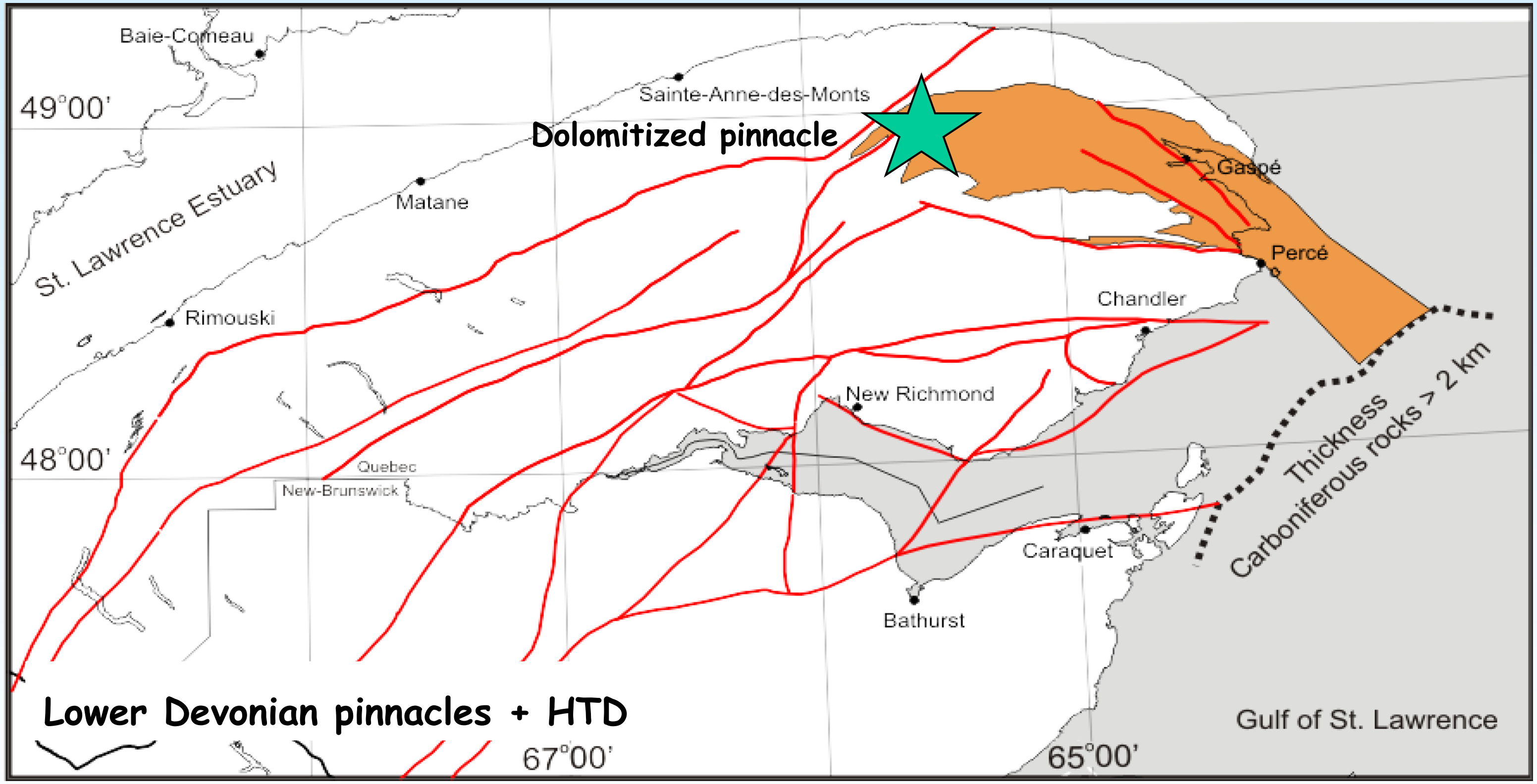
Paleozoic Saddle Dolomites
Mg Isotopes



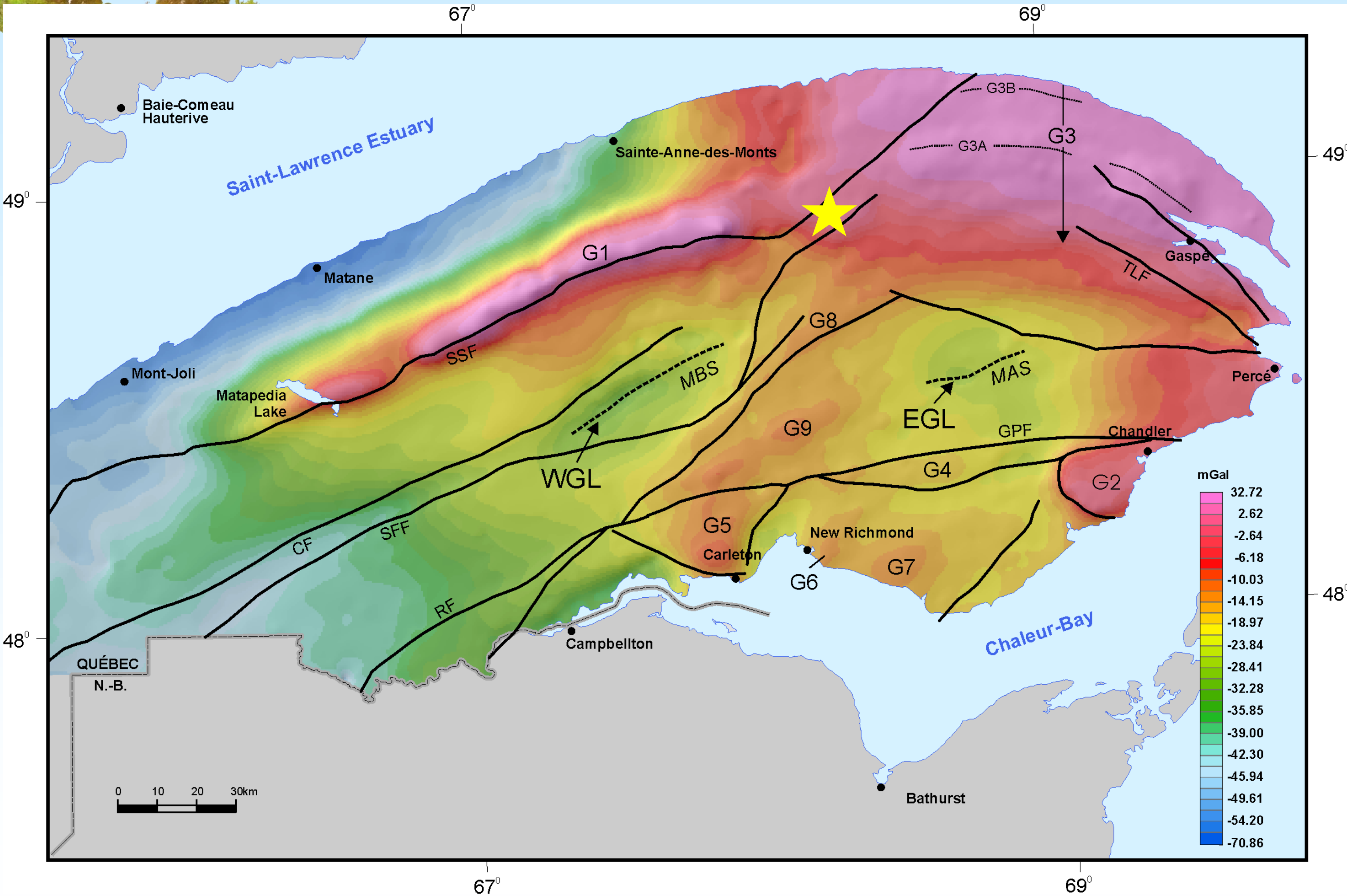
Fault-controlled hot fluid migration in carbonate reservoirs



Lower Devonian HTD in sub-surface Extending the play in NE Gaspé Belt



Bouguer anomaly map



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Pinet et al (2005); Brouillette et al (2006)

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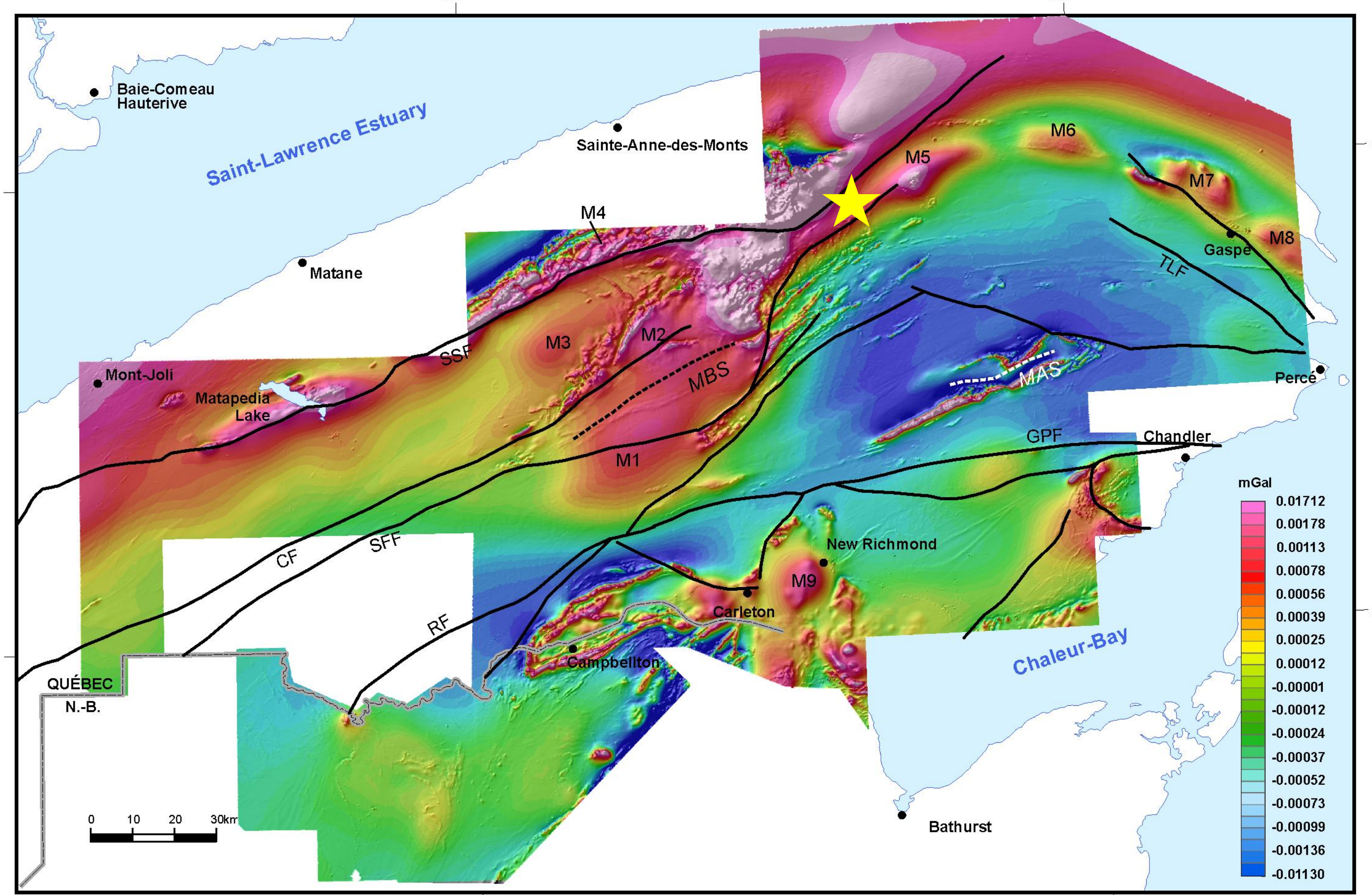
Residual total magnetic field



Pinet et al (2005); Brouillette et al (2006)

CONCLUSIONS

The Lower Devonian West Point pinnacles formed during a major sea level rise – only the bioconstructed margin was able to keep pace with rising sea level

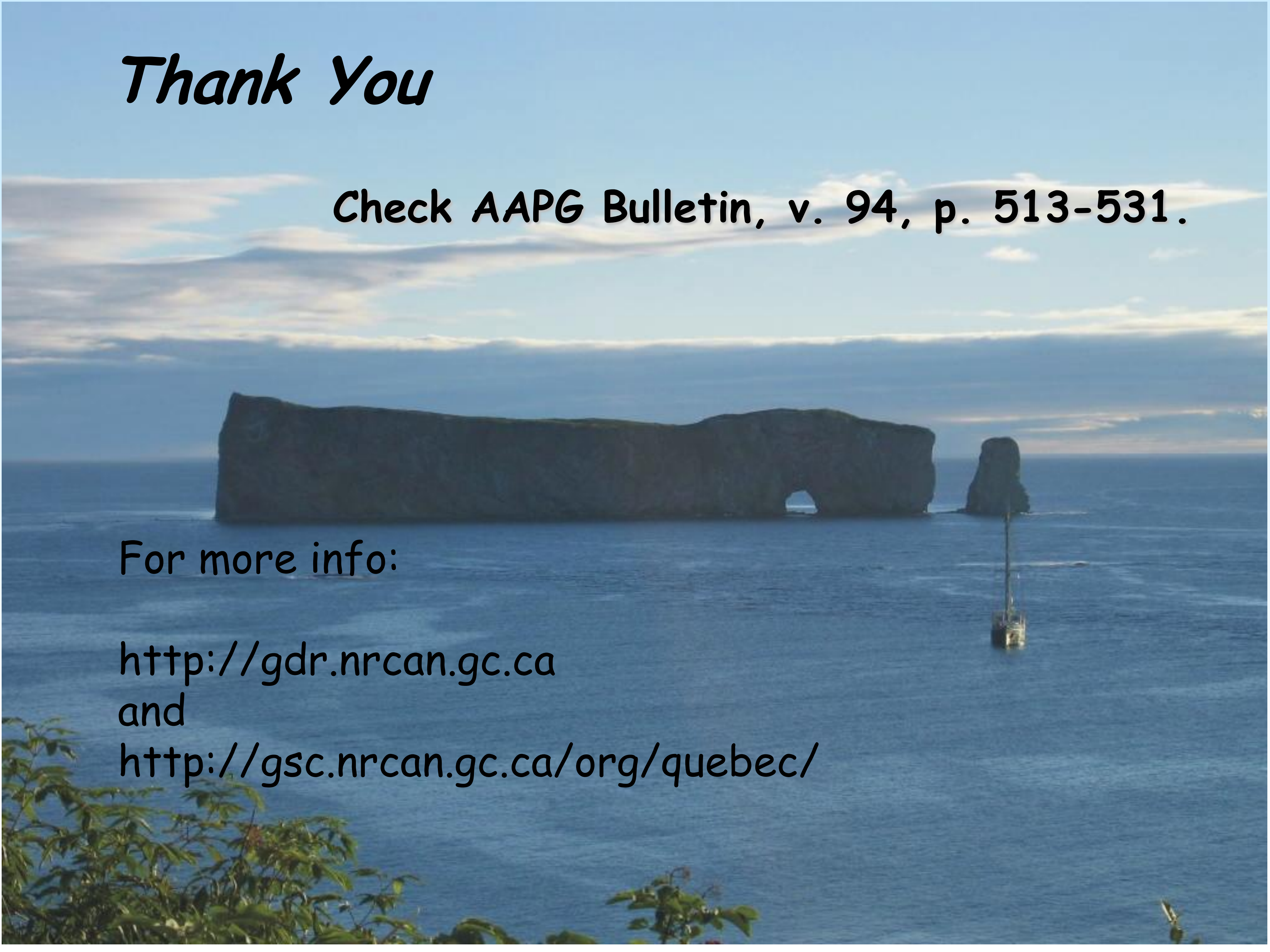
In Northern Gaspé, the pinnacles formed on top of paleotopographic highs left after the Salinic erosion, these highs commonly coincide with the faulted margin of tectonic blocks

These margin-faults were active as extensional and dextral strike-slip from the Late Early Silurian to the Middle Devonian.

This specific pinnacle is at the junction of two major faults; the Shichshock Sud (with Lower Silurian HTD) and the Rivière-Madeleine (with Lower Ordovician HTD) faults.

Hydrothermal dolomitization proceeded from very high temperature magmatic fluids that had some interactions with clastic units

Dolomitization occurred prior to a regional hydrocarbon charge event



Thank You

Check AAPG Bulletin, v. 94, p. 513-531.

For more info:

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and
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