PS Micrometer and Nanometer Porosity in Dolomites of Tremadocian Boat Harbour Formation Carbonates, Western Newfoundland, Canada*

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*Adapted from poster presentation given at 2014 AAPG Annual Convention and Exhibition, Houston, Texas, April 6-9, 2014. Please see closely related article, "Nature and Origin of Dolomitization of the Boat Harbour Formation Carbonates in Northern Peninsula, Western Newfoundland, Canada: Implications for Porosity Controls", Search and Discovery article #50533.

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Abstract

Dolomite rocks are very important hydrocarbon reservoirs. However, besides the fact that the mode of dolomite formation is not fully understood, the origin of porosity associated with dolomitization remains, to some extent, a matter of debate. Study of porosity in dolomites is commonly focused on micrometer (greater than tens of micrometer) scale intercrystalline pores of dolomites that are visible in hand samples and thin sections. Meanwhile, comprehensive formation evaluation process should incorporate the properties of pores at the micrometer to nanometer scale.

Diagenetic dolomite of the Lower Ordovician (Tremadocian) Boat Harbour Formation of the St George Group carbonates in western Newfoundland, Canada was subjected to Focused Argon-ion beam milling (FIB). Thereafter, Scanning Electron Microscope (SEM) was used to examine, at high resolution levels, micrometer to nanometer scale pores hosted in the crystals of the dolomites. The FIB is a novel approach which provides flat surfaces that lack topography due to differential hardness and also reduces the probability of creating artifact induced pores that may be caused by plucking during manual sample polishing. The study shows micro- to nanopores (~500 nm - ~3 μm) that occur in the dolomite crystals. These pores are indiscriminately distributed within the crystals cores, which are rimmed by non-porous cortices. Many of the micro-/nanometer pores have

etched edges. The pores are mostly irregular in shapes but sometimes polygonal. Nanometer pores (200-600 nm) were also found in co-occurring euhedral and framboidal pyrite crystals. It seems that the intracrystalline pores hosted in the dolomite crystals result from preferential dissolution of calcite remnant that hosted within the replacive dolomite crystals, due to the solubility difference between dolomite and calcite minerals. Dissolution may have been caused by local H+ enrichment of the diagenetic fluid associated with pyrite formation. Dolomite crystals from partially dolomitized sections of the same formation contain abundant calcite inclusions as revealed by Energy Dispersive X-ray analyses. On the other hand, the intercrystalline micropores within the pyrite crystals aggregates were likely created during the coalescing of framboidal and euhedral pyrite microrhombs (100 nm -3 μm). Further research will focus on a geometrical 3D reconstruction of the pores to investigate their connectivity.

Micro- and nanometer porosity in dolomites of Tremadocian Boat Harbour Formation carbonates, western Newfoundland, Canada.

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1 Abstract

- Dolomite rocks are very important hydrocarbon reservoirs. However, besides the fact that the mode of dolomite formation is not fully understood, the origin of porosity associated with dolomitization remains, to some extent, a matter of debate. Study of porosity in dolomites is commonly focused on micrometer (greater than tens of micrometer) scale intercrystalline pores of dolomites that are visible in hand samples and thin sections. Meanwhile, comprehensive formation evaluation process should incorporate the properties of pores at the micrometer to nanometer scale.
- Diagenetic dolomite of the Lower Ordovician (Tremadocian) Boat Harbour Formation of the St George Group carbonates in western Newfoundland, Canada was subjected to Argon-ion beam milling. Thereafter, Scanning Electron Microscope (SEM) was used to examine, at high resolution levels, micrometer to nanometer scale pores hosted in the crystals of the dolomites. The ion milling is a novel approach which provides flat surfaces that lack topography due to differential hardness and also reduces the probability of creating artifact induced pores that may be caused by plucking during manual sample polishing.
- The study shows micro- to nanopores (~500nm- ~3µm) that occur in the dolomite crystals. These pores are indiscriminately distributed within the crystals cores, which are rimmed by non-porous cortices. Many of the micro-/nanometer pores have etched edges. The pores are mostly irregular in shapes but sometimes polygonal. Nanometer pores (200-600nm) were also found in co-occurring euhedral and framboidal pyrite crystals.
- It seems that the intracrystalline pores hosted in the dolomite crystals result from preferential dissolution of calcite remnant that hosted within the replacive dolomite crystals, due to the solubility difference between dolomite and calcite minerals. Dissolution may have been caused by local H^+ enrichment of the diagenetic fluid associated with pyrite formation. Dolomite crystals from partially dolomitized sections of the same formation contain abundant calcite inclusions as revealed by Energy Dispersive X-ray analyses.
- On the other hand, the intercrystalline micropores pores within the pyrite crystals aggregates were likely created during the coalescing of framboidal and euhedral pyrite microrhombs (100nm-3µm).
- Late calcite cement probably formed from diagenetic fluid that exhausted its Mg composition after dolomitization episode
- Further research will focus on a geometrical 3D reconstruction of the pores to investigate their connectivity.

2 Study area and Stratigraphic Framework

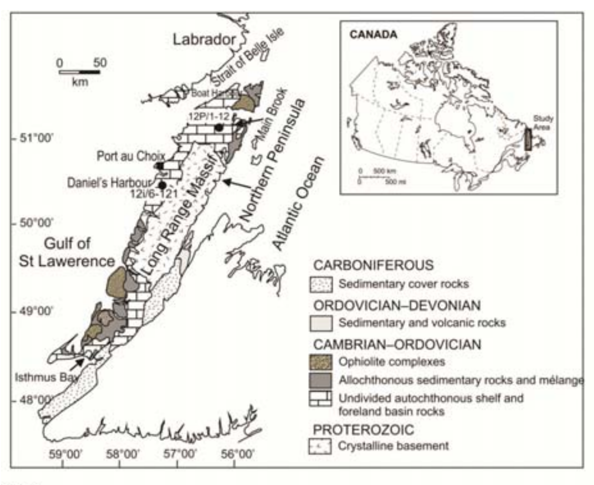


Fig. 2.Map of study area showing location of the sampled drill holes (modified from Zhang and Barnes, 2004).

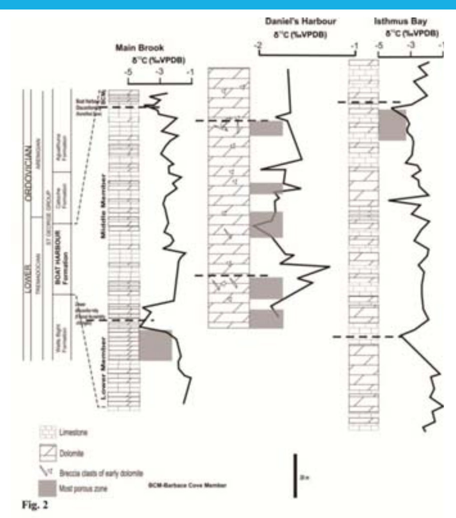


Fig. 2.Stratigraphic log showing dolomite distribution in the cores. Note: Main Brook contains is about 40% dolomitized while Daniel's Harbour is about 100% dolomitized(Olanipekun et al., 2014).

3 Methods

Representative samples of epigenetic dolostones of the Boat Harbour Formation (two drillholes from Main Brook and Daniel's Harbour localities; Fig 1) were chosen for study.

Initial semi-manual polishing showed micrometer to nanometer scale pores and micro inclusions which were thought to could be artifacts

The sample from Daniel's Harbour was then subjected to argon ion milling using Leica Em-TIC 3X cross section polisher. Subsequently, Scanning Electron Microscope (SEM) was used to examine the pores, pyrite crystals and crystal-hosted calcite inclusions.

Additionally this method provides nanometer to micrometer scale e calcite cement that were not abundant in hand polished samples were

Fig. 3A.Mounting stage of Leica Em-TIC 3X cross-section polisher.

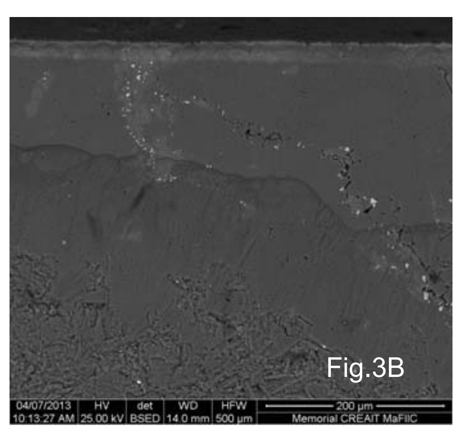


Fig. 3B.Milled and Unmilled (semi-manual polished) area of the dolomite sample. Note the topography of the two areas.

4 Result and Interpretation

4.1 Micro- and nano- pores in ion-milled dolomite crystals

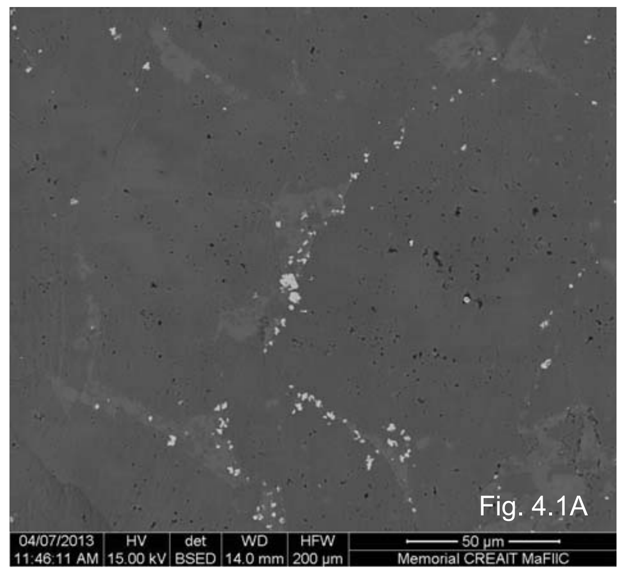


Fig. 4.1A.Ion milled area showing intercrystalline cement and intracrystalline pores. Note the scale.

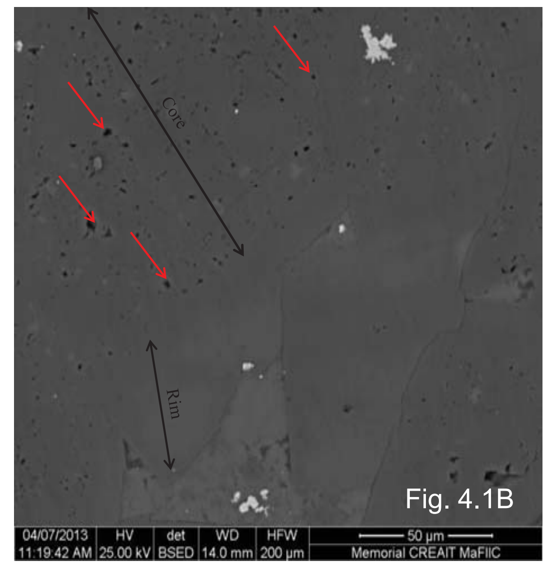
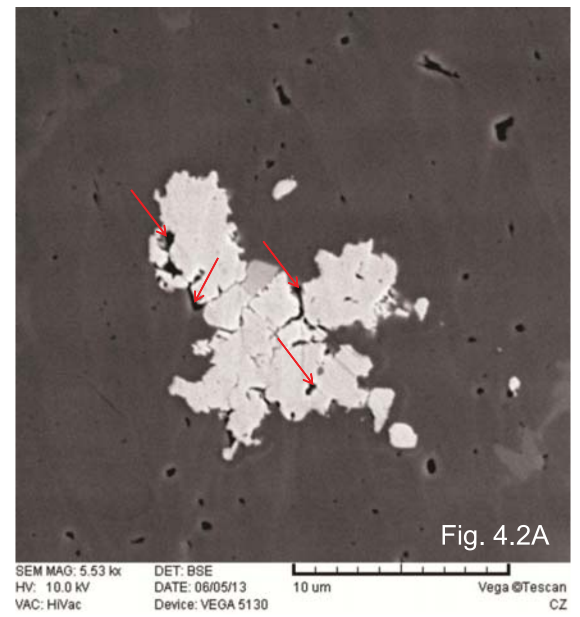
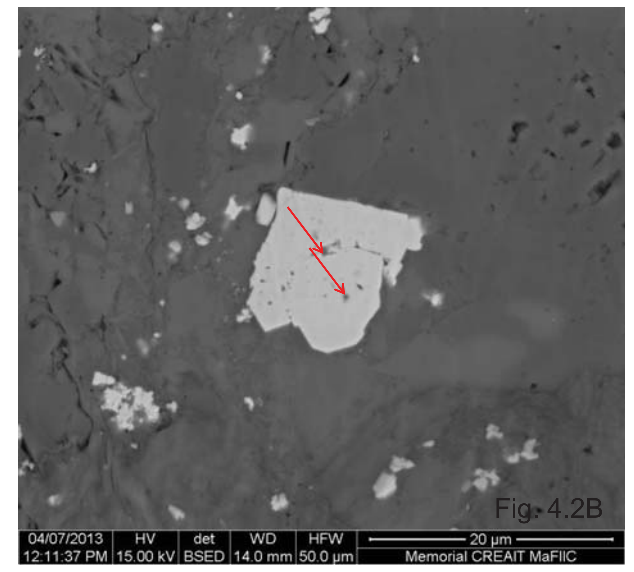


Fig. 4.1B.Ion milled view of dolomite crystal showing intra-crystalline nano-meter pores dominated core and non-porous rim.

4.2 Nanopores in ion-milled pyrite crystal aggregates

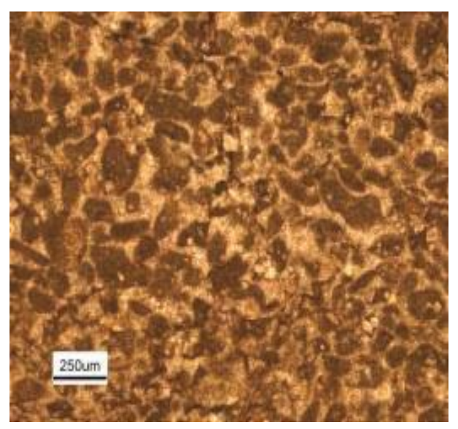




Figs 4.2A and 4.2B. Nano intercrystallinre pores within pyrite crystals aggregate as a result of their coalescence during recrystallization.

4.3 Conceptual paragenetic process: Micrometer to nanometer scale pores and calcite inclusions

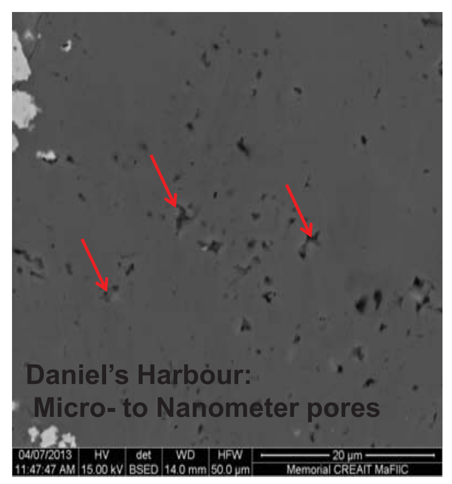
Tremadocian → Present

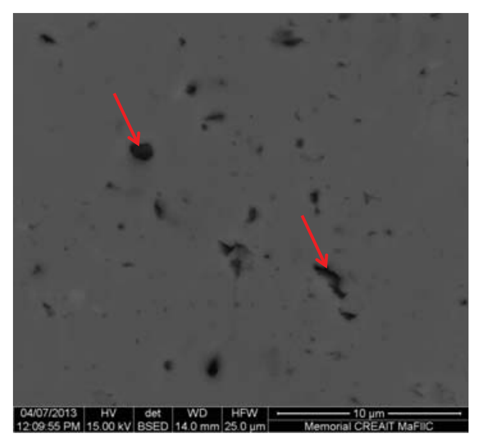


Tidal flat lime mud dominated deposition that formed on passive margin of the Iapetus ocean during the Early Ordovician (Tremadocian).

Shallow to intermediate burial Diagenesis :

Incomplete dolomitization with remnant calcite inclusions(RCI) and little pore development.

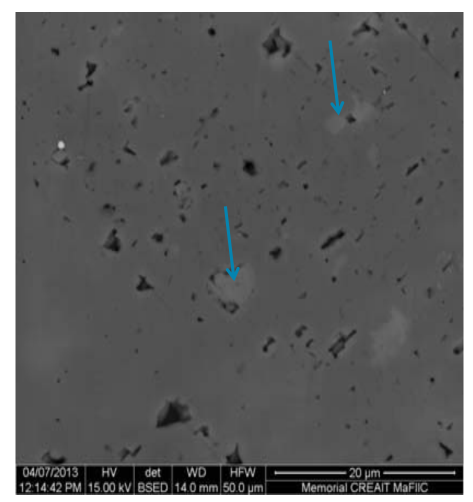




Intermediate burial diagenesis: Pervasive dolomitization:

Dissolution of RCI as a result of solubility difference between calcite and dolomite.

Generation of micro- nanometer (red arrows) scale pores in dolomite crystals.



Deeper intermediate burial diagenesis:

Late calcite cement (blue arrows) precipitation into micro- to nanometer scale pores.

5 Works Cited

Olanipekun, B., Azmy, K., & Brand, U. (2014). Dolomites of the boat harbour formation in the northern peninsula, western newfoundland, canada: Implications for dolomitization history and porosity control. *AAPG Bulletin, 98*(4), 765-791.

Zhang, S., and C. R. Barnes, (2004). Arenigian (Early Ordovician) sea-level history and the response of conodont communities, Western Newfoundland: *Canadian Journal of Earth Sciences, 41*(7; 7), 843-865.

Leica EM TIC 3X images: http://www.leica-microsystems.com/products/em-sample-prep/industrial-materials/solid-state-technology/details/product/leica-em-tic-3x/showcase/

6 Acknowledgements

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