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

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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.

1.1 Nanopores in ion-milled pyrite crystal aggregates

The study shows micro- to nanopores (~500nm- ~3µm) that occur in the dolomite crystals. These pores are indiscriminately distributed within the crystal cores, which are trimmed by non-porous cortices. Many of the micro-crystalline 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. Nanometer pores were also present within the pyrite crystals aggregates. 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.

1.2 The study shows micro- to nanopores (~500nm- ~3µm) that occur in the dolomite crystals. These pores are indiscriminately distributed within the crystal cores, which are trimmed by non-porous cortices. Many of the micro-crystalline 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.

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2 Study area and Stratigraphic Framework

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 brought to could be artificats. 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 the method provides nanometer to micrometer scale e calcite cement that were not abundant in hand polished samples were

3 Methods

Subjecting the sections to high resolution imaging techniques such as Scanning Electron Microscope (SEM) is critical in the determination of pore type and size. The SEM images can be used to interpret the origin of pores and their implications on the hydrocarbon potential of the dolomite reservoirs.

3.1 Setting the milling angle

Fig. 3A. Mounting stage of Leica Em-TIC 3X cross section polisher. Area of the dolomite sample. Note the topography of the two areas.

Fig. 3B. Ion milled area showing intercrystalline cement and intracrystalline pores. Note the scale.

Fig. 4.1A. Ion milled view of dolomite crystal showing intra-crystalline nanopores. Note the scale.

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

Fig. 4.1B. Ion milled view of dolomite crystal showing intra-crystalline nanopores

4.2 Nanopores in ion-milled pyrite crystal aggregates

Fig. 4.2A. Nano crystalline pores within pyrite crystals aggregate as a result of their coalescence during recrystallization.

Fig. 4.2B. Nano crystalline 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

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

Deep water carbonates: Variety of sedimentary structures, CCO and dolomite porosity.

Shallow to intermediate burial Diagenesis: Complete dolomitization without remnant calcite inclussions (RCI) and little pore development.

Intermediate burial diagenesis: Pervasive dolomitization: Dissolution of RCI as a result of solubility difference between calcite and dolomite.

Intermediate burial diagenesis: Dolomite cement precipitation into micro- to nanometer scale pores.

Shallow to intermediate burial Diagenesis: Complete dolomitization without remnant calcite inclussions (RCI) and little pore development.

5 Works Cited

6 Acknowledgements

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