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Mg isotopes and hydrothermal saddle dolomites; current data for Paleozoic dolomites of eastern Canada and implications for Mg source

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Introduction

Hydrothermal dolomites are host to major hydrocarbon fields in North America and abroad. The process leading to the formation of these high temperature dolomites is controversial with end-members that consist of 1) early, tectonically-controlled, high temperature fluid migration upward along faults and laterally in porous limestones and 2) late, burial-dominated, regional migration of high-temperature formation brines. In both cases, large amounts of magnesium (Mg) are needed for the formation of the dolomite, either as limestone replacement or void-filling cement. We present magnesium stable isotope ratios in saddle dolomites as a potential tool for recognition of Mg source and hence new data that could be of use in the ongoing debate.

Material and Methods

In the Paleozoic of eastern Canada (Fig. 1), saddle dolomites interpreted as hydrothermal in origin are recognized in Lower Ordovician shallow marine platform and slope carbonate in Quebec and Newfoundland, in Middle to Upper Ordovician carbonate ramp facies also known as the Trenton-Black River (TBR) interval, in the Lower Silurian carbonate ramp and in Lower Devonian pinnacle reef both in northern Gaspé Peninsula. The various occurrences of saddle dolomites that have been analyzed are distributed from southern Quebec to the Gaspé Peninsula with the host successions overlying lithologically dissimilar basements with the potential of having Mg derived from diverse sources. The saddle dolomite samples were chemically characterized (ICP-ES) and their $\delta^{26/24}Mg_{NBS88a}$, $\delta^{25/24}Mg_{NBS88a}$ and $\delta^{26/25}Mg_{NBS88a}$ ratios measured (MC-ICP-MS).

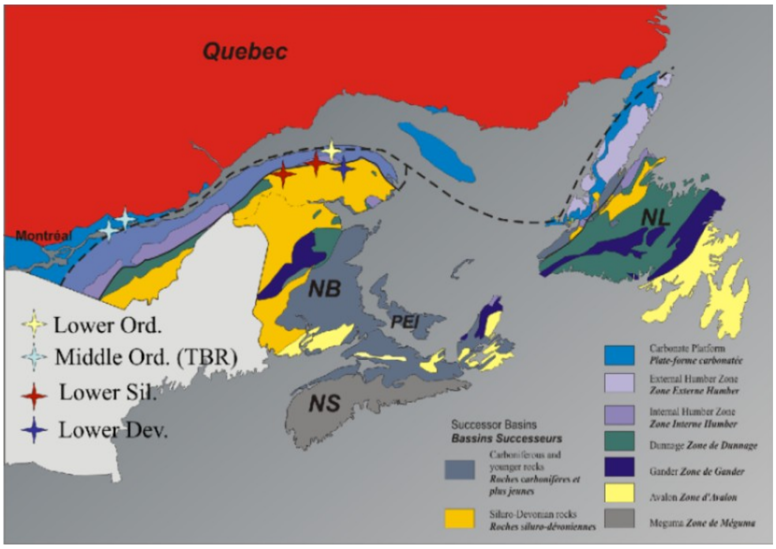

Fig 1: Simplified geological Paleozoic map of eastern Canada with the location of saddle dolomite samples analyzed for their Mg isotopes.

Results

The saddle dolomites in Lower Silurian carbonates in northern Gaspé (Fig. 2a, b) are related to fluid circulation along the Shickshock Sud Fault. Their Mg was hypothesized to have been sourced, through active foreland faulting, from underlying Ordovician ultramafic slivers (Lavoie and Morin, 2004). The saddle dolomite precipitated from a saline (21-28 wt% $NaCl_{equiv.}$), high temperature fluid (150 to 200°C) with very positive $\delta^{18}O_{SMOW}$ values (+ 8 to + 10l) (Lavoie and Chi, 2010). In northern Gaspé, one field occurrence of Lower Ordovician slope carbonates was found associated with the Rivière Madeleine Sud (Fig. 2c, d). However, temperature data are not available from these saddle dolomites. These first two intervals with saddle dolomites are characterized by $\delta^{26/24}Mg_{NBS88a}$, $\delta^{25/24}Mg_{NBS88a}$ and $\delta^{26/25}Mg_{NBS88a}$ values lower than or around 0l (Fig. 3).

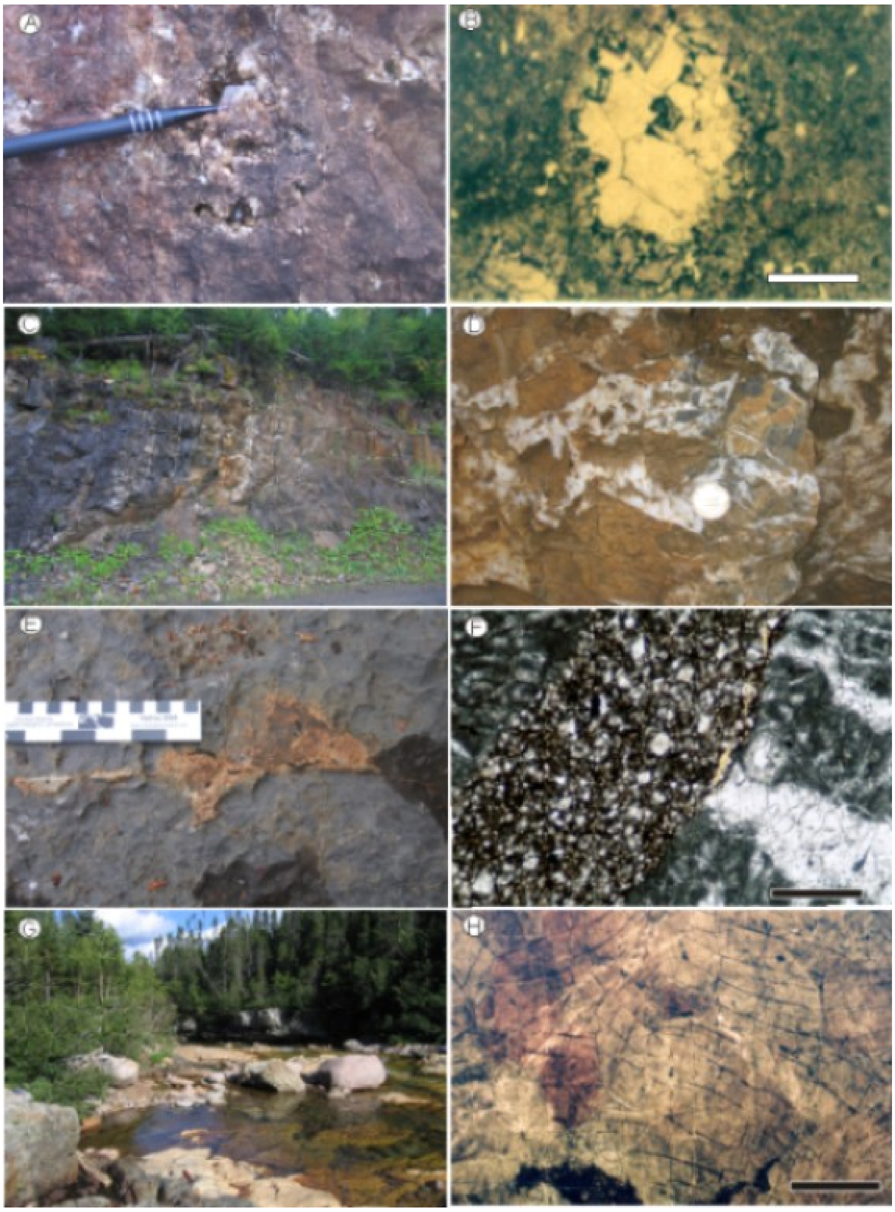

Fig 2: Selected field and microscope views of Paleozoic saddle dolomite occurrences. Scale bars are 0,1 mm. See text for details.

Middle Ordovician (or TBR) saddle dolomites are found in the St. Lawrence Platform and on Anticosti Island (Lavoie et al., 2005; Lavoie and Chi, 2010). They are, in the field and subsurface, associated with various faults that connect with the underlying Precambrian basement (Fig. 2e, f). The saddle dolomites precipitated out of a saline (20-25 wt% $NaCl_{equiv.}$), high temperature fluid (90 to 120°C) with positive $\delta^{18}O_{SMOW}$ values (+3 to +6l) (Lavoie and Chi, 2010). These saddle dolomites are characterized by positive $\delta^{26/24}Mg_{NBS88a}$, $\delta^{25/24}Mg_{NBS88a}$ and $\delta^{26/25}Mg_{NBS88a}$ values over +1, +0.4 and +0.5l, respectively (Fig. 3).

A massively dolomitized Lower Devonian pinnacle reef in northern Gaspé (Lavoie et al., 2010) is found at the junction between the Shickshock Sud and Rivière Madeleine Sud faults. The dolomitized body occurs 50 km SSW of the Lower Ordovician dolomite and 15 km to the E of an occurrence of Lower Silurian dolostone. The massive replacement saddle dolomite (Fig. 2g, h) formed from a saline (9 to 17 wt% $NaCl_{equiv}$), very high temperature fluid (300 to 350°C) with elevated $\delta^{18}O_{SMOW}$ values (+7 to +10l; Lavoie et al., 2010). Even though the dolomites are adjacent to the ultramafic slivers, they are characterized by positive Mg isotope ratios (Fig. 3) that strongly contrast from those of the nearby Lower Ordovician and Lower Silurian dolomites of northern Gaspé. This specific massive replacement dolomite has been interpreted to originate from magmatic fluid and not from basinal brines that interacted with the ultramafic slivers in the adjacent basement (Lavoie et al., 2010); the new Mg stable isotope data indicates a different source of Mg compared with the nearby Lower Ordovician and Lower Silurian dolomites even though elements other that source alone could be involved in Mg isotopic ratios.

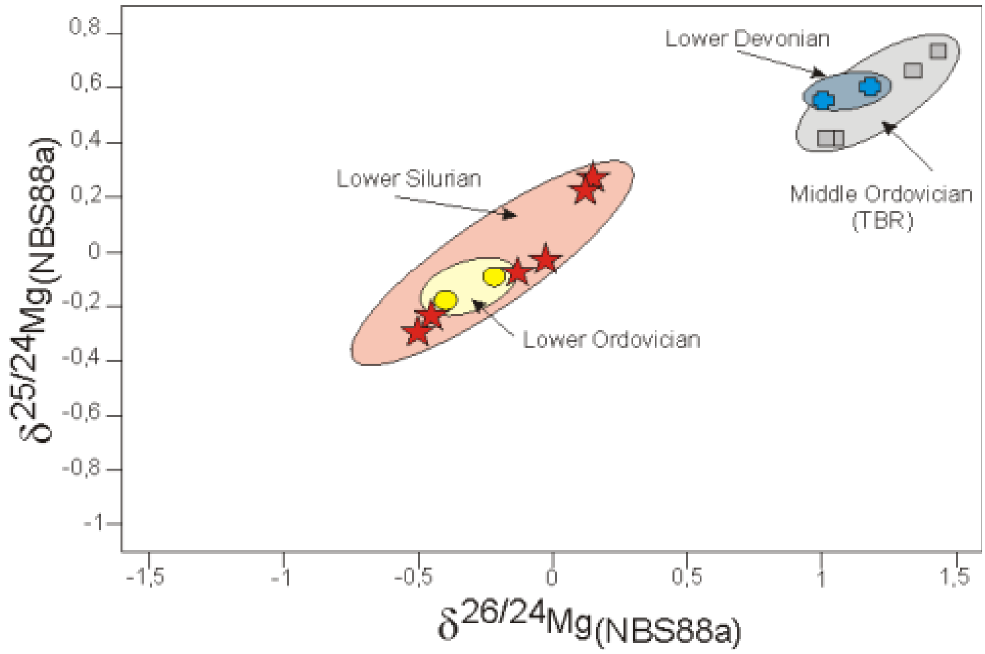

Fig. 3: Magnesium isotope ratios for selected Paleozoic saddle dolomites in Quebec.

There is no significant correlation between the chemical composition of the matrix and the Mg isotope ratios, suggesting that the measured Mg isotope variations are not a product of instrumental matrix effects; it is, therefore, tentatively proposed that the isotopic variations reflect different sources of Mg for dolomitization, although conditions of dolomitization (e.g., temperature, rate of dolomite growth, precipitation versus replacement phases) may also have controlled isotopic fractionation between the dolomitizing fluid and the dolomite itself and have influenced the measured values. At the time of writing of this abstract, procedures are being developed for chemical separation of Mg from complex matrices, which will allow isotope ratios of potential Mg sources for dolomitization in the Gaspé (Lower Ordovician ultramafics and shales) and southern Quebec (Upper Ordovician shales) to be determined. Results should be available for discussion at the time of the meeting.

Conclusions

The current data suggest that Mg isotopes can offer important insights into sources and processes involved in dolomitization but further research is needed to better constrain the applicability of this new tool.

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