Mg isotope tracing of paleofluid migration during dolomite formation in the Williston Basin

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Dolomite in the Williston Basin is more common below the Devonian Prairie Evaporite than above. It is therefore not surprising that brine reflux is the most often cited model for dolomitization in the Williston Basin. However, $^{87}Sr/^{86}Sr$ ratios of two prominent dolomite bodies, the Ordovician Red River Formation and the Devonian Winnipegosis Formation, are higher than contemporaneous seawater. Instead suggesting that the dolomitizing fluids moved upwards from deeper levels in the basin where formation waters in the present day are known to be very radiogenic. Here we explore the possibility that Mg isotopes may trace the direction of fluid-flow during dolomitization. Dolomite preferentially takes up light Mg isotopes during its formation, thus enriching the dolomitizing fluid in heavy isotopes. Accordingly, dolomite should increase its $\delta^{26}Mg$ value in the direction of paleo-fluid flow. We looked for gradients in $\delta^{26}Mg$ values that may be preserved in the Red River and Winnipegosis dolomites, and found $\delta^{26}Mg$ values increasing from the deep center (–1.9‰) to the edge of the basin (–1.4‰) in all directions. We interpret this finding as evidence that the dolomitizing fluids that dolomitized both units ascended, rather than descended, through the Paleozoic carbonate succession, which is consistent with the radiogenic Sr isotope signatures in the dolomites. The burial history of the basin is punctuated by two heat flow anomalies, one in the early Carboniferous and the other in the early Cretaceous. Fluid movement at these times are indicated by the resetting of thermal remnant magnetization in dolomite and evaporate minerals in the basin. We speculate that one or both of these heating events triggered Mg-bearing formation waters to ascend from the fractured crystalline basement through a series of down-to-the basement faults located in the center of the basin. The ascending fluids then flowed laterally along the most permeable sedimentary units to the basin margins, partially dolomitizing the units composed of carbonate sediment. If this interpretation is correct, the Prairie Evaporite basin was not the source of the dolomitizing fluids, but the salt deposit blocked the upwardly flowing fluids from dolomitizing the overlying carbonates.