Conditions of Quartz Cementation in Mt. Simon Sandstone: Evidence from in situ Microanalysis of Oxygen Isotopes*

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Abstract

Samples of the Mt. Simon Formation have been analyzed in situ for oxygen isotope ratio (δ¹⁸O, 10μm and 3μm spots) from three depth intervals in Illinois Basin cores as well as outcrop samples from Wisconsin. Diagenetic cements account for a major fraction of the intergranular volume of many samples. Almost all core samples contain quartz cements that occlude between 30 and >90% of the original porosity, while overgrowths in outcrop samples are quartz and feldspar which fill between 0 and 50% of original porosity. This reduction in porosity has a significant effect on permeability and reservoir quality. The δ¹⁸O of diagenetic quartz cements allows estimation of the variability in precipitation temperature, if δ¹⁸O (fluid) is known. Alternatively, changes in fluid source can be detected if thermal history is known. Values of δ¹⁸O of detrital and pore-filling quartz were measured on an IMS-1280 ion microprobe. δ¹⁸O values for the detrital quartz are similar across all depths (9.8 ± 4.2‰ VSMOW) consistent with a source dominated by igneous rocks. The quartz cements are distinctly higher in δ¹⁸O than detrital grains and define a trend to lower values deeper in the basin (from 27.9 to 15.6‰ for the latest cement in each overgrowth). In a fluid-dominated system, the lower values are expected for quartz precipitated under warmer conditions, suggesting that the decrease in δ¹⁸O down-dip in the basin is largely dominated by increasing burial temperature.

In addition to the basin-wide trend to lower δ¹⁸O values with increasing depth, most individual overgrowths show a trend of decreasing δ¹⁸O from early to late quartz growth. This suggests that cement growth started early in the burial history, continued while rocks were heated during burial, and ceased before unroofing and basin uplift. δ¹⁸O zonation was measured in 84 overgrowths. Most overgrowths show a decrease in δ¹⁸O, on average by 2.1‰ (max. = 8.7‰), as growth proceeded. If δ¹⁸O (H₂O) = -3‰ for a fluid-dominated system, this indicates that cements grew from 30-160°C consistent with published temperatures from fluid inclusions and vitrinite reflectance in the Illinois Basin.

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These results indicate that the majority of quartz cements formed in the Mount Simon sandstone during burial and heating. There is no evidence in these samples of later quartz cementation or cross-cutting cements.

References


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Abstract

Microanalysis of oxygen isotopes in quartz cement of the Mt. Simon Sandstone of the Illinois Basin shows a decrease in δ¹⁸O down-dip in the basin is largely dominated by increasing burial. However, overgrowths on detrital grains show a decrease in δ¹⁸O over time in cores from the Illinois Basin. These results indicate that the δ¹⁸O of cement is controlled by both δ¹⁸O of the fluid and the burial history. The δ¹⁸O of the fluid is diagnostic for determining the δ¹⁸O of the fluid at the time of cementation.

Sample Preparation

Two rock chips are mounted in a one-inch epoxy mount with quartz standards in the center. The samples are then polished to a shiny surface. The polished samples are then coated with a thin layer of gold and imaged with a scanning electron microscope (SEM).

Isotope Fractionation

The δ¹⁸O value of a quartz overgrowth precipitating in equilibrium with a fluid in a system with a high water-rock ratio is a function of the temperature at which it precipitates and the δ¹⁸O of the fluid. Using calibrations of δ¹⁸O versus temperature it is possible to calculate cement temperatures with an assumed constant δ¹⁸O of the fluid. If this χ value is not known it is possible to calculate δ¹⁸O of the fluid from the calculated cement temperatures.

References


Conclusions

Values of δ¹⁸O measured in optical quartz overgrowths from the Mt. Simon Sandstone in the Illinois Basin indicate that cements began to grow at near surface, low temperature conditions. Cements continued to grow during burial and heating and record this history. The variability of δ¹⁸O can be explained simply with heating due to burial and does not require isothermal modification of pore fluid composition as proposed by Chen et al. (2001).
Maps of Illinois Basin from MGSC
Blue circles are locations of cores used in this study

Gamma ray and Neutron logs of core C12996 (UPH-3) Purple lines indicate locations of some of the samples used in this study

Multi-spot traverses. Large spots are 15 μm and are represented by red dots on graphs. Small spots are 3 μm and are represented by black diamonds on graphs.