Low temperature quartz cementation of the Upper Cretaceous white sandstone of Lochaline, Argyll, Scotland.

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Introduction

Quartz cements grow in the pore space of sandstones, reducing porosity and permeability. The compositions and origins of palaeo-fluids in sedimentary basins are recorded by the geochemical signatures of the quartz which precipitate from these fluids. Predicting quartz cement distribution requires reconstruction of palaeo-fluid movement and therefore a knowledge of sources and pathways of fluids, the temperature distribution, and the origins of silica for cementation. A major uncertainty in predictive modelling of quartz cementation is the source of silica. The objective of this project was to examine the use of high spatial resolution silicon isotope ($^{30}Si/^{28}Si$) micro-analysis of quartz cements in an economically important quartz glass sandstone to distinguish the sources of silica.

The ion microprobe is capable of analysing $\delta^{30}Si$ and $\delta^{18}O$ in quartz in-situ with a spatial resolution of ~20µm and with an analytical precision of ±0.7‰ and ±1‰ respectively. This enables resolution of biogenic ($\delta^{30}Si$ ~ -1-2‰) from detrital silica ($\delta^{30}Si$ ~0‰) sources in quartz overgrowths. Also, the oxygen isotope analyses of the same samples help constrain quartz cement precipitation temperature and the composition of the pore fluid during quartz cementation.

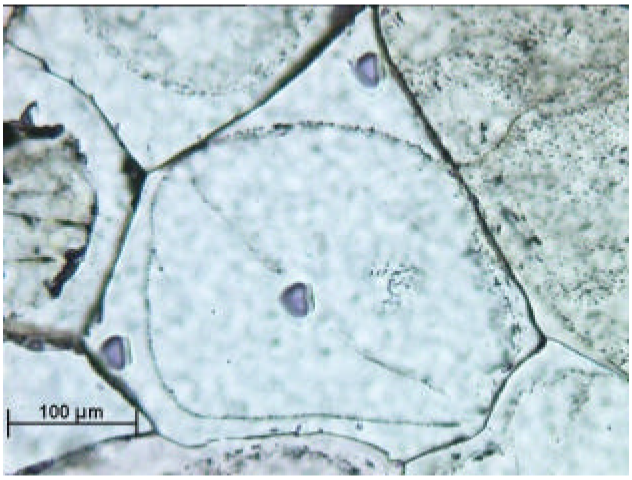
Lochaline Sandstone

The Lochaline quartz cements were sampled from the Upper Cretaceous Lochaline Sandstone from Argyll western Scotland (Humphries, 1961). Potential silica sources in most sandstones are numerous, and include detrital quartz and feldspar dissolution, clay mineral reactions, and dissolution of biogenic silica from siliceous sponge spicules. The Lochaline sandstones are unusual, however, in being exceptionally pure quartz sandstones (99.95%SiO_2). Also, they are mostly uncemented and friable, except for two completely quartz cemented bands approximately 1m thick near the top of the sandstone. These quartz cemented bands are important for mining operations, but their origins had, until now, remained obscure. The sandstone is mined for high grade military optics.

Analytical parameters

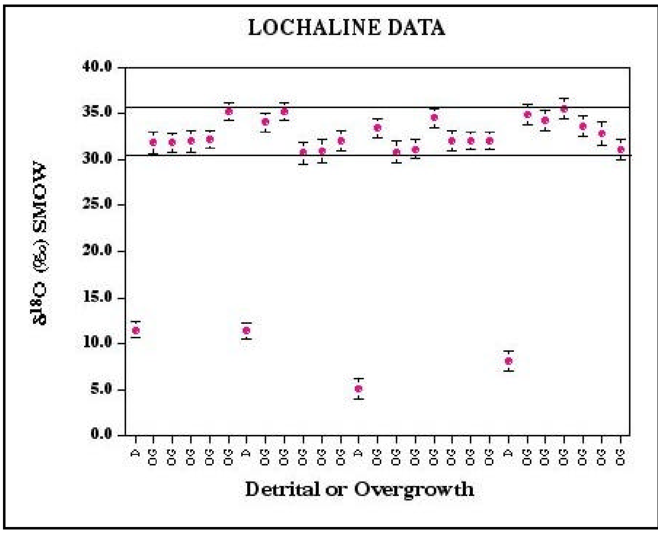
Silicon isotope analyses were made with a primary beam of $^{16}O^-$ from the duo-plasmatron source and a primary beam current of 8nA. The primary beam was defocused to give a spot size of ~ 20µm diameter. High energy secondary ions of ^{28}Si and ^{30}Si were collected using a sample energy offset of 120eV±20ev, which yielded a 2e6cps for ^{30}Si.The analytical error (‰) for $^{28}Si/^{30}Si$ analyses, based on counting statistics, was ±0.7‰. At the mass resolution used (~500) the interefence of $^{28}Si+H_2$ and $^{29}Si+H$ are not resolved and will a enhance the ^{30}Si signal by ~0.002%.

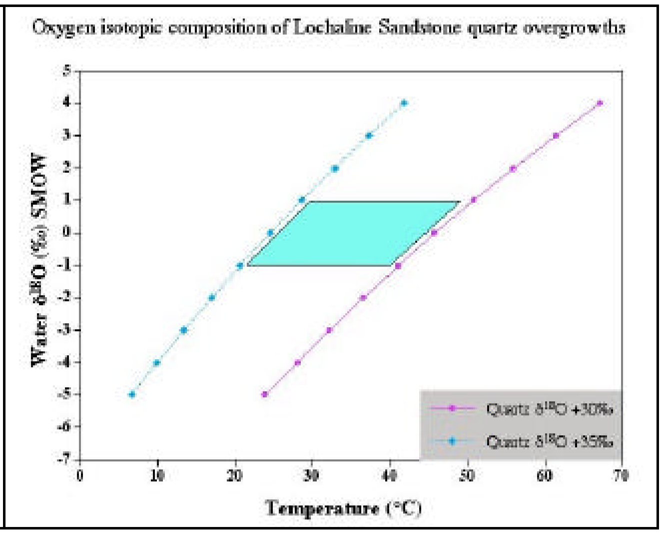
Oxygen isotope analysis of diagenetic quartz in the Lochaline Sandstone were made with a primary beam of 133Cs+ defocused to ~20µm accelerated on to a Au-coated polished 1" round thin section with a net impact energy of 14.15keV. Charge neutralisation of analysed areas was effected using the Cameca normal-incidence electron flood gun. High energy negative secondary oxygen ions ($^{16}O^-$ and $^{18}O^-$) were extracted following techniques developed by Hervig et al. (1992).



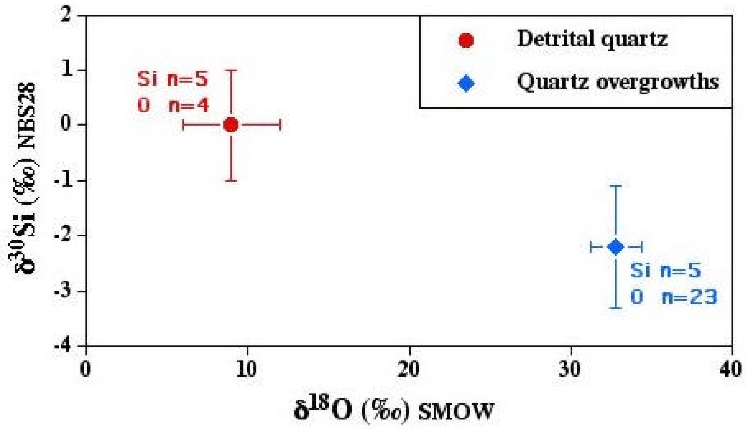
~20mm Oxygen Isotope Pits in Detrital and Overgrowths of quartz.

Results

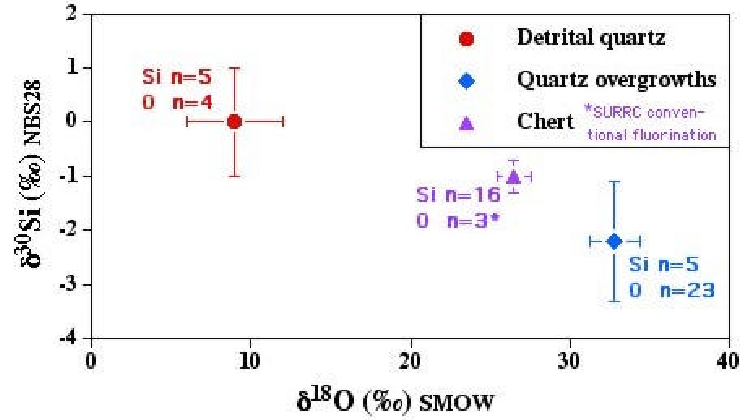




The consistently high overgrowth $\delta^{18}O$ values of 30-35‰ combined with independent fluid inclusion analyses, show that the quartz cements grew at temperatures below 60°C from a fluid with a mixed marine/meteoric water composition. Such low temperature quartz precipitation is very unusual.



The silicon isotopic composition of the quartz overgrowths is low (mean -2.2‰) suggesting a biogenic silica source.



A thin chert horizon which overlies the Lochaline Sandstone also contains diagenetic quartz with negative δ^{30}Si values

Interpretation

In Ulster, Upper Cretaceous sandstones are overlain by chalks which in places contain abundant siliceous sponge spicules. In western Scotland, the chalk was largely eroded during uplift associated with Tertiary igneous activity. We hypothesise that in the Lochaline area, during subaerial uplift and erosion of the chalk the sponge spicules contained in the chalk were dissolved. Some ofthe dissolved silica precipitated as the chert which records the former stratigraphic position of the chalk, and some of the silica precipitated in the underlying sandstones to form the heavily quartz cemented horizons observed today. The extensive lateral continuity of the quartz cemented horizons suggests that they precipitated at an interface, such as at a water table as seen in the Fontainbleau Sandstone (Thiry et al., 1988), which varied in depth to form the two quartz cemented horizons now present.

General Conclusions and Future Work

We have shown that stable silicon and oxygen isotopes in diagenetic quartz provide a powerful tool for constraining sources of silica and timing of cementation. This new combination of tracers will support the reconstruction of diagenetic histories and quality controls in aquifers and reservoir sandstones.

References

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