Mechanisms of Metamorphic Fluid Flow in Marble

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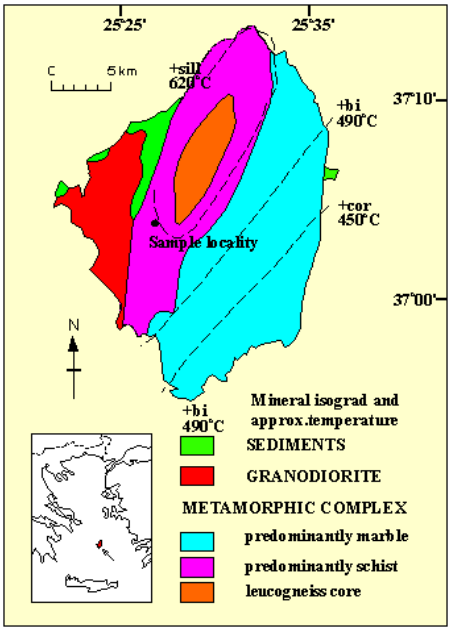
Introduction

Modification of the stable isotope compositions of marbles in metamorphic terrains by fluid infiltration has been extensively modelled to try to constrain both the magnitudes and time scales of metamorphic fluid fluxes. Models make important but unsubstantiated assumptions about fluid transport through rocks. Understanding the grain-scale flow regime is fundamental to modelling fluid transport at larger scales. This project combines textural observations and ion microprobe analyses of marbles from Naxos to test the assumptions upon which modelling of fluid flow is based and to identify fluid transport mechanisms.

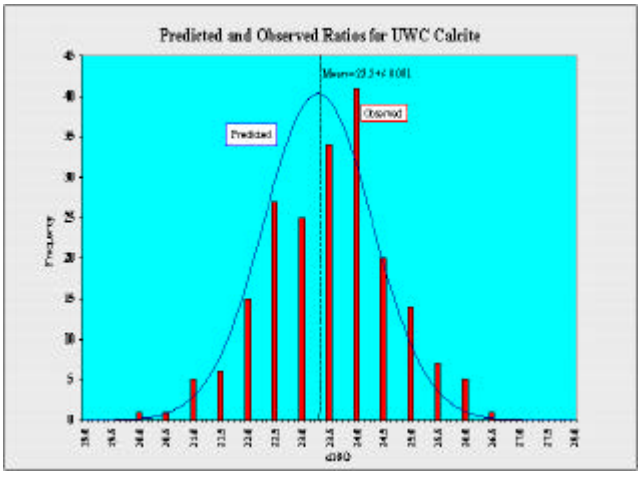


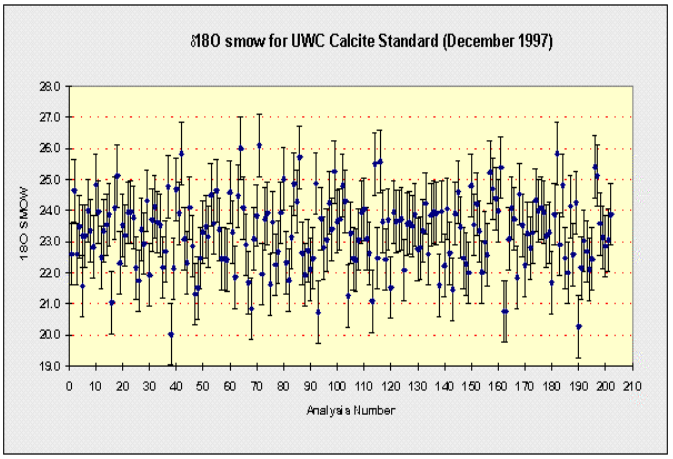
Methods

A series of marble samples were collected from schist-marble contacts of varying metamorphic. Samples from 12 localities were selected for ion microprobe analysis.

Oxygen isotope analyses were made using a 25µm diameter primary Cs+ ion beam High energy secondary ^{18}O- and ^{16}O- ions were collected, using an energy offset of 350eV with an energy window of ±25eV, with counting times of 600 and 120 s respectively. This resulted in 10e6 counts (on ^{18}O) per analysis giving a precision of ±1 per mil. The standard (UWC) was measured routinely throughout the secession.

Standard Information

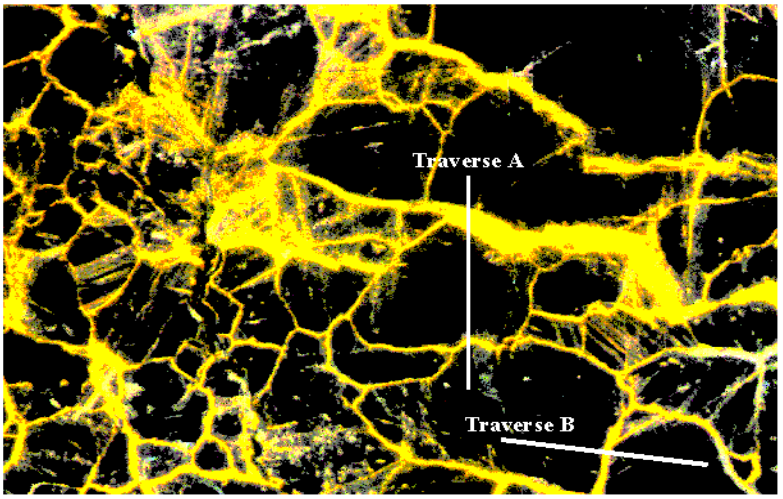




Results

Samples from localities close to the granodiorite on the western side of the island showed large variations in $\delta^{18}O$.

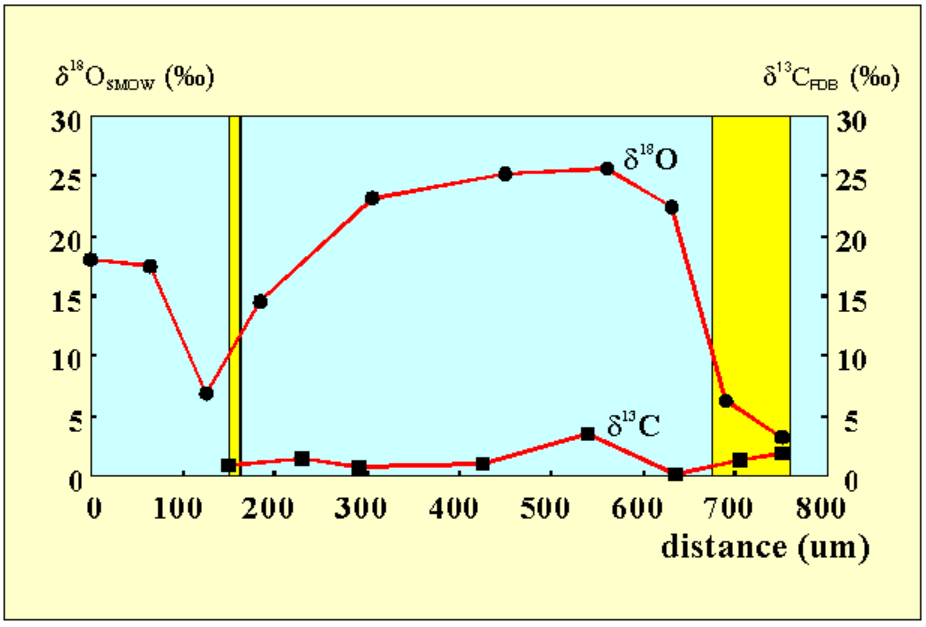
We have made a detailed study of one locality where infiltration occurred by channelling of fluid along cracks and grain boundaries within the marble. To constrain the timescale of this infiltration, a total of 10 grain-scale traverses were made crossing a range of features such as cracks, grain boundaries, grain centres and cleavage.



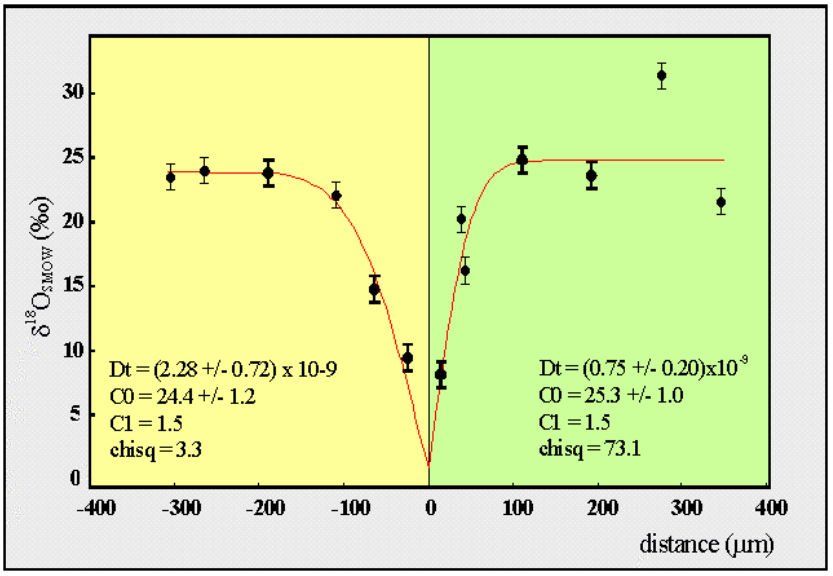
Cathodoluminescence Montage Showing the Position of Two d18O Traverses

Each analysis was standardised against crystals of University of Wisconsin Calcite (UWC). The $\delta^{18}O$ could be correlated with textural features and trace element compositions.

Discussion



Large variations are observed in δ18O (over 20 per mil). In contrast, no significant variation in δ13C is observed. The infiltrating fluids were likely to have been very water-rich. Very low values of δ18O at grain edges suggest a meteoric source for fluids rather than a 'metamorphic' source as previously assumed.



The resulting $\delta^{18}O$ profiles fit curves predicted for modification by volume diffusion of O in calcite. The degree of alteration in $\delta^{18}O$ depends on the original $\delta^{18}O$ of the calcite (C0), the $\delta^{18}O$ of the infiltrating fluid (C1), the diffusion coefficient of O in calcite (D) and the timescale (t). Preliminary modelling of this data gives estimated values of Dt in the range 0.74 to 3.78 x 10-9 m2. Using an estimated temperature of 620 ± 50°C (Baker et al. 1989) and the diffusion data of Farver (1994), the calculated timescale of the event is 101 ± 157 years

The timescale calculated for this infiltration event is extremely short. Water-rich fluids have been channelled along cracks and grain boundaries with limited fluid-rock equilibration. The main assumptions made in applying chromatographic theory to fluid flow in rocks (e.g. constant porosity and total fluid-rock equilibration) are not valid in this example

References

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