

Oxygen isotope composition of quartz- Al_2SiO_5 veins on Naxos as indicators of the fluid-temperature history of high-grade metamorphism

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Veins are important manifestations of fluid channeling in rocks. Their structure and geochemistry potentially records the kinematics and temperature interval over which the vein developed and the sources and mechanism of mobilization of the fluids involved in vein formation. It has long been recognized that the oxygen isotope composition of veins within metamorphic rocks preserve a record of the fluid history. Less well studied, however, is their potential for oxygen isotope thermometry, particularly so in quartz-rich veins from high grade metamorphic rocks. Quartz is intrinsically a high-diffusivity mineral susceptible to retrograde re-equilibration during cooling. However in quartz-rich veins its modal dominance means that its $\delta^{18}\text{O}$ will not change during cooling (Ghent and Valley, 1989). Thus the oxygen isotope fractionation between quartz and minerals resistant to retrograde re-equilibration (such as Al-silicates) potentially can provide accurate thermometry of the event during which the vein formed. Accurate temperatures correspondingly enable us to pinpoint the oxygen isotope composition of the vein formation fluid and to study the relation between this fluid and the source rocks. In this study we demonstrate the power of such methods through laser probe studies of the oxygen isotope compositional variations of a single quartz- Al_2SiO_5 vein and its pelitic host rock located in the high grade rocks of Naxos island (Greece)

The quartz- Al_2SiO_5 vein occurs within a biotite schist located in the kyanite-sillimanite zone of the Naxos thermal dome. Kyanite and/or sillimanite + quartz \pm white mica form the vein assemblage. Kyanites are up to a few cm large and fibrolitic sillimanite is prominent on vein- or shear surfaces. The host rock has a modal composition of biotite + quartz + kyanite \pm opaque \pm plagioclase \pm garnet. Kyanite porphyroblasts are coarse grained in the host rock and quartz occurs either as extremely fine

grained crystals in the matrix or in mm-scale schistosity parallel veinlets.

The oxygen isotopic compositions of quartz, kyanite and sillimanite in the vein are remarkably homogenous throughout the vein; quartz $\delta^{18}\text{O}$ values vary from 13.09 to 13.51‰ (7 samples, 22 analyses); kyanite values show a similar small variation from 10.44 to 10.93‰ (6 samples, 18 analyses); sillimanite values range between 10.32 to 10.87‰ (3 samples, 6 analyses). The fractionations between quartz and kyanite are consistent and independent of small variations in the minerals. Analyses on quartz from different parts of the same sample indicate that the variability over distances of a few centimeters is <0.3‰. The host rocks exhibit less uniform compositions. The kyanites from two host rock samples give $\delta^{18}\text{O}$ values of 10.80 and 10.85‰, whereas biotite values are quite distinct from each other with $\delta^{18}\text{O}_{\text{Biot}} = 7.18\text{‰}$ and 6.19‰. The fine grained quartz of the matrix have $\delta^{18}\text{O}$ values of 13.86‰, whereas quartz from s-parallel veinlets have values between 13.07 and 13.17‰.

Oxygen isotope temperatures calculated using the fractionation equation of Sharp (1995) are $653 \pm 10^\circ\text{C}$ for quartz-kyanite pairs in the vein samples and agree well with the petrologically-deduced peak metamorphic temperatures of between 620°C (sillimanite-in) and 700°C (melt-in) (Buick and Holland, 1989). In contrast temperatures of 584°C to 592°C are estimated from quartz-kyanite pairs of the host rocks and 430°C and 377°C for quartz-biotite pairs using the calibration of Bottinga and Javoy (1975).

The similarity between the isotopic compositions of vein and host rock quartz, suggest that the fluids involved in vein formation were in isotopic equilibrium with the host rocks, thus favouring a mechanism of vein formation by local segregation at peak metamorphic temperatures. The thermometric results indicate that the host rock samples have

undergone substantial isotopic re-equilibration compared to the veins, which record peak-metamorphic temperatures. The slight ^{18}O -enrichment of the matrix quartz in the host rock relative to the vein quartz can be explained in terms of closed system re-equilibration due to diffusional exchange between quartz and biotite.

Our data demonstrate that vein mineral assemblages, such as quartz-Al silicate, can be used as effective thermometers in high temperature rocks where retrograde equilibration is a major problem. In our future work, we aim to develop a systematic regional study of the Naxos veins. Accurate oxygen isotope thermometry will enable us to more correctly estimate isotopic composition of the fluids, thus potentially distinguishing between prograde fluid events (Baker *et al.*, 1989) and retrograde fluid infiltration related to the crystallization of the migmatite melts (Baker and Matthews, 1994), and

also will give us valuable constraints on the regional temperature evolution of the Naxos complex.

References

- Baker, J., Bickle, M.J., Buick, I.S., Holland, T.J.B., Matthews, A. (1989) *Geochim. Cosmochim. Acta*, **53**, 2037–50.
- Baker, J. and Matthews, A. (1994) *Contrib. Mineral. Petrol.*, **116**, 130–44.
- Bottinga, Y. and Javoy, M. (1975) *Rev. Geophys. Space Physics*, **13**, 401–18.
- Buick, I.S. and Holland, T.J.B. (1989) In: Daly, J.S., Cliff, R.A., Yardley, B.W.D. (eds.) The evolution of metamorphic belts. *Geol. Soc. London. Spec. Pub.*, **40**, 365–71.
- Ghent, E. and Valley, J. (1998) *J. Metamorph. Geol.*, **16**, 223–30.
- Sharp, Z.D. (1995) *Amer. J. Sci.*, **295**, 1058–76.