A strontium isotopic investigation of fluid–solid exchange during hydrothermal circulation in the Troodos Ophiolite

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The structure of sea floor hydrothermal systems and the nature of fluid–solid exchange processes are still poorly constrained despite the significance of the hydrothermal activity to the chemical structure of the ocean crust and oceanic chemistry. Here we report preliminary results of an investigation into the structure of fluid flow and the nature of fluid–solid exchange mechanisms in the upper part of the oceanic crustal sequence preserved in the Troodos ophiolite. The lava sequence on Troodos exhibits a wide range of 90 Ma $^{87}Sr/^{86}Sr$ interpreted to imply that fluid-solid exchange was kinetically limited in the upper part of the recharge zone of the high temperature hydrothermal systems (Bickle and Teagle, 1992). The extent of fluid channelling, fluid $^{87}Sr/^{86}Sr$ isotopic composition and possible controls on fluid-solid exchange processes have been investigated by analysing altered basalt, zeolite minerals crystallised from hydrothermal fluids and mapping strontium isotopic gradients on centimetre to metre scales. Results from two localities are reported.

At the first locality pillows and a single cross-cutting dyke from within the lower pillow lavas have been profiled in detail (Figs. 1,2). Samples from the dyke locality (Fig. 1) scatter about a 98 ± 13 Ma errorchron. No obvious gradients in $^{87}Sr/^{86}Sr$ are resolved (Fig. 3) despite mineralogical differences between dyke margin and pillow rims with mica-type clays compared to country rock and dyke core with smectite-mica interlayered clay minerals. Four zeolites from the pillow give a precise 90Ma $^{87}Sr/^{86}Sr$ of 0.706656 ± 34. $^{87}Sr/^{86}Sr$ of the zeolites are substantially elevated compared with altered basalt samples (90Ma $^{87}Sr/^{86}Sr = 0.7040 \pm 2$). Only hyaloclastite samples from the pillow margin exhibit elevated 90Ma 87Sr/86Sr of approximately 0.7060. Again a sample profile across the pillow exhibits no resolvable gradient in 90Ma $^{87}Sr/^{86}Sr$ (Fig. 4) as might be expected if flow was channelled around the pillow margin. The zeolite $^{87}Sr/^{86}Sr$ compositions are interpreted to represent fluid composition at the time of alteration. The lack of gradients in 90Ma $^{87}Sr/^{86}Sr$ values across the pillow imply that fluid flow was pervasive and not significantly channelled on the scale sampled. The elevated $^{87}Sr/^{86}Sr$ of glassy samples may reflect increased mineralogical reaction and growth of new minerals with high, fluid-like $^{87}Sr/^{86}Sr$ ratios. If so fluid–solid

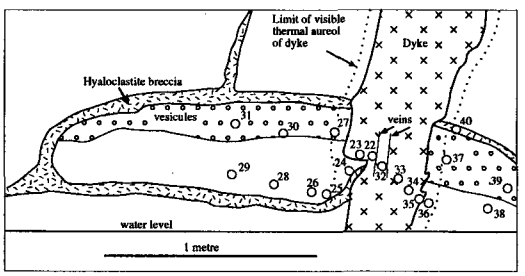

FIG. 1. Drawing of dyke cutting pillows, Akaki river gorge. Numbered circles are drill-core locations.

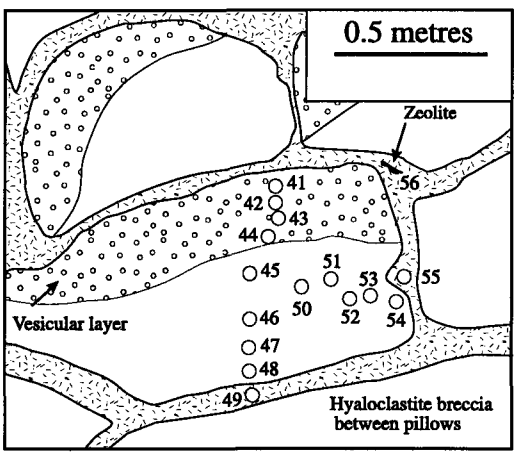

FIG. 2. Drawing of pillow, Akaki river gorge. Pillows (no ornament) are set in hyaloclastite. Numbered circles are drill-core locations.

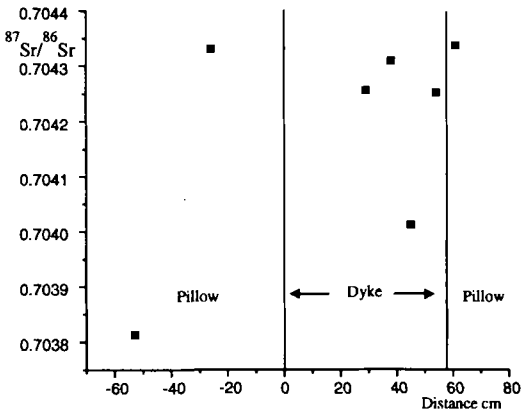

FIG. 3. 90 Ma $^{87}Sr/^{86}Sr$ profile across the dyke, Akaki river gorge.

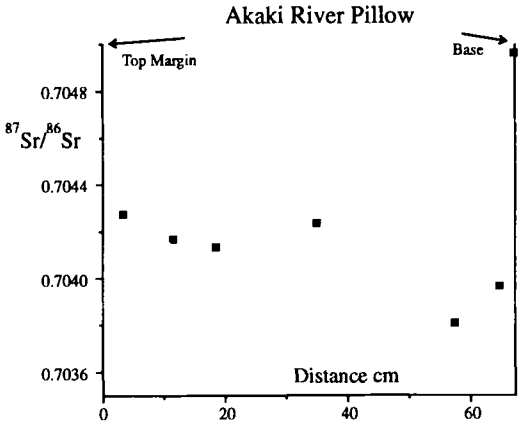

FIG. 4. 90 Ma $^{87}Sr/^{86}Sr$ data plotted as a vertical profile across the pillow (sliced samples plotted as average), Akaki river gorge.

exchange kinetics are controlled by mineral reaction rates rather than by fluid channelling with diffusion transport into wall rock.

The second locality sampled is at the top of the basal group and comprises a five metre section across dykes intruding a massive lava. Initial isotopic ratios vary, with a coarser mineral assemblage forming in regions sub parallel to dyke margins exhibiting a distinctly higher value (90 Ma average $^{87}Sr/^{86}Sr = 0.705101$) than finer zones dominating the dyke ($^{87}Sr/^{86}Sr = 0.704582 \pm 67$). A slight initial isotopic gradient across the finer assemblage is evident.

We conclude that fluid-rock disequilibrium was produced by kinetically limited strontium isotopic exchange within the extrusive series of the Troodos ophiolite. The kinetics were probably limited by mineral reaction rates. Zeolites may record local fluid strontium isotopic composition although the extent of later strontium isotopic alteration needs to be constrained.

Bickle, M. J. and Teagle, D. A. H. (1992) *Earth Planet. Sci. Lett.*, **113**, 219–37.