Diffusion-limited uptake of HREE: consequences for Lu/Hf dating

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Understanding REE zoning patterns and growth mechanisms in garnets are the key for
interpreting Lu/Hf age determinations (Lapen et al. 2003).

La-ICP-MS traverses on centrally-cut garnets from the Zermatt-Saas-Fee eclog-
ites (Western Alps) expose narrow, exponentially decreasing central peaks for
Lu+Yb+Tm+Er as well as an additional, less pronounced, maximum towards the rim.
The width of these peaks is approx. 1/5 of the radius. In contrast, Sm+Eu+Gd+Tb+Dy
are depleted in the cores but contain at least one prominent peak close to the rim.

Radius-rate relationships using major element compositional zoning suggests that
the garnets grow limited by a surface-reaction mechanism (interface-controlled, IC).
However, HREE concentrations in the cores of smaller garnets are always enriched
relative to their contents at the co-precipitated distance from the rims of larger garnets.
We interpret this pattern to be the result of concentration gradients as a consequence
of diffusion halos surrounding earlier crystallized garnets.

We have used a transient numerical model, where the REE uptake is controlled by
diffusion (DC) in the matrix surrounding the porphyroblast. Observed profiles are
well fitted assuming overall IC growth while fits fail assuming overall DC growth.
The appearance of a second maximum is well explained by this model assuming a
temperature increase leading to diffusion acceleration. Each maximum observed in
trace element profiles has been traditionally interpreted to be the result of an accessory

mineral breakdown containing these elements. In our model, it is the diffusion halo which relaxes due to higher diffusion rates.

Moreover, our model predicts that Lu will approach the matrix value when it reaches the steady state (after about 1/5 of the radius). The same prediction also applies to Hf. In this case, the Lu/Hf ratio will be the same for the majority of the garnet as for the matrix. Hence, diffusion-limited uptake of Lu will limit the magnitude of 176Lu/177Hf ratios, which in turn will limit the precision of Lu/Hf isochrones in young rocks.

In conclusion, our model explains the appearance of an additional maximum in trace element profiles as a consequence of diffusion acceleration. It provides a powerful tool to distinguish between the different principal growth-limiting mechanisms. Moreover, it predicts a low precision in Lu/Hf age dating when used for young rocks.