Short-lived orogenic cycles: evidence from untransformed "metastable" domains buried to depths ≥ 40 km

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Subduction dynamics are strongly controlled by the transformation of crustal rocks to eclogite due to the large (~15%) density increase. Fluid and/or deformation are commonly considered to play a central role in promoting this transformation [1]. Many exposed high-pressure terranes are only partly transformed, however, suggesting that this may be a controlling factor in their exhumation [2]. Granulites in these terranes are considered to be "metastable" because they are thought to have experienced the same pressures and temperatures as the surrounding eclogites. The alternative explanation, that thermal perturbations were confined to zones of high strain while the country rock remained cool, has been considered only recently [3,4], and indicates that the rates of tectonometamorphic processes are probably much faster than previously thought.

We illustrate our methodology for extracting the duration of an orogenic cycle (subduction and exhumation) with two examples from contrasting tectonic settings: (a) Intracratonic; Musgrave Block, central Australia, where deformation is the main mechanism for transforming the granulites to eclogite, and (b) Continental collision; Holsnøy, western Norway where fluids have facilitated the same transformation. The two areas are comparable to the extent that granulites have been locally transformed to eclogite at ~700°C, with a clear spatial association between shear zones and eclogite formation. Minerals in the untransformed granulites preserve Proterozoic ages, whereas minerals in the shear zones yield Palaeozoic ages. Using diffusion theory in combination with the different isotopic diffusivities in minerals, we calculate the temperature-time conditions under which all isotopic data sets are internally consistent. We then couple isotopic diffusion modelling with thermal modelling of the subducting lithosphere to estimate the P-T-t path of a particle that is subducted and then exhumed. Our results indicate that the orogenic cycle in both terranes was short-lived (<40 Ma), considerably less time than what is commonly accepted.

In conclusion, in tectonic settings where crust is rapidly buried and exhumed, temperatures recorded in shear zones need not reflect the ambient thermal regime. The non-equilibrium temperature difference between shear zones and surrounding country rocks can be explained in several ways (e.g., shear-heating, heat advection by fluids or melt) depending on the tectonic setting.

References

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