Focused pulses of regional metamorphism

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Growing evidence is emerging to support the idea that metamorphism, even in a regional context, may be punctuated – or dominated – by relatively short pulses of heating, fluid flow, and/or mineral growth. Here, we describe data from two Barrovian metamorphic terranes which test this idea.

In the Barrovian zones of Scotland, garnet Sm/Nd geochronology from the garnet and sillimanite zones yield the same peak metamorphic ages [1] (~465 Ma). The age is similar to the age of crystallization of large igneous bodies in the area. The contemporaneity of peak ages is explained by an efficient, advective component of heating, perhaps mediated by synchronous fluid flow [2]. The duration of this region-wide pulse of peak metamorphism is constrained by new Sr-in-apatite diffusion modeling. Apatite grains have detrital cores and metamorphic overgrowths and are included within porphyroblasts (e.g. garnet, staurolite). Modeling of intragrain diffusion of Sr constrains the duration of peak metamorphism to <250 kyr for garnet through staurolite zone samples. Garnet multi-component diffusion modeling from the sillimanite zone corroborates this brief pulse duration.

The Wepawaug Schist of Connecticut USA, also yields contemporaneous peak-T garnet Sm/Nd ages from different grades across the terrane (~380 Ma). This age matches a population of texturally young zircons associated with igneous intrusions in these rocks. Garnet cores from the kyanite zone, which have growth textures indicative of extremely rapid growth [3], have been dated by Sm/Nd at 388.6 Ma. This age is matched by another population of zircons also associated with igneous intrusions. This earlier prograde growth event may be related to another pulse of metamorphic growth, brought on by magmatic fluid and heat.

Brief pulses of metamorphic heating and mineral reactions, perhaps catalyzed by the introduction of fluids, may be superimposed on regional scale conductive heating at tectonic rates. Such short pulses could help explain the discrepancy between rapid lab-based reaction kinetics and much slower time-integrated field-based reaction kinetics [4].

References

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U-Th stratigraphy of a cold seep carbonate crust

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Uranium and thorium concentrations and isotope compositions were measured on a set of 16 samples drilled across an authigenic carbonate pavement, providing the first stratigraphy for a cold seep carbonate crust. The 5.5-cm thick crust (NL7-CC2) was collected by submersible on the Nile deep-sea fan in an area of active fluid venting. U-Th analyses were corrected for initial Th using isochron methods.

Our calculated ^{230}Th/U age-depth profile for NL7-CC2 provides evidence for continuous carbonate precipitation at the studied location over the last ~ 5000 years. Three distinct phases can be distinguished from top to bottom with average growth rates of ~ 0.4, 5.5 and 0.7 cm/kyr, respectively, corresponding to carbonate precipitation rates ranging from ~ 8 to 125 μmol/m^2/h, consistent with previous estimates. High-resolution profiles for δ^{13}C and major elements across NL7-CC2 show that those variations in carbonate precipitation rates were also accompanied by changes in carbonate mineralogy and composition of contemporaneous fluids.

We suggest that all those changes reflect primarily modification of the diagenetic environment, i.e. a progressive depletion of dissolved sulphate through anaerobic oxidation of methane, caused by carbonate crust formation. Overall, U-Th dating of cold seep carbonates offers a promising tool to bring new insights into biogeochemical processes at cold seeps and to assess the timing and duration of fluid venting on continental margins.