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Boosting the petrochronology arsenal: REE partitioning between garnet and monazite in Bhutanese pelitic metasediments

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Metamorphic studies are increasingly striving to integrate timing information with petrographic analysis and thermobarometry – the developing field of petrochronology [1]. Recent advances in analytical techniques, in particular a variety of *in situ* methods that can potentially extract the information preserved in disequilibrium features, have reinvigorated metamorphic studies. The strength of petrochronology lies in linking the isotopic age *directly* to the metamorphic stage, in contrast to earlier studies where accessory phase ages existed in isolation from the thermobarometric data with which they were tentatively linked.

Garnet has proved itself an invaluable tool in metamorphic studies, yielding microstructural, thermobarometric, geochemical and even geochronological information. Although common in amphibolite-facies pelitic metasediments, garnet does not easily yield its chronological data, so the common accessory phase monazite has been used more routinely. Typically, monazite isotopic ages cannot be linked to the development of different metamorphic assemblages because their textural relationships, especially with fabric-forming phases, are commonly obscure. However, their distribution as matrix grains versus inclusions in porphyroblast minerals such as garnet, or in retrograde textures [2], can yield useful information. *In situ* investigations of chemical zoning in both monazite and garnet offer the potential to link crystallisation of the two minerals more closely. Since both monazite and garnet incorporate rare earth elements (REE), their equilibrium partitioning behaviour provides not only a useful test of equilibration, but also a way of linking time to temperature. Previously reported garnet-monzite partitioning data record the behaviour expected under granulite-facies (>750°C) conditions [3]. We document REE concentration data from sub-solidus amphibolite-facies (~650-700°C) rocks from the eastern Himalaya (Bhutan), where age and inclusion relationships suggest that garnet and monazite grew simultaneously. The garnet/monazite ratios show steeper heavy REE patterns than those reported from the higher-temperature experimental data.

These data suggest either that the partitioning relationships vary with temperature, or that different relationships hold in sub-solidus vs. supra-solidus rocks. Bhutan is an excellent location to test these relationships; abundant pelitic metasediments within a single tectonic unit span metamorphic grades ranging from sub-solidus to supra-solidus. Moreover, these metamorphic rocks (and their counterparts along the strike of the orogen) have been extensively studied in recent years both in terms of their metamorphism and their monazite geochronology, providing an ideal framework for petrochronological research with applications to all major orogens.

References:

[1] Fraser et al. (1997) *Geology* 25: 607-610

[2] Foster et al. (2000) *EPSL* 181: 327-340

[3] Rubatto et al. (2006) *J. Pet* 47(10): 1973-1996

