Accessory phases, metamorphic reactions, and V.M. Goldschmidt: using bulk-rock chemical variations to determine orogenic *P-T-t* paths

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Metamorphic rocks store pressure-temperature-time (*P-T-t*) data as they move through the crust and provide an important record of orogenesis. If integrated *P-T-t* data are obtained for continuous parts of the paths followed by such rocks, we can establish heating, cooling, burial and exhumation rates for different parts of an orogen and construct a tectonic model for the changing rock velocity field in space and time during orogenesis.

One problem is that *P-T* and *t* data are difficult to link in a temporal framework [1]. Phases like garnet, pyroxene, feldpsar and mica provide the best *P-T* data. They have high modal abundances and are easy to link to rock fabrics. U-rich accessory phases like monazite and zircon yield the best *t* data, but are difficult to link texturally or chemically to major rock-forming minerals or to tectonic fabrics due to their small size, low modal abundance, and chemistry dominated by elements present at trace levels in other phases. However, accessory phase growth is driven by the same reactions that control modal abundances of the major minerals, and careful petrography and trace-element geochemistry can establish a connection between the *P-T* and *t* histories of metamorphic rocks [2,3].

Another difficulty is that monazite and zircon grow at limited time periods in a rock's history, and *t* data from one rock might be insufficient to calculate accurate rates of *P-T* change. This can be addressed with data from a range of rock compositions that stabilize different mineral assemblages at one *P-T* condition [4] and therefore have different reaction histories for the same *P-T* evolution. Thus many pelitic rocks have a major pulse of monazite growth during garnet breakdown to staurolite, but some rocks are too Mg- or Fe-rich to intersect this reaction and contain monazite of different age [5], while variable Mn or Ca contents will cause garnet breakdown and monazite growth to occur at different times. Composite *P-T-t* data from such rocks will define near-continuous *P-T-t* paths whose quality is limited only by analytical precision.

References

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