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Fluid Control on Crustal Melting During Orogenesis

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Crustal melting is a predictable consequence of prograde heating of orogenic belts resulting from the interaction between fluid infiltration and tectonic processes. However our knowledge of metamorphism and anatexis during the orogenic cycle is largely restricted to events that occurred during peak conditions and along the subsequent cooling path. Until recently this has been particularly true for the Himalayan orogen where metamorphism and crustal melting is well-documented during the Early Miocene (22-17 Ma) yet there have been few empirical constraints on the post-collision evolution of the orogen during the previous 30 Ma.

The Miocene magmas crystallised as late or post-kinematic muscovite-tourmaline leuco-granites, intruding the sillimanite-grade metasediments of the orogen (Harris et al., 1995). Trace-element modelling and experimental studies (Patino Douce and Harris, 1998) indicate that melts were generated by the incongruent, fluid-absent melting of muscovite-quartz-plagioclase assemblages at T= 750 ±50ºC, P= 600 ±100 MPa. PTt paths derived from pseudo-sections of garnet-bearing protoliths, dated by high-precision garnet chronometry (Vance and Harris, 1999), indicate that melting occurred during a period of rapid decompression of metasediments exhumed from deep (>1000 MPa) crustal levels, probably associated with orogenic collapse (Fig. 1).

In contrast, a suite of syn-kinematic two-mica leuco-granites intruding the high-grade metasediments of the Garhwal Himalaya has recently been recognised. Sm-Nd garnet dating indicates a crystallisation age of 39.9 ±1.4 Ma, some 15 Ma before the emplacement of the Miocene leuco-granites during a period of burial and heating of the tectonic pile. These Eocene intrusives are characterised by low Rb/Sr ratios, low abundances of HFS elements and positive Eu anomalies that contrast strongly with the Miocene leuco-granites. Their origin can be modelled from fluid-present, disequilibrium melting of metapelitic protoliths at temperatures of 640 ±30ºC. Such conditions would be encountered on the prograde PTt path of metasediments exhumed from pressures of <800 MPa (Fig. 1).

Fluid-present melting is likely to be a common feature of prograde upper amphibolite-facies metamorphism. Fluids resulting from subsolidus dehydration reactions migrate to low-strain zones allowing localised melting at structurally controlled sites. Fluid infiltration will be facilitated by channelised advection along active shear zones. The resulting melts will either escape from their protoliths and crystallise at shallower crustal levels, as in the case of the Eocene leuco-granites, or may persist over long timescales (~15 Ma) ultimately crystallising as migmatite leucosomes during exhumation. The apparent absence of prograde melting in many orogenic belts may result not only from the localised distribution of a free fluid phase, but also from the fact that unless these melts escape from their protoliths they will record young crystallisation ages similar to those of magmas formed during, or shortly following, peak metamorphism. This is exemplified by accessory phase dating of leucosomes from Himalayan migmatites (Godin et al., 1999) that yields Early Miocene crystallisation ages with components that are ~10 Ma older, indicative of early melting. Identification of melts formed along the prograde path in other orogens may be aided by their distinctive geochemical signature. The recognition that such melts persist within an orogen for several millions of years has fundamental implications for fluid behaviour along the prograde PTt path, for the rheology of the mid-crust and for the nature of its deformational history.

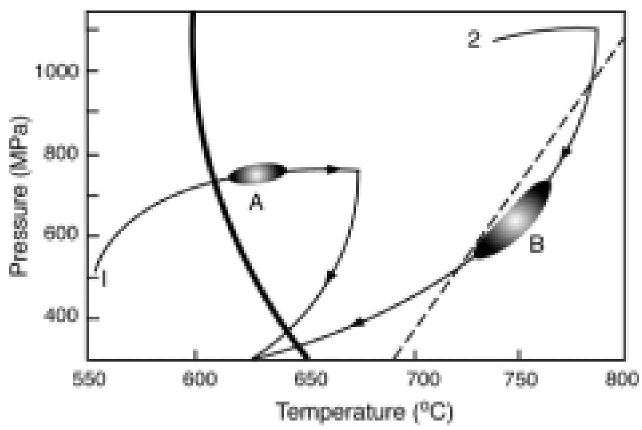

Figure 1: PTt paths obtained from garnet-bearing assemblages from the High Himalaya formations exhumed from pressures of (1) ~800MPa (Prince, 2000) and (2) ~1200MPa (Dezes et al., 1999). Prograde melting occurs under fluid-saturated conditions at ~40 Ma

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