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Geochemical signatures of pelitic melt reactions: A case study from the Garhwal Himalaya

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Anatexis in orogenic systems has wide-reaching implications for the structure, mechanical strength, and later exhumation of the orogenic middle crust. Determining the specific melting reactions that occur and dominate within individual settings can provide a greater understanding of the system in question, as reactions can be tied to P-T-X_{H_2O} conditions, and the melt itself can be dated using accessory phases. Melt reactions in metapelitic rock have been previously extensively studied, with three major melt-producing reactions identified: fluid-present incongruent melting, fluid-absent muscovite-dehydration melting, and fluid-absent biotite-dehydration melting. Each of these reactions have implications for the release, transport, and final destination of particular elements, depending on the compositions of the reacting phases and whether peritectic phases are formed. It is, therefore, important to recognise and distinguish between the geochemical signatures that these processes create and to delineate more precisely the relevant mechanisms and timescales leading to magma genesis.

Former leucogranitic melt is exposed across the Himalaya in the Greater Himalayan Sequence (GHS) as granite bodies and source migmatites. Many of these granites formed during decompression of high-grade metamorphic rocks during the Miocene. Using samples from the Alaknanda valley, near Badrinath, in the Garhwal Himalaya, we present constraints on the melt reactions, source, and timescales of melting episodes that form the migmatites and leucogranites of the upper GHS. Detailed petrographic observations and geochemical characterisation of feldspars, micas, and garnet reveal melt reaction systematics through peritectic crystallisation textures and large-ion lithophile element concentrations. We have identified characteristics that are indicative of fluid-present, muscovite-dehydration, or biotite-dehydration melting contributions. Zircon U-Pb dates suggest partial melting in migmatites occurred over an extended period, with predominately fluid-mediated, low volume (<8%) melting occurring between 34-25 Ma, followed by a shift to muscovite-dehydration melt production. This led to runaway decompression melting and the formation of leucogranites from ~20 Ma. Eu anomalies in zircon link crystallisation ages to peritectic phases and melt-forming reactions. Discrete episodes of fluid-present melt generation around peak metamorphic conditions likely weakened the GHS, priming it for exhumation and subsequent decompression melt generation.