

## **Apatite geochemistry records crustal anatexis: A case study of metapelites and granitic gneisses from the Cona area in the eastern Himalaya**

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### **ABSTRACT**

Apatite is a common accessory mineral in metamorphic rocks, yet its behavior during progressive metamorphism involving extensive anatexis remains underexplored. To address this issue, we conducted petrographic and geochemical analyses of apatite in a series of amphibolite-to-granulite-facies metapelites and granitic gneisses from the Cona area, Southern Tibet, in the eastern Himalaya. These analyses were complemented by phase equilibrium modeling to characterize mineral reaction sequences during anatexis across different pressure-temperature conditions. The results indicate that the minor and trace element compositions of apatite can effectively differentiate protolith type, metamorphic grade, and anatectic mechanism. Apatites in the granitic gneisses exhibit higher F, light rare earth elements (LREE), Y, and Th contents, but lower Sr and Eu contents, as well as a lower positive slope between Cl and FeO contents in the covariant diagram, compared to those in the metapelites. These differences are attributed to variations in protolith composition and the associated mineral assemblage. In both the metapelites and granitic gneisses, apatite grain sizes increase with metamorphic grade; geochemically, apatite LREE contents, as well as its relative contributions to whole-rock LREE and middle rare earth element (MREE) contents, increase with metamorphic grade. Notably, apatites in samples subjected to biotite dehydration melting show lower FeO and MnO contents and higher Tb<sub>N</sub>/Lu<sub>N</sub> ratios than those in samples subjected to muscovite dehydration melting. This observation is linked to the formation of peritectic garnet during biotite dehydration melting. These variations with metamorphic grade can be ascribed to the dissolution of pre-existing LREE-rich monazite and MREE-rich apatite, coupled with the recrystallization of residual grains or new growth through incongruent melting reactions during progressive anatexis. Our findings suggest that apatite can act as both a reactant and a product during crustal anatexis, and its geochemistry can serve as an indicator of anatectic mechanisms. Several processes that were not considered in the equilibrium thermodynamic modeling, such as incongruent melting involving accessory minerals and recrystallization or Ostwald ripening under suprasolidus conditions, might enable apatite to develop larger grain sizes and capture the geochemical signatures of anatectic reactions.

**Keywords:** Himalayan orogen, progressive metamorphism, crustal anatexis, incongruent melting, apatite geochemistry