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Reconstruction of pluton assembly using trace elements in rock-forming minerals: a LA ICP-MS study of augite and hornblende in the Wooley Creek batholith, Klamath Mountains, California.

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The volume of interconnected melt capable of chemically and physically interacting within batholiths emplaced in the middle to upper crust is still debated. In this study, we take an alternative and/or complementary approach to geochronology and use the trace element record in minerals crystallizing early in magmatic systems to reconstruct the assembly history of a batholith. The Wooley Creek batholith (WCb) is a tilted calc-alkaline pluton situated in the Klamath Mountains, northern California, USA. The intrusion can be divided in three main units. The lower WCb ranges from two pyroxene biotite hornblende diorite to quartz-diorite. Trace elements in augite suggest that each sample analyzed belongs to a different magma batch and that individual batches underwent various extents of fractional crystallization. The upper WCb (80km2), ranging from hornblende biotite tonalite to granite, is zoned upward with more felsic rocks toward the structurally highest levels. The REE patterns of hornblende from samples that range from tonalite to granite are essentially identical and their REE abundances vary by a factor ≤ 3. Dacitic dikes that crop out along the structurally highest, southwestern contact of the intrusion contain hornblende crystals identical in composition to those from the upper part of the batholith, illustrating that the upper WCb was once eruptible. The central part of the WCb displays intermediate characteristics, with rocks ranging from hornblende biotite quartz-diorite to tonalite. Pyroxene is present only as relict inclusions in hornblende. Swarms of partially mingled Mafic Magmatic Enclaves (MME) and syn-plutonic dikes are locally common. The REE compositions of hornblende cores are similar to the hornblende found in the upper WCb, whereas the rims contain lower REE abundances and display no negative Eu anomaly, suggesting that they crystallized from a more mafic magma. This zoning pattern is interpreted as evidence of mixing in the central WCb, and specifically in the boundary zone that separates the upper and lower parts of the system. This zoning evidence is consistent with field relations that indicate mingling of the upper and lower units. We conclude that trace element compositions of minerals provide a useful tool to reconstruct and understand pluton assembly. In the case of the WCb, the lower part is constituted of numerous batches of magma, whereas the upper WCb crystallized from a large volume of chemically interconnected magma. The arrival of mafic magma in the central area provided heat, allowing the upper part of the system to mobilize and homogenize (Burgisser and Bergantz , 2011; Nature). CA-TIMS geochronology is in progress and will give absolute dates for the various part of the intrusion.