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Metamorphic evolution of the crust-to-mantle transition zone: constraints from titanite and zircon U-Pb petrochronology, Val Malenco (eastern Central Alps)

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The continental crust-to-mantle transition zone is a global signature of planetary differentiation and yet competing hypotheses have been proposed for its formation. These include tectonic underthrusting, magmatic underplating, metamorphic density separation and metasomatic reaction. Motivated by this uncertainty, here, we report new titanite and zircon U-Pb and trace element constraints on the metamorphic evolution of the Val Malenco fossil crust-mantle transition zone (Italy). Euhedral titanite and zircon grains are hosted in calc-silicate gneisses comprising the granulite-facies paragenesis: diopside + clinozoisite + plagioclase + garnet + calcite + quartz. Straight grain boundaries between titanite and peak-T phases, including zircon, imply that titanite was the stable high-T Ti-phase, likely forming through the decarbonation reaction: calcite + rutile + quartz -> titanite + CO_2. Titanite grains are characterized by multiple growth zones: i) a BSE-dark interior that preserves both oscillatory and sector zonation; ii) a volumetrically dominant BSE-bright mantle that is discordant to BSE-dark domains and separated by a lobate, irregular interface and iii) a narrow (<50 mm) rim domain characterized by intermediate BSE brightness. ^{207}Pb-corrected LA-ICPMS U-Pb dates collected using 40 mm spot diameters are 240-250 Ma and do not vary systematically between grain cores and mantle domains. Dates obtained from grain rims are slightly younger (230-240 Ma). Grain interiors are enriched in P, V and exhibit flat REE_N patterns distinct to mantle domains that are enriched in LREE, Al, Sc, Cr, Sr, Y, Zr, Nb, Th, U, Pb and show pronounced depletions in $HREE_N$. The absence of systematic variation in U-Pb dates with spatial position within individual grains combined with the morphology of intracrystalline chemical zonation imply a key role for fluid-driven processes in controlling titanite U-Pb and trace element systematics. Work is ongoing to interpret zircon U-Pb dates and resolve the tectonic importance of the titanite U-Pb dates that are systematically younger than those reported from zircon and monazite (280-260 Ma[1,2]) and yet cannot readily be explained by diffusive closure.

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