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Assessing the Extent of Metamorphic Transformation in a Subducted Continental Slab: Titanite Petrochronology of the Western Gneiss Region, Norway

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Petrochronology – the interpretation of isotopic dates with complementary elemental data – requires understanding the relationship between trace elements in chronometers and the petrologic evolution of their host rocks. Titanite (sphene) incorporates a wide variety of trace elements and is a useful petrochronometer for crustal processes, but how titanite records host rock evolution is uncertain. A large titanite LA-ICP-MS dataset from ultrahigh-pressure (UHP) Western Gneiss Region (WGR) granitic gneisses and leucosomes indicates that titanite age and composition depends strongly on textural setting: some titanites formed after the decomposition of other phases at mantle depths, but other titanites preserve inherited isotopic dates and chemistry with variable recrystallization at grain rims. Using a principal components analysis, we show that different titanite trace-element patterns represent the extent to which different rock reactions occurred during continental subduction and exhumation, in contrast to thermal and partitioning effects that comprise a statistically distinct signal. These data indicate that titanite is a robust marker for plastic deformation and fluid flow in subducted continental crust; the persistence of titanite at mantle depths is coupled with limited prograde fluid infiltration, which restricted the efficacy of metamorphic reactions, likely increased rock strength, and caused heterogeneities in the density of the subducting slab. Our statistical approach shows the utility of dimensional reduction in geochemical studies: rather than comparing individual element or isotopic abundances or ratios, principal components or discriminant analyses can condense variables and help efficiently distinguish between distinct geologic agents or geochemical reservoirs.