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Apatite petrochronology and microtextural analyses: a new tool to directly date and geochemically characterize subduction processes in the seismogenic zone

MARGARET ODLUM[1], CAILEY B CONDIT[2], MEGAN FERRELL[1], EIRINI POULAKI[3], ARMEL MENANT[4] AND KONSTANTINOS SOUKIS[5]

[1]Scripps Institution of Oceanography, UCSD
[2]University of Washington
[3]University of Miami
[4]Université Côte d'Azur
[5]National and Kapodistrian University of Athens
Presenting Author: maodlum@ucsd.edu

The subduction plate interface, a fluid-rich fault and shear zone which accommodates most of the movement between the down going and overriding plates in subduction zones, hosts earthquakes, creeping deformation, slow slip events, chemical transformations, and fluid flow and production. Many of these chemical and mechanical processes occur within the relatively cool greenschist and blueschist metamorphic facies (200°C - 500°C) that lack of many typical petrologic tools (e.g., common thermobarometric phases, disequilibrium behavior) and efficient geochronometers sensitive to these temperatures to place absolute time constraints on the processes recorded in these rocks. Apatite is a common accessory mineral in many subduction zone lithologies, is amenable to U-Pb and Lu-HF geo-thermochronology, and a sensitive recorder of petrogenic conditions in its geochemistry. In this study, we compare apatite microstructures, geochemistry, and U-Pb petrochronology from two subduction zones: Catalina Island, CA, and Andros Island, Greece. We demonstrate that apatite dynamically recrystallizes during deformation, dissolves and reprecipitates during fluid flow, and chemically tracks metamorphic and metasomatic reactions at the base of the subduction seismogenic zone. Apatite from Catalina Island across a range of blueschist to amphibolite P-T conditions dominantly record dissolution-precipitation creep during Cretaceous peak metamorphism. Apatite from a greenschist facies metabasalt on Andros Island show multiple deformation mechanisms including dislocation creep and dissolution-precipitation creep and that the geochemistry informs on the nature and composition of fluids during peak and early exhumation, suggesting infiltration of CO_2-rich fluids derived from carbonates. Detailed in-situ characterization of apatite allows us to distinguish phases of deformation and fluid flow during the subduction cycle to better understand and date processes like creeping deformation, chemical transformations, fluid production and flow, and brittle deformation in exhumed subduction complexes.