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Style of exhumation and rheological evolution of a Mediterranean subduction complex

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We examine the style of exhumation and rheological evolution of a subduction complex forming part of the Betic Cordillera in the Western Mediterranean. Rocks within the Nevado-Filabride complex (NFC) were subducted and exhumed to the surface within ∼10 m.y. in the Miocene. Ti-in-quartz thermobarometry, Raman spectroscopy on graphite, and chlorite thermometry indicate that the exhumation path of the NFC was close to linear, reaching peak T and P of 550 ± 50°C and 15 ± 3 kbar. Two-dimensional thermal modeling allows us to fit this P-T-t path using exhumation rate and exhumation geometry as free parameters. We find that the P-T-t path is best fit by a model in which the rocks are subducted to > 50 km depth, exhumed rapidly along the same trajectory within a subduction channel, then captured by a low angle detachment fault cutting through the overlying crust. This model can be reconciled with the thermal history preserved in the overlying plate and is supported by the kinematics recorded in high strain fabrics within the NFC itself.

We also link the exhumation history of the NFC subduction channel to the rheology of quartz-rich rocks within it by tracking changes in deformation mechanism, stress, strain rate, water content, and crystallographic preferred orientation (CPO) over time. Increasing localization during cooling allowed earlier microstructures to be preserved, such that the rocks record several stages in their exhumation history. Early deformation during initial subduction was accommodated by pressure solution under low-stress (<6 MPa), low-strain-rate, variable T conditions, and produced an inverted metamorphic gradient within the NFC. At the early stages of exhumation, the deformation mechanism at the top of the channel switched to dislocation creep at stresses of ∼6-20 MPa, strain rates of < 5E-13/s and temperatures of 500-550°C. Both stress and strain rate increased with decreasing T in the channel margin, culminating in stresses of ∼180 MPa, strain rates of ∼5E-11/s and temperatures of ∼340°C at the brittle-ductile transition. The high stresses recorded along the channel margin likely reflect both stress amplification at the mouth of the channel and edge forces generated along the trench interface by slab rollback.