



Miocene upper-crustal extension and coeval mid-crustal shortening in the hinterland of the Betics (western Mediterranean)

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The Nevado-Filabride complex, the lowest metamorphic terrain in the Betic hinterland (western Mediterranean, southern Spain), is exhumed in the Sierra Nevada elongated dome where it forms the footwall of sequentially-developed core-complex-type extensional detachments, middle to upper Miocene in age. The architecture of the Nevado-Filabride complex consists in a nappe-stack formed by the thick Calar Alto unit (7 km thick) sandwiched between the lower less-metamorphic Ragua unit and the upper more-metamorphic Bédar-Macael unit. The stacking of the units was accomplished by ductile flow along basal syn-metamorphic shear zones (several hundred meters thick). Structural analysis of the Calar Alto unit together with the P-T path of samples from both the bottom and top of the unit served us to understand the tectonic significance of this episode of mid-crustal shortening in the context of a strongly extended orogen. In the Calar Alto unit there is a kinematically compatible vertical variation of structural style from the basal ductile shear zone, characterized by a blastomylonitic foliation, WSW-ENE stretching lineation, subparallel recumbent folds and sheath folds, to the upper part of the unit that shows WSW-vergent folds with associated axial plane crenulation cleavage. Multiequilibrium thermobarometric results indicate that these crustal-shortening structures developed during decompression and heating under greenschist conditions after the main HP/LT metamorphic event registered in the Calar Alto unit by eclogites and by metapelites with kyanite + Mg-rich chloritoid assemblages. Garnets in the eclogites (Lu-Hf) and zircons (U-Pb SHRIMP) have recently been dated

as early to middle Miocene. Thus, the later ductile flow and contractive structures observed in the Calar Alto unit formed coeval to the overlying extensional detachments. This combination of mid-crustal shortening and upper-crustal extension resulted in a mode of exhumation where the material rise entails an important lateral component of displacement, following a complex S-shaped P-T path after the HP metamorphic peak.