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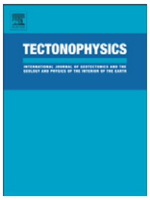

Continental subduction, intracrustal shortening, and coeval upper-crustal extension: P-T evolution of subducted south Iberian paleomargin metapelites (Betics, SE Spain)

G. Booth-Rea *, J.M. Martínez-Martínez, F. Giaconia

Departamento de Geodinámica, Universidad de Granada y Instituto Andaluz de Ciencias de la Tierra (UGR-CSIC), Granada 18002, Spain

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ABSTRACT

The Nevado–Filabride complex represents the basement and Permo-Triassic cover of the south Iberian passive margin, metamorphosed during Miocene continental subduction under the Alboran crustal domain. It forms a nappe stack with the thick Calar-Alto unit (6 km thick) sandwiched between the Ragua unit below and the Bédar-Macael unit above. The nappe stacking occurred by ductile flow along basal syn-metamorphic shear zones. Structural analysis of the Calar-Alto unit together with thermobarometric data of samples from both the bottom and top of the unit served us to understand the tectonic significance of this episode of intracrustal shortening in the context of a strongly extended orogen. Multiequilibrium thermobarometry shows that the Calar-Alto schist underwent a prograde P-T path at mantle depths from 1.6 GPa at 450–500 °C to 1.0 GPa at 550–570 °C during the growth of the schistosity (S_1), parallel to the compositional layering. After detachment from the downgoing slab and underplating, the unit underwent nearly isobaric cooling by up to 250 °C from peak metamorphic conditions. The main crenulation cleavage (S_2) and the mylonitic foliation (S_m) developed within the crustal nappe stack during decompression and heating. S_m at the base of the unit grew between 0.8 GPa at 400 °C and 0.4 GPa at 500 °C, while S_2 at the top of the unit developed between 0.6 GPa at 300 °C and 0.2 GPa at 400 °C. These shortening structures developed simultaneously to the activity of overlying middle Miocene extensional detachments. Intracrustal shortening and coeval upper-crustal extension resulted in a mode of exhumation where the material rise entailed an important horizontal component of displacement at rates of approximately 15 mm/year, being exhumed along an S-shaped P-T path after peak metamorphic conditions and its detachment from the subducting slab.

1. Introduction

Extended orogens show examples of dome structures that host HP rocks in their core, for example, the Hellenic Arc (e.g., Parra et al., 2002; Ring et al., 2010; Trotet et al., 2001), the Apennines and Tyrrhenian sea (e.g., Rossetti et al., 2001; Vignaroli et al., 2009), the Betics (e.g., Martínez-Martínez and Azañón, 1997; Martínez-Martínez et al., 2002, 2004), the Alps (e.g., Axen et al., 1995; Behrmann, 1988; Frisch et al., 2000), the Dabieshan (Faure et al., 1999), and the Entrecasteaux Island core complexes, where Pliocene eclogites have been exhumed (Baldwin et al., 2004), among others. Many studies have dealt with the processes necessary to exhume these HP rocks, based on field analysis and, mostly, from numerical modeling. From field evidence, the exhumation of these rocks has been proposed to occur by extensional detachments that root in the HP units (e.g., Jolivet et al., 2003), in extrusion wedges by simultaneous thrusting at the base and normal-sense opposite shearing at the top (Ring et al., 2007) or by shallow extension and underplating at lower-crustal depths (Platt, 1986, 1993). These processes are usually assisted by vertical ductile thinning (e.g., Feehan and Brandon, 1999; Ring and Kumerics, 2008), erosion, and extension (e.g., Ring et al., 1999). Meanwhile, exhumation mechanisms dealt with by numerical modeling include, buoyancy forces (Burov et al., 2001; Ernst, 2001; Warren et al., 2008; Yamada and Endo, 2008; Yamato et al., 2008) unrelated to particular structures, forced return flow in a low-viscosity channel (e.g., Gerya et al., 2002) or mechanical decoupling of HP sheets from the slab after heating and mechanical weakening, and later accreted to crustal thrust stacks (Carry et al., 2009; Chemenda et al., 1996).

The analysis of the core-complex dome structures mentioned above and associated mylonites shows that the extensional faults detach in the middle or lower crust, not reaching HP conditions (e.g., Axen and Bartley, 1997; Booth-Rea et al., 2012; Isik and Tekeli, 2001; Martínez-Martínez et al., 2002, 2004). Thus, these extensional faults on their own are not capable of exhuming the HP-LT rocks to the surface, probably even in the case of sequential activity of two sets of detachments like those documented in the Sierra Nevada elongated dome in the Betics (Martínez-Martínez et al., 2002).

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* Corresponding author.
E-mail address: gbooth@ugr.es (G. Booth-Rea).

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Extensional detachments in the Sierra Nevada elongated dome exhumed HP rocks of the Nevado–Filabride complex in their footwall. These HP rocks represent the leading edge of the subducted Iberian paleomargin and crop out in the Sierra Nevada, the Sierra de los Filabres, and in mountain ranges of the eastern Betics (e.g., Platt et al., 2006; Behr and Platt, 2012; Fig. 1). The timing between HP metamorphism of the Nevado–Filabride rocks (16 ± 2 Ma, López Sánchez-Vizcaíno et al., 2001; Platt et al., 2006) and their final exhumation to the surface, in the earlier exhumed areas at the Sierra de Filabres (11 ± 1 Ma, Johnson et al., 1997) does not exceed 5 Ma, implying vertical displacement rates that double the plate convergence one, in the area (e.g., de Jong, 2003). This time framework requires other exhumation processes working together with the extensional detachments to exhume the HP rocks from mantle depths. Hence, new metamorphic and structural constraints are necessary to understand the exhumation processes that occurred below the detachments that formed the Sierra Nevada elongated dome.

Peak HP metamorphic conditions and the prograde P-T path undergone by the Nevado–Filabride complex, which forms the core of the Sierra Nevada elongated dome, have been determined in metabasites, metapelites, and ultrabasic rocks (e.g.Augier et al., 2005a; Gómez-Pugnaire and Fernández-Soler, 1987; Gómez-Pugnaire et al., 1994; López Sánchez-Vizcaíno et al., 2001; Platt et al., 2006; Puga et al., 2000). These data evidence that rocks of the Nevado–Filabride complex reached variable HP metamorphic conditions typical of subcontinental mantle depths, ranging between 1.1 and 2.0 GPa at temperatures between 550 °C and 650 °C. However, few data exist on the P-T conditions undergone during their crustal emplacement and later exhumation after peak temperature metamorphic conditions. Existing P-T paths for these rocks are clearly contradictory showing isothermal decompression (Augier et al., 2005a) and cooling during decompression (Behr and Platt, 2012; Gómez-Pugnaire et al., 1994; Puga et al., 2002) followed or not by late isobaric heating (Bakker et al., 1989; de Jong, 2003). Here we present new thermobarometric multiequilibrium and structural data that help to constrain the P-T paths and blastesis–deformation evolution followed by the Nevado–Filabride metapelites in the Central and Eastern Betics (Fig. 1). We use these data together with published radiometric ages to discuss the tectonic processes, movement rates, and mechanisms leading to the fast exhumation of the subducted south Iberian metapelites from subcontinental mantle depths in the core of the Betics.

2. Geological setting

The Gibraltar Arc formed by Early to Late Miocene collision of the Alboran domain over the south Iberian and Maghrebian paleomargins at the northern and southern branches of the arc, respectively (e.g., Faccenna et al., 2004; Booth-Rea et al., 2005; Behr and Platt, 2012; Booth-Rea et al., 2012; Jabaloy-Sánchez et al., 2015, Fig. 1). Collision was coeval to subduction of the Tethys oceanic lithosphere under the Alboran domain at the hinge of the arc (Booth-Rea et al., 2007; Lonergan and White, 1997), producing the Flysch–Trough accretionary

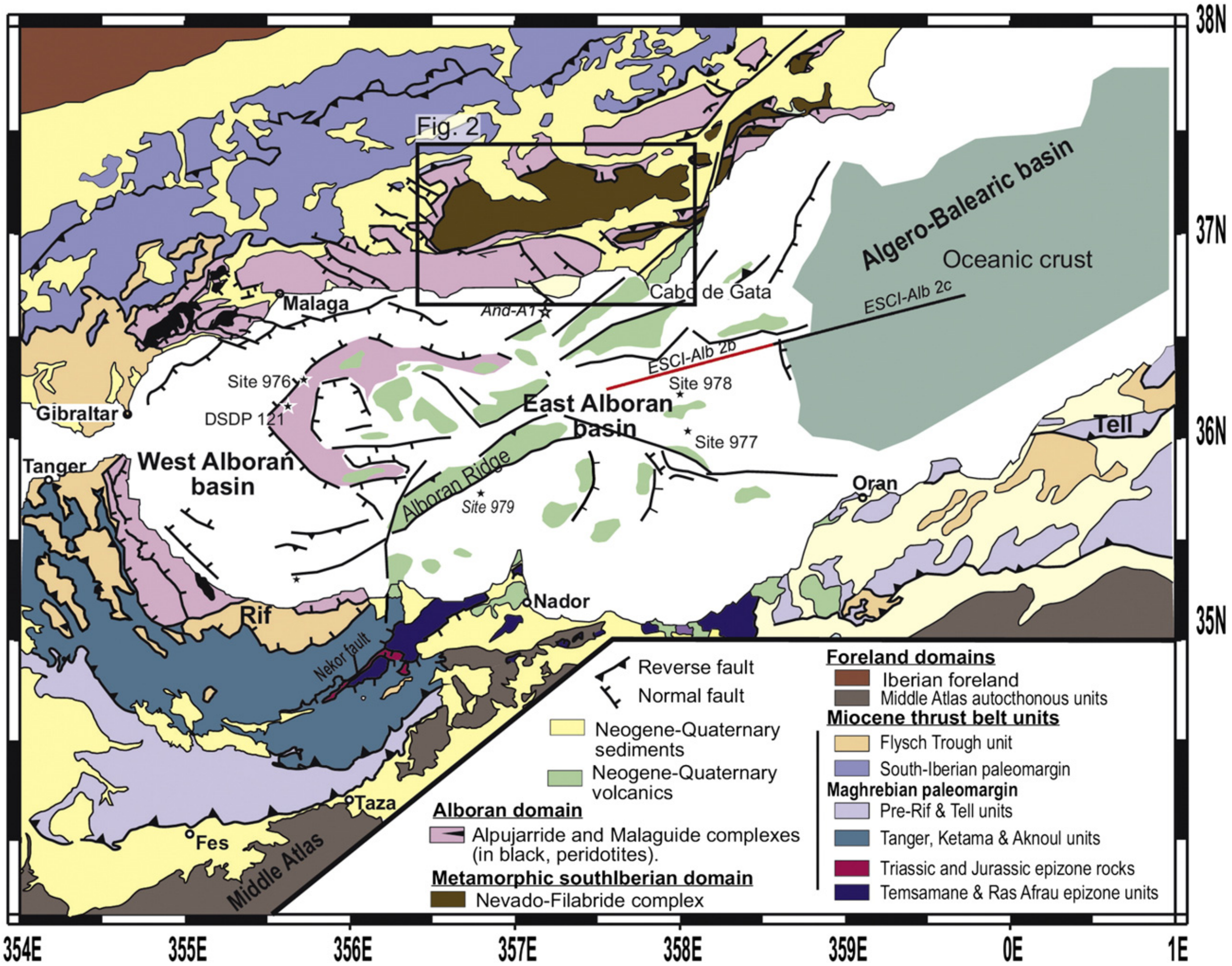

Fig. 1. Simplified geological map of the Betics and Rif modified from Booth-Rea et al. (2007).