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Tectonic evolution of the Betic–Rif arc: New constraints from $^{40}Ar/^{39}Ar$ dating on white micas in the Temsamane units (External Rif, northern Morocco)

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ABSTRACT

The Betic–Rif orogen, at the western end of the Mediterranean, is a key region to improve our knowledge on the Africa–Eurasia convergence. The Temsamane units, in spite of their external position in the Rif (northern Morocco), underwent medium-pressure low-temperature (MP–LT) conditions (ca. 7–9 kbar; 330–430 °C). We propose a new tectonic and metamorphic evolution scenario for the Rif (southern) branch of the orogen on the basis of first $^{40}Ar/^{39}Ar$ dating on petrologically and structurally characterized white micas. Three groups of $^{40}Ar/^{39}Ar$ ages are observed: (1) Chattian or older Si-rich (highest-pressure) mica relics, (2) 15–12.5 Ma corresponding to the micas defining the foliation and (3) Messinian or younger late micas and alteration. We propose that the MP–LT metamorphic event in the External Rif is Oligocene in age, highlighting a subduction event during this period which could be almost contemporaneous with the burial of HP–LT units from the internal Rif (Alboran Domain). The exhumation of these units characterized by an intense E–W stretching and by top-to-the-west shear senses, is Middle to Late Miocene in age. We propose a correlation of tectonic and metamorphic events at the Betic–Rif arc scale. We argue that the exhumation of the external units of the Rif (1) is younger than that of the Alboran Domain (internal) unit of the Rif, and mirrors a different tectonic setting, but (2) strongly resembles to that documented in the lower Alboran Domain units of the Betics. We show that a regional E–W extension is recorded on both sides of the Betic–Rif arc during the Middle Miocene. This extension probably reflects back-arc deformation of an eastward dipping subduction that retreated westward during the Middle to Late Miocene in the Western Mediterranean.

1. Introduction

The building of the Rif (northern Morocco) and the Betics (southern Spain), which represent the western termination of the Alpine orogenic system, has been the subject of many debates and several hypotheses are proposed to explain the formation of the Betic–Rif arc including: (1) convective removal of subcontinental lithosphere (Platt & Vissers, 1989; Platt et al., 2003a, Platt et al., 2006), (2) lithospheric delamination (Seber et al., 1996; Calvert et al., 2000; Tubía et al., 2004), (3) slab break off (Blanco and Spakman, 1993; Zeck, 1996) or (4) roll-back of an east dipping subduction zone (e.g. Lonergan and White, 1997; Frizon de Lamotte et al., 2000; Faccenna et al., 2004; Jolivet et al., 2006). The internal zones (Alboran Domain) (Fig. 1) of this orogen recorded high pressure–low temperature (HP–LT) (Gómez-Pugnaire and Fernandez Soler, 1987; Goffé et al., 1989) metamorphism generally considered to be Eocene–Oligocene in age (e.g. Platt et al., 2005; Michard et al., 2006), but more recently dated as Miocene in the lower Alboran Domain units (Platt et al., 2006). This event is overprinted during the early Miocene by HT–LP metamorphism related to the crustal extension that follow the shortening, and affected the whole Alboran Domain units (Balanyá et al., 1997; Platt et al., 2003a; Negro et al., 2006). This high thermal event reset most of isotopic systems in the whole area (e.g. Zeck et al., 1992; Platt et al., 2003a) and the betico–rifan accretionnary wedge early building stages remain difficult to constrain. Furthermore, even if several geochronological studies have been carried out to constrain the Alboran Domain metamorphic evolution, data are lacking in the External Rif.

Recent studies show that the Temsamane units (External Rif), in spite of their external position in the Rif, underwent medium-pressure low-temperature (MP–LT) conditions (ca. 7–9 kbar; 330–430 °C). We propose that these metamorphic conditions are due to the subduction of Temsamane units as it is proposed for the high pressure units of the internal Rif (Negro et al., 2007). The exhumation of Temsamane units, which is characterized by an intense ~E–W stretching and by top-to-the-west shear senses, looks like the one documented in the core of the internal Betics (Galindo-Zaldívar et al., 1989; García-Dueñas et al., 1992; Jabaloy et al., 1993; Martínez-Martínez and Azañon, 1997; Martínez-

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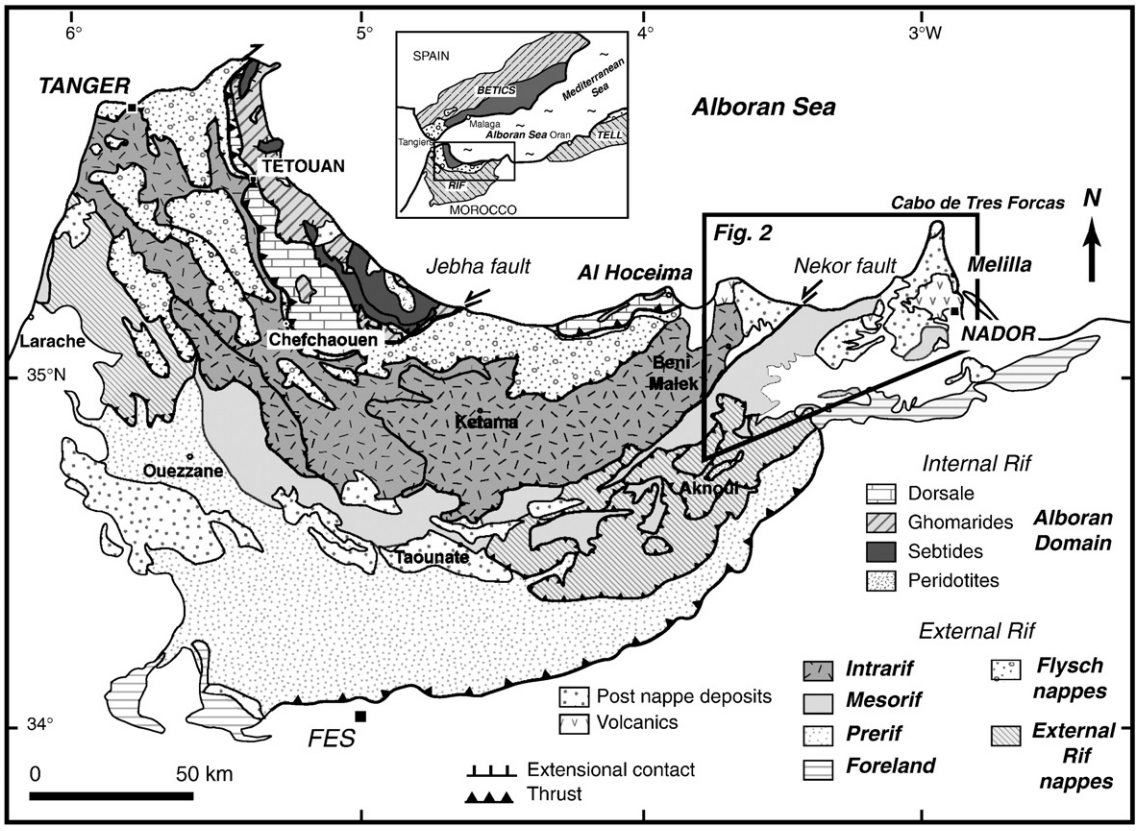

Fig. 1. Geological and tectonic map of the Rif. Modified after Chalouan et al. (2001) and Frizon de Lamotte (1987) for the External Rif.

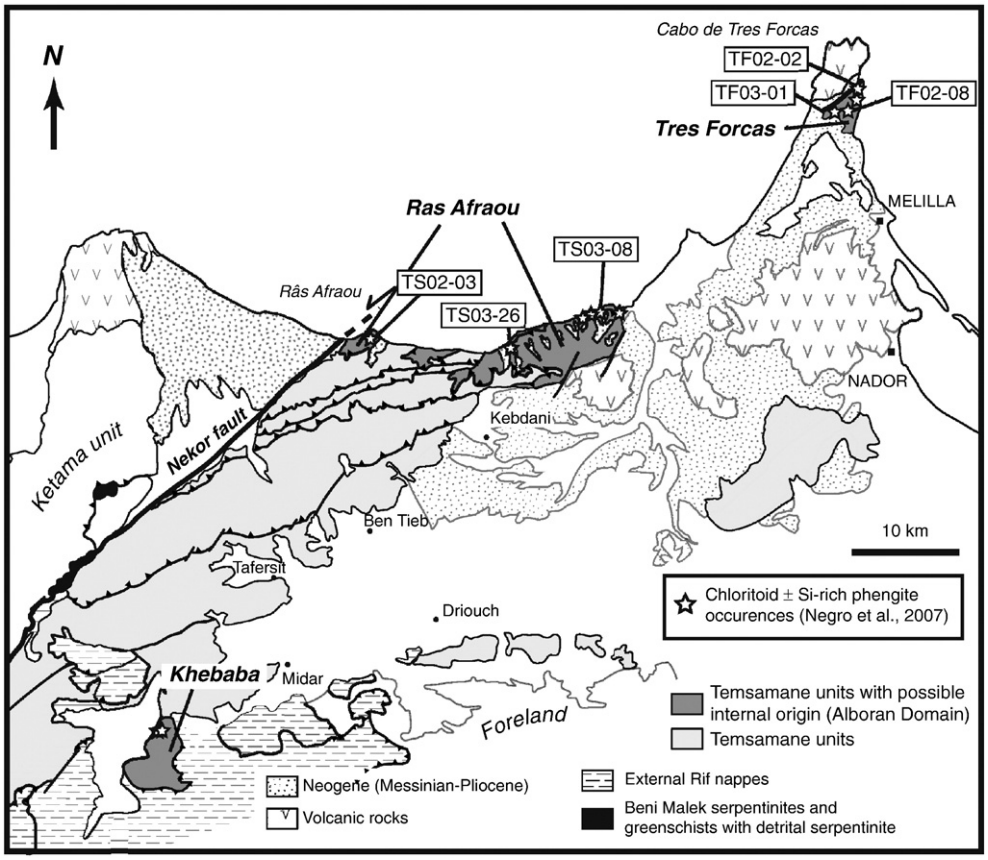

Fig. 2. Geological map of the Temsamane units (modified after Frizon de Lamotte, 1987) showing locations of dated samples by $^{40}Ar/^{39}Ar$ (for location see Fig. 1).