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Age of UHP metamorphism in the Western Mediterranean: Insight from rutile and minute zircon inclusions in a diamond-bearing garnet megacryst (Edough Massif, NE Algeria)

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ABSTRACT

Diamond-bearing UHP metamorphic rocks witness for subduction of lithospheric slabs into the mantle and their return to shallow levels. In this study we present U–Pb and trace elements analyses of zircon and rutile inclusions from a diamond-bearing garnet megacryst collected in a mélange unit exposed on the northern margin of Africa (Edough Massif, NE Algeria). Large rutile crystals (up to 300 μm in size) analyzed in situ provide a U–Pb age of 32.4 ± 3.3 Ma interpreted as dating the prograde to peak subduction stage of the mafic protolith. Trace element analyses of minute zircons (≤30 μm) indicate that they formed in equilibrium with the garnet megacryst at a temperature of 740–810 °C, most likely during HP retrograde metamorphism. U–Pb analyses provide a significantly younger age of 20.7 ± 2.3 Ma attributed to exhumation of the UHP units. This study allows bracketing the age of UHP metamorphism in the Western Mediterranean Orogen to the Oligocene/early Miocene, thus unambiguously relating UHP metamorphism to the Alpine history. Exhumation of these UHP units is coeval with the counterclockwise rotation of the Corsica–Sardinia block and most likely resulted from subduction rollback that was driven by slab pull.

1. Introduction

A paradigm in Earth Sciences has long been buoyancy of the continental crust. The discovery of coesite and metamorphic diamonds (Chopin, 1984; Smith, 1984; Sobolev and Shatsky, 1990), the hallmark of ultra-high pressure (UHP) metamorphism, in continental crust units demonstrated however that the latter can be subducted deep down into the mantle (>100 km assuming only a lithostatic pressure) where these minerals formed before to be subsequently returned to shallow levels. Although tomographic studies leave no doubts that entire slabs can be buried down to the 660 km deep discontinuity (e.g. Fukao et al., 2009), exhumed UHP units of oceanic origin are paradoxically more scarce.

In the Western Mediterranean Orogen (WMO), evidence for crustal rocks affected by UHP metamorphism are restricted to only few areas in the Betic-Rif orocline (Ruiz-Cruz and Sanz de Galdeano, 2013a, 2013b) and more recently in the Maghrebides (Caby et al., 2014). The timing of UHP metamorphism in the WMO is however still the matter of controversy, with two alternatives corresponding to the two last main orogenic events that have affected this area, i.e. Hercynian or Alpine. This controversy mainly stems from the lack of firm geochronological determinations on UHP metamorphic units. Unraveling the age of UHP metamorphism in the WMO is therefore paramount to every model describing the formation and geodynamic evolution of this area.

In this article, we investigate the timing of UHP metamorphism recorded by mineral inclusions (rutile and zircon) in a diamond-bearing garnet megacryst from the Edough Massif of northeastern Algeria (Fig. 1), which has been the focus of a recent geochemical study (Caby et al., 2014).

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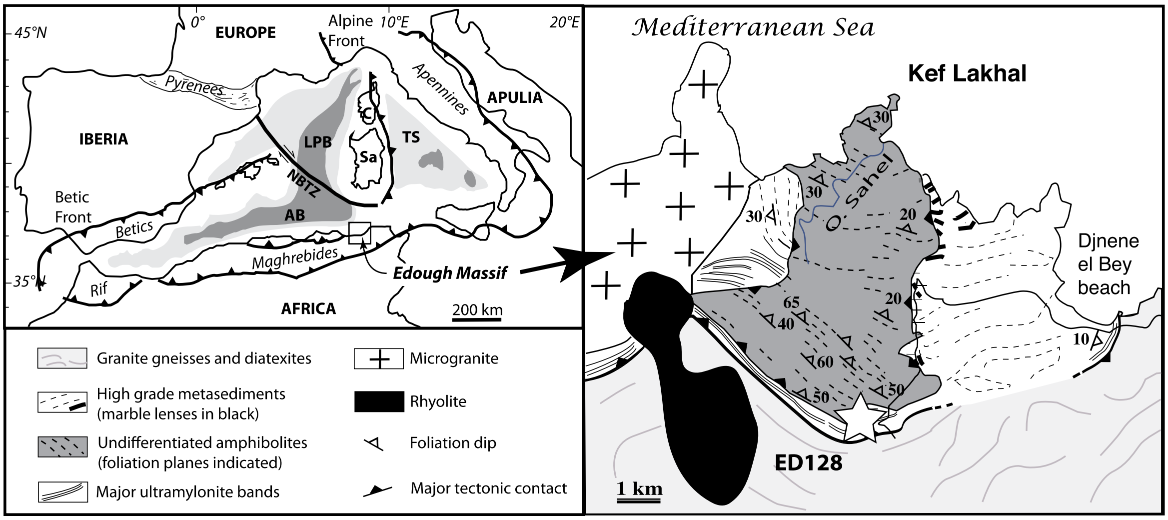

Fig. 1. Geological setting of the western Mediterranean region. The square delimits the Edough massif in NE Algeria. The enlargement shows the northern part of the massif and the location of the garnet megacryst ED128. AB = Algerian Basin; C = Corsica; LPB = Liguro-Provençal Basin; NBTZ = North Balearic Transform Zone; Sa = Sardinia; TS = Tyrrhenian Sea; dark gray = oceanic crust; light gray = extended continental crust.

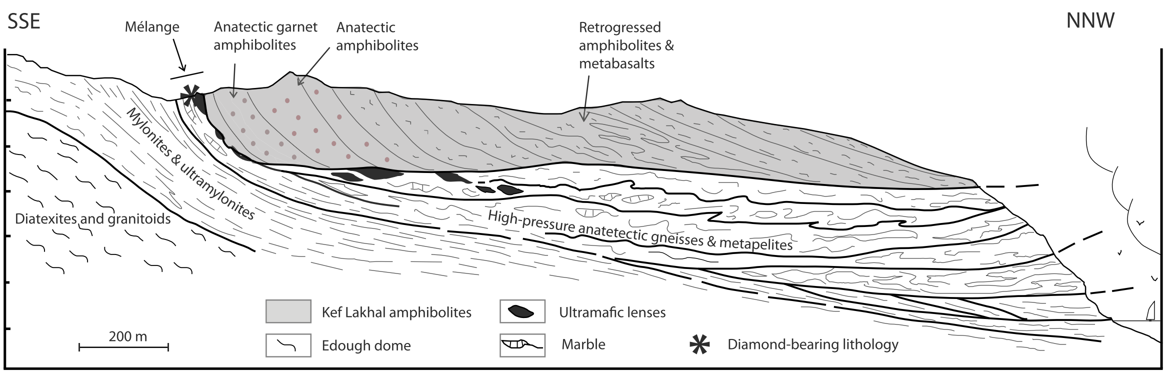

Fig. 2. Cross section across the Kef Lakhal amphibolites indicating the position of the dated sample (∗) in the regional tectonic architecture (modified from Caby et al., 2001).

2. Geological setting

The Edough Massif of NE Algeria is part of the Maghrebides, a *c*. 1200 km long peri-Mediterranean Alpine belt that extends from Morocco to Tunisia (Fig. 1). In the West Mediterranean jigsaw, which is constituted by oceanic and continental fragments squeezed between Africa and Eurasia, the Maghrebides of Algeria occupy a central position, midway from the Betic-Rif on the West and from the Calabrian-Peloritans on the East. The belt resulted mainly from the broadly eastward retreat of the Tethyan slab and from the drift of continental fragments originated from the fragmentation of the Paleo-European margin that finally collided with the North African margin (for a review see Michard et al., 2006). The retreat of the slab was responsible for the formation of back-arc basins, some of which developed sea-floor spreading during the Aquitanian/Burdigalian (21–16 Ma for the Liguro-Provençal basin after Faccenna et al., 1997), the Burdigalian/Tortonian (16–8 Ma for the Algerian basin after Mauffret et al., 2004) or during the Pliocene (since 5 Ma for the Tyrrhenian Sea after Faccenna et al., 1997).

Since the pioneering work of Caby et al. (2001), the Edough Massif of NE Algeria has been recognized as a Cenozoic metamorphic core complex. The massif consists of a gneissic dome (up to 1000 m above sea-level) mainly made of complexly deformed gneisses and migmatites. On top is exposed the allochtonous Kef Lakhal HT-HP amphibolite unit of oceanic origin (Bosch et al., 2014) that rests above a *c*. 50 m thick mélange (see Fig. 2). Rocks from the footwall of the Kef Lakhal amphibolites record deep amphibolite facies metamorphic conditions that approached 700–750 °C and 12–14 kbars (Caby et al., 2001) dated at 20.85 ± 0.34 Ma (U–Pb zircon age on low Th/U rims; Fernandez et al., 2016). Extensional movements affecting the crust of the North African margin, after the emplacement of the Tellian nappes, resulted in the formation of a metamorphic core complex and led to the rapid exhumation of the massif, including (U)HP units and mafic/ultramafic rocks at *c*. 17–18 Ma (Bruguier et al., 2009; Fernandez et al., 2016). The studied sample (ED128) is a garnet megacryst (>5 cm in diameter) taken from the tectonic mélange of mylonitic metapelites, marble, ultramafic and actinolite lenses reworked as a major extensional mylonite band (Fig. 1). In this horizon, garnet megacrysts are apparently hosted by actinolitite, but can only be sampled from the saprolitic soil, which hampered collecting a representative sample of the garnet host rock. The garnet megacryst has been the subject of a previous geochemical study (see Caby et al., 2014) and only the most salient features are reported below. The garnet is almandine rich and displays a remarkable chemical zonation (REE, Y and Mn) with decreasing contents from the core to the rim, typical of a growth in a closed system. It contains metamorphic diamond inclusions (up to 50 μm in size, see Fig. 3A) that document UHP metamorphic conditions of ≥750 °C (after the Zr-in-rutile thermometry reported in Caby et al., 2014) and ≥3.6 GPa (minimum pressure for entering the diamond stability field at 750 °C, based on the graphite/diamond transition curve of Day, 2012) undergone by a mafic protolith.