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Permo-Triassic thermal events in the lower Variscan continental crust section of the Northern Calabrian Arc, Southern Italy: Insights from petrological data and in situ U–Pb zircon geochronology on gabbros

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ABSTRACT

The Calabride nappe is the uppermost structural element of the Calabria–Peloritani Arc, it consists of a Variscan continental crust section intruded by late-Variscan granitoids, on which a Mesozoic syn-rift sedimentary cover was deposited. The deepest part of the Variscan continental section crops out in Northern Catena Costiera. The transition from crustal to mantle-derived rocks is often marked by gabbros. P–T estimates for gabbro emplacement have been calculated applying conventional thermobarometry and a mean crystallization temperature of about 800 °C at pressures between ~0.46 and 0.65 GPa has been determined. Gabbro emplacement occurs at the base of the crust, during a low-pressure granulitic stage that affected the country rocks at the end of an isothermal decompression. The gabbros can be classified as tholeiites with MORB affinity. In situ LA-ICP-MS U–Pb analyses have been performed on zircons from representative samples of gabbro. U–Pb concordia ages range from 224 ± 4 Ma to 296 ± 6 Ma. Two age populations of middle–early Permian and middle Triassic age, respectively, seem to document the magmatic activity responsible for gabbros intrusion. According to cathodoluminescent images and REE pattern of zircon, the early Permian age refers to a metamorphic inherited core.

Lithospheric thinning and a positive thermal anomaly, related to the exhumation of the deepest portion of the continental lithosphere, can explain the post-Variscan metamorphic evolution of the Calabride lithosphere and the underplating gabbroic magmatism. Since the major episode of gabbro emplacement is Triassic, this event could be related to the continental rifting that led to the opening of the Jurassic Tethys and Alpine cycle.

1. Introduction

Lithospheric thinning is generally associated with the exhumation of lower continental crust and upper subcontinental mantle through simple shear extensional processes (Whernicke, 1985). In this context, decompression and an anomalous high geothermal gradient induced by mantle upwelling lead to underplating of gabbros with tholeiitic affinity. Permo-Triassic gabbro emplacement in the lower to intermediate Variscan crust is well documented in the Southalpine and Austroalpine domains and in the External Liguride Units of Northern Apennines (Handy et al., 1999; Herman et al., 1997; Miller and Thoni, 1997; Montanini and Tribuzio, 2001; Peressini et al., 2007; Rebay and Spalla, 2001; Sinigoi et al., 1996).

This igneous activity, associated with regional scale deformation developed under high-temperature/low-pressure (HT-LP) metamorphic conditions (Lardeaux and Spalla, 1991), has been interpreted as the result of a late orogenic collapse of the Variscan collisional belt or as a lithospheric thinning event related to the rifting process that led to the opening of the Jurassic Tethys. In the second hypothesis, the distribution of these gabbro bodies within the Alpine chain area is localized within the African paleo-margin, suggesting an asymmetric rift-related evolution for the Austroalpine and Southalpine lower crust during Permo-Triassic times (Rebay and Spalla, 2001), although mafic intrusions of lower Permian age have been also reported in Corsica (Cocherie et al., 2005; Paquette et al., 2003; Tribuzio et al., 2009).

In this paper, we present a case study from the Northern Calabrian Arc, where a complete Variscan lithospheric section is exposed, from the crust–mantle boundary up to the transgressive Mesozoic syn-rift sedimentary cover. The crust-to-mantle transition is marked by gabbros with tholeiitic affinity, whose geodynamic significance is still ambiguous. In order to unravel this problem, we use petrological data, whole rock geochemistry and zircons REE pattern to constrain the emplacement conditions and in situ U–Pb geochronology on zircons to define the age of gabbro emplacement. This study provides an opportunity to better understand the evolution of the deeper portions of the pre-Mesozoic Calabrian continental fragment during the transition from the Variscan cycle to the Alpine cycle.

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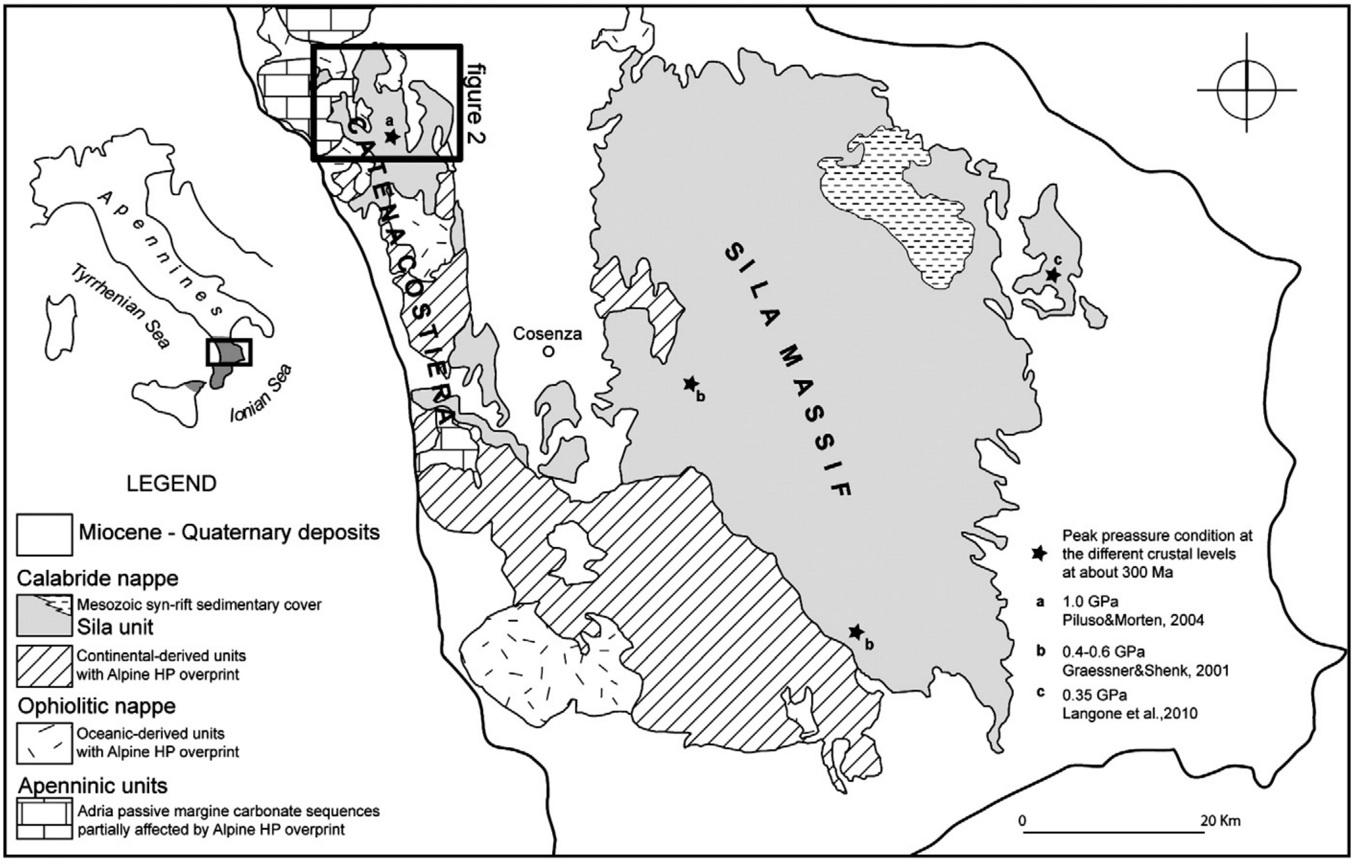

Fig. 1. Tectonic sketch map of the Northern Calabrian Arc with the location of the crustal sections for which petrological descriptions are available in the literature.

2. Regional geology

A fossil Variscan crustal section (Caggianelli et al., 2000; Graessner and Schenk, 2001; Piluso and Morten, 2004) is widely exposed and well-preserved in the Northern Calabrian Arc, despite this area being subjected to a complex tectonic history during Meso-Cenozoic geodynamic events. During this period it was involved in the Alpine orogenesis and then rifted apart as a consequence of the Tyrrhenian basin opening. This pre-Mesozoic continental fragment is referred to the Sila unit (Messina et al., 1994) and is part of the Calabride nappe complex (Fig. 1) (Ogniben, 1973; Amodio-Morelli et al., 1976). The Calabride nappe is the uppermost structural element of the Calabria–Peloritani Arc, overthrusting the high-pressure (HP) orogenic complex related to the Tertiary Alpine/Ionian subduction (Fig. 1) (Cello et al., 1996; Iannace et al., 2007; Liberi and Piluso, 2009; Liberi et al., 2006; Rossetti et al., 2001, 2004). The pre-Alpine paleogeographic position of this continental fragment is still debated, it is placed either onto the European paleomargin (Bouillin, 1984; Cello et al., 1996; Dietrich, 1988; Ogniben, 1973; Rossetti et al., 2001, 2004), the African paleomargin (Alvarez, 1976; Amodio-Morelli et al., 1976; Grandjacquet and Mascle, 1978; Scandone, 1982), or formed a microcontinent between these two paleomargins (Bonardi et al., 2001; Guerrera et al., 1993; Perrone, 1996; Vai, 1992).

The Sila unit consists of Variscan crystalline basement rocks intruded by late-Variscan granitoids. It is widely exposed in the Sila Massif, but appears strongly thinned in the Catena Costiera area (Fig. 1). The regional metamorphic grade and the equilibration pressure progressively decrease from West to East (Caggianelli et al., 2000; Graessner and Schenk, 2001), indicating that the deepest levels of the section crop out toward west, where mantle rocks are exposed in the Northern Catena Costiera (Piluso and Morten, 2004). In fact, the metamorphic evolution of the lower-intermediate crust rocks belonging to the Sila unit is characterized by peak metamorphic conditions ranging between 0.4 and 1.0 GPa at 700 °C and 800 °C respectively, depending on the crustal level (Graessner and Schenk, 2001; Piluso and Morten, 2004) (Fig. 1). The upper crust, after an early, medium pressure regional event, experienced a low pressure/high temperature metamorphic overprint (Langone et al., 2010) caused by the intrusion of huge volumes of granitoids at intermediate crustal levels. Peak metamorphic conditions in the lower-intermediate and upper crust and an anatectic event in the lower-intermediate crust occurred at about 300 Ma, coevally with the intrusion of calcalkaline melts within the intermediate crustal level (Graessner et al., 2000; Langone et al., 2010). The retrograde path of rocks belonging to the Sila unit is marked by isothermal decompression followed by cooling. The entire evolution is interpreted as reflecting crustal thickening and subsequent thinning stages during late Variscan times (Acquafredda et al., 2006; Caggianelli et al., 2007). The crustal thinning lasted until the early Permian, as documented by a dike swarm intruding the crystalline basement with a geometrical arrangement consistent with a transtensional stress regime (Festa et al., 2010). This extensional regime is further documented by a Mesozoic syn-rift sedimentary cover, which is still preserved only along the eastern margin of the Sila massif (Santantonio and Teale, 1987; Young et al., 1986); it was deposited directly above the upper crustal rocks of the Sila unit and the age of the oldest sediments is reported as Upper Triassic (Perrone et al., 2006; Young et al., 1986). The peak metamorphic phase and the anatectic event, that produced calcalkaline melts intruding the Sila unit, are about 300 Ma (Graessner et al., 2000).

3. Gabbro occurrence in the Sila unit of the Northern Catena Costiera

In the Northern Catena Costiera, the Sila unit is very thinned and comprise continental crust rocks and ultramafic rocks of sub-