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Structural and petrological analyses of the Frido Unit (southern Italy): New insights into the early tectonic evolution of the southern Apennines–Calabrian Arc system

Stefano Vitale [a,*], Lorenzo Fedele [b], Francesco D'Assisi Tramparulo [a], Sabatino Ciarcia [a,c], Stefano Mazzoli [a], Alessandro Novellino [d]

[a] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Università degli Studi di Napoli Federico II, Largo San Marcellino 10, 80136 Naples, Italy
[b] Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse (DiSTAR), Università degli Studi di Napoli Federico II, via Mezzocannone 8, 80134 Naples, Italy
[c] Dipartimento di Scienze per la Biologia, la Geologia e l'Ambiente, Università del Sannio, via dei Mulini 59/A, 82100 Benevento, Italy
[d] Dipartimento di Ingegneria Idraulica, Geotecnica ed Ambientale, Università degli Studi di Napoli Federico II, Via Claudio 21, 80125 Naples, Italy

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ABSTRACT

This study provides new data on the deformation and metamorphic evolution of the Jurassic to Upper Oligocene Frido Unit, an Ocean Continent Transition (OCT) Unit belonging to the Ligurian Accretionary Complex (LAC), by means of the integration of structural analysis, petrological investigations and a revision of the stratigraphical setting. The Frido Unit, representing the main metamorphic component of the Lower–Middle Miocene LAC in southern Italy, is characterized by a multistage tectonic evolution including: (i) two progressive deformation phases involving the development, under relatively high-pressure metamorphic conditions, of an early cleavage associated with isoclinal folds within the framework of a dominant SE-ward tectonic transport; (ii) a third deformation stage involving the growth of lower-pressure Na-amphibole along extensional shear surfaces (therefore probably marking the onset of tectonic exhumation); and (iii) two very low-temperature deformation phases characterized by the development of kink folds and associated thrusts, probably related to the late tectonic emplacement of the accretionary wedge onto the outer sectors of the Apennine domain (with a prevailing tectonic transport first toward the NE and then toward the NW). In order to clarify the metamorphic evolution of the Frido Unit, petrologic analyses were focused on its metasedimentary pelitic succession. Here, mineral paragenes-ses including carpholite (well-documented for the first time in this study) and potassic white mica yielded peak pressure of ~1.2–1.4 GPa and temperature around 350 °C, thus indicating a high pressure/very low temperature metamorphism and a P–T–t path characterized by a rapid exhumation without any greenschist-facies overprint. In comparison with similar units cropping out in northern Calabria, Tuscany and Corsica, the Frido Unit experienced one of the coldest burial-exhumation histories.

1. Introduction

The Apennines are a NW–SE-trending orogenic belt with a general eastward tectonic transport coeval with back-arc extension in the Tyrrhenian Sea (e.g., Carmignani et al., 2001; Carminati et al., 2012; Liotta et al., 1998; Mantovani et al., 2009; Mazzoli et al., 2008; Molli, 2008; Roure et al., 1991; Turco et al., 2012; Vitale and Ciarcia, 2013). The orogenic accretion of the Apennine prism, from the Early Miocene to the Middle Pleistocene, was characterized by a relatively fast migration of the thrust front-foredeep system (Faccenna et al., 2001; Vitale and Ciarcia, 2013), mainly driven by the eastward retreat of a west-directed oceanic slab (roll-back mechanism; Malinverno and Ryan, 1986; Carminati et al., 2012, and references therein). The development of the Apennine mountain belt and the associated fast E–W opening of the Tyrrhenian Sea (with spreading values up to ~10 cm/yr, Faccenna et al., 2001), compared with the slow N–S convergence between the Eurasian and the African/Adria plates (of the order of ~1 cm/yr; e.g., Mazzoli and Helman, 1994), indicate that a complex pattern of forces controlled the evolution of the proto-Central-Western Mediterranean Sea (e.g., Lustrino et al., 2011). The closure of the oceanic domain (E-Ligurian Ocean; Handy et al., 2010) interposed between the continental paleomargins and the still active subduction of the Ionian lithosphere (Minelli and Faccenna, 2010) allowed the overriding Calabria–Peloritani Terrane (CPT; Bonardi et al., 2001) to move E/SE-ward by at least 1000 km from ~30 Ma to the Present (Carminati et al., 2012; Vitale and Ciarcia, 2013). In such a geodynamic setting, slices of oceanic and continental crust and related sedimentary cover were subducted, reaching relatively high pressure conditions, and then quickly exhumed, allowing to preserve high pressure–low temperature (HP/LT) metamorphic assemblages (e.g., Brogi and Giorgetti, 2012; Brun and Faccenna, 2008; Iannace et al., 2007; Liberi and Piluso, 2009; Oberhänsli et al., 2001; Rossetti et al., 2004; Stöckhert et al., 1999; Vignaroli et al., 2009).

* Corresponding author. Tel.: +39 812538124; fax: +39 812538338.
E-mail address: stefano.vitale@unina.it (S. Vitale).

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A HP/LT event has been documented in the southern Apennines since the '70s (De Roever, 1972; Lanzafame et al., 1979; Spadea, 1976; 1982) within the ophiolitic succession of the Frido Unit (Knott, 1987, 1994) cropping out along the northern edge of Calabria (Fig. 1). More recently, Fe–Mg-carpholite-bearing metapelites have been found in Lower Miocene foredeep deposits stratigraphically overlying carbonate successions of the distal part of the Adria continental paleomargin (Lungro–Verbicaro Unit; Iannace et al., 2005, 2007).

By means of field structural, stratigraphical analysis and petrological investigations, integrated with microstructural observations on the metasedimentary succession, this study aims to provide an interpretation of the tectonic and metamorphic evolution of the Ocean Continent Transition (OCT)-derived Frido Unit, within the general framework of the southern Apennine/CPT system. This multidisciplinary approach may be effectively applied to the study of OCT-derived units in circum-Mediterranean settings characterized by significant tectonic burial and subsequent fast exhumation (e.g., Brun and Faccenna, 2008).

2. Geological setting

The Early Cretaceous to present convergence between the Eurasian and African plates (e.g., Dewey et al., 1989; Mazzoli and Helman, 1994, and references therein) resulted in the NW-directed subduction of the Alpine Tethys oceanic (E-Ligurian Ocean in Handy et al., 2010) and thinned continental lithosphere (Ciarcia et al., 2012) originally interposed between a northern continental margin (ascribed to the so-called AlKaPeCa micro-plate by Michard et al., 2002, and Guerrera et al., 2005; but see Turco et al., 2012 for an alternative paleogeographic setting) and the Adria block, of African affinity, to the south. In the central sector of the proto-Central-Western Mediterranean Sea, these processes led to the development of a large accretionary wedge named Ligurian Accretionary Complex (LAC; Ciarcia et al., 2012), which can be considered as the counterpart of the ophiolitic and deep basin successions extensively cropping out in the northern Apennines (Elter, 1975). The metamorphic Frido Unit (Bonardi et al., 1988a), is part of this accretionary complex, which also includes three tectonic units made of unmetamorphosed sedimentary successions (the Nord-Calabrese, the Parasicilide and the Sicilide Units; Bonardi et al., 1988a; Ciarcia et al., 2009; Fig. 2a). According to Cello and Mazzoli (1998) and most recent studies by Ciarcia et al. (2012) and Vitale et al. (2011), all of these units originally formed part of an OCT domain.

2.1. Study area

The Frido Unit crops out along the northern edge of Calabria region, forming a NW–SE elongated tectonic unit overlying the Nord-Calabrese Unit (which is locally exposed in tectonic windows; Fig. 3) in the south-eastern sector of the study area. On the other hand, in the north-western sector (Seluci area; Fig. 3) the Frido Unit is overlain by the Nord-Calabrese and Parasicilide Units.

The Upper Cretaceous (?)–lowermost Burdigalian Nord-Calabrese succession, extensively cropping out in the study area (Fig. 3), includes tens to hundreds of meter-sized ophiolitic bodies (gabbros, pillow lavas, radiolarian cherts), as well as subcontinental mantle rocks (serpentinized peridotities) and associated lower continental crust gneisses (Cello and Mazzoli, 1998) embedded in the Crete Nere Fm. The latter consists of black shales and intercalations of quartz-rich sandstones, dark-brownish

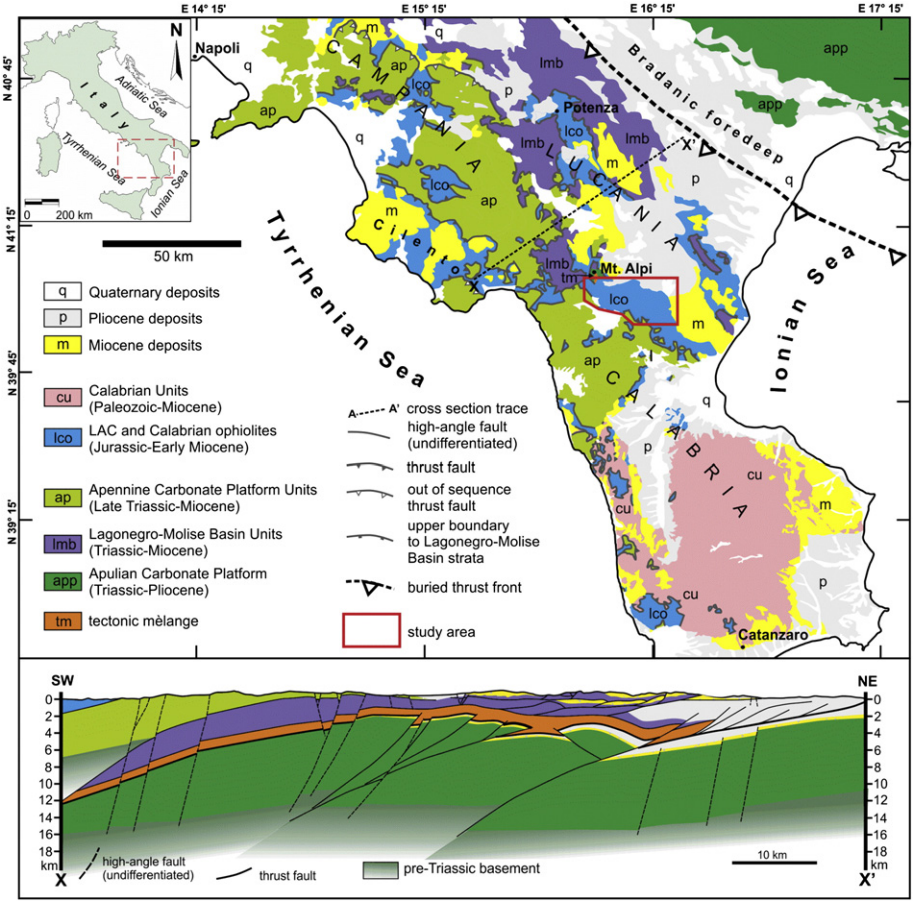

Fig. 1. Geological sketch map (from Amodio-Morelli et al., 1976 and Bonardi et al., 1988b, modified) and cross section (after Mazzoli et al., 2008, modified) of the southern Apennines.