

**THE LIGURIDE ACCRETIONARY WEDGE IN THE
CALABRIA-LUCANIA BORDER AREA (SOUTHERN APENNINES):
A THERMOCHRONOLOGICAL AND STRUCTURAL STUDY**

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Accretionary wedges represent a long-lasting tectonic environment where rock bodies can be underplated at great depths and subsequently exhumed in a relatively short time interval (Platt, 1986; Ernst, 1988). Exhumation mechanisms are still not well understood and much effort has been focused in understanding how the HP rocks return to the surface.

The accretionary wedge is considered as an open system (Platt, 1986), in which the material is removed by tectonic processes or by erosion (Ring & Brandon, 1994). In many cases, extensional shear zones have been recognised (Platt, 1986).

The Liguride Complex (Ogniben, 1969) represents the uppermost structural unit of the Southern Apennines (Patacca & Scandone, 2007, and reference therein). This mountain belt, resulting from convergence of different paleogeographic domains of the European and the Adria plates, developed during Neogene time with ENE vergence (Patacca & Scandone, 2007, and references therein). The Liguride Units represent the remains of a Jurassic ocean, which laid between the Calabrian and Apulian terrains. Late Cretaceous - Tertiary subduction of this oceanic domain gave rise to the Liguride accretionary wedge that finally collided with the Adriatic margin during the Late-Oligocene early-Miocene times (Knott, 1987, 1994).

During this evolution the accreted material was divided into two main tectonic units: the metamorphic Frido Unit (Amodio Morelli *et al.*, 1976; Bonardi *et al.*, 1988) and the non-metamorphic Nord Calabrese Unit (Bonardi *et al.*, 1988). The Frido Unit mainly consists of polydeformed metasediments, showing a low-grade metamorphic overprint, with associated blocks of oceanic and continental crust (Monaco & Tortorici, 1995; Knott, 1987, 1994; Spadea, 1982, 1994).

The meta-sedimentary rocks of the Frido Unit (Monaco *et al.*, 1995; Monaco & Tortorici, 1995) can be subdivided in a lower phyllite subunit, consisting of phyllites, meta-arenites, quartzites and isolated bodies of meta-limestones, and in an upper calcschist subunit mainly consisting of meta-limestones. Bodies of continental crust rocks, generally overlying slices of serpentinites (Spadea, 1982), are mainly composed of altered garnet gneisses, garnet biotitic gneisses and leucocratic gneisses. Often gneisses contain lenticular bodies of amphibolite, generally crosscut by mafic dikes (Spadea, 1982).

Petrographic and structural studies on the rocks of the Frido Unit shows that this entire domain was subjected to high pressure-low temperature conditions during the Alpine evolution (Spadea, 1982). In more detail, Spadea (1982) identified high pressure and low temperature mineral assemblages in the continental crust rocks. According to Knott (1987, 1994) the mineral assemblage of the HP/LT overprint formed during subduction by underplating processes. The HP/LT metamorphism evolved in the greenschist facies during exhumation of the lower portions of the accretionary wedge. According to Monaco *et al.* (1991) and Spadea (1982), the HP-LT metamorphic event was connected to crystallization of glaucophane-lawsonite in mafic rocks and aragonite in metasedimentary rocks.

Even though the main structural and petrographic features of the Liguride Units have been already described in the literature, the evolution of the Liguride accretionary wedge is still matter of debate. Two main hypotheses have been proposed in the literature to explain the geodynamic evolution of the Liguride units. The first hypothesis considers the Liguride terrains as elements of an Apulia-verging accretionary wedge (e.g. Ogniben, 1969; Knott, 1987; Monaco & Tortorici, 1995; Cello & Mazzoli, 1999), related to the Late Cretaceous to Oligocene subduction of the neotethyan oceanic crust. The second hypothesis considered these terrains as remnants of an Europe-verging Alpine wedge of Cretaceous-Eocene age, later incorporated in the construction of the Apulia-verging Apennine chain during the Oligocene-Miocene times (e.g. Amodio Morelli *et al.*, 1976; Bonardi *et al.*, 1988).

The thesis work aims to define more clearly the evolution of the Liguride accretionary complex by means of structural, microstructural, petrographical, mineralogical and geochronological data. In particular, age determinations on the exhumation of underplated have been used to reconstruct the internal dynamics of the accretionary wedge and the age of the subduction process. Mineralogical data for the metasediments provided more precise determinations of the metamorphic conditions that have been compared with petrological evidence obtained from ophiolitic and continental crust rocks. Structural and microstructural data gave new indications on the deformation history and on the shear sense of the major mylonitic levels. These new data provide new constraints in the geodynamic modelling of the western Mediterranean area and on the thermotectonic evolution (*sensu* Brandon, 1992; Hasebe *et al.*, 1993; Tagami & Dumitru, 1996) of the Liguride wedge.

Field, mineralogical and petrographical data allowed to subdivide the Liguride accretionary complex into three main tectonic units: i) the uppermost Frido Unit, characterized by low-grade metamorphic conditions; ii) the intermediate M. Tumbarino Unit, characterized by metamorphic conditions intermediate between anchizone and diagenesis; iii) the lowermost North Calabria Unit, showing only diagenetic conditions.

The study has been concentrated on the Frido Unit that documents deformation and metamorphic features typical of the deep portions of the Liguride accretionary wedge. Geological mapping has been carried out in five significant areas (from the East to the West: Seluci-Perruttieri-M. Nandiniello, Gallizzi, Cropani-Episcopia, Timpa delle Murge and M. Tumbarino), where the main lithologies and structures of the Frido and M. Tumbarino units crop out (Fig. 1).

In the Frido Unit the ophiolitic rocks are characterized by differences in deformation features and metamorphic grade. The more widely exposed metabasites show well-developed foliation and lineation. They consist of meta-pillow lavas, meta-pillow breccias and meta-hyaloclastites. Frequently, these rocks are in contact with metalimestones and phyllites. In turn, blocks of metabasites (metadolerites) associated with serpentinites are devoid of planar and linear fabrics.

The detailed structural analysis carried out in the study area allowed to recognize structures related to a polyphase deformation history, well developed in metasedimentary rocks of the Frido Unit. Structures and fabric elements related to two early deformation phases (D1 and D2) are overprinted by a later phase developing decametre D3 E-W oriented folds.

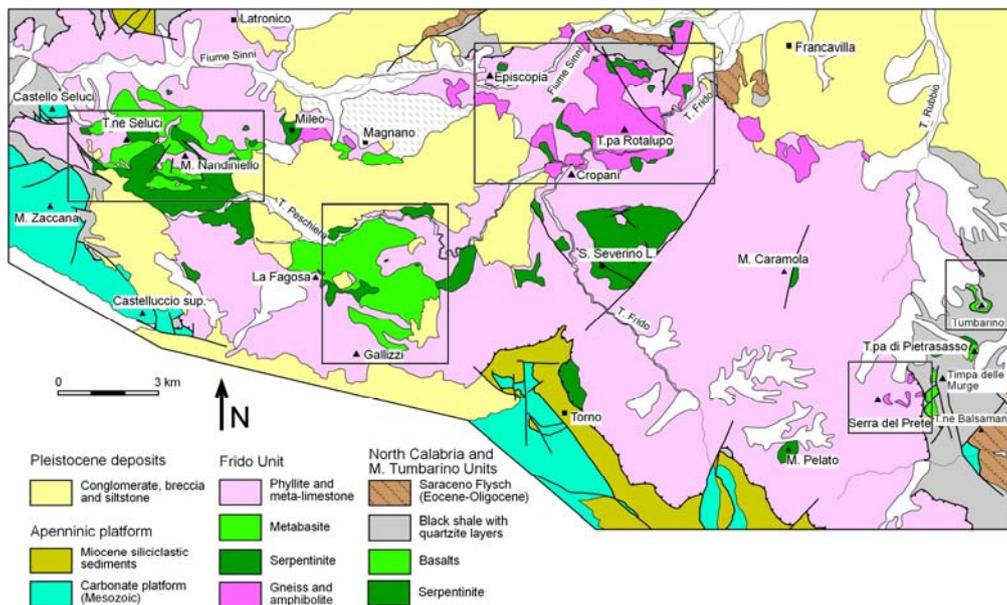


Fig. 1 - Geological sketch map of the Liguride Units in the Calabria-Lucania border area. Boxes outline the areas where detailed fieldwork has been carried out.

D1 foliation is associated with metamorphism under blueschist facies conditions. In places, metabasites affected by D1 mylonitic foliation are overprinted by static crystallisation of euhedral lawsonite porphyroblasts, indicating that high-pressure conditions outlasted the D1 deformation. Later D2 folds and crenulations overprint the previous fabrics, producing a well-developed crenulation cleavage. Local occurrence of riebeckite along the crenulation cleavage suggests that HP-LT conditions operated also during the D2 deformation.

Shear sense indicators obtained from mylonitic bands are mainly coherent with top-to-the-W and top-to-the-NW shear sense. However, indicators showing S- to SE-directed shear have been also found.

A mineralogical and petrological analysis of metabasites, which represent the major component of the ophiolitic sequences of the Frido Unit, has been performed by means of optical microscopy and electron microprobe. Mineral and whole-rock analyses have been used to document the composition of minerals belonging to the HP-LT assemblage and to reconstruct the P-T path.

In the present work the P-T conditions of selected samples of metabasites in the blueschist zone have been estimated using thermobarometric methods. Estimates have been done for glaucophane-omphacite- and jadeite-bearing rocks using the Theriak/Domino software (de Capitani, 1994). This software allows the construction of P-T phase diagrams that have been applied in order to reconstruct the P-T path in metabasites.

The common blueschist facies mineral assemblage in the massive metadolerites consists of sodic amphibole + sodic pyroxene + chlorite. Sodic pyroxene forms prismatic crystals, commonly replaced at the rims by glaucophane. P-T conditions of the blueschist facies metamorphism are estimated to 8-12 kbar and 300-400°C. In particular, absence of lawsonite in metadolerites indicates that pressure did not

exceed about 13 kbar. The blueschist facies metamorphism was followed by a decrease in pressure and temperature up to the pumpellyite stability field.

Metamorphic conditions deduced in mafic rocks have been compared with mineralogical data obtained by X-ray diffraction in low-grade metasediments. This analysis has been performed by using methods taken from studies on diagenesis or anchimetamorphism, such as illite crystallinity (Frey & Robinson, 1999), the percentage of $2M_1$ polytype (Maxwell & Hower, 1967) and the b_0 parameter of illite-muscovite (Sassi & Scolari, 1974). By these means, an average temperature of 250°C and a pressure ranging between 7 and 9 kbar can be estimated for the Frido Unit. Estimated pressures are coherent with the widespread presence of aragonite in the metalimestones. Even higher pressures (and, possibly, temperatures) are probably recorded in the southern sector (Seluci-Perruttieri-M. Nandiniello and Gallizzi areas) where quartz veins in phyllites contain carpholite. Metapelites of the M. Tumbarino Unit show a metamorphic overprint occurring at a distinctly lower temperatures (about 200°C) and pressures (about 6 kbar).

In this study the exhumation age of the underplated material has been investigated by the fission track (FT) method. This allows to obtain information on the thermotectonic evolution of the Liguride accretionary wedge, now incorporated within the Southern Apennine chain. Fission track analyses are a useful tool to unravel the cooling history experienced by rocks at low temperatures, generally acquired by upper crustal levels. In particular, closure temperatures of fission tracks in zircon are close to maximum temperatures reached by the Liguride Units during the HP-LT metamorphism.

The fission track method (FT) has greater sensitivity to metamorphic overprinting at temperatures between 200-320°C (Tagami *et al.*, 1996) or $240\pm 50^\circ\text{C}$ (Hurford, 1986) or 260°C (Liu *et al.*, 2001) compared with other techniques and thus is well suited for low-temperature thermochronology. The temperature of 260°C (Liu *et al.*, 2001) corresponds to the limit between the prehnite-pumpellyite facies and the greenschist facies metamorphism (Naeser, 1979; Gleadow *et al.*, 1983; Green *et al.*, 1989). Coupling petrological data with FT analyses is possible to fix the paleogeothermal gradients during exhumation of the HP-LT rocks.

Thermotectonic evolution of continental crust slices from the Liguride accretionary wedge is presently unknown. Here we report the first results of FT analyses of zircons from continental crust fragments (garnet gneiss, garnet-biotite gneiss and metagranite) and a metapelite sample from the Frido Unit. The minor thermal input provided by HP/LT metamorphism, eventually coupled with the later greenschist facies overprint, was likely capable to reset the zircon fission track geochronometer.

Results indicate that FT in zircons from the main continental crust slice of Timpa Rotalupo (Cropani-Episcopia area) record exhumation ages of about 65-56 Ma, corresponding to the Paleocene. A younger Oligocene event is supported by “mixed” ages obtained in some metagranitoids and in a basement slice from the Episcopia area. A sample of low-grade metasediments yields poorly constrained Cretaceous ages, indicating that locally FT in zircons were not reset during the HP-LT event.

Geochronologic data of continental crust rocks indicate that possibly the Liguride Complex underwent a multistage subduction and exhumation history. However, the overall evolution took place under a low geothermal gradient, typical of HP-LT metamorphism. This is well documented by the presence of HP-LT parageneses statically overgrowing the D1 mylonitic foliation and growing syntectonically along the D2 crenulation cleavage. Paleocene ages can be related to the early evolution of the “Alpine” accretionary wedge, as documented by the W- to NW-directed shearing found in some

mylonitic bands. On the other hand, Oligocene ages possibly record the incorporation of the Liguride Units in the Apennine chain.

Finally, we propose that the exhumation processes recorded in HP-LT rocks from the Frido Unit shows some similarities with respect to the evolution recognised in the Franciscan Complex. In particular, both subduction complexes are characterized by exhumation taking place in an overall “cold” environment. In the Frido Unit this is clearly shown by the widespread occurrence of well-preserved HP/LT minerals (glaucophane, Na-pyroxene, lawsonite, riebeckite and aragonite) and by the lack of a significant overprint in the greenschist facies.

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