

Calabria and Peloritani: Where did they stay before the Corsica-Sardinia rotation? Boundary conditions, internal geological constraints and first-order open problems

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RIASSUNTO

Dove erano la Calabria e i Monti Peloritani prima della rotazione della Sardegna e della Corsica? Condizioni ai margini del sistema, vincoli geologici all'interno del sistema e principali problemi aperti.

Vengono discusse due alternative ricostruzioni palinspastiche del Mediterraneo centrale entrambe riferite all'Oligocene intorno al limite Rupeliano-Chattiano. In tutte e due le ricostruzioni l'Unità di Stilo è interpretata come una falda di provenienza europea ed è ricollocata in corrispondenza del margine orientale della Sardegna. La successione stratigrafica di Longobucco (appartenente all'Unità della Sila) e la successione stratigrafica dell'Unità Longi-Taormina affiorante nei Monti Peloritani vengono riferite allo stesso dominio paleogeografico. Questo dominio è stato ricollocato a nord della catena cretacico-eocenica, in una posizione adiacente al dominio di Stilo, nella prima ricostruzione e a sud della Catena cretacico-eocenica nella seconda ricostruzione.

KEY WORDS: *Mediterranean region, Calabria, Peloritani, Sardinia, Oligocene, palinspastic restoration.*

INTRODUCTION

Relationships between Corsica-Sardinia and Calabria-Peloritani have fascinated geologists for long time. However, no univocal solution has been reached as yet.

Starting from the early seventies, i.e. from the time in which Calabria began to be interpreted as the southward continuation of Alpine Corsica (HACCARD *et alii*, 1972; ALVAREZ *et alii*, 1974; ALVAREZ, 1976; AMODIO MORELLI *et alii*, 1976), most of the authors have taken from granted that the crystalline nappes of Calabria and Peloritani had been piled up before 25 Ma, i.e. before the onset of the rifting in the Valencia Trough. In such a picture, Calabria and Peloritani were located somewhere east of Sardinia already incorporated in the Cretaceous-Paleogene mountain chain (see among many others GUEGUEN *et alii*, 1998; ROSENBAUM *et alii*, 2002a; ROSENBAUM & LISTER, 2004; SCHETTINO & TURCO, 2006; PATACCA & SCANDONE, 2007). According to other authors, on the contrary (GUERRERA *et alii*, 1993, 2005), at 25 Ma Calabria and Peloritani had not yet been incorporated in the mountain chain and were part of a microplate (Mesomediterranean Microplate) separating two branches of the Tethys Ocean (Piemontese-Ligurian Ocean, westwards linked to the Nevado-Filabride Ocean and Lucanian Ocean, westwards passing into the Maghrebian Flysch Basin).

A paleogeographic position of the Calabria-Peloritani domains out of the Paleogene orogenic wedge would be testified by the

early Miocene age (see DE CAPOA *et alii*, 1997; BONARDI *et alii*, 2002, 2003) attributed to the top of the Alpine sedimentary covers of the Longi-Taormina and Stilo Units (the lowest nappe and the highest one, respectively, in the southern sector of the Calabrian Arc).

Before discussing problems concerning palinspastic restorations, let us give a look to the structural architecture of the Calabria-Peloritani tectonic edifice. The Calabrian Arc is currently interpreted as a composite terrane (BONARDI *et alii*, 2001, 2004) made up of a northern terrane which includes the Calabrian Coastal Chain, the Sila Massif and the northern slope of the Serre Massif and a southern terrane which includes the bulk of the Serre Massif, the Aspromonte Massif and the Peloritani Mountains.

In the northern sector three groups of nappes can be distinguished (see AMODIO MORELLI *et alii*, 1976; SCANDONE, 1982; BONARDI *et alii*, 2001, 2004; ALVAREZ & SHIMABUKURO, 2009 and references therein). Moving upsection, they are represented by:

- Piedmont-type and Liguria-type ophiolite-bearing nappes, both affected by Alpine metamorphism (Diamante-Terranova, Gimigliano p.p. and Malvito Units);
- Basement nappes with or without a post-Hercynian sedimentary cover, affected by Alpine metamorphism (Bagni Unit and Castagna Unit);
- Basement nappes with a post-Hercynian sedimentary cover not affected by Alpine metamorphism (Sila Unit sensu MESSINA *et alii*, 1991 and Stilo Unit).

The ophiolite bearing nappes and the overlying Bagni and Castagna Units are supposed to represent the nucleus of a mountain chain built up in Cretaceous-Eocene times with European vergence according to some authors (e.g. AMODIO MORELLI *et alii*, 1976; TORTORICI *et alii*, 2009) and with African vergence according to others (e.g. BOULLIN *et alii*, 1986; DIETRICH, 1988). The Bagni and Castagna Units are supposed to have been derived from the African continental margin (or from the Mesomediterranean Microplate) in the first case and from the European continental margin in the second case.

In the southern sector (BONARDI *et alii*, 2001, 2004, 2008), there is no trace of the Cretaceous-Eocene mountain chain. The lowest units crop out in the Peloritani Mountains where the general structural architecture may be schematized as a northward-dipping imbricate fan with southward vergence. Moving upsection, the following units or groups of units have been distinguished:

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- Basement nappes with post-Hercynian sedimentary covers not affected by Alpine metamorphism (Longi-Taormina, Fondachelli and Piraino Units) or affected by very low-grade Alpine metamorphism (Mandanici and Ali Units, sandwiched between the Fondachelli and Piraino Units). These units crop out only in the Peloritani Mountains;
- Basement nappes without Alpine sedimentary covers, not affected by Alpine metamorphism (Mela Unit in the Peloritani Mountains; Africo Unit in Southern Calabria) or affected by low-grade Alpine metamorphism (Cardeto Unit in Calabria);
- Pre-Variscan Aspromonte Unit, showing a low to medium-grade Alpine metamorphic overprint;
- Stilo Unit, composed of a Variscan basement and a post-Hercynian sedimentary cover not affected by Alpine metamorphism. The Stilo Unit is the highest nappe of the Calabrian Arc and crops out both in Southern Calabria and Northern Calabria.

The lowest element of the nappe pile (Longi-Taormina Unit) displays close similarities with the Sila Unit of Northern Calabria and thus the two units are supposed to have derived from the same paleogeographic realm.

In the southern sector of the Calabrian Arc the entire pile of nappes is sealed by the terrigenous deposits of the Stilo-Capo d'Orlando Formation (BONARDI *et alii*, 1980; CAVAZZA & DE CELLES, 1993; CAVAZZA *et alii*, 1997). The time in which nappe stacking took place is constrained by the age of the youngest deposits involved in the shortening and by the age of the oldest thrust-top deposits sealing the tectonic edifice. In order to obtain reliable palinspastic reconstructions, it would be useful to reach a general consensus about the age of the base of the Capo d'Orlando Formation and about the age of the youngest deposits of the Stilo, Longi-Taormina and Longobucco stratigraphic sequences. Unfortunately there is at present no certainty on all these important points. As concerns the top of the Longi-Taormina Unit (Frazzandò Formation) the age attributions existing in the literature span from the early Oligocene (e.g. WELTJE, 1992; LENTINI *et alii*, 1995) to the Aquitanian (DE CAPOA *et alii*, 1997). Still more problematic is the top of the Longobucco sequence since the available geological information is insufficient for a reliable definition of the terrigenous Paludi Formation which may be interpreted as a thrust-top deposit (see BONARDI *et alii*, 2005 who propose this interpretation and attribute to the formation an age not older than the Aquitanian) or as a wavyflysch comparable to the Frazzandò Formation. Uncertainties exist also on the top of the Stilo stratigraphic sequence, represented by shallow-water limestones rich in larger foraminifers. The microfacies of these limestones, showing no trace of reworking, points to a late Rupelian-early Chattian age (*Nephrolepidina praemarginata* associated with small *Nummulites* and *Halkyardia minima* in the absence of *Miogypsina* or *Miogypsinoides*). However, the ages attributed to these deposits in the geological literature span from the Chattian (e.g. PATTERSON *et alii*, 1995; CAVAZZA *et alii*, 1997, $^{87}\text{Sr}/^{86}\text{Sr}$ isotope stratigraphy results) to the Aquitanian (BONARDI *et alii*, 2002, 2003, nannoplankton analysis results). As concerns the age of the Stilo-Capo d'Orlando Formation, there is in the geological literature a general consensus about the top of the formation (Burdigalian) but not about the base, which ranges from the Rupelian (e.g. WELTJE, 1992) or the Chattian (e.g. PATTERSON *et alii*, 1995; CATALA-

NO & DI STEFANO, 1996) to the Burdigalian (BONARDI *et alii*, 2002, 2003). Besides the biostratigraphic uncertainties, we also miss reliable geological data to decide whether the lignite-bearing deposits of Agnana and Antonimina represent the lower portion of the Stilo-Capo d'Orlando Formation or belong to an older, pre-orogenic sedimentary cycle. We recall here that these deposits have yielded a form of *Anthracotherium* considered by ESU & KOZAKIS (1983) more primitive than *A. magnum* and attributed by these authors to the latemost Suevian-earliest Arvernian (roughly latemost Rupelian-earliest Chattian).

The uncertainties on the ages of the above key deposits have dramatic consequences on palinspastic restorations, as well as on the choice of the reference time for the initial fit. If the base of the Stilo-Capo d'Orlando Formation had an Oligocene age nappe stacking would have been completed before 25 Ma and the tectonic units forming the Calabrian Arc, telescopically shortened and confined in the mountain belt, would occupy a relatively narrow space. Consequently, the space between Europe and Africa established by the boundary condition, i.e. by the relative position of the two plates at that time, would be exclusively filled with the restored Apenninic-Maghrebian paleogeographic domains, apart from a relatively narrow belt occupied by the mountain chain. In the second case, on the contrary, we should relocate in their original position all the Calabria-Peloritani nappes not yet interested by orogenic transport and consequently a significant portion of the available space would be occupied by these realms. Both scenarios will be discussed. Anyway we have chosen to refer the initial fit to 30 Ma because we feel quite sure that at that time only the ophiolite-bearing nappes and the Bagni plus Castagna Units were part of the mountain chain whilst all the other Calabria-Peloritani domains had not been reached by the compression front.

Figures 1 and 2 provide two alternative palinspastic restorations at 29 Ma which differ in the relocation of the Longi-Taormina-Longobucco paleogeographic domain. Boundary conditions have been established by the Africa-Europe relative position according to ROSENBAUM *et alii* (2002b), considering Apulia, Southern Sicily and Istria attached to stable Africa. Corsica and Sardinia have been rotated clockwise following FERRARINI *et alii* (2003) and GATTACCECA *et alii* (2007). The fit of Corsica-Sardinia takes into account WESTPHAL *et alii* (1976), REHAULT (1982), GUEGUEN (1995), MAUFFRET *et alii* (1995), OLIVET (1996), SÉRANNE (1999), GUENNOC *et alii* (2000) and BACHE *et alii* (2010). The fit of the Balearic Islands closely follows MAILLARD & MAUFFRET (1999). Basic criteria guiding the restoration of the Apenninic-Maghrebian domains have been discussed in PATACCA & SCANDONE (1989, 2007, 2009) and in PATACCA *et alii* (1990, 1993).

In both figures the Stilo Unit has been relocated close to Sardinia, as already suggested by AMODIO MORELLI *et alii* (1976), BOULLIN *et alii* (1986) and VAI (1992), because of the remarkable analogies recognized both in the Paleozoic basements and in the Mesozoic sedimentary covers. Referring to the sedimentary cover, we wish to stress the following facts:

- The terrigenous deposits overlying the Paleozoic basement, frequently reported in the geologic literature as a Triassic Verrucano (e.g. CRITELLI & FERRINI, 1988; PERRONE *et alii*, 2006), have in reality a middle Jurassic age

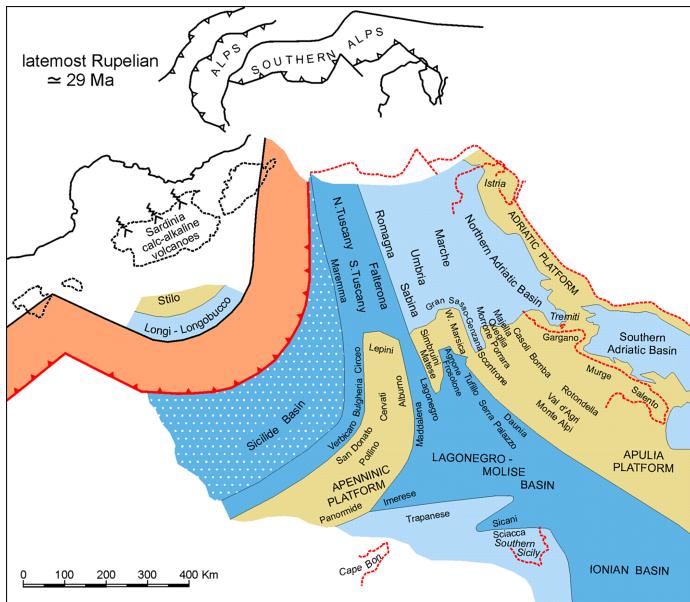


Fig. 1 – Palinspastic restoration of the Central Mediterranean region at about 29 Ma when the “Mid-Oligocene” global sea-level fall caused widespread subaerial exposure over the platform areas (yellow). Both Stilo and Longi-Taormina-Longobucco depositional domains have been relocated in Europe, north of the mountain chain. Dark-blue colours indicate deep-sea basins floored by thinned continental crust and, at least in part, by oceanic crust. Light blue colour indicates basins and pelagic plateaux floored by continental crust.

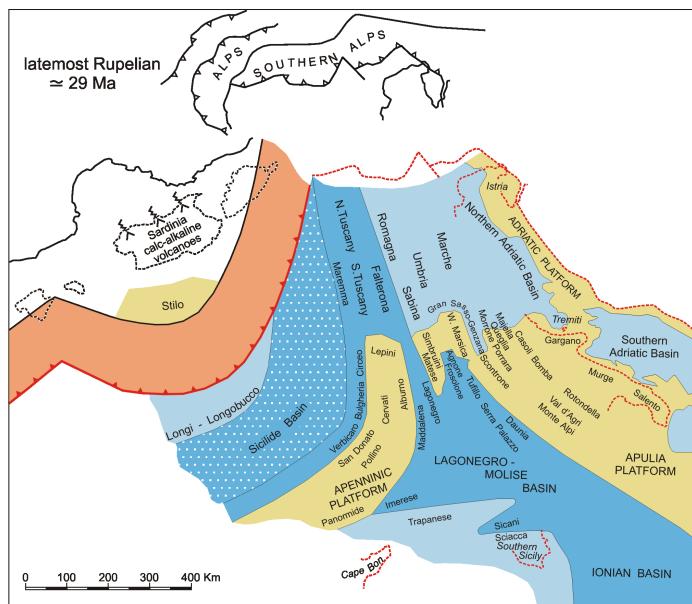


Fig. 2 – Idem fig. 1 with the relocation of the Longi-Taormina-Longobucco depositional domain south of the mountain chain.

(TAUGOURDEAUX-LANTZ & DUBOIS, 1979) and correlate with the coeval Genna Selole Formation of eastern Sardinia which shows identical lithological composition and (see DEL RIO, 1984) similar palynological content;

- Both in Sardinia and at Tiriolo the middle Jurassic terrigenous deposits are conformably followed by dolomites (Dorgali Formation of eastern Sardinia, late Bathonian-Callovian);

- The iron mineralization of Bivongi at the base of the Mesozoic carbonates of Monte Consolino-Monte Stella-Monte Mammicomito has its counterpart in the “ferro dei Tacchi” of Ogliastra;
- The upper Jurassic-lower Cretaceous limestones of Monte Consolino-Monte Stella-Monte Mammicomito, as well as the upper Jurassic limestones of Monte Mutolo near Canolo (see RODA, 1965) are identical to the coeval deposits of the Monte Bardia Formation in eastern Sardinia.

The palinspastic restoration of the Sila Unit is more problematic and in any case whatever solution we choose for the original position of the Longobucco domain the same solution must be applied to the Longi-Taormina domain because of the remarkable similarities of the stratigraphic sequences. No Mesozoic deposits correlatable with the Peloritani and Sila sedimentary sequences are known either in Sardinia or in the Insubric domains. According to VAI (1992) the absence (or the scarcity) of Permo-Triassic deposits in the Longobucco sequence suggests a provenance from areas close to eastern Sardinia. The same author has also underlined some analogies between the Paleozoic basement of Sardinia and the pre-Alpine metamorphites exposed in the Longobucco-Bocchigliero area. However, no counterparts of the high-grade Monte Gariglione and Polia-Copanello metamorphites exist in eastern Sardinia. Figure 1 shows our preferred solution. This solution agrees with the nappe geometry in Northern Calabria, where the Stilo and Sila Units overlie the Cretaceous-Eocene mountain chain, and agrees with the structural features of the Sila Nappe all indicating a tectonic transport towards the NE (in present-day coordinates). The model, however, does not explain the absence of the Cretaceous-Eocene mountain chain in the southern sector of the Calabria-Peloritani Arc unless we imagine a continuation of this tectonic element north of the Sicilian Coast as a buried duplex system underlying the stack of the Peloritani nappes. Figure 2 shows an alternative solution according to which all units of the southern sector of the Calabria-Peloritani Arc except the Stilo Unit have been relocated in a paleogeographic domain belonging to the Mesomediterranean Microplate of GUERRERA *et alii* (1993, 2005). This model agrees with the overall geometry of the Aspromonte and Peloritani mountains but does not explain the absence of the Cretaceous-Eocene mountain chain between the Stilo Unit and the Aspromonte Unit. In addition, the model does not explain the absence of Europe-verging structures in the Sila nappe which in Northern Calabria lies on top of the Cretaceous Eocene mountain chain.

Let us conclude citing a statement of the great master Maurice Gignoux: “pas tectonique sans stratigraphie”.

We expect that integrated structural-stratigraphic studies will shed new light on the major open problems of the Calabria-Peloritani geology.

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