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SOME REMARKS ON THE CALABRIA-PELORITANI ARC AND ITS RELATIONSHIP WITH THE SOUTHERN APENNINES

Abstract. Interpretations of the structure and evolution of the Calabria-Peloritani Arc are briefly reviewed, emphasizing its interpretation as the result of a juxtaposition of two sectors. Their different tectonic and metamorphic evolution is stressed, as well as open questions on their interactions. The currently proposed correlations between the ophiolitic and crystalline basement nappes of the Northern sector of the Calabrian Arc and those outcropping at the Calabria-Lucania border area are criticized on the basis of biostratigraphic data and field evidence from a recent revision of the "Liguride Complex" Auct. Three working hypotheses about the paleogeography and the tectonic evolution of the corresponding segment of the oceanic area are suggested to account for a deformation of the Calabria-Lucania border ophiolitic units occurring later than that of the Northern Calabrian ophiolitic units.

INTRODUCTION

The Calabria-Peloritani Arc (Fig. 1), with its extensive outcrops of igneous and metamorphic rocks, appears to break the continuity of the Apenninic-Maghrebian Chain, formed almost exclusively of Meso-Cenozoic sedimentary cover. Probably due to this peculiarity, its structure and evolution have been till now a matter of debate, and many contrasting interpretations have been proposed. They can be schematically grouped and summarized as follows, tracing them back to the interpretations introduced between the end of the last century and the beginning of the present:

1) the Calabria-Peloritani Arc is an autochthonous massif, as proposed in the first regional synthesis by Cortese (1895). During the Alpine orogenic cycle it underwent horizontal displacements, rotations, subsidence and uplift without any important internal deformation (Goerler and Giese, 1978).

2) the arc is either an Hercynian tectonic construction or a portion of the African crystalline basement, which was affected during the Alpine tectogenesis by more and less important thrusts (Quitzow, 1935; Caire et al., 1960; Grandjacquet et al., 1961; Glangeaud et al., 1962; Dubois, 1970; 1976; Lorenzoni and Zanettin Lorenzoni, 1983; Ferla et al., 1983; Acquafredda et al., 1988).

3) the arc is formed from several nappes, piled up during the Alpine tectogenesis involving also an ancient crystalline basement, as proposed for the first time by Lugeon and Argand (1906) and Limanowsky (1913).

The latter interpretation is presently followed by a large number of Authors, some of whom will be quoted later on. We believe that it agrees best both with field evidence and with the

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overall framework of the Alpidic Western Mediterranean Chains.

STRUCTURE AND EVOLUTION OF THE ARC: STATE OF THE ART

Leaving out models in which the Calabria-Peloritani Arc (or a part of it) is interpreted as autochthonous or only slightly deformed by the Alpine tectogenesis, among the Authors who recognize its structure as a pile of unrooted nappes, there is a general agreement in distinguishing in Northern Calabria three main tectonic elements. From bottom to top they are as follows:

1) units formed by Triassic phyllites, evaporites and dolomites and by Liassic limestones;

2) ophiolite bearing units;

3) three or more, depending on the Author, tectonic units formed by a pre-Alpine crystalline basement, sometimes with a sedimentary or weakly metamorphosed cover.

This geometrical arrangement has been the subject of different interpretations, which diverge mainly on the origin of the crystalline nappes, whereas they generally accept a correlation between the units of element 1), outcropping in tectonic windows of the Catena Costiera, and the carbonatic units widely represented in the Southern Apennines. Similarly, it was the general opinion that in Southern Calabria and in the Peloritani Mts only element 3) crops out.

Ignoring minor contrasts among the Authors about the definition of the individual nappes, two opposing interpretations have been proposed:

a) the crystalline nappes originated from the European continental margin. They were piled up, together with the ocean-derived elements, during the Paleogene. In the Miocene, both overthrust the Apenninic domains (Ogniben, 1969, 1973, 1985; Bouillin, 1984; Bouillin et al., 1986);

b) the crystalline nappes originated from the African continental margin (Austroalpine belt). They were piled up together with the ophiolitic units during the Cretaceous-Paleogene, and transported toward a European foreland to form an Eo-Alpine chain. During the Neogene a large fragment of this chain was backthrust, overriding the Apenninic domains. Afterwards it followed the build up of the Africa-verging Apennine-Maghrebian Chain as the uppermost tectonic element (Haccard et al., 1972; Alvarez, 1976; Amodio Morelli et al., 1976; Grandjacquet and Mascle, 1978).

Till now there has been no evidence strong enough to exclude without doubt either of these two alternatives. Even the meso- and microstructural analyses do not give any real contribution to solving the controversy, since some authors support the first model (Knott, 1987; Dietrich, 1988), some the second (Alvarez, 1976; Faure, 1980; Cello et al., 1991).

It should be noted that a transform fault is required by the model a) to account for the provenance from different continental blocks of the Calabria crystalline nappes and of the Austroalpine nappes of the Alps (Boullin, 1984). According to model b) there is no need for such a structure, but a backthrust of an earlier chain with an orogenic transport greater than that known in the Ligurian Alps and in Corsica has to be assumed. In both models the Calabria-Peloritani Arc is considered a segment of chain with an unitary evolution, by somehow tracing some tectonic units from end to end.

Since 1980 there has been a tendency to distinguish two sectors in the arc, characterized by differences in Alpine tectonic and/or metamorphic evolution (Bonardi et al., 1980; Bonardi et al., 1982a; Bonardi et al., 1982b; Bonardi and Giunta, 1982; Scandone, 1982; Bonardi et al., 1984; Boccaletti et al., 1984; Dercourt et al., 1986; Bonardi et al., 1991). As proposed by some of us, the boundary between them corresponds more or less to a Soverato-Mesima Valley alignment, presently not evidenced by an important tectonic line.

In our opinion, in the Northern sector of the arc, there are data that seem to fit better the second model:

- the petrological analogies with the Alps (e.g. the HP/LT metamorphism);
- the occurrence of mega-structures antithetic to the Apenninic vergence, first described

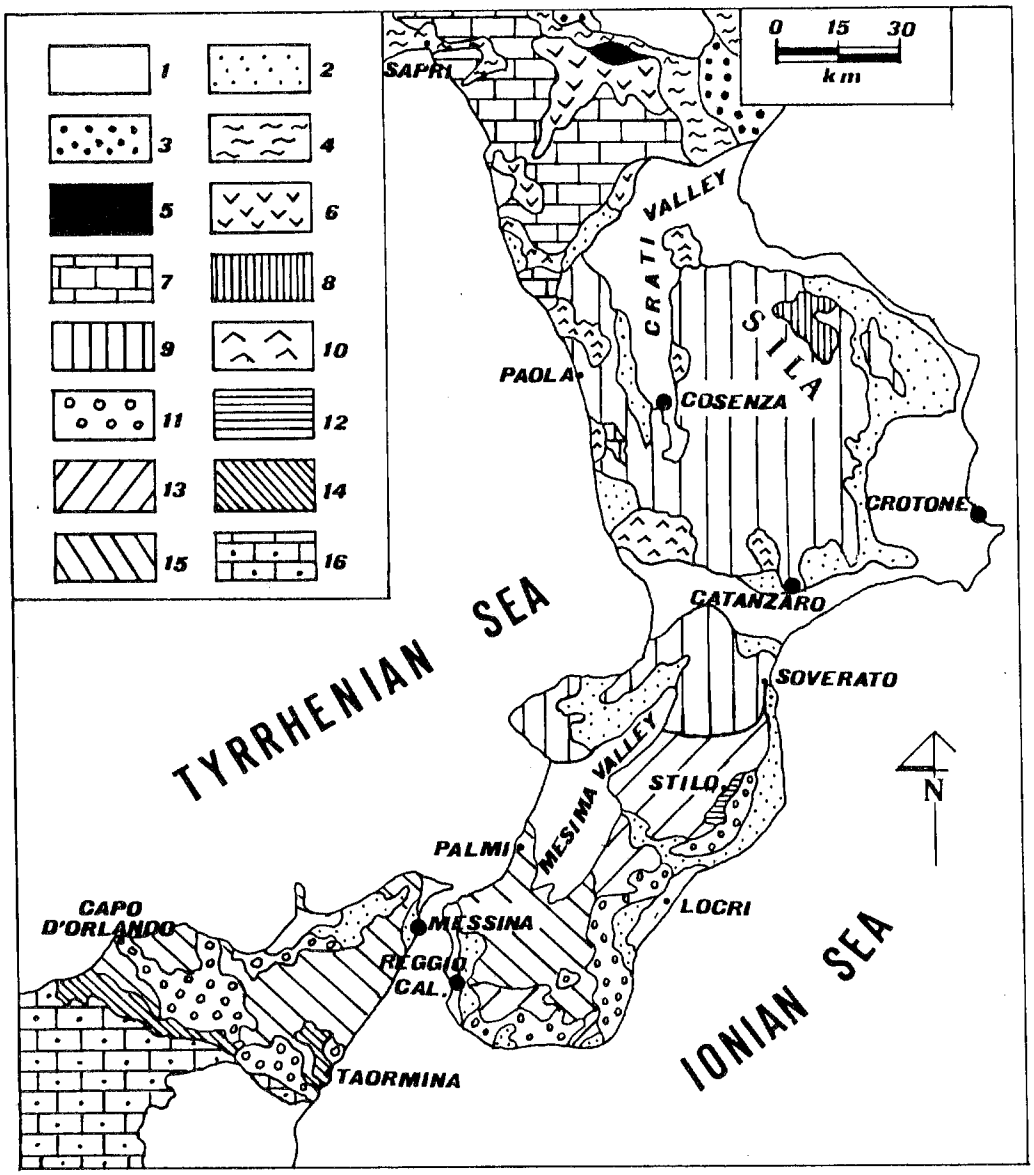

Fig. 1 - Tectonic sketch map of the Calabria-Peloritani Arc. 1. Plio-Quaternary; volcanics. 2. Messinian-Upper Tortonian clastics and evaporites. 3. Cilento Group (Middle Miocene). Liguride Units: 4. North-Calabrian Unit (Upper Oligocene-Upper Jurassic); 5. Episcopia-San Severino melange; 6. Frido Unit (Upper Oligocene-Upper Jurassic). 7. External Apenninic Units. Calabria-Peloritani Arc Northern Sector: continental crust Units (Sila, Castagna and Bagni Units): 8. Sedimentary cover (Eocene-Liassic), 9. Basement; 10. Ophiolitic Units (Lower Cretaceous-Upper Jurassic). Calabria-Peloritani Arc Southern Sector: 11. Stilo-Capo d'Orlando Formation (Lower Miocene) and "Antisicilide Complex"; Stilo Unit: 12. Sedimentary cover (Cretaceous-Upper Triassic?), 13. Basement (Paleozoic); Aspromonte, Africo, Mandanici, Fondachelli and Longi-Taormina Units: 14. Sedimentary cover (Lower Oligocene-Liassic), 15. Basement. 16. Maghrebian Units.

by Quitzow (1935);

- the age of the sedimentary cover, both of the ophiolitic and the crystalline basement nappes, doesn't exceed the Early Paleogene, according to the fossils reported (Bousquet, 1963; Amodio Morelli et al., 1976; Dubois, 1976; Lanzafame and Tortorici, 1980).

On the contrary, no indication suggesting a Europe-verging Eo-Alpine tectogenesis is known in the Southern sector of the arc. Its tectogenesis is chronologically well constrained between the Late Eocene-Early Oligocene and the Early Miocene by the biostratigraphic data obtained, respectively, from the most recent term (Frazzanò Flysch) of the pre-orogenic sedimentary sequences, and from the clastics (Stilo-Capo d'Orlando Formation) unconformably resting on the whole nappe structure. Furthermore, the metamorphic overprint affecting one of the uppermost tectonic units of the Southern sector (Aspromonte Unit) has intermediate pressure and temperature characteristics, and a Rb/Sr age of 24-28 Ma (Bonardi et al., 1991).

The reported biostratigraphic ages cannot be used to date the tectogenesis of the whole arc, as assumed by Ogniben (1969, 1973), because in its Northern sector the Frazzanò Flysch has no equivalent (the Middle Eocene Paludi Formation is a wildflysch perhaps related to the Africa-verging tectonic phases) and Lower Miocene clastics, comparable to the Stilo-Capo d'Orlando Formation, are completely unknown.

Lacking the ophiolites, any discussion about either a European or African provenance of the continental crust nappes forming the Southern sector is somewhat speculative. Nevertheless, in the Northern sector of the arc, the possible tectonic evolution of the crystalline basement nappes still allows a comparison with the Austroalpine element of the Alps, whereas the evolution of the whole Southern sector seems more similar to that of the South-Alpine element.

The interactions between the two sectors are still rather obscure, as is their present boundary. Approaching the area of their presumed contact, the uppermost units of both sectors disappear under a problematic unit (Stilo Unit), which is also represented by some klippen north ad south of the main outcrop (le Serre Massif). Due to this geometrical position - the uppermost of both sectors - its appurtenance to one or the other is questionable.

The Stilo Unit has been kinematically linked to the Southern sector since the Early Miocene, because the syn-late orogenic Stilo-Capo d'Orlando Formation unconformably transgresses it. Therefore, the klippen of the unit found north of Catanzaro graben, which include the Stilo-Capo d'Orlando Formation, can be interpreted as a thrust of the Southern sector up on to the Northern during the Middle Miocene.

Assuming a paleogeographic and kinematic appurtenance of a Stilo belt to the Southern sector even before the Miocene, in le Serre Massif, the geometrical position of the Stilo Unit up on the Sila Unit - the uppermost of the Northern sector - may be the effect of the aforesaid thrust. Nevertheless, the tectonic nature of such a contact is under discussion (Del Moro et al., 1986) and there is the possibility that the Stilo Unit is actually part of the Sila Unit. In this case, it would have followed the evolution of the Northern sector up to the Oligocene, when it overthrust the Southern.

In both hypotheses the relationships between the two sectors would have been characterized by transcurrent movements to allow a kinematic independence, followed by thrusting of one over the other.

RELATIONSHIP BETWEEN THE NORTHERN SECTOR OF THE ARC AND THE SOUTHERN APENNINES

Looking at a small scale geological map of Northern Calabria, the most impressive feature is the abrupt ending of the crystalline basement outcrops at an alignement between Belvedere Marittimo and the Crati River flood-plain: the so-called Sangineto line. North of it, outcrops of the external, mostly carbonatic, Apenninic Units prevail, whereas the crystalline rocks are represented only by very small outcrops near San Severino Lucano. On the contrary, south of the Sangineto line, the latter are widespread, while the Apenninic Units outcrop only in some tectonic windows along the Catena Costiera. Ophiolite bearing units are present on both

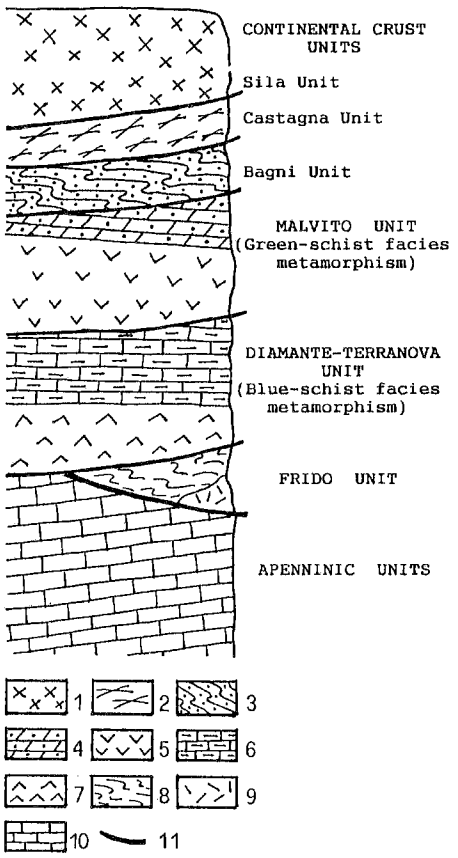

Fig. 2 - The tectonic units in Northern Calabria and at the Calabria-Lucania border area according to different Authors.

sides of the line.

After an interpretation of the Sangineto area as an ophiolitic suture (Caire et al., 1960; Grandjacquet et al., 1961; Glangeaud et al., 1962), the Sangineto line was first defined as a deep-seated strike-slip fault (Scandone et al., 1974; Amodio Morelli et al., 1976). Ogniben (1973) denied any transcurrent role to the Sangineto line, considering it a flexure or a set of normal faults. Later, it was considered to be only a tear fault in the Calabrian nappes (Scandone, 1982). Currently, the tectonic significance of the line is still a matter of debate.

Correlations between the Southern Apennines and the Calabrian arc across the Sangineto line have been proposed by many Authors, even by those admitting its transcurrent role.

As already mentioned, the lowermost tectonic element outcropping in the tectonic windows of the Catena Costiera has generally been considered a prosecution of the Southern Apennine carbonatic units under the Calabrian nappes, as first proposed by Quitzow (1935). Similarly, the Calabria ophiolitic and crystalline nappes have been compared respectively with the ophiolite bearing terrains and with the crystalline rocks (San Severino Lucano gneisses) of the Calabria-Lucania border area by many Authors, even in the framework of different interpretations. We shall summarize the correlations proposed more recently (Fig. 2).

Ogniben (1969) defined a "Liguride Complex" at the Calabria-Lucania border area, characterized by a eugeosynclinal sequence ranging from Early Cretaceous to Middle Eocene. Its lower epimetamorphic part (Frido Formation) contains tectonic scales of ophiolites, and it probably rests on an ophiolitic basement (Timpa delle Murge pillow-lavas). According to the same

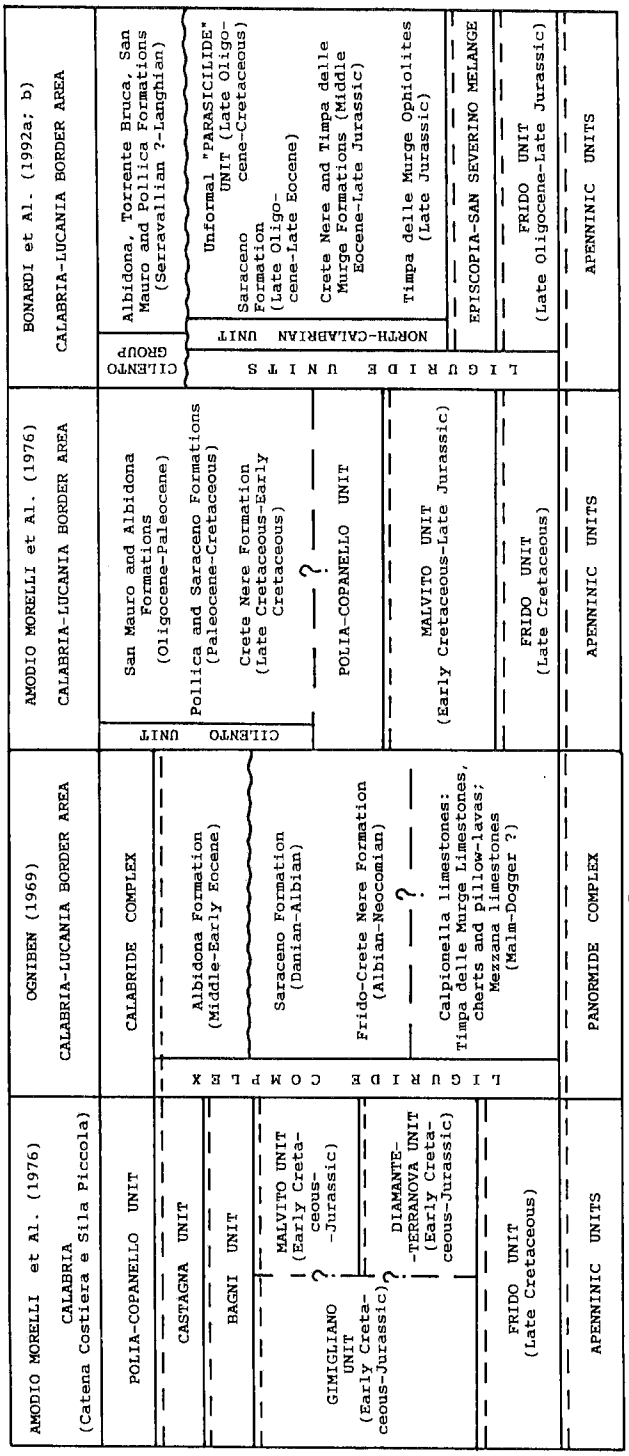

Fig. 3 - Accretionary diagrams to the Terrane Map of the Southern Apennines and Calabria-Peloritani Arc (Northern Sector: 1. continental clastics. Marine environment: 2. pelites (includes radiolarites); 3. arenites; 4. conglomerates; 5. pelagic carbonates (includes cherty limestones); 6. shallow water carbonates. Volcanics: 7. felsic; 8. mafic; 9. stitching plutons. 10. ophiolitic sequences. 11. stratigraphically important fossils (not indicated for terranes 1 and 2). 12. post-accretionary thrust. R = red beds; E = evaporites; e = euxinic; B = high pressure/low temperature metamorphism. Ages: R = Rb/Sr; U = U/Pb.

Author (Ogniben, 1973), despite some tectonic slicing and overturning, there is a bulk equivalence between the Calabria-Lucania border "Liguride Complex" and the phyllites, radiolarites and metalimestones associated with the ophiolites of Northern Calabria. The "San Severino gneisses" are referred to as klippen of the Calabride Complex (Ogniben, 1969).

In Northern Calabria, Amodio Morelli et al. (1976) distinguish in their north-verging Eo-alpine chain a lower part formed by a Frido Unit, thought to be an oceanic cover or perhaps a mélange with blocks of ophiolites (Dietrich and Scandone, 1972), and two ophiolitic units (substituted by another one South of Fuscaldo). The upper part is formed by three crystalline basement nappes. According to these Authors, north of the Sangineto line, mainly in the Calabria-Lucania border area, extensive outcrops of the Frido Unit and small klippen of the Malvito Unit (=Timpa delle Murge pillow-lavas and Calpionella limestones) and of the Polia-Copanello Unit (=San Severino gneisses) can be recognized. A Cilento Unit rests with poorly defined contact up on those remnants of the Eo-Alpine chain. According to this interpretation, Ogniben's "Liguride Complex" is split into two parts separated by the klippen of the "Calabride Complex" of the same Author.

Even Spadea et al. (1976) describe a tectonic superposition of two ophiolitic units in the area between Tarsia and Spezzano Albanese. According to these Authors, the metasedimentary cover of the lowest one can be compared with the Frido Formation (Vezzani, 1968) of the Calabria-Lucania border area, assuming a N-S metamorphic gradient.

In recent years, the stratigraphy of the terrains referred to as the "Liguride Complex", as well as their mutual relationships have been completely revised, from the Calabria-Lucania border area up to Cilento (Amore et al., 1992; Bonardi et al., 1992a). The previously supposed continuous sequence actually corresponds to a pile of four tectonic units, unconformably covered by a thick Middle Miocene sequence of siliciclastic and calciclastic turbidites, defined as Cilento Group (Pollica, San Mauro, Torrente Bruca and Albidona Formations). The lowermost tectonic unit (Frido Unit) corresponds reasonably to the Frido Formation of Vezzani (1968). It is composed of an ophiolitic basement (mainly serpentinite and massive basalts) and a sedimentary cover: their original stratigraphic contact is presently preserved in very few outcrops. Both have been affected by a HP/VLT metamorphism (Spadea, 1976).

The Frido Unit is overlain by a North-Calabrian Unit (Selli, 1962), formed from a few outcrops of unmetamorphosed ophiolites (mainly pillow-lavas) with a thin cover of radiolarites, allodapic limestones and variegated shales, grading upward to a widely outcropping sequence of quartzarenites and black shales (Crete Nere Formation), followed by calcareous and calcareo-arenaceous turbidites (Saraceno Formation). Locally (Episcopia-San Severino Lucano), a melange unit (Spadea, 1982), containing blocks of serpentinites, garnet and amphibolic gneisses, amphibolites and granitoids, is interposed between the above two units.

Biostratigraphic analyses of the North-Calabrian Unit sedimentary sequence, based on calcareous nannoplankton assemblages, indicate an age ranging from Late Jurassic to Late Oligocene (Bonardi et al., 1992a).

Due to severe deformation, it is very difficult to reconstruct the original stratigraphic sequence of the Frido Unit metasediments. It seems that phyllites and quartzites in its lower part and metalimestones in the upper part prevail. Since the fossil content has been strongly reduced by the metamorphic event and/or by solution, only the metalimestones bear nannofossils, which are not older than Upper Oligocene (Bonardi et al., 1992b).

According to these data, the metamorphism of the Frido Unit, as well as the piling up of the Liguride units, would have occurred between the Late Oligocene and the Langhian, recorded at the base of the Cilento Group, unconformably resting on them. Therefore - with the exception of a few outcrops of the Frido Unit in the tectonic windows of Northern Calabria - no correlation can be mantained between the ophiolitic units of the Calabria-Lucania border area and those of the Calabrian Arc, whose deformation age is reported as no more recent than Cretaceous (Amodio Morelli et al., 1976; Grandjacquet and Mascle, 1978) or Early Paleogene (Bouillin, 1984). Moreover, the "San Severino gneisses", being blocks in a melange unit, can no longer be regarded as klippen of the uppermost Calabrian crystalline nappe.

The reported data suggest that the ophiolitic units of the Calabria-Lucania border area and

those of the Northern sector of the Calabria-Peloritani Arc were deformed in different ages. This can be explained by the following hypotheses:

1) they originated from different branches of the oceanic realm, one of which separated the Austroalpine belt from the Apenninic domains; in this case, a Europe-verging followed by an Africa-verging orogenic transport must be assumed;

2) a progressive consumption of the oceanic area throughout the Paleogene, assuming a European origin for the crystalline basement nappes;

3) the Calabria-Lucania border ophiolitic units originated from a relic of the oceanic area separated by transform faults from the earlier deformed segments.

Fig. 3 is an attempt to interpret the Southern Apennines (data from Patacca et al., 1992 were also considered) and the Northern sector of the Calabria-Peloritani Arc in terms of terrane philosophy. It was prepared for a Terrane Map of the Alpine-Himalayan belt, which is one of the aims of the I.G.C.P. 276 (see Neubauer and Ebner, 1992). The diagrams are drawn according to hypothesis 1). Diagrams from 5 to 11 must be reversed to show hypothesis 2); while hypothesis 3) probably cannot be schematized in a single figure. It should be noted that, according to the latter, a paleotectonic role at least must be inferred for the Sangineto line.

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