Geo-Tectonic Evolution and Metallogenesis of the Calabrian-Peloritanian Arc in the Tethys Realm

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With 4 Figures

Zusammenfassung

Der Calabrisch-Peloritanische Bogen, die Südspitze Italiens und Nord-Sizilien umfassend, gehört zum Südteil der Europäischen Platte. Er ist vorwiegend aus praeherzynischen und herzynischen Serien aufgebaut. Die Entwicklung seiner Tektonik wird eingehend beschrieben. Die nicht sonderlich reiche Vererzung ist zumeist paläozoisch; die spärliche alpidische Metallogenese ist auf die Abwesenheit triassischen Riftings und tertiärer saurer Magmatite zurückzuführen.

Summary

The Calabrian-Peloritanian Arc is mainly made of Hercynian/pre-Hercynian terranes, moulded in complicated structures, by both the Hercynian and the Alpidic tectogeneses.

The ore/mineral accumulations are prevailingly related the Hercynian/pre-Hercynian metallogeny and have been partially dispersed and/or altered in connection with subsequent orogeneses and metamorphism.

The interpretation of the evolution of the Arc is controversial: the differences in opinion concern the domains to which the complexes belong, the origin of the ophiolites, the position of the Tethys, the age of tectogenesis, the dynamics of the orogenesis, the vergence of the orogene.

To solve these problems, new contributions particularly on the basis of the metamorphic and magmatic history of the area, are presented in this paper.

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1. Foreword

The Calabrian-Peloritanian Arc represents a well defined geological and metallogenic province, covering almost the whole Calabria and the Northern corner of Sicily; it is delimited by two tectonic lineaments: the "Sangineto line" in the North and the "Taormina line" in the South (Fig. 1).

From the geological and metallogenic stand-points, the Arc is undoubtedly different from the other parts of the Apennines and of Sicily, and it is rather similar to Sardinia and to the Alps. As a matter of fact the Arc, like Sardinia and large sections

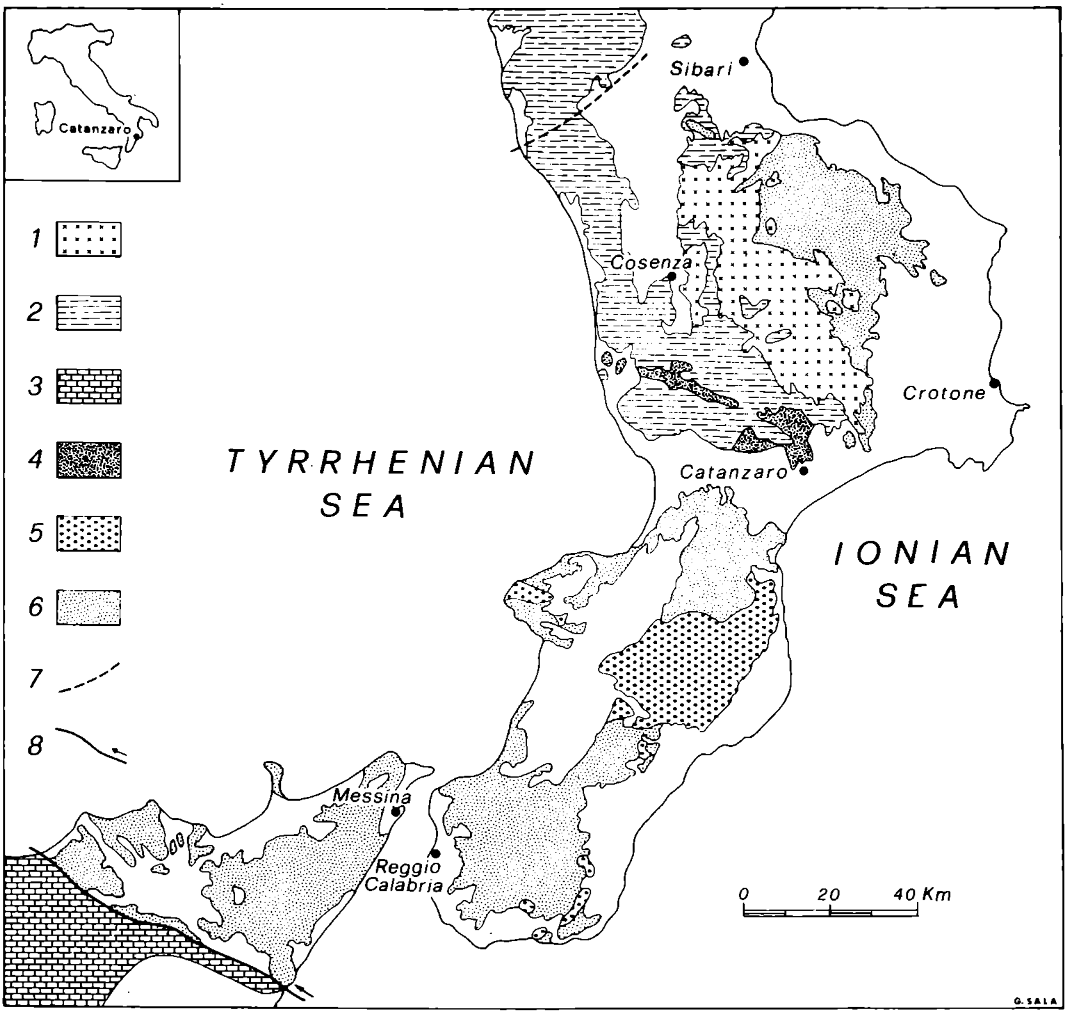

Fig. 1. Tectonic sketch of the Calabrian-Peloritanian Arc. 1 = Monte Gariglione Unit; 2 = Calabrian Apennine Range; 3 = Sicilian Maghrebids; 4 = Tiriolo Unit; 5 = Stilo Unit; 6 = Calabrian-Peloritanian Hercynian Range; 7 = Sangineto Line; 8 = Taormina Line.

of the Alps, is mainly composed of pre-Hercynian terranes, whilst post-Hercynian ones are dominant in the Apennines and in Sicily, at least at the surface and till the depths reached by drilling and mine works.

These differences and similarities inspired some conclusions and recommendations, that frequently turned out deceiving: first of all, the suggested probability of finding rich ore deposits in Calabria, like those that are well known in Sardinia.

The geo-tectonic evolution of the Calabrian-Peloritanian Arc is still controversial; some new data and the most recent hypotheses will be dealt with in the next chapters, that has been entirely compiled by E. ZANETTIN LORENZONI. The other chapters of the present paper are the results of debates between the two co-authors.

2. Geo-Tectonic Evolution of the Calabrian-Peloritanian Arc

The Calabrian-Peloritanian Arc is key zone for understanding the geological evolution of the Mediterranean and, as such, it has been investigated by many workers. Among these, interpretations of a synthetic character have been put forward recently by OGNIBEN (1973), DUBOIS (1976), AMODIO MORELLI et al. (1976), GÖRLER & GIESE (1978), GRANDJAQUET & MASCLE (1978), LORENZONI & ZANETTIN LORENZONI (1980, 1980a), SCANDONE (1979, 1982), WEZEL (1980), and ZANETTIN LORENZONI (1982). The interpretations differ both concerning the geo-tectonic structure of the Arc and its history. The differences stem not only from the basic complexity of the problems but also from the fact that often the authors have considered only a few of the many involved aspects, completely ignoring or undervaluing, in particular, the information provided by the metamorphic and magmatic history of the area. The differences in opinion concern such fundamental facts as the domains to which the terranes belong, whether or not the ophiolites are oceanic, the position of the Tethys, the age of the tectogenesis, the dynamics of the orogenesis and the vergence of the orogene.

The aim of this paper is to help solve the geological and tectonic problems of the Calabrian-Peloritanian Arc on the basis of knowledge acquired to date (December 1983).

The geotectonic structure of the Arc has been discussed in previous papers (ZANETTIN LORENZONI, 1982; LORENZONI & ZANETTIN LORENZONI, 1983; ACQUAFREDDA et al., 1983; FERLA et al., 1983). The interpretation put forward here (Figs. 1 and 2, Table 1) is that the Calabrian-Peloritanian Arc is formed of two ranges which came together and were partly overthrusted (the Calabrian-Peloritanian Hercynian Range mainly of Hercynian tectongenesis and the Calabrian Apennine Range mainly of Alpine tectogenesis) and of three minor tectonic elements of Alpine age (the Stilo Unit, the Tiriolo Unit and the Monte Gariglione Unit).

The Calabrian-Peloritanian Hercynian Range is the frontal, outermost unit of the Arc (or more precisely the emergent part thereof). During the Alpine orogeny the Range was subject to essentially fracture deformations, while metamorphic effects were only local, weak and of limited extent. The main phases of Alpine compression are Eocene-Oligocene.

Table 1: Main tectonic elements of the Calabrian-Peloritanian Arc. C = Cainozoic; M = Mesozoic; P = Paleozoic; pD = pre-Devonian; dotted lines = unconformities; unbroken lines = Alpine contacts; wavy lines = late-Hercynian contacts; dashed lines = Hercynian contacts.

MONTE GARIGLIONE UNIT

pD	medium-grade gneisses and metabasites	late-Hercynian magmatites
pD	high-grade gneisses and metabasites	
	— Middle-Upper Miocene —	

CALABRO-PELORITAN HERCYNIAN RANGE

pD	S. Sofia d'Epiro Unit: medium-high grade gneisses and metabasites
pD	Castagna Unit: dynamic metamorphites of "granites" and gneisses
pD	Bagni Unit: metapelites, metapsammites, metavolcanites, marbles
	— Upper Cretaceous —
M	Reventino-Gimigliano Unit: metabasites, serpentinites, phyllites, marbles
	— Lower Miocene —
MC	Verbicaro Unit: slightly metamorphic limestones and dolomites, locally mafic lavas
	— Lower Miocene —
MC	San Donato Unit: phyllites, metabasites, marbles
	— Middle Miocene —

TIRIOLO UNIT

C	conglomerates, sandstones	
M	limestones, quartzose conglomerates	
P	metapelites, metalimestones	late-Hercynian magmatites
pD	medium-grade gneisses	(granites-tonalites)
	— Oligocene —	
pD	high-grade gneisses and metabasites	
	— Middle-Miocene —	

STILO UNIT

M	limestones, quartzose conglomerates	
P	metapelites, metalimestones	late-Hercynian magmatites
pD	medium-grade gneisses	(granites-tonalites)
	— Oligocene —	

CALABRIAN APENNINE RANGE

MC	conglomerates, sandstones, limestones, marls, clays	
pD	numerous pre-alpine tectonic units constituted by gneisses, micaschistes, metabasites, porphyroids, marbles, phyllites	late-Hercynian magmatites (granites-tonalites)
P	metapelites, metapsammites, metavolcanites, metalimestones	

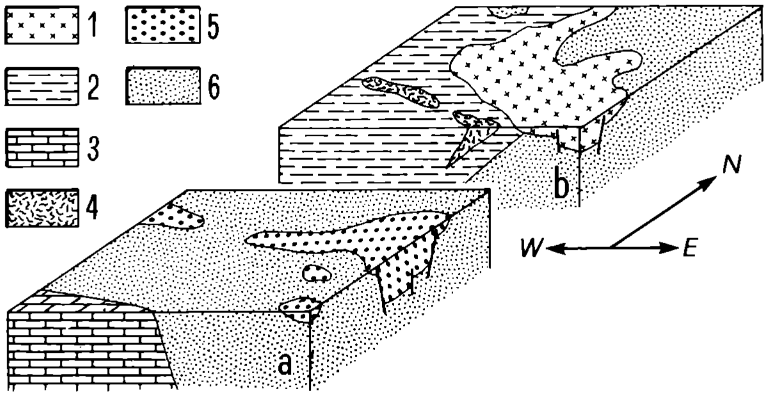

Fig. 2. Tectonic block-diagram of the Calabrian-Peloritanian Arc (a = southern stretch, b = northern stretch). 1 = Monte Gariglione Unit; 2 = Calabrian Apennine Range; 3 = Sicilian Maghrebids; 4 = Tiriolo Units; 5 = Stilo Unit; 6 = Calabrian-Peloritanian Hercynian Range.

The Calabrian Apennine Range is a more internal element. It can be attributed to an original domain with thin continental crust and Triassic-Miocene basins. The Alpine deformations were accompanied by metamorphism. The main compressive phases are Lower Cretaceous and Lower Miocene.

During the Middle Miocene the two ranges were juxtaposed with partial overthrusting of the Calabrian Apennine Range on the Calabrian-Peloritanian Hercynian Range (on which the Stilo Unit had already been overthrusted).

The Stilo Unit is an Alpine tectonic element in which we find evidence of Hercynian and pre-Hercynian sedimentary, metamorphic, tectonic and magmatic events. It was overthrusted on the Hercynian Range coming from more internal regions during the Oligocene compressive phases without metamorphism.

The Tiriolo Unit is a fragment that broke away from the Calabrian-Peloritanian Hercynian Range + Stilo Unit in the Middle Miocene during the overthrusting of the Calabrian Apennine Range; there are no Alpine metamorphic effects.

The Monte Gariglione Unit is the innermost element of the Arc and the last to be emplaced in the Middle-Upper Miocene by overthrusting on the Calabrian Apennine Range and the Calabrian-Peloritanian Hercynian Range; there are no Alpine metamorphic effects.

Before going on to discuss the Alpine evolution of the Calabrian-Peloritanian Arc, it will be usefull to clarify some particularly significant geological aspects of the matter.

The first aspect concerns the attribution of all the pre-Triassic formations of the Calabrian-Peloritanian Arc to the same Hercynian orogenic domain (a hypothesis advanced by LORENZONI & ZANETTIN LORENZONI, 1983). This attribution was proposed on the basis of analogies regarding the tectonic, metamorphic-deformational and magmatic history of the pre-Triassic rocks of the Arc now represented in the Calabrian-Peloritanian Hercynian Range, the Stilo Unit, the Tiriolo Unit, the upper part of the Calabrian Apennine Range and the

Monte Gariglione Unit. All these elements of diverse Alpine evolution, in fact, have the following points in common:

— The tectonic superimposition—at the end of the Hercynian—of units consisting of higher-grade metamorphic rocks on those of a lower grade (it is very likely that the upper units of the Calabrian Apennine Range are an exception to this case).

— The tectonically highest Hercynian elements all consist of complexes that are essentially polymetamorphic, the metamorphism being Hercynian and pre-Hercynian.

— The rocks of the Paleozoic basins with only Hercynian metamorphism always occur in the lower Hercynian tectonic positions.

— Hercynian metamorphism is characterized by a dynamic phase followed by thermal phases (only the rocks of the Stilo Unit seem not to have been affected by the latter).

— The emplacement of the Hercynian tectonic units was later than the thermal metamorphism phases.

— The late-Hercynian intrusive magmatism is characterized by an initial cycle due to deep anatectic magmas followed by a second cycle due to moderate-depth anatectic magmas (there are only very rare magmatites attributable to the second cycle in the Calabrian Apennine Range).

— Alpine metamorphic effects are absent, or weak and local, except in the upper part of the Calabrian Apennine Range where the pre-Triassic rocks are affected by weak but widespread high-pressure/low-temperature effects.

An interpretation of the Hercynian evolution, recently advanced for the Calabrian-Peloritanian Range by FERLA et al. (1983), postulates that the Range was formed on the southern edge of paleo-Europe due to subduction of the southern plate with a crust that was oceanic at least in part.

According to the interpretation proposed by the authors (Fig. 3a)—which of course takes account of the Alpine evolution and the present geometry, as well as of the Hercynian history—the domains of the Calabrian-Peloritanian Hercynian Range and of the Stilo Unit occurred in the relatively more external parts of the Hercynian orogen, while the domains of the three upper units of the Calabrian Apennines Range and the Monte Gariglione Unit belonged to the relatively internal parts. Indeed, terranes of the Paleozoic basins on which the pre-Hercynian basement was overturned, and magmas intruded under conditions of greater tension, are represented in the Hercynian Range and in the Stilo Unit. The position attributed to the Monte Gariglione Unit, instead, is in accordance with the syn-late-tectonic and relatively deep-crust character of the magmatic intrusions (GURRIERI et al., 1982), thus implying also the absence of Paleozoic basin complexes. The position attributed to the upper units of the Calabrian Apennine Range is explained by the great scarcity of late-Hercynian intrusive magmatites, as well as by the lack of Paleozoic basin terrains.

Mention should be made here to the correlation noted by DAL PIAZ et al. (1983) between the rocks of Monte Flavio Gioia in the Tyrrenian basin and those of the Calabrian-Peloritanian Hercynian Range. The Authors consider that the Monte Flavio Gioia phyllites, with their Alpine tectonic-metamorphic overtones, fit in well

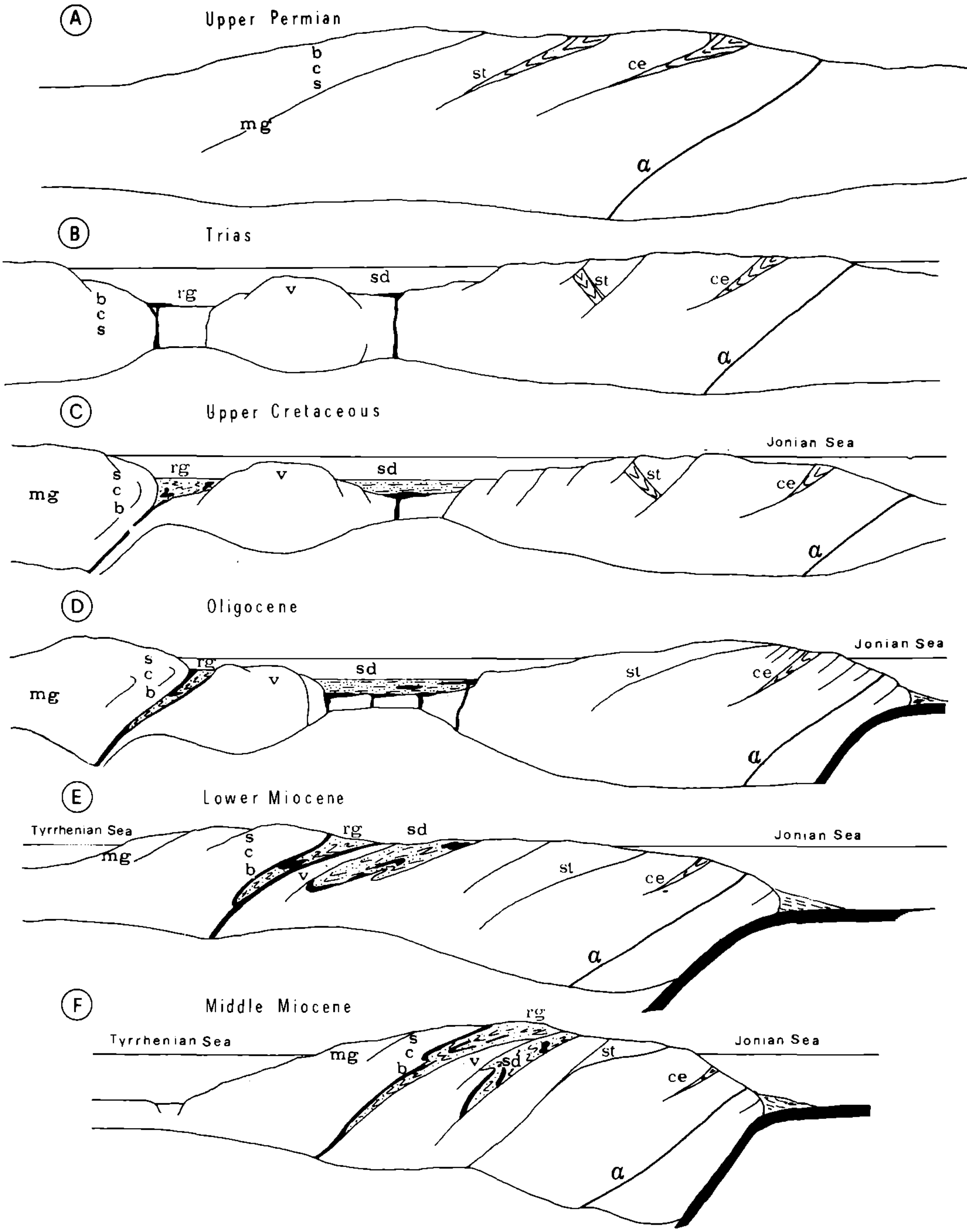

Fig. 3. Geo-tectonic evolution of the Calabrian-Peloritanian Arc from Upper Permian to Middle Miocene. mg = Monte Gariglione Unit; s = S. Sofia d'Epiro Unit; c = Castagna Unit; b = Bagni Unit; rg = Reventino-Gimigliano Unit; v = Verbicaro Unit; sd = San Donato Unit; st = Stilo Unit; ce = Calabrian-Peloritanian Hercynian Range; a = scar of the Hercynian subduction.

with this correlation, and not merely because of their marked mineralogical and structural resemblance to the pre-Hercynian phyllites of the Hercynian Range. The presence of Alpine metamorphic effects in domains that on the whole exhibit no such effects, is also characteristic of the Hercynian domains outcropping in Calabria, as will be made clear ahead.

A second aspect of fundamental importance in the interpretation of the Alpine evolution of the Calabrian-Peloritanian Arc concerns the possibility that the "ophiolitic" terrains may belong to a thin-crust continental basin (Fig. 3b). It should be made quite clear here that the authors consider that the ophiolitic terrains of the Calabrian-Peloritanian Arc belong to a single tectonic unit (the Reventino-Gimigliano Unit; the reservations expressed in LORENZONI & ZANETTIN LORENZONI, 1983, on the Malvito Unit have now been withdrawn). The possibility of the ophiolitic areas belonging to a thin mainly continental crust basin is supported by various considerations.

The first significant factor is that all the "ophiolites" are associated with flysch-like, mainly clastic formations. Of these, suffices to mention here the minute metaconglomerates (common throughout the "ophiolite" outcrop area) with clasts deriving almost certainly from rocks of the upper units of the Calabrian Apennine Range. Also of great significance is the existence of metabasite-gneiss associations in southern Lucania (SPADEA, 1982)—attributable to the Reventino-Gimigliano Unit and S. Sofia d'Epiro Unit, respectively—their characters indicate a common geological history from the time of the basalt outpourings onto the pre-Triassic rocks of the Calabrian Apennine Range (LORENZONI & ZANETTIN LORENZONI, 1983). According to this interpretation, there was a sedimentation basin in which the basement and the feed area included the rocks which subsequently have formed the Calabrian Apennine Range. Further support for this thesis comes from considerations on the tectonic and metamorphic situation as a whole. The ophiolitic unit lies tectonically above a unit formed of continental basin or shelf rocks (Varbicaro and San Donato Units), and below units formed of pre-Triassic metamorphites. In the former, tectogenesis—and metamorphism—started in the Lower Miocene, in the latter in the Lower Cretaceous. Again as regards the latter, unlike the former, overturning occurred, as it did in the case of many of the rocks of the ophiolitic basin. It is clear, therefore, that the domain of the pre-Triassic units of the Apennine Range could not be on the same side of the basin as that where the Verbicaro and San Donato domains were located. Their position is thus "northerly".

A second point concerns the existence of continental crust subduction which is demonstrated by the high-pressure metamorphism encountered in the Reventino-Gimigliano Unit and the overlying units. Additional evidence is provided by the fact that the terrains nearest the "southern" edge of the ophiolitic basin now visible are of continental shelf type.

In addition to all the statements made so far, it must be accepted that subduction occurred in a very short space of time, entirely within the Albian, according to SPADEA (1982), and that there is no proof of any involvement of the oceanic crust in the subduction; so the most convincing idea is that the basin is continental. In the line of this idea are the analogies of lithological associations between the Reventino-Gimigliano Unit and the San Donato Unit, which are certainly those of a continental basin. The Authors' interpretation of this fact also fits in with the reconstruction made on a paleomagnetic basis by MANZONI & VANDERBERG (1982), who consider Sardinia, the southern Apennines, the Calabrian-Peloritanian Arc and Sicily as forming part of Africa at least up to the start of the Tertiary.

The third fundamental aspect to be considered is the vergence of the Calabrian-Peloritanian Arc. It is held that all the tectonic elements, Hercynian and Alpine, were emplaced when moving in the "African" direction. As regards the Calabrian-Peloritanian Hercynian Range, FERLA et al. (1983) postulate its southern Hercynian vergence on the basis of its geometry and the fact that it belongs to the southern margin of the paleo-European continent. The vergence effect of the Alpine compressions that generated a slice structure with major movements in the Eocene-Oligocene was also "African". Where the Stilo Unit is concerned, its assignment to a more "northerly" paleogeographic position in the Hercynian Range (FERLA et al., 1983; ACQUAFREDDA et al., 1983) at the end of the Hercynian orogeny establishes the southerly direction of the movement in the Oligocene. The vergence of the San Donato and Verbicaro Units commonly considered as the continuation of the southern Apennines in Calabria, is evidently in keeping with that of the Apennines themselves and hence is southerly. In the case of the upper units of the Calabrian Apennine Range, the Authors consider their vergence to be African and not European (as held by AMODIO MORELLI et al., 1976; FAURE, 1978; SCANDONNE, 1983), since the domain of the three upper units (BAGNI, CASTAGNA and S. SOFIA D'EPIRO) was on the northern edge of the ophiolitic basin. The nature of the vergence is, of course, independent of the fact as to whether the basin is oceanic or not, while attribution of the domain of the units in question to Europe or Africa would vary. There are no special problems with the Tiriolo Unit if the interpretation of ZANETTIN LORENZONI (1982) is correct, namely that this is a fragment which broke away when the Calabrian Apennine Range collided with the Calabrian-Peloritanian Hercynian Range + Stilo Unit. In fact, in this case the unit is the effect of movement in a "southerly" direction. In the Alpine, the Monte Garigline Unit (attributed, in the reconstruction at the end of the Hercynian, to a deeper part of the crust than the S. Sofia d'Epiro Unit) is placed farther from the continental margin, because it exhibits non-Alpine metamorphic effects. The Monte Garigione Unit, the last to be emplaced, is thus considered to be of more internal origin and it was evidently moved in a southern direction. The interpretations made by the authors — which await confirmation or rebuttal in particular by structural analysis — are in accordance with the interpretations (on paleomagnetic basis of MANZONI & VIGLIOTTI, 1983) which exclude the existence in the Sila of opposite vergences for the different tectonic elements.

The Alpine geo-tectonic history of the Calabrian-Peloritanian Arc can now be reconstructed on the basis of present knowledge and the interpretations presented above.

At the end of the Paleozoic (Fig. 3a) the Hercynian orogen—which was subsequently dismembered by Alpine dynamic action, with the fragments going to form various structural elements—had already been highly eroded.

Tension stresses began to occur in the Triassic (Fig. 3b). These led to the creation of basins where basalt lavas spread out and where deposits were laid down; they sub-sequently formed the San Donato and the Reventino-Gimigliano Units (this basin can be dated Triassic according to the discovery of fossils, probably of Anisian-Ladinian age, in the lower parts of the Gimigliano sequence; see COLONNA & ZANETTIN LORENZONI, 1972). The existence of tension was probably also the cause of the partial overturning of that sector of the crust which subsequently formed the Stilo Unit; this overturning occurred after the intrusion of the late-Hercynian magmas and before the start of deposition of the Mesozoic cover (which would, however, appear to be Liassic rather than Triassic). The tension phases were interrupted by compression phases which became more marked towards the Lower Cretaceous; in the "ophiolite" basin (future Reventino-Gimigliano Unit) the build up of basalts and volcanic products gradually declined, while terrigenous flysch-type sedimentation started to prevail.

In the Cretaceous (Albian, of SPADEA, 1982) (Fig. 3c), with the opening up of the Ionian (GÖRLER & GIESE, 1978), there was subduction of the thin continental crust (and perhaps also of limited areas of oceanic crust) and of the basic vulcanites and the flysch, beneath the "northern" edge of the basin itself. The basement and the mesozoic formations that lay towards the edge of the basin were overturned and high-pressure, low-temperature metamorphism occurred, but only in the plate undergoing subduction, and in the trench area.

It is held that in the Cretaceous the sector including the Calabrian-Peloritanian Hercynian Range now outcropping in the Sila, was rotated about 60 ° counter-clockwise with respect to southern Calabria (Fig. 4). In fact, considering the position of the Paleozoic basins (after having brought the Peloritanian Mountains ideally to their original position, namely the southern edge of the Aspromonte: see FERLA et al., 1983) and also the trend of the late-Hercynian tension lines which governed the intrusion of the magmatic bodies, the Sila sector of the Hercynian Range appears to be roteted about 90 ° counter-clockwise as regards the Aspromonte-Peloritanians sector. The direction of vergence of the Hercynian slices in the two sectors, instead, forms and angle of not more than 30 °. Hence there was rotation of about 60 ° between the Permian and the Eocene. A similar type of rotation is reported by MANZONI & VANDERBERGER (1982) on the basis of paleomagnetic measurements; this is dated as post-Liassic. Taking account of all these data, it would seem that rotation most probably occurred in the Cretaceous, in connection with the subduction movements which occurred at differential speed from present north to present south. It should be observed in this respect that the "ophiolitic" basin probably did not extend much beyond what can be seen in outcrop nowadays: to the south of the Catanzaro isthmus there are no traces of rocks that can be ascribed to that basin nor even of Cretaceous dynamic movements or Alpine metamorphism. At this point, mention should be made of the traces of metamorphism encountered on a geochronological basis by SCHENK (1980) in the northwestern Serre, namely in the postulated closure zone of the "ophiolitic" basin.

Subduction ceased in the Upper Cretaceous and the Lower-Middle Eocene, but the compression regime remained, while tension increased in the Ionian. The most marked effects are the stratigraphic gaps in the cover formations (especially in the domains of the Stilo Unit and the Calabrian-Peloritanian Hercynian Range) and the deposition of the Eocene breccias on the latter.

Subduction of the Ionian bathyal area beneath the Calabrian-Peloritanian Arc started in the Oligocene (Fig. 3d) (GÖRLER & GIESE, 1978) while, at the same time (DURAN DELGA, 1980) or at the latest in the Lower Miocene (FABBRI et al., 1980), the Tyrrhenian opened. A regime involving intense compression occurred in the frontal part of the Calabrian-Peloritanian Arc which gave rise to the slice structure with "African" vergence of the Calabrian-Peloritanian Hercynian Range (perhaps this structure had already started to form in the Upper Eocene) and caused the Stilo Unit to be overthrusted on the Hercynian Range. The Oligocene deformations were brittle and occurred without metamorphism.

In the Lower Miocene (Fig. 3e) the compressions shifted towards the inner part of the Arc and affected only what is today its northern sector, namely that of the thin crust basins. The basin complexes were deformed, and the terranes of the more internal carbonate shelf (Verbicaro Unit), the already metamorphosed formations of the ophiolitic basin (Reventino-Gimigliano Unit) and the basement of their northern margin (Bagni, Castagna and S. Sofia d'Epiro Units) were shifted over them. The miocene deformations were accompanied by metamorphism, and the authors consider that it was caused basically by high tectonic pressures. In fact, on the Calabrian-Lucanian boundary the metamorphic restructuring is intense in the San Donato Unit (the lowest), extremely weak in the Verbicaro Unit (overlying) and absent—relative to post-Cretaceous metamorphic effects—in the Reventino-Gimigliano Unit (again overlying). In this latter unit, instead, metamorphic effects of normal pressure are evident in southern direction, with a sharp gradient a little to the south of Sybaris Plain where the tectonic units of the Calabrian Apennine Range are thickening rapidly. Yet another effect of the Lower Miocene compressions is postulated: the further anticlockwise rotation of the Sila "basement" by about 30 ° as regards southern Calabria (Fig. 4).

In the Middle Miocene (Fig. 3f), the Calabrian Apennine Range which had already been formed, moved in the "African" direction, coming alongside and being partially overthrusted on the Calabrian-Peloritanian Hercynian Range (on which the Stilo Unit had already been overthrusted): at the same time a fragment of the "southern" element broke away and became wedged in the upper part of the Calabrian Apennine Range to form the Tiriolo Unit. The compressive phases were followed by tension phases with formation of fault systems, some of which were reactivated subsequently (the Crati and Catanzaro grabens). The compressing started again. In the Middle and Upper Miocene this caused the overthrusting of the Monte Gariglione Unit on the Calabrian Apennine Range and on the Calabrian-Peloritanian Hercynian Range. All the deformations of the Middle and Middle-Upper Miocene occurred without any metamorphic effects.

In the sector which now corresponds to southern Calabria and the Peloritanian Mountains, tectogenesis had already ceased by the beginning of the Miocene and no compression is encountered here after the start of deposition of the Capo d'Orlando Flysch (as the authors have no direct knowledge of the processes of the emplacement of the "Argille Scagliose Varicolori", nothing will be said on this matter). Ten-

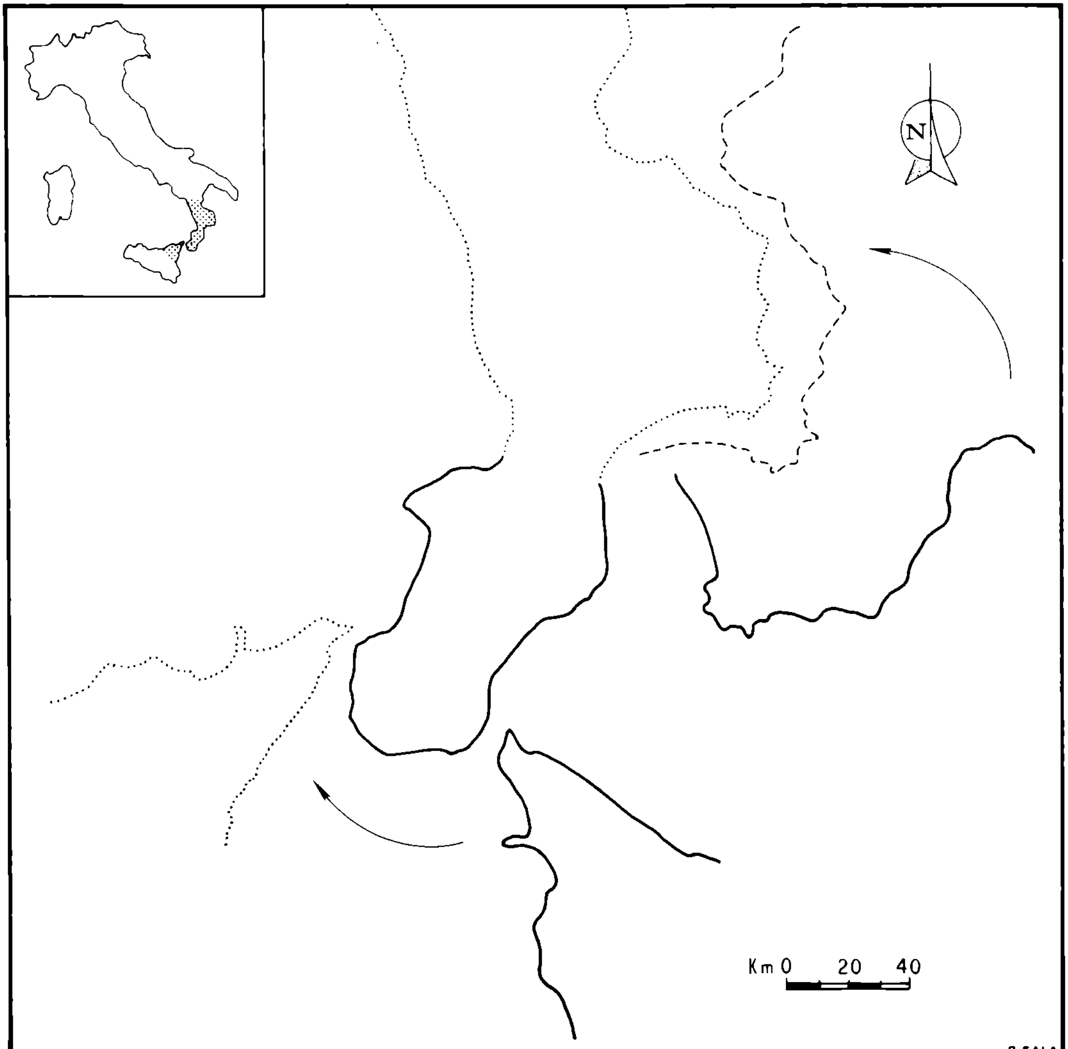

Fig. 4. Comparative position of southern Calabria, Sila, Peloritani in Upper Jurassic (unbroken line) and Oligocene (dashed line).

sion again occurred in the Miocene, with dismemberment and movement (and/or rotation) of the fragments. The breakaway from the Aspromonte of the sector that now corresponds to the Peloritanian Mountains occurred in particular in the Middle Miocene with a 90 ° clockwise rotation of the Peloritanians which were juxtaposed—along the "Taormina line"—with the Sicilian Maghrebids (Fig. 4). The suggested interpretation is that the Taormina line is thus a left transurrent fault, whose significance is quite different from that of the "Sangineto line" (commonly considered as the northern limit of the Arc) which the authors hold to be a fault zone within one and the same domain.

3. The Calabrian-Peloritanian Metallogenesis

If one takes into consideration deposits/districts having a size more than 1 of the conventional scale adopted in the metallogenic maps of the Mediterranean Region, the Calabrian-Peloritanian Arc has to be considered a barren region.

As a matter of fact ore/mineral occurrences in that area are numerous and various, but they are of small (size 1) or even they can be classified as simple indications (size 0).

According to the most recent authors (LORENZONI et al., 1983; BONARDI et al., 1982; CASTALDO and STAMPANONI (eds.), 1975) about a hundred ore/mineral occurrences are known in the Calabrian-Peloritanian Arc (excluding coal, feldspar and quartz); they may be grouped, in the optics of the present paper, in 11 paragenetic types and in five metallogenetic epochs, as it is shown in Table 2. For more details, the above-mentioned papers should be consulted.

A first factual observation stands out: the post-Hercynian pre-Tethyan and pre-rifting volcanism, which is well known all along the Alps (WINTERER and BOSELLINI, 1981) and is responsible of interesting ore/mineral depositions of U, Fe, Ba (CADEL, G. et al., 1984), is absent (at least: not yet recognized) in the Calabrian-Peloritanian Arc.

The second remark is that the largest majority of Calabrian-Peloritanian ore/mineral deposits are held in, and have been generated by, pre-Hercynian/Hercynian events, involving (according to LORENZONI et al., 1983) deposition in connection to various Hercynian/pre-Hercynian metallogenic processes, and remobilization, reshaping, partial dispersion by the Hercynian and by the Alpine metamorphism and magmatism.

Coming to the post-Hercynian events, we can distinguish four stages, namely: i) post-Hercynian pre-Alpine events, not related to the ophiolitic volcanism; ii) the ophiolitic volcanism—whatever its domain (oceanic or non-oceanic); iii) Alpine; iv) post-Alpine orogenesis.

The following factual observations can be made:

i) ore/mineral deposition related to the first above-mentioned stage are neither so big nor so rich; as a matter of fact the only not negligible ore accumulations are the residual Fe Oxides (with minor sulfides at places) of Pazzano-Stilo on the post-Hercynian peneplane and below to the Mesozoic (Jurassic?) carbonate platform. They are quite similar to the coeval deposits of western Sardinia.

Table 2. Ore/mineral occurrences in the Calabrian-Peloritanian Arc

Main Paragenesis	Metallogenic Epoch (pre)-Hercynian	post-Hercynian pre-Alpine non-ophiolite	Ophiolite	Alpine	late- and post-Alpine
Mixed Sulf.	A	C	C	No new contributions, only (partial) remobilization, displacement, dispersion of pre-existing ores/minerals	
Pb-Zn-Ag	A				
F-Ba	A	C			
Pyr-Cu	B				
U-Th-REE	C				C
Mo-Cu	A				
Fe ox, Ti		A			B
Mn-Fe ox			A		C
Hg		B			
Sb-W-Hg	B				
Na-K-S					A

Relative importance (in the Calabrian-Peloritanian metallogenesis)

A: frequent and someones of not negligible tonnages
B: not so frequent and often small
C: occasional and small

For details: see LORENZONI et al., 1983.

Small accumulations of Ba, F, pyrite, Zn, Pb, Cu, Hg are known in a section of the Northern part of the Western Coastal Range (North-North-East of Cetraro). If these occurrences can be considered equivalents to the rich, paragenetically similar, Triassic deposits of Central-Western Alps (but this hypothesis needs confirmation), the difference between them is stricking and has to be explained.

ii) very few and not so rich ore/mineral deposits generated in connection to the ophiolitic magmatism. As it was said at point 2 the ophiolite sequences occur in not so large outcrops, scattered along the Northern section of the Western Coastal Range (from the Sangineto Line to the Lamezia-Catanzaro trench). The related ore concentrations consist of some poor pyrite-chalcopyrite occurrences.

This is a real difference from the, generally rich, deposits related to the ophiolitic sequences of the other parts of Mediterranean.

iii) no new deposit have ben generated in connection to the Alpine orogenesis and metamorphism; we do not speak of Alpine magmatism, because there is no evidence of it in the Calabrian-Peloritanian Arc.

The Alpine orogenesis and metamorphism are responsible of displacements, remobilization, dispersion of pre-existing ore/mineral deposits, as it has been fully demonstrated by LORENZONI et al., 1983.

These events cover large areas of the region under investigation, particularly its North-Western part, from the Sangineto line down to the Stilo area. Important sections of the Hercynian/pre-Hercynian regions, and the related mineral accumulations, have been (partially) involved.

iv) The metallogenic importance of late- and post-Alpine events consists in Messinian evaporite and biogenic S deposition of considerable tonnages, even of size no. 1.

Some beach sands, enriched in heavy minerals, and some lacustrine U occurrences, have been also deposited in these times.

The only evidence of recent volcanism and related ores, which are so largely present in Central-Southern Italy, is the submarine accumulation of sulfides (mainly pyrite) in the Eolian basin.

4. Conclusive Remarks

As a conclusion we may say that the (very scarce) ore/mineral wealth of the Calabrian-Peloritanian Arc has been built up mainly in connection to Hercynian/pre-Hercynian metallogenic events; it was partially reshaped or dispersed and only very poorly enriched in connection to the post-Hercynian events.

The absence of the Cambrian carbonatic platform formations*) and—consequently—of their rich metal stock, so well represented in Sardinia (where they are meaningfully called "Metalliferous"), may be one of the causes of the poverty of the metal reserves.

"One of the causes"—we said—but not the only one: other factors had probably played a role; without entering into details, and sticking to the metallogenic Thetyan events, the following characters have to be taken into consideration:

i) the (probable) absence of the Permian-Lower Triassic rifting and related Permian volcanism, well known in the Alps, where it is associated to interesting, U, Fe, Ba accumulations.

ii) the scanty development of Middle-Upper Triassic and its difference from the (richly mineralized) South-Alpine Triassic.

iii) the probable different nature of the Calabrian ophiolites in comparison with the other mediterranean ophiolitic complexes, as suggested by LORENZONI and ZANETTIN LORENZONI, 1980, and confirmed in the previous point.

The geological and metallogenic outline of the Calabrian-Peloritanian Arc, as it comes out from this paper, even if it is not so detailed, suggests that this region has peculiar characters, partly similar and partly clearly different from the other Mediterranean regions.

As a matter of fact the likeness of some Paleozoic formations in the Alpine Arc, in Sardinia and in the Calabrian-Peloritanian Arc speaks for a possible paleogeographic connections among them.

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*) Cambro-Ordovician terrains have been recently discovered in Calabria (BOUILLIN et al., in print), but they have not carbonatic platform facies.

The presence of the Middle-Paleozoic Sb-W-Hg complex in all three regions is another supporting evidence; the occurrences of similar residual Fe Oxide concentrations on the Hercynian peneplane, at the base of the carbonatic Mesozoic formations, in West Sardinia and in Central Calabria, may be considered as another evidence of a similar early post-Hercynian climatic-erosional evolution.

The regional distribution of some ore/mineral deposits in Southern Europe, the Sardinian-Corsic massif and in Calabria—as pointed out by one of us (ZUFFARDI, 1978)—appears consistent with the paleogeographic reconstruction of the Alpine orogenic belt proposed by ALVAREZ et al., 1974, according which the Calabrian-Peloritanian Arc should be considered a microplate of that belt.

On the other hand, many other factual observations discussed in point 2 of this paper, demand for going deeper into this problem and for seeking explanation of not negligible details.

In particular, taking into account the possible relationship between Sardinia and the Calabrian-Peloritanian Arc (which are most interesting on the metallogenic point of view), it has to be noted that there are substantial differences between the distributions of the whole (pre-Hercynian+Hercynian+Alpine) metamorphic-magmatic-tectonic history and in the structural setting of these two regions: to quote the most striking example—in the aim of Tethyan investigations—we point out the decidely different effects of the Alpine orogenesis in these regions (absent or at most rigid in Sardinia, intensive and mainly plastic in the Arc).

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