Geotectonic Evolution and Metallogeny of Italy in the Tethys Realm: A Summary of Data and Hypotheses

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With 3 Figures

Zusammenfassung

Der tektonische Aufbau Italiens und die plattentektonische Entwicklung der Apennin-Halbinsel sowie der benachbarten Inseln wird zusammenfassend beschrieben. Fig. 1 stellt die komplexe Zusammensetzung des Gebietes aus Teilen der europäischen und der afrikanischen Platte dar. Das Wechselspiel von permo-triassischem Rifting, jurassischem Seafloor-Spreading und kretazisch-tertiärer Kollisions- und Kompressionstektonik findet Entsprechung in den magmatischen (Fig. 2) und metallogenetischen Produkten (Fig. 3). Die metallogenetische Armut der italienischen Ofiolithe im Gegensatz zum Erzreichtum der ostmediterranen wird hervorgehoben. Die wirtschaftlich wichtigsten Lagerstätten wurden im Jungtertiär und im Quartiär gebildet.

1. Foreword

Many studies have been carried out till now and are carried on at present about the geo-dynamic evolution of Italy and of the Mediterranean region. Recently (1984) a volume on this topic has been published at the Italian Geological Society.

A number of hypotheses have been put forward; of course someones fit in each others, someones are in disagreement; this fact is connected both to the intrinsec difficulties of the area and to the lack of sufficient data.

The working group charged of preparing the various chapters of the Italian report for this session of IGCP 169 (a short resumé of which is presented here) preferred to summarize the most relevant knowledge on the theme, without venturing

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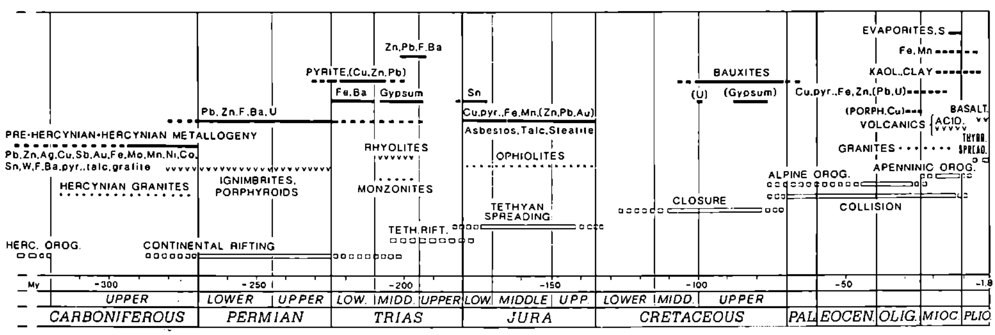

Fig. 2. Schematic chronological sequence of the geo-dynamic events and metallogeny from Middle-Upper Carboniferous to Pliocene.

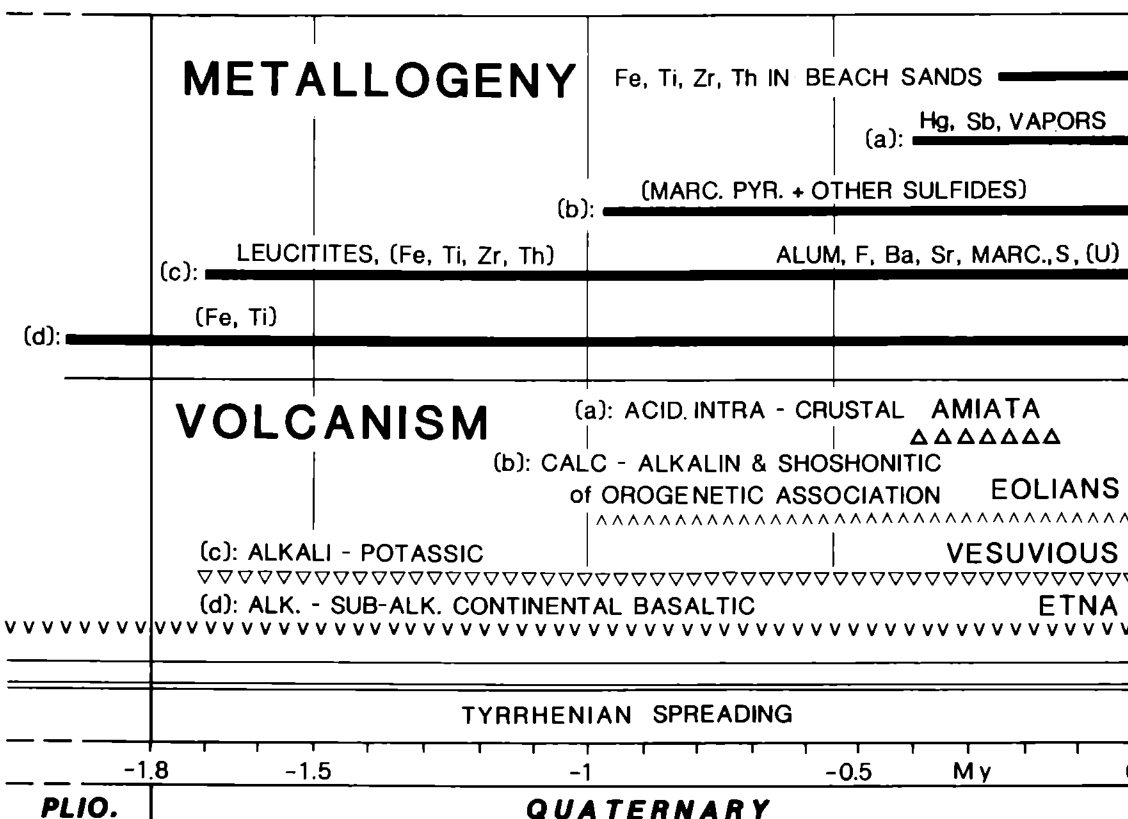

Fig. 3. Schematic chronological sequence of the geo-dynamic events and metallogeny from Pliocene up to Actual times.

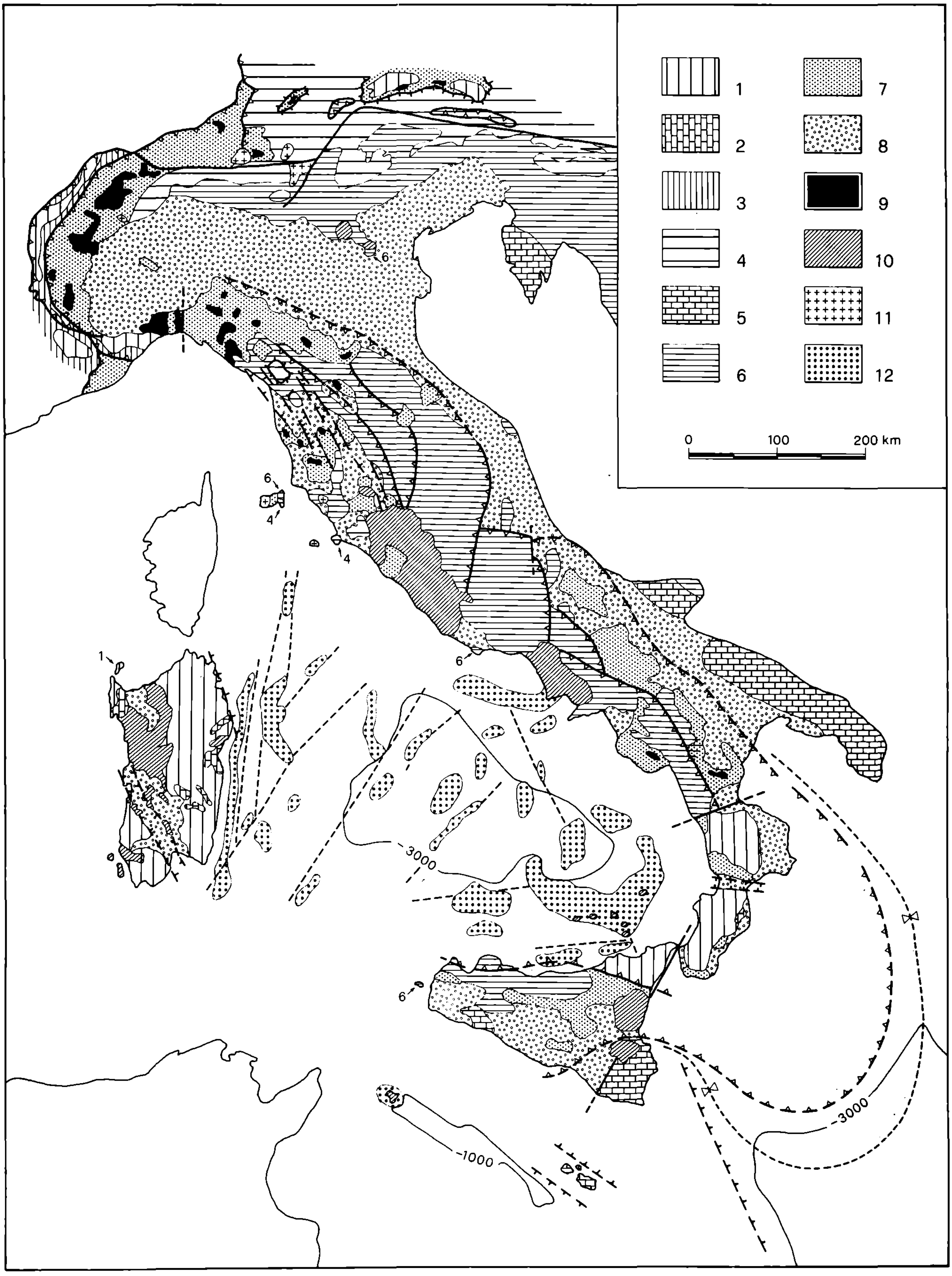

Fig. 1. Geo-tectonic map of Italy (after Parotto & Praturlon, 1980, simplified).

EUROPEAN PLATE: 1, 2, 3

AFRICAN PLATE: 4, 5, 6

1 and 4 = Hercynian/Pre -Hercynian basements and their pre-Tethyan (Permian to Lower/Middle Triassic), continental and/or littoral, covers.

2, 3, 5, 6 = Mesozoic (from Middle Triassic) and (partially) Tertiary covers; 2 and 5 = tabular, autochtonous; 3 and 6 = overthrusted and/or folded.

INTERNAL UNITS: 7 = Flyshoid complexes often overthrusted, frequently including masses of ophiolites (9), and locally carbonate platforms. They are called "calc-schists and green stones" in the Alps, "scaly clays", "Ligurides" (ophiolitiferous), "Sicilides" (non ophiolitiferous) in the Apennines. Large sections of the basement (not reported in the map) outcrop within the "calc-schists and greenstones". 8 = Molasses and post-orogenic deposits.

MAGMATISM: 9 – Ophiolites.

10 = Tertiary and Quaternary undifferentiated volcanics (see Fig. 2 and 3).

11 = Alpidic granites.

ELEMENTS OF MARINE GEOLOGY: 12 = Sea-mounts, partially volcanic (mainly tholeiitic), partially made of crystalline basement, and locally of Mesozoic cover and/or of ophiolites.

general theories, just elucidating some more or less obvious deductions, and pointing out the doubts that still remain.

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2. Pre-Tethyan events

We will not enter into details on this point, which is rather outside the aims of this paper. We will just recall that two main tectonic-metamorphic-magmatic-metallogenic pre-Tethian groups of events have to be mentioned; namely:

2.1. Hercynian and pre-Hercynian

Strong effects of the Hercynian tectonics and metamorphism*) are known in the Alps, in Sardinia, in Tuscany, in the Calabrian-Peloritanian Arc. Hercynian granitoid rocks are known in the same region except Tuscany; Pb, Zn, Ag, Cu, Sb, Au, Fe, Mo, Mn, Ni, Co, Sn, W, F, Ba, pyrite, talc, graphite accumulations generated in those times; some of them are very rich in Sardinia (MONTEVECCHIO and MONTEPONI Pb, Zn deposits, for instance), someones are fairly rich in the Alps; they are not so important in the Calabrian-Peloritanian Arc, no deposit of this age is known in Tuscany.

The pre-Hercynian sequences are not the same in the above-mentioned regions; some remarks may be of interest, from the metallogenic point of view, about these terrains. In fact, it has to be noted that the Cambrian is well developed only in Sardinia, where the metallogenically important platform carbonate complex (meaningfully called "Metalliferous") crops out over a vast area, in the South-West section of the Island. Recently Cambro-Ordovician terrains have been recognized in Calabria on the basis of micro-paleontological evidence, but they are terrigenous and barren.

The differences in the distribution of Cambrian (particularly of the Metalliferous and of its huge stock of metals) may be a reason for the different mining importance of the above-mentioned regions. In any case the correlation among the various sections of the Italian Hercynian/pre-Hercynian belt and of their metallogenic districts is much more complex than it appears at a first analysis; considering them simply as various pieces to be shouldered together may became dangerous for prospecting purposes: suffice it to recall the disappointments experienced in Calabria, when one was hoping to find there deposits of Sardinian type.

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*) The presence of Caledonian effects is controversial: the only undebatable case of pre-Hercynian tectonics is shown by the Cambro-Ordovician unconformity in Sardinia; the latter was not associated with metamorphism and magmatism, but deserves a certain metallogenic interest (karstic Pb, Ba accumulations).

2.2. Post-Hercynian/Pre-Tethyan

A cycle of continental rifting and of acidic volcanism took place after the end of the Hercynian orogenesis (Upper Carboniferous) till Lower-Middle Trias.

It is very developed all along the Alpin chain, where some wide complexes have been generated (such as the so-called "porphyric platform of Adige Valley"); it occurs in two different units, namely: Pennines and Southern Alps. The fact that Tethyan ophiolites are part of the first unit and not in the second, may be considered an evidence for non-correlation between the events under discussion and the Tethyan ones.

Similar cycles are present in South-Eastern Sardinia and in Northern Tuscany; they are not known with certainty elsewhere.

This event is not to be considered as pre-Tethyan rifting, but rather a "tail" of the Hercynian cycle. U, Fe, Zn, Pb, F, Ba, pyrite accumulations generated (in part by remobilization of (pre)-Hercynian pre-concentrations – of Pb, Zn in particular –) in connection to this cycle. Some of these deposits are important in Tuscany (pyrite deposits of GROSSETO area) and in the Alps (U of NOVAZZA, VALVEDELLO); no similar deposit is known in Sardinia.

3. Tethyan events

The evolution of the Italian territory and the adjoining seas was not the same: there are differences between Western and Eastern Alps, between Northern and Southern Apennines, between Sardinia and the other parts of Italy. A schematization to extremes is here described.

3.1. Tethyan rifting

The Tethyan rifting started in Middle Trias, with particular evidence in the Carnian Alps; far less so (or even debatable) in other areas (Liguria, Northern Tuscany, Lucania, Calabria, Sicily).

This rifting lasted till Upper Trias-Lias, as it is proved by the presence of basinal areas originated in Middle Liassic time by "drowning" of large sectors of Liassic-Triassic shallow water domains. Oceanization started in the same moment, since the first oceanic mafites are dated as Liassic.

A scanty magmatic activity is related to this event: the monzonites and the mainly acidic lavas of Eastern Alps are the main instances; minor volcanic complexes of the same age occur in the other above-mentioned regions.

Sedimentary deposits of Zn, Pb, F, Ba, Sn originated in connection to this rifting; they are important in the Central and the Eastern Alps (among them, the Zn, Pb deposits of RAIBL and of SALAFOSSA), not so important, or inexistent, in the other regions.

3.2. Oceanization and ophiolitic volcanism

Oceanization should have started in the Upper Trias, according to the facies of the Norian sediments of the Eastern section of the Southern Alps; the first deposition of mafic rocks – as it was said in the previous chapter – took place in the Lias (the absolute ages being 185–160 My); but the climax of spreading and of the ophiolitic volcanism should have been Middle-Upper Jura; soon after the oceanic closure started.

The intense deformations caused by the subsequent Alpidic-Apeninic orogeneses make the palinspastic reconstruction of the Tethyan domain in Italy difficult. Some characteristies of the ophiolitic sequences can help for this purpose; it has to be remembered that the distribution of the ophiolites in Italy is uneven, so far as both their geographical location and their origin are concerned (and probably their ages).

As a matter of fact, (i) typical oceanic ophiolites occur in Central-Eastern Liguria, in Tuscany and episodically along the Northern border of the Emilian Apennines. The ophiolite bearing sequences are strongly tectonized and displaced as olistolites of various dimension in the last two regions. In any case this group of ophiolites is identical with those of North-Eastern Corsica. (ii) ophiolites, defiled by and/or interbedded with terrigenous sediments, occur in Calabria and along the Alps (in this latter region they make part of the so-called "Calc-schists with greenstones" complex, equivalent to the French "schistes lustrés"). A deduction ensues immediately: the origin of the latter type of ophiolites should have been non-oceanic or at last – should have been closer to a continental margin, than the ones of Liguria and Tuscany. (iii) no evidence of ophiolites or of comparable rocks is known in Sardinia.

These observations suggest that Central-Eastern Liguria (particularly the Bracco zone, according to a more careful examination), should have occupied a middle oceanic ridge type position in the Tethys. This same structure should have been the source of the ophiolite bearing olistostromes of Tuscany and of Emilia.

The "greenstones" of the Alps and the ophiolites of Calabria should outline a belt more or less close to a continental margin (may be at least in part, running in back arc position?).

Sardinia should represent a piece of the (European) continental area in the Tethys domain. As a matter of fact comparative studies of the Mesozoic sediments in the Provence, in the Sardinian-Corsican Massif, in Western Tuscany, suggest that the Massif played a rôle of an emerged craton separated from the Provence by a narrow intracratonic basin with sediments of Germanic facies, and separated from Tuscany by an epi-continental sea, connected with the Triassic Alpine open sea basins.

The tearing of the sialic crust and the Jurassic-Cretaceous marine transgression gave cause to the formation of the "Ligurian-Piedemontese oceanic basin" in the first phase and to the "Paleo-Tyrrhenian" in the second: they represent the Tethys in this area. On the whole it is current opinion that the Tethys, in our area, was not more than a narrow oceanic basin, more or less a strait widening out eastwards, connecting the Atlantic with the eastern paleo-ocean.

A number of deposits of Cu, pyrite, Fe, Mn, (Zn), (Pb), (Au), asbestos, talc and steatite, of various sizes and grades generated in connection with the ophiolitic volcanism, but the only industrially important one is the huge asbestos deposit of BALANGERO (Western Alps); all others (even the historically important Cu ore-body of MONTECATINI included) are modest.

The fact that the Italian "oceanic" ophiolites are lithologically alike the Cr, Ni, Co, Pt bearing ones in the other sections of the Mediterranean, but containing only traces of these metals, represents a puzzling problem from the scientific standpoint and a disappointment from the industrial one.

The only example of a probable remobilization and heredity, connected with the ophiolitic volcanism, is represented by the Au content of some pyrite-Cu deposits and by some (small) Au-pyrite (and minor others sulfides) veinlets occurring in the ophiolitic complexes close to Au bearing sections of the basement: the main localities occur in Valsesia (ALAGNA), in Aosta Valley (BRUSSON) and in Central Liguria (OVADA).

3.3. Closure and collistional stages

As already mentioned, the closure of Tethys started during the Lower Cretaceous collision, initiating the Alpidic-Apenninic orogenesis which began in late Cretaceous-Paleocene and can be considered as terminated in Upper Miocene-Lower Pliocene.

It has to be said that collisional phenomena are yet going on, at present, in the Southern Tyrrhenian, but they have to be considered as a Post-Tethyan event because they are separated from the Tethyan collisional effects by an extension stage (the opening of the Tyrrhenian sea).

Epirogenic emersion of vast carbonatic platforms (Apulia, Central Italy, Southern Alps, Istria, Sardinia, Sicily) characterized the pre-collisional stage, and a number of noteworthy bauxite deposits generated in this time span.

The Alpidic-Apenninic orogenesis deserves particular attention, because the present shape and structure of the whole Italy (Sardinia in a minor scale) are related to it.

The Alpidic and the Apenninic tectonics, metamorphic and magmatic phases, even if belonging to a same event, are slightly displaced in time and affected in various ways the different sections of Italy.

As a matter of fact the Alpidic tectonics are characterized by motions in North-South direction, with intensive overthrusting and recumbent folding; the Apenninic tectonics are instead characterized by motions in latitudinal direction (mainly from West to East), accompained by overthrusting, recumbent folding and collapse structures in particular sites of the displaced masses.

The formation of syntectonic troughs and of insulated evaporitic basins (the so-called "Messinian salinity crisis") are other important phenomena controlled by the Alpidic-Apenninic orogenesis.

The Apenninic cycle started later than the Alpidic one, and reached its climax in Upper Miocene, when the Alpidic orogenesis was practically finished.

The curvature of the Western section of the Alpine chain is a consequence of the overlapping of Apenninic motions on pre-existing Alpidic structures.

On the basis of plate movements it is currently agreed that the Alpidic tectonics were a consequence essentially of frontal approaching of the European and African plates, whilst the Apenninic tectonics were controlled also by longitudinal relative motions of the two plates. The latters are related to the opening of the Northern Atlantic ocean.

It is also agreed that, whilst the Southern front of the European plate was – at those time – fairly smooth and had an East-West trend, the Northern front of the African plate – at the contrary – was uneven and formed a vast nose (the so-called "Adria promontory"), more or less opposite the actual position of Italy. The Apulian and the Sicilian carbonatic platforms are considered to be two major residues of that promontory.

The existence of this structure should explain the involvment of African slabs (the "Austro-Alpin unit") in the Alpine chain, that is mainly made of European and of Tethyan terrains.

The complicated movements, through which the Calabrian-Peloritanian Arc reached its present position (as proved by paleomagnetic studies), could also be explained taking into account that this micro-plate was moving close to a peculiar point of the African plate: the Western root of the Adria promontory.

Meaningful enough is the fact that only collapse structures have been generated in Sardinia by these tectonics, since early Tertiary: this suggests that Sardinia was outside the orogenic Alpidic-Apenninic belt. As a matter of fact, since lower Tertiary a number of extension structures generated in Sardinia; this tensional regime caused, from Upper Oligocene to Lower Miocene, the separation of the Sardo-Corsican massif from the stable Europe and the start of its counterclockwise rotation.

In this same time, intensive, eastwards verging overthrust phenomena, younger and younger in this direction, started in the Apennines.

In Lower-Middle Miocene the counterclockwise rotation stopped and so did the compressive tectonics along the western Apennines; an extensive stage commenced in this area, leading to the opening of the Tyrrhenian sea.

So far as the Calabrian-Peloritanian Arc is concerned, the opinions are divided; the first Authors dealing with this problem proposed that the Arc be simply a microplate coming from the paleo-Europe, such as the Sardo-Corsican massif and the Cabylies.

Subsequent Researchers (see the paper devoted to the Calabrian-Peloritanian Arc in this same volume) proposed a more complex evolution of the Arc.

We shall say here that the problem cannot be considered, at the moment, fully and satisfactory solved, particularly on the metallogenic standpoint, and fig. 1, drawn on the basis of the primitive hypotheses, has to be considered only as a first approximation.

In any case the metallogenic Calabrian-Peloritanian province is different from the Sardinian one, at least on the economic point of view.

The magmatic activity of this stage includes: (i) granitoids rocks: they are widespread in the Alps (the ADAMELLO group is the most important); only small occurrences are known in Tuscany (ELBA Island and GROSSETO district); the small grano-dioritic stock of CALABONA (North-Western Sardinia), that holds the only (small and poor) porphyry copper deposit of Italy, pertain to this group. It is worthwile to quote it, for its possible geodynamic significance. (ii) Volcanic rocks of various composition; they occur: between VICENZA and PADUA, and are mainly made of middle alkaline basalts; in Tuscany: "Selagites" of MONTECATINI, and minor acidic others; in Sardinia: andesites, dacites, rhyolites (in part hyperalkaline: the "commandites" of S. PIETRO and S. ANTIOCO).

The metallogenesis related to the closure/collisional stages and connected magmatisms yielded:

(i) noteworthy bauxite deposits: MONTE ROTONDO (Apulia) and OLMEDO (Sardinia) among others; as already mentioned they generated in pre-collisional stage;

(ii) important Na- K-salts, native S deposits generated during Upper-Miocene (Messinian) in Northern Tuscany (VOLTERRA: Na, alabaster), Eastern Emilia and Marche (gypsum, S) , Campania (S), Calabria (NA, S) and – specially – Sicily (CATTOLICA ERACLEA: Na; PASQUASIA and S. CATALDO: K; TRABONELLA, COZZODISI, GESSOLUNGO: gypsum, anhydrite, S).

(iii) remobilization and (partial) transformation (at places – Calabria – dispersion) of pre-existing metal accumulations in relation to metamorphism and granitization.

The main examples of concentrations are:

(iii – 1): the skarn deposits of Fe_3O_4, Fe S, $Fe S_2$ of TRAVERSELLA (Western Alps), of U (ADAMELLO district), of high purity $Fe S_2$ (GAVORRANO, in Tuscany), of Fe_2O_3, Fe S, $Fe S_2$ of ELBA Island;

(iii – 2): the mixed sulfide veins with quartz gangue of GROSSETO district (BOCCHEGGIANO, CAMPIANO p. p.).

(iv) Ore deposits, with no evident connection to pre-concentrations, and – hence – to be considered "new". They are a few, the mixed sulfide skarn of CAMPIGLIA (Grosseto) is the main example.

(v) porphyry copper deposits: as mentioned before, the only example is CALABONA (North-Western Sardinia). Unfortunately it is of low grade and small tonnage. In the same area the coeval andesites recovering this deposit, hold small, fairly rich Cu, Zn, Fe, Pb sulfide accumulations.

(vi) Industrial deposits, related to (some) volcanic complexes; they include:

(vi –1): Kaolin and Clays (PONZA Island, SARDINIA, South-Eastern Alps between VICENZA and PADUA).

(vi – 2): Mn and Fe Ox (SARDINIA).

4. Post-Tethyan events

The post-collision evolution, encompasses the Neogene-Quaternary events; they are characterized by a new crustal extension, that was responsible both for the opening of the Western Mediterranean basins (the Tyrrhenian in particular), and for several basins in the Apenninic chain and of the compressive stage still going on in the Calabrian-Peloritanian Arc, causing eartquakes, volcanism, quick land upheaval.

The age of the bathyal plain basalts of the Tyrrhenian sea is 7.5 My (Lower-Middle Pliocene), post-dating the beginning of its opening.

The magmatic activity related to this stage includes four types of volcanics; namely:

(i) Alkali-potassic (at places with high K content); it stretches along the Tyrrhenian coast from Northern Latium down to Neaples (VESUVIUS active volcano); also the VULTURE apparatus (Northern Lucania) pertains to the same type.

The age of this volcanism is from 1.7 My to 0 and it is associated with tensional tectonic that followed the Tethys closure.

(ii) acidic intra-crustal: it occurs in Northern Latium and in Tuscany, MOUNT AMIATA being the major apparatus. It is also related to the same above-mentioned structures. The rock age is 0.4 to 0,2 My, but some fumaroles are still active and the LARDERELLO vapor field is connected to it.

(iii) Alkaline/sub-alkaline continental basaltic: important rock masses occur in SARDINIA, in Sicily (MOUNT IBLEI and the active ETNA volcano), in some islets of the Sicilian Seas (PANTELLERIA and others), and of the Tyrrhenian in front of PISA (Isle of CAPRAIA).

Their ages range from 5.4 My to 0. The basaltic deposition in Sardinia followed soon after the volcanic activity quoted at the previous point and is related to the same collapse structures. In Sicily it is thought to be related to tensional structures of the African plate, ensuing from the active convergence of the Calabrian-Peloritanian Arc.

(iv) Calc-alkaline and shoshonitic of orogenetic association: the only example is shown by the Eolian archipelago: its age is very recent (probably from less than 1 My to 0), and is an evidence of the above-mentioned active convergence.

The metallogenesis related to the post-Tethyan event has noteworty industrial interest. One may distinguish:

(i) metallogenesis related to the alkali-potassic volcanism: it includes: huge accumulations of leucitic rocks; huge accumulations of volcano-sedimentary fluorite, at places with admixed baryte, and minor deposits of baryte and celestite; small deposits of volcanic sulfur and marcasite; sub-economic accumulation of U ores; small deposits of alum; traces of Fe, Ti, Zr, Th.

(ii) metallogenesis related to the acidic intra-crustal volcanism: the very important Hg deposits of MOUNT AMIATA and the not negligible Sb deposits of the same region pertain to this group.

Also the vapor fields of LARDERELLO are related to the same volcanism;

(iii) heavy mineral accumulations in beach sands (Fe, Ti, Th, Zr ores) occur in many places of the Tyrrhenian, the Ionian and the Sardic coasts;

(iv) sub-economic sulfide (mainly pyrite) volcano-sedimentary submarine accumulations, related to the Eolian volcanism;

(v) haematite, magnetite, Ti mineral pre-concentrations (giving rise, by erosion, to black sands) occur in some basalts of Sardinia.

Sources of Informations

Boccaletti, M., Cita, M. B., Parotto, M., Sartori, R. (Editors) (1984): „Evoluzione geodinamica del Mediteraneo con particolare riguardo all-Appennino, Sicilia e Sardegna". Mem. Soc. Geol. It., XXIV–1982, 482 p.

COCOZZA, T., DECANDIA, F. A., MARCELLO, A., PRETTI, S., SALVADORI, I., URAS. I., VALERA, R. (1984): "Geo-tectonic Evolution and Metallogeny of the Sardo-Corsican Massif", in this same volume.

GELATI, R., PRATURLON, A., ZUFFARDI, P. (1984): "The Apenines: geotectonic evolution and metallogeny-an overview", in this same volume.

OGNIBEN, L., PAROTTO, M., PRATURLON, A. (ED.) (1973): „Modello Strutturale d'Italia", geological map, scale 1 : 1,000.000 – C. N. R.

PRATURLON, A.(1980): „Cadre géologique général de l'Italie. Sa place dans le cadre europeen et méditerraneen". In: „Introduction à la géologie générale d'Italie", XXVI Int. Geol. Congress, 3–14.

ZANETTIN LORENZONI, E., ZUFFARDI, P. (1984): "Geo-tectonic evolution and metallogenesis of the Calabrian-Peloritanian Arc in the Tethys Realm", in this same volume.