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HERCYNIAN AND PRE-HERCYNIAN MAGMATISM IN THE CALABRIA-PELORITANI ARC (SOUTHERN ITALY)

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RIASSUNTO. — Entro le metamorfiti paleozoiche affioranti lungo l'Arco Calabro-Peloritano sono presenti numerose testimonianze di attività magmatiche erciniche e pre-erciniche. In questo lavoro si cerca di fornire un quadro generale di questa attività sulla base di alcune centinaia di analisi chimiche, facendo riferimento specialmente agli elementi meno mobili durante l'alterazione e il metamorfismo.

I prodotti del magmatismo pre-ercinico (datazione U-Pb su zirconi) e quelli possibilmente tali mostrano similitudini con le vulcaniti eruttate in corrispondenza di convergenza di placche.

Le metavulcaniti e le plutoniti erciniche (datazioni paleontologiche e Rb-Sr su biotiti e su roccia totale) sono rappresentative, in ordine cronologico, di un magmatismo basico alcalino di tipo « intraplate », di un magmatismo di ambiente orogenico e di un magmatismo post-metamorfico anatettico-crustale.

ABSTRACT. — Hercynian and pre-Hercynian magmatic rocks are widespread in the Paleozoic range of Calabria-Peloritani region. On the basis of the geochemically « immobile » elements an overall consistent picture comes out.

The pre-Hercynian meta-igneous rocks as well as those which probably have same age display similarities with the volcanites erupted at converging plates.

The Hercynian meta-igneous rocks may be related to the succession of the following magmatic activities: alkaline « intra-plate » magmatism, tholeiitic-calc-alkaline orogenic magmatism, post metamorphic plutonism derived from crustal anatexis.

Introduction

The Calabria-Peloritani arc is a structure in which the piling of several nappes may easily be seen; nappe structures of both Alpine and Hercynian ages have been reported (AMODIO MORELLI et al., 1975 and references).

The products of Hercynian and pre-Hercynian magmatic activity occur in several nappes formed of Paleozoic metamorphic rocks. This work aims at the interpretation of the available data on these materials, in order to give an overall picture of pre-Alpine magmatic activity recorded along the Calabria-Peloritani structure. As a consequence, some information concerning the features of the Hercynian and pre-Hercynian orogens will also be given. Attention is drawn particularly to the meta-igneous and igneous rocks which have been geochemically investigated up till now.

Pre-Hercynian magmatic products

A zircon age of 450 m.y. (SCHENK, 1980) has been determined for one granulite-facies metabasite from the Polia-Copanello Unit,

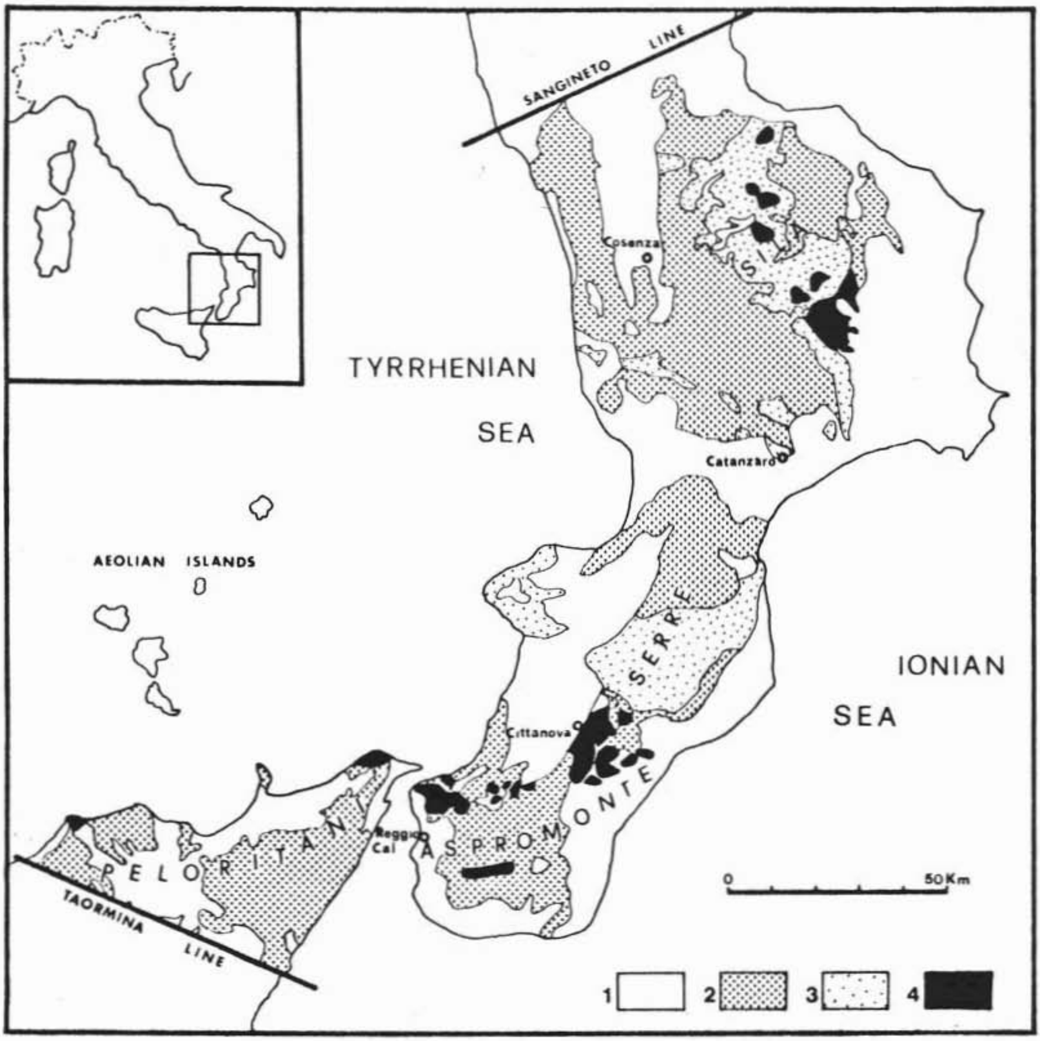

Fig. 1. — Location of the area: 1) Tertiary and quaternary sediments; 2) Pre-Alpine and Alpine metamorphic rocks; 3) Mesoaluminous plutonic rocks; 4) Peraluminous plutonic rocks.

a fragment of the deep Paleozoic continental crust now at surface. This has been interpreted by SCHENK as the minimum age for the magmatic crystallization of the protolith, although it might also represent the age of a metamorphic event, presuming that the pre-Alpine polymetamorphic model suggested by DUBOIS (1976) and PAGLIONICO & PICCARRETA (1978) is correct.

The metabasites interbedded with the metasediments are evidence of synsedimentary magmatic activity which produced subalkaline basic volcanites (MORESI et al., 1978, 1980). Geochemical data show that the protoliths derived from different parental magmas. In the Al_2O_3-$FeO+Fe_2O_3$-MgO plot (fig. 2) of BESSON & FONTEILLES (1974), the data points cluster in different homogeneous groups displaying diverse affinities. Such a diagram is preferred to the *A-F-M* one, owing to the lower mobility of Al_2O_3 relative to the alkalis. Most of the rock-samples are Al-rich and Ni-poor, and follow the trends of the modern volcanites erupting at converging plates, whereas some rock-samples show lower Al-contents relative to $FeO +$ $+ Fe_2O_3$ and MgO. These differences are also evident in the FeO^* vs. FeO^*/MgO

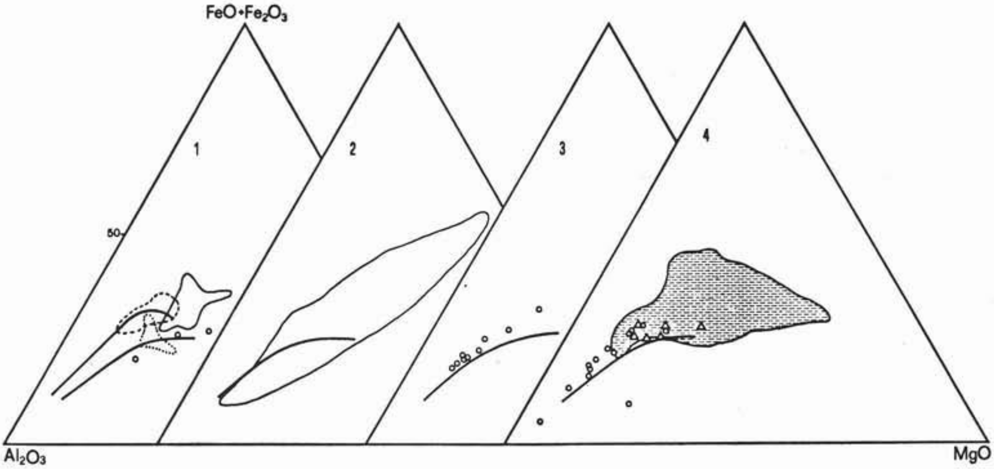

Fig. 2. — Al_2O_3-$FeO+Fe_2O_3$-MgO plot (BESSON & FONTEILLES, 1974): tholeiitic and calc-alkaline trends of orogenic areas reported according to data from JACKES and WHITE (1972). - 1) Synsedimentary metabasites of Polia-Copanello Unit (Calabria): unbroken line limits field of metabasites interbedded with kinzigitic gneisses ($n = 8$); other symbols indicate fields or samples of metabasites interbedded with underlying stronalite-like rocks ($n = 33$); data from MORESI et al. (1978, 1980); IOPPOLO et al. (1978) and unpublished. 2) Fragments of layered complex occurring at bottom of Polia-Copanello Unit ($n = 27$); data from MORESI et al. (1978) and unpublished. 3) Tonalitic gneisses of Polia-Copanello Unit, data from LORENZONI and PAGLIONICO (1970). 4) Tonalitic gneisses (circles) and amphibole-biotite-bearing gneisses (triangles) from Palmi-Bagnara area (Calabbria); data from ROTTURA et al. (1975). Dashed area encloses amphibolites from Aspromonte nappe *auctorum* in Peloritani area ($n = 69$); data from ATZORI (1972); D'AMICO et al., (1972); GURRIERI & MACCARRONE (1978); FERLA & AZZARO (1978).

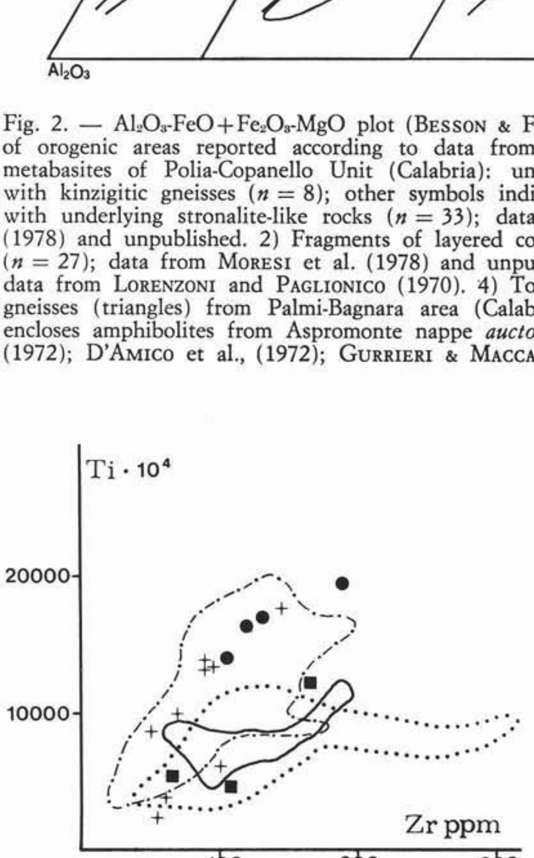

Fig. 3. — Ti × 10^4 vs Zr plot relative to synsedimentary metabasites of Polia-Copanello Unit: spotted-dashed line contours dredged and drilled MORB (DONNELLY & ROGERS, 1980); spotted and unbroken lines encloses Al-richer metabasites interbedded with stronalite-like rocks; dots and squares represent Al-poorer metabasites interbedded with overlying kinzigitic gneisses; crosses indicate some retrogressed metabasites interbedded with stronalite-like rocks.

($FeO^* =$ total Fe as FeO) and Ti × 10^4 vs. Zr plots. In the latter, the rocks poorer in Al plot in the field of dredged and drilled MORB (fig. 3). According to MORESI et al. (1980) the chemical features of these rock-types may be due to pre-metamorphic alteration.

Both in Calabria and the Peloritani Mountains other meta-igneous rocks occur, the age of which is still unknown. They were involved in the Hercynian metamorphism and may be Hercynian or pre-Hercyinan in age. In Calabria they occur in the Polia-Copanello Unit and the Palmi-Bagnara area (Aspromonte); in the Peloritani Mountains they occur in the Aspromonte nappe *auctorum*.

In the Polia-Copanello Unit fragments of layered metagabbros occur at the bottom of the sequence; dioritic-tonalitic gneisses lie at the top. They display clear calc-alkaline affinities in the Al_2O_3-$FeO+Fe_2O_3$-MgO plot (fig. 2). Furthermore, according to the discriminant plots proposed by PEARCE and CANN (1973) and PEARCE (1976) for basaltic rocks, the layered metagabbros fall in the field of calc-alkaline types of orogenic areas (MORESI et al., 1978).

Tonalitic gneisses associated with minor biotite-amphibole-bearing gneisses are widespread in the Palmi Bagnara area. They probably originated from volcanogenic sediments (ROTTURA et al., 1975) and display some calc-alkaline affinities (fig. 2): relatively low Ti contents ($TiO_2 < 1$ % in tonalitic gneisses; approx. 1 % in mafic gneisses) and high Al contents.

Amphibolites, amphibolic gneisses and augen-gneisses occur in the Aspromonte Nappe of the Peloritani Mountains. The former rocks occur as lenticular and stratoid bodies of irregular masses, testifying to synsedimentary magmatic activity; according to FERLA (1974), they underwent Hercynian and pre-Hercynian metamorphism. Chemical data show that most of these rocks derive from sub-alkaline basic parental magmas showing affinities with arc tholeiites (fig. 2). In addition some metabasites occur, although further investigations clarifying their alkaline or non-alkaline nature (ATZORI et al., this volume) must still be undertaken.

Augen-gneisses deriving from acidic plutonic and extrusive protoliths are widespread in the Aspromonte nappe.

Hercynian magmatism

Separate intrusive and extrusive magmatic activities are reported in the Paleozoic terrains occurring along the Calabria-Peloritani structure. These magmatic activities could be classified as pre-metamorphic, syn-tectonic and post-metamorphic, on the basis of both geological and chemical features.

The assumed pre-metamorphic phase occurred in the middle Devonian, as suggested by the occurrence of Tentaculite limestones (Peloritani) associated with the meta-igneous rocks. The products of this magmatic activity show alkaline features (fig. 4) characteristic of an « intra-plate » distensive environment (FERLA, 1978). Complete crustal laceration, however, did not occur, as suggested by the lack of Hercynian ophiolites.

The successive activity, testified by meta-igneous rocks ranging from basaltic to rhyolitic compositions, is recorded in the metasediments overlying the Tentaculite limestones (Peloritani).

This activity was synsedimentary and probably contemporaneous with the initial stage of Hercynian orogenesis. The metavolcanites display mainly calc-alkaline features (fig. 4) and are comparable with volcanites from orogenic zones. It is noteworthy that they show overall high Zr contents (FERLA, 1978; ATZORI et al., 1979), similar to those found in volcanites from active continental margins (JACKES & WHITE, 1972; PEARCE & NORRY, 1980). Similar metavolcanites perhaps also occur in some Calabrian tectonic units (FERLA & AZZARO, 1978; Co-

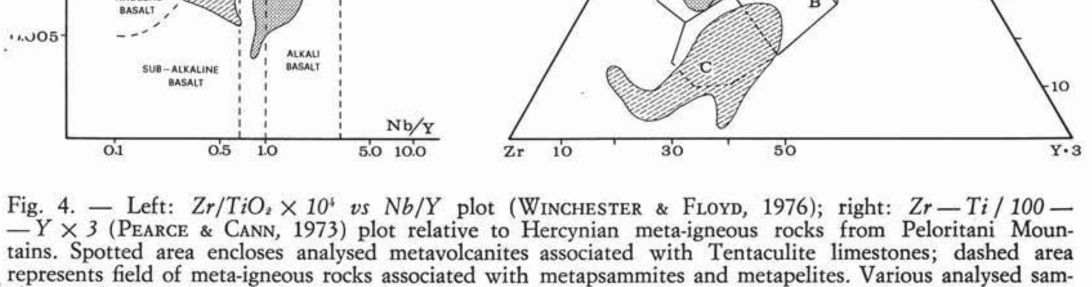

Fig. 4. — Left: $Zr/TiO_2 \times 10^4$ *vs* Nb/Y plot (WINCHESTER & FLOYD, 1976); right: $Zr — Ti / 100 — Y \times 3$ (PEARCE & CANN, 1973) plot relative to Hercynian meta-igneous rocks from Peloritani Mountains. Spotted area encloses analysed metavolcanites associated with Tentaculite limestones; dashed area represents field of meta-igneous rocks associated with metapsammites and metapelites. Various analysed samples are plotted in the graphs. Left: dashed area encloses 71 out of 81 analysed samples (ATZORI et al., this volume); right: as for spotted area $n = 26$, as for dashed area $n = 31$ (FERLA, 1978).

LONNA et al., in preparation), but more data are required to evaluate the possibility of a correlation between the metavolcanites from Calabria and those from the Peloritani.

The post-metamorphic magmatism covers the time interval from 297 ([1]) m.y. to 238 m.y. according to BORSI et al. (1976), WIELAND (1979), SCHENK (1980). This activity produced intrusive bodies having mostly granodioritic and granitic compositions with minor tonalites. Dikes of aplites, pegmatites, porphyritic rhyolites and dacites cut the plutonic bodies. The plutonic rocks intrude low-grade and medium to high-grade metamorphic rocks, and belong to two separate suites (PAGLIONICO & ROTTURA, 1979; D'AMICO et al., 1981): the mesoaluminous and the peraluminous suites (fig. 5).

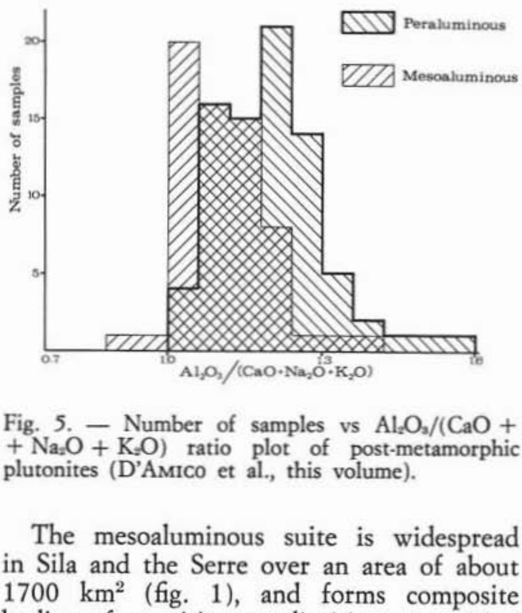

Fig. 5. — Number of samples vs $Al_2O_3/(CaO + Na_2O + K_2O)$ ratio plot of post-metamorphic plutonites (D'AMICO et al., this volume).

The mesoaluminous suite is widespread in Sila and the Serre over an area of about 1700 km^2 (fig. 1), and forms composite bodies of granitic-granodioritic composition mineralogically characterized by the frequent occurrence of muscovite, the scarcity or absence of hornblende and with biotite as mafic mineral (HIEKE MERLIN & LORENZONI, 1972; LORENZONI & ZANETTIN LORENZONI, 1975; MORESI & PAGLIONICO, 1975; AMODIO MORELLI et al., 1976; BORSI et al., 1976; CRISCI et al., 1979; LORENZONI et al., 1979; CRISCI et al., 1980). Melanocratic xenoliths are abundant in these rocks. The plutonic bodies formed through multiple intrusions which were probably emplaced in the Serre area in the following order: tonalites, granodiorites, granites and microgranodiorites. The various rock-types display different geochemical patterns (MORESI & PAGLIONICO, 1975), showing that they cannot be derived from a single parental liquid.

The values of the Sr^{87}/Sr^{86} initial ratio (BORSI unpublished data; SCHENK, 1980) around 0.710-0.711, point to crustal origin for the magmas which produced the mesoaluminous suite; these magmas probably reflect different degrees of partial melting from different source rocks whose composition is still unknown.

The peraluminous plutonic rocks outcrop over an area of about 350 km^2 along the Calabria-Peloritani arc (FERLA & NEGRETTI, 1969; D'AMICO et al., 1973; PUGLISI e ROTTURA, 1973; MESSINA et al., 1974; CRISCI et al., 1979; LORENZONI et al., 1979 a; IOPPOLO & PUGLISI, 1980; MESSINA & RUSSO, 1980). Locally they intrude the plutonic rocks of the mesoaluminous suite, and have monzogranitic to leucogranodioritic compositions. The general occurrence of primary muscovite associated with fibrolitic sillimanite, and the local occurrence of cordierite, andalusite and garnet, are the most important petrographical features. The occurrence of these minerals accounts for the high values of normative corundum (up to 4.21) in the rocks of this suite (D'AMICO et al., 1981). Relic metamorphic textures frequently occur (e.g., elongated aggregates of ms $\pm$ sill $\pm$ $\pm$ cord $\pm$ qtz $\pm$ pl $\pm$ apatite, clusters of ms + bi + sill).

The chemical differences displayed by these rocks both in and between the various masses (D'AMICO et al., this volume) are so important that a genetic link through either magmatic evolution or different degree of partial melting of a homogeneous source seems to be excluded. Textural, mineralogical, geochemical and $(^{87}Sr/^{86}Sr)_i$ data [0.710 according to WIELAND (1979), DEL MORO et al. (1982)] suggest a crustal origin for the peraluminous melts through partial melting of heterogeneous metapelites containing fibrolite $\pm$ cordierite and rich in muscovite (cf. D'AMICO et al., 1981).

Summing up it is clear that:

a) the post-metamorphic plutonic rocks from the Calabria-Peloritani arc match the

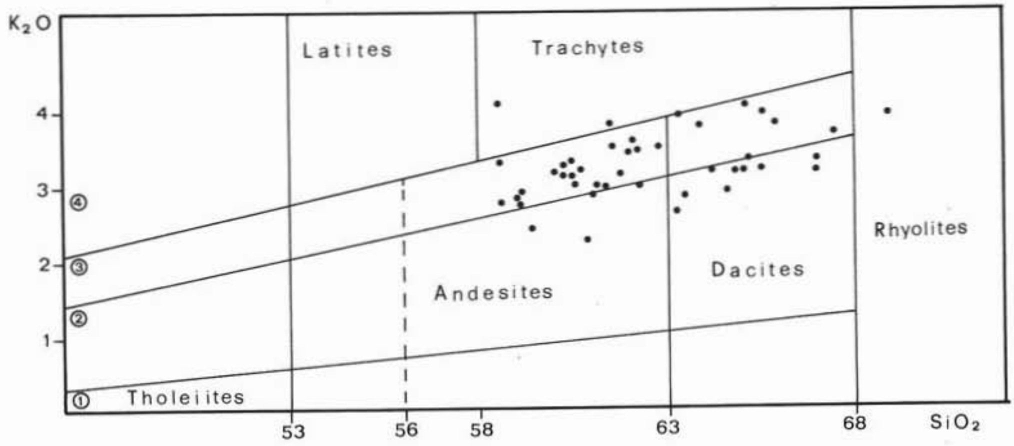

Fig. 6. — K_2O *vs* SiO_2 plot of pebbles of volcanites present in Miocene conglomerates: from FERLA and ALAIMO (1976).

S-type granites of CHAPPEL and WHITE (1974);

b) they cannot be related either to a single fractionation trend, or to melts deriving from homogeneous crustal sources.

It is noteworthy that traces of magmatic activity post-dating anatectic plutonism are relatively abundant along the Calabria-Peloritani arc. Dikes of porphyries, felsites and porphyrites cut the mesoaluminous and peraluminous granites (e.g. DE FINO and LA VOLPE, 1970; MESSINA et al., 1974; BORSI et al., 1976); pebbles of volcanic and subvolcanic rocks (from K-andesite to dacite: fig. 6) are common in Miocene sediments (FERLA & ALAIMO, 1976 a, b). Unfortunately, geochronological data on this subject are very scarce; the few data available so far, however, indicate an age of 238 m.y. for some dikes cutting the mesoaluminous granites of the Stilo Unit (Rb/Sr age on biotite: BORSI et al., 1976) and about 200 m.y. for the volcanic altered pebbles occurring in the Miocene conglomerates (K/Ar whole rock analysis: FERLA, 1978). Thus, the possibility of a Permian volcanism cannot be excluded, but further data are needed to give a more complete picture of the magmatic activity (ies) which occurred after the Permian-Carboniferous intrusions.

Concluding remarks

In the Calabrian-Peloritan arc, the pre-Hercynian magmatic rocks and those for which a similar age can be assumed, display features similar to those of volcanites at convergent plates. Thus, a converging-plate regime may tentatively be presumed for the pre-Hercynian (Caledonian?) event.

A similar regime has been referred by FERLA (1978) to the Hercynian orogeny, on the basis of the chemical features of the calc-alkaline orogenic magmatism, Carboniferous or earlier in age, as well as the post-orogenic K-andesitic volcanism recorded in the Miocene sediments. However, an ensialic development cannot be excluded for the Hercynian event, considering the pre-metamorphic alkaline magmatism, orogenic calc-alkaline volcanism, and post-metamorphic anatectic plutonism, together with the lack of ophiolites and Andean-type plutonites. More data are needed to verify the above suggestions.

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(1) Age corrected for $\lambda^{87}Rb = 1.42 \cdot 10^{-11}$ y^{-1}.

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