RENDICONTI Società Italiana di Mineralogia e Petrologia, 38 (1): pp. 35-52
Comunicazione presentata al Congresso SIMP di Cagliari il 16 ottobre 1981

PERALUMINOUS GRANITIC SUITE OF CALABRIA-PELORITANI ARC

(SOUTHERN ITALY)

CLAUDIO D'AMICO, ALESSANDRO ROTTURA
Istituto di Mineralogia e Petrografia dell'Univ., P.zza di Porta S. Donato 1, 40127 Bologna (Italy)

ELEONORA MACCARRONE
Istituto di Mineralogia e Petrografia dell'Università, Via dei Verdi 75, 98100 Messina (Italy)

GIUSEPPA PUGLISI
Istituto di Scienze della Terra dell'Università, Corso Italia 55, 95129 Catania (Italy)

RIASSUNTO. — Una suite di granitoidi peraluminosi, di composizione da granitica a leucogranodioritica, si trova nell'arco calabro-peloritano. È data da corpi di varia dimensione, da pochi kmq a circa 150 kmq, intrusi in rocce metamorfiche o in rocce plutoniche appartenenti ad una più diffusa e precedente suite granitico-granodioritica mesaluminosa. Entrambe le suites sono di età ercinica.

I granitoidi peraluminosi contengono muscovite + sillimanite ± cordierite ± andalusite. I caratteri tessiturali, mineralogici e geochimici sono consistenti con un'origine per parziale fusione da una fonte metapelitica. Nel magma peraluminoso coesistono fuso + residui: plagioclasi, quarzo, biotite, alcalifeldspato, muscovite e andalusite cristallizzarono per la massima parte dal magma; sillimanite e cordierite per gran parte e plagioclasi, biotite, quarzo e muscovite in piccola parte appaiono di natura residua. La fusione anatettica si ebbe a pressione inferiore a 9-7 kb, dando luogo ad un magma sottosaturo in acqua che risalì nella crosta fino a livello non precisabile.

La fonte anatettica è possibile sia stata la stessa serie di micascisti + paragneiss che affiora nel basamento calabro-peloritano, ma che per anatessi e degranitizzazione potè in profondità, nei tempi successivi all'allontanamento dei fusi granitici, evolversi in direzione granulitica.

In un quadro geodinamico l'origine dei granitoidi peraluminosi e mesaluminosi, quasi privi di partners metaluminosi, è consistente con processi intracontinentali tardo-orogenici.

ABSTRACT. — A suite of peraluminous granitoids occurs in the Calabria-Peloritan arc. It consists of variously-sized bodies (from a few km^2 to a maximum of about 150 km^2), ranging from monzogranites to leucogranodiorites in composition; they were intruded into metamorphic rocks as well as into plutonics pertaining to a more widespread « mesaluminous » granitic-granodioritic suite; both suites are late Hercynian in age.

The peraluminous granitoids are muscovite + sillimanite ± cordierite ± andalusite bearing rocks. Textural, mineralogical and geochemical features are consistent with an origin by partial melting from a metapelitic source. Within the peraluminous magma, melt + residuum did coexist: plagioclases, quartz, biotite, alkali feldspar, muscovite and andalusite were crystallized for the most part from the magma; most sillimanite, cordierite and a part of plagioclases, biotite, quartz and muscovite being residual materials. Anatectic fusion occurred at pressure conditions certainly lower than 9-7 kbars, giving rise to water-undersaturated magma bodies, which rose into the crust.

Source rocks were probably micaschists ± paragneisses similar to those from the basement of the Calabrian-Peloritan area; they are assumed to have changed toward a granulitic grade with depth following anatexis and degranitization.

Within a geodynamic framework, the origin of late-Hercynian peraluminous and mesaluminous granitoids is not consistent with Arc- or Cordillera-type orogenic belts, but rather with intracontinental late-orogenic processes.

1. Introduction

The Calabrian-Peloritan Arc (fig. 1) is a complex nappe structure built up of several tectonic units emplaced before the Upper Miocene. Most nappes are made of basement rocks (metamorphics, from phyllites to granulites; granitic-granodioritic plutonics), often having Liassic to Eocene sedimentary covers. Post-Miocene covers are lying upon the nappes, although only the Upper Pliocene and Quaternary sediments may be considered as true post-nappe formations (GRANDJACQUET and MASCLE, 1978). The structure and origin of the arc are the subject of controversial debates (AMODIO MORELLI et al., 1976 and references therein; DUBOIS, 1976; SCANDONE, 1979; LORENZONI and ZA-

Fig. 1. — Map of the Calabria-Peloritani arc showing the location of the Hercynian peraluminous granitic suite.

NETTIN LORENZONI, 1980); even the number of tectonic units, their nature and age, as well as regional correlations therein are under discussion.

The plutonic masses crop out over an area of about 2000 km^2 in different tectonic units. The commonest rocks are granodiorites, followed by granites and, to a limited extent, tonalites. There are no basic members.

About one sixth of all the plutonics are peraluminous granitoids, ranging in sizes from tiny blocks to masses as large as 150 km^2; in some areas (Serre, Sila) they appear to be associated with the « mesaluminous » (for this term see section 4) granodiorites; in these cases the peraluminous granitoids are always younger than the other granitoids. On radiometric and geological grounds, all these granitoids are considered to be of late Hercynian age (AMODIO MORELLI et al., 1976; ATZORI et al., 1977; CRISCI et al., 1979; LORENZONI et al., 1979 a, b; PAGLIONICO and ROTTURA, 1979; WIELAND, 1979; SCHENK, 1980. Radiometric ages between 269 and 295 m.y.).

Peraluminous granitoids crop cut: 1) in Sila, within the Longobucco tectonic unit, within both Mandatoriccio and Bocchigliero subunits (LORENZONI et al., 1979 a, b); 2) along the boundary between Serra and Aspromonte, within the Stilo tectonic unit (ATZORI et al., 1977; CRISCI et al., 1979) or possibly within a different unit (discussed by LORENZONI and ZANETTIN LORENZONI, 1979; PEZZINO and PUGLISI, 1980); 3) in the Aspromonte and Peloritani chains, within the « Aspromonte nappe » (OGNIBEN, 1973), now partly reallocated to the Longobucco unit (after LORENZONI and ZANETTIN LORENZONI, 1979) or to an « intermediate unit » (after BONARDI et al., 1979). According to PEZZINO and PUGLISI (1980) the Cittanova, Delianuova, Villa S. Giovanni, Capo Rasocolmo and Capo d'Orlando granites (fig. 1) belong to the same tectonic unit; this grouping seems to be geologically reasonable.

The aim of the present paper is to provide a synthesis of geological and petrological knowledge on the peraluminous granitoids in the Calabria-Peloritani region, as well as to discuss their petrogenetic and geodynamic relationships.

2. **Geological setting, petrography, geochemistry**

2.1. *Geology*

Most peraluminous intrusions are of small size. The largest occurrence are about 100 km^2 in Sila (near Cotronei), 150 km^2 between Serre and Aspromonte (Cittanova), 40 km^2 in Aspromonte (Villa S. Giovanni). All other masses are of smaller size, some being smaller than a few km^2 or even 100 m^2; the smallest ones, such as patches, dykes, veins, are found nearly always near the borders of the larger bodies. Septa of the country rocks, sometimes of large size and mostly from the roofs, are common in Cittanova, Delianuova, Villa S. Giovanni and Capo Rasocolmo masses.

The peraluminous granitoids (FERLA and NEGRETTI, 1969; D'AMICO et al., 1973; PUGLISI and ROTTURA, 1973; MESSINA et al., 1974; ATZORI et al., 1977; BONARDI et al., 1979; CRISCI et al., 1979; LORENZONI et al., 1979 a, b; IOPPOLO and PUGLISI, 1980; MESSINA and RUSSO, 1980) are found intruded: 1) in the Hercynian mesaluminous granodiorites (Sila, Cittanova); 2) in a complex of paragneisses, augen gneisses and amphibolites (Villa S. Giovanni, Delianuova, Monte S. Demetrio, Capo Rasocolmo, Capo d'Orlando, Cittanuova); and 3) on the boundaries between the preceding metamorphic complex and a phyllitic sequence (Sila, Cittanova) along a Hercynian tectonic line (COLONNA et al., 1973; ATZORI et al., 1977; LORENZONI and ZANETTIN LORENZONI, 1979) which may be attributed to a nappe structure according to a model proposed for other Hercynian areas by some authors (CARMIGNANI et al., 1978, 1980; ZWART and DORNSIEPEN, 1978). After the Hercynian emplacement of the nappe, extensive tectonic activity allowed the intrusion of the granitoid magmatic bodies.
Contact metamorphic crystallization appears to be very limited, occurring as patchy or spotted transformations, without true hornfelses (AMODIO MORELLI et al., 1976; ATZORI et al., 1977; CRISCI et al., 1979; GURRIERI, 1980). The highest contact-crystallization seems to be the local formation of cordierite and K-feldspar within the paragneisses of Capo Rasocolmo (MACCARRONE et al., 1978). Muscovite, biotite, andalusite and tourmaline are more common contact minerals.

The study of the contact rocks is not adequately developed and some of their characteristics described (e.g. fibrolite) may perhaps have been misinterpretated (see also GURRIERI, 1980).

Contacts between intrusive and metamorphic rocks are often clear-cut, but are also frequently invaded by a network of granite, aplite and pegmatite veins.

The granitoids are frequently associated with pegmatite-aplite dykes and veins. Dykes of porphyry and felsites are rare and restricted to the Villa S. Giovanni, Cittanova and Sila masses.

2.2. *Petrography*

The peraluminous granitoids are fine- ($\leqslant$ 1 mm) to medium- ($\simeq$ 1-2 mm) grained, often heterogranular, normally isotropic, sometimes slightly foliated. Microcline-perthite megacrysts, a few centimeters long and irregularly distributed, characterize some parts of the intrusions. The margins of the bodies are usually more heterogeneous and leucocratic than the inner parts.

The modal means (table 1, fig. 2) indicate the following compositions: monzogranitic in the Sila masses; between monzogranitic and leucogranodioritic in the Delianuova and Cittanova masses; leucogranodioritic in the

Villa S. Giovanni and Capo Rasocolmo intrusions; modal data are not available for the Capo d'Orlando bodies. The composition range is very wide in all these cases, extending from single syenogranitic compositions on the one hand to trondhjemitic ones on the other. The modal heterogeneity is a feature common to all the masses above mentioned, without a recognizable spatial distribution trend in any of them (op. cit. in 2.1.).

The texture is hypidiomorphic-subhypidiomorphic in the leucogranodiorites, allotriomorphic to subhypidiomorphic in the monzogranites. The plagioclases (andesine to oligoclase) may be idiomorphic or subidiomorphic, zoned and/or patchy; the biotite may be also partly idiomorphic. The other minerals may be subidiomorphic or anhedral. Among accessory minerals the apatite occurs quite frequently; the opaques, zircon and epidotes are rarer.

Among peraluminous minerals, the muscovite is always present and in a few cases forms as much as 20-22 % of the modal composition. The sillimanite (nearly always fibrolite) occurs in nearly all the masses, but not in all the samples within each mass (table 1). However, even where the sillimanite is absent, there are traces of its former presence within the muscovite. The andalusite, often replaced by muscovite, sporadically occurs as isolated crystals in a few samples from all the areas, being relatively more frequent in the northern half of the Sila area (LORENZONI et al., 1979 a, b). The cordierite, usually pinitized, may occur in very small amounts or be absent (Sila and Delianuva); it is present in small percentage only in a few points of the Cittanova mass. Locally (Villa S. Giovanni, Capo Rasocolmo, Capo d'Orlando), rectangular-shaped, micaceous-chloritic aggregates have been found (FERLA and NEGRETTI, 1969; PUGLISI and ROTTURA, 1973; MESSINA et al., 1974); they may be attributed to cordierite by comparison with similar pseudomorphic associations on cordierite in the Capo Rasocolmo paragneisses (MACCARRONE et al., 1978); see also WHITE and CHAPPELL (1977, p. 18) and HINE et al. (1978, p. 226). The garnets are very rare.

Aggregates showing evident metamorphic textures, having millimetric sizes, are very common. They are elongated aggregates of muscovite + fibrolite ± cordierite ± ± quartz ± plagioclases ± apatite ± opaques; aggregates of cordierite + biotite; clusters of muscovite + biotite with relics of fibrolite etc. (PUGLISI and ROTTURA, 1973; MESSINA et al., 1974). These textures are more common in the Capo d'Orlando, Capo Rasocolmo and Villa S. Giovanni granitoids than in the Cittanova granites. In the rocks where these aggregates are more frequent, the texture appears to be more irregular; plagioclases display a stronger, both regular and patchy, zoning (e.g. An_{38-20}; An_{46-22}; An_{35-20}), with jumps in composition of as much as 10 % An from one zone to another.

The tiny metamorphic aggregates cannot be considered as xenoliths (like the septa in 2.1) because they are present everywhere,

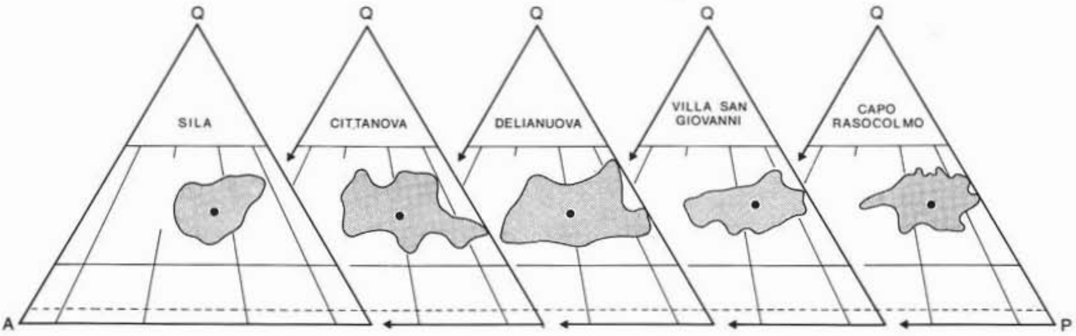

Fig. 2. — *Q-A-P* modal diagrams (after IUGS 1973) of the peraluminous granitoids from Calabria-Peloritani. Compositional fields and modal means (●) are reported.

although irregularly scattered, within the mass, and not only near the borders, and because they have a spatial distribution which is independent of the roof and wall rocks. Moreover they are often intermingled with the surrounding, plutonic textures so that a definite limit between one and the other cannot be distinguished. They were discussed and interpreted as anatectic relics in all the regional papers cited above.

TABLE 1

Peraluminous granitic suite of Calabria-Peloritani. Modal data (vol. %)

	Sila		Cittanova		Delianuova		Villa S.Giovanni		Capo Rasocolmo	
n	54		98		74		194		119	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
qtz	32.2	4.3	32.7	4.1	32.6	4.1	34.6	3.3	35.0	3.1
kf	22.1	6.7	19.6	6.5	19.5	8.8	13.7	6.9	13.2	5.8
pl	31.4	4.8	36.4	7.7	35.8	7.8	37.6	5.8	38.9	5.7
bi	7.0	3.5	6.9	2.4	5.5	2.4	7.0	2.5	5.7	1.8
ms	6.4	2.8	3.4	2.7	6.3	4.9	6.4	3.1	6.4	4.4
others	0.9		1.0		0.3		0.7		0.8	
sill"	3.0 max (49%)		3.4 max (40%)		1.9 max (20%)		2.2 max (79%)		4.0 max (92%)	
and "	1.3 max (57%)		tr (4%)		tr (1%)		tr (3%)		tr (4%)	
cord"	--		4.4 max (15%)		--		tr		tr	

n = number of samples; $\bar{x}$ = means; *SD* = standard deviation; *qtz* = quartz; *kf* = kfeldspar; *pl* = plagioclase; *bi* = biotite; *ms* = muscovite; *sill* = sillimanite; *and* = andalusite; *cord* = cordierite; *tr* = traces. " Maximum values given; in brackets the percentage of samples in which the mineral is present. *Sila*: data from LORENZONI et al. (1979); *Cittanova*: data from CRISCI et al. (1979); *Delianuova*: data from IOPPOLO and PUGLISI (1980); *Villa S. Giovanni*: data from MESSINA et al. (1974); *Capo Rasocolmo*: data from PUGLISI and ROTTURA (1973).

Other features to be noted are: 1) muscovite flakes contained in magmatic, zoned plagioclases (fig. 3; see also PUGLISI and ROTTURA, 1973; MESSINA et al., 1974), certainly not caused by post-magmatic sericitization, and 2) single crystals of andalusite, and sometimes sillimanite and cordierite, spread out in the rock texture, out of the metamorphic aggregates. Texturally, muscovite may be considered partly as a metamorphic relic, but for the most part it formed during the main to late magmatic crystallization (large, poikilitic-interstitial plates) and partly as pseudomorphic after Al-silicates.

Some dykes are present within the masses or on their borders, and are moderately to highly muscovitic pegmatites-aplites. Where studied (Villa S. Giovanni, Monte S. Demetrio, Capo Rasocolmo, Capo d'Orlando; cf. FERLA and NEGRETTI, 1969; PUGLISI and ROTTURA, 1973; MESSINA et al., 1974; MESSINA and RUSSO, 1980), they display three compositional populations. The prevalent one is similar to the peraluminous granitoids, the second is syenogranitic and the third is leucotrondhjemitic.

2.3. *Geochemistry*

Table 2 shows the chemistry of the major and some of the trace elements in five of the seven regional groups and figs. 4, 5, 6, 7 show some type of internal correlation. Typology of major elements is well defined: high SiO_2 and Al_2O_3; relatively high CaO; rather low alkalies, with K_2O/Na_2O about = 1; P_2O_5 relatively high.

Dispersion is quite wide within each single mass. There are some small but clear chemical differences between the masses, in accordance with the modal differences (cf. table 1): e.g. leucogranodiorites tend to be, on the average, slightly more ca-femic than granites (table 2).

The distribution of some elements (Mg,

TABLE 2

Peraluminous granitic suite of Calabria-Peloritani. Chemical data

n	Cittanova 27		Delianuova 21		Villa S.Giovanni 18		Capo Rasocolmo 10		Capo d'Orlando 4	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
(wt.%)										
SiO_2	72.66	0.88	72.68	1.74	70.52	1.50	73.40	1.72	74.91	0.44
TiO_2	0.24	0.06	0.21	0.10	0.24	0.10	0.20	0.10	0.07	0.03
Al_2O_3	14.77	0.48	15.46	0.93	16.29	0.66	14.75	1.07	14.46	0.13
Fe_2O_3	0.57	0.19	0.48	0.23	0.82	0.32	0.66	0.26	0.10	0.09
FeO	1.14	0.25	0.98	0.46	1.41	0.53	1.17	0.62	0.97	0.20
MnO	0.05	0.01	0.04	0.01	0.05	0.01	0.05	0.01	0.03	0.01
MgO	0.50	0.18	0.42	0.18	0.90	0.42	0.72	0.24	0.49	0.12
CaO	1.28	0.37	1.26	0.42	1.67	0.58	1.37	0.64	1.14	0.30
Na_2O	3.78	0.55	3.22	0.48	3.50	0.42	3.39	0.49	3.30	0.27
K_2O	3.79	0.79	3.83	0.78	3.41	0.69	3.48	0.93	3.84	0.37
P_2O_5	0.13	0.04	0.12	0.05	0.17	0.03	0.12	0.03	0.11	0.03
C	2.43	--	4.02	--	4.21	--	3.20	--	3.07	--
(ppm)										
Cr	5	4	n.d.		3	1	3	1		
V	5	4	6	5	3	2	7	4		
Ni	3	2	7	2	3	1	5	6		
Ce	57	20	47	27	61	26	60	38		
La	30	12	29	17	31	13	29	19		
Ba	891	306	1112	555	848	186	1079	344		
Sr	243	85	306	107	300	108	300	164		
Rb	151	42	116	27	94	24	95	33		
Y	17	4	15	2	9	4	14	4		
Nb	19	18	7	3	14	5	10	5		
Zr	121	41	94	49	99	35	102	60		
Rb/Sr	0.81	0.70	0.47	0.36	0.39	0.24	0.45	0.30		

n = number of samples; $\bar{x}$ = means; SD = standard deviation; $n\ d$ = not determined; C = average C.I.P.W. normative corundum. *XRF analyses*: *Cittanova* (from CRISCI et al., 1979), *Delianuova* (from IOPPOLO and PUGLISI, 1980), *Villa S. Giovanni* and *Capo Rasocolmo* (new analyses). Analyses have been made by Dr. G.M. CRISCI at the Department of Earth Sciences, Cosenza University. For analytical procedure see CRISCI et al., 1979. *Wet chemical analyses*: *Capo d'Orlando* (major elements only) from FERLA and NEGRETTI, 1969.

Na, K, P) vs. SiO_2 appears to be mostly scattered, with quite weak correlations; other elements appear to be better correlated vs. SiO_2. Random dispersion appears dominant in the Capo Rasocolmo mass, while the other bodies display better internal geochemical correlations. Geochemical data will be discussed in section 3.2.

We only have major element chemical data on the aplite-pegmatite dykes and then only for two subregions (table 3). However, their chemistry confirms the different character of the groups, as defined by the modal data (section 2.2.).

3. **Petrology**

3.1. *Crystallization*

The petrographic and geochemical characters of the peraluminous granitoids (Section 2) are typical for S-type granites (CHAPPELL and WHITE, 1974) and are consistent with an origin by crustal anatexis of metapelitic rocks (e.g. HARRIS, 1974;

O'NEIL et al., 1977; WHITE and CHAPPELL, 1977; HINE et al., 1978).

The granitic magma moved to higher levels as a mixture of prevalent melt and minor solid residual materials (cf. 2.2.). Such a physical state of the granitic magma seems widely accepted (e.g. PIWINSKI and WYLLIE, 1970; FYFE, 1973; WHITE and CHAPPELL, 1977; WYLLIE, 1977; WINKLER and BREITBART, 1978; WINKLER, 1979). The magmatic mush, liquid + residuum, can be seen either as « quasi minimum melt + residuum » — and this applies to subhypidiomorphic/allotriomorphic monzogranites — or as « non-minimum melt + residuum » — and this applies to subhypidiomorphic/hypidiomorphic leucogranodiorites.

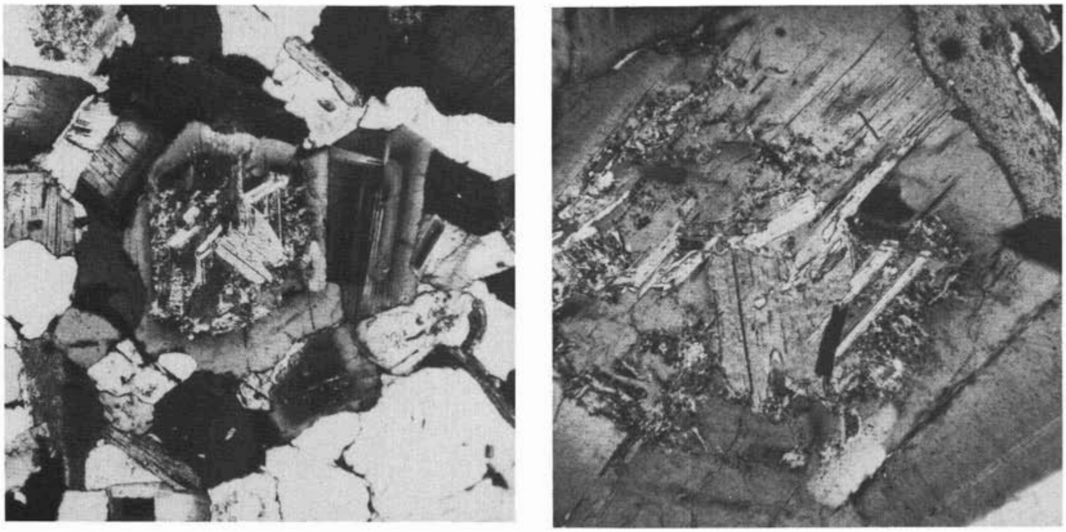

Fig. 3. — Primary muscovite enclosed within magmatic plagioclases. Crossed Polars, 15 x (*a*) and 42 x (*b*).

In the monzogranites the amount of melt can be estimated, to a first approximation, as about three times the percentage of alkali feldspar, as suggested by WYLLIE (1977, p. 68). The 60 % so obtained (cfr. table 1) is certainly a minimum value which must be increased by a certain amount of quartz and plagioclase besides some muscovite and biotite. In fact, quartz and plagioclases may follow, for a short step, a line of descent on the cotectic surface qtz-pl (Qz-Ab-Or-An-H_2O model system of WINKLER, 1979, Chapter 18), even without any evident signs of hypidiomorphism.

It is therefore reasonable to assume that at least 75-80 % or more of the mass was melted, with a residuum (metamorphic relics plus single crystals) charge not greater than 20-25 % of the total.

With regard to the leucogranodiorites, the melt was certainly not minimum, because both hypidiomorphic texture (sect. 2) and modal composition (table 1) suggest a noticeable development along a line of descent in the plagioclase space and on the cotectic surface qtz + pl (WINKLER, op. cit.). On this basis, it is again possible to suppose that the quantity of melt was about 75-80% of the total of the mass; of course the starting temperature of the leucogranodioritic magma had to be necessarily higher than that of the monzogranitic magma.

The possibility of ascent of the magmas depended on the difference between the composition of the liquids and the « minimum » composition, as well as, above all, on the degree of water undersaturation in the melt (cf. 3.2.), a well-known physicochemical constraint for interpreting the rise of granitic melts (e.g. FYFE, 1973; WYLLIE, 1977 and references therein).

The crystallization of quartz, alkali feldspars and plagioclases proceeded according to the well known models (e.g. cf. WINKLER, 1979). Texture (sect. 2) and composition

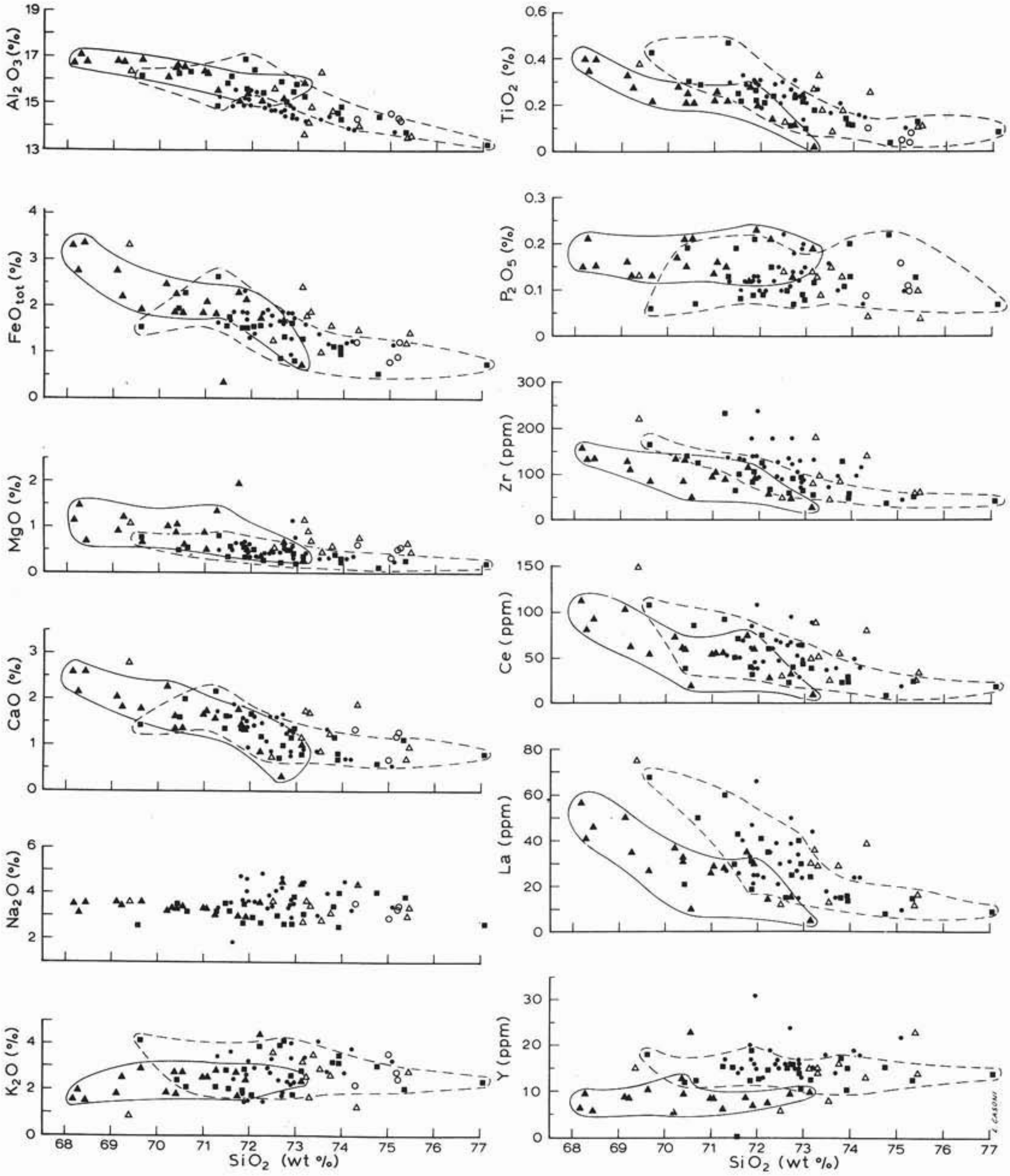

Fig. 4. — Variation diagrams of major and trace elements versus SiO_2. ● = Cittanova; ■ = Delianuova; ▲ = Villa S. Giovanni; △ = Capo Rasocolmo; ○ = Capo d'Orlando. For the sake of clarity, the fields of Villa S. Giovanni and Delianuova granitoids are contoured.

(tables 1-2) gives evidence that the absolutely prevalent succession of crystallization was pl + qtz → pl + qtz + kf. The second step was only prevalent in monzogranites. No doubt, biotite is present as residuum phase (cf. 2.2.), but it is very probable that at least a part of the isolated and subhypidiomorphic crystals grew directly from the melt. The role of muscovite and Al-silicates will be discussed more extensively.

Muscovite is found: *a*) in metamorphic relics, probably in equilibrium with the melt (sect. 2; PUGLISI-ROTTURA, 1973; MESSINA et al., 1974; CRISCI et al., 1979); *b*) in flakes within plagioclases (fig. 3); *c*) in large poikilitic-interstitial plates; *d*) and pseudomorphic on Al-silicates. Muscovite is therefore always present, from the source rocks (*a*) to the magmatic (*b, c, d*) and probably also postmagmatic (*d*) crystallization. Sericite on plagioclases is obviously not considered here.

The petrologic problems linked to muscovite in peraluminous granites have been extensively discussed in D'AMICO et al. (1981) and D'AMICO and ROTTURA (1981). The conclusion was reached that the experimental curves Ms + qtz — out, according to the most commonly used diagrams (EVANS, 1965; ALTHAUS et al., 1970), should be shifted towards higher T and lower P.

In the peraluminous granites from the Calabria-Peloritani region, the frequent presence of subhedral or embayed, rather large, disoriented muscovite lamellae may be noted enclosed in slightly zoned plagioclases. This muscovite cannot be considered to be secondary because it is radically different (fig. 3) from the minute, oriented secondary flakes or the sericite felts, and there is no gradual passage or connection with these. This muscovite is included within magmatic plagioclases, like biotite or other early minerals.

The above observation and discussion obviously imply an early crystallization of muscovite. D'AMICO et al. (1981) observed that early muscovite only occurred in rocks lacking andalusite. It seems probable, therefore, that aH_2O played a major role in determining either the early crystallization of andalusite (lower aH_2O) or the primary crystallization of muscovite (higher aH_2O), as on alternative.

Petrographic interpretation finds support in experimental data and thermodynamic models in WYLLIE (1977), THOMPSON and ALGOR (1977), THOMPSON and TRACY (1979). The muscovite enclosed in plagioclases (*b*) had been foreseen by crystallization from a melt in a path *PT* discussed by THOMPSON and ALGOR (1977; fig. 8 and p. 263). The last model is based on water-saturated conditions, but should not change under water-undersaturated conditions, except for the larger range of temperature at which crystals + liquid may coexist (WYLLIE, 1977).

It seems to us that textures such as those in fig. 3 give a petrographic verification of the THOMPSON and ALGOR theoretical prevision. In any case, they also suggest an important displacement, towards higher temperatures, of the muscovite stability field in peraluminous granitic melts.

The poikilitic-interstitial muscovite plates (*c*) appear to grow during the main-to-terminal cotectic crystallization, in conditions of increasing water activity in the residual melt. Alteration of Al-silicates into muscovite (*d*) can be interpreted in two ways: as a discontinuous magmatic reaction Al-silicates + liquid → muscovite (D'AMICO and ROTTURA, 1981) and/or as a subsolidus autometasomatic transformation.

The *Al-silicates* appear to play different roles: sillimanite and cordierite on the one hand andalusite on the other. We have not dealt with the garnets as they occur too sporadically.

Sillimanite and cordierite are certainly relics, for the most part, contained in residual metamorphic aggregates (cf. 2.2.). They are, however, also found in isolated, well-formed crystals: thus, partial crystallization from the melt cannot be excluded. This may occur in the earlier periods of solidification, when high T and reduced aH_2O do not permit the crystallization of muscovite or muscovite + biotite. Such a possibility is expressly mentioned by FLOOD and SHAW (1975, p. 161), WHITE and CHAPPELL (1977, pp. 18-19), ABBOTT and CLARKE (1979), SPEER (1981) and is implied in THOMPSON and ALGOR (1977; fig. 8 and p. 263) and in WYLLIE (1977; e.g. fig. 14); it becomes most probable in the case of water-undersaturated magma (cf. 3.2.).

Andalusite raises a more complex problem, more extensively discussed in D'AMICO et al. (1981). In the Calabria-Peloritani region, andalusite has been considered residual in the peraluminous granites of the Sila (LORENZONI et al., 1979 a, b) and magmatic in the peraluminous granites of Cittanova (CRISCI et al., 1979). The first interpretation should be critically revised for a number of reasons: *a*) andalusite is lacking in metamorphic relics within the granites; *b*) in the granitoids it is found as small, isolated crystals, devoid of inclusions, sometimes idiomorphic; or in monomineralic aggregates rimmed by near-solidus or subsolidus muscovite. On the other hand, andalusite in the regional metamorphics is found in large, anhedral crystals, often rich in inclusions (cf. Crisci et al., 1979, pp. 298-299); *c*) there is no spatial correlation between the distribution of regional metamorphic andalusite and andalusite in granitoids; *d*) it is theoretically difficult to conceive of andalusite as an anatectic relic, because this would require two alternative improbable paths: either anatexis would occur at usual *PT* conditions in the stability range of sillimanite, in which case andalusite should reveal an incredible metastability at a high temperature in the presence of melt; or anatexis occurred following a very high regional geothermal gradient (50-70° C/km) in which case there would be no explanation for having such sparse andalusite and such abundant muscovite.

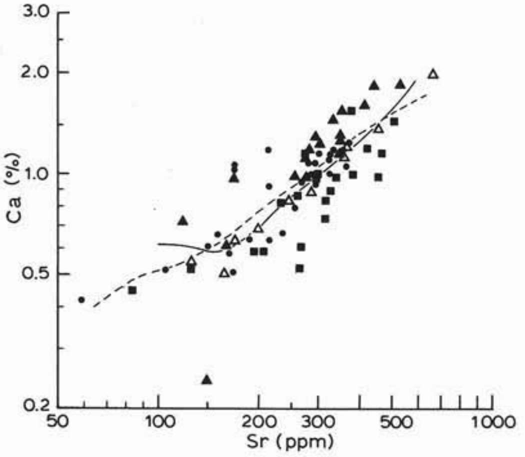

Fig. 5. — Ca-Sr plot. Symbols as in fig. 4. Logarithmic scale. The Villa S. Giovanni and Delianuova populations are distinguished.

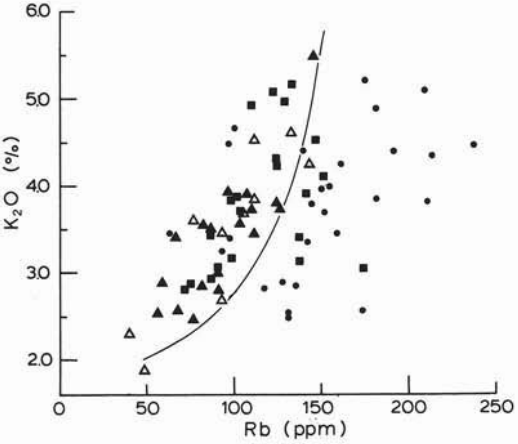

Fig. 6. — K_2O-Rb plot. Symbols as in fig. 4. The whole Villa S. Giovanni population lies at the left of the line.

There are therefore a number of petrological constraints for the assumption that andalusite is of magmatic crystallization. The possibility was assumed by White and Chappell (1977), and petrographically suggested by de Albuquerque (1971, 1973), Clarke et al. (1976), Crisci et al. (1979), Abbott and Clarke (1979), Clarke (1981) and, we feel, clearly demonstrated by D'Amico et al. (1981).

Some of the petrological problems connected with magmatic andalusite in S-granites have been discussed in D'Amico et al. (1981) and do not need to be repeated here. The conclusion was that the reaction curves And/Sill according to Richardson et al. (1969) and Greenwood (1976) are consistent with the coexistence of andalusite and granitic melt, whereas the And/Sill curves according to Holdway (1971) and Althaus (1967, 1969) are not.

The general sequence of crystallization in the paraluminous granites of Calabria-Peloritani region is schematically represented in fig. 9.

3.2. *Geochemical evolution*

Some geochemical features may be briefly discussed on the basis of the data in section 2.3. A number of correlations (e.g. Al_2O_3, CaO, MgO, TiO_2, Zr, La, Ca vs. SiO_2; Ca/Sr; K_2O/Rb; La/Zr; figs. 4-5-6-7-8) suggest some internal fractionation within the whole population and within each single mass.

The slightly fractionated portions are

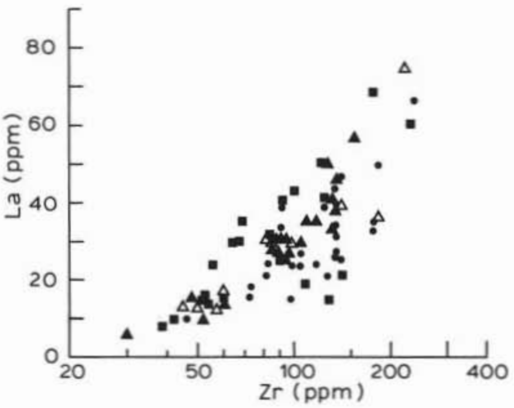

Fig. 7. — La-Zr plot. Symbols as in fig. 4.

TABLE 3
Pegmatites-aplites of the peraluminous granitic suite. Wet chemical analyses
$\bar{x}$ = mean; ( ) = number of samples for the groups having more than 1 analysis.

	Villa S. Giovanni··			Capo Rasocolmo···		
(wt.%)		$\bar{x}$(2)		$\bar{x}$(3)		$\bar{x}$(3)
SiO_2	74.01	74.68	74.47	72.36	72.88	74.75
TiO_2	0.04	0.09	0.04	0.08	0.02	0.04
Al_2O_3	14.29	14.21	14.73	15.34	16.66	15.46
Fe_2O_3	0.04	0.36	--	0.27	0.45	0.28
FeO	0.25	0.36	0.27	0.32	0.31	0.41
MnO	0.03	0.02	0.03	0.01	0.03	0.02
MgO	0.28	0.11	0.18	0.32	0.37	0.36
CaO	0.84	0.73	0.78	0.61	1.03	0.75
Na_2O	2.40	4.09	5.58	2.90	3.28	3.78
K_2O	5.80	4.22	2.88	6.92	4.27	2.87
P_2O_5	0.61	0.19	0.32	0.19	0.10	0.12
H_2O	1.14	0.96	0.90	0.61	0.54	1.18

·· Data from MESSINA et al. (1974).
··· Data from PUGLISI and ROTTURA (1973).

scattered within each single mass (PUGLISI and ROTTURA, 1973; MESSINA et al., 1974; CRISCI et al., 1979; MESSINA and RUSSO, 1980), showing no significant spatial distribution in the bodies excepting in the more leucocratic aplite-pegmatite dykes (the two groups having $K_2O > Na_2O$, table 3) or spots, which are abundant on the border. This indicates that fractional crystallization, although present, did not play a preminent role, except in the final stage.

The diagrams of figs. 4, 5, 6, 7, 8 show some other features. The compositional fields of the various masses appear to overlap widely in some diagrams, but they are clearly distinguishable in several others (e.g. Zr, La, Ce, Y, TiO_2 vs. SiO_2; Ca/Sr; K_2O/Rb), in which the correlation patterns tend to run along subparallel bands. For example the Zr, La, Y values are higher in the Delianuova and Cittanova granitic bodies than in the Villa S. Giovanni leucogranodioritic pluton, at the same SiO_2 level.

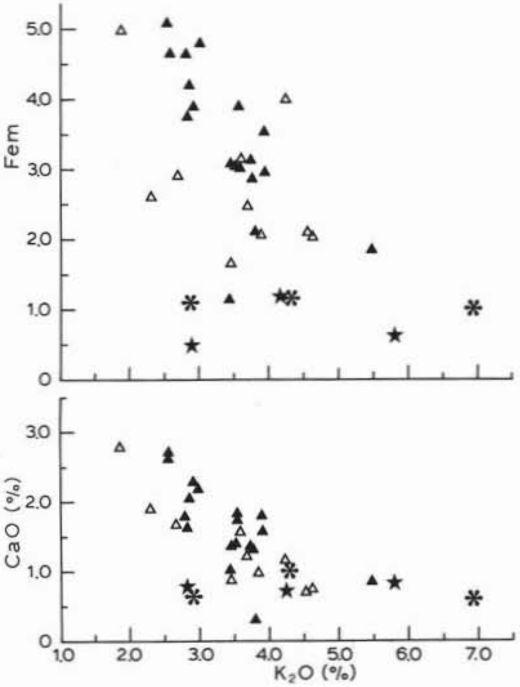

Fig. 8. — Plot of Fem (i.e. $TiO_2 + Fe_2O_3 + FeO + MnO + MgO$) and CaO contents versus K_2O for the Villa S. Giovanni and Capo Rasocolmo peraluminous granitoids. *Stars* = Villa S. Giovanni pegmatites-aplites; *Flowers* = Capo Rasocolmo pegmatites-aplites. Other symbols as in fig. 4. The two pegmatite-aplites, having low K_2O content, are clearly out of the fractionation trend.

But one cannot distinguish statistically between the mean values of Zr, Y, La in the Delianuova and Cittanova granitic masses and in the Villa S. Giovanni and Capo Rasocolmo leucogranodioritic masses, which are slightly more cafemic. If all the masses belonged to a unique fractionation sequence (e.g. KOLBIE, 1966; CONDIE and LO, 1971; FERRARA et al., 1976; MUECKE and CLARKE, 1981), one ought to have found higher Zr, La and Y values, in the Villa S. Giovanni and Capo Rasocolmo masses.

These observations show that fractional crystallization played a very minor role, if any, even between the masses which do not belong to a unique differentiation line of a single parental magma in the crust.

Therefore, it is clear that other factors played a major role among the masses. Excluding differentiation at very high pressure (on account of the presence of plagioclases, andalusite, cordierite, sillimanite) we may assume a different degree of partial melting of the sources and/or a provenance from heterogeneous metapelitic source rocks. We favour an origin from geochemically heterogeneous sources, which would seem to explain better the distributions displayed by figs. 4, 5, 6 and to be in accordance with what is to be expected from the almost general heterogeneity of the crustal sequences.

Fig. 9. — Crystallization sequence of the peraluminous granitoids.

The third dyke family showing $Na_2O > K_2O$ gives a further indication of heterogeneity of the sources, as fractionation (fig. 8) from the main population is not conceivable.

3.3. *Magmatic evolution and source rocks*

On the basis of the above discussion, we can outline the history of the peraluminous granitoids.

TUTTLE and BOWEN (1958), LUTH (1969), ROBERTSON and WYLLIE (1971), CARMICHAEL et al. (1974), FYFE (1973), STEINER et al. (1975), WYLLIE et al. (1976), WYLLIE (1977) and many other authors reasonably maintain that the water-saturation conditions in granitic melts cannot normally be assumed: 2 % H_2O is often given as an acceptable value (« still generous » according to WYLLIE, 1977, p. 62).

We agree with these evaluations. Let us thus assume that, at the time of formation, the peraluminous magma was water-undersaturated; a part of the water possibly derived through dissociation of muscovite and biotite.

Although S-type granites do not necessarily mean a metasedimentary source (e.g. CLARKE, 1981; MARTIN-BOWDEN, 1981), the Calabria-Peloritani rocks are very probably derived from metapelitic sources (see relics in section 2.2.).

On the basis of the above described relics, we argue that the source rocks should have been fibrolite ± cordierite paragneisses-micaschists, rich in muscovite. Similar rocks are not rare in the Calabria-Peloritani arc, even at the height of the granitoid intrusions.

Melting should have occurred in regions where the temperature was certainly above the minimum for the water-saturated system, that is to say, approximately $\simeq 750°$ C (e.g. WHITE and CHAPPELL, 1977) or $\simeq 800°$ C (e.g. GREEN, 1976), or a little less (cf. THOMPSON and TRACY, 1979, fig. 5). Similar temperatures are compatible with our case, because conditions $P_t > P_{H_2O}$ should increase the stability temperature of muscovite within the melt (WYLLIE, 1977, p. 51). Anyway, the water-undersaturated melt was able to coexist with quartz and feldspars over a rather wide range of falling temperature (WYLLIE, 1977, pp. 45-46); this facilitates the interpretation of crustal ascent. The anatexis temperature should have been higher for the leucogranodiorites (about 750°-800° C?) than for the monzogranites (about 700°-750° C?), on the basis of the textural data (cf. 3.1.), which suggest varying lengths of the crystallization paths.

Pressure in the source zone should not have been higher than 7-9 kbars corresponding to depth of about 25-30 km, as the absence of residual kyanite suggests (cf. also GREEN, 1976; WHITE and CHAPPELL, 1977). The presence of cordierite is consistent with this evaluation. It is reasonable however, to assume that the actual depth of the source zone could have been less.

Anatectic melting proceeded employing all vapour present as well as that produced from the dissociation of muscovite and biotite, thus producing a peraluminous melt (cf. the four component system SiO_2-Al_2O_3-K_2O-H_2O in LAMBERT et al., 1969; HUANG and WYLLIE, 1974), charged with residues. Dissociation of muscovite and biotite was clearly not completed; moreover, it occurred only rarely in the relics, which remained in contact with the melt (cf. 2.2.).

Anatexis involved metapelitic levels; the peraluminous magmas did not achieve a complete homogenization as most of the data scattering indicates (cf. 2.2. and 2.3.): this may suggest slightly heterogeneous metapelitic sources and perhaps a limited ascent, since a longer ascent would probably have led to a greater homogenization.

Some heterogeneities of the metapelitic sources are suggested by some of the geochemical features (cf. 3.2.), by which each mass seems to differ a little from the others. Such features should have been inherited from the source region. On this ground, it can be considered that the ascending masses had a degree of reciprocal independence, coming out from different crustal sectors, although they are all metapelitic in composition, during the same petrogenetic event. Fractional melting played an additional role, as well as fractional crystallization within each mass, with the aplite-pegmatite dykes as an end result.

We may speculate tentatively on the evolution of the source region. When the anatectic melts moved up, the restitic rocks remained in situ, possibly evolving through dehydration and degranitization towards a granulitic nature. This however was not the case of the dispersed residual aggregates within the raising magma, where muscovite + biotite paragenesis was maintained due to the sufficiently high aH_2O in the magma.

Granulitic-kinzigitic rocks occur in the Calabrian basement (AMODIO MORELLI et al., 1976; DUBOIS, 1976; IOPPOLO et al., 1978; PAGLIONICO and PICCARRETA, 1978; SCHENK, 1980). Thus, there is perhaps some reasons to connect, on a large scale, granitic rock formation with the evolution of the middle-deep crust of the Hercynian basement in accordance with SCHENK's (1980) geochronological data. However, the problem is highly speculative and should be surely further investigated. The petrogenetic link suggested above should only represent, for now, a stimulating working hypothesis.

During the ascent, small variation in thermodynamic values, particularly aH_2O, were able to create alternative conditions in the melt, so that sillimanite and/or andalusite instead of muscovite (and/or cordierite instead of biotite), or vice versa nucleated. Nucleation of sillimanite and/or cordierite appear to have occurred more probably during an early crystallization period.

Moreover there is a clear possibility of direct crystallization of andalusite from the magma (D'AMICO et al., 1981). The nucleation of andalusite instead of muscovite probably depends on aH_2O fluctuations and temperature. Unfortunately there is no quantitative reference to this question.

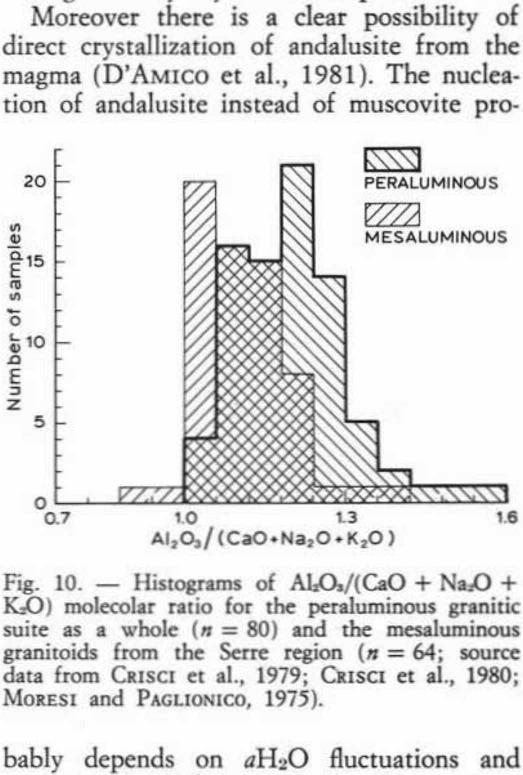

Fig. 10. — Histograms of $Al_2O_3/(CaO + Na_2O + K_2O)$ molecolar ratio for the peraluminous granitic suite as a whole ($n = 80$) and the mesaluminous granitoids from the Serre region ($n = 64$; source data from CRISCI et al., 1979; CRISCI et al., 1980; MORESI and PAGLIONICO, 1975).

With lowering temperature and increasing water activity, muscovite became the proper peraluminous mineral being nucleated: Al-silicates were enveloped by other growing minerals and/or reacted with the melt, thus generating muscovite.

The small regional differences found in the distribution of andalusite (cf. 2.2.; LORENZONI et al., 1979 a, b), appear to be petrologically unimportant (cf. also table 1); they can be easily explained through minor *PT* variations and through minor fluctuations of aH_2O (see also D'AMICO and ROTTURA, 1981).

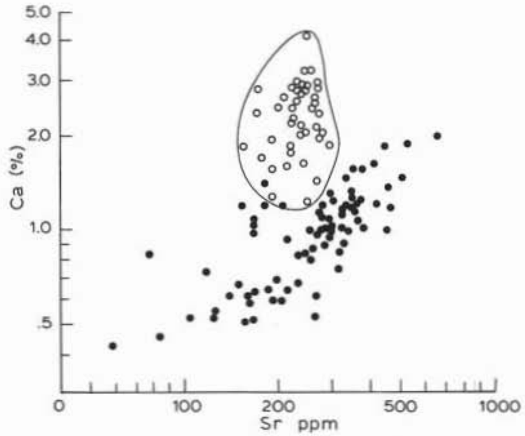

Fig. 11. — Ca-Sr plot for the peraluminous (●) granitic suite of Calabria-Peloritani and the mesaluminous (○) granitoids from the Serre region ($n = 42$; data from Crisci et al., 1979; Crisci et al., 1980).

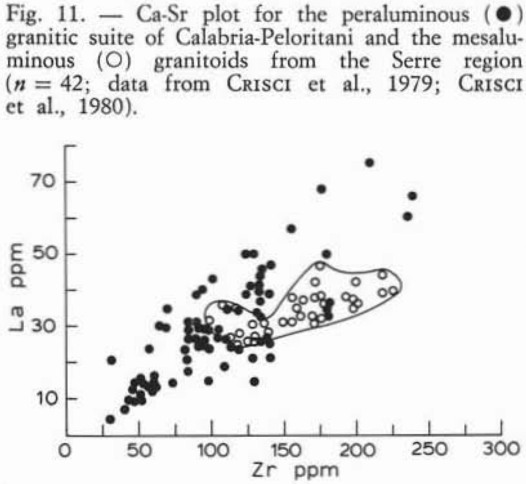

Fig. 12. — La-Zr plot for the peraluminous and mesaluminous granitoids. Symbols as in fig. 11.

During its ascent and crystallization, the peraluminous magma shifted to $P_t \simeq P_{H_2O}$ conditions, which are probably achieved in the final position of emplacement, bearing a two fold effect: the end of the ascent on account of massive crystallization, and the separation of pegmatitic-aplitic fractions, especially on the border of the intrusions. Minor scattered fractionation could develop within each body.

4. **Geological remarks**

A brief comparison between the peraluminous suite and the prevalent mesaluminous suite, already mentioned in section 1, can be set out here in a preliminary way for the Serre region.

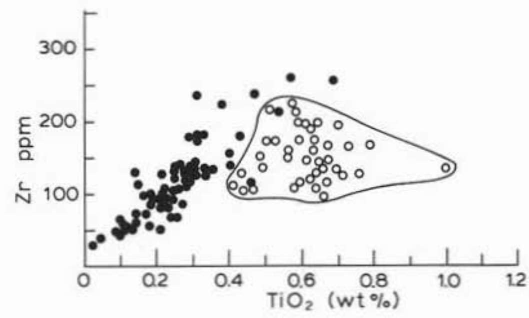

Fig. 13. — Zr-TiO_2 plot for the peraluminous and mesaluminous granitoids. Symbols as in fig. 11.

The term « mesaluminous » is here used to indicate a suite not so strongly peraluminous as the one discussed in this paper, but still having a peraluminous character (fig. 10); mineralogically, it is characterized by the frequent presence of primary muscovite, total absence of Al-silicates and scarceness or absence of hornblende (Moresi and Paglionico, 1975; Crisci et al., 1979; Lorenzoni et al., 1979 b; Crisci et al., 1980).

The two suites are spatially and temporarily associated, but the mesaluminous one is clearly the larger and older of the two (Crisci et al., 1979; Lorenzoni et al., 1979 a; Paglionico and Rottura, 1979). This situation is similar to many examples described in other segments of the Hercynian orogen in Europe (e.g. Didier and Lameyre, 1969; Capdevila et al., 1973; Orsini, 1979 a; Michard-Vitrac et al., 1980) and elsewhere (e.g. Chappell and White, 1974; Flood and Shaw, 1975, 1977; Price and Taylor, 1977; Hine et al., 1978).

However, the existence of two peraluminous suites, even though clearly different from each other, indicates a different situation from the prevalent plutonic model, deducible from the areas mentioned above, where metaluminous suites usually prevail. Calabria-Peloritani is therefore a case of extreme Hercynotype plutonic association, in the sense of Pitcher (1979).

The two suites, peraluminous and mesaluminous, have the obvious features of S-granites and should therefore be considered as the products of crustal genesis (according also to isotopic studies still under way and by Schenk's (1980) and Wieland's (1979) estimation of $^{87}Sr/^{86}Sr$ initial ratios 0.710-0.711).

However, the two suites display some different geochemical trends (e.g. figs. 11, 12 and 13) and this excludes both a fractionation link between them, and their origin from a homogeneous source. Different crustal materials, different melting levels in the crust, different degrees of partial melting, different aH_2O conditions etc. may be cited as alternative or concomitant causes to explain such geochemical diversities.

We feel that different crustal materials are the main cause. Fig. 13 may suggest a possible contribution of some crustal materials of previous igneous origin to the anatexis of the mesaluminous suite.

On account of the S-typology of most granitoids, as well as the scarsity of I-granitoids in the late Hercynian suites of Calabria-Peloritani, the geodynamic model to be chosen is subject to a severe constraint; it should be selected from the various proposals (Krebs and Wachendorf, 1973; Arthaud and Matte, 1977; Windley, 1977; Zwart and Dornsiepen, 1978; Matte and Burg in Orsini, 1979 b; Vai, 1979) excluding the model of consuming plate boundary, such as that of the Cordilleran belts (e.g. Bateman and Dodge, 1970; Pitcher, 1978) in favour of a plutonism of intracontinental orogen.

In a spatial zonation of the European Hercynian chain, the Calabria-Peloritani sector seems possibly to be a continuation, as a southern branch, of the « zone centrale » Margeride-Cévennes type, according to Orsini (1979 b), characterized by a typical ensialic anatectic plutonism.

Hercynian structural settlement was disturbed by Alpine tectogenesis which gave rise to a complex nappe structure, in which many yet unresolved problems exist (cf. Section 1). On the ground of the geological homogeneity of its major features, as well as its distribution in nearly all mesoepicrustal nappes, the peraluminous granitoidic plutonism suggests the existence of a unitary pre-Alpine basement (cf. also Paglionico and Rottura, 1979).

Aknowledgments. — This work was supported by Italian C.N.R., CT 79.00070.05 and CT 80.00985.05. G.M. Crisci has provided new chemical analyses from the Villa S. Giovanni and Capo Rasocolmo granitoids. G.B. Vai has given useful contribution on some geological arguments. We are very grateful to them both.

REFERENCES

Abbott R.N., Clarke D.B. (1979) - *Hypothetical liquidus relationships in the subsystem Al_2O_3-FeO-MgO projected from quartz, alkali feldspar and plagioclase for $a(H_2O) < 1$.* Can. Mineral., vol. 17, 549-560.

Albuquerque C.A.R., de (1971) - *Petrochemistry of a serie of granitic rocks from Northern Portugal.* Geol. Soc. Am. Bull., vol. 82, 2783-2798.

Albuquerque C.A.R., de (1973) - *Geochemistry of biotites from granitic rocks, Northern Portugal.* Geochim. Cosmochim. Acta, vol. 37, 1779-1802.

Althaus E. (1967) - *The triple point andalusite-sillimanite-kyanite.* Contrib. Mineral. Petrol., vol. 16, 29-44.

Althaus E. (1969) - *Die Stabilitätsbeziehungen zwischen den Aluminumsilikaten mit der Zusammensetzung Al_2SiO_5.* N. Jb. Miner. Abh., vol. 111, 111-161.

Althaus E., Karotke E., Nitsch K.H., Winkler H.G.F. (1970) - *An experimental re-examination of the upper stability limit of Muscovite plus Quartz.* N. Jb. Miner. Mh., vol. 1970, 325-336.

Amodio Morelli L., Bonardi G., Colonna V., Dietrich D., Giunta G., Ippolito F., Liguori V., Lorenzoni S., Paglionico A., Perrone V., Piccarreta G., Russo M., Scandone P., Zanettin Lorenzoni E. & Zuppetta A. (1976) - *L'arco Calabro-Peloritano nell'Orogene Appenninico-Maghrebide.* Mem. Soc. Geol. It., vol. 17, 1-60.

Anderson J.L., Cullers R.L. & Van Schmus W.R. (1980) - *Anorogenic metaluminous and peraluminous granite plutonism in the Mid-Proterozoic of Wisconsin, USA.* Contrib. Mineral. Petrol., vol. 74, 311-328.

Anderson P.A.P., Newton R.C. & Kleppa O.J. (1977) - *The enthalpy change of the andalusite-sillimanite reaction and the Al_2SiO_5 diagram.* Am. J. Sci., vol. 277, 585-593.

Anderson J.L., Rowley M.C. (1981) - *Synkinematic intrusion of peraluminous and associated metaluminous granitic magmas, Whipple Mountains, California.* Can. Mineral., vol. 19, 83-101.

Arthaud F. & Matte P. (1977) - *The Paleozoic strike-slip faulting in southern Europe and northern America: result of a right-lateral shear zone between the Appalachians and the Urals.* Geol. Soc. Am. Bull., vol. 88, 1305-1320.

Atzori P., Pezzino A. & Rottura A. (1977) - *La massa granitica di Cittanova (Calabria meridionale): relazioni con le rocce granitoidi del massiccio delle Serre e con le metamorfiti di Canolo, S. Nicodemo e Molochio.* Boll. Soc. Geol. It., vol. 96, 387-391.

Bateman P.C. & Dodge F.C.W. (1970) - *Variation of major chemical constituents across the Central Sierra Nevada batholith.* Geol. Soc. Am. Bull., vol. 81, 409-420.

Bonardi G., Gurrieri S., Messina A., Perrone V., Russo M. & Zuppetta A. (1979) - *Osservazioni geologiche e petrografiche sull'Aspromonte.* Boll. Soc. Geol. It., vol. 98, 55-73.

Borsi S., Hieke Merlin O., Lorenzoni S., Paglionico A. & Zanettin Lorenzoni E. (1976) - *Stilo Unit and « dioritic-kinzigitic » Unit in Le Serre (Calabria, Italy). Geological, petrological, geochronological characters.* Bull. Soc. Geol. It., vol. 95, 219-244.

Capdevila R., Corretge G. & Floor P. (1973) - *Les granitoides varisque de la Meseta Iberique.* Bull. Soc. Geol. Fr., vol. 15, 208-228.

Carmichael I.S.E., Turner F.J. & Verhoogen J. (1974) - *Igneous Petrology.* Mc Graw-Hill, New York, pp. 739.

Carmignani L., Cocozza T., Minzoni N. & Pertusati P.C. (1978) - *Falde di ricoprimento erciniche nella Sardegna a Nord Est del Campidano.* Mem. Soc. Geol. It., vol. 19, 501-510.

Carmignani L., Cocozza T., Minzoni N. & Pertusati P.C. (1980) - *Sardaigne.* In: G. Fagnani, P. Zuffardi (eds.), « Introduction à la géologie générale d'Italie », 26ᵉ Congrès Geologique International, Paris. Soc. It. Miner. Petrol., pp. 49-51.

Chappell B.W. & White A.J.R. (1974) - *Two contrasting granite types.* Pacif. Geol., vol. 8, 173-174.

Clarke D.B. (1981) - *The mineralogy of peraluminous granites: a review.* Can. Mineral., vol. 19, 3-17.

Clarke D.B., McKenzie C.B., Mueke G.K. & Richardson S.W. (1976) - *Magmatic andalusite from south Mountain Batholith, Nova Scotia.* Contrib. Mineral. Petrol., vol. 56, 279-287.

Colonna V., Lorenzoni S. & Zanettin Lorenzoni E. (1973) - *Sull'esistenza di due complessi metamorfici lungo il bordo sud-orientale del massiccio « granitico » delle Serre (Calabria).* Boll. Soc. Geol. It., vol. 92, 801-830.

Condie K.C. & Lo H.H. (1971) - *Trace element geochemistry of the Louis lake batholith of early Precambrian age, Wyoming.* Geochim. Cosmochim. Acta, vol. 35, 1099-1119.

Crisci G.M., Maccarrone E. & Rottura A. (1979) - *Cittanova peraluminous granites (Calabria, Southern Italy).* Miner. Petrogr. Acta, vol. 23, 279-302.

Crisci G.M., Leoni L., Mazzuoli R., Moresi M. & Paglionico A. (1980) - *Petrological and geochemical data on two intrusive stocks of the « Serre » (Calabria, Southern Italy).* N. Jb. Miner. Abh., vol. 138, 274-294.

D'Amico C., Messina A., Puglisi G., Rottura A. & Russo S. (1973) - *Confronti petrografici nel cristallino delle due sponde dello stretto di Messina. Implicazioni geodinamiche.* Boll. Soc. Geol. It., vol. 92, 939-953.

D'Amico C., Rottura A. (1981) - *Occurrence of late-Hercynian peraluminous granites in the Southern Alps.* Rend. Soc. Ital. Miner. Petrol., vol. 38/1, 27-33.

D'Amico C., Rottura A., Bargossi G.M., Nannetti M.C. (1981) - *Magmatic genesis of andalusite in peraluminous granites. Examples from Eisgarn type granites in Moldanubikum.* Rend. Soc. Ital. Mineral. Petrol., vol. 38/1, 15-25.

Didier J. & Lameyre J. (1969) - *Les granites du Massif Central français: étude comparée des leucogranites et granodiorites.* Contrib. Mineral. Petrol., vol. 24, 219-238.

Dubois R. (1976) - *La suture Calabro-Apenninique Cretaceo-Eocene et l'ouverture Tyrrenienne Neogene; étude petrographique et structurale de la Calabre centrale.* Thèse Doct. Univ. Pierre et Marie Curie, Paris, pp. 567.

Ferla P. & Negretti G. (1969) - *Le migmatiti di Capo d'Orlando-S. Gregorio.* Ist. Miner. Petr. Univer. Palermo, Quad. 2, 1-162.

Ferrara G., Leoni L. & Macera P. (1976) - *La distribuzione di Zr, La e Ce nelle rocce magmatiche toscane.* Rend. Soc. Ital. Miner. Petrol., vol. 32, 539-549.

Flood R.H. & Shaw S.E. (1975) - *A cordierite-bearing granite suite from the New England batholith, N.S.W., Australia.* Contrib. Mineral. Petrol., vol. 52, 157-164.

Flood R.H. & Shaw S.E. (1977) - *Two « S-type » granite suite with low initial* $^{87}Sr/^{86}Sr$ *ratios from the New England batholith Australia.* Contrib. Mineral. Petrol., vol. 61, 163-173.

Fyfe W.S. (1973) - *The generation of batholith.* In: Wyllie P.J. (ed.), « Experimental Petrology and Global Tectonics ». Tectonophysics, vol. 17, 273-283.

Grandjacquet C. & Mascle G. (1978) - *The structure of the Ionian sea and Calabria-Lucania.* In: Nairm A.E.M. & Stehli (eds.), « Ocean Basins and Margins ». Plenum Press, New York, pp. 257-329.

Green T.H. (1976) - *Experimental generation of cordierite- or garnet-bearing granitic liquids from a pelitic composition.* Geology, vol. 4, 85-88.

Greenwood H.J. (1976) - *Metamorphism at moderate Temperatures and Pressures.* In: Bailey D.K. & MacDonald R. (eds.), « The Evolution of the Crystalline Rocks », Academic Press, London, New York, San Francisco, pp. 187-259.

Gurrieri S., Lorenzoni S. & Zanettin Lorenzoni E. (1978) - *L'unità pre-alpina di Bocchigliero (Sila - Calabria).* Boll. Soc. Geol. It., vol. 97, 711-716.

Gurrieri S. (1980) - *Le metamorfiti intruse dal plutone di Cittanova (Calabria meridionale).* Per Miner., vol. 49/2-3, 175-201.

Harris N.B.W. (1974) - *The petrology and petrogenesis of some muscovite granite sills from the Barousse Massif, Central Pyrenees.* Contrib. Mineral. Petrol., vol. 45, 215-230.

Hine R., Williams I.S., Chappell B.W. & White A.J.R. (1978) - *Contrasts between I- and S-type granitoids of the Kosciusko batholith.* J. Geol. Soc. Austr., vol. 25, 219-234.

Holdaway M.J. (1971) - *Stability of andalusite and the aluminum silicate phase diagram.* Am. J. Sci., vol. 271, 97-131.

Huang W.L. & Wyllie P.J. (1974) - *Melting relations of muscovite with quartz and sanidine in the* K_2O-Al_2O_3-SiO_2-H_2O *system to 30 kilobar and an outline of paragonite melting relations.* Am. J. Sci., vol. 274, 378-395.

Ioppolo S. & Puglisi G. (1980) - *I graniti di Delianuova (Aspromonte, Calabria meridionale).* Boll. Soc. Geol. It., vol. 99, 269-280.

Ioppolo S., Rottura A. & Russo S. (1978) - *Le metabasiti di alto grado dell'area Vibo Valentia-Fiumara Angitola (Calabria meridionale).* Boll. Soc. Geol. It., vol. 97, 73-92.

I.U.G.S. (1973) - *Classification and nomenclature of plutonic rocks. Recommendations.* N. Jb. Miner. Mh., vol. 4, 149-164.

Kolbie P. (1966) - *Geochemical investigation of the Cape Granite South-Western Cape Province, South Africa.* In: Wedephol K.H. (ed.), « Handbook of Geochemistry », vol. II-4, Springer, Berlin, Heidelberg, New York, 40-E-18.

Krebs W. & Wachendorf H. (1973) - *Proterozoic-Paleozoic geosynclinal and orogenic evolution of Central Europe.* Geol. Soc. Am. Bull., vol. 84, 2611-2630.

Lambert I.B., Robertson J.K. & Wyllie P.J. (1969) - *Melting reactions in the system* $KAlSi_3O_8$-SiO_2-H_2O *to 18.5 kilobars.* Am. J. Sci., vol. 267, 609-626.

Lorenzoni S., Messina A., Russo S., Stagno F. & Zanettin Lorenzoni E. (1979 a) - *The two-mica* Al_2SiO_5 *granites of the Sila (Calabria).* N. Jb. Miner. Mh., vol. 9, 421-436.

Lorenzoni S., Messina A., Russo S., Stagno F. & Zanettin Lorenzoni E. (1979 b) - *Le magmatiti dell'unità di Longobucco (Sila - Calabria).* Boll. Soc. Geol. It., vol. 97, 727-738.

Lorenzoni S. & Zanettin Lorenzoni E. (1979) - *Problemi di correlazione tettonica Sila-Aspromonte. Il significato dell'Unità ercinica di Mandatoriccio e dei graniti ad* Al_2SiO_5. Boll. Soc. Geol. It., vol. 98, 227-238.

Lorenzoni S. & Zanettin Lorenzoni E. (1980) - *Calabre et Péloritains.* In: Fagnani G. & Zuffardi P. (eds.), « Introduction à la géologie générale d'Italie », 26^e Congrès Géologique International, Paris. Soc. It. Miner. Petrol., pp. 45-48.

Luth W.C. (1969) - *The system* $NaAlSi_3O_8$-SiO_2 *and* $KAlSi_3O_8$-SiO_2 *to 20 kbar and the relationship between* H_2O *content,* P_{H_2O} *and* P_{total} *in in granitic magmas.* Am. J. Sci., vol. 267, 325-341.

Luth M.C., Jahns R.H. & Tuttle O.F. (1964) - *The granite system at pressure of 4 to 10 kilobars.* J. Geophys. Res., vol. 69, 759-773.

Maccarrone E., Messina A., Puglisi G. & Rottura A. (1978) - *I paragneiss e leucosomi di Capo Rasocolmo (Peloritani nord orientali).* Boll. Soc. Geol. It., vol. 97, 401-415.

Martin R.F. & Bowden P. (1981) - *Peraluminous granites produced by rock-fluid interaction in the Ririwai nonorogenic ring-complex, Nigeria: mineralogical evidence.* Can. Mineral., vol. 19, 65-82.

Messina A., Rottura A. & Russo S. (1974) - *Le leucogranodioriti muscovitiche dell'entroterra di Villa S. Giovanni (Reggio Calabria).* Per. Miner., vol. 43, 51-92.

Messina A. & Russo A. (1980) - *I « graniti » peraluminosi del versante meridionale dell'Aspromonte (Calabria).* Boll. Soc. Geol. It., vol. 100/1, 3-14.

Michard-Vitrac A., Albarede F., Dupuis C. & Taylor H.P. Jr. (1980) - *The genesis of Variscan (Hercynian) plutonic rocks: Inferences from Sr, Pb and O studies on the Maladeta igneous complex, Central Pyrenees (Spain).* Contrib. Mineral. Petrol., vol. 72, 57-72.

Miller C.F., Stoddard E.F., Bradfish L.J., Dollase W.A. (1981) - *Composition of plutonic muscovite: genetic implications.* Can. Mineral., vol. 19, 25-34.

Moresi M. & Paglionico A. (1975) - *Osservazioni geologiche, petrografiche e geochimiche sulle rocce granitoidi delle Serre orientali (Calabria).* Boll. Soc. Geol. It., vol. 94, 1-28.

Moresi M., Paglionico A., Piccarreta G. & Rottura A. (1979) - *The deep crust in Calabria (Polia-Copanello Unit): a comparison with the Ivrea-Verbano zone.* In: Proceeding of the 2nd Symposium Ivrea-Verbano. Mem. Sci. Geol., vol. 33, 233-242.

Moresi M., Paglionico A., Piccarreta G. & Rottura A. (1980) - *Geochemical features of granulite-amphibolite facies metabasites from the Serre, Calabria (Southern Italy).* N. Jb. Miner. Abh., vol. 138, 49-63.

Muecke G.K., Clarke D.B. (1981) - *Geochemical evolution of the South Mountain batholith, Nova Scotia: rare-earth evidence.* Can. Mineral., vol. 19, 133-145.

Ogniben L. (1973) - *Schema geologico della Calabria in base ai dati odierni.* Geol. Romana, vol. 12, 243-585.

O'Neil J.R., Shaw S.E. & Flood R.H. (1977) - *Oxygen and hydrogen isotope composition as indicator of granite genesis in the New England batholith, Australia.* Contrib. Mineral. Petrol., vol. 62, 313-328.

Orsini J.B. (1979 a) - *Existence de trois associations magmatiques dans les granitoides post-viséen moyen (groupe des granodiorites-monzogranites) de la chaine varisque française.* Compt. Rend. Acad. Sci., vol. 289, 981-984.

Orsini J.B. (1979 b) - *Existence d'une zonation spatiale de la chaine varisque française aux temps carbonifères à l'aide de marqueurs plutoniques. Implications géodynamiques.* Compt. Rend. Acad. Sci., vol. 289, 1109-1112.

Paglionico A. & Piccarreta G. (1978) - *History and petrology of a fragment of the deep crust in the Serre (Calabria, Southern Italy).* N. Jb. Miner. Mh., vol. 9, 385-396.

Paglionico A. & Rottura A. (1979) - *Variscan magmatism in the Calabro-Peloritani arc.* In: Sassi F.P. (ed.), « IGCP Project no. 5 », Newsletter, 1, 83-92.

Puglisi G. & Rottura A. (1973) - *Le leucogranodioriti muscovitiche della zona di Capo Rasocolmo (Messina).* Per. Miner., vol. 42, 1-51.

Pezzino A. & Puglisi G. (1980) - *Indagine geologico-petrografica sul cristallino dell'Aspromonte* *centro-settentrionale (Calabria)*. Boll. Soc. Geol. It., vol. 99, 255-268.

Pitcher W.S. (1978) - *The anatomy of a batholith.* J. Geol. Soc. London, vol. 135, 157-182.

Pitcher W.S. (1979) - *The nature, ascent and emplacement of granitic magmas.* J. Geol. Soc. London, vol. 136, 627-662.

Piwinskii A.J. & Wyllie P.J. (1970) - *Experimental studies of igneous rocks series: « Felsic Body Suite » from the Needle Point pluton, Wallowa batholith Oregon.* J. Geol., vol. 78, 52-76.

Price R.C. & Taylor S.R. (1977) - *The rare earth element geochemistry of granite, gneiss, and migmatite from the western metamorphic belt of South-Eastern Australia.* Contrib. Mineral. Petrol., vol. 62, 249-263.

Richardson S.W., Gilbert M.C. & Bell P.M. (1969) - *Experimental determination of kyanite-andalusite and andalusite-sillimanite equilibria: the aluminum silicate triple point.* Am. J. Sci., vol. 267, 259-272.

Robertson J.K. & Wyllie P.J. (1971) - *Rock-water systems, with special reference to the water-deficient region.* Am. J. Sci., vol. 271, 252-277.

Scandone P. (1979) - *Origin of the Tyrrhenian Sea and Calabrian Arc.* Boll. Soc. Geol. It., vol. 98, 27-34.

Schenk V. (1980) - *U-Pb and Rb-Sr radiometric events in the granulite-facies basement of the Serre, Southern Calabria (Italy).* Contrib. Mineral. Petrol., vol. 73, 23-38.

Schenk V. & Schreyer W. (1978) - *Granulite-facies metamorphism in the Northern Serre, Calabria, Southern Italy.* In: Closs H., Roeder D. & Schmidt K. (eds.), « Alps, Apennines, Hellenides ». Stuttgart Schweizerbart, pp. 341-346.

Spear J.A. (1981) - *Petrology of cordierite- and almandine-bearing granitoid plutons of the southern Appalachian Piedmont, U.S.A.* Can. Mineral., vol. 19, 35-46.

Steiner J.C., Jahns R.H. & Luth M.C. (1975) - *Crystallization of alkali feldspar and quartz in the haplogranite system* $NaAlSi_3O_8$-SiO_2-H_2O *at 4 kbar.* Geol. Soc. Am. Bull., vol. 86, 83-93.

Thompson A.B. & Algor J.R. (1977) - *Model systems for anatexis of pelitic rocks. I. Theory of melting reactions in the system* $KAlO_2$-$NaAlO_2$-Al_2O_3-SiO_2-H_2O. Contrib. Mineral. Petrol., vol. 63, 247-269.

Thompson A.B. & Tracy R.J. (1979) - *Model system for anatexis of pelitic rocks. II. Facies series melting and reactions in the system* CaO-$KAlO_2$-$NaAlO_2$-Al_2O_3-SiO_2-H_2O. Contrib. Mineral. Petrol., vol. 70, 429-438.

Tuttle O.F. & Bowen N.L. (1958) - *Origin of granite in the light of experimental studies in the system* $NaAlSi_3O_8$-$KAlSi_3O_8$-H_2O. Geol. Soc. Am. Mem., vol. 74, 153 pp.

Vai G.B. (1979) - *Tracing the Hercynian structural zone across neo-Europa. A model for correlation purposes within IGCP Project No. 5.* In: Sassi F.P. (ed.), « Newsletter », vol. 1, 141-149.

White A.J.R. & Chappell B.W. (1977) - *Ultrametamorphism and granitoid genesis.* In: Green D.H. (ed.), « Experimental petrology related to extreme metamorphism ». Tectonophysics, vol. 43, 7-22.

Wieland B. (1979) - *Age determinations in the Longobucco-Unit Calabria, Italy.* Lecture hold at ECOG-VI, Lillehammer, Norway.

Windley B.F. (1977) - *The Evolving Continents.* Wiley, London, 385 pp.

Winkler H.G.F. (1979) - *Petrogenesis of Metamorphic Rocks.* Fifth edition. Springer, Berlin, Heidelberg, New York, pp. 348.

Winkler H.G.F. & Breitbart R. (1978) - *New aspect of granitic magmas.* N. Jb. Miner. Mh., vol. 10, 463-480.

Wyllie P.J. (1977) - *Crustal anatexis: an experimental review.* In: Green D.H. (ed.), « Experimental Petrology Relate to Extreme Metamorphism ». Tectonophysics, 43, 41-71.

Wyllie P.J., Huang W.L., Stern C.R. & Maaloe S. (1976) - *Granitic magmas: possible and impossible sources, water contents, and crystallization sequences.* Can. J. Earth Sci., vol. 13, 1007-1019.

Zwart H.J. & Dornsiepen U.F. (1978) - *The tectonic framework of central and western Europe.* Geol. Mijnbouw, vol. 57, 627-654.