

Petrochemistry and mineralogy of Monte Cacciagrande granite Stilo Unit (Calabrian-Peloritan Arc, Southern Italy)

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ABSTRACT. — The Stilo Unit crystalline pre-Triassic basement (southern sector of Calabrian-Peloritan Arc) is mainly composed of late-Hercynian composite plutons. This paper describes the results of studies on the Monte Cacciagrande intrusive body, southernmost Serre, near the tectonic contact with the underlying Aspromonte Unit.

The monzogranitic to granodioritic Monte Cacciagrande mass is characterized by the occurrence of K-feldspar megacrysts. Its calc-alkaline peraluminous character is shown by the presence of magmatic muscovite, sillimanite, andalusite and cordierite. The chemical composition of the intrusion indicates that it is a single body with internal chemical fractionation. This granitoid was affected by a non-pervasive cataclastic to flaser deformation probably related to the result of emplacement of the Stilo and Aspromonte Units in Alpine times.

Compared with other intrusives of the Stilo Unit, the Monte Cacciagrande granite appears petrologically distinct from the nearby peraluminous Cittanova granite, and shows similar petrology to the two «Serre stocks» (biotite +/— muscovite and biotite +/— amphibole granite to granodiorite respectively and shows a higher degree of magmatic evolution.

Key words: Peraluminous granites, major and trace element chemical analyses, electron microprobe mineralogical analyses, Stilo Unit, Calabrian-Peloritan Arc.

Introduction and geological outlines

The Monte Cacciagrande granitic mass occurs in Southern Serre, Calabria, Italy. It belongs to the Stilo Unit, which is regarded as the uppermost tectonic element of the Calabrian-Peloritan Arc, a complex nappe pile related to the Alpine Orogeny (AMODIO

MORELLI et al., 1976).

According to BONARDI et al. (1984a) the Stilo Unit in the Serre extends from the Satriano area to Fiumara di Antonimina. It is also present as several klippen, both north and south of this area. It consists of a basement of Paleozoic metamorphics, intruded by late-Hercynian granitoids and all covered by Mesozoic carbonates. The *metamorphic basement* is derived from an arenaceous-pelitic sequence with interbedded volcanoclastic and felsic volcanics, together with rare basic volcanics. A later thermal event is irregularly distributed, locally reaching the hornblende-hornfels facies. This thermal event is due to the intrusion of the plutons and is superimposed on the regional metamorphism. The Stilo Unit *plutons* have been divided into two suites (PAGLIONICO & ROTTURA, 1979; D'AMICO et al., 1981b): a mesaluminous suite, including the Serre composite granitic to tonalitic stock, and a peraluminous suite, including the Cittanova monzogranite to leucogranodiorite and the Serre «fine-grained granitic to granodioritic bodies».

according to CRISCI et al. (1985) and DEL MORO et al. (1986) the tectonic contact between the Stilo Unit (Auct.) and the underlying Polia-Copanella Unit (Auct.) (AMODIO MORELLI et al., 1976; BONARDI et al., 1984a) crisscrosses two calc-alkaline tonalitic intrusions showing similar petrology and a common origin. Consequently this contact is

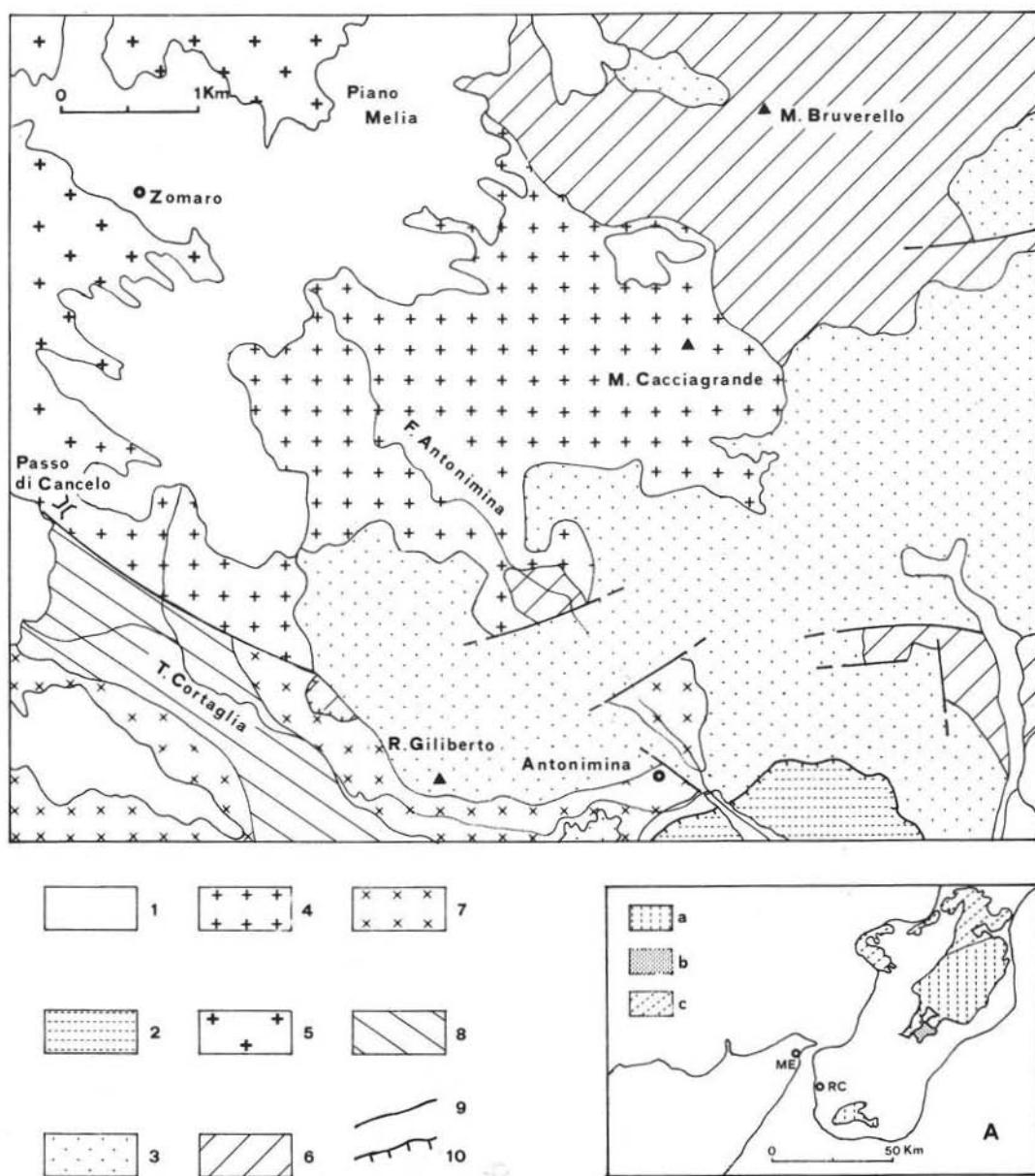


Fig. 1. — Geological sketch map of boundary between Stilo Unit (Southern Serre Massif) and Aspromonte Unit. Legend: 1) Quaternary; 2) «Argille varicolori» (Cretaceous-Oligocene); 3) Stilo-Capo d'Orlando Formation (Late Oligocene - Early Miocene). *Stilo Unit*: 4) Monte Cacciagrande granite; 5) Cittanova granite; 6) Metamorphics. *Aspromonte Unit*: 7) Granites; 8) Metamorphics; 9) Faults; 10) Overthrusts. A = southern sector of Calabrian-Peloritan Arc: a) Stilo Unit (Auct.); b) Monte Cacciagrande granite; c) Polia-Copanello Unit (Auct.).

not considered an Alpine overthrust but a shear 130-140 Ma in age (Rb/Sr method). According to the above-mentioned opinion, the Stilo Unit (Auct.) and the Polia Copanello

Unit (Auct.) form a single Alpine tectonic Unit.

Very little information on the Monte Cacciagrande granitic mass is given in ATZORI

TABLE 1
Modal data of the Monte Cacciagrande granite

(n = 27)	range	$\bar{x}$	S.D.
quartz	21.2 - 38.2	32.6	4.5
plagioclase	27.4 - 37.7	31.1	2.2
K-feldspar	13.2 - 41.1	23.1	6.2
biotite	4.6 - 12.4	8.2	2.1
muscovite	2.4 - 6.9	4.9	1.0
sillimanite	≤ 0.3	-	-
andalusite	≤ 0.6	-	-
cordierite	≤ 0.1	-	-
accessories	≤ 0.6	-	-
opaques	≤ 0.7	-	-

n = number of samples; $\bar{x}$ = average;
S.D. = standard deviation.

et al., 1977; GURRIERI, 1980; BONARDI et al., 1984a.

The Monte Cacciagrande granite extends for about 20 Km² from the tectonic contact with the Aspromonte Unit, marked by the Antonimina - Passo di Canelo line, to the Melia plain (Fig. 1). It intrudes chlorite-sericite phyllites, phyllitic calcschists, actinolite schists, micaschists characterized by porphyroblasts of chlorite $\pm$ muscovite $\pm$

biotite $\pm$ garnet $\pm$ andalusite $\pm$ cordierite, biotite - albite gneisses, biotite - oligoclase gneisses and granitic gneisses.

The mass, inequigranular and medium to coarse - grained, is characterized by the occurrence of K-feldspar megacrysts. The texture mostly massive in the northern part, becomes strongly foliated near Antonimina, especially at the border with the pluton and within the cataclastic zone. The intrusion is crosscut by a few aplite to pegmatite dikes. It contains rare metamorphic xenoliths.

In the studied area the host rocks are overprinted by an irregular thin contact aureole locally reaching the hornblende-hornfels facies, with the widespread occurrence of andalusite and cordierite.

Petrography

Microscopic study

The northern part of the Monte Cacciagrande granite is generally massive (samples 18/40) and exhibits a hypidiomorphic «porphyritic» texture with evident cataclastic effects. In the central and southern parts of the area, from Passo di Canelo to Fiumara di Antonimina, the granite has a cataclastic-augen texture. This suggests that it was affected by a deformation event decreasing

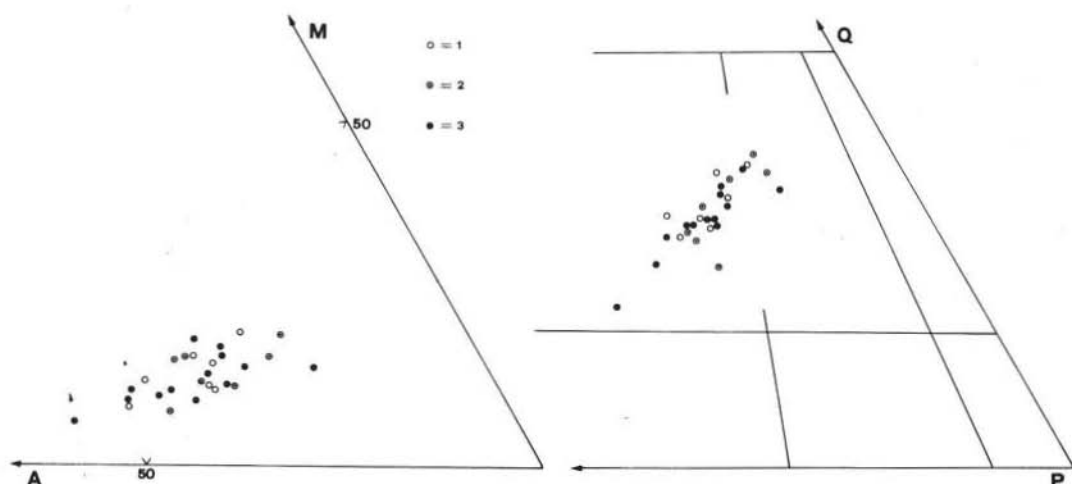


Fig. 2. — Modal Q-A-P (after JUGS, 1973) and M-A-P diagrams of the Monte Cacciagrande granite. Massive (1), cataclastic (2) and flaser (3) samples.

TABLE 2
Crystallization sequence of mineral phases in the Monte Cacciagrande granite

phases	m a g m a t i c			post-magmatic	deformative
minerals	magmatic relic	magmatic	late-magmatic	subsolidus	
plagioclase	(47%)	(32-18% An)		ab+ser+ep	(7-16% An)
biotite		ms+op		ms+op	ms+op**
quartz				chl+rut+ep+op	ms+op**
muscovite					
K-feldspar				perth	micr perth
sillimanite		ms+qz			
		+	ms	ser	
cordierite			bi+ms	?	?
andalusite			ms	ser	
accessories***					****

* Xenoliths are not considered.

** The muscovite derives also from magmatic biotite and subsolidus chlorite.

*** Apatite, zircon, allanite, monazite and magnetite.

**** Opaques.

ab = albite
ser = sericite
ep = epidote
chl = chlorite
rut = rutile
op = opaques
ms = muscovite
bi = biotite
qz = quartz
perth = perthite
micr = microcline

in intensity to the north.

Modal analysis (Table 1) shows that this intrusion has a composition ranging from granite to granodiorite (Fig. 2). The early minerals that formed during *magmatic crystallization* (Table 2) consist of zoned euhedral *plagioclase*, followed by red-brown *biotite*. *Quartz*, *muscovite* in large flakes (type 1, Table 3), and in smaller flakes associated with biotite (type 2, Table 3), and poikilitic *K-feldspar* are late crystallizing phases. *Apatite*, *zircon*, *allanite*, *monazite* and *magnetite* are accessory minerals. Corroded cores of *plagioclase* with An 47% and small euhedral *biotite* included in feldspars may be relics of a previous magmatic stage.

Sillimanite, *andalusite* and *cordierite* show different crystal habits and modes of occurrence. *Sillimanite*, occurring either as

needles or as small euhedral prism, may be included in the zones of *plagioclase* (never in their core), epitaxial to *quartz* and *feldspar* or random crystals. Pink pleochroic *andalusite*, usually zoned and free of inclusions, occurs

TABLE 3
Types of muscovites in the Monte Cacciagrande granite and their occurrence

TYPE	MODE OF OCCURRENCE
1	Magmatic large individual grains.
2	Magmatic smaller grains associated with biotite.
3	Late magmatic rims on andalusite.
4	Pseudomorphic replacement of cordierite
5	Decussate micas in xenoliths
6	Sericite alteration of fibrolite clusters in xenoliths
7	Post magmatic rims on biotite.

as: a) subhedral cores surrounded by fibrolite, from which it appears to be formed; b) euhedral crystals, isolated or included in the external portions of plagioclase and/or K-feldspar. In both cases andalusite is usually rimmed by muscovite type 3 (Tables 2 and 3). *Cordierite*, when present, occurs as single euhedral crystals, pseudomorphically replaced by green biotite and muscovite of type 4 (Tables 2 and 3). These modes of occurrence are suggestive of a magmatic origin for the cordierite (GREEN, 1976; PHILLIPS et al., 1981; CLEMENS & WALL, 1981) and aluminosilicates (CLARKE et al., 1976; DE ALBUQUERQUE, 1971).

The *late-magmatic stage* of the intrusion is characterized by muscovite of type 3 and 7 growing at the expense of aluminosilicates and biotite respectively (Tables 2 and 3). In addition, quartz-muscovite intergrowths and muscovite + green biotite pseudomorphs after cordierite also belong to this stage. More than 50% of the samples show *subsolidus* features such as plagioclase alteration, mainly in the core, K-feldspar perthitization, and replacement of sillimanite and andalusite by sericite.

The *xenoliths*, mm-sized, consist of assemblage of decussate micas (muscovite type 5, Table 3) with a metamorphic texture locally sericite (type 6, Table 3) can be seen growing on relic clusters of fibrolite.

The effects of *deformation* range from minor cataclasis to the development of a true foliation characterized by flattening of quartz-feldspar aggregates and alignment of platy minerals. In the latter case, the rock shows evidence of grain size reduction and development of an augen texture. This textural development is accompanied by recrystallization of quartz into polygonal aggregates, rotation and fracturing of K-feldspar with fractures often filled by quartz, albite and more rarely pumpellyite, rotation and orientation of mica flakes along the shear planes and the development of kink-bands in some of the micas.

Mineral chemistry

The major minerals of two samples, representative respectively of only minor

cataclasis (B 2006) and significant deformation (B 1640), were chemically analyzed, using an electron microprobe.

All analyzed *muscovites* (Table 4, Fig. 3), although with chemical composition close to theoretical values, show small but significant compositional variations related to their petrographic occurrence (Fig. 3b). In comparison with the large isolated muscovite (type 1), muscovite rimming biotite (type 7) has higher Ti, Si, Mg and Fe contents and a lower Na/(Na + K) ratio; decussate muscovite from xenoliths (type 5) shows similar composition to type 1 but has lower Fe and Mg contents; sericite pseudomorph after sillimanite (type 6) is characterized by higher Al and lower Si, Fe, Na and Ti contents. Types 2 and 3 muscovites respectively, associated with biotite and rimming andalusite, have compositions similar

TABLE 4
Microprobe analyses of muscovites from the Monte Cacciagrande granite

sample	B 2006	B 1640	B 1640	B 2006	B 2006	B 1640	B 2006
type	1	1	2	6	3	7	5
nr. analyses *	5	3	5	2	3	5	3
SiO ₂	44.02	44.01	45.11	43.22	45.52	45.64	45.50
TiO ₂	0.04	0.04	0.41	0.68	0.29	1.10	0.96
Al ₂ O ₃	36.79	36.38	36.85	38.85	36.91	35.60	36.02
Cr ₂ O ₃	-	-	-	-	-	0.01	-
FeO	0.77	0.79	0.82	0.66	0.96	1.24	1.01
MnO	0.01	-	-	0.01	-	0.02	tr
MgO	0.35	0.34	0.40	0.37	0.49	0.67	0.52
CaO	tr	tr	tr	0.01	0.01	-	0.01
Na ₂ O	0.48	0.45	0.37	0.29	0.43	0.37	0.39
K ₂ O	10.77	10.78	11.08	9.77	10.52	10.90	10.88
Total	93.23	92.79	95.04	93.86	95.13	95.55	95.29
Number of ions on the basis of 22 (O)							
Si _{IV}	5.991	6.019	6.026	5.806	6.055	6.077	6.065
Al _{IV}	2.009	1.981	1.974	2.194	1.945	1.923	1.935
	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Al _{VI}	3.893	3.884	3.828	3.958	3.843	3.664	3.725
Ti	0.004	0.004	0.041	0.069	0.029	0.110	0.096
Mg ₂₊	0.071	0.069	0.080	0.074	0.097	0.133	0.103
Fe	0.088	0.090	0.092	0.074	0.107	0.138	0.112
Mn	0.001	-	-	0.001	-	0.002	-
Cr	-	-	-	-	-	0.001	-
	4.057	4.047	4.041	4.176	4.076	4.048	4.038
Ca	-	-	-	0.001	0.001	-	0.001
Na	0.127	0.119	0.096	0.075	0.111	0.095	0.101
K	1.870	1.881	1.888	1.674	1.785	1.852	1.850
	1.997	2.000	1.984	1.750	1.897	1.947	1.952

* Performed analyses. Data refers to the most representative analysis

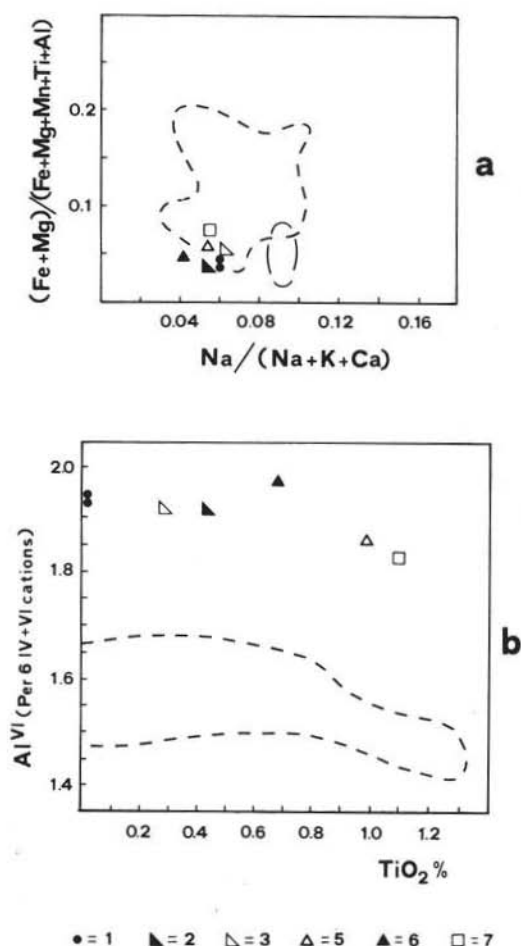


Fig. 3. — $(Fe+Mg)/(Fe+Mg+Mn+Ti+Al)$ vs $Na/(Na+K+Ca)$ (a) and Al^{VI} vs. TiO_2 (b) diagrams for muscovites of the Monte Cacciagrande granite: 1 = magmaic flakes; 2 = small flakes associated with magmaic biotite; 3 = flakes replacing aluminosilicates; 5 = decussate flakes in xenoliths; 6 = sericite pseudomorph after sillimanite in xenoliths; 7 = flakes replacing biotite. These numbers correspond to muscovite types of Table 3. Dashed lines contour muscovite fields of other peraluminous granites from literature: a) short dashes = CLARKE (1981), long dashes = D'AMICO et al. (1981a); b) ANDERSON & ROWLEY (1981).

to type 1. In general, the muscovite of the Monte Cacciagrande granite appears to be less celadonitic (Fig. 3) than that of other peraluminous granitoids (ANDERSON & ROWLEY, 1981; CLARKE, 1981; D'AMICO et al., 1981a).

Biotites analyzed (Table 5, Fig. 4) in the

TABLE 5
Microprobe analyses of biotites from the Monte Cacciagrande granite

sample	B 2006	B 2006	B 1640	B 1640	B 2006
structure	1	2	2	3	4
nr. analyses *	3	4	6	3	3
SiO ₂	33.67	34.01	34.06	34.45	34.01
TiO ₂	3.49	3.10	3.16	3.01	3.22
Al ₂ O ₃	20.62	19.81	19.79	19.74	19.59
Cr ₂ O ₃	0.03	0.01	0.03	—	—
FeO ^{2,3}	21.59	22.56	22.64	22.79	22.86
MnO	0.24	0.21	0.26	0.23	0.23
MgO	5.64	6.21	6.03	5.92	5.59
CaO	0.01	—	0.01	0.02	—
Na ₂ O	0.05	0.01	0.06	—	—
K ₂ O	9.73	9.72	9.71	9.73	9.58
Total	95.07	95.64	95.75	95.89	95.08

Number of ions on the basis of 22 (O)

Si ^{IV}	5.216	5.261	5.266	5.313	5.298
Al ^{IV}	2.784	2.739	2.734	2.687	2.702
	8.000	8.000	8.000	8.000	8.000
Al ^{VI}	0.081	0.873	0.873	0.902	0.895
Ti	0.406	0.361	0.367	0.349	0.377
Mg ₂₊	1.302	1.432	1.389	1.361	1.298
Fe	2.797	2.918	2.927	2.940	2.978
Mn	0.031	0.027	0.034	0.030	0.030
Cr	0.004	0.001	0.004	—	—
	5.521	5.612	5.594	5.582	5.578
Ca	0.002	—	0.002	0.003	—
Na	0.015	0.003	0.018	—	—
K	1.923	1.918	1.915	1.915	1.904
	1.940	1.921	1.935	1.918	1.904

* Performed analyses. Data refers to the most representative analysis.

same samples, have high Al contents in both octahedral and tetrahedral positions, related to the peraluminous character of the granite (CLARKE, 1981). When plotted on the diagrams used by GANGY (1968) and DE ALBUQUERQUE (1973) (Fig. 4a), the Monte Cacciagrande biotites fall in the region of biotites coexisting with muscovite and primary aluminosilicates respectively. The biotites are also relatively rich in Fe and Ti, although the chemical variation of biotite in different petrographic positions is very limited. All analyzed biotites, independent of their mode of occurrence, have a siderophyllitic (or zinnwalditic, ALBERNETY, 1980 in MARTIN & BOWDEN, 1981) trend, in that they have intermediate $Fe/(Fe+Mg)$

TABLE 6

Microprobe analyses of andalusite from the Monte Cacciagrande granite

sample	B 2006*	B 1640**
n. analyses***	4	3
SiO ₂	36.66	36.44
TiO ₂	0.06	0.04
Al ₂ O ₃	62.97	63.61
Cr ₂ O ₃	0.00	0.00
FeO	0.40	0.40
MgO	0.02	0.01
K ₂ O	0.01	0.00
Total	100.12	100.50

Number of ions on the basis of 20 (O)

Si	3.961	3.924
Al	8.020	8.074
Fe ²⁺	0.036	0.036
Mg	0.003	0.002
Ti	0.005	0.003
K	0.001	0.000

* idiomorphic andalusite.

** relics of idiomorphic andalusite partly pseudomorphosed by sericite.

*** performed analyses. Data refers to the most representative analysis.

ratios and lower Ca and Na contents with respect to other peraluminous granitoids (Fig. 4) (DE ALBUQUERQUE, 1973; CLARKE, 1981; D'AMICO et al., 1981a).

Andalusite (Table 6) has an almost theoretical composition and its FeO content is typical of magmatic andalusite from peraluminous granitoids of the South Mountain Batholith - Nova Scotia (CLARKE et al., 1976) and of the Eisgarn type Moldanubikum - Moravia (D'AMICO et al., 1981a).

In massive samples *plagioclase* shows normal zoning and a compositional range from andesine to oligoclase (Table 7). In deformed samples, however, where plagioclase is

TABLE 7

Or-Ab-An contents of feldspars from the Monte Cacciagrande granite determined by electron microprobe

K-feldspar					
sample	B 2006			B 1640	
n. analyses *					
Or%	96.6	84.6	72.9	71.7	73.6
Ab%	3.1	14.7	26.5	26.5	25.7
An%	0.3	0.7	0.6	1.8	0.7
plagioclases					
sample	B 2006			B 1640.	
n. analyses *	(r.c.)	(c.)	(r.)	**	***
An %	47.2	31.7	18.3	6.8	16.1
Ab%	52.0	67.5	78.4	92.4	81.7
Or%	0.8	0.8	3.3	0.8	2.2

* Performed analyses. Data refers to the most representative analysis.

** Broken plagioclases

*** Rim of a broken plagioclase with sericitized core
r.c. = relic core; c = core; r = rim.

fractured and has sericitized cores (locally sericitization is complete), plagioclase ranges in composition from albite to oligoclase (Table 7).

K-feldspar is usually an orthoclase microperthite, but in the most deformed samples it is a microcline-perthite (Table 7).

Geochemistry

The analytical data for major and trace elements, of the 15 representative samples are given in Table 8.

Major and trace elements were determined by X-ray fluorescence with a Philips PW 1400 spectrometer, using the method suggested by FRANZINI et al. (1972, 1975) and LEONI & SAIITTA (1976). MgO was determined by Atomic Absorption Spectrometry, Fe⁺ by titration with KMnO₄, Na₂O by direct flame

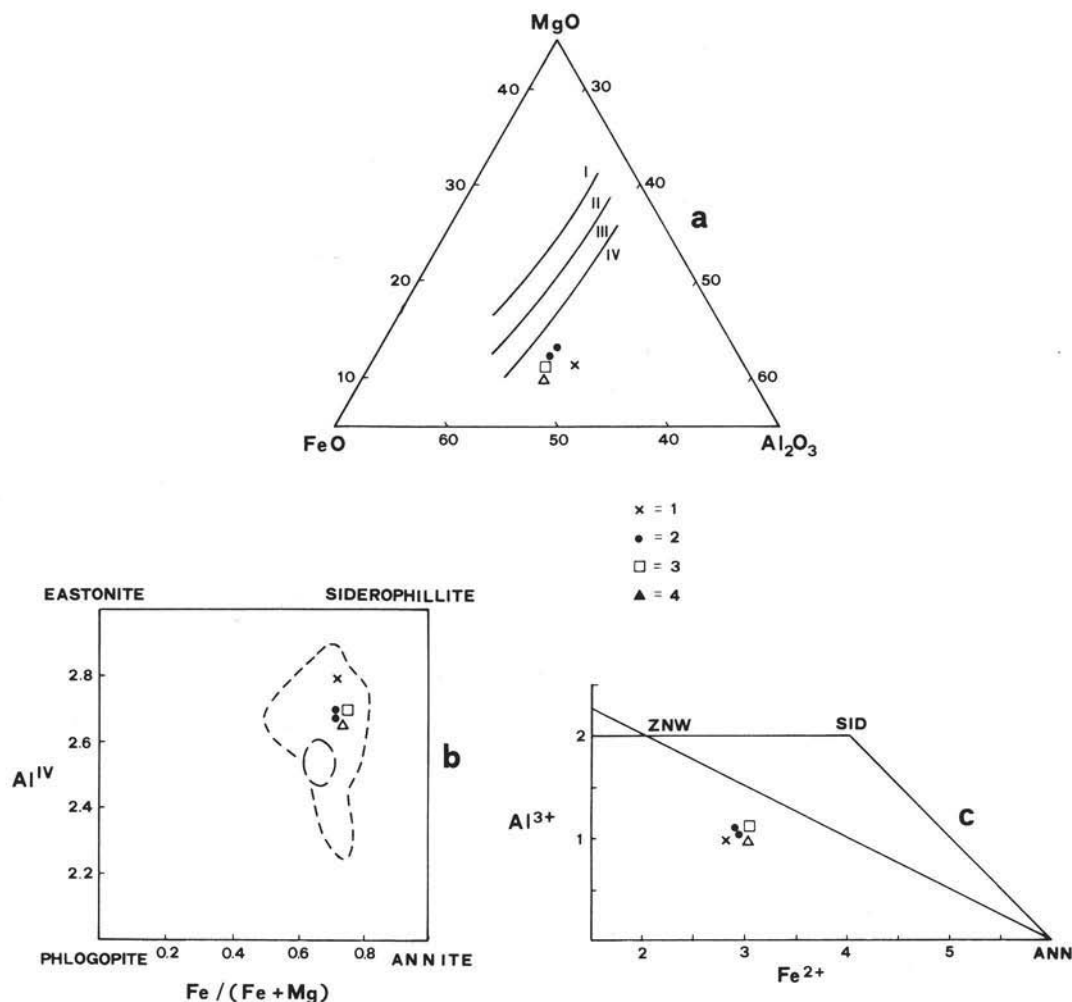


Fig. 4. — MgO—FeO—Al₂O₃ (a); Al^{IV} vs. Fe/(Fe + Mg) (b) and Al³⁺ vs. Fe²⁺ (c) diagrams for biotites of the Monte Cacciagrande granite. 1 = relic flakes associated with fibrolite in xenoliths; 2 = magmatic flakes; 3 = flakes frayed and/or broken by deformative event; 4 = decussate flakes in xenoliths. a) MgO—FeO—Al₂O₃ diagram after DE ALBUQUERQUE (1973); b) dashed lines contour biotite fields of peraluminous granites after CLARKE (1981) (short dashes) and D'AMICO et al. (1981a) (long dashes); c) after ALBERNETY in MARTIN & BOWDEN (1981).

spectrophotometry, and H₂O by loss on ignition at 1000°C.

The chemical features of the Monte Cacciagrande granite show felsic, peraluminous and calc-alkaline characters with: a) SiO₂ ranging from 70.85 to 72.77 wt.%; b) Al₂O₃ > Na₂O + K₂O; c) K₂O > Na₂O; d) relatively high FeO_{tot}, TiO₂ and P₂O₅. The major oxides versus SiO₂ diagrams (Fig. 5) show the typical trends of felsic rocks with marked compositional homogeneity. CaO, MgO, FeO + Fe₂O₃ and

TiO₂ show an inverse correlation with SiO₂ content. Trace elements Sr and Ba (average values 136 and 648 ppm respectively) also decrease with increasing SiO₂, while Rb (like K) is nearly constant and high ($\bar{x}$ = 232 ppm). The K/Rb ratio is therefore quite low ($\bar{x}$ = 154), whereas the Sr/Ca ratio is relatively high ($\bar{x}$ = 20.3). Zr and V exhibit a negative correlation with SiO₂, whereas Nb and Y are rather constant.

The geochemistry indicates that the Monte Cacciagrande granite is a single body with

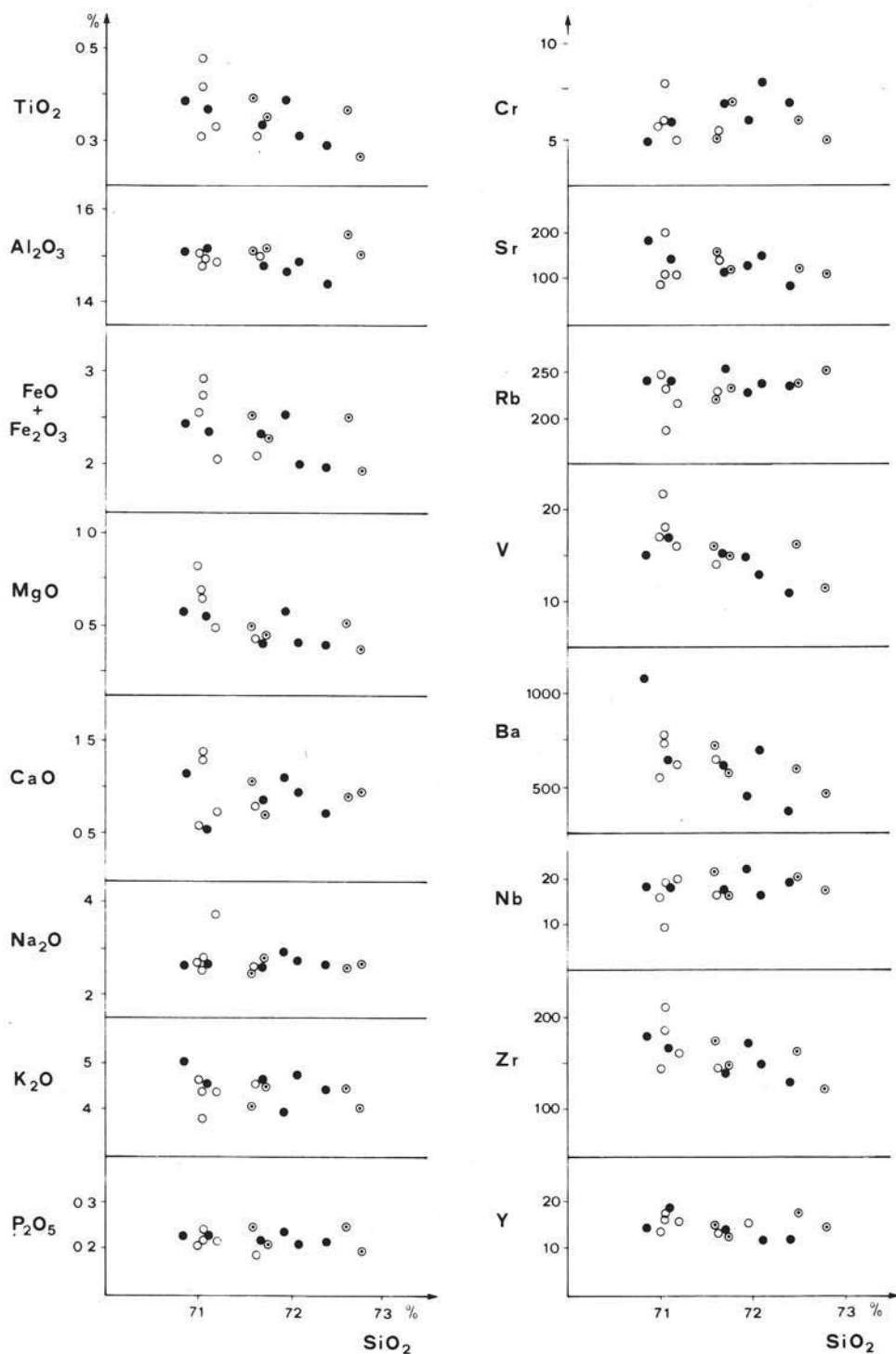

 Fig. 5. — SiO_2 vs. major and trace elements diagrams for the Monte Cacciagrande granite. Symbols as in Fig. 2.

TABLE 8
Chemical analyses of the Monte Cacciagrande granite

(wt %)	BS 143	BS 147	BS 148	BS 149	BS 1108	BS 1109	BS 1114	BS 1115	BS 1116	BS 1146	BS 1147	B 1637	B 1640	B 1641	B 1647
	*	*	*	*	*	***	**	***	**	**	***	***	***	***	**
SiO ₂	71.63	71.05	71.04	71.18	71.00	70.85	72.77	71.95	71.72	71.60	71.21	72.41	71.71	72.13	72.62
TiO ₂	0.31	0.48	0.42	0.34	0.31	0.39	0.27	0.39	0.35	0.39	0.37	0.29	0.34	0.31	0.37
Al ₂ O ₃	15.02	14.99	14.90	14.93	15.11	15.18	15.12	14.76	15.17	15.16	15.20	14.43	14.83	14.92	15.54
Fe ₂ O ₃	0.89	0.84	2.34	0.61	2.38	0.70	0.90	0.84	0.95	0.91	1.02	0.68	1.01	0.82	0.87
FeO	1.20	2.10	0.43	1.46	0.19	1.75	1.06	1.72	1.41	1.64	1.35	1.29	1.32	1.21	1.65
MnO	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.03
MgO	0.43	0.69	0.65	0.49	0.83	0.57	0.38	0.59	0.46	0.50	0.55	0.39	0.41	0.41	0.51
CaO	0.80	1.41	1.33	0.74	0.57	1.15	0.94	1.13	0.70	1.08	0.94	0.71	0.87	0.94	0.92
Na ₂ O	2.55	2.64	2.65	3.78	2.64	2.60	2.65	2.95	2.81	2.49	2.64	2.65	2.65	2.69	2.55
K ₂ O	4.65	3.79	4.45	4.43	4.65	5.07	4.11	4.00	4.56	4.11	4.61	4.52	4.65	4.81	4.52
P ₂ O ₅	0.19	0.24	0.22	0.22	0.21	0.23	0.20	0.24	0.21	0.25	0.22	0.22	0.22	0.21	0.25
H ₂ O ₂	2.30	1.74	1.54	1.80	2.08	1.48	1.57	1.41	1.63	1.84	1.87	2.39	1.96	1.53	0.18
C (ppm)	4.79	4.56	3.83	3.10	5.20	3.88	5.08	4.10	4.84	5.25	4.69	4.42	4.38	4.08	5.38
V	14	22	18	16	17	15	13	15	15	16	17	11	15	13	16
Cr	<5	6	8	5	6	5	<5	6	7	5	6	7	7	8	6
Ni	3	3	4	<2	<2	3	3	2	<2	3	3	<2	5	3	3
Rb	228	184	232	214	248	242	250	228	232	226	242	234	253	237	237
Sr	148	201	169	108	94	187	111	128	122	149	144	85	116	152	122
Y	14	17	18	16	14	15	15	16	13	15	19	12	14	12	18
Zr	147	215	187	164	147	182	124	175	152	175	169	133	147	150	164
Nb	16	9	19	20	16	18	17	22	16	21	19	19	17	16	20
Ba	645	787	787	631	567	1091	468	465	581	721	659	387	622	717	595
K/Ba	59.8	40.0	46.9	58.2	68.3	38.5	72.9	71.4	65.1	47.3	58.1	97.0	62.0	55.6	63.0
K/Rb	169.3	170.9	159.2	171.8	155.6	173.9	136.4	145.6	163.1	150.9	158.1	160.3	152.2	168.4	158.3
Rb/Sr	1.5	0.9	1.4	2.0	2.6	1.3	2.2	1.8	1.9	1.5	1.7	2.7	2.2	1.6	1.9
A/CNK	1.41	1.36	1.29	1.21	1.45	1.28	1.44	1.31	1.40	1.44	1.38	1.37	1.35	1.32	1.44

C = C.I.P.W. normative corundum

A/CNK = $\text{Al}_2\text{O}_3 / (\text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O})$ on molecular proportion

* = massive

** = cataclastic

*** = flaser

internal fractionation. The lack of significant chemical differences between massive and deformed samples suggests that tectonic and metamorphic re-equilibration was isochemical.

Discussion and Conclusions

The Monte Cacciagrande mass is a typical peraluminous body as suggested by the presence of muscovite, sillimanite, andalusite and cordierite, by the high normative corundum value and by $A > \text{CNK}$ and $A/\text{CNK} > 1.1$ (SHAND, 1927; CLARKE, 1981; CHAPPELL & WHITE, 1974 (Table 8).

Peraluminous granitoids, ranging in composition from granodiorite to leucomonzogranite, are widespread in the Calabrian-Peloritan Arc, in the Aspromonte, Stilo and Sila Units. In the Aspromonte Unit, the peraluminous granitoids are intruded into medium - high grade metamorphics of

Hercynian age partly re-equilibrated during the Alpine orogeny (BONARDI et al., 1984b). In the Stilo and Sila Units, they are intruded either into low to medium-high grade metamorphics (BONARDI et al., 1984a; BARBIERI et al., 1985; MESSINA et al., 1988) or into older biotite-bearing plutons with rare primary muscovite or hornblende (HIEKE MERLIN & LORENZONI, 1972; LORENZONI & ZANETTIN LORENZONI, 1975; MORESI & PAGLIONICO, 1976; BORSI et al., 1976; CRISCI et al., 1979; LORENZONI et al., 1979; CRISCI et al., 1980; BARBIERI et al., 1985; MESSINA et al., 1988).

In order to ascertain possible genetic relations with other granitoids of the Stilo Unit, the Monte Cacciagrande granite is compared with the Cittanova peraluminous granite (CRISCI et al., 1979) (284 - 291 Ma in age; initial ratio $^{87}\text{Sr}/^{86}\text{Sr} > 0.708$, DEL MORO et al., 1982) and with the «main» and

TABLE 9
 Modal data of some Stilo Unit granitoids

M. CACCIAGRANDE * CITTANOVA **

S E R R E ***

	fine grained rocks						main rocks				
	n = 27		n = 98		granodiorites n = 12		granites n = 4		granodiorites n = 18		granite n = 1
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	
quartz	32.6	4.5	32.7	4.1	29.2	2.0	34.1	3.0	29.2	4.1	26.8
plagioclase	31.1	2.2	36.4	7.7	41.6	2.4	30.4	2.2	45.3	5.3	32.6
K-feldspar	23.1	6.2	19.6	6.5	14.6	2.2	26.3	5.8	11.0	3.4	23.7
biotite	8.2	2.1	6.9	2.4	12.3	3.8	4.2	1.9	14.1	2.8	16.6
muscovite	4.9	1.0	3.4	2.7	2.0	1.0	4.9	3.2	0.1	0.2	0.3
sillimanite	≤ 0.3		≤ 3.4		-		-		-		-
andalusite	≤ 0.6		tr		-		-		-		-
cordierite	≤ 0.1		≤ 4.4		-		-		-		-

* This work.

*** CRISCI et al., 1980.

 ** CRISCI et al., 1979. n = number of samples; $\bar{x}$ = average; S.D. = standard deviation.

 TABLE 10
 Chemical analyses of some Stilo Unit granitoids

MONTE CACCIAGRANDE *

CITTANOVA **

S E R R E ***

Wt %	n = 15				n = 27				FINE GRAINED GRANODIORITES n = 12				MAIN GRANODIORITES n = 22			
	range		$\bar{x}$	S.D.	range		$\bar{x}$	S.D.	range		$\bar{x}$	S.D.	range		$\bar{x}$	S.D.
SiO ₂	70.85 - 72.77		71.68	0.62	71.31 - 75.08		72.66	0.88	65.27 - 72.20		68.02	1.60	63.81 - 70.52		66.54	1.82
TiO ₂	0.27 - 0.48		0.35	0.05	0.10 - 0.33		0.24	0.06	0.29 - 0.66		0.56	0.10	0.41 - 0.79		0.62	0.11
Al ₂ O ₃	14.43 - 15.54		15.02	0.25	13.87 - 15.65		14.77	0.48	14.48 - 16.48		15.62	0.46	14.43 - 16.41		15.71	0.58
Fe ₂ O ₃	0.61 - 2.38		1.05	0.54	0.26 - 1.02		0.57	0.19	0.06 - 2.00		1.00	0.54	0.73 - 3.07		1.62	0.62
FeO	0.19 - 2.10		1.32	0.49	0.29 - 1.60		1.14	0.25	1.39 - 3.22		2.56	0.47	1.52 - 3.68		2.60	0.62
MnO	0.02 - 0.03		0.03	0.01	0.04 - 0.07		0.05	0.01	0.07 - 0.09		0.08	0.01	0.07 - 0.10		0.09	0.01
MgO	0.38 - 0.83		0.52	0.13	0.25 - 1.15		0.50	0.18	0.53 - 1.63		1.29	0.30	0.92 - 2.16		1.64	0.33
CaO	0.57 - 1.41		0.95	0.24	0.61 - 1.73		1.28	0.37	1.40 - 3.28		2.57	0.63	1.76 - 4.56		3.53	0.76
Na ₂ O	2.49 - 3.78		2.73	0.31	1.89 - 4.86		3.78	0.55	2.58 - 3.32		3.03	0.18	2.16 - 3.83		2.87	0.35
K ₂ O	3.79 - 5.07		4.46	0.33	2.50 - 5.20		3.79	0.79	2.87 - 4.45		3.61	0.43	2.74 - 4.18		3.35	0.53
P ₂ O ₅	0.19 - 0.25		0.22	0.02	0.07 - 0.22		0.13	0.04	0.17 - 0.22		0.18	0.02	0.10 - 0.20		0.15	0.03
C	3.10 - 5.38		4.50	0.63	1.22 - 3.59		2.53	1.00	1.86 - 3.34		2.50	0.46	0.34 - 2.32(3.89)		1.28	0.73
(ppm)																
V	11 - 22		15.5	2.5	1.0 - 20		5.4	3.9	(7)29 - 58		38	14.0	22 - 95		68	19.0
Cr	<5 - 8		6.1	1.1	1.0 - 9.7		5.1	3.9	1.0 - 9.0		4.7	2.5	1.0 - 19		9.7	4.4
Ni	<2 - 5		2.9	0.8	1.0 - 10		2.9	2.2	3.0 - 14		4.8	3.0	3.0 - 8.0(26)		5.9	4.7
Rb	184 - 250		232	16.8	63 - 237		151	42	80 - 138		108	20	75 - 143		101	23
Sr	85 - 201		136	33	59 - 373		243	85	180 - 304		255	33	177 - 278		234	28
Y	12 - 18		15.2	2.1	13 - 24		17.1	3.7	5.0 - 29		20	7.9	9.0 - 35		26	6.5
Zr	124 - 215		162	23	46 - 239		121	41	106 - 225		182	37	96 - 198		146	29
Nb	9 - 22		17.7	3.1	4.8 - 79		19.4	18.0	11 - 20		13	3.7	1.0 - 17		11.2	4.2
Ba	387 - 1091		648	168	(198)386 - 1512		891	306	683 - 980		859	83	478 - 828		685	89
La	-		-	-	10 - 66		30	12.0	31 - 44		38	3.3	25 - 37		32	5.4
Ce	-		-	-	19 - 108		57	20	67 - 90		74	7.6	54 - 91		66	10.1

* This work.

 n = number of samples; $\bar{x}$ = average; S.D. = standard deviation;

** CRISCI et al., 1979. C = C.I.P.W. normative corundum

*** CRISCI et al., 1980.

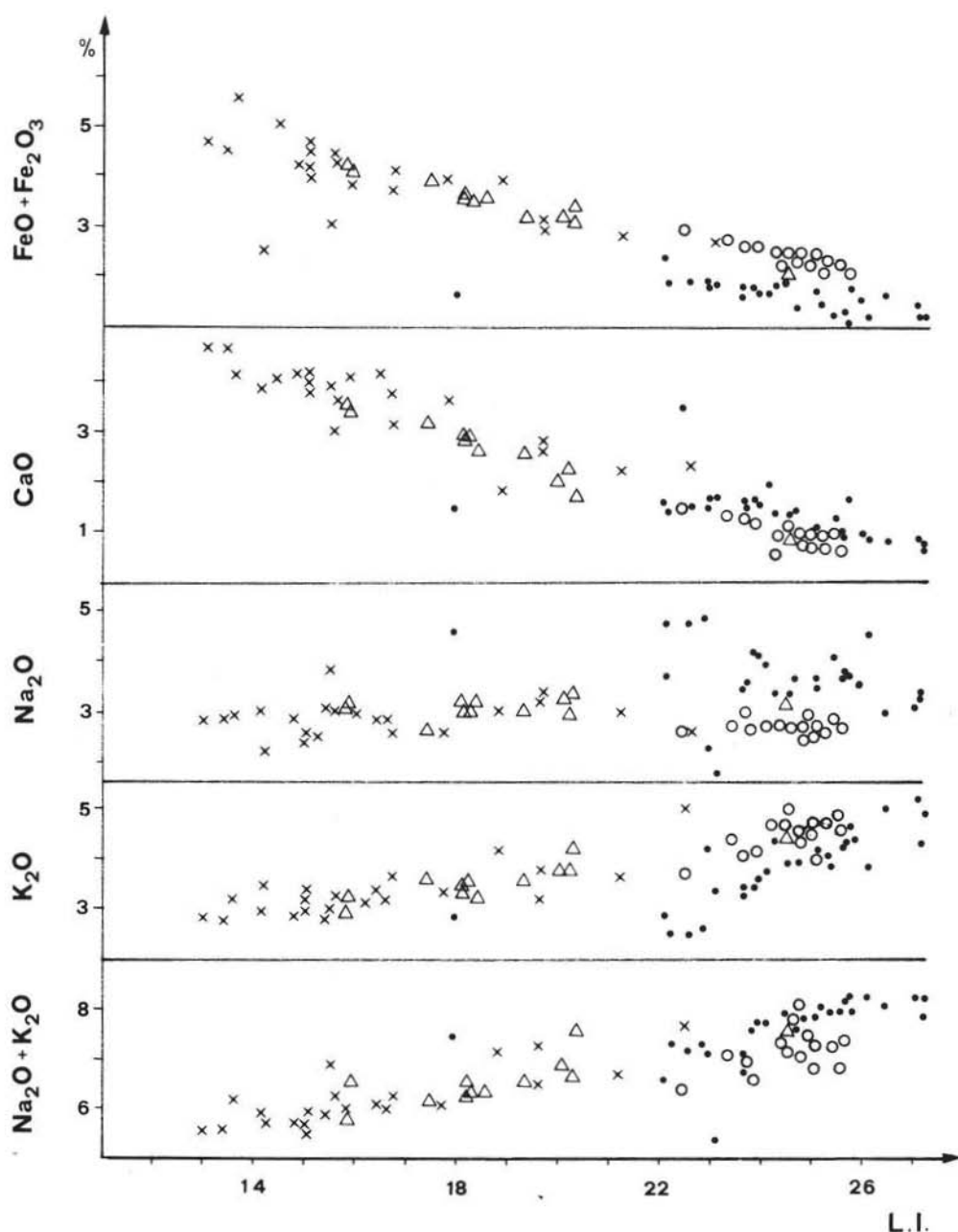


Fig. 6. — Larsen Index $[1/3 \text{ SiO}_2 + \text{K}_2\text{O} - (\text{CaO} + \text{MgO} + \text{FeO} + \text{Fe}_2\text{O}_3)]$ variation diagrams for major elements of some Stilo Unit granitoids. Monte Cacciagrande = circles; Cittanova (CRISCI et al., 1979) = dots; Serre (CRISCI et al., 1980) fine-grained granodiorite = triangles; main granodiorite = crosses.

the «fine-grained» stocks of the Serre (CRISCI 1979; CRISCI et al., 1980; D'AMICO et al., 1980). For these three intrusions anatectic crustal genesis from different materials has been suggested (CRISCI et al., 1981b; PAGLIONICO & ROTTURA, 1982). The Monte Cacciagrande intrusion is mineralogically similar to the Cittanova body

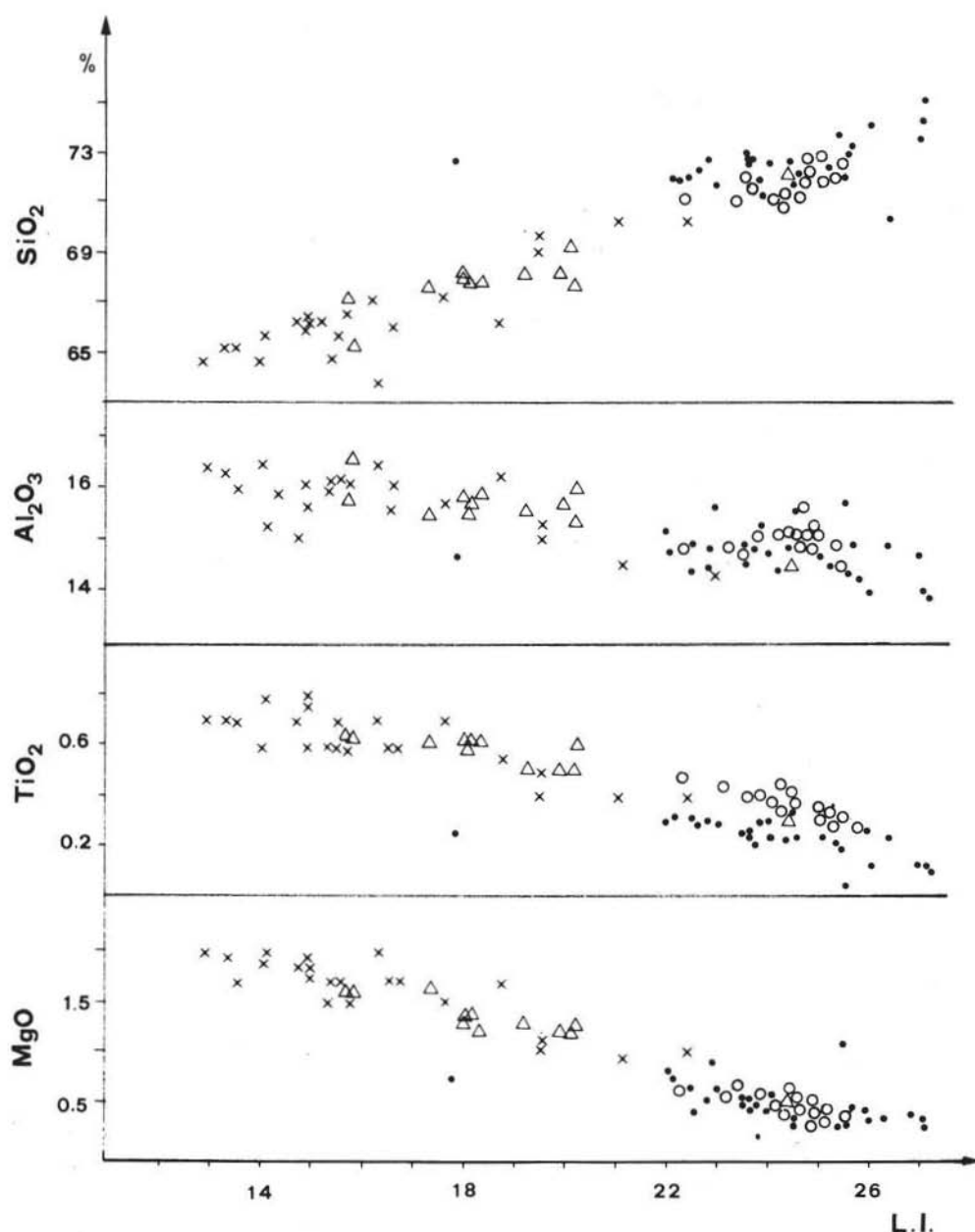


Fig. 6. (Continued) — Larsen Index $[1/3 \text{SiO}_2 + \text{K}_2\text{O} - (\text{CaO} + \text{MgO} + \text{FeO} + \text{Fe}_2\text{O}_3)]$ variation diagrams for major elements of some Stilo Unit granitoids. Monte Cacciagrande = circles; Cittanova (CRISCI et al., 1979) = dots; Serre (CRISCI et al., 1980) fine-grained granodiorite = triangles; main granodiorite = crosses.

owing to the presence of abundant muscovite and minor andalusite, sillimanite and cordierite (Table 9); however, the latter is heterogranular, fine-grained and only locally

porphyritic. The two Serre stocks are both structurally and compositionally different from the Monte Cacciagrande mass, in fact the «fine-grained granodiorite» is muscovite-

bearing and the «main granodiorite» is biotite-amphibole-bearing (Table 9).
 homeogranular, medium-grain sized and Table 10 lists the chemical data of the

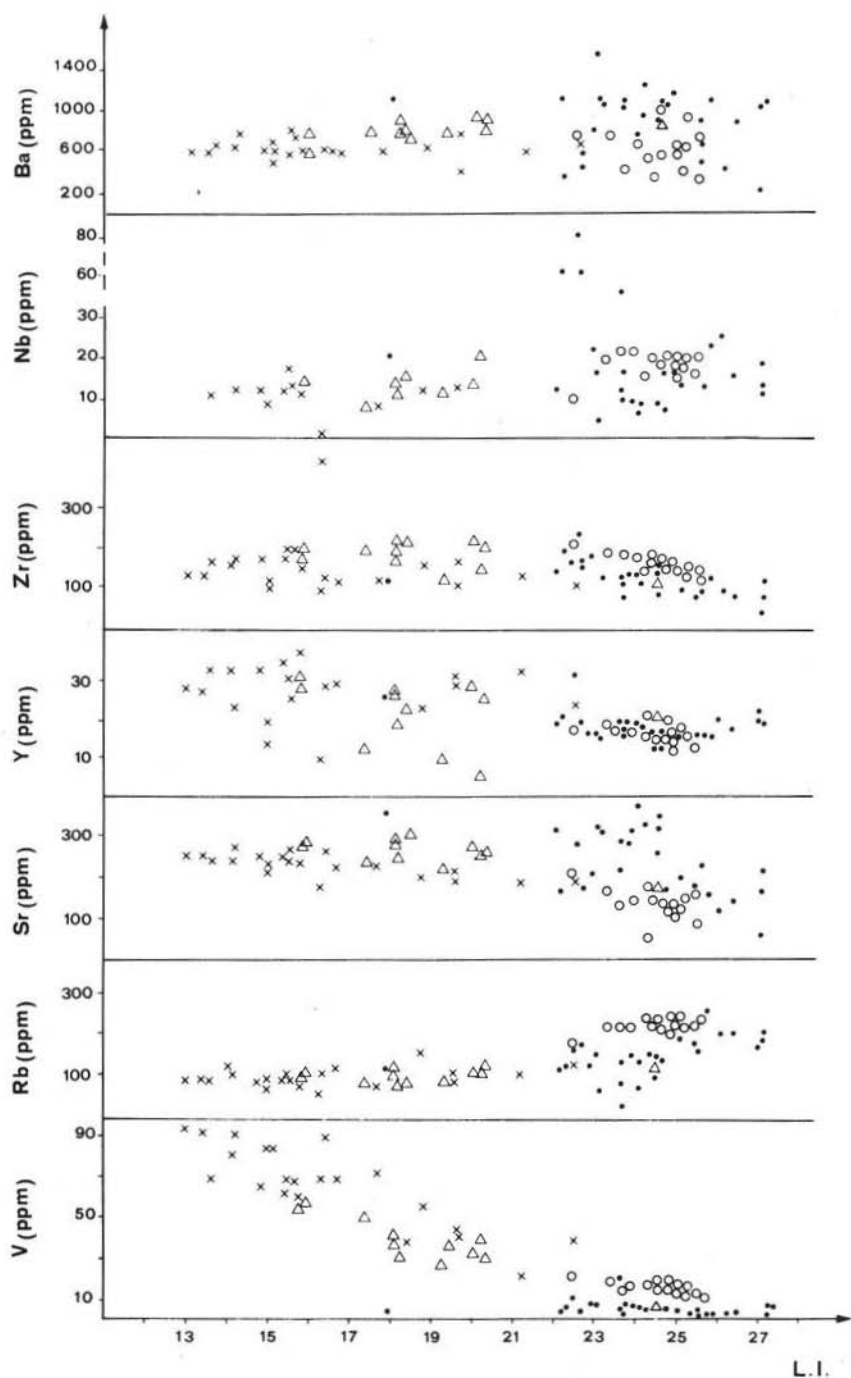


Fig. 7. — Larsen Index $[1/3 \text{ SiO}_2 + \text{K}_2\text{O} - (\text{CaO} + \text{MgO} + \text{FeO} + \text{Fe}_2\text{O}_3)]$ variation diagrams for trace elements of some Stilo Unit granitoids. Symbols as in Fig. 6.

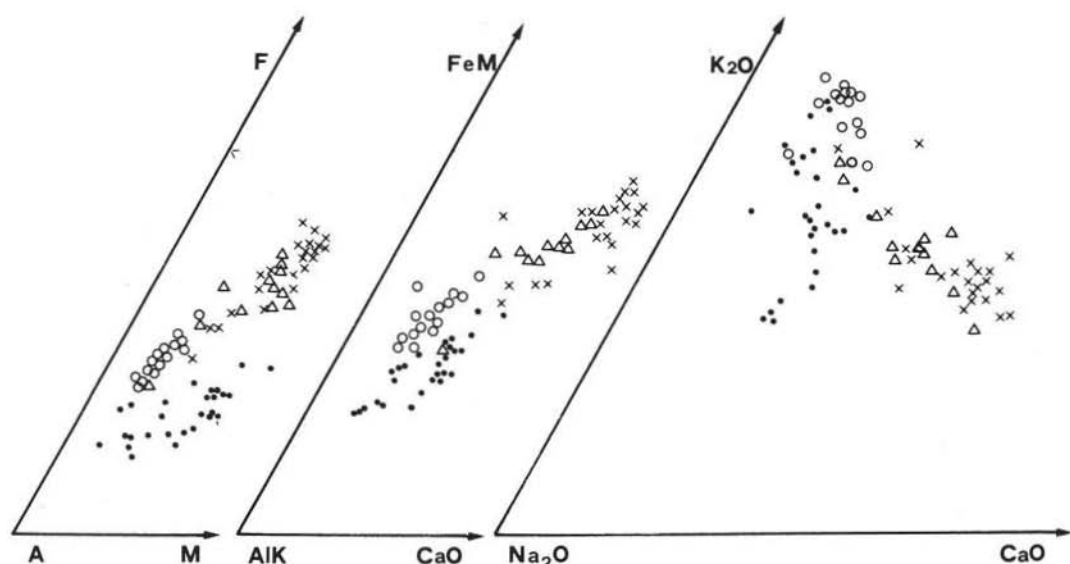


Fig. 8. — Chemical diagrams of some Stilo Unit granitoids: $\text{FeO}_{\text{tot}}-(\text{Na}_2\text{O} + \text{K}_2\text{O})-\text{MgO}$; $(\text{FeO} + \text{Fe}_2\text{O}_3 + \text{MgO} + \text{MnO} + \text{TiO}_2)-(\text{Na}_2\text{O} + \text{K}_2\text{O})-\text{CaO}$; $\text{K}_2\text{O}-\text{Na}_2\text{O}-\text{CaO}$. Symbols as in Fig. 6.

compared types. In the major oxides and trace elements vs. Larsen Index diagrams (Figs. 6 and 7) the Monte Cacciagrande samples appear to follow trends parallel with the Cittanova samples because of higher $\text{FeO} + \text{Fe}_2\text{O}_3$, K_2O , TiO_2 , Nb, Zr, V and Rb contents and lower CaO, Na_2O , Ba and Sr contents. The studied samples appear to be correlated with those of the two Serre stocks, in fact most elements define smooth variation trend with clear positive correlations for SiO_2 , K_2O , Na_2O , Rb and Nb, and clear negative correlations for the other oxides, V and Sr. Y shows a certain degree of scattering in the two stocks. The overall pictures (Figs. 6 and 7) are typical of a calc-alkaline intrusive suite.

The evidence seen in Figs. 6 and 7 is supported by the F-A-M, Fem-ALK-CaO, $\text{K}_2\text{O}-\text{Na}_2\text{O}-\text{CaO}$ (Fig. 8) and Sr-Ca, SiO_2 -Rb/Sr (Fig. 9) diagrams, as a whole, the two Serre stock samples and the Monte Cacciagrande samples define a typical calc-alkaline magmatic trend. The Cittanova samples, scattered only in the $\text{K}_2\text{O}-\text{Na}_2\text{O}-\text{CaO}$ diagram, appear to be aligned along parallel trends.

On the basis of the above considerations, it may be suggested that the Monte Cacciagrande peraluminous granite is related to the two Serre stocks. These three intrusions appear to originate from a common calc-alkaline magma, representing different stages of magmatic evolution. The Monte Cacciagrande granite, showing a higher felsic and peraluminous character, is the most fractionated body. It is more difficult to consider the Cittanova body as also belonging to this series.

As regard the parental magma which gave rise to this small calc-alkaline suite, a hypothesis may be made when knowledge on the Serre granitoids is more advanced.

The Monte Cacciagrande granite is analogous to other peraluminous bodies, granodioritic to leucomonzogranitic in composition, characterized by magmatic aluminosilicates and cordierite, outcropping in the Sila Nappe (Northern Calabria). They are considered (BARBIERI et al., 1985; MESSINA et al., 1988) as the most fractionated members of a magmatic calc-alkaline series, ranging in composition from gabbro to leucomonzogranite, which derived from

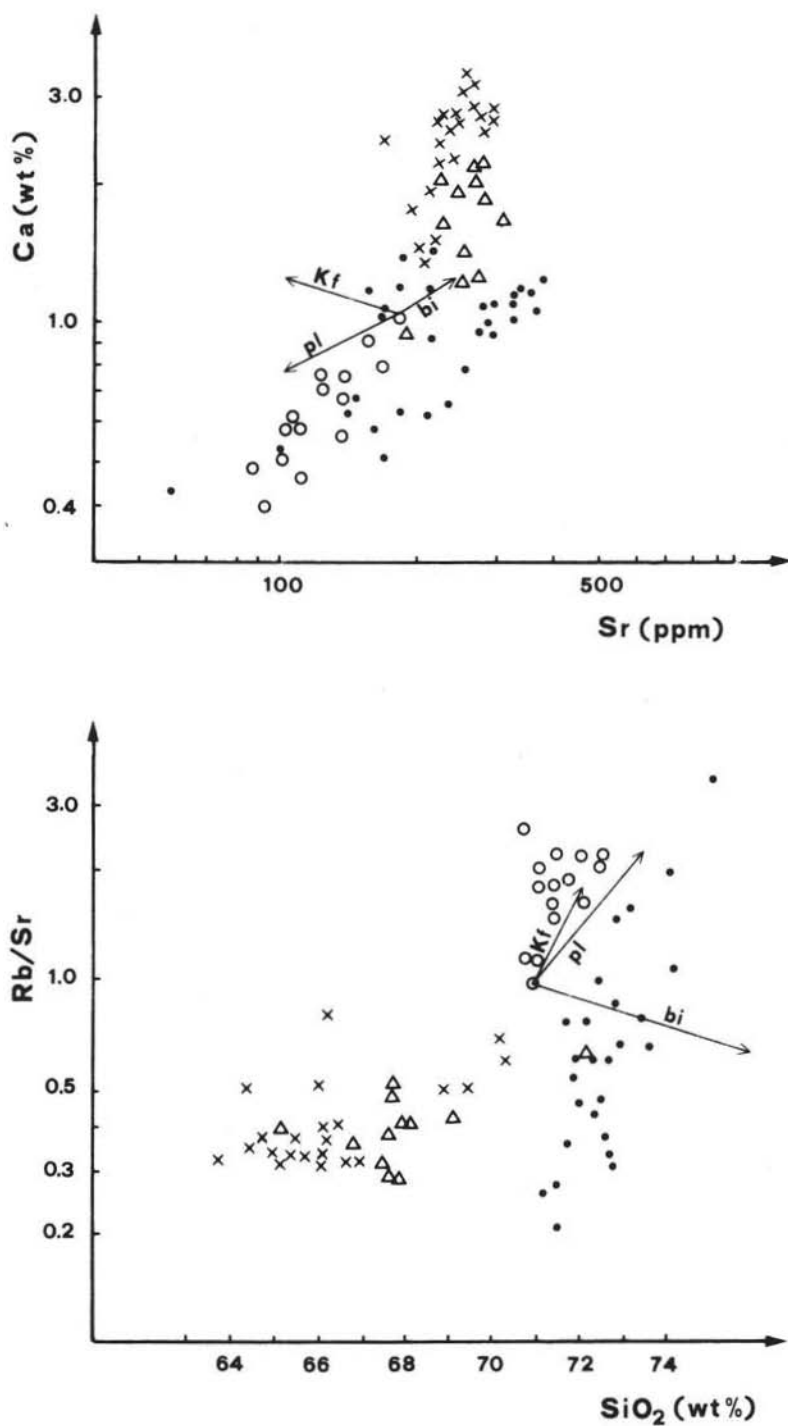


Fig. 9. — Ca vs. Sr and Rb/Sr vs. SiO₂ diagrams of some Stilo Unit granitoids. Symbols as in Fig. 6. Vectors indicate elemental variations for 20% fractionation of the three most abundant phases.

fractional crystallization of a subcrustal magma, supplemented by crustal contamination.

The crystallization conditions of the studied granitic mass may be inferred from the relations shown by the Al-rich minerals. The presence of sillimanite and cordierite, as magmatic phases, indicates $T > 710^{\circ}\text{C}$ and P not exceeding 6 Kb (FLOOD & SHAW, 1975) and the transformation andalusite to magmatic muscovite indicates $T \approx 660 - 710^{\circ}\text{C}$ and $\text{PH}_2\text{O} \approx 3.9$ Kb (CLARKE et al., 1976).

As far as the deformative event is concerned, the location of the Monte Cacciagrande granite at the southernmost end of the Stilo unit suggests that the deformation was the result of emplacement of the Stilo and Aspromonte Units in Alpine times.

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