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MINERALOGICAL AND GEOCHEMICAL STUDY OF K-FELDSPAR MEGACRYSTS FROM THE ELBA (ITALY) GRANODIORITE **

Abstract — K-feldspar megacrysts from the M.te Capanne granodiorite stock (Elba Island, Italy) have been studied. Petrographical mineralogical and chemical data about these megacrysts and the associated minerals have been collected. All these data, mainly the petrographic features of the megacrysts and their chemical data together with those of groundmass K-feldspar (distribution of the Na, Rb, Sr and Ba) suggests that the great K-feldspar individuals have crystallized in an early magmatic stage.

Riassunto — Vengono riportati i risultati di uno studio petrografico, mineralogico e chimico sui megacristalli di feldspato potassico presenti nella granodiorite del M. Capanne (Isola d'Elba). I dati raccolti ed in particolare le caratteristiche tessiturali e chimiche (distribuzione di Na, Rb, Sr e Ba) dei megacristalli di feldspato potassico e del feldspato potassico della massa di fondo, suggeriscono che i grossi cristalli di feldspato potassico hanno cristallizzato in uno stadio magmatico precoce e che debbono quindi essere considerati come veri e propri fenocristalli.

INTRODUCTION

Almost everywhere in the world is a plutonic intrusion ranging in composition from granite to granodiorite, K-feldspar megacrysts (K.F.m) have been found. The K.F.m may be microcline or orthoclase. They are almost always distributed in the peripheral portion of the intrusion and characterized by an external morphology dominated by the expansion of (010), planes. There are in the literature two prevailing opinion about the genesis of these K.F.m:

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** Running title: «K-feldspar megacrysts from Elba granodiorite (Italy)».

a) the K.F.m are of magmatic genesis. This interpretation is supported by chemical data (PIRANI and SIMBOLI [1963]; KERRICK [1969]; FERNANDEZ and SABOURDY [1969]) and microscopic observations (HIBBARD [1965]; FRANZINI and LEONI [1973]).

b) The K.F.m are of postmagmatic genesis. This interpretation is supported by the observations that the megacrysts contain the minerals of the groundmass (TRIAT [1969]; MARINELLI [1959]).

In this work we report the results obtained in a chemical and mineralogical study of the K-feldspar megacrysts from the Elba granodiorite. We conclude that the Elba K.F.m are of magmatic genesis.

The M.te Capanne (Elba Island, Italy) granodiorite forms a small pluton (the extension of the outcrop is about 42 Km²) of tertiary age (about six m.y.) (BORSI, FERRARA and TONGIORGI [1967]).

The M.te Capanne granodiorite has been carefully studied by MARINELLI [1959]; GOTTARDI [1954] [1957]; COCCO, GOTTARDI and TONANI [1957]. These authors clarified many petrographical and chemical features of the M.te Capanne granodiorite and of its minerals.

As to K.F.m no conclusive evidence is presented for the relative time of their crystallization. The opinion expressed by MARINELLI [1959] is that they are of a late stage of crystallization, and in particular that they have crystallized after the crystallization of the orthoclase of the groundmass. For a detailed description of the M.te Capanne granodiorite see the quoted authors. For our purposes it is sufficient to quote the following data

— In the M.te Capanne pluton two facies can be distinguished: a normal facies and a peripheral one. The distinction is based on the distribution of the K.F.m. The peripheral facies contains many K.F.m. (more than about 60 per m²), while the normal facies contains only a very small number of K.F.m or no K.F.m at all. There is obviously a complete and continuous passage between the two facies; sometimes there are some small bands which may contain up to 40% by volume of megacrysts (MARINELLI [1959]). Sometimes the megacrysts disappear in the neighborhood of the contact with the wall rocks. In this instance the K.F.m are substituted by allotriomorphic quartz megacrysts (MARINELLI [1959]). The normal facies and the peripheral facies have the same modal

composition and chemical composition (MARINELLI [1959]), (COCO, GOTTARDI and TONANI [1957]). The mean modal analysis of the granodiorite is the following (MARINELLI [1959]):

Plagioclase	35 - 37%
Orthoclase	23 - 25%
Quartz	23 - 25%
Biotite and acc.	11 - 14%

SAMPLES STUDIED

Nine samples (Table 1) of granodiorite of the M.te Capanne (Elba Island, Italy) were selected for this study. All the samples were collected in active quarries. The nine samples can be subdivided into two groups: samples 3, 10, 11, 16, 17 normal facies; samples 6, 7, 8, 9 peripheral facies.

TABLE 1 - *Some features of the samples studied.*

Sample	Facies	K-Feldspar megacrysts vol. %	Locality
3	normal	0.5	Poggio
10	normal	0.1	Fosso di Vallebuia
11	normal	0.1	Fosso di Vallebuia
16	normal	0.1	S. Piero in Campo
17	normal	0.1	S. Ilario in Campo
9	peripheral	2.5	Pomonte
6	peripheral	10.0	Aia
7	peripheral	10.0	Aia
8	peripheral	16.0	Colle d'Orano

For every sample of normal facies at least one K.F.m. has been collected. Samples 6 to 9 have been collected in order to have the greatest variation in the content of K.F.m. Samples containing more than 16% by volume of K.F.m have not collected because field observations (as an example isoorientation of K.F.m) suggest that they represent local phenomena of concentration of K.F.m subsequent to their crystallization.

Microscopic observations

The K.F.m contains all the minerals that are present in the groundmass. There are however some peculiar features of the minerals included in the K.F.m which have to be considered with some details. The mean modal analysis of K.F.m. (MARINELLI [1959]) is the following:

Orthoclase	90%
Quartz	2%
Plagioclase	6.8%
Biotite	1.2%

The composition and thermal state of plagioclase have been determined utilizing a method proposed by FRANZINI [1965]. The method is based on the measures of extinction angles on Albite-Karlsbad twins oriented by the universal stage. In the range of compositions of interest here the position $\lambda = 45^\circ$ is well suited to make measures. With this orientation it is easy to demonstrate that the standard error is $\pm 15\%$ of the range between high and low temperature and $\pm 1\%$ of the An content. Great care has to be used to avoid Karlsbad twins originated by synneusis (VANCE [1969]). A survey of the thin section has shown that the Karlsbad twins originated by synneusis are very frequent, at least as the growing twins. All the measured plagioclases have low temperature optics. Fig. 1 and 2 report some determinations respectively for groundmass plagioclases and for plagioclases included in K.F.m. The groundmass plagioclases, with mean apparent dimensions of about 2 - 3 mm have almost always a highly corroded nucleus (40 - 45% An), a large intermediate portion, characterized by an oscillatory zoning (25 - 35% An), which represents the bulk of the crystal and a very thin peripheral zone (10 - 15% An). The plagioclases included in the megacrysts are smaller (0.2 - 0.5 mm) than the groundmass plagioclases. They are sometimes perfectly idiomorph and sometimes highly corroded.

Concerning their composition they correspond to the central portion of the plagioclases of the groundmass. They have corroded nucleus (40 - 45% An) followed by a peripheral portion, characterized by oscillatory zoning, with 25 - 35% An. This portion is not as well developed as in groundmass plagioclases. The acid border (10 - 15% An) is lacking; there is sometimes a very thin

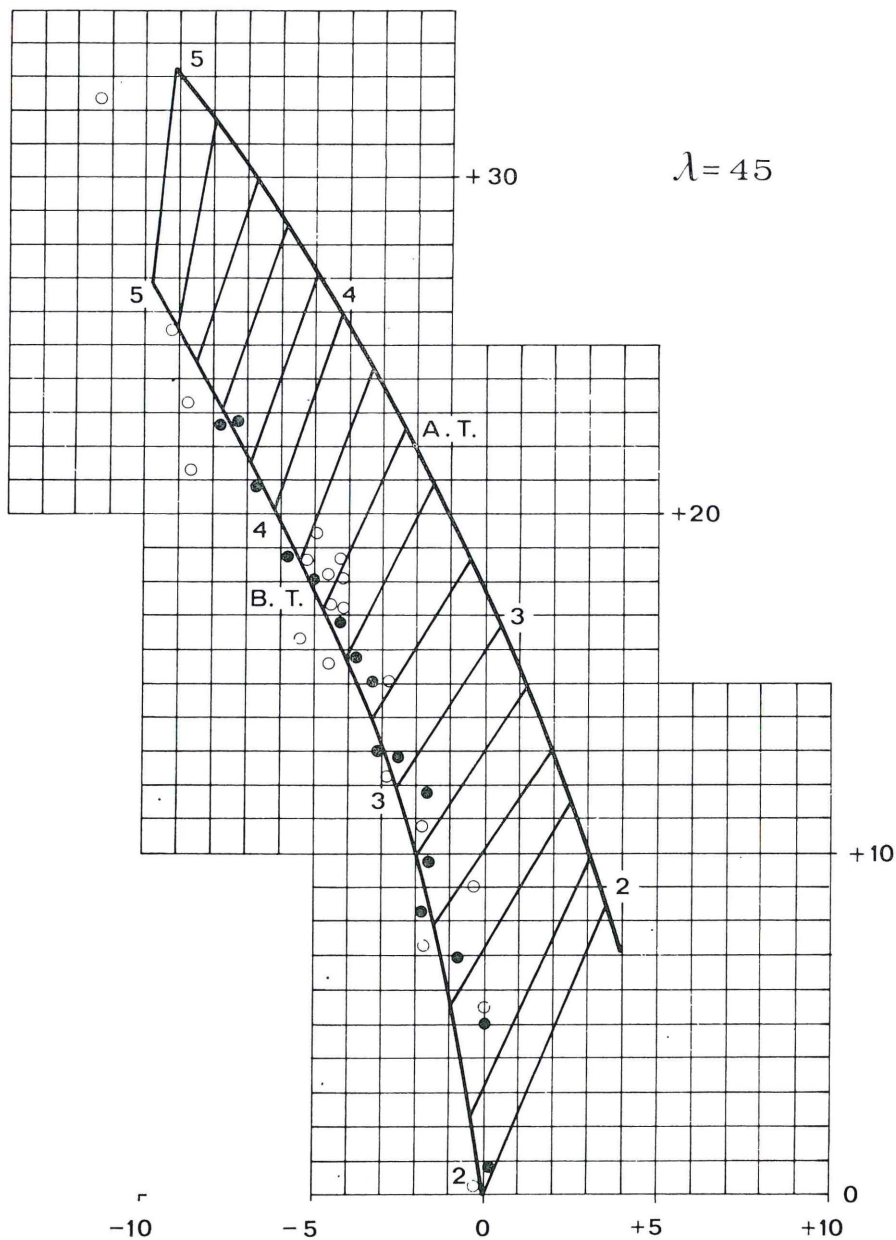


Fig. 1 - Diagram showing the compositions and thermal state of the groundmass plagioclases; the diagram has been drawn for Albite-Karlsbad twins at $\lambda = 45$ (FRANZINI M. [1965]). Open circles: normal facies; solid circles: peripheral facies

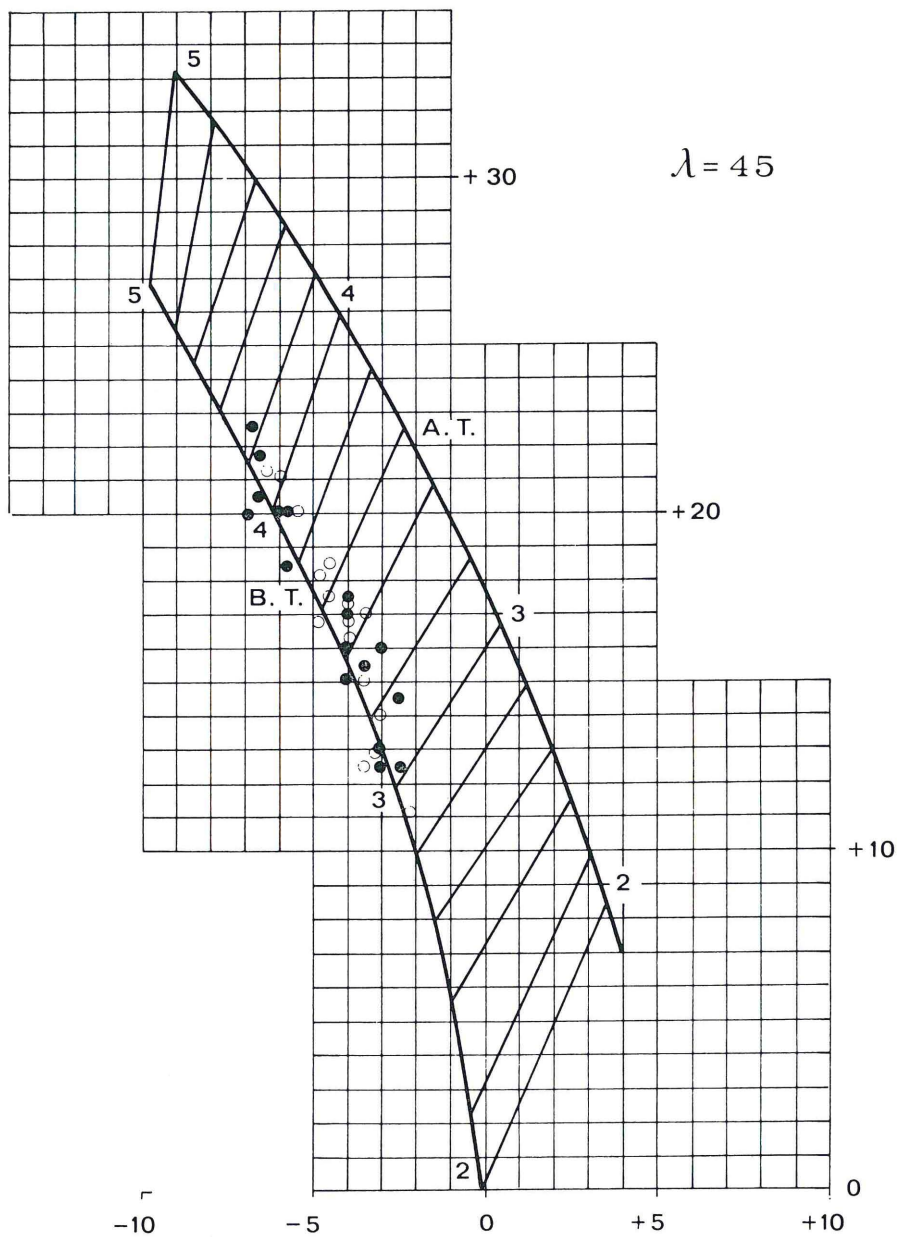


Fig. 2 - Diagram showing the composition and thermal state of the plagioclases included in megacrysts: the diagram has been drawn for Albite-Karlsbad twines at $\lambda = 45$ (FRANZINI M. [1965]). Open circles: normal facies; solid circles: peripheral facies.

rim of almost pure albite, which however is not in optical continuity with the included plagioclases, or a myrmeckite border.

In a thin section of a megacrysts the composition of all the included plagioclases have been measured optically (this is possible owing to the isorientation of the included plagioclases). The results are reported in Table 2. It appears that the composition of included plagioclases is independent from their position in the K.F.m. At least 90% of the plagioclases crystals included in K.F.m are fully oriented against the orthoclase, exhibiting very strong synneusis phenomena (M. FRANZINI and L. LEONI [1973]).

TABLE 2 - *An contents of plagioclases contained in a megacryst (sample 8).
Optical determinations.*

Zone of the megacryst	number of determinations	composition of the plagioclase nucleus	the plagioclase external bord
core	11	35 - 45	21 - 30
interm. zone	20	37 - 44	23 - 30
peripher. zone	10	34 - 43	25 - 32

The quartz crystals included in K.F.m have sometimes rounded and sometimes skeletal forms. The skeletal forms resembles highly graphic granites. They are distributed at random throughout the whole K.F.m. Fig. 3 reports the optic axis orientations of all the quartz crystals in a K.F.m against the orthoclase crystallographic orientation.

Biotite crystals included in the K.F.m and present in the groundmass have the same pleochroism colours and dimensions. Biotite crystals in the K.F.m are almost fully oriented with their cleavages plane parallel to {010} or {110} of the orthoclase.

X-ray diffraction data

X-ray powder diffraction data have been collected exclusively on orthoclase utilizing a Philips wide range goniometer. Structural state has been determined utilizing the method proposed by (GOLDSMITH and LAVES [1954]) and by (RAGLAND [1970]). Following the method of Goldsmith and Laves all the measured K-feldspars are monoclinic; no separation of (131) peaks has been observed.

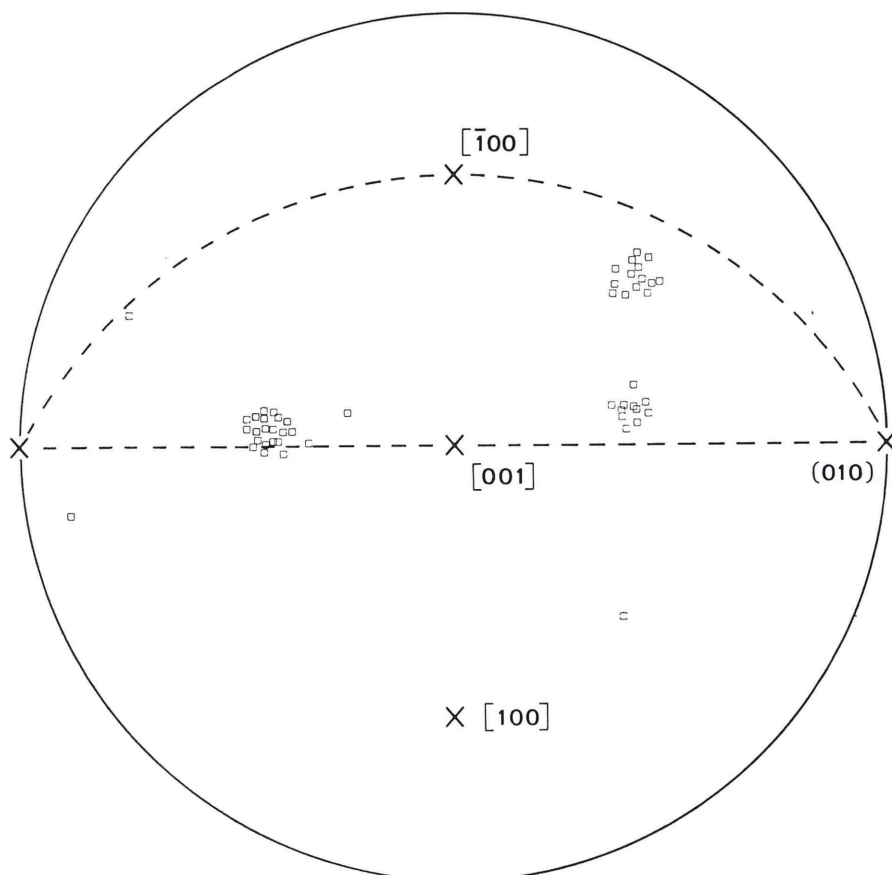


Fig. 3 - Stereographic projection of the optical orientation of the quartz included in a megacrysts against the standard projection of the K-feldspar optical axis of quartz.

The collected data obtained with the other method are reported in table 3. As to the determination of the ratio $Ab/Or + Ab$ Bowen and Tuttle's method [1950] as modified by Orville [1963] has been used. Details of these measurements are given by FRANZINI and LEONI [1973]; these data are reported in table 4.

Chemical analyses

Two powders of each sample have been prepared. The ground-mass, carefully purified from megacrysts, and the megacrysts, carefully purified from groundmass, were ground separately. No effort

TABLE 3 - *The structural state of megacrysts and groundmass K-Feldspars. X-ray data obtained with the method proposed by REGLAND C. [1970].*

Sample	Megacrysts		Groundmass	
	d	Struct. State	d	Struct. State
10	.009	Orthoclase	.070	Orthoclase
11	.066	Orthoclase	.122	Orthoclase
16	.050	Orthoclase	.038	Orthoclase
	— .123	Orthoclase	.070	Orthoclase
7	— .034	Orthoclase	.037	Orthoclase
8	.037	Orthoclase	.090	Orthoclase

TABLE 4 - *The (Ab+An) contents (weight %) in the megacrysts and groundmass K-Feldspars. X-ray and chemical data.*

Sample	Groundmass		Megacrysts	
	X-ray	chemical	X-ray	chemical
6	24.0 (6)	25.8	26.0 (10)	27.4
7	21.0	21.3	25.5	26.5
8	21.0 (8)	21.1	23.0 (11)	24.3
9	18.0	19.5	22.5	22.7
3	17.5 (6)	19.9	22.0 (9)	22.3
10	17.0 (5)	18.2	22.5 (9)	23.7
11	18.0 (6)	17.9	24.0 (12)	25.5
16	16.5	17.8	21.5	22.9
17	16.5	18.1	21.5	22.2

In brackets the values of (Ab+An) contents obtained in natural samples (before their homogeneization).

has been made to prepare a powder of the whole rock owing to the difficulty to have a truly representative powder in presence of the scattered K.F.m. Chemical analyses were carried out on the K.F.m, on groundmass minerals and on the groundmass. Results are reported in tables 5, 6, 7, 8, 9.

Table 5 and 6 report chemical data on megacrysts and K.F.g. From K_2O , Na_2O CaO contents, the composition expressed as (Or + Ab + An) has been computed. The bracketed values give the contents of Al_2O_3 and SiO_2 necessary to construct Ab, An, Or molecules from the Na_2O , CaO , K_2O observed values. We observe

that the measured SiO_2 is always in excess suggesting that the purified K-feldspar samples contain some quartz (about 1.2%). This excess of quartz may be due to the presence of myrmekite. The computed Al_2O_3 values give an idea of the accuracy of the chemical analyses.

TABLE 5 - *Chemical compositions of the megacrysts K-Feldspars.*
The ricalculated values of Ab, Or and An are expressed as weight %.

sample	6	7	8	9	3	10	11	16	17
K_2O	11.97	12.19	12.54	12.89	12.89	12.65	12.36	12.79	12.90
Na_2O	3.06	2.80	2.58	2.45	2.48	2.65	2.85	2.50	2.43
CaO	0.28	0.46	0.42	0.34	0.18	0.16	0.18	0.26	0.24
Al_2O_3	18.54 (18.50)	18.54 (18.64)	18.26 (18.58)	18.50 (18.60)	18.42 (18.36)	18.45 (18.34)	18.34 (18.39)	18.36 (18.43)	18.48 (18.40)
SiO_2	66.15 (64.19)	66.01 (63.90)	66.20 (63.88)	65.82 (64.29)	66.03 (64.12)	66.09 (64.15)	66.27 (64.24)	66.09 (64.03)	65.95 (64.00)
Rb	547	474	521	530	478	444	468	429	480
Sr	236	351	330	424	417	358	417	393	368
Ba	1631	2309	2335	2507	3335	3177	3048	2761	2634
Or	72.2	73.5	75.6	77.3	77.7	76.3	74.5	77.1	77.8
Ab	26.4	24.2	22.3	21.0	21.4	22.9	24.6	21.6	21.0
An	1.4	2.3	2.1	1.7	0.9	0.8	0.9	1.3	1.2

TABLE 6 - *Chemical compositions of the groundmass K-Feldspars.*
The ricalculated values of Ab, Or and An are expressed as weight %.

sample	6	7	8	9	3	10	11	16	17
K_2O	12.32	13.22	13.21	13.33	13.12	13.37	13.83	13.84	13.80
Na_2O	2.78	2.31	2.29	2.07	2.16	1.99	2.00	1.94	1.99
CaO	0.35	0.33	0.30	0.31	0.18	0.16	0.18	0.26	0.24
Al_2O_3	18.60 (18.54)	18.50 (18.70)	18.50 (18.61)	18.32 (18.39)	18.24 (18.08)	18.20 (18.03)	18.35 (18.59)	18.23 (18.64)	18.40 (18.64)
SiO_2	65.95 (64.05)	65.64 (64.72)	65.70 (64.50)	65.97 (63.70)	66.30 (63.14)	66.28 (63.07)	65.64 (64.93)	65.73 (64.79)	65.57 (64.88)
Rb	712	718	692	630	510	617	577	521	578
Sr	172	254	176	200	309	211	218	298	228
Ba	674	843	860	929	1100	951	1105	1268	989
Or	74.2	78.7	78.9	80.5	80.1	81.8	82.1	82.2	81.9
Ab	24.0	19.6	19.6	17.9	18.9	17.4	17.0	16.5	16.9
An	1.0	1.7	1.5	1.6	1.0	0.7	0.9	1.3	1.2

Table 7 reports the chemical analyses of groundmass plagioclases. From Na_2O , CaO , and K_2O values the theoretical values of Al_2O_3 and SiO_2 have been computed (bracketed values). It results that the analyzed samples are very impure containing from about 40% to about 50% of quartz. A K-feldspar with a composition (expressed as $\text{Or}_x\text{Ab}_{1-x}$) given by table 4 has been computed from

TABLE 7 - *Chemical compositions of groundmass plagioclases.*
The ricalculated values of Ab and An are expressed as weight %.

sample	6	7	8	9	3	10	11	16	17
Na_2O	3.72	3.78	3.82	4.09	4.25	3.80	3.91	3.64	3.19
CaO	1.50	2.75	2.73	3.20	3.29	2.91	2.78	3.24	2.41
K_2O	1.54	0.79	0.92	1.06	0.91	1.93	1.66	2.37	0.91
Al_2O_3	10.66 (10.51)	12.26 (12.08)	12.39 (12.25)	14.07 (13.69)	14.07 (13.96)	14.10 (13.63)	13.26 (13.28)	14.82 (14.44)	10.85 (10.61)
SiO_2	82.58 (30.73)	80.42 (30.90)	80.14 (31.58)	77.58 (34.70)	77.48 (35.24)	77.26 (35.72)	78.39 (35.04)	75.94 (37.18)	82.64 (27.20)
Rb	68	18	16	20	30	14	29	13	20
Sr	210	394	364	415	450	481	445	505	460
Ba	66	139	140	92	95	145	140	150	140
Ab	80.0	70.0	70.5	69.0	69.0	69.0	70.0	67.0	69.0
An	20.0	30.0	29.5	31.0	31.0	31.0	30.0	33.0	31.0

TABLE 8 - *Chemical compositions of the groundmass biotites.*

sample	6	7	8	9	3	10	11	16	17
SiO_2	41.26	36.18	37.19	36.78	36.87	37.00	37.84	37.16	36.26
Al_2O_3	17.16	15.41	14.91	15.30	15.92	15.33	15.22	15.38	15.46
Fe_2O_3	16.80	21.79	21.27	21.35	21.01	20.66	20.14	19.86	20.57
MgO	8.00	9.76	9.65	9.53	9.74	9.83	9.90	10.55	10.61
CaO	0.80	0.89	0.63	0.96	0.91	0.70	0.85	0.87	0.88
Na_2O	n.	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
K_2O	8.09	7.42	8.02	7.45	7.20	7.70	8.09	7.86	7.71
MnO	0.29	0.36	0.26	0.37	0.31	0.33	0.33	0.30	0.33
TiO_2	3.47	3.42	3.54	3.21	3.35	3.18	3.29	3.24	3.25
P_2O_5	0.25	0.28	0.23	0.27	0.31	0.33	0.40	0.39	0.36
I.L	4.66	5.59	5.36	5.80	5.30	5.43	5.26	5.09	5.30
Rb	1857	1094	1148	1148	1095	970	1174	984	1019
Sr	10	18	16	9	24	20	16	19	21
Ba	530	779	690	661	802	610	677	821	814

K₂O values. The remaining Na₂O and the total CaO have been utilized to compute the composition of plagioclase.

Tables 8 and 9 report the chemical compositions of biotites contained respectively in the groundmass and in K.F.m.

In table 10 are reported the chemical compositions of the

TABLE 9 - *Chemical compositions of the biotites included in megacrysts*

	7	8	9	3	10	11	16	17
SiO ₂	39.68	39.98	38.88	36.99	36.76	36.87	36.70	36.69
Al ₂ O ₃	15.80	15.91	16.15	16.09	15.58	15.43	15.26	16.20
Fe ₂ O ₃	20.07	19.39	20.20	20.67	20.80	21.01	20.43	20.63
MgO	8.71	9.10	9.32	10.36	10.80	10.54	11.01	11.18
CaO	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Na ₂ O	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
K ₂ O	8.30	8.49	8.12	8.22	8.64	8.48	8.48	8.39
MnO	0.32	0.30	0.33	0.34	0.33	0.31	0.30	0.33
TiO ₂	3.28	3.21	3.17	3.42	3.54	3.57	3.60	3.20
P ₂ O ₅	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
I.L.	5.42	5.11	5.40	5.60	5.32	5.53	5.34	5.28
Rb	902	928	1024	1145	992	1007	1042	987
Sr	9	14	15	10	17	11	11	7
Ba	809	753	802	834	781	689	836	791

n.d. = no determined

TABLE 10 - *Chemical composition of the Graniodorite (groundmass).*

sample	6	7	8	9	3	10	11	16	17
SiO ₂	70.74	67.97	68.78	67.99	66.87	67.57	66.91	66.77	66.98
Al ₂ O ₃	15.62	15.71	15.30	15.72	15.76	15.22	15.71	15.36	15.60
Fe ₂ O ₃	1.69	3.16	3.13	3.17	3.45	3.48	3.27	3.83	3.23
MgO	0.81	1.37	1.50	1.37	1.84	1.86	1.71	2.19	1.85
CaO	1.37	2.63	2.71	2.63	2.78	2.53	2.79	2.98	2.76
Na ₂ O	3.44	3.17	3.16	3.18	3.32	3.02	3.34	3.09	2.96
K ₂ O	4.94	4.13	3.72	4.13	3.92	4.11	4.13	4.31	4.24
MnO	0.02	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06
TiO ₂	0.33	0.54	0.56	0.54	0.60	0.58	0.59	0.69	0.54
P ₂ O ₅	0.15	0.16	0.13	0.16	0.18	0.17	0.15	0.20	0.18
I.L.	0.89	1.10	0.96	1.05	1.22	1.40	1.34	0.52	1.60
Rb (p.p.m)	400	301	288	284	273	274	275	275	278
Sr (p.p.m)	145	217	209	218	234	230	236	270	255
Ba (p.p.m)	291	339	205	306	342	428	403	500	420

TABLE 11 - *Chemical composition of the whole rock (samples of the peripheral facies).*

Sample	6	7	8	9
SiO ₂	70.22	67.74	68.30	67.92
Al ₂ O ₃	15.91	16.00	15.82	15.79
Fe ₂ O ₃	1.55	2.87	2.67	3.10
MgO	0.75	1.25	1.28	1.34
CaO	1.30	2.44	2.39	2.58
Na ₂ O	3.36	3.11	3.07	3.17
K ₂ O	5.65	4.92	5.03	4.33
MnO	0.02	0.05	0.04	0.06
TiO ₂	0.30	0.49	0.48	0.53
P ₂ O ₅	0.14	0.14	0.11	0.16
I.L.	0.80	0.99	0.81	1.02
Rb (p.p.m.)	413	317	321	290
Sr (p.p.m.)	155	231	228	222
Ba (p.p.m.)	407	511	503	360

TABLE 12 - *Abundance of the megacrysts in the samples of the peripheral facies and average chemical composition (this analysis is comprehensive also of the included minerals).*

Sample	average number of megacrysts per m ² of outcrop		average dimensions	volume %
6	95		5 x 3 x 2.5	10
7	95		5 x 3 x 2.5	10
8	100		6 x 3.5 x 3	16
9	15		6 x 3.5 x 3	2.5
SiO ₂	65.77	K ₂ O	11.95	
Al ₂ O ₃	18.51	MnO	—	
Fe ₂ O ₃	0.28	TiO ₂	0.05	
MgO	0.15	P ₂ O ₅	—	
CaO	0.67	I.L.	0.08	
Na ₂ O	2.62			

groundmass granodioritic rock. For samples 6, 7, 8, 9 (peripheral facies) the chemical composition of the whole rock (table 11) has been computed adding to the data of table 10 the contributions due to K.F.m following the data of table 12. For samples 3, 19, 11, 17 the groundmass analysis can be assumed as representative of the chemical composition of the whole rock.

DISCUSSION OF THE RESULTS

a) All the minerals included in K.F.m are strongly isooriented against crystallographic direction of K-feldspar. In particular we observe every time a clear parallelism between developed faces of included minerals and $\{010\}$, $\{110\}$, $\{001\}$ planes of K.F.m. These observed isoorientations can be explained assuming that the included have entered the K.F.m when the crystallization of the magmatic melt was in an early stage (HIBBARD [1966]), VANCE [1969]) and (FRANZINI and LEONI [1973]). To the same interpretations points also the observed relative dimensions of plagioclases included in K.F.m and those of groundmass as well as their compositions. Many included plagioclases are perfectly euhedral and therefore their smaller dimensions cannot be due to corrosion of the bigger groundmass plagioclases as suggested by MARINELLI [1959]. The observed skeletal and rounded shapes of included quartz crystals are typical of quartz-Orthoclase eutectic crystallization. They cannot be interpreted as due to corrosion.

b) X-ray powder data have shown that the Ab content of K.F.m is greater than that of K.F.g; however the exolved Ab is greater in groundmass K-feldspar than in megacrysts. This last feature is confirmed also by microscopic observations in thin section. For what concerns the total Ab content see table 4 and 5. The problem of exolved albite is puzzling. According to Tuttle and Bowen diagrams [1958], exsolution starts at a temperature inferior to 600° degrees. It is therefore a phenomenon which is independent from the relative crystallization times of K.F.m and K.F.g. Both the minerals were obviously crystallized before that the exsolution took place. It is worth noting that in the megacrysts exsolution in the core of the crystal is scarce whilst at the periphery it is more pronounced, very similar to that of groundmass K-feldspars. Doubtless the cooling velocity has been equal for megacrysts and groundmass K-feldspar. This particular feature may be due to the presence of volatiles which, as is well known, accelerate such chemical reactions as exsolution. Owing to the very great dimensions of the K.F.m it can not be excluded that the effect of volatiles has been more pronounced on the K.F.g and the megacryst periphery than on megacryst cores.

c) MARINELLI [1959]; COCCO, GOTTARDI and TONANI [1957] on the

basis of model analysis and chemical data on the alkali distribution, concluded that no correlation exists between granodiorite chemical composition and megacrysts number. Our chemical data support this conclusion as is particularly well shown by the data of Ba content. It is obvious, as already stated by MARINELLI [1959], that this conclusion is valid only when the megacrysts represent no more than about 10-15% by volume of the rock.

d) The granodiorite chemical analysis emphasize that the granodiorite is substantially homogeneous as far as chemical composition (see MARINELLI [1959], (COCCO, GOTTARDI and TONANI [1957])). The only exception is represented by the sample 6, a sample never analyzed before. Sample 6 has been collected from a great granodiorite block (about 100 m³) in a landslide. The sample has been collected being absolutely non altered. Obviously we do not know its original position in the M.te Capanne granodiorite stock. Sample 6 represent an acid differentiation of the granodiorite, as well shown by chemical analysis of groundmass and its minerals.

e) K-feldspar megacrysts contain more sodium than the groundmass K-feldspar. The enrichment of Na₂O in megacrysts is illustrated in Fig. 3. SECK [1970] studying the distribution of Na₂O between coexisting K-feldspar and plagioclases has shown that, at equilibrium, the content of Na₂O in K-feldspar is a function of plagioclase composition, temperature and total H₂O pressure. In particular the Na₂O content of K-feldspars diminishes with increasing total H₂O pressure and lowering the temperature and the Ab content of plagioclase. As to the Elba granodiorite we can assume that the composition of plagioclases in equilibrium with K-feldspars remained constant during the time in which crystallization of K-feldspars took place. With this assumption confirmed by the collected data, the lower Ab content of groundmass K-feldspars, in comparison with that of megacrysts, suggests that the former have crystallized at a smaller temperature and/or greater H₂O pressure.

The diagrams of SECK [1970] do not permit to evaluate temperature and pressure of crystallization of our feldspars. However they indicate that K.F.m have crystallized, or more precisely, have started their crystallization before the crystallization of K.F.g. In fact we are safe to assume that during the crystallization of the granodioritic magma the temperature lowers and H₂O pressure increases. We have to observe that the high Ab content observed

in the K.F.m of Elba island is not a necessary feature of the K.F.m of other localities. As an example we may quote from the literature K.F.m which contain a smaller Ab quantity than groundmass K-feldspar (KERRICK [1969]). In this instance however K.F.m and K.F.g are accompanied by strongly zoned plagioclases, and this is sufficient to conclude, following Seck's data, that K.F.m (with a lower Ab content) have crystallized before K.F.g (with a higher Ab content). During the crystallization of a granitic magma we may have an increase as well as a lowering of the Ab content in K-feldspars. The two alternatives are linked the first to a preponderance of physical parameters (increase of H₂O pressure and lowering of temperature) and the second to a preponderance of the fractional crystallization of plagioclases.

g) Table 13 report the distribution coefficient of Ba, Sr, Rb between biotites, plagioclase, K.F.m and groundmass orthoclase. The distribution coefficients between biotites and K.F.m and between plagioclase and K.F.m show a smaller variance than the ones between plagioclase and F.K.g and biotites and K.F.g. These data point out the homogeneity of the M.te Capanne granodiorite and suggests that the K.F.m have crystallized before the K.F.g. The feature of the trace elements distribution are illustrated in figures 4, 5, 6.

TABLE 13 - *Distributions coefficients of Ba and Rb between Biotite/K.F.m and Biotite/K.F.g, and distribution coefficient of Sr between Plagioclase/K.F.m and Plagioclase/K.F.g.*

	Rb		Ba		Sr	
	Aver.	Stand. dev.	Aver.	Stand. dev.	Aver.	Stand. dev.
Biot./K.F.m	2.26	0.11	0.276	0.049	—	—
Biot./K.F.g	1.80	0.22	0.742	0.107	—	—
Plag./K.F.m	—	—	—	—	1.12	0.13
Plag./K.F.g	—	—	—	—	1.82	0.30

Ba is distributed between biotite, plagioclases and K-feldspar. The Ba content of plagioclases is very low compared with the one of other minerals. The average K/Ba ratio is 38 for Megacrysts, (for the granodiorite and 107 for groundmass K-feldspar (fig. 4). Therefore the Ba is enriched in megacrysts and depleted in groundmass K-feldspar against the whole rock. Furthermore the Ba is

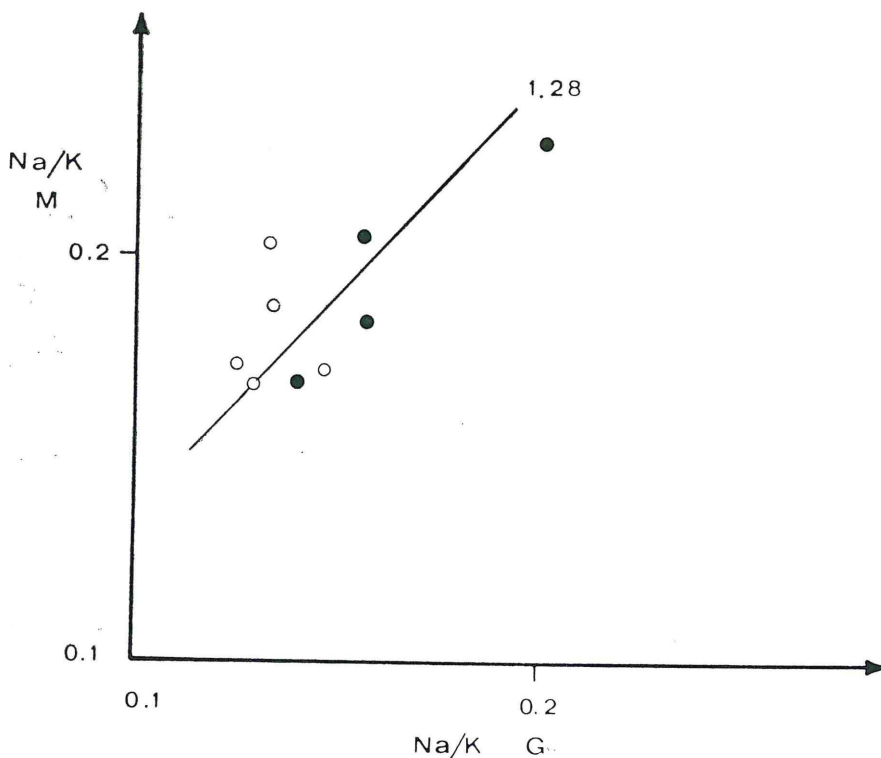


Fig. 4 - The Na/K ratio of megacrysts (M) are reported against the Na/K of groundmass K-feldspars (G). Open circles: normal facies; solid circles: peripheral facies.

enriched in megacrysts against groundmass K-feldspars (average enrichment 2.82). The K/Ba ratio in both the K-feldspars is greater in peripheral facies than in normal one. This feature is due to the presence of a greater number of K-feldspar megacrysts (containing a great amount of Ba) in peripheral facies than in normal ones) whilst the total Ba content of the two studied facies is very similar. The observed Ba distribution suggests strongly that K.F.m have crystallized before K.F.g.

The distribution of Sr in K-feldspars (fig. 5) follows that of Ba and Ca. However the informations given by this element for what concerns the relative times of crystallization of the two K-feldspars are not so easy to interpretate. A great amount of Sr is in fact contained in plagioclase, that is a mineral whose crystallization is partially contemporaneous to that of K-feldspars.

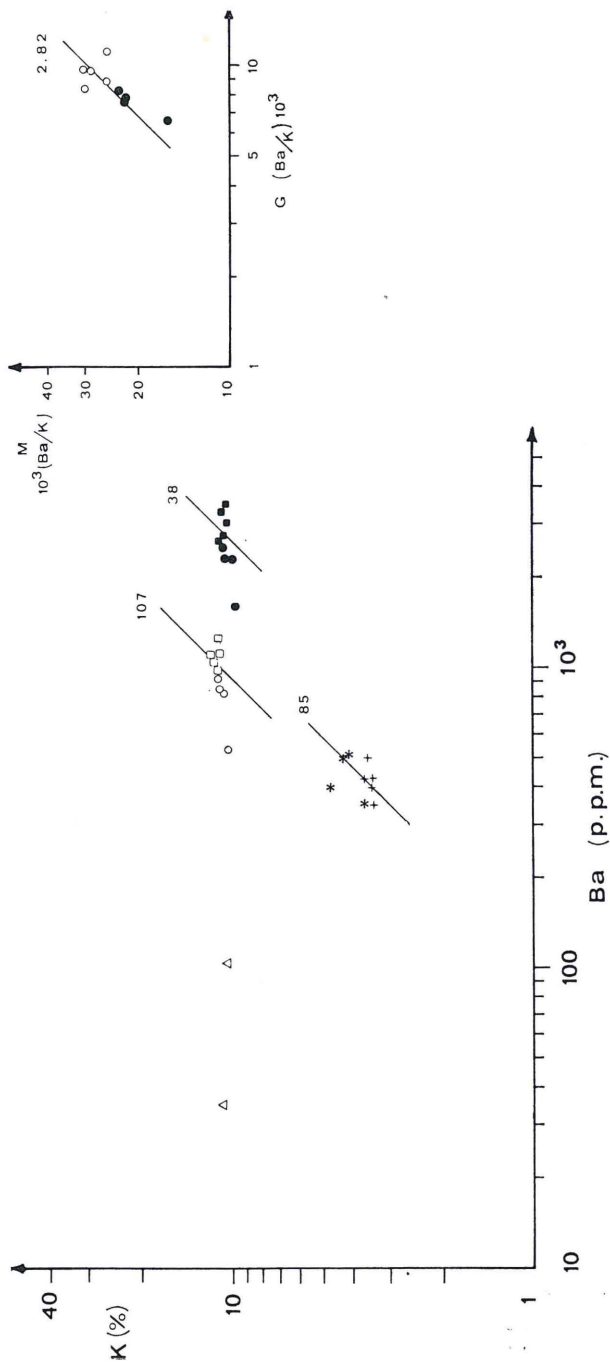


Fig. 5 - The contents of K (weight %) are plotted against the contents of Ba (p.p.m.). Open circles: groundmass K-feldspars of the peripheral facies; solid circles: megacrysts of the peripheral facies; solid square: megacrysts of the normal facies; cross: groundmass of the normal facies; asterisk: groundmass of the peripheral facies; on the top right of the figure is reported the diagram showing the Ba/K ratio of megacrysts (M) against the Ba/K ratio of groundmass K-feldspars (G). Open circles: normal facies; solid circles: peripheral facies.

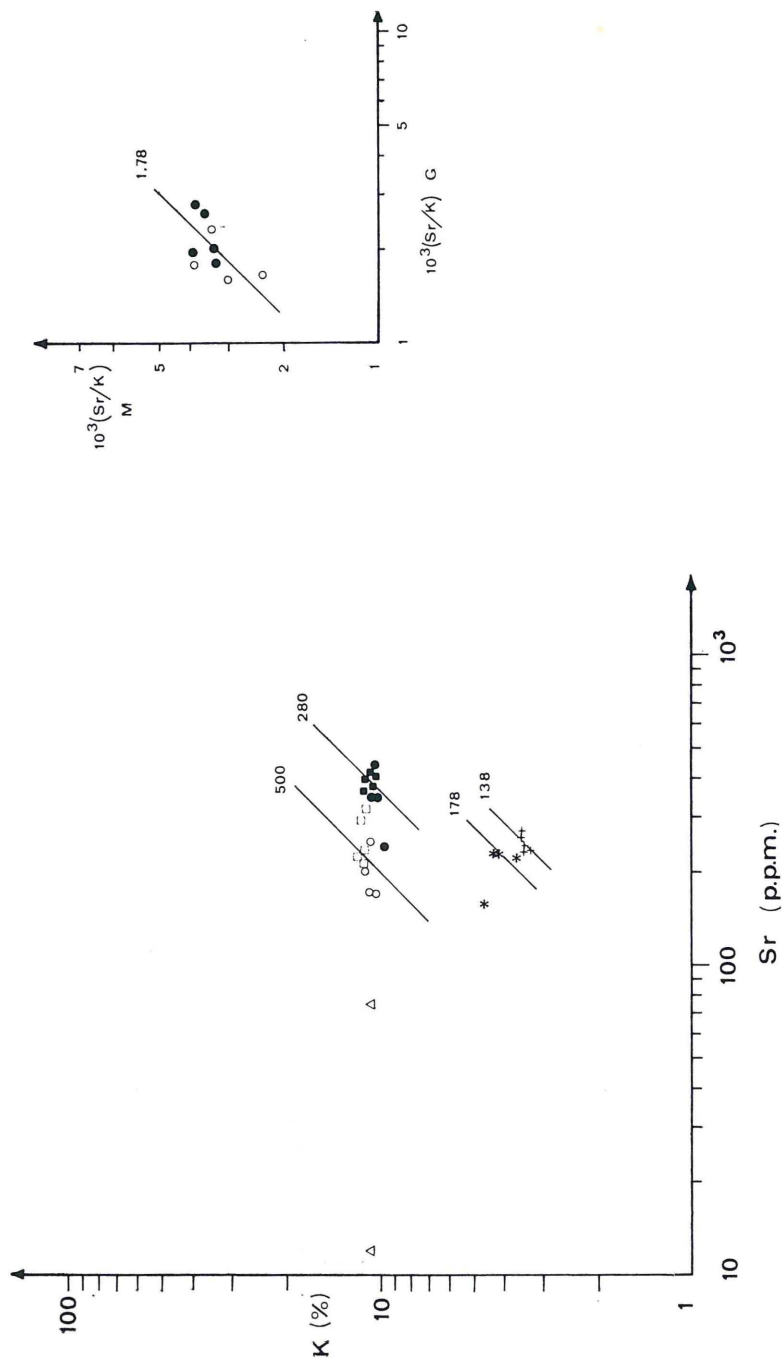


Fig. 6 - The content of K (weight %) are plotted against the contents of Sr (p.p.m.). On the top right of the figure is reported the diagram showing the Sr/K ratio of megacrysts (M) against the Sr/K ratio of groundmass K-feldspars. The same notations of Fig. 4 has been used.

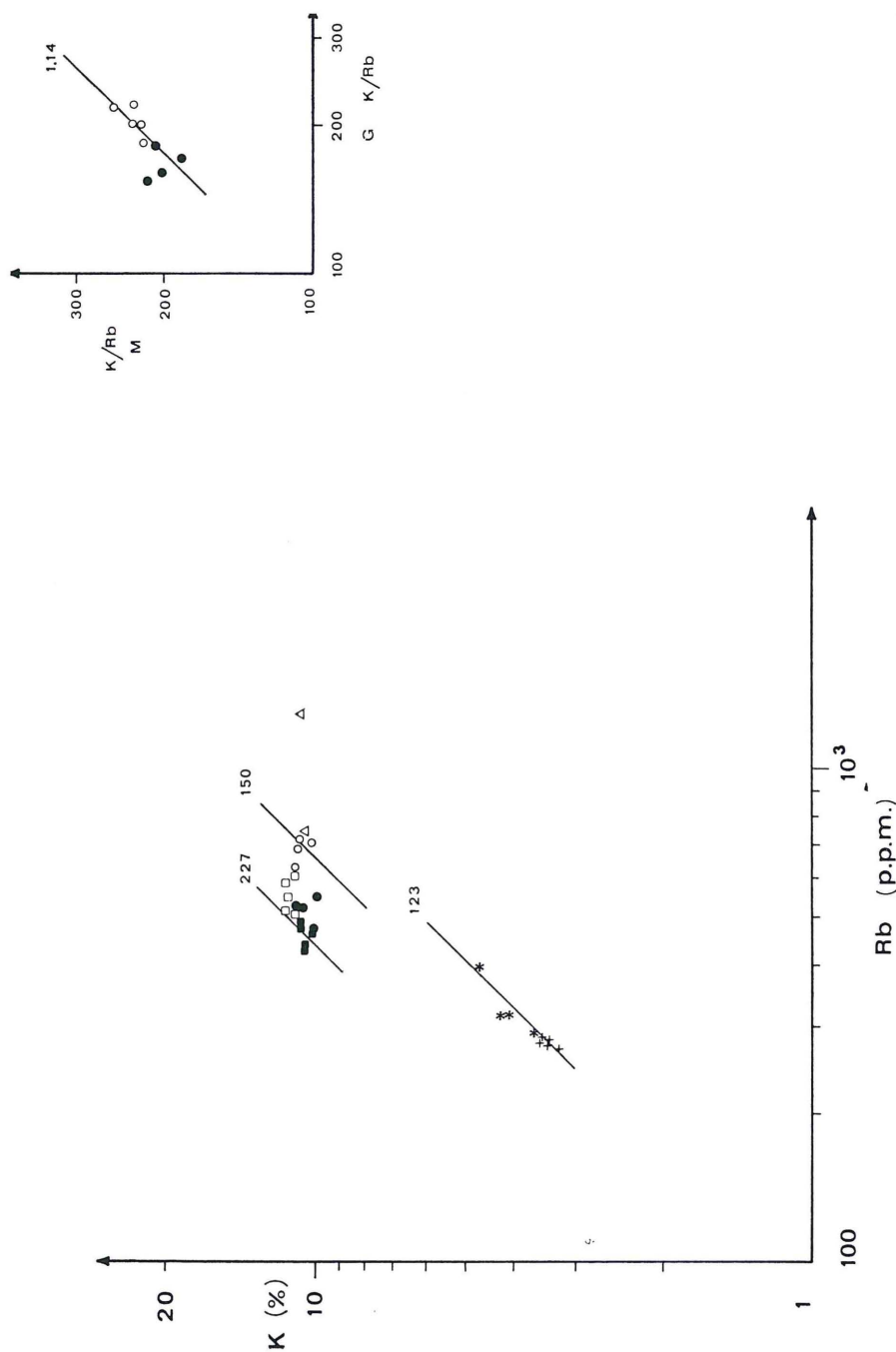


Fig. 7 - The contents of K (weight %) are plotted against the contents of Rb (p.p.m.). On the top of the figure is reported the diagram showing the K/Rb ratio of megacrysts (M) against the K/Rb ratio of groundmass K/feldspars. The same notations of Fig. 4 has been used.

The following table reports the mean values of Ba/K, Sr/K, Ca/K in the two K-feldspars:

	Megacrysts ($\times 10^3$)	Groundmass K-feldspars ($\times 10^3$)	K.Fm/K.F.g
Ba/K	26.3	9.34	2.82
Sr/K	3.6	2.02	1.78
Ca/K	18.8	15.66	1.20

The data, with some care for what concerns the Sr/K and Ca/K ratios, which may be modified by the presence of plagioclases, follow the observation of HEIR and TAYLOR [1959].

The Rb distribution (fig. 6) follows that of K. Therefore this element is contained in biotite and K-feldspar. The Rb is slightly enriched (1.14) in K.F.g against K.F.m. Following the data of DUPUY [1968] and BARBIERI et al. [1968] the distribution of Rb suggests that the megacrysts have crystallized before groundmass K-feldspar.

CONCLUSION

The discussion of the collected data has pointed out that the K-feldspar megacrysts of the Elba granodiorite have an early magmatic genesis. We can specify that K-feldspar megacrysts have started their crystallization after biotite, and almost contemporaneously to plagioclase.

Their crystallization has continued until the total solidification of the rock; their peripheral portion therefore is contemporaneous to groundmass K-feldspar.

The genesis of the K-feldspar megacrysts in the peripheral facies is probably to be referred either to the particular chemical composition of the melt which caused an early crystallization of K-feldspars or to particular physical condition as a relatively high volatile pressure which permitted an high ionic mobility in the melt. These physical conditions have been realized in the peripheral facies, and not in the normal ones.

The last field observations, we have to explain, is the presence of concentration zone of K-feldspar megacrysts (up to 40% by

volume). In our hypothesis this phenomena are local secondary phenomena. We think that they are due to mechanical concentrations of performed K-feldspar megacrysts due to convective motions in the pluton. This interpretation is supported by observed partial isoorientation of K-feldspar megacrysts.

REFERENCES

- BARBIERI M., FORNASERI M., PENTA A. (1968) - Rubidium and Potassium relationship in some volcanoes of central Italy. *Chem. Geology*, **3**, 189-197.
- BORSI S., FERRARA G., TONGIORGI E. (1967) - Determinazione col metodo K/Ar dell'età delle rocce magmatiche della Toscana. *Boll. Soc. Geol. Ital.*, **86**, 403-410.
- COCCO G., GOTTARDI G., TONANI F. (1957) - Ricerche di metodologie geochimiche. III. Confronto tra il metodo chimico e metodo fotometrico di fiamma nella determinazione degli alcali. Distribuzione degli alcali nella granodiorite del M. Capanne (Isola d'Elba). *Period. Mineral.*, **26**, 103-305.
- DUPUY C. (1968) - Rubidium and Caesium in biotite, sanidine and glass in Tuscany ignimbrites (Italy). *Chem. Geology*, **3**, 281-291.
- FERNANDEZ A., SABOURDY G. (1969) - Contribution à l'étude géochimique des Megacrists de feldspath dans les granites porphyroïdes. *C.R. Acad. Science, Paris, Ser. D*, **269**, 2066-2069.
- FRANZINI M. (1965) - Sulla determinazione della composizione e dello stato termico dei plagioclasi geminati albite-karlsbad. *Atti Soc. Tosc. Sc. Nat., Mem., Serie A*, **72**, 3-22.
- FRANZINI M., LEONI L. (1972) - A full matrix correction in X-ray fluorescence analysis of rock samples. *Atti Soc. Tosc. Sc. Nat., Mem., Serie A*, **79**, 7-22.
- FRANZINI M., LEONI L. (1973) - Synneusis of plagioclase with K-feldspar in M.te Capanne (Elba Island) granodiorite. *Rendic. Soc. Ital. Miner. e Petrol.*, in press.
- GOLDSMITH J. R., LAVES F. (1954) - Potassium feldspars structurally intermediate between microcline and sanidine. *Geochim. et Cosmochim. Acta*, **6**, 100-118.
- GOTTARDI G. (1954) - Studi sulla distribuzione del Sodio e del Potassio nella granodiorite elbana. *Rend. Soc. Min. Ital.*, **10**, 3-15.
- GOTTARDI G. (1957) - Sui feldspati della granodiorite terziaria elbana. *Atti Soc. Tosc. Sc. Nat., Serie A*, **64**, 120-132.
- HEIR K. S., TAYLOR S. R. (1959) - Distribution of Ca, Sr and Ba in southern Norwegian pre-Cambrian alkali feldspars. *Geochim. et Cosmochim. Acta*, **17**, 286-304.
- HIBBARD M. J. (1965) - Origin of some alkali feldspar phenocrysts and their bearing in petrogenesis. *Am. Journal Science*, **263**, 193-203.
- KERRICK D. M. (1969) - K-feldspar megacrysts from a porphyritic quartz monzonite, Central Sierra Nevada, California. *Amer. Mineral.*, **54**, 839-847.
- JAMES R. S., HAMILTON D. L. (1969) - Phase relations in the system $\text{NaAlSi}_3\text{O}_8$ - $\text{KAl}_2\text{Si}_2\text{O}_8$ at 1 Kilobar water vapour pressure. *Contr. Mineral. Petr.*, **21**, 111-141.

- ORVILLE P. M. (1963) - Alkali ion exchange between wapor and feldspar phases. *Amer. J. Science*, **261**, 201-237.
- RAGLAND P. C. (1970) - Composition and structural state of the potassic phase in perthites as related to petrogenesis of a granite pluton. *Lithos*, **9**, 161-167.
- PIRANI R., SIMBOLI G. (1963) - La genesi del granito sardo dell'altipiano di Budduso. Nota di geochimica e di struttura dei principali costituenti mineralogici. I. Il feldspato potassico. *Min. Petrogr. Acta*, **9**, 179-214.
- SECK H. A. (1971) - Der Einfluss des Druck auf Zusammensetzung Koexistierender Alkalifeldspate und plagioklase im System $\text{NaAlSi}_3\text{O}_8$ - KAlSi_3O_8 - $\text{CaAl}_2\text{Si}_2\text{O}_8$ - H_2O . *Contr. Mineral. and Petrol.*, **31**, 67-86.
- TRIAT J. M. (1969) - La symmetrie des feldspath alcaline du granite de plan de la Tour (Var). *Bull. Soc. Franç. Mineral. Cristall.*, **92**, 49-59.
- TUTTLE O. F., BOWEN N. L. (1958) - Origin of granite in the light of experimental studies in the System $\text{NaAlSi}_3\text{O}_8$ - SiO_2 - H_2O . *Geol. Soc. Am. Mem.*, **74**.
- VANCE A. J. (1969) - On synneusis. *Contr. Mineral. Petrol.*, **24**, 7-29.

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