Chemical Geology, 16 (1975) 153—177
© Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

GEOCHEMISTRY OF COEXISTING APLITES AND PEGMATITES AND OF THEIR MINERALS FROM CENTRAL NORTHERN PORTUGAL

A.M.R. NEIVA*

Department of Mineralogy and Geology, University of Coimbra, Coimbra (Portugal)

(Received October 31, 1974; revised and accepted June 25, 1975)

ABSTRACT

Neiva, A.M.R., 1975. Geochemistry of coexisting aplites and pegmatites and of their minerals from central northern Portugal. Chem. Geol., 16: 153—177.

The major-, minor- and trace-elements chemistry of Hercynian granitoids and their minerals from the central area of northern Portugal indicates that the composition of the rocks and also of their minerals varies in the comagmatic sequence of granite, aplite and pegmatite. The compositional variation appears to be the result of a magmatic fractionation process and the minor and trace elements play an important role mainly in the trend aplite→pegmatite coexisting in the same vein, particularly for the minerals. A subsequent recrystallization of granites and aplites apparently did not alter the chemistry.

INTRODUCTION

Several aplite—pegmatite veins cutting different types of granites and others cutting schists occur in the central area of northern Portugal.

In the literature no references were found for the geochemistry between aplite and pegmatite coexisting in the same vein, nor for their minerals, hence the reason for this paper.

GEOLOGY

In Alijó-Sanfins, northern Portugal, there are different types of muscovite—biotite albite granites and their magmas intruded the crystalline and schist—metagraywacke complexes. These granites were studied geochemically by Neiva (1971, 1973).

The older granite is the fine-grained gneissose muscovite—biotite granite (G I) and is geochemically different from the others.

The coarse-grained gneissose porphyritic muscovite—biotite granite (G II), the fine-grained gneissose porphyritic muscovite—biotite granite (G III), the medium-grained muscovite—biotite granite (G IV), the fine-grained feebly porphyritic muscovite—biotite granite (G VI), the medium-grained muscovite

*Present address: Department of Geosciences, University of Brasilia, 70.000 Brasilia DF, Brasil.

granite (G VII) and the coarse-grained porphyritic muscovite—biotite granite (G VIII) are harmonic granites with the Hercynian orogeny.

A fine-grained gneissose muscovite—biotite "granite" with tourmaline (G V) occurs in outcrops inside the granite G IV which are thought to be large phyllite xenoliths which were intensively granitized by the G IV granitic magma; the granite G V was not, therefore, considered in the geochemical study.

The granites G II—G VII form a series of magmatic differentiates with a general increase in the amount of modal albite and muscovite and decrease in microcline and biotite+chlorite (after biotite). The differentiation is confirmed chemically. G VIII is not in the sequence of those of G II—G VII.

The fine-grained feebly porphyritic muscovite—biotite granite (G IX) cuts the granites G IV and G VIII along faults and is a less acid granite.

The fine to medium-grained porphyritic muscovite—biotite granite (G X) is disharmonic with the Hercynian orogeny and the geochemical and geological evidence causes G X to be regarded as a new granite not related to the earlier ones.

The medium-grained gneissose porphyritic pink muscovite—biotite granite (G XI), the medium to fine-grained porphyritic pink muscovite—biotite granite (G XII) and the medium to fine-grained porphyritic red muscovite—biotite granite (G XIII) occur in veins and small stocks and form another series of magmatic differentiates similar to that of G II—G VII.

There are several aplite and pegmatite veins cutting the different types of granites and also some cutting the schists. Sometimes aplite and pegmatite coexist in the same vein and here only the aplite—pegmatite veins are studied.

Some aplite—pegmatite veins cut the granites and others cut the schists; their minerals are macro- and micro-scopically similar. The pegmatites occur as elongated homogeneous unzoned lenticles inside the aplites and they pass laterally to them in a strip of 2 to 5 cm wide. These lenticles are elongated parallel to the strike of the vein bodies, this is parallel to the aplite—pegmatite vein outcrops and parallel to their walls. But there are some exceptions, namely those lenticles dispersed inside the aplite vein, with several oblique orientations to the walls of the aplite vein. There are also aplite—pegmatite veins where the pegmatite is situated near the roof and the aplite towards the wall with a gradational passage between them. Tourmaline quartz veins sometimes cut the assemblage.

The aplite—pegmatite veins which cut the schists are generally much longer and wider than those which cut the granites. The aplite—pegmatite veins which cut the granites are generally some meters to 600 m long and some centimeters to 2 m wide; exceptionally some wide veins were found which attain 5 m, and rarely 20 m, in width. Those which cut the schists are from some centimeters to 3 000 m long and from some centimeters to 35 m wide. The aplite portions are generally wider than the pegmatite.

Every granite contains
apatite, zircon, ilmenite a
except in granite G VII. S
lowing minerals were onl
G XIII, beryl in G II, pyr
and zoisite in G XIII.

The texture of the gra
cataclasis due to the fact
small grains; the muscovi
Most of the granites are
but the granites G IX an

The aplites are relativ
texture. Every aplite co
nant minerals, together
chlorite are very rare an
cassiterite and columbit
studied here; but they o
zoisite, magnetite and c

The pegmatites are c
The texture is subhedral
are the main constituen
garnet, cassiterite and c
every pegmatite. Biotite
galena, torbernite, magr
or are rare.

The microperthitic m
but sometimes shows w
porphyritic, the microc
pink or red granites wh
they are euhedral with
Carlsbad law, but seldo

The microperthitic m
hatch twinning, but Ca
SM-593A VIII, which
only orthoclase which

In the pegmatites, th
generally anhedral but
hatch twinning only in
crystals are sometimes
occasionally.

The albite of the ap
is twinned on the Carl
Considering all the gra

PETROGRAPHY

Every granite contains quartz, microperthitic microcline, albite, muscovite, apatite, zircon, ilmenite and rutile. Biotite is present in almost every granite, except in granite G VII. Schorlite occurs in most of the granites. The following minerals were only found in some granites: sphene in G VIII and G XIII, beryl in G II, pyrite in G XII and G XIII, fluorite in G X and G XII and zoisite in G XIII.

The texture of the granites is subhedral-granular with some evidence of cataclasis due to the fact that quartz shows wavy extinction and occurs in small grains; the muscovite is sometimes bent and the edges are cut slightly. Most of the granites are porphyritic with phenocrysts of microcline and albite, but the granites G IX and G X have only phenocrysts of microcline.

The aplites are relatively fine grained with typical anhedral-granular aplitic texture. Every aplite contains quartz, potassium feldspar and albite as dominant minerals, together with a certain amount of muscovite. Biotite and chlorite are very rare and occur only in some. Schorlite, garnet, ilmenite, cassiterite and columbite—tantalite are accessory minerals in the aplites studied here; but they occur in very small amounts. Beryl, pyrite, fluorite, zoisite, magnetite and cordierite were occasionally found.

The pegmatites are coarse to very coarse grained and are homogeneous. The texture is subhedral granular and quartz, microcline, albite and muscovite are the main constituents, while schorlite, apatite, rutile, zircon, ilmenite, garnet, cassiterite and columbite—tantalite are common accessory minerals in every pegmatite. Biotite, wolframite, arsenopyrite, pyrite, blende, chalcopyrite, galena, torbernite, magnetite, cordierite and zoisite occur in very small amounts or are rare.

The microperthitic microcline of the granites has undulatory extinction, but sometimes shows well-defined cross-hatch twinning. When the granite is porphyritic, the microcline phenocrysts are normally white, except in the pink or red granites where they contain hematitic and goethitic pigments; they are euhedral with cross-hatch twinning and sometimes twinned on the Carlsbad law, but seldom on the Baveno law.

The microperthitic microcline of the aplites shows well-defined cross-hatch twinning, but Carlsbad twinning is rare. The aplites SM-641A VI and SM-593A VIII, which cut the granites G VI and G VIII respectively, contain only orthoclase which was identified by determining the triclinicity and $2V$.

In the pegmatites, the microcline, which is very feebly microperthitic, is generally anhedral but sometimes euhedral and shows well-defined cross-hatch twinning only in the crystals which are in contact with the aplite. The crystals are sometimes partially replaced by albite. Graphic texture was found occasionally.

The albite of the aplites and pegmatites and of the matrix of the granites is twinned on the Carlsbad, Albite-Carlsbad, Albite-Ala B and Pericline laws. Considering all the granites of the area studied, the An content varies between

1 and 8% in granites. The phenocrysts of albite from the granites are generally twinned on the Albite and Pericline laws; the An content varies between 3 and 9%.

The albite from the aplites is twinned on the same laws as the albite from the granites; the An content varies between 0 and 2%.

In the pegmatites, the albite is generally subhedral, but it also occurs in small euhedral crystals (clevelandite), which partially replace microcline in vuggs. The An content varies between 0 and 2%.

The albite of the granites, aplites and pegmatites is in the low-temperature state as was confirmed by X-ray diffraction records and Universal stage. Microclinization from the centre to the edges of the crystals of albite was sometimes found in granites and aplites.

The muscovite from the granites, aplites and pegmatites is subhedral to anhedral, but in the pegmatites there is also a muscovite in radial arrangement and rarely like feathers. The tabular muscovite contains inclusions of zircon with pleochroic haloes and of apatite. By diffractometer records, using $Cu{-}K_{\alpha}$ radiation and some single-crystal Weissenberg photographs, $2M_1$ structure was found in all the muscovites chemically analysed.

Schorlite is euhedral in granites, aplites and pegmatites; it is often zoned in pegmatittes and is brown coloured on the edges and blue in the centre. It contains inclusions of zircon with pleochroic haloes. Schorlite partially replaces biotite and muscovite in the granites. In aplites and pegmatites it partially replaces quartz, potassium feldspar, albite and muscovite and also beryl and apatite in pegmatites.

The garnet, which occurs in some aplites and pegmatites, is euhedral almandine—spessartine with a_0 = 11.55 Å.

ANALYTICAL METHODS

The minerals were separated with a magnetic separator and by centrifuging with heavy liquids. A purity of about 99.9% for muscovite, 99.8% for potassium feldspar, schorlite and garnet and 99.0—99.5% for albite was estimated by optical examination. The principal contaminants are zircon for muscovite and schorlite; muscovite for potassium feldspar, ilmenite for garnet and quartz for albite.

Some chemical analyses were done completely by the classical wet method, except for Na and K which were determined by flame photometry.

SiO_2, TiO_2, Al_2O_3, total Fe_2O_3, MnO, MgO and CaO were determined in some rock samples by XRF using the method of Norrish and Hutton (1969).
A CSIRO standard FS 25 was used. The muscovite, schorlite and garnet were analysed by XRF.

In order to check the results, the oxides mentioned above were determined in some samples by both methods.

CaO of the feldspars were determined by titration with EDTA.

The trace elements Be, Ga, Cr, V, Sn, Li, Ni, Zr, Sc, Y, La, Sr, Pb, Ba, Rb and Cs were determined by emission spectroscopy, having prepared for the rocks a granitic base, as a standard, with a similar composition to that of the average of the chemical analyses of the studied granites, and for the minerals a muscovitic base, as a standard, with a similar composition to that of the average of the chemical analyses of the muscovites of the analysed granites. Pd was used as an internal standard. A large quartz-glass Hilger spectrograph was used and the readings were done optically and on a Jarrell-Ash photodensitometer and a precision of ±20—25% was obtained. The limits of sensitivity are: Be, 5; Ga, 2; Cr, 4; V, 4; Sn, 5; Li, 1; Ni, 2; Sc, 5; Zr, 5; Y, 3; La, 10; Sr, 3; Pb, 5; Ba, 5; Rb, 5; and Cs, 5 ppm.

Cl, F, Ge, W, Mo, Nb, Zn, In, Cu, Sc, Bi, Er, Y, Dy, Tb, Gd, Sm, Nd, Pr, Ce, La and Tl of micas and schorlites were determined by an Associated Electrical Industries Ltd. MS7 spark-source mass spectrograph. The technique of Nicholls et al. (1967) with Re as internal standard was used. A precision of ± 7% was obtained. The limit of detection was 0.01 ppm.

The obliquity of potassium feldspars was defined as $\Delta = 12.5 \times (d_{131} - d_{1\bar{3}1})$ and the error should not exceed ± 0.003 though it may reach ± 0.005. $2V$ was measured conoscopically with the Universal stage and the estimated error is ± 1°.

GEOCHEMICAL RELATIONSHIP BETWEEN THE APLITES AND THE PARENTAL GRANITES

The chemical analyses and trace elements of the aplites, pegmatites and granites they cut and of the aplites and pegmatites which cut the schists and their parental granite are given in Tables I and II.

The aplites generally contain more quartz, albite and less potassium feldspar, biotite+chlorite than the parental granites which indicates that the aplite is a differentiate of the parental granite.

The differentiation is also confirmed chemically because it is found that the aplites generally contain more SiO_2, Na_2O, Sn, Rb, Cs and less Al_2O_3, TiO_2, Fe_2O_3, FeO, FeO_t, MgO, CaO, K_2O, Li, Zr, Sr, Pb and Ba.

The ratios Na_2O/K_2O, Fe^{2+}/Mg, $Mn \cdot 10^3/Fe^{2+}$, $Li \cdot 10^3/Mg$, K/Pb are greater, $Ga \cdot 10^3/Al$ is greater or similar and K/Rb, K/Cs, $Sr \cdot 10^3/Ca$, $Sr \cdot 10^3/(K+Ca)$, $Ba \cdot 10^3/K$, $Ba \cdot 10^3/(K+Ca)$ are lower in the aplites than in the parental granites.

Some of the results obtained by comparing the trace elements of the aplites with those of the parental granite are in concordance with the findings of the other investigators: cf. Vlasov (1966) for Sr, Li, and Rb; Hahn-Weinheimer and Ackermann (1967) for Ba; Ratiyev (1964) for Cs. But they disagree with Stravov and Znamenskii (1961) for Cs.

GEOCHEMICAL RELATIONSHIP BETWEEN THE PEGMATITES AND THE PARENTAL GRANITES

With few exceptions, the pegmatites have more SiO_2, Sn, Rb, Cs and less

TABLE I

Parental granites and aplites and pegmatittes coexisting in the same vein and cutting the granites

	G I	A I	P I	G II	A II	P II	G III	A III	P III
	Average of three	SM-25	SM-25A	Average of two	N-5798	N-5798A	Average of three	N-5554	N-5554B
SiO_2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71.64	74.71	74.44
TiO_2	0.15	0.04	0.01	0.26	n.d.	n.d.	0.22	0.07	n.d.
Al_2O_3	14.36	15.55	14.79	15.22	17.03	[illegible]	15.50	14.76	14.77
Fe_2O_3	0.59	0.46	0.04	0.25	n.d.	0.06	0.30	0.17	0.03
FeO	0.70	0.24	0.55	1.15	0.71	0.35	0.99	0.59	0.37
MnO	0.03	0.04	0.01	0.02	0.03	0.01	0.02	0.02	0.02
MgO	[illegible]	n.d.	0.07	0.33	n.d.	n.d.	0.14	n.d.	n.d.
CaO	0.62	0.59	0.51	0.94	1.00	0.35	0.77	0.65	0.55
Na_2O	3.47	5.05	5.71	3.36	5.72	5.45	3.49	4.38	4.34
K_2O	[illegible]	4.23	[illegible]	[illegible]	[illegible]	[illegible]	4.62	4.35	4.24
P_2O_5	0.37	0.35	[illegible]	0.79	0.52	[illegible]	0.29	0.31	0.25
[illegible]	n.d.	n.d.	0.07	n.d.	[illegible]	[illegible]	0.12	0.07	0.31
[illegible]	1.04	1.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.74	0.44
[illegible]	0.41	[illegible]	[illegible]	0.23	0.25	0.32	0.11	0.09	0.07
	100.15	[illegible]	100.05	100.17	99.72	100.60	100.04	100.05	99.53
Analysts		A.Neiva	A.Neiva		A.Neiva	A.Neiva		A.Neiva	A.Neiva
Trace elements (ppm)									
[illegible]	13	15	174	14	175	45	25	40	65
Ga	2	26	26	22	25	19	25	24	15
[illegible]	53	36	33	36	9	85	32	36	35
Li	116	40	23	255	22	100	408	42	22
[illegible]	*	5	12	*	*	*	*	12	*
[illegible]	70	5	12	72	27	*	45	35	*
Y	33	*	*	4	21	*	13	13	*
[illegible]	*	*	*	*	*	*	33	*	*
[illegible]	47	20	31	2	21	5	56	31	14
[illegible]	30	6	6	135	5	5	20	6	6
Ba	292	12	50	420	110	12	306	72	12
Rb	410	625	2150	400	765	1760	447	190	900
Cs	33	36	67	25	58	170	29	41	45

	G IV	A IV	P IV	G VI	A VI	P VI	G VII	A VII	P VII
	Average of six	N-592	N-592A	Average of six	SM-641A	SM-641	Average of four	SM-632	SM-37A
SiO_2	72.25	72.76	75.07	71.78	72.95	73.71	72.44	73.49	73.05
TiO_2	0.11	n.d.	n.d.	0.07	n.d.	0.01	0.16	0.01	0.01
Al_2O_3	15.41	16.14	14.72	15.27	15.74	15.98	14.44	14.47	15.06
Fe_2O_3	0.47	0.30	n.d.	0.21	0.04	0.08	0.40	n.d.	n.d.
FeO	0.60	0.01	0.35	0.56	0.46	0.51	0.72	0.38	0.25
MnO	0.02	0.01	0.02	0.02	0.01	0.02	0.05	0.04	0.06
MgO	0.05	0.02	n.d.	0.04	n.d.	n.d.	0.04	n.d.	n.d.
CaO	0.66	0.42	0.44	0.56	0.35	0.46	0.43	0.41	0.72
Na_2O	3.64	5.02	3.61	3.64	4.77	4.19	3.61	5.30	3.62
K_2O	4.94	3.95	7.23	4.61	2.93	4.17	4.78	3.03	6.47
P_2O_5	0.27	0.32	0.29	0.30	0.36	0.19	0.30	0.17	0.47
[illegible]	0.07	0.07	0.11	0.04	0.05	0.11	0.06	0.07	n.d.
[illegible]	0.77	1.70	0.43	1.04	1.31	0.89	1.15	0.62	0.44
[illegible]	0.53	0.17	0.12	0.34	0.29	0.09	[illegible]	0.07	0.06
	100.15	100.54	99.77	100.23	99.60	100.34	100.05	100.43	100.02
Analysts		A.Neiva	A.Neiva		A.Neiva	A.Neiva		A.Neiva	A.Neiva
Trace elements (ppm)									
[illegible]	26	19	95	77	15	45	13	10	400
Ga	22	46	20	20	34	10	20	26	19
[illegible]	35	220	110	41	58	96	49	23	54
Li	415	170	58	445	150	150	525	100	32
[illegible]	*	5	16	*	12	16	*	6	6
[illegible]	62	35	13	47	17	9	47	12	*
Y	9	9	*	17	*	*	6	*	*
[illegible]	*	*	*	*	*	*	*	*	*
[illegible]	49	6	7	33	*	*	10	*	*
[illegible]	29	6	16	8	5	5	*	*	*
Ba	153	12	45	147	*	*	35	12	10
Rb	563	770	2150	627	765	1050	753	770	1350
Cs	73	257	115	110	120	157	157	100	135

	G VIII	A VIII	P VIII	G XI	A XI	P XI	G XII	A XII	P XII
	Average of four	N-593A	N-592B	Average of three	SM-506B	SM-506A	Average of three	SM-439	SM-439A
SiO_2	73.33	74.00	74.95	70.97	72.93	76.12	71.69	74.49	74.70
TiO_2	0.29	n.d.	n.d.	0.34	0.04	n.d.	0.38	0.02	n.d.
Al_2O_3	15.56	14.99	14.04	15.21	14.62	13.77	14.95	14.78	14.02
Fe_2O_3	0.34	0.07	0.04	0.68	0.22	0.09	1.04	0.22	0.18
FeO	1.16	0.52	0.18	0.93	0.42	0.23	0.70	0.46	0.22
MnO	0.03	0.05	n.d.	0.01	n.d.	n.d.	0.01	0.02	0.01
MgO	0.06	n.d.	n.d.	0.27	n.d.	n.d.	0.08	n.d.	0.03
CaO	0.85	0.47	0.48	0.73	0.45	0.28	0.73	0.49	0.40
Na_2O	3.74	5.77	4.14	2.99	3.50	3.45	2.95	4.55	3.95
K_2O	5.15	3.34	3.20	5.13	4.67	5.57	5.48	3.43	5.26
P_2O_5	0.33	0.36	0.26	0.37	0.35	0.34	0.34	0.24	0.32
[illegible]	0.07	0.25	0.11	0.07	0.31	n.d.	0.07	0.14	0.13
[illegible]	0.89	0.41	0.74	0.50	0.07	0.77	0.91	0.31	0.39
[illegible]	0.22	0.14	0.20	0.24	0.27	0.54	[illegible]	0.07	n.d.
	100.03	99.93	100.16	99.25	99.46	100.44	99.84	99.07	99.78
Analysts		A.Neiva	A.Neiva		A.Neiva	A.Neiva		A.Neiva	A.Neiva
Trace elements (ppm)									
[illegible]	20	100	40	*	*	*	*	27	*
Ga	29	25	26	36	18	19	28	21	26
[illegible]	10	43	59	20	10	33	*	9	33
Li	[illegible]	100	27	105	17	2	135	23	33
[illegible]	*	*	9	*	9	*	*	*	12
[illegible]	106	35	*	158	35	*	213	12	9
Y	9	*	*	33	*	*	8	4	*
[illegible]	36	*	*	120	*	*	105	*	*
[illegible]	110	*	11	97	42	4	63	*	*
[illegible]	81	5	6	35	15	6	37	6	6
Ba	520	*	45	406	110	*	236	*	*
Rb	553	770	1200	563	615	1050	625	765	1350
Cs	48	58	30	29	42	57	29	44	74

Analyst: A. Neiva.
n.d. = not detected; * = below the limit of sensitivity.
A = aplite; G = granite; P = pegmatite.

TABLE II

Parental granites and aplites and pegmatites coexisting in the same vein cutting the schists

	Granite GX Average of six	Aplite SM-604	Pegmatite SM-604A	Aplite SM-605	Pegmatite SM-605A	Aplite SM-615A	Pegmatite SM-615	Aplite SM-165	Pegmatite SM-165A	Aplite SM-10B	Pegmatite SM-10A	Aplite SM-603	Pegmatite SM-603A
SiO_2	72.33	74.39	72.57	74.38	74.40	74.00	73.80	73.48	73.67	73.11	70.04	72.65	72.99
TiO_2	0.23	0.02	0.09	n.d.	0.07	0.03	0.03	0.05	0.04	0.02	0.07	0.04	0.03
Al_2O_3	[illegible]	14.21	15.45	15.02	14.77	14.60	14.45	14.89	14.56	[illegible]	17.71	15.53	15.64

TABLE II

Parental granites and aplites and pegmatites coexisting in the same vein cutting the schists

	Granite GX Average of six	Aplite SK-604	Pegmatite SK-604A	Aplite SK-605	Pegmatite SK-605A	Aplite SK-615A	Pegmatite SK-615	Aplite SK-165	Pegmatite SK-165A	Aplite SM-10B	Pegmatite SM-10A	Aplite SK-603	Pegmatite SK-603A
SiO_2	72.33	74.39	72.57	74.38	74.40	74.00	73.80	73.48	73.67	73.11	70.04	72.65	72.99
TiO_2	0.23	0.02	0.09	n.d.	0.07	0.03	0.03	0.05	0.04	0.02	0.07	0.04	0.03
Al_2O_3	15.22	14.61	15.46	15.02	14.72	14.80	14.49	14.89	14.59	16.22	17.21	15.58	15.04
Fe_2O_3	0.34	0.29	0.33	0.43	0.07	0.41	0.52	0.22	0.73	0.18	0.51	0.34	0.11
FeO	1.08	0.66	0.43	0.36	0.40	0.40	0.51	0.34	0.44	0.34	0.58	0.40	0.31
MnO	0.02	0.02	n.d.	0.04	0.02	0.01	0.01	0.01	0.03	0.02	0.02	0.07	0.06
MgO	0.12	0.07	0.01	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
CaO	0.65	0.54	0.62	0.27	0.41	0.38	0.68	0.48	0.50	0.44	0.44	0.95	0.99
Na_2O	3.73	3.70	3.86	5.17	4.09	5.41	2.38	4.45	4.10	5.39	1.68	5.02	3.17
K_2O	4.94	3.97	3.98	3.07	4.97	3.38	4.82	3.96	4.52	3.43	6.24	2.83	5.21
P_2O_5	0.35	0.37	0.37	0.18	0.30	0.25	0.40	0.33	0.35	0.26	0.27	0.60	0.64
B_2O_3	0.06	n.d.	n.d.	n.d.	n.d.	0.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
H_2O+	0.91	1.19	1.40	0.93	0.64	0.75	1.38	1.19	0.74	0.91	2.02	0.99	0.84
H_2O-	0.16	0.35	0.69	0.29	0.11	0.30	0.69	0.67	0.45	0.12	0.94	0.42	0.55
	100.14	100.19	100.07	100.17	100.20	100.29	99.71	100.03	100.16	100.44	100.02	100.09	99.94
Analyst:		A.Neiva	A.Guimarães	A.Neiva	J.Guimarães	A.Guimarães	E.Cortez	A.Neiva	A.Guimarães	E.Cortez	E.Cortez	J.Guimarães	J.Guimarães
Trace elements (ppm)													
Be	25	100	120	*	*	100	5	15	120	*	*	200	120
Ga	28	25	25	35	25	25	25	30	23	25	35	25	25
Sn	18	60	58	100	33	33	58	58	33	58	100	58	33
Li	195	550	83	57	130	46	158	83	40	63	58	68	145
Sc	*	*	*	*	*	*	*	*	*	*	*	*	*
Zr	108	21	*	21	13	17	13	35	21	13	155	21	*
Y	9	9	*	*	*	*	*	11	4	*	*	22	*
La	45	26	*	*	*	*	*	*	*	*	*	*	*
Sr	38	13	9	4	4	5	9	4	3	7	7	7	27
Pb	28	10	15	15	15	15	*	10	*	15	15	15	15
Ba	174	24	18	*	*	*	*	13	*	*	*	18	6
Rb	466	840	800	420	680	545	840	640	930	680	1000	330	1000
Cs	35	190	200	52	88	22	79	39	38	39	238	40	190

Analyst: A. Neiva.
n.d. = not detected; * = below the limit of sensitivity.
A = aplite; G = granite; P = pegmatite.

Al_2O_3, TiO_2, Fe_2O_3, FeO, FeO_t, MgO, CaO, Li, Zr, Y, Sr, Pb and Ba than the parental granites. Variations of the same kind hold between the aplites and their related granites, which implies that the pegmatite is some kind of differentiate of the parental granite.

The pegmatites, which contain more albite than the parental granite, naturally have more Na_2O; and the others with less Na_2O than the corresponding parental granite have less albite.

Some pegmatites have less K_2O than the parental granites because they also have less microcline+muscovite+biotite and others have more K_2O because they also have more microcline+muscovite.

The ratios Fe^{2+}/Mg, $Mn \cdot 10^3/Fe^{2+}$, $Li \cdot 10^3/Mg$, K/Pb are greater; $Ga \cdot 10^3/Al$ is similar; and K/Rb, K/Cs, $Sr \cdot 10^3/Ca$, $Sr \cdot 10^3/(K+Ca)$, $Ba \cdot 10^3/K$, $Ba \cdot 10^3/(K+Ca)$, are lower in the pegmatites than in the parental granites.

Some of the results found here are in concordance with the findings of other investigators: cf. Vlasov (1966) for Ti, Li, Y, Sr, Rb, Cs and K/Cs ratio; and Vejnar (1968) for Li.

GEOCHEMICAL RELATIONSHIP BETWEEN THE PEGMATITE AND THE APLITE WHICH COEXIST IN THE SAME VEIN

The pegmatites generally have more K_2O, Rb, Cs, similar or less Ba, Ga and less Al_2O_3, FeO_t, Na_2O, H_2O+, Li, Zr than the aplites coexisting in the same vein.

The pegmatites H-592A IV and H-593B VIII, however, have less Cs than the coexisting aplites which is due to the fact that the Cs content of the muscovite of those pegmatites is lower than that of the muscovite of the associated aplites.

The fact that pegmatites generally contain less Li than the coexisting aplites agrees with other authors, cf. Vlasov (1966) and Vejnar (1968).

Sn content is the same or higher in the pegmatite than in the coexisting aplites agrees with other authors, cf. Vlasov (1966) and Vejnar (1968). muscovite from the pegmatite H-592A IV is lower than that of the muscovite from the aplite H-592 IV; but Sn can be more or less in the pegmatite than in the coexisting aplite cutting the schists.

The normative Or/Ab ratio is always greater in the pegmatite than in the coexisting aplite.

The ratio $Ga \cdot 10^3/Al$ is constant and K/Rb, K/Cs ratios generally decrease from the aplite to the coexisting pegmatite.

GEOCHEMISTRY OF THE MINERALS FROM THE APLITE—PEGMATITE VEINS

POTASSIUM FELDSPAR

Some major, trace elements, obliquity and $2V$ of the potassium feldspars are given in Tables III and IV.

The potassium feldspar from the aplites and pegmatites generally contains more Rb, Cs, similar Ga and less Ca, Sr, Pb, Ba than the microcline from the parental granite, as would be expected if the aplites and pegmatites are to be regarded as differentiates of the parental granite.

In the aplites, the potassium feldspar generally has less Na than the microcline from the parental granite, which also happens in the microclines from the pegmatites which cut granites, and as Na and K vary inversely, they have more K than the microcline from the parental granite. As the microclines from the pegmatites which cut the schists are more perthitic than the others, having some blebs of albite, which are probably due to replacement, they have more Na and less K than the microcline from the parental granite (G X).

The ratios $Sr \cdot 10^3/Ca$, Rb/Sr, Rb/Ba, $Cs \cdot 10^3/K$ are greater and K/Rb, $Sr \cdot 10^3/K$, $Pb \cdot 10^3/K$, $Ba \cdot 10^3/K$, Ba/Sr are lower in the potassium feldspar from the aplites and pegmatites than in the microcline from the parental granite, which confirms the differentiation. However, the $Sr \cdot 10^3/Ca$ ratio of the microcline from the pegmatites which cut the schists is lower than that of the microcline from the parental granite (G X), which is certainly due to schist contamination.

The results obtained for the geochemistry of the relationship between the microcline from the pegmatites and the microcline from the parental granite are in concordance with the findings obtained by other investigators, cf. Heier (1962) and Smith (1974), but disagree with findings of Walenczak (1959) for Ga.

According to Heier and Taylor (1959), the Sr content in the potassium feldspar from Norwegian granites is directly proportional to the Ba content and this is also the case for the potassium feldspars from granites, aplites and pegmatites here.

The potassium feldspars from aplite and pegmatite coexisting in the same vein generally do not show any differences for their major and trace elements. Though, in some cases, pegmatite potassium feldspar tends to have a slightly greater content of Ab, mostly marked in H-558B III, SM-615 and SM-10A; Rb and Cs contents have a tendency to be slightly higher, and Ba and Sr contents to be lower in the potassium feldspar from the pegmatite.

The ratios Rb/Ba, Rb/Sr, $Cs \cdot 10^3/K$ generally slightly increase and K/Rb, $Ba \cdot 10^3/K$ and Ba/Sr generally slightly decrease from the potassium feldspar of the aplite to that of the coexisting pegmatite in the same vein, but there are rare exceptions.

ALBITE

Some major and trace elements of albites are given in Tables V and VI.

The albite from the aplite and pegmatite generally has more Na and less Ca, Sr, Ba than the albite from the parental granite, which indicates differentiation.

The ratios $Na \cdot 10^3/Ca$ and $Sr \cdot 10^3/Ca$ are higher in the albite from the aplites and pegmatites than in that from the parental granite, which confirms the differentiation.

TABLE III

Potassium feldspars from parental granites and aplites and pegmatites coexisting in the same vein cutting the granites

	G I SM 426	A I SM 635	P I SM 635A	G II average of two	A II SM 578B	P II SM 578A	G III SM 568	A III H 558A	P III H 558B	G VI SM 594	A VI SM 641A	P VI SM 641	G VII average of two	A VII SM 633
K	13.07	13.48	13.54	12.65	13.23	13.12	12.81	13.46	13.24	13.17	12.56	12.51	13.07	13.64
Na	0.47	0.36	0.32	0.69	0.47	0.57	0.56	0.33	0.50	0.50	0.92	0.96	0.50	0.25
Ca	0.24	—	—	0.30	0.05	—	0.34	0.05	—	0.09	0.02	—	0.18	—
2*V*	84	83	81	83	81	85	83	85	81	88	71	84	88	86
Δ	0.76	0.78	0.68	0.75	0.70	0.78	0.76	0.85	0:68	0.89	0.38	0.76	0.90	0.84
Trace elements (ppm):														
Ga	25	20	20	23	25	20	25	11	25	11	20	20	25	11
Li	4	15	34	18	34	22	2	15	34	8	34	42	10	3
Sr	160	80	150	100	38	20	120	80	65	100	4	3	35	30
Pb	70	32	32	220	70	32	100	45	70	45	22	10	25	15
Ba	700	43	125	810	250	43	800	250	100	410	10	6	78	10
Rb	1600	1950	1950	1120	2000	2400	1400	1650	2450	1740	2250	2800	1900	2050
Cs	32	100	100	18	100	160	32	37	55	58	180	135	60	275

TABLE III (*continued*)

	P VII SM 633A	G VIII SM 46	A VIII SM 593A	P VIII H 593B	G X average of four	A X SM 286C	P X SM 286A	G XI SM 585	A XI SM 586B	P XI SM 586A	G XII SM 579	A XII SM 639	P XII SM 639A
K	13.36	12.53	13.32	13.20	13.12	13.26	13.12	13.14	13.26	13.28	13.24	13.26	13.12
Na	0.37	0.76	0.45	0.53	0.47	0.40	0.51	0.40	0.45	0.48	0.42	0.49	0.57
Ca	0.09	0.30	—	—	0.18	0.14	0.11	0.26	0.06	—	0.13	—	0.01
2*V*	86	82	73	87	86	87	82	86	87	83	87	85	84
[illegible]	[illegible]	[illegible]	0.88	0.56	0.85	0.86	0.75	0.78	0.90	0.76	0.81	0.85	0.80

TABLE III (*continued*)

	P VII SM 633A	G VIII SM 46	A VIII SM 593A	P VIII H 593B	G X average of four	A X SM 286C	P X SM 286A	G XI SM 585	A XI SM 586B	P XI SM 586A	G XII SM 579	A XII SM 639	P XII SM 639A
K	13.36	12.53	13.32	13.20	13.12	13.26	13.12	13.14	13.26	13.28	13.24	13.26	13.12
Na	0.37	0.76	0.45	0.53	0.47	0.40	0.51	0.40	0.45	0.48	0.42	0.49	0.57
Ca	0.09	0.30	—	—	0.18	0.14	0.11	0.26	0.06	—	0.13	—	0.01
2*V*	86	82	73	87	86	87	82	86	87	83	87	85	84
Δ	0.83	0.73	0.38	0.86	0.85	0.86	0.75	0.78	0.90	0.76	0.81	0.85	0.80
Trace elements (ppm):													
Ga	20	25	25	20	24			25	20	11	25	20	25
Li	3	6	15	6	5			*	3	*	2	10	6
Sr	30	140	7	6	96			150	150	65	130	10	11
Pb	15	220	32	45	45			45	45	10	45	22	15
Ba	5	900	20	20	550			950	250	43	800	10	10
Rb	2900	1040	1500	1700	1565			1200	1700	1900	1300	2100	2150
Cs	82	14	180	260	35			10	100	125	10	100	137

Analyst: A. Neiva.
— = not determined; * = below the limit of sensitivity.
A = aplite; G = granite; P = pegmatite.

TABLE IV

Microclines from parental granite and aplites and pegmatites coexisting in the same vein cutting the schists

	Granite GX average of four	Apl. SM 604	Pegm. SM 604A	Apl. SM 605	Pegm. SM 605A	Apl. SM 615A	Pegm. SM 615	Apl. SM 185	Pegm. SM 185A	Apl. SM 10B	Pegm. SM 10A	Apl. SM 603	Pegm. SM 603A
K	13.12	13.02	12.89	13.00	13.00	13.26	13.07	13.15	13.30	13.40	13.07	13.03	12.92
Na	0.47	0.50	0.60	0.53	0.62	0.43	0.60	0.41	0.44	0.37	0.55	0.59	0.59
Ca	0.18	0.23	0.19	0.19	0.05	0.10	0.02	0.24	0.05	0.10	0.10	0.08	0.19
$2V$	86	85	85	82	81	82	82	84	86	81	84	88	80
Δ	0.85	0.85	0.81	0.76	0.69	0.74	0.73	0.70	0.81	0.69	0.70	0.86	0.66
Trace elements (ppm):													
Ga	24	20	20			20	20						
Li	5	18	6			3	6						
Sr	96	38	75			10	10						
Pb	45	32	35			32	10						
Ba	550	100	90			20	10						
Rb	1565	2000	2050			2250	2250						
Cs	35	180	180			75	152						

Analyst: A. Neiva.
A = aplite; G = granite; P = pegmatite.

The albite from the apl
not show any difference i
and Rb content is the san
content seems to be high
and Ga content is about t

MUSCOVITE

The chemical analyses
in Tables VII and VIII.
The muscovites from t
F, Be, Ge, W, Nb, Zn, Sn,
Sm, Nd, Pr, Ce, La, Pb, B
which indicates different
The ratios Mn·10^3/Fe^2
are greater and K/Rb, K/
Ba·10^3/(K+Ca), Nd/La, F
aplites and pegmatites th
from the pegmatites pres
Sc·10^3/Fe^{2+}, Sc·10^3/Mg
The results obtained b
pegmatites and of the m
with findings of: Serafim
for F, and (1967) for Nb
However they disagree w
(1967) for F; and Vejna
The major elements o
pegmatite in the same ve
the case of Mg, and this
determination of MgO b
may be illusory. There is
in the muscovite from th
Cl is much the same,
also slightly more in the
from the coexisting apli
Ba tend to be less. Ther
VIII and XI.
The ratio Li·10^3/Mg i
(K+Ca) ratios are lower
muscovite from the coe

SCHORLITE

Neiva (1974) studied
and also from some oth
same vein.

The albite from the aplite and pegmatite coexisting in the same vein do not show any difference in Na, K and Ca, but Sr content is the same or lower and Rb content is the same or higher in the albite from the pegmatite. Be content seems to be higher in the albite from the pegmatite, when detected, and Ga content is about the same in both.

MUSCOVITE

The chemical analyses and trace-element contents of muscovites are given in Tables VII and VIII.

The muscovites from the aplites and pegmatites generally contain more Cl, F, Be, Ge, W, Nb, Zn, Sn, Li, Cu, Bi, Er, Rb, Tl, Cs and less Ti, Cr, V, In, Gd, Sm, Nd, Pr, Ce, La, Pb, Ba, ΣCe than the muscovite from the parental granite which indicates differentiation.

The ratios $Mn \cdot 10^3/Fe^{2+}$, $F \cdot 10^3/K$, F/Li, F/Rb, Sn/Ti, $Li \cdot 10^3/Mg$, $Cs \cdot 10^3/K$ are greater and K/Rb, K/Tl, $V \cdot 10^3/Fe^{3+}$, $Ni \cdot 10^3/Fe^{2+}$, $Ni \cdot 10^3/Mg$, $Ba \cdot 10^3/K$, $Ba \cdot 10^3/(K+Ca)$, Nd/La, Rb/Tl, Σ Ce/Σ Y are lower in the muscovites from the aplites and pegmatites than in those from the parental granites. The muscovites from the pegmatites present also greater Fe^{2+}/Mg, F/Cs and lower $Cr \cdot 10^3/Fe^{3+}$, $Sc \cdot 10^3/Fe^{2+}$, $Sc \cdot 10^3/Mg$ ratios than the muscovites from the parental granites.

The results obtained between some trace elements of muscovites from the pegmatites and of the muscovite from the parental granites are in concordance with findings of: Serafim (cited by Gilberg, 1964) and Odikadze (1967, 1971) for F, and (1967) for Nb; Vejnar (1968) for Li; and Vlasov (1966) for Cs. However they disagree with findings of Shimer (1952) reported in Odikadze (1967) for F; and Vejnar (1968) for Sn and Rb.

The major elements of the muscovites from the aplite and coexisting pegmatite in the same vein generally do not show any differences, except in the case of Mg, and this makes the FeO_t/MgO ratio variable. However the determination of MgO by XRF is not very reliable, so the variation in Mg may be illusory. There is a general tendency for Al in the Z group to be higher in the muscovite from the pegmatite.

Cl is much the same, Ge, Sn, Er, Rb, Tl and Cs are also similar but can be also slightly more in the muscovite from the pegmatite than in the muscovite from the coexisting aplite; F, Nb, Zn, Cu tend to be slightly more and Cr, In, Ba tend to be less. There are a few exceptions: for Sn in IV, Cs in IV, VII, VIII and XI.

The ratio $Li \cdot 10^3/Mg$ is generally greater and K/Rb, $Ba \cdot 10^3/K$ and $Ba \cdot 10^3/(K+Ca)$ ratios are lower in the muscovite from the pegmatite than in the muscovite from the coexisting aplite.

SCHORLITE

Neiva (1974) studied the schorlites from these granites, aplites and pegmatites and also from some other aplites and pegmatites which do not coexist in the same vein.

TABLE V

Albites from parental granites and aplites and pegmatites coexisting in the same vein cutting the granites

	G I SM 426	A I SM 635	P I SM 635A	G II average of two	A II SM 578B	P II SM 578A	G III SM 568	A III H 558A	P III H 558B	G VI SM 594	A VI SM 641A	P VI SM 641	G VII H 266	A VII SM 633
K	0.54	0.49	0.54	0.42	0.47	0.39	0.51	0.35	0.51	0.26	0.46	0.46	0.35	0.29
Na	8.06	8.44	8.42	7.78	8.47	8.49	8.04	8.38	8.28	8.48	8.42	8.45	8.46	8.55
Ca	0.61	0.04	0.02	1.20	—	0.05	0.67	0.29	0.27	0.22	0.10	0.05	0.16	0.06
An (%): $2\theta(111) - 2\theta(1\bar{1}1)$	4	1	0	9	0	1	6	4	4	4	1	4	2	1
An (%): $2\theta(\bar{1}32) - 2\theta(131)$	6	2	5	9	3	3	6	6	0	3	3	3	2	5
An (%): Optically	3	1	1	7			5	4	2	3			2	1
Trace elements (ppm):														
Be	*	*	400	18	*	36	5	22	60	*	10	*	*	*
Ga	25	25	25	28	25	25	25	25	15	25	11	25	25	25
V	6	*	*	9	*	*	10	*	*	5	*	*	5	*
Sr	65	15	10	83	30	6	65	30	30	38	18	10	30	12
Ba	200	8	43	25	10	*	18	10	10	*	*	*	*	*
Rb	30	40	65	9	10	10	20	20	45	*	12	12	10	*

TABLE V (*continued*)

	P VII SM 633A	G VIII SM 46	A VIII H 593A	P VIII H 593B	G X average of four	A X SM 286C	P X SM 286A	G XI SM 585	A XI SM 586B	P XI SM 586A	G XII SM 579	A XII SM 639	P XII SM 639A
K	0.19	0.46	0.16	0.31	0.56	0.33	0.41	0.50	0.45	0.50	0.42	0.54	0.46
Na	8.65	7.96	8.64	8.52	8.01	8.47	8.49	8.15	8.39	8.40	8.26	8.40	8.45
Ca	—	0.86	0.05	0.10	0.68	0.14	0.05	0.50	0.16	0.09	0.42	0.06	0.06
[illegible]	0.5	8	4	4	5	2	3	5	4	1	4	1	

TABLE V (*continued*)

	P VII SM 633A	G VIII SM 46	A VIII H 593A	P VIII H 593B	G X average of four	A X SM 286C	P X SM 286A	G XI SM 585	A XI SM 586B	P XI SM 586A	G XII SM 579	A XII SM 639	P XII SM 639A
K	0.19	0.46	0.16	0.31	0.56	0.33	0.41	0.50	0.45	0.50	0.42	0.54	0.46
Na	8.65	7.96	8.64	8.52	8.01	8.47	8.49	8.15	8.39	8.40	8.26	8.40	8.45
Ca	—	0.86	0.05	0.10	0.68	0.14	0.05	0.50	0.16	0.09	0.42	0.06	0.06
$2\theta\,(111)-2\theta\,(1\bar{1}1)$ An (%)	0.5	8	4	4	5	2	3	5	4	1	4	1	
$2\theta\,(\bar{1}32)-2\theta\,(131)$ An (%)	0.5	6	2	3	3	4	4	7	5	4	5	3	
Optically An (%)	1	4			4			5	3	1	3	1	
Trace elements (ppm):													
Be	170	18	15	200	*			*	*	*	*	*	*
Ga	25	25	25	25	25			25	15	25	30	25	25
V	*	13	*	*	8			6	*	*	8	*	*
Sr	4	120	30	15	52			45	100	28	40	15	10
Ba	*	100	*	*	25			10	6	6	10	*	*
Rb	*	36	*	10	64			22	10	60	22	45	45

Analyst: A. Neiva.

— = not determined; * = below the limit of sensitivity.

A = aplite; G = granite; P = pegmatite.

TABLE VI

Albites from parental granite and aplites and pegmatites coexisting in the same vein cutting the schists

		Granite GX average of four	Apl. SM 604	Pegm. SM 604A	Apl. SM 605	Pegm. SM 605A	Apl. SM 185	Pegm. SM 185A	Apl. SM 10B	Pegm. SM 10A	Apl. SM 603	Pegm. SM 603A
K		0.56	0.50	0.32	0.21	0.48	0.12	0.16	0.12	0.37	0.12	0.35
Na		8.01	8.33	8.51	8.61	8.46	8.67	8.67	8.64	8.47	8.67	8.49
Ca		0.68	0.21	0.11	0.05	0.02	0.05	—	0.09	0.11	0.04	0.09
2θ (111) − 2θ (1$\bar{1}$1)	An (%)	5	1	1	1	2	1	2	1	1	2	2
2θ ($\bar{1}$32) − 2θ (131)	An (%)	3	5	1	4	4	3	3	5	2	6	4
Optically	An (%)	4	2	0	1	1					2	1
Trace elements (ppm):												
Be		*	10	60								
Ga		25	15	20								
V		8	*	*								
Sr		52	10	10								
Ba		25	5	5								
Rb		64	20	*								

Analyst: A. Neiva.
— = not determined; * = below the limit of sensitivity.
A = aplite; G = granite; P = pegmatite.

TABLE VII

Muscovites from parental granites and aplites and pegmatites coexisting in the same vein cutting the granites

	G III SM-560	A III B-568A	P III B-568B	G IV Average of three	A IV B-592	P IV B-592A	G VI Average of three	A VI SM-641A	P VI SM-641	G VII Average of four	A VII SM-633	P VII SM-633A
SiO_2	45.60	45.74	45.15	44.55	45.50	45.05	45.72	45.70	45.80	47.14	45.61	46.24
TiO_2	0.42	0.22	0.18	0.40	0.17	0.09	0.26	0.17	0.18	0.14	0.10	0.10
Al_2O_3	34.25	35.84	35.29	33.76	33.45	35.24	33.73	34.45	34.00	32.55	32.68	35.45
Fe_2O_3	0.76	n.d.	0.08	0.48	1.94	0.56	n.d.	2.50	0.10	0.45	1.20	n.d.
FeO	1.67	1.47	1.78	2.41	2.33	2.38	3.45	1.29	3.20	3.00	2.70	2.98
MnO	0.04	[illegible]	[illegible]	0.05	0.09	0.14	0.10	0.09	0.14	0.07	0.11	0.10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	G VIII SM-46	A VIII B-593A	P VIII B-593B	G X Average of five	A X SM-286C	P X SM-286A	G XI Average of two	A XI SM-586B	P XI SM-586A	G XII SM-579	A XII SM-639	P XII SM-639A
SiO_2	45.86	44.63	45.14	45.74	47.18	45.36	45.60	44.65	[illegible]	47.01	45.35	45.01
TiO_2	1.23	0.03	0.20	0.60	0.45	0.26	1.48	0.39	0.36	1.41	0.21	0.12
Al_2O_3	34.71	34.50	34.77	32.97	33.06	34.41	33.32	33.42	33.16	32.42	35.49	34.79
Fe_2O_3	0.42	0.88	0.75	0.91	0.77	0.84	0.07	1.24	2.42	0.26	1.25	[illegible]
FeO	1.10	2.20	1.50	2.34	2.19	1.02	1.66	1.45	[illegible]	[illegible]	[illegible]	[illegible]
MnO	0.01	0.15	0.09	[illegible]	0.07	0.12	[illegible]	[illegible]	0.30	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE VII

Muscovites from parental granites and aplites and pegmatites coexisting in the same vein cutting the granites

	G III	A III	P III	G IV	A IV	P IV	G VI	A VI	P VI	G VII	A VII	P VII
	SM-568	H-565A	H-558B	Average of three	H-592	H-592A	Average of three	SM-641A	SM-641	Average of four	SM-633	SM-633A
SiO_2	45.60	45.74	45.15	44.56	45.50	45.05	45.72	45.70	45.80	47.14	45.61	46.24
TiO_2	0.42	0.22	0.19	0.40	0.17	0.09	0.26	0.17	0.15	0.14	0.10	0.10
Al_2O_3	34.25	35.84	35.29	33.26	33.45	35.24	33.73	34.45	34.60	32.55	32.68	35.45
Fe_2O_3	0.76	n.d.	0.08	0.48	1.94	0.56	n.d.	2.50	0.10	0.45	1.20	n.d.
FeO	1.62	1.87	1.78	2.41	2.33	2.38	3.45	1.29	3.20	3.00	2.70	2.98
MnO	0.04	0.05	0.03	0.05	0.09	0.14	0.10	0.09	0.14	0.07	0.11	0.10
MgO	1.38	1.06	1.31	2.16	0.70	1.09	1.49	0.74	1.01	1.38	1.68	0.81
CaO	n.d.	n.d.	0.01	n.d.	n.d.	n.d.	n.d.	0.01	n.d.	n.d.	n.d.	0.02
Na_2O	0.71	0.61	0.64	0.75	0.49	0.59	0.54	0.61	0.40	0.54	0.51	0.41
K_2O	10.58	9.99	10.34	10.08	10.57	10.50	10.27	9.48	10.10	10.58	10.83	10.34
Cl	0.08	0.10	0.11	0.10	0.11	0.10	0.11	0.14	0.29	0.14	0.15	0.16
F	0.09	0.29	0.49	0.31	0.40	0.46	0.27	0.40	0.77	0.45	0.59	0.89
H_2O^+	4.11	4.35	4.42	4.69	4.19	4.04	4.51	4.52	4.00	3.60	3.96	3.40
H_2O^-	n.d.	n.d.	n.d.	0.20	0.21	0.10	0.09	n.d.	n.d.	n.d.	0.03	n.d.
	99.64	100.11	99.83	99.54	100.05	100.14	100.54	100.10	100.73	100.04	100.15	100.90
O ≡ Cl	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.06	0.03	0.03	0.04
O ≡ F	0.04	0.12	0.21	0.13	0.17	0.19	0.11	0.17	0.30	0.19	0.25	0.37
	99.58	99.97	99.60	99.39	99.86	99.93	100.41	99.90	100.37	99.82	99.87	100.49
Trace elements (ppm)												
Be	5	28	28	8	36	10	5	36	28	11	36	36
Ge	0.65	3.0	12	1.5	4.0	14	1.7	10	5	2.1	1.2	13
Ga	110	90	95	103	75	90	103	75	110	105	92	92
V	8	9	10	9	13	15	11	16	17	14	22	108
Cr	6	4.0	*	5	4.0	*	5	*	*	4.0	*	*
T	22	*	*	21	*	*	13	*	*	16	*	*
Mo	0.30	*	0.60	0.20	1.3	0.40	0.40	0.80	0.60	0.03	0.90	0.40
Nb	32	33	137	36	65	220	39	159	165	40	177	140
Zn	186	190	204	277	282	314	380	408	418	407	549	641
Sn	100	140	150	207	1000	370	205	300	320	210	240	300
Li	800	940	940	1717	2700	1900	2100	2900	2550	2225	2500	2600
Ni	2.0	*	2.0	2.0	*	7.0	2.0	*	*	2.0	*	2.0
Zr	8	*	*	18	*	*	10	*	*	32	*	64
In	9	3.4	0.80	1.8	1.3	1.0	1.5	1.0	0.80	1.3	1.2	0.60
Cu	20	23	29	21	26	31	39	62	66	40	66	72
Sc	12	14	4.0	7	6	12	2.2	2.1	31	0.10	19	7
Bi	2.1	2.0	4.0	0.40	9	2.5	2.3	1.8	4.0	1.0	*	2.5
Er	1.0	1.8	2.0	1.0	1.1	1.3	1.2	2.0	2.8	1.6	1.6	2.8
Y	0.07	*	0.50	0.05	0.94	0.75	0.64	0.50	0.44	0.12	0.60	4.5
Dy	*	*	*	*	*	*	*	*	*	*	*	*
Tb	*	*	*	*	*	*	*	*	*	*	*	*
Gd	*	*	*	*	*	*	*	*	*	*	*	*
Sm	0.20	*	*	0.20	*	*	*	*	*	*	*	*
Nd	2.9	*	*	0.70	*	*	0.30	*	*	0.20	*	*
Pr	0.80	*	*	0.60	*	*	0.60	*	*	*	*	*
Ce	0.70	*	0.20	0.50	*	*	0.40	*	*	*	*	*
La	0.90	0.50	0.50	0.80	0.30	0.20	0.80	*	*	0.70	0.60	1.7
Sr	*	4.0	*	3.0	*	*	3.0	*	4.0	*	4.0	5
Pb	10	*	*	13	*	*	10	*	*	10	*	*
Ba	100	43	20	72	43	20	60	10	*	13	5	*
Rb	960	1600	1750	1113	1500	2650	1300	2700	2700	1745	2300	3300
Tl	0.20	0.30	0.80	0.30	0.90	0.90	0.60	0.90	0.90	1.0	1.3	2.4
Cs	100	150	150	153	1000	250	173	450	450	190	1000	200

	G VIII	A VIII	P VIII	G X	A X	P X	G XI	A XI	P XI	G XII	A XII	P XII
	SM-46	H-593A	H-593B	Average of five	SM-296C	SM-296A	Average of two	SM-586B	SM-586A	SM-579	SM-639	SM-639A
SiO_2	45.86	44.83	45.34	45.74	47.18	45.16	45.60	44.65	45.52	47.01	45.35	45.01
TiO_2	1.25	0.03	0.20	0.60	0.45	0.26	1.48	0.39	0.16	1.41	0.21	0.12
Al_2O_3	34.71	34.50	34.77	32.97	33.06	34.41	33.32	33.42	33.16	32.42	35.49	34.79
Fe_2O_3	0.42	0.88	0.75	0.91	0.77	0.84	0.07	1.24	2.42	0.26	1.28	1.33
FeO	1.10	2.20	1.50	2.34	2.39	1.92	1.66	1.45	1.63	2.30	1.38	1.76
MnO	0.01	0.15	0.09	0.06	0.07	0.12	0.01	0.08	0.10	0.02	0.07	0.05
MgO	1.41	1.64	1.04	2.17	1.07	1.82	1.57	2.36	1.01	1.76	1.23	0.77
CaO	n.d.	n.d.	0.01	n.d.	n.d.	0.03	n.d.	0.41	0.09	n.d.	n.d.	n.d.
Na_2O	0.54	0.48	0.62	0.41	0.39	0.49	0.57	0.48	0.40	0.54	0.54	0.44
K_2O	10.41	10.61	10.55	10.56	10.41	10.77	10.49	10.65	10.19	10.19	10.75	10.61
Cl	0.09	0.14	0.13	0.07	—	—	n.d.	0.07	0.09	0.02	0.10	0.10
F	0.04	0.13	1.04	0.03	—	—	0.12	0.19	0.69	0.16	0.39	0.76
H_2O^+	4.52	4.27	4.29	4.04	4.02	4.24	4.65	4.59	4.97	4.06	4.03	4.57
H_2O^-	0.20	0.05	0.13	n.d.	n.d.	n.d.	0.15	n.d.	n.d.	0.26	n.d.	0.05
	100.54	99.91	100.66	100.15	99.56	100.06	99.69	99.96	100.42	100.41	100.82	100.32
O ≡ Cl	0.02	0.03	0.23	0.00	—	—	—	0.02	0.02	—	0.02	0.02
O ≡ F	0.02	0.06	0.44	0.01	—	—	0.05	0.08	0.29	0.07	0.16	0.32
	100.50	99.82	99.79	100.14	99.56	100.06	99.64	99.86	100.11	100.34	100.64	99.98
Trace elements (ppm)												
Be	*	28	28	8			*	36	22	5	36	10
Ge	0.21	3.0	4.0	0.17			0.07	6	8	0.35	8	13
Ga	110	75	90	102			110	75	92	110	75	90
V	5	10	16	4.0			5	11	13	6	13	15
Cr	22	*	*	13			25	6	*	5	*	*
T	60	*	*	34			49	8	*	22	*	*
Mo	0.20	*	0.70	0.20			0.14	0.40	0.12	0.20	0.30	0.60
Nb	19	28	72	23			2.4	37	42	13	58	90
Zn	306	481	528	30			96	120	169	251	260	265
Sn	100	300	420	144			57	100	140	55	200	275
Li	600	1200	3400	1460			360	550	480	470	600	850
Ni	6	*	*	5			2.0	*	*	*	*	*
Zr	*	*	*	24			30	57	*	23	22	*
In	6	0.40	0.09	5			4.0	0.80	0.24	0.60	0.40	0.20
Cu	27	29	31	11			17	19	23	21	23	25
Sc	5	2.3	11	6			6	7	1.7	5	11	5
Bi	1.4	*	5	0.90			0.80	*	0.90	*	1.5	4.0
Er	0.70	2.5	3.0	1.0			0.40	0.46	0.50	0.60	0.70	2.0
Y	0.27	0.02	0.49	*			1.7	0.50	0.41	0.04	0.02	0.41
Dy	0.30	*	*	*			*	*	*	*	*	*
Tb	0.10	*	*	*			*	0.30	*	*	*	*
Gd	1.0	*	*	1.9			1.9	0.40	*	1.0	*	*
Sm	0.70	*	*	0.60			1.7	1.1	*	0.70	*	*
Nd	1.8	0.60	0.60	8			7	1.5	*	1.5	1.2	0.50
Pr	1.0	*	*	1.8			1.7	0.60	*	1.4	*	*
Ce	0.60	*	*	1.7			1.6	0.80	*	1.0	0.40	*
La	2.8	2.9	1.3	6			5	0.80	0.09	4.0	0.40	4.0
Sr	*	*	*	*			3.0	*	*	*	*	4.0
Pb	15	*	*	5			10	*	*	10	*	*
Ba	180	10	*	79			158	43	10	100	*	*
Rb	700	2000	2100	1780			600	900	2150	640	1400	2950
Tl	0.30	0.40	0.50	0.20			0.50	0.70	1.0	0.70	0.90	3.5
Cs	32	1000	100	137			52	250	180	42	320	400

Analyst: A. Neiva.
— = not determined; n.d. = not detected; * = below the limit of sensitivity.
A = aplite; G = granite; P = pegmatite.

TABLE VIII

Muscovites from parental granite and aplites and pegmatites coexisting in the same vein cutting the schists

	Granite G X	Apl. SM-604	Pegm. SM-604A	Apl. SM-615A	Pegm. SM-615B	Pegm. SM-615C	Apl. SM-185	Pegm. SM-185A	Apl. SM-603	Pegm. SM-603A
SiO_2	45.74	45.29	45.21	46.77	45.13	47.20	45.50	45.67	45.58	45.58
TiO_2	0.60	0.23	0.43	0.09	0.06	0.06	0.21	0.17	0.10	0.10
Al_2O_3	32.97	34.79	33.90	35.81	34.18	33.00	34.85	34.96	36.49	36.23
Fe_2O_3	0.91	0.68	1.09	0.51	0.60	0.21	n.d.	n.d.	n.d.	0.01
FeO	2.34	3.04	2.19	2.03	2.66	3.09	2.22	2.40	1.66	2.09
MnO	0.06	0.15	0.15	0.04	0.05	0.06	0.10	0.09	0.04	0.08
MgO	2.17	0.41	1.11	1.00	1.29	1.41	1.46	1.01	0.58	0.41
CaO	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	0.25	0.15	0.11
Na_2O	0.41	0.44	0.49	0.53	0.50	0.57	0.40	0.56	0.73	0.58
K_2O	10.86	10.42	10.28	9.50	10.70	10.62	10.02	10.21	10.06	10.23
Cl	0.02	0.04	0.07	0.10	0.14	0.14	—	—	—	—
F	0.03	0.15	0.05	0.13	0.25	0.37	—	—	—	—
H_2O+	4.04	4.12	4.79	4.06	4.20	4.03	4.40	4.60	3.81	4.15
H_2O-	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	0.09	0.15
	100.15	99.76	99.76	100.57	99.76	100.76	99.35	99.92	99.29	99.72
$O \equiv Cl$	0.00	0.01	0.02	0.02	0.03	0.03	—	—	—	—
$O \equiv F$	0.01	0.06	0.02	0.05	0.11	0.16	—	—	—	—
	100.14	99.69	99.72	100.50	99.62	100.57	99.35	99.92	99.29	99.72

TABLE VIII (*continued*)

	Granite G X	Apl. SM-604	Pegm. SM-604A	Apl. SM-615A	Pegm. SM-615B	Pegm. SM-615C
Trace elements (ppm):						
Be	8	36	36	28	28	36
Ge	0.17	0.17	1.6	0.19	1.0	1.1
Ga	102	110	110	90	90	105
W	4.0	5	119	7	20	9
Cr	13	*	*	*	*	*
V	34	*	*	*	*	*
Mo	0.20	0.10	0.26	0.30	0.80	0.30
Nb	23	26	41	61	114	123
Zn	30	80	208	210	576	660
Sn	144	370	300	220	*	175
Li	1460	3400	1500	2000	900	1500
Ni	5	*	*	*	*	*
Zr	24	*	*	*	*	*
In	5	0.30	0.40	1.5	1.2	0.40
Cu	11	18	27	22	12	29
Sc	6	0.11	3.0	1.1	1.4	11
Bi	0.90	1.0	1.7	3.0	1.5	1.9
Er	1.0	1.6	1.8	1.1	2.6	2.9
Y	*	0.02	0.22	0.34	0.30	*
Dy	*	*	*	*	*	*
Tb	*	*	*	*	*	*
Gd	1.9	0.60	*	1.8	1.4	1.2
Sm	0.60	*	*	*	*	*
Nd	8	1.7	1.3	5	0.80	0.60
Pr	1.8	0.20	0.18	*	*	*
Ce	1.7	1.3	*	*	1.4	*
La	6	1.3	0.47	*	1.4	1.3
Sr	*	10	*	4.0	175	*
Pb	5	*	*	*	*	*
Ba	79	20	15	10	*	*
Rb	1780	3300	3000	2400	2500	3000
Tl	0.20	0.80	0.37	0.40	2.6	0.80
Cs	137	1200	1000	150	135	200

Analyst: A. Neiva.
— = not determined; n.d. = not detected; * = below the limit of sensitivity.
A = aplite; G = granite; P = pegmatite.

It can be seen that the variation between the trace elements of the schorlite of the aplite and that of the coexisting pegmatite in the same vein is similar to the variation found between the schorlite of granite and aplite or granite and pegmatite, which shows that schorlite is a good mineral to present the trend of differentiation.

GARNET

Only the garnet (variety almandine—spessartine) from the aplite H-578B and of the coexisting pegmatite H-578A could be separated and analysed for both major and trace elements (Table IX).

The only noticeable differences among the major constituents are less MnO, more total FeO and negligible Fe_2O_3 in the pegmatite garnet. Furthermore, the garnet from the pegmatite contains more Ga, Sn and Li. The ratio $Li \cdot 10^4/Mg$ is greater in the garnet from the pegmatite.

TABLE IX

Garnets from an aplite and a pegmatite coexisting in the same vein cutting the granite G II

	Apl. SM-578B	Pegm. SM-578A		Apl. SM-578B	Pegm. SM-578A
SiO_2	34.99	35.00	*End-members (mol %):*		
TiO_2	0.03	n.d.			
Al_2O_3	20.62	20.73	Almandine	61.1	62.7
Fe_2O_3	1.92	n.d.	Pyrope	2.5	5.3
FeO	26.06	28.76	Spessartine	36.4	32.0
MnO	14.99	13.14			
MgO	0.71	1.52	*Trace elements (ppm):*		
CaO	0.08	n.d.			
Na_2O	0.10	0.09	Ga	11	50
K_2O	0.08	0.06	Sn	*	45
H_2O+	0.13	0.46	Mo	8	*
H_2O-	n.d.	n.d.	Li	25	110
			Zr	175	175
	99.71	99.96	Sr	10	*

Analyst: A. Neiva.
n.d. = not detected; * = below the limit of sensitivity.

ORIGIN OF THE GRANITES, APLITES AND PEGMATITES

Figs. 1 and 2 illustrate the relationship between the distribution of normative Ab+An, Or and Q of the granites, aplites and pegmatites and Figs. 3 and 4 also illustrate the same relationship after removing the orthoclase corresponding to corundum and making the necessary recalculations. The position of the isobaric minimum-melting curve in the system Ab—Or—Q—H_2O, determined at pressures P_{H_2O} from 500 to 10 000 bar (Tuttle and Bowen, 1958; Luth et al., 1964), is given for comparison. As anorthite occurs in very small amounts in every rock analysed, it was added to albite.

In Figs. 1 and 2 the granites are situated on the potassium-rich side, which is due to the fact that they contain a large amount of micas, particularly muscovite, and also they are generally situated more towards this side than

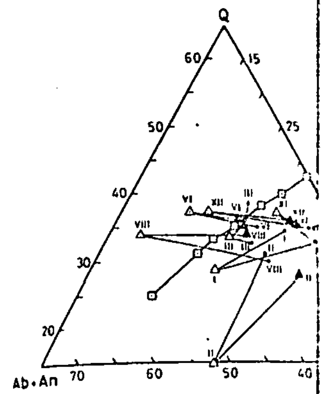


Fig. 1. Distribution of normat
pegmatites coexisting in the sa
curve for the system Ab—Or—
(Tuttle and Bowen, 1958; Lut
• = granites; △ = aplites; ▲ = p

Fig. 2. Distribution of normat
and pegmatites coexisting in t
Fig. 1.

the associated aplite and
603A.

After removing the ort
(corresponding to micas)
melting curve, which con

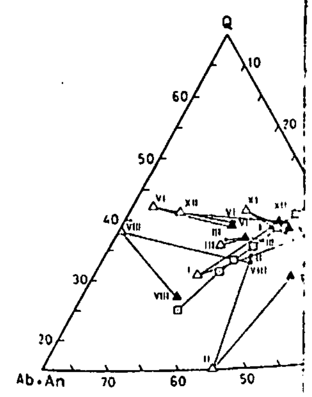
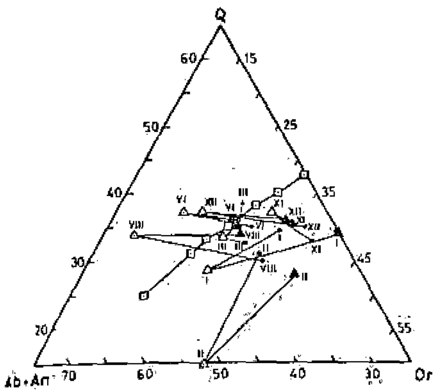


Fig. 3. Distribution of recalc
aplites and pegmatites coexi
corresponding to corundum

Fig. 4. Distribution of recalc
G X and aplites and pegmati
details see legend of Fig. 1.



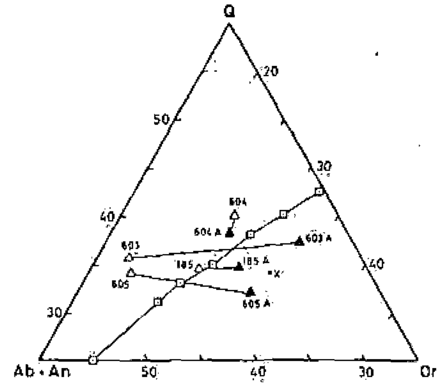
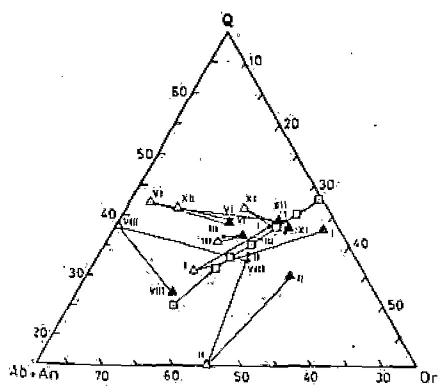


Fig. 1. Distribution of normative Ab+An, Or and Q of the parental granites and aplites and pegmatites coexisting in the same vein cutting the granites. The isobaric minimum-melting curve for the system Ab—Or—Q—H_2O determined at pressures P_{H_2O} from 500—10 000 bars (Tuttle and Bowen, 1958; Luth et al., 1964) is given.
♦ = granites; △ = aplites; ▲ = pegmatites; ▫ = minimum-melting point.

Fig. 2. Distribution of normative Ab+An, Or and Q of the parental granite G X and aplites and pegmatites coexisting in the same vein cutting the schists. For further details see legend Fig. 1.

the associated aplite and pegmatite, except for the pegmatites I, II, and SM-603A.

After removing the orthoclase corresponding to the corundum content (corresponding to micas) (Figs. 3 and 4), the granites are close to the minimum-melting curve, which confirms that a silicate melt was involved in the origin



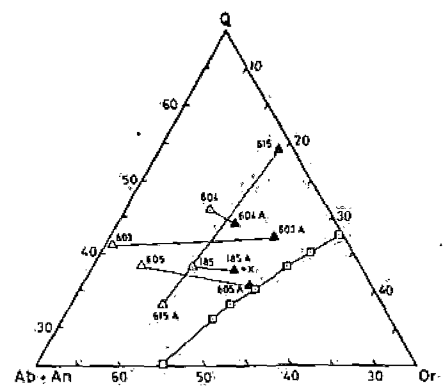


Fig. 3. Distribution of recalculated normative Ab+An, Or and Q of the parental granites and aplites and pegmatites coexisting in the same vein cutting the granites, after the orthoclase corresponding to corundum has been removed. For further details see legend of Fig. 1.

Fig. 4. Distribution of recalculated normative Ab+An, Or and Q of the parental granite G X and aplites and pegmatites coexisting in the same vein cutting the schists. For further details see legend of Fig. 1.

of the granites. However, the aplites are now situated towards the Ab+An—Q side line, which indicates that they underwent recrystallization with some albitization.

After removing the orthoclase corresponding to corundum (micas) (Figs. 3 and 4), all the aplites have less Or than the parental granites which indicates that the muscovite is primary.

Most of the pegmatites have less Or than the parental granites (Figs. 1 and 2), and when Or corresponding to corundum is removed (Figs. 3 and 4) some pegmatites have less Or than the parental granites, so their muscovite is primary. Other pegmatites show then more or similar Or to the parental granite, which may indicate that they have some secondary muscovite.

The granites have their origin in different pulses of granite magmas probably by partial refusion and they underwent recrystallization; their albite is primary, because they are not associated with magmas of more basic composition and they are close to the minimum-melting curve (Figs. 3 and 4) (Neiva, 1971, 1973).

As the granites contain biotite, the author calculated f_{O_2}, f_{H_2O} and P_{H_2O} of the granite magmas using this mineral (Neiva, in press).

Considering the temperature of crystallization of 700°C, f_{O_2} was calculated by the Fe^{3+}—Fe^{2+}—Mg triangular diagram of biotite by the method of Wones and Eugster (1965). Also f_{H_2O} was calculated according to the method of the same investigators and P_{H_2O} was then deduced.

Considering $P_{total} > P_{H_2O}$, P_{total} would be >2 kbar for G II—G VI, >1 kbar for G VIII, >4 kbar for G IX and >5 kbar for G X. The results, at least for G IX and G X were in agreement with Neiva's conclusions (1971, 1973), based on the mineralogical composition (mainly absence of sillimanite and kyanite) and chemistry of the granites, that the rocks were formed at depths greater than 15 km. It was impossible to calculate P_{H_2O} for G I, G XI—G XII, because G I biotite had a suspicious position in the Fe^{3+}—Fe^{2+}—Mg diagram and G XI—G XII biotites presented oxidation which was especially noteworthy in G XII biotite.

Using muscovite and considering the temperature of crystallization of 700°C, f_{O_2} is 10^{-17} calculated by the equation $\log f_{O_2} = 33\,000/T$ (°K) + 17.2 ± 15% of Wones and Eugster (1965) which is similar to the average f_{O_2} calculated (10^{-16}) by biotite using the Fe^{3+}—Fe^{2+}—Mg triangular diagram.

Using the Wones and Eugster's method (1965) f_{H_2O} was determined with muscovite from the granites as for the determination of f_{H_2O} with biotite. P_{H_2O} was calculated based on the f_{H_2O}. Both f_{H_2O} and P_{H_2O} were very low, which must be due to the fact that there is not any proper method to do these calculations using muscovite. If the temperature considered should be less than 700°C, f_{H_2O} and P_{H_2O} would be lower, as the calculation method implied.

Considering the temperature of crystallization of 700°C, f_{H_2O} and P_{H_2O} for the aplite and pegmatite magmas were also deduced using muscovite.

They were low. However, P_{H_2O} for the aplite and pegmatite magmas is generally higher than for the granite magma they are related to, and P_{H_2O} for the pegmatite magma is higher than for the coexisting aplite magma in the same vein.

As the temperature for muscovite crystallization must decrease in the sequence granite → aplite → pegmatite, P_{H_2O} values were obtained assuming the temperature for muscovites from aplites and pegmatites to be lower than 700°C. They were so low that the temperature for muscovites from aplites and pegmatites should not be much less than 700°C.

Burnham (1967) found that at water pressures of 4.0 kbar and higher, muscovite crystallizes as a primary phase from the water-saturated melt, whereas below 4.0 kbar alkali feldspar or quartz appears at the liquid instead of muscovite, thus as the granites were formed at water pressures about or above 4 kbar, the muscovite from granites, aplites and pegmatites is mainly primary.

According to Burnham (1967), in the rocks or magmas which contain normative corundum, the magmatically derived aqueous phase ordinarily enters the stability field of muscovite only at its highest temperature limit, which is about 682°C at 4 kbar according to Althaus et al. (1970) and about 710°C at 5 kbar according to Storre and Karotke (1972), so the muscovite from granite, aplite and pegmatite is mainly primary.

An attempt was made to find out which could be the position of the aplites and pegmatites in the model of Jahns and Burnham (1967) for the derivation and crystallization of the granitic pegmatites. It was concluded that the aplites containing lenticles of pegmatite are the product *V* in the same model and they could apparently have been formed by two processes *K* and *I*. However, the latter is not appliable here because it involves marked reduction in total confining pressure on the system, and it was already shown by muscovite that P_{H_2O} of the magma increases in the sequence granite → aplite → pegmatite.

The process *K* ("partitioning of nonvolatile constituents between silicate melt and increasing amounts of aqueous fluid with diffusion of materials along concentration gradients, especially in the aqueous phase; crystallization from both fluid phases, segregation of solid products according to amount and degree of interconnection on the aqueous fluid, and reaction between solid phases and the fluid phases") is responsible for the formation of the aplite—pegmatite veins.

ACKNOWLEDGEMENTS

Most of the research work was carried out in the Department of Mineralogy and Petrology, University of Cambridge, England, and the author is grateful to Dr. S.R. Nockolds for his valuable advice and criticism. Mr. R. Allen is grateful acknowledged for his help in the determination of some trace elements. Thanks are due to Dr. G.D. Nicholls for the facilities in his laboratory of mass spectrography of the Department of Geology, University of Manchester, England. Prof. J.M. Cotelo Neiva is thanked for his encouragement, valuable help in the field work and facilities in the Department of Mineralogy and Geology, University of Coimbra, Portugal; and Mr. M.M. Azevedo is also thanked for his help in the field work. Thanks are due to Comissão Coordenadora da Investigacão para a O.T.A.N. and Instituto de Alta Cultura, Portugal, for their grants.

REFERENCES

Althaus, E., Karotke, E., Nitsch, K.H. and Winkler, H.G.F., 1970. An experimental re-examination of the upper stability limit of muscovite plus quartz. Neues Jahrb. Mineral., Monatsh., 7: 325—336.

Burnham, C.W., 1967. Hydrothermal fluids at the magmatic stage, New York. In: H.L. Barnes (Editor), Geochemistry of Hydrothermal Ore Deposits. Holt, Rinehart and Winston, New York, N.Y., pp.34—76.

Gilberg, M., 1964. Halogens and hydroxyl contents of micas and amphiboles in Swedish granitic rocks. Geochim. Cosmochim. Acta, 28: 495—516.

Hahn-Weinheimer, P. and Ackermann, H., 1967. Geochemical investigations of differentiated magmatic granite plutons of the Southern Black Forest, II. The zoning of the Malsburg granite pluton as indicated by the elements titanium, zirconium, phosphorus, strontium, barium, rubidium, potassium and sodium. Geochim. Cosmochim. Acta, 31: 2197—2218.

Heier, K.S., 1962. Trace elements in feldspars — a review. Nor. Geol. Tidsskr., (Feldspar Volume), 42: 415—454.

Heier, K.S. and Taylor, S.R., 1959. Distribution of Ca, Sr and Ba in Southern Norwegian pre-Cambrian alkali feldspars. Geochim. Cosmochim. Acta, 17: 286—304.

Jahns, R.H. and Burnham, C.W., 1969. Experimental studies of pegmatite genesis, I. A model for the derivation and crystallization of granitic pegmatites. Econ. Geol., 64: 843—864.

Luth, W.C., Jahns, R.H. and Tuttle, O.F., 1964. The granite system at pressures of 4 to 10 kilobars. J. Geophys. Res., 69: 759—773.

Neiva, A.M.R., 1971. Geochemistry of late stage granitic rocks from Northern Portugal. Ph.D. Dissertation, Univeristy of Cambridge, Cambridge (unpublished).

Neiva, A.M.R., 1973. Geochemistry of the granites and their minerals from central area of northern Portugal. Mem. Not. Mus. Lab. Mineral. Geol. Univ. Coimbra, 76: 1—43.

Neiva, A.M.R., 1974. Geochemistry of tourmaline (schorlite) from granites, aplites and pegmatites from northern Portugal. Geochim. Cosmochim. Acta, 38: 1307—1317.

Neiva, A.M.R., in press. Geochemistry of biotites from central northern Portugal and the role of their tin content. Mineral. Mag.

Nicholls, G.D., Graham, A.L., Williams, E. and Wood, M., 1967. Precision and accuracy in trace elements analysis of geological materials using solid source spark mass spectrography. Anal. Chem., 39: 584—590.

Norrish, K. and Hutton, J.I., 1969. An accurate X-ray spectrographic method for the analysis of a wide range of geological samples. Geochim. Cosmochim. Acta, 33: 431—453

Odikadze, G.L., 1967. Distribution of tantalum, niobium, tin and fluorine in micas from granitoids of the Greater Caucasus and the Dzirula crystalline massif. Geochem. Int., 4: 754—763.

Odikadze, G.L., 1971. Distribution of fluorine in the granitoids of the Greater Caucasus and Dzirul' Massif. Geochem. Int., 8: 314—323.

Ratiyev, L.A., 1964. Lithium and cesium contents in the Trigrad regions (Southern Bulgaria). Geochem. Int., 5: 1011—1013.

Smith, J.V., 1974. Feldspar minerals, 2. Chemical and textural properties. Springer-Verlag, Berlin, 690 pp.

Storre, B. and Karotke, E., 1972. Experimental data on melting reactions of muscovite+quartz in the system K_2O—Al_2O_3—SiO_2—H_2O to 20 Kb water pressure. Contrib. Mineral. Petrol., 36: 343—345.

Stravov, O.D. and Znamenskii, E.B., 1961. The distribution of rare alkali mineralizers (B, F) in granitoids of the Kalbinskii Massif (Eastern Kazakhstan). Geochem. Int., 12: 1237—1243.

Tuttle, O.F. and Bowen, N.L., 1958. Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$—$KAlSi_3O_8$—SiO_2—H_2O. Geol. Soc. Am., Mem., 74: 1—145.

Vejnar, Z., 1968. The genesis of pegmatites and its relationship to the metamorphic and magmatic development of the West-Bohemian crystalline complexes. Rada Mat. Přérodnich Věd, 78(1): 1—69.

Vlasov, K.A., 1966. Geochemistry of Rare Elements, I. Israel Program for Scientific Translations, Jerusalem, 688 pp. (translated from Russian).

Walenczak, Z., 1959. Gallium content in feldspars of the granites and pegmatites of Karkonsze and Strzegom (Lower Silesia). Bull. Acad. Pol. Sci., Cl. 3, 7: 595—603.

Wones, D.R. and Eugster, H.P., 1965. Stability of biotite: experiment, theory and application. Am. Mineral., 50: 1228—1272.