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THE COMPOSITIONAL SPACE OF MUSCOVITE IN GRANITIC ROCKS

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Abstract

The compositional range of igneous muscovite (Ms) and the nature and extent of the solid solutions are defined. For this purpose, a database of 189 muscovite compositions taken from the literature has been used. Most (159) are from peraluminous granites (*sensu lato*), and a few (30) are from pegmatites and aplites. The compositions were recalculated on the basis of 22 O, and all iron was considered as Fe^{2+}. A quality screen was applied to the whole dataset; about 10% of the compositions were rejected owing to the anomalous chemical contents of the octahedral or interlayer sites. All chemical data were then processed by statistical analysis of the chemical variability, and plotted on specific binary diagrams useful to assess the extent of the main substitutions. Muscovite in granitic rocks turns out to have moderate celadonitic and paragonitic contents. In 98.8% of the cases, the indicators of celadonitic substitution fall in the following ranges: s = Si – 6 between 0.031 and 0.036 *apfu*, Fm = Fe^{2+} + Mg between 0.135 and 1.349 *apfu*, and a = 6 – Al between 0.019 and 2.087 *apfu*. Concerning the extent to the solid solution toward paragonite, the value of 100 Na/(Na + K) varies between 5 and 23.2% in 87.5% of the cases. On the basis of limited data, muscovite from pegmatites and aplites shows limited extents of the celadonite and paragonite substitutions.

Keywords: muscovite, chemical composition, granitic rocks.

Sommaire

Nous définissons ici l'intervalle de composition de la muscovite primaire et la nature et l'importance des solutions solides. A cette fin, nous avons extrait de la littérature une banque de données comprenant 189 compositions. La plupart (159) proviennent de granites hyperalumineux (*sensu lato*), et quelques compositions (30) proviennent de pegmatites et d'aplites. Les compositions ont été recalculées sur une base de 22 atomes d'oxygène, et tout le fer est considéré fer bivalent. Nous avons appliqué un filtre de qualité, qui a causé l'élimination d'environ 10% des compositions à cause de taux d'occupation anomales dans les sites octaédriques ou inter-feuillet. Toutes les données chimiques retenues ont été traitées par analyse statistique de leur variabilité, et placées sur des diagrammes binaires afin d'évaluer l'étendue des substitutions importantes. La muscovite des roches granitiques a une teneur moyenne des composants céladonitique et paragonitique. Dans 98.8% des cas, les indicateurs de la substitution céladonitique définissent les intervalles suivants: s = Si – 6 entre 0.031 et 0.036 atomes par unité formulaire (*apuf*), Fm = Fe^{2+} + Mg entre 0.135 et 1.349 *apuf*, et a = 6 – Al entre 0.019 et 2.087 *apuf*. L'étendue de la solution solide vers le pôle paragonite se mesure par la valeur de 100 Na/(Na + K), qui va de 5 à 23.2% dans 87.5% des cas. A la lumière de données peu nombreuses, la muscovite des pegmatites et des aplites fait preuve d'une solution solide plus restreinte vers les pôles céladonite et paragonite.

(Traduit par la Rédaction)

Mots-clés: muscovite, composition chimique, roches granitiques.

Introduction

An effort has been made over the last thirty years at the University of Padova to evaluate the variability of rock-forming micas, in particular muscovite (Cipriani *et al.* 1968, 1971, Sassi 1971, 1972, Guidotti & Sassi 1998a, b). Among other relevant results, the compositional space of metamorphic muscovite and the control of the intensive and extensive variables on its composition have been assessed, but no attention has been paid to muscovite from igneous rocks. The present research is a contribution intended to fill this gap. Specifically, our aim is to define the compositional space of muscovite from granitic rocks, and to ascertain the nature and extent of the solid solutions (disregarding trace elements), on the basis of data from the literature.

Review of the Literature

Although not abundant, a number of analytical data on igneous muscovite are to be found in the literature. However, only a few studies of more limited scope have

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been published to assess the general compositional features of these micas.

The most comprehensive of these attempts was that of Miller *et al.* (1981), who presented compositional data on muscovite from 41 rock samples representing 16 plutons, mostly from North America. One of the major goals of their research was to determine possible compositional differences between primary and secondary muscovite in granites: the grains of primary origin turned out to be considerably richer in Ti, Al and Na (and poorer in Mg and Si) than the grains of secondary muscovite. However, these authors did not attempt to define the compositional volume of primary muscovite, which is the goal of the present paper. On this topic, they concluded that the analyzed samples of muscovite are far from the ideal end-member muscovite. They contain appreciable Fe, Mg, Ti, Na and F, and they are deficient in Al and have a modest excess of Si.

The paper by Speer (1984) is a major contribution to the assessment of the composition of biotite in igneous rocks, and its relation to conditions of crystallization. However, the author barely touched upon the topic of igneous muscovite (p. 325-328), and mostly focused on muscovite to show the compositional difference among different generations. Therefore, the need to assess the compositional volume of the igneous muscovite, in terms of nature and extent of its deviation from the ideal composition, still remains.

The Database

In order to fill this gap, we used a database of 189 chemical compositions of muscovite taken from the literature, all pertaining to peraluminous granitic rocks (granites and granodiorites), and related pegmatites and aplites. Actually, the compositions in our database are somewhat disparate because they were obtained by different analytical methods in different laboratories: electron-microprobe analyses (EMPA), X-ray fluorescence (XRF), Atomic Absorption (AA), Inductively Coupled Plasma – Atomic Emission Spectrography (ICP–AES). However, considering their relatively large number and the reconnaissance character of the present research, this database is appropriate for our needs.

In order to minimize the possible effects of spurious data (including those related to possible microscopic and submicroscopic inclusions in the crystals), which may obscure or alter the compositional patterns to be recognized, all compositions were checked with a quality-control screen, after having recalculated all of them on the basis of 22 atoms of oxygen and considering all iron as Fe^{2+}. Consequently, 24 out of the compositions 189 collected were disregarded because of the following anomalous chemical contents: i) $(Na + K + Ca) < 1.8$ *apfu* (atoms per formula unit), ii) $(Fe + Mg) \geq 2$ *apfu*, and iii) Si in the range 6.30 – 7.00 *apfu* with $(Fe + Mg) < 0.25$ *apfu*.

Each of the anomalous situations is probably related to one of the following reasons: a) extreme analytical conditions (*e.g.*, counting time is too long: Kontak *et al.* 1988), which causes a depletion in the alkali contents, b) noticeably high content of trace elements (*e.g.*, Charoy *et al.* 1995), and c) suspected interlayering between muscovite and biotite or chlorite (*e.g.*, Konings *et al.* 1988).

The edited database of 165 compositions (see Appendix) has been analyzed using a statistical approach aimed at defining, for each of the main chemical components, the frequency distribution of the contents and the major correlations among them.

The results of this statistical analysis are presented and discussed also by means of diagrams designed to show the extent of the main solid-solutions in muscovite: a) the celadonitic substitution: Si, $(Fe^{2+} + Mg) \Rightarrow$ ^{IV}Al, ^{VI}Al, b) the paragonite substitution: Na $\Rightarrow$ K, and c) the margarite substitution: Ca, Al $\Rightarrow$ K, Si. Furthermore, the deficiency affecting the interlayer site and the substitution of Fe^{3+} for ^{VI}Al also are considered, although through indirect inferences.

Statistical Analysis of the Chemical Variability of Muscovite in Igneous Rocks

The compositional space of 165 samples of muscovite from granitic rocks (including aplites and pegmatites) has been determined within the above-mentioned database. We calculate i) the main statistical parameters (average, standard deviation, minimum, maximum, *etc.*) of the nine major components of muscovite: Si, Al, Fe, Mg, Ti, Mn, K, Na, and Ca; they are shown in Table 1. We also show ii) the frequency distributions of these major-element contents; they are represented in Figure 1 by cumulative curves and histograms (class width = $\sigma/4$, where σ is the standard deviation). Figure 1 shows that about 60% of the data concerning Si and Al contents falls respectively in the range 6.109–6.440 and 5.232–5.805 *apfu*, whereas about 70% of Fe and Mg data falls in the range 0.145–0.622 and 0.022–0.231 *apfu*, respectively. Na shows a possible bimodal distribution: 7.9% of Na data falls between 0.039 and 0.059 *apfu*, and 64.7% between 0.099 and 0.21 *apfu*, with 6.7% in the range 0.059–0.099. Finally, we provide iii) the occurrence and sign of binary correlations among the above-listed chemical contents (Table 2). For a database of 165 compositions and a probability level of 95%, the minimum value of r (correlation coefficient) for significant correlations is very low (about 0.2). Therefore, we can consider values of $r \geq 0.4$ as good, and values of $r \geq 0.6$ as excellent.

All these correlations are strictly related to the well-known solid-solutions affecting muscovite. The database shows positive correlations for Si *versus* Fe_{tot}, Si *versus* *Fm*, where *Fm* is equal to $(Fe_{tot} + Mg)$, and nega-

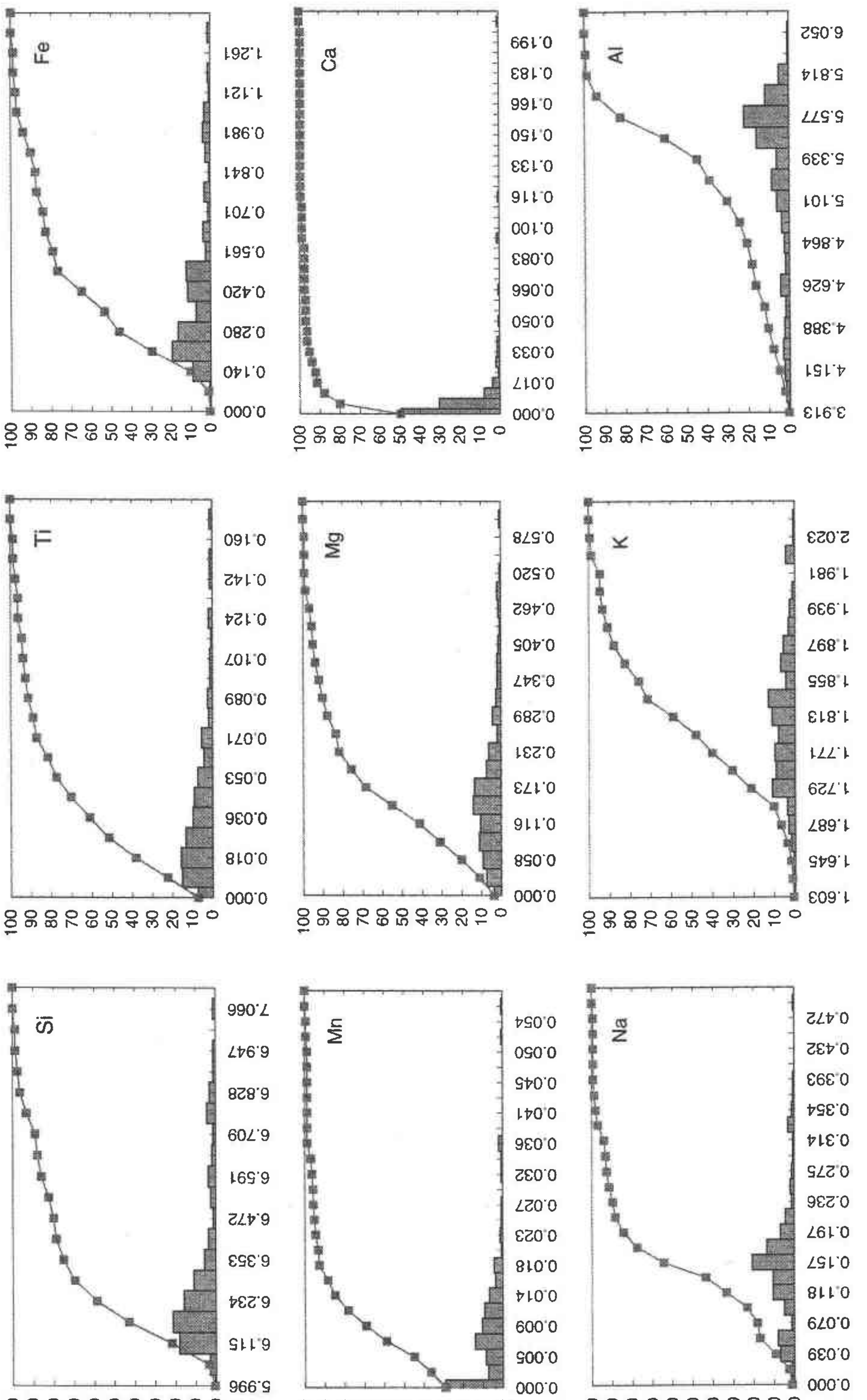

FIG. 1. Cumulative curves and histograms representing frequency distribution of the element content (class width = σ/4, where σ is the standard deviation). Units for the abscissa: *apfu*.

TABLE 1. MAIN STATISTICAL PARAMETERS DESCRIBING THE MAJOR COMPONENTS OF MUSCOVITE

Statistical parameters	Si	Ti	Mn^{2+}	Mg	Na	K	Fe	Ca	Al^{tot}	*Na/Na+K*	*2- Σ(Na+K+Ca)*
Mean	6.287	0.036	0.007	0.153	0.145	1.800	0.399	0.007	5.204	7.388	0.045
Standard error	0.019	0.003	0.001	0.009	0.006	0.007	0.022	0.002	0.037	0.300	0.006
Median	6.201	0.026	0.006	0.135	0.145	1.799	0.312	0.001	5.368	7.542	0.047
Mode	6.636	0.000	0.000	0.000	0.045	1.803	0.737	0.000	4.625	2.424	0.150
Standard deviation	0.238	0.036	0.009	0.116	0.079	0.084	0.280	0.022	0.475	3.848	0.078
Kurtosis	0.978	2.654	8.230	1.453	2.390	0.070	0.961	47.520	0.408	1.839	2.232
Skewness	1.381	1.638	2.438	1.208	1.028	0.437	1.287	6.256	-1.138	0.809	-0.837
Minimum	5.996	0.000	0.000	0.000	0.000	1.603	0.000	0.000	3.913	0.000	-0.312
Maximum	7.036	0.165	0.055	0.582	0.485	2.027	1.281	0.209	6.000	23.215	0.195

Based on 165 analytical datasets on muscovite from granitic rocks.

TABLE 2. BINARY CORRELATION TABLE INDICATING THE SIGNIFICANT CORRELATIONS AT THE 95% PROBABILITY LEVEL IN THE DATABASE OF 165 DATASETS

	^{IV}Si	^{IV}Al	^{VI}Al	^{VI}Ti	Mn^{2+}	Mg	Ca	Na	K	Fm	Al_{tot}	Fe_{tot}
IV Si	1.000											
IV Al	-1.000	1.000										
VI Al	**-0.846**	**0.846**	1.000									
VI Ti	-0.058	0.058	-0.168	1.000								
Mn^{2+}	0.078	-0.078	-0.126	-0.205	1.000							
Mg	-0.057	0.057	-0.176	0.290	-0.170	1.000						
Ca	-0.074	0.074	0.104	-0.148	-0.101	-0.040	1.000					
Na	***-0.524***	***0.524***	***0.506***	-0.060	-0.246	-0.085	0.207	1.000				
K	***0.465***	***-0.465***	**-0.605**	-0.025	0.195	0.020	-0.065	**-0.608**	1.000			
Fm	**0.808**	**-0.808**	**-0.913**	-0.062	0.232	-0.168	-0.145	-0.488	***0.587***	1.000		
Altot	**-0.957**	**0.957**	**0.964**	-0.062	-0.107	-0.067	0.093	***0.536***	***-0.560***	**-0.898**	1.000	
Fetot	**0.796**	**-0.796**	**-0.908**	-0.061	0.235	-0.155	-0.141	-0.478	**0.606**	1.000	**-0.892**	1.000

$r \geq 0.6$ bold
$0.6 > r \geq 0.4$ bold italic

Note that 0.2 is the minimum value of r, the correlation coefficient.

tive ones for Na *versus* K, Si *versus* Al_{tot}, Al *versus Fm*, and Al *versus* Fe_{tot}. The positive correlations of Si *versus* K, Al_{tot} *versus* Na, K *versus* Fe_{tot}, K *versus Fm*, and the negative ones of Si *versus* Na, and Al_{tot} *versus* K are also related to the main solid-solution, although indirectly. In particular, the negative correlation of Si *versus* Na is consistent with the decrease of the extent of solid solution toward paragonite with increase in the degree of celadonitic substitution, observed by Guidotti *et al.* (1994) and discussed by Guidotti & Sassi (1998a).

Finally, deviation of these muscovite compositions from the ideal composition was investigated by preparing specific binary diagrams useful to assess the extent of the main substitutions affecting muscovite (Fig. 2).

The results of all these statistical analyses suggest the following comments, which apply to the entire database.

Celadonitic substitution

Muscovite from granitic rocks is invariably affected by a celadonitic substitution to an important extent. In our database, Si ranges between 5.996 and 7.036 *apfu* (Table 1, Fig. 1), but 98.9% of the Si data falls in the range 6.03–7.036, and 20% of the data exceeds 6.47 (Fig. 1). The significant extent of this substitution can be evaluated by means of the related parameters proposed by Guidotti & Sassi (1976): $s = (Si - 6) > 0$, $Fm = (Fe^{2+} + Mg) \geq 0$ (Fig. 2a) and $a = (6 - Al) > 0$. In 98.8% of the cases, the value of s varies between 0.031 and 1.036 *apfu*, that of *Fm,* between 0.135 and 1.349 *apfu*, and that of *a,* between 0.019 and 2.087 *apfu*.

Paragonite substitution

The substitution toward paragonite is important in most cases of igneous muscovite. In fact, the value of 100 Na/(Na + K), which is in the range 1–18% in 96.9% of the cases, falls between 5 and 23.2% in 87.5% of the cases (Fig. 2b, Table 1).

Margarite substitution

Ca enters to a minimal extent the structure of muscovite in granitic rocks (< 0.09 *apfu* in 97% of the cases), as well as, in general, in all cases of natural muscovite (Guidotti & Sassi 1998a). As suggested by those authors, the difference in charge and size between Ca and

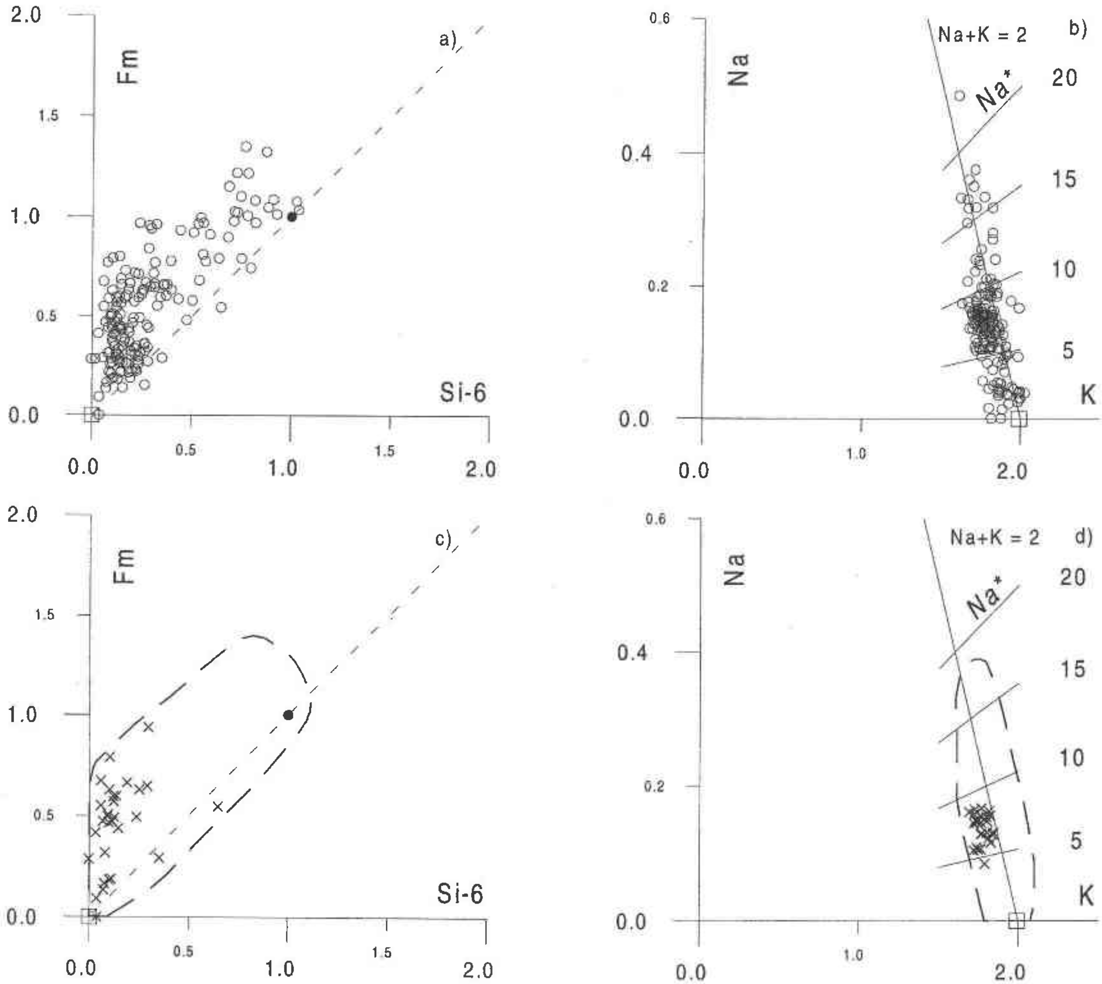

FIG. 2. Extent of celadonitic substitution (a) and of paragonite substitution (b) for all the database, and for muscovite from pegmatite and aplites (c, d). Full dot is phengite, open square is the ideal muscovite. Fm = (Fe_{tot} + Mg), and Na^* = 100 Na /(Na + K).

K is a serious limitation to the extent of the solid solution between margarite and muscovite.

Incorporation of Fe^{3+}

The departure of data points from the 1:1 line in Figure 2a provides indirect evidence of the variable Fe^{3+} content in these micas; in fact, spreading of the data points in the area above the 1:1 line reveals relative contents of R^{3+} (Fe^{3+} and Cr^{3+}, for example).

Deficit in the interlayer sites

The 2 – Σ(Na + K + Ca) value varies from 0 to 0.19 *apfu* (Table 1), in agreement with muscovite from metamorphic rocks. However, several chemical compositions (26%) included in this database show an apparent excess in the interlayer sites, revealing probably inaccuracies in the analytical data reported in the literature.

Other substitutions

Unfortunately, only a few authors (Neiva 1975, Le Bel 1979, Černý & Burt 1984, Lee *et al.* 1984, Evans & Patrick 1987, Ham & Kontak 1988, Jolliff *et al.* 1992, Du Bray 1994, Charoy *et al.* 1995) reported data on the concentration of minor and trace elements in muscovite. Consequently, nothing new can be added with respect to statements in the overview by Guidotti & Sassi (1998b). As regards Ti content, the compositions stud-

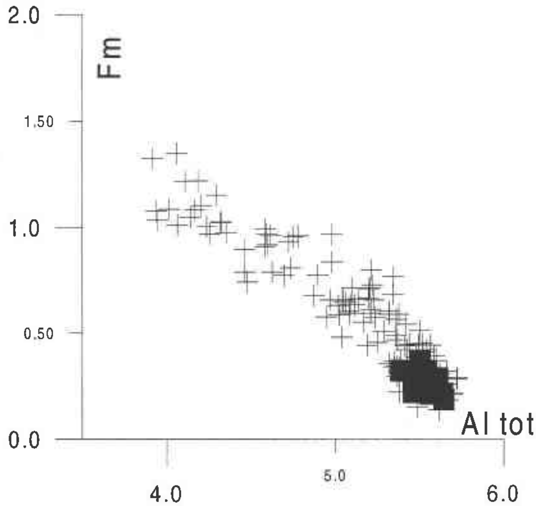

FIG. 3. The data points pertaining to muscovite from "strongly peraluminous" granites (squares) are confined within the part of the distribution field of all data points richest in Al and poorest in *Fm*.

ied are highly scattered, and fall between 0 and 0.10 *apfu* in 93% of the cases.

Additional comments can be made concerning the muscovite from aplites and pegmatites alone, on the basis of the limited amounts of data (30 compositions). An unusual composition of muscovite may be expected in these rocks, considering the particularly high contents of minor and trace elements in the related melts. In any case, interesting results are obtained if we distinguish the data points pertaining to muscovite from these rocks with respect to the whole database (contours in Figs. 2c, d). Muscovite from granitic pegmatites shows the lowest extent of the celadonitic substitution (99% of the compositions have $Si - 6 < 0.35$); furthermore, the unusual trend of these data points with respect to 1:1 line reveals that the incorporation of Fe^{3+} plays an important role in the composition of such muscovite, and that this substitution of Fe^{3+} for ^{VI}Al increases with the Fe_{tot} content. Solid solution toward paragonite is invariably present in muscovite of pegmatites, and the value of 100Na/(Na + K) lies in the narrow range 5–10 (Fig. 2d).

CONCLUDING REMARKS

Muscovite in granitic rocks turns out to have moderate celadonitic and paragonitic contents, the extents of which have been quantitatively assessed. Therefore, the main conclusion by Miller *et al.* (1981) (their point 1, pag. 33) is basically confirmed. However, our data points cover a larger area (*e.g.*, including Si > 55% in the "Al – Si – other" triangle of Miller *et al.* 1981); this finding may be related to the fact that most of their data points come from only two plutonic bodies.

No significant compositional difference between primary and secondary muscovite could be documented. Therefore, the statement of Miller *et al.* (1981) that "grains that appear texturally to be primary typically have higher content of Ti, Na, Al and lower Si and Mg than those that appear to be secondary", cannot be considered generally applicable.

The moderate celadonite contents recorded in our database could be related to bulk-composition constraints. In fact, from the petrological point of view, these contents are consistent with crystallization of muscovite in Al-poor, K-feldspar-bearing systems, which impose a celadonitic content to the muscovite, following the reasoning of Guidotti & Sassi (1976, p.100 and 125; 1998a, p. 829 and 830). These contents, however, remain moderate, owing to the absence of high pressures.

As regards the invariably present but moderate Na contents, to some extent they are also a result of the same bulk-composition constraints above outlined for the celadonitic substitution. In fact, this substitution inhibits, to some extent, the solid solution toward paragonite, for the reasons pointed out by Guidotti *et al.* (1994) and Guidotti & Sassi (1998a, b): "the longer bond lengths of the enlarged XII sites in *Fm*-rich Muscovite, combined with the small size of Na^+, apparently favour a low Na/(Na + K) ratio".

The importance of the bulk-rock composition as a factor controlling the composition of muscovite also is shown in Figure 3: the data points pertaining to muscovite from the "strongly peraluminous" granites are confined to the area richest in Al (and poorest in *Fm*) in the field of data points.

Finally, a provocative remark on the possible implication of a bimodal distribution of the Na values. If this type of distribution turns out to be significant after increasing the number of data from petrologically selected crystals of muscovite, it could be a petrologically significant division between igneous muscovite, crystallized from melts under the bulk-composition constraints outlined above (they are expected to have moderate to high celadonite contents and moderate Na contents), and metamorphic grains, inherited by the anatectic melt from the parent metamorphic rocks (they should have very low Na contents as well as very low celadonitic contents: see Guidotti & Sassi 1976, Figs. 12, 13, 14).

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APPENDIX: SAMPLES OF MUSCOVITE FROM GRANITIC ROCKS INCLUDED IN THE DATABASE

Sample	Rock type	References	Special remark	
n. 1	granite	1	P	*
n. 2	granite	1	P	*
n. 3	granite	1	P	*
n. 4	granite	1	P	*
n. 5	granite	1	P	*
n. 6	granite	1	P	*
n. 7	granite	1	P	*
n. 8	granite	1	P	*
n. 5 core	granite	2	P	**
n. 6 core	granite	2	P	**
n. 7 core	granite	2	P	**
n.8 core	granite	2	P	**
n. 9 core	granite	2	P	**
n. 10 core	granite	2	P	**
n. 11 core	granite	2	P	**
C 1825	granite	3	P	*
C1878 core	granite	3	P	*
C1878 rim	granite	3	S	*
C1888 1A	granite	3	P	*
C1888 2B	granite	3	S	*
C1888 3C	granite	3	S	*
C1888 4D	granite	3	S	*
C1888 4E	granite	3	S	*
C1888 5F	granite	3	S	*
169601	granodiorite to alkali-feldspar granite	4	P	*
169609	granodiorite to alkali-feldspar granite	4	P	*
169618	granodiorite to alkali-feldspar granite	4	P	*
169635	granodiorite to alkali-feldspar granite	4	P	*
169584	alkali-feldspar granite	4	P	*
169575	alkali-feldspar granite	4	P	*
1- TAB 2	leucomonzogranite porphyry	5	P	*
2- TAB 2	leucomonzogranite porphyry	5	S	*
3- TAB 2	leucomonzogranite porphyry	5	S	*
4- TAB 2	leucomonzogranite	5	P	*
5- TAB 2	leucomonzogranite	5	S	*
6- TAB 2	leucomonzogranite	5	S	*
7- TAB 2	granodiorite	5	S	*
8- TAB 2	granodiorite	5	S	*
9- TAB 2	leucomonzogranite	5	S	*
10- TAB 2	leucomonzogranite	5	P	*
11- TAB 2	leucomonzogranite	5	S	*
12- TAB 2	leucomonzogranite	5	S	*
13- TAB 2	leucomonzogranite	5	S	*
14- TAB 2	biotite monzogranite	5	S	*
1- TAB 3	muscovite-biotite monzogranite	5		*
2- TAB 3	muscovite-biotite monzogranite	5		*
3- TAB 3	muscovite-biotite monzogranite	5		*
4- TAB 3	muscovite-biotite monzogranite	5		*
5- TAB 3	muscovite-biotite leucomonzogranite	5		*
7- TAB 3	muscovite-biotite leucomonzogranite	5		*
8- TAB 3	muscovite-biotite leucomonzogranite	5		*
10- TAB 3	muscovite-biotite leucogranite	5		*
11- TAB 3	muscovite-biotite leucogranite	5		*
12-1- TAB 3	muscovite-biotite leucogranite	5		*
12-2- TAB 3	muscovite-biotite leucogranite	5		*
13- TAB 3	muscovite-biotite leucogranite	5		*
14- TAB 3	muscovite-rich greisens	5		*
15- TAB 3	muscovite-rich greisens	5		*
16- TAB 3	muscovite-rich greisens	5		*
17- TAB 3	muscovite-rich greisens	5		*
18- TAB 3	muscovite-rich greisens	5		*
EK-86-105	leucogranite	5	P	*
EK-86-105	leucogranite	5	P	*
EK-86-23C	leucogranite	5	P	*
EK-86-23C	leucogranite	5	P	*
EK-86-69	leucogranite	5	P	*
EK-86-69	leucogranite	5	P	*
TM-86-1	leucogranite	5	P	*
TM-86-1	leucogranite	5	P	*
BF 1	granitic pegmatites	6	P	*
DP 1	granitic pegmatites	6	P	*
ED 3	granitic pegmatites	6	P	*
ET 1	granitic pegmatites	6	P	*
HH 1	granitic pegmatites	6	P	*
RS 1	granitic pegmatites	6	P	*
BN1/79	granite	7		*
BN6/94	granite	7		*
BN3/98	granite	7		*
BN3/11	pegmatite	7		*
ms-1 79	granite	8	S	*
ms-1 79	granite	8	S	*
ms-1 04	granite	8	S	*
ms-2 80	granite	8	S	*
ms-2 07	granite	8	S	*
ms-3 04	granite	8	S	*
ms-3 79	granite	8	S	*
AC 25	granite	8	S	*
BE 05	granite	8	S	*
EK-86-23C	leucogranite	9	P	*
EK-86-132	leucogranite	9	P	*

APPENDIX: SAMPLES OF MUSCOVITE FROM GRANITIC ROCKS INCLUDED IN THE DATABASE

Sample	Rock type	References	Special remark	
EK-86-161	leucogranite	9	P	*
EK-86-1075b	leucogranite	9	P	*
EK-23C	leucogranite	9	P	*
EK-23C	leucogranite	9	P	*
EK 98	leucogranite	9	P	*
EK 98	leucogranite	9	P	*
EK 69	leucogranite	9	P	*
EK69	leucogranite	9	P	*
TM-86-1	leucogranite	9	P	*
EK-105	leucogranite	9	P	*
13	leucogranite	10	P	*
29	leucogranite	10	P	*
88	leucogranite	10	P	*
101	leucogranite	10	P	*
76	leucogranite	10	P	*
81	leucogranite	10	P	*
6 PH	quartz monzonite	11	S	
119-MW-60	aplite	12		
199-MW-61	aplite	12		
121-MW-60	aplite	12		
245-MW-60	aplite	12		
1	granite	13	P	*
2	granite	13	P	*
3	granite	13	P	*
4	granite	13	P	**
2 Mu(a)	leucogranite	14	P	*
2 Mu(c)	leucogranite	14	P	*
3 Mu(a)	leucogranite	14	P	*
3 Mu(b)	leucogranite	14	P	*
G II	granite	15		*
G III	granite	15		*
G IV	granite	15		*
G VI	granite	15		*
G VII	granite	15		*
G VIII	granite	15		*
G IX	granite	15		*
G X	granite	15		*
G XI	granite	15		*
G XII	granite	15		*
P II	pegmatite	15		
P III A	pegmatite	15		
P III B	pegmatite	15		
P IV	pegmatite	15		
P VI	pegmatite	15		
P VII	pegmatite	15		
P VIII	pegmatite	15		
P IX	pegmatite	15		
P X C	pegmatite	15		
P X D	pegmatite	15		
P XI	pegmatite	15		
P XII	pegmatite	15		
1	pegmatite	15		
2	pegmatite	15		
3	pegmatite	15		
4	pegmatite	15		
5	pegmatite	15		
6	pegmatite	15		
7	pegmatite	15		
A5 - 119	"granitoid"	16	P	**
A5- 7A	"granitoid"	16	P	**
A5 - 22	"granitoid"	16	P	**
A5 - 5	"granitoid"	16	P	**
A5- 5/9x	"granitoid"	16	P	**
A5 - 9 - 1/57	"granitoid"	16	P	**
A5 - 119	"granitoid"	16	S	**
A5 - 22	"granitoid"	16	S	**
2	granite	17	P	*
3	granite	17	P	*
4	granite	17	P	*
5	granite	17	P	*
6	granite	17	P	*
S205	granite	18	P	*
S116	granite	18	P	*
S098	granite	18	P	*
S111	granite	18	P	*

P: primary muscovite, S: secondary muscovite.
*: peraluminous: the relatively high Al-content is inferred from the occurrence of muscovite.
**: strongly peraluminous; the very high Al content is inferred from the occurrence of other aluminous phases (Sil, And, Crd) in addition to Ms.

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