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Muscovite and K–feldspar from two-mica adamellite in northwestern Maine: composition and petrogenetic implications

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Abstract

New analyses of muscovite and K–feldspar in adamellites from northwestern Maine show that the composition of muscovite [especially the $K(Mg,Fe)_2Al_2(Si_8O_{20})(OH)_4$ or celadonite content] systematically changes with mineral assemblage in a pattern similar to that found in metamorphic parageneses. The data also support the suggestion that the alumina content of the environment during crystallization and cooling strongly influences the structural state attained by K–feldspar.

Introduction

Previous studies, (Evans and Guidotti, 1966; Guidotti, 1973) of muscovites from medium- to high-grade metapelites of northwestern Maine showed: (1) distinctive patterns for the composition of muscovite as a function of grade, and (2) a clear relationship at a given grade between the composition of muscovite and the mineral assemblage. No compositional data, however, have been reported for the abundant muscovite in the two-mica adamellites commonly associated with the lower sillimanite through K–feldspar + sillimanite zone metapelites of the area (*e.g.*, see Doyle, 1967, or Moench and Zartman, 1976).

This note compares such data with that from muscovites of the metapelites. It also assesses the effect of change of igneous mineral assemblage on mineral composition.

Guidotti *et al.* (1973) argued that the structural state of igneous and metamorphic K–feldspars of northwestern Maine might be related to the activity of Al_2O_3 in a given specimen (*i.e.*, in the pore fluid or magma) at the time of formation or during cooling. They found orthoclase in sillimanite-bearing pelitic rocks but intermediate microcline in the interbedded calc–silicates and biotite granulites (the feldspars characterized in the manner of Wright and Stewart, 1968). The argument of Guidotti *et al.* (1973) was based on the model of Martin (1967), which suggests that high Al_2O_3 in the environment inhibits Al–Si ordering in feldspars during crystallization and subsequent cooling. Alternatively, low Al_2O_3 (or high alkalinity) facilitates ordering.

Guidotti *et al.* (1973) did not consider the systematic difference in the Ab content between the specimens with the higher and lower structural states (average Ab percent of 14 and 6.5 to 9.5 respectively). The data presented here show a small and overlapping range of Ab contents in the K–feldspars and provide support for the model independent of possible influence of the feldspar composition.

Petrography and analytical results

All specimens (from the Oquossoc 15′ quadrangle and the north-central part of the Bryant Pond quadrangle) are medium- to coarse-grained, foliated to equigranular rocks. Most have quartz + plagioclase ($\sim An_{26}$) + biotite + K–feldspar + muscovite, but a few Bryant Pond specimens also contain sillimanite (see Table 1). This sillimanite is commonly associated with coarse (to 1 cm) megacrysts of muscovite, but some also occurs as small prisms scattered in the quartz + feldspar groundmass. Field and petrographic observations of Guidotti (1965, p. 52) suggest that much of the sillimanite in the adamellites may result from partial assimilation of the highly aluminous pelitic schists making up the bulk of the surrounding country rocks. Indeed, much of the sillimanite in the upper sillimanite and K–feldspar + sillimanite zone metapelites is associated with coarse megacrysts of muscovite as sprays radiating out into the enclosing groundmass.

Table 2 presents analyses of muscovite from the adamellites of both areas and Table 3 analyses of the coexisting K–feldspars of the Bryant Pond speci-

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Table 1. Representative visually-estimated modes of six adamellite specimens from the Bryant Pond 15′ quadrangle, Maine

	7- 8/5/59	7- 8/3/59	25- 8/26/59	27- 9/10/59	12- 8/19/59	28- 8/22/59
quartz	15	25	35	25	35	40
plagioclase	35	20	25	20	30	35
K-feldspar	25	30	35	40	10	5
biotite	15	20	5	10	16	5
muscovite	10	5	tr*	5	8	12
sillimanite	--	--	--	tr†	1	2
garnet	tr	tr	tr	tr	tr	1
% An in plagioclase	nd††	20	nd	28	nd	20
K-feldspar "bc" value(2)	0.93	0.98	0.97	0.92	0.82	0.86

**No probe analysis due to inadequate muscovite.*

(2) In an approximate fashion, based on Fig. 2b of Wright and Stewart (1968), 0.93, 0.98, and 0.97 would be maximum microclines; 0.92 would be a slightly disordered microcline; 0.86 would be a little more disordered than intermediate microcline (Spencer U); and 0.82 would be about in between orthoclase and intermediate microcline.

†Sillimanite as inclusions in one muscovite plate.

††Not determined.

mens. All analyses were done on the electron probe of the University of Wisconsin, and details of procedures used are given in Guidotti *et al.* (1973) and Guidotti (1973).

K-feldspars of the Bryant Pond adamellites range from $Ab_{7.82}$ to $Ab_{11.08}$ and average $Ab_{9.5}$. Most are virtually An-free. They are compositionally quite similar to K-feldspars from the associated biotite granulites (Group II) described by Guidotti *et al.* (1973). The *bc* values of the K-feldspars from the Bryant Pond adamellites range from 0.82 to 0.98 with an average of 0.91 (see Table 1). The more disordered K-feldspars of the adamellites have structural states quite similar to the average structural state (0.86) of the biotite granulites mentioned above. However, the more ordered ones are considerably more ordered than most of the K-feldspars from the associated metamorphic rocks (*e.g.* the highest *bc* value in Group II is only 0.92). Although no X-ray work has been done on the K-feldspars from the sillimanite-free adamellites of the Oquossoc area, the strong development of grid twinning suggests that they have highly-ordered structures.

Discussion

Several aspects of the muscovite and K-feldspar data presented above are worth further consideration.

(1) Comparison of analyses of muscovite (Table 2)

Table 2. White micas from the K-feldspar + sillimanite zone and upper sillimanite zone of the Bryant Pond and Oquossoc quadrangles respectively

Specimen #	7-8/5/59*	7-8/3/59*	27-9/10/59*	12-8/19/59*	28-8/22/59*	O-K-27**	O-K-47**	O-b-41**
FeO	1.92	1.84	1.45	1.15	1.20	1.78	2.00	2.10
MnO	0.03	0.04	0.02	0.01	0.02	0.03	0.05	0.07
MgO	0.92	0.86	0.57	0.65	0.63	0.83	0.82	1.00
SiO_2	46.94	46.64	46.83	46.41	46.58	46.84	46.67	46.60
Al_2O_3	34.47	34.30	35.45	35.38	35.89	34.82	34.62	33.63
K_2O	10.82	10.60	10.68	10.78	10.72	10.59	10.64	10.84
BaO	0.07	0.08	0.04	0.13	0.08	0.03	0.05	0.02
Na_2O	0.31	0.38	0.40	0.41	0.36	0.45	0.43	0.40
TiO_2	0.87	0.84	0.74	0.71	0.46	0.66	0.69	0.75
$H_2O^{\dagger}$	3.69	4.48	3.87	4.43	4.13	4.01	4.08	4.64
Formula based on 22 oxygen								
Si^{IV}	6.21	6.21	6.18††	6.16††	6.16††	6.20	6.20	6.24
Al^{IV}	1.79	1.79	1.82	1.84	1.84	1.80	1.80	1.76
Al^{VI}	3.58	3.59	3.69	3.70	3.75	3.63	3.62	3.55
Fe	0.21	0.205	0.16	0.13	0.13	0.20	0.22	0.24
Mg	0.18	0.17	0.11	0.13	0.12	0.16	0.16	0.20
Mn	0.004	0.004	0.002	0.002	0.002	0.004	0.006	0.008
Ti	0.086	0.084	0.074	0.071	0.046	0.066	0.069	0.08
Σ	4.060	4.053	4.036	4.033	4.048	4.060	4.075	4.078
K^{XII}	1.83	1.80	1.80	1.83	1.81	1.79	1.80	1.85
Na	0.08	0.10	0.10	0.105	0.09	0.12	0.11	0.11
Ba	0.004	0.004	0.002	0.007	0.004	0.002	0.002	0.001
Σ	1.914	1.904	1.902	1.942	1.904	1.912	1.912	1.961
ΣAl	5.37	5.38	5.51	5.54	5.59	5.43	5.42	5.31
Na/Na + K	4.18	5.26	5.26	5.43	4.97	6.28	5.76	5.62
Σ(Mg + Fe)	0.39	0.38	0.27	0.26	0.25	0.36	0.38	0.44
Mg/Fe	0.857	0.830	0.688	1.000	0.923	0.800	0.727	0.833

**From the K-feldspar + sillimanite grade terrain of the Bryant Pond 15′ Quadrangle, Maine.*
***From the sillimanite grade terrain of the Oquossoc 15′ Quadrangle, Maine.*
†Value cited for H_2O by difference from 100%.
††These specimens with Si < 6.20 are from the sillimanite-bearing adamellites.

Table 3. Analyses of K-feldspar from Bryant Pond adamellite specimens

	7-8/5/59	7-8/3/59	25-8/26/59	27-9/10/59	12-8/19/59	28-8/22/59
Wt %						
CaO	.02	nd	nd	nd	nd	nd
K_2O	15.30	15.37	15.55	15.31	14.82	14.99
Na_2O	1.11	0.97	0.88	1.00	1.22	1.17
Mole %						
An	0.44	---	---	---	---	---
Or	89.67	91.27	92.17	91.03	88.91	89.45
Ab	9.82	8.72	7.82	8.96	11.08	10.54

nd = Not detected

from sillimanite-bearing adamellites with those from the associated sillimanite-bearing upper sillimanite and K-feldspar + sillimanite zone metamorphic rocks (Guidotti, 1973; Cheney, 1975) shows that all are similar in terms of Si^{IV}, Al^{VI}, ΣAl, $\Sigma(Mg + Fe)$, *etc.*[1] (the values for the adamellite muscovites being within the high end of the range of values present in the metamorphic samples). Moreover, muscovites from the sillimanite + K-feldspar-bearing igneous and metamorphic specimens have quite similar $Na/(Na + K)$ ratios. On the other hand, muscovite from sillimanite-free adamellite specimens tends to have systematically higher Si^{IV}, lower Al^{VI}, lower ΣAl, and higher $\Sigma(Mg + Fe)$, *etc.* than muscovite of sillimanite-bearing metapelites or adamellites. Guidotti *et al.* (1975) noted similar observations with respect to Al in biotite of these same parageneses.

The strong correlation between mineral composition and mineral assemblage shown previously for muscovite in the metapelites of northwestern Maine seems to exist equally as well in the associated igneous parageneses. The existence of such systematic relationships for the micas in both the igneous and metamorphic rocks suggests that both parageneses represent a fairly close approach to equilibrium, and that the thermal peak of regional metamorphism was syn- to post-adamellite.

(2) Consideration of the *bc* values (Table 1) of K-feldspars from sillimanite-bearing adamellites shows that they are less ordered than those from the sillimanite-free specimens. The higher Al in both micas from the former group suggests higher Al_2O_3 activity in the environment during initial crystallization and subsequent cooling. Higher Al_2O_3 activity is, of course, also implied by the presence of sillimanite in these specimens.

The $Na/(Na + K)$ ratio is similar for all of the Bryant Pond K-feldspar specimens and likewise for the coexisting muscovites (see Tables 2 and 3). If all of the adamellite bodies formed at about the same temperature and pressure, it is reasonable to assume that all of the K-feldspar crystallized originally as orthoclase or as some phase at least as disordered as specimen 12-8/19/59. The only recognizable difference between the adamellites with the more ordered and less ordered K-feldspar structural states is the activity for Al_2O_3 (or alternatively for K_2O and Na_2O) during crystallization and cooling that one can infer, based on the presence or absence of sillimanite and the Al content of the micas present.

The above considerations seem to support the suggestion that the structural state of K-feldspar is influenced by the activity of Al_2O_3 (relative to that of Na_2O and K_2O) in the environment. At the very least a difference in Al_2O_3 activity seems to be the only recognizable difference between the adamellite specimens with the more ordered and the less ordered K-feldspar structural states. However, as pointed out by Stewart and Wright (1974, p. 371), a factor like Al_2O_3 activity may cause a different rate of Al-Si ordering in K-feldspar, but it does not seem to affect the process of ordering.

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[1] Comparison is made here with the analyses of upper sillimanite and K-feldspar + sillimanite zone muscovites of Guidotti (1973) and Cheney (1975). The analyses reported by Evans and Guidotti (1966) are systematically less celadonitic (as indicated by Si^{IV}) than those of the above-cited studies, but other constituents (*e.g.* Na_2O, ΣAl, *etc.*) compare quite well. This systematic difference in celadonite content probably reflects the fact that the analyses of Evans and Guidotti were done at a time when good probe standards were not readily available.

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