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Paragonite Contents of Coexisting, but Texturally Different, Muscovites from Pelitic Schists of the Puzzle Mountain Area, Maine

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Abstract

Partial electron microprobe analyses of muscovite from 32 Puzzle Mountain (Maine) meta pelites reveal that paragonite (Pg) content systematically decreases from the lower sillimanite zone (LSZ) to the upper sillimanite zone (USZ) whereas TiO_2 content increases. The average mole percent Pg in either muscovite megacrysts or pseudomorphs after staurolite is 21.6 (LSZ) and 18.3 (USZ); groundmass muscovites average 21.7 (LSZ) and 18.6 (USZ). Weight percent TiO_2 in these muscovites averages 0.61 (LSZ psuedomorphs), 0.62 (LSZ groundmass), and 0.75 (for USZ pseudomorphs as well as groundmass). The virtual identity in Pg and TiO_2 contents for the groundmass and the pseudomorph muscovite in each metamorphic environment supports Guidotti's (1968) suggestion that muscovite pseudomorphs after staurolite are equilibrium features of prograde metamorphism.

Introduction

Guidotti (1968) suggested that the muscovite pseudomorphs after staurolite in the Rangeley-Oquossoc area (Maine) represent equilibrium features of prograde metamorphism from the lower to the upper sillimanite facies. Moreover, he proposed that, with increasing grade of metamorphism, the multigranular pseudomorphs become optically continuous megacrysts. These conclusions were largely based on measurements of basal spacings of muscovites from different size fractions of mineral separates. This present paper further substantiates the thesis by demonstrating an explicit compositional likeness between muscovite pseudomorphs (or megacrysts) and muscovite groundmass (laths) from metapelites from Puzzle Mountain, Maine (Fig. 1).

The pelitic schists of the Puzzle Mt. area are Silurio-Devonian and vary from lower sillimanite to sillimanite + K-feldspar grades of metamorphism. Geologic mapping has been completed by Milton (1961) and more recently by Moench (in preparation). Because of the similarity in rock types, general petrographic characteristics, metamorphic history, and relative proximity of the Puzzle Mountain area to the Rangeley-Oquossoc area, reiteration of these descriptive aspects seems unnecessary. Suffice it to say that as the isograd marked by the AKFM topology change[1]—Staurolite $\rightleftharpoons$ Sillimanite + Biotite + Garnet—is approached (from the low grade side) and crossed, the following features are sequentially observed in the pelitic schists of the Puzzle Mountain area: (1) pseudomorphing of staurolite by muscovite, (2) disappearance of staurolite from the pseudomorphs, and (3) disappearance of pseudomorphs concomitant with the appearance of muscovite megocrysts.

The transition from pseudomorph to megacryst is quite gradational. An additional complexity occurs in that some megacrysts also appear to form from the coalescence of groundmass muscovite laths without an intervening pseudomorph stage.

Methods

Partial electron microprobe analyses were made on thirty-two specimens (fourteen LSZ and eighteen USZ[2]). All but one of these samples contain the AKNa limiting assemblage (*i.e.,* an assemblage where the number of phases equals the number of components in the AKNa system of Thompson, 1961), sillimanite + muscovite + plagioclase (~An 20),

[1] An AKFM topology change is a change in the configuration of tie lines on the AKFM projection of Thompson (1957).

[2] LSZ and USZ refer to Lower and Upper Sillimanite Zones.

and all are relatively free from obvious alteration (*i.e.*, sericitization of plagioclase or sillimanite). Some specimens do have minor chlorite replacement of biotite. Muscovite as groundmass laths and in pseudomorphs after staurolite (or megacrysts) was analyzed for K_2O, TiO_2, and Na_2O for each specimen. TiO_2 was selected because it is well known that TiO_2 in muscovite systematically increases as a function of metamorphic grade. Thus measurement of TiO_2 serves as a useful indicator of prograde behavior of muscovite. Two sets of counts were made on a minimum of five different muscovite grains (of each textural habit, pseudomorph (or megacryst), and groundmass), the results being averaged to obtain the concentrations.

Secondary muscovite standards were used for direct comparison, with no corrections (except for dead time). The standards employed were muscovites analyzed at the California Institute of Technology and reported in Guidotti (1970a; *i.e.*, specimens O–C–13 and O–C–35). Moreover duplicate analyses made on these muscovites at the University of Wisconsin are presented in Guidotti (in press). Because of both the relatively large deviation in counts for TiO_2 on muscovite standard O–C–13 and the small amount of TiO_2 present in muscovite,

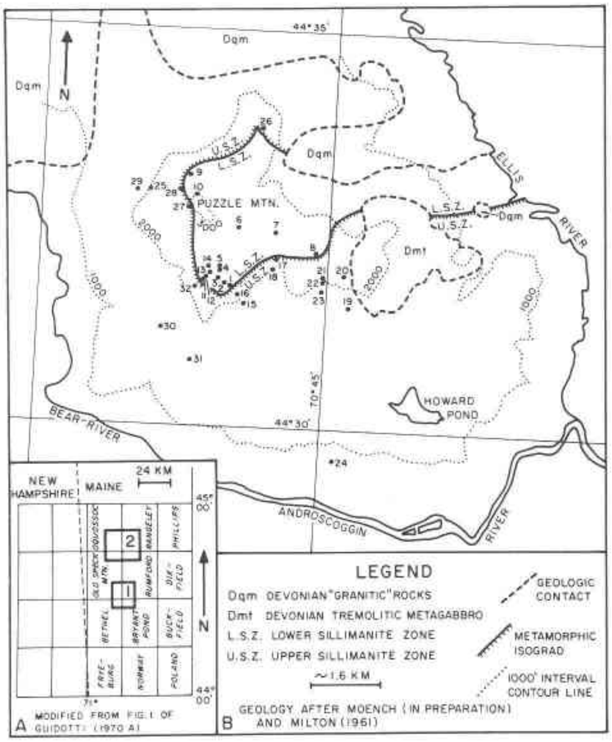

FIG. 1. A. Location of (1) Puzzle Mountain area and (2) the Rangeley-Oquossoc area of Guidotti (1968). B. Geologic and specimen location map of the Puzzle Mountain area.

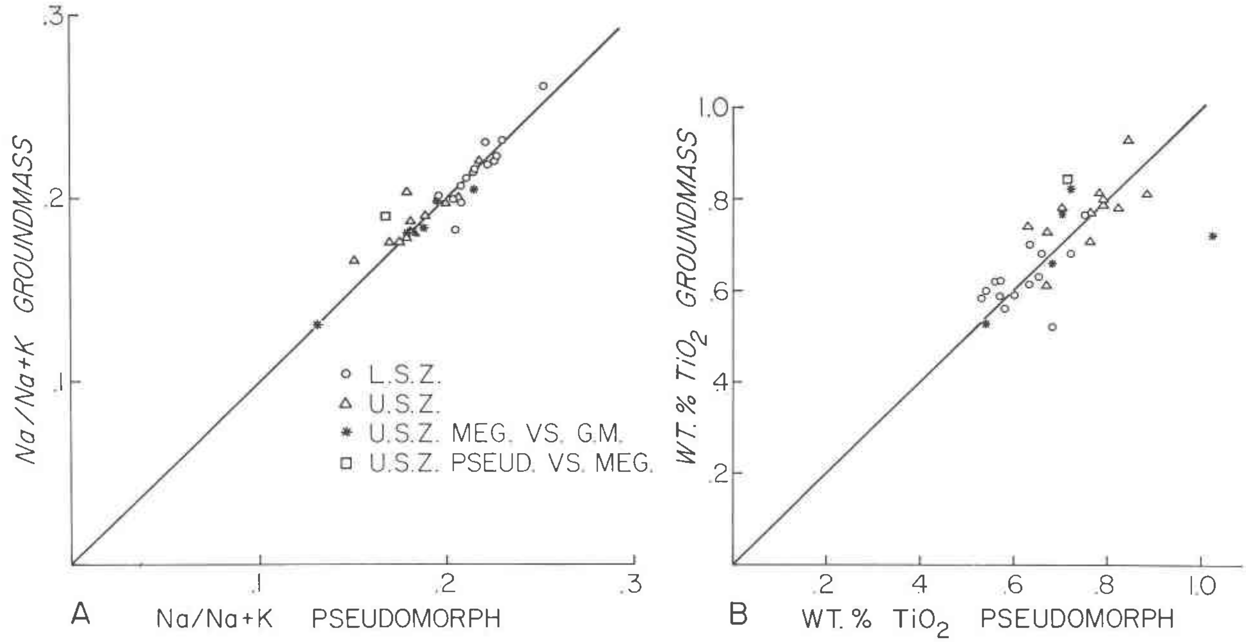

FIG. 2. (A) Na/Na + K, and (B) distribution of TiO_2 in coexisting groundmass and pseudomorph (megacryst) muscovites.

all specimens were corrected to standard O–C–35 (for TiO_2 only).

Machine conditions, set to minimize loss of sodium, were: 15 kV acceleration potential, sample current of 0.03 μA set on scheelite, defocused 10 micron beam, and a fixed beam current count of 20,000 (an approximate counting time of 12–15 seconds).

Results

The results are summarized in Figure 2 and tabulated in Table 1. A one-to-one reference line is plotted in both Figures 2A and 2B. Regarding Figure 2A, points plotting slightly off the one-to-one line do not necessarily imply sample disequilibrium. Utilizing Table 1 to compare the wt percent K_2O and Na_2O of muscovite pairs, it is evident that dis-

TABLE 1. Partial Analyses of Muscovites by Metamorphic Grade and Textural Habit

Lower Sillimanite Zone*							Upper Sillimanite Zone**						
		Weight Percent							Weight Percent				
Specimen No.	Location No. on Fig. 1B	K_2O	TiO_2	Na_2O	Na/Na+K	Muscovite Type***	Specimen No.	Location No. on Fig. 1B	K_2O	TiO_2	Na_2O	Na/Na+K	Muscovite Type***
B28	1	8.95	.54	1.44	.196	ps	B24	15	9.25	.67	1.52	.200	ps
		9.05	.60	1.50	.201	gm			9.21	.73	1.50	.198	gm
B29	2	8.45	.65	1.88	.252	ps	B26	16	9.34	.79	1.26	.170	ps
		8.45	.63	1.97	.261	gm			9.29	.80	1.31	.176	gm
B30	3	8.99	.56	1.55	.208	ps	B44	17	9.45	.70	1.32	.175	ps
		8.98	.62	1.54	.207	gm			9.41	.76	1.32	.176	gm
B31	4	8.82	.60	1.59	.215	ps	B45	18	8.91	.82	1.64	.218	ps
		8.89	.59	1.61	.216	gm			8.82	.78	1.65	.221	gm
B31b	5	8.82	.57	1.59	.215	ps	B51b	19	9.48	.79	1.36	.179	ps
		8.83	.59	1.59	.215	gm			9.27	.77	1.56	.204	gm†
B36	6	8.65	.51	1.67	.227	ps	B56	20	9.29	.54	1.42	.188	meg
		8.75	.59	1.65	.223	gm			9.11	.53	1.35	.184	gm
B40	7	8.60	.56	1.65	.226	ps	B62	21	9.38	.63	1.35	.179	ps
		8.55	.54	1.61	.222	gm			9.25	.72	1.35	.179	gm
B60	8	8.91	.57	1.54	.208	ps	B63	22	9.21	.78	1.41	.189	ps
		8.86	.62	1.44	.198	gm			9.14	.81	1.42	.191	gm
B73	9	9.45	.63	1.61	.205	ps	B65	23	9.11	.76	1.56	.206	ps
		9.31	.61	1.39	.183	gm			9.07	.69	1.48	.199	gm
B74	10	8.82	.68	1.74	.230	ps	B77	25	9.38	.70	1.35	.179	meg
		8.69	.52	1.72	.232	gm			9.33	.77	1.33	.177	gm
A77	11	9.10	.75	1.53	.204	ps	B84	26	9.13	.68	1.46	.195	meg
		9.01	.76	1.48	.200	gm			9.18	.66	1.51	.200	gm
A78	12	8.50	.66	1.59	.221	ps	A44	27	9.20	.67	1.34	.181	ps
		8.61	.68	1.73	.231	gm			8.97	.61	1.37	.188	gm
A79B	13	8.53	.63	1.60	.222	ps	A45	28	9.36	.71	1.25	.168	ps
		8.57	.70	1.58	.219	gm			9.36	.84	1.44	.190	meg
A80	14	8.91	.72	1.57	.211	ps	A46	29	9.19	.88	1.32	.179	ps
		8.75	.68	1.54	.211	gm			8.82	.81	1.27	.179	gm
							A47	30	9.21	.76	1.35	.182	ps
									9.22	.77	1.34	.181	gm
							A49	31	9.31	.84	1.09	.151	pod
									9.33	.93	1.22	.166	gm
							B71	24	10.18	1.02	1.01	.131	meg
									10.10	.70	1.01	.132	gm
							A75	32	8.82	.72	1.59	.215	meg
									9.05	.82	1.53	.205	gm

* All specimens except B-36 contain: sillimanite (except B36) staurolite + muscovite + garnet + biotite + plagioclase + quartz + ilmenite

** All specimens contain: sillimanite + muscovite + garnet + biotite + plagioclase + quartz + ilmenite

*** Muscovite type abbreviations

ps Pseudomorph

gm Groundmass lath

meg Megacryst

† Only 2 groundmass grains analyzed

crepancies arise from variations in Na_2O rather than K_2O. This discrepancy is easily atttributable to the difficulty of analyzing for sodium because of the minor amount present, the low number of counts, volatilization, and the problems inherent to using a defocused beam on narrow groundmass laths of muscovite. Figure 2A shows that, for comparable grades of metamorphism, the mole percent paragonite of pseudomorph (or megacryst) muscovites from pairs plotting off the one-to-one line are similar to those paragonite contents from pairs plotting on the line. This suggests that this slight problem lies in analyses of the groundmass muscovite.

The scatter in Figure 2B may be attributed to (1) the small amount of TiO_2 present in the muscovites, and/or (2) minor sample inhomogeneity with respect to TiO_2.

Discussion

As shown by Figure 2A, the mole percent paragonite varies systematically with metamorphic grade in a predictable (and previously observed) manner. The lower sillimanite zone muscovites tend to have paragonite contents above twenty mole percent and average 21.7 for the pseudomorph types and 21.6 for the groundmass laths. Upper sillimanite zone muscovites commonly contain less than twenty mole percent paragonite, the pseudomorph (or megacryst) muscovites averaging 18.3 and the groundmass laths 18.6. These data are consistent with the divariant reaction:

Na-Muscovite + Quartz $\leftrightharpoons$ K richer Muscovite
+ Na richer Plagioclase + Sillimanite + Water (1)

discussed in Evans and Guidotti (1966) and with the univariant, isograd defining reaction:

Staurolite + Muscovite + Quartz $\leftrightharpoons$ Sillimanite
+ Biotite + K richer Muscovite + Albite
+ Water $\pm$ Garnet (2)

from Guidotti (1970). That the paragonite composition data plot approximately on a straight, one-to-one line substantiates Guidotti's (1968) suggestion and once again demonstrates that textural disequilibrium does not necessarily indicate chemical disequilibria as pointed out by Zen (1963).

Muscovites from the upper sillimanite zone generally contain more TiO_2 than those from the lower sillimanite zone. For example, USZ groundmass and pseudomorph (or megacryst) muscovites both average 0.75 wt percent TiO_2 whereas LSZ groundmass and pseudomorph muscovites average 0.62 and 0.61 wt percent TiO_2 respectively. To a first approximation, the increase in TiO_2 can be attributed to a modal decrease in the amount of muscovite as a function of increasing metamorphic grade. This increase, albeit small, is systematic and, when viewed in the context that distribution of TiO_2 between muscovite pairs approximates a one-to-one plot, further indicates a close approach to equilibria on a hand specimen and regional scales.

In summary, data presented here show (1) that muscovite pseudomorphs after staurolite have the same paragonite composition (as well as TiO_2 content) as do coexisting groundmass laths; and (2) that the observed compositions vary systematically with grade. Close approach to equilibria on both hand specimen and regional scales is thereby documented. Moreover, these results demonstrate that the pseudomorphs (and megacrysts) are equilibrium features of prograde metamorphism. However, as developed in Guidotti (1970b), the prograde event results from a sillimanite grade metamorphism superimposed on an earlier staurolite terrane.

Acknowledgments

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