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Margarite pseudomorphs after chiastolite in the Georgetown area, California

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Abstract

Margarite, paragonite, and muscovite occur together in graphitic metapelites near Georgetown, California. Most of the margarite occurs as a pseudomorphic replacement of coarse-grained chiastolite, whereas muscovite and paragonite are largely confined to the groundmass. Microprobe analyses of the three white micas provide further information about the margarite + paragonite + muscovite three-phase field in the system Al_2O_3–Na_2O–K_2O–CaO–SiO_2–H_2O.

Introduction

Margarite has been recognized as a rock-forming mineral only since the papers of Sagon (1967, 1970) and Frey and Niggli (1972). Guidotti and Cheney (1976) reviewed briefly the several types of margarite occurrences described since these initial studies. One of the apparently common types of occurrence is as aggregates forming pseudomorphs after aluminosilicates—especially in graphitic rocks. This brief report describes a similar paragenesis (discovered by J.L.P.) from the metapelites on the western slope of the Sierra Nevada in California.

This occurrence is of interest because it increases the number of known margarite localities and especially because the specimens contain all three white micas. Hence, knowledge about the orientation of tie lines in the white-mica plane of the system Al_2O_3–Na_2O–K_2O–CaO–SiO_2–H_2O may be further refined. Parageneses containing all three white micas are not common, and some of the recorded occurrences involve a rather celadonitic muscovite (*e.g.* Höck, 1974).

Geologic setting

The specimens were collected from a locality in the Georgetown 7½′ topographic sheet. The specific locality is near the 2600 ft (790 m) contour in Rock Canyon, 2.7 km S35°E of the village of Georgetown, California.

The only geologic mapping that included the specimen locality is that by Lindgren and Turner (1894). As determined from the Sacramento 1:250,000 compilation sheet (Strand and Koenig, 1965), the specimen locality is in undivided Paleozoic marine strata which outcrop just to the east of some bodies of Mesozoic basic and ultrabasic rocks. At the collecting site the strata trend N20°E with vertical dips, and consist of interbedded fine-grained, graphitic muscovite schist and quartzite. Chiastolite, now replaced mainly by margarite, is common in much of the schist, ranging from sparse to up to 50 modal percent in a few beds. The "chiastolite crystals" range from 0.3 to 5.0 cm on the basal plane and up to 15 cm parallel to [001]. In some beds to the east of the locality studied, cursory X-ray work shows that the chiasto-

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lite has been pseudomorphed by muscovite rather than margarite.

Extrapolation along strike of the more recent mapping of Chandra (1961) in the Colfax–Foresthill area, which lies immediately north of the Georgetown 7½′ quadrangle, suggests that the specimens collected are from part of the Upper Paleozoic Calaveras Group. According to Chandra's work, the strata of the Calaveras group have NNW trends and nearly vertical dips. Moreover, these strata appear to have been subjected to two deformations, the first prior to deposition of the overlying Jurassic strata and the second during the Nevadan Orogeny.

Although the Jurassic strata have been folded, they are largely unmetamorphosed. In contrast, the Calaveras Group has been metamorphosed to the greenschist and epidote amphibolite facies, and argillaceous rocks have been converted to slates, phyllites, and some schists. Chandra (1961) makes no mention of chiastolite development in the argillites—although some garnet schist appears to have developed. Furthermore, based upon study of the metamorphosed mafic rocks, Chandra claims that the greenschist and epidote amphibolite facies rocks suffered a later retrograde metamorphism. However, no details are given as to the timing or magnitude of this later event.

Petrography

The groundmass of the specimens is a black, fine-grained phyllite. In thin section it is dark to almost opaque due to the abundance of graphite. Pyrite occurs in the phyllites near the margarite locality and is probably present in our specimens also. The silicates present are quartz, white micas, some chlorite, and minor tourmaline pleochroic in shades of light yellow. The birefringence of the groundmass white micas suggests that they are muscovite and/or paragonite whereas margarite is largely confined to the pseudomorphs. Probe work confirms the presence of abundant muscovite and paragonite in the groundmass.

The margarite pseudomorphs after chiastolite are largely characterized by rectilinear to irregularly-oriented thin straight veinlets spaced on a scale ranging from 0.1 to 1.0 mm. Fairly coarse margarite plates and laths (to 1.0 mm) are oriented perpendicular to the centers of the veinlets. In some cases the length of the coarse margarite laths decreases progressively, so that the growth along the veinlet tapers and forms a pattern similar to that of a feather. These feather-like patterns of margarite laths are very similar in appearance and scale to those shown in Figure 1A of Guidotti and Cheney (1976). Those portions of the pseudomorphs in which margarite laths are not oriented along the veinlets consist of irregular aggregates of medium-grained margarite and minor amounts of muscovite and paragonite. However, most of the muscovite and paragonite associated with the pseudomorphs seems to be located in the graphite bands that form the crosses within the "chiastolite."

Possibly some andalusite is still present in a few of the pseudomorphs, but this could not be confirmed in thin section due to the ubiquitous presence of fine-grained margarite. X-ray diffractograms also failed to confirm the presence of any andalusite.

Mineral data

Initial chemical analyses, done on a non-automated microprobe at the University of Wisconsin (U.W.), did not at the time seem completely adequate for the finer-grained micas (intergrown muscovite and paragonite in the pseudomorphs and adjacent groundmass). Hence, additional work was done on the automated microprobe at the University of Massachusetts at Amherst (U.M.).

A total of four specimens (P-1, P-2, P-3, and P-4) were studied and Tables 1A, 1B, 1C, and 1D[1] present all of the analyses obtained from both laboratories. Because of the difficulty of analyzing groundmass materials, most of the analyses are for white micas within the pseudomorphs. Comparison of the values obtained for a given specimen from each laboratory shows a very good correspondence—the margarite analyses are almost duplicates. Only MgO shows a systematic discrepancy (U.M. values being low), but subsequently it was found that the MgO standard used was inappropriate for the U.M. instrument. However, because MgO is quite low in all three white micas this causes no difficulties for the purpose of this paper. The analyses shown in Tables 1A–D show several interesting patterns which were predictable based on previous work. For example, Σ(Mg + Fe) and Ti are higher in muscovite than in the coexisting margarite and paragonite. Also, Ba is highest in muscovite.

[1] To obtain a copy of these tables, order Document AM-79-107 from the Business Office, Mineralogical Society of America, 2000 Florida Ave., N.W., Washington, DC 20009. Please remit $1.00 in advance for the microfiche.

Table 2. Representative analyses of white micas

	U.W.[1]	U.W.	U.M.[1]	U.W.	U.W.	U.W.
	P-1	P-1	P-1	P-2	P-2 Groundmass	P-2
Spec. #	Marg.	Parag.	Musc.	Marg.	Parag.	Musc.
FeO	.165	.237	.26	.121	.158	.302
MnO	.028	.020	.04	.021	.022	.031
MgO	.182	.499	.31	.180	.264	.756
CaO	11.196	1.091	.06	11.111	.988	.098
SiO_2	31.761	46.971	47.71	31.352	45.704	46.613
Al_2O_3	50.493	40.156	38.07	51.250	39.197	35.886
K_2O	.065	1.515	7.69	.064	1.121	7.914
BaO[2]	.039	.058	--	.040	.024	.190
Na_2O	1.722	5.784	1.56	1.656	5.957	1.372
TiO_2	.025	.164	.23	.019	.151	.459
H_2O[3]	4.45	3.58	4.07	4.31	6.55	6.48
	Formula Based On 22 Oxygen					
Si^{IV}	4.185	5.942	6.163	4.123	5.949	6.203
Al^{IV}	3.815	2.058	1.837	3.877	2.051	1.797
Al^{VI}	4.026	3.929	3.963	4.067	3.962	3.831
Fe	.018	.025	.028	.013	.017	.034
Mg	.036	.094	.060	.035	.051	.150
Mn	.003	.002	.004	.002	.002	.004
Ti	.002	.016	.022	.002	.015	.046
Σ	4.085	4.066	4.077	4.119	4.047	4.065
K^{XII}	.011	.244	1.269	.011	.186	1.343
Na	.440	1.419	.390	4.22	1.503	.354
Ca	1.581	.148	.008	1.566	.138	.014
Ba	.002	.003	--	.002	.001	.010
Σ	2.034	1.814	1.667	2.001	1.828	1.721
ΣAl	7.841	5.987	5.800	7.944	6.013	5.628
Σ(Mg+Fe)	.054	.119	.088	.048	.068	.184
Mg/Fe	2.000	3.76	2.143	2.692	3.000	4.411
Na/ΣXII[4]	.216	.784	.234	.211	.823	.207
K/ΣXII	.005	.135	.761	.005	.102	.785
Ca/ΣXII	.778	.082	.005	.783	.075	.008

(1) U.W. = Analyses done at the Univ. of Wisc.; U.M. = Analyses done at the Univ. of Mass.
(2) BaO not analyzed in Univ. of Mass. Analyses.
(3) Water based on difference from 100%.
(4) Sum of XII excludes Ba.

Table 2 presents some representative analyses of the three white micas, and Table 3 summarizes the ratios Na/ΣXII, K/ΣXII, and Ca/ΣXII for all the micas analyzed. Table 3 also gives the cell parameters for margarite in specimens P-2, P-3, and P-4 [cell parameters obtained by using the program of Appleman and Evans (1973)]. Although these margarite samples have Ca/ΣXII at about 0.78 in contrast with 0.71 for the specimen described by Guidotti and Cheney (1976), the cell parameters are almost identical.

The margarite analyses (Table 3) all plot within a small region on an Na–Ca–K triangular plot (Figs. 1A–C), whereas the muscovite and paragonite show considerably more scatter. These observations probably reflect the fact that few problems arose in analyzing the coarse margarite plates, whereas considerable difficulty was encountered with the fine-grained and often intergrown muscovite and paragonite. Hence, the minor crossing of muscovite–paragonite or margarite–paragonite tie lines between specimens is probably not very significant. To compensate for this analytical problem, Figure 1D shows a plot with average values for the white micas of specimens P-1 and P-2.

Discussion

This paper records petrographic and chemical data for the white micas of another occurrence of margarite forming pseudomorphs after chiastolite in highly graphitic rocks. Presumably the white micas, especially in the pseudomorphs, have formed by a reaction involving chiastolite and groundmass plagioclase and having the general form:

$$\text{plagioclase (groundmass)} + \text{andalusite} + H_2O = \text{white mica} + \text{quartz} \quad (1)$$

On a more local scale in the chiastolite crystal itself, the reaction taking place might have the form (suggested by D. M. Burt):

$$2Al_2SiO_5 + CaO\ (\text{dissolved}) + H_2O = CaAl_2[Al_2Si_2O_{10}](OH)_2 \quad (2)$$

Table 3. Summary of atom percents of end-member white micas

Specimen P-1

	Marg. UW[3]	Marg. UM[12][1]	Parag. UW	Parag. UM[4]	Musc. UM[7]
Na/ΣXII[4]	.216	.204	.784	.770	.234
K/ΣXII	.005	.002	.135	.146	.761
Ca/ΣXII	.778	.795	.082	.084	.005

Specimen P-2

	Marg. UW	Marg. UM[15]	Parag. UW	Parag. UM[3]	Musc. UW	Musc. UM[2]
Na/ΣXII	.211	.213	.823	.769	.207	.186
K/ΣXII	.005	.000	.102	.104	.785	.810
Ca/ΣXII	.783	.787	.075	.127	.008	.003

Margarite cell parameters: a = 5.122(5)[2], b = 8.860(7), c = 19.170(1), β = 95.36(6)°, Vol. = 866.23(7).

Specimen P-3

	Marg. UW
Na/ΣXII	.214
K/ΣXII	.005
Ca/ΣXII	.781

Margarite cell parameters: a = 5.123(4), b = 8.864(6), c = 19.164(1), β = 95.38(6)°, Vol. = 866.42(6).

Specimen P-4

	Marg. UW	Marg. UM[10]
Na/ΣXII	.220	.206
K/ΣXII	.005	.001
Ca/ΣXII	.774	.793

Margarite cell parameters: a = 5.123(4), b = 8.862(5), c = 19.168(9), β = 95.41(5), Vol. = 866.26(5).

(1) [ ] = number of points analyzed on the University of Massachusetts automated probe.
(2) Estimated standard errors are in parentheses and refer to the last decimal place.
(3) UW = Analyses done at the Univ. of Wisconsin, and UM = analyses done at the University of Massachusetts.
(4) Sum of XII sites excludes Ba.

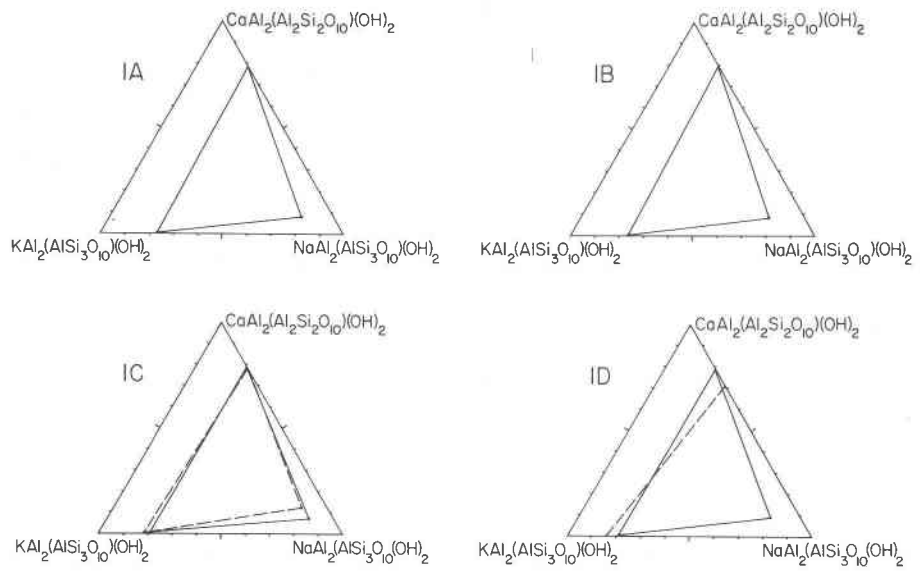

Fig. 1. Compositions of coexisting margarite + paragonite + muscovite in terms of end-member white micas. (A) Specimen P-1, using margarite and paragonite analyses done on the U.W. probe and muscovite analyzed on the U.M. probe. (B) Specimen P-1, using only analyses done on the U.M. probe. (C) Specimen P-2. Solid lines used for analyses done on the U.W. probe; dashed lines used for analyses done on the U.M. probe. (D) Plot showing average end-member values for margarite, paragonite, and muscovite in specimens P-1 and P-2 (solid lines). Average includes U.W. and U.M. analyses. Dashed line shows the margarite–muscovite pair reported by Guidotti and Cheney (1976).

or

$$2Al_2SiO_5 + Ca^{2+} + 2H_2O = CaAl_2[Al_2Si_2O_{10}](OH)_2 + 2H^+ \quad (3)$$

Note that aluminosilicates have the correct Al:Si ratio for margarite, so that only CaO and H_2O need to be added. This factor may provide an explanation for the apparently common replacement by margarite of aluminosilicate megacrysts.

Because all three white micas are present and the muscovite does not have a high celadonite content, the data provide another set of joins for the white-mica plane of the system Al_2O_3–Na_2O–K_2O–CaO–SiO_2–H_2O. The pattern of tie lines is similar to that on the feldspar plane in the sense that the Na phase has the greatest amount of solid solution toward *both* of the other end members. In contrast the Ca and K end members have very little mutual solubility.

An interesting difference exists in the orientation of the margarite–muscovite tie line of this study and that of Guidotti and Cheney (1976), Höck (1974), and Fox (1974). On a relative basis, margarite of this study is *less* sodic and muscovite *more* sodic than that recorded in the above-cited studies. Figure 1D illustrates this point by including the muscovite–margarite tie line (dashed) determined by Guidotti and Cheney (1976). Moreover, the degree of mutual solid solution between the pairs muscovite–paragonite and paragonite–margarite in the Georgetown specimens is considerably greater than that found in the three white-mica specimens described by Höck (1974).

An obvious question involves the cause and significance of the above-described difference in tie-line orientation and degree of solid solution between end members. Presumably T and to a lesser extent P were the controlling factors. Unfortunately, because the geology and petrology of the Georgetown region are poorly known, it is difficult to assess any difference in P–T conditions between this area and, for example, the Rangeley area considered by Guidotti and Cheney (1976). Indeed, on the basis of available data, one cannot even determine whether the Georgetown specimens represent equilibrium assemblages. However, at present there seems to be no *a priori* reason to assume that they are not in equilibrium.

Before the significance of our data can be properly assessed, it will be necessary to know the detailed geology and petrology of the Georgetown area. Future refinement of such data on the influence of P and T on the orientation of tie lines in the white-mica plane and on the opening and closing of the three solvi

present should provide insights on the solution properties of the three white micas.

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