

## Margarite pseudomorphs after chiastolite in the Rangeley area, Maine

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### Abstract

In recent years margarite has been recognized as an important rock-forming mineral in several widely distributed localities. This paper reports an occurrence of margarite pseudomorphs after chiastolite in metamorphosed black shales of the Rangeley area, Maine. Analyses are presented for coexisting margarite, muscovite, and chlorite. As with most reported analysis of margarite, a considerable amount of the paragonite end-member is present in solid solution (~28.4 mole %).

### Introduction

Until fairly recently margarite has been considered as a mineral of special compositional environments. More recently it has been found as a rock-forming mineral in numerous localities: in Europe, Sagon (1967, 1970), Frey and Niggli (1972), Höck (1974), and Ackermann and Morteani (1973); in the Scottish Dalradian, Chinner (1974); in Vermont, Lanphere and Albee (1974) and A. B. Thompson (personal communication); and in British Columbia, Jones (1971). Moreover, experimental data is now becoming available on margarite and its phase relations; *e.g.*, Velde (1971), Chatterjee (1974), and Storre and Nitsch (1974). In addition, some theoretical treatments have also been made of margarite phase relations; *e.g.*, Frey and Orville (1974) and Thompson (1974).

This paper describes an occurrence of margarite in northwestern Maine where margarite occurs as pseudomorphs of chiastolitic andalusite with even the fine details of the graphitic crosses preserved.

### Geologic setting

The margarite-bearing rocks occur in the Small's Falls Formation in a road cut at a locality on Highway 4 known as Small's Falls (about 8 miles east-southeast of the town of Rangeley). The Small's Falls Formation contains lithologies ranging from gran-

ular calc-silicate to pelitic schist (Moench, 1971). It is an unusually distinctive unit inasmuch as it commonly contains up to 10 modal percent of pyrrhotite and several modal percent of graphite.

The stratified rocks of northwestern Maine have been metamorphosed to various grades during the Acadian event in Lower Devonian time, *e.g.*, Guidotti (1970), Boone (1973). In the vicinity of Small's Falls the metamorphic history involves poly-metamorphism. In some specimens chiastolite is completely replaced by coarse margarite, and staurolite from adjacent stratigraphic units is commonly replaced by aggregates of coarse chlorite and muscovite. The most recent metamorphism took place under garnet-zone conditions.

### Petrography

The specimen in which margarite has been identified is fairly typical of the pelitic varieties of the Small's Falls Formation in the middle grades of metamorphism. It is a well-foliated phyllite or schist which is dark grey to black on fresh surfaces and has some minor crinkling. Lenticular blebs of pyrrhotite are readily seen in hand specimen, and in some cases tiny chlorite plates are also visible.

The most interesting mineralogical feature of the pelites in the vicinity of Small's Falls is the development of chiastolite megacrysts with dimensions up to

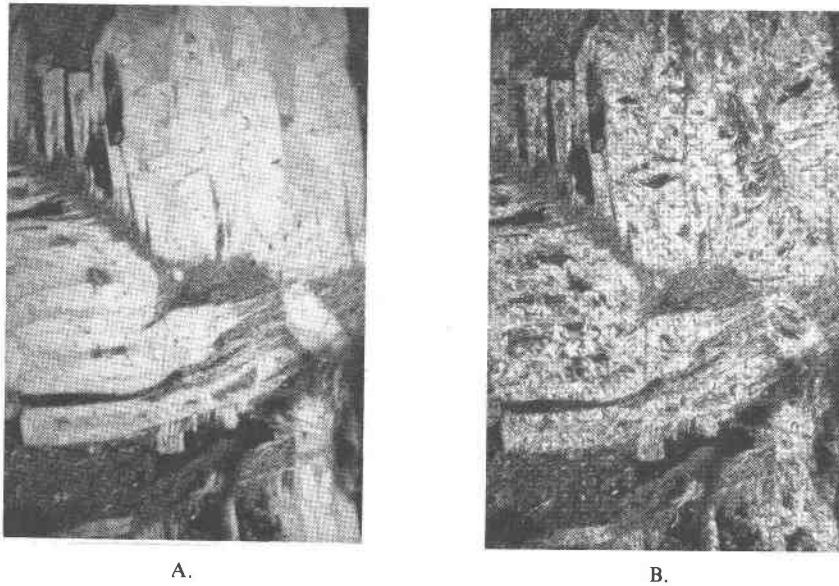


FIG. 1. Photomicrograph of margarite pseudomorphous after chiastolite, all at 10X. (A) A portion of a large pseudomorph showing detailed distribution of graphite. (B) Same view in crossed nicols.

TABLE 1. Analyses\* of coexisting margarite, muscovite, and chlorite from specimen Ra-a86'-66, Rangeley area, Maine.

	Margarite	Muscovite	Chlorite
SiO <sub>2</sub>	32.23	47.60	28.04
Al <sub>2</sub> O <sub>3</sub>	50.35	35.57	23.50
FeO	.13	.32	9.07
MgO	.29	1.08	25.49
TiO <sub>2</sub>	.04	.71	.05
MnO	.01	.02	.66
K <sub>2</sub> O	000	9.16	000
Na <sub>2</sub> O	2.23	1.16	000
CaO	10.00	000	000
H <sub>2</sub> O**	4.86	4.45	13.10
<b>Formulas Based on 22 Oxygen (Micas) and 28 Oxygen (Chlorite)</b>			
IV Si	4.248	6.233	5.459
Al	3.752	1.767	2.541
Total Al	7.820	5.489	5.391
VI Al	4.068	3.722	2.850
Fe	.014	.035	1.477
Mg	.056	.212	7.396
Ti	.003	.070	.007
Mn	.001	.002	.109
Σ	4.142	4.041	11.839
XII K	000	1.530	000
Na	.570	.294	000
Ca	1.412	000	000
Σ	1.982	1.824	000
Mg/Fe			5.006
Mn/Fe			.074
Na/(Na+Ca+K)	.288	.161	

\*Analyses by electron microprobe; see Guidotti *et al.* (1975) for details of run conditions.

\*\*Value for H<sub>2</sub>O by difference from 100%

Margarite cell parameters:  $a = 5.126(2)$ ,  $b = 8.855(3)$ ,  $c = 19.188(5)$ ,  $\beta = 95.45(2)^\circ$ ,  $Vol. = 866.09(3) \text{ \AA}^3$   
 Estimated standard errors are in parentheses and refer to the last decimal place.

3 cm in width and 15 cm in length. These megacrysts tend to lie within the foliation planes. In the specimens studied thus far the aluminum silicate has been completely converted to margarite. The margarite occurs as coarse sheaves which make up virtually all of the pseudomorph. Only minor quartz and the graphite of the original chiastolite are present as additional minerals in the pseudomorphs (Fig. 1).

Visual modal estimates of the groundmass of the specimen provide the following data: quartz 50%, muscovite 33%, chlorite 5%, graphite 3%, pyrrhotite 8%, and rutile 1%. Muscovite and chlorite occur as fine-grained laths which define the foliation. No plagioclase or paragonite was detected either by thin-section investigation or by electron microprobe. Because graphite is abundant, fine-grained, and widely dispersed, it causes a darkening or blurring of the thin sections—a feature which makes petrography and modal estimates difficult. The rutile occurs as tiny amber-colored prisms, some of which display knee-shaped twins. Tourmaline is present as tiny yellow prisms.

#### Mineral data

Table 1 provides chemical data for the margarite, muscovite, and chlorite. Figure 2 is a plot of the coexisting margarite and muscovite on the white mica plane of the system Al<sub>2</sub>O<sub>3</sub>-CaO-Na<sub>2</sub>O-K<sub>2</sub>O with SiO<sub>2</sub> in excess and an H<sub>2</sub>O-rich fluid assumed present. As has been found in most studies on margarite

coexisting with other white micas, this margarite contains a considerable amount of the paragonite end-member in solid solution (e.g., see the margarite-muscovite pairs from Höck (1974) and Fox (1974) as plotted on Fig. 2). Table 1 also presents cell dimensions of the margarite from the Small's Falls locality, obtained via the program of Appleman and Evans (1973).

### Discussion

This paper presents data which establish another tie line of the white mica plane. It thereby contributes further to understanding the miscibility relations among the white micas.

Of interest is the fact that this margarite, like those in a number of other occurrences [e.g., Chinner (1974), Lanphere and Albee (1974)], seems to have formed in association with a pseudomorph-producing event. This suggests that in some cases the presence of margarite may be related to aspects of poly-metamorphism rather than being direct primary formation.

Many (but not all) occurrences of margarite as a rock-forming mineral seem to involve the presence of graphite [e.g., this report, Sagon (1967, 1970), Chinner (1974), Frey and Orville (1974), and Frey and Niggli (1972)]. Graphite may be present in other parageneses involving margarite but the published reports have not always listed the opaques present [e.g., graphite is present in many of the specimens studied by Höck (1974), according to Frey (personal communication)]. This is regrettable, because it is possible that in some cases the presence or absence of margarite as a rock-forming mineral might be a function of fluid composition during metamorphism.<sup>1</sup> For example, at a given *PT*, fluid composition may control not only the stability field of pure margarite but also its reactions with other phases, and thus determine whether margarite can occur in rocks with common pelitic bulk compositions.

Obviously many more data are needed on margarite-bearing parageneses to fully understand their significance. As pointed out by Chatterjee (1974), the phase relations of margarite in the context of the tetrahedron defined by the components  $\text{Al}_2\text{O}_3$ - $\text{CaO}$ - $\text{Na}_2\text{O}$ - $\text{K}_2\text{O}$  (quartz-saturated) will be of prime interest for understanding the petrologic implications of margarite. However, to date, the available experimental data have provided little help on this

<sup>1</sup> As pointed out by Eugster and Skippen (1967), the opaque minerals in a rock commonly provide a means of assessing the composition of the fluid phase present during metamorphism.

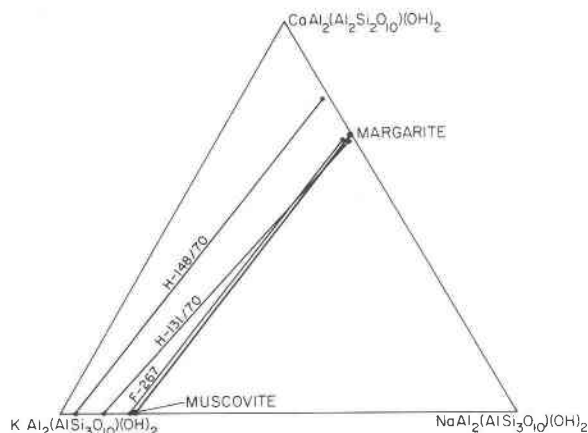


FIG. 2. Plot of margarite-muscovite pair from specimen Ra-a86'-66 on the margarite-muscovite-paragonite plane of the system  $\text{Al}_2\text{O}_3$ - $\text{Na}_2\text{O}$ - $\text{K}_2\text{O}$ - $\text{CaO}$  (quartz and an  $\text{H}_2\text{O}$ -rich fluid assumed present); also shown are margarite-muscovite pairs from Höck (1974) (H-148/70 and H-131/70) and Fox (1974) (F-267).

point, because they have dealt with water-saturated systems that are free of  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$ .

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### References

- ACKERMANN, D. AND G. MORTEANI (1973) Occurrence and breakdown of paragonite and margarite in the Greiner Schiefer Series (Zillertal Alps, Tyrol). *Contrib. Mineral. Petrol.* **40**, 293-304.
- APPLEMAN, D. E. AND H. T. EVANS, JR. (1973) Job 9214: Indexing and least-squares refinement of powder diffraction data. Natl. Tech. Inf. Serv., U.S. Dep. Commer., Springfield, Virginia 22151, Document PB 216 188.
- BOONE, G. M. (1973) Metamorphic stratigraphy, petrology, and structural geology of the Little Bigelow Mountain map area, western Maine. *Maine Geol. Surv. Bull.* **24**, Dep. of Conservation, 136 p.
- CHATTERJEE, N. D. (1974) Synthesis and upper thermal stability limit of 2 M-margarite,  $\text{CaAl}_2[\text{Al}_2\text{Si}_2\text{O}_{10}(\text{OH})_2]$ , *Schweiz. Mineral. Petrol. Mitt.* **54**, 753-767.
- CHINNER, G. A. (1974) Dalradian margarite: a preliminary note. *Geol. Mag.* **111**, 75-78.
- EUGSTER, H. P. AND G. P. SKIPPEN (1967) Igneous and metamorphic reactions involving gas equilibria. In P. H. Abelson, Ed., *Researches in Geochemistry*, Vol. 2, New York: John Wiley and Sons, p. 492-520.
- FOX, J. S. (1974) *Petrology of some low-variance meta-pelites from the Lukmanier Pass area, Switzerland*. Ph.D. thesis, Cambridge University, 220 p.
- FREY, M. AND E. NIGGLI (1972) Margarite, an important rock-forming mineral in regionally metamorphosed low-grade rocks. *Naturwiss.* **59**, 214-215.
- AND P. M. ORVILLE (1974) Plagioclase in margarite-bearing rocks. *Am. J. Sci.* **274**, 31-47.

- GUIDOTTI, C. V. (1970) Metamorphic petrology, mineralogy, and polymetamorphism in a portion of N. W. Maine. In G. M. Boone, Ed., *1970 New England Intercoll. Geol. Conf., 62nd Annu. Meet. Field Trip B-1*, p. 1-29.
- , J. T. CHENEY AND P. D. CONATORE (1975) Coexisting cordierite + biotite + chlorite from the Rumford quadrangle, Maine. *Geology*, **3**, 147-148.
- HÖCK, V. (1974) Coexisting phengite, paragonite and margarite in metasediments of the Mittlere Hohe Tauern, Austria. *Contrib. Mineral. Petrol.*, **43**, 262-273.
- JONES, J. W. (1971) Zoned margarite from Badshot formation (Cambrian) near Kaslo, British Columbia. *Can. J. Earth Sci.* **8**, 1145-1147.
- LANPHERE, M. A. AND A. L. ALBEE (1974)  $^{40}\text{Ar}/^{39}\text{Ar}$  age measurements in the Worcester Mountains: evidence of Ordovician and Devonian metamorphic events in northern Vermont. *Am. J. Sci.* **274**, 545-555.
- MOENCH, R. H. (1971) Geologic map of the Rangeley and Phillips quadrangles, Franklin and Oxford Counties, Maine. *U. S. Geol. Surv. Misc. Geol. Invest. Map I-605*.
- SAGON, J. P. (1967) Le métamorphisme dans le Nord-Est du bassin de Châteaulain découverte de chloritoïde et de margarite dans les schistes dévoniens. *Soc. Géol. Fr. Compte Rendu*, **5**, 206-207.
- (1970) Minéralogie des schistes paléozoïques du Bassin de Châteaulain (Massif armoricain): distribution de quelques minéraux phylliteux de métamorphisme. *Acad. Sci. Paris Comptes Rendus*, **270**, 1853-1856.
- STORRE, B. AND K.-H. NITSCH (1974) Zur Stabilität von Margarit im System  $\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2-\text{H}_2\text{O}$ . *Contrib. Mineral. Petrol.* **43**, 1-24.
- THOMPSON, A. B. (1974) The instability of feldspar in metamorphism. In W. S. Mackenzie and J. Zussman, Ed., *The Feldspars*. Manchester University Press, England, p. 645-672.
- VELDE, B. (1971) The stability and natural occurrence of margarite. *Mineral. Mag.* **38**, 317-323.

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