

**Margarite pseudomorphs after chiastolite in the Georgetown area, California**

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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  $\text{Al}_2\text{O}_3\text{-Na}_2\text{O-K}_2\text{O-CaO-SiO}_2\text{-H}_2\text{O}$ .

**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  $\text{Al}_2\text{O}_3\text{-Na}_2\text{O-K}_2\text{O-CaO-SiO}_2\text{-H}_2\text{O}$  may be further refined. Parageneses containing all three white micas are not common, and some of the recorded occurrences involve a rather celadonic 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-

TABLE 1A. WHITE MICAS OF SPECIMEN P-1

| Spec. #                        | U.W. (1)  |                         | U.M. (1)            |                            | U.M.                 |                     | U.W.                 |                     | U.M. |  |
|--------------------------------|-----------|-------------------------|---------------------|----------------------------|----------------------|---------------------|----------------------|---------------------|------|--|
|                                | Margarite | Margarite Area 2[7] (2) | Margarite Area 4[5] | Margarite Sample Ave. [12] | Paragonite Area 5[4] | Muscovite Area 5[7] | Paragonite Area 5[4] | Muscovite Area 5[7] |      |  |
| FeO                            | .165      | .14                     | .15                 | .144                       | .237                 | .14                 | .26                  |                     |      |  |
| MnO                            | .028      | .03                     | .02                 | .026                       | .020                 | .03                 | .04                  |                     |      |  |
| MgO                            | .182      | .09                     | .10                 | .094                       | .499                 | .03                 | .31                  |                     |      |  |
| CaO                            | 11.196    | 11.43                   | 10.89               | 11.205                     | 1.091                | 1.11                | .06                  |                     |      |  |
| SiO <sub>2</sub>               | 31.761    | 31.33                   | 31.50               | 31.401                     | 46.971               | 46.47               | 47.71                |                     |      |  |
| Al <sub>2</sub> O <sub>3</sub> | 50.493    | 50.69                   | 50.96               | 50.802                     | 40.156               | 40.82               | 38.07                |                     |      |  |
| K <sub>2</sub> O               | .065      | .01                     | .03                 | .018                       | 1.515                | 1.61                | 7.69                 |                     |      |  |
| BaO (3)                        | .039      | --                      | --                  | --                         | .058                 | --                  | --                   |                     |      |  |
| Na <sub>2</sub> O              | 1.722     | 1.54                    | 1.65                | 1.586                      | 5.784                | 5.59                | 1.56                 |                     |      |  |
| TiO <sub>2</sub>               | .025      | .03                     | .02                 | .026                       | .164                 | .06                 | .23                  |                     |      |  |
| H <sub>2</sub> O (4)           | 4.45      | 4.71                    | 4.68                | 4.70                       | 3.58                 | 4.14                | 4.07                 |                     |      |  |
| Formula Based on 22 Oxygen     |           |                         |                     |                            |                      |                     |                      |                     |      |  |
| Si IV                          | 4.185     | 4.142                   | 4.155               | 4.147                      | 5.942                | 6.119               | 6.163                |                     |      |  |
| Al IV                          | 3.815     | 3.858                   | 3.845               | 3.853                      | 2.058                | 1.881               | 1.837                |                     |      |  |
| Al VI                          | 4.026     | 4.045                   | 4.084               | 4.061                      | 3.929                | 4.027               | 3.963                |                     |      |  |
| Fe                             | .018      | .016                    | .016                | .016                       | .025                 | .015                | .028                 |                     |      |  |
| Mg                             | .036      | .019                    | .020                | .019                       | .094                 | .007                | .060                 |                     |      |  |
| Mn                             | .003      | .003                    | .003                | .003                       | .002                 | .003                | .004                 |                     |      |  |
| Ti                             | .002      | .003                    | .002                | .003                       | .016                 | .006                | .022                 |                     |      |  |
| Z                              | 4.085     | 4.086                   | 4.125               | 4.102                      | 4.066                | 4.093               | 4.077                |                     |      |  |
| K XII                          | .011      | .011                    | .005                | .003                       | .244                 | .262                | 1.269                |                     |      |  |
| Na                             | .440      | .396                    | .423                | .407                       | 1.419                | 1.380               | .390                 |                     |      |  |
| Ca                             | 1.581     | 1.620                   | 1.540               | 1.587                      | .148                 | .150                | .008                 |                     |      |  |
| Ba                             | .002      | --                      | --                  | --                         | .003                 | --                  | .008                 |                     |      |  |
| Z                              | 2.034     | 2.017                   | 1.968               | 1.997                      | 1.814                | 1.792               | 1.667                |                     |      |  |
| ZAl                            | 7.841     | 7.903                   | 7.929               | 7.914                      | 5.987                | 5.908               | 5.800                |                     |      |  |
| Z(Mg+Fe)                       | .054      | .035                    | .036                | .035                       | .119                 | .022                | .088                 |                     |      |  |
| Mg/Fe                          | 2.000     | 1.187                   | 1.250               | 1.213                      | 3.76                 | .467                | 2.143                |                     |      |  |
| Na/ZXII (5)                    | .216      | .196                    | .215                | .204                       | .784                 | .770                | .234                 |                     |      |  |
| K/ZXII                         | .005      | .0005                   | .003                | .002                       | .135                 | .146                | .761                 |                     |      |  |
| Ca/ZXII                        | .778      | .803                    | .782                | .795                       | .082                 | .084                | .005                 |                     |      |  |

(1) U.W. = analyses done at the University of Wisconsin and U.M. = analyses done at the University of Massachusetts.  
 (2) Area refers to the areal designation on polished thin section. Number in [ ] refers to the number of points analyzed.  
 (3) BaO not analyzed on U. Mass. analyses.  
 (4) Water based on difference from 100%.  
 (5) Sum of XII Sites excludes Ba.

TABLE 1B. WHITE MICAS OF SPECIMEN P-2

| Spec. #                        | U.W. (1) | U.M. (1) | U.M.  | U.M.   | U.M.   | U.W.   | U.M.    | U.W.   | U.M.  |  |
|--------------------------------|----------|----------|-------|--------|--------|--------|---------|--------|-------|--|
| FeO                            | .121     | .15      | .15   | .15    | .15    | .158   | .16     | .302   | .42   |  |
| MnO                            | .021     | --       | .01   | .006   | .006   | .022   | .04     | .031   | .05   |  |
| MgO                            | .180     | .08      | .07   | .074   | .074   | .264   | --      | .756   | .81   |  |
| CaO                            | 11.111   | 11.09    | 11.34 | 11.240 | 11.240 | .988   | 1.74(6) | .098   | .04   |  |
| SiO <sub>2</sub>               | 31.352   | 31.47    | 31.53 | 31.506 | 31.506 | 45.704 | 46.03   | 46.613 | 47.46 |  |
| Al <sub>2</sub> O <sub>3</sub> | 51.250   | 50.86    | 50.74 | 50.788 | 50.788 | 39.197 | 41.08   | 35.886 | 37.12 |  |
| K <sub>2</sub> O               | .064     | --       | --    | --     | --     | 1.121  | 1.20    | 7.914  | 7.51  |  |
| BaO(3)                         | .040     | --       | --    | --     | --     | .024   | --      | .190   | --    |  |
| Na <sub>2</sub> O              | 1.656    | 1.74     | 1.64  | 1.68   | 1.68   | 5.957  | 5.85    | 1.372  | 1.14  |  |
| TiO <sub>2</sub>               | .019     | .05      | .03   | .038   | .038   | .151   | .09     | .459   | .53   |  |
| H <sub>2</sub> O(4)            | 4.31     | 4.56     | 4.49  | 4.518  | 4.518  | 6.55   | 3.81    | 6.48   | 4.92  |  |
| Formula Based On 22 Oxygen     |          |          |       |        |        |        |         |        |       |  |
| Si <sup>IV</sup>               | 4.123    | 4.151    | 4.158 | 4.155  | 4.155  | 5.949  | 5.841   | 6.203  | 6.181 |  |
| Al <sup>IV</sup>               | 3.877    | 3.849    | 3.842 | 3.845  | 3.845  | 2.051  | 2.159   | 1.797  | 1.819 |  |
| Al <sup>VI</sup>               | 4.067    | 4.061    | 4.048 | 4.053  | 4.053  | 3.962  | 3.989   | 3.831  | 3.883 |  |
| Fe                             | .013     | .017     | .017  | .017   | .017   | .017   | .017    | .034   | .046  |  |
| Mg                             | .035     | .015     | .014  | .014   | .014   | .051   | --      | .150   | .157  |  |
| Mn                             | .002     | --       | .001  | .001   | .001   | .002   | .005    | .004   | .005  |  |
| Tl                             | .002     | .005     | .003  | .004   | .004   | .015   | .009    | .046   | .052  |  |
| Σ                              | 4.119    | 4.098    | 4.083 | 4.089  | 4.089  | 4.047  | 4.020   | 4.065  | 4.091 |  |
| K <sup>XIII</sup>              |          |          |       |        |        |        |         |        |       |  |
| Na                             | .011     | --       | --    | --     | --     | .186   | .195    | 1.343  | 1.248 |  |
| Ca                             | .422     | .445     | .419  | .429   | .429   | 1.503  | 1.441   | .354   | .287  |  |
| Ba                             | 1.566    | 1.568    | 1.603 | 1.589  | 1.589  | .138   | .237    | .014   | .005  |  |
| Σ                              | .002     | --       | --    | --     | --     | .031   | --      | .010   | --    |  |
| Σ                              | 2.001    | 2.013    | 2.022 | 2.018  | 2.018  | 1.828  | 1.873   | 1.721  | 1.540 |  |
| LaI                            |          |          |       |        |        |        |         |        |       |  |
| Σ(Mg+Fe)                       | 7.944    | 7.910    | 7.890 | 7.898  | 7.898  | 6.013  | 6.148   | 5.628  | 5.702 |  |
| Mg/Fe                          | .048     | .032     | .031  | .031   | .031   | .068   | .017    | .184   | .203  |  |
| Na/ΣXIII(5)                    | 2.692    | .882     | .823  | .847   | .847   | 3.000  | .000    | 4.411  | 3.413 |  |
| K/ΣXIII                        | .211     | .220     | .207  | .213   | .213   | .823   | .769    | .207   | .186  |  |
| Ca/ΣXIII                       | .005     | .000     | .000  | .000   | .000   | .102   | .104    | .785   | .810  |  |
| Ca/ΣXIII                       | .783     | .779     | .793  | .787   | .787   | .075   | .127    | .008   | .003  |  |

Footnotes (1)-(5) as on Table 1A

(6) This value seems anomalously high. Moreover, the analysis of this specimen involves counts only on three points.

TABLE 1-C.  
WHITE MICAS OF SPECIMEN P-3.

| Spec. #                        | U.W. (1)<br>Margarite |
|--------------------------------|-----------------------|
| FeO                            | .133                  |
| MnO                            | .027                  |
| MgO                            | .127                  |
| CaO                            | 11.134                |
| SiO <sub>2</sub>               | 31.084                |
| Al <sub>2</sub> O <sub>3</sub> | 51.617                |
| K <sub>2</sub> O               | .057                  |
| BaO(3)                         | .029                  |
| Na <sub>2</sub> O              | 1.682                 |
| TiO <sub>2</sub>               | .017                  |
| H <sub>2</sub> O(4)            | 4.22                  |
| Formula Based on 22 Oxygen     |                       |
| Si <sup>IV</sup>               | 4.086                 |
| Al <sup>IV</sup>               | 3.914                 |
| Al <sup>VI</sup>               | 4.082                 |
| Fe                             | .015                  |
| Mg                             | .025                  |
| Mn                             | .003                  |
| Ti                             | .002                  |
| Σ                              | <u>4.127</u>          |
| K <sup>XII</sup>               | .010                  |
| Na                             | .429                  |
| Ca                             | 1.568                 |
| Ba                             | .002                  |
| Σ                              | <u>2.009</u>          |
| ΣAl                            | 7.996                 |
| Σ(Mg+Fe)                       | .040                  |
| Mg/Fe                          | 1.667                 |
| Na/Σ <sup>XII</sup> (5)        | .214                  |
| K/Σ <sup>XII</sup>             | .005                  |
| Ca/Σ <sup>XII</sup>            | .781                  |

Footnotes as on Table 1A

TABLE 1D. WHITE MICAS OF SPECIMEN P-4.

| Spec. #                        | U.W. (1)  | U.M. (1)                   | U.M.                   | U.M.                          |
|--------------------------------|-----------|----------------------------|------------------------|-------------------------------|
|                                | Margarite | Margarite<br>Area 3[5] (2) | Margarite<br>Area 4[5] | Margarite<br>Sample Ave. [10] |
| FeO                            | .181      | .17                        | .20                    | .19                           |
| MnO                            | .026      | .03                        | .02                    | .03                           |
| MgO                            | .168      | .03                        | .03                    | .03                           |
| CaO                            | 11.289    | 11.59                      | 11.68                  | 11.64                         |
| SiO <sub>2</sub>               | 31.365    | 31.40                      | 31.15                  | 31.28                         |
| Al <sub>2</sub> O <sub>3</sub> | 50.315    | 50.35                      | 50.97                  | 50.66                         |
| K <sub>2</sub> O               | .068      | --                         | .02                    | .01                           |
| BaO (3)                        | .030      | --                         | --                     | --                            |
| Na <sub>2</sub> O              | 1.775     | 1.64                       | 1.70                   | 1.67                          |
| TiO <sub>2</sub>               | .024      | .08                        | .05                    | .07                           |
| H <sub>2</sub> O (4)           | 4.90      | 4.71                       | 4.18                   | 4.42                          |
| Formula Based On 22 Oxygen     |           |                            |                        |                               |
| Si <sup>IV</sup>               | 4.157     | 4.156                      | 4.106                  | 4.131                         |
| Al <sup>IV</sup>               | 3.843     | 3.844                      | 3.890                  | 3.869                         |
| Al <sup>VI</sup>               | 4.016     | 4.016                      | 4.027                  | 4.022                         |
| Fe                             | .020      | .019                       | .022                   | .021                          |
| Mg                             | .033      | .007                       | .005                   | .006                          |
| Mn                             | .003      | .003                       | .002                   | .003                          |
| Ti                             | .002      | .008                       | .005                   | .007                          |
| Σ                              | 4.074     | 4.053                      | 4.061                  | 4.059                         |
| K <sup>XII</sup>               | .011      | --                         | .003                   | .002                          |
| Na                             | .456      | .421                       | .453                   | .427                          |
| Ca                             | 1.603     | 1.644                      | 1.651                  | 1.648                         |
| Ba                             | .002      | --                         | --                     | --                            |
| Σ                              | 2.072     | 2.065                      | 2.084                  | 2.077                         |
| ΣAl                            | 7.859     | 7.860                      | 7.921                  | 7.891                         |
| Σ(Mg+Fe)                       | .053      | .026                       | .027                   | .027                          |
| Mg/Fe                          | 1.650     | .368                       | .227                   | .286                          |
| Na/ΣXII (5)                    | .220      | .204                       | .208                   | .206                          |
| K/ΣXII                         | .005      | .000                       | .001                   | .001                          |
| Ca/ΣXII                        | .774      | .796                       | .792                   | .793                          |

Footnotes as on Table 1A