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Gaston Godard · David Smith

Preiswerkite and Na-(Mg,Fe)-margarite in eclogites

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Abstract Preiswerkite and Na-(Mg,Fe)-margarite are two unusual micas very rare in Nature. They have been observed together in two eclogite occurrences (La Compointrie, France; Liset, Norway) as retrogression products in coronae or symplectites around kyanite. The chemical compositions and some physical properties of these micas are presented. The possible solid solutions and the conditions of stability are discussed. The preiswerkites display slight solid solution towards phengitic muscovite and Na-phlogopite. On the other hand, there is negligible solid solution towards more aluminous compositions; $Al^{IV} \leq 4$ appears to be a composition limit for natural (K,Na)-micas. The margarites have an unusual Na-(Mg,Fe)-rich composition. They can be considered as a solid solution of about 2/3 mol% of margarite and 1/3 mol% of the theoretical end-member $Na_2(Mg,Fe)_1Al_4^{VI}[Si_4Al_4^{IV}]O_{20}(OH)_4$ (“Mica L”), with a possible substitution towards paragonite. The $Marg_{2/3}Mica_{L1/3}$ composition (i.e. $NaCa_2(Mg,Fe)_{0.5}Al_6^{VI}[Si_6Al_6^{IV}]O_{30}(OH)_6$) might represent a particularly stable crystallographic configuration and could be considered as a true end-member. Many “sodian” margarites described in the literature are, in fact, complex solid solutions between margarite, paragonite and $Marg_{2/3}Mica_{L1/3}$. The rarity of these micas is not related to extreme or unusual *P-T* conditions. They seem to be related to unusual chemical compositions, appearing in H_2O -saturated Na-Al-rich Si-poor systems, principally, if not only, at greenschist- or amphibolite-facies *P-T* conditions. Moreover, they are subject to crystallo-

graphic constraints whereby the high proportion of Al-tetrahedra create considerable distortion which prevents the entry of K into the interlayer site, thus necessitating Na (preiswerkite or ephesite) or Ca (margarite or clintonite) instead.

Introduction

Preiswerkite, a sodic trioctahedral mica, is very rare in Nature. Its ideal formula of $Na_2Mg_4Al_2^{VI}[Si_4Al_4^{IV}]O_{20}(OH)_4$ corresponds to the most aluminous composition of the trioctahedral (K,Na)-(Mg,Fe)-micas (Fig. 1). It was first described by Keusen and Peters (1980) from a metarodingite in the Geisspfad ultramafic complex in the Swiss Penninic Alps. It was subsequently reported at eight localities (see Table 1). Most of these occurrences have in common a polymetamorphic history involving the retrogression of high-pressure rocks. Three of them (La Compointrie, Liset, Koralpe/Saualpe) consist of eclogites in which preiswerkite appeared during retrogression as coronae or symplectite around kyanite.

In the same kyanite eclogites, and again linked to the breakdown of kyanite, there also exists another very rare mica, Na-(Mg,Fe)-margarite (Table 1). This mica can be described as being a solid solution between margarite (i.e. $Ca_2\Box_2Al_4^{VI}[Si_4Al_4^{IV}]O_{20}(OH)_4$) and a hypothetical 2.5-octahedral end-member with the ideal formula of $Na_2\Box_1(Mg,Fe)_1Al_4^{VI}[Si_4Al_4^{IV}]O_{20}(OH)_4$ (“Mica L” of Smith, 1988). This last composition can be considered as the (Mg, Fe) equivalent of the trioctahedral Li-mica ephesite $Na_2Li_2Al_4^{VI}[Si_4Al_4^{IV}]O_{20}(OH)_4$ (Fig. 1). These last three micas are related by the cation exchanges: $Ca_2\Box_2 = Na_2\Box_1(Mg,Fe)_1 = Na_2Li_2$.

These micas are of particular interest due to their extreme rarity, which might be related to very specific metamorphic conditions in pressure (*P*), temperature (*T*), nature of fluid, and/or chemical potentials. In this article, we firstly describe the petrology of the La Compointrie and Liset occurrences, and then we discuss

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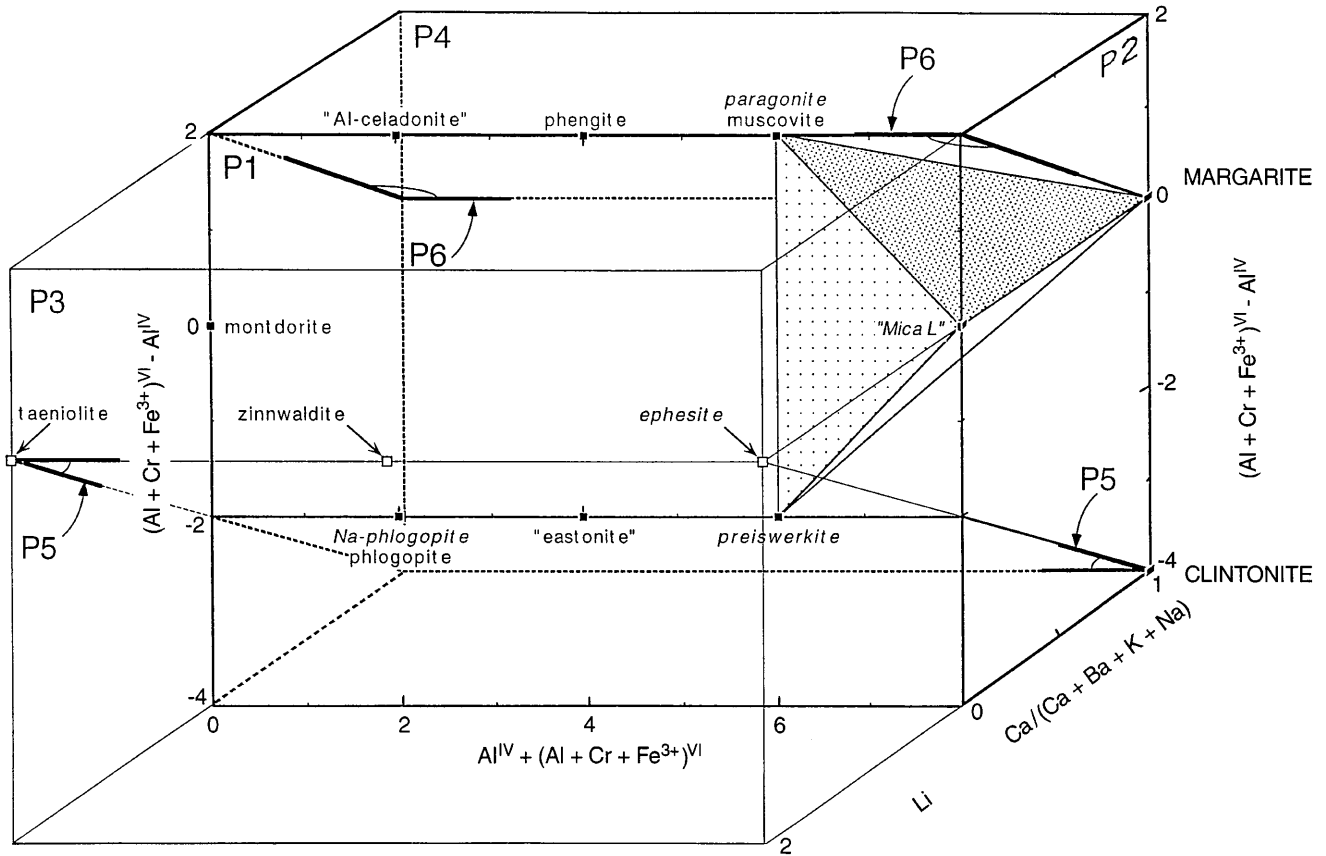


Fig. 1 Chemographic representation of mica compositions. Mica compositions are presented in the following space: $(Al + Cr + Fe^{3+})^{VI} - Al^{IV}$; $(Al + Cr + Fe^{3+})^{VI} + Al^{IV}$; $X_{Ca} = Ca / (Ca + Ba + Na + K)$; Li. [P1 plane of the (K,Na)-(Mg,Fe²⁺)-micas, P3 plane of some (K,Na)-Li-micas, P4 plane of the principal Ca-micas, P5 plane of trioctahedral micas, P6 plane of dioctahedral micas, P2 plane perpendicular to the preceding ones and passing through margarite and "Mica L" (see Fig. 3), dotted tetrahedron see text and Fig. 4]. Ca-micas are in *capitals*, Na-micas in *italics* and K-micas in *normal type*

the physical and chemical properties (in particular the possible solid solutions, the optical properties and the Raman spectra) and the conditions of stability of these unusual micas. This may contribute to a better understanding of their genesis and to predictions of new occurrences.

Petrology

The La Compointrie eclogite

The host rock

The kyanite-bearing eclogites from La Compointrie (Saint-Philbert-de-Grand-Lieu, Vendée, western France) are well known as ornamental rocks because of their emerald-green matrix studded with large pink garnet crystals (up to 5 cm in size). Discovered by Baret (1900), they were further studied by Brière (1920) and Godard

(1981, 1988). The preiswerkite-bearing rocks were sampled as loose blocks at the two following locations: 47°2'24"N-1°40'33"W and 47°2'15"N-1°40'23"W (grid reference Lambert II extended: 295.30-2234.07 and 295.10-2234.15). Sample VC50 described here was sampled at the second location. The bulk composition of these rocks is that of Al-Mg-rich troctolitic leucogabbros which would correspond to cumulates of a tholeiitic differentiation sequence. The eclogite-facies paragenesis consists of garnet, omphacite, kyanite, zoisite, magnesiohornblende and minor rutile (cf. samples C2, C3, C9 in Godard, 1988). The eclogite-facies physical conditions of the Vendée eclogites were estimated at around $T = 700\text{ °C}$ and $15 < P < 20\text{ kbar}$ (Godard 1981, 1988).

The preiswerkite and Na-(Mg,Fe)-margarite-bearing coronae

The kyanite/amphibole interface was reactive during retrogression in some of these kyanite-bearing eclogites and produced a composite preiswerkite-bearing corona (Fig. 2a-c). This corona is clearly related to the kyanite/amphibole contact as it is interrupted at kyanite/amphibole/omphacite triple points (Fig. 2a). It is made up as follows:

[kyanite] | micas | andesine | [amphibole],

Table 1 Occurrences of preiswerkite and Na-(Mg,Fe)-margarite associated with preiswerkite, from the literature [$X_{Mg} = Mg/(Mg + Fe^{2+} + Mn)$]

Preiswerkite					
Localities	Host rocks	Petrography	Metamorphic conditions	X_{Mg}	References
Geisspfad, Switzerland	Metaroddingite	Mica + zoisite nodules	Greenschist to amphibolite facies	0.93	Keusen and Peters (1980)
Allalinhorn, Valais, Switzerland	Eclogitized gabbro	Symplectite	Depressurisation	–	Meyer (1983)
Liset, Vestlandet, Norway	Kyanite eclogite	Symplectite around kyanite	Depressurisation	0.76	Smith and Kechid (1983), Kechid (1984), Smith (1988), this study
La Compointrie, Vendée, France	Kyanite eclogite	Coronae around kyanite	Depressurisation	0.96	Godard and Smith (1984), Godard (1988), this study
Vumba, Botswana	Serpentinite	Symplectite around spinel and högbomite	Retrogression	0.73	Rammlmair et al. (1988)
Koralpe and Saualpe, Austria	Kyanite eclogite	Symplectite around kyanite	Depressurisation	0.90	Miller (1990)
Rio La Palmilla, Guatemala	Jadeitite	Mostly with alteration products	Albitisation	0.75-0.86	Harlow (1994, 1995)
Blengsvatn, Bamble, Norway	Scapolite	Tourmaline + biotite + scapolite ± corundum ± plagioclase + ...	Greenschist to amphibolite facies	0.81-0.85	Visser et al. (1999)
Na-(Mg,Fe)-Margarite associated with preiswerkite					
Localities	Host rocks	Petrography	Metamorphic conditions	Mica L mol%	References
Liset, Vestlandet, Norway	Kyanite eclogite	Symplectite after kyanite	Depressurisation	27	Smith and Kechid (1983), Kechid (1984), Smith (1988), this study
La Compointrie, Vendée, France	Kyanite eclogite	Coronae around kyanite	Depressurisation	30	Godard and Smith (1984), Godard (1988), this study
Koralpe and Saualpe, Austria	Kyanite eclogite	Symplectite after kyanite	Depressurisation	13	Miller (1990)

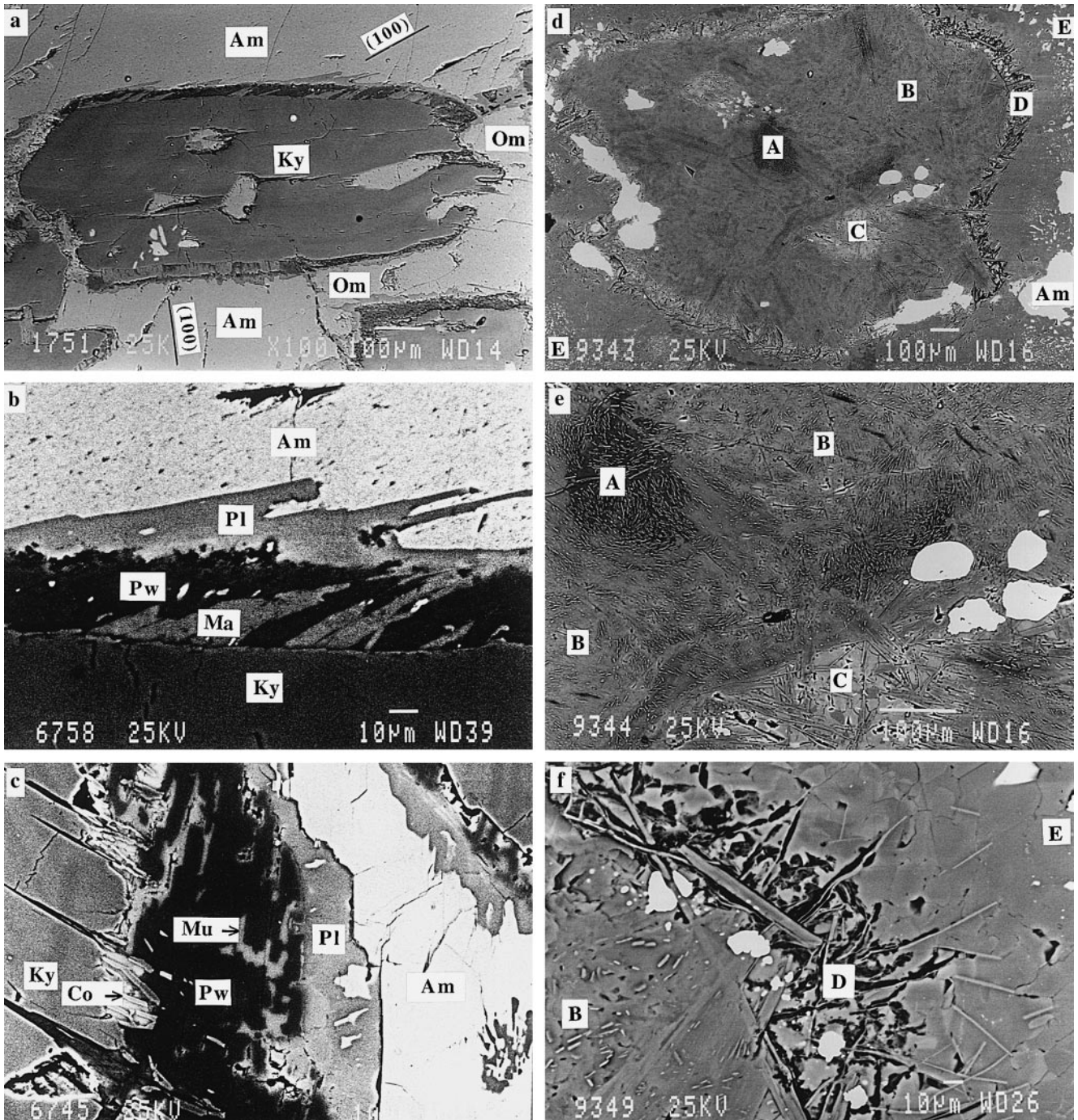
where “micas” indicates the assemblage: Na-(Mg,Fe)-margarite + preiswerkite ± phengitic muscovite.

Kyanite contains some rare, tiny isolated inclusions of talc and phlogopite (Table 2); these are thought to belong to an early eclogite paragenesis. Where retrogression is advanced, kyanite has been generally replaced by a symplectite of anorthite + corundum ± spinel, a common phenomenon in kyanite eclogites (e.g. Godard and Mabit 1998). The incipient growth of this symplectite, which apparently developed later than the preiswerkite-bearing corona, is responsible for the uneven presence of corundum and anorthite immediately adjacent to kyanite (Fig. 2c).

The relative abundance of margarite and preiswerkite in the mica corona is highly variable. Margarite is usually close to kyanite whereas preiswerkite is on the amphibole side, but exceptions do occur. The two micas display the same crystallographic orientation but are clearly distinguishable because of their different birefringence (0.017 for margarite *versus* 0.027 for preiswerkite). They grew in such a way that (001) in the micas is parallel to (100) of the amphibole, the mica sheets being parallel to the plane of the double chains in amphibole (Fig. 2a).

Some phengitic muscovite, negligible in volume, is locally associated with preiswerkite (Fig. 2c; Table 2). It forms either planar microinclusions within preiswerkite (Fig. 2c) or a very thin and discontinuous layer between preiswerkite and plagioclase visible only using a scanning electron microscope by X-ray mapping of K. This latter structure can be interpreted as a corona unevenly present at the preiswerkite/feldspar boundary. On the other hand, the planar microinclusions within preiswerkite might be related to exsolution from preiswerkite since they are elongated parallel to the (001) sheets (Fig. 2c). In the corona of Fig. 2c, the phengitic muscovite volume, estimated from image analysis, represents 10.7% of the overall mica volume. A possible composition before the hypothetical exsolution can thus be proposed ($[Musc + Pheng]_{0.10} Preisw_{0.90}$; star in Fig. 3). However, we cannot rule out that this structure is due to parallel intergrowth of muscovite + preiswerkite dating from the corona formation, or possibly to a late-stage alteration phenomenon along the (001) cleavage.

The mica/plagioclase contact is rectilinear and more regular than the other contacts (kyanite/margarite, margarite/preiswerkite and plagioclase/amphibole). It is suggested that the mica/plagioclase contact coincides



with the previous kyanite/amphibole interface (i.e. Al-rich/Al-poor contact), Al-rich micas and plagioclase having grown at the expense of kyanite and amphibole respectively.

The plagioclase composition ranges from An_{36} to An_{41} , without any clear zonation. The amphibole, a magnesiohornblende according to the classification of Leake et al. (1997), was considered to belong to an eclogite paragenesis (Godard 1988). In a zone of about 50 μm away from the reaction interface, it displays, towards the rim, an enrichment in Al, slight decreases of Si, Mg, Fe^{2+} , and a minor increase of Na. This zonation

Fig. 2 Preiswerkitite and Na-(Mg,Fe)-margarite after kyanite. Back-scattered electron images: **a, b, c** Coronae; kyanite eclogite from La Compointrie, France. [Ky kyanite, Co corundum (associated with anorthite), Ma Na-(Mg,Fe)-margarite, Pw pre-isawerkitite, Mu phengitic muscovite included within preiswerkitite, parallel to (001), Pl plagioclase, Am amphibole, Om omphacite, (100) trace of (100) crystallographic plane of the amphibole parallel to (001) in the micas]. **b** is an enlargement of **a**. **d, e, f** Symplectites; kyanite eclogite from Liset, Norway. [A+B+C kyanite pseudomorph, E+Am omphacite pseudomorph. A paragonite (dark grey) + corundum (light-grey rods), B Na-(Mg,Fe)-margarite (grey) + corundum (light-grey rods), C An_{40} plagioclase (light grey) + Na-(Mg,Fe)-margarite laths (grey), D An_{15} plagioclase + preiswerkitite laths (with minor margarite), E An_{15} plagioclase (grey) + magnetite (white)]. **e, f** are enlargements of **d**

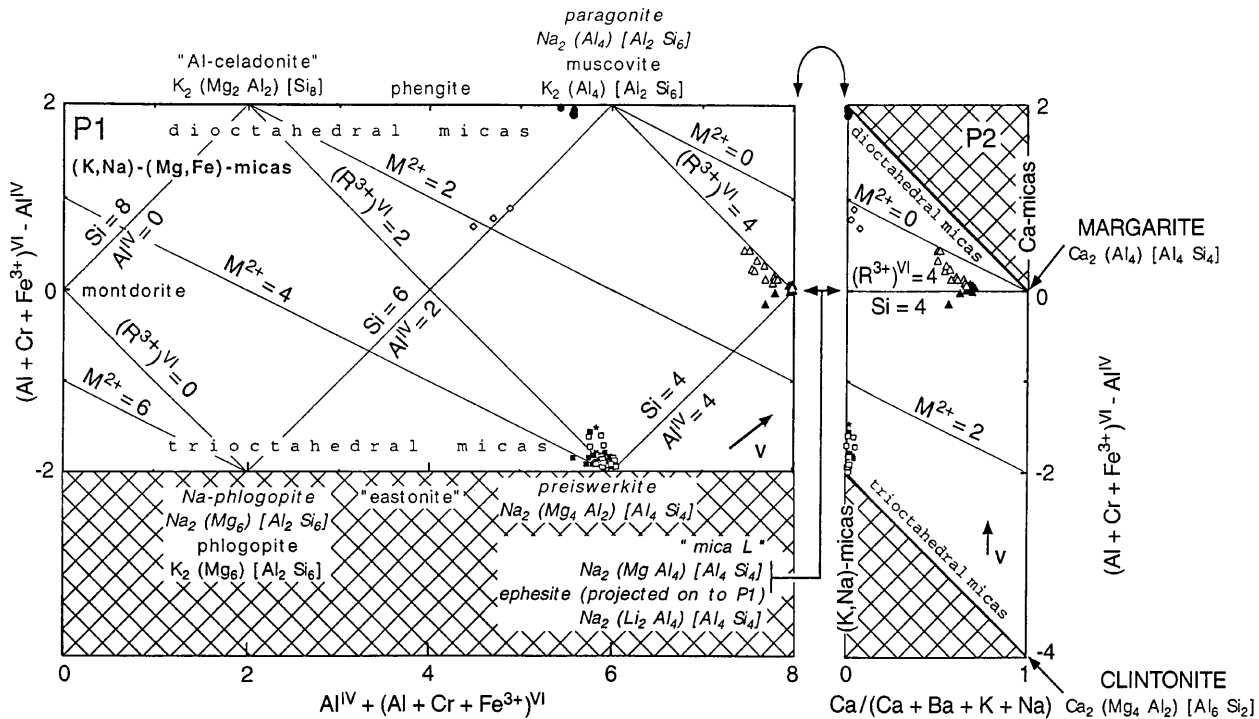


Fig. 3 Mica compositions. Compositions are projected from the space of Fig. 1 on to its planes P1, P2. P1: $(Al + Cr + Fe^{3+})^{VI} - Al^{IV}$ versus $(Al + Cr + Fe^{3+})^{VI} + Al^{IV}$ (with $X_{Ca} = 0$ and $Li = 0$); P2: $(Al + Cr + Fe^{3+})^{VI} - Al^{IV}$ versus X_{Ca} [with $(Al + Cr + Fe^{3+})^{VI} + Al^{IV} = 8$ and $Li = 0$]. [Open symbols Liset eclogite, solid symbols La Compointrie eclogite; squares preiswerkite, triangles Na-(Mg,Fe)-margarite, circles muscovite associated with preiswerkite, diamonds phengite and preiswerkite analysed together (Liset: phengite micro-layers are not thick enough to be analysed separately), star hypothetical preiswerkite composition before exsolution of muscovite (La Compointrie; cf. Fig. 2c; see text), shaded area non-existing compositions. $M^{2+} = Mg + Mn + Fe^{2+}$, $(R^{3+})^{VI} = (Al + Cr + Fe^{3+})^{VI}$]. Fe^{3+} in micas cannot be calculated satisfactorily by stoichiometry since an infinity of solutions are possible. The data presented here correspond to $Fe^{3+} = 0$. For $Fe^{3+} > 0$, data points would be slightly translated parallel to vector V . The mineral names are of the pure Cr-Mn-Fe-free end-members. Ca-micas are in *capitals*, Na-micas in *italics* and K-micas in *normal type*

indicates the operation of the Tschermakitic substitution $(Al^{VI}Al^{IV}(Mg,Fe)_1Si_{-1})$ during the reaction, together with minor edenitic substitution $(NaAl^{IV}Si_{-1})$. Hence, the reaction occurred in a divariant P - T field causing a sliding evolution of the amphibole composition.

Stoichiometric calculations

Attempts to balance the reaction by the method of least squares led to results with high residuals (Table 3). Evolution of the amphibole composition during the reaction (see above) cannot explain these residuals properly. Most probably, the system was slightly open during the reaction, exchanging elements (i.e. Ca, Na, Si: cf.

residuals in Table 3) with other simultaneously reactive sites in the rock.

The calculated volumes of the product plagioclase and micas are similar to those of the reactant amphibole and kyanite respectively, which again supports the hypothesis that the plagioclase and mica contact coincides with the previous kyanite/amphibole interface.

The Liset eclogite

The host rock

This unique eclogite pod is one of many different kinds of eclogite, in terms of petrography, mineralogy, chemistry and age, which occur as lensoid bodies enclosed within a group of very diverse polymetamorphic gneisses of the "Western Gneiss Region" (WGR) of western South Norway (e.g. Eskola 1921; Smith 1988). It is this group of "country-rock" or "external" eclogites (to be distinguished from "internal" eclogites which occur within garnet-bearing ultramafic bodies in the same region) which contributed to the recognition of the concept of ultra-high pressure metamorphism (UHPM) by means of discoveries of various UHP parageneses (Lappin and Smith 1978, 1981; Smith 1988) including definite coesite (Smith 1984; Wain 1997) and more recently the intriguing definite microdiamond recorded from gneiss at Fjörtoft (Dobrzhinetskaya et al. 1995; Smith 1995).

The 60 m long, partially retrogressed, irregularly layered kyanite-eclogite pod at Liset is well known for its

Table 2 Mica compositions. Miccas were analysed with the Cameca SX-50 electron microprobe at the University Paris 7, at an accelerating voltage of 15 kV and a beam current of 10 nA. Structural formulae are calculated on the basis of 22 equivalent oxygens, with total iron as Fe^{2+} . [n number of averaged analyses, σ standard deviation, * isolated inclusions within kyanite, ** total (wt%) = $\Sigma_{oxides} + (F-1/2O) + (Cl-1/2O) + (H_2O$ is not taken into account), *** calculated by stoichiometry, $X_{Mg} = Mg / (Mg + Fe^{2+} + Mn)$]

	Liset, Vestlandet, Norway														
	La Compointrie, Vendée, France				Preiswerkite				Na-(Mg,Fe)-Margarite						
	Preiswerkite		Na-(Mg,Fe)-Margarite		Muscovite		Phlogopite (*)		Talc (*)		Preiswerkite		Na-(Mg,Fe)-Margarite		
n = 21 ($\pm\sigma$)	n = 1	n = 1	n = 11 ($\pm\sigma$)	n = 1	n = 1	n = 1	n = 1	n = 1	n = 1	n = 8 ($\pm\sigma$)	n = 1	n = 1	n = 12 ($\pm\sigma$)	n = 1	n = 1
SiO ₂	30.08 ± 0.65	29.85	30.06	30.72 ± 0.50	30.40	29.86	46.82	40.79	59.53	29.93 ± 0.46	29.79	29.45	32.03 ± 1.11	33.14	31.36
TiO ₂	0.04 ± 0.04	0.07	0.04	0.09 ± 0.07	0.14	0.19	0.04	0.55	0.03	0.02 ± 0.02	0.06	0.02	0.11 ± 0.04	0.06	0.13
Al ₂ O ₃	36.45 ± 0.89	36.98	37.00	51.23 ± 1.00	51.20	50.55	35.78	19.01	6.50	35.98 ± 0.44	36.13	36.11	49.03 ± 0.93	48.92	49.94
Cr ₂ O ₃	0.16 ± 0.09	0.10	0.10	0.20 ± 0.09	0.11	0.06	0.00	0.37	0.05	0.04 ± 0.02	0.06	0.04	0.02 ± 0.03	0.02	0.00
FeO	1.37 ± 0.08	1.39	1.37	0.21 ± 0.10	0.17	0.29	0.15	2.20	0.86	6.98 ± 0.13	7.02	7.19	1.32 ± 0.09	1.40	1.41
MnO	0.02 ± 0.03	0.01	0.00	0.30 ± 0.04	0.00	0.00	0.02	0.11	0.00	0.04 ± 0.05	0.00	0.04	0.02 ± 0.03	0.04	0.02
MgO	18.42 ± 0.45	17.89	18.79	1.56 ± 0.65	1.43	1.44	1.35	21.40	25.06	14.78 ± 0.33	14.97	15.29	1.01 ± 0.08	1.00	1.09
CaO	0.22 ± 0.11	0.51	0.21	9.44 ± 0.69	9.94	9.13	0.09	0.14	0.08	0.16 ± 0.15	0.16	0.11	8.12 ± 0.71	7.20	8.16
BaO	0.02 ± 0.05	0.00	0.00	0.02 ± 0.04	0.00	0.03	0.03	0.00	0.00	0.11 ± 0.10	0.00	0.00	0.04 ± 0.09	0.00	0.14
Na ₂ O	7.15 ± 0.22	6.89	7.27	2.41 ± 0.27	2.38	2.52	0.39	1.14	0.13	7.02 ± 0.12	7.10	7.12	3.17 ± 0.45	3.82	3.20
K ₂ O	0.30 ± 0.18	0.19	0.24	0.03 ± 0.03	0.01	0.04	10.73	7.96	1.50	0.06 ± 0.01	0.05	0.02	0.01 ± 0.02	0.01	0.03
F	0.018 ± 0.029	0.032	0.019	0.000 ± 0.000	0.000	0.000	0.000	0.000	0.084	0.041 ± 0.050	0.097	0.000	0.060 ± 0.090	0.022	0.000
Cl	0.003 ± 0.008	0.000	0.019	0.004 ± 0.009	0.008	0.000	0.000	0.021	0.019	0.006 ± 0.013	0.003	0.041	0.005 ± 0.005	0.000	0.000
Total (**)	94.24	93.91	95.11	95.93	95.77	94.13	95.40	93.69	93.80	95.14	95.38	95.40	94.91	95.52	95.48
Si	4.115 ± 0.082	4.091	4.075	4.038 ± 0.035	4.007	4.003	6.188	5.729	7.708	4.154 ± 0.061	4.126	4.083	4.262 ± 0.134	4.366	4.158
Al ^{IV}	3.885 ± 0.082	3.909	3.925	3.962 ± 0.035	3.993	3.997	1.812	2.271	0.292	3.846 ± 0.061	3.874	3.917	3.738 ± 0.134	3.634	3.842
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Al ^{VI}	1.992 ± 0.055	2.066	1.987	3.974 ± 0.080	3.963	3.990	3.763	0.877	0.701	2.040 ± 0.027	2.022	1.985	3.950 ± 0.038	3.961	3.962
Ti	0.004 ± 0.004	0.007	0.004	0.009 ± 0.006	0.013	0.019	0.004	0.058	0.003	0.002 ± 0.002	0.006	0.002	0.011 ± 0.004	0.006	0.013
Cr	0.018 ± 0.010	0.011	0.011	0.020 ± 0.009	0.011	0.006	0.000	0.041	0.005	0.004 ± 0.003	0.006	0.004	0.002 ± 0.003	0.002	0.000
	2.014	2.084	2.002	4.003	3.987	4.015	3.767	0.976	0.709	2.046	2.034	1.991	3.963	3.970	3.975
Fe	0.156 ± 0.010	0.159	0.156	0.023 ± 0.011	0.018	0.033	0.016	0.258	0.093	0.810 ± 0.011	0.812	0.833	0.147 ± 0.009	0.154	0.156
Mn	0.002 ± 0.004	0.001	0.000	0.003 ± 0.004	0.000	0.000	0.003	0.013	0.000	0.005 ± 0.006	0.000	0.004	0.003 ± 0.003	0.005	0.002
Mg	3.755 ± 0.078	3.656	3.796	3.306 ± 0.129	0.282	0.288	0.265	4.481	4.837	3.059 ± 0.066	3.090	3.160	0.200 ± 0.015	0.197	0.216
	3.913	3.816	3.952	0.332	0.300	0.321	0.284	4.752	4.930	3.874	3.902	3.997	0.350	0.356	0.374
Ca	0.032 ± 0.015	0.075	0.031	1.329 ± 0.089	1.405	1.311	0.012	0.021	0.012	0.024 ± 0.022	0.023	0.017	1.158 ± 0.107	1.016	1.159
Ba	0.001 ± 0.003	0.000	0.000	0.001 ± 0.002	0.000	0.002	0.002	0.000	0.000	0.006 ± 0.005	0.005	0.000	0.002 ± 0.003	0.000	0.007
Na	1.897 ± 0.053	1.832	1.910	0.613 ± 0.073	0.608	0.656	0.101	0.311	0.031	1.888 ± 0.029	1.905	1.913	0.818 ± 0.113	0.976	0.821
K	0.052 ± 0.032	0.034	0.042	0.004 ± 0.005	0.001	0.007	1.809	1.426	0.247	0.011 ± 0.002	0.008	0.003	0.002 ± 0.003	0.001	0.005
	1.982	1.941	1.982	1.948	2.014	1.976	1.924	1.759	0.290	1.929	1.937	1.933	1.980	1.994	1.992
F	0.008 ± 0.013	0.014	0.008	0.000 ± 0.000	0.000	0.000	0.000	0.000	0.034	0.018 ± 0.022	0.042	0.000	0.025 ± 0.037	0.009	0.000
Cl	0.001 ± 0.002	0.000	0.004	0.001 ± 0.002	0.002	0.000	0.000	0.005	0.004	0.001 ± 0.003	0.001	0.010	0.001 ± 0.001	0.002	0.000
OH (***)	3.991	3.986	3.987	3.999	3.998	4.000	4.000	3.995	3.961	3.981	3.957	3.990	3.794	3.991	4.000
X _{Mg}	0.960 ± 0.003	0.958	0.961	0.921 ± 0.025	0.939	0.897	0.932	0.943	0.981	0.790 ± 0.004	0.792	0.791	0.572 ± 0.030	0.553	0.578

Table 3 Results of balancing of the preiswerkite-forming reaction in La Compointrie eclogite. Site of Fig. 2a (bottom). Stoichiometric coefficients are obtained by minimizing $\sum_i (R_i^2)$, where R_i is the

residual for the element i (i.e. the difference between the quantity of the element involved in the reactants and that in the products). The stoichiometric coefficient of kyanite is arbitrarily fixed at 1

	Phase	Moles	Volume (cm ³)	Composition
Reactants	Kyanite	1.0000	44.14	Si _{1.000} Al _{2.000} Cr _{0.000} O ₅
	Amphibole	0.0453	12.28	Si _{7.445} Al _{0.997} Ti _{0.007} Fe _{0.200} Mn _{0.004} Mg _{4.360} Ca _{1.712} Na _{0.564} K _{0.058} O ₂₂ (OH) ₂
	Fluid	0.4391	–	H ₂ O
Products	Plagioclase	0.0923	9.26	Si _{2.595} Al _{1.410} Cr _{0.002} Fe _{0.001} Ca _{0.385} Na _{0.599} K _{0.010} O ₈
	Preiswerkite	0.0335	9.20	Si _{4.066} Al _{5.939} Cr _{0.028} Fe _{0.142} Mn _{0.001} Mg _{3.787} Ca _{0.023} Na _{1.882} K _{0.046} O ₂₀ (OH) ₄
	Margarite	0.2087	54.11	Si _{4.027} Al _{7.963} Ti _{0.007} Cr _{0.020} Fe _{0.0165} Mn _{0.004} Mg _{0.266} Ca _{1.374} Na _{0.591} K _{0.003} O ₂₀ (OH) ₄
Residuals	Out (–)	1		Si _{–0.121} Al _{–0.054} Fe _{–0.001} Mg _{–0.015}
	In (+)	1		Ti _{+0.001} Cr _{+0.005} Mn _{+0.001} Ca _{+0.246} Na _{+0.216} K _{+0.001} O _{+0.025}

mineralogical complexity and has been the source of several new mineral species: nyböite and Mg-Al-taramite (Ungaretti et al. 1981; Kechid and Smith 1982); Fe-Al-taramite (Ungaretti et al. 1985); lisetite (Smith et al. 1986); and K-free Ca-rich nepheline (Rossi et al. 1989).

Intense pre- and/or syn-eclogite deformation created or accentuated compositional layering into extremes of garnet-zoisite-titanite-rich clinopyroxene-poor eclogite and jadeite-rich garnet-poor omphacitite or jadeitite with or without quartz. In contrast, the extensive amphibolite- to greenschist-facies retrogression was essentially a static phenomenon since it largely conserved the grain boundaries of the former eclogite-facies phases (Kechid 1984; Smith 1988). Thus, in hand specimens which are totally composed of various symplectites, it is possible to reconstruct most of the retrogressive evolution. The replacement of eclogite minerals by unusual combinations of phases can be attributed to the combination of: extreme oxidation and hydration; extreme mobility of Na, Ca and Fe; very limited mobility of Al and Si; extremely low K-content; limited amounts of Mg and abundant Na and Al. Hence, garnet is often replaced by “Na-eastonite” + plagioclase + magnetite; jadeite-rich clinopyroxene by (Mg,Fe)-Al-taramite + plagioclase + magnetite; and kyanite by minute bead-like grains of corundum + plagioclase + mica(s).

Eight kinds of micas have been recorded in the whole pod: margarite, preiswerkite, Na-eastonite (Smith and Kechid 1983), paragonite, phengite (rare), muscovite (rare) (Kechid 1984), Na-(Mg,Fe)-margarite and Ca-(Mg,Fe)-paragonite (Smith 1988, pp. 76–79). The Na-(Mg,Fe)-margarite and preiswerkite always occur as replacements of kyanite that is still present in some places. In this report, attention will focus upon these two mica types (with minor discussion on co-existing Ca-(Mg,Fe)-paragonite) and on three thin sections (G184, K26, K29) in which preiswerkite is best developed.

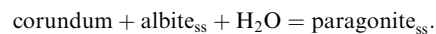
The pyroxene pseudomorphs

The material surrounding the previous kyanite grains was essentially a jadeite-rich clinopyroxene (stage I) which has been replaced by a symplectite of Na-rich plagioclase (around An₁₅) + magnetite (E in Fig. 2d, f)

+ taramitic or pargasitic amphibole (Am in Fig. 2d) (stage II) (Kechid 1984).

The Na-(Mg,Fe)-margarite-bearing kyanite pseudomorphs

No kyanite remains in the three mentioned thin sections, but a great concentration of Al is represented by innumerable rods of corundum disseminated in a matrix of diffuse plagioclase (of variable composition, often around An₄₀) and blades of mica, which are exclusively of Na-(Mg,Fe)-margarite in K26 but of an admixture of Ca-(Mg,Fe)-paragonite (A in Fig. 2d, e) and Na-(Mg,Fe)-margarite (B in Fig. 2d, e) in K29. In the latter case, the two different mica species (with different space group) are easily distinguishable by their birefringence (interference colour) and the margarite phase generally surrounds the paragonite phase (Fig. 2d). They often seem to occur in the same optical and crystallographic orientation; this implies epitaxial/topotaxial superposition during growth rather than exsolution as they are not interleaved. Kechid (1984) and Kechid and Smith (1985) deduced for K26 that the mica(s) (stage III) within the kyanite pseudomorph grew later than the corundum + plagioclase symplectite (stage II) which had previously replaced the kyanite (stage I) because it followed a cooling path which crossed in rapid succession the hydration reactions:



Combined with other data, a clockwise P - T trajectory was proposed by Kechid (1984).

The preiswerkite-bearing interface

The interface between the kyanite pseudomorphs and the matrix is not so well defined at Liset as it is at La Compointrie. The precise composition of the former clinopyroxene is unknown and those of the plagioclase and amphibole are variable such that it is not possible in the Norwegian samples even to attempt stoichiometric calculations.

Preiswerkite laths grew either adjacent to margarite blades at the edge of the kyanite pseudomorph (D in Fig. 2d, f) or up to about 1 mm away within the amphibolite matrix, in a zone that is richer in plagioclase and poorer in clinoamphibole and magnetite than elsewhere in the matrix (Fig. 2d, f). Preiswerkite has not been observed inside the kyanite pseudomorphs and margarite has not been found outside them. It is clear that the preiswerkite occurs only in the interface zone which was constituted during stage II by the coupled migration of Na from the matrix and of Al from the kyanite pseudomorph. There remains considerable doubt whether the preiswerkite grew contemporaneously with the Na-(Mg,Fe)-margarite (stage III: amphibolite facies) or later (stage IV: greenschist facies).

The X-ray mapping of K with a scanning electron microscope revealed microlayers, parallel to (001), of a K-bearing mica in some preiswerkite flakes (sample K29). The microprobe analyses of these microlayers give composite compositions between phengite and preiswerkite (open diamonds in Fig. 3). As in the case of the La Compointrie preiswerkite, this can be interpreted either as intergrowth or exsolution.

Mineralogy

Preiswerkite

The preiswerkites from both localities have compositions close to the theoretical end-member $\text{Na}_2\text{Mg}_4\text{Al}_2^{\text{VI}}[\text{Si}_4\text{Al}_4^{\text{IV}}]\text{O}_{20}(\text{OH})_4$ with minor amounts of the $\text{Fe}_1^+ \text{Mg}_{-1}$ substitution, and traces of Ti, Cr, Mn, Ba, F and Cl (Table 2; Fig. 3). The main difference in composition between Liset and La Compointrie preiswerkites appears in the X_{Mg} ratio [$X_{\text{Mg}} = \text{Mg}/(\text{Mg} + \text{Mn} + \text{Fe}^{2+}) = 0.79$ and 0.96 respectively; Table 2]. This is clearly related to differences in the X_{Mg} value of the bulk rock compositions. More generally, X_{Mg} in natural preiswerkites scatters from 0.7 to almost 1 (Table 1).

At both localities, there exists a slight divergence of compositions towards dioctahedral micas (Fig. 3). This could be related to minor solid solution of phengitic muscovite (< 10 mol%). As mentioned above, phengite or phengitic muscovite has been observed in both Liset and La Compointrie preiswerkites, in which they form microlayers or microinclusions parallel to the (001) plane (Fig. 2c). This texture could be due to exsolution. A hypothetical composition of $(\text{Musc} + \text{Pheng})_{0.10}$ Preisw_{0.90} is proposed here (star in Fig. 3) for the preiswerkite of Fig. 2c, assuming the muscovite is a product of exsolution.

The Liset and La Compointrie preiswerkites also display a limited solid solution towards Na-phlogopite (Fig. 3). However, complete solid solution has been demonstrated experimentally at 2 kbar, 600 °C (Liu 1989; Tlili 1990). Figure 3 also shows that there is neg-

ligible solid solution to more aluminous compositions, whether along the extrapolated Tschermakitic substitution or towards Mica L or margarite. Contents of $\text{Al}^{\text{IV}} \leq 4$ appear to be a composition limit for natural (K,Na)-micas, as is the case in synthetic compositions (Liu 1989).

Preiswerkite is stable with Mg completely replaced by Fe^{2+} or Mn^{2+} , but solution towards Na-Fe-phlogopite or Na-Mn-phlogopite is rather limited (Smith et al. 1999). In other words, the solid solution domain between Na-phlogopite and preiswerkite (complete with Mg) moves to the right of the P1 plane of Fig. 3 as Fe^{2+} or Mn^{2+} replaces Mg (i.e. Na-phlogopite unstable). On the other hand, when Al is replaced by Ga, or when Si is replaced by Ge, the opposite situation arises whereby preiswerkite becomes unstable as the solid solution domain is shifted to the left of the P1 plane (i.e. Ga- or Ge-eastonite and -phlogopite are stable). All of these stability relationships can be explained by the necessity to make the tetrahedral and octahedral layers of the 2:1 mica sandwich fit together, as manifested by variation in the ditrigonal rotation angle α of the tetrahedra and the flattening angle ψ of the octahedra (Smith et al. 1999).

In pure Mg-Al-Si micas, Al-rich tetrahedra create considerable geometrical and electronic charge distortion. In particular, the lower charge and greater size of Al^{3+} , with respect to that of Si^{4+} , causes rotation of the tetrahedra (i.e. increase in α) which in turn changes the co-ordination of the interlayer W site from twelve to six, which is ideal for Na and Ca but unsuitable for K (Oberti et al. 1993; Smith et al. 1999). For this reason, any K-bearing hyperaluminous mica is unstable, whereas (Ca,Na)-Al-rich micas (e.g. preiswerkite, ephesite, clintonite, margarite, Mica L_{ss}) are stable.

Since the optical properties of preiswerkite have been described only once, by Keusen and Peters (1980), it is useful to list them here for the preiswerkites of the present study: colourless in thin section; perfect (001) cleavage; O.A.P. and α perpendicular to (001); $2V_\alpha$ very small (i.e. sub-uniaxial ellipsoid); maximum birefringence: $\gamma - \alpha = 0.027 \pm 0.002$ (La Compointrie) and $\gamma - \alpha = 0.026 \pm 0.003$ (Liset). The $\gamma - \alpha$ was estimated with a universal stage, from the birefringence tint (second order) and the thickness measured by focusing on both sides of the rock slice. These properties are consistent with those reported by Keusen and Peters (1980), except for the birefringence $\gamma - \alpha$ which is lower here (0.027 versus 0.055 calculated from measured refractive indices).

Preiswerkite from Liset has already been investigated by Raman spectrometry (Tlili et al. 1989), as has a pure synthetic powder (Liu 1989; Tlili 1990; Tlili and Smith 1996). Preiswerkite from La Compointrie has been studied here by the same technique. All three spectra are identical in wavenumber positions within $\pm 4 \text{ cm}^{-1}$, a range that is almost insignificant with respect to the experimental uncertainties ($\pm 2 \text{ cm}^{-1}$).

Na-(Mg,Fe)-margarite

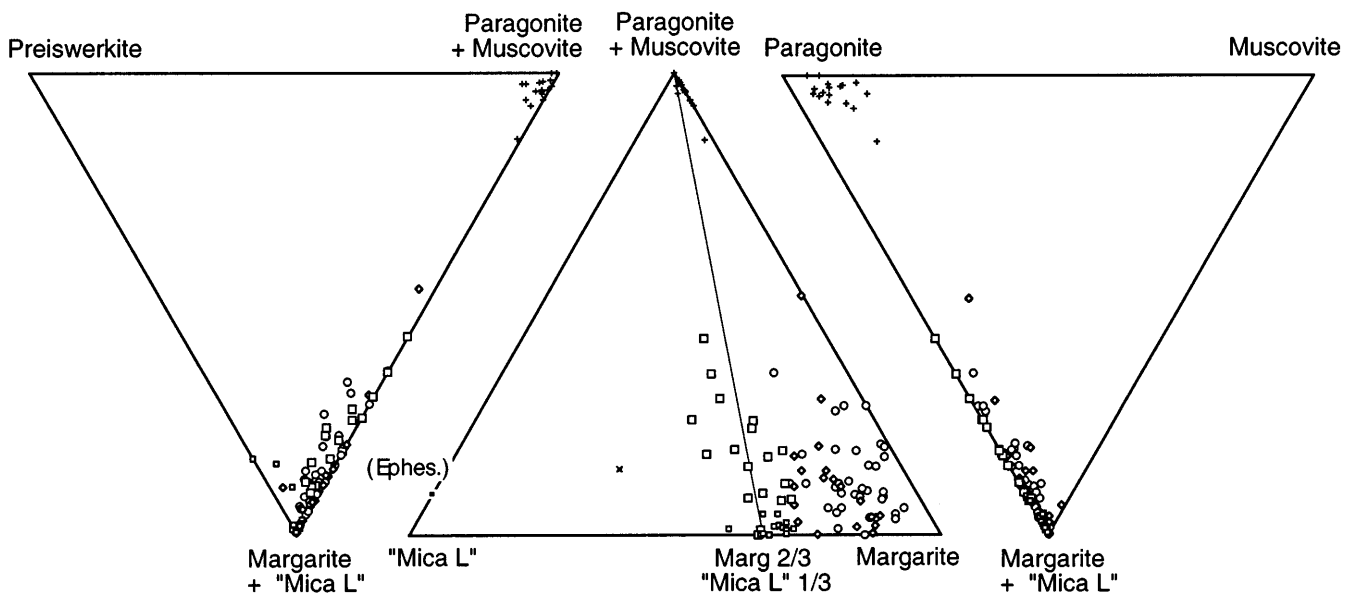
The margarites from both localities have an unusual Na-(Mg,Fe)-rich composition (Table 2; Fig. 3). It can be considered roughly as a solid solution of about 1/3 mol% of Mica L ($\text{Na}_2(\text{Mg,Fe})_1\text{Al}_4^{\text{VI}}[\text{Si}_4\text{Al}_4^{\text{IV}}]\text{O}_{20}(\text{OH})_4$) and 2/3 mol% of margarite. The Liset margarite in sample K26 displays a trend from $\text{Marg}_{2/3}$ Mica $\text{L}_{1/3}$ towards paragonite (Figs. 3,4). On the other hand, the La Compointrie margarite is very close to $\text{Marg}_{2/3}$ Mica $\text{L}_{1/3}$; the slight trend towards preiswerkite (Figs. 3, 4) is likely to be caused by a physical mixture during analysis resulting from the small size of the two coexisting minerals.

Many margarites in Nature contain appreciable amounts of Na. These micas have been interpreted as being solid solutions between margarite and paragonite (e.g. Ackermann and Morteani 1973; Höck 1974; Guidotti et al. 1979; Enami 1980; Baltatzis and Katagas 1981; Frey et al. 1982; Gomez-Pugnaire et al. 1985; Cotkin et al. 1988; Lahti 1988; Gal and Ghent 1991; Nijland et al. 1993; Feenstra 1996), or between margarite and ephesite (often Be-bearing) (e.g. Schaller et al. 1967; Velde 1971; Farmer and Velde 1973; Joswig et al. 1983; Lahti 1988; Chopin et al. 1991). The solid solutions and miscibility gap between margarite and paragonite are well known in Nature and have been investigated experimentally (Franz et al. 1977; Velde 1980; Tili 1990; Tili et al. 1990).

However, apart from a few studies (Smith and Kechid 1983; Kechid 1984; Godard and Smith 1984; Godard 1988; Smith 1988; Feenstra 1996), little attention has been paid to the fact that many of the sodian margarites also contain significant amounts of Mg and Fe. These Na-(Mg,Fe)-margarites are in effect complex solid solutions of margarite–Mica L–paragonite (Fig. 4), with minor amounts of muscovite, preiswerkite and perhaps ephesite. Preiswerkite, the trioctahedral mica

closest in composition, is arbitrarily taken here to reveal a possible solid solution between margarite and the trioctahedral micas. Because Li analyses are often unavailable, it is difficult to determine if deviations from the margarite–paragonite join are related either to ephesite or to Mica L in solid solution. In Fig. 4, a true ephesite lacking analysed Li would project on to the Mica L–paragonite join [i.e. “(Ephes.)” in Fig. 4]. Analyses plotting within the domain (Parag + Musc)–Marg–(Ephes.) and lacking Mg and Fe must contain true ephesite, whereas sodian margarite containing Mg or Fe must contain either Mica L or preiswerkite. The Na-(Mg,Fe)-margarites from Liset and La Compointrie

Fig. 4 Na-bearing margarite compositions from the literature. End-member proportions are calculated with respect to the system Preisw-Parag-Musc-“Mica L”-Marg, applicable to micas whose composition is included within the tetrahedron of Fig. 1, i.e. with $\text{Al}^{\text{IV}} + (\text{Al} + \text{Cr} + \text{Fe}^{3+})^{\text{VI}} - 2X_{\text{Ca}} \geq 6$, $\text{Al}^{\text{IV}} \leq 4$ and $(\text{Al} + \text{Cr} + \text{Fe}^{3+})^{\text{VI}} \leq 4$. The calculation sequence is as follows: $\text{Fe}^{3+} = 0$; $X_{\text{Musc}} = X_{\text{K}}$; $X_{\text{Marg}} = X_{\text{Ca}}$; $X_{\text{Parag}} = (4 - \text{Al}^{\text{IV}})/2 - X_{\text{Musc}}$; $X_{\text{MicaL}} = (\text{Al}^{\text{IV}} + [\text{Al} + \text{Cr}]^{\text{VI}} - 6)/2 - X_{\text{Marg}}$; $X_{\text{Preisw}} = (4 - [\text{Al} + \text{Cr}]^{\text{VI}})/2$. Data are projected from the tetrahedron of Fig. 1 on to the following triangles: $(X_{\text{Parag}} + X_{\text{Musc}})$, X_{Preisw} , $(X_{\text{Marg}} + X_{\text{MicaL}})$; $(X_{\text{Parag}} + X_{\text{Musc}})$, X_{MicaL} , X_{Marg} ; X_{Musc} , X_{Parag} , $(X_{\text{Marg}} + X_{\text{MicaL}})$. [Open squares Na-margarite, after kyanite in eclogites, associated with preiswerkite from Liset (*large squares* data from: Kechid 1984; Tili 1990; this study) and from La Compointrie (*small squares* data from: Godard 1988; this study). Open diamonds Na-margarite after kyanite (data from: Enami 1980; Baltatzis and Katagas 1981; Dachs 1986; Stähle et al. 1986; Spear and Franz 1986; Cotkin et al. 1988; Cotkin 1997; Miller 1990; Chopin et al. 1991; Schmädicke et al. 1992; Nijland et al. 1993; Zhang and Liou 1994; Caby 1994). Open circles other Na-margarites (data from: Ackermann and Morteani 1973; Höck 1974; Gibson 1979; Guidotti et al. 1979; Frey et al. 1982; Lahti 1988; Gal and Ghent 1991; Oliveriova 1993; Zhang et al. 1997). Sign x ephesite after kyanite (data from: Chopin et al. 1991). Sign + paragonite associated with Na-margarite (data from: Ackermann and Morteani 1973; Höck 1974; Guidotti et al. 1979; Enami 1980; Dachs 1986; Spear and Franz 1986; Tili 1990; Chopin et al. 1991). (Ephes.) Apparent composition $(\text{Na}_{2.1}\text{Al}_4^{\text{VI}}[\text{Al}_{3.81}^{\text{IV}}\text{Si}_{4.19}]\text{O}_{20}(\text{OH})_4)$ of a pure ephesite $(\text{Na}_2\text{Li}_2\text{Al}_4^{\text{VI}}[\text{Al}_4^{\text{IV}}\text{Si}_4]\text{O}_{20}(\text{OH})_4)$ whose analysis lacks Li]



display the greatest Mica L proportion (1/3) ever reported for sodian margarite (Fig. 4).

As noted above, both margarite and paragonite are well known as stable pure end-members with considerable mutual solid solution, with or without a solvus. Figure 4 reveals that margarite also shows considerable solid solution towards Mica L, and in many cases, ternary solutions of Marg–Mica L–Parag occur. However, these compositions are almost always restricted to $X_{\text{MicaL}} \leq 1/3$, both in Nature (Fig. 4) and in the products of experiments (Tlili 1990). In contrast, there is no significant solid solution from these ternary compositions towards muscovite or preiswerkite (Fig. 4). A striking feature of the margarite from La Compointrie (Figs. 3, 4) is that the compositions are essentially constrained to precisely Marg_{2/3} Mica L_{1/3}. Interestingly, the compositions from Liset lie on a trend from this point towards the paragonite end-member (Figs. 3, 4). These features could be explained by the existence of a crystal-chemical phenomenon, which prevents solution extending further towards Mica L. Thus, the Marg_{2/3} Mica L_{1/3} composition (i.e. on the basis of 30 O + 6 OH: NaCa₂(Mg,Fe)_{0.5}□_{2.5}Al₆^{VI}[Si₆Al₆^{IV}]O₃₀(OH)₆) could represent a true end-member which would be (2 + 1/6)-octahedral (on the standard basis of 10 O + 2 OH). The simple ratio 1:2 of Na to Ca may well be related to ordering in the interlayer sites. Significant support for the stability of this composition is provided by some experimental data (Tlili 1990, Fig. 51; Tlili et al. 1990) that showed that, at 2 kbar and 600 °C, the only Na-(Mg,Fe)-margarite compositions surviving dehydration are those very close to the above-mentioned trend from Marg_{2/3} Mica L_{1/3} towards paragonite.

The Na-(Mg,Fe)-margarite has also been studied by Raman spectrometry for the Liset (Tlili et al. 1989) and La Compointrie (unpublished data) samples. Pure synthetic powders with X_{MicaL} ranging from 0.0 to 0.4 were investigated by Tlili (1990). The spectra from the natural samples are mostly compatible in wavenumber positions within $\pm 2 \text{ cm}^{-1}$ with those of the synthetic micas having $0.2 \leq X_{\text{MicaL}} \leq 0.4$, except for a few weak bands.

Petrogenesis

Classical geothermobarometry cannot be performed on preiswerkite or Na-(Mg,Fe)-margarite, as the thermodynamic properties of these micas are unknown. However, some qualitative considerations may be deduced from the studied eclogites. The mica-forming reaction is clearly a hydration reaction (Table 3). Because of the high entropy of H₂O, it is therefore favoured by a drop of T . Moreover, several lines of evidence also clearly indicate that the appearance of preiswerkite and Na-(Mg,Fe)-margarite is favoured by a drop in P during retrogression:

1. These micas occur together with minerals that are unstable in eclogite-facies conditions, notably plagioclase;

2. The reaction results in a volume increase (Table 3);

3. There is conversion of some Al^{VI} into Al^{IV}: the Al^{VI}/(Al^{IV} + Al^{VI}) ratio evolves from 0.988 to 0.452 for the reaction in Table 3; Al cations have too large a volume to be stable in tetrahedral sites in silicates at high P where only minerals with a high Al^{VI}/(Al^{IV} + Al^{VI}) exist (e.g. jadeite, garnet, kyanite); when P drops, Al^{IV} reappears with minerals having a low Al^{VI}/(Al^{IV} + Al^{VI}) ratio (e.g. plagioclase, margarite, preiswerkite, Tschermakitic substitution in amphibole).

At La Compointrie and Liset, preiswerkite and Na-(Mg,Fe)-margarite appear during the retrogression of eclogites. Amongst the petrographical differences between the two localities, the most significant is that the pseudomorphing of kyanite by corundum + plagioclase symplectite occurred before the growth of the various micas at Liset, whereas the opposite situation occurred at La Compointrie. This may be explained by different relative positions of the respective P - T paths and mica dehydration curves, the latter being mainly controlled by water activities.

Preiswerkite was synthesised by Franz and Althaus (1976), who called it “sodium-brittle mica”, by Liu (1989) and by Tlili (1990). Other sodic trioctahedral micas that are more-or-less close to the Na-phlogopite–preiswerkite solid solution were also synthesized by Carman (1974), Franz and Althaus (1976), Hewitt and Wones (1975), Koons (1982), Liu (1989) and Tlili (1990). These data indicate a range of P and T for the stability

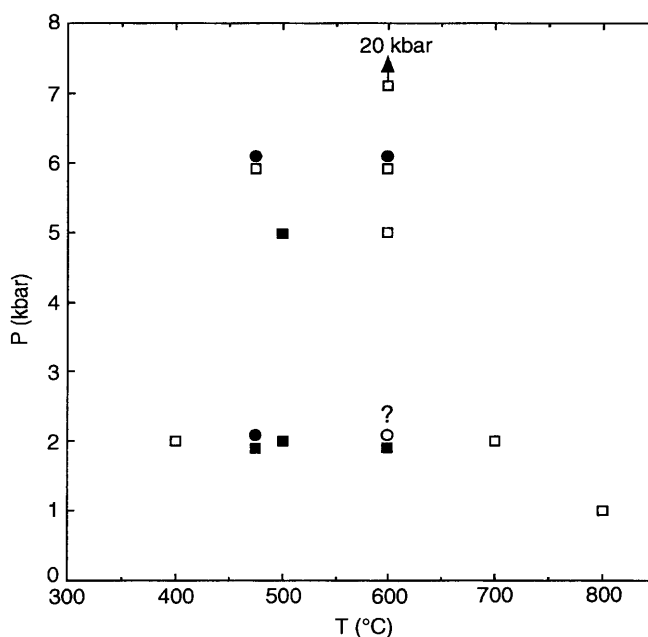


Fig. 5 Experimental data on the P - T stability conditions for preiswerkite and Na-(Mg,Fe)-margarite. [Open symbols mica unstable, solid symbols mica stable; Circles Marg_{2/3} “Mica L”_{1/3} (data from Tlili 1990), squares preiswerkite (data from: Franz and Althaus 1976; Liu 1989; Tlili 1990)]. $P = P_{\text{H}_2\text{O}}$

of preiswerkite, which corresponds roughly to ordinary amphibolite-facies conditions (Fig. 5).

In Nature, preiswerkite appears mainly in former high-*P* rocks but its genesis is favoured by a drop in *P* (Table 1). In experiments, it is stable in amphibolite-facies or greenschist-facies conditions (Fig. 5). All these considerations indicate that preiswerkite's rarity is not related to extreme or unusual *P-T* conditions but to unusual chemical compositions. Preiswerkite is a trioctahedral (K,Na)-mica with the maximum Tschermakitic substitution ($\text{Al}^{\text{VI}}\text{Al}^{\text{IV}}\text{Mg}_{-1}\text{Si}_{-1}$), i.e. it is abnormally Al-rich and Si-poor. Margarite contains even more Al than preiswerkite from which it is derived by the substitution $\text{CaNa}_{-1}\text{Mg}_{-2}\text{Al}^{\text{VI}}$. Instead of the common margarite-paragonite solid solution, the more aluminous solid solution margarite-Mica L is observed. Corundum appeared at the expense of kyanite during retrogression in the eclogites studied and is also symptomatic of high $\mu\text{Al}_2\text{O}_3$ and low μSiO_2 .

These facts indicate that preiswerkite and Na-(Mg,Fe)-margarite appear in H_2O -saturated, abnormally Si poor and Na-Al rich systems, principally, if not only, at greenschist- or amphibolite-facies *P-T* conditions. These chemical and physical conditions are found during retrogression of eclogites because these rocks can contain very aluminous minerals (e.g. kyanite) surrounded by Na-bearing minerals such as jadeitic pyroxene which will consume silica during retrogression (i.e. $\text{jadeite}_{\text{ss}} + \text{SiO}_2 \rightarrow \text{albite}_{\text{ss}}$) and thus maintain a low μSiO_2 .

Conclusions

The studied preiswerkites have compositions close to the theoretical end-member $\text{Na}_2\text{Mg}_4\text{Al}_2^{\text{VI}}[\text{Si}_4\text{Al}_4^{\text{IV}}]\text{O}_{20}(\text{OH})_4$ with the minor substitution $\text{Fe}^{+1}\text{Mg}_{-1}$. They also display slight solid solutions towards phengitic muscovite and Na-phlogopite, but no solid solution towards more aluminous compositions, $\text{Al}^{\text{IV}} \leq 4$ appearing to be a composition limit for (K,Na)-micas.

The studied margarites have an unusual Na-(Mg,Fe)-rich composition. They can be considered as a solid solution of about 2/3 mol% of margarite and 1/3 mol% of the theoretical end-member $\text{Na}_2(\text{Mg,Fe})_1\text{Al}_4^{\text{VI}}[\text{Si}_4\text{Al}_4^{\text{IV}}]\text{O}_{20}(\text{OH})_4$ (Mica L), with a slight substitution towards paragonite. It is suggested that the $\text{Marg}_{2/3}$ Mica $\text{L}_{1/3}$ composition could represent a particularly stable crystallographic configuration. Many "sodian" margarites described in the literature as being solid solutions between margarite, paragonite, and even ephesite, are, in fact, complex solid solutions between margarite, paragonite and $\text{Marg}_{2/3}$ Mica $\text{L}_{1/3}$.

As indicated by experiments and natural occurrences, the stabilities of preiswerkite and Na-(Mg,Fe)-margarite are not restricted to extreme or unusual *P-T* conditions. Rather, the rarity of these micas in Nature seems to be due to unusual chemical compositions; they appear in H_2O -saturated Na-Al-rich Si-poor compositions, prin-

cipally at greenschist- or amphibolite-facies *P-T* conditions. Such conditions are notably realised during retrogression of kyanite-bearing quartz-free high-*P* rocks among the breakdown products of the kyanite.

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