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Conjugate cummingtonite and hornblende at Sgeir nan Sgarbh, South Harris, Outer Hebrides

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SUMMARY. Chemical analyses, cell parameters, and optical data are presented for conjugate cummingtonite and hornblende, which occur in a paragneiss. A metasomatic origin for the development of hornblende from cummingtonite, during retrogressive metamorphism, is proposed.

THE conjugate amphiboles occur in a biotite-hornblende metasediment of the eastern paragneisses of South Harris (Dearnley, 1963) that is contiguous with an actinolite-chlorite schist selvedge of an altered ultrabasic lens, which forms the Sgeir nan Sgarbh promontory (NF 025 950). The rock can be divided into three divisions with the plagioclase compositions being determined by the method of Smith and Gay (1958): (1) 6 mm wide—cummingtonite, biotite, plagioclase An_{35}, and quartz; (2) 3 mm wide—conjugate cummingtonite–hornblende, biotite, plagioclase, and quartz; (3) Remainder—hornblende, biotite, plagioclase An_{42}, and quartz. The third division is mineralogically identical to the general paragneiss type in the Sgeir nan Sgarbh region, and can be traced throughout the Langavat valley.

Basal sections of the conjugate amphiboles may optically simulate a 'twin' with halves of colourless cummingtonite and green hornblende. Prismatic sections display hornblende with patchy relict cummingtonite regions. The conjugate amphiboles are in topotaxial relationships. Slicing the rock through the narrow second zone, and removing the actinolite–chlorite schist, produced material physically free from hornblende but yielded insufficient cummingtonite for chemical analysis by conventional methods. Hornblende from the third zone was separated (containing a trace of cummingtonite) and analysed by gravimetric and colorimetric methods and the results together with an electronprobe microanalysis of the cummingtonite and hornblende are given in Table I.

Both Al_2O_3 and CaO in the cummingtonite fall below Klein's (1968) established maximum limits of 3·2 % Al_2O_3 and 1·9 % CaO. The similarity of the two hornblende analyses suggests that the hornblende in the Sgeir nan Sgarbh paragneisses has developed from cummingtonite. Petrographic evidence of hornblende-tipped cummingtonite in other regions of the eastern metasediments supports this thesis.

Choudhuri (1970) established a systematic distribution of Mg and Fe between coexisting cummingtonite and hornblende in supposed equilibrium, and the Sgeir nan Sgarbh amphibole pair, when plotted according to the method of Choudhuri, are in apparent equilibrium. If the very minor quantity of residual cummingtonite in the hornblende zone is ignored the implication is that chemical equilibrium within the rock was achieved over a very short distance.

TABLE I. *Chemical analysis of hornblende* (A), *electron microprobe analysis of hornblende* (B), *and cummingtonite* (C), *atomic ratios* (A′) *to* 24 (O,OH,F) *and* (B′) (C′) *to* 23 (O), *optical properties, and cell dimensions*

	A	B*	C*		A′		B′		C′	
SiO_2	41·53	42·2	51·2	Si	6·20	8·00	6·43	8·00	7·67	8·00
TiO_2	0·52	0·8	0·1	Al^{iv}	1·80		1·57		0·33	
Al_2O_3	12·73	12·0	2·2	Al^{vi}	0·42		0·58		0·06	
Fe_2O_3	3·73	17·8‡	22·4‡	Ti	0·05		0·09		0·01	
FeO	14·33			Fe^{3+}	0·41		—		—	
MnO	0·22	0·4	1·0	Fe^{2+}	1·78	5·44	2·27	5·36	2·81	7·13
MgO	12·28	10·5	17·7	Mn	0·03		0·04		0·12	
CaO	10·30	10·8	0·9	Mg	2·75		2·38		3·95	
Na_2O	1·84	1·7	0·1	Ca	1·64		1·76		0·14	
K_2O	0·43	0·2	—	Na	0·52	2·23	0·50	2·30	0·04	
H_2O^+	2·09†	—	—	K	0·07		0·04		—	
	100·00	96·4	95·6	OH	2·08		—		—	
Mg	41·8	37·1	57·2	α	1·652 (A′, B′)				1·642	
Fe	33·3	35·4	40·7	β	1·658 (A′, B′)				1·650	
Ca	24·9	27·5	2·1	γ	1·666 (A′, B′)				1·668	
100 Mg/(Mg+Fe)	55·6	51·2	58·4	*a*	9·788±0·006 Å				9·501±0·008 Å	
				b	18·01±0·01 Å				18·01±0·01 Å	
				c	5·303±0·003 Å				5·346±0·006 Å	
				β	104·93°				102·58°	
				V	903·38 Å³				893·09 Å³	

* Average of numerous grains and numerous spot analyses within a single grain

† By difference

‡ Total iron as FeO

Cummingtonite in the Sgeir nan Sgarbh gneisses has conceivably formed from orthopyroxene, as rare relict orthopyroxene and garnet grains occur in heavy mineral separates. A cummingtonite of the same Fe/Mg ratio could have developed from orthopyroxene of about En_{60} as orthopyroxene–cummingtonite reaction relationships are well documented (Deer *et al.*, 1963). Hornblende derivation from cummingtonite is possible if the latter reacted with the anorthite component of the associated plagioclase:

$$\underset{\text{(cummingtonite)}}{3(Mg,Fe)_7Si_8O_{22}(OH)_2} + \underset{\text{(anorthite)}}{14CaAl_2Si_2O_8} + 4H_2O \rightarrow \underset{\text{(hornblende)}}{7Ca_2(Mg,Fe)_3Al_4Si_6O_{22}(OH)_2} + 10SiO_2$$

Examination of the plagioclase compositions from the cummingtonite-only zone and the hornblende-only zone indicates that the hornblende zone plagioclase is more An-rich. This suggests the above reaction has not operated although Na has not been considered despite the hornblende containing 1·8 % Na_2O so that An depletion would admittedly be partly offset by Ab abstraction. Kisch and Warnaars (1969) have demonstrated a relationship between Mg–Fe distribution in coexisting cummingtonite and hornblende and associated plagioclase, and the Sgeir nan Sgarbh conjugate amphiboles plot in the expected oligoclase field.

Alteration of adjacent ultrabasic rocks (originally dunite and harzburgite) to greenschist facies assemblages (actinolite–chlorite) was accomplished mainly by Ca, Al, and Na addition; their mobilization resulting from Late Laxfordian retrogressive basement granitization. Hornblende generation in the Sgeir nan Sgarbh gneisses is therefore attributed to Ca, Al, and Na metasomatism, under epidote amphibolite facies conditions, rather than from a cummingtonite–anorthite component reaction. Finally, it is inferred that cummingtonite in metamorphic terrains is stable between the epidote–amphibole facies and the onset of granulite facies conditions.

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