PLAGIOCLASE-SCAPOLITE EQUILIBRIUM

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ABSTRACT

An electron microprobe study of coexisting plagioclase and scapolite demonstrates that scapolite is generally more calcium-rich than the coexisting plagioclase. However, at high calcium contents the reverse is true. The tendency for the calcium content of scapolite to increase with increasing calcium content of plagioclase is evident. Analysis of random scapolite standards indicate that a high SO_2 and CO_2 potential favours the stability of meionite while a high Cl_2 potential favours the stability of marialite.

INTRODUCTION

In recent studies there is some disagreement over the variations in composition of coexisting plagioclase and scapolite. The purpose of the present study is to clarify the apparent conflict in observed trends. Barth (1952) presents a tentative equilibrium diagram which shows scapolite enriched in calcium with respect to plagioclase by as much as 60 mole per cent and usually richer in calcium by 25 mole per cent meionite. Marakushev (1964) suggests that under equilibrium conditions, in the two phase assemblage plagioclase-scapolite, scapolite is generally more calcic than the associated plagioclase. Shaw (1960) gives data illustrating that scapolite is not always richer in calcium than coexisting plagioclase and that there is no regular relationship between scapolite and plagioclase. Hietanen (1967) reports that the anorthite content of plagioclase which crystallized with scapolite is about 20-25 per cent lower than the meionite content of the scapolite, this difference being smaller toward the calcic end of the series.

With the advent of the electron microprobe, more accurate analysis of coexisting plagioclase and scapolite has become possible. Plagioclase glass standards were provided by D. H. Lindsley and thirteen scapolites were selected as probe standards after undertaking chemical analysis, cell dimension determination, specific gravity and refractive index determinations.

CHOICE AND PREPARATION OF ELECTRON MICROPROBE STANDARDS

Thirty three scapolite-bearing rocks were crushed, sieved and the scapolite separated. Heavy liquid separation was utilized to further purify the scapolite powder (−100+200 fraction). The remaining sample was placed in a covered beaker containing dilute acetic acid for eight hours to remove included calcite. From the thirty-three samples examined, the thirteen purest were used for detailed study. These included ON8, ON6A, Q87, and Q85 which have been studied in detail by Shaw (1960) and later by Papike (1964). Sample GL is described by Shaw *et al.* (1965). Table 1 lists the mineral assemblages and localities associated with these thirteen scapolites.

CHEMICAL AND PHYSICAL PROPERTIES OF SCAPOLITE STANDARDS

Seven of the thirteen scapolite samples used as standards were analyzed by J. Muysson, McMaster University. Sample GL had previously been analyzed by J. Muysson. Analyses by C. O. Ingamells, were available for Q85, Q87A, ON6A, and ON8 (Table 2).

TABLE 1. MINERAL ASSEMBLAGES AND LOCALITIES OF SCAPOLITE STANDARDS

Sample	Mineral assemblage	Comments on powder	Locality
ON8	Scapolite Feldspar Nepheline	Slight fibrous alteration and staining	Glamorgan Twp. Ontario
GL	Scapolite Amphibole Mica Plagioclase	1% feldspar	Pontefract Twp. Quebec
ON6A	Scapolite Pyroxene Sphene		Monmouth Twp. Ontario
ON70	Scapolite		Mpwapwa Tanzania
ON3B	Scapolite Pyroxene	Very slight staining on some grains	Lyndoch Twp. Ontario
Q30	Scapolite Pyroxene		Clarendon Twp. Quebec
CA63A	Scapolite Apatite Fluorite Uranothorite Allanite		Grand Calumet Twp. Quebec

The meionite percentage is given as the following ratio :

$$\frac{Ca + Mg + Fe + Mn + Ti}{Na + K + Ca + Mg + Fe + Mn + Ti}$$

The above relation may be written $\frac{Ca^*}{Ca^* + Na^*}$ where $Ca^* = Ca + Mg + Fe + Mn + Ti$; $Na^* = Na + K$; this function arises from the general formula established by Shaw (1960) : $W_4Z_{12}O_{24}R$ where $W = Ca^* + Na^*$; $Z = Si + Al$; R = volatile components Cl, CO_3, SO_3. Each chemical analysis was converted to gram atom values on the basis of Si + Al = 12,000 (Table 3).

From the study of Tables 2 and 3 it appears that there is no regular relationship between mole per cent meionite and the elements Ti, Fe,

TABLE 1. CONT'D.

Sample	Mineral assemblage	Comments on powder	Locality
Q87	Scapolite Pyroxene Sphene Fluorite Calcite		Huddersfield Twp. Quebec
Q26	Scapolite Quartz Sphene		Clapham Twp. Quebec
Q13A	Scapolite Augite Phlogopite Calcite		Huddersfield Twp. Quebec
ON27	Scapolite Pyroxene Graphite Calcite		Olmsteadville N.Y.
Q85	Scapolite Calcite Amphibole Diopside	1% feldspar slight fibrous alteration	Huddersfield Twp. Quebec
ON47	Single crystal of scapolite with inclusions of pyroxene		Slyudyanka Siberia, U.S.S.R. R.O.M. M18778

Note : All samples except ON70 were provided by D.M. Shaw. (ON70 was a gift of F.W. Solesbury).

TABLE 2. CHEMICAL ANALYSES OF SCAPOLITE STANDARDS

Wt.%	ON8	GL	ON6A	ON70	ON3B	Q30	CA63A	Q87	Q26	Q13A	ON27	Q85	ON47
SiO_2	57.89	55.44	54.73	53.06	52.20	52.50	52.04	52.10	51.67	50.14	48.98	47.17	44.05
TiO_2	0.01	trace	0.01	0.00	0.02	0.00	0.01	0.02	0.00	0.00	0.02	0.03	0.01
Al_2O_3	21.62	22.89	22.85	23.30	23.74	23.45	22.55*	23.79	23.98	24.57	25.51	26.29	28.67
Fe_2O_3***	0.07	0.00	0.08	0.19	0.07	0.10	0.10	0.23	0.16	0.03	0.25	0.15	0.08
MnO	0.01	0.00	0.00	0.02	0.01	0.01	0.01	trace	0.01	0.00	0.00	0.01	0.01
MgO	0.03	0.30	0.03	0.02	0.15	0.34	0.09	0.18	0.02	0.06	0.08	1.00	0.07
CaO	4.81	7.72	8.29	9.88	10.43	10.45	11.05	11.13	11.30	12.56	14.11	14.31	18.65
Na_2O	10.50	9.36	8.55	7.65	7.45	7.27	7.20	6.86	6.30	5.70	4.63	3.82	2.55
K_2O	1.16	0.22	1.08	0.95	0.58	0.86	0.93	0.87	1.07	0.93	1.27	1.01	0.24
P_2O_5	—	0.05	—	0.00	0.03	0.00	0.00	—	0.01	0.01	0.01	—	0.00
H_2O+	0.44	0.22	0.13	0.08	0.22	0.20	0.14	0.07	0.11	0.07	—	0.93	0.26
H_2O-	0.06	0.03	0.00	0.03	0.01	0.09	0.00	0.10	0.03	0.22	—	0.50	0.13
CO_2	1.11	1.85	1.69	2.18	2.53	1.77	—	2.14	2.55	3.04	—	2.66	3.20
SrO	—	—	—	0.07	0.21	0.10	0.32	—	0.20	0.25	0.14	—	0.19
BaO	—	—	—	0.00	0.00	0.00	0.00	—	0.00	0.00	0.00	—	0.00
SO_3	0.03	0.18	0.39	1.10	1.1**	0.88	0.6**	0.80	1.08	1.16	—	1.42	1.63
Cl	2.96	2.30	2.19	1.90	1.5**	2.00	1.6**	1.85	1.75	1.52	—	0.56	0.03
F	0.00	0.00	0.00	0.00	0.00	0.00	0.76	0.11	0.00	0.00	—	0.04	0.00
Sum	100.70	100.37	100.02	100.33	100.25	100.02	97.40	100.25	100.24	100.26	(95.00)	99.90	99.77
Less—O=Cl+F	0.67	0.48	0.49	0.43	0.34	0.45	0.68	0.46	0.39	0.34		0.14	0.01
Total	100.03	99.89	99.53	99.90	99.9	99.57	96.70	99.79	99.85	99.92		99.76	99.76

* It is possible that F interferes.

** Lack of precision according to the analyst.

*** Total Fe as Fe_2O_3.

Table 3. Scapolite Standards: Gram atom values and corresponding mole per cent meionite (Si + Al = 12000)

Sample	ON8	GL	ON6A	ON70	ON3B	Q30	CA63A	Q87	Q26	Q13A	ON27	Q85	ON47
Si	8334	8054	8046	7919	7812	7861	7943	7803	7757	7607	7436	7243	6791
Ti	1	—	1	0.0	2.2	0.0	1.1	2	0.0	0.0	2.2	4	1.1
Al	3666	3946	3954	4081	4188	4139	4057	4197	4243	4393	4564	4757	5209
Fe	8	—	9	21.3	7.8	11.2	11.4	26	18.0	3.4	28.5	18	9.2
Mn	1	—	—	2.5	1.2	1.2	1.2	—	1.2	0.0	0.0	1	1.3
Mg	7	55	7	4.4	33.4	75.8	20.4	41	4.4	13.5	18.1	231	16.0
Ca	744	1234	1309	1579	1672	1677	1807	1786	1818	2042	2295	2362	3080
Na	2934	2639	2435	2213	2162	2111	2131	1995	1834	1677	1363	1137	762
K	214	41	203	180.8	110.7	164.2	181.0	167	205	179.9	246	198	47
P	—	—	—	0	3.8	0	0	—	1.2	1.2	1.2	—	0.0
H	422	214	127	79.6	219.6	199.8	142.5	70	110.1	70.8	—	950	267.3
C	218	371	339	444	516.9	361.8	—	438	522.6	630	—	558	673.5
Sr	—	—	—	6	18.2	8.6	68.7	—	17.4	21.9	12.3	—	16.9
Ba	—	—	—	0	0	0	0	—	0.0	0.0	0.0	—	0.0
S	3	20	43	123.2	123.5	98.8	68.7	90	121.6	132.0	—	163	188.5
Cl	721	589	54	480.5	380.4	507.5	413.9	471	445.2	391.0	—	146	7.8
F	—	—	—	0.0	0.0	0.0	366.8	52	0.0	0.0	—	19	0.0
Na*	3148	2680	2638	2395	2273	2275	2312	2162	2039	1857	1609	1335	809
Ca*	753	1289	1322	1608	1717	1765	1842	1829	1841	2059	2344	2598	3108
AN	942	980	927	1047	1021	968	850	1051	1090	1153	—	886	869.9
W	3901	3969	3960	4003	3990	4040	4153	3991	3880	3915	3953	3933	3918
%Me	19.4	32.5	33.5	40.18	43.04	43.69	44.34	46.2	47.46	52.58	59.30	66.2	79.34

Na* = Na + K; Ca* = Ca + Ti + Mg + Mn; AN = C + F + Cl + S; *W* = Ca* + Na*.

Mn, Mg, P, H, F, K, Ba, Sr. The relationship between components NaO, CaO, Al_2O_3, SiO_2, Cl, SO_3 and CO_2 and mole per cent meionite within the range of composition studied is linear and is represented by the equation wt% component $= \alpha + \beta$ mole % meionite. α and β are listed in Table 4. Those wt% values having analyst's notes (see footnotes in Table 2), indicating lack of precision, have not been considered in the linear regression analysis.

The specific gravity of each sample, determined with a pycnometer, is given in Table 5.

TABLE 4. LINEAR REGRESSION EQUATIONS FOR MOLE % ME *vs* WT% COMPONENT
Wt% component $= \alpha + \beta$ mole % Me

Component	α	β	Correlation Coefficient
SO_3	−0.4335	+0.028	0.926
Cl	3.9839	−0.492	−0.989
CO_2	0.7201	0.0334	0.875
Na_2O	13.3840	−0.1418	−0.992
CaO	0.5249	0.2295	0.999
Al_2O_3	18.8741	0.1139	0.979
SiO_2	62.4769	−0.2311	−0.999

(Evans *et al.* 1969 discuss the stoichiometry of scapolite with respect to these and other samples in detail.)

TABLE 5. SPECIFIC GRAVITY OF SCAPOLITE STANDARDS

Sample	Mole % Me	S.G.*
ON8	19.4	—
GL	32.5	2.626
ON6A	33.5	2.633
ON70	40.18	2.667
ON3B	43.04	2.656
Q30	43.69	2.669
CA63A	44.34	2.629
Q87	46.2	2.681
Q26	47.46	2.674
Q13A	52.58	2.672
ON27	59.30	2.694
Q85	66.2	2.693
ON47	79.34	2.733

* Accuracy is estimated as ± .005.

Cell dimensions calculated, using a least squares computer program, from measurements taken from Debye-Scherrer (114.6 mm. diameter camera) films, and diffractometer traces are given in Table 6. Quartz was used as an internal standard.

Refractive indices (Table 7) were determined using a new set of Cargille index of refraction liquids and sodium light. Under ideal

TABLE 6. CELL DIMENSIONS AND CELL VOLUMES OF SCAPOLITE STANDARDS *

Sample	*a*	*c*	*V*
ON8	12.060 Å	7.577 Å	1102.03 Å
ON6A	12.075	7.580	1105.21
ON70	12.068	7.577	1103.49
ON3B	12.057	7.579	1101.77
Q30	12.090	7.579	1107.81
CA63A	12.087	7.584	1107.99
Q87	12.095	7.579	1108.72
Q26	12.099	7.579	1109.46
Q13A	12.113	7.576	1111.59
ON27	12.135	7.558	1112.98
Q85	12.142	7.756	1116.92
ON47	12.154	7.575	1118.98

*— In all cases accuracy is better than ± .0005.
— Insufficient sample for GL.

TABLE 7. REFRACTIVE INDICES OF SCAPOLITE STANDARDS
Na light; accuracy of refractive indices ± 0.001

Sample	n_ω	n_ε	$n_\omega - n_\varepsilon$	$\frac{n_\omega + n_\varepsilon}{2}$
ON8	1.546	1.542	0.004	1.544
GL	1.562	1.546	0.016	1.554
ON6A	1.561	1.546	0.015	1.5535
ON70	1.566	1.550	0.016	1.558
ON3B	1.564	1.548	0.016	1.556
Q30	1.565	1.548	0.017	1.5565
CA63A	1.559	1.545	0.014	1.552
Q87	1.566	1.550	0.016	1.558
Q26	1.570	1.552	0.018	1.561
Q13A	1.570	1.550	0.020	1.5645
ON27	1.579	1.550	0.029	1.5645
Q85	1.581	1.558	0.023	1.5695
ON47	1.592	1.561	0.031	1.5765

conditions with media available in steps of 0.002 and calibrated to an accuracy of ± 0.0002 an accuracy of ±0.001 is possible. The new determinations are in excellent agreement with those given by Shaw (1960).

ELECTRON MICROPROBE STUDIES

Analyses were made with a MS-64 Acton electron microprobe. Since the linear regresssion line of Ca versus mole per cent meionite had a correlation coefficient of 0.999; $CaK\alpha_1$ intensities were used to determine the mole percentages of meionite in scapolite. All analyses were performed with an accelerating voltage of 26kv and a beam current of 100 na $CaK\alpha_1$ was also utilized to determine the composition of plagioclase. All specimens analyzed were polished thin sections.

Localities, descriptions and donors of the plagioclase scapolite rocks are listed in Table 8. The results of the analyses of the plagioclase scapolite rocks are listed in Table 9. Where possible plagioclase and scapolite grains in contact, were analyzed. Plagioclase and scapolite grains were not compared if the minerals appeared in separate gneissic bands.

DISCUSSION OF PLAGIOCLASE SCAPOLITE ANALYSES

The mole per cent meionite is plotted against mole per cent anorthite in Figure 1. Points falling above a 45° line indicate that scapolite is more calcic than coexisting plagioclase. From this graph the following conclusions may be drawn :

1. Scapolite is generally more calcium rich than coexisting plagioclase. The mole per cent meionite may exceed the mole per cent anorthite generally by 20% and by as much as 50%.
2. There is a tendency for the Ca content of plagioclase to increase with increasing Ca content of scapolite.

COMPOSITIONAL REPRESENTATION OF END-MEMBER FORMULAE

Linear regression curves obtained from the scapolite analyses (Table 4) confirm that there is a simple relation among the components of scapolite and the mole per cent meionite. For this particular group of samples end-member formulae may thus be derived. For the purposes of illustration the weight percentages of the components determined by extrapolation at the 0 and 100 mole per cent meionite points have been used to determine the gram atom values for major elements in this group of 13 scapolites. The low correlation coefficient for wt% CO_2 *vs.* mole % Me

TABLE 8. ROCK TYPES AND LOCALITIES OF PLAGIOCLASE SCAPOLITE ROCKS

Sample	Rock Type	Locality
Samples supplied by *D.M. Shaw*		
CA30	Scapolite-Pyroxene Gneiss	Grand Calumet Twp. Quebec
CA40	Garnet-Scapolite-Quartz Gneiss	"
CA63B	Skarn Rock : Scapolite Diopside, Plagioclase	"
CA75	Skarn Rock : Hornblende Plagioclase, Sphene	"
CA76	Hedenbergite-Hornblende Sphene Gneiss	"
68–81–8	Scapolite-Hornblende-Quartz Epidote Gneiss	Chandos Twp. Ontario
69–28–6A	Scapolite Marble	"
69–35–4	Augite-Quartz-Biotite Scapolite-Plagioclase Schist	"
69–35–5	Quartz-Plagioclase-Scapolite-Pyroxene Granulite	"
70–146–5	Hornblende-Biotite Schist	"
70–148–3	Hornblende-Plagioclase-Scapolite Gneiss	"
72–198–2	Quartz-Scapolite-Hornblende-Pyroxene-Microcline-Plagioclase Granulite	"
72-202-5	Augite-Scapolite-Garnet Skarn Rock	"
73–110–2	Biotite-Hornblende-Pyroxene Scapolite-Plagioclase Granulite	"
Samples supplied by *I. Mason*		
3	Anorthosite : Plagioclase Diopside Hornblende Scapolite	Anorthosite in McKenzie, Hagerman, Buree and Ferguson Twp. Ontario
8		
10		
14		
16		
27		

Table 8. Cont'd.

Sample	Rock Type	Locality
111	Scapolite-Garnet-Plagioclase Gneiss	"
205	Anorthosite: Plagioclase Diopside Hornblende Scapolite	"
209		
226		
353		
355		
356		
357		
381		
Samples supplied by *E. Speelman*		
S–44	Anorthosite: Plagioclase Hornblende Biotite Scapolite (Diopside)	Minden Twp. Ontario
S–48		
S–49		
S–51		
S–53		
S–54		
S–105	Microcline-Biotite-Quartz Gneiss	Chandos Twp. Ontario
S–162	Plagioclase-Quartz-Biotite Hornblende Gneiss	Wollaston Twp. Ontario
S–164	Diopside-Plagioclase-Scapolite Gneiss	
S–165	Plagioclase-Quartz-Biotite Hornblende Gneiss	
Samples supplied by *R. Bradshaw*		
193	Scapolite-Biotite-Hornblende Gneiss	Near the village Sørfinnset County Gildeskool Norway
194	Scapolite-Biotite-Hornblende-Plagioclase Gneiss	
230	Quartz-Biotite-Plagioclase-Scapolite-Hornblende Gneiss	
256	Quartz-Biotite-Hornblende Garnet Gneiss	

Table 9. Microprobe Analyses for Calcium of Coexisting Scapolite and Plagioclase

Sample	Mean S = mole % Meionite P = mole % Anorthite		Number of Scapolite-Plagioclase Pairs	Standard Deviation	*K'* *
Samples supplied by *D.M. Shaw*					
CA30	(S)	62.3	3	2.7	1.30
	(P)	56.1		2.8	
CA40	(S)	67.10	4	1.36	4.81
	(P)	29.78		2.43	
CA63B	(S)	34.40	2	3.11	2.29
	(P)	18.65		3.89	
CA75	(S)	54.9	10	6.6	1.32
	(P)	48.0		6.2	
CA76	(S)	59.2	7	5.3	2.30
	(P)	38.7		1.8	
68–81–8	(S)	68.3	10	11.3	3.10
	(P)	41.0		4.3	
69–28–6A	(S)	57.9	10	1.9	2.62
	(P)	34.4		1.3	
69–35–4	(S)	64.9	6	3.6	2.08
	(P)	47.1		2.4	
69–35–5	(S)	63.3	7	8.9	0.93
	(P)	64.9		3.8	
70–146–5	(S)	41.7	3	1.7	1.62
	(P)	30.7		0.3	
70–148–3	(S)	59.6	4	1.0	1.80
	(P)	45.0		1.6	
72–198–2	(S)	63.1	9	4.9	3.37
	(P)	33.6		1.9	
72–202–5	(S)	73.0	4	3.9	4.90
	(P)	35.5		1.1	
73-110-2	(S)	83.5	10	2.9	11.28
	(P)	31.0		4.3	

* See page 867.

TABLE 9. CONT'D.

Sample	Mean S = mole % Meionite P = mole % Anorthite		Number of Scapolite-Plagioclase Pairs	Standard Deviation	K' *
Samples supplied by *I. Mason*					
3	(S)	82.7	4	4.4	2.46
	(P)	66.1		1.9	
8	(S)	83.2	4	4.3	3.44
	(P)	59.1		4.9	
10	(S)	73.5	4	9.2	1.82
	(P)	60.4		1.3	
14	(S)	70.7	10	3.8	1.28
	(P)	65.3		2.04	
16	(S)	73.4	9	5.3	1.76
	(P)	61.1		2.8	
27	(S)	79.69	9	4.0	2.54
	(P)	60.8		4.9	
111	(S)	76.2	9	4.2	3.48
	(P)	47.9		6.4	
205	(S)	78.5	10	5.1	3.47
	(P)	51.2		4.2	
209	(S)	72.1	10	14.0	1.42
	(P)	64.5		3.9	
226	(S)	77.3	10	4.9	3.44
	(P)	49.7		2.7	
353	(S)	75.8	10	7.7	2.54
	(P)	55.2		3.0	
355	(S)	75.2	10	4.6	1.49
	(P)	67.0		3.8	
356	(S)	78.3	10	8.2	2.96
	(P)	54.9		3.4	
357	(S)	80.6	10	3.3	0.83
	(P)	83.4		4.5	
381	(S)	75.2	10	3.8	2.91
	(P)	51.0		6.6	

TABLE 9. CONT'D.

Sample	Mean S = mole % Meionite P = mole % Anorthite		Number of Scapolite-Plagioclase Pairs	Standard Deviation	*K'* *
Samples supplied by *R. Bradshaw*					
193	(S)	76.0	10	3.2	1.65
	(P)	65.7		2.2	
194	(S)	80.0	10	7.1	2.73
	(P)	59.4		8.5	
230	(S)	78.8	6	4.7	5.75
	(P)	39.3		0.9	
256	(S)	65.1	2	1.6	0.95
	(P)	66.2		2.6	
Samples supplied by *E.L. Speelman*					
S44	(S)	69.8	10	1.8	1.98
	(P)	53.9		2.9	
S48	(S)	75.6	10	4.01	1.64
	(P)	65.4		3.9	
S49	(S)	71.8	10	1.4	2.28
	(P)	52.7		4.5	
S51	(S)	72.9	9	3.8	0.39
	(P)	87.3		3.2	
S53	(S)	65.3	10	2.3	1.52
	(P)	55.4		2.8	
S54	(S)	70.2	10	4.3	2.86
	(P)	45.2		2.7	
S105	(S)	61.6	5	3.2	1.33
	(P)	54.7		2.9	
S162	(S)	54.8	10	1.8	1.66
	(P)	52.3		2.1	
S164	(S)	72.0	10	3.8	2.69
	(P)	48.9		2.2	
S165	(S)	73.6	10	6.7	2.60
	(P)	51.8		3.7	

allows this component to be treated in a qualitative manner only. As previously mentioned the stoichiometry of scapolite is discussed in more detail in the light of new analyses, (see Evans *et al.* 1969).

The compositional variation in the samples studied may be represented in the form $Ca_xNa_yAl_pSi_qO_{24}(CO_3)_r\ (SO_3)_s\ (Cl)_t$ where x and y define the mole per cent meionite as $\frac{100x}{x+y}$ and p, q, r, s, and t are functions of x and y; $p = 3 + \frac{3x}{x+y}$, $q = 9 - \frac{3x}{x+y}$, $r = f(x,y)$ increasing as $\frac{x}{x+y}$ approaches 1; $s = -0.05444 + 0.3544\ \frac{x}{x+y}$, $t = 1 - 1.2358\ \frac{x}{x+y}$

The appearance of negative values for SO_3 and Cl suggest that scapolite may become unstable at the 0 wt% component value or that anion substitution may be complete at these values of mole % meionite, (Evans *et al.*). Substituting $x = 4$, $y = 0$ in the above equations the formula for meionite is $Ca_4Al_6Si_6O_{24}(CO_3)_{f(x)}\ (SO_3)_{(.3)}$.
If $y = 4$, $x = 0$, the formula for marialite is $Na_4Al_3Si_9O_{24}(CO_3)_{p(x)}(Cl)$ where $p(x)$ indicates that p is a function of x.

The above formulae for meionite and marialite may be used as representational end-members in a scapolite plagioclase reaction.

Within the samples studied the compositional variation of scapolite may be defined by two end members only. The sodic end member is rich in chlorine and the calcic end member is rich in carbonate and sulphite ions; SO_3 indicates an analytical component as opposed to a structural component.

The reaction between plagioclase and scapolite minerals is presented as follows (The formulae for meionite and marialite have been reduced to minimize coefficients):

$$\underset{\text{Ma in Scap.}}{NaAlSi_3O_8 \,.\, 0.33NaCl} + \underset{\text{An in Plag.}}{CaAl_2Si_2O_8} + 0.33nCO_2 + 0.1SO_3 + 0.33Ca^{++} + 0.167nO_2 \rightleftharpoons \underset{\text{Me in Scap.}}{CaAl_2Si_2O_8 \,.\, 0.33Ca(CO_3)_n(SO_3)_{.3}} + \underset{\text{Ab in Plag.}}{NaAlSi_3O_8} + 0.33Na^{+} + 0.167Cl_2$$

n is an undefined function of mole per cent meionite. The equilibrium constant for the above reaction is written :

$$K = \frac{a_{Me}^{Scap} \ .\ a_{Ab}^{Plag}}{a_{Ma}^{Scap} \ .\ a_{An}^{Plag}} \cdot \frac{[f_{Cl_2}]^{.167} \qquad [a_{Na}]^{.33}}{[f_{CO_2}]^{.33n}\ [f_{SO_3}]^{.1}\ [f_{O_2}]^{.167n}\ [a_{Ca}]^{.33}} = K'\ .K''$$

f is defined as fugacity. The term K' may be simplified, assuming that $\overset{B}{aA}$ = activity of A in B, which may be assumed to be equal to mole fraction. From the data available, only the function K' may be evaluated.

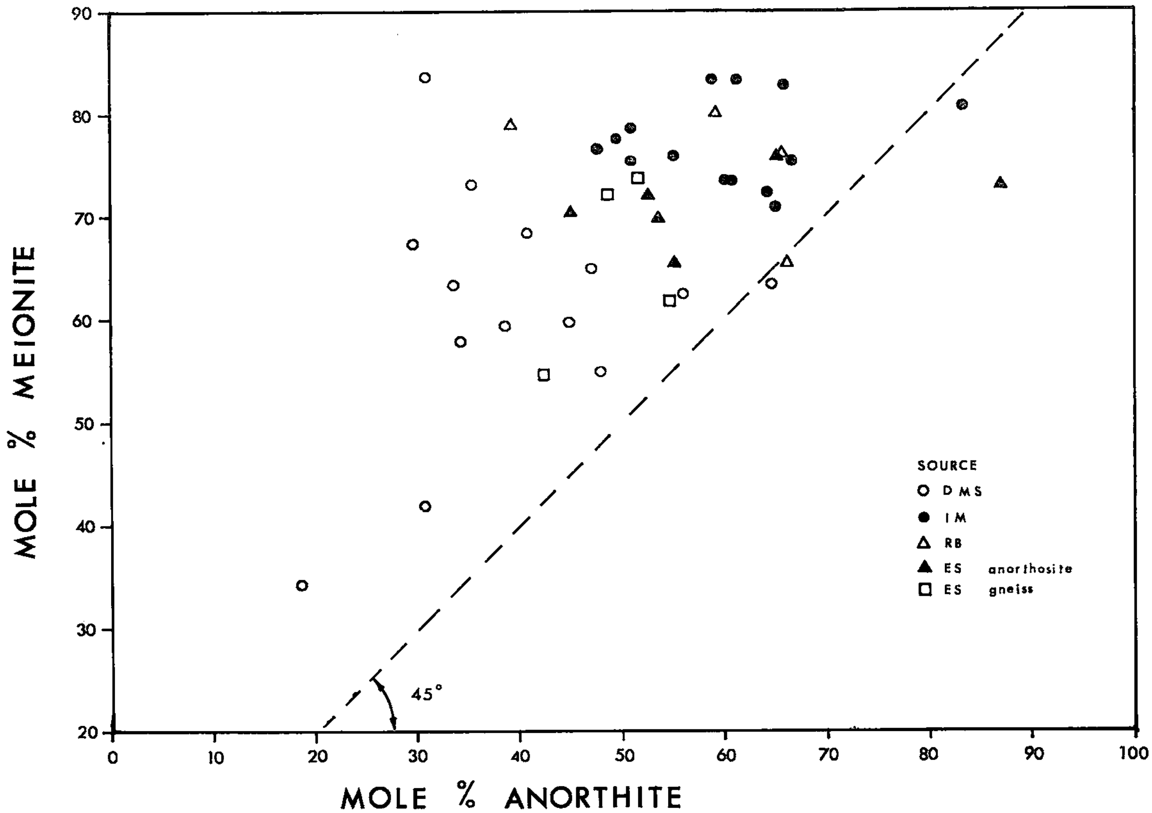

Fig. 1. Mole per cent anorthite versus mole per cent meionite in coexisting plagioclase and scapolite. All samples above the 45° line are richer in mole per cent meionite than mole per cent anorthite.

In Table 9 the range of K' 11.28 to 0.39 indicates that K'' is important in plagioclase-scapolite equilibrium reactions and that non equilibrium associations may be present in some of the samples.

TEMPERATURE EFFECTS

Hietanen (1967) has illustrated that the calcium content of scapolite and plagioclase increases with increasing grade of metamorphism. Figure 1 would suggest that while this may generally be true, at higher temperatures such as those of the granulite facies, the Ca content of scapolite with respect to that of plagioclase may decrease or maintain a relatively constant value.

CONCLUSIONS

Scapolite-plagioclase assemblages of low calcium content are typified by scapolite which is more calcium rich than the coexisting plagioclase. When the calcium content of these minerals is high, however, scapolite may be more sodic than the coexisting plagioclase. Those assemblages having a calcium rich scapolite are thought to be indicative of high metamorphic grade.

Upon consideration of a possible reaction between scapolite and plagioclase it is concluded that $f_{CO_2}\, f_{Cl_2}$, and f_{SO_3} are important factors in the distribution of Ca between plagioclase and scapolite. Furthermore, analysis of the scapolite standards indicates that a high SO_2 and CO_2 potential favours the stability of the Ca rich end member, while a high Cl_2 potential favours the stability of the sodium rich end member.

ACKNOWLEDGMENTS

The receipt of standards and samples from D. M. Shaw, I. Mason, R. Bradshaw, E. Speelman, F. W. Solesbury and D. Lindsley is appreciated.

Thanks go to J. Muysson for chemical analyses, and to D. M. Shaw, and H. P. Schwarcz for their assistance in the preparation of the author's MSc thesis (Haughton 1967) from which this paper was developed. The constructive criticism of L. G. Berry is also appreciated.

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Manuscript received February 1970, emended June 1970.