

Minerals of the heulandite series in Norway - a progress report

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Introduction

The zeolite nomenclature report of the International Mineralogical Association (IMA), Commission on New Mineral and Mineral Names, distinguished between four species in the heulandite series: heulandite-Ca, heulandite-Sr, heulandite-K and heulandite-Na, with calcium, strontium, potassium or sodium, respectively, as the dominating extra-framework cation (COOMBS et al. 1997). Investigations abroad have also revealed a distinct barium content in some heulandites, up to 6.9 weight % BaO (Miller & Ghent 1973).

During investigation of heulandites in the Kongsberg silver deposits, high contents of the extra-framework cations barium and strontium were found in the minerals. This discovery prompted an investigation on heulandites from selected Norwegian localities in order to establish the correct mineral names according to the new IMA nomenclature. The analyses of 24 heulandites from 22 occurrences in this report (Fig. 1) were carried out by electron microprobe at the Institute for Geology, University of Oslo.

Analysing conditions

The chemical analyses were performed on a CAMECA SX-100 electron microprobe using an operating voltage of 15 kV, a beam current of 5 nA, and a beam spot of 20 μm . The instrument was operating in wave-length dispersive mode. The following standards were used: Wollastonite ($\text{SiK}\alpha$, $\text{CaK}\alpha$), MgO ($\text{MgK}\alpha$), Fe_2O_3 ($\text{FeK}\alpha$), Sr-silicate glass ($\text{SrL}\alpha$), BaSO_4 ($\text{BaL}\alpha$), albite ($\text{NaK}\alpha$) and orthoclase ($\text{KK}\alpha$). Back-scattered electron imaging was used to investigate the compositional zonation of the crystals.

Results

Tables 1-17 give the chemical composition (in weight %), structural formula based on 72 O (anhydrous), and mol-% of heulandite-Ca (heu-Ca), heulandite-Sr (heu-Sr), heulandite-Ba (heu-Ba), heulandite-Na (heu-Na), and heulandite-K (heu-K). Each analysis is denoted by two letters which assign the locality, a number which denotes the mineral fragment (crystal), and a capital letter which denotes the analytical spot within the fragment.

Most heulandite crystals are zoned, often showing large chemical differences within the same crystal. In some cases more than one species are present within the same crystal.

From the Kongsberg area, Fiskeløs prospect contained a barian heulandite-Ca with a distinct potassium content, Ringnesgangen mine a barian-sodian heulandite-Ca, and Anne Sophie mine a potassian heulandite-Ca with a distinct strontium content (Tables 1 & 2).

Investigated samples from the central Oslo region include heulandite from Watersborg in Holmestrand, Lauvtjenn in Nedre Eiker, Hørtekollen in Lier and Bjørndalen in Nittedal. Strontian heulandite-Ca with a certain content of sodium and potassium was found in the sample from Holmestrand. Two analyses show an equal atomic proportion of Ca and Sr. The sample from Lauvtjenn was a potassian heulandite-Ca, Hørtekollen was a barian heulandite-Ca, while Bjørndalen was a strontian heulandite-Ca with a distinct potassium content (Tables 3 & 4).

From the syenite pegmatites in the larvikite area of the southern Oslo region, heulandite from Røyås and Bjørndalen quarries in Tvedalen, Hasle quarry in Tjølling and Buer on Vesterøya

were analysed. Potassian heulandite-Ca was found at Buer, sodian heulandite-Ca at Bjørndalen and sodian potassian heulandite-Ca at Hasle and Røyås (Tables 5 & 6).

Within the Bamble region, heulandite crystals from two pockets at Valberg quarry, Kragerø, two pockets at Ravneberget quarry, Risør, and two finds from the Arendal area were analysed. In general, the barium content in heulandite from these occurrences was very low, strontium and sodium were low, while calcium and potassium were high. Most analyses showed potassian heulandite-Ca, but from Langsev mine in Arendal about half of the crystal contained calcian heulandite-K, and in both crystals from Valberg, Kragerø, a narrow zone of calcian heulandite-K was present (Tables 7, 8, 9, 11 & 12).

In the Flåt nickel mine at Evje heulandite-Ca with quite low contents of the other extra-framework cations was found (Table 10).

Osterøy og Naustdal in western Norway both had potassian heulandite-Ca with extremely low contents of sodium and barium (Table 13).

Inset in Rennebu, Sør-Trøndelag, had potassian barian heulandite-Ca with an extremely low sodium content (Table 14).

Majavatn in Nordland had strontian heulandite-Ca with a distinct potassium content and very low sodium content. In a narrow zone in the crystal the atomic proportion of strontium was higher than that of calcium (Table 17).

Crystals from two pockets at the Sulitjelma mines were analysed. The zoned crystals contained both strontian heulandite-Ca and calcian heulandite-Sr (Tables 15 & 16).

Conclusion

Most analysed crystals consisted completely of, or were dominated by **heulandite-Ca**, but zones in crystals from Valberg, Kragerø, and Langsev, Arendal, showed calcian **heulandite-K**. Distinct zones in crystals from Sulitjelma and a very narrow zone in a crystal from Majavatn consisted of calcian **heulandite-Sr**. Some heulandite-Ca had distinct contents of strontium, potassium, barium or sodium.

The highest contents (in weight %) of the five cation oxides being: CaO 5.30 (Flåt mine, Evje), SrO 7.70 (Sulitjelma), BaO 7.15 (Fiskeløs prospect, Kongsberg), Na₂O 1.48 (Ringnesgangen mine, Kongsberg), and K₂O 3.84 (Langsev mine, Arendal).

Heulandite from the Fiskeløs prospect, with 7.15 wt.% BaO, has the highest barium content hitherto reported.

Acknowledgement

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References

COOMBS, D. S., ALBERTI, A., ARMBRUSTER, T., ARTIOLI, G., COLELLA, C., GALLI, E., GRICE, J. D., LIEBAU, F., MANDARINO, J. A., MINATO, H., NICKEL, E. H., PASSAGLIA, E., PEACOR, D. R., QUARTIERI, S., RINALDI, R., ROSS, M., SHEPPARD, R. A., TILLMANN, E. & VEZZALINI, G. (1997): Recommended nomenclature for zeolite minerals: Report of the subcommittee on zeolites of the International Mineralogical Association, Commission on New Mineral and Mineral Names. *Canadian Mineralogist* **35**, 1571-1606 (also published 1998: *Mineralogical Magazine* **62**, 533-571).

MILLER, B. E. & GHENT, E. D. (1973): Laumontite and barian-strontian heulandite from the Blairmore Group (Cretaceous), Alberta. *Canadian Mineralogist* **12**, 188-192.

Fig. 1. Heulandite occurrences and donators

<i>Occurrences</i>	<i>Donators of material</i>
Valberg quarry, Kragerø (pocket I)	Norwegian Mining Museum, Kongsberg (BVM)
Valberg quarry, Kragerø (pocket II)	BVM
Ravneberget quarry, Risør (sample RB1)	BVM
Ravneberget quarry, Risør (sample RB2)	Harald Breivik
Unknown mine, Arendal	Agder Naturmuseum, Kr. sand (O. F. Frigstad)
Langsev iron mine, Arendal	Gunnar Helvig Hansen (GHH)
Flåt nickel mine, Evje	Ørnulf Nordli (ØN)
Røyås quarry, Tvedalen, Larvik	Alf Olav Larsen (AOL)
Bjørndalen quarry, Tvedalen, Larvik	AOL
Hasle quarry, Tjølling	AOL
Buer, Vesterøya, road cut	AOL
Watersborg, Holmestrand, road cut	ØN
Lauvtjønn, Nedre Eiker	ØN
Hørtekollen prospect, Lier	ØN
Bjørndalen quarry, Nittedal	BVM
Fiskeløs prospect, Øvre Eiker	BVM
Ringnesgangen mine, Flesberg	BVM
Anne Sophie mine, Flesberg	Harald Kristiansen
Osterøy, road cut	BVM
Naustdal, road cut	ØN
Innset, Rennebu	BVM
Majavatn, road cut	BVM
Unknown mine, Sulitjelma	BVM
Mons Petter mine, Sulitjelma	GHH

Table 1	Anne Sophie mine					Fiskeløs prospect		
	AS1-A	AS1-B	AS2-A	AS3-A	AS4-A	FL1-A	FL1-B	FL1-C
SiO ₂	59,22	55,43	56,62	57,22	56,80	60,10	56,84	55,87
Al ₂ O ₃	15,59	16,18	15,81	15,91	16,18	14,12	15,21	15,01
MgO	0,00	0,01	0,00	0,00	0,00	0,06	0,04	0,05
CaO	4,63	4,44	4,18	4,42	4,03	4,17	3,53	3,64
FeO	0,00	0,03	0,00	0,03	0,00	0,05	0,00	0,00
SrO	4,17	4,91	4,42	4,68	4,73	1,51	1,69	1,65
BaO	1,36	1,13	0,88	1,12	1,37	4,53	7,15	6,64
Na ₂ O	0,21	0,28	0,25	0,24	0,28	0,28	0,28	0,41
K ₂ O	2,74	2,96	3,05	2,86	2,80	0,93	1,56	1,67
Total	87,92	85,37	85,21	86,48	86,19	85,75	86,30	84,94
Si	27,356	26,658	27,040	27,009	26,930	28,231	27,382	27,314
Al	8,488	9,171	8,899	8,851	9,041	7,817	8,636	8,649
Mg	0	0,007	0	0	0	0,042	0,029	0,036
Ca	2,291	2,288	2,139	2,235	2,047	2,099	1,822	1,907
Fe	0	0,012	0	0,012	0	0,020	0	0
Sr	1,117	1,369	1,224	1,281	1,300	0,411	0,472	0,468
Ba	0,246	0,213	,165	0,207	0,255	0,834	1,350	1,272
Na	0,188	0,261	,231	0,220	0,257	0,255	0,262	0,389
K	1,615	1,816	1,858	1,722	1,694	0,557	0,959	1,042
Heu-Ca	42	38	38	39	37	51	37	38
Heu-Sr	20	23	22	23	23	10	10	9
Heu-Ba	5	4	3	4	5	20	27	25
Heu-Na	3	4	4	4	5	6	5	8
Heu-K	30	31	33	30	31	13	20	21

Table 2	Ringnesgangen mine			
	RG1-A	RG1-B	RG1-C	RG1-D
SiO ₂	58,34	56,45	55,83	57,16
Al ₂ O ₃	15,26	16,21	16,11	15,72
MgO	0,00	0,00	0,00	0,00
CaO	4,39	4,40	4,06	4,40
FeO	0,00	0,03	0,00	0,01
SrO	2,31	2,65	2,37	2,52
BaO	3,40	6,44	6,05	3,82
Na ₂ O	1,14	1,13	1,26	1,48
K ₂ O	0,27	0,25	0,26	0,26
Total	85,11	87,56	85,94	85,37
Si	27,578	26,808	26,866	27,185
Al	8,502	9,073	9,137	8,811
Mg	0	0	0	0
Ca	2,223	2,239	2,093	2,242
Fe	0	0,012	0	0,004
Sr	0,633	0,730	0,661	0,695
Ba	0,630	1,198	1,141	0,712
Na	1,045	1,040	1,176	1,365
K	0,163	0,151	0,160	0,158
Heu-Ca	47	42	40	43
Heu-Sr	14	14	13	13
Heu-Ba	13	22	22	14
Heu-Na	22	19	22	26
Heu-K	3	3	3	3

Table 3	Bjørndalen Bruk				Lauvtjern, N. Eiker	
	BB1-A	BB1-B	BB1-C	BB1-D	LT1-A	LT1-B
SiO ₂	56,81	54,37	55,68	61,07	57,96	57,34
Al ₂ O ₃	15,21	16,17	16,08	13,73	15,14	16,65
MgO	0,00	0,00	0,36	1,06	0,00	0,00
CaO	4,69	4,03	3,77	3,87	5,29	4,82
FeO	0,10	0,02	0,00	0,01	0,00	0,01
SrO	4,78	5,07	4,65	2,63	2,00	2,85
BaO	0,48	1,85	3,43	1,30	4,24	4,29
Na ₂ O	0,37	0,59	0,46	0,16	0,08	0,13
K ₂ O	1,91	1,85	1,05	0,32	1,69	2,22
Total	84,35	83,95	85,48	83,83	86,40	88,31
Si	27,241	26,616	26,812	28,452	27,395	26,780
Al	8,596	9,329	9,126	7,539	8,434	9,165
Mg	0	0	0,258	0,736	0	0
Ca	2,409	2,114	1,945	1,932	2,679	2,412
Fe	0,040	0,008	0	0,004	0	0,004
Sr	1,329	1,439	1,298	0,710	0,548	0,772
Ba	0,090	0,355	0,647	0,237	0,785	0,785
Na	0,344	0,560	0,429	0,145	0,073	0,118
K	1,168	1,155	0,645	0,190	1,019	1,323
Heu-Ca	45	38	39	60	52	45
Heu-Sr	25	26	26	22	11	14
Heu-Ba	2	6	13	7	15	15
Heu-Na	6	10	9	5	1	2
Heu-K	22	21	13	6	20	24

Table 4	Hørtekollen		Watersborg, Holmestrand				
	HK1-A	HK1-B	HS1-A	HS1-B	HS1-C	HS1-D	HS1-E
SiO ₂	59,39	56,66	56,49	55,25	55,65	55,95	55,55
Al ₂ O ₃	14,00	14,54	15,60	16,72	16,65	17,20	16,38
MgO	1,18	0,91	0,00	0,02	0,00	0,00	0,00
CaO	3,98	4,49	3,91	3,35	2,98	3,18	3,73
FeO	0,12	0,00	0,04	0,00	0,00	0,00	0,00
SrO	1,02	1,33	4,27	5,07	5,45	5,77	4,44
BaO	4,36	5,11	1,82	2,16	3,56	3,45	2,86
Na ₂ O	0,22	0,23	1,21	1,30	1,17	1,25	1,04
K ₂ O	0,20	0,36	1,90	1,67	1,63	1,58	1,84
Total	84,47	83,63	85,24	85,54	87,09	88,38	85,84
Si	28,078	27,4877	27,051	26,557	26,596	26,393	26,676
Al	7,801	8,313	8,804	9,472	9,378	9,563	9,271
Mg	0,832	0,658	0	0,014	0	0	0
Ca	2,016	2,334	2,006	1,725	1,526	1,607	1,919
Fe	0,047	0	0,016	0	0	0	0
Sr	0,280	0,374	1,186	1,413	1,510	1,578	1,236
Ba	0,808	0,971	0,342	0,407	0,667	0,638	0,538
Na	0,202	0,216	1,123	1,212	1,084	1,143	0,968
K	0,121	0,223	1,161	1,024	0,994	0,951	1,127
Heu-Ca	59	57	34	30	26	27	33
Heu-Sr	8	9	20	24	26	27	21
Heu-Ba	24	24	6	7	12	11	9
Heu-Na	6	5	19	21	19	19	17
Heu-K	4	5	20	18	17	16	19

Table 5	Røyås, Tvedalen				Hasle, Tjølling		Bjørndalen, Tvedalen	
	RS1-A	RS1-B	RS2-A	RS3-A	HA1-A	HA2-A	BJ1-A	BJ2-A
SiO ₂	62,84	62,83	62,4	64,14	61,41	61,62	62,68	63,03
Al ₂ O ₃	15,11	15,3	15,57	14,86	15,33	14,93	14,45	14,52
MgO	0,41	0,46	0,41	0,45	0,98	0,97	0,09	0,03
CaO	4,86	4,90	4,80	4,75	4,12	3,23	5,21	4,92
FeO	0,18	0,45	0,23	0,38	0,00	0,69	0,05	0,02
SrO	1,54	1,59	1,78	1,31	1,53	1,56	1,80	1,86
BaO	0,00	0,01	0,10	0,00	1,13	1,42	0,00	0,03
Na ₂ O	1,12	0,97	0,96	1,05	1,26	1,09	1,29	1,23
K ₂ O	1,31	1,49	1,41	1,44	1,78	1,51	0,76	1,00
Total	87,37	88,00	87,66	88,38	87,54	87,02	86,33	86,64
Si	28,072	27,953	27,876	28,276	27,724	27,974	28,305	28,367
Al	7,955	8,022	8,198	7,721	8,157	7,988	7,690	7,702
Mg	0,273	0,305	0,273	0,296	0,660	0,656	0,061	0,020
Ca	2,326	2,336	2,297	2,244	1,993	1,571	2,521	2,372
Fe	0,067	0,167	0,086	0,140	0	0,262	0,019	0,008
Sr	0,399	0,410	0,461	0,335	0,401	0,411	0,471	0,485
Ba	0	0,002	0,018	0	0,200	0,253	0	0,005
Na	0,970	0,837	0,831	0,897	1,103	0,959	1,129	1,073
K	0,747	0,846	0,804	0,810	1,025	0,875	0,438	0,574
Heu-Ca	52	53	52	52	42	39	55	53
Heu-Sr	9	10	10	8	8	10	10	11
Heu-Ba	0	<1	<1	0	4	6	0	<1
Heu-Na	22	19	19	21	23	24	25	24
Heu-K	17	19	18	19	22	22	10	13

Table 6	Buer, Vesterøya			
	BU1-A	BU1-B	BU1-C	BU1-D
SiO ₂	60,33	62,10	64,24	58,34
Al ₂ O ₃	14,76	14,19	13,03	14,47
MgO	0,97	1,10	0,81	1,00
CaO	4,33	3,94	3,07	3,93
FeO	0,29	0,71	3,15	0,19
SrO	1,56	1,32	0,84	1,80
BaO	0,75	0,80	0,34	0,98
Na ₂ O	0,31	0,28	0,45	0,39
K ₂ O	1,80	2,04	1,99	1,96
Total	85,10	86,48	87,02	83,06
Si	27,893	28,229	28,733	27,785
Al	8,043	7,602	6,869	8,122
Mg	0,669	0,745	0,540	0,710
Ca	2,145	1,919	1,471	2,005
Fe	0,112	0,270	1,178	0,076
Sr	0,418	0,348	0,218	0,497
Ba	0,136	0,143	0,060	0,183
Na	0,278	0,247	0,390	0,360
K	1,062	1,183	1,136	1,191
Heu-Ca	53	50	45	47
Heu-Sr	10	9	7	12
Heu-Ba	3	4	2	4
Heu-Na	7	6	12	8
Heu-K	26	31	35	28

Table 7	Valberg quarry, Kragerø							
	VB1-A	VB2-A	VB2-B	VB2-C	VB2-D	VB3-A	VB3-B	VB3-C
SiO ₂	62,48	64,29	64,26	63,69	63,85	62,97	59,85	60,37
Al ₂ O ₃	14,78	15,16	15,55	15,36	15,16	14,72	16,45	16,18
MgO	0,43	0,29	0,30	0,26	0,27	0,27	0,33	0,15
CaO	3,70	2,67	3,82	3,65	4,10	3,76	3,69	4,36
FeO	0,00	0,00	0,00	0,00	0,07	0,00	0,06	0,02
SrO	1,13	1,27	1,44	1,67	1,10	1,09	2,59	2,97
BaO	0,22	0,09	0,23	0,27	0,59	0,20	0,79	0,18
Na ₂ O	1,13	1,09	1,21	1,08	1,05	1,21	1,15	2,11
K ₂ O	2,55	2,76	2,97	2,84	2,84	2,97	3,02	2,40
Total	86,42	87,62	89,78	88,82	89,03	87,19	87,93	88,74
Si	28,265	28,527	28,119	28,175	28,195	28,306	27,251	27,230
Al	7,880	7,928	8,019	8,008	7,890	7,798	8,828	8,601
Mg	0,290	0,192	0,196	0,172	0,178	0,181	0,224	0,101
Ca	1,793	1,269	1,791	1,730	1,940	1,811	1,800	2,107
Fe	0	0	0	0	0,026	0	0,023	0,008
Sr	0,296	0,327	0,365	0,428	0,282	0,284	0,684	0,777
Ba	0,039	0,016	0,039	0,047	0,102	0,035	0,141	0,032
Na	0,991	0,938	1,027	0,926	0,899	1,055	1,015	1,845
K	1,471	1,562	1,658	1,603	1,600	1,703	1,754	1,381
Heu-Ca	39	31	37	37	40	37	33	34
Heu-Sr	6	8	7	9	6	6	13	13
Heu-Ba	1	<1	1	1	2	1	3	<1
Heu-Na	22	23	21	20	19	22	19	30
Heu-K	32	38	34	34	33	35	33	22

Table 8	Valberg quarry, Kragerø							
	VB4-A	VB4-B	VB4-C	VB4-D	VB5-A	VB5-B	VB5-C	VB5-D
SiO ₂	60,57	60,89	60,96	62,20	61,11	59,58	58,44	58,39
Al ₂ O ₃	14,96	14,97	15,36	15,21	14,93	15,54	15,95	16,00
MgO	0,16	0,20	0,09	0,20	0,14	0,25	0,06	0,00
CaO	4,04	4,27	4,60	4,80	4,52	5,41	4,74	4,75
FeO	0,00	0,07	0,07	0,02	0,00	0,09	0,00	0,00
SrO	1,95	2,01	2,05	1,33	2,12	1,89	2,95	3,29
BaO	0,39	0,37	0,17	0,11	0,05	0,18	0,64	0,25
Na ₂ O	0,50	0,50	0,55	0,49	0,49	0,40	0,58	0,65
K ₂ O	3,77	3,59	3,28	3,40	3,43	2,87	3,41	3,44
Total	86,34	86,87	87,13	87,76	86,79	86,21	86,77	86,77
Si	27,867	27,843	27,750	27,877	27,898	27,409	27,146	27,126
Al	8,112	8,068	8,241	8,034	8,033	8,426	8,732	8,760
Mg	0,182	0,226	0,101	0,332	0,158	0,284	0,069	0
Ca	1,992	2,092	2,244	2,304	2,211	2,667	2,359	2,364
Fe	0	0,027	0,027	0,007	0	0,035	0	0
Sr	0,520	0,533	0,541	0,346	0,561	0,504	0,795	0,886
Ba	0,070	0,066	0,030	0,019	0,009	0,032	0,116	0,046
Na	0,446	0,443	0,485	0,426	0,434	0,357	0,522	0,585
K	2,213	2,094	1,905	1,944	1,998	1,684	2,021	2,039
Heu-Ca	38	40	43	46	42	51	41	40
Heu-Sr	10	10	10	7	11	10	14	15
Heu-Ba	1	1	<1	<1	<1	<1	2	<1
Heu-Na	9	8	9	8	8	7	9	10
Heu-K	42	40	37	39	38	32	35	34

Table 9	Ravneberget quarry, Søndeled						
	RB1-A	RB1-B	RB1-C	RB2-A	RB2-B	RB2-C	RB2-D
SiO ₂	59,39	57,74	56,13	60,29	58,11	55,60	58,25
Al ₂ O ₃	15,27	16,24	16,71	16,45	15,98	15,27	15,98
MgO	0,04	0,00	0,00	0,00	0,00	0,01	0,01
CaO	5,57	6,03	5,89	5,57	5,76	5,90	5,71
FeO	0,02	0,00	0,00	0,00	0,00	0,00	0,00
SrO	1,21	1,88	1,83	2,04	1,71	1,59	1,43
BaO	0,04	0,04	0,00	0,00	0,05	0,26	0,29
Na ₂ O	1,78	1,98	1,98	1,11	1,19	0,92	1,02
K ₂ O	1,06	0,72	0,76	2,36	2,24	2,06	2,23
Total	84,38	84,63	83,30	87,82	85,04	81,61	84,92
Si	27,599	26,972	26,662	27,234	27,127	27,092	27,192
Al	8,363	8,941	9,355	8,758	8,792	8,769	8,792
Mg	0,028	0	0	0	0	0,007	0,007
Ca	2,773	3,018	2,998	2,696	2,881	3,080	2,856
Fe	0,008	0	0	0	0	0	0
Sr	0,326	0,509	0,504	0,534	0,463	0,449	0,387
Ba	0,007	0,007	0	0	0,009	0,050	0,053
Na	1,604	1,793	1,824	0,972	1,077	0,869	0,923
K	0,628	0,429	0,461	1,360	1,334	1,281	1,328
Heu-Ca	52	52	52	48	50	54	51
Heu-Sr	6	9	9	10	8	8	7
Heu-Ba	<1	<1	0	0	<1	1	1
Heu-Na	30	31	32	17	19	15	17
Heu-K	12	7	8	24	23	22	24

Table 10	Flåt mine, Evje			
	FT1-A	FT1-B	FT1-C	FT1-D
SiO ₂	55,46	55,51	57,43	56,87
Al ₂ O ₃	16,67	16,48	15,43	16,07
MgO	0,00	0,02	0,09	0,13
CaO	5,30	4,33	4,65	4,68
FeO	0,00	0,00	0,05	0,08
SrO	4,79	2,53	2,97	2,79
BaO	0,48	6,43	3,64	3,94
Na ₂ O	0,97	0,64	0,42	0,43
K ₂ O	1,37	1,15	0,98	1,09
Total	85,04	87,09	85,66	86,08
Si	26,471	26,616	27,298	26,992
Al	9,377	9,313	8,644	8,989
Mg	0	0,014	0,064	0,092
Ca	2,710	2,224	2,368	2,380
Fe	0	0	0,020	0,032
Sr	1,326	0,703	0,819	0,768
Ba	0,090	1,208	0,678	0,733
Na	0,898	0,595	0,387	0,396
K	0,834	0,703	0,594	0,660
Heu-Ca	46	41	49	48
Heu-Sr	23	13	17	16
Heu-Ba	2	22	14	15
Heu-Na	15	11	8	8
Heu-K	14	13	12	13

Table 11	Langsev mine, Arendal					
	LS1-A	LS1-B	LS1-C	LS1-D	LS1-E	LS1-F
SiO ₂	57,01	57,30	58,90	59,84	60,48	58,10
Al ₂ O ₃	15,44	15,13	14,54	14,55	14,50	15,31
MgO	0,05	0,00	0,09	0,06	0,00	0,05
CaO	3,89	4,32	4,88	4,23	4,34	4,07
FeO	0,04	0,06	0,00	0,00	0,04	0,00
SrO	3,20	3,21	1,99	2,04	1,84	3,08
BaO	0,91	1,56	0,64	0,64	0,81	0,91
Na ₂ O	0,24	0,24	0,09	0,16	0,15	0,19
K ₂ O	3,84	3,88	3,53	3,70	3,15	3,62
Total	84,62	85,64	84,66	85,22	85,31	85,33
Si	27,276	27,285	27,787	27,982	28,127	27,460
Al	8,706	8,491	8,084	8,019	7,948	8,528
Mg	0,036	0	0,063	0,042	0	0,035
Ca	1,994	2,204	2,467	2,119	2,163	2,061
Fe	0,016	0,024	0	0	0,016	0
Sr	0,888	0,886	0,544	0,553	0,496	0,844
Ba	0,171	0,291	0,118	0,117	0,148	0,169
Na	0,223	0,222	0,082	0,145	0,135	0,174
K	2,344	2,357	2,131	2,207	1,869	2,183
Heu-Ca	35	37	46	41	45	38
Heu-Sr	16	15	10	11	10	16
Heu-Ba	3	5	2	2	3	3
Heu-Na	4	4	2	3	3	3
Heu-K	42	40	40	43	39	40

Table 12	Arendal (unspecified iron mine)						
	AD1-A	AD1-B	AD1-C	AD1-D	AD1-E	AD1-F	AD1-G
SiO ₂	58,90	59,56	59,48	58,76	59,04	62,22	61,00
Al ₂ O ₃	15,31	16,00	15,61	15,90	15,42	15,43	15,06
MgO	0,07	0,02	0,08	0,01	0,01	0,05	0,01
CaO	4,39	4,41	4,53	4,27	4,24	4,54	4,48
FeO	0,00	0,03	0,00	0,05	0,05	0,00	0,00
SrO	3,08	2,85	2,72	2,64	2,69	2,11	2,16
BaO	0,22	0,41	0,57	0,41	0,45	0,37	0,43
Na ₂ O	1,08	1,03	1,12	1,09	1,14	1,07	1,21
K ₂ O	2,74	2,83	2,99	3,14	3,15	3,29	3,14
Total	85,79	87,14	87,10	86,27	86,19	89,08	87,49
Si	27,477	27,349	27,396	27,293	27,462	27,797	27,791
Al	8,418	8,659	8,474	8,704	8,453	8,124	8,086
Mg	0,049	0,014	0,055	0,007	0,007	0,033	0,007
Ca	2,194	2,170	2,235	2,125	2,113	2,173	2,187
Fe	0	0,012	0	0,019	0,019	0	0
Sr	0,833	0,759	0,726	0,711	0,726	0,547	0,571
Ba	0,040	0,073	0,103	0,075	0,082	0,065	0,077
Na	0,977	0,917	1,000	0,982	1,028	0,927	1,067
K	1,631	1,658	1,757	1,861	1,869	1,875	1,825
Heu-Ca	39	39	38	37	36	39	38
Heu-Sr	15	14	12	12	12	10	10
Heu-Ba	<1	1	2	1	1	1	1
Heu-Na	17	16	17	17	18	17	19
Heu-K	29	30	30	32	32	34	32

Table 13	Osterøy			Naustdal		
	OY1-A	OY1-B	OY1-C	ND1-A	ND1-B	ND1-C
SiO ₂	58,9	59,61	59,00	57,59	57,90	59,87
Al ₂ O ₃	15,36	15,89	15,37	15,66	15,70	16,79
MgO	0,37	0,57	0,42	0,00	0,00	0,00
CaO	4,33	5,29	5,02	05,69	5,79	6,28
FeO	0,00	0,11	0,04	0,04	0,00	0,06
SrO	2,98	2,79	2,87	2,38	2,16	2,22
BaO	0,07	0,35	0,00	0,15	0,00	0,23
Na ₂ O	0,29	0,22	0,25	0,28	0,17	0,27
K ₂ O	1,88	1,98	2,06	2,60	2,24	2,14
Total	84,18	86,81	85,03	84,39	3,96	87,86
Si	27,649	27,310	27,508	27,214	27,318	27,076
Al	8,498	8,580	8,446	8,722	8,730	8,949
Mg	0,259	0,389	0,292	0	0	0
Ca	2,178	2,597	2,508	2,881	2,927	3,043
Fe	0	0,042	0,016	0,016	0	0,023
Sr	0,811	0,741	0,776	0,652	0,591	0,582
Ba	0,013	0,063	0	0,028	0	0,040
Na	0,264	0,195	0,226	0,257	0,156	0,237
K	1,126	1,157	1,225	1,567	1,348	1,235
Heu-Ca	50	55	53	54	58	59
Heu-Sr	18	16	16	12	12	11
Heu-Ba	<1	1	0	<1	0	<1
Heu-Na	6	4	5	5	3	5
Heu-K	26	24	26	29	27	24

Table 14	Innset					
	IS1-A	IS1-B	IS1-C	IS1-D	IS1-E	IS1-F
SiO ₂	55,46	57,19	56,92	54,36	56,02	54,60
Al ₂ O ₃	16,18	15,40	14,88	15,54	15,06	15,88
MgO	0,00	0,00	0,04	0,00	0,01	0,00
CaO	3,57	4,29	4,69	3,82	4,69	4,17
FeO	0,00	0,00	0,00	0,00	0,00	0,00
SrO	3,81	2,41	1,57	1,85	1,89	1,91
BaO	4,85	5,19	4,98	7,42	4,49	6,70
Na ₂ O	0,16	0,10	0,11	0,11	0,05	0,08
K ₂ O	2,25	2,08	1,99	2,04	1,61	1,87
Total	86,28	86,66	85,18	85,14	83,82	85,21
Si	26,791	27,259	27,419	26,868	27,320	26,789
Al	9,212	8,651	8,448	9,052	8,656	9,183
Mg	0	0	0,0287	0	0,007	0
Ca	1,848	2,190	2,421	2,023	2,451	2,192
Fe	0	0	0	0	0	0
Sr	1,067	0,666	0,439	0,530	0,534	0,543
Ba	0,918	0,969	0,940	1,437	0,858	1,288
Na	0,151	0,092	0,103	0,105	0,047	0,076
K	1,387	1,265	1,223	1,286	1,002	1,170
Heu-Ca	34	42	47	38	50	42
Heu-Sr	20	13	9	10	11	10
Heu-Ba	17	19	18	27	18	24
Heu-Na	3	2	2	2	1	1
Heu-K	26	24	24	24	20	22

Table 15	Sulitjelma (unspecified mine)								
	SU1-A	SU1-B	SU1-C	SU1-D	SU1-E	SU1-F	SU1-G	SU1-H	SU1-I
SiO ₂	57,01	56,63	56,2	56,73	57,56	56,74	56,58	53,38	54,31
Al ₂ O ₃	15,69	15,81	15,51	15,46	15,24	15,61	15,37	16,11	16,01
MgO	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
CaO	4,54	4,38	3,62	3,43	3,80	3,89	3,47	3,52	3,96
FeO	0,15	0,05	0,00	0,00	0,00	0,00	0,00	0,01	0,05
SrO	5,89	5,07	7,34	7,70	7,51	7,35	7,35	7,22	6,28
BaO	0,42	0,28	2,00	1,35	1,13	0,19	1,75	2,97	2,29
Na ₂ O	0,45	0,38	0,36	0,31	0,30	0,36	0,31	0,62	0,53
K ₂ O	1,01	0,99	0,82	0,77	0,77	0,82	0,70	0,59	0,68
Total	85,16	83,59	85,85	85,75	86,31	84,96	85,53	84,72	84,11
Si	27,110	27,184	27,046	27,1848	27,316	27,153	27,205	26,443	26,656
Al	8,794	8,944	8,797	8,731	8,524	8,804	8,710	9,405	9,261
Mg	0	0	0	0	0	0	0	0	0
Ca	2,313	2,253	1,867	1,761	1,932	1,995	1,788	1,868	2,082
Fe	0,060	0,020	0	0	0	0	0	0,004	0,020
Sr	1,624	1,411	2,048	2,140	2,067	2,040	2,049	2,074	1,787
Ba	0,078	0,053	0,377	0,254	0,211	0,036	0,330	0,577	0,440
Na	0,415	0,354	0,336	0,288	0,277	0,334	0,289	0,595	0,504
K	0,613	0,606	0,503	0,471	0,466	0,501	0,429	0,373	0,426
Heu-Ca	46	48	36	36	39	41	37	34	40
Heu-Sr	32	30	40	44	42	42	42	38	34
Heu-Ba	2	1	7	5	4	1	7	11	8
Heu-Na	8	8	7	6	6	7	6	11	10
Heu-K	12	13	10	10	9	10	9	7	8

Table 16	Mons Petter mine, Sulitjelma					
	MP1-A	MP1-B	MP1-C	MP1-D	MP1-E	MP1-F
SiO ₂	56,44	56,91	55,10	56,33	55,10	56,66
Al ₂ O ₃	15,30	15,14	15,44	15,30	15,59	15,12
MgO	0,00	0,03	0,00	0,00	0,00	0,00
CaO	4,88	5,54	3,83	3,83	3,77	3,89
FeO	0,01	0,06	0,05	0,00	0,00	0,01
SrO	5,80	5,55	7,41	7,17	7,60	6,74
BaO	0,49	0,28	1,07	0,78	2,24	1,75
Na ₂ O	0,30	0,28	0,36	0,37	0,53	0,37
K ₂ O	0,85	0,84	0,80	0,82	0,91	0,77
Total	84,07	84,63	84,06	84,60	85,74	85,31
Si	27,172	27,181	26,948	27,191	26,773	27,257
Al	8,681	8,522	8,900	8,704	8,928	8,572
Mg	0	0,021	0	0	0	0
Ca	2,517	2,835	2,007	1,981	1,963	2,005
Fe	0,004	0,024	0,020	0	0	0,004
Sr	1,619	1,537	2,101	2,007	2,141	1,880
Ba	0,092	0,052	0,205	0,148	0,427	0,330
Na	0,280	0,259	0,341	0,346	0,499	0,345
K	0,522	0,512	0,499	0,505	0,564	0,473
Heu-Ca	50	55	39	40	35	40
Heu-Sr	32	30	41	40	38	37
Heu-Ba	2	1	4	3	8	7
Heu-Na	6	5	7	7	9	7
Heu-K	10	10	10	10	10	10

Table 17	Majavatn					
	MV1-A	MV1-B	MV1-C	MV1-D	MV1-F	MV1-G
SiO ₂	57,40	59,03	56,49	56,88	59,19	58,08
Al ₂ O ₃	16,27	15,27	15,11	15,34	15,80	14,85
MgO	0,06	0,30	0,59	0,71	0,00	0,02
CaO	5,82	5,39	3,14	3,40	5,87	5,60
FeO	0,00	0,04	0,00	0,04	0,00	0,00
SrO	4,90	4,22	5,94	4,37	4,20	3,88
BaO	0,12	0,19	2,33	2,98	0,34	0,34
Na ₂ O	0,14	0,09	0,07	0,06	0,10	0,08
K ₂ O	1,97	1,17	0,59	1,07	1,43	1,36
Total	86,68	85,70	84,26	84,85	86,93	84,21
Si	26,807	27,480	27,345	27,292	27,287	27,553
Al	8,955	8,378	8,620	8,675	8,585	8,303
Mg	0,0418	0,208	0,4267	0,508	0	0,014
Ca	2,912	2,688	1,629	1,748	2,899	2,846
Fe	0	0,016	0	0,016	0	0
Sr	1,327	1,139	1,667	1,216	1,123	1,067
Ba	0,022	0,035	0,442	0,560	0,061	0,063
Na	0,127	0,081	0,066	0,056	0,089	0,074
K	1,174	0,695	0,364	0,655	0,841	0,823
Heu-Ca	52	58	39	41	58	58
Heu-Sr	24	25	40	29	22	22
Heu-Ba	<1	<1	11	13	1	1
Heu-Na	2	2	2	1	2	2
Heu-K	21	15	9	15	17	17