

Minerals of the heulandite- and axinite series in Norway - additional data

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Introduction

Investigations on heulandite series minerals from Norwegian localities with special emphases on the chemical composition were published by Nordrum et al. (2003, 2005a). In addition, chemical data on heulandites from the syenite pegmatites in the Larvik plutonic complex were reported by Larsen (2002). Some of the species in the previous papers showed results that needed further investigations. The present paper reports data on these species. In addition, a few samples from new localities have been analysed.

Investigation on minerals of the axinite series from Norwegian localities was reported by Nordrum et al. (2005b). Samples from two additional occurrences of axinite have now been analysed.

Analysing conditions

The chemical analyses were conducted on a CAMECA SX-100 electron microprobe at the Institute for Geology, University of Oslo, using the same analytical conditions as reported in the heulandite investigation by Nordrum et al. (2003) and the axinite investigation (Nordrum et al. 2005b). Back-scattered electron imaging was used to investigate the compositional zoning of the crystals.

Occurrences and results

Heulandite

Larsen (2002) reported heulandite-K from Buer, Vesterøya, Sandefjord. The same material was analysed by Nordrum et al. (2003), but the investigated samples showed to be potassian heulandite-Ca. No heulandite-K was determined. In order to clarify the ambiguity, several new samples from the locality were analysed (Tables 1 and 2). The results show that the samples from Buer are mainly potassian heulandite-Ca, but with zones of calcian heulandite-K. A sample of heulandite from Kamfjord quarry, Sandefjord showed to be a homogeneous calcian heulandite-K (analyses #1, Table 1). The existence of heulandite-K from the syenite pegmatites in the Larvik plutonic complex is hereby confirmed.

Heulandite from Falkensten, Horten, is a calcian heulandite-K with a rather high content of Sr, Ba and Na.

Heulandite from Ramberg, Kleiverud, Holmestrand, is a heulandite-Ca with a high content of Sr, Ba, Na and K.

Heulandite from Sjøskogen, Holmestrand, is a calcian strontian heulandite-K.

Heulandite from Nautnes, Øygarden, Hordaland, is a calcian heulandite-K with a rather high content of barium, strontium and potassium.

Axinite

The axinites from a mine adit in Barbusalen, Arendal, and Myrdammen, Drammen, both turned out to be manganaxinites. The manganese content in the Barbusalen

axinite is extremely high (90 mol-% manganaxinite), which was also suspected from its yellow colour (like the manganese-rich axinites from Årvoll and Nødebro (Nordrum et al. 2005b)). The manganaxinite from Myrdammen has a rather high content of iron (35 mol-% ferro-axinite).

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Additional analyses of Norwegian heulandites

Table 1	Kamfjord, Sandefj. n = 5	Buer, Vesterøya, Sandefjord					
		Buer1-A	Buer1-B	Buer1-C	Buer1-D	Buer1-E	Buer1-F
SiO ₂	61.92	61.85	61.44	63.22	65.35	63.39	60.72
Al ₂ O ₃	15.63	15.87	14.71	13.85	14.19	15.26	15.31
MgO	0.61	1.03	1.01	1.30	1.02	1.00	1.04
CaO	3.91	4.13	3.72	3.37	3.23	4.15	4.05
FeO	0.45	0.70	0.73	2.40	2.25	0.37	0.87
SrO	1.96	2.09	1.50	0.82	0.93	1.41	1.76
BaO	0.00	1.01	0.64	0.39	0.29	0.70	0.74
Na ₂ O	0.63	0.20	0.00	0.23	0.38	0.28	0.17
K ₂ O	3.51	2.50	2.58	2.34	2.54	2.38	2.44
Total	88.62	89.38	86.33	87.92	90.18	88.94	87.10
Si	27.703	27.540	28.042	28.303	28.466	28.020	27.643
Al	8.241	8.328	7.913	7.308	7.285	7.950	8.214
Mg	0.407	0.684	0.687	0.868	0.662	0.659	0.706
Ca	1.874	1.970	1.819	1.616	1.507	1.965	1.975
Fe	0.168	0.261	0.279	0.899	0.820	0.137	0.331
Sr	0.508	0.540	0.397	0.213	0.235	0.361	0.465
Ba	0.000	0.176	0.114	0.068	0.050	0.121	0.132
Na	0.546	0.173	0.000	0.200	0.321	0.240	0.150
K	2.003	1.420	1.502	1.336	1.411	1.342	1.417
Heu-Ca	38	46	47	41	43	49	48
Heu-Sr	10	13	10	5	7	9	11
Heu-Ba	0	4	3	2	1	3	3
Heu-Na	11	4	0	5	9	6	4
Heu-K	41	33	39	34	40	33	34

Table 2	Buer, Vesterøya, Sandefjord										
	Buer2-A	Buer2-B	Buer2-C	Buer2-D	Buer2-E	Buer2-F	Buer3-A	Buer3-B	Buer3-C	Buer3-D	Buer3-E
SiO ₂	61.78	62.10	63.46	61.29	62.44	63.52	61.82	60.78	60.34	58.13	58.58
Al ₂ O ₃	14.88	15.36	13.28	14.00	13.68	14.05	14.82	14.16	14.39	14.82	14.97
MgO	0.99	1.10	0.93	0.71	0.96	0.98	1.05	1.24	1.36	1.15	1.07
CaO	4.14	4.08	2.77	2.73	3.30	3.25	4.02	3.24	3.72	2.55	3.82
FeO	0.52	0.38	3.57	4.70	3.36	2.58	0.81	2.64	0.98	3.79	0.81
SrO	1.79	1.85	0.98	1.21	1.00	1.04	1.53	0.92	1.35	0.82	1.68
BaO	0.99	0.77	0.49	0.63	0.30	0.54	0.52	0.30	0.73	0.68	1.01
Na ₂ O	0.37	0.37	0.60	0.44	0.36	0.25	0.31	0.40	0.21	0.43	0.27
K ₂ O	2.28	2.14	3.33	3.53	2.96	3.01	1.97	2.83	2.37	3.74	2.34
Total	87.74	88.15	89.41	89.24	88.36	89.22	86.85	86.51	85.45	86.11	84.55
Si	27.897	27.8097	28.351	27.777	28.137	28.239	27.988	27.880	27.896	27.245	27.546
Al	7.919	8.107	6.992	7.478	7.265	7.362	7.907	7.655	7.841	8.186	8.296
Mg	0.666	0.734	0.619	0.480	0.645	0.649	0.709	0.848	0.937	0.804	0.750
Ca	2.003	1.958	1.326	1.326	1.593	1.548	1.950	1.592	1.843	1.281	1.925
Fe	0.196	0.142	1.334	1.781	1.266	0.959	0.307	1.013	0.379	1.486	0.319
Sr	0.469	0.481	0.254	0.318	0.261	0.268	0.402	0.245	0.362	0.223	0.458
Ba	0.175	0.135	0.086	0.112	0.053	0.094	0.092	0.054	0.132	0.125	0.186
Na	0.324	0.321	0.485	0.387	0.315	0.215	0.272	0.356	0.188	0.391	0.246
K	1.313	1.223	1.898	2.041	1.702	1.707	1.138	1.656	1.398	2.236	1.404
Heu-Ca	47	48	33	31	41	40	51	41	47	30	46
Heu-Sr	11	12	6	8	7	7	10	6	9	5	11
Heu-Ba	4	3	12	9	8	6	7	9	5	9	6
Heu-Na	8	8	12	9	8	6	7	9	5	9	6
Heu-K	31	30	47	50	43	45	30	42	36	53	33

Table 3	Falkenstein, Horten							
	Falk1-A	Falk1-B	Falk1-C	Falk1-D	Falk2-A	Falk2-B	Falk2-C	Falk2-D
SiO ₂	59.26	58.39	60.91	60.12	58.05	59.10	59.29	60.00
Al ₂ O ₃	16.45	15.95	15.21	15.27	15.45	15.55	14.95	14.75
MgO	0.18	0.23	0.21	0.34	0.10	0.62	0.23	0.54
CaO	3.12	3.41	2.23	2.94	3.08	2.36	3.31	2.92
FeO	0.06	0.00	0.02	0.08	0.04	0.00	0.00	0.06
SrO	3.45	2.75	2.23	2.52	3.27	1.53	2.67	1.80
BaO	4.15	3.28	2.08	3.48	3.21	1.99	3.46	2.34
Na ₂ O	0.74	0.60	1.15	0.70	0.82	0.94	0.58	0.39
K ₂ O	2.90	2.96	4.60	3.05	3.23	4.57	2.60	3.55
Total	90.31	87.57	88.64	88.50	87.25	86.66	87.09	86.35
Si	27.098	27.242	27.829	27.675	27.335	27.517	27.716	27.932
Al	8.865	8.770	8.190	8.285	8.574	8.533	8.236	8.093
Mg	0.123	0.160	0.143	0.233	0.070	0.430	0.160	0.375
Ca	1.529	1.705	1.092	1.450	1.554	1.177	1.658	1.456
Fe	0.023	0.000	0.008	0.031	0.016	0.000	0.000	0.023
Sr	0.915	0.744	0.591	0.673	0.893	0.413	0.724	0.486
Ba	0.744	0.600	0.372	0.628	0.592	0.363	0.634	0.427
Na	0.656	0.543	1.019	0.625	0.749	0.849	0.526	0.352
K	1.692	1.762	2.681	1.791	1.940	2.715	1.551	2.108
Heu-Ca	28	32	19	28	27	21	33	30
Heu-Sr	17	14	10	13	16	7	14	10
Heu-Ba	13	11	6	12	13	15	10	7
Heu-Na	12	10	18	12	13	15	10	7
Heu-K	31	33	47	35	34	49	31	44

Table 4	Ramberg, Kleiverud, Holmestrand						Sjøskogen, Holmestrand					
	Ram1-A	Ram1-B	Ram1-C	Ram1-D	Ram1-E	Ram1-F	Sjø1-A	Sjø1-B	Sjø1-C	Sjø1-D	Sjø1-E	Sjø1-F
SiO ₂	57.02	55.52	56.38	56.87	58.85	57.81	55.76	55.17	56.89	58.79	58.39	57.94
Al ₂ O ₃	15.87	15.41	16.36	17.13	16.03	15.90	17.39	17.01	17.61	16.38	16.19	16.14
MgO	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	3.71	3.01	3.93	3.68	3.41	3.54	3.36	3.37	3.42	3.55	3.63	3.55
FeO	0.00	0.05	0.00	0.00	0.03	0.02	0.00	0.02	0.00	0.00	0.00	0.00
SrO	2.81	3.67	4.73	5.02	3.73	3.82	6.18	6.12	6.27	4.50	5.02	4.76
BaO	5.01	6.31	1.63	2.42	3.13	2.62	1.40	1.03	1.17	0.63	0.46	0.87
Na ₂ O	0.94	1.17	1.20	1.29	1.38	1.01	0.94	0.42	1.20	0.07	0.26	0.61
K ₂ O	1.07	1.30	1.11	1.01	1.40	1.44	2.82	3.58	3.51	4.50	4.11	4.76
Total	86.47	86.45	85.34	87.42	87.96	86.16	87.85	86.72	90.07	88.42	88.06	88.63
Si	27.131	26.986	26.857	26.637	27.277	27.262	26.291	26.362	26.245	27.110	27.078	26.924
Al	8.900	8.828	9.185	9.456	8.757	8.837	9.663	9.579	9.575	8.902	8.849	8.839
Mg	0.028	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	1.891	1.568	2.006	1.847	1.693	1.789	1.697	1.725	1.690	1.754	1.804	1.767
Fe	0.000	0.020	0.000	0.000	0.012	0.008	0.000	0.008	0.000	0.000	0.000	0.000
Sr	0.775	1.034	1.307	1.363	1.003	1.045	1.690	1.696	1.677	1.203	1.350	1.283
Ba	0.934	1.202	0.304	0.444	0.569	0.484	0.259	0.193	0.212	0.114	0.084	0.158
Na	0.867	1.103	1.108	1.171	1.240	0.923	0.859	0.389	1.073	0.063	0.234	0.550
K	0.650	0.806	0.675	0.604	0.828	0.866	1.696	2.182	2.066	2.647	2.432	2.822
Heu-Ca	37	27	37	34	32	35	27	28	25	30	31	27
Heu-Sr	15	18	24	25	19	20	27	27	25	21	23	19
Heu-Ba	18	21	6	8	11	9	4	3	3	2	1	2
Heu-Na	17	19	21	22	23	18	14	6	16	1	4	8
Heu-K	13	14	13	11	16	17	27	35	31	46	41	43

Table 5	Nautnes, Øygarden								
	Naut1-A	Naut1-B	Naut1-C	Naut1-D	Naut1-E	Naut1-F	Naut1-G	Naut1-H	Naut1-I
SiO ₂	57.46	57.29	54.03	57.35	58.50	55.37	57.38	57.21	57.21
Al ₂ O ₃	15.35	15.85	16.60	16.67	15.89	17.36	15.69	15.95	16.13
MgO	0.40	0.45	0.11	0.90	0.72	0.22	0.47	0.23	0.38
CaO	2.43	2.47	2.32	2.61	2.63	2.29	1.98	2.62	1.99
FeO	0.06	0.05	0.00	0.18	0.03	0.12	0.10	0.00	0.02
SrO	2.01	1.92	4.49	0.97	0.75	3.67	2.02	2.64	1.89
BaO	4.50	6.13	5.41	2.99	1.89	4.68	5.04	6.52	4.97
Na ₂ O	0.71	0.69	0.86	0.92	0.87	0.96	0.86	0.48	0.87
K ₂ O	3.24	3.06	2.80	3.97	4.45	3.08	3.23	2.73	3.53
Total	86.16	87.91	86.62	86.56	85.73	87.75	86.77	88.38	86.99
Si	27.400	27.120	26.392	26.880	27.375	26.372	27.280	27.089	27.137
Al	8.627	8.843	9.557	9.208	8.763	9.745	8.791	8.901	9.017
Mg	0.284	0.318	0.080	0.629	0.502	0.156	0.333	0.162	0.269
Ca	1.242	1.253	1.214	1.311	1.319	1.169	1.009	1.329	1.011
Fe	0.024	0.020	0.000	0.071	0.012	0.048	0.040	0.000	0.008
Sr	0.556	0.527	1.272	0.264	0.204	1.014	0.557	0.725	0.520
Ba	0.841	1.137	1.036	0.549	0.347	0.873	0.939	1.210	0.924
Na	0.656	0.633	0.814	0.836	0.789	0.887	0.793	0.441	0.800
K	1.971	1.848	1.745	2.374	2.657	1.871	1.959	1.649	2.136
Heu-Ca	24	23	20	25	25	20	19	25	19
Heu-Sr	11	10	21	5	4	17	11	14	10
Heu-Ba	16	21	17	10	7	15	18	23	17
Heu-Na	12	12	13	16	15	15	15	8	15
Heu-K	37	34	29	45	50	32	37	31	40

Additional analyses of Norwegian axinites

Chemical composition (in wt.%), structural formula based on 20 cations, and mol-% of ferroaxinite (Fe-axn), manganaxinite (Mn-axn) and magnesioaxinite (Mg-axn). The proportions of H₂O and B₂O₃ were calculated assuming 2 B and 2 (OH) in the chemical formula.

	Barbudalen, Arendal n = 9	Myrdammen Drammen n = 7
SiO ₂	42.00	42.06
B ₂ O ₃	6.10	6.12
Al ₂ O ₃	16.95	17.47
FeO	1.23	4.78
MnO	12.57	6.78
MgO	0.06	1.19
CaO	19.49	19.66
Na ₂ O	0.04	0.04
K ₂ O	0.00	0.00
H ₂ O	1.58	1.59
Total	100.01	99.69
Si	7.982	7.945
B	2.000	2.000
Al	3.797	3.890
Fe ²⁺	0.200	0.755
Mn	2.024	1.085
Mg	0.017	0.335
Ca	3.969	3.979
Na	0.015	0.015
K	0.000	0.000
OH	2.000	2.000
Fe-axn	9	35
Mn-axn	90	50
Mg-axn	1	15