Ferguson, J. 1970: The significance of the kakortokite in the evolution of the Ilímaussaq intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **89** (also *Meddr Grønland* **190,** 1), 193 pp.

Institut for Petrologi,
University of Copenhagen,
Øster Voldgade 10,
1350 København K.

Preliminary geochemical work on the Ilímaussaq alkaline intrusion, South Greenland

John Bailey, Raymond Gwozdz, John Rose-Hansen and Henning Sørensen

As part of the geological investigation of the Ilímaussaq intrusion (Sørensen, 1970; Ferguson, 1964; Andersen, *et al.,* 1973; Sørensen *et al.,* 1974), trace-element analyses have been performed on carefully chosen rock samples. Material was selected on the basis of detailed field mapping and with particular attention paid to its fresh and representative nature; in every case more than 15 kg was obtained by blasting. The samples have already been used for the separation of accessory ore minerals and for analysis of fluid inclusions.

To date, the rocks have been analysed for trace elements by neutron activation (R.G.) and X-ray fluorescence (J.B.) analysis. Comparisons with earlier analytical results indicate closest agreement with the work of Gerasimovsky (1969), except for the element Ga where his results are consistently higher. Experiments by Ib Sørensen (GGU Chemical Laboratory) indicate that fused samples yield low totals for many Ilímaussaq rocks; the absorption effects of heavy minor elements (Zr, Nb, REE) on the light major elements will be quantitatively corrected for. Analyses by isotope fluorescence, delayed neutron analysis, X-ray spectrometry and other techniques are in progress.

Average trace-element analyses are presented for seven agpaitic rocks types from the Ilímaussaq intrusion in Table 3; sample localities are indicated in figure 25.

The alkali elements (Rb, Cs) typically occur at high levels and the rocks exhibit low K/Rb and K/Cs ratios. These tendencies become more pronounced in the final lujavrite differentiates.

Sr and Eu^{2+} are considered to be largely removed in the early stages of fractionation by feldspars. In the agpaitic rocks, they mainly enter eudialyte.

Rare-earth elements (REE, La-Lu, Y) reach exceptionally high levels in the eudialyte-rich kakortokites, and in the final lujavrites where a number of REE minerals are developed. In earlier agpaites (sodalite-bearing foyaite and naujaite, kakortokites), REE contents correlate with Zr and the REE are mainly located in eudialyte. Whole-rock REE spectra (fig. 27) reveal (a) a general increase in total REE, (b) increase in light REE/heavy REE in the lujavrites and (c) a more or less uniformly negative Eu anomaly.

Table 3. Average (median) trace-element contents for agpaitic rocks from the Ilímaussaq alkaline intrusion, South Greenland (in ppm)

	1	2	3	4	5	6	7
Rock type	Sodalite foyaite	Naujaite	Black kakortokite	Red kakortokite	White kakortokite	Green lujavrite	Medium to coarse grained lujavrite
Cs	6.5	3.6	4.5	6.0	7.0	6.6	67.0
Rb	397	307	169	426	496	608	1060
Sr	11	10	83	100	62	66	33
La	506	266	407	1030	588	1360	4065
Ce	918	672	769	2100	1056	3190	4600
Nd	370	258	282	717	349	1170	2320
Sm	64.4	50.6	64.9	179	92.5	172	95.6
Eu	5.69	4.12	5.29	15.3	6.60	18.4	8.71
Tb	9.33	6.67	9.68	26.6	11.1	24.6	10.8
Yb	28.7	21.7	41.3	101	41.7	67.7	32.3
Lu	3.59	3.04	6.03	13.8	6.17	8.16	3.96
Y	273	236	328	859	417	869	454
Th	60.0	31.9	34.8	59.4	52.8	68.1	597
Zr	3180	2960	6990	15100	7460	7500	878
Hf	80.7	69.4	181	376	175	119	10.9
Nb	425	359	469	983	570	476	307
Ta	29.9	24.2	38.1	79.4	41.0	37.3	15.1
Co	0.45	0.27	3.37	1.52	0.82	0.38	0.21
Sc	0.21	0.12	5.3	1.9	1.3	0.04	0.09
Cr	4.4	5.4	13.4	7.8	4.6	19.0	22.9
Ga	66	66	48	53	64	82	87
Ge	1.6	1.6	3.4	1.9	1.8	1.2	1.6
Zn	432	257	581	512	395	818	1900
Pb	70	41	38	85	78	352	371
Sb	1.5	0.8	0.9	0.6	0.5	1.1	7.3
Br	41	62	5	2	2	1	1
GGU sample numbers	154303 154304 154347 154349 154350 154351	154309 154310 154311 154328 154329 154344 57041	154320 154322 154325 154335 154338 154343	154319 154323 154326	154318 154324 154327 154337 154340	154359 154360 154366 154370 57033	154397 154724

The large highly charged cations (Zr, Hf, Nb, Ta, Th) reach abnormally high levels of concentration. Zr, Hf, Nb and Ta contents are maximal at the kakortokite stage but Th continues to increase throughout the final lujavrites. There is an increase in the Zr/Hf (from about 40 to 80) and Nb/Ta (from about 13 to 20) ratios in the late lujavrites.

Of the transition metals, Zn and to some extent Cr are concentrated in the final agpaites but Sc and Co show their highest concentrations in black kakortokite. Zn enters arfvedsonite but in addition it exhibits marked chalcophile properties and along with Pb and Sb attains notably high concentrations in the final lujavrites.

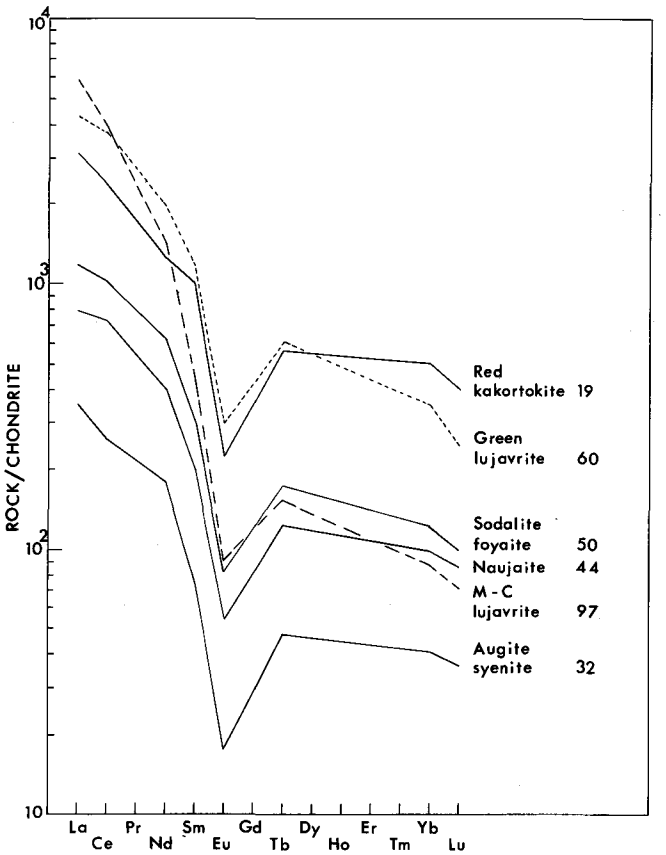

Fig. 27. Rare-earth element patterns for selected rocks from the Ilímaussaq alkaline intrusion. Only last two figures of full GGU sample number given e.g. (154319).

Ge tends to be preferentially incorporated in the black kakortokite and presumably enters arfvedsonite; absolute contents are comparable with other igneous rocks. Ga maintains high levels in the agpaitic rocks, particularly the late lujavrites.

High Br contents occur in the sodalite-rich (Cl-rich) foyaites and naujaites but decrease sharply in the sodalite-poor kakortokites and lujavrites.

Table 4 compares the geochemistry of lujavrites from the Ilímaussaq intrusion with those from Lovozero (Kola, USSR) and Pilanesberg (South Africa). All these rocks are characterised by high contents of 'residual' trace elements and by fractionated element ratios. The Ilímaussaq lujavrites are generally the most extreme of the three localities in this respect. The Fe-rich oversaturated peralkaline lavas (pantellerites) share many of the extreme geochemical features shown by the Fe-rich undersaturated lujavrites.

Future work will extend the multi-element analysis of Ilímaussaq rocks and minerals, and integrate the results with the physical-chemical history of the intrusion. Geochemical work will also supplement the increasingly detailed mapping of the intrusion, and continue to provide basic information for economic assessment of the intrusion.

Table 4. Geochemical indices for lujavrites of the Ilímaussaq alkaline intrusion, with comparisons

	1	2	3	4	5
	Ilímaussaq Greenland	Lovozero USSR	Pilanesberg S. Africa	Average granite	Average pantellerite
Agpaitic index	1.37	1.47	1.41	0.82	1.68
K/Rb	47	180	251	247	240
$K/Cs.10^{-2}$	43	198	159	105	73
$Sr/Ca.10^{3}$	13	90	190	20	1.0
$La/Zr.10^{3}$	181	27	20	310	167
$La/Nb.10^{2}$	286	27	22	260	100
La/Lu	167	270	280	46	95
La/Sm	7.9	2.5	17.5	5.5	5.8
Sm/Eu	9.3	4.0	8.5	6.3	9.8
$Th/Zr.10^{4}$	91	32	62	971	210
$Nb/Ti.10^{2}$	28	15	32	1.8	6.9
$Li/Mg.10^{3}$	47	8.9	32	25	79
$Zn/Fe.10^{4}$	109	49	47	27	57
$Ga/Al.10^{5}$	97	69	75	24	72
$Sc/Fe.10^{6}$	0.5	-	3.8	493	38

1. Table 1, column 6 (this report). Major elements and Li (Gerasimovsky, 1969)
2. Mainly average of composites C6, C7 (Gerasimovsky et al., 1966)
3. Geochemical standard, NIM-L (Flanagan, 1973; Erasmus et al., 1977)
4. Low-Ca granite (Turekian & Wedepohl, 1961)
5. Unpublished compilation (J. Bailey, 1977)

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References

Andersen, S., Bailey, J., Karup-Møller, S., Løkkegaard, L., Rose-Hansen, J., Steenfelt, A. & Sørensen, H. 1973: Research projects on the Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **55,** 38–40.

Erasmus, C. S., Fesq, H. W., Kable, E. J. D., Rasmussen, S. E. & Sellschop, J. P. F. 1977: The NIMROC samples as reference materials for neutron activation analysis. *Radioanalyt. Chem.* **39,** 323–334.

Ferguson, J. 1964: Geology of the Ilímaussaq alkaline intrusion. South Greenland. Description of map and structure. *Bull. Grønlands geol. Unders.* **39** (also *Meddr Grønland* **172,** 4) 82 pp.

Flanagan, F. J. 1973: 1972 values for international geochemical reference samples. *Geochim. Cosmochim. Acta* **37,** 1189–1200.

Gerasimovsky, V. I. 1969: *Geochemistry of the Ilímaussaq alkaline massif (South-West Greenland)* (in Russian). Moskva: Nauka, 174 pp.

Gerasimovsky, V. I., Volkov, V. P., Kogarko, L. N., Polyakov, A. I., Saprykina, T. V. & Balashov, Yu.A. 1966: *The Geochemistry of the Lovozero Alkaline Massif,* Pt. II (in Russian). Moskva: Nauka, 149–396.

Sørensen, H. 1970: Internal structures and geological setting of the three agpaitic intrusions – Khibina and Lovozero of the Kola Peninsula and Ilímaussaq, South Greenland. *Can. Mineral.* **10,** 3, 299–334.

Sørensen, H., Rose-Hansen, J., Nielsen, B. L., Løvborg, L., Sørensen, E. & Lundgaard, T. 1974: The uranium deposit at Kvanefjeld, the Ilímaussaq intrusion, South Greenland. Geology, reserves and beneficiation. *Rapp. Grønlands geol. Unders.* **60,** 54 pp.

Turekian, K. K. & Wedepohl, K. H. 1961: Distribution of elements in some major units of the Earth's crust. *Bull. geol. Soc. Amer.* **72,** 175–192.

Institut for Petrologi,
University of Copenhagen,
Øster Voldgade 10,
1350 Copenhagen K.

High zinc contents of sea water in Kangerdluarssuk, the Ilímaussaq area, South Greenland

Gert Asmund and John Rose-Hansen

Samples of sea water were collected in Kangerdluarssuk in the summers of 1974 and 1975 (fig. 28) as part of the geochemical-ecological Narssaq project (Bohse *et al.,* 1975; Nielsen *et al.,* 1976). These have been analysed for dissolved zinc, cadmium, lead and copper by anodic

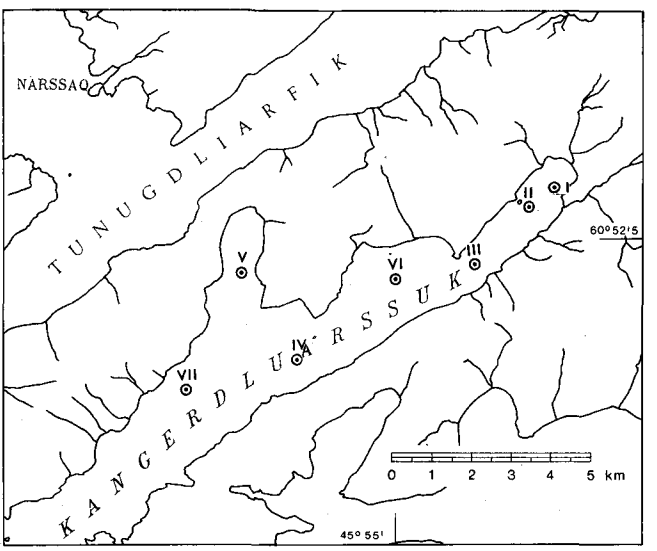

Fig. 28. Sketch map of the head of Kangerdluarssuk, South Greenland, showing positions of the analysed sea water samples discussed by Asmund & Rose-Hansen.