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The Ilímaussaq alkaline complex, South Greenland: status of mineralogical research with new results

Edited by
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Contributions to the mineralogy of Ilímaussaq, no. 100
Anniversary volume with list of minerals

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Cover
Igneous layering in kakortokites in the southern part of the Ilímaussaq alkaline complex, South Greenland. The central part of the photograph shows the uppermost part of the layered kakortokite series and the overlying transitional kakortokites and aegirine lujavrite on Laksefjeld (680 m), the dark mountain in the left middle ground of the photograph. The cliff facing the lake in the right middle ground shows the kakortokite layers + 4 to + 9. The kakortokite in the cliff on the opposite side of the lake is rich in xenoliths of roof rocks of augite syenite and naujaite making the layering less distinct. On the skyline is the mountain ridge Killavaat ('the comb'), the highest peak 1216 m, which is made up of Proterozoic granite which was baked and hardened at the contact to the intrusive complex. The lake (987 m) in the foreground is intensely blue and clear because it is practically devoid of life. The whole area is devoid of vegetation, with crumbly rocks typical of the nepheline syenites of the complex.

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Preface

The Mesoproterozoic Ilímaussaq alkaline complex located near the town of Narsaq in South Greenland is the type locality for agpaitic nepheline syenites and represents an enormous concentration of a number of rare elements, particularly Li, Be, Nb, Zr, REE, Y, U and Th. This explains the presence of about 220 minerals, 27 of these discovered in and first described from the complex, and nine only found there.

In 1965 it was decided to collate papers on the mineralogy (in a broad sense) of the complex published in various scientific journals into a consecutively numbered series: *Contributions to the mineralogy of Ilímaussaq*. The first issue appeared in 1965, no. 102 in 1999, and the series has now reached no. 113. Issue no. 100 was reserved for the anniversary volume presented here. This volume contains a brief account of the geology of the complex and the history of exploration, a list of the minerals identified so far in the complex, and papers which review selected topics and present new information on the mineralogy and geochemistry of Ilímaussaq. A companion report, *Danmarks og Grønlands Geologiske Undersøgelse Rapport* **2001/102**, compiled by J. Rose-Hansen, H. Sørensen and W.S. Watt, presents an inventory of the literature of the complex, collated from an unusually wide variety of sources and containing about 750 entries, together with a list of the series *Contributions to the mineralogy of Ilímaussaq*. The report brings these both in print and on a CD-ROM, accessible for electronic searching.

We hope that this collection of papers on Ilímaussaq will be received in the same positive way as was its predecessor, 'The Ilímaussaq intrusion, South Greenland. A progress report on geology, mineralogy, geochemistry and economic geology', published as Contribution to the mineralogy of Ilímaussaq no. 63 in *Rapport Grønlands Geologiske Undersøgelse* **103** edited by J.C. Bailey, L.M. Larsen & H. Sørensen in 1981.

Contribution no. 63 was compiled after more than ten years of intensive field activity and presented new information on the geology and geochemistry of the Ilímaussaq complex together with papers on mineralogy, fluid inclusions and economic geology. Since then there has only been limited field activity in the complex. Contribution no. 100 (this volume) therefore presents results of the continued laboratory investigations of material collected during the earlier field work and drilling programmes together with discussions of a few selected topics in the light of new developments in the study of agpaitic rocks and their minerals.

The paper by J.C. Bailey, R. Gwozdz, J. Rose-Hansen and H. Sørensen contains the first general discussion of the geochemistry of the complex since V.I. Gerasimovsky's 1969 memoir on this subject. This overview of the geochemistry is based on the on-going detailed analysis of 120 large samples of the major rock types collected by blasting in order to obtain fresh material. Mineral separates have been prepared of many of the samples with the aim of analysing the rock-forming and accessory minerals, together with the bulk rocks, for more than 50 elements. The ultimate purpose is to evaluate the composition of the agpaitic melts and the distribution of a number of elements between minerals and the melt and fluid phases in order to better understand the conditions of formation of agpaitic mineral associations. The following paper by J.C. Bailey illustrates this by describing the distribution of germanium in the rocks and minerals of the complex.

Eudialyte may be called the typomorphic mineral of agpaitic rocks *sensu stricto* and is one of the minerals first found and described from Ilímaussaq. The nomenclature of the mineral has, however, been rather confusing. Based on the optical properties three varieties, eudialyte, mesodialyte and eucolite, have been distinguished, but it has been impossible to relate these differences to chemical properties. In recent years it has been demonstrated that eudialyte comprises a group of minerals. It was therefore felt timely to include a review of this mineral group in the anniversary volume (the paper by O. Johnsen, J.D. Grice and R.A. Gault).

The most highly evolved agpaitic rocks and mineral associations have been called hyper-agpaitic by Russian colleagues working in the Khibina and Lovozero complexes of the Kola Peninsula. Hyper-agpaitic rocks are extremely rich in rare minerals, a result of crystallisation of peralkaline, volatile-rich, low-viscosity melts over a broad temperature interval, ending at low temperatures. This results in long-range ordering of the crystal structures and the predominance of triclinic minerals (paper by A.P. Khomyakov). In Ilí-

maussaq, hyper-agpaitic mineral associations are found not only in pegmatites and hydrothermal mineralisations as in the Kola complexes but also in the most evolved lujavrites; a review is presented in the paper by H. Sørensen and L.M. Larsen.

The mineral naujakasite presents an enigmatic problem. It is composed of the most common elements, Na, Al, Fe, Mn and Si, but has nevertheless until now only been known from the Ilímaussaq complex, where it is sometimes a rock-forming mineral which may constitute more than 75 vol.% of some lujavrites. The recent discovery of a Mn-rich naujakasite, manganonaujakasite, in a pegmatite from the Lovozero complex of the Kola Peninsula is reported in the paper by A.P. Khomyakov, H. Sørensen, O.V. Petersen and J.C. Bailey. This paper also reviews the occurrence of naujakasite in hyper-agpaitic lujavrites of the Ilímaussaq complex and examines why this mineral is common in Ilímaussaq, very rare in Lovozero and absent in the Khibina complex of the Kola Peninsula.

Steenstrupine is a very important rock-forming mineral in the hyper-agpaitic mineral associations of Ilímaussaq and is the main radioactive mineral in the Kvanefjeld uranium deposit. The mineral is generally metamict. Varieties with marginal anisotropic zones have, however, been known for a long time, but their origin was not well understood. New microprobe analyses of zoned steenstrupine crystals have demonstrated chemical differences which can explain the coexistence of metamict and crystalline steenstrupine (paper by A.P. Khomyakov and H. Sørensen).

Some rare minerals, as for instance steenstrupine, rinkite, epistolite and ussingite, are found in considerable quantities throughout the Ilímaussaq complex. Others like semenovite and chalcothallite have only been found in a few places as isolated grains. Until recently, leucophanite was considered to belong to the last-named group but is now known to occur in a number of localities within the complex (paper by H. Bohse, O.V. Petersen and G. Niedermayr).

In E.I. Semenov's pre-microprobe 1969 memoir on the mineralogy of Ilímaussaq, a number of minerals were described under preliminary names. E.I. Semenov's paper in the present volume reports the status of some of these minerals, including the occurrence of a new mineral, Na-komarovite.

In spite of a low average content of 1.9 ppm thallium in the complex, four minerals having Tl as a major component have been found. The paper by S. Karup-Møller and E. Makovicky reports the discovery of a new occurrence of thalcusite and discusses the tarnishing of polished sections of this mineral.

Brown prismatic crystals of rinkite are of widespread occurrence in Ilímaussaq. It was therefore a surprise that rinkite-looking crystals in a naujaite pegmatite were found to be hiortdahlite (the paper by E.R. Robles, F. Fontan, P. Monchoux, H. Sørensen and P. de Parseval). This brings important information about a stage of reduced alkalinity, in conformity with the occurrence of fayalite and hedenbergite in the adjacent naujaite.

More than 80 water-soluble minerals are known from the Khibina and Lovozero complexes. Until recently only three such minerals were known from Ilímaussaq: villiaumite, trona and thermonatrite. Water-soluble minerals have been looked for in drill cores and the material from the Kvanefjeld adit, but unfortunately not immediately after drilling and blasting. Therefore only two additional water-soluble minerals have been found: the discovery of natrophosphate is reported in the paper by O.V. Petersen, A.P. Khomyakov and H. Sørensen.

Nacareniobsite-(Ce) and vitusite are additional examples of minerals considered to be rare at Ilímaussaq. The paper by I.V. Pekov and I.A. Ekimenkova shows that these minerals are of more widespread occurrence, and provides examples of new types of rare-earth mineralisation in the complex.

Agpaitic and hyper-agpaitic nepheline syenites contain a number of rare Na–Be-minerals such as chkalovite and tugtupite, whereas common Be minerals such as beryl, euclase and chrysoberyl are absent. The paper by G. Markl examines the stability relations of the various Be minerals and explains why the agpaitic rocks contain Na–Be minerals and the order of formation of the minerals.

The fluid phase of agpaitic nepheline syenites is rich in hydrocarbons, especially methane. The paper by J. Konnerup-Madsen reviews the evolution of the fluids and brings new isotopic evidence in support of the non-biogenic origin of these hydrocarbons.

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