*Rapp. Grønlands geol. Unders. 103, 63–67 (1981)*

# Extension of Zr-REE-Nb resources at Kangerdluarssuk, Ilímaussaq intrusion

**John. C. Bailey, Henning Bohse and Aelita Demina**

The high contents of zirconium in many rocks and minerals of the Ilímaussaq alkaline intrusion have been known for over 150 years. The early geologists were particularly attracted by the red kakortokites of Kangerdluarssuk with their high contents of eudialyte, (Na, Ca)$_5$(Zr, Fe$^3$ )(Si$_6$O$_{18}$)(OH, Cl). Bohse *et al.* (1971) concluded from field and laboratory studies that the kakortokites (here, the lower layered kakortokites) as a whole possess a geometric mean $ZrO_2$ content of 1.2% with reserves of 51.6 million tons $ZrO_2$. Sørensen *et al.* (1974) recalculated the data and suggested reserves of 61 million tons $ZrO_2$. The purpose of the present note is to show that similar $ZrO_2$ contents are also present in some of the overlying rocks, notably aegirine lujavrite I – the earliest of the lujavrite varieties. It is also shown that the eudialyte in this lujavrite has significantly higher levels of REE, Nb, Th and U than the eudialytes of the lower layered kakortokites.

Figure 1A summarises the igneous stratigraphy for the kakortokite-lujavrite sequence in the Kangerdluarssuk area. The base of the lower layered kakortokites is not exposed, but 210 m of these density-stratified crystal cumulates are preserved on the south side of the fjord. They consist of a cyclically layered series with units composed of black (arfvedsonite), red (eudialyte) and white (feldspar) layers, named from bottom to top in a unit. The layered kakortokite is conformably overlain by homogeneous, virtually unlayered kakortokite but there is a return to black, red and white layers in the overlying transitional layered kakortokites. Above these lies aegirine lujavrite I.

Bore hole 7, nearly 200 m deep, was drilled approximately in the middle of the aegirine lujavrite I sequence (fig. 1A) and fig. 3, Bailey, Larsen & Sørensen (1981). Since the lujavrite dips at 45 ± 10°, the vertical core represents a real stratigraphic thickness of close to 140 m. Apart from a few naujaite xenoliths derived from the roof rock and minor zeolite veins, it consists entirely of aegirine lujavrite I. The drill core was divided into 1 m intervals and the powdered splits were analysed by X-ray fluorescence spectrometry.

The $ZrO_2$ profile for the drill core is presented in fig. 1B. It reveals a fairly regular sequence of $ZrO_2$-rich zones imposed on a background level of about 0.8% $ZrO_2$. These zones correspond to eudialyte-rich layers; the layers are occasionally visible in the field and may extend over considerable lateral distances.

Ninety-three percent of the aegirine lujavrite I samples contain between 0.5 and 2.0% $ZrO_2$ with a geometric mean close to 1.1% (fig. 2). The lower layered kakortokites possess virtually the same mean for $ZrO_2$ (1.2%) but exhibit a much wider range of $ZrO_2$ contents, only 55% of the samples falling between 0.5 and 2.0% $ZrO_2$. A small collection of transitional layered kakortokites gives a mean close to 1.3% $ZrO_2$ with a considerable range of values.

The Zr and eudialyte-rich nature of aegirine lujavrite I has proved difficult to distinguish because: (a) there are no layers exceptionally rich in eudialyte, (b) the grain size of the rock

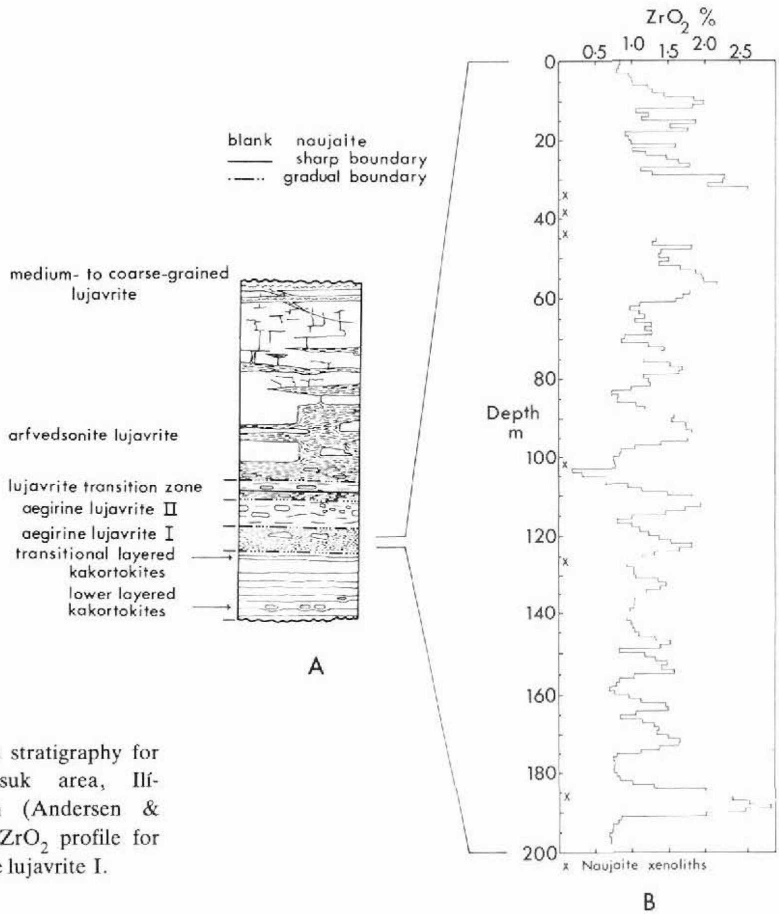


Fig. 1. A: Igneous stratigraphy for the Kangerdluarssuk area, Ilímaussaq intrusion (Andersen & Bohse, 1978); B: $ZrO_2$ profile for drill core 7, aegirine lujavrite I.

is finer than in the kakortokites, (c) the red colour of eudialyte is paler in the lujavrite and (d) an optical illusion is produced by the myriads of small green aegirine needles which impart the dominant colour to the rock. Only in recent years has detailed mapping around the head of Kangerdluarssuk distinguished aegirine lujavrite I from the other lujavrite varieties (Demin, 1971; Andersen & Bohse, 1978; Demina, 1979).

The much wider range of $ZrO_2$ in the lower layered kakortokites reflects their more effective separation into eudialyte-rich layers ($\bar{x}$ $ZrO_2$ 3.8%) and eudialyte-poor layers (black 1.1% and white 1.3% $ZrO_2$) (Bohse *et al.,* 1971). This presumably stems from the greater vertical interval over which density differentiation of the cumulus phases took place possibly combined with the fluid state of the 'kakortokite' magma. Aegirine lujavrite I is considered to be a viscous crystal-rich mush which crystallised much closer to the naujaite roof. The possibilities for crystal-liquid separation are thus seriously curtailed.

Approximately 95% of the $ZrO_2$ in aegirine lujavrite I is held by eudialyte (13.2% $ZrO_2$). $ZrO_2$ contents of the other phases are: aegirine 0.21%, arfvedsonite 0.07%, microcline + nepheline 0.01%, analcime + natrolite 0.01%.

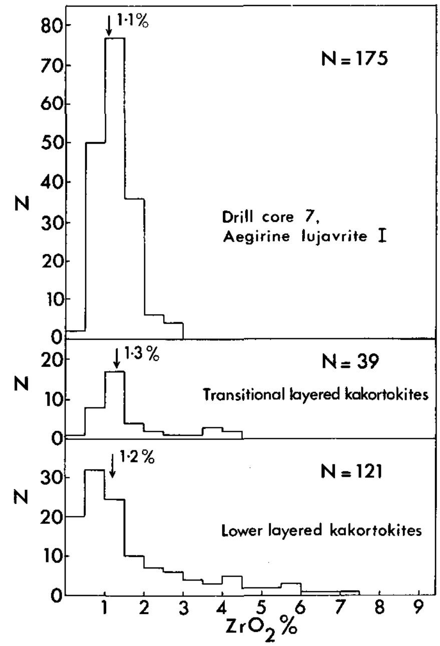


Fig. 2. Histograms for $ZrO_2$ contents in lower layered kakortokites (Bohse *et al.*, 1971: Fig. 18), transitional layered kakortokites and aegirine lujavrite I, Ilímaussaq intrusion.

The major and trace element chemistry of eudialyte has been investigated by X-ray fluorescence analysis following mineral separation using a magnetic separator and heavy liquids (Table 1). The eudialyte from aegirine lujavrite I has significantly higher levels of REE, Nb, Th and U than eudialyte from the kakortokites. Contents of Hf and Ta, however, are reduced. Steenfelt & Bohse (1975) have previously demonstrated the increase in U contents of eudialyte through the kakortokite-lujavrite sequence, values rising to 869 ppm in the highest examined lujavrites. Whole-rock values for the above elements in the two

*Table 1. Mean contents of selected rare elements in kakortokites and aegirine lujavrite I*

| | $ZrO_2$ % | $RE_2O_3$ % | $Nb_2O_5$ % | Hf ppm | Ta ppm | Th ppm | U ppm | La ppm | Ce ppm | Y ppm |
|---|---|---|---|---|---|---|---|---|---|---|
| Whole-rocks[1] | | | | | | | | | | |
| Lower layered kakortokites[2] | 1.2 | 0.28 | 0.11 | 190 | 44 | 38 | 14 | 460 | 860 | 420 |
| Transitional layered kakortokites | 1.3 | 0.30 | 0.11 | 200 | 50 | 35 | 15 | 490 | 920 | 500 |
| Aegirine lujavrite I | 1.1 | 0.56 | 0.09 | 140 | 36 | 35 | 20 | 850 | 1590 | 760 |
| Eudialytes[3] | | | | | | | | | | |
| Lower layered kakortokites | 13.3 | 2.57 | 0.99 | 1950 | 450 | 30 | 50 | 3380 | 7550 | 3210 |
| Transitional layered kakortokites | 13.6 | 3.17 | 0.86 | 1740 | 370 | 40 | 86 | 3990 | 9260 | 3990 |
| Aegirine lujavrite I | 13.2 | 5.21 | 1.17 | 1400 | 385 | 90 | 190 | 6770 | 15900 | 6030 |

1. Gerasimovsky (1969; Bohse *et al.* (1971); Bailey *et al.* (1978); Bailey (unpublished data).
2. Weighted: 0.760 white, 0.094 red, 0.146 black (thicknesses of Bohse *et al.*, 1971; densities of Forsberg & Rasmussen, 1978).
3. Analyst: H. Bohse. Method: XRF analysis.

kakortokite groups and in aegirine lujavrite I (Table 1) are distinctly lower than contents in eudialyte and indicate that eudialyte is a major carrier of these elements.

## Economic comments

Only a rough estimate of the tonnage of $ZrO_2$ in the transitional layered kakortokites and aegirine lujavrite I can be made at the present time. These rock types extend for about 5 km along both sides of the stream Lakseelv, though partly covered by the valley sediments. Their combined stratigraphic thickness varies considerably along the northern side of Lakseelv, being about 220 m at the mouth of the stream, 250 m at 0.5 km upstream but perhaps only 150 m at 3 km upstream. On the southern side, in general, only aegirine lujavrite I is exposed, so the combined thickness is unknown. We estimate that about 25 million tons of $ZrO_2$ are present. Given an $RE_2O_3/ZrO_2$ ratio of about 0.36, some 9 million tons of $RE_2O_3$ are also present, while 2 million tons of $Nb_2O_5$ can be calculated. These figures can be viewed against the 61 million tons of $ZrO_2$ and 6.5 million tons of $Nb_2O_5$ estimated for the lower layered kakortokites of Kringlerne (Sørensen *et al.*, 1974), and the 14.2 million tons of $RE_2O_3$ estimated from the values in Table 1.

The mineral eudialyte is named from the Greek for 'easily dissolved', in reference to its ready solubility in dilute acids. A few leaching experiments on rock powders of aegirine lujavrite I revealed that over 50% of the $ZrO_2$ and $Y_2O_3$ could be removed by stirring with 2% sulphuric acid for a few hours. An efficient method of eudialyte extraction and dissolution has been developed by Superfos a/s.

Unlike the lower layered kakortokites, there are no readily accessible layers with exceptionally high $ZrO_2$ contents in the overlying rocks. Unit +16 of the lower layered kakortokites – about 3.5 m thick – outcrops over a wide area and contains 4% $ZrO_2$ (Bohse *et al.*, 1971). The most eudialyte-rich layer in aegirine lujavrite I has $ZrO_2$ contents of 2.3–3.0%. The layer can be traced for a considerable distance in the field but nowhere are outcrop areas extensive. Red kakortokites A, D and E within the transitional layered kakortokites contain more than 4% $ZrO_2$ but again outcrops are not extensive.

In conclusion, it has been shown that the transitional layered kakortokites and the overlying aegirine lujavrite I of the Ilímaussaq intrusion possess mean $ZrO_2$ contents of 1.3 and 1.1%, respectively. Together they contain approximately 25 million tons $ZrO_2$, 9 million tons $RE_2O_3$ and 2 million tons $Nb_2O_5$. Combining these tonnages with those in the lower layered kakortokites, the known resources of these elements at the head of Kangerdluarssuk are thus enlarged to 86 million tons $ZrO_2$, 23.2 million tons $RE_2O_3$ and 8.5 million tons $Nb_2O_5$. The intervening, unlayered kakortokites have not yet been investigated. The elements of interest are dominantly held by the mineral eudialyte which can be readily dissolved in dilute acids. The eudialyte also contains significant contents of Th, U, Hf and Ta.

*Acknowledgement.* The Danish Natural Science Research Council (SNF) supported the X-ray fluorescence analytical programme.

## References

Andersen, S. & Bohse, H. 1978: Field work on the kakortokites and lujavrites in the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 73–75.

Bailey, J. C., Gwozdz, R., Rose-Hansen, J. & Sørensen, H. 1978: Preliminary geochemical work on the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 75–79.

Bailey, J. C., Larsen, L. M. & Sørensen, H. 1981: Introduction to the Ilímaussaq intrusion with a summary of the reported investigations. *Rapp. Grønlands geol. Unders.* **103** (this volume).

Bohse, H., Brooks, C. K. & Kunzendorf. H. 1971: Field observations on the kakortokites of the Ilímaussaq intrusion, south Greenland. *Rapp. Grønlands geol. Unders.* **38**, 43 pp.

Demin, A. 1971: Detailed mapping in the southern part of the Ilímaussaq intrusion (Kangerdluarssuk fjord). *Rapp. Grønlands geol. Unders.* **35**, 29–30.

Demina, A. 1979: Field geology and petrography of the upper kakortokites and a section through the lujavrites of the Ilímaussaq intrusion, South Greenland. Unpubl. int. GGU report, 52 pp.

Forsberg, R. & Rasmussen, K. L. 1978: Gravity and rock densities in the Ilímaussaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 81–84.

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

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.

Steenfelt, A. & Bohse, H. 1975: Variations in the content of uranium in eudialyte from the differentiated alkaline Ilímaussaq intrusion, south Greenland. *Lithos* **8**, 39–45.

A.D.,
Grønlands Geologiske Undersøgelse,
Øster Voldgade 10
DK-1350 Copenhagen K.

J.C.B., H.B.,
Institut for Petrologi,
University of Copenhagen,
Øster Voldgade 10,
DK-1350 Copenhagen K.