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Preliminary results on the distribution of uranium in drill cores from Kvanefjeld, Ilímaussaq intrusion

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Introduction

As part of the uranium extraction research programme carried out at the Risø National Laboratory, geochemical and mineralogical investigations of the Kvanefjeld area were conducted at the Geological Survey of Greenland. In the present contribution the principal conclusions on the distribution of uranium and the mineralogy of the potential uranium ore from Kvanefjeld are summarised. Detailed results are given in a GGU interim report (Makovicky *et al.*, 1979).

The material for the study was selected from 70 drill holes distributed over the entire area of Kvanefjeld (Sørensen *et al.*, 1974, Nyegaard *et al.*, 1977) and with a total length of 9000 m. From this material 102 samples were selected. The selection was based both on petrological data and uranium contents with the aim to sample all the principal ore types in each drill hole. The following rock types displayed significant U mineralization: the arfvedsonite, naujakasite, aegirine and M-C (medium- to coarse-grained) lujavrites and some of the deformed lavas. The methods used in the study are autoradiography, fission track investigation, general microscopy and microprobe analysis.

Autoradiography

Autoradiography of the split drill cores was performed with the aim of recognizing the distribution of radioactive minerals in the rocks prior to their detailed study.

Five types of distribution were recognized in the studied area:

(1) Homogeneous (or relatively homogeneous) distribution of fine- to medium-grained radioactive minerals.

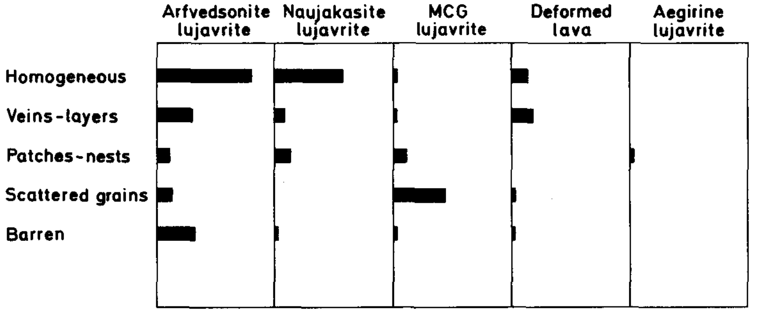

Fig. 1. Frequencies of different types of distributibution of radioactive minerals in the principal rock types.

(2) Vein- or layer-like distribution of medium- to fine-grained radioactive minerals.
(3) Patches or nests of medium- to coarse-grained radioactive minerals.
(4) Rocks containing scattered, large radioactive grains.
(5) Rocks with no discernible traces of radioactive grains on autoradiograms.

Fig. 1 illustrates the abundance of the various types of distribution in the mineralized rocks. The most abundant mineralized rock, arfvedsonite lujavrite, shows all types of distribution, especially the homogeneous and layered types. The homogeneous type is also typical for naujakasite lujavrite whereas the layered type occurs in deformed lavas. M-C lujavrite primarily contains large scattered grains of steenstrupine.

The autoradiograms of the split cores served as the basis for the exact location of polished thin sections which were used for microscope study, microprobe analysis and fission track investigation.

Microscope study

Steenstrupine

Special attention was given to steenstrupine which represents the principle uranium-bearing mineral in the Kvanefjeld area. In the studied rock types steenstrupine occurs in two distinct forms, here called A and B. This division is in general agreement with the classification of steenstrupine in lujavrites by Buchwald & Sørensen (1961), Sørensen (1962) and Sørensen *et al.*, (1974).

Type A represents small to medium sized (0.10–0.15 × 0.10–0.30 mm), fairly regular grains with hexagonal cross-section. The crystals show euhedral outlines against arfvedsonite and the felsic components, indicating a primary origin for steenstrupine A. Arfvedsonite (and aegirine) occasionally occur as small grains in steenstrupine.

The B type of steenstrupine is less abundant. Its crystals are generally larger, subhedral and often poikilitic. Parts of each crystal are bounded by large crystal faces whereas other parts overgrow and engulf the adjacent minerals. The B type is almost exclusively found in M-C lujavrite. Its formation may be connected with late-stage recrystallization processes.

The A and B types of steenstrupine may be present in both the original crystalline state, and in metamict or variously altered states. Crystalline steenstrupine A is very rare but the clear, yellowish isotropic metamict grains are common. Alteration appears as zones or as altered cores in steenstrupine crystals which acquire a deep rusty brown colour and show aggregate polarization. Sometimes entire steenstrupine grains are heavily altered and the brown pigmentary material in them occurs together with analcime, natrolite, acmite, and other minerals.

The anisotropic crystalline steenstrupine B often occurs together with the light brown, metamictized variety in the same crystal. The alteration of steenstrupine B may have the same character as in the A type or it may exhibit an early replacement of steenstrupine by well crystallized aggregates of monazite and uranothorite.

The combination of the A and B types of steenstrupine together with the variable intensity and structure of alteration yields seven principal types of the mineral and of its alteration aggregates:

Type A: (a) metamict (unaltered)
(b) altered, unzoned
(c) altered, zoned
(d) extremely altered

Type B: (a) fresh anisotropic
(b) metamict
(c) altered

Rock hydration

Alteration of the primary felsic minerals into hydrated phases (analcime, natrolite or ussingite) is a common but very variable phenomenon. In order to find a potential correlation between this alteration and the alteration of steenstrupine, the rock specimens were divided into three groups: the weakly hydrated rocks, the medium hydrated rocks and the intensely to completely hydrated (but not otherwise decomposed) rocks. A special, only locally developed group, are the (variably) hydrated rocks with ussingite as the main hydration phase.

The degree of hydration shows strong dependence on the location of the samples. The weakly to medium hydrated rocks are widely distributed over the Kvanefjeld area. However, the intensely hydrated rocks are primarily concentrated in the 'mine area'. They represent M-C lujavrites and the rocks situated to the north-east of the M-C lujavrite body below the sheets of roof rocks. No correlation could be established between the rock hydration and the alteration of steenstrupine.

Fission track investigation

For the detailed recognition and determination of uranium minerals, the fission track method was used. Lexan polycarbonate plastic was employed as a solid state detector (Wollenberg, 1971). After some experimenting, an irradiation time of 1 minute was chosen in the DR3 research reactor at Risø. For estimation of the density of tracks produced by a grain we used uniform track densities produced by standard glass compositions.

The results obtained to date show that steenstrupine and its *in situ* alteration products are the only uranium-bearing minerals of importance in the majority of samples. A general correlation is found between the intensity of alteration of steenstrupine and its uranium content. The lighter, metamict A type of steenstrupine yields lower densities of fission tracks than the darker, altered A type (about 3000–5000 ppm U_3O_8 in lighter parts and usually more than 8000 ppm U_3O_8 in darker parts). The fission track record from steenstrupine B shows both the *content of U in the original material and also its redistribution on alteration*. The metamict, unaltered parts are almost homogeneous with about 7000–10 000 ppm U_3O_8. The well crystallized monazite which forms on alteration has about 1000–3000 ppm U_3O_8. It is associated with very small grains of uranothorite which contain U in concentrations far above 10 000 ppm U_3O_8. Our systematic research generalizes the earlier studies of Wollenberg (1971) and Hansen (1977) performed on more limited material.

Summary

In the Kvanefjeld area, uranium is primarily distributed in the lujavrite varieties and in deformed lavas. The radioactive grains may show homogeneous, layer- (vein-) like, nest-like or single-crystal, coarse-grained types of distribution in the rocks. Steenstrupine of two types (generations), A and B, represents the main uranium-bearing mineral. It is generally metamictized or altered into secondary *in situ* phases. The metamictization and alteration of steenstrupine are primarily dependent on its U-Th content and not on the rock type or on the degree of hydration of the primary felsic minerals.

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