The Ilímaussaq nepheline syenite complex in South Greenland. A general overview of exploratory activities and environmental studies

Jan Bondam

Open File Series 95/2

April 1995

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND
Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

The Geological Survey of Greenland (GGU) is a research institute affiliated to the Mineral Resources Administration for Greenland (MRA) within the Danish Ministry of Environment and Energy. As with all other activities involving mineral resources in Greenland, GGU's investigations are carried out within the framework of the policies decided jointly by the Greenland Home Rule Authority and the Danish State.

Open File Series

The Open File Series consists of unedited reports and maps that are made available quickly in limited numbers to the public. They are a non-permanent form of publication that may be cited as sources of information. Certain reports may be replaced later by edited versions.

Citation form

Open File Series Grønlands Geologiske Undersøgelse

conveniently abbreviated to:

Open File Ser. Grønlands geol. Unders.

GGU's Open File Series består af uredigerede rapporter og kort, som publiceres hurtigt og i et begrænset antal. Disse publikationer er midlertidige og kan anvendes som kildemateriale. Visse af rapporterne vil evt. senere blive erstattet af redigerede udgaver.

ISSN 0903-7322

GRØNLANDS GEOLOGISKE UNDERSØGELSE

Open File Series 95/2

The Ilímaussaq nepheline syenite complex in South Greenland. A general overview of exploratory activities and environmental studies

Jan Bondam

April 1995

ABSTRACT

An overview is presented of the available documentation on a variety of studies related to exploratory efforts carried out in the realm of the Ilímaussaq alkaline intrusive complex. The greater part of the research has been concentrated on the possible exploitation of the uranium deposit on Kvanefjeld, the northernmost extension of the intrusion. Elemental enrichment that occurs in the mineral assemblages of the alkaline rock series has attracted attention as possible resources for future development.

The variety of subjects that are briefly summarised encompasses the geological setting of the intrusion and the various geophysical surveys. An account is given of processing and other technical studies related to exploitation, mainly of the uranium deposit.

Environmental studies are presented in summary.

CONTENTS

PREFACE

This Open File Series report on the Ilímaussaq intrusion in South Greenland is meant to be a brief overview of the broad spectrum of subjects related to geoscientific research, surveys and experimental development of extraction techniques, combined with planning and assessment approaches that have been carried out since 1955, within the realm of the complex.

Basically, the aim has been to refine the overall knowledge of the mode of emplacement of the different rock types and of the elemental distribution and enrichments that took place during solidification of a unique type of peralkaline magma. As a consequence of the early discovery of uranium enrichment efforts were concentrated on a restricted part of the intrusion, a marginally situated area called Kvanefjeld. Hence this overview is to a certain extent biased towards exploration and further development of the uranium resources.

In order to facilitate the search for relevant information it was decided to introduce a chronological approach to the fields of study whenever needed.

Studies carried out in areas outside the realm of the intrusion, but motivated by the urge to collect supplementary information needed in relation to a possible exploitation of the uranium resources, have been included in the present overview.

Since the references quoted in this report cover a restricted number of papers and reports dealing with the different aspects reviewed, a number of appendices are added, containing bibliographies, lists of reports etc. of studies carried out within the framework of dedicated projects, together with a list of internal reports and theses on file at the Geological Survey of Greenland and the Risø National Laboratory (earlier Research Establishment Risø). In this respect the overview tends to be a catalogue, containing a nearly exhaustive coverage of documented activities along with assessment, planning and evaluation considerations on the prospective exploitation of mineral occurrences, primarily the uranium deposit at Kvanefjeld. For that reason a number of references in the text of this report have been omitted though registered in the appendix. Likewise, references included in the report may also appear in the appendix.

Though a new spelling has been introduced for Greenlandic place names, it has been decided to retain old spelling when needed for clarity.

Ilimmaasaq is the new spelling of the name of the mountain top that was used to identify the whole intrusive complex. The designation "Ilímaussaq complex" is maintained thoughout. New spelling is used in this report when the place names appear on maps that have been published recently. This is true for the 1:20 000 geological map of the southern part of the intrusion and for the names of townships like that of Narsaq, formerly spelt Narssaq.

GEOLOGY AND GEOCHEMISTRY OF THE ILÍMAUSSAQ INTRUSION

The first comprehensive description of the rock types and lithochemistry of the Ilímaussaq igneous complex was given by Ussing (1912). Ferguson (1964) prepared a new geological map of the intrusion and discussed aspects of its mode of emplacement (Ferguson 1970a, b, c).

Hamilton (1964) initiated a geochemical approach to the successive development of the undersaturated magma in connection with the renewed mapping of the intrusion.

Detailed geological mapping has continued since in different parts of the intrusive complex, generally in connection with surveys aimed at aspects of economic geology. This is particularly the case for the northernmost part of the complex called Kvanefjeld, of which a black and white map at the scale of 1:3484 was prepared (see Sørensen *et al.*, 1974), and of the southern part, south of the fjord Tunulliarfik, for which a geological map at scale 1:20 000 was prepared by the Geological Survey of Greenland in 1988 (Andersen *et al.*, 1988). This map was based on detailed field work carried out between 1972 and 1983 (cf. Andersen *et al.*, 1981).

In addition a detailed map at a scale of 1:8000 has been published of the layered cumulates of the floor sequence, the so-called kakortokite series, in conjunction with a report by Bohse *et al.* (1971).

Numerous scientific studies dedicated to detailed geology and petrology, to mineralogy and the geochemistry of the rock units, occasionally combined with aspects of economic geology, including the use of geophysical methods, have been published since low grade uranium and thorium enrichment was discovered on Kvanefjeld (Bondam & Sørensen, 1959). Besides the then obvious incentive for further development of this possible uranium resource, it soon became evident that further detailed study of the Ilímaussaq igneous complex was required. As a result, other elemental enrichments in a number of specific rock types of the complex were thoroughly analysed. This explains the studies of enrichment of lithium, beryllium, zirconium, REE and to a certain extent niobium and tantalum.

The growing number of papers and reports that were published since the early 60s has been reviewed by Sørensen (1967) and by Bailey *et al.* (1981a). The bibliographies of these two reviews are elaborate, they have been selectively combined in the appendix to this report under the headings "Contributions to the mineralogy of Ilimaussaq" and "Bibliography of the geology og Ilimaussaq", which both include the publications that appeared after 1981.

Recently Larsen & Sørensen (1987) reviewed the present state of knowledge of the progressive formation of the agpaitic rock suites in the intrusion.

SETTING AND GENERAL STRATIFICATION OF THE INTRUSION

The centre of the Ilímaussaq intrusion is situated at 60°55′N and 45°50′W. The intrusion is an ellipsoidal body measuring approximately 17 by 8 km, covering an area of 85 km^2. It is intersected by a deep fjord, called Tunulliarfik, that runs parallel to a NE-SW trending rift zone.

The Ilímaussaq intrusion belongs to the mid-Proterozoic Gardar Province of South Greenland. The oldest rocks of this period are continental sandstones and lavas of the Eriksfjord Formation with an assumed age of 1300 Ma. This formation rests on syn- to late orogenic Julianehåb granite of the Ketilidian mobile belt. The granite yields a Rb-Sr whole rock isochron age of about 1745 Ma.

The active phase of the Gardar Province lasted from 1299 to 1119 Ma. Almost all the extrusive and intrusive rocks from this period have alkaline affinity. They include alkali gabbro and basalt, hawaiitic to trachytic, phonolitic and rhyolitic lavas and dykes besides intrusive bodies of alkali granite, syenite and nepheline syenite. In addition relatively small pipes of carbonatitic rocks and various lamprophyres have been observed. The whole rock Rb-Sr isochron age of the Ilímaussaq intrusion is 1168$\pm$21 Ma (Blaxland *et al.*, 1976).

As to the framework in which the intrusion is placed, reference is made to the geological map: Sydgrønland, sheet 1, 1:500 000, with the descriptive text by Kalsbeek *et al.* (1990).

A simplified geological sketch map is depicted in Fig. 1; it has been published in a number of treatises dealing with geological and geochemical aspects of the rock formations of the intrusion.

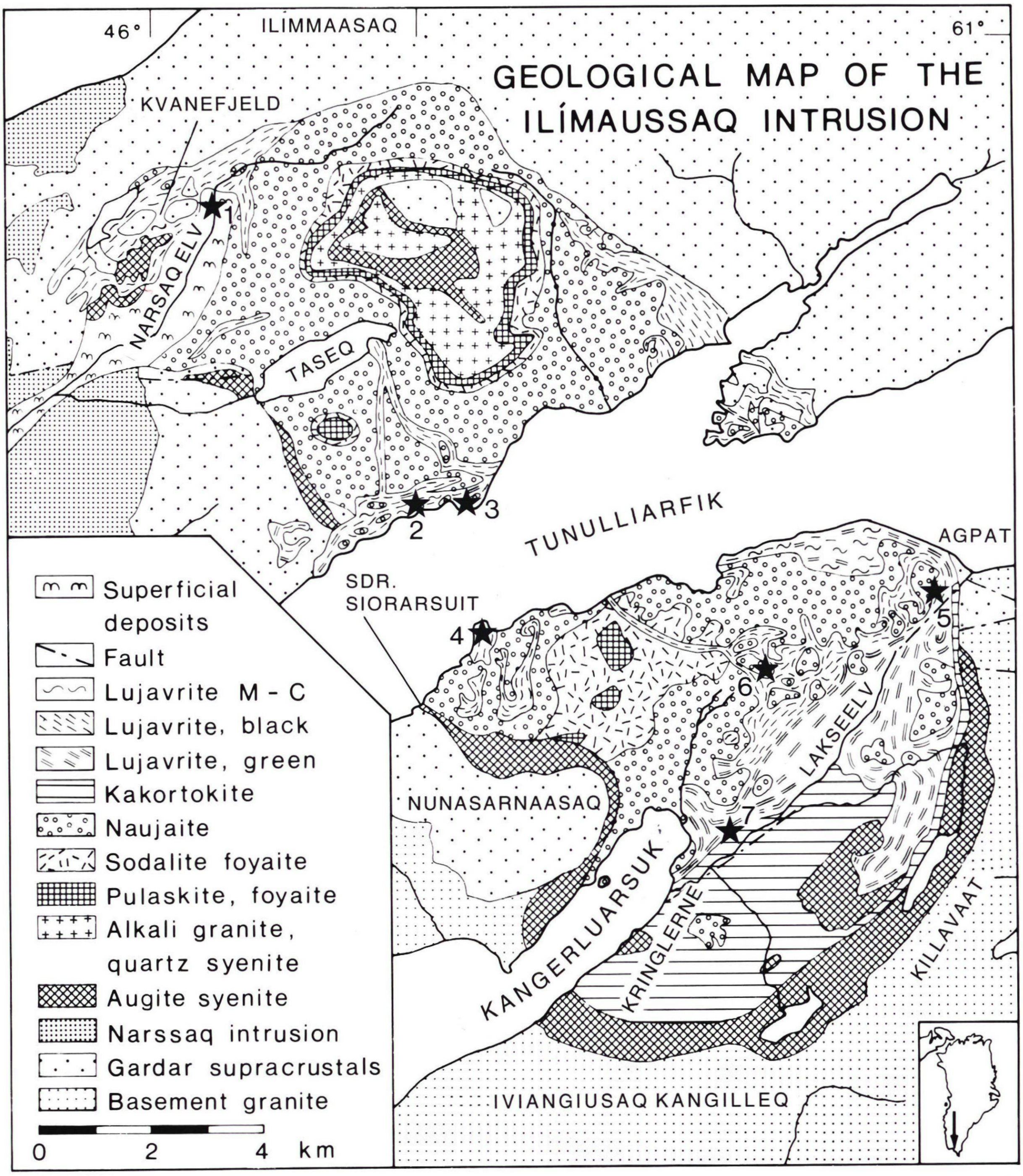

Fig. 1. Geological summary map of the Ilímaussaq intrusion based on Ferguson (1964).

★ 1-7 Position of diamond drill holes (Bondam & Ferguson, 1961) cf. p. 20.

Successive intrusive phases within the complex have been recognised. After the initial emplacement of augite syenite, a pulse of alkali granite and quartz syenite separated out. With the formation of an agpaitic magma chamber the third phase of development was initiated. The final derivate, lujavrite, formed an intrusive stage after consolidation of the roof and bottom sequences. The lujavrite primarily intruded overlying syenites and the adjacent cover of rocks of the Eriksfjord Formation.

The litho-stratigraphical order of the rock units that constitute the intrusive complex are typified briefly, as follows.

Augite syenite steeply rims the complex along the southern and western margins and forms a cap at a high level in its central part. It is a saturated to slightly undersaturated syenite with a compact, rather coarse-grained texture. Alkali feldspar and a titaniferous augite characterise the mineral content. The second intrusive phase consists of a single layer of **alkali granite** and **quartz syenite**, exposed at a high level where it is intruded into the augite syenite roof cover. These acidic intrusives have been designated the "upper border zone" (Sørensen, 1992). They are rather fine-grained rocks that carry alkali feldspar and aegirine augite as typical minerals. Xenoliths of these rock types have been observed in foyaite.

The agpaitic rock suite has been divided into a floor sequence, solidifying upwards, and a roof sequence solidifying downwards.

Litho-stratigraphically the exposed bottom accumulates consist of a rhythmically layered rock type, called **kakortokite**. The rock forming minerals are alkali feldspar, nepheline, eudialyte, arfvedsonite and to a certain extent aegirine. The sequence is composed of 29 layered units that have been numbered from −11 to +17. Each unit consist of a lower black coloured layer that is enriched in arfvedsonite, after which a red, eudialyte enriched layer is formed and an upper white layer rich in alkali feldspar and nepheline. The total magnitude of the exposed series is 280 m of which the upper 70 m only shows intermittent layering.

The kakortokite merges upwards into the final unit of solidification, the lujavrite series. The lowest layer is designated green **aegirine lujavrite** that has been subdivided into two units, a lower unit carrying lath-shaped aegirine (I) and an equally thick unit which has needle-shaped aegirine (II), cf. Fig. 2. These rock types are generally laminated and mesocratic. Aegirine is the dominant dark mineral. The other rock forming minerals are alkali feldspar and nepheline. A transitional zone, about 50 metres thick, separates this unit of green lujavrite from the following sequence, black **arfvedsonite lujavrite**, in which the amphibole arfvedsonite predominates as a dark mineral. This rock type has been mobilised in the final stage of solidification. It contains numerous inclusions of the overlying naujaite, the main rock type of the roof sequence, after its collapse in a solid state. Reactions between naujaite and lujavrite have produced a rock variety that is called **augen lujavrite**, found in a restricted area in the eastern part of the complex. The latest, truly intrusive phase of the sequence is called **M-C lujavrite**, a hetrogeneous, medium to coarse grained unlaminated variety that is found predominantly along the northern and eastern part of the complex.

Geochemical studies indicate a gradual compositional change in the development of the lujavrite series in certain elemental ratios in the residual magma. As an example the Zr/U and Zr/Y stratigraphy in the solidification sequence of the kakortokites and lujavrites in the southern part of the intrusion, is compared to the different lujavrite varieties on Kvanefjeld, is shown in Fig. 2. Studies of other geochemical distribution patterns point in the same direction (Andersen *et al.*, 1981).

The first cumulate of the roof sequence of the agpaitic magma is **pulaskite**, a slightly undersaturated syenite with a very restricted extent. This likewise applies to **foyaite**, a nepheline syenite with tabular feldspar texture. The foyaite carries xenoliths of alkali granite and quartz syenite of the "upper border zone".

Sodalite foyaite constitutes the upper zone of the main agpaitic rock type of the roof sequence that is called **naujaite**. Both rock types are coarse-grained rocks, carrying alkali feldspar, nepheline and sodalite as major rock forming minerals, besides some arfvedsonite, aegirine and eudialyte. The texture of sodalite foyaite is massive in contrast to the poikilitic crystallisation pattern of naujaite. Slightly less than half of the volume of naujaite consists of sodalite that is poikilitically enclosed into large crystals of feldspar and nepheline as well as eudialyte. The naujaite layer is considered to have developed towards a flotation cumulate on the grounds of its textural pattern.

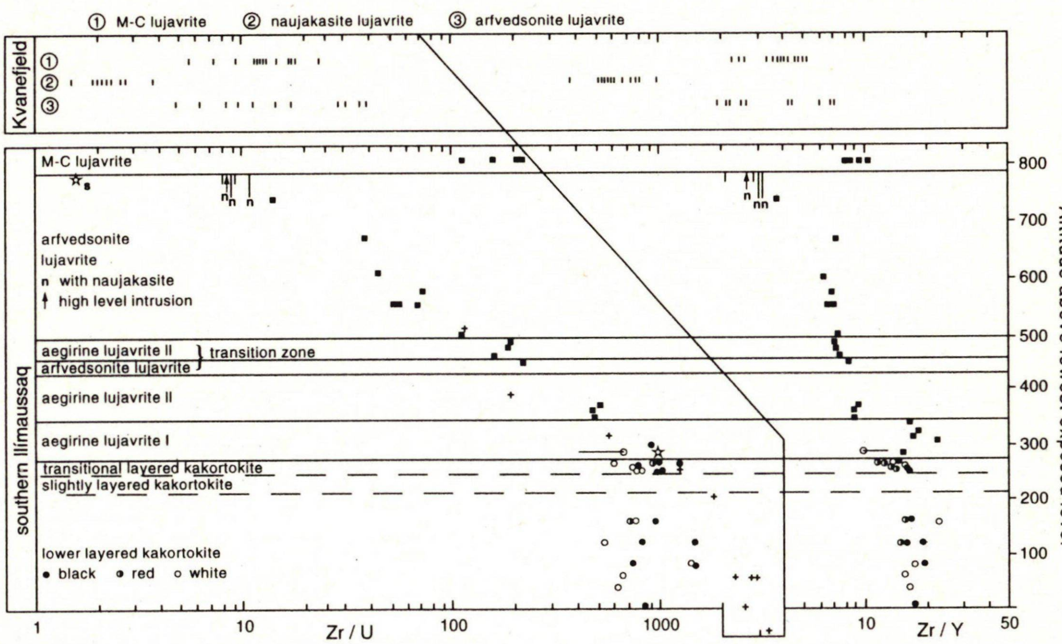

Fig. 2. Zr/U and Zr/Y stratigraphy of the kakortokite-lujavrite sequence in the southern part of the Ilímaussaq intrusion compared to the lujavrite sequence on Kvanefjeld. After Andersen *et al.* (1981).

● ◑ ○ Black, red and white kakortokite respectively,

■ Lujavrites: vertical bar points out uncertainty in stratigraphic position,

\+ Zr/U ratio based on fission track analyses of eudialyte (Steenfelt & Bohse, 1975), Analyses of eudialyte concentrate (e) and steenstrupine concentrate (s).

ELEMENTAL ENRICHMENT IN THE ILÍMAUSSAQ INTRUSION RELATED TO EXPLORATION

Introductory remarks

The agpaitic rock suites of the Ilímaussaq alkaline complex show characteristic enrichment of the following chemical elements in ascending order of atomic weight: Li, Be, F, Y, Zr, Nb, REE, Th and U, often contained in rare minerals. The dominant minerals arfvedsonite, eudialyte, steenstrupine, rinkite, pyrochlore, chkalovite and villiaumite are listed in Table 1 with their compositions.

Table 1. Mineral species contributing to elemental enrichment in the Ilímaussaq intrusive complex

Arfvedsonite	$Na_3Fe_4^{2+}Fe^{3+}Si_8{\cdot}O_{22}(OH)_2$
Eudialyte	$(Na,Ca,Fe)_6Zr\,|(OH,Cl)(Si_3O_9)_2|$
Steenstrupine	$Na_{12-X}H_XCa(La,Ce,Nd)_6(Mn,Fe,Th,Zr,U)_5$ $(Si_6O_{18})_2|(CP,Si)O_4|_6(OH,Ce)nH_2O$
Rinkite	$Na_2Ca(Ca,Ce)_4(Ti,Nb)\,|(F,O)_2Si_2O_7|_2$
Pyrochlore	$(Ca,Na)_2(Nb,Ta)_2O_6(O,OH,F)$
Chkalovite	$Na_2BeSi_2O_6$
Villiaumite	NaF

The abundance of these minerals varies in the different rock types of the complex. Three of these, arfvedsonite, eudialyte and steenstrupine, occur widespread in the series of agpaitic rocks. While eudialyte is a rock forming mineral of both the naujaite in the roof zone and the bottom accumulate, i.e. the kakortokites, it is a less conspicuous rock component in the different types of lujavrite, which upwards in the sequence contains steenstrupine as a scavenger for incompatible chemical elements. The beryllium containing mineral chkalovite is mainly found in veins in hydrothermally altered naujaite and lujavrite. Pyrochlore and rinkite, the niobium carrying minerals, are preferentially found in different lujavrite varieties. The same is the case for villiaumite.

In the following chapters the exploration of the mineral occurrences found in the Ilímaussaq complex are briefly reviewed. By far the most extensive exploration efforts have been carried out on Kvanefjeld, where uranium is mainly contained in steenstrupine.

The exploration of eudialyte occurrences started already in 1888 and has been resumed intermittently since then. These surveys have exclusively taken place in the southern part of the Ilímaussaq complex, south of the fjord Tunulliarfik.

Exploration for chkalovite and efforts to extract villiaumite from lujavrite have been carried out in close conjunction with the on-going exploration of the Kvanefjeld uranium occurrence.

Lately Steenfelt (1991), Sørensen (1992) and Kalvig & Appel (1994) have underlined the statement that peralkaline nepheline syenites, including the Ilímaussaq alkaline intrusion and related rocks, may be a potential source of rare elements currently utilised in advanced materials.

Lithium

The enrichment of lithium in the agpaitic rock suite of the Ilímaussaq intrusion is largely confined to the content of the widely distributed rock-forming mineral arfvedsonite. Judged from the accumulated data a progressive increase of the lithium content in arfvedsonite occurs in the late magma derivatives, i.e. the different lujavrites. Bailey *et al.* (1993) and Bailey & Gwozdz (1994) have treated the subject of the lithium content in minerals from the intrusion.

The other Li-bearing minerals that have been identified in the Ilímaussaq complex are listed in Table 2.

The lithium content of the late, black arfvedsonite lujavrites varies between 600 and 1000 g/t. Lepidolite and neptunite have been found scattered in pegmatites. The lithium grades of the uraniferous rocks of the Kvanefjeld deposit and the estimated tonnage of the total content have been given by Nyegaard (1979). However, no efforts have so far been undertaken to evalue the possible recovery of lithium from these rocks.

Table 2. Lithium minerals found in the Ilímaussaq intrusion

Mineral	Formula
Lepidolite	$KLi_2Al\|(F,OH)_2\|Si_4O_{10}$
Neptunite	$KNa_2Li(Fe,Mn)_2Ti_2\|OSi_4O_{11}\|_2$
Riebeckite	$Na_2Fe_3^{2+}Fe_2^{3+}Si_8O_{22}(OH,F)_2$
Cookeite	$Al_2\|(OH)_2AlSi_3O_{10}\|^1LiAl_2(OH)_6^{1+}$
Ephesite	$NaLiAl_2\|(OH)_2\|Al_2Si_2O_{10}$
Gerasimovskite	$TiNb(OH)_9$
Astrophyllite	$(K,Na)_3(Fe,Mn)_7(Ti,Zr)_2\|Si_8(O,OH)_{31}\|$

Source: Semenov (1969).

Beryllium

Since the turn of the century it has been known that leucophane occurs in sodalite foyaite of the Ilímaussaq intrusion (Bøggild, 1953). Later a number of other beryllium containing minerals have been identified as listed in Table 3.

Tugtupite and sorensenite are new mineral species so far only found in this alkaline intrusion. By far the most common mineral species is chkalovite. Chkalovite occurs in late stage veins that consist of albite, analcime, natrolite and ussingite, often confined to the roof sequence of the alkaline rock series. More specifically these veins are found in rock types that have been subjected to hydrothermal alteration and subsequent veining, including different varieties of lujavrite on Kvanefjeld.

In the northernmost part of the naujaite zone, on the mountain slope between Taseq and Narsaq Elv, beryllium enrichment is most prominent. Detailed prospecting was carried out in this area from 1965 until 1967 under the auspicies of the Geological Survey of Greenland by staff members of the Geological Institute of the University of Copenhagen. Construction of the beryllometer that was used in the field was undertaken by the Research Establishment Risø. The instrument has been described by Løvborg *et al.* (1968).

Table 3. Beryllium minerals found in the Ilímaussaq intrusion

Mineral	Wt% BeO	Formula
Bertrandite	40-43	$Be_4(OH)_2(Si_2O_7)$
Beryllite	40	$Be_3SiO_4(OH)_2H_2O$
Chkalovite	11-13	$Na_2BeSi_2O_6$
Epididymite	11	$NaBe(OH)Si_3O_7$
Eudidymite	11	$NaBeOHSi_3O_7$
Gelbertrandite	*c.* 34	$Be_4(Si_2O_7)(OH)_2{\cdot}H_2O$
Genthelvine	11-14	$ZnS_2(BeSiO_4)_6$
Leucophane	10-12	$NaCaBe(Si_2O_6)F$
Sorensenite	7-8	$Na_4SnBe_6Si_2O_{16}(OH)_4$
Spherobertrandite	40-43	$Be_5(Si_2O_7)(OH)_4$
Tugtupite	5	$Na_8Cl_2(Be{\cdot}AlSi_4O_{12})_2$

Hansen (1965) presented a description of different types of beryllium mineralisation that had been observed in the intrusion. A full account of this exploration effort has been given by Engell *et al.* (1971).

The area that was covered is approximately 3 km^2, positioned at altitudes between 600 and 430 m a.s.l. Within this area, a sub-area was selected for sampling on the basis of very detailed field observations with the beryllometer. In the economic appraisal of this exercise a rough estimate is given of an indicated 180,000 tons of rock with an average content of 0.1% BeO.

As mentioned before, beryllium containing minerals also occur in the uranium occurrence at Kvanefjeld. No further attempts have been made to pinpoint local enrichment. Nyegaard (1979) mentions an average Be content of 67 g/t in the hydrothermally affected lujavrite variety containing the mineral naujakasite. The average Be content of the total rock volume of the Ilímaussaq intrusion is 30 ppm according to Gerasimovsky (1969).

Zirconium, niobium, REE (yttrium, lanthanum and lanthanides) and tantalum

The above chemical elements are all contained in eudialyte, a mineral of variable composition. Its compositional variation is mainly dependant on the solidification stratigraphy of the enclosing intrusive rocks.

Markland (1974) has given a recent chemical analysis of an eudialyte concentrate obtained from red kakortokite. The purity of this sample is 97%, the remainder being mainly rinkite. This analytical result is given in Table 4. Bøggild (1953) gave older chemical analyses of eudialyte.

Table 4. Chemical analysis of a eudialyte concentrate

Element	%
ZrO_2	11.66
HfO_2	0.18
Nb_2O_5	1.04
Ta_2O_5	0.072
REE_2O_3	2.80
Na_2O	11.50
K_2O	0.28
CaO	10.80
Fe_2O_3	4.81
Al_2O_3	0.66
TiO_2	0.30
MnO	0.65
SiO_2	47.10
Cl	1.45
OH	1.02
W	0.016
U	24 ppm
Th	88 ppm

The REE composition of eudialyte in different rock types is presented in Table 5 (Sørensen, 1992).

The distribution of uranium in eudialyte has been studied by Steenfelt & Bohse (1975).

Table 5. REE composition of eudialyte from the Ilímaussaq complex (ppm)

		Red kakortokite			Green lujavrite		
	Naujaite	Layer-9	Layer-0	Transitional			Sodalite
	D7-34.5	109269	109202	60755	D7-96	D7-46	foyaite
La	3012	3424	3298	3986	6601	7539	3620
Ce	6560	7750	7130	9260	15,650	17,550	5810
Pr	806	992	884	1197	2081	2276	782
Nd	2615	3227	2823	4008	6953	7658	2600
Sm	506	652	557	838	1449	1528	588
Eu	n.a.	67	56	78	135	n.a.	52.3
Gd	586	737	642	926	1472	1548	614
Tb	91	113	108	139	201	199	-
Dy	644	778	695	932	1369	1407	682
Ho	156	174	167	196	284	286	-
Er	434	515	488	574	793	796	-
Tm	(74)	(81)	(78)	(78)	(94)	(90)	-
Yb	41	500	480	535	727	734	579
Lu	61	70	67	78	102	101	105
Y	2814	3274	3072	3989	6148	6410	3720
Total	15,962	19,080	17,473	22,825	37,911	41,712	15,880
La/Yb	7.2	6.8	6.9	7.5	9.1	10.3	6.2

Exploration

The exploration for eudialyte occurrences in the Ilímaussaq complex dates back to the last century. It was known then that eudialyte is easily dissolved in dilute acid, hence the name given to this mineral, derived from Greek.

In 1888 and 1889, 59 metric tons of hand picked eudialyte-rich pegmatitic rock were collected on the tiny island Qeqertaasaq at the head of Kangerluarsuk, with the aim of extracting cerium. However, it was not possible then to find an industrial outlet for a eudialyte concentrate prepared from this material. In 1946 Kryolitselskabet Øresund A/S undertook a new effort to utilise eudialyte. This time attention was focused on the eudialyte-rich cumulates of kakortokite. Again the outcome was futile. No detailed records are available of these early explorations. They were only mentioned in brief notes by Bøgvad (1949, 1950). From 1968 until 1976 Superfos A/S explored the southern part of the Ilímaussaq intrusion. A number of bulk samples of the eudialyte-rich red kakortokite variety and of beach sand were tested. Several reports, registered under the heading Superfos A/S, Udviklingsafdelingen (1971), describe milling and magnetic separation tests. One report deals with chemical processing of eudialyte concentrates.

Finally a draft concept of the utilisation and mining of the eudialyte occurrences was presented by Markland (1974).

In 1986 A/S Carl Nielsen (Calkas A/S) obtained an exclusive licence to explore the floor sequence of the alkaline complex. Not only were the repetitive bands of kakortokite sampled and analysed for zirconium, yttrium and niobium, also the lowermost aegirine lujavrite layer was examined. Two diamond drillings were carried out in order to delineate the true width of one particular layer of red kakortokite, designated +16, situated at a high level in the banded kakortokite series. (A/S Carl Nielsen, 1986-87, 1988). In 1987, a joint venture in which Highwood Resources Ltd., Platinova Resources Ltd. and Aber Resources Ltd. participated, obtained exclusive exploration rights at three different sites in the area between Tunulliarfik and Kangerluarsuk, an area that is largely covered by naujaite and pulaskite. Detailed sampling was carried out and nine shallow holes were drilled. Bulk sampling of the eudialyte carrying rock types provided material for further testing and processing. In 1990 the two concessionaires in the area south of Tunulliarfik joined forces and obtained a revised permit to further explore the most promising occurrences of rock types containing eudialyte. This licence is still in force. Further details can be obtained from the operator in this recent joint venture, Highwood Resources Ltd. In 1992 an exclusive exploration licence, covering an area of 58 km^2 of exposed naujaite was issued to Mineral Development International A/S in order to investigate possible utilisation of sodalite, found in association with eudialyte.

Besides the above mentioned activities by private companies, the Geological Survey of Greenland carried out exploration in the area south of Tunulliarfik, in cooperation with the Geological Institute of the University of Copenhagen and the Research Establishment Risø.

In 1962 seven diamond drillings, all to a depth of 200 m were completed in different lujavrite localities, especially in the southern part of the complex (Bondam & Ferguson, 1961). The position of these drill holes is indicated in Figure 1. The aim of the drilling program was to obtain a more detailed picture of the lujavrite magma solidification stratigraphy and gradual uranium enrichment at higher levels of the sequence as compared to the distribution of among others, yttrium, zirconium, hafnium, niobium and tantalum in the floor sequence.

Preliminary descriptions of the drill holes and of the geochemical distribution were given by Rose-Hansen (1969) and Andersen (1982). One of these drill holes in particular, the southernmost one, designated number 7, was studied in great detail as it cuts the aegirine lujavrite I layer found on top of the kakortokite sequence. As an example the distribution of ZrO_2 in the drill core is given in Fig. 3.

The mean contents of a number of selected chemical elements present in the floor sequence rocks of the intrusion and in eudialyte found in these rocks is given in Table 6. As can be deduced from these figures, eudialyte that occurs in aegirine lujavrite I is particularly enriched in rare earth elements and niobium.

Andersen *et al.* (1981) further elaborated the Zr-Y-U solidification stratigraphy in the floor sequence of igneous rocks in the Ilímaussaq intrusion, as illustrated in Fig. 2.

The drill cores from borehole 4, situated at Naajakasik at the southern shore of Tunulliarfik and from borehole 2, situated at Tugtup Agtakorfia on the northern shore of the fjord have served as models for the distribution of Zr, Y, U and REE in the two upper levels of the floor sequence, aegirine lujavrite II and arfvedsonite lujavrite. Unpublished data are given in a report by Andersen (1982).

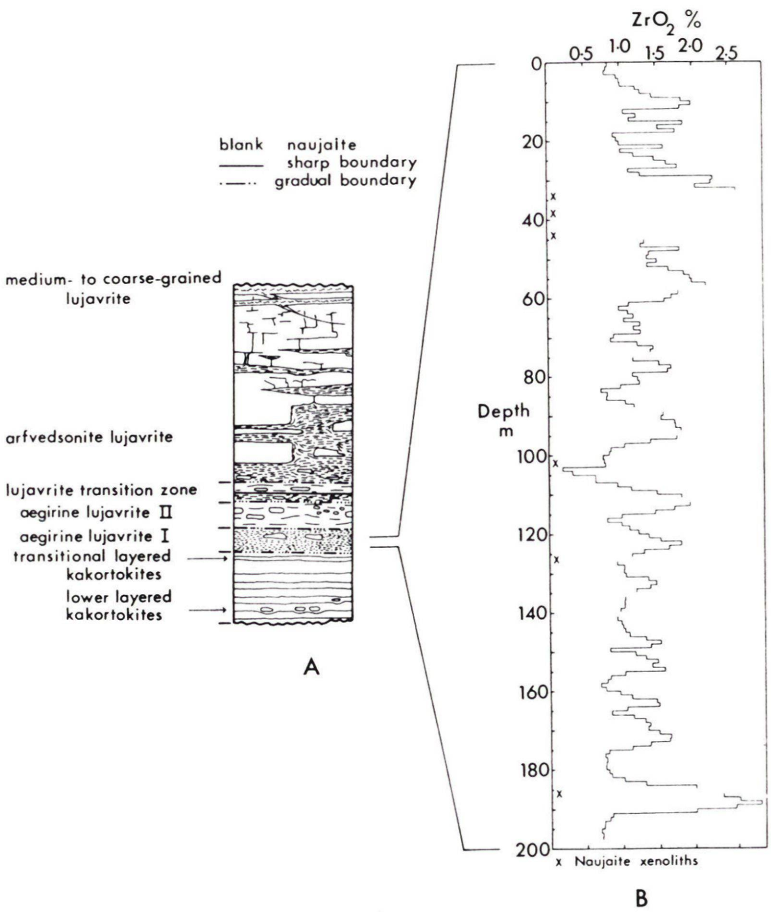

Fig. 3. ZrO_2 profile of diamond drill core 7 (cf. Fig. 1) in aegirine lujavrite I (B) and its position in the igneous stratigraphy for the Kangerluarsuk area (Bailey *et al.*, 1981b).

An interesting exploratory study was carried out in 1968 and 1969 by Bohse *et al.* (1971) when portable X-ray fluorescence equipment was used to delineate the rhythmically layered succession of kakortokite varieties. An account is given of the Zr and Nb contents in different rock types. From the field observations (n = 268) it is concluded that the ZrO_2/Nb_2O_5 ratio on average is 9.5 in red kakortokite, 9.8 in the white kakortokite and 10.7 in black kakortokite.

Several rough estimates of the total content of ZrO_2 and Nb_2O_5 in the kakortokite series have been presented. None of these estimates are based on detailed evaluation of drill cores or careful delineation of prospective occurrences. Sørensen (1992) cited the

Table 6. Mean contents of selected rare elements in kakortokites and aegirine lujavrite I in the Ilímaussaq alkaline intrusion

	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	3390
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; densitites of Forsberg & Rasmussen, 1978).

3. Analyst: H. Bohse. Method: XRF analysis.

maximum figures given as 61 Mt ZrO_2 and 6.5 Mt Nb_2O_5 for the whole volume of kakortokites.

The use of eudialyte as a stabilising agent in ceramics was the object of study of a recent BRITE EURAM research project "Alternative stabilizers for zirconia ceramics: powders derived by processing eudialyte". The registration number of the research contract is MAIE-0019.

Niobium and tantalum

Consistent moderately elevated levels of niobium and tantalum are found in a variety of rock types in the Ilímaussaq intrusion (Hansen, 1967, 1968). A number of niobium containing rare minerals have been identified in different late-stage environments, in particular in hydrothermal veins in metasomatically altered older rock types. In these occurrences pyrochlore and murmanite are the dominant niobium and tantalum bearing minerals (Sørensen *et al.*, 1974). The niobium and tantalum containing minerals found in the intrusion are listed in Table 7.

Fluorine

Fluorine is primarily concentrated in villiaumite (NaF); to a far lesser extent it is found in other rock forming and accessory minerals in the intrusion, i.e. arfvedsonite, eudialyte, rinkite, pyrochlore and steenstrupine. According to Makovicky *et al.* (1980) steenstrupine contains 0.27 % F. Since villiaumite is soluble in water it is only present in fresh rock. Bondam & Ferguson (1962) described the presence of villiaumite in naujaite and in lujavrite, as well as from pegmatic veins, more specifically in mineral parageneses which have undergone late-stage alteration. Villiaumite is conspicuously present in the lujavrites of the Kvanefjeld uranium occurrence. Although it is a common accessory mineral, the distribution of villiaumite in lujavrite is irregular. The fluorine content of the fine-grained lujavrite variety is reported to vary between 0.65 and 1.07 % (Kalvig, 1983).

Table 7. Niobium and tantalum containing minerals found in the Ilímaussaq intrusion

		Wt%	
		Nb_2O_5	Ta_2O_5
Epistolite	$(Na,Ca)_2(Nb,Ti,Mg,Fe,Mn)_2(OH)_2Si_2O_7$	31.8-37.0	0.24-0.47
Gerasimovskite	$TiNb(OH)_9$	40.6	0.0
Igdloite	$NaNbO_3$	58.5-62.4	0.15
Ilimaussite	$Na_2Ba(CeFe)NbSi_4O_{14}{\cdot}2.5H_2O$	13.2	n.d.
Murmanite	$Na_2MnTi_3[O\|Si_2O_7]_2{\cdot}8H_2O$	0.7-9.4	0.10
Nenadkevichite	$(Ca,K,Na)(Ti,Nb)Si_2O_{72}H_2O$	28.1	0.37
Niobophyllite	$(K,Na)_3(Fe,Mn)_7(Nb,Ti)_2Si_8(O,OH)_{31}$	4.2-7.1	0.01-0.04
Pyrochlore	$(Na,Ca)_2(Nb,Ta)_2O_6(OH,F,O)$	40.9-59.9	0.11-1.30
Tundrite	$Na_2Ce_2Ti\|O_4{\cdot}SiO_2\|_4H_2O$	4.3-6.1	n.d.
Eudialyte	$(Na,Ca,Ce)_6Zr(OH,Cl)(Si_3O_9)_2$	0.6-1.0	0.07
Rinkite	$Na_2Ca(Ca,Ce)_4\|(Ti,Nb)(F,O)_2Si_2O_7\|_2$	2.4	0.09
Sorensenite	$Na_4SnBe_2(OH)_4Si_6O_{16}$	1.36	n.d.

Another source (Nyegaard, 1979) mentions an average of 1.17 % F in the villiaumite containing lujavrites.

Preliminary studies of the distribution of fluorine in the lujavrite sequences, in which a number of samples from drill cores were included, were carried out by Bailey *et al.* (1981c).

Fluorine is considered a by-product in the possible exploitation of the uranium occurrence. Flotation of villiaumite from naujakasite lujavrite by means of sodium oleate has been developed in a small scale operation (Sørensen, 1973).

Since the solubility of villiaumite may pose environmental hazards in exploitation it has also been considered to extract sodium fluoride in solution in the carbonate pressure leaching process which was carried out on a pilot plant scale (Sørensen, 1983). The solution was precipitated with gypsum to produce calcium fluoride. Another possibility that has been preliminary tested is the use of a sodium fluoride solution as an agent in the precipitation of synthetic cryolite (Na_3AlF_6), as reported by Vandel (1983). Nyegaard (1979) has calculated the total tonnage of fluorine present in the northern part of Kvanefjeld to be 0.457×10^6 tons at an average grade of 0.96 % F in the total volume of uraniferous lujavrite.

Thorium and uranium

The dominant radioactive mineral in the Ilímaussaq intrusive series is steenstrupine, a complex phosphosilicate with the generalised formula
$Na_{12-x}H_x\ Ca(La,Ce,Nd)_6\ (Mn,Fe,Th,Zr,U)_5\ (Si_6O_{18})_2\ [(P,Si)O_4]_6\ (OH,Cl)\cdot nH_2O$.

To a far minor extent thorium is concentrated in thorianite. Steenstrupine is subject to alteration and may be replaced by monazite and uranothorite (see Makovicky, 1981). Small amounts of thorium and uranium are also present in eudialyte, britholite, pyrochlore and rinkite. A thorough discussion of the distribution of thorium and uranium in the different rock types of the intrusion is given by Bailey *et al.* (1981d).

Exploration

Long term and extensive exploration efforts were undertaken with respect to the occurrences of uranium. As the mining law for Greenland specifically excludes private exploration for radioactive minerals, all operations were carried out under the auspicies of the state authority. The Geological Survey of Greenland and the Research Establishment Risø cooperated closely in the execution of the exploration efforts.

The Geological Institute of the University of Copenhagen took part in geological and mineralogical studies related to the exploration activities, and subsequently initiated a broad environmental study programme, called "Narssaq Project" which lasted from 1974 until 1976 covering the whole area occupied by the intrusion.

In 1956 it was clear that the most promising grades of uranium occurred on Kvanefjeld in the northernmost part of the Ilímaussaq intrusion. At this locality late-stage lujavrites intrude, and include, a variety of older rocks, ultimately forming an extensive intrusive breccia located at the fringe of the complex, bordering extrusives of the Eriksfjord Formation.

The final evaluation of the Kvanefjeld uranium deposit was carried out from 1978 until 1983, under the heading "Uranprojekt Kvanefjeld". This project was managed by the Research Establishment Risø. In a final report, the project group in charge gives an account of the assessments with respect to mine planning and further development of extractive processing, energy supply, radiation exposure and protective measures, economic considerations and finally the environmental impact of an integrated mining operation, based on an annual capacity of 4.2 million tons of mill feed (Uranprojekt Kvanefjeld, 1983).

A list of references of special and technical reports prepared under the heading of this research project is given in the appendix. Some of these reports will be referred to in more detail under different chapters in the present report.

No further exploration efforts were undertaken after the above project was terminated, partly because uranium oxide spot market prices sharply declined during the period 1979-1982 and partly because the Home Rule Authority in Greenland voted against the exploitation of the uranium resources on Kvanefjeld.

A number of reports prepared for the "Uranprojekt Kvanefjeld" deal with relevant background information collected during previous studies of the deposit and its environment. Many aspects which are treated in this context are reviewed under separate headings in the present report. Reports on work carried out exclusively related to exploration activity on Kvanefjeld since the discovery of the uranium deposit have so far only been reviewed to a limited extent. This accounts for the results of drilling operations and reserve estimates, extractive metallurgy, environmental considerations, and actual mining operations carried out so far. It also accounts for earlier views and studies on the possible exploitation of the uranium deposit.

THE URANIUM DEPOSIT AT KVANEFJELD

The deposit was discovered in 1956 during a systematic radiometrical reconnaissance survey of the whole Ilímaussaq intrusion. The subsequent exploration of the deposit has been reviewed by Nielsen (1981).

In retrospect, an unusually long period of time elapsed between the initial drilling programme and detailed radiometric surveys in 1957 and 1958, until all further efforts were finally terminated in 1983. This is mainly due to the singular nature of this type of uranium enrichment, in lujavrites, which encouraged further, often scientifically motivated research and development, on an extensive scale.

Geological setting

The geological structure of this part of the Ilímaussaq intrusion is complicated and prevents a straightforward description of the mode of emplacement in relation to succesive phases of hydrothermal alteration and elemental enrichment.

In general terms the whole assemblage of different rock types found on Kvanefjeld, is an intrusion breccia, the ultimate result of forcefull emplacement of several late-stage lujavrite injections, causing not only brecciation, but also deformation and alteration of adjacent earlier intrusive phases.

The oldest brecciated rocks are considered partly as remnants from the Eriksfjord Formation, i.e. quartzitic sandstone, lavas, gabbroic sills and deep-seated anorthosite, partly as augite-syenite emplaced at an early stage of alkaline intrusion. To this can be added younger rock inclusions of earlier emplaced cumulates of the agpaitic magma, i.e. foyaite, pulaskite and naujaite.

The lujavrites of the uranium deposit at Kvanefjeld occur in a variety of different types, frequently intersecting and accompanied by late-stage apophyses and pegmatitic veins (Sørensen *et al.*, 1984). The prominent types have been named medium- to coarse-grained black lujavrite, often abbreviated to m-c lujavrite, fine-grained black arfvedsonite lujavrite, green aegirine lujavrite, and naujakasite lujavrite. This subdivision has been applied in drill core logging (Nyegaard *et al.*, 1977) and in leaching studies (Makovicky *et al.*, 1980).

M-c lujavrite is presumably the youngest member of the intrusive suite of late-stage agpaitic rock types. Its main occurrence on Kvanefjeld is a single sheet underlying a gabbroic roof remnant. The sheet is furthermore characterised by internal folding of the fabric and pegmatitic veining, particularly enriched in analcime, but also carrying pyrochlore and chkalovite (Sørensen *et al.*, 1971). A few thin lamprophyre dykes cut the intrusion breccia of Kvanefjeld in a south-western direction.

An account of the structural pattern of the Kvanefjeld plateau is given by Sørensen *et al.* (1969). A detailed geological map of part of the Kvanefjeld area in a scale of 1:3484 has been prepared by Sørensen *et al.* (1974).

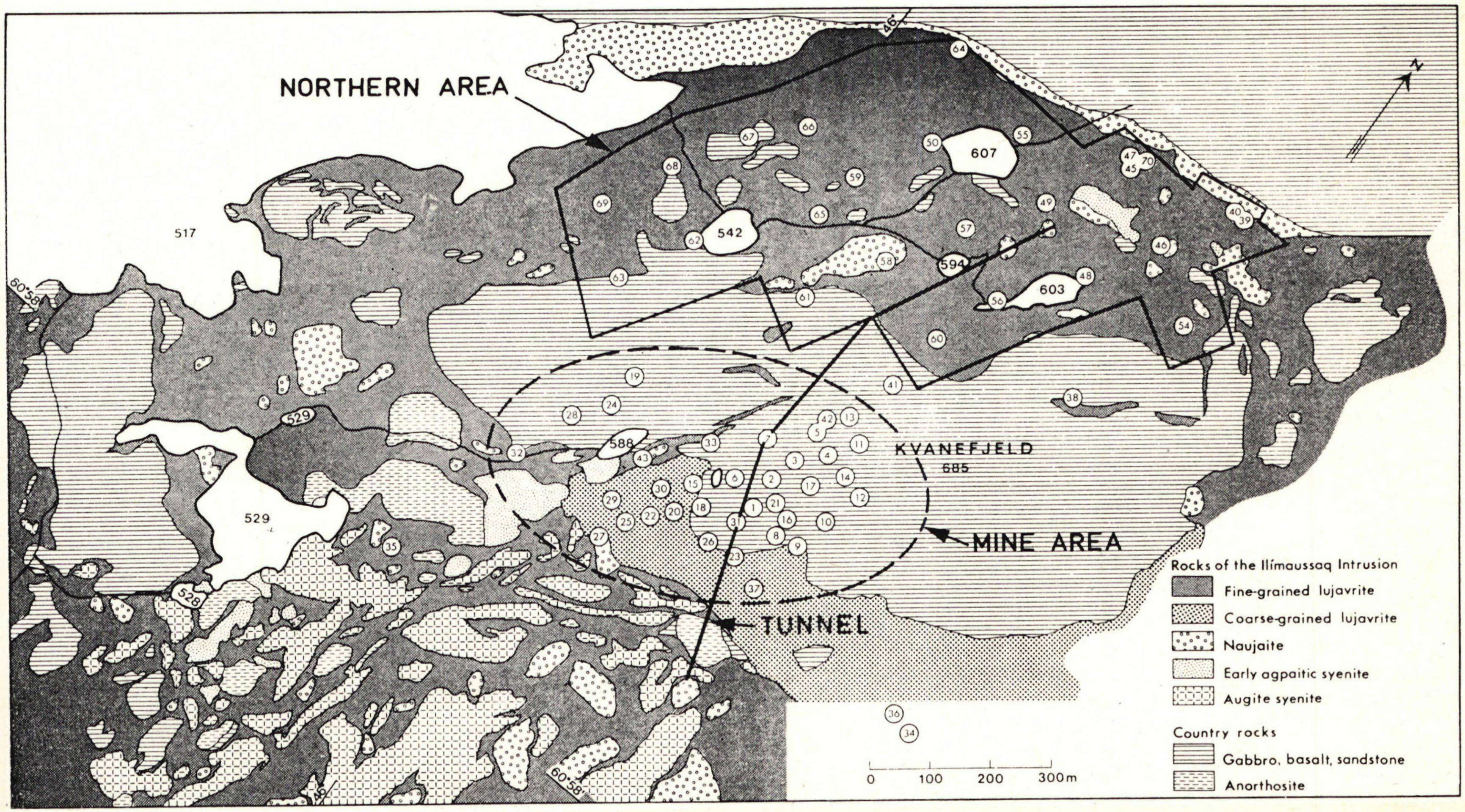

Fig. 4. Simplified geological map of Kvanefjeld plateau showing the position of numbered diamond drill holes and the exploration tunnel, after Nielsen & Steenfelt, 1979.

A simplified geological map of the Kvanefjeld plateau, also showing the location of diamond drill holes, the exploration tunnel and designation of sub-areas is given in Fig. 4.

Drilling operations

The first drilling programme was carried out in 1958 at the discovery site on Kvanefjeld, an area that later has been named "Mine area". It comprised 36 drill holes with a total length of 3728 m. Of these holes 30 were drilled in the "Mine area" in a grid of approximately 50 m: the remaining 6 were drilled in the valley beneath the discovery site. A gamma-logger, Mount Sopris, was used in the field. The cores were relogged in 1969 at the Research Establishment Risø (Løvborg *et al.*, 1972).

In 1962 a minor drilling operation was carried out at a number of localities in the southern part of the intrusion, both to ensure that the Kvanefjeld uranium occurrence could be considered to be the most prospective one, albeit of low grade, and to obtain further data on the stratigraphy of the lujavrite sequence. A total of 7 drill holes were completed, with a combined length of about 1400 m. In the same season 2 previous drill holes at Kvanefjeld were deepened (Andersen, 1981).

A third drilling programme was carried out at Kvanefjeld in 1969. In all 1621 metres were drilled covered by 6 holes.

Finally a drilling programme was carried out in 1977 in the northern part of the Kvanefjeld deposit, along the contact of the intrusion with a series of volcanic rocks of early Gardar age. In all 27 holes were drilled with a total core length of 5103 metres. Four of these drill holes were positioned downslope of the deposit to establish the possible eastern extent of the uranium deposit. A full report on this drilling programme has been compiled by Nyegaard *et al.* (1977). The coordinates of a total of 70 drill holes in a chosen grid system and their length have been reported by Erlendsson (1981). The position of a number of the above drill holes is given in Figure 4.

Reserve calculations

In a detailed report by Nyegaard (1979) the results of systematic chemical analyses of core samples from the succesive drilling programmes are compiled. The report offers a comprehensive geochemical spectra of the uranium-bearing lujavrites found within the deposit. The content and distribution of different elements is evalued, i.e. tonnages and grades are estimated for U, Th and F as major enrichments, besides Zr, Nb, Zn, Li and Rb, employing frequency distribution diagrams etc.

A total reserve calculation, based on 5658 analysed drill core samples, using geostatistical estimation methods, was undertaken by Clausen (1982) on the basis of a model previously described by Clark & Clausen (1981). Tilsley & Fisher (1982) applied a more convential method for estimating the uranium ore grade and available tonnage, by creating a 3-dimensional model of the deposit based on sections at a scale of 1:1000. Both these estimates were based on a cut-off grade of 250 g U/t. The discrepancy between the two reserve calculations has been discussed by Kalvig (1983). An elaborate assessment is presented with respect to an ultimate exploitation of the uranium deposit on Kvanefjeld in an open pit operation. As potential byproducts Li, Be, F, Mn, Ga, Zn, Y and the lanthanides are mentioned. The report offers a very comprehensive list of references, including a number of internal reports from the Geological Survey of Greenland, covering the whole period in which active exploration activity has been carried out, beginning in 1956.

PROCESSING OF URANIUM-THORIUM ORES FROM THE KVANEFJELD DEPOSIT

As mentioned previously, uranium is chiefly contained in a rare, unstable phospho-silicate of varying composition called steenstrupine which usually occurs in a more or less altered form. The alteration is essentially a gradual decomposition of the hexagonal matrix into a number of phases with different P/Si ratios. Uranium tends to accumulate in P-deficient phases and may ultimately occur as uranium oxide stain. The decomposition of steenstrupine is partly due to post-magmatic processes, partly to atmospheric weathering. A certain amount of uranium is thus present in ill-defined "pigmentary material" that is found irregularly distributed in the lujavrites, mostly as a coating on the outer rim of other minerals or dispersed interstitially. This "pigmentary material" is particularly enriched in Fe, Mn, Zr and Si.

Uranium is also contained in monazite and eudialyte, accessory minerals that may occur in some of the lujavrite types. Another commonly occurring radioactive accessory mineral is thorite.

Erratic and often unsatisfactory results of uranium beneficiation tests in the laboratory, on different types of lujavrite, gave rise to detailed mineralogical and leaching studies in order to obtain a better understanding of the problems encountered. Makovicky *et al.* (1980) found that the recovery of uranium from the different rocks of the Kvanefjeld deposit was dependent on a variety of parameters. They recognised that autometamorphic hydration of the lujavrites, variations in the mineral paragenesis of the different rock types and the stage of alteration of the steenstrupine are the dominant factors that influence the uranium yield.

With the available knowledge of the distribution of uranium in the lujavrites a number of benefication methods were tested in the laboratory and on a minor pilot plant scale for a number of years. These included froth flotation and high intensity magnetic mineral separation, besides sulphating roasting and carbonate pressure leaching as uranium extraction methods.

In 1962 about 180 metric tons of uraniferous lujavrite containing 380 g/t U was quarried in the southernmost part of the deposit. In 1980 an additional 4700 tons of lujavrite was extracted from an exploration addit in order to obtain a more representative bulk ore sample of uraniferous lujavrites for further metallurgical processing in a pilot plant. To this end uranium recovery was carried out by continuous carbonate leaching under high pressure in a pipe autocalve. The experiments were discontinued in 1984.

In the following sections a short review is given of available data of the benefication aspects mentioned above.

Froth flotation, high intensity magnetic separation

Sørensen & Lundgaard (1966) reported on 7 laboratory experiments to classify steenstrupine and monazite from −100 mesh samples of m-c lujavrite, using a Fagergren cell.

It was found that linoleic acid is a more efficient collector than oleic acid. Trace amounts of $La(NO_3)_3$ added to the raw pulp enhances the adsorption of the collector agent. Though good separation of both steenstrupine and monazite was obtained, a considerable amount of uranium remained in the tailings due to its distribution in very fine grained material of less well-defined composition and of a partially amorphous structure.

An "Appendix I" was added to these preliminary experiments by the same authors (Sørensen & Lundgaard, 1967). Further elaboration of flotation techniques indicated that uranium and thorium recoveries in excess of 70 per cent could be achieved.

In order to verify these findings Klassen (1979) completed 103 flotation tests on 4 different samples that covered the different types of ore found in the deposit. He also carried out 5 high intensity magnetic separation runs on the different types of lujavrite.

In addition, high intensive magnetic separation tests were conducted on flotation concentrates in order to evalue the feasibility of further upgrading prior to metallurgical extraction of uranium. A number of different reagents were tested, i.e. desliming with sodium silicate "N" and Quebracho, and conditioning with both pine oil, Acintol FA-1 and FA-2 and Cyanamid 845. The effects of increased reagent rates and the influence of pH control have also been considered. As experienced previously the recovery of uranium and thorium varied between wide ranges; only in a few test runs could a uranium recovery slightly over 70 per cent be obtained. Further testing of mechanical separation methods was deemed to be futile.

Sørensen (1973) described the adsorption of a number of collectors on villiaumite.

Sulphating roasting

Ways to solubilize uranium from the refractive type of ore like lujavrite has been studied in detail over a period of years.

After discarding leaching with diluted sulphuric acid on the grounds of the alkalinity of the ore, and carbonate leaching as being ineffective, sulphating roasting was found to be applicable as a first approach.

The method is basically treatment of milled ore with SO_2 gas mixed with dry air at temperatures around 700°C. In the process the refractory uraniferous minerals are selectively affected and disintegrated, after which a number of different soluble sulphates are formed. After subsequent extraction of the pregnant liquid, uranium is recovered either by precipitation or by solvent extraction using Alamine 336 (Sørensen & Lundgaard, 1967). It was found that steenstrupine, arfvedsonite and monazite are the most reactive minerals present in the ore, when subjected to sulphating roasting. However it was evident from laboratory experiments that the yield of uranium could vary appreciably from sample to sample.

The reactivity of the mineral content and the uranium recovery of the sulphating roasting process was studied by Hansen (1977).

The chemistry of the uranium carrying silicate phases and the kinetics of sulphating roasting were investigated by Asmund (1971). A general account of the findings of this experimental work on uranium extraction from the lujavrites was presented by Asmund *et al.* (1971).

It was decided to carry out sulphating roasting on a semi-pilot plant scale at a capacity of 100 kg/h. About 130 metric tons of m-c lujavrite were available for the test runs. A continuous process, including pelletising of ground ore, roasting, dissolving, clarifying and final recovery of uranium was established. Test runs were carried out over a number of weeks in 1976 and 1977. The results of these tests have been reported by Sørensen *et al.* (1978). The obtainable recovery of uranium was unsatisfactory, hovering around 60 ± 10 % of the contained ore grade. For that reason sulphating roasting was no longer considered a feasible way of uranium extraction from lujavrite.

Carbonate pressure leaching (CPL)

The next approach to metallurgical benefication was to initiate carbonate pressure leaching (CPL) experiments on a laboratory scale (Sørensen *et al.*, 1979a, b; Lurgi Chemie und Hüttentechnik GmbH, 1979), prior to continuous extraction of uranium by the CPL method in a pipe autoclave on a pilot plant scale.

Carbonate pressure leaching is based on the observation that steenstrupine is decomposed by soda at an optimal temperature of 260°C. The leach liquor contains 120 g/l sodium bicarbonate and 20 g/l sodium carbonate. Addition of oxygen is required to bring the uranium present in the ore to its highest oxidation state. Grinding the ore with the carbonate leach liquor down to a size of around 80 % minus 200 mesh, feeding a suitable slurry with a solid-liquid ratio 1:1 into a pipe autoclave at a rate of 3 m^3/h and pressure of 120 atm., leads to an effective carbonatisation of uranium. The uranium pregnant filtrate obtained from the successive filtering process is then precipitated to form yellow cake. A simplified flow sheet of the pilot plant processing is given in Figure 5. The CPL experiments on a pilot plant scale were carried out under the aegis of "Uranprojekt Kvanefjeld", mentioned previously, at the Research Establishment Risø. A bulk sample of 4700 tons of ore was available, of which 1100 tons have so far been processed.

A full report of both the laboratory experiments and of the pilot plant leaching runs is given in Danish by Sørensen *et al.* (1983). An abbreviated English version was prepared by the same authors. Sørensen & Jensen (1985) presented a short description of the CPL process employed.

Several minor reports deal with technical aspects of the CPL process. An important subject for further testing has been a study of corrosion effects under the prevailing conditions of high pressure and high temperature in the pipe autoclave. Test results have been reported by Weidemann (1979) and by Nielsen (1983). The recovery of sodium fluorite, present at around 1 % in the ore as the soluble mineral villiaumite, has been

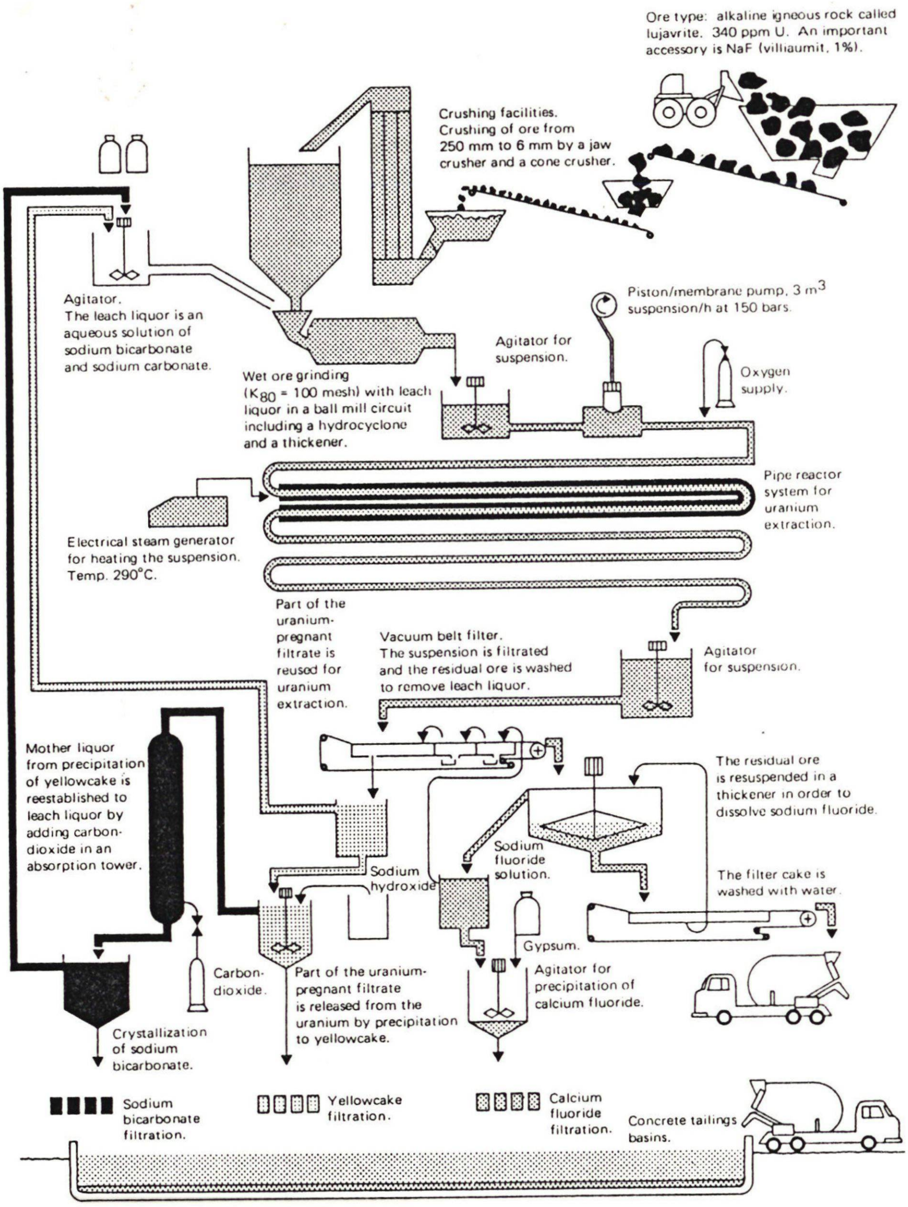

Fig. 5. Flow sheet for uranium extraction on a pilot plant scale, utilising the carbonate pressure leaching (CPL) process after Sørensen & Jensen, 1985.

another topic of CPL processing. A laboratory study aimed at optimising the conditions for washing and subsequent precipitation of calcium fluoride is reported by Koefoed (1983).

Preliminary leaching tests on a laboratory scale were also carried out on steenstrupine concentrates as reported by Holm *et al.* (1982). These tests indicated that a 2 M ammonium sulphate solution is an effective leaching medium with a recovery of 80 to 98 percent of the uranium content.

STUDIES RELATED TO THE POSSIBLE EXPLOITATION OF THE KVANEFJELD URANIUM DEPOSIT

Several studies have been devoted to different aspects of the exploitation of the uranium deposit at Kvanefjeld.

In 1964 the Atomic Energy Commission of Denmark, a governmental advisory body, commissioned the preparation of a preliminary estimate for the economic development of the deposit as delineated so far by diamond drilling carried out in 1958 and 1962, i.e. before the northern extent of the mineralised lujavrites was proven by further drilling (Smidth & Co. A/S, 1965). This estimate offers a detailed account of capital investment and operating costs for integrated mining and processing operations, based on an annual capacity of 0.6 million tons of mined ore.

The next approach appeared in 1974 in a study by Pryor *et al.* (1974). Since this study more specifically concernes a sensitivity analysis on which a preliminary pre-feasibility study was based, a number of recommendations were put forward in the report, stressing further initiatives to be taken before an evaluation of a possible exploitation of the deposit could be anticipated. In particular, ore processing as experimented so far, gave prohibitively low uranium recoveries, varying between 15 and 60 per cent, depending on different types of lujavrite mill feed. The uranium extraction method considered so far was based on sulphating roasting of the ore.

A second evaluation of a possible exploitation of the deposit was undertaken a few years later (Robertson *et al.*, 1977). This report comprises an analysis of existing data related to ore reserves and ore grade, and to pilot plant testing with respect to uranium extraction by the sulphating roasting process. The study moreover seeks to outline areas in which the available data are deficient or lacking in one way or another. Further evaluation was carried out with respect to pre-feasibility studies (Robertson *et al.*, 1979) and ore benefication (Klassen, 1979).

The Danish administration commissioned an analysis of the socio-economic consequences of the establishment of open pit mining and affiliated uranium extraction plant near the township of Narsaq, as part of a more general analysis of supply services and employment on future development of a mining industry in Greenland (Arbejdsgruppen, 1978).

Tunneling

Considerations on the possible future exploitation of the uranium deposit resulted in further activities related to mining and radiological hazards and an urgent need for bulk samples of different types of lujavrite.

On the basis of drill hole profiles a tunnel project was proposed (Nyegaard, 1978). The actual position of the adit that was driven in 1979 is given in Figure 4. Ultimately 4700 tons of ore were selected for metallurgical processing and shipped to the Research Establishment Risø. Selection of suitable ore batches was carried out according to a proposal made by Clausen (1979).

Technical descriptions of the tunneling operations have been given by Pihl & Søn A/S (1979, 1980). A report on systematic chip sampling and gamma spectometric assaying was presented by Nyegaard (1980a), accompanied by a continuous geological registration of the rock types encountered during tunneling, on a scale of 1:100 (Nyegaard, 1980b).

Sørensen (1980a, 1983a) has summarized the current regulations for transportation of radioactive materials, and given figures for both expected and actually measured exposure levels in connection with the tunneling in progress.

Mine planning

A detailed draft project for mining operations and the deposition of mine waste rock and tailings from the uranium extraction plant was presented by Erlendsson *et al.* (1983).

The starting point for this excercise is a proven ore reserve of 56 M tons containing 365 g U/t on average. The proportion of ore to waste rock is 1 to 1.43.

With an annual mining capacity of 4.2 M tons in an open pit, an expected life time of 15 to 20 years is foreseen. On this basis an extraction plant, with an hourly capacity of about 500 tons mill-feed, would ultimatively produce around 1500 t UO_2 annually.

The total volume of mine waste is 24 M tons, the amount of processing waste is close to 55 M tons.

The report encompasses details on a number of different aspects related to a full-scale mining operation.

Apart from open pit design in five successive years of exploitation and the erection of the uranium processing plant, further data are given in terms of energy supply, facilities, infrastructure, mine waste and tailings disposal, investment and general economic considerations. Two alternative sites for placement of the extraction plant, one near the open pit, the other one at a coastal locality called Nuussuaq, about 20 kilometres north-east of the pit, are discussed.

The need for both electrical and thermal energy, estimated to be 450 Gwh/year combined, is assumed to be met from two different sources: electrical energy to be generated in a hydropower plant in Johan Dahl Land, near the Narsarsuaq airfield; thermal energy generated in a coal-fired district heating plant as part of the processing complex.

The total investment, over a period of 4 to 5 years before full production, has been estimated to be of the order of 4000 M DKK (1983 - prices). The ultimate production costs would then have been 121 DKK/t of ore in the first 7 years of development, ultimatively reduced to 115 DKK/t.

All calculations are based on a sales value of US $ 35 for one pound of U_3O_8, and on a rate of exchange of US $ 1.00 to 8.74 DKK.

Technical details of the open pit mining of the deposit have been discussed by Kalvig (1983) encompassing slope stability considerations and the consequences on stripping related to the ore to waste rock ratio.

Potential pollutants in mining

Background information with reference to ecological aspects, potential pollutants, critical pathways and other environmental issues related to a mining and processing operation at Kvanefjeld is elaborated in Pilegaard (1983).

A concentrated effort to identify, and if possible to quantify, potential pollutants is presented on the basis of a limited number of leaching experiments and of data collected in the field.

The most important gaseous effluent is obviously radon which is exhaled from several sources in the mining and milling operation. Sørensen (1983) treated the different aspects of the radiogenic hazards in a full-scale operation. Based on sets of measurements of gamma-exposure velocities, and of actual doses received under normal working conditions during tunelling, it is concluded that the sum of both external gamma-radiation, inhaled radon-thoron-daughter products and of inhaled ore dust outlines the range of an annual dose in an open pit operation a: H ~ 3.1-16.5 m SV.

See also Sørensen (1979), Sørensen (1980) and Bøtter-Jensen *et al.* (1978) for further details. The level of radiation as measured in the exsisting tunnel is illustrated in Fig. 6.

To evaluate possible concentration of pollutants in solid effluents, Pilegaard (1983) has given the chemical analyses of four different size fractions of milled ore (Table 8). None of these fractions were appreciably different from the mill-feed analysis.

The liquid effluents constitue the principal hazard in the mining and processing operations, partly because of the solubility of enclosed minerals, i.e. villiaumite and

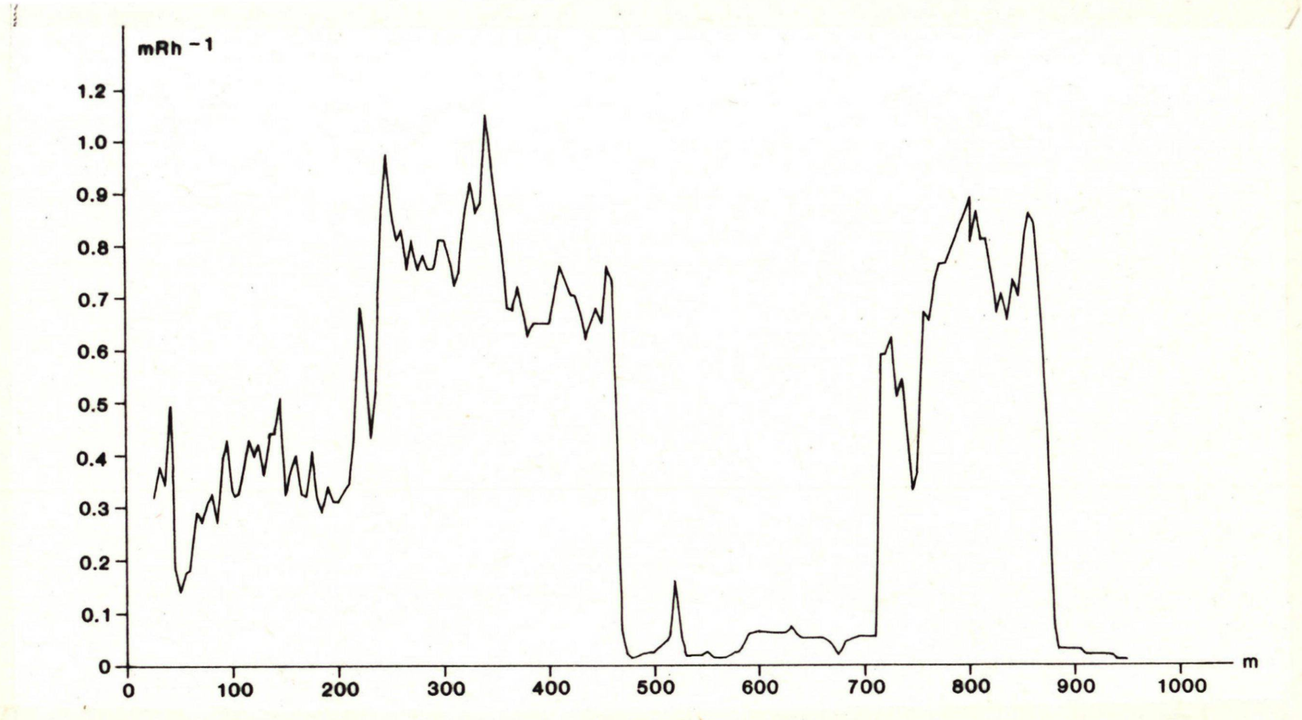

Fig 6. Radiation level (mRh^{-1}) in the exploration tunnel at Kvanefjeld. (Sørensen, A., 1980).

Table 8. Chemical analyses of ore particles (lujavrite in different size classes)

	45-71μ	71-100μ	100-200μ	200-300μ	crude ore
Na %	8.56		9.36	-	
Sc ppm	0.35		0.35	0.35	
Cr ppm	74.9		84.1	93.2	
Fe %	10.5		8.76	6.61	
Co ppm	1.08		1.01	0.974	
Zn %	0.186		0.200	0.235	
Rb ppm	678		694	697	
Zr %	0.412		0.486	0.601	
Sn ppm	-	-	-	-	-
Sb ppm	7.25	8.31	8.27	5.48	8
Cs ppm	6.82	8.21	7.34	9.16	7.8
La %	0.220	0.260	0.278	0.148	0.23
Ce %	0.309	0.344	0.377	0.451	0.37
Nd %	0.143	0.162	0.171	0.220	0.17
Sm %	0.011	0.012	0.014	0.018	0.014
Eu ppm	10.7	11.8	12.2	15.6	13
Tb ppm	15.2	16.6	16.8	21.2	18
Yb ppm	41.0	43.8	33.0	511.0	41
Lu ppm	4.5	4.96	6.26	6.44	5.7
Hf ppm	13.0	14.5	14.0	14.9	15
Ta ppm	7.75	7.4	6.94	7.44	8
Th ppm	697	542	350	647	600
U ppm	341	384	378	497	400

Pilegaard (1983).

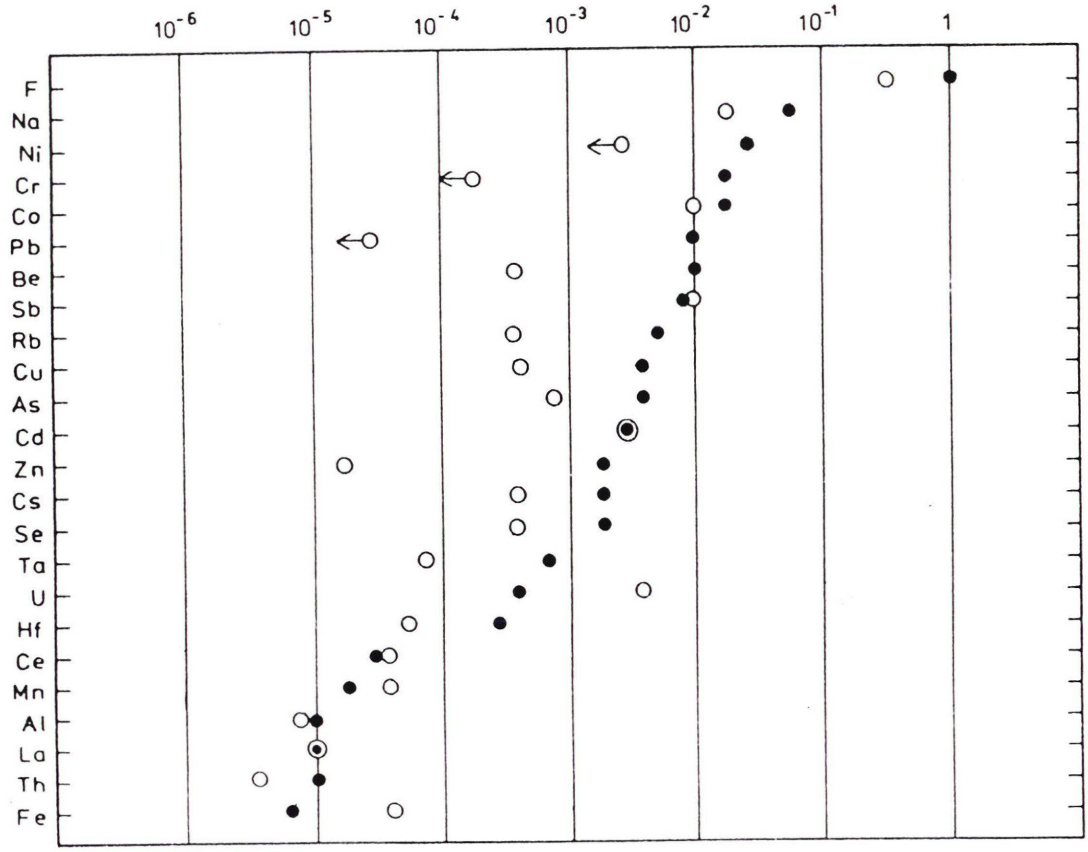

Fig. 7. Relative solubility of chemical elements both in uranium ore (•) and tailings (o). ←o indicates values below detection limit (Pilegaard, 1983).

natrosilite, and partly because of relative elemental solubility, as illustrated in Fig. 7, where the elements in question are ranked in descending order of solubility. Two leaching experiments were conducted on the tailings after CPL extraction of uranium. It appears that the solubility of these elements is reduced by processing, with the exception of Fe, Mn and U, clearly due to the breakdown of steenstrupine. In general the solubility of elements in the tailings is appreciably lower than that of the mill-feed. This may be due to reprecipitation as less soluble carbonates formed in the CPL extraction process (Pilegaard, 1983). It is concluded that there is still a considerable lack of knowledge on the environmental characteristics of the area, as well as of some technical aspects of a full-scale uranium extraction operation by the CPL method.

SURVEYS AND GEOPHYSICAL STUDIES

General introduction

As a direct consequence of the emerging "Peacefull uses of atomic energy", the newly established Danish Atomic Energy Commission (=Atomenergikommissionen) made funds available in 1955 for a search for uraniferous minerals in Greenland. Upon advice from the Geological Survey of Greenland radiometric field surveys were initiated within the area covered by the Ilímaussaq intrusion as it was known that the radioactive mineral steenstrupine was found there in pegmatities etc.

Apart from radiometric surveys and observations on the natural radiation levels, only scant geophysical field observations were carried out.

The beryllometer was introduced as a prospecting tool and tested in a survey aimed at the delineation of the aereal extent of chkalovite found in rocks of the roof sequence on a mountain slope adjacent to the Kvanefjeld uranium deposit. The results of the beryllometer tests are briefly discussed in the chapter on economic minerals (cf. p. 7).

Scientists of the Danish Geodetic Institute, now Kort- og Matrikelstyrelsen (KMS), made a study of Bouguer anomalies that occur in relation to the intrusion.

No further magnetic and electromagnetic field surveys for prospecting purposes have so far been carried out within the area covered by the intrusion beyond the Kvanefjeld plateau. The magnetic properties of lujavrite have only been considered in relation to mineral separation tests.

A regional airborne geomagnetic survey was carried out over an extensive area in South Greenland, including the Ilímaussaq intrusion. Satellite images have been utilised as a means of discrimination in weathering patterns etc.

Radiometric surveys

A succesion of radiometric surveys have been carried out in the field within the realm of the intrusion. They were conducted in the very early stage of uranium exploration in order to pinpoint promising prospects (GEOX 55, GEOX 56). Since the immediate results of these early surveys in 1956 led to the discovery of the Kvanefjeld uranium occurrence, only scant detailed field surveys were carried out at a later stage at other localities, i.e.

Agpat, Tugtup Agtakorfia and Søndre Siorarsuit, along the shores of Tunulliarfik (Bondam, 1957a, b, 1958a, b; Larsen-Badse, 1958). These later surveys provided background data for the positioning of 7 additional drill holes in the lujavrite sequence of the intrusion (Bondam & Ferguson, 1962). A number of radiometric field maps of the Kvanefjeld area have been published (Løvborg *et al.*, 1968; Nyegaard *et al.*, 1977). In connection with the design and use of gamma-ray spectrometric analytical tools, the Research Establishment Risø maintained a number of calibration pads on the Kvanefjeld deposit, and ultimately extended coverage with the use of portable equipment (Løvborg *et al.*, 1968; Løvborg, 1968). Aspects of the applicability and reliability of spectrometric techniques for uranium, thorium and potassium determination in the field, have been treated by Løvborg (1972) and Løvborg *et al.* (1972, 1978).

The use and the results of spectral gamma-ray logging of the additional drill holes in the Kvanefjeld deposit have been reported by Løvborg *et al.* (1980).

A regional airborne radiometric map, covering South Greenland between latitudes 60° and 61°30′N, was prepared by the Geological Survey of Greenland under a uranium prospecting drive that took place between 1977 and 1981 (Armour-Brown *et al.*, 1983).

Natural background radiation

A number of studies have been carried out to determine the natural gamma-ray radiation levels and exposure rates, primarily on the Kvanefjeld plateau, where monitoring during a period of three months was performed at four different localities using LiF thermoluminescence dosimeters (TLD). In summary, the average radio-element concentrations and exposure rates at the above localities is given in Table 9. The skyshine exposure rate was determined to be 10 mR/h, the cosmic ray contribution was approximately 4 mR/h (Løvborg *et al.*, 1980). Bøtter-Jensen *et al.* (1979) compared the results obtained from the study on the Kvanefjeld plateau with natural exposure rates measured at a number of localities in West and East Greenland by Nielsen & Bøtter-Jensen (1973).

Table 9. Average radio-element concentrations and exposure rates determined for the four monitored areas on Kvanefjeld

				μR/hr		
Area	ppm Th	ppm U	% K	Calculation	TLD	Ionization chamber
1	476	223	3.1	254	255	251
2	20.6	7.1	1.4	30.5	25.3	23.0
3	418	248	1.7	251	253	240
4	1314	454	1.7	578	575	

Løvborg *et al.* (1978).

Supplementary, personnel radiation exposure was monitored for an extended period of time. It has been estimated that the annual radiation dose at Kvanefjeld amounts to a maximum of 1.3 rad (Bøtter-Jensen *et al.*, 1978).

Thermoluminescence dosimetry has been tested as a feasible and reliable alternative to bore-hole logging by scintillation detectors (Nielsen & Mejdahl, 1970). Despite a number of advantages, in particular a high level of precision with a standard deviation less than 3 per cent, the method is not recommended for general logging purposes.

As a consequence of driving a 960 m long adit into the Kvanefjeld uranium deposit it was regarded as essential to determine the exposure to natural radiation and radon gas of the work force in the adit. Routine monitoring was carried out by personnel employed at the site. Extraction of about 5000 tons of ore took place between June 1979 and May 1980. Sørensen (1980) has given an account of the findings, and described the methods and analytical procedures in use.

Prior to this exercise the natural radon gas exhalation and the background levels were measured in the autumn of 1978, both at the uranium deposit and in the nearby township of Narsaq. These analyses are summarised in Sørensen (1979). The apparent exhalation rate of radon and radon daughters from the ore body is calculated to be J=1.74 pCi $m^{-2}s^{-1}$, while the same rate for crushed ore is J=0.085 pCi $kg^{-1}s^{-1}$.

An assessment of the exposure hazards in mining and milling of the uranium ore from the Kvanefjeld deposit is given by Sørensen (1983).

Heat flow measurements

Sass *et al.* (1972) determined the heat flow in four drill holes at Kvanefjeld, designated DH-I, DH-1, DH-37 and DH-38. The result of the measurements of both temperature and thermal conductivity of 83 rock samples versus depth is reproduced in Fig. 8. The average corrected heat flow, HFU, at Kvanefjeld is 0.9 ± 0.1 μ cal cm $^{-2}$ sec $^{-1}$. This is a rather low HFU value compared with heat flow determinations made at Ivittuut in Archaean gneiss where the average heat flow has been measured to be 1.0 ± 0.1 HFU, despite a far lower radiogenic heat production than at Kvanefjeld. This observation implies that the layer of strongly radioactive lujavrites of the Ilímaussaq intrusion is not more than about 1000 m thick, provided that the heat flow from the mantle is not unexpectedly low beneath that part of South Greenland in which Gardar Province igneous activity is dominant.

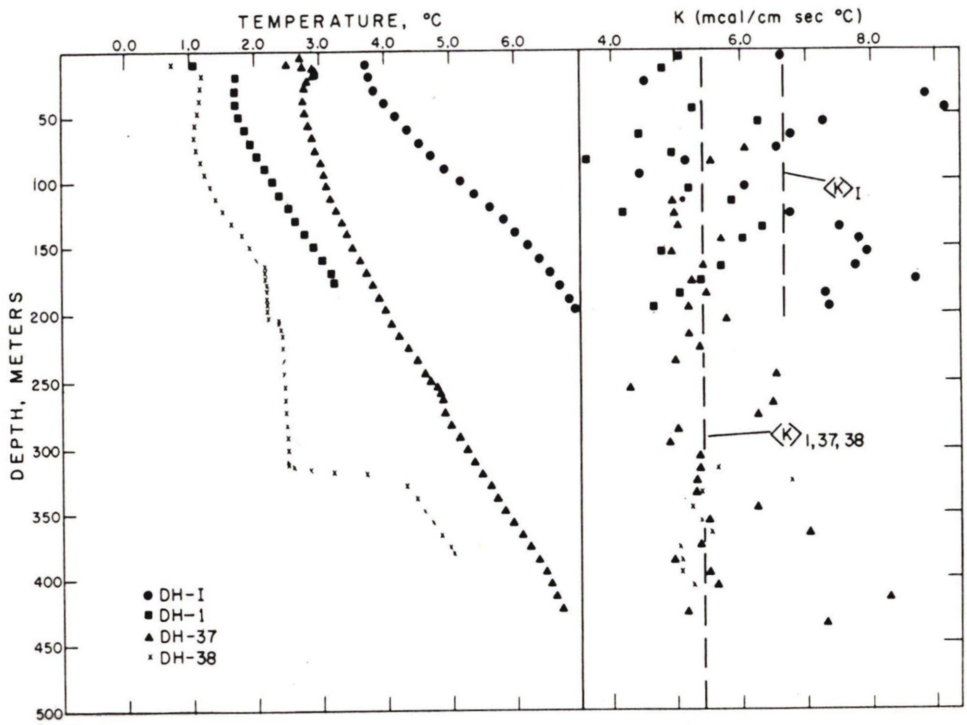

Fig. 8. Temperatures and thermal conductivities versus depth as measured in four diamond drill holes (DH) at Kvanefjeld. The dashed vertical lines show the harmonic mean conductivities (K) for the holes indicated. (After Sass *et al.*, 1972).

Gravity

Already in the 1950s it was known that a large positive gravity anomaly occurred close to the township of Narsaq (Kejlsø, 1958). More detailed observations of the gravity distribution and the determination of the densities of the agpaitic rock suits by Forsberg & Rasmussen (1977, 1978) led to refinement of the existing Bouguer anomaly covering the Ilímaussaq intrusive complex, cf. Fig. 9. Modelling suggests that the intrusion is underlain by a dense rock type with a density of at least 2.9 g/cm^3. This rock mass seems to have nearly vertical intrusive boundaries, i.e. prismatic shaped. It is present at a depth of between 2 and 5 km below surface, reaching down to at least a depth of 20 km.

This is all the more remarkable as the Ilímaussaq nepheline syenite complex is apparently the only intrusion of the Gardar period that is situated on top of a dense rock type at depth. Blundell (1978) extended the gravity survey over the immediate

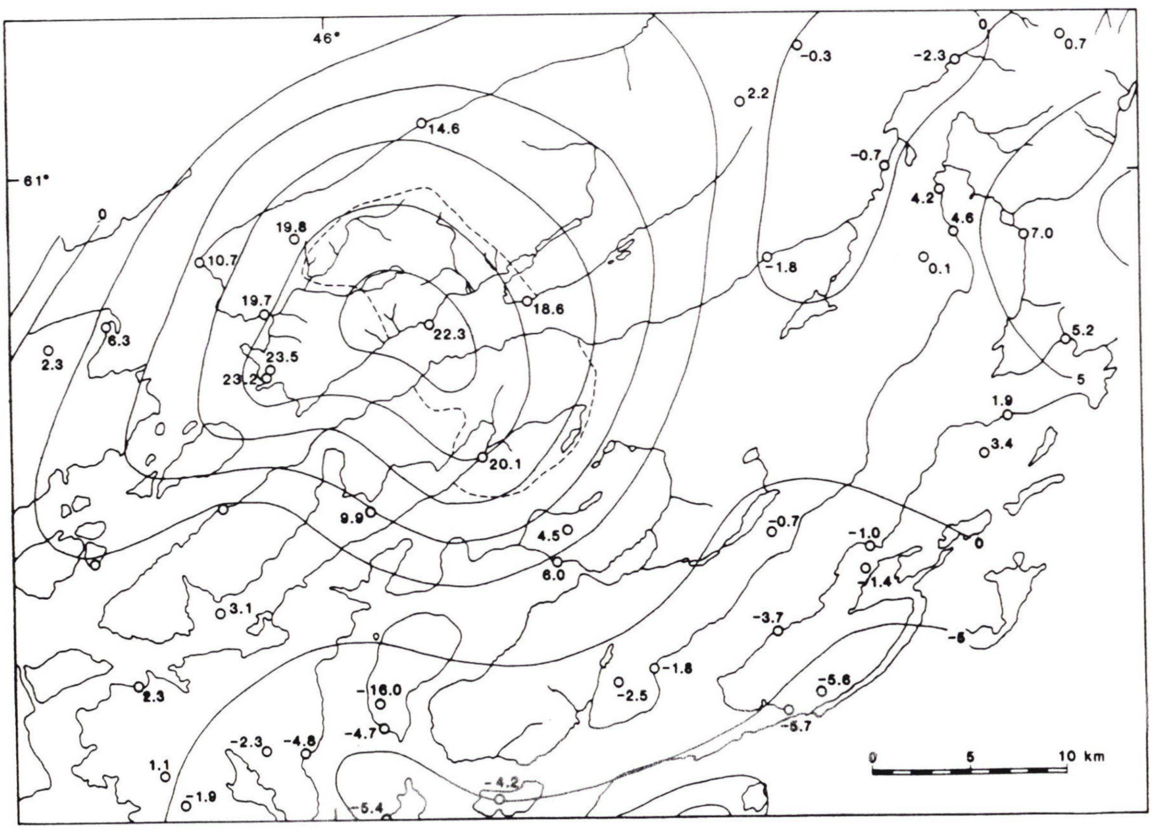

Fig. 9. Residual Bouguer anomaly contours at 5 mGal intervals, covering the Ilímaussaq intrusion and its surroundings. (After Forsberg & Rasmussen, 1978).

surroundings of the complex. The consequences for the geological setting of the agpaitic rock suite in relation to the observed gravity anomaly covering the area have been discussed in Larsen & Sørensen (1987).

Geomagnetism

Regional airborne total field and gradient geomagnetic surveys have been carried out over South Greenland. A short note by Thorning *et al.* (1985) marks the position of the flight lines. The data collected on these flights are on file at the Geological Survey of Greenland and are incorporated in a recently issued thematic map series. The map also includes the geomagnetic data from surveys carried out by mining companies that have operated in South Greenland (GGU, Thematic Map Series No. 94/1, Kap Farvel-Ivittuut, South Greenland).

Part of the geomagnetic data from such a survey in the area bordering Tunulliarfik were provided by Kryolitselskabet Øresund A/S for use in a research project sponsored by the ECC/Euratom, contract EXU-41-DK(G), to evaluate the applicability of remote sensing techniques in uranium exploration. From a composite IHS image, combining Landsat Band 7, aeromagnetic values and kriged values of the iron content in stream sediments, it appears that the Ilímaussaq intrusion stands out as a significant negative magnetic anomaly (Conradsen *et al.* 1984, 1986). Piper (1976) made a palaeomagnetic study on samples collected in the marginal augite syenite and the main cumulates in the southern part of the Ilímaussaq intrusion.

ENVIRONMENTAL STUDIES

A concentrated effort to combine geochemical and ecological background data in relation to the Ilímaussaq intrusion was undertaken with the support of the Danish Natural Science Research Council in the period from 1974 to 1977. This so-called "Narssaq Project" was managed by the Geological Institute of the University of Copenhagen. The object of the studies undertaken was to provide background data for a number of parameters indicative for the environmental equilibrium in the area prior to possible mining activity, in particular the exploitation of the uranium-thorium deposit on Kvanefjeld. To this end a number of biologists participated in the project. Several field studies were carried out by graduate students; their theses are listed in the appendix, together with a number of other reports and scientific papers published under the aegis of the Narssaq Project. Hansen (1980) reviewed all these publications in a report to the Mineral Resources Administration for Greenland. In a preliminary environmental impact statement (Pilegaard, 1983) it is stated that although much information is available there is still a lack of analyses of a number of chemical elements and other variables in the aquatic environments within the area. Monitoring the run-off in three drainage basins within the realm of the intrusion, and automatic registration of an extended number of meteorological parameters were undertaken as a supplement to the environmental studies. The results are discussed in a separate chapter.

The topics for the environmental studies have thus been subdivided into:

- soil, recent bottom sediments, Quaternary cover,
- terrestrial vegetation, fresh water and marine faunas,
- hydrological, hydrochemical and meteorological data.

For references, see also the appendix with respect to environmental studies carried out under the aegis of the "Narssaq Project".

Soils, recent bottom sediments, Quaternary cover

In a thesis by Larsen (1977) a large number of soil profiles within and adjacent to the Ilímaussaq intrusion are described. Soil cover is restricted to the low lands and valleys.

The distribution of a selected number of trace elements, i.e. Nb, Ta, Zr, Hf, Li, Rb, Sc, Y and the lanthanides, that are specific for the agpaitic rock suites, have been determined in profile. The main conclusion drawn from these findings is that all the chosen trace elements are mobilised under the prevailing climatic conditions.

In order to gain some quantitative measure for weathering processes in the area Nielsen (1979) analysed a large number of soils, recent bottom sediments in lakes, streams and the adjacent fjords, for an extended number of both major elements and trace elements, including U and Th. The content of organic carbon was also determined. The over-all picture gained from these analyses is, that Fe, Mn, Co, U, Th, Zn, Mg, P, Y and the lanthanides are washed out from the mineral particles in the soils, and only to a limited extent reprecipitated in bottom sediments or not at all. Uranium is adsorbed to organic matter. This is not the case for thorium. The figures obtained for apparent outwash of the above named elements are not quite comparable to the hydrochemistry in the area, as investigated by Christensen (1980) on the grounds of seasonal variations of dissolved matter content in stream water. With support from the European Communities (grant 016-79-1 EXU-DK), the supergene distribution of 22 chemical elements, including U and Th, was studied in the soils and bottom sediments in rivers, lakes and fjord areas, covering and adjacent to two main alkaline intrusions in South Greenland, Ilímaussaq and Igaliko. The analytical data have been treated statistically using the PCA (i.e. principal component analysis) technique (Rose-Hansen *et al.*, 1986).

The Quaternary geology of the Narsaq area has been treated by Funder (1979). Besides observations on different phases of glaciation, ice movements and Holocene retreat of the ice cover, an estimate is given of the dissipation of agpaitic rock types in the surroundings. It is concluded that 72 percent of stony material and boulders have been transported by glacial movement less than 1 km from the outcrops in the field, indicating that the glacial cover has not been affected by glaciers extending from the central Inland Ice.

Terrestrial vegetation, fresh water and marine faunas

Feilberg (1976) systematically listed all vesicular plant species found in South Greenland, and described the different plant populations in relation to geographical disposal and climatological conditions. The vegetational cover, graduated according to the different species found in the area, is given for 31 localities in the Narsaq region. A preliminary map of this vegetational cover is given in Rose-Hansen *et al.* (1977). In order to gain insight into the airborne heavy metal dispersion Pilegaard (1981, 1987) analysed samples taken of a lichen (*Cetraria nivalis*), a moss (*Hylocomium splendens*) and a grass (*Calamagrostis langsdorffii*) at 26 localities both within and outside the limits of the Ilímaussaq intrusion. The spread of the analysed heavy metals, i.e. Cd, Cu, Fe, Pb and Zn, is due to small-scale particulate dust transportation. Thus the metal values found in all samples taken within the realm of the intrusion are markedly higher than those found for the analysed plant species outside.

The proportional enrichment given for *Cetraria nivalis*, as an example, is Ce 1.5, Fe 1.8, Pb 1.8 and Zn 2.2, reflecting a markedly higher content of these metals in the intrusive rocks. The copper content of the agpaitic rocks is very low, not more than 65 g/t on average in the latest magma derivates, the lujavrites (Løvborg *et al.*, 1979).

Further biological observations are reported in Mæhl (1978), Lindegaard *et al.* (1978) and Nygaard (1978). Mæhl's thesis is a study of variations in the production rate of phytoplankton and zoobenthos in an ultra-oligotrophic lake in the southern part of the Ilímaussaq intrusion; the other two publications are primarily dedicated to taxometric surveys of fresh water phytoplankton and zoobenthos in lakes within and outside the intrusion.

The fresh water zoobenthos in two lakes in the southern part of the Ilímaussaq intrusion have been studied by Nielsen (1977) and Mosegaard (1978). In the first-named study, a general picture is given of the number of species present, the variations in populations and life cycles are described and conditions for growth are given. The thesis by Mosegaard (1978) is on the population dynamics of a single copepod species (*Leptodiaptomus minutus*) in a single lake. This lake, which has been named "Sø 95", has also been used by Mæhl (1978) in the study mentioned above. As a curiosity it is noted here that a new diptera species, *Micropsectra Crundini n.sp.*, was discovered as a result of the above cited detailed limnic studies (Säwedal, 1979). In the littoral zone along the fjords and inlets adjacent to the Ilímaussaq intrusion samples of both seaweed (*Fucus vericulosus*) and mussel (*Mytilus edilus*) were collected and analysed for their content of a number of trace elements. The findings have been reported by Hansen (1979). Among other valuable data on the spread of background values in different parts of South Greenland, this study is concerned with, among other parameters, the load and annual variations of the content of Zn, lanthanides, Hf, Ta and Th, which are specific for the uranium-thorium deposit at Kvanefjeld. These trace elements in particular are carried to the marine environment by Narsaq Elv that drains the area in question and discharges in an inlet called "Dyrnæsbugt" or Narsap Ilua. These trace element contents, plus a number of others, were monitored at 16 stations. In particular the content of lanthanides in mussels was markedly higher at the mouth of the stream than further outwards along the shores of the inlet (Hansen, 1978). As can be seen from the appendix, a number of minor accounts on the environmental studies as part of the "Narssaq Project", have been published in *Reports of Activities*, issued yearly by the Geological Survey of Greenland. In connection with a proposed construction of a hydroelectric plant the invertebrate fauna of Narsaq Elv and the lake Taseq was sampled (Vandkraftværk Taseq, Narssaq, 1981).

Hydrological, hydrochemical and meteorological data

The Greenland contribution to the International Hydrological Decade (IHD), under the anspices of UNESCO, was chosen to be the "Narssaq Representative Basin" - project, catalogue no: 2.2013 (Larsen, 1973), cf. Fig. 10.

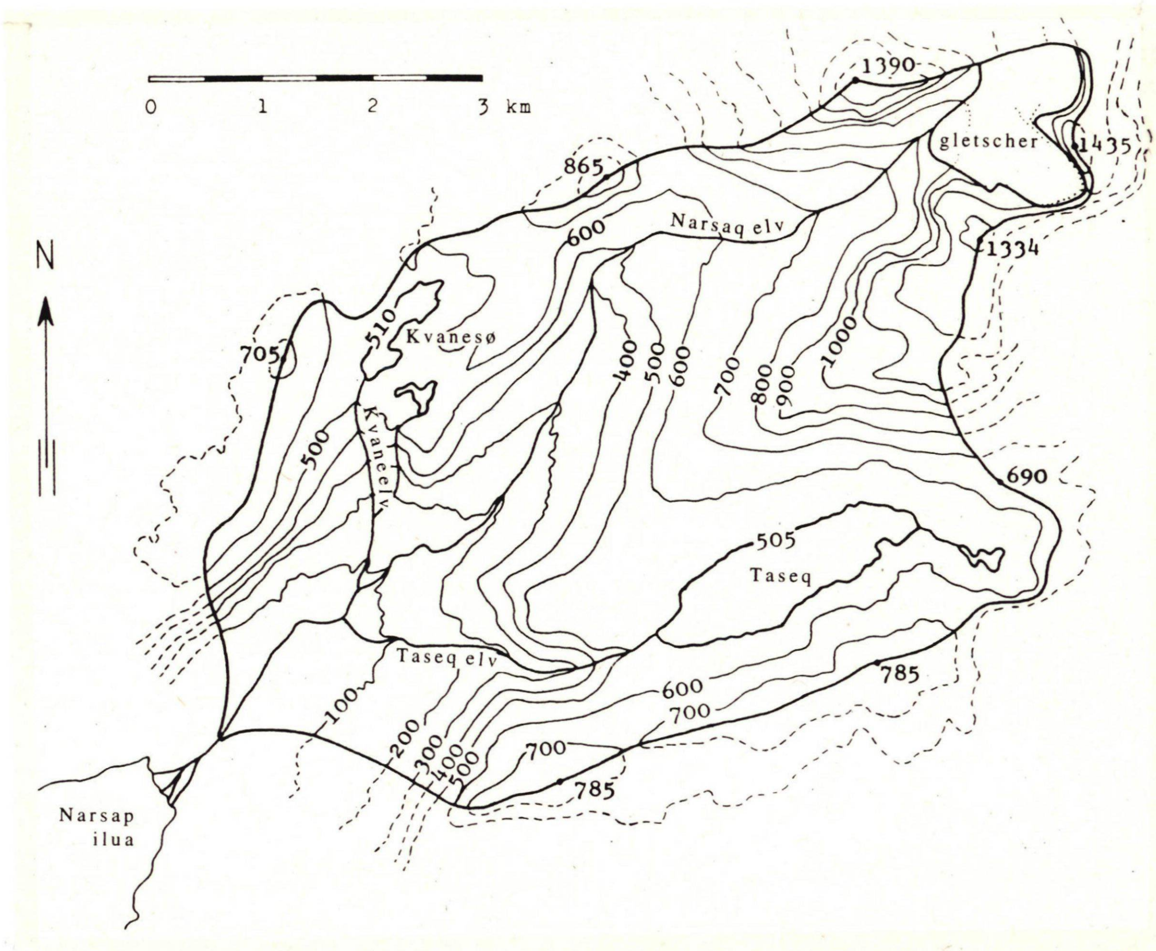

Fig. 10. The topography and drainage of the "Narssaq Representative Basin" or Narsaq basin from Larsen (1973).

A network of recording stations was erected which were operated from 1966 to 1972. The main research object was to account for the water budget on the basis of intermittent and continuous monitoring of a number of parameters, not only of the usual meteorological nature, such as precipitation, evaporation, air temperature and wind directions and speed, but also including run-off, soil cover permeability, ground water level fluctuations and ground water movement. A special study was made of accumulation and ablation of a local glacier, and of its movements.

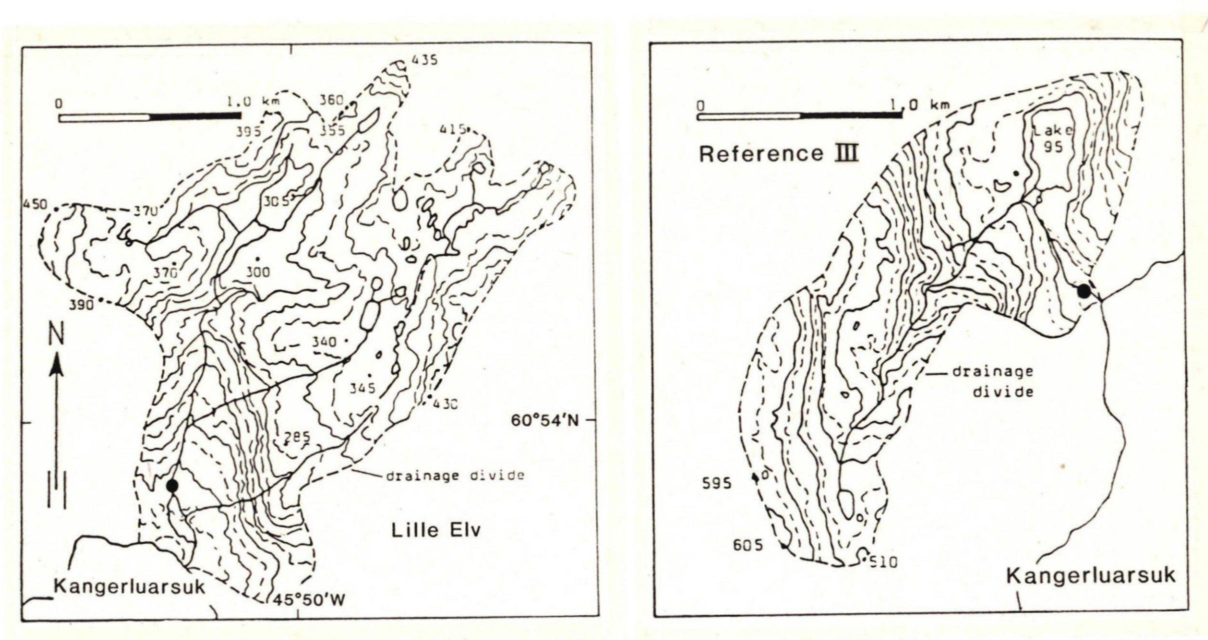

Fig. 11. Lille Elv and Reference III drainage basins. Position of monitoring gauges is marked with a dot. (Christensen, 1980).

An extension of the hydrological and local meteorological monitoring was supported by the Danish Natural Science Research Council (SNF) under the heading of the already established "Narssaq Project". Further automatic monitoring was undertaken between 1 January, 1977 and 1 January, 1980 (Christensen, 1980). The equipment in use has been an Anderaa datalogger, type DL-1, set at automatic logging with 2 hour intervals. The records and the computer transcripts are on file at the Geological Survey of Greenland.

Monitoring and water sampling was carried out in three minor drainage basins within the area covered by the Ilímaussaq intrusion. They were called Narsaq Elv - Lille Elv - and Reference III drainage basins respectively (cf. figs. 10 and 11).

Most observations over a longer period of time have been made in the Narsaq Elv basin, originally called "Narssaq representative basin", as mentioned above. This basin covers an area of 33.2 km^2. The area is drained by three streams, the main one called Narsaq Elv, originating at the local glacier. The other two originate from lakes at altitudes of 505 and 510 m respectively; they are named Taseq elv and Kvaneelv. The total annual discharge for the three-year period 1977-79 is shown in Table 10, together with the estimated net precipitation in the same period of time.

Under the heading "Vandkraftværk Taseq, Narssaq" (1981) Grønlands Tekniske Organisation (GTO) and Grønlands Fiskeriundersøgelser (GF) presented a proposal for a hydropower plant to be constructed downstream in the Narsaq basin, north of Narsaq township. A number of reports dealing with the hydrological and environmental aspects are available, besides the final planning with its financial implications, as estimated by a number of consultants, cf. GTO (1981).

Ground water storage in the Narsaq Elv basin is very limited. The total storage capacity has been calculated to be approximately 7.10^6 m^3, corresponding to about 17 per cent of the annual precipitation.

Table. 10. Annual river water discharges and estimates of net precipition for the Narsaq basin, 1977-1979, according to Christensen (1980)

Annual river water discharges	
1977	1.30×10^8 m^3
1978	1.45×10^8 m^3
1979	1.66×10^8 m^3
Estimates of net precipitation based on the river discharges and a basin area of 33.2 km^2	
1977	3916 mm
1978	4367 mm
1979	5010 mm

Larsen (1973) made a survey of the local glacier, situated in the north-eastern part of the Narsaq drainage basin. The glacier occupies two coalescing cirques. Accumulation and ablation were measured as well as glacial movements in the period from 1967 to 1971. These investigations indicated that the glacier at present must be considered stationary, or even slightly retreating. From photographic records at irregular intervals, dating back to the year 1900, it is apparent that the mass balance of the glacier has been negative during the greater part of the 20th century. Records of the actual discharge from the glacier correspond, within an accuracy of 2 per cent, for total precipitation and ablation.

The discharge from the largest lake in the area, Taseq, has been estimated by Grønlands Tekniske Organisation (GTO, 1981), based on monitoring its run-off conditions during a restricted period of time. For observations on ground water storage, 7 shallow drill holes were positioned around the lake.

Braithwaite (1981) recalculated the water balance of the lake on the basis of modelling, showing close agreement to previous figures given by GTO (1981). According to the above estimates the annual run-off varies between 27.2 and 29.9 M cubic metres. Expressed in terms of annual electrical power generation these figures are supposed to be equivalent to 21-26 GWh.

In 1975 glacier-hydrological studies were initiated in the so-called "Nordbosø basin" in Johan Dahl Land, situated at 61°25′N, 45°30′W, north of Narsarsuaq airport. The aim of these studies was to collect sufficient data for an evaluation of the hydropower potential available for utilisation in adjacent areas and townships, including the Kvanefjeld uranium deposit. The field work was carried out jointly by the Geological Survey of Greenland (GGU) and Grønlands Tekniske Organisation (GTO). It lasted until 1983. The background data obtained, including general climatic conditions, meteorological observations, glacial conditions, ablation and mass-balance, and run-off have been summarised by Clement (1982, 1983a, b) on the basis of annual records and reports that are on file at GGU and at GTO.

The available hydropower potential of the Nordbosø basin is included in an evaluation of the energy supply for full-scale mining operations on Kvanefjeld (Erlendsson *et al.*, 1983).

The hydrochemistry of the Narsaq drainage basin has been treated at length by Larsen (1973) and Christensen (1980). Based on the analytical results, Christensen (1980) estimated the annual discharge of dissolved matter in the period 1977 to 1979 into the surrounding fjord system at Narsap Ilua. This estimate, expressed in metric tons, is reproduced in Table 11. It is noted that the content of dissolved fluorine is fairly high in the streams of the Narsaq drainage basin. This also applies to the zinc content compared to the other base metals. The enhanced fluorine values are attributed to the occurrence of villiaumite (NaF) in the lujavrites of Kvanefjeld, while the main sulphide phase in these rocks is sphalerite. A study of the dissolution rates of fluorine from samples of lujavrite containing accessory villiaumite has been carried out by Asmund (1980). The results of the tests has given a measure for the determination of the dissolution rate of exposed rock on the basis of fluorine content, and can be expressed as $D = (7.5 + 0.98Cs) \times 10^{-5}$ cm^2/h. In this formula D stands for "dissolution rate", Cs expresses the fluorine content in mg/cm^3.

Table 11. Annual discharge of dissolved matter by river water into Narsap Ilua, 1977-1979

Element	tons 1977	tons 1978	tons 1979	tons 1977-79
F	376	419	480	425
Cl	754	841	963	853
HCO_3	1781	1987	2274	2014
NO_3	39	44	50	44
SO_4	260	290	332	294
Na	1274	1421	1627	1441
K	62	70	80	71
Mg	47	52	60	53
Ca	286	319	365	322
NH_4	26	29	33	29
Li	0.28	0.32	0.37	0.32
Cu	0.05	0.05	0.06	0.05
Zn	0.75	0.84	1.00	0.86
Pb	0.02	0.02	0.02	0.02
Cd	0.02	0.03	0.03	0.03
U	0.03	0.03	0.03	0.03
SiO_2	481	537	614	544
Sum, tons	5387	6010	6880	6091

Source: Christensen (1980a).

The actual content of dissolved fluorine in stream water sampled weekly at the month of Narsaq Elv, between November 1974 and November 1975, fluctuates depending on the seasonal variation of the discharge. A high fluorine content corresponds to a low level of discharge (Asmund, 1980).

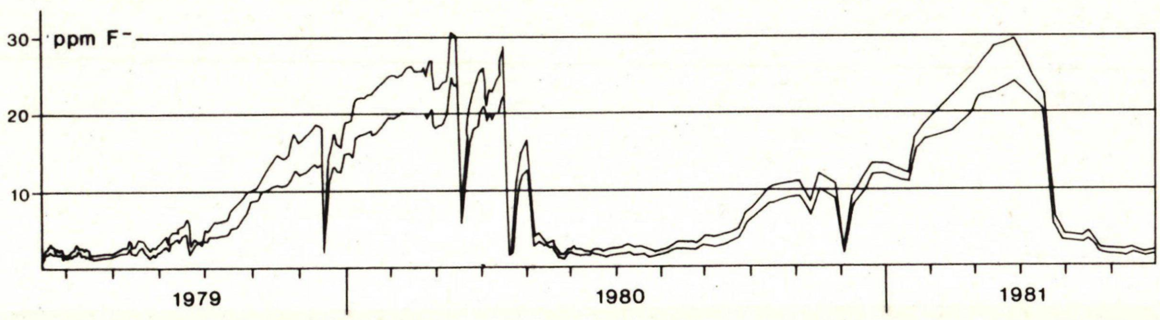

Fig. 12. Seasonal variations in the ionic fluorine content in Narsaq Elv, after Sørensen (1983).

Monitoring the content of dissolved fluorine in Narsaq Elv was repeated between June 1979 and June 1981 in connection with tunelling and uranium ore extraction that took place simultaneously, as part of the "Uranprojekt Kvanefjeld". Frequent sampling of stream water at two sites, one upstream and the other downstream of the excavated ore pile, revealed fluctuations similar to those observed earlier. Figure 12 shows the result of specific ion determinations of the dissolved fluorine content in stream water during that period, as reported by Sørensen (1983).

The content of dissolved uranium in Narsaq Elv has been determined with the help of ion exchange resin (Asmund, 1975). It was found that the ionic uranium content varied from 0.15 to 15.7 ppb U, depending on the passage of surface water through environments in which organic matter presumably acts as an adsorber of ionic uranium. Scattered assays taken in streams in the central and southern part of the Ilímaussaq intrusion generally showed low ionic uranium levels varying from 0.05 to 0.98 ppb U.

In connection with "Uranprojekt Kvanefjeld", meteorological observations were carried out between September 1979 and March 1983. Data on wind speed, wind direction, temperature, humidity and atmospheric pressure were automatically recorded at two stations close to the uranium deposit at Kvanefjeld. One of these stations was positioned at an altitude of 564 m a.s.l., the other in the adjacent valley, at an altitude of 206 m a.s.l. The records are included in reports by Kristensen (1983).

Under the same heading of "Uranprojektet Kvanefjeld", a study was made of the wind field in the valley of Narsaq (Gryning & Lyck, 1983). A limited number of experiments was carried out in the mid-summer period of 1981. Sulphur hexa-fluoride was used as a tracer in these experiments. The aim of this study was to gain some knowledge of the distribution and dilution pattern of air polluting dusts that would be released as a result of mining operations.

REFERENCES

Andersen, S. 1982: Boringerne i Ilímaussaq syd for Tunugdliarfik - et forsøg på en magma-stratigrafisk inddeling. Unpubl. intern. rep. Grønlands geol. Unders., 7 pp., 9 figs., appendix.

Andersen, S., Bailey, J. C. & Bohse, H. 1981: Zr-Y-U stratigraphy of the kakortokite-lujavrite sequence, southern Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 69-76.

Andersen, S., Bohse, H. & Steenfelt, A. 1988: The southern part of the Ilímaussaq alkaline intrusion, South Greenland. Geological map 1:20 000. Copenhagen: Grønlands Geologiske Undersøgelse.

Arbejdsgruppen 1978: Uranudvinding ved Narssaq. (Hoff Overgaard A/S, for Arbejdsgruppen vedrørende forsyningsvirksomhed og arbejdskraftanvendelse i mine- og olieindustrien i Grønland), 23 pp., appendices.

Armour-Brown, A., Steenfelt, A. & Kunzendorf, H. 1983: Uranium districts defined by reconnaissance geochemistry in South Greenland. *J. Geoch. Expl.* **19**, 127-145.

Asmund, G. 1971: Chemistry and kinetics of the sulphating roasting of uranium-bearing silicates. *Risø Report* **253**, 125 pp.

Asmund, G. 1975: Uranium content in rivers of the Narssaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **75**, 84-86.

Asmund, G. 1980: Udludning af fluor fra Kvanefjelds-malmen. Unpubl. intern. Rep. Grønlands geol. Unders., 23 pp.

Asmund, G., Lundgaard, T., Sørensen, E. 1971: Sulphating roasting, a way to solubilize uranium in refractory ores. *In: The recovery of uranium* (Proc. Symp. São Paulo, 1970), 185. Vienna: IAEA.

Bailey, J. C. & Gwozdz, R. 1994: Li distribution in aegirine lujavrite, Ilímaussaq alkaline intrusion, South Greenland: role of cumulus and post-cumulus processes. *Lithos* **31**, 207-225.

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

Bailey, J. C., Larsen, L. M. & Sørensen, H. (ed.) 1981a: The Ilímaussaq intrusion, South Greenland. A progress report on geology, mineralogy, geochemistry and economic geology. *Rapp. Grønlands geol. Unders.* **103**, 130 pp.

Bailey, J. C., Bohse, H. & Demina, A. 1981b: Extension of Zr-REE-Nb resources at Kangerdluarssuk, Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 63-67.

Bailey, J. C., Gwozdz, R., Rose-Hansen, J., Andersen, L. S. & Sørensen, H. 1981c: Distribution of lithium and flurine in lujavrites from the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 77-86.

Bailey, J. C., Rose-Hansen, J., Løvborg, L. & Sørensen, H. 1981d: Evolution of Th and U whole-rock contents in the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders* **103**, 87-98.

Bailey, J. C., Bohse, H., Gwozdz, R. & Rose-Hansen, J. 1993: Li in Minerals from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. geol. Soc. Denm.* **40**, 288-299.

Blaxland, A. B., van Breemen, O. & Steenfelt, A. 1976: Age and origin of agpaitic magmatism at Ilímaussaq, South Greenland: Rb-Sr study. *Lithos* **9**, 31-38.

Blundell, D. J. 1978: A gravity survey across the Gardar Igneous Province, SW Greenland. *J. geol. Soc. Lond.* **135**, 545-554.

Bøggild, O. B. 1953: The mineralogy of Greenland. *Meddr Grønland* **149**(3), 442 pp.

Bøgvad, R. 1949: Dansk interesse for en teknisk udnyttelse af nefelinsyenit fra Grønland, *Bull. geol. Soc. Denmark* **11**, 503-506.

Bøgvad, R. 1950: Nepheline syenite and iron ore deposits in Greenland. *Arctic* **3**(2), 86-94.

Bohse, H., Brooks, C. K. & Kunzendorf, H. 1971: Field observations on the kakortokites of the Ilímaussaq intrusion, South Greenland, including mapping and analyses by protable X-ray fluorescence equipment for zirconium and niobium. *Rapp. Grønlands geol. Unders.* **38**, 43 pp.

Bondam, J. 1957a: Rapport over undersøgelser ved uranforekomsten på Kvanefjeldet (Narssaq) i sommeren 1957. Unpubl. intern. rep. Grønlands geol. Unders., 19 pp. + bilag.

Bondam, J. 1957b: Oversigt over planlagte detailundersøgelser i Gletscherelvs området ved Narssaq i sommeren 1957. Unpubl. intern. rep. Grønlands geol. Unders., 2 pp.

Bondam, J. 1958a: Radiometriske målinger ved Agpat og Tugtup Agtakorfia, sommeren 1958. Unpubl. intern. rep. Grønlands geol. Unders., 7 pp. + 1 fig.

Bondam, J. 1958b: Rapport vedrørende undersøgelserne på Kvanefjeldet i sommeren 1958. Unpubl. intern. rep. Grønlands geol. Unders., 9 pp. + 1 tabel, 22 figs.

Bondam, J. & Ferguson, J. 1961: Forslag vedrørende boringer i Ilímaussaq 1962. Unpubl. intern. rep. Grønlands geol. Unders., 19 pp. + 2 figs.

Bondam, J. & Ferguson, J. 1962: An occurrence of villiaumite in the Ilímaussaq intrusion. *Meddr Grønland* **172**(2), 12 pp.

Bondam, J. & Sörensen, H. 1959: Uraniferous nepheline syenites and related rocks in the Ilimaussaq area, Julianehaab District, southwest Greenland. Proc. 2nd int. Conf. U.N. Peace. *Atom. Energy* **2**, 555-559.

Bøtter-Jensen, L., Christensen, P. & Nielsen, B. L. 1978: External radiation exposure associated with uranium-thorium mineralization on the Kvanefjeld plateau, Greenland. M-1989. Unpubl. intern. rep. Res. Est. Risø, 16 pp.

Bøtter-Jensen, L., Løvborg, L. & Nielsen, B. L. 1979: Gamma exposure levels from natural radioactivity in Greenland. Seminar "Radiological burden of man from natural radioactivity in the countries of the European Community", Le Vesinet, France, 4th-6th December 1979, 6 pp., 2 tables, 4 figs.

Braithwaite, R. J. 1981: Remarks on the Johan Dahl Land hydropower project in the light of recent model calculations. *Grønlands geol. Unders. Gletscher.-hydrol. Meddr* **81/2**, 24 pp.

Carl Nielsen A/S 1987: Rapport over aktiviteter indenfor AS Carl Nielsens efterforskningskoncession i et område ved Narssaq i Sydgrønland i sæsonen 1986-1987. J.nr. 1470-165. Unpubl. intern. rep. AS Carl Nielsen, 17 pp.

Carl Nielsen A/S 1988: Midtvejsrapport af aktiviteter indenfor AS Carl Nielsens efterforskningskoncession i et område ved Narssaq i Sydgrønland. Feltsæson 1988. J.nr. 1470-165. Unpubl. intern. rep. AS Carl Nielsen. Vol. 1, 37 pp. Vol. 2, 26 pp., 2 app., 7 plates.

Christensen, N. P. 1980: The hydrochemistry of three drainage basins in South Greenland. Unpublished thesis, University Copenhagen. 111 pp.

Clark, I. & Clausen, F. L. 1981: Simple alternative to disjunctive kriging. *Trans. Instn. Min. Metall. (Sect. A: Min. Industry)* **90**, A13-A24.

Clausen, F. L. 1980: Forslag til udtagning af prøvemalm fra minegang under Kvanefjeld og Kvanefjeldsplateau, Mineralogisk Institut, Danmarks Tekniske Højskole, Lyngby 1979, 20 pp.

Clausen, F. L. 1979: Forslag til udtagning af prøvemalm fra minegang under Kvanefjeld og Kvanefjeldsplateau, Mineralogisk Institut, Danmarks Tekniske Højskole, Lyngby 1979, 20 pp.

Clausen, F. L. 1982: A geostatistical study of the uranium deposit at Kvanefjeld, the Ilímaussaq intrusion, South Greenland. Risø-R-468, 289 pp.

Clement, P. 1982: Glaciologi på Narssaq Bræ. Massebalancen 1981 og 1982. *Grønlands geol. Unders. Gletscher-hydrol. Meddr* **82/5**, 27 pp.

Clement, P. 1982: Glaciological investigations in connection with hydropower, South Greenland. *Rapp. Grønlands geol. Unders.* **110**, 91-95.

Clement, P. 1983: Glaciologiske undersøgelser i Johan Dahl Land 1982. *Grønlands geol. Unders. Gletscher-hydrol. Meddr* **83/1**, 56 pp.

Clement, P. 1983a: Glacial-hydrologiske forhold i Nordbosø bassinet, Johan Dahl Land. *Grønlands geol. Unders., Gletscher-hydrol. Meddr* **83/9**, 54 pp.

Clement, P. 1983b: Mass balance measurements on glaciers in South Greenland. *Rapp. Grønlands geol. Unders.* **115**, 118-123.

Conradsen, K., Nielsen, B. K., Nilsson, G. & Thyrsted, T. 1984: Application of remote sensing in uranium exploration in South Greenland. IMSOR (Inst. Math & Stat. Oper. Res.) Tech. Univ. Denmark, under Euratom/CEC contract EXU-041-DK(G). 164 pp.

Conradsen, K., Nilsson, G. & Thyrsted, T. 1986: Remote sensing in uranium exploration. *Uranium* **2**, 301-316.

Engell, J., Hansen, J., Jensen, M., Kunzendorf, H. & Løvborg, L. 1971: Beryllium mineralization in the Ilímaussaq intrusion, South Greenland with description of a field beryllometer and chemical methods. *Rapp. Grønlands geol. Unders.* **33**, 40 pp.

Erlendsson, G. 1981: Koordinering af borehuller på Kvanefjeld. Oktober 1981, Uranprojekt Kvanefjeld Uranium Project, progress report, Unpubl. intern. rep. Res. Est. Risø, 5 pp.

Erlendsson, G., Jensen, J., Koefoed, S. & Paulsen, J. L. 1983: Skitseprojekt, Mine- og oparbejdningsanlæg. Unpubl. intern. rep. Res. Est. Risø, 149 pp.

Feilberg, J. 1976: Sydgrønlands karplanteflora. Unpublished thesis, University of Copenhagen. 177 pp.

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.

Ferguson, J. 1970a: 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.

Ferguson, J. 1970b: On the schistose structure of some lujavrites. *Bull. geol. Soc. Denmark* **20**, 67-68.

Ferguson, J. 1970c: The differentiation of agpaitic magmas: the Ilimaussaq intrusion, South Greenland. *Can. Miner.* **10**, 335-349.

Forsberg, R. & Rasmussen, K. L. 1977: Preliminary investigations on the densities and gravity in the Ilímausssaq area, South Greenland. Unpubl. rep. Inst. Geophysics, Univ. Copenhagen. 23 pp.

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

Funder, S. 1979: The Quaternary geology of the Narssaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **86**, 24 pp.

Gerasimovsky, V. I. 1969: Geokhimiya Illimaussakskogo shchelochnogo massiva. (Yugo-Zapadnaya Grenlandiya) [Geochemistry of the Ilímaussaq alkaline massif (South-West Greenland)], 174 pp. Moskva: Nauka.

Gryning, S. E. & Lyck, E. 1983: A tracer investigation of the atmospheric dispersion in the Dyrnæs Valley, Greenland. Risø-R-481, 67 pp.

GTO 1981: Energiforsyning til Kvanefjeldsprojektet - vurdering af alternative energiforsyningsmuligheder fra vandkraft og kraftvarmeværk, København: Grønlands Tekniske Organisation, 39 pp.

Hamilton, E. I. 1964: The geochemistry of the northern part of the Ilímaussaq intrusion, S.W. Greenland. *Bull. Grønlands geol. Unders.* **42** (also *Meddr Grønland* **162**, 10), 104 pp.

Hansen, J. 1965: Kortfattet beskrivelse af beryllium mineralisering i Ilímaussaq, Sydgrønland. Unpubl. intern. rep. Grønlands geol. Unders. 21 pp.

Hansen, J. 1967: Niobium mineralization in the Ilímaussaq massif, South-west Greenland. Unpubl. intern. rep. Grønlands geol. Unders. 21 pp.

Hansen, J. 1968: A study of radioactive veins containing rare-earth minerals in the area surrounding the Ilímaussaq alkaline intrusion in South Greenland. *Bull. Grønlands geol. Unders.* **76** (also *Meddr Grønland* **181**, 8), 47 pp.

Hansen, J. K. G. 1977: Sulphating roasting of a Greenlandic uranium ore, reactivity of minerals and recovery. *Risø Report* **355**, 144 pp.

Hansen, M. M. 1978: Muslingers forhold over for tungmetaller. Unpubl. thesis, Univ. of Copenhagen, 95 pp.

Hansen, M. M. 1979: Marine biological report, Narssaq Project. 41 pp.

Hansen, M. M. 1980: Oversigt over arbejde udført under Narssaq projektet af relevans for uranminemiljøundersøgelserne. Grønlands Fiskeriundersøgelser, 1.73.30.03.

Holm, P. M., Konnerup-Madsen, J. & Makovicky, M. 1982: Laboratory investigations of refractory uranium minerals from the Kvanefjeld uranium deposit, Greenland. Final Report EEC contract 018-79-1-EXU-DK.

Kalvig, P. 1983: Preliminary mining assessment of the uranium resource af Kvanefjeld, the Ilimaussaq intrusion, South Greenland. Kvanefjeld Uranium Project, special report 4, 109 pp. Risø: Risø National Laboratory.

Kalvig, P. & Appel, P. W. U. 1994: Greenlandic mineral resources for use in advanced materials. *Industrial Minerals* **319**, 45-51.

Kalsbeek, F., Larsen, L. M. & Bondam, J. 1990: Geological map of Greenland. 1:500 000. Descriptive text. Sheet 1. Sydgrønland, 36 pp. Copenhagen: Grønlands Geologiske Undersøgelse.

Kejlsø, E. 1958: Gravity measurements in western Greenland 1950-1952. *Geod. Inst. Skr., Kbh.* (3), **27**, 69 pp.

Klassen, I. P. 1979: Kvanefjeld ore benefication. 125 pp. Hatch Associates Ltd.

Koefoed, S. 1983: Filtrering, laboratorieundersøgelser. Unpubl. intern. rep. Risø National Lab., 33 pp.

Kristensen, L. 1983: Meteorological measurements at Kvanefjeld in the period September 1979- March 1983. Unpubl. intern. rep. Risø National Lab., 25 pp.

Larsen, C. L. 1977: A reconnaissance study of the exogeneous environment and the abundance of selected trace elements in the soils of the Ilímaussaq region, South Greenland. 74 pp.

Larsen, L. B. 1973: Water balance investigations in the Narssaq River Basin, South Greenland. Unpublished dissertation, Copenhagen University. 157 pp.

Larsen, L. M. & Sørensen, H. 1987: The Ilímaussaq intrusion - progressive crystallization and formation of layering in an agpaitic magma. *In* Fitton, J. G. & Upton, B. G. J. (ed.) Alkaline rocks. *Spec. Publ. geol. Soc. Lond.* **30**, 473-488.

Larsen-Badse, J. 1958: Radiometriske målinger: Agpat, Tugtup, Agtakorfia, Kvanefjeld, Kvanefjelds Ø-skråning. Unpubl. int. rep. GGU. ?? pp.

Lindegaard, C., Mæhl, P. & Nielsen, B. H. 1978: Zoobenthos of lakes located within and outside the Ilímaussaq intrusion in South Greenland. *Verh. Internat. Verein. Limnol.* 20, 159-164.

Løvborg, L. 1968: A portable γ-spectrometer for field use. *Risø report* **168**, xx pp.

Lovborg, L. 1972: Assessment of uranium by gamma-ray spectrometry. *In* Bowie, S. H. T., Davis, M. & Ostle, D. (ed.) *Uranium prospecting handbook*, 157-171. London: Institution of Mining and Metallurgy.

Løvborg, L., Kunzendorf, H. & Hansen, J. 1968a: Portable beryllium prospecting instrument with large sensitive area. *In: Nuclear techniques and mineral resources*, 55-63, Vienna: IAEA.

Løvborg, L., Kunzendorf, H., Hansen, J. 1968b: Use of field gamma-spectrometry in the exploration of uranium and thorium deposits in South Greenland. *In: Nuclear techniques and mineral resources*, 197-211, Vienna: IAEA.

Løvborg, L., Wollenberg, H., Rose-Hansen, J. & Nielsen, B. L. 1972: Drill-core scanning for radioelements by gamma-ray spectrometry. *Geophysics* **37**, 675-693.

Løvborg, L., Bøtter-Jensen, L., Christiansen, E. M. & Nielsen, B. L. 1978: Gamma-ray measurements in an area of high natural radioactivity, Proc. 31 Int. Symp. on the natural radiation environment, April 23-28, Houston, 14 pp.

Løvborg, L., Bøtter-Jensen, L., Christiansen, E. M. & Nielsen, B. L. 1980a: Gamma-ray measurements in an area of high natural radioactivity. *In* Gesell, T. F. & Lowder, W. M. (ed.) *Natural radiation environment III*, 2, 912-926. U.S. Dept. Energy, Tech. Inf. Center.

Løvborg, L., Nyegaard, P., Christiansen, E. M. & Nielsen, B. L. 1980b: Borehole logging for uranium by gamma-ray spectrometry. *Geophysics* **45**, 1077-1090.

Lurgi Chemie u. Hüttentechnik GmbH 1979a: Carbonate pressure leaching, laboratory tests. Lurgi Chemie G.m.b.h., Frankfurt, Germany, 1979. Risø Uranium project, 7 pp.

Lurgi Chemie u. Hüttentechnik GmbH 1979b: Carbonate pressure leaching Pi autoclave tests. Lurgie Chemie G.m.b.h., Frankfurt, Germany, 1979. Risø Uranium project, 7 pp.

Mæhl, P. 1978: Produktionsforholdene i en ultraoligotrof sø i Narssaq-området, Sydgrønland, specielt med henblik på phytoplankton- og zoobenthosproduktionen. Unpubl. thesis, University of Copenhagen, 113 pp.

Makovicky, M. 1981: Preliminary results on the distribution of uranium in drill cores from Kvanefjeld, Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 109-112.

Makovicky, M., Makovicky, E., Nielsen, B. L., Karup-Møller, S. & Sørensen, E. 1980: Mineralogical, radiographic and uranium leaching studies on the uranium ore from Kvanefjeld, Ilimaussaq Complex, South Greenland. Risø-R-416, 186 pp.

Markland, S. Aa. 1974: Skitseprojekt for oparbejdning af Grønlandsk eudialyt. Unpubl. intern. rep. Res. Est. Risø., 99 pp.

Mosegaard, H. 1978: Spatial and dynamic structure of a population of *Leptodiaptomus minutus* (Lillj) (Calanoida, Cpepoda) in relation to the limnological conditions of a small subarctic lake in the Narssaq area, South Greenland. Unpublished thesis, Univ. Copenhagen, 116 pp.

Nielsen, B. H. 1977: Benthosfaunaens sammensætning og livsvilkår i 2 af Ilímaussaq områdets søer. Unpubl. thesis, University of Copenhagen. 68 pp.

Nielsen, B. L. 1981: Exploration history of the Kvanefjeld uranium deposits, Ilímaussaq intrusion, South Greenland. *In: Uranium exploration case histories*, 353-388. Vienna: IAEA.

Nielsen, B. L. & Bøtter-Jensen, L. 1973: Natural background radiation levels from areas of major geological units in Greenland, determined by means of thermoluminescence dosimetry. *Modern Geol.* **4**, 119-129.

Nielsen, B. L. & Mejdahl, V. 1970: Gamma-ray logging by means of thermoluminescence dosimeters. *Risø Report* **219**, 17 pp.

Nielsen, B. L. & Steenfelt, A. 1979: Intrusive events at Kvanefjeld in the Ilímaussaq igneous complex. *Bull. geol. Soc. Denmark* **27**, 143-155.

Nielsen, L. 1979: En geokemisk undersøgelse af udvalgte grundstoffers fordeling i jord, sø-, elv- og havsedimenter i Narssaq området, Sydgrønland. 70 pp. Unpubl. thesis Univ. Copenhagen.

Nielsen, T. S. 1983: Undersøgelser af korrosionsforhold i forbindelse med pilotanlægget til udvinding af uran fra Kvanefjeldmalm ved Carbonate Pressure Leaching. Unpubl. intern. rep. Risø National Lab., 63 pp.

Nyegaard, P., Nielsen, B. L., Løvborg, L. & Sørensen, H. 1977: Kvanefjeld uranium project drilling programme 1977. Unpubl. intern. rep. Geological Survey of Greenland, 46 pp., tables.

Nyegaard, P. 1978: Drilling programme on the uranium mineralisation at Kvanefjeld, Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 64-67.

Nyegaard, P. 1979: Evaluation of uranium deposit at Kvanefjeld. With appendix: Løvborg, L., Nyegaard, P., Christiansen, E. M. & Nielsen, B. L.: Borehole logging for uranium by gamma-ray spectrometry. Unpubl. intern. rep. Grønlands geol. Unders. 58 pp. + tables and figs.

Nyegaard, P. 1980a: Geologisk kort over Kvanefjelds tunnelen (1:100). Unpubl. intern. rep. Grønlands geol. Unders., 1978, 6 pp.

Nyegaard, P. 1980b: Geologisk arbejde i Kvanefjeld tunnelen. Grønlands Geologiske Undersøgelse 1979/1980, 19 pp.

Nygaard, G. 1978: Freshwater phytoplankton from the Narssaq area, South Greenland. *Bot. Tidsskrift* **73**, 191-238.

Pihl, E. & Søn A/S 1979: Kvanefjeld tunnel, teksnisk beskrivelse. E. Pihl & Søn A/S, 1979, 18 pp.

Pihl, E. & Søn A/S 1980: Kvanefjeld tunnel, slutrapport. E. Pihl & Søn A/S, 1980, 18 pp.

Pilegaard, K. 1987: Biological monitoring of airborne deposition within and around the Ilimaussaq intrusion, Southwest Greenland. *Bioscience* **24**, 1-27.

Pilegaard, K. 1981: Deposition of airborne metals in the Narssaq area monitored by terrestrial vegetation. Report Inst. of Plant Ecology, Univ. Copenhagen, 19 pp., 11 tables, 6 figs.

Pilegaard, K. 1983: Preliminary environmental impact statement for the Kvanefjeld uranium mine. Unpubl. intern. rep. Risø National Lab., 123 pp.

Piper, J. D. A. 1976: Palaeomagnetism of marginal syenites and fractionated rocks of the Ilímaussaq intrusion, South Greenland. *Bull. geol. Soc. Denm.* **25**, 89-97.

Pryor, R. N., Burkin, A. R., St. John, C. M., White, B., Heidecker, A. A., Clark, I., Firmin, K. & Moore, D. 1974: Kvanefjeld Uranium Project Greenland, Pre-feasibility study by sensitivity analysis. Unpubl. intern. rep. 2 vol. incl. appendices.

Robertson, D. S. & Associates Ltd. 1977: Study of Kvanefjeld Uranium Project for the Ministry for Greenland. Intern. rep., 33 pp.

Robertson, D. S. & Associates Ltd. 1979: Review of the pre-feasibility studies of the Kvanefjeld deposit, South Greenland. Intern. rep., 60 pp.

Rose-Hansen, J. 1969: Preliminary description of drill cores from the Ilímaussaq intrusion in South Greenland. Unpubl. Intern. rep. Grønlands geol. Unders. 42 pp.

Rose-Hansen, J., Nielsen, C. O. & Sørensen, H. (ed.) 1977: The Narssaq project. A geochemical-ecological research project. Progress report No. 1 (2 vols). The 1974 field season. Copenhagen: Institute for Petrology.

Rose-Hansen, J., Sørensen, H. & Holm, P. M. 1986: The supergene distribution of uranium and accompanying elements associated with alkaline intrusions in South Greenland including the Ilìmaussaq complex. *Uranium* **2**, 185-214.

Sass, J. H., Nielsen, B. L., Wollenberg, H. A. & Munroe, R. J. 1972: Heat flow and surface radioactivity at two sites in southern Greenland. *J. geophys. Res.* **77**, 6435-6444,

Säwedal, L. 1979: Micropsectra Crundini n.sp. (Diptera: Chiromidae) and geographical variation in the Micropsectra in signilobus aggregate. *Ent. scand. Suppl.* **10**, 133-138.

Semenov, E. I. 1969: Mineralogiya shchelochogo massiva Ilimausak (Yuzhnaya Grenlandiya). [Mineralogy of the Ilímaussaq alkaline massif (South Greenland)]. Institut Mineralogii, Geokhimii i Kristallokhimii Redkikh Elementov. 164 pp. Moskva: Nauka.

Smidth, F. L. & Co. 1965: Skitseprojekt vedr. anlæg til brydning og oparbejdning af uranmalm fra Kvanefjeld på Grønland, Intern. rep., 25 pp., 10 app.

Sørensen, A. 1979: Målinger af radon på Kvanefjeld og i Narssaq by, januar 1979. Uranudvindingsprojekt Risø. Unpubl. intern. rep. Res. Est. Risø, 10 pp.

Sørensen, E. & Bukholt, B. 1979a: Brintfældningsautoklaveforsøg, Risø, 5 pp.

Sørensen, E., Bukholt, B. & Lundgaard, T. 1979b: Karbonatudludning, laboratorieforsøg, Risø. Rørautoklaveforsøg i Lünen. Risø, 27 pp.

Sørensen, A. 1980a: Strålingsdoser i forbindelse med tunneldrivningen i Kvanefjeld, december 1980, Uranudvindingsprojekt Risø. Unpubl. intern. rep. Res. Est. Risø, 19 pp.

Sørensen, A. 1980b: Transport af uranmalm fra Nassaq til Forsøgsanlæg Risø, august 1980. Uranudvindingsprojekt. Unpubl. intern. rep. Res. Est. Risø, 7 pp.

Sørensen, E. 1973: On the adsorption of some anionic collectors on fluoride minerals. *J. Colloid and Interface Sci.* **45**, 601-607.

Sørensen, A. 1983a: Lovgivningsmæssige rammer for uranudvinding på Grønland med særlig henblik på sikkerheds- og miljømæssige forhold, august 1983. Uranporjekt. Risø. 5 pp.

Sørensen, A. 1983b: Målinger af fluorid-koncentrationen i Narssaq elv i forbindelse med tunneldrivningen i Kvanefjeld 1979-1981. Uranprojekt. Risø, 12 pp.

Sørensen, E. & Jensen, J. 1985: Uranium extraction by continuous carbonate leaching in a pipe autoclave. *In: Advances in uranium ore processing and recovery from non-convential resources* (Proc. Tech. Comm. Meeting Vienna, 1973), 41-52. Vienna: IAEA.

Sørensen, E. & Lundgaard, T. 1966: Selective flotation of steenstrupine and monazite from Kvanefjeld lujavrite. *Risø Report* **133**, 17 pp.

Sørensen, E. & Lundgaard, T. 1967: Uranium from leaching liquors by precipitation. *Risø Report* **166**, 13 pp.

Sørensen, E., Lundgaard, T., Rasmussen, I. & Dibbern, H. C. 1978: Pilot plant testing on uranium extraction from the Kvanefjeld ore deposit. Risø-M-2102, 62 pp.

Sørensen, E. Koefoed, S. & Lundgaard, T. 1983: Uranudvinding ved udludning med natriumkarbonat under højt tryk og temperatur. Risø 1983, 86 pp.

Sørensen, E., Koefoed, S. & Lundgaard, T. 1990: Uranium recovery by leaching with sodium carbonate at high temperature and pressure. Risø-M-2876. 89 pp.

Sørensen, H. 1967: On the history of exploration of the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68**, 33 pp. (also *Meddr Grønland* **181**(3)).

Sørensen, H. 1969: Field work in the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **19**, 37-38.

Sørensen, H. 1992: Agpaitic nepheline syenites: a potential source of rare elements. *Applied Geochem.* **7**, 417-427.

Sørensen, H., Hansen, J. & Bondesen, E. 1969: Preliminary account of the geology of the Kvanefjeld area of the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **18**, 40 pp.

Sørensen, H., Danø, M. & Petersen, O. V. 1971: On the mineralogy and paragenesis of tugtupite $Na_8Al_2Be_2Si_8O_{24}(Cl,S)_2$ from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **95**^{I} (also *Meddr Grønland* **181**,13), 38 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. 1991: High-technology metals in alkaline and carbonatitic rocks in Greenland: recognition and exploration. *J. Geochem. Expl.* **40**, 263-279.

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.

Superfos A/S, Udviklingsafdelingen 1971: P. 68.18.05 - Forsøg med formaling og magnetseparation af kakortokit, naujait og pegmatit i samarbejde med Sala Maskinfabrik AB. - Undersøgelse af prøver fra lag 16. - Magnetseparationsforsøg hos Rapid. - Magnetseparationsforsøg hos professor H. T. Hukki. - Undersøgelse af prøver af sand opsamlet ved bredden af Kangerdluarsuk. - Forsøg med formaling af rød kakortokit på Aerofall mølle. - Oplukning, calcinering og udludning af eudialyt fra kakortokit. Company reports, 57 pp. combined.

Thorning, L., Bower, M., Hardwick, C. D. & Hood, P. J. 1985: Greenland ice cap aeromagnetic survey 1984: reconnaissance lines in southern Greenland. *Rapp. Grønlands geol. Unders.* **125**, 83-84.

Thorning, L., Tukiainen, T. & Steenfelt, A. 1994: Regional compilations of geoscience data from the Kap Farvel - Ivittuut area, South Greenland. *Thematic Map Ser. Grønlands geol. Unders.* **94/1**, 27 pp., 4 figs, 5 tables, 71 maps with legends.

Tilsley, J. E. & Ass. Ltd., Fisher, A. T. & Ass. Ltd. 1982: Mineral resources studies - Kvanefjeld deposit South Greenland. Intern. rep., 52 pp., appendices etc.

Uranprojekt Kvanefjeld 1983: Uranprojekt Kvanefjeld, hovedrapport. Risø: Risø National Lab., 86 pp.

Ussing, N. V. 1912: The geology of the country around Julianehaab, Greenland. *Meddr Grønland* **38**, 426 pp.

Vandel, P. S. 1983: Natriumfluorid fra Kvanefjeldet. Unpubl. intern. rep. Kryolitselskabet Øresund A/S, 18 pp.

Vandkraftværk Taseq, Narsaq, GTO 1981: Disposionsforslag, oktober 1981, 49 pp. + fig.

Vandkraftværk Taseq, Narsaq, GTO 1981: Disposionsforslag-sammenfatning, november 1981, 24 pp.

Vandkraftværk Taseq, Narsaq, GTO 1981: Disposionsforslag, revideret, december 1981, 57 pp. + fig.

Vandkraftværk Taseq, Narsaq, GTO 1981: Miljømæssig vurdering af dispotitionsforslag, november 1981, 21 pp. (Grønlands Fiskeriundersøgelser).

Vandkraftværk Taseq, Narsaq, GTO 1981: Ferskvandsbiologiske undersøgelser i Narssaq elv, 1981, december 1981, Grønlands Fiskeriundersøgelser, 48 pp.

Weidemann, R. 1979: Korrosions- og erosionsforsøg. Metallgesellschaft AG. Metall-Laboratorium, Februar 1979, 12 pp.

APPENDIX

The appendix is subdivided into a number of topics, as follows:

- Internal reports and diaries, Geological Survey of Greenland,
- Unpublished theses on file in the library of the Survey,
- Reports prepared for the "Kvanefjeld Uranium Project", 1978-83, Research Establishment Risø,
- Theses, reports and other publications prepared for the "Narssaq Project", 1974-1979, Geological Insitute, University of Copenhagen,
- "Contributions to the mineralogy of Ilímaussaq", Geological Institute, University of Copenhagen, 1994,
- Bibliography of the geology of Ilímaussaq.

Internal reports and diaries. The Geological Survey of Greenland

Andersen, S. 1964: Beskrivelse af den syd-østligste del af Kvanefjelds plateauet.

Andersen, S. 1981: Boringer i Ilímaussaq S for Tunugdliarfik, - et forsøg på en magma-stratigrafisk inddeling.

Boesen, K. 1958: Rapport vedrørende opmålingsarbejdet i Narssaq-området, foretaget i somrene 1957 og 1958.

Bondam, J. 1956a: Geologisk rapport vedrørende arbejde udført under den af Atomenergikommisionen udsendte expedition til Julianehåb distrikt i sommeren 1956.

Bondam, J. 1956b: Rapport vedrørende geologiske undersøgelser i Tunugdliarfik området, S-Grønland.

Bondam, J. 1957a: Rapport over undersøgelser ved uranforekomsten på Kvanefjeldet (Narssaq) i sommeren 1957.

Bondam, J. 1957b: Oversigt over planlagte detailundersøgelser i Gletscherelvs området ved Narssaq i sommeren 1957.

Bondam, J. 1958a: Radiometriske målinger ved Agpat og Tugtup Agtakorfia, sommeren 1958.

Bondam, J. 1958b: Rapport vedrørende undersøgelserne på Kvanefjeldet i sommeren 1958.

Bondam, J. & Ferguson, J. 1961: Forslag vedrørende boringer i Ilímaussaq 1962.

Bondesen, E. 1964: En strukturel-kronologisk undersøgelse af Kvanefjeldet og omgivelser. Narssaq.

Christensen, B. 1966: Rapport vedrørende det i sommeren 1966 udførte opmålingsarbejde i Narssaq-området.

Demina, A. 1979: Field geology and petrography of the upper kakortokites and a section through the lujavrites of the Ilímaussaq intrusion, South Greenland.

Engell, J. & Pedersen, A. K. 1965: Kortfattet kommentar til karteringen foretaget på Kvanefjeld.

Ferguson, J. 1960: Report on the mapping of the Ilímaussaq batholith South of Tunugdliarfik Fjord, Summer 1960, 35 pp., 7 plates, 1 fig., 1 map.

Ferguson, J. 1961: Report on the mapping of the Ilímaussaq batholith North of Tunugdliarfik Fjord, 28 pp., 7 plates.

G.G.U. 1976: Projektbeskrivelse af Kvanefjelds undersøgelser.

Greve, E. 1965: Undersøgelse af borekerne nr. 22, fra 74.30 til 99.30 m samt prøver af fin- og mellemkornet augit-syenit fra Ilímaussaq.

Hamilton, E. 1957: Geological report.

Hamilton, E. 1958: Progress report.

Hamilton, E. 1959a: Field report for the season 1959.

Hamilton, E. 1959b: Geochemical report.

Hansen, J. 1962: Radioaktive sprækkefyldninger på Narssaq halvøen. 118 pp., 2 maps.

Hansen, J. 1964: Kortfattet oversigt over Nb-mineraliseringer på Kvanefjelds plateauet og Taseq-skråningen, Ilímaussaq Syd Grønland. 14 pp., 1 map.

Hansen, J. 1964: Foreløbig rapport over boringer på Kvanefjeldsplateauet 1965.

Hansen, J. 1965: Kortfattet beskrivelse af Be-mineraliseringer i Ilimaussaq, Syd Grønland.

Hansen, J. R. 1965: Preliminary descriptions of drill cores from the Ilimaussaq alkaline intrusion in South Greenland.

Hansen, J. R. 1967a: Nb-mineralization in the Ilimaussaq alkaline massif, SW-Greenland. 15 pp., 2 tables.

Hansen, J. R. 1967b: Undersøgelser over fordelingen af Be-bjergarter og årer på Taseq-skråningen.

Hjort, L. & Led, J. J. 1961: Dyrnæs laboratoriets arbejde i 1961.

Houken, J. 1960: Dyrnæslaboratoriets arbejde i 1960.

Jacobsen, F. L. 1955: Rapport om geologiske undersøgelser udført i tilknytning til den af Atomenergikommisionen udsendte ekspedition til Julianehåb district i 1955.

Jensen, E. S. 1965: Rapport over feltarbejdet sommeren 1965.

Johansen, J. M. 1968: Dagbogsfortegnelse over pyrochlor og monazitførende årer på Kuanit Qaqa-plateauet, Ilimaussaq intrusionen ved Narssaq.

Ketelaar, J. 1962: Report Kvanefjeld, Nb and U. 9 pp., 3 maps.

Kunzendorf, H., Lundgaard, T., Rose-Hansen, J. & Sørensen, E. 1973: Estimation of niobium and fluorine in the Kvanefjeld area, the Ilimaussaq intrusion, S-Greenland, with description of the methods used.

Larsen-Badse, J. 1958: Radiometriske målinger: Agpat, Tugtup, Agtakorfia, Kvanefjeld, Kvanefjelds Ø-skråning.

Makovicky, M., Nielsen, B. L. & Karup-Møller, S. 1979: Distribution of uranium in lujavrite from drill cores from Kvanefjeld. 17 pp.

Nielsen, B. L. 1965: Dagbog over geologisk kartering på Kvanefjeld, sommeren 1965.

Nielsen, B. L. & Nyegaard, P. 1977: Kvanefjeld Uranium Project. Drilling programme 1977.

Nielsen, K. & Nissen, J. P. 1965: Rapport vedr. opmålings-arbejde i Narssaq området udført i sommeren 1965. 8 pp., 2 maps.

Nyegaard, P., Nielsen, B. L., Løvborg, L. & Sørensen, P. 1977: Kvanefjeld Uranium Project, Drilling Programme.

Nyegaard, P. 1977: Kvanefjeld Project. June 1977. GGU-interim.

Nyegaard, P. 1978: Uranudvindingsprojekt. placering af minegang under Kvanefjeld-Plateau.

Nyegaard, P. 1979: Evaluation of Uranium Deposit at Kvanefjeld. July, 1979.

Nyegaard, P. 1980a: Geologisk arbejde i Kvanefjeld tunnelen 1979/1980.

Nyegaard, P. 1980b: Geologisk kort over Kvanefjelds tunnelen (1:100).

Østergaard, T. V. 1964: Rapport over feltarbejdet i arfvedsonit-malingit området, Kvanefjeld, Ilímaussaq, Syd-Vest Grønland, sommeren 1964.

Østergaard, T. V. 1964: Afskrift af dagbog for tiden 1.7.-12.8.-64, vedrørende kortlægning af kvanit-området på Kvanefjeld.

Petersen, O.V. 1965: Naujakasite lujavrites in the Kvanefjeld area, the Ilimaussaq intrusion.

Petersen, O. V. 1966: Naujakasite and naujakasite-lujavrite. Part I.

Petersen, O. V. 1966: Naujakasite and other related lujavrites in Ilimaussaq. Part II.

Pulawski, B. 1966: Vandbalancen og terrassestudier i Narssaq elvdalen.

Scintrex Ltd. 1977: Logistics report on a radiometric borehole logging project in Southern Greenland on behalf of the Geological Survey of Greenland.

Sørensen, H. 1955: Foreløbig rapport over radioaktivitetsundersøgelser i Grønland, sommeren 1955.

Sørensen, H. 1957a: Rapport over geologiske undersøgelser udført i Ilímaussaq-området i 1957.

Sørensen, H. 1957b: Rapport over mineralogiske-petrografiske undersøgelser af Ilímaussaq: steenstrupin-holdige bjergarter.

Sørensen, H. 1959: Summary of a petrographic and autoradio-graphic examination of the lujavrites from Ilimaussaq. 24 pp.

Sørensen, H. 1962: Rapport om et besøg i Ilímaussaq, sommeren 1962.

Sørensen, H. 1974a: Rapport vedrørende feltsæsonen 1974 i Ilimaussaq området.

Sørensen, H. 1976: Rapport over rejse til Dyrnæs/Narssaq 25/6-9/7-1976. 17 pp. + appendix.

Sørensen, H. & Nielsen, B. L. 1975: Forslag til boreprogram i Kvanefjeldsområdet i 1976.

Sørensen, H., Hansen, J. & Nielsen, B. L. 1970: Rapport over undersøgelser af uranforekomsten på Kvanefjeldsplateauet 1964-1968, med forslag til nyt boreprogram.

Sørensen, H., Rose-Hansen, J. & Nielsen, B. L. 1971: Geologisk beskrivelse af uranforekomsterne på Kvanefjeldsplateauet, S-Grønland.

Steenfelt, A. 1972: Beskrivelse af pulaskit, heterogen foyait, sodalit-foyait, naujait og kakortokit på Kvanefjeld-plateauet, Ilímaussaq. 58 pp.

Steenfelt, A. & Bohse, H. 1973: Variations in the content of U in eudialyte from differentiated alkaline Ilímaussaq intrusion, South Greenland. 10 pp.

Stewart, J. W. 1960: Field report on the geology of the Narssaq District, South Greenland, Summer 1960. 38 pp.

Westergaard, A. S. 1968: Dagbog over ekspedition til Grønland, sommeren 1968.

Unpublished theses and dissertations, dealing with geoscientific subjects of the Ilímaussaq intrusion. Available at the library of the Geological Survey of Greenland

Blaxland, A. B. 1976: Geochronology and isotope geochemistry of the Gardar alkaline complexes. Ph.D. thesis, Edinburgh University.

Blundell, D. J. 1973: Crustal structure of the Gardar rift, South Greenland. Department of Environmental Sciences, University of Lancaster, England. 40 pp.

Christensen, N. P. 1980: The hydrochemistry of three drainage basins in South Greenland. Dissertation, University Copenhagen. 111 pp.

Clausen, F. L. 1982: A geostatistical study of the uranium deposit at Kvenfjeld, the Ilimaussaq intrusion, South Greenland. Risø-R-468, 289 pp.

Engell, J. E. 1968: Beskrivelse af forekomsten og dannelsen af nogle ussingiterer i Ilimaussaq-intrusionen. Dissertation, University of Copenhagen (Review Festskrift København Univ., Nov. 1968, 335-340). 166 pp.

Ferguson, J. 1967: The alkaline igneous intrusion of Ilmmaussaq, South Greenland. Ph.D. thesis, Univ. Witwatersrand. 305 pp.

Francis, G. H. 1957: Geological observations in the Tasermiut fjord and neighbouring area. Manuscript, British Museum (Natural History).

Hansen, J. 1962: Radioaktive sprækkefyldninger på Narssaq-halvøen. Dissertation, Copehagen University.

Konnerup-Madsen, J. 1980: Fluid inclusions in minerals from igneous rocks belonging to the Precambrian continental Gardar rift province, South Greenland: the alkaline Ilmmaussaq intrusion and the alkali acidic igneous complexes. M.Sc. thesis, University of Copenhagen. 140 pp.

Larsen, C. L. 1982: Udvalgte lanthaniders exogene kredsløb inden for Ilmmaussaq intrusionen og dele af Junianehåbsgranitten omkring Narssaq, Sydgrønland. Bidrag til kvantitative modeller. Licenciate thesis, Copenhagen University.

Larsen, J. G. 1974: Stratigrafi, geokemi og petrologi i den øvre vulkanske del af Eriksfjord Formation, Gardar-provinsen, Sydgrønland. Dissertation, Inst. for Petrologi, University Copenhagen. 2 vols, 134 pp. & 47 pp.

Larsen, L. B. 1973: Water balance investigations in the Narssaq River Basin, South Greenland. Dissertation, Copenhagen University. 157 pp.

Larsen, L. M. 1974: En kemisk undersøgelse af pyroxenerne i Ilimaussaq-Intrusionen, Sydgrønland. M.Sc. thesis, University Copenhagen. 2 vols, 148 pp.

Larsen, O. 1963: Ægirin-akmit-problemet belyst ved en undersøgelse af alkali-pyroxener fra nefelinsyenitintrusionen Ilmmaussaq i Sydwestgrønland. M.Sc. dissertation, Copenhagn University.

Martin, A. R. 1985: The evolution of the Tugtutog-Ilimaussaq dyke swarm, Southwest Greenland. Ph.D thesis, University Edinburgh. 565 pp.

Østergaard, T. V. 1964: En undersøgelse af hovedmineralerne og hovedkomponenternes fordeling i lagdelt "kvanit" fra Ilímaussaq, Sydgrønland, med en omtale af alkalimetallernes petrogene betydning. Dissertation, University of Copenhagen [Review: Festskrift Københavns Univ., Nov. 1964, 222-227].

Olesen, B. L. 1984: Geochemical mapping of South Greenland. Licentiate thesis, Dept. Mineral Industry, Technical University of Denmark.

Patchett, P. J. 1976: Rb-Sr geochronology and geochemistry of Proterozoic basic intrusions in Sweden and South Greenland. Ph.D thesis, University of Edinburgh.

Pearce, N. J. G. 1988: The petrology and geochemistry of the Igaliko Dyke Swarm, South Greenland. Ph.D thesis, University Durham. 2 vols, 322 pp & 141 pp.

Steenfelt, A. 1972: Beskrivelse af pulaskit, heterogen foyait, sodalitfoyait, naujait og kakortokit på Kvanefjeldsplateauet, Ilímaussaq. Dissertation, Copenhagen University, 52 pp.

Stewart, J. W. 1964: The earlier Gardar igneous rocks of the Ilímaussaq area, South Greenland. Ph.D. thesis, Durham University. 423 pp.

Winther, T. 1986: A petrological study of feldspar megacryst- and anorthosite xenolith bearing dykes from two dyke swarms in the Gardar province, South Greenland. Unpubl. thesis, Copenhagen University. 75 pp.

Reports prepared for the "Kvanefjeld Uranium Project", 1978-83

The following list of references is drawn from the final summary report issued by the Research Establishment Risø in November 1983, entitled: " Uranprojekt Kvanefjeld, Hovedrapport".

Reports on topics

A.C.G.: Uranprojekt Kvanefjeld. Samfundsøkonomisk vurdering, Arctic Consultant Group, 1983, 28 pp.

A.C.G.: Uranprojekt Kvanefjeld. Infrastruktur. Arctic Consultant Group 1983, 34 pp.

Erlendsson, G., Jensen, J., Koefoed, S. & Paulsen, J. L.: Skitseprojekt, Mine- og oparbejdningsanlæg. Risø 1983, 149 pp. + appendix.

Kalvig, P.: Preliminary Mining Assessment of the Uranium Resource at Kvanefjeld, the Ilímaussaq Intrusion, South Greenland. Risø 1983, 110 pp. + appendix.

Pilegaard, K. : Preliminary Environmental Impact Statement for the Kvanefjeld Uranium Mine. Risø 1983, 123 pp.

Sørensen, E., Koefoed, S. & Lundgaard, T.: Uranudvinding ved udludning med natriumkarbonat under højt tryk og temperatur. Risø 1983, 86 pp.

Progress reports

Bukholt, B. & Lundgaard, T.: Anlægsbeskrivelse af uranudvindingsanlæg (UP-2). Risø 1983, 70 pp. + appendix. (Internal repport).

Clausen, F. L.: Forslag til udtagning af prøvemalm fra minegang under Kvanefjeld og Kvanefjeldsplateau, Mineralogisk Institut, Danmarks Tekniske Højskole, Lyngby 1979, 20 pp.

Clausen, F. L.: A Geostatistical Study of the Uranium Deposit at Kvanefjeld, The Ilimaussaq Intrusion, South Greenland. Risø-R-468, Risø 1983, 289 pp.

Erlendsson, G.: Koordinering af borehuller på Kvanefjeld. Risø 1981, 2 pp. + appendix.

Erlendsson, G.: Skitseprojekt, Mine- og oparbejdningsanlæg. Appendix, Risø 1983, 118 pp.

Grønlands Geologiske Undersøgelse: Kvanefjeld Uranium Project Drilling Programme 1977, Summary. 10 pp. + appendix.

Grønlands Tekniske Organisation: Energiforsyning til Kvanefjeldsprojektet - Vurdering af alternative energiforsyningsmuligheder fra vandkraft og kraftvarmeværk, København 1981, 39 pp.

Gryning, S. E. & Lyck, E.: A Tracer Investigation of the Atmospheric Dispersion in the Dyrnæs Valley, Greenland. Risø-R-481, 1983, 67 pp.

Hatch Associates Ltd.: Kvanefjeld Ore Benefication. Toronto 1979, 125 pp.

Jensen, J.: Energiestimate, Uranprojekt Kvanefjeld. Risø 1981, 9 pp.

Johansen, A. Kjær, Sørensen, E. & Lundgaard, T.: Oplagsplads for 4200 tons lujavrit på Risø - Teknisk rapport. Risø 1980, 8 pp. + appendix.

Kalvig, P.: A preliminary pit slope stability study, Kvanefjeld, South Greenland. Risø, 1983. 16 pp. + appendix.

Koefoed, S.: Filtrering, laboratorieundersøgelser. Risø 1983, 33 pp. + appendix.

Kristensen, L.: Meteorological measurements at Kvanefjeld in the period September 1979 - March 1983. Risø 1983, 25 pp. + appendix.

Kristensen, L.: Meteorologiske målinger ved Kvanefjeld, Statusrapport 1, 2 og 3. Risø 1983, 5, 121 and 150 pp.

Lundgaard, T.: Oplagsplads for tunnelmateriale, Grønland. Risø 1981, 4 pp.

Lurgi Chemie: Carbonate Pressure Leaching, Laboratory Tests. Lurgi Chemie G.m.b.h., Frankfurt, Germany, 1979, 7 pp. + appendix.

Lurgi Chemie: Carbonate Pressure Leaching Pipe Autoclave Tests. Lurgie Chemie G.m.b.h., Frankfurt, Germany, 1979, 7 pp.

Makovicky, M., Makovicky, E., Nielsen, B. L., Karup-Møller, S. & Sørensen, E.: Mineralogical, Radiographic and Uranium Leaching Studies on the Uranium Ore from Kvanefjeld, Ilimaussaq Complex, South Greenland. Risø-R-416, 1980, 186 pp.

Nielsen, T. S.: Undersøgelser af korrosionsforhold i forbindelse med pilotanlægget til udvinding af uran fra Kvanefjeldmalm ved Carbonate Pressure Leaching. Risø 1983, 63 pp.

NUEXCO: Uranium World Market Study and Price Forecast, 1982 to 1996. (del 1 og 2). Menlo Park, Calif., 1982, 150 pp.

Nyegaard, P.: Placering af minegang under Kvanefjeld og Kvanefjeld-plateau. Grønlands Geologiske Undersøgelse, 1978, 6 pp. + appendix.

Nyegaard, P.: Geologisk arbejde i Kvanefjeld tunnelen. Grønlands Geologiske Undersøgelse 1979/1980, 19 pp. + appendix.

Nyegaard, P.: Kvanefjelds tunnelens geologi. Grønlands geologiske Undersøgelse 1980, 75 pp.

Pedersen, P. A.: Varmeenergiforsyning til Uranprojekt Kvanefjeld. København 1983, 23 pp. + appendix.

Pihl, E. & Søn A/S: Kvanefjeld tunnel, teknisk beskrivelse. E. Pihl & Søn A/S, 1979, 18 pp. + appendix.

Pihl, E. & Søn A/S: Kvanefjeld tunnel, slutrapport. E. Pihl & Søn A/S, 1980, 18 pp. + appendix.

Risø: Procesanlæg, skitseprojekt, budgetoverslag fra komponentleverandøren. Risø 1983, 125 pp.

Robertson, D. S. & Associates Ltd.: Review of the Pre-Feasibility Studies of the Kvanefjeld Deposit, Southern Greenland. Toronto 1979, 60 pp.

Sørensen, A.: Transport af uranmalm fra Narssaq til Forsøgsanlæg Risø. Risø 1980, 7 pp.

Sørensen, A.: Lovgivningsmæssige rammer for uranudvinding på Grønland med særlig henblik på sikkerheds- og miljømæssige forhold, Risø 1983, 5 pp.

Sørensen, A.: Måling af radon på Kvanefjeld og i Narssaq by. Risø 1979, 10 pp.

Sørensen, A.: Strålehygiejniske problemer i forbindelse med brydning af uranmalm i Kvanefjeld og oparbejdning af uran. Risø 1983, 23 pp.

Sørensen, A.: Strålingsdoser i forbindelse med tunneldrivningen i Kvanefjeld. Risø 1980, 19 pp.

Sørensen, A.: Måling af fluorid-koncentrationen i Narssaq elv i forbindelse med tunneldrivningen i Kvanefjeld 1979-1981. Risø 1983, 12 pp. + appendix.

Sørensen, E.: Carbonate Pressure Leaching (CPL) Laboratory tests at Risø, June 1979. Risø 1979, 12 pp.

Sørensen, E.: Water-soluble Substances in Kvanefjeld Lujavrite. Risø 1982, 4 pp.

Sørensen, E. & Bukholt, B.: Brintfældningsautoklaveforsøg, Risø 1979, 5 pp.

Sørensen, E., Bukholt, B. & Lundgaard, T.: Karbonatudludning, laboratorieforsøg, Risø. Rørautoklaveforsøg i Lünen. Risø 1979, 27 pp.

Tilsley, J. E. & Fisher, A. T.: Mineral Resource Studies - Kvanefjeld Deposit, South Greenland. Toronto 1983, 52 pp. + appendix.

Tilsley, J. E. & Fisher, A. T.: Mineral Resource Studies - Kvanefjeld Deposit, South Greenland: Geological Plans and Sections. Toronto 1983.

Vandel, P. S.: Natriumfluorid fra Kvanefjeldet, Kryolitselskabet Øresund A/S, København 1983, 18 pp.

Weidemann, R.: Korrosions- og erosionsforsøg. Metallgesellschaft AG. Metall-Laboratorium, Februar 1979, 12 pp.

Theses, reports and other publications prepared for the "Narssaq Project", 1974-1979

Unpublished theses; University of Copenhagen

Christensen, N. P. 1980: The hydrochemistry of three drainage basins in South Greenland, 111 pp.

Feilberg, J. 1976: Sydgrønlands karplanteflora. 177 pp.

Hansen, M. M. 1978: Muslingers forhold over for tungmetaller. 95 pp.

Mæhl, P. 1978: Produktionsforholdene i en ultraoligotrof sø i Narssaq-området, Larsen, C. L. 1977: A reconnaissance study of the exogeneous environment and the abundance of selected trace elements in the soils of the Ilímaussaq region, South Greenland. 74 pp.

Mosegaard, H. 1978: Spatial and dynamic structure of a population of *Leptodiaptomus minutus* (Lillj) (Calanoida, Copepoda) in relation to the limnological conditions of a small subarctic lake in the Narssaq area, South Greenland. 116 pp.

Nielsen, B. H. 1977: Benthosfaunaens sammensætning og livsvilkår i 2 af Ilímaussaq områdets søer. 68 pp.

Sydgrønland, specielt med henblik på phytoplankton- og zoobenthosproduktionen. 113 pp.

Nielsen, L. 1979: En geokemisk undersøgelse af udvalgte grundstoffers fordeling i jord, sø-, elv- og havsedimenter i Narssaq området, Sydgrønland. 70 pp.

Reports

Hansen, M. M. 1979: Marine biological report, Narssaq Project. 41 pp.

Nielsen, C. O., Rose-Hansen, J. & Sørensen, H. 1975: Narssaq projektet. Et miljøgeokemisk-økologisk forskningsprojekt. Rapport nr. 1. Baggrunden for projektet. Forberedelsesfasen. Logbog for sommeren 1974. Planlægning af analyseprogrammet. Institut for Petrologi. 35 pp.

Nielsen, C., Rose-Hansen, J. & Sørensen, H. 1975: Narssaq Projektet. Et miljøgeokemisk-økologisk forskningsprojekt. Rapport nr. 2. Oversigt over arbejder udført i 1975. Institut for Petrologi, 56 pp.

Rose-Hansen, J., Nielsen, C. O. & Sørensen, H. (ed.) 1977: The Narssaq Project. A geochemical-ecological research project. Progress report no. 1. The 1974 field season. Institut for Petrologi, vol. I+II, 82 pp.

Other publications

Alstrup, V. 1979: Notes on selected Greenlandic Lichens. *Bot. Tidsskr.* **74**, 155-163.

Asmund, G. & Rose-Hansen, J. 1978: High zinc contents of sea water in Kangerdluarssuk, the Ilímaussaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 79-81.

Christensen, N. P. 1979: Automatisk registrering af hydrologiske og meteorologiske data i Sydgrønland. *Vannet i Norden* **4**, 7-14.

Christensen, N. P. 1980: Automatiske "miljø-målinger" i Sydgrønland. Kujatâne Ûgtortautit ingmingne pârissut. *Forskning i Grønland/tusaut*, **80/1-2**, 14 pp.

Funder, S. 1979: The Quaternary geology of the Narssaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **86**, 1-24.

Heydorn, K., Skanborg, P. Z., Gwozdz, R., Schmidt, J. O. & Wacks, M. E. 1976: Determination of lithium by instrumental neutron activation analysis. *Proc. 1976 International Conference: Modern Trends in Activation Analysis*, vol. **I**, 21-31.

Larsen, C. & Gwozdz, R. 1979: Anvendelse af instrumentel neutronaktiveringsanalyse til bestemmelse af sporelementer i suspenderet materiale (foredragsreferat). 7. Nordiske Sporelementkonference i Vejle 24.-27. juni 1979. 2 pp.

Lindegaard, C., Mæhl, P. & Nielsen, B. H. 1978: Zoobenthos of lakes located within and outside the Ilímaussaq intrusion in South Greenland. *Verh. Internat. Verein. Limnol.* **20**, 159-164.

Nielsen, C. O., Rose-Hansen, J. & Sørensen, H. (ed.) 1975: Environmental, geochemical and ecological studies in the region around the Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **80**, 93-97.

Nielsen, C. O., Rose-Hansen, J. & Sørensen, H. 1979: Narssame pilerssarut. *VARV* 1-29 (special issue).

Nygaard, G. 1978: Freshwater phytoplankton from the Narssaq area, South Greenland. *Bot. Tidsskrift* **73**, 191-238.

Rose-Hansen, J. & Sørensen, H. 1977: Current research in hte Ilímaussaq region, South Greenland. *Rapp. Grønlands geol. Unders.* **85**, 67-73.

Rose-Hansen, J. & Sørensen, H. (ed.) 1977: Geological, geochemical and ecological research in the Ilímaussaq region, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 67-73.

Rose-Hansen, J., Sørensen, H. & Nielsen, C. O. 1978: Narssaq-projektet 2, *VARV* **3**, 89-96.

Rose-Hansen, J. & Sørensen, H. 1979: Geological, geochemical and ecological studies in the Ilímaussaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **95**, 79-81.

Sørensen, H., Rose-Hansen, J. & Gwozdz, R. 1976: Forekomster af sjældne grundstoffer og miljøgeokemiske undersøgelser i Sydgrønland. Nordisk Vintermøde Göteborg (foredragsrefereat).

Sørensen, H. & Rose-Hansen, J. 1978: Narssaq-projektet. Et miljø-geokemisk-økologisk forskningsprojekt. *VARV* **1978(1)**, 3-14.

Contributions to the mineralogy of Ilímaussaq

No. 1 Semenov,E.I., Gerassimovsky,V.I., Maksimova,N.V., Andersen,S. & Petersen,O.V. 1965: Sorensenite, a new sodium-beryllium-tin-silicate from the Ilímaussaq intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **61** (also *Meddr Grønland* **181**,1) 19 pp.

No. 2 Semenov,E.I. & Sørensen,H. 1966: Eudidymite and epididymite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **63** (also *Meddr Grønland* **181**,2) 21 pp.

No. 3 Sørensen,H. 1967: On the history of exploration of the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**,3) 33 pp.

No. 4 Bollingberg,H. & Petersen,O.V. 1967: Genthelvite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**,4) 1-9.

No. 5 Andersen,S. 1967: On beryllite and bertrandite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**,4) 11-27.

No. 6 Semenov,E.I., Kazakova,M.E. & Aleksandrova,R.A. 1967: The Lovozero minerals nenadkevichite, gerassimovskite and tundrite – from Ilímaussaq, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**,5) 1-11.

No. 7 Semenov,E.I., Sørensen,H., Bessmertnaja,M.S & Novorossova,L.E. 1967: Chalcothallite a new sulphide of copper and thallium from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**,5) 13-26.

No. 8 Petersen,O.V. 1966: Crossed axial plane dispersion in epididymite. *Amer. Miner.* **51**, 916-919.

No. 9 Petersen,O.V. 1967: The mineralogy of naujakasite. *Bull. Grønlands geol. Unders.* **75** (also *Meddr Grønland* **181**,6) 17 pp.

No. 10 Semenov,E.I., Kazakova,M.E. & Bukin,V.J. 1968: Ilimaussite, a new rare earth-niobium-barium silicate from Ilímaussaq, South Greenland. *Bull. Grønlands geol. Unders.* **75** (also *Meddr Grønland* **181**,7) 3-7.

No. 11 Semenov,E.I., Sørensen,H. & Katajeva,Z.T. 1968: On the mineralogy of pyrochlore from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **75** (also *Meddr Grønland* **181**,7) 9-24.

No. 12 Hansen,J. 1968: A study of radioactive veins containing rare-earth minerals in the area surrounding the Ilímaussaq alkaline intrusion in South Greenland. *Bull. Grønlands geol. Unders.* **76** (also Meddr Grønland **181**,8) 47 pp.

No. 13 Andersen,E.K., Danø,M. & Petersen,O.V. 1969: A tetragonal natrolite. [from the Ilímaussaq alkaline intrusion, South Greenland.] *Bull. Grønlands geol. Unders.* **79** (also *Meddr Grønland* **181**,10) 19 pp.

No. 14 Sørensen,H., Hansen,J. & Bondesen,E. 1969: Preliminary account of the geology of the Kvanefjeld area of the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **18**, 40 pp.

No. 15 Sobolev,V.S., Bazarova,T.Y., Shugurova,N.A., Bazarov,L.Sh., Dolgov,Yu.A. & Sørensen,H. 1970: A preliminary examination of fluid inclusions in nepheline, sorensenite, tugtupite and chkalovite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **81** (also *Meddr Grønland* **181**,11) 32 pp.

No. 16 Semenov,E.I., Bukin,V.I., Balashov,Yu.A. & Sørensen,H. 1967: Rare earths in minerals of the joaquinite group. *Amer. Miner.* **52**, 1762-1769.

No. 17 Sørensen,H., Leonardsen,E.S. & Petersen,O.V. 1970: Trona and thermonatrite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. geol. Soc. Denmark* **20**, 1-19.

No. 18 Petersilie,I.A. & Sorensen,H. 1970: Hydrocarbon gases and bituminous substances in rocks from the Ilímaussaq alkaline intrusion, south Greenland. *Lithos* **3**, 59-76.

No. 19 Povarennykh,A.S., Platonov,A.N. & Belichenko,V.P. 1970: On the colour of ussingite from the Ilímaussaq (South Greenland) and Lovozero (Kola Peninsula) alkaline intrusions. *Bull. geol. Soc. Denmark* **20**, 20-26.

No. 20 Sørensen,H., Danø,M. & Petersen,O.V. 1971: On the mineralogy and paragenesis of tugtupite $Na_8Al_2Be_2Si_8O_{24}(Cl,S)_2$ from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **95**[I] (also *Meddr Grønland* **181**,13) 38 pp.

No. 21 Povarennykh,A.S., Platonov,A.N., Tarashchan,A.N. & Belichenko,V.P. 1971: The colour and luminescence of tugtupite (beryllosodalite) from Ilímaussaq, South Greenland. *Bull. Grønlands geol. Unders.* **95**^{II} (also *Meddr Grønland* **181**,14) 12 pp.

No. 22 Engell,J., Hansen,J., Jensen,M., Kunzendorf,H. & Løvborg,L. 1971: Beryllium mineralization in the Ilímaussaq intrusion, South Greenland, with description of a field beryllometer and chemical methods. *Rapp. Grønlands geol. Unders.* **33**, 40 pp.

No. 23 Løvborg,L., Wollenberg,H., Sørensen,P. & Hansen,J. 1971: Field determination of uranium and thorium by gamma-ray spectrometry, exemplified by measurements in the Ilímaussaq alkaline intrusion, South Greenland. *Econ. Geol.* **66**, 368-384.

No. 24 Wollenberg,H., Kunzendorf,H. & Rose-Hansen,J. 1971: Isotope-excited X-ray fluorescence analyses for Nb, Zr, and La + Ce on outcrops in the Ilímaussaq intrusion, South Greenland. *Econ. Geol.* **66,** 1048-1060.

No. 25 Bohse,H., Brooks,C.K. & Kunzendorf,H. 1971: Field observations on the kakortokites of the Ilímaussaq intrusion, South Greenland, including mapping and analyses by portable X-ray fluorescence equipment for zirconium and niobium. *Rapp. Grønlands geol. Unders.* **38**, 43 pp.

No. 26 Petersen,O.V. & Rönsbo,J.G. 1972: Semenovite – a new mineral from the Ilímaussaq alkaline intrusion, south Greenland. *Lithos* **5**, 163-173.

No. 27 Cannilo,E., Mazzi,F. & Rossi,G. 1972: The structure type of joaquinite. *Tschermaks miner. petrogr. Mitt.* **17**, 233-246.

No. 28 Engell,J. 1973: A closed system crystal-fractionation model for the agpaitic Ilímaussaq intrusion, South Greenland with special reference to the lujavrites. *Bull. geol. Soc. Denmark* **22**, 334-362.

No. 29 Petersen,O.V. & Andersen,S. 1975: The crystal habit of naujakasite with note on some new occurrences. *Bull. Grønlands geol. Unders.* **116**, 5-9.

No. 30 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.

No. 31 Larsen,L.M. & Steenfelt,A. 1974: Alkali loss and retention in an iron-rich peralkaline phonolite dyke from the Gardar province, south Greenland. *Lithos* **7**, 81-90.

No. 32 Karup-Møller,S. 1974: Mineralogy of two copper-antimony-sulphide-oxide occurrences from the Ilímaussaq alkaline intrusion in South Greenland. *Neues Jb. Miner., Abh.* **122**, 291-313.

No. 33 Karup-Møller,S. & Makovicky,E. 1974: Skinnerite Cu_3SbS_3, a new sulfosalt from the Ilímaussaq alkaline intrusion, South Greenland. *Amer. Miner.* **59**, 889-895.

No. 34 López-Soler,A., Bosch-Figueroa,J.M., Karup-Møller,S., Besteiro,J. & Font-Altaba,M. 1975: Optical study of cuprostibite (Cu_2Sb). *Fortschr. Miner.* **52**, 557-565.

No. 35 Bohse,H., Rose-Hansen,J., Sørensen,H., Steenfelt,A., Løvborg,L. & Kunzendorf,H. 1974: On the behaviour of uranium during crystallization of magmas - with special emphasis on alkaline magmas. In: *Formation of uranium ore deposits,* 49-60. Vienna: International Atomic Energy Agency.

No. 36 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.

No. 37 Karup-Møller,S. 1975: On the occurrence of native lead, litharge, hydrocerussite and plattnerite within the Ilímaussaq alkaline intrusion in South Greenland. *Neues Jb. Miner., Mh.* **1975,** 229-241.

No. 38 Larsen,L.M. 1976: Clinopyroxenes and coexisting mafic minerals from the alkaline Ilímaussaq intrusion, South Greenland. *J. Petrol.* **17**, 258-290.

No. 39 Platt,R.G. & Rose-Hansen,J. 1975: The system ussingite-water and its bearing on crystallization in persodic portions of the system Na_2O-Al_2O_3-SiO_2-H_2O at 1 kb total pressure. *J. Geol.* **83**, 763-772.

No. 40 Andersen,E.B., Fenger,J. & Rose-Hansen,J. 1975: Determination of $[Fe^{2+}]/[Fe^{3+}]$-ratios in arfvedsonite by Mössbauer spectroscopy. *Lithos* **8**, 237-246.

No. 41 Blaxland,A.B., van Breemen,O. & Steenfelt,A. 1976: Age and origin of agpaitic magmatism at Ilímaussaq, south Greenland: Rb-Sr study. *Lithos* **9**, 31-38.

No. 42 Karup-Møller,S. 1976: Gmelinite and herschelite from the Ilímaussaq intrusion in South Greenland. *Mineralog. Mag.* **40**, 867-873.

No. 43 Petersen,O.V. 1978: The twin formation of tugtupite, a contribution. *Mineralog. Mag.* **42**, 251-254.

No. 44 Oen I.S., Burke,E.A.J. & Kieft,C. 1977: Westerveldite from Igdlúnguaq, Ilímaussaq alkaline massif, South Greenland. *Mineralog. Mag.* **41**, 77-83.

No. 45 Karup-Møller,S. & Makovicky,E. 1977: Westerveldite from the Ilímaussaq alkaline intrusion in South Greenland. Mineralogy, crystallography, mineral associations and alteration products. *Neues Jb. Miner., Abh.* **130**, 208-242.

No. 46 Karup-Møller,S., Løkkegaard,L., Semenov,E.I. & Sørensen,H. 1978: The occurrence of cuprostibite. *Bull. Grønlands geol. Unders.* **126**, 7-22.

No. 47 Karup-Møller,S. 1978: Primary and secondary ore minerals associated with cuprostibite. *Bull. Grønlands geol. Unders.* **126**, 23-47.

No. 48 Karup-Møller,S. 1978: The ore minerals of the Ilímaussaq intrusion: their mode of occurrence and their conditions of formation. *Bull. Grønlands geol. Unders.* **127**, 51 pp.

No. 49 Larsen,L.M. 1977: Aenigmatites from the Ilímaussaq intrusion, south Greenland: chemistry and petrological implications. *Lithos* **10**, 257-270.

No. 50 Hansen,J.K.G. 1977: Sulphatising roasting of a Greenlandic uranium ore, reactivity of minerals and recovery. *Risø Rep.* **355**, 129 pp.

No. 51 Mazzi,F., Ungaretti,L., Dal Negro,A., Petersen,O.V. & Rönsbo,J.G. 1979: The crystal structure of semenovite. *Amer. Miner.* **64**, 202-210.

No. 52 Konnerup-Madsen,J., Larsen,E. & Rose-Hansen,J. 1979: Hydrocarbon-rich fluid inclusions in minerals from the alkaline Ilímaussaq intrusion, South Greenland. *Bull. Minér.* **102**, 642-653.

No. 53 Larsen,J.G. 1977: Petrology of the late lavas of the Eriksfjord Formation, Gardar province, South Greenland. *Bull. Grønlands geol. Unders.* **125**, 31 pp.

No. 54 Sørensen,H. 1978: The position of the augite syenite and pulaskite in the Ilímaussaq intrusion, South Greenland. *Bull. geol. Soc. Denmark* **27**, spec. issue, 15-23.

No. 55 Nielsen,B.L. & Steenfelt,A. 1979: Intrusive events at Kvanefjeld in the Ilímaussaq igneous complex. *Bull. geol. Soc. Denmark* **27**, 143-155.

No. 56 Larsen,L.M. 1979: Distribution of REE and other trace elements between phenocrysts and peralkaline undersaturated magmas, exemplified by rocks from the Gardar igneous province, south Greenland. *Lithos* **12**, 303-315.

No. 57 Rønsbo,J.G., Khomyakov,A.P., Semenov,E.I., Voronkov,A.A. & Garanin,V.K. 1979: Vitusite a new phosphate of sodium and rare earths from the Lovozero alkaline massif, Kola, and the Ilímaussaq alkaline intrusion, south Greenland. *Neues Jb. Miner., Abh.* **137**, 42-53.

No. 58 Makovicky,E., Johan,Z. & Karup-Møller,S. 1980: New data on bukovite, thalcusite, chalcothallite and rohaite. *Neues Jb. Miner., Abh.* **138**, 122-146.

No. 59 Nielsen,B.L. 1981: Exploration history of the Kvanefjeld uranium deposit, Ilímaussaq intrusion, South Greenland. In: *Uranium exploration case histories,* 353-388. Vienna: International Atomic Energy Agency.

No. 60 Makovicky,E. & Karup-Møller,S. 1981: Crystalline steenstrupine from Tunugdliarfik in the Ilímaussaq alkaline intrusion, South Greenland. *Neues Jb. Miner., Abh.* **140**, 300-330.

No. 61 Petersen,O.V. 1981: The first natural crystals of NaF, villiaumite. *Neues Jb. Miner., Mh.* **1981**, 111-116.

No. 62 Larsen,L.M. 1981: Sector zoned aegirine from the Ilímaussaq alkaline intrusion, South Greenland. *Contr. Miner. Petr.* **76**, 285-291.

No. 63 Bailey,J.C., Larsen,L.M. & Sørensen,H. (ed.) 1981: The Ilímaussaq intrusion, South Greenland. A progress report on geology, mineralogy, geochemistry and economic geology. *Rapp. Grønlands geologiske Unders.* **103**, 130 pp.

No. 64 Bailey,J.C., Rose-Hansen,J. & Sørensen,H. 1983: Leaching of uranium and thorium as a petrogenetic indicator in the agpaitic Ilímaussaq intrusion, South Greenland. *In* Augustithis,S.S. (ed.) *Significance of Trace Elements in Solving Petrogenetic Problems & Controversies*, 861-885. Athens: Theophrastus Publ.

No. 65 Konnerup-Madsen,J. & Rose-Hansen,J. 1982: Volatiles associated with alkaline igneous rift activity: fluid inclusions in the Ilímaussaq intrusion and the Gardar Granitic complexes (South Greenland). *Chem. Geol.* **37**, 79-93.

No. 66 Karup-Møller,S. 1982: Tundrite from the Ilímaussaq alkaline intrusion, South Greenland. *Neues Jb. Miner., Mh.* **1982**(11), 481-494.

No. 67 Rønsbo,J.G., Leonardsen,E.S., Petersen,O.V. & Johnsen,O. 1983: Second occurrence of vuonnemite the Ilímaussaq alkaline complex, South West Greenland. *Neues Jb. Miner., Mh.* **1983**(10), 451-460.

No. 68 Petersen,O.V., Johnsen,O., Leonardsen,E.S. & Rønsbo,J.G. 1984: Kvanefjeldite, a new mineral species from the Ilímaussaq alkaline complex, Southwest Greenland. *Can. Miner.* **22,** 465-467.

No. 69 Karup-Møller,S. 1983: Lomonosovite from the Ilímaussaq intrusion, South Greenland. *Neues Jb. Miner., Abh.* **148** (1), 83-96.

No. 70 Karup-Møller,S. 1986: Nenadkevichite from the Ilímaussaq intrusion in South Greenland. *Neues Jb. Miner., Mh.* **1986**(2), 49-58.

No. 71 Konnerup-Madsen,J. 1984: Compositions of fluid inclusions in granites and quartz syenites from the Gardar continental rift province (South Greenland). *Bull. Minéral.* **107,** 327-340.

No. 72 Konnerup-Madsen,J. & Rose-Hansen,J. 1984: Composition and significance of fluid inclusions in the Ilímaussaq peralkaline granite, South Greenland. *Bull. Minéral.* **107,** 317-326.

No. 73 Johnsen,O., Leonardsen,E.S., Fälth,L. & Annehed,H. 1983: The crystal structure of kvanefjeldite; the introduction of (Si_3O_7OH) layers with eight-membered rings. *Neues Jb. Miner., Mh.* **1983**(11), 505-512.

No. 74 Konnerup-Madsen,J., Dubessy,J. & Rose-Hansen,J. 1985: Combined Raman microprobe spectrometry and microthermometry of fluid inclusions in minerals from igneous rocks of the Gardar province (South Greenland). *Lithos* **18,** 271-280.

No. 75 Sørensen,H., Makovicky,M. & Rose-Hansen,J. 1985: Reconnaissance studies on the synthesis and stability of steenstrupine. *Bull. geol. Soc. Finland,* spec. Sahama Memorial vol. **57** (1-2), 103-112.

No. 76 Karup-Møller,S. & Petersen,O.V. 1984: Tuperssuatsiaite, a new mineral species from the Ilímaussaq intrusion in South Greenland. *Neues Jb. Miner., Mh.* **1984**(11), 501-512.

No. 77 Rose-Hansen,J., Sørensen,H. & Holm,P.M. 1986: The supergene distribution of uranium and accompanying elements associated with alkaline intrusions in South Greenland including the Ilímaussaq complex. *Uranium* **2,** 185-214.

No. 78 Konnerup-Madsen,J., Kreulen,R. & Rose-Hansen,J. 1988: Stable isotope characteristics of hydrocarbon gases in the alkaline Ilímaussaq Complex, South Greenland. *Bull. Minéral.* **111,** 567-576.

No. 79 Karup-Møller,S. 1986: Murmanite from the Ilímaussaq alkaline complex, South Greenland. *Neues Jb. Miner., Abh.* **155** (1), 67-88.

No. 80 Karup-Møller,S. 1986: Epistolite from the Ilímaussaq alkaline complex in South Greenland. *Neues Jb. Miner., Abh.* **155** (3), 289-304.

No. 81 Sørensen,H. & Larsen,L.M. 1987: Layering in the Ilímaussaq alkaline intrusion, South Greenland. *In* Parsons,I. (ed.) *Origin of Igneous Layering*. NATO Adv. Sci. Inst. Ser. C. Mat. Phys. Sci. **196**, 1-28.

No. 82 Larsen,L.M. & Sørensen,H. 1987: The Ilímaussaq intrusion - progressive crystallization and formation of layering in agpaitic magma. *In* Fitton,J.G. & Upton,B.G.J. (ed.) *Alkaline Igneous Rocks. Spec. Publ. geol. Soc., Lond.* **30,** 473-488. London.

No. 83 Petersen,O.V., Rønsbo,J. & Leonardsen,E. 1989: Nacareniobsite - (Ce), a new mineral species from the Ilímaussaq alkaline complex, South Greenland, and its relation to mosandrite and the rinkite series. *Neues Jb. Miner., Mh.* **1989**(2), 84-96.

No. 84 Rønsbo, J., 1989: Coupled substitutions involving REEs and Na and Si in apatites in alkaline rocks from the Ilímaussaq intrusion, South Greenland, and the petrological implications. *Am. Mineral.* **74,** 896-901.

No. 85 Henderson,C.M.B. & Taylor,D. 1989: Structural behaviour of chkalovite, $Na_2BeSi_2O_6$, a member of the cristobalite family. *Mineralog. Mag.* **53,** 117-119.

No. 86 Sebald,A., Merwin,L.H., Dollase,W.A. & Seifert,F. 1990: A multinuclear, high-solution solid-state NMR study of sorensenite ($Na_4SnBe_2(Si_3O_9) \times 2H_2O$) and comparison with wollastonite and pectolite. *Phys. Chem. Miner.* **17,** 9-16.

No. 87 Rønsbo,J.G., Petersen,O.V. & Leonardsen,E.S. 1990: Vinogradovite from the Ilímaussaq alkaline complex, South Greenland, a beryllium bearing mineral. *Neues Jb. Miner., Mh.* **1990**(11), 481-492.

No. 88 Sørensen,H., 1989: Materials resources. *In* Bilde-Sørensen,J.B., Hansen,N. Jensen,D.J., Leffers,T., Lilholt,H. & Pedersen,O.B. (ed.) *Materials architecture. Proceedings of the tenth Risø International Symposium on Metallurgy and Materials Science,* 665-673. Roskilde: Risø National Laboratory.

No. 89 Petersen,O.V., Ranløv,J., Leonardsen,E.S. & Rønsbo,J.G., 1991: Barylite from the Ilímaussaq alkaline complex and associated fenites, South Greenland. *Neues Jb. Miner., Mh.* **1991**(5), 212-216.

No. 90 Petersen,O.V., Rønsbo,J.G., Leonardsen,E.S., Johnsen,O., Bollingberg,H. & Rose-Hansen,J. 1994: Leifite from the Ilímaussaq alkaline complex, South Greenland. *Neues Jb. Miner., Mh.* **1994**(2), 83-90

No. 91 Petersen,O.V., Johnsen,O., Bernhardt,H.-J. & Medenbach,O. 1993: Dorfmanite, $Na_2HPO_4.2H_2O$ from the Ilímaussaq alkaline complex, South Greenland. *Neues Jb. Miner., Mh.* **1993**(6), 254-258.

No. 92 Bailey,J.C., Bohse,H., Gwozdz,R. & Rose-Hansen,J. 1993: Li in minerals from the alkaline Ilímaussaq intrusion, South Greenland. *Bull. geol. Soc. Denmark* **40,** 288-299.

No. 93 Bailey,J.C. & Gwozdz,R. 1994: Li distribution in aegirine luyavrite, Ilímaussaq alkaline intrusion, South Greenland: role of cumulus and post-cumulus processes. *Lithos* **31,** 207-225.

No. 94 Sørensen,H. 1992: Agpaitic nepheline syenites: a potential source of rare elements. *Appl. Geochemistry* **7,** 417-427.

No. 95 Bailey,J.C. in press: Cryptorhythmic and macrorhythmic layering in aegirine lujavrite, Ilímaussaq alkaline intrusion, South Greenland. Submitted to: *Bull. geol. Soc. Denmark*

No. 96 Petersen,O.V., Micheelsen,H.I. & Leonardsen,E.S. in press: Bavenite, $Ca_4Be_3Al(Si_90_{25}(OH)_3$, from the Ilimaussaq alkaline complex, South Greenland. Submitted to: *Neues Jb. Miner., Mh.*

Bibliography of the geology of Ilímaussaq

Ahmed,M. 1978: Synthesis and stability of eudialyte – eucolyte series. Unpublished Ph.D. thesis, Victoria Univ., Manchester. 156 pp.

Allaart,J.H. 1964: Review of the work on the Precambrian basement (pre-Gardar) between Kobberminebugt and Frederiksdal, South Greenland. *Rapp. Grønlands geol. Unders.* **1**, 38 pp.

Allaart,J.H. 1973: Julianehåb 60 V.2 Nord. Descriptive text. Geological map of Greenland 1:100 000. Copenhagen: Grønlands Geologiske Undersøgelse. 41 pp.

Allan,T. 1813: Memorandums respecting some minerals from Greenland. *Ann. Phil.* **1**, 99-110.

Andersen,E.B., Fenger,J. & Rose-Hansen,J. 1975: Determination of [Fe^{2+}]/[Fe^{3+}]-ratios in arfvedsonite by Mössbauer spectroscopy. *Lithos* **8**, 237-246.

Andersen,E.K., Danø,M. & Petersen,O.V. 1969: A tetragonal natrolite. [from the Ilímaussaq alkaline intrusion, South Greenland.] *Bull. Grønlands geol. Unders.* **79** (also *Meddr Grønland* **181**,10) 19 pp.

Andersen,S. 1967: On beryllite and bertrandite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68**. (also *Meddr Grønland* **181**(4), part 2), 11-27.

Andersen,S. 1974: Detailed mapping in the southern part of the Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **65**, 69-71.

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.

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.

Andersen,S., Bailey,J.C. & Bohse,H. 1981: Zr-Y-U stratigraphy of the kakortokite-lujavrite sequence, southern Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 69-76.

Andersen,S., Bohse,H. & Steenfelt,A. 1981: A geological section through the southern part of the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 39-42.

Asmund,G. 1971: Chemistry and kinetics of the sulphating roasting of uranium-bearing silicates. *Risø Rep.* **253**, 125 pp.

Asmund,G. 1974: Hydrogeochemical investigations on river water in west, south and east Greenland. *Rapp. Grønlands geol. Unders.* **65**, 71-73.

Asmund,G. 1975: Uranium content in rivers of the Narssaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **75**, 84-86.

Asmund,G. & Rose-Hansen,J. 1978: High zinc contents of sea water in Kangerdluarssuk, the Ilímaussaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 79-81.

Bailey,J.C. in press: Cryptorhythmic and macrorhythmic layering in aegirine lujavrite, Ilímaussaq alkaline intrusion, South Greenland. Submitted to: *Bull. geol. Soc. Denmark*

Bailey,J.C. & Gwozdz,R. 1994: Li distribution in aegirine luyavrite, Ilímaussaq alkaline intrusion, South Greenland: role of cumulus and post-cumulus processes. *Lithos* **31,** 207-225.

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

Bailey,J., Bohse,H., Demina,A., Gwozdz,R., Rose-Hansen,J. & Sørensen,H. 1979: Geochemical studies of rocks and minerals [of the Ilímaussaq intrusion] *Rapp. Grønlands geol. Unders.* **95**, 80-81.

Bailey,J.C., Bohse,H. & Demina,A. 1981: Extension of Zr-REE-Nb resources at Kangerdluarssuk, Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 63-67.

Bailey,J.C., Gwozdz,R., Rose-Hansen,J., Andersen,L.S. & Sørensen,H. 1981: Distribution of lithium and fluorine in lujavrites from the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 77-86.

Bailey,J.C., Larsen,L.M. & Sørensen,H. (ed.) 1981: The Ilímaussaq intrusion, South Greenland. A progress report on geology, mineralogy, geochemistry and economic geology. *Rapp. Grønlands geologiske Unders.* **103**, 130 pp.

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**, 5-17.

Bailey,J.C., Rose-Hansen,J., Løvborg,L. & Sørensen,H. 1981: Evolution of Th and U whole-rock contents in the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 87-98.

Bailey,J.C., Rose-Hansen,J. & Sørensen,H. 1983: Leaching of uranium and thorium as a petrogenetic indicator in the agpaitic Ilímaussaq intrusion, South Greenland. *In* Augustithis,S.S. (ed.) *Significance of Trace Elements in Solving Petrogenetic Problems & Controversies*, 861-885. Athens: Theophrastus Publ.

Balashov,Yu.A. 1963: Differentsiatsiya redkozemel'nykh elementov v magmaticheskom protsesse. In: Khimiya Zemnoy kory - Geochimicheskaya konferentsiya "Khimiya Zemnoy Kory," posvyashchennaya stoletniyu so dnya rozhdeniya V.I.Vernadskogo, Trudy **1**, 352-365. Moskva: Akad. Nauk SSSR Inst. Geokhimii i Anaalit. Khimii.

Balashov,Yu.A. 1976: [Geochemistry of the rare earth elements]. 267 pp. Moskva: Nauka. (in Russian)

Bank,H. 1972: Roter durchsichtiger Tugtupit aus Gronland. *Z. dt. Gemmol. Ges.* **21**, 7-8.

Blaxland,A.B., van Breemen,O. & Steenfelt,A. 1976: Age and origin of agpaitic magmatism at Ilímaussaq, south Greenland: Rb-Sr study. *Lithos* **9**, 31-38.

Blaxland,A.B., van Breemen,O., Emeleus,C.H. & Anderson,J.G. 1978: Age and origin of major syenite centers in the Gardar province of south Greenland: Rb-Sr studies. *Bull. geol. Soc. Amer.* **89**, 231-244.

Blundell,D.J. 1978: A gravity survey across the Gardar Igneous Province, SW Greenland. *J. geol. Soc. Lond.* **135**, 545-554.

Böggild,O.B. 1902: On ilvaite from Siorarsuit at Julianehaab, Greenland. *Meddr Grønland* **25**, 43-89.

Bøggild,O.B. 1903: On some minerals from the nepheline-syenite at Julianehaab, Greenland. [erikite and schizolite] *Meddr Grønland* **26**, 91-139.

Bøggild,O.B. 1905: Mineralogia Groenlandica. *Meddr Grønland* **32**, 625 pp.

Böggild,O.B. 1911: Über die Krystallform des Britholiths. [britholite from Naujakasik] *Z. Krystallogr. Miner.* **50,** 430-436.

Bøggild,O.B. 1913: Ussingit, et nyt mineral fra Kangerdluarsuk. *Meddr Grønland* **51,** 103-110.

Böggild,O.B. 1914: Ussingit, ein neues Mineral von Kangerdluarsuk. *Z. Krystallogr. Miner.* **54,** 120-126.

Bøggild,O.B. 1915: Dahllit fra Kangerdluarsuk. *Meddr Grønland* **51,** 435-443.

Böggild,O.B. 1920: Dahllit von Kangerdluarsuk. *Z. Krystallogr. Miner.* **55,** 417-424.

Bøggild,O.B. 1933: Igalikite and naujakasite, two new minerals from South Greenland. *Meddr Grønland* **92**(9), 12 pp.

Bøggild,O.B. 1953: The mineralogy of Greenland. [Complete revision of Mineralogia Groenlandica] *Meddr Grønland* **149**(3), 442 pp.

Boeggild,O.B. [Bøggild,O.B.] & Winther,C. 1899: On some minerals from the nephelite-syenite at Julianehaab, Greenland (epistolite, britholite, schizolite and steenstrupite), collected by G.Flink. *Meddr Grønland* **24**, 181-213.

Bøgvad,R. 1950: Nepheline syenite and iron ore deposits in Greenland. *Arc*tic **3,** 86-94.

Bøgvad,R. 1950: Dansk interesse for en teknisk udnyttelse af nefelinsyenit fra Grønland. [lecture summary] *Meddr dansk geol. Foren.* **11** [for 1949], 503-506.

Bohse,H. 1976: På spor efter fortidens atomspaltninger. *Varv* 1976, 46-52.

Bohse,H. & Andersen,S. 1981: Review of the stratigraphic divisions of the kakortokite and lujavrite in southern Ilímaussaq. *Rapp. Grønlands geol. Unders.* **103**, 53-62.

Bohse,H., Brooks,C.K. & Kunzendorf,H. 1971: Field observations on the kakortokites of the Ilímaussaq intrusion, South Greenland, including mapping and analyses by portable X-ray fluorescence equipment for zirconium and niobium. *Rapp. Grønlands geol. Unders.* **38**, 43 pp.

Bohse,H., Rose-Hansen,J., Sørensen,H., Steenfelt,A., Løvborg,L. & Kunzendorf,H. 1974: On the behaviour of uranium during crystallization of magmas - with special emphasis on alkaline magmas. In: *Formation of uranium ore deposits,* 49-60. Vienna: International Atomic Energy Agency.

Bohse,H., Larsen,L.M., Rose-Hansen,J., Nielsen,C.O. & Sørensen,H. 1975: Current research on the Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **75**, 81-83.

Bollingberg,H. & Petersen,O.V. 1967: Genthelvite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**(4), part 1), 1-9.

Bondam,J. 1955: Sydgrønlands nefelinsyeniter. *Grønland* **1955,** 108-114.

Bondam,J. 1959: En beretning om uranundersøgelser på Kvanefjeldet ved Narssaq. *Grønland* **1959,** 389-396.

Bondam,J. 1960: Uranundersøgelser på Kvanefjeldet ved Narssaq. [abstract] *Meddr dansk geol. Foren.* **14,** 271-272.

Bondam,J. 1963: Villiaumit. *Grønland* **1963,** 143-146.

Bondam,J. & Ferguson,J. 1962: An occurrence of villiaumite in the Ilímaussaq intrusion, South Greenland. *Meddr Grønland* **172**(2), 12 pp.

Bondam,J. & Sörensen,H. 1959: Uraniferous nepheline syenites and related rocks in the Ilimaussaq area, Julianehaab District, southwest Greenland. *Proc. 2nd int. Conf. U.N. Peace. Atom. Energy* **2,** 555-559.

Borodin,L.S. (ed.) 1974: *Glavneyshiye provintsii i formatsii shchelochnykh porod.* 376 pp. Moskva: Nauka. [Major provinces and formations of alkaline rocks]

Borutskii,B.E. & Semenov,E.I. 1969: Polevye shpaty shchelochnogo massiva Ilimausak. [Feldspars from the Ilímaussaq alkaline massif] *Trudy miner. Muz.* **19**, 3-11.

Bøtter-Jensen,L., Christensen,P. & Nielsen,B.L. 1978: External radiation exposure associated with uranium-thorium mineralization on the Kvanefjeld plateau, Greenland. Risø-M-1989, 16 pp.

Bøtter-Jensen,L., Løvborg,L. & Nielsen,B.L. 1979: Gamma exposure levels from natural radioactivity in Greenland. Seminar on the 'Radiological Burden of Man from Natural Radioactivity in the Countries of the European Community.' Le Vesinet, France, 4th-6th Dec. 1979, 13 pp. (duplicated manuscript).

Bridgwater,D. 1965: Isotopic age determinations from South Greenland and their geological setting. *Bull. Grønlands geol. Unders.* **53** (also *Meddr Grønland* **179**(4)), 56 pp.

Bridgwater,D. & Harry,W.T. 1968: Anorthosite xenoliths and plagioclase megacrysts in Precambrian intrusions of South Greenland. *Bull. Grønlands geol. Unders.* **77** (also *Meddr Grønland* **185(2)**), 243 pp.

Brooke,H.J. 1823: A description of the crystalline form of some new minerals. [arfvedsonite, Kangerdluarssuk] *Ann. Phil.* **5**, 381-384.

Brooks,C.K. & Bohse,H. 1969: New field investigations of the Ilímaussaq kakortokite. *Rapp. Grønlands geol. Unders.* **19**, 41-42.

Buchwald,V.F. 1958: Efterforskning af radioaktive mineraler. Autoradiografi af radioaktive mineraler fra Grønland. *Ingeniøren* **67,** 133-137.

Buchwald,V.[F.] & Sørensen,H. 1961: An autoradiographic examination of rocks and minerals from the Ilímaussaq batholith, south-west Greenland. *Bull. Grønlands geol. Unders.* **28** (also *Meddr Grønland* **162**(11)), 36 pp.

Cannilo,E., Mazzi,F. & Rossi,G. 1972: The structure type of joaquinite. *Tschermaks miner. petrogr. Mitt.* **17**, 233-246.

Christensen,N.P. 1977: The use of dataloggers. *Rapp. Grønlands geol. Unders.* **85**, 70-72.

Christensen,N.P. 1979: Hydrology and hydrogeochemistry [of the Narssaq river valley] *Rapp. Grønlands geol. Unders.* **95**, 80 only.

Christensen,N.P. 1979: Automatisk registrering af hydrologiske og meteorologiske data i Sydgrønland. *Vannet i Norden* **4**, 7-14.

Christensen,N.P. 1980: The hydrochemistry of three drainage basins in South Greenland. Unpublished thesis, University Copenhagen, 111 pp.

Clark,I. & Clausen,F.L. 1981: Simple alternative to disjunctive kriging. *Trans. Instn Min. Metall. A*, **90**, 13-24.

Clausen,F.L. 1980: Kvane - a Kvanefjeld drill core database. Risø-M-2210, 18 pp.

Clausen,F.L. 1981: Geostatistical ore reserve estimation at Kvanefjeld uranium deposit - South Greenland. *In* Haskuldsson,A. et al. (ed.) *Symposium i anvendt statistik*, 283-313. Copenhagen: NEUCC, RECAU, RECKU.

Conradsen,K. & Clausen,F.L. 1981: Classification and clustering of some drill core samples from Kvane-I fjeld - South Greenland. *In* Haskuldsson,A. *et al.* (ed.) *Symposium i anvendt statistik*, 339-361. Copenhagen: NEUCC, RECAU, RECKU.

Currie,K.L., Curtis,L.W. & Gittins,J. 1975: Petrology of the Red Wine alkaline complexes, central Labrador and a comparison with the Ilimaussaq complex, southwest Greenland. *Pap. geol. Surv. Can.* **75-1**, A, 271-280.

Curtis,L.W. 1975: Petrology of the Red Wine Complex, central Labrador. Thesis, University of Toronto, 265 pp.

Damour,A. 1856: Examen comparatif et analyse de l'eudialyte et de l'eukolite: réunion de ces substances minérales en une seule espèce. [analysis, eudialyte, Kangerdluarssuk] *C.r. hebd. Séanc. Acad. Sci., Paris* **43,** 1197-1199.

Danø,M. 1966: The crystal structure of tugtupite - a new mineral, $Na_8Al_2Be_2Si_8O_24(Cl,S)_2$. *Acta crystallogr.* **20,** 812-816.

Danø,M. & Sørensen,H. 1959: An examination of some rare minerals from the nepheline syenites of South West Greenland. *Bull. Grønlands geol. Unders.* **20** (also *Meddr Grønland* **162**(5)), 35 pp.

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

Demin,A. 1972: Interpretation of field observations in the southern part of the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **45**, 33-35.

Des Cloizeaux,[A.L.O.] 1876: Mémoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chimique du microcline, nouvelle espèce de feldspath tricliniques à la base potasse. *C.r. hebd. Séanc. Acad. Sci., Paris* **82,** 885-891.

Dragsted,O. 1971: Kakortokite, and other ornamental eudialyte rocks. *J. Gemmology* **12,** 312-315.

Edgar,A. 1977: A comment on 'Agpaicity revisited: pattern recognition in the chemistry of nepheline syenite rocks' by Dagbert *et al. Geochim. cosmochim. Acta* **41**, 439-440.

Edgar,A.D. & Parker,L.M. 1974: Comparison of melting relationships of some plutonic and volcanic peralkaline undersaturated rocks. *Lithos* **7**, 263-273.

Eggenkamp,H.G.M. 1994: Stable chlorine isotopes in rocks. A new method for the extraction of chlorine from rocks. Case study: the Ilímaussaq intrusion, South Greenland. *Geol. Ultraiectina* **116**, 123-129.

Emeleus,C.H. & Upton,B.G.J. 1976: The Gardar period in southern Greenland. *In* Escher,A. & Watt,W.S. (ed.) *Geology of Greenland*, 152-181. Copenhagen: Geological Survey of Greenland.

Engell,J. 1973: A closed system crystal-fractionation model for the agpaitic Ilímaussaq intrusion, South Greenland with special reference to the lujavrites. *Bull. geol. Soc. Denmark* **22**, 334-362.

Engell,J., Hansen,J., Jensen,M., Kunzendorf,H. & Løvborg,L. 1971: Beryllium mineralization in the Ilímaussaq intrusion, South Greenland, with description of a field beryllometer and chemical methods. *Rapp. Grønlands geol. Unders.* **33**, 40 pp.

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. .

Ferguson,J. 1967: The alkaline igneous intrusion of Ilímaussaq, South Greenland. Unpublished Ph.D. thesis, Univ. Witwatersrand.

Ferguson,J. 1970: The differentiation of agpaitic magmas: the Ilimaussaq intrusion, South Greenland. *Can. Miner.* **10**, 335-349.

Ferguson,J. 1970: On the schistose structure of some lujavrites. *Bull. geol. Soc. Denmark* **20**, 67-68.

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.

Ferguson,J. & Pulvertaft,T.C.R. 1963: Contrasted styles of igneous layering in the Gardar province of South Greenland. *Spec. Pap. Miner. Soc. Amer.* **1**, 10-21.

Fleischer,M. 1936: The formula of aenigmatite. [material from Naujakasik] *Amer. J. Sci.* (5) **32,** 343-348.

Flink,G. 1894: Beschreibung eines neuen Mineralfundes aus Grönland. *Z. Kristallogr. Miner.* **23,** 344-367.

Flink,G. 1898: Berättelse om en mineraligisk resa i Syd-Grönland sommeren 1897. *Meddr Grønland* **14,** 221-262.

Flink,G., Bøggild,O.B. & Winther,C. 1901: Undersøgelser af mineraler fra Julianehaab insamlede af G. Flink 1897. *Meddr Grønland* **24,** 1-213.

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

Fryer,B.J. & Edgar,A.D. 1977: Significance of rare earth distributions in coexisting minerals of peralkaline undersaturated rocks. *Contr. Miner. Petr.* **61**, 35-48.

Funder,S. 1979: The Quaternary geology of the Narssaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **86**, 24 pp.

Funder,S. & Andsbjerg,J. 1977: Quaternary geology of the Narssaq area. *Rapp. Grønlands geol. Unders.* **85**, 69-70.

Galimow,E.M. 1969: Die Isotopenzusammensetzung des Kohlenstoffs in den Gasen der Erdkruste. *Z. angew. Geol.* **15**, 63-69.

Galimov,E.M. & Petersilie,A. 1967: Ob izotopnom sostave ugleroda uglevodorodnykh gazov i CO_2, soderzhoshchikhsya v shchelochnykhizverzhennykh porodakh Khibinskogo, Lovozerskogo i Illimaussakskogo massivov. [Isotopic composition of carbon from hydrocarbon gases and CO_2 held in alkalic igneous rocks of the Khibiny, Lovozero and Ilímaussaq plutons] *Dokl. Akad. Nauk SSSR* **176** (4), 914-917. [transl: *Dokl. Acad. Sci. USSR, Earth Sci. Sect.* **176**, 200-203]

Gay,P. 1957: An X-ray investigation of some rare-earth silicates: cerite, lessingite, beckelite, britholite, and stillwellite. *Mineralog. Mag.* **31,** 455-468.

Geological Survey of Greenland 1979: The South Greenland regional uranium exploration program. Interim report June 1979, 59 pp., December 1979, 12 pp. Unpublished internal report, Geological Survey of Greenland.

Gerasimovskii,V.I. 1965: Kharakteriuie chertui mineralogii massiva Ilimaussak. *Zap. vses. miner. Obshch.* (2) **94,** 444-447.

Gerasimovskii,V.I. 1965: Ekspeditsiya geologov v Grenlandiyu. [visit to Ilímaussaq] *Vest. Akad. Nauk SSSR* **1965**(1), 65-68.

Gerasimovsky,V.I. 1967: [Characteristic features of the mineralogy of agpaitic nepheline syenites] *In* [Problems of the crystalchemistry of the minerals of endogenous mineralizations], 145-151. Leningrad: Nauka. (in Russian).

Gerasimovsky,V.I. 1968: Geokhimiya agpaitovykh nefelinovykh sienitov. [Geochemistry of agpaitic nepheline syenites] *In* Problemy geokhimii i kosmologii, 151-159. *Mezhdunarodnyi geologicheskii kongress 23 Sessiya. Dokl. Sovetskikh Geologov Problemy* 6 i 13a. Moskva: Nauka.

Gerasimovsky,V.I. 1968: Geochemistry of agpaitic nepheline syenites. *Rep. 23rd int. geol. Congr., Czechoslovakia 1968*, **6**, 259-265.

Gerasimovsky,V.I. 1969: Geokhimiya Ilimaussakskogo shchelochnogo massiva. (Yugo-Zapadnaya Grenlandiya). [Geochemistry of the Ilímaussaq alkaline massif (South-West Greenland)] 174 pp. Moskva: Nauka.

Gerasimovsky,V.I. 1969: Kharakternyye osebennosti khimicheskogo sostava shchelochnykh porod Ilimaussakskogo massiva (Yugo-Zapadnaya Grenlandiya). [Specific characteristics of chemical composition of alkalic rocks from the Ilímaussaq massif, South-west Greenland] [abstract] *In* Afanas'yev,G.D. (ed.) *Vsesoyunoye Petrograficheskoye Soveshchaniye, Materialy, IV* [Proc. 4th Petrographical Conference in the USSR], 454-455. Baku: Akad. Nauk Azerb. SSR.

Gerasimovsky,V.I. & Balashov,Yu.A. 1968: K geokhimii redkozemel'nykh elementov v Ilimaussakckom shchelochnom massive (Yu.-Z. Grenlandiya). [Geochemistry of rare earth elements in the Ilímaussaq alkaline massif (S.W. Greenland)] *Geokhimiya* **1968** (5), 523-538. [transl: *Geochem. int.* **5**, 453-467]

Gerasimovsky,V.I. & Borisenok,L.A. 1968: K geokhimii olova v nefelinovykh sienitakh. [Geochemistry of tin in nepheline syenites] *Geokhimiya* **1968** (7), 773-785. [transl: *Geochem. int.* **5**, 675-686]

Gerasimovskii,V.I., Karpushina,V.A. 1966: O geokhimii niobiya i tantala v nefelinovykh sienitakh. [Geochemistry of niobium and tantalum in nepheline syenites] *Geokhimiya* **1966**(7), 777-789. [transl: *Geochem. int.* **3**, 609-620]

Gerasimovsky,V.I. & Kholina,Yu.B. 1965: [On the geochemistry of lithium in nepheline syenites] *In* Khitarov,N.I. (ed.) [Problems of geochemistry], 325-337. Moskva: Nauka. [transl: *Problems of geochemistry*, 347-359. Jerusalem: Israel Program for Scientific Translations.]

Gerasimovsky,V.I. & Kuznetsova,S.Ya. 1967: Khimicheskii sostav porod Ilimaussakskogo shchelochnogo massiva. [On the petrochemistry of the Ilímaussaq intrusion, South Greenland] *Geokhimiya* **1967** (3), 274-283. [transl: *Geochem. int.* **4**, 236-246]

Gerassimovsky,V.I. & Kuznetsova,S.Ya. 1967: On the petrochemistry of the Ilimaussaq intrusion, South Greenland. *Geochem. int.* **4,** 236-246.

Gerasimovsky,V.I. & Tuzova,A.M. 1964: K geokhimii khlara v nefelinovykh sienitakh. [Geochemistry of chlorine in nepheline syenites] *Geokhimiya* **1964** (9), 872-885. [transl: *Geochem. int.* **1** (1964), 855-867; *Geochem. int.* **6**, 845 only].

Gerasimovsky,V.I. & Tuzova,A.M. 1964: The geochemistry of chlorine in nepheline syenites. *Geochem. int.* **1** (1964), 855-867.

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] 396 pp. (in Russian) (English translation by D.A.Brown 1969. Canberra: Australian National University Press, 369 pp.)

Gerasimovsky,V.I., Borisenok,L.A. & Tuzova,A.M. 1968: Geokhimiya galliya v nefelinovykh sienitakh. [Geochemistry of gallium in nepheline syenites] *Geokhimiya* **1968** (10), 1183-1194. [transl: *Geochem. int.* **5**, 985-995]

Gerasimovsky,V.I., Stupnikova,N.I. & Zykov,S.I. 1968: O vozraste intruzii Ilimaussak i Igaliko gardarskoi provintsii (Yu-Z. Grenlandiya). [On the age of the Ilímaussaq and Igaliko intrusions of the Gardar Province (S.W. Greenland)] *Geokhimiya* **1968** (9), 1134-1136. [abstract *Geochem. int.* **5**, 935 only]

Gerasimovsky,V.I., Kakhana,M.M. & Nesmeyanova,L.I. 1969: K geokhimii strontsiya v nefelinovykh sienitakh. [Geochemistry of strontium in nepheline syenites] *Geokhimiya* **1969** (7), 779-790. [abstract]

Gerassimovsky,V.I., Stupnikova,N.I. & Zykov,S.I. 1969: On the age of the Ilímaussaq and Igaliko intrusions in the Gardar province of southern Greenland. *Meddr dansk geol. Foren.* **19**, 224-226.

Gordon,S.G. 1924: The second Vaux-Academy mineralogical expedition: the Julianehaab district of Greenland. *Yb. Acad. nat. Sci. Philad.* [for] **1923,** 3-12.

Gordon,S.G. 1924: Minerals obtained in Greenland on the Second Academy-Vaux expedition, 1923. *Proc. Acad. nat. Sci. Philad.* **76,** 249-268.

Gordon,S.G. 1927: On arfvedsonite, riebeckite and crocidolite from Greenland. *Proc. Acad. nat. Sci. Philad.* **79,** 193-205.

Gossner,B. & Kraus,O. 1933: Über Kristallform und molekulare Einheit von Rinkit. [rinkite from Kangerdluarssuk] *Zentbl. Miner. Geol. Paläont.* **1933, A**, 369-374.

Gossner,B. & Kraus,O. 1934: Beitrag zur Kenntnis der Wöhlerit- und der Mosandritgruppe. [rinkite from Kangerdluarssuk] *Zentbl. Miner. Geol. Paläont.* **1934, A**, 72-79.

Gossner,B. & Mussgnug,F. 1930: Über die strukturelle und molekulare Einheit von Eudialyt. [material from naujakasik] *Zentbl. Miner. Geol. Paläont.* **1930, A**, 81-88.

Gottardi,G. 1966: X-ray crystallography of rinkite. [rinkite from Kangerdluarssuk] *Amer. Miner.* **51**, 1529-1535.

Grønlands Geologiske Undersøgelse 1967: Contributions to the mineralogy of Ilímaussaq, Nos 3-7. *Bull. Grønlands geol. Unders.* **68**.

Hamilton,E.[I.] 1960: The distribution of radioactivity in the major rock forming minerals. *Meddr Grønland* **162(8)**, 41 pp.

Hamilton,E.I. 1964: The geochemistry of the northern part of the Ilímaussaq intrusion, S.W. Greenland. *Bull. Grønlands geol. Unders.* **42** (also *Meddr Grønland* **162(10)**), 104 pp.

Hansen,J. 1962: Radioaktive sprækkefyldninger på Narssaq-halvøen. Unpublished dissertation, Copenhagen University.

Hansen,J. 1966: Report on the survey of beryllium, niobium, uranium and thorium mineralization in the Ilímaussaq complex, South Greenland. *Rapp. Grønlands geol. Unders.* **11**, 47-49.

Hansen,J. 1966: På spor af sjældne mineraler i Sydgrønland. VI. Niobium - et værdifuldt metal. *Grønland* **1966**, 306-312.

Hansen,J. 1967: Sjældne stoffer. *Varv* **1967**, 35-44.

Hansen,J. 1968: Niobium mineralization in the Ilímaussaq alkaline complex, South-West Greenland. *Rep. 23rd int. geol. Congr. Czechoslovakia 1968* **7**, 263-273.

Hansen,J. 1968: A study of radioactive veins containing rare-earth minerals in the area surrounding the Ilímaussaq alkaline intrusion in South Greenland. *Bull. Grønlands geol. Unders.* **76** (also *Meddr Grønland* **181**,8) 47 pp.

Hansen,J. & Løvborg,L. 1966: På spor af sjældne metaller i Sydgrønland. IV. Beryllium-efterforskning. *Grønland* **1966**, 243-256.

Hansen,J. & Løvborg,L. 1966: Beryllium efterforskning i Grønland. *Forskning* **1966(2)**, 35-37.

Hansen,J. & Pulawski,B. 1966: Water balance in Narssaq river valley. *Rapp. Grønlands geol. Unders.* **11**, 50-51.

Hansen,J.K.G. 1977: Sulphatising roasting of a Greenlandic uranium ore, reactivity of minerals and recovery. *Risø Rep.* **355**, 129 pp.

Hansen,M.M. 1979: Marine biology [in the Narssaq area]. *Rapp. Grønlands geol. Unders.* **95**, 80 only.

Henderson,C.M.B. & Taylor,D. 1977: Infrared spectra of anhydrous members of the sodalite family. *Spectrochim. Acta* **33A**, 283-290.

Henderson,C.M.B. & Taylor,D. 1977: The thermal expansion of tugtupite. *Mineralog. Mag.* **41**, 130-131.

Henderson,C.M.B. & Taylor,D. 1989: Structural behaviour of chkalovite, $Na_2BeSi_2O_6$, a member of the cristobalite family. *Mineralog. Mag.* **53,** 117-119.

Hendricks,S.B. 1939: Polymorphism of the micas. *Amer. Miner.* **24**, 729-771.

Ito,T. 1939: The determination of lattice constants of triclinic crystals from one crystal setting - a special case. *Z. Kristallogr.* **100**, 437-439.

Ito,J. 1968: Silicate apatites and oxyapatites. *Amer. Miner.* **53**, 890-907.

Jensen,O. 1968: På mineraljagt i Grønland. *Superfossen* **23**(2), 3-6.

Johnsen,O. & Bohse,H. 1981: Helvine from the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 25-29.

Johnsen,O., Leonardsen,E.S., Fälth,L. & Annehed,H. 1983: The crystal structure of kvanefjeldite; the introduction of (Si_3O_7OH) layers with eight-membered rings. *Neues Jb. Miner., Mh.* **1983**(11), 505-512.

Karup-Møller,S. 1974: Mineralogy of two copper-antimony-sulphide-oxide occurrences from the Ilímaussaq alkaline intrusion in South Greenland. *Neues Jb. Miner., Abh.* **122,** 291-313.

Karup-Møller,S. 1975: On the occurrence of native lead, litharge, hydrocerussite and plattnerite within the Ilímaussaq alkaline intrusion in South Greenland. *Neues Jb. Miner., Mh.* **1975,** 229-241.

Karup-Møller,S. 1976: Gmelinite and herschelite from the Ilímaussaq intrusion in South Greenland. *Mineralog. Mag.* **40**, 867-873.

Karup-Møller,S. 1978: Primary and secondary ore minerals associated with cuprostibite. *Bull. Grønlands geol. Unders.* **126**, 23-47.

Karup-Møller,S. 1978: The ore minerals of the Ilímaussaq intrusion: their mode of occurrence and their conditions of formation. *Bull. Grønlands geol. Unders.* **127**, 51 pp.

Karup-Møller,S. 1982: Tundrite from the Ilímaussaq alkaline intrusion, South Greenland. *Neues Jb. Miner., Mh.* **1982**(11), 481-494.

Karup-Møller,S. 1983: Lomonosovite from the Ilímaussaq intrusion, South Greenland. *Neues Jb. Miner., Abh.* **148** (1), 83-96.

Karup-Møller,S. 1986: Nenadkevichite from the Ilímaussaq intrusion in South Greenland. *Neues Jb. Miner., Mh.* **1986**(2), 49-58.

Karup-Møller,S. 1986: Murmanite from the Ilímaussaq alkaline complex, South Greenland. *Neues Jb. Miner., Abh.* **155** (1), 67-88.

Karup-Møller,S. 1986: Epistolite from the Ilímaussaq alkaline complex in South Greenland. *Neues Jb. Miner., Abh.* **155** (3), 289-304.

Karup-Møller,S. & Makovicky,E. 1974: Skinnerite Cu_3SbS_3, a new sulfosalt from the Ilímaussaq alkaline intrusion, South Greenland. *Amer. Miner.* **59**, 889-895.

Karup-Møller,S. & Makovicky,E. 1977: Westerveldite from the Ilímaussaq alkaline intrusion in South Greenland. Mineralogy, crystallography, mineral associations and alteration products. *Neues Jb. Miner., Abh.* **130**, 208-242.

Karup-Møller,S. & Petersen,O.V. 1984: Tuperssuatsiaite, a new mineral species from the Ilímaussaq intrusion in South Greenland. *Neues Jb. Miner., Mh.* **1984**(11), 501-512.

Karup-Møller,S., Løkkegaard,L., Semenov,E.I. & Sørensen,H. 1978: The occurrence of cuprostibite. *Bull. Grønlands geol. Unders.* **126**, 7-22.

Kogarko,L.N. 1974: Rôle of volatiles. *In* Sørensen,H. (ed.) *The alkaline rocks*, 474-487. London: Wiley-Interscience.

Kogarko,L.N. 1977: Problemy genezisa agpaitovkh magm. [Problems of genesis of agpaitic magmas] 294 pp. Moskva: Nauka.

Kogarko,L.N. 1979: Microcomponents as indicators of the differentiation of alkaline magmatic series. *In* Ahrens,L.H. (ed.) *Origin and distribution of the elements. Phys. Chem. Earth* **11**, 217-222.

Kogarko,L.N., Ryabchikov,I.D. & Sørensen,H. 1974: Liquid fractionation. *In* Sørensen,H. (ed.) *The alkaline rocks*, 488-500. London: Wiley Interscience.

Konnerup-Madsen,J. 1980: Fluid inclusions in minerals from igneous rocks belonging to the Precambrian continental Gardar rift province, South Greenland: the alkaline Ilímaussaq intrusion and the alkali acidic igneous complexes. Unpublished thesis, University of Copenhagen, 149 pp.

Konnerup-Madsen,J. 1984: Compositions of fluid inclusions in granites and quartz syenites from the Gardar continental rift province (South Greenland). *Bull. Minéral.* **107,** 327-340.

Konnerup-Madsen,J. 1985: Composition of gases in the Earth's upper mantle. *Mat. Fys. Meddr* **41,** 399-429.

Konnerup-Madsen,J. 1988: Abiogenic hydrocarbon gases associated with alkaline igneous activity. *Mem. geol. Soc. India* **11,** 13-24.

Konnerup-Madsen,J. & Rose-Hansen,J. 1982: Volatiles associated with alkaline igneous rift activity: fluid inclusions in the Ilímaussaq intrusion and the Gardar Granitic complexes (South Greenland). *Chem. Geol.* **37**, 79-93.

Konnerup-Madsen,J. & Rose-Hansen,J. 1984: Composition and significance of fluid inclusions in the Ilímaussaq peralkaline granite, South Greenland. *Bull. Minéral.* **107,** 317-326.

Konnerup-Madsen,J., Larsen,E. & Rose-Hansen,J. 1979: Hydrocarbon-rich fluid inclusions in minerals from the alkaline Ilímaussaq intrusion, South Greenland. *Bull. Minéral.* **102**, 642-653.

Konnerup-Madsen,J., Holm,P.M. & Rose-Hansen,J. 1981: An experimental study of the decomposition of steenstrupine in Na_2CO_3 solution. *Rapp. Grønlands geol. Unders.* **103**, 113-118.

Konnerup-Madsen,J., Dubessy,J. & Rose-Hansen,J. 1985: Combined Raman microprobe spectrometry and microthermometry of fluid inclusions in minerals from igneous rocks of the Gardar province (South Greenland). *Lithos* **18,** 271-280.

Konnerup-Madsen,J., Kreulen,R. & Rose-Hansen,J. 1988: Stable isotope characteristics of hydrocarbon gases in the alkaline Ilímaussaq Complex, South Greenland. *Bull. Minéral.* **111,** 567-576.

Konnerup-Madsen,J., Rose-Hansen,J. & Larsen,E. 1981: Hydrocarbon gases associated with alkaline igneous activity: evidence from compositions of fluid inclusions. *Rapp. Grønlands geol. Unders.* **103**, 99-108.

Kovalenker,V.A., Laputina,I.N., Semenov,E.I. & Evstigneeva,T.L. 1978: Kaliisoderzhashchii talkusit iz massiva Ilimausak i novye dannye ro khal'kotallitu [Potassium-bearing thalcusite from the Ilimaussak pluton and new data on chalcothallite] *Dokl. Acad. Nauk SSSR* **239**, 1203-1206. [transl: *Dokl. Akad. Sci. USSR, Earth Sci. Sect.* **239**, 159-162].

Kühnel,O. 1958: Uranforekomsterne i Sydgrønland. *Dansk tekn. Tidsskr.* **82**, 41-44.

Kullerud,G. 1953: The FeS-ZnS system a geological thermometer. [data on sphalerite from Ivigtut and Mârmorilik] *Norsk geol. Tidsskr.* **32,** 61-147.

Kunzendorf,H. 1971: An instrumental procedure to determine Fe, Rb, Sr, Y, Zr, Nb and Mo in rock powders by Si(Li) X-ray spectrometry. *J. radioanal. Chem.* **9**, 311-324.

Kunzendorf,H. 1973: Non-destructive determination of metals in rocks by radioisotope X-ray fluorescence instrumentation. *In* Jones,M.J. (ed.) *Geochemical exploration 1972*, 401-414. London: Institution of Mining and Metallurgy.

Kunzendorf,H. 1973: Die Isotop-Rontgenfluoreszenz Analyse und ihre Anwendung bei geochemischen Untersuchungen in Gronland. Risø M-1610, 125 pp.

Kunzendorf,H., Løvborg,L. & Wollenberg,H. 1971: Assay of powdered metallic ores by means of a portable X-ray fluorescence analyser. *Risö Rep.* **251**, 29 pp.

Kunzendorf,H., Nyegaard,P. & Nielsen,B.L. 1982: Distribution of characteristic elements in the radioactive rocks of the northern part of Kvanefjeld, Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **109**, 32 pp.

Larsen,C.L. 1977: A reconnaissance study of the exogeneous environment and the abundance of selected trace elements in the soils of the Ilímaussaq region, South Greenland. Unpublished thesis, University Copenhagen, 74 pp.

Larsen,E. & Rose-Hansen,J. 1978: Bestemmelse af gassammensætninger i gas-væske-indeslutninger i mineraler fra Grønland. Abstr. Nordisk Kongres i Massespektrometri, Sandefjord, 1978, [abstract].

Larsen,E., Konnerup Madsen,[J.] & Rose-Hansen,[J.] 1975: Bobler og dråber i mineraler - gas-væske indeslutninger i krystaller. *Varv* **1975**, 67-72.

Larsen,J.G. 1973: Petrochemical work on the Precambrian lavas, Eriksfjord Formation, South Greenland. *Rapp. Grønlands geol. Unders.* **55**, 40-41.

Larsen,J.G. 1977: Petrology of the late lavas of the Eriksfjord Formation, Gardar province, South Greenland. *Bull. Grønlands geol. Unders.* **125**, 31 pp.

Larsen,L.B. 1972: Hydrological project at Narssaq Bræ, South Greenland, as part of the International Hydrological Decade Programme. *Rapp. Grønlands geol. Unders.* **45**, 27-29.

Larsen,L.B. 1973: Water balance investigations in the Narssaq River Basin, South Greenland. Unpublished dissertation, University Copenhagen, 157 pp.

Larsen,L.M. 1976: Clinopyroxenes and coexisting mafic minerals from the alkaline Ilímaussaq intrusion, South Greenland. *J. Petrology* **17**, 258-290.

Larsen,L.M. 1977: Aenigmatites from the Ilímaussaq intrusion, south Greenland: chemistry and petrological implications. *Lithos* **10**, 257-270.

Larsen,L.M. 1979: Distribution of REE and other trace elements between phenocrysts and peralkaline undersaturated magmas, exemplified by rocks from the Gardar igneous province, south Greenland. *Lithos* **12**, 303-315.

Larsen,L.M. 1981: Sector zoned aegirine from the Ilímaussaq alkaline intrusion, South Greenland. *Contr. Miner. Petr.* **76**, 285-291.

Larsen,L.M. & Sørensen,H. 1987: The Ilímaussaq intrusion - progressive crystallization and formation of layering in agpaitic magma. *In* Fitton,J.G. & Upton,B.G.J. (ed.) *Alkaline Igneous Rocks. Spec. Publ. geol. Soc., Lond.* **30,** 473-488. London.

Larsen,L.M. & Steenfelt,A. 1974: Alkali loss and retention in an iron-rich peralkaline phonolite dyke from the Gardar province, south Greenland. *Lithos* **7**, 81-90.

Larsen,L.M. 1981: Chemistry of feldspars in the Ilímaussaq augite syenite with additional data on some other minerals. *Rapp. Grønlands geol. Unders.* **103**, 31-37.

Larsen,O. 1963: Ægirin-akmit-problemet belyst ved en undersøgelse af alkali-pyroxener fra nefelinsyenitintrusionen Ilímaussaq i Sydwestgrønland. Unpublished dissertation, Copenhagen University.

López-Soler,A., Bosch-Figueroa,J.M., Karup-Møller,S., Besteiro,J. & Font-Altaba,M. 1975: Optical study of cuprostibite (Cu_2Sb). *Fortschr. Miner.* **52**, 557-565.

Løvborg,L. & Hansen,J. 1968: Prospecting instruments used in the survey of uranium-thorium and beryllium in the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **15**, 53-58.

Lovborg,L., Kunzendorf,H. & Hansen,J. 1968: Portable beryllium prospecting instrument with large sensitive area. *In: Nuclear techniques and mineral resources*, 55-63. Vienna: International Atomic Energy Agency.

Lovborg,L., Kunzendorf,H. & Hansen,J. 1968: Use of field gamma-spectrometry in the exploration of uranium and thorium deposits in South Greenland. *In: Nuclear techniques and mineral resources*, 197-211. Vienna: International Atomic Energy Agency.

Løvborg,L., Wollenberg,H., Sørensen,P. & Hansen,J. 1971: Field determination of uranium and thorium by gamma-ray spectrometry, exemplified by measurements in the Ilímaussaq alkaline intrusion, South Greenland. *Econ. Geol.* **66**, 368-384.

Løvborg,L., Kirkegaard,P. & Rose-Hansen,J. 1972: Quantitative interpretation of the gamma-ray spectra from geologic formations. *In* Adams,J.A.S. et al. (ed.) *The natural radiation environment II*. Proc. 2nd int. Symp. Natural Radiation Environment, 155-180.

Løvborg,L. Wollenberg,H., Rose-Hansen,J. & Nielsen,B.L. 1972: Drill-core scanning for radioelements by gamma-ray spectrometry. *Geophysics* **37**, 675-693.

Løvborg,L., Bøtter-Jensen,L., Christiansen,E.M. & Nielsen,B.L. 1980: Gamma-ray measurements in an area of high natural radioactivity. *In* Gesell,T.F. & Lowder,W.M. (ed.) *Natural radiation environment III*, 2, 912-926. U.S. Dep. Energy Tech. Inf. Cent.

Løvborg,L., Nyegaard,P., Christiansen,E.M. & Nielsen,B.L. 1980: Borehole logging for uranium by gamma-ray spectrometry. *Geophysics* **45**, 1077-1090.

Lorenzen,J. 1881: Undersøgelse af nogle Mineralier i Sodalith-Syeniten fra Julianehaabs Distrikt. *Meddr Grønland* **2**, 43-79.

Lorenzen,J. 1884: Undersøgelse af nogle Mineralier fra Kangerdluarsuk i Grønland. *Ofvers VetenskAkad. Forh.* **41(2)**, 105-117.

Lorenzen,J. 1884: Undersøgelse af Mineralier fra Grønland. *Meddr Grønland* **7**, 1-31. (2nd ed. 1893)

Lorenzen,J. 1884: Fortsatte Undersøgelser af Mineralier fra Kangerdluarsuk. *Meddr Grønland* **7**, 33-46.

Lorenzen,J. 1884: Untersuchung einiger Mineralien aus Kangerdluarsuk in Grönland. *Z. Kristallogr. Miner.* **9**, 243-254.

Lorenzen,J. 1886: Untersuchungen grönlandischer Mineralien. [abstract of: Undersøgelse af Mineralier fra Grønland. *Meddr Grønland* **7**, 1-31] *Z. Kristallogr. Miner.* **11**, 315-318.

Macdonald,R. 1966: Petrological studies of some alkalic and peralkalic dyke rocks from the Tugtutôq-Narssaq area. *Rapp. Grønlands geol. Unders.* **11,** 44-47.

Macdonald,R. 1974: The rôle of fractional crystallization in the formation of the alkaline rocks. *In* Sørensen,H. (ed.) *The alkaline rocks.* 442-459, London: Wiley-Interscience.

Macdonald,R. & Saunders,M.J. 1973: Chemical variation in minerals of the astrophyllite group. *Mineralog. Mag.* **39**, 97-111.

Machatschki,F. 1931: Über den Steenstrupin. *Neues Jb. Miner. Geol. Paläont.*, BeilBd **64**, A, 235-250.

Machatschki,F. 1939: Sind Abukumalit und Britholith Glieder der Apatitreihe? [includes material from Naujakasik] *Zentbl. Miner. Geol. Paläont.* **1939**, A, 161-164.

Machatschki,F. 1942: Zur Prage der Stellung des Erikits im Mineralsystem. *Zentbl. Miner. Geol. Paläont.* **1942**, A, 1-3. [erikite from Naujakasik]

Makovicky,E. & Karup-Møller,S. 1981: Crystalline steenstrupine from Tunugdliarfik in the Ilímaussaq alkaline intrusion, South Greenland. *Neues Jb. Miner. Abh.* **140**, 300-330.

Makovicky,E., Johan,Z. & Karup-Møller,S. 1980: New data on bukovite, thalcusite, chalcothallite and rohaite. *Neues Jb. Miner., Abh.* **138**, 122-146.

Makovicky,M. 1981: Preliminary results on the distribution of uranium in drill cores from Kvanefjeld, Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **103**, 109-112.

Makovicky,M., Nielsen,B.L., Karup-Møller,S., Makovicky,E. & Sørensen,E. 1981: Mineralogical, radiographic and uranium leaching studies on the uranium ore from Kvanefjeld, Ilímaussaq complex, South Greenland. Risø R-416, 184 pp.

Markland,S.Aa. 1972: Eudialyt - et grønlandsk zirconiummineral. *Naturens Verd.* **1972**, 213-216.

Mazzi,F., Ungaretti,L., Dal Negro,A., Petersen,O.V. & Rönsbo,J.G. 1979: The crystal structure of semenovite. *Amer. Miner.* **64**, 202-210.

Merlino,S. 1970: Crystal structure of aenigmatite. *Chem. Communs* **1970** (2), 1288-1289.

Metcalf-Johansen,J. 1977: Willemite from the Ilímaussaq alkaline intrusion. *Mineralog. Mag.* **41**, 71-75.

Metcalf-Johansen,J. & Hazell,R.G. 1976: The crystal structure of sorensenite, $Na_4SnBe_2(Si_3O_9)_2 \cdot 2H_2O$. *Acta crystallogr.* **B32**, 2553-2556.

Micheelsen,H. 1975: In situ measurements of the refractive indices of liquid and gaseous inclusions in minerals. *Fortschr. Miner.* **52**, 465-473.

Montgomery,A. 1974: An American mineralogist. III. Expedition to Greenland. *Mineralog. Rec.* **5**, 59-66.

Moorbath,S., Webster,R.K. & Morgan,J.W. 1960: Absolute age determination in south-west Greenland. The Julianehaab granite, the Ilímaussaq batholith and the Kûngnât syenite complex. *Meddr Grønland* **162**(9), 1-14.

Newsome,D. 1974: Some notes on tugtupite. *J. Fluoresc. Miner. Soc.* **3**, 28-30.

Nielsen,B.L. 1971: Heat flow investigations in the Narssaq and Ivigtut areas. *Rapp. Grønlands geol. Unders.* **35**, 25-27.

Nielsen,B.L. 1973: A survey of the economic geology of Greenland (exclusive fossil fuels). *Rapp. Grønlands geol. Unders.* **56**, 45 pp.

Nielsen,B.L. 1976: Economic minerals. *In* Escher,A. & Watt,W.S. (ed.) *Geology of Greenland*, 460-486. Copenhagen: Geological Survey of Greenland.

Nielsen,B.L. 1981: Radioactive albitites bordering the Ilímaussaq complex: Agpat and Søndre Siorarssuit. *Rapp. Grønlands geol. Unders.* **103**, 119-123.

Nielsen,B.L. 1981: Exploration history of the Kvanefjeld uranium deposit, Ilímaussaq intrusion, South Greenland. In: *Uranium exploration case histories,* 353-388. Vienna: International Atomic Energy Agency.

Nielsen,B.L. & Bøtter-Jensen,L. 1973: Natural background radiation levels from areas of major geological units in Greenland, determined by means of thermoluminescence dosimetry. *Modern Geol.* **4**, 119-129.

Nielsen,B.L. & Secher,K. 1979: Grønlands mineralrigdomme. *Grønland* **1979**, 44-51.

Nielsen,B.L. & Steenfelt,A. 1979: Intrusive events at Kvanefjeld in the Ilímaussaq igneous complex. *Bull. geol. Soc. Denmark* **27**, 143-155.

Nielsen,B.L. & Steenfelt,A. 1979: Intrusive rocks. *Bull. Geol. Soc. Denmark* **27**, 143-155.

Nielsen,C.O., Rose-Hansen,J. & Sørensen,H. (ed.) 1975: Narssaq projektet. Et miljøgeokemisk-økologisk forskningsprojekt. Rapport 1. Baggrunden for projektet, Forberedelsesfasen. Logbog for sommeren 1974. Planlægning af analyseprogrammet, 35 pp. København: Institut for Petrologi.

Nielsen,C.O., Rose-Hansen,J. & Sørensen,H. (compiler) 1976: Environmental, geochemical and ecological studies in the region around the Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **80**, 93-97.

Nielsen,C.O., Rose-Hansen,J. & Sørensen,H. (ed.) 1977: Narssaq projektet. Et miljøgeokemisk-økologisk forskningsprojekt. Rapport 2, Oversigt over arbejder udført i 1975, 56 pp. København: Institut for Petrologi.

Nielsen,C.O., Rose-Hansen,J. & Sørensen,H. 1977: Environmental geochemistry and ecology [at Narssaq]. *Rapp. Grønlands geol. Unders.* **85**, 69 only.

Nielsen,C.O., Rose-Hansen,J. & Sørensen,H. 1979: Narssame pilerssarut. *Varv* **1979**, Spec. nr., 32 pp.

Nielsen,C.O., Rose-Hansen,J. & Sørensen,H. 1980: Narssaq projektet. Et miljøgeokemisk-økologisk forskningsprojekt. Rapport 3, 112 pp. København: Institut for Petrologi.

Nielsen,L. 1979: En geokemisk undersøgelse af udvalgte grundstoffers fordeling i jord, sø-, elv- og havsedimenter i Narssaq området, Sydgrønland. Unpublished thesis, University Copenhagen. 70 pp.

Nyegaard,P. 1978: Drilling programme on the uranium mineralisation at Kvanefjeld, Ilímaussaq alkaline intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 64-67.

Noe-Nygaard,A. 1958: Uran-eftersøgning på Grønland. *Naturens Verd.* **1958**, 35-41.

Nyegaard,P. 1979: Evaluation of the uranium deposit at Kvanefjeld. Unpublished internal report, Geological Survey of Greenland.

Nyegaard,P., Nielsen,B.L., Løvborg,L. & Sørensen,H. 1977: Kvanefjeld uranium project, drilling programme 1977. Unpublished internal report, Geological Survey of Greenland.

Oen Ing Soen & Sørensen,H. 1964: The occurrence of nickel-arsenides and nickel-antimonide at Igdlúnguaq, in the Ilímaussaq alkaline massif, South Greenland. *Bull. Grønlands geol. Unders.* **43** (also *Meddr Grønland* **172**(1)), 50 pp.

Oen I.S., Burke,E.A.J. & Kieft,C. 1977: Westerveldite from Igdlúnguaq, Ilímaussaq alkaline massif, South Greenland. *Mineralog. Mag.* **41**, 77-83.

[Østergaard,T.V.] 1964: En undersøgelse af hovedmineralerne og hovedkomponenternes fordeling i lagdelt "kvanit" fra Ilímaussaq, Sydgrønland, med en omtale af alkalimetallernes petrogene betydning. Unpublished prize dissertation, University of Copenhagen [Review: *Festskrift Københavns Univ.*, Nov. **1964**, 222-227]

Petersen,O.V. 1966: Crossed axial plane dispersion in epididymite. *Amer. Miner.* **51**, 916-919.

Petersen,O.V. 1967: The mineralogy of naujakasite. *Bull. Grønlands geol. Unders.* **75**$^{\mathrm{I}}$ (1968) (also *Meddr Grønland* **181**(6)), 17 pp.

Petersen,O.V. 1978: The twin formation of tugtupite, a contribution. *Mineralog. Mag.* **42**, 251-254.

Petersen,O.V. 1981: The first natural crystals of NaF, villiaumite. *Neues Jb. Miner., Mh.* **1981**, 111-116.

Petersen,O.V. & Andersen,S. 1975: The crystal habit of naujakasite with note on some new occurrences. *Bull. Grønlands geol. Unders.* **116**, 5-9.

Petersen,O.V. & Rönsbo,J.G. 1972: Semenovite – a new mineral from the Ilímaussaq alkaline intrusion, south Greenland. *Lithos* **5**, 163-173.

Petersen,O.V., Johnsen,O., Leonardsen,E.S. & Rønsbo,J.G. 1984: Kvanefjeldite, a new mineral species from the Ilímaussaq alkaline complex, Southwest Greenland. *Can. Miner.* **22,** 465-467.

Petersen,O.V., Rønsbo,J. & Leonardsen,E. 1989: Nacareniobsite - (Ce), a new mineral species from the Ilímaussaq alkaline complex, South Greenland, and its relation to mosandrite and the rinkite series. *Neues Jb. Miner., Mh.* **1989**(2), 84-96.

Petersen,O.V., Ranløv,J., Leonardsen,E.S. & Rønsbo,J.G., 1991: Barylite from the Ilímaussaq alkaline complex and associated fenites, South Greenland. *Neues Jb. Miner., Mh.* **1991**(5), 212-216.

Petersen,O.V., Johnsen,O., Bernhardt,H.-J. & Medenbach,O. 1993: Dorfmanite, $Na_2HPO_4.2H_2O$ from the Ilímaussaq alkaline complex, South Greenland. *Neues Jb. Miner., Mh.* **1993**(6), 254-258.

Petersen,O.V., Rønsbo,J.G., Leonardsen,E.S., Johnsen,O., Bollingberg,H. & Rose-Hansen,J. 1994: Leifite from the Ilímaussaq alkaline complex, South Greenland. *Neues Jb. Miner., Mh.* **1994**(2), 83-90

Petersen,O.V., Micheelsen,H.I. & Leonardsen,E.S. in press: Bavenite, $Ca_4Be_3Al(Si_90_{25}(OH)_3$, from the Ilimaussaq alkaline complex, South Greenland. Submitted to: *Neues Jb. Miner., Mh.*

Petersilie,I.A. & Sorensen,H. 1970: Hydrocarbon gases and bituminous substances in rocks from the Ilímaussaq alkaline intrusion, South Greenland. *Lithos* **3**, 59-76.

Petersilie,I.A., Sørensen,H. 1971: [Hydrocarbon gases and bitumens in rocks of the Ilímaussaq massif.] *In* [Geochemistry, petrology and mineralogy of alkaline rocks], 159-172. Moskva: Nauka. (in Russian).

Piotrowski,J.M. & Edgar,A.D. 1970: Melting relations of undersaturated alkaline rocks from South Greenland compared to those of Africa and Canada. *Meddr Grønland* **181**(9), 62 pp.

Piper,J.D.A. 1976: Palaeomagnetism of marginal syenites and fractionated rocks of the Ilímaussaq intrusion, South Greenland. *Bull. geol. Soc. Denmark* **25**, 89-97.

Piper,J.D.A. 1977: Magnetic stratigraphy and magnetic-petrologic properties of Precambrian Gardar lavas, South Greenland. *Earth planet. Sci. Lett.* **34**, 247-263.

Platt,R.G. & Rose-Hansen,J. 1975: The system ussingite–water and its bearing on crystallization in persodic portions of the system Na_2O–Al_2O_3–SiO_2–H_2O at 1 kb total pressure. *J. Geol.* **83**, 763-772.

Platt,R.G. & Rose-Hansen,J. 1976: The system ussingite-water and crystallization of persodic liquids at a total pressure of 1 kb. *Progr. exper. Petr.* **3**, 281-283.

Poulsen,V. 1964: The sandstones of the Precambrian Eriksfjord Formation in South Greenland. *Rapp. Grønlands geol. Unders.* **2**, 16 pp.

Povarennykh,A.S., Platonov,A.N. & Belichenko,V.P. 1970: On the colour of ussingite from the Ilímaussaq (South Greenland) and Lovozero (Kola Peninsula) alkaline intrusions. *Bull. geol. Soc. Denmark* **20**, 20-26.

Povarennykh,A.S., Platonov,A.N., Tarashchan,A.N. & Belichenko,V.P. 1971: The colour and luminescence of tugtupite (beryllosodalite) from Ilímaussaq, South Greenland. *Bull. Grønlands geol. Unders.* **95**^{II} (also *Meddr Grønland* **181**,14) 12 pp.

Pulawski,B. 1966: Vandbalancen og terrassestudier i Narssaqelvdal. Unpublished internal report, Geological Survey of Greenland.

Raguin,E. 1970: *Pétrographie des roches plutoniques dans leur cadre géologique*. Masson & Cie. 239 pp.

Rønsbo, J. 1989: Coupled substitutions involving REEs and Na and Si in apatites in alkaline rocks from the Ilímaussaq intrusion, South Greenland, and the petrological implications. *Am. Mineral.* **74,** 896-901.

Rønsbo,J.G., Khomyakov,A.P., Semenov,E.I., Voronkov,A.A. & Garanin,V.K. 1979: Vitusite – a new phosphate of sodium and rare earths from the Lovozero alkaline massif, Kola, and the Ilímaussaq alkaline intrusion, south Greenland. *Neues Jb. Miner., Abh.* **137**, 42-53.

Rønsbo,J.G., Leonardsen,E.S., Petersen,O.V. & Johnsen,O. 1983: Second occurrence of vuonnemite the +Ilímaussaq alkaline complex, South West Greenland. *Neues Jb. Miner., Mh.* **1983**(10), 451-460.

Rønsbo,J.G., Petersen,O.V. & Leonardsen,E.S. 1990: Vinogradovite from the Ilímaussaq alkaline complex, South Greenland, a beryllium bearing mineral. *Neues Jb. Miner., Mh.* **1990**(11), 481-492.

Rose-Hansen,J. & Sørensen,H. 1977: Current research in the Ilímaussaq region, South Greenland. *Rapp. Grønlands geol. Unders.* **85**, 67-73.

Rose-Hansen,J. & Sørensen,H. 1978: Geological, geochemical and ecological research in the Ilímaussaq region South Greenland. *Rapp. Grønlands geol. Unders.* **90**, 67-73.

Rose-Hansen,J. & Sørensen,H. 1979: Geological, geochemical and ecological studies in the Ilímaussaq area, South Greenland. *Rapp. Grønlands geol. Unders.* **95**, 79-81.

Rose-Hansen,J., Sørensen,H. & Sørensen,E. 1976: Uranet på Kvanefjeld. *Forsk. Samfund.* **2**(6), 9-10 & 36.

Rose-Hansen,J., Nielsen,C.O. & Sørensen,H. (ed.) 1977: The Narssaq project. A geochemical-ecological research project. Progress report No.1. (2 vols) The 1974 field season. Copenhagen: Institute for Petrology.

Rose-Hansen,J., Karup-Møller,S., Sørensen,E. & Sørensen,H. 1977: Uranium-rich albitites from the northern contact of the Ilímaussaq alkaline intrusion. *Rapp. Grønlands geol. Unders.* **85**, 68 only.

Rose-Hansen,J., Sørensen,H. & Holm,P.M. 1986: The supergene distribution of uranium and accompanying elements associated with alkaline intrusions in South Greenland including the Ilímaussaq complex. *Uranium* **2,** 185-214.

Rossi,G., Tazzoli,V. & Ungaretti,L. 1974: The crystal structure of ussingite. *Amer. Miner.* **59**, 335-340.

Rossman,G.R. 1975: Joaquinite: the nature of its water content and the question of four-coordinated ferrous iron. *Amer. Miner.* **60**, 435-440.

Sabina,A.P. & Traill,R.J. 1960: Catalogue of X-ray diffraction patterns and specimen mounts on file at the Geological Survey of Canada. [specimen of apatite plus monazite from Kangerdluarssuk] *Pap. geol. Surv. Can.* **60-4**, 116 pp.

Sahama,T.G. 1956: Optical anomalies in arfvedsonite from Greenland. *Amer. Miner.* **41**, 509-512.

Sahama,Th.G. & Hytönen,K. 1957: Unit cell of mosandrite, johnstrupite and rinkite. *Geol. Fören. Stockh. Förh.* **79**, 791-796.

Sass,J.H., Nielsen,B.L., Wollenberg,H.A. & Munroe,R.J. 1972: Heat flow and surface radioactivity at two sites in southern Greenland. *J. geophys. Res.* **77**, 6435-6444.

Schrocke,H. 1955: Uber Alkaligesteine und deren Lagerstatten. *Neues Jb. Miner., Mh.* **1955**, 169-189.

Sebald,A., Merwin,L.H., Dollase,W.A. & Seifert,F. 1990: A multinuclear, high-solution solid-state NMR study of sorensenite ($Na_4SnBe_2(Si_3O_9) \times 2H_2O$) and comparison with wollastonite and pectolite. *Phys. Chem. Miner.* **17,** 9-16.

Semenov,E.I. 1967: O vodnykh silikatakh tsirkoniya. [On hydrous zirconium silicates] *In* Tikhonenkova,R.P. & Semenov,E.I. (ed.) *Mineralogiya pegmatitov i gidrotermalitov shchelochnykh massivov.* [Mineralogy of pegmatites and hydrothermalites from alkaline massifs] 3-13. Moskva: Nauka.

Semenov,E.I. 1967: Mineralogo-geokhimicheskiye tipy nefelin-siyenitovykh derivatov. [The mineralogical geochemical types of derivatives of nepheline syenites] *In* Tikhonenkova,R.P. & Semenov,E.I. (ed.) *Mineralogiya pegmatitov i gidrotermalitov shchelochnykh massivov* [Mineralogy of pegmatites and hydrothermalites from alkaline massifs] , 52-71. Moskva: Nauka.

Semenov,E.I. 1969: Mineralogiya shchelochogo massiva Ilimausak (Yuzhnaya Grenlandiya). [Mineralogy of the Ilímaussaq alkaline massif (South Greenland)] 164 pp. Moskva: Nauka.

Semenov,E.I. (ed.) 1974: Mineralogiya shchelochnykh massivov i ikh mestorozhdeniy. [Mineralogy of alkaline massifs and associated deposits] 248 pp. Moskva: Nauka..

Semenov,E.I. 1977: [Type-chemistry of minerals of alkaline massifs]. Moskva: Nedra. 119 pp. (in Russian). Simonov,V.I. & Belov,N.V. 1967: Osobennosti kristallicheskoi struktury rinkita. [Characteristics of the crystal structure of rinkite] *Kristallogr.* **12** (5), 848-853. (transl: *Soviet Physics Crystallogr.* **12**, 740-744 (1968).

Semenov,E.I. & Sørensen,H. 1966: Eudidymite and epididymite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **63** (also *Meddr Grønland* **181**(2)), 21 pp.

Semenov,E.I., Gerassimovsky,V.I., Maksimova,N.V., Andersen,S. & Petersen,O.V. 1965: Sorensenite, a new sodium-beryllium-tin-silicate from the Ilímaussaq intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **61** (also *Meddr Grønland* **181**(1)), 19 pp.

Semenov,E.I., Bukin,V.I., Balashov,Yu.A. & Sørensen,H. 1967: Rare earths in minerals of the joaquinite group. *Amer. Miner.* **52**, 1762-1769.

Semenov,E.I., Kazakova,M.E. & Aleksandrova,R.A. 1967: The Lovozero minerals - nenadkevichite, gerassimovskite and tundrite - from Ilímaussaq, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**(5), part 1), 1-11.

Semenov,E.I., Sørensen,H., Bessmertnaja,M.S & Novorossova,L.E. 1967: Chalcothallite - a new sulphide of copper and thallium from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**(5), part 2), 13-26.

Semenov,E.I., Kazakova,M.E. & Bukin,V.J. 1968: Ilimaussite, a new rare earth-niobium-barium silicate from Ilímaussaq, South Greenland. *Bull. Grønlands geol. Unders.* **75** (also *Meddr Grønland* **181**(7), part 1), 3-7.

Semenov,E.I., Sørensen,H. & Katajeva,Z.T. 1968: On the mineralogy of pyrochlore from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **75** (also *Meddr Grønland* **181**,7) 9-24.

Sobolev,V.S., Bazarova,T.Y., Shugurova,N.A., Bazarov,L.Sh., Dolgov,Yu.A. & Sørensen,H. 1970: A preliminary examination of fluid inclusions in nepheline, sorensenite, tugtupite and chkalovite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **81** (also *Meddr Grønland* **181**,11) 32 pp.

Sørensen,E. 1959: Udvinding af dansk uran. *Ing. Ugebl.* **1959**(19), 10-11.

Sørensen,E. 1965: Skitseprojekt til udvinding af den grønlandske uranmalm udarbejdet. *Ing. Ugebl.* **41**, 9.okt.1965, 3-6.

Sørensen,E. 1966: På spor af sjældne metaller i Sydgrønland. V. Uran og thorium - forekomst og udvinding. *Grønland* **1966**, 275-286.

Sørensen,E. & Lundgaard,T. 1966: Selective flotation of steenstrupine and monazite from Kvanefjeld lujavrite. *Riso Rep.* **133,** 17 pp.

Sørensen,E., Lundgaard,T., Rasmussen,I. & Dibbern,H.C. 1978: Pilot plant testing on uranium extraction from the Kvanefjeld ore deposit. Risø-M-2102, 46 pp.

Sørensen,H. 1956: Uran og thorium. Mulighederne for forekomster af disse to metaller i Vestgrønland. *Grønland* **1956**, 217-226.

Sørensen,H. 1958: The Ilímaussaq batholith. A review and discussion. *Bull. Grønlands geol. Unders.* **19** (also *Meddr Grønland* **162**(3)), 48 pp.

Sørensen,H. 1958: Uran og thorium. En oversigt over disse grundstoffers forekomstmåde i naturen. *Ingeniøren* **67**, 107-112.

Sørensen,H. 1958: Hydrotermale gang i nefelinsyenit fra Sydgrønland. [abstract] *Geologi* **10**, 20 only.

Sørensen,H. 1960: On the agpaitic rocks. *Rep. 21st int. geol. Congr. Norden, 1960*, **13,** 319-327.

Sørensen,H. 1960: Beryllium minerals in a pegmatite in the nepheline syenites of Ilímaussaq, south west Greenland. *Rep. 21st int. geol. Congr. Norden, 1960*, **17,** 31-35.

Sørensen,H. 1962: On the occurrence of steenstrupine in the Ilímaussaq massif, southwest Greenland. *Bull. Grønlands geol. Unders.* **32** (also *Meddr Grønland* **167**(1)), 251 pp.

Sørensen,H. 1963: Beryllium minerals in a pegmatite in the nepheline syenites of Ilimaussaq, South West Greenland. *Rep. 21st int. geol. Congr. Norden, 1960*, **27**, 157 & 159.

Sørensen,H. 1965: De første russiske geologer i Grønland. *Grønland* **1965,** 1-13.

Sërensen,Kh. [Sørensen,H.] 1965: O magmaticheskoi evolyutsii shchelochnoi provintsii Yuzhnoi Grenlandii. [On the magmatic evolution of the alkaline igneous province of South Greenland] Inst. Geokhimii i Analiticheskoi Khimii.i Problemui Geokhimii 1, 338-349. Moscow: Nauka.

Sørensen,H. 1966: På spor af sjældne metaller i Sydgrønland. I. Træk af udforskningens historie. *Grønland* **1966,** 113-126.

Sørensen,H. 1966: På spor af sjældne metaller i Sydgrønland. II. Gardar rift-systemet. *Grønland* **1966,** 163-176.

Sørensen,H. 1966: På spor af sjældne metaller i Sydgrønland. III. Ilímaussaq-intrusionen - rosiner i pølseenden. *Grønland* **1966**, 185-197.

Sørensen,H. 1966: On the magmatic evolution of the alkaline igneous province of South Greenland. [translation of: O magmaticheskoi evolyutsii shchelochnoi provintsii Yuzhnoi Grenlandii] *Rapp. Grønlands geol. Unders.* **7**, 19 pp.

Sørensen,H. 1967: Hydrothermal veins in the Ilímaussaq intrusion. [abstract] *Trans. Instn Min. Metall.* **76**, B, 230 only.

Sørensen,H. 1967: On the history of exploration of the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **68** (also *Meddr Grønland* **181**(3)), 33 pp.

Sørensen,H. 1968: På spor af sjældne metaller i Sydgrønland. VII. Zirconium - et af fremtidens metaller. *Grønland* **1968**, 353-365.

Sørensen,H. 1968: Lidt om lag. *Varv* **1968**, 113-119.

Sørensen,H. 1969: Field work in the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **19**, 37-38.

Sorensen,H. 1969: Rhythmic igneous layering in peralkaline intrusions. An essay review on Ilímaussaq (Greenland) and Lovozero (Kola, USSR). *Lithos* **2**, 261-283.

Sørensen,H. 1970: Low-grade uranium deposits in agpaitic nepheline syenites, South Greenland. *In: Uranium exploration geology*, 151-159. Vienna: International Atomic Energy Agency.

Sørensen,H. 1970: Occurrence of uranium in alkaline igneous rocks. *In: Uranium exploration geology*, 161-168. Vienna: International Atomic Energy Agency.

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. Miner.* **10**, 299-334.

Sørensen,H. 1973: Ore deposits of agpaitic nepheline syenites. *In* Morin,P. (ed.) *Les roches plutoniques dans leurs rapports avec les gîtes minéraux*, 331-341. Paris: Masson et C^{ie}.

Sørensen,H. 1974: Uranet ved Narssaq i Sydgrønland. *Naturens Verd.* **1974**, 11-12 & 345-351.

Sørensen,H. 1975: Uranet ved Narssaq i Sydgrønland. *Naturens Verd.* **1975**, 49-56.

Sørensen,H. 1975: Grønlands uran. *Energi Oplysnings Udvalgets Grundbøger* **2**, 26-27.

Sørensen,H. 1977: Features of the distribution of uranium in igneous rocks - uranium deposits associated with igneous rocks. *In: Recognition and evaluation of uraniferous areas*, 47-52. Vienna: International Atomic Energy Agency.

Sørensen,H. 1978: The position of the augite syenite and pulaskite in the Ilímaussaq intrusion, South Greenland. *Bull. geol. Soc. Denmark* **27**, spec. issue, 15-23.

Sørensen,H. 1979: Miljøundersøgelser på Kvanefjeld. *Forsk. Samfund.* **5**(9), 13-15.

Sørensen,H. 1980: On the role of volatile components in the evolution of alkaline rocks. [abstract] *Lithos* **13**, 221-222.

Sørensen,H. 1980: Narssaq-egnens geologi - Narssap erkâta píngoriartorsimanera. *In* Fisker,J. (ed.) *Narssaq*, 237-246. Nordiske Landes Bogforlag.

Sørensen,H. 1980: Tugtupit. *In* Fisker,J. (ed.) *Narssaq*, 247-251. Nordiske Landes Bogforlag.

Sørensen,H. 1980: Uranefterforskning i Norden. *In:* Nordisk Seminar: Kernebrændslets kredsløb i nordisk perspektiv. NKA/NS 80, 19 pp.

Sørensen,H. 1986: The alkaline rocks - a review. *Fortschr. Miner.* **64,** 63-86.

Sørensen,H. 1989: Materials resources. *In* Bilde-Sørensen,J.B., Hansen,N. Jensen,D.J., Leffers,T., Lilholt,H. & Pedersen,O.B. (ed.) *Materials architecture. Proceedings of the tenth Risø International Symposium on Metallurgy and Materials Science,* 665-673. Roskilde: Risø National Laboratory.

Sørensen,H. 1992: Agpaitic nepheline syenites: a potential source of rare elements. *Appl. Geochemistry* **7,** 417-427.

Sørensen,H. & Buchwald,V.[F.] 1958: Redegørelse for undersøgelser af radioaktive grønlandske mineraler og bjergarter. *Medd. dansk geol. Foren.* **13**, 545-550.

Sørensen,H. & Larsen,L.M. 1978: Aspects of the crystallization of volatile-rich peralkaline undersaturated magmas - exemplified by the Ilímaussaq intrusion, South Greenland. *Jorn. Miner.* **7**, 135-142.

Sørensen,H. & Larsen,L.M. 1987: Layering in the Ilímaussaq alkaline intrusion, South Greenland. *In* Parsons,I. (ed.) *Origin of Igneous Layering*. NATO Adv. Sci. Inst. Ser. C. Mat. Phys. Sci. **196**, 1-28.

Sørensen,H. & Petersen,O.V. 1975: Edelsteine und Halbedelsteine von Gronland. *Sb. nár. Muz. Praze* **29B** [for 1973], 35-42.

Sørensen,H. & Rose-Hansen,J. 1978: Narssaq-projektet. Et miljøgeokemisk-økologisk forskningsprojekt. *Varv* **1978**, 3-14.

Sørensen,H., Hansen,J. & Bondesen,E. 1969: Preliminary account of the geology of the Kvanefjeld area of the Ilímaussaq intrusion, South Greenland. *Rapp. Grønlands geol. Unders.* **18**, 40 pp.

Sorensen,H, Semenov,E.I., Bezsmertnaya,M.S. & Khalezova,E.B. 1969: Kuprostibit - novoe prirodnoe soedenenie medi i sur'my. [Cuprostibite - a new natural compound of copper and antimony] *Zap. vses. miner. Obshch.* (2) **98**, 716-724.

Sørensen,H., Leonardsen,E.S. & Petersen,O.V. 1970: Trona and thermonatrite from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. geol. Soc. Denmark* **20**, 1-19.

Sørensen,H., Danø,M. & Petersen,O.V. 1971: On the mineralogy and paragenesis of tugtupite $Na_8Al_2Be_2Si_8O_{24}(Cl,S)_2$ from the Ilímaussaq alkaline intrusion, South Greenland. *Bull. Grønlands geol. Unders.* **95**[1] (also *Meddr Grønland* **181**,13) 38 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.

Sørensen,H., Rose-Hansen,J. & Gwozdz,R. 1976: Forekomster af sjældne grundstoffer og miljøgeokemi-I ske undersøgelser i Sydgrønland. Abstr. XII Nordiska Geologvintermotet, Goteborg, 1976, 60 only.

Sørensen,H., Nielsen,B.L. & Jacobsen,F.L. 1979: Denmark and Greenland. *In* Bowie,S.H.U., Kvalheim,A. & Haslam,H.W. (ed.) *Mineral deposits of Europe.* 1: Northwest Europe, 251-261. London: Institution of Mining and Metallurgy and Mineralogical Society.

Sørensen,H., Christensen,N.P., Gwozdz,R., Larsen,C.L., Nielsen,L. & Rose-Hansen,J. 1980: Environmental geochemistry in the area of the Ilímaussaq intrusion, South Greenland. *Abstr. 26th int. geol. Congr., Paris,* **2**, 795 only.

Sørensen,H., Makovicky,M. & Rose-Hansen,J. 1985: Reconnaissance studies on the synthesis and stability of steenstrupine. *Bull. geol. Soc. Finland,* spec. Sahama Memorial vol. **57** (1-2), 103-112.

Sørensen,P. 1971: Field measurements of thorium and uranium in lujavrites from the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **35**, 27-29.

Sokolova,M.N., Organova,N.I., Kazakova,M.E. & Rudnitskaya,E.S. 1968: Pervaya nakhodka ilimausita v SSSR. [First discovery of ilimaussite in the USSR] *Dokl. Akad. Nauk USSR* **182**, 1178-1181. [transl: *Dokl. Acad. Sci. USSR, Earth Sci. Sect.* **182**, 139-142].

Sood,M.K. & Edgar,A.D. 1970: Melting relations of undersaturated alkaline rocks from the Ilímaussaq intrusion and Grønnedal-Íka complex South Greenland, under water vapour and controlled partial oxygen pressure. *Meddr Grønland* **181**(12), 41 pp.

Stakheev,Yu.I., Gerasimovskii,V.I. & Stakheeva,S.A. 1975: O soderzhanii rtuti v magmaticheskikh. [On mercury content in igneous rocks] *Geokhimiya* **1975** (11), 1668-1675. [transl: *Geochem. int.* **12**, 37-44]

Steenfelt,A. 1981: Field relations in the roof zone of the Ilímaussaq intrusion with special reference to the position of the alkali acid rocks. *Rapp. Grønlands geol. Unders.* **103**, 43-52.

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.

Steenstrup,K.J.V. & Kornerup,A. 1881: Beretning om Expeditionen til Julianehaabs Distrikt i 1874. *Meddr Grønland* 2, 1-26.

Stewart,J.W. 1964: The earlier Gardar igneous rocks of the Ilímaussaq area, South Greenland. Unpublished Ph.D. thesis, Durham University. 423 pp.

Strunz,H. 1944: Zur Kristallographie von Steenstrupin. *Neues Jb. Miner. Geol. Paläont.*, *Mh.* A, **1944**, 244 only.

Thomson,T. 1811: A chemical analysis of sodalite, a new mineral from Greenland. *J. nat. Phil.* **29**, 285-292.

Thomson,T. 1812: A chemical analysis of sodalite, a new mineral from Greenland. *Trans. roy. Soc. Edinb.* **6**, 387-395.

Upton,B.G.J. 1961: Textural features of some contrasted igneous cumulates from South Greenland. *Bull. Grønlands geol. Unders.* **29**, part 1 (also *Meddr Grønland* **123**(6), Pt.1), 31 pp.

Upton.B.G.J. 1974: The alkaline province of south-west Greenland. *In* Sørensen,H. (ed.) *The alkaline rocks*, 221-238. London: Wiley-Interscience.

Upton,B.G.J. & Blundell,D.J. 1978: The Gardar igneous province: evidence for Proterozoic continental rifting. *In* Neumann,E.-R & Ramberg,I.B. (ed.) *Petrology and geochemistry of continental rifts*, 163-172. Reidel Publ. Co.

Ussing,N.V. 1888: Om et forméntlig nyt mineral fra Kangerdluarsuk. *Geol. Fören. Stockh. Förh.* **10**, 190-192.

Ussing,N.V. 1892: Nogle Grænsefaciesdannelser af Nefelinsyenit. *Forh. skand. Naturf. Møte*, **1892**, 443-447.

Ussing,N.V. 1894: Mineralogiske-petrografiske Undersøgelse af Grønlandske Nefelinsyeniter og beslægtede Bjærgarter. *Meddr Grønland* **14**, 1-220.

Ussing,N.V. 1912: The geology of the country around Julianehaab, Greenland. *Meddr Grønland* **38**, 426 pp.

von Hevesy,G. & Jantzen,V.T. 1923: The hafnium content of zirconium ores. *J. chem. Soc. Lond.* **123**, 3218-3223.

Watt,W.S. 1966: Chemical analyses from the Gardar igneous province, South Greenland. *Rapp. Grønlands geol. Unders.* **6**, 92 pp.

Wegmann,[C.]E. 1937: Sur la genèse des roches alcalines de Julienahaab (Groenland). *C.r. hebd. Séanc. Acad. Sci., Paris* **204**, 1125-1127.

Wegmann,C.E. 1938: Geologische Untersuchungen in Südgrönland. *Geol. Rdsch.* **29**, 511-513.

Wegmann,C.E. 1938: Geological investigations in southern Greenland. Part I. On the structural divisions of southern Greenland. *Meddr Grønland* **113**(2), 148 pp.

Westergaard,A.S. 1969: The border pegmatites of the Ilímaussaq intrusion. *Rapp. Grønlands geol. Unders.* **19**, 39-40.

Wollenberg,H. 1971: Fission track radiography of uranium and thorium in radioactive minerals. *Risö Rep.* **228**, 40 pp.

Wollenberg,H.A. 1973: Fission-track radiography of uranium and thorium in radioactive minerals. *In* Jones,M.J. (ed.) *Geochemical exploration 1972*, 347-358. London: Institution of Mining and Metallurgy.

Wollenberg,H., Kunzendorf,H. & Rose-Hansen,J. 1971: Isotope-excited X-ray fluorescence analyses for Nb, Zr, and La + Ce on outcrops in the Ilímaussaq intrusion, South Greenland. *Econ. Geol.* **66**, 1048-1060.

Wychoff,R.W.G., Merwin,H.E. & Washington,H.S. 1925: X-ray diffraction measurements upon the pyroxenes. *Amer. J. Sci.* (5) **10,** 383-397.

Zachariasen,W.H. 1930: Bemerkung zu der Arbeit B.Gossner und F.Massgnug: Uber die strukturelle und molekulare Einheit von Eudialyt. *Zentbl. Miner. Geol. Paläont.* **A** **1930**, 315-317.

Zambonini,F. 1921: Osservazioni sulla composizions chimica di alcuni minerali. [rinkite fron Kangerdluarssuk] *Atti Soc. ital. Sci. nat.* **60**, 258-277.

ISSN 0903-7322