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Introduction to the Ilímaussaq intrusion with a summary of the reported investigations

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Geology and petrology

Geological setting

The Ilímaussaq intrusion belongs to the late Precambrian Gardar province of South Greenland (fig. 1). The province can be regarded as a cratogenic rift province with similarities to the East African rift system and the Oslo igneous province (Upton, 1974; Emeleus & Upton, 1976). The province consists of continental sandstones, and a variety of volcanic and plutonic igneous rocks many of which are alkaline. An important series of faults have influenced the position of the plutonic centres and presumably facilitated the rise of magma into the upper crust. The alkaline rocks evolved towards Si-rich melts such as comendites and alkali granites, and towards Si-poor melts such as phonolites and nepheline syenites. Both types of evolution are present at Ilímaussaq (fig. 2).

The Ilímaussaq intrusion (17 × 8 km) is situated in the mid-eastern part of the Gardar province and has been dated by the Rb-Sr isotope method to 1168 ± 21 m.y. (Blaxland *et al.*, 1976). The position of the intrusion, and its steep margins, suggest that the intrusion was largely emplaced by block subsidence (Sørensen, 1978; Nielsen & Steenfelt, 1979) into a Precambrian granite basement and the overlying Gardar sandstones and lavas. In the roof zone there are local signs of piecemeal stoping and the final nepheline syenites (lujavrites) intruded nearby country rocks in a few places.

Interim petrologic synthesis

Important contributions to the petrology of the Ilímaussaq intrusion have been presented by Ussing (1912), Sørensen (1962, 1969, 1970), Ferguson (1970a), Sood & Edgar (1970), Engell (1972), Bohse *et al.* (1974), Steenfelt & Bohse (1975), Larsen (1976, 1977), Sørensen & Larsen (1978), Karup-Møller (1978) and Konnerup-Madsen *et al.* (1979). Many other papers contain essential information for a petrological model. We have combined the existing work with the papers presented in this report, and assimilated the current understanding of our Ilímaussaq colleagues, in order to present an interim petrological synthesis.

Geological and geochemical evidence suggests that the intrusion was emplaced in three main pulses – augite syenite, acid rocks, and agpaitic rocks.

Augite syenite stage. An early shell of augite syenite occurs along the sides and roof of the intrusion. It shows an outer chilled margin and local, steeply dipping banding in the wall sections. The magma crystallized successively inwards from the walls. The augite syenite has been regarded by many authors as representative of the parent magma for the Ilímaussaq intrusion, but recent work suggests it is largely cumulitic.

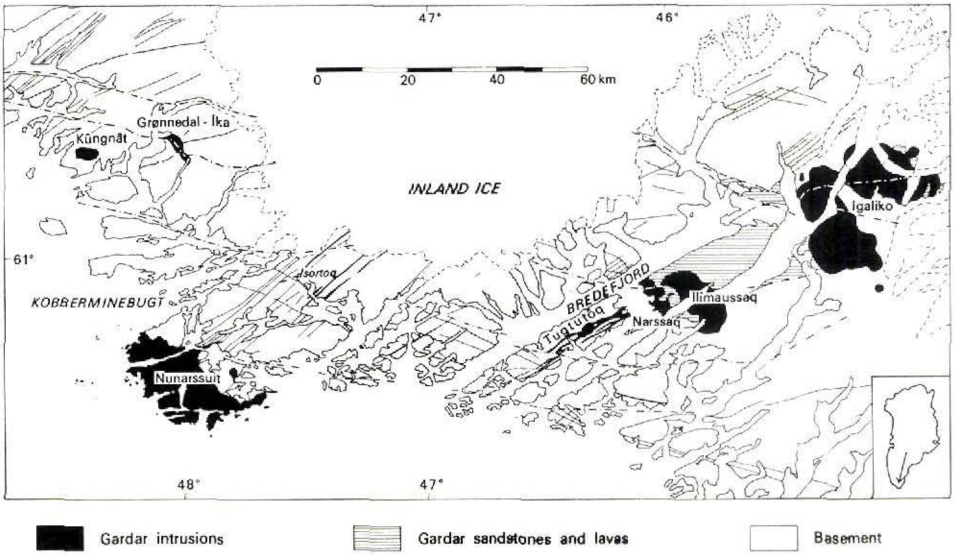

Fig. 1. Simplified geological map of the Gardar igneous province showing the position of the intrusions.

The magma was slightly silica undersaturated and aluminous, with a composition similar to other augite syenites of the Gardar province. Separation of ternary feldspar, olivine (Fo_{17}–Fo_4), ferrosalite, Fe-Ti oxide and apatite yielded more alkaline and undersaturated syenites, probably with lower Fe contents. Separation of aluminous phases such as feldspar and ferrosalite would drive residual liquids to a peralkaline state. Pyrrhotite and chalcopyrite probably crystallized from immiscible sulphide droplets in the augite syenite magma.

Alkali acid rock stage. The second pulse of magma was a peralkaline granite magma with geochemical affinities to the other Ilímaussaq rocks. It was emplaced as two sheets in the uppermost part of the augite syenite. The evolution, and the genetic relation of these alkali acid rocks (granite, quartz syenite) to other Ilímaussaq rocks is not clear.

Agpaitic stage. The third, and main, pulse of magma was peralkaline and silica-undersaturated. It formed a layered series of agpaitic nepheline syenites in the centre of the intrusion (see Table 1). This pulse underwent a complex differentiation history. From the magma, the roof rocks pulaskite, foyaite, sodalite foyaite and naujaite crystallized successively downwards; contemporaneous bottom cumulates are inferred to be present at depth. The exposed bottom cumulates, the kakortokites, are younger than the roof cumulates and may have formed from a new pulse of agpaitic magma. The kakortokites pass conformably upwards into lujavrites; the transition probably reflects physical changes in the magma chamber which at this stage measured about 10000 × 5000 × 200 m, i.e. disc-shaped. Subsidence and fracturing of the roof, with the establishment of two or more, largely isolated sub-chambers of lujavrite would fit the field and geochemical evidence. At a very late stage, arfvedsonite lujavrite and medium- to coarse-grained (M-C) lujavrite, including those at Kvanefjeld, were intruded. After this event only hydrothermal activity remained.

At the *pulaskite-foyaite substage,* the cumulate crystallization was dominated by alkali feldspar with lesser amounts of fayalite, hedenbergite, titanomagnetite and apatite. These

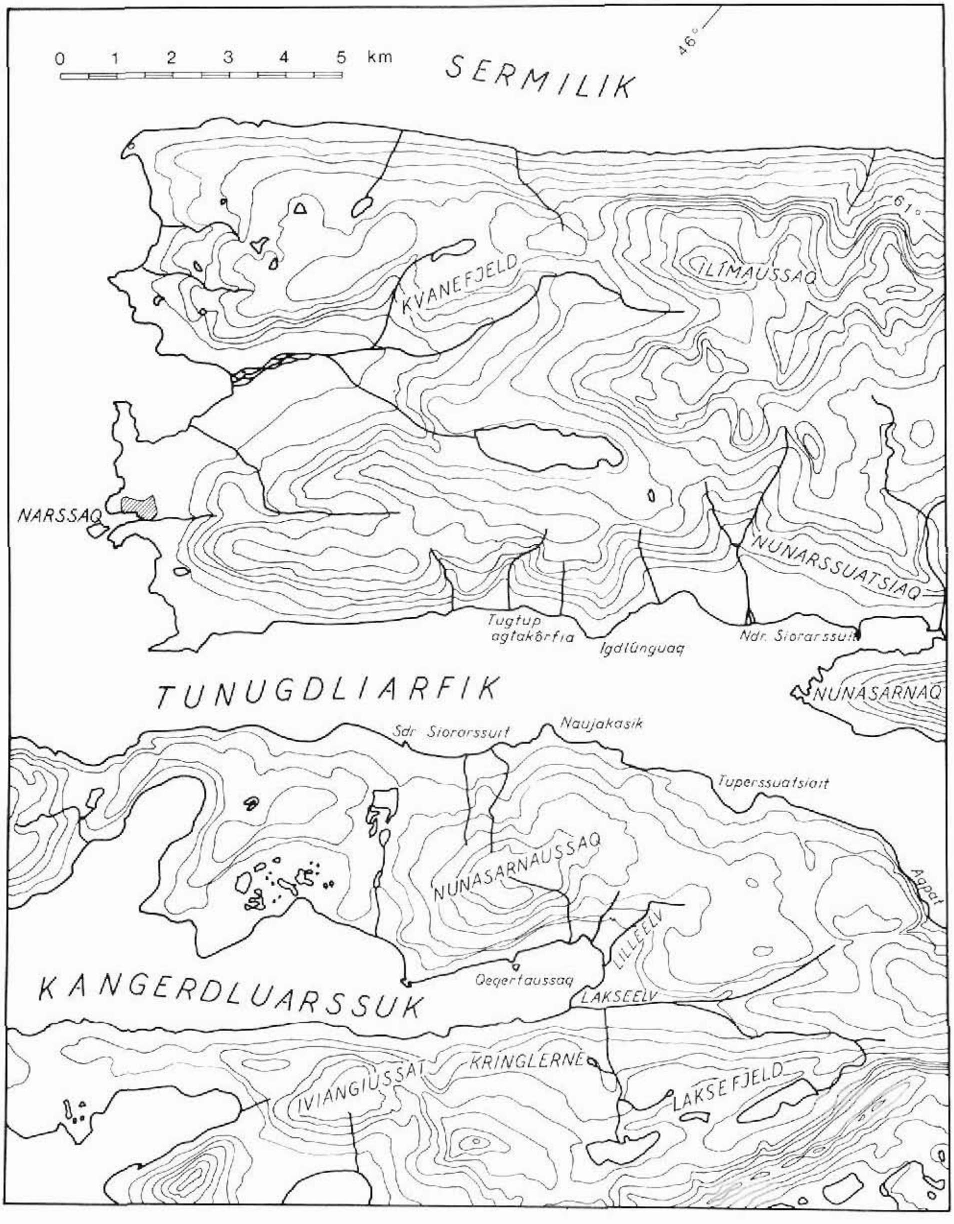

Fig. 2. Topography and names in the region of the Ilímaussaq intrusion.

phases were plastered onto the roof. The magma approached the agpaitic stage, and nepheline, sodalite, alkali amphibole, alkali pyroxene and aenigmatite occur interstitially.

At the transition to the *sodalite foyaite-naujaite substage,* sodalite and nepheline became additional cumulus phases, and this substage is characterized by the increasingly pronounced

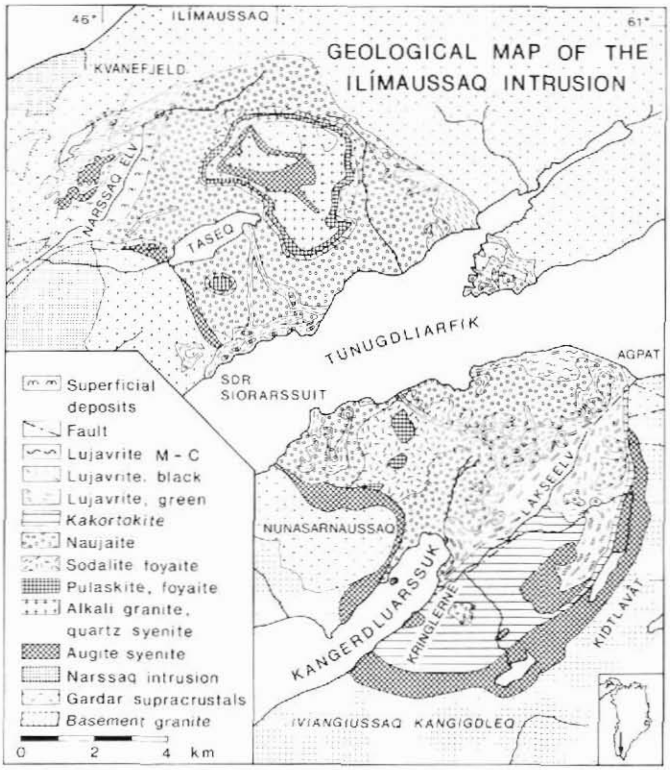

Fig. 3. Geological map of the Ilímaussaq alkaline intrusion. Lujavrite, green includes aegirine lujavrite I and II and later aegirine lujavrites. Lujavrite, black comprises all the varieties of arfvedsonite-bearing lujavrite including the naujakasite-bearing variety.

flotation of sodalite crystals under the roof. The mafic minerals are dominantly interstitially formed: alkali amphibole, aegirine, aenigmatite and eudialyte. The mafic cumulus phases are the same as in the pulaskite and foyaite, but they are only present in extremely small quantities and an unknown amount of these have dropped out of the crystallising magma. The water-free character of the liquidus mineral assemblage shows that the main magma was water-undersaturated; this stands in marked contrast to the interstitial assemblage. Very low oxygen fugacity which further decreased during crystallization can be deduced from the mineral assemblage (fayalite, aenigmatite, arfvedsonite), the mineral chemistry, and from the presence of hydrocarbon-rich fluid inclusions. Low sulphur fugacity is indicated by the sulphide assemblage troilite-djerfisherite. Uranium contents of the interstitial eudialyte decrease with evolution; this may reflect the increased solubility of U as complex ions in the coexisting volatile (H_2O, F), alkali-rich magma. The magma composition at this stage was fully agpaitic; copious extraction of feldspar, nepheline and sodalite probably reversed the Fe-depletion trend of earlier stages and the later agpaitic rocks are distinctly rich in Fe.

At the *kakortokite substage*, density-stratified bottom cumulates were developed. They consist of cyclically layered series with units composed of black (arfvedsonite), red (eudialyte) and white (feldspar) layers, named from bottom to top in a unit. Cumulus eudialyte indicates saturation of the magma in Zr, and from this point Zr contents begin to decline.

Table 1. The major rock types of the Ilímaussaq intrusion

Rock types	Texture, grain size	Essential minerals	Minor minerals
augite syenite	hypidiomorphic to xenomorphic granular, massive or banded, medium to coarse	alkali feldspar, fayalitic olivine, ferrosalite	titanomagnetite, apatite, Ti-rich hastingsite, biotite
pulaskite and foyaite	massive, medium to coarse, platy feldspars	alkali feldspar, hedenbergite, katophorite, nepheline, fayalite, alkali pyroxene	apatite, titanomagnetite, aenigmatite, biotite, fluorite, eudialyte
sodalite foyaite	massive, coarse	alkali feldspar, nepheline, sodalite, alkali pyroxene alkali amphibole	fayalite, apatite, magnetite, eudialyte, aenigmatite, rinkite, fluorite
naujaite	poikilitic, coarse	sodalite, alkali feldspar, alkali pyroxene, alkali amphibole	eudialyte, rinkite, zeolites, aenigmatite, nepheline
kakortokite	laminated, layered, medium	alkali feldspar, nepheline, alkali amphibole, eudialyte	aegirine, aenigmatite, rinkite, zeolites
lujavrite	laminated, fine; and massive, layered, medium to coarse	microcline, albite, nepheline, arfvedsonite, aegirine, eudialyte	sphalerite, steenstrupine, monazite, sodalite, zeolites, Li-mica
alkali acid rocks	hypidiomorphic granular, medium to coarse	alkali feldspar, quartz, alkali amphibole, aegirine	aenigmatite, eucolite, neptunite, ilmenite, pyrochlore

White kakortokite has apparently trapped a significant amount of coexisting magma; it shows adcumulus growth and eventually crystallises accessory rinkite, Li-mica, galena and sphalerite interstitially. Oxygen and sulphur fugacities were still low in the agpaitic magma and accessory troilite, djerfisherite, loellingite, westerveldite and native Pb occur.

At the *lujavrite substage,* the earliest rocks (aegirine lujavrite I) reveal a weak development of cumulus horizons and probably occurred as crystal-liquid mushes prior to the weak density stratification. Cumulus K-feldspar, nepheline, aegirine and eudialyte are poikilitically enclosed by arfvedsonite and zeolites which crystallised from an interstitial, residual magma. The overlying lujavrite varieties probably evolve through partial cumulates to virtually liquid compositions. Contents of cumulus eudialyte (and contents of Zr) show an overall decrease through the kakortokite-lujavrite sequence. The U content in the eudialyte increases. Interstitial steenstrupine comes to hold more and more of the U, Th, REE and P in the later lujavrites. Changes from aegirine (green) to arfvedsonite (black) lujavrites are thought to reflect variability in the activity of oxygen and/or water.

The *final lujavrite substages* are marked by local emplacement of arfvedsonite lujavrite and M-C lujavrite with (?)largely liquid compositions. There are important areas of lujavrite rich in villiaumite and naujakasite. Contents of many rare elements (F, REE, P, Th, U, Sn, Li, Be, Ga) reached their highest values, and the Kvanefjeld uranium deposit was formed. Th and U were partly lost to a fenitic exocontact zone and to hydrothermal veins in the country rocks. Pegmatites and hydrothermal veins, mainly composed of microcline, nepheline, arfvedsonite, aegirine and zeolites, locally contain rare mineral species (Nb, Ta, Be, Sn minerals, sulphides and antimonides of Tl and Cu).

Further work is needed to assess the genetic interrelations of the three main intrusive events observed at Ilímaussaq – augite syenite, acid rocks and agpaitic rocks.

It is worth recalling that the Ilímaussaq intrusion is the home of the term "agpaitic" (from the locality Agpat near the eastern margin of the intrusion). The term was introduced by Ussing (1912) as a common denominator for the peculiar nepheline syenites of the intrusion. The term is now used to describe peralkaline nepheline syenites which contain complex volatile-bearing minerals such as eudialyte and rinkite (Sørensen, 1960, 1974). Agpaitic rocks have also been described from the Kola Peninsula (USSR), South Africa, Brazil, and a few other places, but are rare. A growing body of research indicates that the physical-chemical evolution of the Ilímaussaq agpaitic system was distinctly abnormal; its petrological value arises from the contrasting light it throws on the behaviour and properties of normal terrestrial magmas.

Mineralogy

The mineralogy of the Ilímaussaq intrusion, as discussed in numerous papers and especially by Semenov (1969), reflects its agpaitic nature. The main characteristics are:

(a) silica-undersaturated, peralkaline mineralogy; rock-forming minerals include alkali feldspar (partly as separate microcline and albite), nepheline, sodalite, arfvedsonite, aegirine and eudialyte.

(b) numerous rare minerals of Li, Be, REE, Zr, Nb, Th, U etc. reflecting the high contents of these elements.

(c) minerals rich in volatile components (H_2O, F, Cl, S) are common, e.g. villiaumite, eudialyte, arfvedsonite, sodalite and sphalerite and numerous other sulphides.

(d) abundance of sodic rather than potassic minerals.

(e) presence of minerals reflecting exceptionally low oxygen and sulphur fugacities, e.g. aenigmatite, arfvedsonite, native elements, westerveldite, troilite and djerfisherite.

Of the nearly *190 minerals,* there are about 6 native elements, 26 sulphides, 4 sulphates, 100 silicates, 12 carbonates, 10 arsenides and antimonides, 2 halides, 24 oxides and 6 phosphates.

Various aspects of the mineralogy of Ilímaussaq are still being investigated. The aim is to compile a monographic presentation of the mineralogy of the intrusion.

In the following paper there is a compilation of the almost 190 different minerals which have been identified so far in the Ilímaussaq intrusion and its contact zones. The list is an updated version of earlier lists prepared by Sørensen (1967) and Semenov (1969). The paper also presents a list of the series of papers "Contribution to the Mineralogy of Ilímaussaq" which at the time of completing this manuscript numbered 62 papers.

The discovery of an additional beryllium mineral, helvine $Mn_4Be_3Si_3O_{12}S$, is reported in Johnsen & Bohse. It occurs in pegmatite pockets in the kakortokites of the Kangerdluarssuk region. Chemical and optical data, density and unit cell dimensions agree closely with those of other examples of essentially pure helvine quoted in the literature.

L.M. Larsen presents new microprobe data on the feldspars and mafic minerals of the augite syenite. The feldspar of the chill zone of the augite syenite is strongly zoned from oligoclase relict cores to sodic K-feldspar. In the innermost facies of augite syenite, the feldspar is sodic K-feldspar with a restricted compositional range.

The feldspar crystallization path is discussed; it recalls those observed in other intrusions of larvikite-type syenites.

Microprobe analyses of nepheline, magnetite, amphibole and biotite are also presented. There are distinct differences in chemistry between magmatic and subsolidus formed amphibole and biotite.

General geology

Ussing's interpretation of the geology of the Ilímaussaq intrusion and the sketch map in his 1912 memoir served as the basic reference until a new map was prepared by Ferguson in 1964. Since 1964 smaller regions of combined geological and economic interest have been mapped in considerable detail. This applies to the Kvanefjeld area (Sørensen *et al.,* 1969, 1974), the kakortokites (Bohse *et al.,* 1971) and the Taseq slope (Engell *et al.,* 1971).

A remapping of the part of the intrusion lying to the south of Tunugdliarfik fjord was initiated in 1969 by A. Steenfelt (the foyaite area), A. Demina (the head of Kangerdluarssuk), H. Bohse (the area south of Kangerdluarssuk and Lakseelv) and S. Andersen (the area centered on the Agpat plateau). Results of this mapping are presented in this report in three papers which together constitute the section on General Geology.

The first of these papers presents an outline of the stratigraphy of the southern part of the intrusion which has been established as one of the results of the detailed mapping. The second paper brings together new information about the upper rocks of the intrusion and the third paper gives a more detailed description of the kakortokite-lujavrite sequence.

In the paper by A. Steenfelt strong evidence is presented for the xenolithic nature of the small occurrences of alkali granite and quartz syenite in the pulaskite of the southern part of the intrusion. Thus, bodies of alkali quartz syenite are invariably underlain by inch-scale layered pulaskite and overlain by quartz-contaminated foyaite. Elsewhere, the quartz syenite forms a layer overlying pulaskite and, in the best developed section, is overlain by alkali granite. Both the acid rock types are intrusive into the upper sheet of augite syenite.

The recognition that the alkali acid rocks constitute the second of three main intrusive events at Ilímaussaq greatly clarifies the emplacement history of the intrusion.

The paper by H. Bohse & S. Andersen demonstrates beyond any doubt that the bottom kakortokites grade upwards into a series of lujavrites. The general profiles are shown in figs 1 and 2 in this paper. The kakortokite series is now divided into three parts: 200 m lower layered kakortokite (the 'classical' kakortokites), 35 m slightly layered kakortokite, and 40 m transitional layered kakortokite. This is conformably followed by the lujavrite series: 80 m aegirine lujavrite I, 85 m aegirine lujavrite II, 60 m lujavrite transition zone and about 150 m arfvedsonite lujavrite. This bottom sequence is considered to have been built up on a floor which may have formed as a result of major cauldron subsidence.

Igneous lamination steepens towards the external contact and gives an overall saucer shape to the kakortokite-lujavrite sequence. This sequence is separated from the augite syenite by a shell of 'marginal pegmatite'.

In the Agpat region, the arfvedsonite and aegirine lujavrites are cut by schlieren and veins of medium- to coarse-grained (M-C) lujavrite corresponding to the relations at Kvanefjeld (Sørensen *et al.,* 1969).

The geochemistry of the kakortokite-lujavrite sequence is considered in subsequent papers.

Geochemistry

The presence of exceptionally high contents of incompatible trace elements (Cl, F, Zr, Nb) was established by Ussing (1912) and extended to U and Th (Bondam & Sørensen, 1959), Rb, Li and Be (Hamilton, 1964), S, Cs, Tl, Hf, Ta, REE, Sn, Pb (Gerasimovsky, 1969) and to Br and Sb (Bailey *et al.*, 1978). At the same time, contents of Ca, Mg, Ti, Co and Sc are distinctly low. Most authors considered these features as evidence for a high degree of fractionation of the Ilímaussaq magma.

Sørensen (1958, 1960) recognised that these elements, which frequently escape in pegmatite and hydrothermal bodies, had taken part in the crystallization of the magmas, and their high contents could be used to partly define the agpaitic condition.

Gerasimovsky (1969) drew valuable comparisons with similar agpaitic rocks from Lovozero. Many trace elements show a close association with Na, e.g. Cl and S (sodalite), F (villiaumite), Zr (eudialyte), Nb (epistolite), REE (rinkite, steenstrupine) and Be (chkalovite).

Ferguson (1970b) showed that ratios such as K/Ca and Ti/Zr gave trends in agreement with (a) the sequence of intrusion based on field evidence and (b) the upwards accumulation of the kakortokites.

Special studies were made on Nb-Ta (Hansen, 1968), Be (Engell *et al.*, 1971), Zr-Nb (Bohse *et al.*, 1971), REE (Gerasimovsky & Balashov, 1968) and Th-U (many authors).

Fission-track analyses of U in eudialyte provided evidence which could not be explained by fractional crystallization; instead the role of volatiles and complex ion formation was emphasised (Bohse *et al.*, 1974; Steenfelt & Bohse, 1975; Sørensen & Larsen, 1978).

Engell (1972) argued that the five-fold concentration of the incompatible elements Zr and Be between augite syenite and sodalite foyaite pointed to at least 80 per cent (and probably 90–95 per cent) fractionation before the agpaitic stage was reached. Hence there must be a very large underlying magma chamber.

A Rb-Sr isotopic study revealed mantle-type initial $^{87}Sr/^{86}Sr$ ratios for the augite syenite but more radiogenic ratios (probably reflecting crustal contamination) for the later agpaitic rocks (Blaxland *et al.*, 1976).

In the present report, the establishment of a detailed stratigraphy for the kakortokite-lujavrite sequence has provided the basis for systematic geochemical investigations of these rocks.

In the first paper in the section on Geochemistry it is calculated that the transitional layered kakortokite and the overlying aegirine lujavrite I together contain approximately 25 million metric tons ZrO_2, 9 million tons RE_2O_3 and 2 million tons Nb_2O_5. Combining these tonnages with those in the lower layered kakortokites, the estimated resources at the head of Kangerdluarssuk fjord are thus enlarged to 86 million tons ZrO_2, 23.2 million tons RE_2O_3 and 8.5 million tons Nb_2O_5.

Field and laboratory investigations have been combined in a paper by S. Andersen, J. C. Bailey & H. Bohse which shows that variations in Zr/U and Zr/Y ratios can be used to establish a geochemical stratigraphy for the kakortokite-lujavrite sequence in southern Ilímaussaq and to characterise each rock unit. Both these ratios are constant or slightly decreasing through the kakortokite sequence but rapidly decrease through the lujavrite sequence, i.e. with progressive crystallization. These trends add support to the concept that the transition from kakortokite to lujavrite is related to a major physical event, i.e. roof subsidence and the development of sub-chambers of small vertical extent. In these sub-chambers the crystallization and fractionation processes accelerated and cumulus effects were gradually suppressed. The final lujavrites (which include the naujakasite lujavrites) are considered to be close to liquid compositions.

The analytical coverage of Li and F in the Ilímaussaq lujavrites and their minerals has been extended and the method and the results are discussed in a paper by J. C. Bailey *et al.* Both Li and F show generally increasing concentrations from the older to the younger lujavrite varieties, but the data also show increasing scatter, and this is an innate feature of these residual rocks. Arfvedsonite is the main Li-bearing mineral in the lujavrites. No single mechanism can explain in detail the Li-F variations found.

Gamma-ray spectrometric analyses for Th and U on a large number of all rock types from the Ilímaussaq intrusion are presented in another paper by J. C. Bailey *et al.* The rocks show normal Th/U ratios (about 3.5) in augite syenite and the roof series, but abnormally low ratios, down to 0.5, in kakortokites and lujavrites (although the later lujavrites, which seem to re-approach magma compositions, return to ratios of about 3.5). The low ratios are related to accumulation of eudialyte with a Th/U ratio of about 0.5. The extensive crystallization of eudialyte should drive residual liquids towards high Th/U ratios, but rocks with such high ratios have never been found within the intrusion. This indicates that some material has been lost from the system during crystallization. It is probably some of this lost Th that Nielsen (in Economic Geology section) has found in mineralised veins just outside the intrusion.

Fluid inclusions

One of the most important properties of an agpaitic magma is its great capability of dissolving volatile components, resulting in very low fugacities of volatile species such as oxygen and sulphur (e.g. Kogarko, 1974). Moreover, abnormal volatile species are present including large amounts of hydrocarbons (Petersilie & Sørensen, 1970).

Studies of fluid inclusions have been particularly informative concerning the composition and state of the gaseous phase of the agpaitic magmas. Konnerup-Madsen *et al.* (1979) showed that a hydrocarbon-rich fluid phase existed as immiscible droplets in a highly saline aqueous fluid phase. In their paper here these authors have used their previous analyses of gases in fluid inclusions together with published thermodynamic data to calculate $\log f_{O_2}$ as a function of temperature for the gas phase of the agpaitic rocks of Ilímaussaq. Under the given assumptions, the resulting curve lies well below the synthetic FMQ buffer curve and is yet another expression of the reduced state of the system. The composition of the gas phase of Ilímaussaq is similar to that of the agpaitic Lovozero intrusion: rich in hydrocarbons and H_2 and deficient in H_2O, CO_2 and CO, i.e. opposite to that of most other magma types.

Economic geology

The mineralogical wealth of the Ilímaussaq intrusion is not only expressed in the number and variety of minerals, but also in its potential economic interest. So far, only occurrences of minerals of uranium and to a lesser extent zirconium, beryllium and niobium have been explored (see reviews by Sørensen *et al.*, 1974; Nielsen, 1976). The history of exploration of uranium has been presented as a case study by Nielsen (1980).

The present introduction, and the economic geology papers presented in this report, only consider uranium.

A striking feature of uranium geochemistry at Ilímaussaq is the fact that U increases towards the final rock types more rapidly than all other elements. U appears to be the most incompatible element of the intrusion (see Geochemistry section).

The rocks of the intrusion differ from those of most other intrusions in (a) their high contents of U and Th and (b) the great volume of rocks with Th/U ratios less than one. Th and U show a wide range of contents between and within the different rock types, but overall there is a steady increase of median contents from 7 ppm Th and 2 ppm U in the augite syenite to more than 300 ppm Th and 100 ppm U in the final lujavrites.

In most of the Ilímaussaq rocks, Th and U are concentrated in eudialyte, but in the final lujavrites they are largely held by steenstrupine. The stabilization of steenstrupine instead of eudialyte reflects the changing composition of the magma (decreasing Zr, increasing P, REE, U) and perhaps the increasing partial pressure of water and decreasing temperature of consolidation.

During crystallization of the roof series there was a decrease in the U content of the eudialyte from the earlier pulaskite to the later naujaite. This is interpreted by Bohse *et al.* (1974) and Steenfelt & Bohse (1975) as a result of diffusion of uranium out of the top cumulates and into the adjacent magma, possibly because of the formation of stable complex ions in the magma. Uranium, together with other trace elements and volatile components, was then squeezed out of the intercumulus melt into the residual magma and this may explain the strong build-up of U and a number of other elements in the magmas forming the latest lujavrites.

Gaseous transfer of elements may have assisted in the formation of the U-rich lujavrites and the contact mineralization in the gabbros and lavas roofing the intrusion as observed at Kvanefjeld. The escaping fluids may have had high Th/U ratios as the contact-mineralised roof rocks may have Th/U higher than 5 (Sørensen *et al.*, 1969, 1974) and there are Th-rich hydrothermal mineralization occurrences in the country rocks (Hansen 1968; Nielsen, this report).

M. Makovicky reports preliminary results on the distribution of uranium in cores from 70 drill holes in the Kvanefjeld area. The samples represent arfvedsonite lujavrite, naujakasite lujavrite, M-C lujavrite, aegirine lujavrite and contact mineralised lavas.

The role of steenstrupine as a carrier of uranium was especially studied. The steenstrupine crystals are found in all stages of alteration. The host rocks may be strongly hydrated with analcime and natrolite replacing the primary felsic minerals, but no correlation could be observed between the rock hydration and the alteration of the steenstrupine.

Steenstrupine and its alteration products are the only important uranium-bearing phases. The altered varieties of steenstrupine are the most strongly radioactive, and this confirms earlier studies of the mineralization using autoradiography (Buchwald & Sørensen, 1961).

J. Konnerup-Madsen *et al.* present preliminary results of a laboratory investigation of the decomposition of steenstrupine. The aim of the work was to delineate the physical-chemical conditions during the later stages of consolidation of the radioactive rocks. Decomposition of steenstrupine was studied in Na_2CO_3 solutions at 200–600°C and water vapour pressures up to 1000 bars.

Steenstrupine remains after completion of all runs and only a thin outer zone is decomposed. At temperatures above 300°C monazite is formed as a decomposition product. An unidentified phase is formed in all runs with Na_2CO_3 at about 300°C (see Table 2 of Konnerup-Madsen *et al.*, this report.

The experiments reveal decreasing concentrations of uranium in the solutions after each run with increasing temperature. This is due to the formation of the refractory phases mentioned above.

The steenstrupine becomes richer in Na and poorer in Si with increasing temperature of the runs.

In the paper by B. L. Nielsen radioactive albitites from the contact zone of the intrusion are described at two localities in southern Ilímaussaq. Thorium is strongly predominant in these localities, in contrast to a similar occurrence at the northern contact where uranium predominates (Rose-Hansen *et al.*, 1977).

The albitites occur in strongly faulted, brecciated and altered blocks of country rocks in the exocontact zone. Fluorite is of widespread occurrence. The albitites show vein-like features. The radioactivity is due to thorite, uranothorite and a thucolite-like mineral.

The albitites of the southern localities may result from "powder emplacement" during explosive eruptive events. The tuffaceous breccias recrystallised to form the albitites. This type of mineralization is an important exploration target in future work in the region.

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