A notable contrast between the western and eastern parts of the lower Eriksfjord Formation is seen in the relative amounts of basic and evolved lavas. In the west, the volcanics in the lower part of the Eriksfjord Formation are almost exclusively basaltic (Stewart, 1964), whereas the eastern remnants around, and within, the Motzfeldt Centre have an overwhelming preponderance of differentiated lavas, mostly trachytes, while basalts apparently constitute less than 10 per cent of the volcanics. The only other sequence with differentiated lavas is the Ilímaussaq Volcanic Member from the upper westernmost part of the Eriksfjord Formation around the Ilímaussaq intrusion. The trachytic and trachyandesitic lavas make up about one third of the volcanics in this member (Larsen, 1977). There is an apparent correlation between the occurrence of differentiated lavas and later syenitic intrusive centres. Even though the lavas and syenites in one place are not directly related petrogenetically they may owe their origin to the same structures in the deep crust or at the crust-mantle boundary, which facilitated the development of differentiated magmas. Such structures could be cupolas on larger magma pools.

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Ketilidian uranium mineral occurrences in South Greenland

Ashlyn Armour-Brown and Bjarne Wallin

The Sydex project is financed by the Ministry of Energy's Research Programme 1984 in order to evaluate the uranium mineral occurrences found during the earlier reconnaissance project, Syduran.

The main objectives of the field season were:

(1) to map and sample in detail the uranium occurrence at Igdlorssuit (fig. 20) in the Migmatite Complex which was found in 1982 (Armour-Brown *et al.*, 1984), so as to evaluate its economic potential and place it in its geological setting,

(2) to locate the source of a high gamma-spectrometer anomaly on the nunatak north of Nordre Sermilik in the Granite Zone, and to map the surrounding geology.

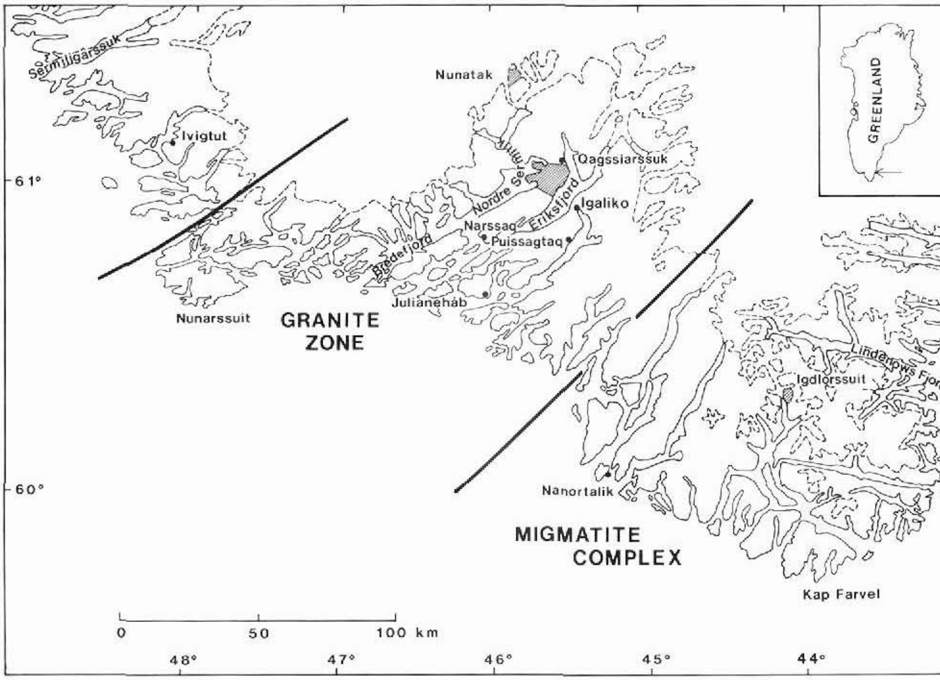

Fig. 20. Map of South Greenland showing described locations (hatched areas).

Igdlorssuit

Igdlorssuit is located at the northerly limit of the fjord system about 60 km north of Kap Farvel (60°23'N; 46°06'W). The uranium mineral showing is on a small alp on the eastern side, 500 m vertically above the fjord. Detailed plane table mapping (1: 1000), and detailed radiometric measurements with a lead collimated scintillometer calibrated for uranium delineated this occurrence. Regional mapping (1: 10 000), however, showed that it was only one of many similar uranium occurrences in the area albeit the largest and richest.

The area contains a series of rafts or pendants of metasedimentary and metavolcanic supracrustal rocks dipping gently to the north-east in rapakivi granite. The uranium minerals are either disseminated along the layering in the supracrustal rafts, or more usually concentrated in small fractures which are themselves stratabound.

Isoclinal folds and sedimentary features indicating overturned beds have been observed so it can be safely assumed that the present layering does not represent the original bedding sequence, and that repetition of the beds, due to structural disturbances and the intrusion of the rapakivi granite, can be expected.

The supracrustal units have been divided on the basis of their texture and mineralogical composition into five units. Their distribution is best illustrated on an uncontrolled section taken from an oblique photo because of the steepness of the area which averages 50° below the alp, and 30° above it (fig. 21).

The most easily mappable unit is the metaconglomerate. It is composed of pebbles and

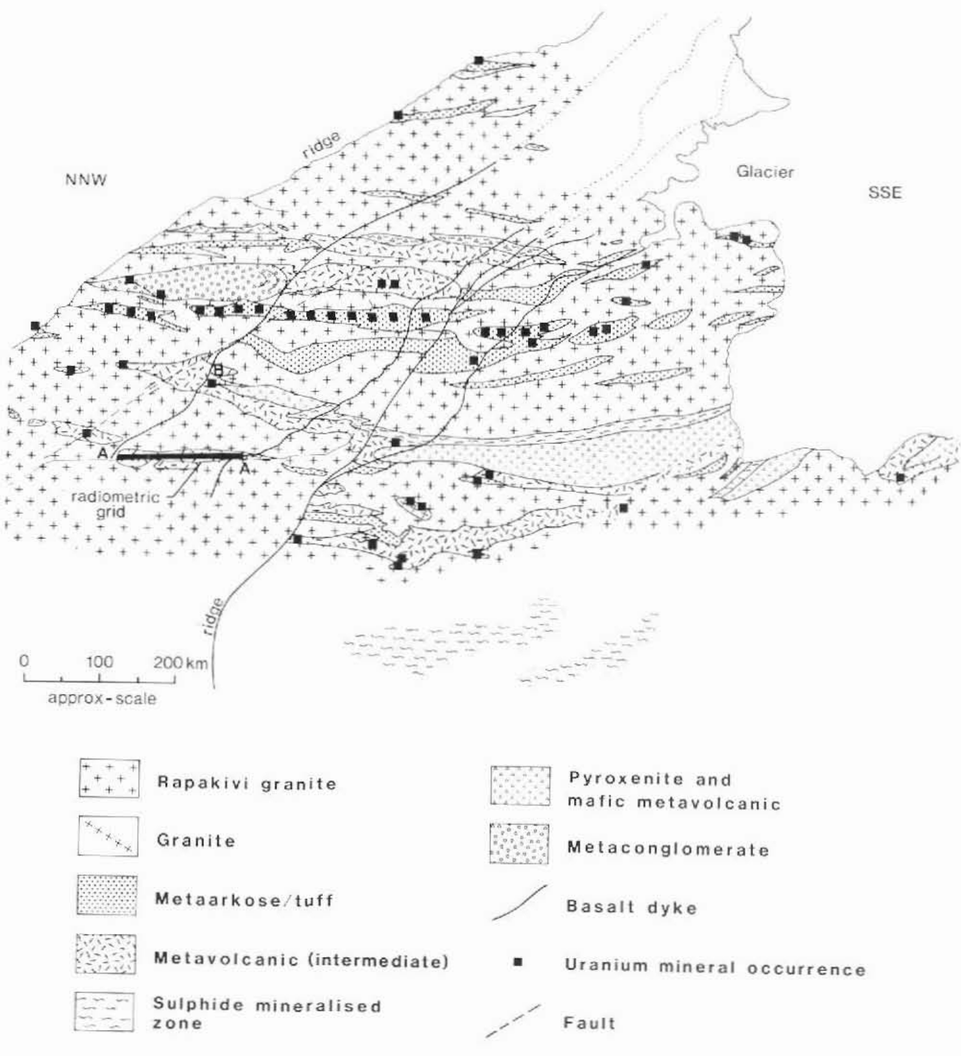

Fig. 21. Distribution of geological units at Igdlorssuit, mapped on an uncontrolled oblique photograph looking east-north-east.

cobbles of felsic composition in a calc-silicate matrix. The cobbles have been slightly deformed by tectonism. The unit outcrops over a horizontal distance of 250 m and has a maximum width of 50 m with its southern limit formed by the crest of a reclining antiform with a horizontal NNW–SSE axis. It is pinched out by the rapakivi granite to the north. It contains only one very rich (1.0–15% U) uraniferous fracture which strikes approximately NNE–SSW and can be traced over some 50 m (fig. 21). The fracture and the mineral rich zone is narrow (5–20 cm), and the uranium minerals can only be found at either end of the fracture and not continuously along it.

The conglomerate is apparently overlain by a metavolcanic tuff of intermediate composition. This is a medium-grained, massive brittle rock which is green when fresh and weathers white, and in some places the weathered surfaces have a lithic or crystal tuff texture. It is the most common supracrustal rock type in the area and a common host rock for the uranium minerals. It is often broken up into large angular blocks within the rapakivi granite, which suggests that it was a relatively brittle rock type at the time of the intrusion of the granite.

The metavolcanic unit is interlayered with a mafic rich volcanic unit and a meta-arkose. The meta-arkose is a fine-grained, grey granular rock with sedimentary layering. It has been differentiated from the metavolcanic unit purely on the basis that it contains sedimentary structures, and it may well contain waterlain tuffs as well as purely sedimentary material. It varies from 5–20 m in thickness and can be traced along strike for considerable distances. One horizon, just below the conglomerate is particularly uraniferous, hosting numerous uranium occurrences, ranging between 0.01 and 0.3% U over a horizontal distance of some 500 m. These are mostly in minor cross-fractures but also occur along the layering which may possibly correspond to the bedding.

The pyroxenite is composed mostly of medium to fine-grained dark green pyroxene, which in places forms up to 90 per cent of the rock, with coarse biotite and other mafic minerals in a grey plagioclase matrix. A lithic tuff texture can occasionally be seen on weathered surfaces in less structurally disturbed areas. As the lensed outcrop pattern forms boudins up to 50 m wide and 200 m long it is suggested that this rock unit was less competent than the other units during metamorphism and folding, and the pyroxenite was formed by metamorphic recrystallisation of either basic volcanic units or basic intrusive sills.

The sulphide-rich metasedimentary unit is, however, intimately associated with the mafic rich volcanic unit and usually outcrops immediately above or below it. It is not usually more than 3 m thick and rarely outcrops along strike for more than 200 m. It is a grey rock, when fresh, of medium to fine grain size with a granular texture and disseminated sulphide minerals in a quartz-feldspar matrix, but it is usually friable, rusty and deeply weathered. The sulphides often include appreciable amounts of molybdenite. Uranium minerals are not usually present.

The supracrustal rocks are intruded by two granite units. The older of the two outcrops only in a relatively small raft in the younger rapakivi granite in the mapped area. It is medium-grained biotite granite with a rather high radioactivity of up to 280 ur*. This is interpreted as being a remnant of an earlier migmatitic granite (Bridgwater *et al.*, 1966), and its high radioactive background reflects the uraniferous nature of the parent supracrustal rock.

Rapakivi granite is the major rock unit in the area and is uniform in both composition and texture. It is very coarse grained with large ovoids of orthoclase feldspar, blue quartz and accessory biotite, and occasionally hornblende. It is a 'biotite pyterlite' in the Finnish classification system for rapakivi granite (Vorma, 1976) because the feldspar ovoids do not have any well developed plagioclase rims. In contrast to the older granite it has a remarkably constant and relatively low radioactivity (25–28 ur) even when adjacent to uraniferous radioactive supracrustal units. This is interpreted as reflecting its largely intrusive allochthonous nature. On a broad scale it appears to have intruded preferentially along the planar struc-

*1 ur is a unit of gamma-radiation which is proportional to the radiation from 1 part per million uranium by weight.

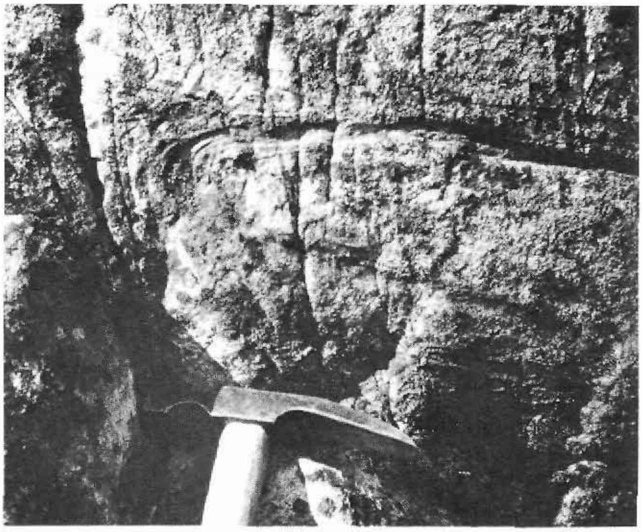

Fig. 22. An example of the isoclinal folding in the meta-arkose, Igdlorssuit. Axis 340°/horizantal, axial plane dips 070°/35°.

tures in the supracrustal units such as the compositional layering and axial planes of the folding, but on a smaller scale it is often seen to cut across these features, particularly the more brittle and competent, intermediate metavolcanic unit.

The basalt (dolerite) dykes cut all the above units. They are mostly rather narrow (0.5–2.0 m) but they are consistent along strike for many kilometres. Within the oblique section shown in fig. 21 they only strike in an E–W direction along one of the dominant fracture directions, but they can also be observed along the sides of the main glacier-fjord valley trending in a NNW–SSE direction, which is also an important fracture direction. They are composed of fine-grained to aphanitic, dark green to black rock which is occasionally vesicular. They have been classified as Gardar dykes by previous workers (Sutton & Watterson, 1968) but this has never been established with certainty.

Structure. Prior to the intrusion of the rapakivi granite, the supracrustal units have been isoclinally folded and fractured. The isoclinal folding was presumably a synmetamorphic feature when the rocks were relatively hot and plastic. In contrast to other areas of the Migmatite Complex (Dawes, 1970; Escher, 1966), only one period of isoclinal folding has been recognised so far. This could well prove to be an oversimplification if the mapping is extended to areas less disrupted by the rapakivi granite. The axis of the folding trends more or less NNW–SSE with a horizontal plunge, and the axial plane dips gently (10–30°) to the WNW. Fig. 22 illustrates something of the sharpness of this folding. At locality B (fig. 21) the mafic volcanic unit is terminated in a sharp antiform which is overlain by intermediate metavolcanic rocks which at this point are highly uraniferous (2.5% U). This suggests that the folding was one of the episodes that helped to mobilise and concentrate the uranium minerals.

The pre-rapakivi fracturing is characterised by narrow (0.5–1.0 cm), irregular fractures without a preferred orientation, which are often curved in ptygmatic-like folds, but also tend to be en échelon and/or to horsetail into small breccia zones (fig. 23). Their form suggests

Fig. 23. Minor fracturing in meta-arkose (light areas) with associated breccia zone filled with mafic minerals and uraninite (dark areas).

relatively brittle deformation compared to the isoclinal folding. They are usually filled with mafic minerals, magnetite, and commonly but not always, host uranium minerals. They have not been observed cutting the older granite and are always terminated by the rapakivi granite. They are, therefore, older than the rapakivi granite and possibly older than the older granite. Their mode of formation is uncertain although they could be related to either late stage tectonic events connected with the regional metamorphism or to tectonic adjustments prior to the intrusion of the rapakivi granite.

Fig. 24. Uraninite (opaque minerals) associated with mafic minerals (grey minerals) in a small veinlet in metavolcanic rock composed mostly of feldspar (light minerals). Photomicrograph × 100, GGU sample no. 304339.

Post-magmatic faulting is only of minor significance within the field area where E–W faults have a minor dextral sense of movement of a few metres, and two inclined faults dipping moderately (40–50) to the NE have a small (2–3 m) reverse sense of movement.

Uranium mineral occurrences. Over 35 uranium mineral occurrences have been found scattered over the hillside (fig. 21). They tend to be restricted to certain members of the meta-arkose and intermediate metavolcanic units. The uranium bearing mineral is uraninite which is disseminated as fine grains through the strata or concentrated as medium sized grains along the pre-rapakivi fractures and associated breccias. This mineralisation, therefore, can be classified as stratabound but locally controlled by folds and veins where it has been concentrated by structural and metamorphic events (fig. 24). Both the lithological setting and structural control of this mineralisation are similar to that found at the Kitts and Michelin deposits in Labrador (Gower *et al.*, 1982).

The largest, highest grade uranium-mineral zone remains the area that was found by B. Wallin in 1982 (Armour-Brown *et al.*, 1984) and mapped with plane table this season (fig. 21, A–A). Radiometric readings with the calibrated scintillometer were taken over a grid (115 ± 10 m) at 1 m intervals every 5 m in order to measure the extent and value of the surface grades. The results outlined a main zone 50 m long by 1–3 m wide with over 0.1% U, and a central zone about 15 m by 2–3 m with grades of over 1.2% U and a maximum point source of over 2.5% U. To the north this unit is broken up into a series of rafts in the rapakivi granite with some radioactive anomalies. To the south the same unit is similarly broken up and dips below the accessible outcrop level. Because of the massive, structureless nature of the host rock it has not been possible to relate the uranium minerals in this showing to any particular feature within the rock, but it seems likely that its brittle nature contributed to its fracturing, which would give more ready access to the uranium-rich fluids and form traps for the uranium minerals.

Conclusions on Igdlorssuit uranium showing. The results of the mapping and sampling have established that this type of mineral occurrence can reach economic grades, and its surface expression suggests a size which could approach economic proportions. The wide distribution of occurrences suggests that uranium was present over larger area than just Igdlorssuit. The stratabound nature of the mineralisation suggests that the uranium was already present in the supracrustal units but was mobilised by the regional metamorphism and concentrated in zones of lower pressure such as on the crests of folds, as at locality B, or in the fractures.

This type of mineral occurrence probably accounts for the many uranium anomalies identified in the Migmatite Complex, both by the airborne gamma-spectrometer and geochemical sampling, and should constitute the type of target to be sought in future exploration in the area.

Uranium mineral occurrences on the nunatak north of Nordre Sermilik

In 1982 B. Wallin found uranium-rich boulders (Armour-Brown *et al.*, 1984) and defined a gamma-spectrometer anomaly, following a detailed helicopter gamma-spectrometer survey (Armour-Brown *et al.*, 1984) on the nunatak which lies to the north of Nordre Sermilik (fig. 20). The disseminated character of the uranite in biotite gneiss suggested that it was formed earlier than the pitchblende associated with the Gardar veins which have been found previously in the Granite Zone and could, therefore, constitute both another type of mineral occurrence in the area, and be a source of the uranium in the veins.

Mapping at 1: 10 000 scale showed that the geology of the nunatak is dominated by weakly foliated and massive members of the Julianehåb Granite which contains sub-horizontal rafts of mostly feldspathic gneiss with some biotite and magnetite-rich gneiss. In general, these rafts are distributed as sub-horizontal sheets and are similar to the supracrustal rafts in the rapakivi granite at Igdlorssuit. They also have a considerably higher radioactive background than the surrounding granite (70–700 ur as compared to 10–20 ur). The gamma-spectrometer anomaly occurs where these uraniferous gneissic units are thickest and are exposed on a cliff on the south-east facing slopes of the highest summit which coincides with the flat-lying crest of a broad antiform of the rafts. This would be enough to account for the 25 ppm eU anomaly measured from the helicopter.

Many other uranium-enriched gneissic rafts were found on the nunatak, particularly in the northern part. The richest of these proved to have concentrations of uranium up to 1.3% and thorium values of 1131 ppm. These values occur disseminated in a raft of feldspathic gneiss surrrounded by weakly foliated, coarse biotite granite. The raft measures 30 × 7 m and varies from 1.5–2.0 m in thickness and has a very irregular outcrop pattern as it lay on a dip slope. Any important down-dip extension of this raft can be precluded because of its thinness and general disposition. The whole raft is uraniferous but the richer part, which contains over 1% U, measures 5 × 2 × 1 m. It is not possible, on the basis of field evidence, to deduce the parent material of the feldspathic gneiss. Its feldspathic composition suggests that it is a member of the acid volcanic rocks which have been mapped in the area (Allaart, 1983). The very high U/Th ratio also suggests that the uranium was present in the parent material of the gneiss, since partitioning of these two elements normally takes place at temperatures well below those indicated by the prevailing gneissic condition of the bedrock (Langmuir, 1978) and thorium usually dominates over uranium under such conditions.

Conclusions on the uranium occurrences on the nunatak. The most important conclusions that can be drawn from the field results described above are that uranium minerals were present in the pre-Gardar Ketilidian gneisses, and that it occurs as uraninite. This type of occurrence is, therefore, a possible source for the uranium in the Gardar veins. This could have been dissolved, transported and redeposited either by meteoric water during the subaerial Gardar erosion or by the hydrothermal activity related to the Gardar igneous events or a combination of the two. They constitute another type of uranium mineral occurrence which can be expected and sought after in any future mineral exploration in the Granite Zone.

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Uranium exploration in the Qagssiarssuk area, South Greenland

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Following the promising results of the Syduran project (Armour-Brown *et al.*, 1984) a spin-off project Sydex was initiated in April 1984. The project is financed under the Ministry of Energy's Research Programmes 1984 and field work was carried out in several areas in South Greenland this summer (Armour-Brown & Wallin, this report). This contribution describes the work in the Qagssiarssuk area (fig. 20). In connection with the prospecting a geophysical survey was also carried out (Thorning & Boserup, this report).

The main objects of the field work were to prospect the granite and sandstone area west of Qagssiarssuk between Tunugdliarfik and Nordre Sermilik (fig. 25) by ground scintillometry and water sampling. The major fault zones and adjacent areas together with the sandstone/granite unconformity were investigated especially. Water samples from both lakes and streams were collected to test the usefulness of the method in this very poorly exposed area.

Pitchblende and other uranium mineral occurrences have previously been found in major fault zones in the western part of the area (fig. 25) (Armour-Brown *et al.*, 1983). Radioactive thorium-dominated dykes have also been found (Hansen, 1968; Armour-Brown *et al.*, 1982). Stream-water and sediment samples with anomalously high uranium are located within the prospected area (Armour-Brown *et al.*, 1982).