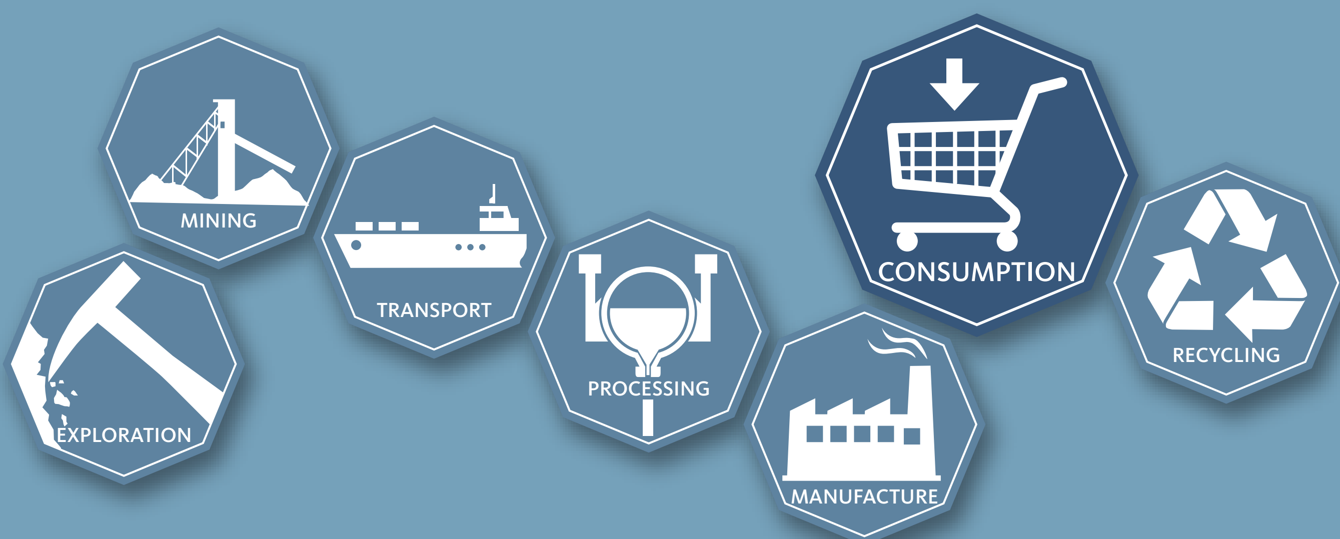
An evaluation of the potential for uranium deposits in Greenland

Nynke Keulen, Kristine Thrane, Bo Møller Stensgaard and Per Kalvig

MiMa report 2014/1



Mi
Ma
CENTER FOR
MINERALS
& MATERIALS

CENTER FOR MINERALS AND MATERIALS
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND

G E U S

An evaluation of the potential for uranium deposits in Greenland

Nynke Keulen, Kristine Thrane, Bo Møller Stensgaard and Per Kalvig

MiMa report 2014/1

CENTER FOR MINERALS AND MATERIALS
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND

Contents

Executive Summary

This report outlines the potential for uranium deposits in Greenland. As a result of this assessment, it is shown that the most prospective types of uranium mineralisations in Greenland are the sandstone type, unconformity-related type, quartz pebble conglomerate type, vein type, intrusive type, volcanic type, and metasomatite type occurences. The areas with a high potential are displayed in Figure 1. In addition to the well-known uranium province in South-Greenland, several areas along the western coast, the Thule Basin in North-West Greenland and central East Greenland are considered to have a high uranium potential.

South Greenland is the area that has been investigated in most detail previously, and it is probably also the area with the highest potential to find uranium deposits. In particular the uranium occurrences and showings that are hosted by intrusive rocks and veins related to the Gardar intrusive complex and by the sandstones of the psammite zone have a very high potential. In addition, the basal unconformity of the Eriksfjord Formation in the Gardar province has a high potential to host a uranium deposit. In the psammite zone, the positive indications to host a typical sandstone deposit in combination with a strong metamorphic overprint, which led to partial melting associated with veining and formation of leucogranitic bodies, leave the whole area as a high potential target. The conglomerates of Midterrnæs and Grænseland have not been extensively investigated, but are considered good target areas too.

Southern West Greenland has been relatively well studied previously. In this region the uranium potential is mainly represented by carbonatite intrusions. Especially Sarfartoq and Qaqarssuk carbonatites have a high potential.

Further to the north on the western coast three potential areas have been indicated where chances to find a uranium deposit are good. These include (1) the Archaean and Palaeoproterozoic sediments with quartz pebble conglomerates on southern Nuussuaq and in the Ataa domain; (2) the conglomerates of the Karrat Group; and (3) the sandstones and the basal contact of the Cretaceous and Paleogene sediments of the Nuussuaq Group that are partially derived from these Precambrian metasediments and were deposited intercalated with coal deposits on western Nuussuaq and on Disko Island.

The Thule Supergroup in North-West Greenland has a very high potential as a sandstone deposit and as an unconformity-related deposit. Furthermore quartz-pebble conglomerates occur in the same area; these might also have some potential to host a uranium deposit. The area has not been investigated very intensively for uranium in previous studies, and might form an interesting target.

Central East Greenland hosts a range of felsic to alkaline intrusive complexes that range from Proterozoic to Palaeogene in age. These outcrops make good targets for uranium deposits, especially the Caledonian and 950-900 Ma intrusive rocks, together with the volcanic rocks and veins in the area. The best known example from this area is Randbøldal. Central East Greenland also hosts a thick series of Mesozoic sandstones, which make another good target for exploration.

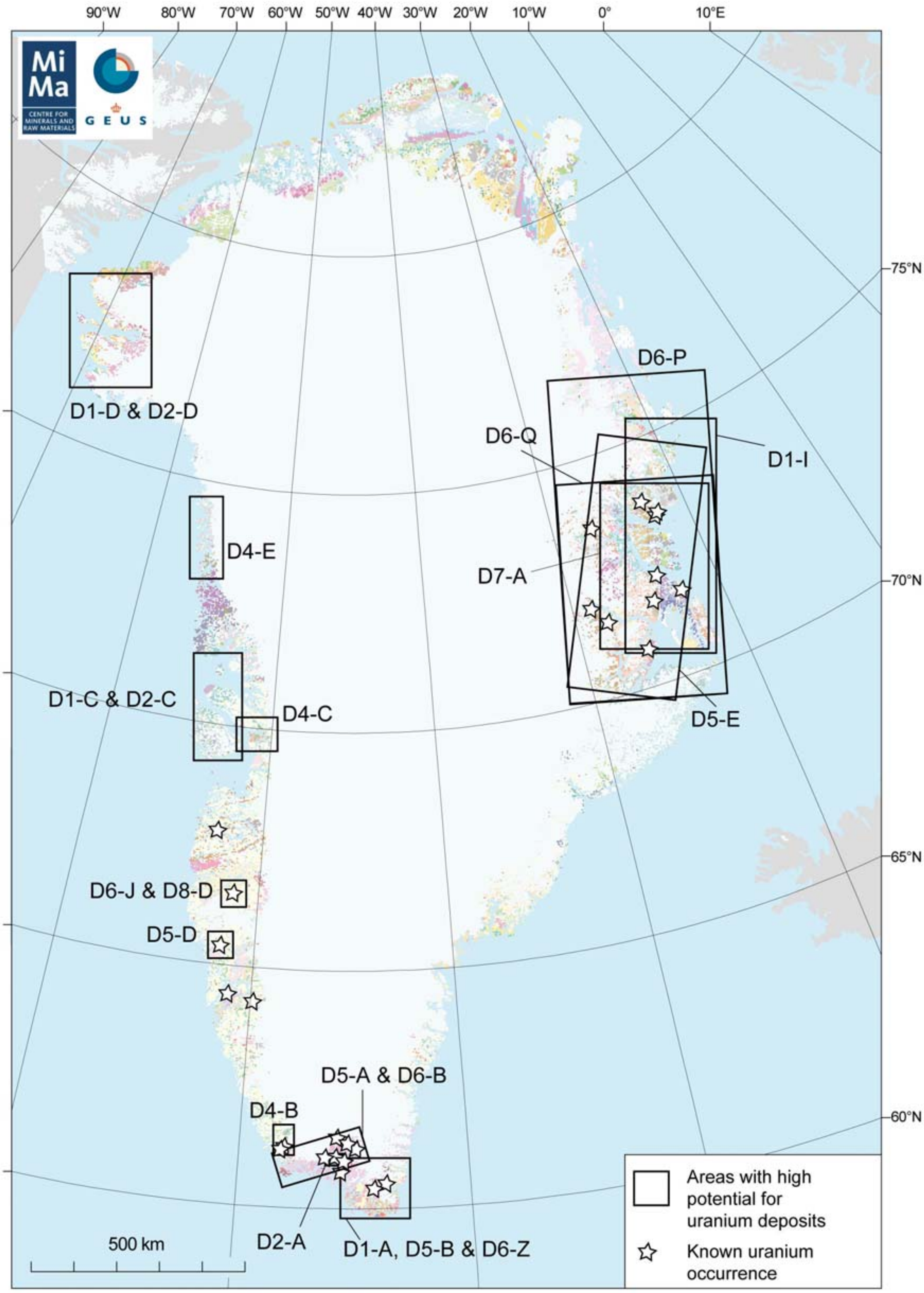


Figure 1: Areas with a high potential to host a uranium deposit in Greenland. Labels refer to the chapters in this report, where the areas are discussed. Already known occurrences are also shown.

1. Introduction

1.1 Background

Uranium exploration in Greenland was initiated by the Greenland Geological Survey (GGU) in 1953, when Geiger counter instruments were applied by the GGU geological mapping teams as part of their duty, and after two years a number of radioactive dykes were identified.

In 1955 more systematic uranium exploration was initiated in South Greenland by a consortium consisting of the Geological Survey of Greenland (GGU), the Atomic Energy Commission, and Kryolitselskabet Øresund A/S. These investigations focused particularly on the vicinity of Narsaq, an area which had been known to host a wide range of rare minerals for more than one-hundred-fifty years. One of these minerals is the uranium-bearing steenstrupine, which was discovered by K.J.V. Steenstrup in the Ilímaussaq igneous complex, South Greenland in 1876 and described by J. Lorenzen in the 1881. The area was later described and mapped by Ussing (1912).

The early exploration included detailed ground and airborne Geiger counter regional reconnaissance surveys using a fixed-wing aircraft. Most of the ground surveys were concentrated in South Greenland in and around the Ilímaussaq complex, where a highly radioactive zone was defined at Kvanefjeld and subsequently drilled in several campaigns by the Danish Atomic Energy Commission‘s research establishment and later on by Risø National Laboratory (Risø; see Kalvig 1983). Furthermore, beneficiation studies were undertaken by Risø in the early 1980’s.

Exploration for uranium was undertaken by GGU and Risø in the period from 1970-82, on behalf of the government, and included radiometric surveys, geochemical prospecting, and geological mapping (Steenfelt et al. 1977; Nielsen 1980). Airborne surveys were undertaken in central East Greenland (1971-74; Nielsen & Løvborg 1976), West Greenland (1975-76; Secher 1976), and South Greenland (1979-82; Armour-Brown et al 1982a, 1983), and a number of uranium anomalies were identified.

Nordisk Mineselskab A/S undertook uranium exploration in central East Greenland working on the basis of an exploration licence granted for the work around the Mestersvig Lead Mine 1952-1985. The licence was later replaced by six small exclusive mineral exploration licences and one oil exploration licence on Jameson Land lasting until the liquidation of the company in 1991.

In the period 1978-1982, the South Greenland Regional Uranium Exploration Project (Syduran), a reconnaissance exploration programme to outline the uranium potential in South Greenland, was executed under the auspices of GGU (Armour-Brown et al. 1982a). Syduran defined a number of mineralisations within the region. For further details on the exploration history, see Sørensen (2001). Afterwards, the South Greenland Exploration Programme (Sydex) aimed at a more detailed evaluation of the uranium showing in Illorsuit (1984-1986). Sydex was carried out by GGU and Risø financed by the Danish Ministry of Energy (Armour-Brown 1986).

In 1985 the Danish Parliament decided to shift the energy policy strategy from nuclear power based to conventional fossil fuel based energy, and consequently it was decided not to continue the investigations of the uranium potential at Kvanefjeld and not to undertake any uranium exploration. The legal framework at this point in time allowed only governmental organisations to undertake investigations on the uranium potential, but was in 1998 replaced with a new mining act (Lovbekendtgørelse nr. 368 af 18. Juni 1998 om mineralske råstoffer i Grønland) in which this clause was no longer included. However, the policy remained, and an administrative practice was introduced to sustain the moratorium on uranium exploration excluding any exploration and exploitation on uranium-bearing rock. Over time, this administrative practice was named the “zero-tolerance” policy. The Greenlandic Government (Naalakkersuisut) has, as per October 24, 2013, lifted the administrative moratorium on uranium. As a result research on the uranium potential in Greenland has been dormant for almost thirty years.

The aim of this report is to present a brief up-to-date assessment of the Greenlandic uranium potential in order to identify prospective areas and to facilitate upcoming uranium exploration campaigns, rather than providing detailed descriptions on known deposits. The uranium assessment methodology is a systematic identification of uranium tracts combining the available geological data and models with the widely accepted uranium type classifications (IAEA 2009). Known uranium occurrences and deposits representing each type are described, to support the assessments only, despite the rather inhomogeneous level of knowledge/data. The reader is referred to the references cited in the text for the exact location of geological and topographical features.

1.2 Available uranium data for Greenland

Data used in this report are taken from published scientific literature and from three GEUS databases. Documentation, reports and information on mineral occurrences are available in the online databases DODEX (Documents and Data for Exploration) and GMOM (Greenland Mineral Occurrence Map).

The GEUS sample and geochemical analysis database called Lapidotek is the GEUS’ registry of collected samples, specifying sample type, coordinates, collector, geochemistry, and other analyses. Rock and stream sediment samples relevant for this report were collected between 1958 and 2012. Many samples were analysed several times for their geochemical signature. Uranium has been determined in the Instrumental Neutron Activation analysis package in geochemical investigatons for many rock samples, irrespective of purpose of the project. Uranium can for example be used as a pathfinder element in gold exploration. Steenfelt (2014) gives an overview.

1.2.1 Company reports and Survey literature (DODEX)

Scanned or digital copies of released, non-confidential company reports as well as published Survey literature (from both GGU and GEUS) is available in the DODEX database (Riisager et al. 2011). The database is also avaible online at http://geusweb01.geus.dk/Dodex/pages/search.jsf. New reports and literature are continually added to the database.

1.2.2 Greenland Mineral Occurrence Map (GMOM)

GMOM is an online dynamic Greenland Mineral Occurrence Map (http://www.geus.dk/gmom/gmom-uk.htm). The facility runs in ArcIMS GIS and gives access to maps of Greenland that show the locations of mineral occurrences plotted on different background maps such as topography, geology, geochemistry and geophysics. The GMOM database behind the various map presentations contains information on more than 700 mineralised sites. Each of the sites represents a mineral occurrence (deposit, mine, prospect, showing or indication), which is described by a number of attributes with details about the occurrence. Each site is also accompanied by a mineral occurrence data sheet which provides longer descriptions of e.g. the geological settings, exploration history etc. To date, only South, southern West and cental West Greenland are covered at a regional scale by the GMOM database. In addition, selected mineral occurrences are present in the database to illustrate the diversities in geological environments and mineralisation styles in entire Greenland.

1.2.3 Rock samples

The methods utilised for uranium analysis are: Instrumental neutron activation analysis (INA), Gamma spectrometry (GAM), X-ray fluorescence spectrometry (XRF), delayed neutron counting (DNC) and inductive coupled plasma emission spectrometry (ICP). There are 4,515 rock samples with coordinates and uranium readings above detection limit (Figure 2, 3).

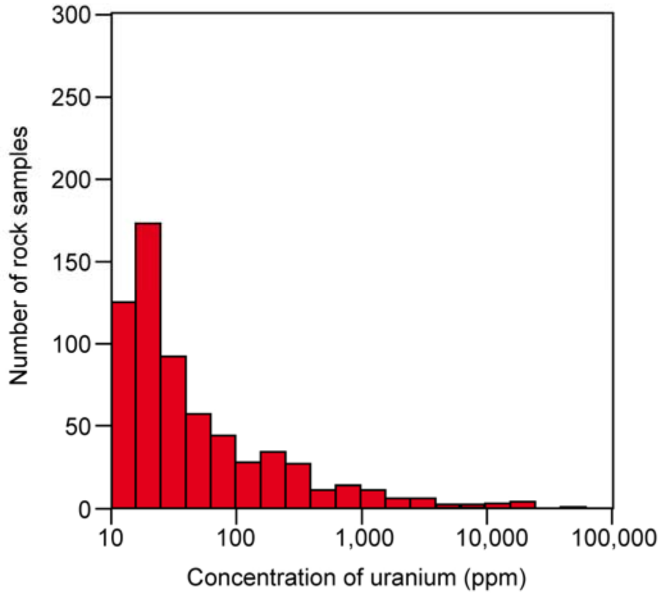


Figure 2: Rock samples with uranium concentrations above 10 ppm in the GEUS sample database.

The samples were collected during field campaigns. One particular noteable campaign aimed at uranium prospection was the Syduran project running from 1979 to 1982, where extensive sampling occurred in South Greenland. In this period *c.* 800 samples were collected, many of those enriched in uranium. Another important campaign was the GGU-Uranium exploration programme in the period from 1972 to 1977 where 1,011 samples were collected, mainly in East Greenland, east of the 42° median.

Figure 3: Geological map of Greenland indicating the localities of rock samples with a uranium concentration above 100 ppm in the GEUS database.

1.2.4 Stream sediment samples

There are 12,691 uranium analyses on stream sediments in the Lapidotek database (Figure 4, 5). The analytical methods applied on these samples are: INA, DNC, GAM, XRF, ICP, X-ray fluorescence spectroscopy with plutonium as source (XPU), X-ray fluorescence spectrometry with cadmium as source (XCD), and Atomic absorption spectrometry (AAS).

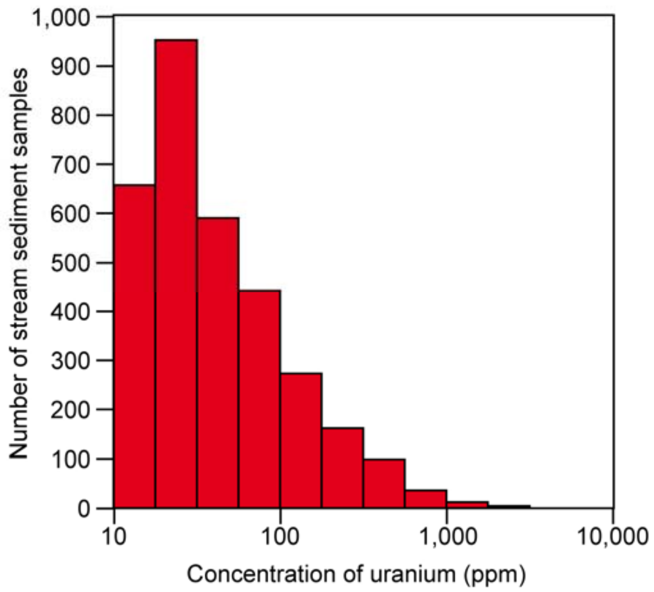


Figure 4: Stream sediment samples with uranium concentrations above 10 ppm in the GEUS sample database.

The stream sediment sampling campaigns were conducted in the period from 1971 to 2013 by GGU and GEUS covering large parts of Greenland. The major stream sediment sampling programmes and compilations are: (1) Between 1977 and 1998 stream sediment samples were collected and analysed from South, southern West and central West Greenland. These were calibrated in the late 1990's into a geochemical atlas (Steenfelt 2001). (2) The Qaanaaq region (Thule), northern West Greenland, was sampled during the early 2000's (Steenfelt et al. 2002). (3) Inglefield Land, North-West Greenland, was sampled in the mid-1990's (Steenfelt & Dam 1996). (4) In North and North-East Greenland sampling was carried out over a time period from 1978 to 1999 (Steenfelt 1980, 1985, 1987, 1991; Ghisler et al. 1979; Ghisler & Stendal 1980; Henriksen 1980) and again in 2012-2013 (Rosa et al. 2014). (5) Central East Greenland was sampled by Nordisk Mineselskab A/S during the time period 1968–83, and the former digital database was restored to a contemporary database system by GEUS in 2009 (Thomassen 2009; Thomassen & Tukiainen 2009). Also during GGU's uranium exploration campaign in East Greenland (east of the 42° median) a large amount of stream sediment samples were collected from 1972 to 1977 in this region (Nielsen & Løvborg 1976). See Steenfelt (2014) for further details.

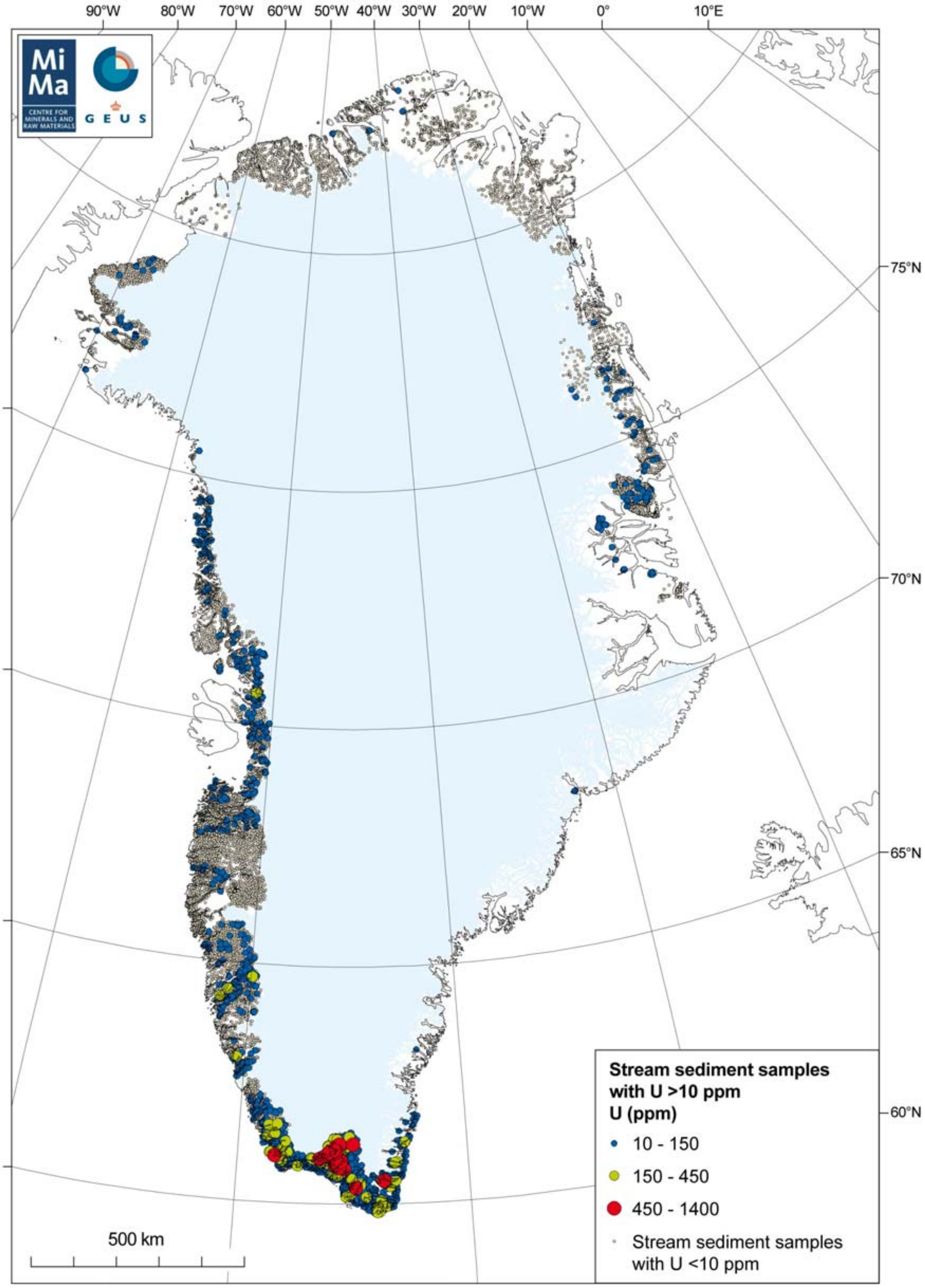


Figure 5: Geological map of Greenland indicating the localities of stream sediment samples with a uranium concentration above 10 ppm in the GEUS database. See text for references to the data.

1.2.5 Ground and airborne scintillometric surveys

As part of the Syduran project, ground scintillometric and airborne gamma-spectrometric surveys have been carried out in South Greenland. Figure 6 gives an overview of the results for the investigated area. The data from the airborne radiometric surveys are processed and callibrated to concentrations of K%, eU ppm (equivalent uranium ppm) and Th ppm using calibration constants by the Risø National Laboratory (Armour-Brown et al. 1982a). The airborne gamma spectrometry survey has been made using a Bell 206 Jet Ranger for contour flying. The spectrometer was a Scintrex GAD-8 Gamma ray spectrometer, with a NaI(Tl) crystal volume 7,413 cm^3. Analogue and digital data were stored on a tape using Quantex 5100 and 3M DC300A data cartridges with ANSI/ECMA (Armour-Brown et al. 1982a). See Steenfelt (2014) for further details.

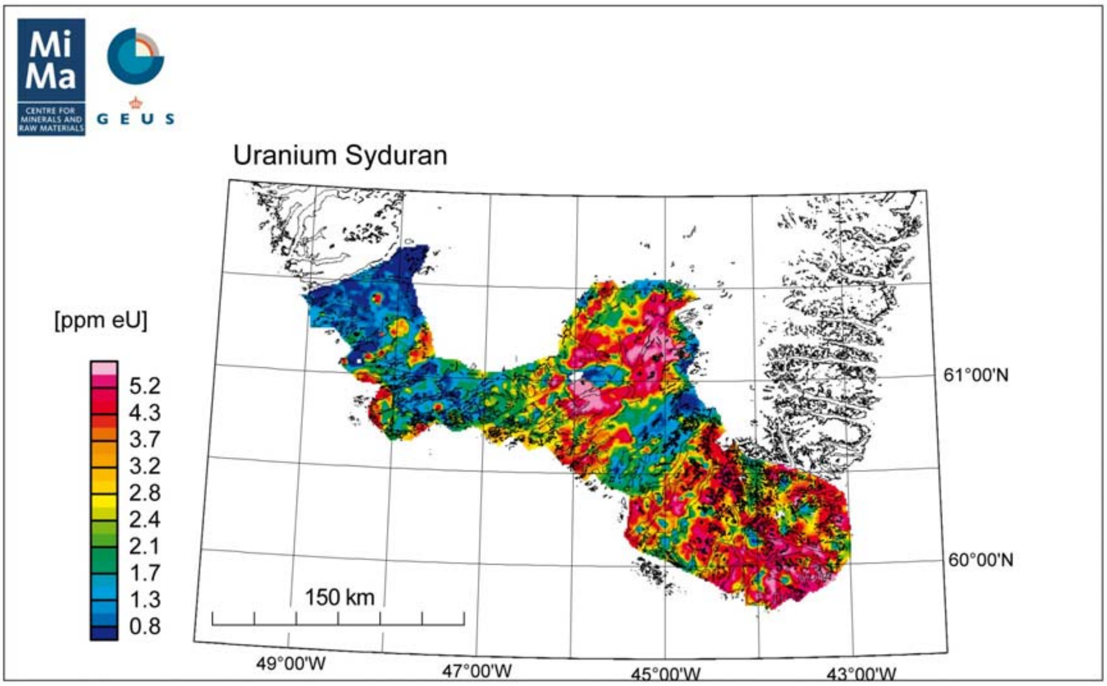


Figure 6: Results of the airborne radiometric survey that was performed as part of the Syduran project; the uranium concentration is expressed as equivalent units. Figure copied from Armour-Brown et al. (1982a).

1.3 Uranium deposit types

The average abundance of uranium in the Earth's upper crust is 2.7 ppm (parts per million = grammes per ton). Its crustal abundance is similar to elements like tin, molybdenum or arsenic. However, the concentration varies widely in the Earth's crust as geological processes have redistributed uranium and formed economic deposits.

Uranium deposits world-wide are found in a range of different geological environments where either distinct processes occurred or certain conditions prevailed (IAEA 2009). Accordingly, these are categorised in several principal types and subtypes, not all types occur in Greenland.

Approximately 75% of the world's uranium reserve is accounted for by five principal types of uranium deposits. These types are (1) sandstone type, (2) hematite breccia complexes (iron-oxide copper-gold (IOCG) type), (3) Quartz-pebble conglomerate type, (4) Proterozoic unconformity-type, and (5) metasomatite type deposits.

1.3.1. Classification of uranium types

Uranium classification systems are generally based on one of the following principles: (1) descriptive schemes based on the host lithology and the ore-body morphology of the uranium deposits (Dahlkamp 1983, IAEA 2009), (2) genetic classification scheme based on the uranium deposit formation conditions through the geological cycle (Cuney 2009, Cuney & Kyser 2009), and (3) a fluid- and process-based classification scheme in which the ore-forming end-member fluids and hybrid-fluids (mixing of different end-member fluids) are used to classify the deposits (Plant et al. 1999, Skirrow et al. 2009).

This report applies the principal deposit types and the associated subtypes defined by the International Atomic Energy Authority (IAEA) in combination with the criteria from the genetic and fluid- and process-oriented classification schemes. Appendix 1 aims at presenting the descriptive approach of these two classification schemes.

This report lists areas in Greenland with a potential to host a uranium deposit. The areas where uranium-enrichment already has been demonstrated are also described. The selection of the potential areas is mainly based on the available geological information on the area and follows loosely the method of the USGS global mineral resource assessment program (but without a panel and quantified estimations; see Briskey & Schulz 2003, Singer 1993, Singer & Menzie 2010 for details). The text is structured according to the different deposit types, as described above, and not according to the economic potential of the areas. Areas in Greenland within a certain deposit type are listed roughly clockwise, starting in South Greenland.

Table 1: Known global and Greenlandic uranium occurrences classified by deposit type. References are listed in Appendix 1.

Uranium deposit type	Commodities (potential byproducts)	Subtypes	Global examples	Greenland examples
D1 **Sandstone deposits**	U (V, Cu)	1. Roll-front deposits 2. Tabular deposits 3. Basal channel	• Colorado Plateau, USA • Grants, USA	1) • Illorsuit 2) • Milne Land 3) No known examples
D2 **Unconformity-related deposits**	U (Au, Ni)	1. Unconformity contact deposit 2. Sub-unconformity-post-metamorphic deposit	• Rabbit Lake, Canada • Cluff Lake, Canada • Key Lake, Canada • Jabiluka, Australia • Ranger, Australia	No known examples
D3 **Hematite breccia complex deposits (IOCG)**	U, Cu, Au,Fe (Ag, REE)		• Olympic Dam, Australia • Cloncurry, Australia • Starra, Australia • Ernest Henry, Australia • Phalabora, South Africa	No known examples
D4 **Quartz-pebble conglomerate deposits**	U, Au, PGE	1. Monometallic 2. Polymetallic	• Blind River/Elliot Lake, Canada • Witwaters-rand, South Africa	1) • Wegener Halvø 2) No known examples
D5 **Vein type (granite-related deposits)**	U (Ni, Co, As, Bi, Cu, Pb, Zn, Mn, Se, V, Mo, Fe, Ag)		• Ace Fay-Verna and Gunnar, Saskat-chewan, Canada • Millet Brook, Nova Scotia, Canada • Schwartzwalder, Colorado, USA • Xiazhuang district, China • La Crouzille area, Massif Central, France • Jachymov, Czech Republic	• Nordre Sermilik • North of Bredefjord • Puissattaq • Vatnaverfi • Moskusokseland • Nedre Arkosedal • Foldaelv • Qaqarssuk carbonatite
D6 **Intrusive deposits**	U, REE (F, Zr, Nb, Ta, Cu)	1. Anatectic deposits 2. Plutonic deposits	1) • Rössing, Namibia • Bancroft area, Ontario, Canada • Campbell Island Mine, Ontario, Canada 2) • Bingham Canyon, Utah, USA • Kvanefjeld and Motzfeldt, Greenland • Pilanesberg, South Africa • Araxa, Brazil	1) • Naassuttooq • Hinks Land 2) • Kvanefjeld • Motzfeldt • Ivigtût • Sarfartoq • Tikiussaq • Qaqarssuk • Frænkel Land
D7 **Volcanic and caldera-related deposits**	U (Mo, F, REE)	1. Structure-bound 2. Strata-bound 3. Volcano-sedimentary deposits	• Streltsovsk district, Russian Federation • Dornot Complex, Mongolia	1) and 2) No known examples 3) • Randbøldal, Greenland • Moskusokseland
D8 **Metasomatite deposits**	U	1. Na-metasomatite deposits 2. K-metasomatite deposits 3. Skarn deposits	1) • Kirovograd district, Ukraine • Krivoi Rog Basin, Ukraine 2) • Elkon Horst Deposits, Russian Federation 3) • Mary Kathleen, Queensland, Australia	1) • Motzfeldt • Grønnedal-Ika 2) • Sarfartoq • Nunatak north of Nordre Sermilik 3) No known examples

Continued overleaf.

Table 1, continued

D9 **Surficial deposits**	U	1. Peat-bog deposits 2. Fluvial deposits 3. Lacustrine-playa deposits 4. Surficial pedogenic and structure fill deposits	• Yeelirrie, Australia • Lake Way, Australia • Lake Maitland, Australia • Langer Heinrich, Namibia	No known examples
D10 **Collapse breccia pipe deposits**	U (Cu, V, Ag, Au)		• Orphan Lode, EZ-2, Pigeon, Arizona, USA	No known examples
D11 **Phosphate/phos-phorite deposits**	U (Sc, REE)	1. Organic (bedded) phosphorite deposits 2. Minerochemical (nodular) phosphorite deposits 3. Continental phosphorite deposits	• Santa Quiteria and Itataia, Brazil • New Wales, Florida (pebble phosphate) • Gantour, Morocco • Al-abiad, Jordan • Melovoe deposit, Kazakhstan	No known examples
D12 **Black shale deposits**	U (Cu, Cr, Mo, Mn, REE, V, P)	1. Humic/kolm in alum shale (Ranstad type) 2. Bituminous/sapro-pelic black shale (Chattanooga type)	• Västergötland, Ranstad, Sweden • Chattanooga, USA • Chanziping deposit, China • Gera-Ronneburg deposit, Germany	No known examples
D13 **Metamorphite deposits**	U (Th, Cu, REE)	1. Strata-bound deposits 2. Structure-bound deposits	1) • Forstau, Austria • Nuottojarvi. Lampinsaari, Finland 2) • Schwartzwalder, USA • Ace-Fay-Verna, Canada • Kamyshevoye, Kazaksthan	No known examples
D14 **Uraniferous coal and lignite deposits**	U (coal, lignite, Mo, As)	1. Stratiform-syngenetic lignite-coal deposits 2. Mixed stratiform/frac-ture-controlled epigenetic lignite-coal deposits	• Serres Basin, Greece • North and South Dakota, USA • Koldjat and Nizhne Iliyskoe deposits, Kazakhstan • Melovoe, Russian Federation • Freital, Germany	No known examples
D15 **Carbonate**	U (Cu, Pb, Zn, Ni)	1. Strata-bound carbonate deposits 2. Cataclastic carbonate deposits 3. Karst deposits (palaeokarst)	1) • Tumalappalle, India 2) • Mailuu-Suu, Kyrgyzstan • Todilto District, USA 3) • Tyuya-Myuyun, Kyrgyzstan • Pryor-Little Mountains district, USA	No known examples

1.4 Known uranium occurrences in Greenland

Nearly 30 uranium occurrences are known in Greenland. These are shown in Figure 7, where they are classified by the amount of information that is available on these occurrences. Most occurrences are either showings with only little exploration activity, or areas where more investigations, like geological mapping or trenching, have been performed. Drilling for uranium as a by-product or product has only been executed in Ivittuut and Kvanefjeld. Sarfartoq has been drilled, but with the aim to investigate the niobium potential of the carbonatite. The occurrences have been classified according to the uranium deposit type classification that was described above. The occurrences are listed here as an aid to illustrate the possibilities of finding other uranium deposits in the larger area.

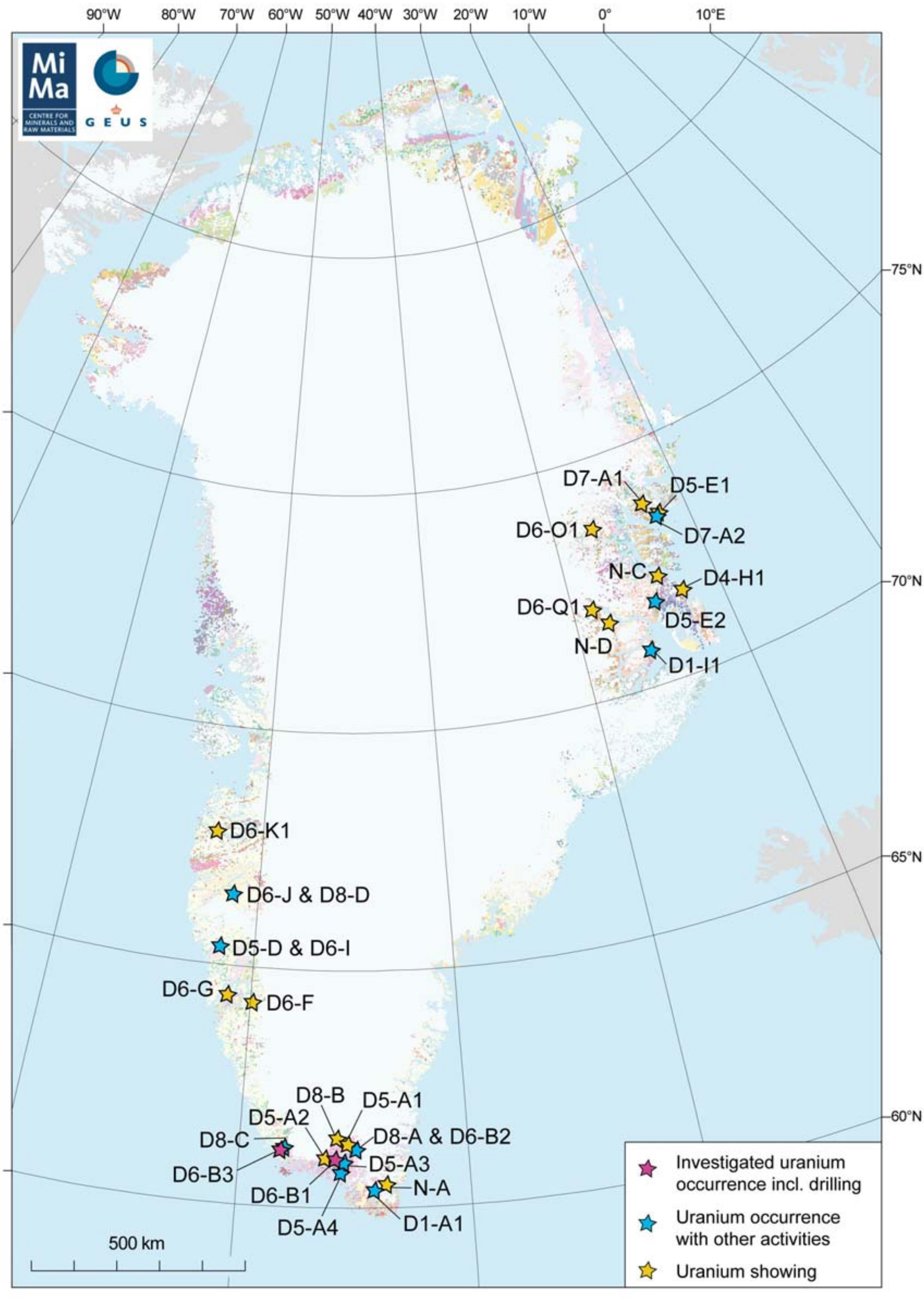


Figure 7: Geological map of Greenland indicating the exploration activity on the investigated uranium occurrences. Occurences with drilling activity, with other investigations than drilling, and with only little investigations are shown. Labels refer to the deposit classification scheme described above and to the chapters in this report where the occurrences are described. This figure discriminates between occurrences and showings; this distinction has not been made in the rest of this report, where all showings also are listed as occurrences.

2. Areas with known uranium occurrences and with a potential to host a uranium deposit

2.1 Sandstone deposits (D1)

2.1.1 Introduction

Uranium-bearing sandstone deposits occur typically at stable continental platforms, in foreland or interior basins, and on shelf margins (Appendix 1). Uplift in adjacent areas may cause the formation of braided river systems, fluvial channels or coastal plains. The uranium is derived from tuffs or feldspathic sediments that originate from contemporaneous felsic volcanism or from the erosion of felsic plutons. Microcrystalline uranium oxides and silicates are formed during diagenesis in localised reducing environments, for example in pores in the sandstone. In some areas uranium has been redistributed by groundwater and concentrated at the redox interface. Most known global deposits are Devonian or younger, where in many cases detrital plant debris (organic matter) is associated with the uranium mineralisation. The areas with a potential for such deposits are described below (see also Figure 8).

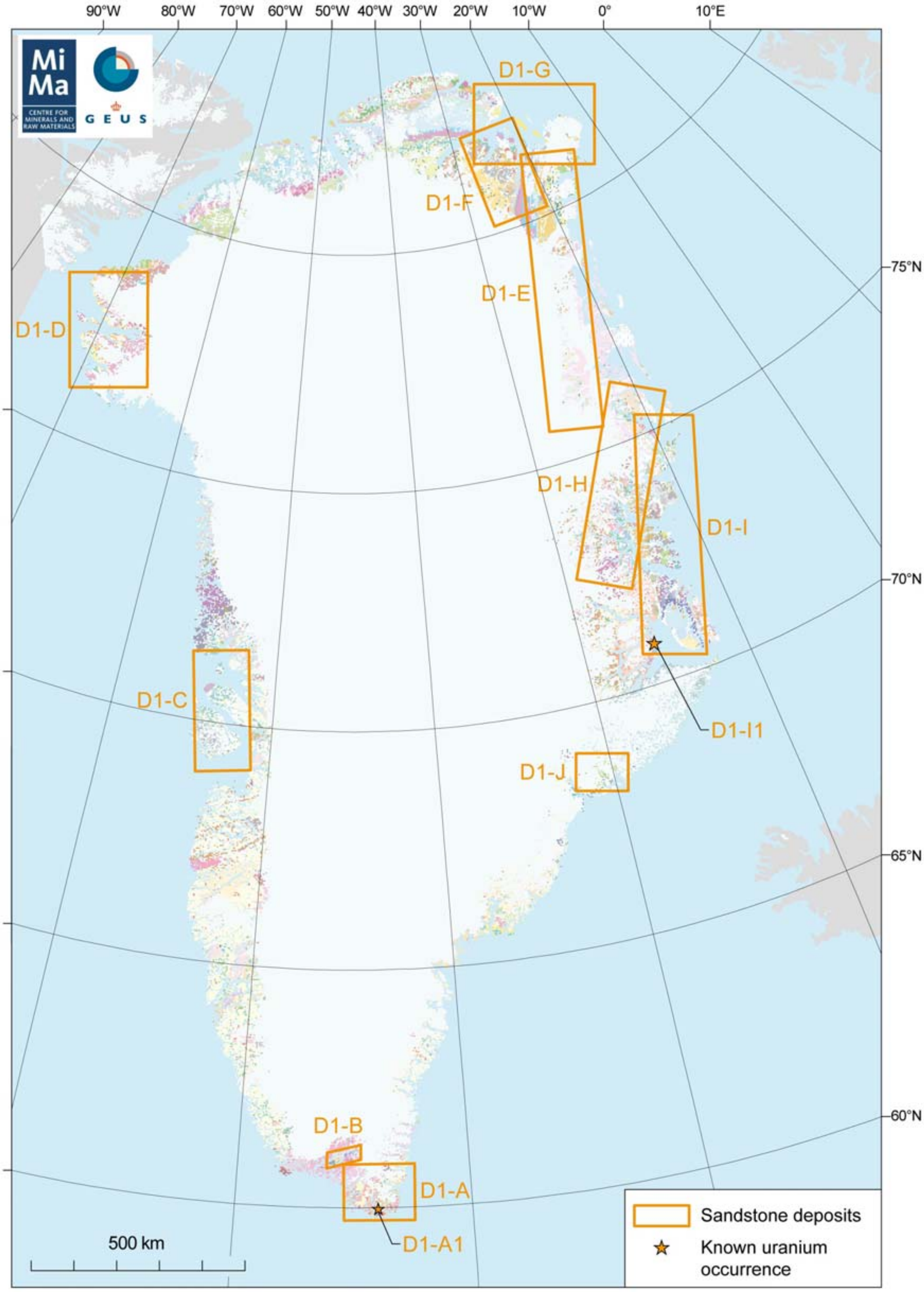


Figure 8: Geological map of Greenland showing the areas with a potential to host a sandstone deposit (uranium deposit type D1). Known Greenlandic occurrences are indicated with stars. Labels refer to chapters in the text.

2.1.2 Psammite zone (metasandstone), South Greenland (D1-A)

The psammite zone in the Tasermiut area consists of arkosic quartzites that are at least 1500m thick (Kalsbeek et al. 1990, Chadwick & Garde 1996). These supracrustal rocks have been subjected to low pressure-high temperature metamorphism, at upper amphibolite facies to granulite facies conditions. The rocks are locally strongly migmatised. Conglomeratic beds occur locally, cross-bedding has been observed locally, even in rocks metamorphosed at granulite facies conditions. The sediments contain large proportions of volcanogenic material, which is often sodic (Allaart 1976). The psammites at the south-eastern coast show cross-bedding and have occasional fragments that are interpreted as possible volcanic bombs. The rocks have locally high proportions of plagioclase or K-feldspar and were metamorphosed at greenschist facies to granulite facies. The timing of deposition of the sediments with respect to the Ketilidian orogeny has been debated in the 1960-ies and 1970-ies, but is currently regarded as ≤1793±2 Ma (Garde et al. 2002a). The contact with the basement has only been observed or described in a few places.

The meta-arkose and meta-volcanic units of the psammite zone are enriched in uranium (Steenfelt & Armour-Brown 1988). The uranium minerals (mainly uraninite) are concentrated around the crests of the folds, and in small fractures formed after folding, but before the intrusion of the rapakivi granites. Steenfelt & Armour-Brown (1988) assume that the volcanic rocks and sediments are the source of the uranium, while concentration of the uranium occurred during metamorphism or during synsedimentary and diagenetic processes.

The Palaeoproterozoic psammite zone metasandstone has a high potential as uranium-bearing sandstone. The area was uplifted during the Ketilidian orogeny and the sediments are rich in feldspathic minerals. Due to the high-grade metamorphism the rocks are no longer typical sandstones, but metamorphism seems to have had a positive effect on the concentration of the uranium in this area. No information on reducing conditions was found (compare to Appendix 1).

2.1.2.1 Illorsuit (D1-A1)

This locality is part of the Migmatite complex, in the Ketilidian supracrustal rocks, investigated during the Syduran and the Sydex project. The main uranium mineralisation is situated on a cliff face 500 m above sea level on the eastern side of the fjord. Regional mapping, however, showed that it was only one of many similar uranium occurrences in the area, albeit the largest and richest (Armour-Brown 1986). Over 35 uranium mineral occurrences have been found scattered over the hillside in a large xenolith enclosed within the rapakivi granite. They are stratabound to certain members of the meta-arkosic 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 fractures and associated breccias. The main mineralisation was found to extend 125 m with a width of 1-5 m and it occurs exclusively in fine grained, granular textured meta-arkosic units surrounded by rapakivi granite. The average grade is 0.3% uranium with highs up to 7% uranium. The fine grained disseminated nature of the uranium minerals and their lack of thorium despite high metamorphic grade suggest diagenetic origin (Armour-Brown et al. 1984). The uraninite crystals have been dated by microprobe and yield an average age of 1730 (± 100 Ma) (Steenfelt & Armour-Brown 1988). This age indicates that the uraninite most likely crystallised during the cooling phase of the intruding rapakivi granite at 1755-40 Ma (Gulson & Krogh, 1975).

If the surface dimensions are projected 60 m down dip, based on the distribution of the supracrustal units, this would give a tonnage of *c.* 17,000 tons of ore and *c.* 50 tons of uranium (Armour-Brown 1986). The license for the area is currently held by Samarium Group Corporation, who are exploring for Au.

2.1.3 Eriksfjord Formation sandstones, Gardar province (D1-B)

The Eriksfjord Formation sandstones are preserved in an ENE trending fault-bounded basin formed at *c.*1350-1260, Ma during a phase of rifting and denudation. The sediments were derived from the Julianehåb batholith (*c.* 1850-1790 Ma), which was uplifted during the Ketilidian orogeny (*c.* 1880-1720 Ma). The sandstones have been deposited under a high rate of tectonic activity and under constant subsidence of the area (Tirsgaard & Øxnevad, 1988). The sandstones stretch over an area of *c.* 100 km between the Inland Ice and the island Tuttutooq. The formation consists of interfingering basaltic and trachytic lavas and sandstones, and is deposited on a floor of ranites of the Julianehåb batholith (Allaart 1983, Henriksen et al. 2009). Interlayered in the sandstones are thin conglomerate layers with quartzite, quartz or hematite coated sandstone pebbles (Poulsen 1964). The Eriksfjord Formation consists of six members with a total cumulative thickness of 3085m, more than half of these are sedimentary rocks. The base of the sandstone, the Mâjût member, is formed by a conglomerate and arkose, which pass upwards into bedded red sandstone with cross-bedding and ripple marks. Boulders at the base of the unit consist of almost disintegrated granite and are up to 2 m in diameter. Laterally and upward the amount of arkose increases. The Mussartût member consists of interbedded sills and red sandstone with conglomerate layers. Near the top of this member a red sandy tuff is found within the conglomerate. On top of this member the Naujarssuit Sandstone Member of soft red sandstone with occasional ripple marks was found. The major part of this member consists of white quartzite. The Ulukasik Volcanic Member only contains sporadic intercalated sandstone. The Nunasarnaq Sandstone Member consists of wind-blown sand with relicts of dunes. The Ilímaussaq Volcanic Member is made up entirely of extrusives. Near Narsarsuaq the Eriksfjord Formation is only 500 m thick and consists mainly of extrusive basalts with carbonatitic pyroclastics in the upper part. The area shows an elevated uranium concentration (Figure 3, 5).

Based on their setting in a rift-system and their derivation as erosional products of the felsic Julianehåb batholith the Mesoproterozoic Eriksfjord Formation has a medium potential to host uranium-bearing sandstones type deposit (compare to Appendix 1). Several layers and beds of red sandstone and red tuffs are found, which indicate the presence of oxidizing layers. Photographs in Tirsgaard and Øxnevad (1988) show reduction spots, but their timing and extent are unknown.

2.1.4 Nuussuaq Group sandstones (D1-C)

The Nuussuaq Group sedimentary rocks crop out between Svartenhuk Halvø and Disko where they were deposited in the Cretaceous to Palaeogene Nuussuaq Basin (Dam et al.

2009). The oldest rocks are of Albian age and consist of syn-rift sediments, overlain by fluvio-deltaic sediments and coeval deep marine sedimentary rocks. Tectonic activity in the Early Campanian caused block faulting and uplift and incision of the earlier sediments by subaerial and submarine canyons that were filled with conglomerates, turbiditic and fluvial sands and mudstones of Maastrichtian to Danian age. During the Selandian marine mudstones overlie the earlier mentioned formations and locally volcaniclastic sandstones and tuffs record the onset of the later volcanic activity in the area. The youngest sediments are fluvial sediments deposited in lakes in a coarsening upward sequence. The cumulative thickness of the sediments is *c.* 500 m. The sediment is derived from the Precambrian basement; the lowermost units (Kome Formation and Upernavik Næs Formation) lie directly on the weathered basement and contain a sparse amount of coal (Dam et al. 2009).

The Cretaceous-Palaeogene Nuussuaq Group sandstones have a high potential to host uranium, owing to its setting in a rift-zone with uplift in the nearby Precambrian basement. The presence of coal and investigations for oil in the area prove that plant debris has been deposited in the area where the rocks are permeable, and that reducing conditions prevailed. The basalts may have acted as a seal over the sandstones and hence fluids have not been able to leave the sediment.

2.1.5 Thule Supergroup sandstones (D1-D)

The Thule Supergroup consists of an unmetamorphosed sedimentary-volcanic succession that is at least 6 km thick and was deposited at middle Mesoproterozoic-late Neoproterozoic times. The Thule Basin is an intracratonic fracture basin characterised by block faulting and basin sagging formed during an extensional tectonic regime. The sediments are deposited in a series of half-grabens on the gneisses and granites of the Precambrian basement and on the Palaeoproterozoic Prudhoe Land supracrustal complex. Alteration of the crystalline rocks, intense reddish-brown banding and strong reduction patterns have been recorded particularly in basal strata close to the Precambrian shield, both in the central basin (e.g. Northumberland Ø) and in basin margins (e.g. Wolstenholme Ø), suggesting that the unconformity acted as a passageway for the reducing solutions (Dawes 2006). Important groups within the Thule Supergroup include the Smith Sound, Nares Strait, Baffin Bay and Dundas groups; these are summarised below.

The Smith Sound Group outcrops in the northern part of the Thule Supergroup in Inglefield Land. It was deposited simultaneously with the Nares Strait Group and Baffin Bay Group, but forms a much more condensed section. It consists of shallow marine sandstones and multi-coloured shales with stromatolitic carbonates. The group is rich in quartz arenites and quartz-pebble conglomerate. The Cape Camperdown Formation, which is the lowermost formation of the Smith Sound Group is subarkosic at the base of the formation (Dawes 1997).

The Nares Strait Group forms the oldest strata of the Thule Supergroup. The sediments are at least 1268 Ma old and consist of sandstone, basic sills, volcanic/redbed sequence of tholeiitic lavas, agglomerates, tuffaceous strata, and stromatolitic carbonates (Dawes 2006). The sediments are of alluvial plain and littoral environments. The Northumberland Formation overlies the Precambrian shield in the central basin and contains up to 10% feldspar (Dawes 1997).

The lowermost formation in the Baffin Bay Group in the Kap York area, the Wolstenholme Formation, mainly consists of the ferruginous sandstone, conglomerate, minor siltstone and shales that were deposited as fluvial deposits settled in an oxidizing environment.

The Dundas Group contains sandstones, siltstones, shales with evaporitic beds, cherts and limestones. The Steensby Land Formation is dominated by black shales with carbonate bands and stromatolitic reefs and the development of pyrite. The depositional area is deltaic to offshore. The Narssârssuk Group is similar in composition to the Dundas Group, but usually richer in carbonate rocks (Dawes 2006).

The Thule Supergroup sediments at the base of the succession have a high potential to contain uranium-bearing sandstones. The Proterozoic sandstones in the Thule Group were deposited in an intracratonic basin with block faulting. The sediments were derived from the Precambrian basement and contain some feldspar in the units that were laid down immediately on the basement. Near the unconformity with the basement, evidence for reduction has been observed as well.

2.1.6 Independence Fjord Group sandstones including the Trekant Series and the sandstones and conglomerates in Kronprins Christian Land (D1-E)

The Independence Fjord Group deposits are among the oldest large depositional basins developed on the Greenlandic shield and the sediments are undeformed and unmetamorphosed. The group is over 2 km thick and is dominated by alluvial clastic sediments. The sediments are mainly sandstones that were deposited in three 300-900 m thick units and are separated by two to four thin but continuous siltstone members. Deposition took place in an intracratonic sag basin after the end of a Palaeoproterozoic orogenic event (*c.* 1750 Ma) and before the intrusion of the Midsommersø Dolerites (1380 Ma) (Henriksen et al. 2009). The base of the Independence Fjord Group is covered by the Inland Ice, but is inferred to be a nonconformity. The Independence Fjord Group is outcropping on both sides of the Independence Fjord and Academy Glacier, but the formations on either side of the fjord cannot be correlated. It is assumed that the area west of the fjord represents the deeper part of the Independence Group (Collinson et al. 2008). The sandstones in both formations are quartzitic to arkosic, with a high amount of feldspars in the Astrup Fjord member. The sandstone members show diagenitically defined colour variations in red intensity.

The conglomerates and sandstones in Kronprins Christian Land are possibly related to the Independence Group sediments and were deposited in an active rift basin and show interbedded volcanic ash beds and volcanic bombs (Collinson et al. 2008). The formations east and west of Hekla Sund have different names but similar properties. The sediments are molasses-type deposits with in the lowermost formation of thick-bedded quartzitic to arkosic sandstones with intercalated conglomerate and heavy mineral placer deposits. These are overlain by 400-1100 m of basalts and andesites. The upper formations have conglomerate horizons at their base, heavy mineral beds, and fluvial or near-shore sandstones. Many arkose and conglomerates with pebbles up to 20 cm of granite, gneiss, basalt, and vein quartz are described, especially east of Hekla Sund. The whole series of sediments were deformed and overprinted by greenschist facies or eclogite facies metamorphism (Gilotti et al. 2008).

The Trekant Series is a sequence of sandstones, siltstones and conglomerates of up to 510 m thick. It is outcropping on Dronning Louise Land and is unconformably overlying the basement. The series has been correlated with the Independence Fjord Group of North Greenland. In the Western Foreland, the rocks are nearly undeformed, but nearer to the Imbrication Zone and in the Eastern Hinterland it is affected by Caledonian metamorphism up to amphibolite facies conditions (Strachan et al. 1992). The Trekant Series were deposited in a fluvial environment. The lowest parts of the sequence are crudely stratified conglomerates composed mainly of angular fragments of orthogneiss, which pass upwards into cross-bedded, grey-green and purple-red arkosic and quartzitic sandstones with interbedded siltstones and quartz-pebble conglomerates.

The Palaeoproterozoic Independence Group and the unmetamorphosed Trekant Series have a low potential to host uranium-bearing sandstones based on their setting in an intracratonic basin and the age of the sediments, even though the feldspar-bearing composition of the rocks and the presence of red beds are positive (compare to Appendix 1). No information about the presence of reducing agents is found. The Kronprins Christian Land sediments have a slightly higher potential due to the presence of volcanic ashes and its setting in a rift-basin. A larger amount of conglomerates and large pebbles suggest high uplift rates. However, these rocks were subject to intermediate grade metamorphism and it is unclear to which extent this influences the uranium concentrations in the rock.

2.1.7 Hagen Fjord Group sandstones (D1-F)

The Hagen Fjord Group is a series of Neoproterozoic shallow marine basin deposits that were laid down between 800-590 Ma. The lower three formations are siliciclastic in nature, followed by two carbonate-dominated formations, and these three formations have a maximum total thickness of 1000-1100 m. The lowermost Jyske Ås Formation consists of basal red shallow marine sandstones, followed by cross-bedded tidal sandstones. Deposition occurred in a half-graben. The two overlying formations consist mainly of fine- to medium-grained sandstone and siltstones with intercalated dolostone and are interpreted as post-rifting sediments (Clemmensen & Jepsen 1992, Sønderholm et al. 2008). No information on the mineralogy of the sandstones was found.

The potential for the Hagen Fjord Group is hard to estimate, owing to a lack of information on the presence of feldspar minerals, reducing agents and porosity of the sandstones.

2.1.8 Wandel Sea Basin sandstones (D1-G)

The Wandel Sea sediments were deposited in the Carboniferous – Triassic and again in the Late Jurassic - Eocene along the northern and north-eastern margin of the Greenland shield. The Carboniferous and Triassic sediments were laid down on the folded Caledonian rocks during a wide-spread block faulting and half-graben formation. The sediments consist of fluvial deposits with medium to coarse-grained sandstones interbedded with shale and minor coal layers (Lower Carboniferous). Afterwards, regional uplift and the deposition of *c.* 1100 m of shallow marine sediments in the Late Carboniferous and Early Permian took place (Stemmerik & Håkansson 1989). This succession is rich in carbonates but also contains Carboniferous sandstones and shales. In Holmland and Amdrup Land, locally red-weathering conglomerates and sandstones were deposited. An unconformity separates these sediments from the overlying Lower and Middle Triassic red-weathering shelf sandstones and shales.

During the Late Jurassic and Early Cretaceous small isolated sub-basins were formed and filled with shelf sandstones and shales. The sedimentation-rate increased during the Late Cretaceous where deltaic to full marine siliciclastica were deposited (Stemmerik et al. 2000, Henriksen et al. 2009). The earliest Paleocene deposits are extrusive volcanic rocks and volcanogenic sediments of peralkaline affinity, which are preserved below a major thrust zone. The youngest sediments are upper Paleocene to lower Eocene fluviatile and marine sandstones of the Thyra Ø Formation. This formation is dominated by laminated, organic-poor siltstones and fine-grained sandstones with coal seams (Lyck & Stemmerik 2000).

The Wandel Sea Basin sandstones of Cretaceous-Palaeogene age have a medium potential to host uranium-bearing sandstones. Considerable uplift and deformation has taken place in the area while the sediments were deposited. Sedimentation occurred within the time window that is favourable for the formation of uranium-bearing sandstones (compare to Appendix 1). In some of the Carboniferous and Eocene units coal layers were found, which hints at a period with reducing conditions during or after deposition. No information is available in the literature on the porosity of the rocks, nor on their mineralogy.

2.1.9 Eleonore Bay Supergroup and Tillite Group sandstones (D1-H)

The Eleonore Bay Supergroup comprises a series of more than 14 km in thickness dominated by shallow-water sedimentary rocks. The basin was formed as a result of early stage Iapetan rifting along the Laurentian margin. The sediments are found in East and North-East Greenland and were laid down between *c.* 900 Ma and 665 Ma (Sønderholm et al. 2008). The lower 12 km of the Eleonore Bay Supergroup consist of the Nathorst Group and Lyell Land Group of alternating arenaceous sandstones and locally red-weathering siltstones with very minor limestone. The rocks were deposited in an inner- and outer shelf environment (Sønderholm et al. 2008, Henriksen et al. 2009). The lower part of the Nathorst Group outcrops as quartzites show stream current bedding and greywackes with small-scale grading and breccia development. The upper part of the alternating sandstones and siltstones has generally thicker sandstone bands and weather dark brown rusty to greenish grey. Metamorphic equivalents of the latter rocks occur as chlorite schists, mica schists, siliceous gneisses and quartzites (Henriksen & Higgins 1976).

The Neoproterozoic Tillite Group overlies the Eleonore Bay Supergroup with a local unconformity and consists of two glacigenic diamictite formations with interlaying shales and sandstone formation and two overlying formations of mainly mudstones, shales and limestone. The upper tillite formation (Storeelv Formation) consists of blocks and pebbles derived from “Multicoloured Series” (mainly mudstones and limestones), and quartzites of the Eleonore Bay Supergroup and from the granitic basement. The matrix of this tillite consists of hematite-coated quartz, feldspar and calcareous to siliceous cement (Henriksen & Higgins 1976).

The Eleonore Bay Supergroup sandstones have a low potential to contain uranium-bearing sandstones. They are poor in feldspar minerals and Neoproterozoic in age (compare to Appendix 1). Some probably continuous uplift occurred in the vicinity and evidence for the weathering of iron was found. The Storeelv Formation of the Tillite Group has a medium potential to contain uranium-bearing sandstones. In these rocks, a feldspar-rich matrix is present. However, no evidence for major uplift is present while these rocks were deposited. For both units no information is available on the porosity of the sandstones or the availability of reducing agents.

2.1.10 Central East Greenland basins sandstones (D1-I)

The East Greenland basins were formed between Devonian and Paleocene times after the Caledonian orogeny, which was followed by rifting and drifting phases associated with the opening of the Northern Atlantic. The Devonian and Carboniferous sedimentary basins are intramontane basins formed as a result of orogenic extensional collapse, and are filled with continental derived siliciclastic sediments with basic and felsic volcanic intervals. The sediments are rich in gravelly red sandstones, conglomerates and siltstone and result from deposition in braided rivers, alluvial fans, and flood plains grading into more aeolian, fluvial, lacustrine and flood plain dominated settings. Sediments were derived from the Caledonian orogen and lie unconformably on top of those. The clasts in the conglomerates and sandstones consist of limestone, granites, gneiss, and sandstone (Olsen & Larsen 1993, Larsen et al. 2008, Henriksen et al. 2009).

In the Carboniferous, a series of north-south trending sedimentary basins developed reflecting prolonged subsidence. Block-faulting and rifting took place in several episodes. The Jameson Land Basin south of Kong Oscar Fjord developed into a sag-basin filled with upper Permian to earliest Cretaceous sediments. The base of the series is a Permian reddish-brown conglomerate. Especially in the Triassic and Jurassic, sandstone is abundant. These are marine sandstones and shales, followed by alluvial conglomerates and lacustrine dolomite and shales in the Triassic. The Pingodal and Wordie Creek Formations Triassic sandstones are arkosic. Middle and Late Jurassic sediments are mainly shallow marine sandstones, grading to more deep-water shales in the southern part of the basin, but granitic and quartz-pebble conglomerate layers have been described as well. Several formations and the Kap Steward and Neil Klinter Groups contain arkosic sandstones and conglomerates interlayered with shales rich in plant fossils and coal seams. In the Wollaston Foreland mainly Jurassic and Cretaceous syn-sedimentary marine breccias and conglomerates passing into sandstones and shales were deposited in a series of half-grabens.

The Devonian-Paleocene East Greenland Basins sandstones have a high potential to host uranium as the area is formed in a rift-zone, immediately after a period with uplift in the nearby Precambrian basement. Arkosic sediments in the Triassic and Jurassic Jameson Land and basement derived sediments and volcanic sediments in the Devonian basins ensure the presence of feldspar minerals in at least part of the rocks. The presence of coal and plant fossils in the area suggests that reducing conditions were in place. The Paleocene and Eocene basalts have acted as a seal over the sandstones and hence fluids have not been able to escape from the area. One known example of uranium enrichment occurs in these sediments on Milne Land.

2.1.10.1 Milne Land (D1-I1)

The fossil placer of Milne Land was first discovered in 1968, due to high Zr, rare earth elements (REE), and Th anomalies detected from pan samples. In 1970, a number of additional Th anomalies were detected during an airborne radiometric survey carried out first by Nordic Mining Company (Hintsteiner et al. 1970) and then by GGU and National Laboratory Risø (Nielsen & Løvborg 1976). Nordic Mining Company supported airborne measurements with ground surveys in 1971-72 (Schatzlmaier et al. 1973).

The Mesozoic sediment of east Milne Land is resting on kaolinised basement of Mesoproterozoic migmatised metasediments. The Jurassic to Cretaceous sedimentary sequence is of clastic composition and represents a marine transgression (Birkelund et al. 1984). The basal unit is *c.* 20 m thick and comprises among others unconsolidated heavy mineral sands rich in garnet, ilmenite, rutile, zircon and monazite, which interfinger with the arkosic sandstone. The heavy mineral sands occur as irregularly distributed 10-40 cm thick lenses within the unit. Uranium is mainly hosted in the monazite, and samples from trenches yield 190-640 ppm U. The Th/U ratio is *c.* 10 (Schatzlmaier et al. 1973, Harpøth et al. 1986).

CGRG Ltd. currently has the license for the area and is exploring for Mo-Zr-REE-Ti.

2.1.11 Kangerlussuaq Basin sandstones (D1-J)

The Kangerlussuaq Basin, which is situated in southern East Greenland north-west of Nansen Fjord, contains a *c.* 1 km thick succession of Cretaceous-Palaeogene sediments of the Kangerdlugssuaq Group. The sediments onlap crystalline basement to the east and north, but the base is not exposed in large parts of the basin. The oldest deposits are fluviatile and estuarine sandstones, which are overlain by deep marine sediments. In the early Paleocene an increased sediment input rate related to extensive uplift is recorded by submarine fan sandstones along the northern margin of the basin and mudstones within the basin that are unconformably overlain by fluvial sheet sandstones and conglomerates. The area is covered by Palaeogene lavas.

The major part of the sedimentary sequence is covered by the Ryberg Formation, which consists mainly of two facies groups: planar sandstones and calcareous siltstones; feldspathic sandstones. The planar sandstones are medium to coarse well-bedded sandstones, alternating with black shale units. These commonly pass into banded or laminated calcareous siltstones. The feldspathic sandstones are coarse, sometimes conglomeratic, white sandstones, rich in basement-derived feldspar and mica. The sediments are conformably overlain by the basal conglomerate of the mainly basaltic Vandfaldsdalen Formation (Soper et al. 1976, Larsen et al. 1999).

The Kangerlussuaq Basin sandstones have a medium potential to host uranium-bearing sandstones. The sediments are derived from a felsic basement that is rich in feldspar minerals. Considerable uplift has taken place in the area and sediments are of Cretaceous-Palaeogene age, which agrees with the most favourable time period for sediment deposition (compare to Appendix 1). However, no information is available on the presence of reducing agents and the porosity of the rocks, but the sandstones are named as the outcropping equivalents to offshore oil and gas-bearing sandstones in drill cores in the Shetland basin (Larsen et al. 1999).

2.2 Unconformity-related deposits (D2)

2.2.1 Introduction

Unconformity-related uranium mineralisations occur in fracture filling and breccia, and in porous zones in clastic sediments that overly metasediments or an intensively weathered crystalline basement (Appendix 1). Chloritisation, hematisation, kaolinisation, illitisation, and silicification are typical forms of alteration associated with these ore deposits. The uranium is found in either the metasediments below the unconformity, in clay-bound deposits at the base of the sedimentary rocks above the unconformity, or around the unconformity as a result of later remobilisation. Unconformity-related uranium deposits are typically found in intracratonic sedimentary basins. Known global deposits are often found in Mesoproterozoic unconformities overlying a Palaeoproterozoic host rock, as those basement rocks often are rich in graphite. However, unconformity related uranium deposits have been reported to have formed during the whole Phanerozoic and Proterozoic time. The areas with a potential to host unconformity related uranium deposits are shown in Figure 9.

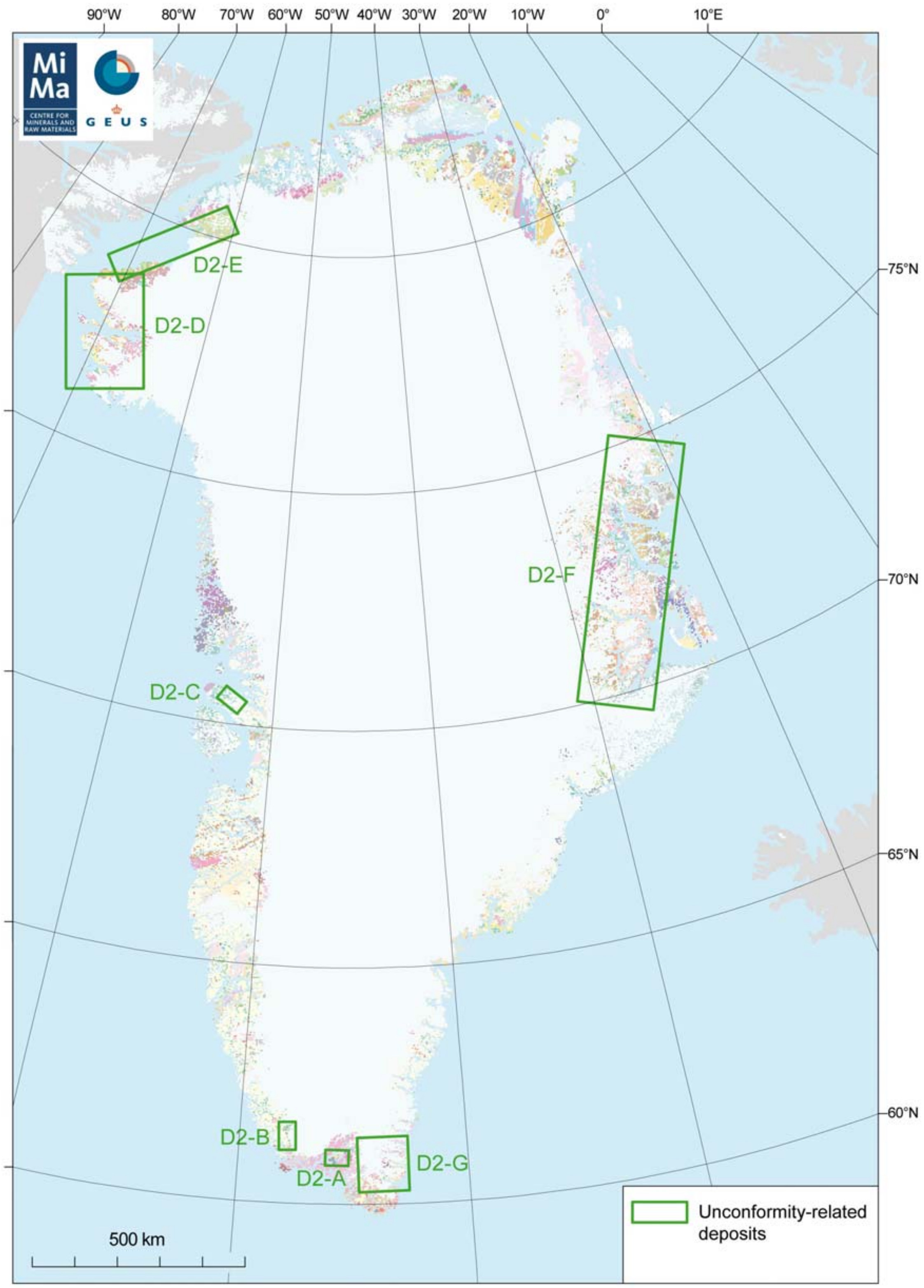


Figure 9: Geological map of Greenland showing the areas with a potential to host an unconformity-related deposit (uranium deposit type D2). Labels refer to chapters in the text.

2.2.2 Base of the Eriksfjord Formation, Gardar province (D2-A)

The sediments of the Mesoproterozoic Eriksfjord Formation, which overlays the Palaeoproterozoic Julianehåb batholith, are described in section 2.1.3 Eriksfjord Formation sandstones, Gardar province (D1-B). The unconformity at the base of the Eriksfjord Formation has a high potential to host uranium for several reasons: the unconformity, crystalline rocks and sediments all are from the most optimal geological time periods, known uranium enrichment occur in the region, and the Eriksfjord Formation is an intracratonic sedimentary basin.

2.2.3 Grænseland (Borderzone) and Midternæs unconformity (D2-B)

Grænseland hosts a series of nearly unmetamorphosed and undeformed supracrustal Ketilidian rocks. The lower part of the succession is the sedimentary Vallen Group. It is overlain by the volcanic Sortis Group, which mainly consists of basic pillow lavas and contemporaneous basic sills. The exact age of deposition for the sediments is unknown, but the Sortis Group sediments are overthrusted by the Vallen Group and intruded by the Ketilidian Granites (Garde et al. 2002b). These granites are associated with the Julianehåb batholith, which was emplaced from 1868 Ma onwards (Garde et al. 1998). Kalsbeek and Taylor (1985) report the age of the dolerite dyke that crosscuts the basement to be 2130 Ma, but no age of the sediment is indicated (Rb-Sr whole rock age).

Bondesen (1970) describes that the Archaean orthogneiss immediately below the contact with the Ketilidian sedimentary rocks was altered to sericite and chlorite, and carbonate-enriched, probably as a result of percolating ground water at the time of deposition of the sediments. The basal conglomerate lies unconformably on the altered basement and consists of unsorted clasts of orthogneiss, pegmatite, vein quartz, dolomite and green mica schist, with a clasts size of up to *c.* 20 cm in diameter. On top of the conglomerate the Lower Dolomite and Varved Shale Members are laid down; each of these members is *c.* 15 m thick. The Rusty Dolomite Member is 0.5 to 1 m thick. The overlying unit was named the Ore-Conglomerate Member by Bondesen (1970) and described it as an oligomict conglomerate consisting of boulders of grey to white cherty quartzite set in a matrix of magnetite or locally pyrite. The Ore-Conglomerate Member on Arsuk Ø was later interpreted as a banded-iron-formation rock by Garde et al. (1998). The top part of the sequence consists of deeper marine greywackes. Sand-sized spherules in a dolomite layer have been reinterpreted as distal impact ejecta by Chadwick et al. (2001). Bondesen (1970) describes the rocks as an accumulation of locally transported material deposited from small streams. The boulders have the composition of Târtoq Group supracrustal rocks and Archaean orthogneiss.

The Palaeoprotorozoic Grænseland unconformity has a medium potential to host uranium as this unconformity zone contains chloritisation in the weathered basement overlain by sedimentary rocks. Both the Archaean basement and the overlying sediments are slightly older than what is normally recorded as optimal for uranium occurrences of this type (see Appendix 1) and the Ketilidian sediments were not deposited in an intracratonic basin.

2.2.4 Kome Formation in the Nuussuaq Group (D2-C)

The sediments of the Cretaceous-Palaeogene Nuussuaq Group, which overlays the Archaean basement, are described in section 2.1.4 Nuussuaq Group sandstones (D1-C). The Kome Formation is the lowermost unit of this Group and the basal part of the Kome Formation overlies and onlaps the Precambrian basement. The basement rocks are weathered to a depth of up to 35 m and contain nearly only kaolinite and quartz in places. Chloritisation has been described as well (Dam et al. 2009 and references herein). The basal sediments consist of 1) poorly sorted sandstones that are rich in kaolinite, 2) diamictites in a sandy clay matrix, and 3) unsorted conglomerates with poorly rounded quartz boulders and slabs of silty mudstones. These poorly sorted, coarse-grained deposits are overlain by thin conglomerates and locally channellised coarse-grained sandstones, mudstones and thin discontinuous coal beds. Root zones and plant debris in mudstones occur frequently. The depositional environment of the Kome formation has been described as talus cones and alluvial fan filled topographic lows on the basement surface with immature sediments (Dam et al. 2009). The alluvial fan deposits were followed by subarial and subaqueous fan deltas, while the sandstones and mudstones represent braided river systems, floodplain and shallow lake deposits.

The unconformity between the Kome Formation and the Precambrian basement on Nuussuaq has a high potential to host uranium as this unconformity zone shows clay-rich sediments deposited directly on weathered, reworked Archaean basement. The sediments are deposited in the topographic lows of the basement in a pre-rift environment. However, the sediments are not of the most ideal age to host uranium (cf. Appendix 1). Elevated uranium concentrations (above 1000 ppm) were found in a rock sample from near Ikorfat (see Figure 3).

2.2.5 Base of the Thule Supergroup (D2-D)

The Thule Supergroup was discussed in section 2.1.5 Thule Supergroup sandstones (D1-D). The Smith Sound Group, Northumberland Formation of the Nares Strait Group and the Wolstenholme Formation of the Baffin Bay Group form the base of the Thule Supergroup. The base of the Thule Supergroup has a high potential to be enriched in uranium, in relation to the criteria listed in Appendix 1. The Mesoproterozoic sediments in the units at the base of the Thule Supergroup contain clay minerals, especially in the Smith Sound Group and the Wolstenholme Formation. The sediments were deposited in an intracratonic fracture basin. The basement on which these sediments were deposited consists of Palaeoprotorozoic and Archaean gneisses and high-grade metamorphic sediments. Alteration and reduction features have been observed in the basement near the contact with the sediments.

2.2.6 Dallas Bugt Formation, Franklinian Basin (D2-E)

The Dallas Bugt Formation outcrops as the southwestern-most part of the Franklinian Basin deposits. It overlies the Inglefield Mobile Belt and locally also the Thule Supergroup. It contains Cambrian clastic red-brown arkosic sandstone and conglomerates as the basal strata

(Kap Scott Member) overlying the Inglefield Mobile Belt. On top of these, white-yellow cross-bedded sandstones, and greenish fine-grained sandstones with mudstone have been deposited. Towards the top, the units become richer in dolomite and grade into the overlying dolomite-defined Cape Leiper Formation.The Franklinian sediments are unmetamorphosed and fossils inside the sandstones are unstrained (Dawes 2004). Steenfelt & Dam (1996) describe enhanced levels of uranium, REE, Th, Hf, Zr, Y in stream sediments collected where the dark red crossbedded sandstones of the Dallas Bugt Formation outcrop, south of Dallas Bugt and Marshall Bugt (Figure 5). They attribute this enhancement to heavy minerals layers within the sandstones. The Dallas Bugt Formation has a medium potential to host an unconformity-related uranium deposit, based on the age of the basement (Palaeozoic) on which it was deposited and the hematisation of the basal strata.

2.2.7 Devonian to Permian clastic sediments in central East Greenland (D2-F)

Extensional collapse at the end of the Caledonian orogeny led to the formation of graben-like structures in which more than 8 km of mainly coarse continental siliciclastic Devonian sediments were deposited in N-S trending graben structures. The earliest sediments, the Vilddal group, which is up to 2500 m thick, are gravelly braided river and sandy to silty alluvial fan deposits (Henriksen et al. 2009). The bottom of the series comprises a conglomerate, with pebbles that are mainly made up of carbonate clasts (50-95%), together with quartzite, sandstone and crystalline clasts (Olsen & Larsen 1991). The clasts are set in a sandstone matrix that weathers red.

After initial rifting in the Devonian and earliest Carboniferous and a period of non-deposition, active half grabens were formed in central East Greenland, which were filled with up to 3000 m of Late Carboniferous-earliest Permian fluvial and lacustrine sediments (Henriksen et al. 2009).

In the Late Permian a sag basin was developed on Jamesonland filled with Upper Permian to earliest Cretaceous sediments, and block fault basins in Wollaston Foreland. The earliest Permian sediments were alluvial fan conglomerates, followed by shallow marine sediments both of the Foldvik Creek Group (Stemmerik et al. 2001).

The sediments mainly overly the folded rocks of the Caledonian orogeny, which include orthogneiss, granite, metasedimentary rocks of the Krummedal Sequence, and mainly sedimentary rocks of the Eleonore Bay Supergroup. No information on weathering of the basement is found in the literature.

There is a low potential that the clastic sediments of central East Greenland are deposited on a uranium-enriched unconformity. The rocks below the unconformity are very variable, and in most places not favourable for uranium enrichment. In a few localities, they consist of Mesoproterozoic Krummedal metasediments and Archaean gneiss, which are of an optimal geological age and composition. The sediments were deposited during the Devonian to Carboniferous, which is later than the optimal age, but unconformity-related deposits of this age are known globally (see Appendix 1).

2.2.8 Base of the pelite and psammite zone, South Greenland (D2-G)

The pelite and psammite zone is described in the section 2.1.2 Psammite zone (metasandstone), South Greenland (D1-A). In large parts of the area, the contact with the basement is not outcropping. In most of the areas where this contact is observed, the contact has not been described in detail. The sediments are deposited on the Julianehåb batholith and metamorphosed at greenschist facies to granulite facies conditions, thus no clay-rich alteration zones remain. Both the unconformities and the host rock are of Palaeoproterozoic age, a suitable time span, yet not ideal, to form a uranium-enriched unconformity (cf. Appendix 1).

2.3 Quartz-pebble conglomerate deposits (D4)

2.3.1 Introduction

Quartz-pebble conglomerates that unconformably overly granitic or metamorphic basement can form a uranium-deposit (see Appendix 1). These conglomerates are often deposited as placers or basal units in fluvial-lacustrine braided stream systems and are usually found in extensional basins or coastal plains formed at or near Archaean craton margins. Deposit formation is limited to Archaean and Palaeoproterozoic times, as the ore concentration is dependent on the possibility to transport detrital uraninite in river systems, which only can be done in an anoxic atmosphere. Areas with a potential to host such deposits in Greenland are shown in Figure 10.

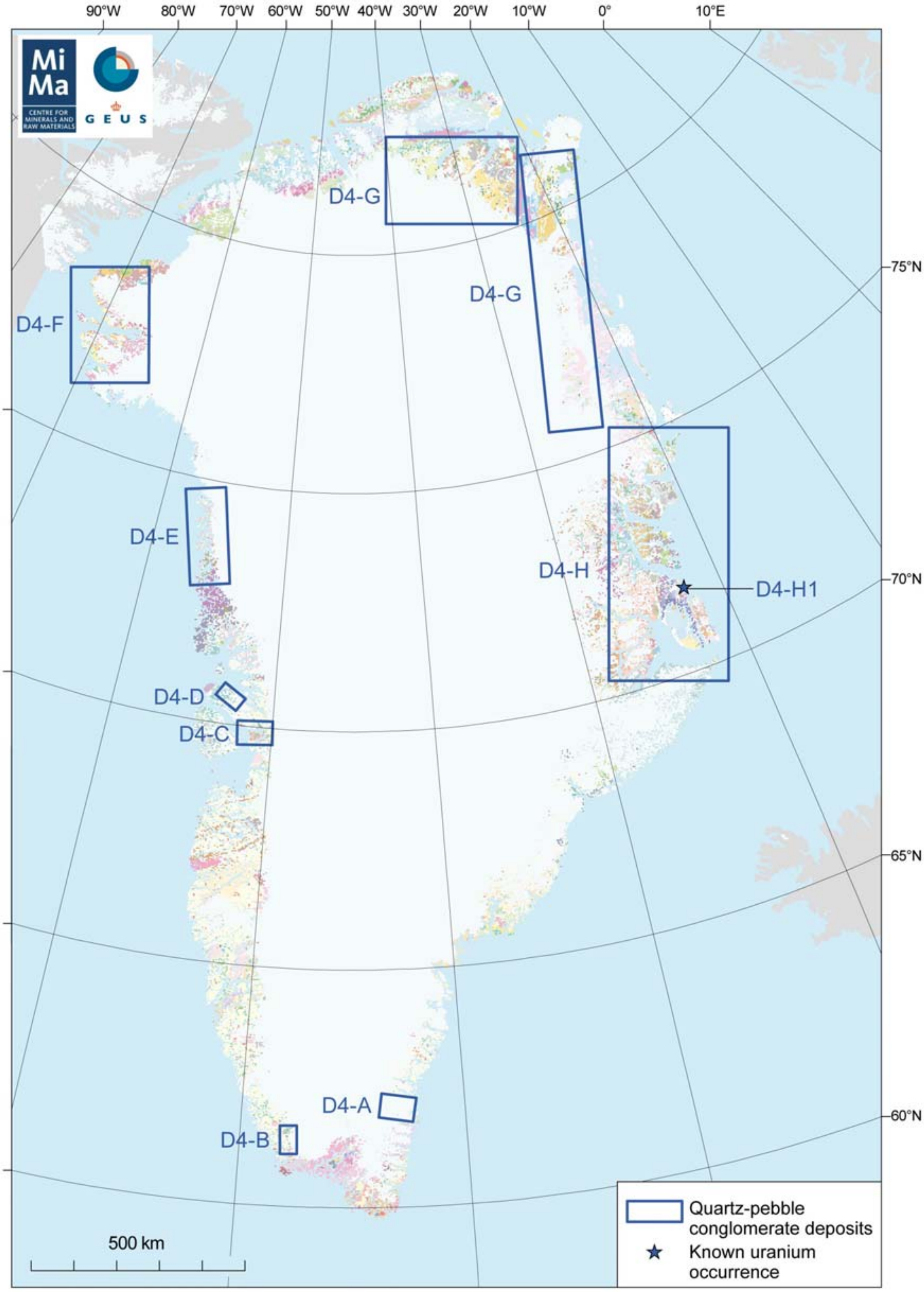


Figure 10: Geological map of Greenland showing the areas with a potential to host quartz-pebble conglomerate deposits (uranium deposit type D3). A known Greenlandic occurrence is indicated with a star. Labels refer to chapters in the text.

2.3.2 Conglomerates associated with the Ketilidian sediments in South-East Greenland (D4-A)

The Ketilidian orogen can be traced under the Inland Ice to a few outcrops on nunataks and near the coast of eastern South Greenland. These outcrops have been described by Garde and co-workers (1999, 2002). They conclude that the north-eastern Border Zone resembles the Ketilidian sediments in South-West Greenland, but the volcanic Sortis Group is missing. On the north face of Nunatak 1120, an over 100 m thick sequence of conglomerate is exposed in faulted contact with the local Archaean basement. It consists of amphibolite lenses and diorite in the outcrop, but mainly of tonalitic orthogneiss in the larger area. The pebbles in the conglomerate consist of granite, quartz veins, gneiss, and sedimentary material. The base of the unconformity was not exposed.

The Ketilidian conglomerates in South-East Greenland have a medium potential to host uranium, as they were formed during the Palaeoproterozoic and are deposited near the boundary of the Archaean craton. The type of sedimentation is not described, but might be fluvial as on the South West Greenlandic coast. Only one outcrop has been described so far.

2.3.3 Grænseland and Midternæs conglomerates (D4-B)

The Grænseland and Midternæs conglomerates have been described above in the section 2.2.3 Grænseland (Borderzone) and Midternæs unconformity (D2-B). These quartz-pebble conglomerates have a high potential to host uranium, as they were formed during the Palaeoproterozoic and are deposited near the boundary of the Archaean craton. The sediments are transported by small streams and are locally derived.

2.3.4 Metasediments on southern Nuussuaq and in the Ataa domain (D4-C)

On Nuussuaq and in the Ataa domain east of the Northern Disko Bay four units of metasedimentary rocks were deposited.

The Saqqaq–Itilliarsuk Supracrustal Sequence consists of two 25 km long strips on southern Nuussuaq. It is considered a typical Archaean greenstone belt with a lower ultramafic–mafic metavolcanic portion and an upper part dominated by clastic metasedimentary rocks, gabbroic sills, and a series of up to 400 m of acid metavolcanic rocks (Garde & Steenfelt 1999). Lenses of conglomerate with meter-sized boulders suggest that the Saqqaq–Itilliarsuk supracrustal sequence was deposited unconformably on existing orthogneisses (Higgins & Soper 1999). The contacts between the Saqqaq–Itilliarsuk supracrustal sequence and Nuussuaq orthogneiss are intensely sheared (Connelly et al. 2006).

The Archaean Arveprinsen-Eqi Supracrustal Sequence in the Ataa domain resembles the Saqqaq-Itilliarsuk supracrustal sequence, but ultramafic and exhalative rocks and contains less clastic material. The rocks were metamorphosed at amphibolite facies conditions (Garde & Steenfelt 1999, Connelly et al. 2006).

The Palaeozoic metasediments on Nuussuaq have been correlated with the Mârmorilik Formation of the Karrat Group sediments (below, section 2.3.6 Karrat Group sediments (D4-E)), and were deposited unconformably on top of those (Garde & Steenfelt 1999). The sediments were metamorphosed at lower greenschist facies conditions.

The Palaeoproterozoic Anap Nunâ Group sediments in the Ataa domain are also correlated with the Karrat Group. It consists of platform and tidal flat sedimentary rocks, grading from sandstones to more silt and clay-rich rocks (Garde & Steenfelt 1999). The sediments are discordantly deposited on top of the Arveprinsen-Eqi Supracrustal Sequence and are mainly derived from the Archaean basement (Connelly et al. 2006).

Only very few conglomerates have been described in the four areas discussed above. The areas have a high potential to host a uranium-enriched unconformity. The clastic sediments in the areas have been derived from the nearby Archaean basement and were deposited during the Archaean and Palaeoproterozoic times. Uranium-enriched stream sediments have been collected in the area. The sediments in the area were metamorphosed at lower greenschist to upper amphibolite facies conditions, which might have had an influence on the concentration of the uranium.

2.3.5 Kome Formation conglomerates (D4-D)

The conglomerates of the Kome Formation, which is part of the Nuussuaq Group, have been described in section 2.2.4 Kome Formation in the Nuussuaq Group (D2-C). The conglomerates have a medium potential to host uranium, based on their composition of quartz-boulder conglomerate derived from an Archaean basement, and on the depositional environment with alluvial fan deposits and braided river systems. The transport of the sediments occurred at Cretaceous times and, therefore, was not under anoxic conditions (see Appendix 1). Dam et al. (2009) describe that no weathering of the basement-derived sediment during transport occurred en route and that the sediments host coal and large amounts of plant debris. Therefore, a reducing environment might have prevailed.

2.3.6 Karrat Group sediments (D4-E)

The Archaean granitoid-tonalitic orthogneisses (Umanak gneiss) in the Rinkian-Nagssugtoqidian Orogen are unconformably overlain by a thick and widely distributed sequence of metasediments of the Palaeoproterozoic Karrat Group (Henderson & Pulvertaft 1987). Both the orthogneisses and the metasediments were intruded by the large Prøven intrusive complex at 1869 Ma (Thrane et al. 2005). The Karrat Group sediments consist of three formations, the two lowermost, the Qeqertarssuaq Formation and Mârmorilik Formation might have been deposited simultaneously, but were separated by a basement high (see references in Henriksen et al. 2008).

The Mârmorilik Formation consists of a thin basal layer of clastics deposited on the eroded surface of the Umanak Gneiss and overlain by a succession of marbles, which make up the major part of the Formation (Pedersen 1980). The clastic sediments consist of irregularly interbedded quartzite, meta-arkose, semipelite, calcareous schists, and small pockets of conglomerate, which occur in depressions in the gneiss palaeosurface. The Qeqertarssuaq Formation consists of shelf and rift type clastic sediments, mainly metasandstones at the base and grading to semi-pelitic material. The quartzite and quartzitic schists contain sulphides and graphite. The upper Nûkavsak Formation consists of a flysch succession of interbedded greywacke and mudstone, now metamorphosed at amphibolite facies (Henriksen et al. 2008). Tectonic interleaving of the sediments with the Archaean basement gneisses by thrusting has also taken place such that locally Proterozoic supracrustal rocks occur as enclaves within Archaean gneisses, but nearly everywhere, the Qeqertarssuaq formation is in contact with the gneiss, even in areas where this formation is so thin that it is not shown on the map (Henderson & Pulveraft 1987). The contact between the orthogneiss and the Karrat Group has, to our knowledge, not been described in detail.

The Palaeozoic Karrat Group, which discordantly overlies Archaean orthogneisses, has a high potential to host uranium in a conglomerate deposit, as the sedimentation of the rocks occurred at the most ideal time (see Appendix 1), and evidence for reducing conditions has been observed in part of the sediment. Uranium-enriched stream sediments have been collected in the area. However, only a small amount of conglomerates were deposited; these are typicially located at the base of the Mârmorilik Formation. The sediments have been metamorphosed at amphibolite facies conditions. It is uncertain how this metamorphism has influenced an enrichment of uranium.

2.3.7 Conglomerates of the Thule Supergroup (D4-F)

The Thule Supergroup was discussed in 2.1.5 Thule Supergroup sandstones (D1-D). The Smith Sound Group and the Wolstenholme Formation of the Baffin Bay Group contain quartz-pebble conglomerates near the base of the Thule Supergroup. The Thule Supergroup has a medium potential to host uranium-bearing quartz-pebble conglomerates as the sediments are partially derived from an Archaean basement and deposited on a coastal plane in an extensional tectonic setting (see Appendix 1). However, the sediments are middle Mesoproterozoic and younger in age and partially derived from Palaeoproterozoic basement rocks and probably laid down under oxidizing conditions.

2.3.8 Independence Fjord Group sandstones including the Trekant Series and the sandstones and conglomerates in Kronprins Christian Land (D4-G)

The sediments in this section were discussed in more detail before; see section 2.1.6 Independence Fjord Group sandstones including the Trekant Series and the sandstones and conglomerates in Kronprins Christian Land (D1-E). Based on the criteria listed in Appendix 1, the conglomerates on Kronprins Christian Land and the Trekant Series have a low potential to host uranium. These conglomerates were deposited in Palaeoproterozoic times and are most likely derived from the Archaean and Palaeoproterozoic Basement that lies under the Inland Ice in North East Greenland. The sediments are fluvial and near shore deposits. However, the quartz-pebble conglomerates in the successions do not always directly overly the Precambrian basement; in many cases the lowermost units of the sequences are not exposed. Part of the sediments has been overprinted by metamorphism, and it is unknown in what way this affects the concentration of the uranium.

2.3.9 Central East Greenland basins conglomerates (D4-H)

The sandstones of the Central East Greenland have been covered in larger detail in section 2.1.10 Central East Greenland basins sandstones (D1-I). Deep water to fluvial conglomerates are abundant in the Carboniferous to Jurassic sediments and occasionally in the Cretaceous and Palaeogene sediments. The sediments are, however, too young (compared to the optimal age given in Appendix 1) and often derived from older sediments (Neoproterozoic and younger) and reworked material that was subject to the Caledonian orogeny, rather than primary Archaean basement. Therefore, it is assumed that the conglomerates in the Central East Greenlandic basins only have a low potential to be enriched in uranium.

2.3.9.1 Wegener Halvø (D4-H1)

Uranium mineralisation associated with phosphorite was found by Nordic Mining Company in the Devonian Red Beds of southern Wegener Halvø in 1975-76 during a follow up on uranium anomalies in pan samples (Hallenstein 1977). The mineralisation is hosted in the upper Devonian Quensel Bjerg Formation, which consists of fluvial sandstones and conglomerates. Mineralisation is found both in boulders and outcrops. It is assumed that several thin horizons are mineralised, but the detailed stratigraphy has not been studied. Analyses of six selected samples yielded values from 210-860 ppm U (Harpøth et al. 1986). Based on the presence of phosphorite, the outcrop could alternatively be classified as a phosphorite deposit. The licence for the area is currently held by Jameson Land Resources A/S, who are investigating the area for Cu and Zn.

2.4 Vein deposits (D5)

2.4.1 Introduction

Uranium-bearing vein deposits can be found in fractures, fissures, shear zones and breccias that are usually associated with major or subsidiary steeply dipping fault systems in all different rock types. However, the most common host rocks are granitic, commonly peralumious two-mica granites or syenitic rocks and their surroundings, including sheared or mylonitised rocks. Alteration zones in the host rock are common, and these can take many forms (see Appendix 1), but especially intense red hematite zones are typical. Individual deposits are often small, but clusters of enriched veins may result in a high tonnage for an entire area.

Veins with slightly elevated uranium concentrations can be found in large parts of Greenland. Therefore, we concentrate here on areas with tectonic and magmatic activity in the Proterozoic to Palaeogene (when the atmosphere had developed to oxygen-rich conditions) and list only the areas where known occurrences are located (Figure 11).

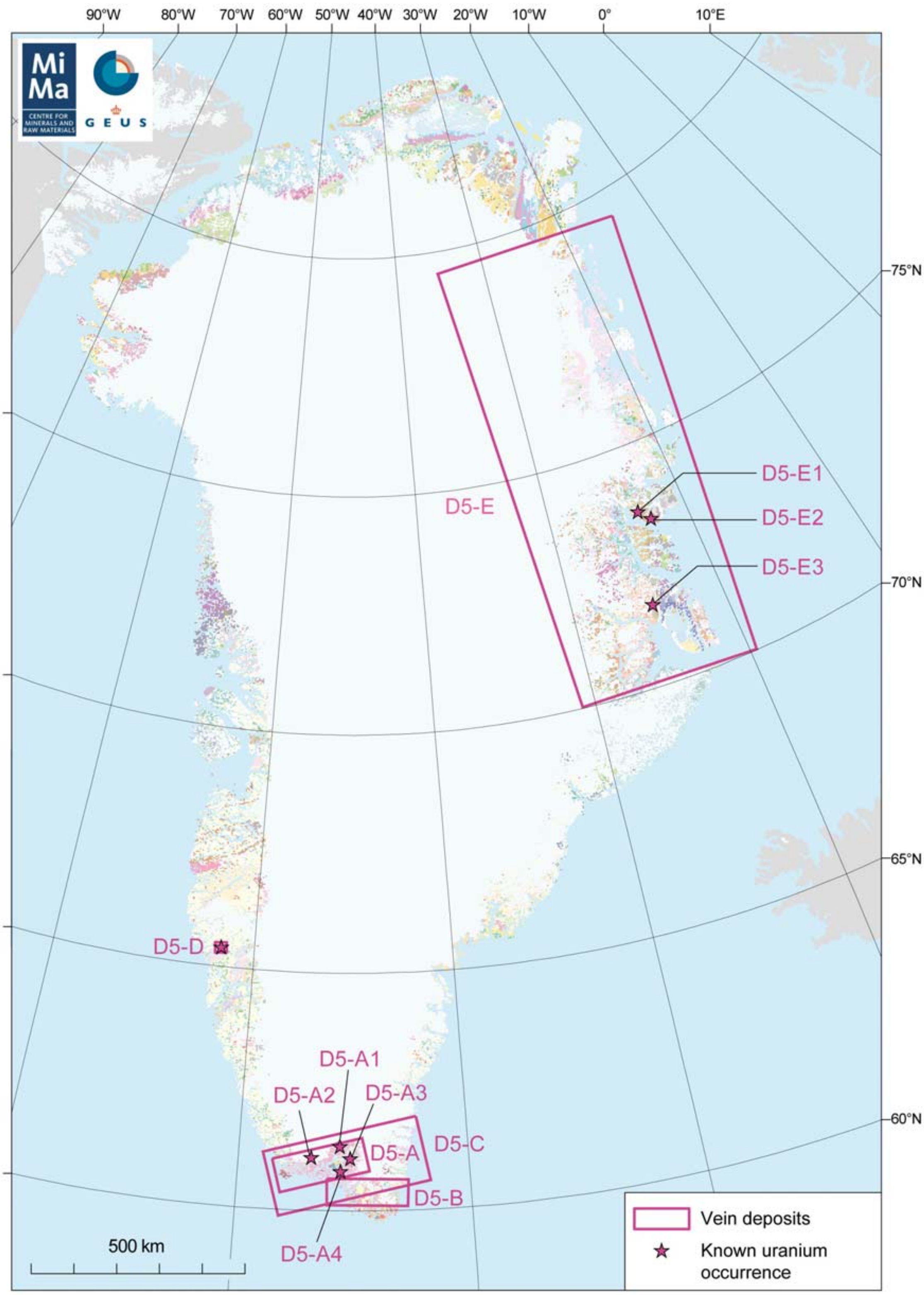


Figure 11: Geological map of Greenland showing the areas with a potential to host a vein-type deposit (uranium deposit type D5). Known Greenlandic occurrences are indicated with stars. Labels refer to chapters in the text.

2.4.2 Veins related to the formation of the Gardar province (D5-A)

The Gardar province of southern Greenland is an area where multiple known uranium-enriched veins occur (see Figure 12). Most veins occur in the Julianehåb batholith, but are related to Gardar province events. Therefore, we describe here first the Gardar province and then the Julianehåb batholith. The Mesoproterozoic Gardar province consists of sediments, volcanic deposits and alkaline igneous intrusive rocks placed in a rift setting. The sediments and volcanic deposits in the continental rift basin form an approximately 3400 m thick succession of sandstones and lavas of the Eriksfjord Formation (Poulsen 1964). Within and outside the rift, major central intrusions and numerous dykes were emplaced. The Gardar intrusive complexes range in age from *c.* 1300 to *c.* 1120 Ma. The larger complexes comprise central ring intrusions, complexes with several individual intrusive centres, and giant dykes (Emeleus & Upton 1976, Upton & Emeleus 1987). Several of these complexes are known uranium occurrences (see Chapter 2.5 on Intrusive deposits). The intrusive complexes are dominated by syenites, nepheline syenites, quartz syenites, and granites, while giant dykes mainly consist of alkaline gabbros and syenogabbros. Figures 3, 5, and 12 show that the whole Gardar province has potential to host more uranium-bearing veins.

The largest and central part of the Ketilidian orogen mainly consists of granites, granodiorites and monzonite, commonly with porphyritic textures, collectively known as the Julianehåb batholith. The batholith forms the basement for the Gardar province and the Ketilidian sandstones. The batholith was emplaced between 1868 and 1796 Ma in a sinistral transpressive setting (Chadwick & Garde 1996, Garde et al. 2002). The activity along major shear zones during emplacement of the batholith, caused deformation of locally a high intensity, hence the most intensely deformed parts of the batholith are now outcropping as gneisses on the geological map, while the major part is still granitic rocks. Basic and intermediate intrusions are also present. These were commonly emplaced simultaneously with felsic magmas, and may occur as mixed rocks in net-veined intrusions (Henriksen et al. 2009). Isotopic data show that the Julianehåb batholith is of juvenile Proterozoic origin (Garde et al. 2002) and does not represent reworked Archaean rocks.

2.4.2.1 Nordre Sermilik (Qingua and Ulungarssuaq) (D5-A1)

The area, consisting of granites of the Julianehåb batholith, was investigated during the Syduran project in 1980. Uranium occurrences are common and are especially related to faults and fractures. In addition, carbonate veins of calcite, siderite and barite are common and there are wide zones of alteration alteration in the fractures, particularly in the clayey fault gauge. This is presumably related to the many carbonatites, which are mapped in the area (Armour-Brown et al. 1984, Nyegaard & Armour-Brown 1986).

In Qingua, in a WNW trending fault, pitchblende is found in thin smears along the related fractures. In the part of the fault where the pitchblende occurs, the granite wall rock has been chloritised and laced with hematite, giving it a dark red colour. Radioactive hematitic and carbonate material occur in the same fault. No pitchblende is found, but samples yield over 1000 ppm U. More exploration is warranted in this area (Armour-Brown et al. 1984).

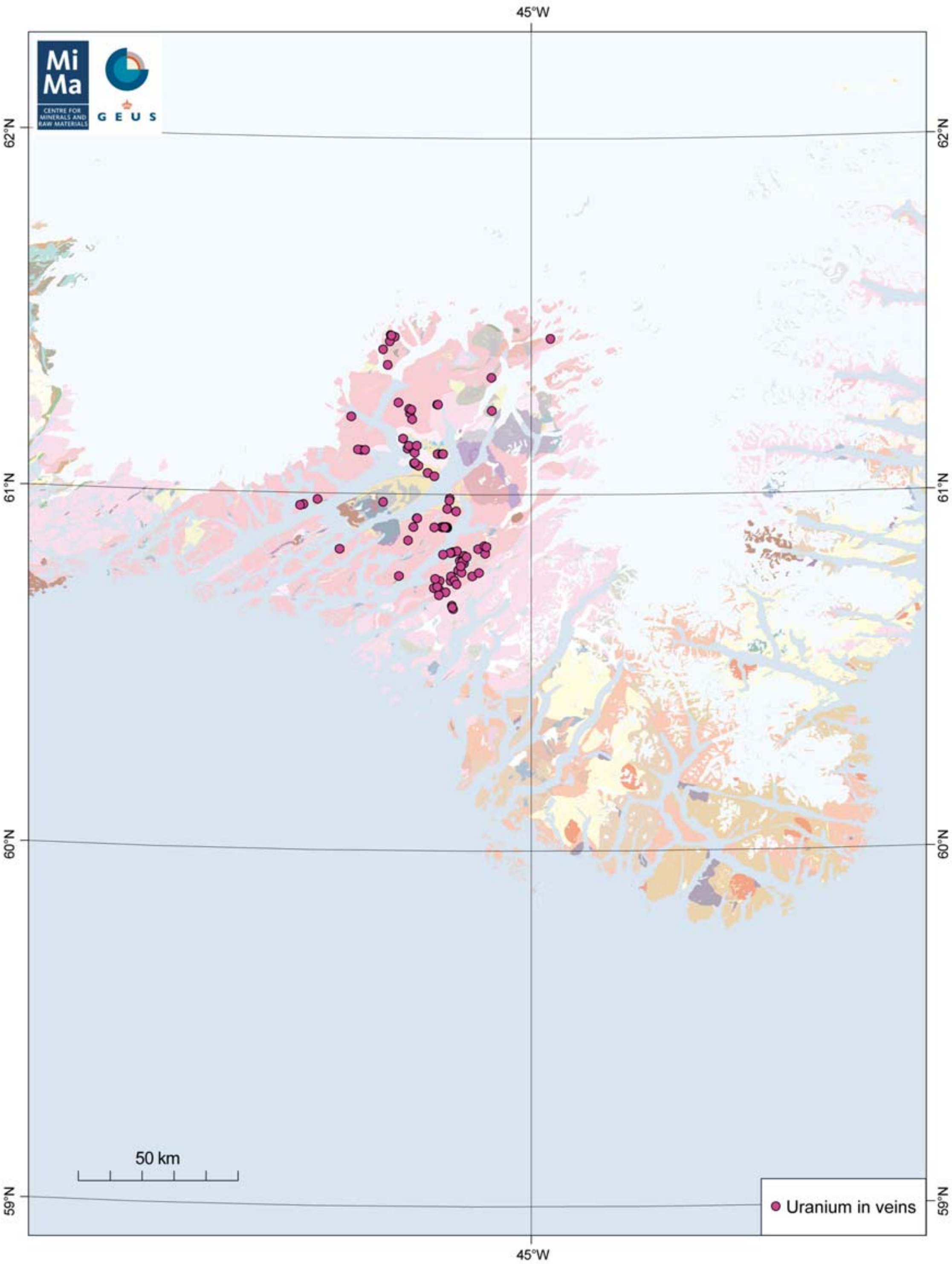


Figure 12: Vein occurences in South Greenland. The localities of the vein deposits are taken from the GEUS database GMOM. Veins in the Julianehåb batholith are associated with the Gardar province.

Several NNE reverse faults occur between Ulungarssuaq and Qingua. The eastern most faults can be traced for over 10 km; veins rich in uranium are present at a number of places along this fault. Pitchblende has been identified in one locality, and samples contain up to 3000 ppm U. Uranium is also disseminated in the sandstone overriding the fault – which contains up to 600 ppm. More exploration is necessary to assess the potential of this area (Armour-Brown et al. 1984).

2.4.2.2 North of Bredefjord (D5-A2)

The area was investigated in 1980 as part of the Syduran project. Eleven radioactive mineral locations, which contain more than 100 ppm U were found. The occurrences are mostly in veins and fractures with some associated minor sulphide minerals and hydrothermal alteration of the Julianehåb granite country rock. The occurrences are most likely hosted in 110° striking faults. In one location a large allanite crystal was sitting in a granite pegmatite (Armour-Brown et al. 1984).

2.4.2.3 Puissattaq (D5-A3)

The Puissattaq area is situated close to the Igaliko Fjord, about 10 km south-southwest of the settlement Igaliku. The basement consists of the Palaeoproterozoic Julianehåb batholith and the area is dominated by an E-W sinistral fault zone with a displacement of 150-200 m. Pitchblende accumulation and veinlets were already found in 1980 during the Syduran project. In 1982 the additional pitchblende veins were found in the northern part of the fault zone. The veins were not exposed, but were found by tracing radioactive boulders, often below the soil, with a scintillometer back to their source. Then veins were exposed after trenching and blasting. Two of the veins follow the direction of the major fault zone, and two have a trend, which is parallel with the direction of the tension direction (NE-SW). The veins have been followed for a maximum of 15 m and have a thickness of about 5 cm. The pitchblende veins are situated in dykes – three in dolerite dykes and one in a felsic dyke. Vein samples assayed by gamma-spectrometry contain from 0.7 to 6.3% U and very little thorium. Minor radioactive spots were also located in the fault zone in the Julianehåb Batholith and felsic dykes (Armour-Brown et al. 1984).

2.4.2.4 Vatnaverfi (including Eqaluit) (D5-A4)

This area is made up of the Palaeoproterozoic Julianehåb batholith and covers the region south of Igaliko Fjord and east of Equaluit. The area was initially investigated during the Syduran project. Geochemical stream sediment surveys proved anomalously high uranium concentrations in the area. In 1982, a great number of faults and fractures in the basement were checked for radioactivity covering an area about 200 km^2, and many radioactive mineral occurrences were found. Exposure is rather poor, and most of the radioactive localities are small, (less than one m^2), but several have been found to extend 50-150 m along the fault zone. In many cases a lineament has several localities with radioactive occurrences along its trend. A good example is a 5 km long, ENE striking fracture zone intruded by a 5-7 m wide lamprophyric dyke. In the contact zone between the Julianehåb batholith and the dyke many uraniferous occurrences were found. The mineralised zone varies between 0.5 and 1 m in width.

In several fault zones, pitchblende has been found as veins or irregular bodies. One pitchblende vein can be followed 1.5 m and is 1-2 cm wide; other veins are only 10-20 cm long and 1-2 mm thick. Besides pitchblende, brannerite is the most common U-mineral in the area. The distribution and the mineral genesis suggest that hydrothermal fluids circulated in the many fractures. The possibility of finding more and larger uranium occurrences in the area is considered to be good (Armour-Brown et al. 1984, Nyegaard & Armour-Brown 1986).

2.4.3 Veins in the psammite zone, South Greenland (D5-B)

The psammite zone in South Greenland is an area with known occurrences of uranium-enrichment in veins. The psammite zone was described in section 2.1.2 Psammite zone (metasandstone), South Greenland (D1-A). The psammite zone has medium potential to host a vein-deposit as the psammites were formed in the Palaeoproterozoic, the general area is enriched in uranium, and shear and fault zones occur in the area.

2.4.4 Veins in the Julianehåb batholith (D5-C)

All veins inside the Julianehåb batholith seem to be associated with the later Gardar intrusions, which were discussed above, see section 2.4.2 Veins related to the formation of the Gardar province (D5-A). Outside the area affected by the Gardar intrusions, a much lower potential to find a uranium vein-deposit is present.

2.4.5 Veins associated with the Qaqarssuk carbonatite complex (Qeqertaasaq) (D5-D)

The Qaqarssuk carbonatite complex, east of Maniitsoq, was found in 1965 by Kryolitselskabet Øresund A/S. The carbonatite intruded into the Archaean basement as dykes and veins over several generations during the Jurassic (165.7 ± 1.9 Ma) (Larsen et al. 1983, Secher et al. 2009). It covers an area of 15 km^2 of which 15% consists of largely concentric steeply outward-dipping ring-dykes. During the years after the finding, the complex was mapped, radiometric and magnetic surveys were carried out and 248 drill holes were made (Gothenborg & Pedersen 1975).

The complex is composed of different types of carbonatites, the most common being sövite, silico-sövite and dolomite carbonatite (rauhaugite). The outermost carbonatite ring-dyke in the complex is the fine-grained dolomite carbonatite, rich in deformed and corroded fenite inclusions. Radioactive, narrow ferrocarbonatite dykes (beforsite) and vents, rich in altered basement fragments, are found in the highly altered basement, often located in shear zones with a higher radioactivity. The ring-dykes are cut by coarse-grained late stage sövite and REE carbonatite veins. Pyrochlore occurs in these late stage sövite veins, which are locally enriched in U, Th, Ta, Ba and REE. Pyrochlore enriched in U and uranopyrochlore also occur in the fenite zone (Knudsen 1991). The average values in the sövitic carbonatite are 1 ppm U, but close to the southern margin values up to 180 ppm U occur.

Currently, NunaMinerals A/S is holding the license for the area. NunaMinerals considers the complex as a multi-element deposit, with potential for producing REE, Nb and Ta, with important potential by-products including P, Sr, Zr and Zn. Additionally, a number of untested uranium anomalies exist within the complex. The Qaqarssuk carbonatite complex prospect has recently been renamed to Qeqertaasaq by Nuna Minerals.

2.4.6 East Greenland (D5-E)

Large parts of East Greenland and North-East Greenland were subject to several orogeny episodes, in the Archaean, Palaeoproterozoic, Mesoproterozoic, Silurian (the Caledonian orogeny) and Palaeogene. During these events bodies of granites and veins intruded into the country rock. The post-Devonian regional fault zone is very important for accommodating hydrothermal mineralisation with a range of elements including U (Harpøth et al. 1986).

2.4.6.1 Moskusokseland (D5-E1)

Minor uranium mineralisation was discovered near Hochwacht in the hinterland during the Geological Survey of Greenland's regional uranium exploration programme (Steenfelt 1976). The mineralisation is associated with Devonian acid volcanics. Scattered pitchblende and beta-uranophane occur in veinlets and disseminated in the volcanics at several localities, but only in negligible amounts. Selected samples contain up to 1% U (Harpøth et al. 1986, Steenfelt 1982). Steenfelt (1982) relates the mineralisation to the Devonian acid magmas and to the Post-Devonian Main Fault, and proposed an epigenetic model in which uranium was remobilised and introduced postmagmatically.

ARC Mining holds the license for the area.

2.4.6.2 Foldaelv, Gauss Halvø (D5-E2)

During reconnaissance by Nordic Mining Company in 1981 minor vein mineralisation was encountered at the mouth of the Foldaelv valley, Giesecke Bjerge (Thomassen 1982). Several veins up to 0.5 m thick and with lateral extension of a few tens of meters are hosted in granite of probable Devonian age. The gangue is predominantly quartz and fluorite, and the larger veins contain dm-sized pockets of massive pyrite. Minor disseminated chalcopyrite occurs throughout the veins. Grey mm-sized inclusions of pitchblende, chalcopyrite intergrown with galena, tetrahedrite, and minor amounts of sphalerite, pyrite, marcasite and gold occur in calcite. Pitchblende is found partly as 0.5 mm large, rounded inclusions with shrinkage cracks and partly as larger aggregates. A selected sample contained 600 ppm U, but in general the grade is much lower. The veins are probably associated with the Devonian magmatic event (Harpøth et al. 1986).

ARC Mining holds the licence for the area.

2.4.6.3 Nedre Arkosedal (Stauning Alper) (D5-E3)

The uranium mineralisation is located in a major fault zone forming the contact between the Caledonian terrane of Mesoproterozoic migmatitic rocks intruded by Caledonian granite and the Lower Permian continental clastics of the Jameson Land basin (Hallenstein 1978). The locality was first observed in 1956 by the Lauge Koch Expeditions. Reinvestigations by Nordmine in 1970 of the lead-zinc-bearing fluorite vein at Nedre Arkosedal revealed high uranium concentrations. Subsequent prospect investigations in 1971 and 1975 included geological and radiometric mapping, trenching, chip and channel sampling and the drilling of a 9.1 m drill hole (Hallenstein 1976). Uranium found in two veins displaying distinct yellow, limonitic zones. The main uranium mineralisation is restricted to brecciated and mylonitised granite and occurs as fine-grained pitchblende in fluorite. The main mineralisation is located at the intersection of two faults. At surface the total strike length is about 200 m and it varies between 5 and 10 m in thickness. 251 surface samples have an average of 252 ppm U with maximum of 3427 ppm. The smaller vein is *c.* 40 m long; the best 2 m of this section average 3100 ppm U. Selected samples from the smaller vein contain up to 2.3% U (Harpøth et al. 1986).

Avannaa Exploration Ltd. is currently holding the licence for the area. They are investigating for Zn, Cu, and Sr.

2.5 Intrusive deposits (D6)

2.5.1 Introduction

Two subtypes of uranium-enriched intrusive deposits are recognised (Appendix 1):

1a. Alaskite type: disseminated uranium occurs in medium to very coarse-grained alaskite bodies (leucocratic, quartz and alkali feldspar-rich granites).

1b. Pegmatite type: uranium in un-zoned granitic and syenitic pegmatitic dykes (siliceous and mafic tendency with aegirine and augite).

2a. Granite, monzonite type: very low-grade uranium disseminations occur in highly differentiated granitic to quartz-monzonitic complexes.

2b. Peralkaline syenite type: low-grade uranium disseminations occur in peralkaline syenitic domes or stocks.

2c. Carbonatite type: disseminated uranium occurs in cupriferous carbonatite complexes.

Uranium enrichment has been documented in syn- to post-orogenic intrusions within intracratonic fold belts and in intrusives emplaced in extensional settings (rift setting). For peralkaline syenites fractional crystallisation is critical in concentrating uranium in the melt as it ascends through the crust. A peralkaline composition is the most effective chemical mechanism for maintaining uranium solubility, which prevents the melt from partitioning of uranium into early accessory phases such as titanite, zircon and monazite in relatively low concentrations at an early stage of the magma crystallisation. Melting of crustal material, and in some cases also further hydromechanical and structural processes, are necessary to create an economic deposit of alaskite bodies, monzogranites and pegmatite occurrences.

A map over the known and potential areas of this deposit type is shown in Figure 13. In the literature on the Greenlandic intrusions, a distinction between (quartz)-monzonite, alaskite, or other types of granites has not always been made, nor are the ratios between these minerals always indicated. This report concentrates on felsic or leucocratic granites that are rich in quartz, alkali-feldspars and plagioclase to cover the alaskite and monzonite potential. Pegmatites occur in large parts of Greenland and therefore only pegmatite areas with other indications for uranium potential (e.g. the presence of allanite or an enhanced radioactivity in the area) are discussed here.

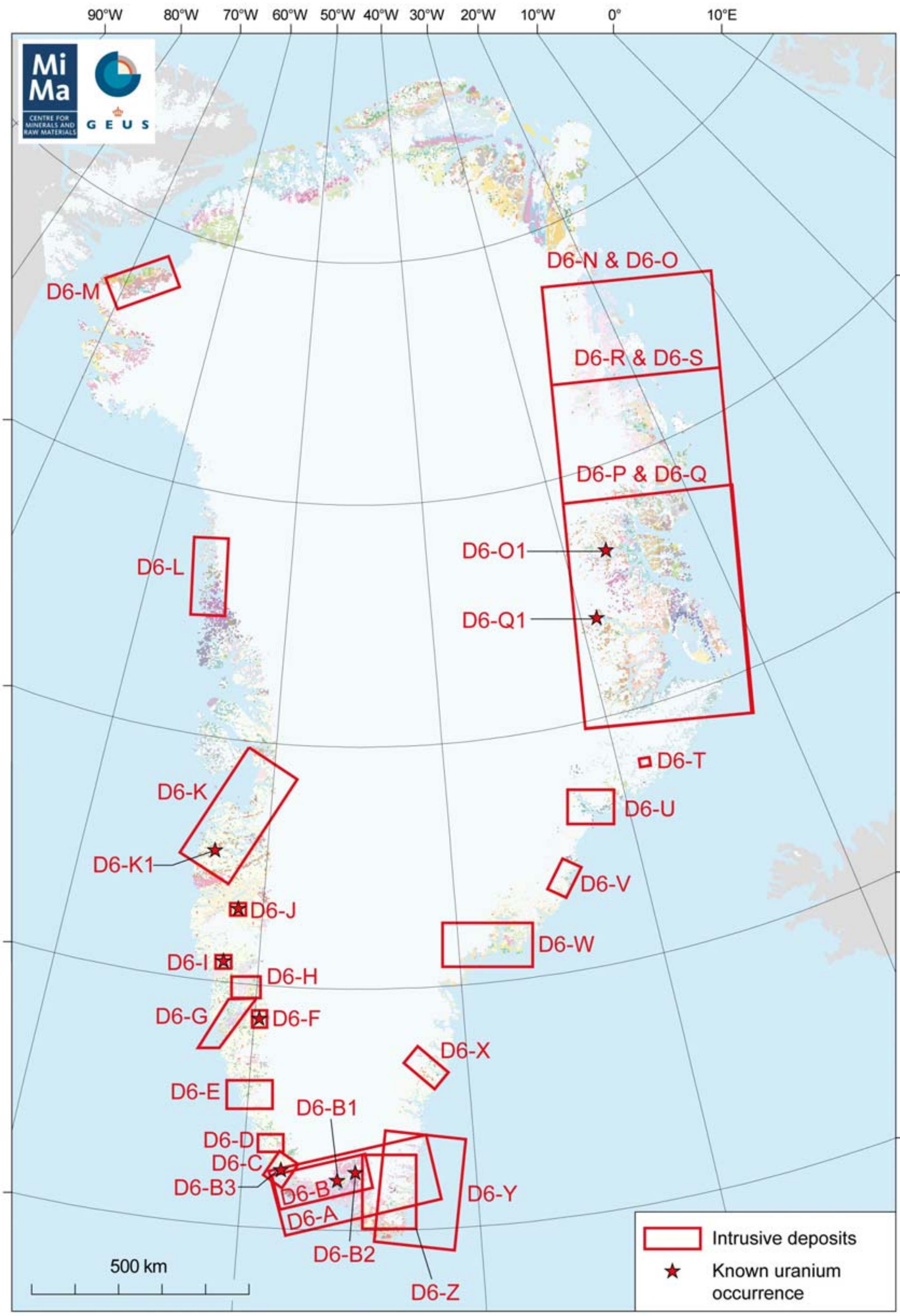


Figure 13: Geological map of Greenland showing the areas with a potential to host an intrusive deposit (uranium deposit type D6). Known Greenlandic occurrences are indicated with stars. Labels refer to chapters in the text.

2.5.2 Granites in the Julianehåb batholith (D6-A)

The Julianehåb batholith has been described in section 2.4.2 Veins related to the formation of the Gardar province (D5-A). The Julianehåb batholith has a medium potential to host a uranium deposit. The batholith intruded in a synorogenic setting. However, intensive studies in the area have so far not revealed elevated uranium concentrations in the granite.

2.5.3 Gardar province (D6-B)

The Gardar province has been described in more detail in section 2.4.2 Veins related to the formation of the Gardar province (D5-A). The large Kvanefjeld deposit of the Ilímaussaq alkaline complex and the large Motzfeldt Complex are located in the Gardar province.

2.5.3.1 Kvanefjeld (Kuannersuit) (D6-B1)

The Mesoproterozoic Ilímaussaq alkaline complex in the Gardar Province hosts the REE-U-Zn-F deposit referred to as Kvanefjeld, or in Greenlandic, Kuannersuit. It is intruded into the Palaeoproterozoic Julianehåb Granite and the unconformably overlying Mesoproterozoic Eriksfjord formation comprising sandstone and basalt. Kvanefjeld represents the top of the Ilímaussaq intrusion and is composed of hyper-agpaitic lujavrites and naujaite. It is the largest of the known uranium occurrences in Greenland and the only one, which is described in great detail. It is a unique type of uranium deposit where the majority of uranium is hosted by the complex phosphor-silicate mineral steenstrupine, containing 0.2-0.5% UO_2. The host rock, lujavrite, contains 200-400 ppm U and 600-800 ppm Th, the typical Th/U ratio lies between 2-3. The enrichment of uranium (and thorium) is thought to have occurred during crystallisation and differentiation of the agpaitic rocks (Sørensen et al. 1974). Research organisations and private exploration companies have evaluated the economic potential of Kvanefjeld since it was discovered in 1956. Prior to the introduction of the “zero tolerance” policy, detailed geological mapping and radiometric acquisition have been carried out, approximately 11 km of core was drilled and a 1 km long adit was constructed. Numerous reports and scientific articles have been published; see e.g. Sørensen et al. (2001), Rose-Hansen et al. (2001) for an overview.

Since 2007, the area has been explored for REE, and the current license-holder is Greenland Minerals and Energy Ltd. (GME). Since the renewed exploration additional REE (and U) resources have been assessed in two other lujavrite bodies, the Sørensen Zone and Zone 3. An additional *c.* 58 km of core has been drilled. GME reports on their homepage that the inferred tonnage of the overall resource inventory of Kvanefjeld, the Sørensen Zone and Zone 3, is 956 Mt containing 575 Mlbs U_3O_8 (at a 150 ppm U_3O_8 cut off).

2.5.3.2 Motzfeldt Complex (D6-B2)

The Mesoproterozoic Motzfeldt Centre within the Igaliko alkaline intrusive complex is part of the Gardar Province. It is made up of multiple intrusions of syenite and nepheline syenite, covering an area of 45 km^2. It is emplaced as two main igneous episodes into the Proterozoic Julianehåb batholith and the unconformably overlying Gardar supracrustal rocks. It contains an extensive U-Nb-Ta-Zr-REE mineralisation that was discovered by the reconnaissance surveys of the Syduran project (Armour-Brown et al. 1982a). The coarser syenitic rocks are intruded by sills or sheets of microsyenite in the north and northeast part of the Motzfeldt Centre. At least two sets of faults cut the intrusion; the older generation of faults strikes SW-NE and those of the younger generation strike E-W. Uranium is hosted in pyrochlore, which is concentrated in a 200-300 m wide zone along the outer margin of the intrusion. The mineral is hosted in both peralkaline microsyenite and altered syenite (Thomassen 1988). The micro-syenite contains 100-500 ppm U and up to 1% Th. Metasomatic processes enriched uranium in zones to concentrations larger than 500 ppm, which extend over several 100 meters. The width of most zones lies in the range several m-100 m, but few are wider than 100 m. The altered rocks are also enriched in Zr, Nb, Ta, REE and Th. Pyrochlore contains 3-9% UO_2 and 0-0.25% ThO_2, with a typical Th/U ratio of 0.5-1.5 (Tukiainen 1986).

Presently, RAM Resources Ltd. has licensed the area and undertakes exploration for REE, Nb and Ta.

2.5.3.3 Ivigtût Granite and associated cryolite body (D6-B3)

The Ivigtût intrusion (1250 Ma) is one of the most evolved granite complexes in the Gardar Province. The unique cryolite body in the intrusion was mined from 1854 to 1984. The Kryolitselskabet Øresund A/S carried out the first investigations around the cryolite mine to look for radioactivity. The main U occurrence was associated with columbite in marginal areas of the cryolite body. The main cryolite body has been mined today, and the mine abandoned; some remaining tailings are stored adjacent to the mine site. The majority of the tailings have been reprocessed. A halo of radioactivity around the Ivigtût intrusion has been recognised and investigated; it contains 50-100 ppm U in the highly altered granites, the U/Th ratio is approximately 1:4 (Pauly 1960).

Rimbal Pty. Ltd. currently holds the license for the area, investigating for ultra-pure quartz.

2.5.4 Pyramidefjeld area (D6-C)

Pyramidefjeld is a granite complex of Palaeoproterozoic Ketilidian age intruded into Archaean basement gneiss of the Ketilidian border zone. Slightly further to the south four other granite complexes of the same age and composition are found (around the 61° latitude), West Sánerut granite, Storø granite, Quiartorfik granite, and Tavdlorutit granite (see Kalsbeek & Taylor 1985). The intrusions formed post-deformation. The Pyramidefjeld granite complex consists of two granite stocks emplaced side by side and veins that protrude into the surrounding gneisses (Berthelsen & Henriksen 1975). The main rocks contain coarse to medium-grained granites (sensu stricto) that contain microcline, microperthite, acid oligoclase, quartz, biotite, allanite, apatite, fluorite, titanite, zircon and opaque minerals. The other four bodies have similar composition. Fluorite is typical for all granites except the Tavdlorutit granite, but aplite dykes and pegmatites are associated with these five granites. The West Sánerut, and Quiartorfik, and Tavdlorutit granites contain alkali feldspar phenocrysts (Berthelsen & Henriksen 1975). The emplacement of the granites is related to the formation of the Ketilidian mobile belt, but the granites consist of large proportions of earlier Archaean material (Kalsbeek & Taylor 1995).

The Pyramidefjeld area has a medium potential to host uranium-enriched intrusions: the area showed a major tectonic activity in the Palaeoproterozoic and the granites consist of partially melted older material (compare to Appendix 1).

2.5.5 Granite northeast of Neria (D6-D)

A larger relatively homogeneous granitic body of ca. 20 x 7 km outcrops northeast of the end of the fjord called Neria (*c.* 40 km south of Paamiut). The granites are leucogranitic to trondhjemmitic biotite granites with gradiational contact to their surrounding gneisses and including nearly intact bands of amphibolite and mica schist. Smaller masses of very white granite occur throughout the body (Higgins 1990). The granite intruded post-tectonically and was dated to *c.* 2600 Ma (T. Kokfelt, unpublished data 2011).

Not enough information is available on the Neria granite to evaluate its potential to host a uranium deposit.

2.5.6 Nukaqpiarssuaq granite (Bjørnesund area) (D6-E)

The Nukaqpiarssuaq granite is the largest of a series of granites sensu lato that intruded into the fold axial plane that defines the Bjørnesund Supracrustal belt (Keulen et al. 2011). The granites are mostly biotite-bearing, medium-grained, homogeneous intrusive rocks that have been slightly deformed. Schlatter & Stensgaard (2012) observed that samples collected near the fjord Bjørnesund contained feldspars that are very rich in albite and poor in orthoclase, concluding that these intrusive rocks are trondhjemites. The rocks further to the east are more granitic in composition and rich in baddeleyite-bearing zircons (Lewerentz 2010). Melting of the granodioritic gneiss and intrusion along the same generation of fold axial planes occurred contemporaneously with the intrusion of the granites in the area north and south of the Bjørnesund Greenstone Belt (Keulen et al. 2011). Gold-enrichment in the area is thought to have occurred simultaneously with the intrusion of the granites (Kolb et al. 2013a, Keulen et al. subm.). Later tectonic activity in the area concentrated the gold (Kolb et al. 2013a) and might also have concentrated uranium.

The Nukaqpiarssuaq granite and surrounding granites have a low potential to bear uranium, as they were intruded synorogenically in an intracratonic fold belt.

2.5.7 Tikiussaq (D6-F)

The Late Jurassic Tikiusaaq carbonatite complex was discovered in 2005 by GEUS (Steenfelt et al. 2006) and further studied during 2006 and 2007. The Tikiusaaq complex comprises massive carbonatite sheets, carbonatite veins and ultramafic lamprophyre dykes. The exposed carbonatite sheets cover 2 by 3 km, and the alteration zone surrounding the carbonatite complex veining extends up to 14 km in diameter. Remote sensing data suggest that a massive carbonatite is hidden below the glacial terraces. The carbonatite contains accumulations of apatite and multi-element mineralisation with Ba, REE, U and Li. Just as elevated values of Nb, Ta, Mg and Be have been recorded. Uranium values up to 169 ppm have been recorded in the carbonatite, while surface samples have yielded up to 243 ppm U (Steenfelt et al. 2007).

NunaMinerals A/S holds the license for the area, and explores it as a REE project. It contains up to 9.6% total REE-oxides in a carbonate float, according to their homepage.

2.5.8 Nuuk region (D6-G)

The Nuuk region, southern West Greenland, has a relatively high level of background radiation, compared to other areas in Greenland (Steenfelt 2001). The enrichment recorded in the U channel of the airborne gamma spectrometry is associated with numerous Neoarchaean pegmatites intruding the supracrustal belts. Allanite, uraninite and euxenite are common in biotite-rich part of leucopegmatites. The sizes of the pegmatites vary, but many are 2 to 10 m wide and can be followed for hundreds of meters. The radioactive minerals usually appear as fine-grained material. However, allanite also occurs as course crystals of up to 5 cm in length. U content in the pegmatites generally ranges from 10-70 ppm, but uraninite-rich samples have reached 6000 ppm U (Secher 1980).

The radioactive pegmatites occur mainly along the Ivinnguit fault zone e.g. on Storø and Sermitsiaq. The emplacement of the pegmatites on Storø occurred during crustal-scale thrusting in the Storø shear zone around 2630 Ma (Hollis *et al.* 2006).

Mineralisation with uraninite forming up to 2 mm crystals has been encountered in amphibolites on Storø. A rock sample returned 8000 ppm U in uraninite (Steenfelt pers. comm. 2013).

In the Nuuk area between Storø in the Godthåbsfjord and Ameralik, the Qôrqut granite complex is outcropping. The granite is a potassium-rich nearly undeformed body that has been dated to *c.* 2550 Ma (Moorbath et al. 1981). The granite has a highly complex internal structure with many sheets of different phases of granitic rocks, rafts of country rock (mainly orthogneiss), and more massive granitic parts. The major part of the complex consists of granites *sensu stricto*, which can be divided into early leucocratic granites, grey biotite granites, and composite aplogranites and pegmatitic sheets. The most common mineralogy is medium grained quartz, Na-plagioclase, microcline and biotite (Brown et al. 1981).

Compared to many other areas in Greenland, the Nuuk region has been relatively well studied. However, only a few small occurrences of uranium have been detected so far. Based on the presence of uranium-bearing samples, the felsic post-tectonic Qôrqut granite and numerous pegmatites in the area, the Nuuk region has a medium potential to host an intrusive uranium deposit.

2.5.9 Qugssuk Granite (D6-H)

The Qugssuk granite is a late-tectonic granite that intruded during the final stages of the accretion of the Akia terrane. It formed by partial melting of grey orthogneiss after a granulite facies event in the region. The Qugssuk granite consists of a number of steep-dipping sheets and a dome. It is a two-feldspar-biotite granite. The Qugssuk granite was emplaced at 2.97 Ga (Garde et al. 2000). Later tectonic activity in the area concentrated gold (Kolb et al. 2013a).

The Qugssuk granite has a medium potential to bear uranium, as it was intruded postorogenically in an intracratonic orogenic belt.

2.5.10 Qaqarssuk carbonatite complex (Qeqertaasaq) (D6-I)

The Qaqarssuk carbonatite complex has been described in section 2.4.5 Veins associated with the Qaqarssuk carbonatite complex (Qeqertaasaq). The Qaqarssuk carbonatite complex prospect has recently been renamed to Qeqertaasaq by Nuna Minerals.

2.5.11 Sarfartoq (D6-J)

The Sarfartoq carbonatite complex was found by airborne radiometric surveys carried out in 1975-76 by the Geological Survey of Greenland. The carbonatite was emplaced at 560 ± 13 Ma in a zone of weakness in the Precambrian shield (Larsen et al. 1983, Secher et al. 2009). It comprises a core area of carbonatite and Na-fenite (15 km^2), mantled by a marginal zone of hydrothermally altered gneisses (K-fenite) with carbonatite dykes (beforsite) (75 km^2). The carbonatite rocks of the core occur as concentric sheets dominated by rauhaugite and sövite occurs only occasionally in schlieren. Pyrochlore occurs both sporadically in the core sövite with peak values up to 400 ppm as disseminated accumulation within the marginal zone. Pyrochlore veining and brecciation are also found as 1-5 m wide monomineralic veining.

Uranium values up to 1% in the veins of the marginal zone are consistently explained by high modal content of pyrochlore and accordingly with Nb content reaching 40 vol% (Secher & Larsen 1980). The pyrochlore mineralisation has been dated separately and is thought to represent an initial burst of the magmatism around 600 Ma. The main carbonatite (rauhaugite) is typically carrying euhedral apatite prismatic crystals with a mean amount of 3.5 wt% and a maximum up to 12 wt%. REE are observed in anomaleous concentrations in carbonate as well as in phosphate minerals gathered in so-called radioactive shear zones that are accompanied with thorium as the predominant fissile element. At the end of the carbonatite activity, hydrothermal activity apparently reached the surface, and hot circulating water locally dissolved the carbonatite (Secher 1986). This hydrothermal activity is thought to have caused the mobilisation of uranium.

Exploration activities conducted by Hecla Mining Company in 1989 were focused on the pyrochlore occurrence located within veining. A total of 13 drill holes (568 cored meters) were sited and drilled into the subsurface extension of a N70ºE-trending mineralised zone. Pyrochlore mineralisation occurs as massive replacement, thin veins and disseminations within the veined zone.

Results of the diamond drilling programme based on assayed core intervals show a relatively wide and continuous low-grade (1-10% Nb_2O_5) envelope enclosing discontinuous pockets and lenses of high-grade (>10%)) pyrochlore material. The mineralisation pinches-out laterally along both ends of the zone and becomes thin and discontinuous at depth. The estimated tonnage at a cut-off grade of 10% Nb_2O_5 is apparently 25,000 – 30,000 Nb_2O_5 tons within Sarfartoq.

The resources estimate of the pyrochlore project has later been recalculated by new owners (New Millennium Resources Ltd.), resulting in an inferred resource of 350,000 tons at a cut-off grade at 2.5% Nb_2O_5.

Hudson Resources Inc. currently has licenced the area and are investigating the REE, Nb, and Ta potential. They have discovered a REE mineral resource in more separate radioactive shear zones within the marginal areas, where thorium is enriched. Hudson Resources drilled over 30,000 m on several zones of that target.

2.5.12 Granites in the Nagssugtoqidian orogen (D6-K)

The granites and granitic gneiss in the central and northern part of the Nagssugtoqidian orogeny consist of a number of small and large bodies. Coarse grained, homogeneous pink granite predominates and locally grade into megacrystic granite, sometimes with rapakivi-textures, pink microgranite, or pegmatite. Both foliated and unfoliated granites occur (Van Gool et al. 2002). Undeformed granite samples collected near Aasiaat and analysed with TIMS for U-Pb ratios in zircon yielded an intrusive age of 2778 Ma (Connelly & Mengel 2000).

During the airborne radiometric survey carried out in 1975-76 by the Geological Survey of Greenland were several anomalies registered that are hosted in the Attu area. Especially the granites yielded rather high radioactivity (Secher 1976). Stendal et al. (2004) studied the Attu occurrence in more detail, while investigating for gold, and related the anomalies to the pegmatites intruding the gneiss. The pegmatites contain large magnetite and allanite crystals and occasionally pyrite. To date, no elevated uranium values have been detected, but one sample showed 1790 ppm of Th in allanite. The licence for the area near Attu is currently held by Greenland Minerals and Energy Ltd and Kavanaru Oil Exploration Corp. who explore the area for graphite, Ni and Cu.

The granites in the Nagssugtoqidian orogeny have a medium potential to host a uranium deposit. The granites and pegmatites are felsic in composition and contain allanite and monazite. One of these occurrences with uranium-enrichment, Nassuttooq, is described below:

2.5.12.1 Nassuttooq (D6-K1)

A cluster of U occurrences is present within the granulite facies reworked Archaean basement South of Nordre Strømfjord. Several bodies of quartz-plagioclase-biotite pegmatites are intruding the basement. They are typically 5 x 50 m in size and are rich in monazite crystals. Dating has been performed on magnetite and monazite, resulting in an intrusion age of around 1800 Ma. The monazites range from 0.5-5 mm in diameter and apart from REE they average *c.* 50 ppm U and 1000 ppm Th (Secher 1980, Stendal et al. 2004, Stendal et al. 2006).

2.5.13 Granites related to the Prøven Igneous Complex (D6-L)

The Prøven Igneous Complex covers an area of more than 100 km in diameter and intrudes into the Rinkian orogenic Belt e.g. Archaean orthogneiss and Karrat Group metasediments near Upernavik. The complex has been dated to 1869 Ma (Thrane et al. 2005). A large part of the Prøven Igneous Complex consists of charnockite. Leucocratic garnet granite occurs in the region between the Prøven Igneous Complex and towards the north, where they intrude into the basement gneiss and the migmatites as lit-par-lit veins and thicker sheets. The leucogranites are probably associated with the Prøven Igneous Complex and intrude into it (Escher & Pulvertaft 1968, Escher & Stecher 1978).

The granites north of the Prøven Igneous Complex have a medium potential to host a uranium deposit. Their composition and possible relation to the Prøven Igneous Complex are favourable.

2.5.14 Alkaline intrusions in Inglefield orogenic belt (D6-M)

The Inglefield orogenic belt, or Inglefield Mobile Belt, is interpreted as a Palaeoproterozoic orogen, formed by the collision of Archaean crustal blocks (Dawes 2004, Nutman et al. 2008a, Henriksen et al. 2009). The northern part of the orogen consists of Archaean orthogneisses and high grade metasedimentary rocks (paragneisses and marbles) of the Etah Group, which were deposited between 1980 and 1915 Ma. The Etah Group and the orthogneisses were intruded by intermediate to felsic plutonic rocks, the Etah meta-igneous complex, consist of diorite and granites (1950-1940 Ma), syenitic and monzonitic rocks (*c.* 1920 Ma). Most intrusive rocks are heavily to moderately deformed, but post-tectonic granites are also found (1780-1740 Ma). The older intrusive rocks are regarded as juvenile intrusive rocks, while the younger granites result from crustal melting. The syenitic and monzonitic rocks are fine- to coarse-grained feldspar rich intrusive rocks with a variable amount of quartz. The rocks are commonly altered, resulting in reddish feldspars and a green colouration after former mafic minerals. Elevated values for uranium in stream sediments within the Inglefield Mobile Belt are associated with late veins (Steenfelt & Dam 1996).

The southern part of the Inglefield orogenic belt consists of the Prudhoe Land supracrustal complex and the Prudhoe Land granulite complex, which consists of metamorphosed sediments of Palaeoproterozoic age and a gneiss complex respectively. The sediments were deposited between 2250 and 1920 Ma and gneiss protolith intrusion age is set to 1984 Ma. Various faults and dykes crosscut the area and are related to both the orogenic activity and later tectonic activity in the region, the major structure is the E–W-trending Sunrise Pynt Straight Belt at *c.* 78°20´N, which is part of the Inglefield orogenic belt (Dawes 2004).

The Inglefield orogenic belt has a medium potential to host uranium-enriched intrusions: the area showed a major tectonic activity in the Palaeoproterozoic, which was associated with the syntectonic intrusion of granitic and syenitic rocks (compare to Appendix 1).

2.5.15 *c.* 1900 Ma granites in North-East Greenland and Central East Greenland (D6-N)

The *c.* 1900 Ma granitic rocks in North-East and Central East Greenland contain substantial components derived from the preexisting Archaean crust. It is probable that these granites were formed by anatectic melting of Palaeoproterozoic sediments, derived from an Archaean continent and deposited in an accretionary wedge adjacent to a continental margin. They are Ca-rich and have granodioritic to tonalitic compositions. The formation of these granites is supposed to correlate with the collision during the Palaeoproterozoic orogenic event in eastern Greenland (Kalsbeek 1995). The granites have been dated to *c.* 1970-1910 Ma (Kalsbeek et al. 1993b).

The *c.* 1900 Ma granites have a low potential to host uranium-enriched granites as most of the rocks are rich in calcium and of a tonalitic to granodioritic nature.

2.5.16 *c.* 1750 Ma granites in North-East Greenland (D6-O)

Post-orogenic A-type granites might be related to the collapse of the Palaeoproterozoic orogeny. The granites are K-rich and were intruded between *c.* 1760 and 1740 Ma. The granites were later on affected intensively by the Caledonian orogeny (Kalsbeek et al. 1993b, Kalsbeek 1995). One occurrence of uranium-enriched granites might be related to this generation of granites in eastern Greenland. Nielsen (1980) assigns a high potential to these crystalline rocks in an earlier assessment of the uranium potential in Greenland.

2.5.16.1 Hinks Land (D6-O1)

A parautochthonous sheet of biotite granite occurs in the Archaean basement of central Hinks Land. The granite is believed to have formed by anatexis of the adjacent gneisses. The age is unknown but field-relationships confine it to pre-Neoproterozoic. The central part of the sheet hosts a coarse-grained, pegmatitic phase, which is *c.* 100 m thick and 10 km long. The pegmatitic part was briefly inspected by Nordisk Mineselskab A/S in 1969. It was found to contain rusty parts with high scintillometer readings and up to *c.* 600 ppm U in selected samples (Harpøth et al. 1986, Frisch et al. 1970).

2.5.17 950-900 Ma granites in central East Greenland (D6-P)

The *c.* 900 Ma granites in central East Greenland are anatectic S-type granites associated with the Krummedal supracrustal succession (deposited between 1100 and 940 Ma). U–Pb zircon SHRIMP dating on the metasediments and granites gave an age of around 950–920 Ma. These granites are muscovite-biotite leucogranites. The occurrence of the granites is either related to an extensional tectonic event or to metamorphism and igneous activity in the Sveconorwegian Belt of Scandinavia (Kalsbeek et al. 2000, Watt & Thrane 2001).

The 950-900 Ma granites in central East Greenland have a high potential to host a uranium deposit. Their composition and origin by partial melting of crustal material are favourable. Their exact tectonic setting is unknown. The granites were later deformed during the Caledonian orogeny.

2.5.18 Caledonian granites in central East Greenland (D6-Q)

The Caledonian granites (*c.* 435 Ma) are formed during the Caledonian orogeny and derived from partial melting of the metasediments of the Krummedal supracrustal succession. No evidence has been found that these granites are derived from Archaean and Palaeoproterozoic orthogneisses that occur in the same area. Most granite bodies are leucocratic and consist almost exclusively of quartz, K-feldspar, sodic plagioclase, biotite and muscovite. Only few accessory phases were observed: zircon, tourmaline, garnet and titanite are the most common. The Caledonian and 950-900 Ma granites are often indistinguishable in the field. At least some of the Caledonian plutons may have formed after decompression during gravitational collapse following crustal thickening by Caledonian collision (Kalsbeek et al. 2001). Most intrusions are subcirular in shape on the map and intrude along the two major extension shear zones in the area (Strachan et al. 2001).

One occurrence of uranium enrichment is reported for Caledonian granites in central East Greenland on Frænkel Land. The Caledonian granites in central East Greenland have a high potential to host a uranium deposit: they are felsic granites, derived from partially molten crust and intruded in an extensional setting during the latest phase of orogenesis.

2.5.18.1 Frænkel Land (D6-Q1)

Uranium–bearing boulders were found by surveys made with a portable scintillometer in two areas in Frænkel Land by Nordisk Mineselskab A/S in 1975-76 (Hallenstein 1977). The mineralised areas belong to the Lower Proterozoic Hagar sheet, and have been observed in local boulders and outcrops of migmatitic gneisses in Haredal and in numerous local moraine boulders of Lystergletscher, which drains into Knækdalen. The mineralised rocks are fine- to medium-grained, two-mica leucogranite with fine-grained pitchblende. Mineralised pegmatite and aplitic rocks were also observed, and one aplitic rock sample contains inclusions of uraninite. The uranium content varies from 100-500 ppm with a single value of 0.5% (Harpøth et al. 1986). The granites are most likely Caledonian in age.

2.5.19 Undeformed Caledonian Granites (D6-R)

The undeformed granites (*c.* 435-425 Ma) are a suite of granites that intrude in the upper plate after extensional shearing in the Caledonian mountains (Strachan et al. 2001, Andresen et al 2007). The granites are undeformed, crosscut foliations and folds and are formed during orogenic collapse in the Caledonian mountains of East Greenland. They have a circular outcrop pattern on geological maps over the area. The granites are mainly granitic (sensu stricto) in composition and most likely derived from crustal melting (Strachan et al. 2001). Steenfelt (1982) notes that these granites are slightly richer in uranium, a much richer in thorium than the older granites in the area.

The undeformed Caledonian Granites have a medium potential to host a uranium deposit based on their intracratonic orogenic setting and their derivation from a partially molten crust.

2.5.20 Palaeogene alkaline intrusions in central East Greenland (D6-S)

A series of gabbroic (tholeiitic) to alkaline basic to salic intrusive complexes with intermediate syenitic-granitic to nepheline syenite composition intrusions outcrops in central East Greenland. The outcrops south of the tholeiitic flood basalts of the Blosseville Kyst are described separately below, while this section is focussed on the outcrops between Scoresby Sund and Hold with Hope. Enhanced radioactivity has been measured in these alkine complexes (Steenfelt, pers. comm 2014, Nielsen & Steenfelt 1977).

A series of alkaline dyke-swarms outcrops in the Werner Bjerge complex, which were formed ca. 30 Ma and is described as tholeiitic and similar to the Kangerdlugssuaq complex (see below). In the same area over- and under-saturated syenites and alkali granites (including the Malmbjerg molybdenum deposit) are found. A few smaller bodies outcrop immediately to the north between Mestersvig and Antartic Havn (Nielsen 1987).

Eastern Traill Ø shows alkali granites and syenites of the Kap Simpson complex (*c.* 38 Ma). Here the roof of the complex is exposed together large sediment blocks and ring-dykes on part of the margins. Sills and dykes extended into the Mesozoic sediments next to the complex. Immediately north, also on Traill Ø the Kap Parry syenite complex (*c.* 40 Ma) is located, which exists of three volcanic centres including acid volcanic breccias, quartz syenites and alkali granites (Nielsen 1987).

On Hold with Hope peninsula two badly exposed complexes, the Myggbukta (34-28 Ma) and Kap Broer Ruys (48-46 Ma) complexes, are found, both with large positive magnetic anomalies. Myggbukta complex consists mainly of sub-volcanic basaltic rocks and Kap Broer Ruys complex andfelsic and granophyric rocks (Nielsen 1987).

The Palaeogene alkaline intrusions in central East Greenland have a medium potential to host an intrusive uranium deposit based on their alkaline to syenitic composition and their setting in an extensional regime. Uranium can be concentrated under the same conditions as molybdenum and the high Mo concentrations in the Malmbjerg deposits might therefore be another positive indicator (Secher 2009).

2.5.21 Borgtinderne foyalite and nepheline syenite (D6-T)

A number of alkaline to granitic intrusions were emplaced in the East-Greenlandic basement during initial rifting of the North Atlantic. Tegner et al. (1998) explain the occurrence and composition of the dykes, gabbros and few lavas by the migration of the Iceland hotspot plume axis underneath the Atlantic rift at 50-47 Ma.

The Borgtinderne foyalite and nepheline syenite consist of a central pluton, numerous contemporary syenite sheets and later lamprophyric dykes that intruded *c.* 45 Ma. Both pale and dark syenites are present. The syenite magma, which was evolving towards an undersaturated peralkaline residuum, underwent extensive compositional modification by incorporation of country rock flood basalt, resulting in the production of a variety of hybrid syenites that vary in colour. The pale syenite consists of up to 90% perthitic alkali feldspar. Nepheline and sodalite are rare to abundant, depending on the degree of evolution of the syenites. Aegerine is the dominant mafic phase, minor titanite, biotite, magnetite and apatite occur (Brown et al. 1978, Noble et al. 1988).

Resulting from its composition, the Borgtinderne syenite has a medium potential to bear uranium, based on its composition, its setting in an extensional regime.

2.5.22 Kangerdlugssuaq Alkaline Intrusion (South-East Greenland) (D6-U)

The largest intrusion related to the opening of the Atlantic is the Paleogene Kangerdlussuaq Alkaline Intrusion, with an outcrop area of over 800 km^2. This intrusion consists of quartz syenites, syenites, pulaskites and foyaites. The different rock types are exposed in rings. Rb-Sr isochrones indicate a crystallisation age of 50 Ma (Pankhurst et al. 1976).

Circular plutons of syenite cut into coast-parallel dyke swarms and gabbro intrusions at Kap Edvard Holm. The pluton has vertical walls, an associated ring dyke system, and was emplaced by cauldron subsidence. The plutons give Rb-Sr isochrones of 52 Ma (Myers 1980 and references therein). Elevated values of uranium have been observed in a stream sediment sample and a rock samples (see Figures 2 and 3).

The Kangerdlugssuaq Alkaline Intrusion and Kap Edvard Holm Complex syenite have a medium potential to bear uranium as the rock intruded in an extensional basin, resulting from the composition, their setting in an extensional regime and the presence of uranium-enriched samples from the area.

2.5.23 Nualik, Kialineq and Kap Gustav Holm Plutonic Centres (Skrækkensbugt) (D6-V)

During the same extensional period mentioned in the previous section, further circular plutons of syenite and granite intruded into the coastal dyke swarm, cutting both dykes and gabbro intrusions at Store Tindholm, Nualik and Kap Gustav Holm. Granitic and dioritic rocks of the Nualik Plutonic Centre and granite at Kap Gustav Holm give Rb-Sr isochrones of *c.* 55 Ma. At Kap Gustav Holm, monzonite and syenite forms ring dykes and partial ring dykes of two distinct compositions: an older subalkaline syenite related to the monzonite and gabbro, and a younger mildly peralkaline syenite. The syenite plug-like plutons at Kap Gustav Holm are layered and contain numerous rafts of volcanic rocks parallel with the igneous layering. Granite forms a small composite pluton. Abundant synplutonic bodies of microdiorite are associated with monzonite, syenite and granite intrusions (Myers 1980, Myers et al. 1993).

A series of minor intrusions is associated with the younger (35 Ma) Kialineq Plutonic Centre and a set of lamprophyric dykes. The Kialineq Plutonic Centre consists of quartz-syenite and granite plutons. These bodies are emplaced by cauldron subsidence and show a ring-dike and bell-jar form. An extensive acid-basic mixed magma complex is associated with the major plutons (Brown & Becker 1986).

As a consequence of their composition, the monzonites, granites and syenites in the Skrækkensbugt have a medium potential to bear uranium. The intrusions are set in an extensional regime.

2.5.24 Granite in Sermilikfjord, South-East Greenland (D6-W)

A post-tectonic suite of granites, diorites, and locally gabbros form the youngest Precambrian rocks in South-East Greenland. The granites intruded at *c.* 1680 Ma, which is *c.* 200 Ma after the intrusion of the nearby Ammassalik Intrusive Complex. Kalsbeek et al. (1993a) interpreted these intrusives with sharp contacts and narrow contact aureoles to have formed long after the main orogenic events when exhumation was nearly complete. The granitic bodies are the youngest of the series and grade locally to rapakivi textures, quartz monzonites and mafic-poor granites Bridgwater & Myers (1979). The potential of the Sermilikfjord granites is difficult to assess owing to lack of information, but based on available data it is likely to have a low potential.

2.5.25 Skjoldungen Alkaline Complex (D6-X)

The Skjoldungen Alkaline Complex consists of syn- to post-tectonic intermediate to mafic intrusions (mainly gabbros and diorites) and syenites and granites (*c.*2750-2700) that were intruded into the Archaean gneiss basement (*c.* 2870-2780 Ma) in South-East Greenland. In the same area older syenitic gneisses (*c.* 2750 Ma) and the younger (*c.* 2664 Ma) Singertât complex occur (Nielsen & Rosing 1990, Kolb et al. 2013b). The description below is summarised from Nielsen & Rosing (1990).

The syenitic gneiss areas are in contact to the surrounding agmatitic gneisses and form coherent sheet-like masses. The gneisses are dominated by perthitic alkali feldspar and may contain up to 10% quartz. These gneisses contain aegirine-augite, alkali amphibole, biotite, titanite, opaques and apatite, but no nepheline and only little plagioclase.

The dioritic-syenitic complexes are virtually undeformed. The Sfinksen Syenite Complex is intruded into the Sfinksen diorite, while the Ruinnæsset Intrusion intruded into the basement and grades from gabbro and monzogabbro in the east to monzonite and syenites in the west. The syenites are nordmarkitic with less than a few percent quartz and strongly dominated by perthitic feldspar, alkali amphibole, aegirine-augite, biotite and titanite.

The felsic complexes occur often as topographic peaks, and constitute most of the exposed nunataks west of the Skjoldungen Island. The contact with the surrounding gneisses is often obscured, especially in cases where intrusions are syn-tectonic and partially deformed. The granites are dominated by alkali feldspar and contain up to 20% quartz. The rocks are distinctively red to pink in colour.

The Singertât complex is nephelinitic and is part of an ijolitic complex. The plutonic rocks are composed of clino-pyroxene/amphibole, nepheline, some albitic plagioclase and biotite. The complex is intruded by narrow syenitic to carbonatitic dykes.

Approximately 75 km south of the Skjoldungen Alkaline Complex the Timmiarmiut Alkaline Province is located. This complex contains ultramafic and alkaline rocks and consists of a series of post-tectonic dykes and a larger intrusive body ranging in composition from lamprophyric to monzonitic (Kolb et al. 2013b).

The granitic, syenitic and carbonatitic elements of the Skjoldungen Alkaline Province have a medium potential to host a uranium-deposit, based on their highly evolved composition and their setting in an intracratonic orogenic system.

2.5.26 Rapakivi suite, South Greenland (D6-Y)

The Rapakivi suite of South Greenland includes a group of posttectonic monzonite, syenite and norite rocks that were intruded in two episodes at 1755 Ma and 1740 Ma (Gulson & Krogh 1975) or 1755-1732 Ma (Garde et al. 2002). It covers a large area between Kap Farvel and Graahs Fjelde. Most intrusions are quartz-bearing syenites and monzonites, with minor norites. Locally mantled K-feldspars are developed, leading to the name rapakivi suite. The mafic minerals are very Fe-rich. The rocks are subconcordant with the gneiss and migmatised metasedimentary rocks in which they have intruded; xenoliths of country rock are found abundantly (Gulson & Krogh 1975).

The monzonites and syenites of the Rapakivi suite in South Greenland have a medium potential to bear uranium, based on their composition, and on the elevated uranium that is present in the migmatised metasediments in which they intrude. The Rapakivi suite intruded post-tectonically in an intracratonic setting.

2.5.27 Leucogranites in the psammite zone, South Greenland (D6-Z)

The psammite zone has been described in detail in section 2.1.2 Psammite zone (metasandstone), South Greenland (D1-A). During deformation and metamorphism (D3 in the nomenclature of Garde et al. 1997) in-situ (local) partial melting of the psammite zone caused the formation of widespread heterogeneous biotite- and locally garnet-bearing leucogranites. Steenfelt & Armour-Brown (1988) indicate that the granites are not mineralised but cut through mineralised sandstone strata. However, these authors also indicate that some uranium is found in the neosome formed during the migmatisition event that created the leucogranites, and along fractures, which suggest that some remobilisation of the uranium has taken place.

The leucogranites in the psammite zone, South Greenland have a medium potential to host an intrusion-related uranium deposit. The potential is dependent though on the potential of the psammite host rocks. If these are uranium-enriched the leucogranites might have concentrated the uranium in low-pressure pockets in the deformed rocks.

2.6 Volcanic and caldera-related deposits (D7)

2.6.1 Introduction

Volcanic and caldera-related deposits occur in association with hydrothermal solutions which leached uranium from silicic volcanic rocks and concentrate them in veins, stock-works, breccia-hosted and stratabound deposits. Volcanic and caldera-related deposits are found in many tectonic different settings: continental rifts, calderas, hot spots, back arc basins and in the extensional regions near subduction zones. Settings with an enhanced heat flow from thinning of the crust often contain mafic magmas. These induce partial melting of relatively uranium-rich upper crustal rocks and create melt compositions that favour enrichment of uranium and other incompatible elements. The volcanic rocks are subaerial or subaqueous, or very shallow intrusives and high-silica alkali rhyolite and potash trachytes. Pre-ore alteration includes alkali metasomatism followed by varying amounts of quartz, sericite, pyrite and carbonate mineral veining. Kaolinite, montmorillonite and allanite are common. A map over the known areas with uranium enrichment is given in Figure 14.

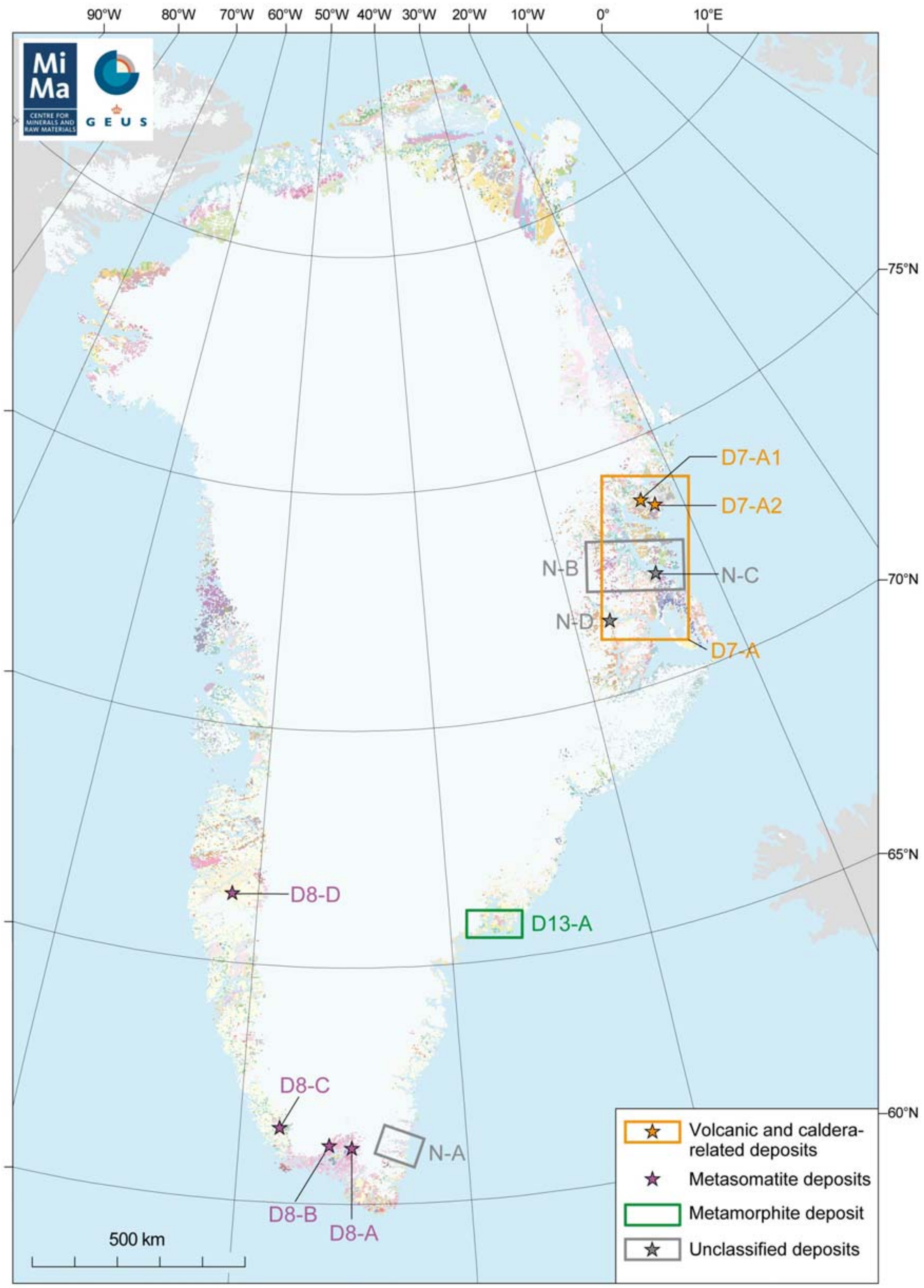


Figure 14: Geological map of Greenland showing the areas with a potential to host a volcanic or caldera-related deposit (uranium deposit type D7), a metasomatite deposit (uranium deposit type D8), a metamorphite deposit (uranium deposit type D13) or an unclassified deposit (N). Known Greenlandic occurrences are indicated with stars. Labels refer to chapters in the text.

2.6.2 Volcanism in central East Greenland (D7-A)

Volcanism in East Greenland has been reported as late-syn to post-orogenic stage of the Caledonian orogeny in the latest Silurian and Devonian (Strachan et al. 2001, Steenfelt 1982). The magma is mainly rhyolitic and contains enhanced levels of uranium in several places (Steenfelt 1982). Some minor volcanic activity took place associated with the intrusion of the Palaeogene intrusive complexes in the area (section 2.5.20 Palaeogene alkaline intrusions in central East Greenland (D6-S), see Nielsen (1987) for details).

2.6.2.1 Moskusokseland (D7-A1)

Moskusokseland has been described in section 2.4.6.1 Moskusokseland (D5-E1).

2.6.2.1 Randbøldal, Gauss Halvø (D7-A2)

During a seven-year regional uranium exploration programme conducted by the Geological Survey of Greenland from 1971-77, outcropping uranium-enriched rocks were located in Randbøldal (Nielsen & Steenfelt 1977). The area comprises Devonian porphyritic rhyolites locally overlain by pyroclastic rocks and Devonian molasse sediments. Small-scale faulting and fracturing is widespread in these Devonian rocks. Intensely altered and limonite-stained radioactive mineralisation is located within *c.* 1 km^2 of the rhyolites close to the boundary of the overlying pyroclastic rocks. Individually mineralised outcrops are concentrated along faults and shear zones. They can rarely be traced for more than 20 m, and contain on average 500-700 ppm U. Selected samples contain up to 0.2% U (Harpøth et al. 1986). Most of the uranium is hosted in uraniferous hydrocarbons (carburan), which occur disseminated and in veinlets; other identified uranium minerals are surface weathering minerals as barian wölsendorfite (Secher et al. 1976). Steenfelt (1982) advocates a genetic model, in which Devonian magmas enriched in uranium and fluorine reacted with circulating meteoric water.

The license for the area is hold by ARC Mining.

2.7 Metasomatite deposits (D8)

2.7.1 Introduction

Uranium-bearing metasomatite deposits form in albitites and elkonites and are usually Proterozoic in age. Uranium deposits are formed in metamorphic terranes that underwent several deformational and metamorphic cycles at craton margins or in former intracratonic rift basins. Typical settings to form these deposits are mylonites in often albitised gneiss/granite, meta-rhyolite, meta-volcaniclastic rocks, amphibolite and metasediments. Uranium is leached from country rocks or from uranium-bearing fluid from a magmatic source is being transported by oxidised hydrothermal fluids that migrate into faults/fracture zones in the country rock. Interaction of the oxidised uranium-bearing fluid with a mineral assemblage like chlorite, hornblende, epidote, or a carbonaceous rock can precipitate the uranium. A map over the areas discussed in this chapter is given in Figure 14.

2.7.2 Motzfeldt Complex (D8-A)

Motzfeldt Complex has been described previously in section

2.5.3.2 Motzfeldt Complex. It is a known uranium occurrence. The Gardar region has a good potential to host more metasomatised uranium occurrences in intrusive rocks.

2.7.3 Nunatak north of Nordre Sermilik (D8-B)

Numerous boulders with pitchblende were found on the talus slopes of the nunatak north of Nordre Sermilik. A helicopter-borne gamma-spectrometer survey carried out around the hill up-slope to the north revealed the probable source of the blocks by the train of anomalous values. In combination with anomalously high K-values, this suggests K-metasomatism and increased element mobility. At two other localities appreciable amounts of uraninite (2000 ppm) occur in the fine grained magnetite rich part of supracrustal rocks, which occur as remnants within the granite batholith. The uraninite is 10-30 µm in size and is disseminated in the rock or occurs as inclusions in the biotite. The localities are not very well exposed (Armour-Brown et al. 1984).

2.7.4 Grønnedal-Ika (D8-C)

The Grønnedal-Ika intrusion is an intensively faulted centre of nepheline syenite penetrated by a central plug of carbonatite, and it is the oldest of the Gardar intrusive centers (1299 Ma). The radioactivity of the carbonatite intrusion is almost solely due to Th (up to 670 ppm) and less to U (<60 ppm). However, minor areas of U-rich, Na-metasomatised syenite occurs around the intrusion. Due to poor exposure the extent of this type of alteration is not known in detail. The radioactive syenite contains cracks filled with carbonate, iron oxides and pyrochlore, yielding U concentrations up to 1000 ppm. It is probable that the metasomatism and mineralisation is controlled by fault and fracture zones with are abundant in the intrusion (Armour-Brown et al. 1982b).

An airborne gamma-spectrometer survey, carried out during the Syduran project, as well as a reconnaissance exploration survey using stream sediments samples yielded elevated U values in the Ivittuut-Grønnedal-Ika area (Armour-Brown et al. 1983), but these might also be related to the nearby Ivigtût Granite described in section 2.5.3.3 Ivigtût Granite and associated cryolite body (D6-B3).

Rimbal Pty. Ltd has currently licensed the area and are exploring for carbonate and REE.

2.7.5 Sarfartoq (D8-D)

The carbonatite in Sarfartoq has been described in section 2.5.11 Sarfartoq (D6-J) and is a known uranium occurrence. It is uncertain whether Sarfartoq should be classified as a metasomite deposit, as the origin of the hydrothermal fluids that cause the uranium-enrichment is not exactly known.

2.8 Metamorphite deposits (D13)

2.8.1 Introduction

Metamorphite uranium deposits are uranium-bearing skarn deposits in uraniferous sediments or volcanic rocks. Uranium-enrichment occurs during regional metamorphism, which usually occurs in an orogenic setting at mid-crustal levels. The skarn exists of calcsilicate rocks that often are metamorphosed by contact or regional metamorphism; a garnetisation of the rocks is common. Most known occurrences on a global scale were formed during Archaean to Proterozoic events. Apart from garnet, allanite is often present the uranium-rich rocks (Appendix 1). One potential area can be pointed at in Greenland (Figure 14):

2.8.2 Ammassalik Intrusive Complex (D13-A)

The Ammassalik Intrusive Complex consist of *c.* 1885 Ma leuconoritic and chanockitic intrusive rocks that were emplaced in three aligned bodies in the East Greenlandic Nagssugtoqidian orogeny. The country rock of the Ammassalik Intrusive Complex, a series of sedimentary rocks, metamorphosed to garnet-rich granitic gneisses and marbles. The area has been interpreted as a Palaeoproterozoic arc formed due to the collision between two Archaean cratons north and south of it (Nutman et al. 2008b). The area was proposed as a potential area to host a metamorphite uranium deposit by Secher (2009).

2.9 Other areas with known uranium enrichments

The following areas (see Figure 14) have known uranium enrichments, but cannot be classified as a specific deposit type, due to lack of information:

2.9.1 Lindenow Fjord (N-A)

This locality is part of the Psammite zone and positioned in the Ketilidian supracrustal rocks, investigated by the Syduran project. A stream sediment sample collected at the southern shore of Lindenows fjord recorded 900 ppm U. A high radiometric reading was also recorded in the vicinity, from an inaccessible cliff face. This is a very interesting anomaly, which requires more investigation (Armour-Brown et al. 1982a; Armour-Brown et al. 1984).

NunaMinerals A/S holds the license for the area and explores for Au, Ni.

2.9.2 Uninvestigated anomalies in central East Greenland (N-B)

Uninvestigated anomalies exists in central Trail Ø, north Stauning Alper and in the Lucia-gletscher area. The anomalies are found by pan samples (Harpøth et al. 1986).

2.9.3 Eremitdal, Andre Land (N-C)

A moraine cobble of semi-massive pitchblende, containing 32% U, has been found (Lind 1980).

2.9.4 Flyverfjord (N-D)

The Flyverfjord mineralisation was found by the Geological Survey of Greenland as a radioactive anomaly in 1968, and briefly visited by Nordic Mining Company in 1970 and 1983 (Thomassen 1983). It is situated on the south coast of Flyverfjord in inner Scoresby Sund. The country rock is amphibolite-bearing gneiss of the Archaean Flyverfjord intrusive complex. The mineralisation is hosted in two southerly dipping rust zones situated 1.5 km apart in the steep coastal cliffs of Flyverfjord. The zones are several tens of meters thick and continue laterally for more than 500 m. The rust zones consist of whitish, sericite-biotite-bearing siliceous gneiss containing up to 20 cm thick, fuchsite-rich bands and up to 10 cm thick, conformable quartz lenses or veins. In general, the zones contain less than 1% sulphides, However, a 1 m thick massive, siliceous horizon with up to 10% disseminated pyrrhotite, pyrite and chalcopyrite occurs in both rust zones. Analyses of ten grab samples from this horizon average 75 ppm U. No uranium minerals have been observed. The origin of the mineralisation is unknown, but could represent either a metamorphosed equivalent of a quartz-pebble conglomerate type or a sulphide accumulation associated with hydrothermally altered acid volcanic rocks (Harpøth et al. 1986).

3. Conclusions

The methodology applied for this pilot-study assessing the uranium potential in Greenland is in accordance with the basic principles set out by USGS (Briskey & Schulz 2003, Singer & Menzie 2010) for this type of work, except that no external panel has participated and no quantified estimates have been made. The amount of available information varies considerably within Greenland, and consequently the potential cannot be assessed with the same amount of confidence in all areas. The uranium potential for each area is discussed in this report and estimation of the uranium potential is given in Table 2. Sixty-six areas were assessed for their potential to host undiscovered uranium deposits, related to one of the following genetic types: Sandstone (10); unconformity (7); conglomerate (8); vein-type (5); intrusion (26); volcanic (1); metasomatites (4); metamorphic (1); and unclassified (4). The authors conclude that of these seven areas have a very high potential and twentyone are considered as high potential areas (see Table 2).

For sandstone deposits, the areas with the highest potential are found in the Mesoproterozoic-Neoproterozoic Thule Supergroup in North-West Greenland and in the psammite zone with high metamorphic grade sandstones in South Greenland. In the psammite zone, the area near the known occurrence Illorsuit shows a very high potential to host a uranium deposit. The Cretaceous to Palaeogene Nuussuaq Group sandstones in central West Greenland and Devonian to Paleocene sandstones in the basins in central East Greenland also show a high potential. The known placer deposit on Milne Land is located in the latter area.

Two areas have a very high potential to host an unconformity-related uranium deposit. These are the base of the Thule Supergroup, which overlies Precambrium basement, and the base of the Eriksfjord Formation in the Gardar Province in South Greenland, which is derived from the Palaeoproterozoic Julianehåb Batholith. Another high potential target could be the Kome Formation at the base of the Nuussuaq Group.

The Palaeoproterozoic conglomerates of Grænseland and Midternæs in South Greenland, of the Karrat Group in central West Greenland and North-West Greenland and the Archaean and Palaeoproterozoic conglomerates on southern Nuussuaq and in the Ataa domain all have a high potential to host a uranium deposit. In all three areas the conglomerate is derived from nearby Precambrian basement.

There is a high potential for vein-related deposits in several areas in Greenland (see Table 2). The highest potential is probably found associated with the veins related to the Gardar province in South Greenland. A high potential is present in at least two known vein deposits in the Gardar Province: in the Nordre Sermilik region (Qingua and Ulungarssuaq) and in Vatnaverfi. But also the veins related to the Qaqarssuk carbonatite complex in southern West Greenland have a high potential, as do veins in central East Greenland. In the latter area the potential is illustrated by two known occurrences with a high potential: Moskusokseland on Wollaston Forland and Nedre Arkosedal in the Stauninger Alper.

For the intrusion deposits the highest potential is found in the Gardar province in South Greenland and in the Neoproterozoic Sarfartoq carbonatite complex. The Gardar province includes the Kvanefjeld multi-element deposit, which is a known uranium occurrence with a very high potential. The Motzfeldt Complex is a second known occurrence in the Gardar Province with a high potential, not only as an intrusion-type deposit, but also as a metasomatite deposit. A large number of granite intrusions occur in central East Greenland and North-East Greenland, of these the 950-900 Ma granites and the Caledonian granites in central East Greenland have a good potential.

Central East Greenland also has a high potential to host a volcanic uranium-deposit. In this context the occurrence on Moskusokseland is mentioned again as a known example with a high potential.

Table 2: Uranium potential of discussed areas in Greenland. xx indicates a very high potential, x indicates high potential. Labels refer to chapters in this report.

		Potential	
Name	**high**	**Medium**	**low**
2.1 Sandstone (D1)			
2.1.2 Psammite zone (metasandstone), South Greenland (D1-A)	x		
2.1.2.1 Illorsuit (D1-A1)	xx		
2.1.3 Eriksfjord Formation sandstones, Gardar province (D1-B)		x	
2.1.4 Nuussuaq Group sandstones (D1-C)	x		
2.1.5 Thule Supergroup sandstones (D1-D)	xx		
2.1.6 Independence Fjord Gr., Kronprins Christian Land (D1-E)			x
2.1.7 Hagen Fjord Group sandstones (D1-F)			x
2.1.8 Wandel Sea Basin sandstones (D1-G)		x	
2.1.9 Eleonore Bay Supergroup and Tillite Group sandstones (D1-H)			x
2.1.10 Central East Greenland basins sandstones (D1-I)	x		
2.1.10.1 Milne Land (D1-I1)	x		
2.1.11 Kangerlussuaq Basin sandstones (D1-J)		x	
2.2 Unconformity (D2)			
2.2.2 Base of the Eriksfjord Formation, Gardar province (D2-A)	xx		
2.2.3 Grænseland (Borderzone) and Midternæs unconformity (D2-B)		x	
2.2.4 Kome Formation in the Nuussuaq Group (D2-C)	x		
2.2.5 Base of the Thule Supergroup (D2-D)	xx		
2.2.6 Dallas Bugt Formation, Franklinian Basin (D2-E)		x	
2.2.7 Devonian-Permian clastic sediments in c. E. Greenland (D2-F)			x
2.2.8 Base of the pelite and psammite zone, South Greenland (D2-G)			x
2.3 Conglomerate (D4)			
2.3.2 Conglomerates, Ketilidian sediments in S-E Greenland (D4-A)		x	
2.3.3 Grænseland and Midternæs conglomerates (D4-B)	x		

Continued overleaf

Name	Potential good	Medium	low
2.3.4 Metasediments on southern Nuussuaq, Ataa domain (D4-C)	x		
2.3.5 Kome Formation conglomerates (D4-D)		x	
2.3.6 Karrat Group sediments (D4-E)	x		
2.3.7 Conglomerates of the Thule Supergroup (D4-F)		x	
2.3.8 Independence Fjord Group, Kronprins Christian Land (D4-G)			x
2.3.9 Central East Greenland basins conglomerates (D4-H)			x
2.3.9.1 Wegener Halvø (D4-H1)		x	
2.4 Veins (D5)			
2.4.2 Veins in the Gardar province (D5-A)	xx		
2.4.2.1 Nordre Sermilik (Qingua and Ulungarssuaq) (D5-A1)	x		
2.4.2.2 North of Bredefjord (D5-A2)		x	
2.4.2.3 Puissattaq (D5-A3)		x	
2.4.2.4 Vatnaverfi (including Eqaluit) (D5-A4)	x		
2.4.3 Veins in the psammite zone, South Greenland (D5-B)		x	
2.4.4 Veins in the Julianehåb batholith (D5-C)			x
2.4.5 Veins of the Qaqarssuk carbonatite complex (D5-D)	x		
2.4.6 East Greenland (D5-E)	x		
2.4.6.1 Moskusokseland (D5-E1)	x		
2.4.6.2 Foldaelv, Gauss Halvø (D5-E2)		x	
2.4.6.2 Nedre Arkosedal (Stauning Alper) (D5-E3)	x		
2.5 Intrusions (D6)			
2.5.2 Granites in the Julianehåb batholith (D6-A)		x	
2.5.3 Gardar province (D6-B)	x		
2.5.3.1 Kvanefjeld (Kuannersuit) (D6-B1)	xx		
2.5.3.2 Motzfeldt Complex (D6-B2)	x		
2.5.3.3 Ivigtût Granite and associated cryolite body (D6-B3)		x	
2.5.4 Pyramidefjeld area (D6-C)		x	
2.5.5 Neria Granite (D6-D)			x
2.5.6 Nukaqpiarssuaq granite (Bjørnesund area) (D6-E)			x
2.5.7 Tikiussaq (D6-F)		x	
2.5.8 Nuuk region (D6-G)		x	
2.5.9 Qugssuk Granite (D6-H)		x	
2.5.10 Qaqarssuk carbonatite complex (Qeqertaasaq) (D6-I)		x	
2.5.11 Sarfartoq (D6-J)	xx		
2.5.12 Granites in the Nagssugtoqidian orogen (D6-K)		x	
2.5.12.1 Nassuttooq (D6-K1)		x	
2.5.13 Granites related to the Prøven Igneous Complex (D6-L)		x	
2.5.14 Alkaline intrusions in Inglefield orogenic belt (D6-M)		x	
2.5.15 *c.* 1900 Ma granites in North-East and c. E. Greenland (D6-N)			x

Continued overleaf

Name	Potential good	medium	low
2.5.16 *c.* 1750 Ma granites in North-East Greenland (D6-O)		x	
2.5.16.1 Hinks Land (D6-O1)		x	
2.5.17 950-900 Ma granites in central East Greenland (D6-P)	x		
2.5.18 Caledonian granites in central East Greenland (D6-Q)	x		
2.5.18.1 Frænkel Land (D6-Q1)		x	
2.5.19 Undeformed Caledonian Granites (D6-R)		x	
2.5.20 Palaeog. alkaline intrusions in central East Greenland (D6-S)		x	
2.5.21 Borgtinderne foyalite and nepheline syenite (D6-T)		x	
2.5.22 Kangerdlugssuaq Alkaline Intrusion (S-E Greenland) (D6-U)			x
2.5.23 Nualik, Kialineq and Kap Gustav Holm Plutonic Centres (D6-V)		x	
2.5.24 Granite in Sermilikfjord, South-East Greenland (D6-W)		x	
2.5.25 Skjoldungen Alkaline Complex (D6-X)		x	
2.5.26 Rapakivi suite, South Greenland (D6-Y)		x	
2.5.27 Leucogranites in the pelite and psammite zone (D6-Z)		x	
2.6 Volcanic (D7)			
2.6.2 Volcanism in central East Greenland (D7-A)	x		
2.6.2.1 Moskusokseland (D7-A1)	x		
2.6.2.2 Randbøldal, Gauss Halvø (D7-A2)		x	
2.7 Metasomatite (D8)			
2.7.2 Motzfeldt Complex (D8-A)	x		
2.7.3 Nunatak north of Nordre Sermilik (D8-B)		x	
2.7.4 Grønnedal-Ika (D8-C)		x	
2.7.5 Sarfartoq (D8-D)		x	
2.8 Metamorphite (D9)			
2.8.3 Ammassalik Intrusive Complex (D13-B)			x
2.9 Unclassified			
2.9.1 Lindenow Fjord (N-A)		x	
2.9.2 Uninvestigated anomalies in central East Greenland (N-B)		x	
2.9.3 Eremitdal, Andre Land (N-C)		x	
2.9.4 Flyverfjord (N-D)		x	

Acknowledgments

The authors would like to thank the following persons for their contribution to this report: M.D. Poulsen for help with the literature research, S.D. Olsen for extracting data from GEUS' databases, and J. Halskov for drawing the figures. Comments by A. Steenfelt, K. Secher, and H. Stendal on earlier versions of this report are highly appreciated. S. Weatherley kindly corrected our spelling and grammar mistakes.

References

Allaart, J.H. 1976: Ketilidian mobile belt in South Greenland. In Escher, A. Watt, W.S. (ed.) Geology of Greenland, 121-151. Copenhagen: Geol. Surv. Greenland.

Allaart, J.H. 1983: Descriptive text to 1: 100 000 sheet Narssarssuaq 61 V.3 Syd. Descriptive text. Grønlands Geologiske Undersøgelse. 20pp.

Andresen, A., Rehnström, E.F. & Holte, M. 2001: Evidence for simultaneous contraction and extension at different crustal levels during the Caledonian orogeny in NE Greenland. Journal of the Geological Society, London, **164**, 869-880.

Armour-Brown, A. 1986: Geology and evaluation of the uranium mineral occurrence at Igdlorssuit, South Greenland. The South Greenland Exploration Programme 1984 - 1986, Report No. 2. Open File Series Grønlands Geologiske Undersøgelse **2**, 60 pp.

Armour-Brown, A., Steenfelt, A. & Kunzenforf, H. 1983: Uranium districts defined by reconnaissance geochemistry in South Greenland. Journal of Geochemical Exploration **19**, 127-145.

Armour-Brown, A., Tukiainen, T. Nyegaard, P. & Wallin, B. 1984: The South Greenland regional uranium exploration programme. Final report of progress 1980-1983. unpublished report, Geological Survey of Greenland, 110 pp.

Armour-Brown, A., Tukiainen, T. & Wallin, B., 1982a: The South Greenland uranium exploration programme. Final report, 95 pp. Unpublished report, Grønlands Geologiske Undersøgelse.

Armour-Brown, A., Tukiainen, T. & Wallin, B., 1982b: Pitchblende Vein Discoveries in the Proterozoic Ketilidian Granite of South Greenland. Geologische Rundschau **71**, 73-80.

Bagby, W.C. 1986: Descriptive model of volcanogenic U. In: Cox, D.P. & Singer, D.A. (eds.): Mineral Deposit Models. **1693**. U.S. Geological Survey, p. 162.

Berthelsen, A. & Henriksen, N. 1975: Geological map of Greenland 1:100 000 Ivigtut 61V.1 Syd. The orogenic and Cratogenic geology of a Precambrian shield area.169pp.

Birkelund, T. & Perch-Nielsen, K. 1976: Late Palaeozoic-Mesozoic evolution of central East Greenland. In: Escher, A. & Watt, W.S. (eds.): Geology of Greenland. Geological Survey of Greenland, Copenhagen, 304-339.

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

Bondesen, E. 1970: The stratigraphy and deformation of the Precambrian rocks of the Grænseland area, South-West Greenland. Bulletin Grønlands Geologiske Undersøgelse **86**, 210 pp. (also Meddelelser om Grønland **185**(1)).

Boyle, R. W., 1982: Geochemical prospecting for thorium and uranium deposits. Elsevier Scientific Publishing Company, 498 p.

Bridgwater, D. & Myers, J.S. 1979: Outline of the Nagssugtoqidian mobile belt of East Greenland. Rapport Grønlands Geologiske Undersøgelse **89**, 9-18.

Briskey, J.A. & Schulz, K.J. 2003: USGS Mineral Resources Program. The Global Meneral Resource Assessment Project. uSGS Fact Sheet 5303, 2p. http://pubs.usgs.gov/fs/fs053-03/fs053-03.pdf

Breit, G.N. & Hall, S.M. 2011: Deposit model for volcanogenic uranium deposits. U.S. Geological Survey Open-File Report **2011–1255**, 5 pp.

Brown P.E. & Becker, S.M. 1986: Fractionation, hybridisation and magma-mixing in the Kialineq centre East Greenland. Contributions to Mineralogy and Petrology **92**, 57-70.

Brown, P.E., Brown, R.D., Chambers, A.D. & Soper, N.J. 1978: Fractionation and Assimilation in the Borgtinderne Syenite, East Greenland. Contributions to Mineralogy and Petrology 67, 25-34.

Brown, M., Friend, C.R.L., McGregor, V.R. & Perkins, W.T. 1981: The Late Archaean Qôrqut Granite Complex of Southern West Greenland. Journal of Geophysical Research B, 86, 10617-10632.

Chadwick, B., Claeys, P. & Simonson, B. 2001: New evidence for a large Palaeoproterozoic impact: spherules in a dolomite layer in the Ketilidian orogen, South Greenland. Journal of the Geological Society (London) **158**, 331–340.

Chadwick, B. & Garde, A.A. 1996: Palaeoproterozoic oblique plate convergence in South Greenland: a reappraisal of the Ketilidian Orogen. In: Brewer, t.s. (ed.): Precambrian Crustal Evolution in the North Atlantic Region. Geological Society Special Publication **112**, 179-196.

Clemmensen, L.B. & Jepsen, H.F. 1992: Lithostratigraphy and geological setting of Upper Proterozoic shoreline-shelf deposits, Hagen Fjord Group, eastern North Greenland. Grønlands Geologiske Undersøgelse Rapport **157**, 27pp.

Collinson, J.D., Kalsbeek, F., Jepsen, H.F., Pedersen, S.A.S. & Upton, B.G.J. 2008: Paleoproterozoic and Mesoproterozoic sedimentary and volcanic successions in the northern parts of the East Greenland Caledonian orogeny and its foreland. In: Higgins, A.K., Gilotti, J.A., and Smith, M.P., eds., The Greenland Caledonides: Evolution of the Northeast Margin of Laurentia: Geological Society of America Memoir **202**, 73-98.

Connelly, J.N. & Mengel, F.C. 2000: Evolution of Archean components in the Nagssugtoqidian Orogen, West Greenland. Geological Society of America Bulletin **112**, 747–763.

Corriveau, L. 2007: Iron oxide copper-gold deposits: A Canadian perspective. In: Goodfellow, W.D. (ed.): Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods **5**, 307–328. Geological Association of Canada, Mineral Deposits Division.

Cox, D.P. & Singer, D.A. 2007: Descriptive and grade-tonnage models and database for iron oxide Cu-Au deposits. U.S. Geological Survey Open-File Report 2007, 13 pp.

Cuney, M. 2009: The extreme diversity of uranium deposits. Mineralium Deposita **44**, 3–9.

Cuney, M. & Kyser, K. 2009: Recent and not-so-recent developments in uranium deposits and implications for exploration. Mineralogical Association of Canada, Short Course Series Volume **39**, 257 pp.

Dahlkamp, F.J. 1990: Uranium Deposits in Collapse Breccia Pipes in the Grand Canyon Region, Colorado Plateau, USA. Mitt, Naturwiss. Ver. Steiermark **120**, 89–98.

Dahlkamp, F.J. 1993: Uranium ore deposits, 460 pp. Berlin, Heidelberg: Spinger-Verlag.

Dam, G., Pedersen, G.K., Sønderholm, M., Midtgaard, H.H., Larsen, L.M., Nøhr-Hansen, H. & Pedersen, A.K. 2009: Lithostratigrphy of the Createceous-Paleocene Nuussuaq Group, Nuussuaq Basin, West Greenland. Geological Survey of Denmark and Greenland Bulletin **19,** 171pp.

Dawes, P.R. 1997: The Proterozoic Thule Supergroup, Greenland and Canada: history, lithostratigraphy and development. Geology of Greenland Survey Bulletin **174**, 150.

Dawes, P.R. 2006: Explanatory notes to the Feological map of Greenland, 1:500 000. Thule, Sheet 5. Geological Survey of Denmark and Greenland Map Series **2**, 97 pp.

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

Escher, A. &, Pulvertaft, T.C.R. 1968: The Precambrian rocks of the Upernavik-Kraulshavn area (72°–74°15'N), West Greenland. Rapport Grønlands Geologiske Undersøgelse **15**,11–14.

Escher, J.C. & Stecher O. 1978: Precambrian geology of the Upernavik—Red Head region (72°15'-75°15'N), northern West Greenland. Rapport Grønlands geologiske Undersøgelse **90**, 23–26.

Fayek, M. 2013: Uranium ore deposits - a review. In: Burns, P.C. & Sigmon, G.E. (eds): Uranium - cradle to grave **43**, 121-146. Winnipeg, Manitoba: Mineralogical Association of Canada.

Finch, W.I. 1992: Descriptive model of solution-collapse breccia pipe uranium deposits. US Geological Survey Bulletin **2004,** p. 36–38.

Finch, W.I., Feng, S., Zuyi, C. & McCammon, R.B. 1993: Descriptive models of major uranium deposits in China. Nonrenewable Resources. Kluwer Academic Publishers **2**, 39–48.

Frisch, W., Heinricher, G.M., Kutchera, S. & Heyrowsky, W. 1970: Montangeologiischer Bericht über die Gebiete Skeldal, Hinks Land, Charcot Land, Pictet Bjerge, Nathorst Land. Internal NM-report **2-8/69**, 58pp.

Garde, A.A., Chadwick, B., Grocott, J. & Swager, C. 1997: Metasedimentary rocks, intrusions and deformation history in the south-east part of the c. 1800 Ma Ketilidian orogen, South Greenland: Project SUPRASYD 1996. Geology of Greenland Survey Bulletin **176**, 60–65.

Garde, A.A., Chadwick, B., McCaffrey, K., and Curtis, M. 1998: Reassessment of the north-western border zone of the Palaeoproterozoic Ketilidian orogeny, South Greenland. Geology of Greenland Survey Bulletin **180**, 111–118.

Garde, A.A., Grocott, J. & McCaffrey, K.J.W 1999: New insights in the north-eastern part of the Ketilidian orogeny in South-East Greenland. Geology of Greenland Survey Bulletin **183**, 23-33.

Garde, A.A., Hamilton, M.A., Chadwick, B., Grocott, J. & McCaffrey, K.J.W. 2002: The Ketilidian orogeny of South Greenland: geochronology, tectonics, magmatism, and fore-arc accretion during Palaeoproterozoic oblique convergence. Canadian Journal of Earth Sciences **39**, 765-793.

Ghisler, M., Henriksen, N., Steenfelt, A. & Stendal, H. 1979: A reconnaissance geochemical survey in the Proterozoic-Phanerozoic platform succession of the Peary Land region, North Greenland. Rapport Grønlands Geologiske Undersøgelse **88**, 85–91.

Ghisler, M. & Stendal, H. 1980: Geochemical and ore microscopic investigations on drainage sands from the Peary Land region, North Greenland. Rapport Grønlands Geologiske Undersøgelse **99**, 121–128.

Gilotti, J.A., Jones, K.A. & Elvevold, S. 2008: Caledonian metamorphic patterns in Greenland. In: Higgins, A.K., Gilotti, J.A., and Smith, M.P., eds., The Greenland Caledonides: Evolution of the Northeast Margin of Laurentia: Geological Society of America Memoir **202**, 201-225.

Gothenborg, J. & Pedersen, J.L. 1975: Exploration of the Qaqarssuk carbonatite complex 1975, part II. Kryolitselskabet Øresund A/S, unpublished company report.

Grauch, R.I. & Mosier, D.L. 1986: Descriptive Model of Unconformity U-Au. In: Cox, D.P. & Singer, D.A. (eds): U.S. Geological Survey Bulletin. **1693**, 248–250.

Gulson, B.L. & Krogh, T.E. 1975: Evidence of multiple intrusion, possible resetting of U-Pb ages, and new crystallization of zircons in the post-tectonic intrusions ("Rapakivi granites") and gneisses from South Greenland. Geochimica et Cosmochimica Acta **39**, 65-82.

Hallenstein, C. 1976: Uranium and thorium prospecting in Nordmine concession, East Greenland. Internal NM-report **4/75**, 111pp.

Hallenstein, C. 1977: Uranium and thorium prospecting in Nordmine concession, East Greenland. Internal NM-report **4/76**, 109pp.

Harpøth, O., Pedersen, J.L., Schønwandt, H.K. & Thomassen, B. 1986: The mineral occurrences of central East Greenland. Meddelelser om Grønland, Geoscience **17**.

Henderson, G. & Pulvertaft, T.C.R. 1987. Descriptive text to geological map of Greenland 1:100 000, Mârmorilik 71 V.2 Syd, Nûgâtsiaq 71 V.2 Nord and Pangnertôq 72 V.2 Syd. Geol. Survey Greenland, Copenhagen, 72 pp.

Henriksen, N. 1980: Collection of stream sediments for a reconnaissance geochemical survey from the Peary Land region, North Greenland. Rapport Grønlands Geologiske-Undersøgelse **99**, 119–120.

Henriksen, N. & Higgins, A.K. 1976: East Greenland Caledonian fold belt. In Escher, A. Watt, W.S. (ed.) Geology of Greenland, 183-246. Copenhagen: Geol. Surv. Greenland.

Henriksen, N., Higgins, A.K., Kalsbeek, F. & Pulvertaft, T.C.R. 2009: Greenland from Archaean to Quaternary. Descriptive text to the 1995 Geological map of Greenland 1:2 500 000. 2nd ed. Geological Survey of Denmark and Greenland Bulletin **18**, 126 pp.

Higgins, A.K., 1990. Descriptive text to 1:100 000 sheets Neria 61 V.1 N and Midternæs 61 V.2 N. Grønlands Geologiske Undersøgelse, Copenhagen, 23 pp.

Hintsteiner, E.A., Kramers, J.D., Løvborg, L. & Wollenberg, H. 1970: Uran. Internal NM-report **SP1/70**.

Hitzman, M.W., 2000 Iron oxide–Cu–Au deposits: what, where, when, and why. In: Porter, T.M. (Ed.), Hydrothermal Iron Oxide–Copper–Gold and Related Deposits: a Global Perspective. Australian Mineral Foundation, Adelaide, Australia, pp. 9–25.

Hollis, J.A., Frei, D., van Gool, J.A.M., Garde, A. & Persson, M. 2006: Using zircon geochronology to resolve the Archaean geology of southern West Greenland. Geological survey of Denmark and Greenland Bulletin **10**, 49-52.

IAEA, 1984: Surficial uranium deposits, Vienna, 1984. International Atomic Energy Agency Technical Documents (IAEA-TECDOC) **322**, 252 pp.

IAEA 2009: World Distriubution of Uranium Deposits (UDEPO) with uranium deposit classification. International Atomic Energy Agency Technical Documents (IAEA-TECDOC) **1629**, 109 pp.

Kalsbeek, F. 1995: Geochemistry, tectonic setting, and poly-orogenic history of Palaeoproterozoic basement rocks from the Caledonian fold belt of North-East Greenland. Precambrian Research **72**, 301-315.

Kalsbeek, F. & Taylor, P.N. 1985: Isotopic and chemical variation in granites across a Proterozoic continental margin – the Ketilidian mobile belt of South Greenland. Earth and Planetary Science Letters **73**, 65-80.

Kalsbeek, F., Larsen, L.M. & Bondam, J. 1990: Descriptive text to 1: 500 000 sheet Sydgrønland Sheet 1. Descriptive text. Grønlands Geologiske Undersøgelse. 20pp.

Kalsbeek, F., Austrheim, H., Bridgwater, D., Hansen, B.T., Pedersen, S. & Taylor, P.N. 1993a: Geochronology of Archaean and Proterozoic events in the Ammassalik area, South-East Greenland, and comparisons with the Lewisian of Scotland and the Nagssugtoqidian of West Greenland. Precambrian Research **62**, 239-270.

Kalsbeek, F., Nutman, A.P. & Taylor, P.N. 1993b: Palaeoproterozoic basement province in the Caledonian fold belt of North-East Greenland. Precambrian Research **63**, 163-178.

Kalsbeek, F., Thrane, K., Nutman, A.P. & Jepsen, H.F. 2000: Late Mesoproterozoic to early Neoproterozoic histroy of teh East Greenland Caledonides: evidence for Grenvillian orogenesis? Journal of the Geological Society London **157**, 1215-1225.

Kalsbeek, F., Jepsen, H. & Nutman, A.P. 2001: From source migmatites to plutons: tracking the origin of ca. 435 Ma S-type granites in the East Greenland Caledonian orogeny. Lithos **57**, 1–21.

Kalvig, P. 1983: Preliminary Mining Assessment of the Uranium Resource at Kvanefjeld. 109 pp. Risø National Laboratory.

Keulen, N., Schumacher, J. & Kokfelt, T.F. 2011: Notes on the structural profiles related to the 1:100 000 digital geological map of southern West and South-West Greenland, 61°30′ - 64°N. Danmark og Grønlands Geologiske Undersøgelse Rapport **2011/13**, 70pp.

Knudsen, C. 1991: Petrology, geochemistry and economic geology of the Qaqarssuk carbonatite complex, southern West Greenland. Monograph Series on Mineral Deposits **29**, 1-110.

Kolb, J., Dziggel, A. & Schlatter, D.M. 2013a:. Gold Occurrences of the Archean North Atlantic Craton, Southern West and South West Greenland: A Review and First Approach to a Comprehensive Genetic Model. Ore Review Letters **54**, 29-58.

Kolb, J., Thrane, K. & Bagas, L. 2013b: Field relationship of high-grade Neo- to Mesoarchaean rocks of South-East Greenland: Tectonometamorphic and magmatic evolution. Gondwana Research **23**, 471–492.

Kreuzer, O.P., Markwitz, V., Porwal, A.K. & McCuaig, T.C. 2010: A continent-wide study of Australia's uranium potential: Part I: GIS-assisted manual prospectivity analysis. Ore Geology Reviews **38**, 334–366.

Larsen, L.M., Rex, D.C. & Secher, K. 1982: The age of carbonatites, kimberlites and lamprophyres from southern West Greenland: recurrent alkaline magmatism during 2500 million years. Lithos **16**, 215-221.

Larsen, M. Hamberg, L., Olaussen, S., Preuss, T. & Stemmerik, L. 1999: Sandstone wedges of the Cretaceous-Lowe Tertiary Kangerlussuaq Basin, East Greenland – outcrop analogues to the offshore North Atlantic. Petroleum Geology Conference series.**5**; 337-348.

Larsen, P.-H., Olsen, H., Clack & J.A. 2008: The Devonian basin in East Greenland-Review of basin evolution and vertebrate assemblages. In: Higgins, A.K., Gilotti, J.A., and Smith, M.P., eds., The Greenland Caledonides: Evolution of the Northeast Margin of Laurentia: Geological Society of America Memoir **202**, 273-292.

Lewerentz, A. 2010: On the occurrence of baddeleyite in silica-saturated rocks (Lund University). Unpublished BSc Thesis, Lund University, Sweden.

Lind, M. 1980: Scheelitprospektering i Forsblad Fjord, Alpefjord, Jelsdal, Ymers Ø og Kalkdal. Internal NM-report **6-10/79**, 58pp.

Lyck, J.M. & Stemmerik, L. 2000: Palynology and depositional history of the Paleocene? Thyra Ø Formation, Wandel Sea Basin, eastern North Greenland. In: Stemmerik, L.: Palynology and deposition in the Wandel Sea Basin, eastern North Greenland. Geology of Greenland Survey Bulletin **187**, 21-49.

McMillan, R.H. 1996: Classical U veins. Geological Survey of Canada. British Columbia Energy and Minerals Division, Special Publication **93**, 96 pp.

Moorbath, S., Taylor, P.N. & Goodwin, R. 1981: Origin of granitic magma by crustal remobilisation: Rb-Sr and Pb/Pb geochronology and isotope geochemistry of the late Archaean Qôrqut Granite Complex of southern West Greenland. Geochimica et Cosmochimica Acta Vol. **45**, 1051-1060.

Mosier, D.L. 1986: Grade and tonnage model of volcanogenic U. In: Cox, D.P. & Singer, D.A. (eds.): United State Geological Survey Bulletin **1693**, 162–164.

Myers, J.S.1980: Structure of the coastal dyke swarm and associated plutonic intrusions of East Greenland. Earth and Planetary Science Letters **46**, 407-418.

Myers, J.S., Gill, R.C.O., Rex, D.C. & Charnley, N.R. 1993: The Kap Gustav Holm Tertiary Plutonic Centre, East Greenland. Journal of the Geological Society London **150**, 259-276.

Nielsen, B.L. 1980: The uranium potential of Greenland – a geological analysis of favourability. **IAEA-SM-239/4**, 18pp.

Nielsen, T.F.D. 1987: Tertiary alkaline magmatism in East Greenland: a review. In. Fitton, J.G. & Upton, B.G.J. (eds.): Alkaline Igneous Rocks. Geological Society Special Publication **30**, 489-515.

Nielsen, B.L. & Løvborg, L. 1976: Radiometric survey between Scoresby Sund and Hold with Hope, central East Greenland. Rapport Grønlands Geologiske Undersøgelse **76**, 44 pp

Nielsen, B.L. & Steenfelt, A. 1977: Distribution of radioactive elements and the recognition of uranium mineralizations in East Greenland. In: Recognition and evaluation of uraniferous areas. International Atomic Energy Agency, Vienna (**IAEA-TC-25/3**), 87-105.

Noble, R.H., Macintyre, R.M. & Brown, P.E. 1988: Age constraints on Atlantic evolution: timing of magmatic activity along the East Greenland continental margin. Geological Society London Special Publications **39**, 201-214.

Nutman, A.P., Dawes, P.R., Kalsbeek, F. & Hamilton, M.A. 2008a: Palaeoproterozoic and Archaean gneiss complexes in northern Greenland: Palaeoproterozoic terrane assembly in the High Arctic. Precambrian Research 161, 419–451.

Nutman, A.P., Kalsbeek, F. & Friend, C:R.L. 2008b: The Nagssugtoqidian orogen in South-East Greenland: evidence for paleoproterozoic collision and plate assembly. American Journal of Science **308**, 529-572.

Nyegaard, P. & Armour-Brown, A. 1986: Uranium occurrences in the Granite Zone. Structural setting - genesis - exploration methods. The South Greenland exploration programme 1984-1986. Report No.1. Open File Series Grønlands Geologiske Undersøgelse **1**, 138 pp.

Olsen, H. & Larsen, P.-H. 1993: Lithostratigraphy of the continental Devonian sediments in North-East Greenland. Grønlands Geologiske Undersøgelse **165**, 108.

Oliver, N.H.S., Pearson, P.J., Holcombe, R.J. & Ord, A. 1999: Mary Kathleen metamorphic-hydrothermal uranium-rare earth element deposit: ore genesis and numericalmodel of coupled deformation and fluid flow. Australian Journal of Earth Sciences 46, 467–484.

Porter, T.M. 2010: Hydrothermal Iron Oxide Copper-Gold and Related Deposits: A Global Perspective, v.3, Advances in the Understanding of IOCG Deposits. 3 & 4. Adelaide: PGC Publishing, 600 pp.Poulsen, V. 1964: The sandstones of the Precambrian Eriksfjord Formation in South Greenland. Grønlands Geologiske Undersøgelse Rapport **2**. 16pp.

Pankhurst, R.J., Beckinsale, R.D. & Brooks, C.K. 1976: Strontium and Oxygen Isotope Evidence Relating to the Petrogenesis of the Kangerdlugssuaq Alkaline Instrusion, East Greenland. Contributions to Mineralogy and Petrology 54, 17-42.

Pauly, H. 1960: Det Radioaktive Mønster om Ivigtut. GEUS Report File no 21546.

Plant, J.A., Simpson, P.R., Smith, B. & Windley, B. 1999: Uranium ore deposits - products of the radioactive earth. In: Burns, P.P. & Finch, R. (eds): Uranium: Mineralogy, geochemistry and the Environment **38**, 255–319. Mineralogical Society of America.

Riisager, P., Pedersen, M., Jørgensen, M.S., Schjøth, F. & Thorning, L. 2011: DODEX – Geoscience Documents and Data for Exploration in Greenland. Geological Survey of Denmark and Greenland Bulletin **23**, 77–80.

Rosa, D., Rasmussen, J.A., Sørensen, E.V. & Kalvig, P. 2014: Reconnassance for Mississippi Valley-type and SEDEX Zn-Pb deposits in the Franklinian Basin, Eastern North Greenland. Results of the 2013 Season. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2014/6**,40 pp.

Rose-Hansen, J., Sørensen. H. & Watt, W.S. 2001: Inventory of the literature on the Ilimaussaq alkaline complex, South Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2001/102** 42p.

Ruzicka, V. 1993: Vein uranium deposits. In: Haynes, S.J. (ed.): Vein-type Ore Deposits **8**, 247–256.

Schatzlmaier, P., Schöllnberger, W. & Thomassen, B. 1973: Untersuchung des Vorkommens von Zirkon und seltenen Erden auf Kote 800 Milneland. Internal NM-report **4/72**, 91 pp.

Schlatter, D.M. & Steensgaard, B.M, 2012: Evaluation of the mineral potential in the Bjørnesund Greenstone belt combining multivariate studies, field work and lithogeochemistry. Danmark og Grønlands Geologiske Undersøgelse Rapport **2012/60**, 60pp.

Schofield, A. 2010: Potential for magmatic-related uranium mineral systems in Australia. Geoscience Australia Record **2010/20**, 56 pp.

Secher, K. 1976: Airborne radiometric survey between 66° and 69°N, southern and central West Greenland. Grønlands Geologiske Undersøgelse rapport **80**, 65-67.

Secher, K. 1980: Distribution of radioactive mineralisation in central West Greenland. Grønlands Geologiske Undersøgelse Rapport **100**, 61-65.

Secher, K. 1986: Exploration of the Sarfartôq carbonatite complex, southern West Greenland. In: Kalsbeek, F. & Watt, W.S. (eds.): Developments in Greenland geology. Rapport Grønlands Geologiske Undersøgelse **128**, 89-101.

Secher, K. 2009: interview on KNR Radioa, March 2009 and map indicating known and potential uranium occurrences.

Secher, K. & Larsen, L.M. 1980: Geology and mineralogy of the Sarfartoq carbonatite complex, southern West Greenland. Lithos **13**, 199-212.

Secher, K., Heaman, L.M., Nielsen,T.F.D., Jensen, S.M., Schjøth, F. & Creaser, R.A. 2009: Timing of kimberlite, carbonatite, and ultramafic lamprophyre emplacement in the alkaline province located 64º – 67ºN in southern West Greenland. Lithos **112**, 400-406.

Singer, D.A., 1993, Basic concepts in three-part quantitative assessments of undiscovered mineral resources: Nonrenewable Resources, v. **2**, no. 2, p. 69–81.

Singer, D.A., & Menzie, W.D. 2010, Quantitative mineral resource assessments: New York, Oxford University Press, 219 p.

Skirrow, R.G., Jaireth, S., Huston, D.L., Bastrakov, E.N., Schofield, A., van der Wielen, S.E. & Barnicoat, A.C. 2009: Uranium mineral systems: Processes, exploration criteria and a new deposit framework. Geoscience Australia Record **2009/20**, 44 pp.

Soper, N.J., Higgins, A.C., Downie, C., Matthews, D.W. & Brown, P.E., 1976: Late Cretaceous-early Tertiary stratigraphy of the Kangerdlugssuaq area, east Greenland, and the age of opening of the north-east Atlantic. Journal of the Geological Society **132**, 85-102.

Sparkes, G.W. & Kerr, A. 2008: Diverse styles of uranium mineralization in the Central Mineral Belt of Labrador: an overview and preliminary discussion. Newfoundland and Labrador Department of Natural Resources Geological Survey Report **08-1**, 193–227.

Steenfelt, A. 1976: Uranium exploration in northern East Greenland. Grønlands Geologiske Undersøgelse Rapport **80**, 110-112.
Steenfelt, A. 1980: The geochemistry of stream silt, North Greenland. Rapport Grønlands Geologiske Undersøgelse **99**, 129–135.
Steenfelt, A. 1982: Uranium and selected trace elements in granites from the Caledonides of East Greenland. Mineralogical Magazine **46**, 201-210.
Steenfelt, A. 1985: Reconnaissance scale geochemical survey in central and western North Greenland. Preliminary results concerning zinc and barium. Rapport Grønlands Geologiske Undersøgelse **126**, 95–104.
Steenfelt, A. 1987: Geochemical trends in central and western North Greenland. Rapport Grønlands Geologiske Undersøgelse **133**, 123–132.
Steenfelt, A. 1991: Economic mineral resources, North Greenland. In: Trettin, H.P. (ed.): Geology of the Innuitian orogen and Arctic Platform of Canada and Greenland. Geology of Canada **3**, 539–541. Ottawa: Geological Survey of Canada (also The geology of North America E, Geological Society of America).
Steenfelt, A. 2001: Geochemical atlas of Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2001/46**.
Steenfelt, A. 2014: Uranium data for Greenland registered by GEUS: data acquisition, coverage and spatial uranium variation. Danmark og Grønlands Geologiske Undersøgelse Rapport **2014/28**, 48pp.
Steenfelt, A. & Armour-Brown, A. 1988: Characteristics of the South Greenland uranium Province. In: Proceedings of a technical committee meeting on recognition of uranium provinces organized by the international atomic energy agency from 18 to 20 september 1985, IAEA Vienna, 305-335.
Steenfelt, A. & Dam, E. 1996: Reconnaissance geochemical mapping of Inglefield Land, North-West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **1996/12**, 27 pp.
Steenfelt, A. & Kunzendorf, H. 1979: Geochemical methods in uranium exploration in northern East Greenland. In: Watterson, J.R. & Theobald, P.K. (eds): Geochemical exploration 1978, 429–442: Ontario: Association of Exploration Geochemists.
Steenfelt, A., Nielsen, B.L. & Secher, K. 1977: Uraniuam geology and prospecting in Greenland. In: Jones, M.J. (ed): Geology mining and extractive processing of uranium, 8 pp. London: Institution of Mining and Metallurgy.
Steenfelt, A., Dawes, P.R., Krebs, J.D., Moberg, E. & Thomassen, B 2002: Geochemical mapping of the Qaanaaq region 77°10' to 78°10'N, North-West Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2002/65**, 77 pp.
Steenfelt, A., Hollis, J.A. & Secher, K. 2006: The Tikiusaaq carbonatite: a new Mesozoic intrusive complex in southern West Greenland. Geological Survey of Denmark and Greenland Bulletin **10**, 41–44.
Steenfelt, A., Schjøth, F., Sand, K., Secher, K., Tappe, S., Moberg, E. & Tukiainen, T. 2007: Initial assessment of the geology and economic potential of the Tikiusaaq carbonatite complex and ultramafic lamprophyre dykes. Mineral resource assessment of the Archaean Craton (66° to 63°30`N) SW Greenland Contribution no. 3.Danmarks og Grønlands Geologiske Undersøgelse Rapport **64**.
Stemmerik, L. & Håkansson, E. 1989: Stratigraphy and depositional history of the Upper Palaeozoic and Triassic sediments in the Wandel sea Basin, central and eastern North Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport. **143**, 21-45.
Stemmerik, L., Larsen, B.D. & Dalhoff, F. 2000: Tectonostratigraphic history of northen Amdrup Land, eastern North Greenland: implications for the northernmost East Green-

land shelf. In: Stemmerik, L.: Palynology and deposition in the Wandel Sea Basin, eastern North Greenland. Geology of Greenland Survey Bulletin **187**, 7-19.

Stemmerik, L., Bendix-Almgreen, S.E. & Piasecki, S. 2001: The Permian-Triassic boundary in centrl East Greenland: past and present views. Bulletin of the Geological Society of Denmark **48**, 159-167.

Stendal, H., Nielsen, B.M., Secher, K. & Steenfelt, A. 2004: Mineral resources of the Precambrian shield of central West Greenland (66° to 70°15N). Part 2. Mineral occurrences. Danmarks og Grønlands Geologiske Undersøgelse Rapport **20**.

Stendal, H., Secher, K. & Frei, R. 2006: 207Pb-206Pb dating of magnetite, monazite and allanite in the central and northern Nagssugtoqidian orogen, West Greenland. Geological Survey of Denmark and Greenland Bulletin **11**, 101-114.

Strachan, R.A., Holdsworth, R.E., Friderichsen, J.D. & Jepsen, H.F., 1992: Regional Caledonian structure within an oblique convergence zone, Dronning Louise Land, NE Greenland. J. Geol. Soc. London **149**, 359-371.

Strachan, R.A., Martin, R.A. & Friderichsen, J.D 2001: Evidence for contemporaneous yet contrasting styles of granite magmatism during extensional collapse of the northeast Greenland Caledonides. Tectonics **20**, 458-473.

Sønderholm, M., Fredriksen, K.S., Smith, M.P. & Tirsgaard, H. 2008: Neoproterozoic sedimentary basins with glacigenic deposits of the East Greenland Caledonides. In: Higgins, A.K., Gilotti, J.A., and Smith, M.P., eds., The Greenland Caledonides: Evolution of the Northeast Margin of Laurentia: Geological Society of America Memoir **202**, 99-136.

Sørensen, H. 1962: On the occurrence of steenstrupine in the Ilímaussaq massif, Southwest Greenland. Bulletin Grønlands Geologiske Undersøgelse **32**, 251pp.

Sørensen, H., Rose-Hansen, J., Nielsen, B.L., Løvborg, L., Sørensen, E. & Lundgaard, T. 1974:The uranium deposit at Kvanefjeld, The Ilimaussaq intrusion, South Greenland. Geology, reserves and benefication. Report Grønlands Geologiske Undersøgelse **60**, 54 pp.

Sørensen 2001: The Ilimaussaq alkanline complex, South Greenland: status of mineralogical research with new results. Edited by Sørensen H.. Geology of Greenland Survey Bulletin **190**, 167 pp.

Tegner, C., Duncan, R.A., Bernstein, S., Brooks, C.K., Bird, D.K. & Storey, M. 1998: ^{40}Ar-^{39}Ar geochronology of tertiary mafic intrusions along the East Greenland rifted margin: Relation to flood basalts and the Iceland hotspot track. Earth and Planetary Science Letters **156**, 75-88.

Thomassen, B. 1982: Prospecting for Cu-Pb-Zn-Au-Ag in the Clavering Ø, Giesecke Bjerge and Canning Land areas. Internal NM-report **1/81**, 59pp.

Thomassen, B. 1983: Reconnaissance for gold in Flyverfjord and Forsblads Fjord 1983. Internal NM-note **4/83**, 41 pp.

Thomassen, B. 1988: The Motzfeldt 87 Project, Final report. Open file Series Grønlands Geologiske Undersøgelse **88/1**, 81pp.

Thomassen, B. 2009: Nordmine Archives: Part 2. Overview of heavy mineral concentrates and stream sediment samples from Nordisk Mineselskab A/S, including microscopic observatons. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2009/72**, 15 pp.

Thomassen, B. & Tukiainen, T. 2009: Nordmine Archives: Part 1. Digital geological and geochemical data from Nordisk Mineselskab A/S' mineral exploration in central East Greenland. Danmarks og Grønlands Geologiske Undersøgelse Rapport **2009/72**, 15 pp.

Thrane, K. & Connelly, J.N. 2006: Zircon geochronology from the Kangaatsiaq-Qasigiannguit region, the northern part of the 1.9-1.8 Ga Nagssugtoqidian orogen, West Greenland. Geological Survey of Denmark and Greenland Bulletin **11**, 87-99.

Thrane, K., Baker, J., Connelly, J. & Nutman, A. 2005: Age, petrogenesis and metamorphism of the syn-collisional Prøven Igneous Complex, West Greenland. Contribution to Mineralogy and Petrology **149**, 541-555.

Tirsgaard, H. & Øxnevad, I.E.I. 1998: Preservation of pre-vegetational mixed fluvio–aeolian deposits in a humid climatic setting: an example from the Middle Proterozoic Eriksfjord Formation, Southwest Greenland. Sedimentary Geology **120**, 295-317.

Turner-Peterson, C. & Hodges, C.A. 1986: Descriptive Model of Sandstone U. In: Cox, D.P. & Singer, D.A. (eds): United State Geological Survey Bulletin **1693**, 209-210.

Tukiainen, T. 1986: Pyrochlore in the Motzfeldt centre of the Igaliko nepheline syenite complex, South Greenland, Final report. Unpublished internal GGU report. 98pp.

Upton, B.G.J. & Emeleus, C.H. 1987: Mid-Proterozoic alkaline magmatism in southern Greenland: the Gardar province. In: Fitton, J.G. & Upton, B.G.J. (eds): Alkaline igneous rocks. Geological Society Special Publication (London) **30**, 449–471.

Ussing, N.V. 1912: Geology of the country around Julianehaab, Greenland. Meddelelser om Grønland **38**, 1–376.

Van Gool, J., Alsop, G.I., Àrting, U.E., Garde, A.a., Knudsen, C., Krawiec, A.W., Mazur, S., Nygaard, J., Piazolo, S., Thomas, C.W. & Thrane, K. 2002: Precambrian geology of the northern Nagssugtoquidian orogeny, West Greenland: mapping in the Kangaatsiaq area. Geology of Greenland Survey Bulletin **191**, 13–23.

Vestergaard, C. 2013: Grønlandske dilemmaer. In: Rose F. (ed.): International debat & analyse. Morgenavisen Jyllands-Posten, Fredag den 1. November 2013. http://www.diis.dk/files/DIIS_generelt/Nyheder/DIIS-JyllandsPosten/Artikler/Gr%C3%B8nlandske%20dilemmaer.pdf

Wenrich-Verbeek K.J., 1980: Geochemical exploration for uranium utilizing water and stream sediments. USGS Technical report USGS-OFR-80-359.

Watt, G.R. & Thrane, K. 2001: Early Neoproterozoic events in East Greenland. Precambrian Research **110**, 165–184.

Wilde, A. 2013: Towards a Model for Albitite-Type Uranium. Minerals **3**, 36–48.

Appendix 1

Uranium deposit type	Com-modities (bypro-ducts)	Subtypes	Description	Tectonic setting	Geological setting / depositional environment	Age of minerali-sation	Host / associa-ted rock types	Deposit form	Alteration [bullet-numbers refer to subtypes]	Ore controls	Genetic model	Typical grades/tonnages [bullet-numbers refer to subtypes]	Exploration signatures [geochemical and geophysical]	Global examples [bullet-numbers refer to subtypes]	Greenland examples *[in italics potential areas]*	References
D1 **Sandstone deposits**	U (V, Cu)	1. Roll-front deposits: mineralised zones convex down the hydrologic gradient, diffuse boundaries with reduced sandstone on the down-gradient side and sharp contacts with oxidized sandstone on the up-gradient side. 2. Tabular deposits: lenticular uranium matrix impregnated masses within reduced sediments. a. Intrinsic carbon related deposits b. Extrinsic carbon related deposits ('Grants type') c. Vanadium-uranium deposits ('salt-wash type'). 3. Basal channel deposits: palaeodrainage channels filled with thick permeable alluvial-fluvial sediments with uranium mineralisations predominantly associated with detrital plant debris.	Micro-crystalline uranium oxides and silicates deposited during diagenesis in localised reducing environments within fine- to medium-grained sandstone beds; some uranium oxides are also deposited during redistribution by ground water at the interface between oxidized and reduced ground.	Continental stable platform or foreland-interior basin, shelf margin; adjacent major uplift provide favourable topographic conditions.	Continental-basin margins, fluvial channels, braided stream deposits, stable coastal plains environments. Contempora-neous felsic volcanism or eroding felsic plutons are sources of U. Porous zones within sandstones with chemically reducing agents.	Predomi-nantly Devonian and younger	Medium to coarse-grained sandstones; feldspathic or tuffaceous sandstones	Stratabound deposit forms: • Elongated and sinuous approxima-tely parallel to the strike and perpendicu-lar to the direction of deposition and groundwater flow • Tabular deposits – irregularly shaped lenticular bodies • Channel-like forms reflecting palaeodrai-nage systems	1. Oxidized iron minerals in rock up-dip, reduced iron minerals in rock down-dip from redox interface 2. Acid mineralising fluids leach iron from detrital magnetite-ilmenite leaving relict TiO_2 minerals in diagenetic ores	Permeability and the presence of reducing agents. Regional redox interface marks the locus of ore deposition.		1. Few hundred tons to several thousands of tons of uranium at grades averaging 0.05–0.25% 2. Several hundreds of tons up to 150.000 tons of uranium at grades 0.05–0.5% 3. Several hundreds to 20.000 tons uranium at grades ranging from 0.01–3% 4. Few hundred tons up to 5.000 tons of uranium at average grades ranging from 0.1–0.5%	Stream sediment data: anomalous U, V, Mo, Se, locally Cu, Ag. Geophysical data: anomalous radioactivity.	• Colorado Plateau, USA • Grants, USA	Illorsuit Milne Land *Palaeozoic and younger:* • *Wandel Sea Basin,* • *Central East Greenland Rift Basin,* • *Nuussuaq Basin* *Proterozoic basins* • *Independence Fjord Basin,* • *Thule basin,* • *Hagen Fjord Basin,* • *Hekla Sund Basin,* • *Elenore Bay Basin,* • *Psammites, South GLD,* • *Gardar Rift Basin*	Fayek 2013 IAEA 2009 Turner-Peterson & Hodges 1986 Skirrow et al. 2009

Uranium deposit type	**Com-modities (bypro-ducts)**	**Subtypes**	**Description**	**Tectonic setting**	**Geological setting / depositional environment**	**Age of minerali-sation**	**Host / associated rock types**	**Deposit form**	**Alteration** [bullet-numbers refer to subtypes]	**Ore controls**	**Genetic model**	**Typical grades/tonnages** [bullet-numbers refer to subtypes]	**Exploration signatures** [geochemical and geophysical]	**Global examples** [bullet-numbers refer to subtypes]	**Greenland examples** *[in italics potential areas]*	**References**
D2 **Unconfor-mity-related deposits**	U (Au, Ni)	1. Unconformity contact deposit: a) either as fracture bound deposits in metasediments below the unconformity or as b) clay-bound deposits associated with clay at the base of the sedimentary cover directly above the unconformity 2. Sub-unconformity-post-metamorphic deposit: strata-structure-bound in metasediments below the unconformity	Uranium mineralisation occurs as fracture-filling and breccia in metapelites, metapsam-mites and quartz arenites located below, above, or across an unconformity separating Early and Middle Proterozoic rocks.	Intracratonic sedimentary basin	Structurally-prepared and porous zones immediately below and above an unconformable contact that separates an intensively altered crystalline basement from overlying sediments	Proterozoic or Phanero-zoic	Clastic sediments (unmetamor-phosed quartz arenites) or metamor-phosed crystalline basement rocks	Tabular, pencil shaped or irregular in shape extending up to few kilometres in length. Depth potential below the unconformity is generally less than 100 m.	Chloritisation, hematisation, kaolinisation, illitisation and silicification	Mid-Proterozoic unconformities and Lower Proterozoic host rocks are re-ported to be favourable due to their commonly high content of graphitic material. Local and regional scale fault zones that intersect the unconformity may also be important features. Generally found close to ba-sement granitic rocks with a high U Clarke values (weighted ave-rages of elemental composition of various rocks ex-posed at the Earth's surface; in this case granitic rocks).	Deposits result from complex processes including regional metamorphism, weathering and supergene enrichment related to Proterozoic unconformities, and form later remobilisation and enrichment beneath cover of younger strata.	Individual ore bodies are generally small, but can be extremely high-grade; up to several percent U. Median size for 36 Saskatchewan and Australian deposits is reported to be 260.000 t at 0.42% U.	Stream sediment data: anomalous increase in U, Mg, P and locally in Ni, Cu, Pb, Zn, Co, As; decrease in SiO_2. Locally Au, associated with Ag, Te, Ni, Pd, Re, Mo, Hg, REE, Y and Rb. Geophysical data: anomalous radioactivity. Graphitic schists in some deposits are strong electromagnetic conductors.	• Rabbit Lake, Canada • Cluff Lake, Canada • Key Lake, Canada • Jabiluka, Australia • Ranger, Australia	No known examples *Proterozoic basins* • *Psammites South GLD* • *Thule Basin,* • *Grænseland, Midternæs* • *Gardar rift basin* *Palaeozoic and younger:* • *Central East Greenland Rift Basin,* • *Nuussuaq Basin*	Fayek 2013 Grauch & Mosier 1986 IAEA 2009 Skirrow et al. 2009
D3 **Hematite breccia complex deposits (IOCG)**	U, Cu, Au, Fe (Ag, REE)		Metasomatic expression of large crustal-scale alteration events driven by intrusive activity.	Craton margin associated with A-type and/or I-type magmatism. Major crustal shear/fault zones may be important loci for the ore deposition. Hitzman (2000) describe two permissive tectonic environment: 1) Continental margin subduction complexes with local extensional features (rifts) and 2) compres-sion, folding and mag-matism of intra-cratonic basin (rifts)	Clear temporal, but usually no close spatial association with batholithic complexes, composed of both anorogenic granitoids and varying proportions of mantle related, fractionated mafic to intermediate phases. Magmatic complexes extends over tens of thousands km^2.	Lower Proterozoic to Miocene	Faulted and deformed volcanic and sedimentary rocks with bedding-parallel permeability, and volcanic, sedimentary, and tectonic breccias. Less common are ores hosted in faults and breccias in intrusive rocks.	Polymetallic enrichment within breccias pipes, veins, disseminated zones and massive ore lenses.	Regional scale alteration: at depth early, usually predating ore Na-Ca±Fe (albite/ scapolite±magne tite) related to either deeply circulating for-mational/ basinal waters or magmatic-hydrothermal fluids. Progres-ses temporally and spatially upwards to K with increasing Fe (biotite/ K-feldspar±magnet ite), to Fe-Na-Ca (magnetite-scapolite-apatite-actinolite) or Fe-K-Na (magnetite -K-feldspar-actinolite±mag-netite) at deep or shallower levels respectively. The latter two altera-tions usually host major Fe-oxide apatite accumulations.	Pre-ore permeability of host rocks and fault/shear zones combined with redox front controls the ore deposition.	Origin is still uncertain. Principal mechanisms are believed to be hydraulic fracturing, tectonic faulting, chemical corrosion and gravity collapse. Brecciation is believed to occur in near surface eruptive environment causing boiling and explosive iinteractions of meteoric water.	Resources vary, with the Olympic Dam being exceptionally big with 9080 Mt at 230 ppm U, 0.87% Cu, 0.32 g/t Au and 0.27 kg/t U_3O_8 (2 million tonnes of uranium). More normal, resources are in the range of *c.* 100 to *c.* 500 Mt @ 0.5–1.5% Cu and variable gold content, generally from 0.3–0.8 g/t Au.	Stream sediment data: anomalous Cu, U, Co, Au, Ag, light REE, F, Ba. Geophysical data: anomalous radioactivity and magnetic high.	• Olympic Dam, Australia • Cloncurry, Australia • Starra, Australia • Ernest Henry, Australia • Phalaborwa, South Africa • La Candelaria, Chile	No known examples • *Inglefield Land Mobile Belt* • *Ketilidian Mobile Belt*	Corriveau 2007 Cox & Singer 2007 Fayek 2013 IAEA 2009 Porter 2010

Uranium deposit type	Com-modities (bypro-ducts)	Subtypes	Description	Tectonic setting	Geological setting / depositional environment	Age of minerali-sation	Host / associated rock types	Deposit form	Alteration [bullet-numbers refer to subtypes]	Ore controls	Genetic model	Typical grades/tonnages [bullet-numbers refer to subtypes]	Exploration signatures [geochemical and geophysical]	Global examples [bullet-numbers refer to subtypes]	Greenland examples *[in italics potential areas]*	References
D4 **Palaeo-quartz-pebble conglo-merate deposits**	U, Au, PGE	1. Monometallic 2. Polymetallic	Detrital uranium oxide ores found in quartz-pebble conglomerates deposited as placers/basal units in fluvial to lacustrine braided stream systems.	Extensional basins or coastal plains formed at Archaean craton margins	Fault-bounded elongated epicontinental half-grabens or basins and on faulted coastal plains formed on or near the margin of an Archaean craton. Middle and basal reaches of alluvial fans deposited on the steeper side of basins.	Major deposits are Archaean to Early Proterozoic (3100–2200 Ma). The Tarkwa deposit, Ghana, is 1900 Ma.	Quartz-pebble conglomerate that unconfor-mably overlies granitic and metamorphic basement			Fluvial transport of detrital uraninite was possible at the time of ore formation (3100-2200 Ma) because of the prevailing anoxic atmosphere.	Detrital uraninite and uranothorite deposited as placer deposits and later modified by post-depositional hydrothermal fluids.	Medium to large size (2,000 – 150,000 t) and low grades (0.01-0.10%)	Stream sediment data: Au, U, PGE anomalies. Geophysical data: anomalous radioactivity.	1) • Blind River / Elliot Lake, Canada 2) • Witwaters-rand, South Africa	Wegener Halvø • *Midternæs & Grænseland West GLD* • *Ketilidian SE Greenland* • *Nuussuaq basin* • *Nuussuaq Precambian* • *Karrat Group* • *Thule Supergroup* • *Independence Fjord Group*	Fayek 2013 IAEA 2009 Turner-Peterson & Hodges 1986 Skirrow et al. 2009
D5 **Vein type (granite-related deposits)**	U (Ni, Co, As, Bi, Cu, Pb, Zn, Mn, Se, V, Mo, Fe, Ag)	1. Endogranitic 2. Perigranitic Vein uranium deposits spatially related to granite occur within and around leucogranitic intrusions.	Vein type uranium deposits are epigenetic concentrations of uranium minerals in open spaces, such as fractures, fissures, shear zones and breccias, in igneous, sedimentary and metamorphic rocks. Spatially related to leucogranitic intrusions.	Postorogenic continental environ-ments, associated with calcalkaline igneous and volcanic rocks	Ore is deposited in open spaces within fracture zones, breccias and stockworks commonly associated with major or subsidiary, steeply dipping fault systems.	Proterozoic to Tertiary (none are older than 2.2 Ga; the time when the atmosphere advanced to the current oxygen-rich condition)	Wide variety of host rocks. Granitic, commonly peraluminous two-mica granites, or syenitic rocks (intragranitic veins), rocks surrounding granitic plutons, or in sheared or mylonitised metamorphic, sedimentary or igneous rocks.	Tabular or prismatic in shape, from centimetres up to a few meters thick (rarely up to 15 m). Depth potential mostly a few hundred meters, but some deposits extend 700 m up to 2 km down dip. Alteration envelopes contain disseminated mineralisa-tions.	Hematitisation, argillisation, albitisation, chloritisation, carbonatisation, silicification, sericitisation, sulphidisation. Intense brick-red hematite adjacent to some high-grade uranium ores is probably due to loss of electrons during radioactive disintegration of uranium and it daughter products.	Structural controls are pronounced. Dilatant in major fault systems and shear zones are favourable traps.	General found in areas of high uranium Clarke value (weighted averages of elemental composition of various rocks ex-posed at the Earth's surface; in this case granitic rocks), and often with other types of uranium deposits in the vicinity. Veins appear to be derived from the late magmatic differentiates of granites and alkaline rocks with high Na and K contents. Uranium is separated from the parent rock by aqueous solutions which may originate as hydrothermal, connate or meteoric fluids. Wall rocks with carbonaceous material, sulphide and ferromagnesian minerals are favourable loci for precipitation of ore. Age dating indicates that mineralisations in general are significantly younger than the associated felsic igneous rocks, but commonly close to the age of associated diabase or lamprophyre rocks.	Individual deposits are generally small to medium (5-10,000 t) with low grades of 0.05 to 0.5%. However, the vein deposits are often found in clusters and individual districts may aggregate considerable tonnages.	Stream sediment data: anomalous U and some or all of Ni, Co, Cu, Mo, Bi, As and Ag are regarded as good pathfinder elements. Stream water geochemistry: U and Ra. Geophysical data: anomalous radioactivity. VLF-EM surveys can be used to map fault zones. Magnetic surveys may be useful to detect areas of magnetite destruction in hematite-altered wall-rocks.	• Ace Fay-Verna and Gunnar, Saskat-chewan, Canada • Christopher Island-Kazn-Angikuni district, Northwest Territories, Canada • Millet Brook, Nova Scotia, Canada • Schwartz-walder, Colorado, USA • Xiazhuang district, China • La Crouzille area, Massif Central and Vendee district, Armorican Massif, France • Jachymov and Pribram districts, Czech Republic	• Nordre Sermilik • North of Bredefjord • Moskusoksel and • Puissattaq • Vatnaverfi • Nedre Arkosedal • Foldaelv • Qaqarssuk carbonatite	Fayek 2013 IAEA 2009 Ruzicka 1993 McMillian 1996

Uranium deposit type	Com-modities (bypro-ducts)	Subtypes	Description	Tectonic setting	Geological setting / depositional environment	Age of minerali-sation	Host / associated rock types	Deposit form	Alteration [bullet-numbers refer to subtypes]	Ore controls	Genetic model	Typical grades/tonnages [bullet-numbers refer to subtypes]	Exploration signatures [geochemical and geophysical]	Global examples [bullet-numbers refer to subtypes]	Greenland examples *[in italics potential areas]*	References
D6 **Intrusive deposits**	U, REE (F, Zr, Nb, Ta)	Two subtypes: 1) Anatectic deposits a) Alaskite: disseminated uranium occurs in medium to very coarse-grained alaskite bodies (leucocratic, quartz and alkali feldspar-rich granites) b) Pegmatite: uranium in un-zoned granitic and syenitic pegmatitic dykes (siliceous and mafic tendency with aegirine and augite) 2) Plutonic deposits a) Granitic to quartz-monzonitic complexes: highly differentiated (cupriferous; copper porphyries) complexes b) Peralkaline granitic or syenitic domes or stocks c) Carbonatite: in cupriferous carbonatite complexes	Uranium deposits associated with peralkaline rocks and carbonatite may be the most prospective intrusive rock association for uranium. Other, lesser prospective igneous rocks are alaskite, crustal-derived granites - monzonite and pegmatites (including I-type and A-type magma).	Syn- to post orogenic intrusions within intra-cratonic mobile belts or intrusive emplace in extensional settings (rift setting).	Preserved upper crustal levels with intrusive peralkaline, carbonatite, alaskite, crustal derived granites – monozonite and pegmatite complexes/stocks are probably the most prospective. Fault structures may have controlled the emplacement of the intrusives.		Peralkaline, carbonatite, alaskite, crustal derived granites – monozonite and pegmatite rocks.	Depending on subtype, the deposit can be found either as smaller isolated lenses or tabular zones or as large domes, stocks or bulk-ore masses/hori-zons.	No diagnostic alteration. Intrusive rocks are generally in sharp contact with country rocks and have none to a narrow metamorphic halo.	2) Fractional crystallisation is critical in concentrating uranium in the melt as it ascends through the crust. The peralkaline composition is the most effective chemical mechanism for maintaining U solubility, which prevents the melt from partitioning U into early accessory phases such as titanite, zircon and monazite in relatively low concentrations at an early stage of the magma crystallisation.	Fractional crystallisation is probably the governing process for the subtype 2b). For the subtype 1a), 1b), and 2a) melting of crustal material and in some cases also further hydromel and structural processes are necessary to create economic ore.	1) Range up to 0.08% U but with tonnages generally low (a few tons uranium to a few hundred tons uranium) 2) Generally low-grade deposits (20–500 ppm U) but large tonnages (more than 100,000 t)		1a) Alaskite • Rössing, Namibia 1b) Pegmatite • Bancroft area, Ontario, Canada. • Campbell Island Mine, Ontario, Canada 2a) Granitic to quartz-monzonitic complexes: • Bingham Canyon, Utah, USA 2b) Peralkaline granitic or syenitic domes or stock: • Kvanefjeld and Motzfeldt, Greenland • Pilanesberg, South Africa • Lolodorf, Cameroon • Catalao, Brazil 2c) Carbona-tite: • Phalaborwa, South Africa • Araxa, Brazil • Sokli, Finland • Sevathur, India	1a) No known examples 1b) • Naassuttooq • Hinks Land 2a) • Frænkel Land 2b) • Kvanefjeld • Motzfeldt • Ivigtut 2c) • Sarfartoq • Tikiussaq • Qaqarssuk • *Granites in West Greenalnd Greenland* • *Granites in South Greenland – Ketilidian* • *Granites in central East Greenland* • *Alkaline intrusions in Inglefield Land Mobile Belt* • *Alkaline intrusions in South-East Greenland*	Fayek 2013 IAEA 2009 Schofield 2010

Uranium deposit type	Com-modities (bypro-ducts)	Subtypes	Description	Tectonic setting	Geological setting / depositional environment	Age of minerali-sation	Host / associated rock types	Deposit form	Alteration [bullet-numbers refer to subtypes]	Ore controls	Genetic model	Typical grades/tonnages [bullet-numbers refer to subtypes]	Exploration signatures [geochemical and geophysical]	Global examples [bullet-numbers refer to subtypes]	Greenland examples *[in italics potential areas]*	References
D7 **Volcanic and caldera-related deposits**	U (Mo, F, REE)	1. Structure-bound 2. Strata-bound 3. Volcano-sedimentary deposits	Volcanic centre and caldera related uranium deposits caused by hydrothermal solutions	Diverse, including: continental rift (caldera), hot spots, back arcs and sub-duction (extensional regime). Settings with enhanced heat flow be-cause of thin-ning of the crust and consequently a rise of mafic magmas to induce partial melting of relatively U-rich upper crustal rocks to create melt compositions that favour enrichment of U and other incompatible elements.	Near-surface volcanic environments, subaerial to subaqueous volcanic complexes. Association with shallow intrusive rocks is important.	Proterozoic to Tertiary.	High-silica alkali rhyolite and potash trachytes. Peralkaline and peraluminous rhyolite host ore.	Vein, stockwork, breccia-hosted and strabound or stratiform deposits (the latter is hosted by lacustrine sediments deposited within a caldera)	Pre-ore alteration includes alkali metasomatism followed by varying amounts of quartz, sericite, pyrite and carbonate mineral veining. Kaolinite, montmorillonite and alunite are common. Silicification is spatially associated with the ore. Grown of U-minerals is commonly associated with argillic alteration and fluorite.	Formation of volcanogenic uranium deposits is dependent on extraction of uranium from felsic rocks, transport by hydrothermal solution, and deposition induced by chemical or physical changes. Fractures and breccias formed along margin of shallow intrusions may be important loci for the ore-mineralising fluid system.	Hydrothermal fluids driven by magmatic heat proximal to volcanic centres leaches uranium from U-bearing silicic volcanic rocks and concentrate it at sites of deposition. U mineralisation also extends into the underlying and adjoining basement rock, where it is concentrated in fractured granite and metamorphic rocks.	Individual deposits are small to medium (10-40,000 t) and relatively low to moderate grades (ppm to 0.4%)	Geological: Felsic volcanic rocks proximal to uranium deposits typically contain U in excess of 10 ppm. Enrichment in U is characteristic of rocks with aluminous and alkaline affinities. Stream sediment data: anomalous As, Sb, F, Mo, Hg ± W occur near and with the ore. Mo is deep, Hg is shallow in the system. REE may be highly anomalous. Geophysical data: anomalous radioactivity.	• Streltsovsk district, Russian Federation • Dornot complex, Mongolia • Nopal deposit, Mexico	• Randbøld al, Greenland • Moskusokse-land	Bagby 1986 Breit & Hall 2011 Fayek 2013 Mosier 1986 IAEA 2009
D8 **Metaso-matite deposits**	U	1. Na-metasomatite deposits (in albitites) a) Granite-derived b) Metasedimenta-ry/metavolca-nic derived 2. K-metasomatite deposits (in elkonites) 3. Skarn deposits	Deposits in fracture/fault zones within sodium or potassium metasomatites (respectively albitites and elkonites).	Orogens/mo-bile belts at craton margins or former intracratonic rift basins.	Located in metamorphic terranes within multiple deformed metamorphic belts	Proterozoic (most known deposits of this type seems to be located within albitites formed around 1.8 Ga). Uranium mineralisa-tion may be later.	Mylonitised and in many cases also albitised gneiss/ granite, meta-rhyolite, meta-volcaniclastic rocks, amphibolite and metasedi-ments.	Disseminated in zones and tabular/lenti-cular bodies and in cemented breccia zones. Rarely as veins.	Pervasive albitisation processes seem to play a major role in the formation of many of the known deposits of this type. Associated with this also sericitisation and chloritisation. Hematisation also occurs. Vuggy porosity is a common feature and may reflect dramatic bulk chemical changes, including complete removal of K and depletion of Si due to quartz and K-feldspar dissolution.	Long-lived, repeatedly activated, deep-seated ancient faults acting as conduits and permeable zones for uranium bearing fluids. Presence of metasomates – albitites (although not always present). These create more permeable zones. Favourable combinations of folds and faults, flexures and junctions, and mechanical heterogeneities (difference in permeability) may also play a role in the formation of deposits.	Uranium is leached from country rocks (commonly intrusives or volcano-sedimentary) or expulsion of uranium-bearing fluid from magmatic sources is being transported by oxidized hydrothermal fluids that migrate into permeable mylonitised and, in many cases also, albitised basement rocks within faults/fracture zones. Interaction of the oxidized uranium-bearing fluid with reduced mineral assemblage (e.g. chlorite, hornblende, epidote) and/or carbonaceous rocks precipitate the uranium.	Grades variably but mostly low (0.13 to 0.16% U_3O_8) and tonnages are small (500 t) to moderate (up to *c.* 100,000 t)	Stream sediment data: anomalous high Pb, Mo, Co, Be at near distance to mineralisation; elevated anomalous K, Y, La more distant to mineralisation. Geophysical data: anomalous radioactivity with high K-U-Th anomaly. Magnetic and gradient gravity response of fault zone.	1a) • Kirovograd district, Ukraine 1b) • Krivoi Rog Basin, Ukraine 2) • Elkon Horst Deposits, Russian Federation 3) • Mary Kathleen, Queensland, Australia Additional examples: • Espinharas and Lagoa Real, Brazil • Valhalla, Australia. • Kurupung, Guyana • Coles Hill, USA • Lianshan-guan, China • Michelin, Canada	• N. of Nordre Sermilik • Motzfeldt • Grønnedal-Ika • Sarfartoq • *Proterozoic reworked parts of Greenland and part of the craton with deep-seated faults (Archaean or Proterozoic)*	Fayek 2013 Finch et al. 1993 IAEA 2009 Kreuzer et al. 2010 Sparks & Kerr 2008 Wilde 2013

Uranium deposit type	Com-modities (bypro-ducts)	Subtypes	Description	Tectonic setting	Geological setting / depositional environment	Age of minerali-sation	Host / associated rock types	Deposit form	Alteration [bullet-numbers refer to subtypes]	Ore controls	Genetic model	Typical grades/tonnages [bullet-numbers refer to subtypes]	Exploration signatures [geochemical and geophysical]	Global examples [bullet-numbers refer to subtypes]	Greenland examples *[in italics potential areas]*	References
D9 **Surficial deposits** (This type is sometimes also referred to as calcrete uranium deposits.)	U	IAEA subdivide the type into: 1. Peat-bog deposits 2. Fluvial deposits • Valley-fill • Flood plain • Deltaic • Colluvial 3. Lacustrine-playa deposits 4. Surficial pedogenic and structure fill deposits • Authigenic • Allogenic	Broadly defined as young near-surface concen-trations in ce-mented to unconsolidated sediments or soils. However, most deposits usually have secondary cementing minerals (cal-cite, gypsum, dolomite, ferric oxide and halite). Deposits in calcrete (calcium and magnesium carbonates) are the largest of the surficial deposits.	Tectonically stable basement environ-ments that have been intruded by uranium-rich granites and later have become deeply weathered.	Most favourable regions are arid to semi-arid regions in which uranium-rich granites are deeply weathered. Calcrete deposits are formed in these regions. Deposits also occur in peat bogs and karst caverns.	Tertiary to recent	Sediments and soils, usually with cementing secondary minerals. Valley-fill sediments, playa lake sediments, peat bogs, karst caverns.	Controlled by the shape of the host sedimentary rocks; generally sub-horizontal horizon or tabular. Sometimes sinuous shapes associated with channel or valley-fill sediments, and irregular ovoid shapes associated with lacustrine and playa sediments.	None	Palaeo- and modern-drainages channels/patterns, topography and structural traps may play an important role in the formation of large surficial deposits.	Leaching of uranium from intrusive or metamorphic basement rock by oxidized meteoric or/and connate water which carry and concentrate the uranium into aquifers. Changes in fluid composition due to evaporation, interaction with other fluids or reaction with e.g. calcium carbonate in calcretised horizons make the uranium precipitate.	Grades in the range 0.01% to 0.1% U_3O_8 within small to large tonnages (100-50,000 t U_3O_8)	Geophysical data: strong anomalous radioactivity, because of the near-surface nature of these deposits	• Yeelirrie, Australia • Lake Way, Australia • Lake Maitland, Australia • Langer Heinrich, Namibia	No known examples	Fayek 2013 IAEA 1984 & 2009 Kreuzer et al. 2010
D10 **Collapse breccia pipe deposits**	U (Cu, V, Ag, Au)		Uranium-bearing minerals and associated sulphide, arsenide, sulphate and arsenic-sulphosalt minerals as disseminated replacements and minor fracture fillings in distinct bodies in near-vertical cylindrical solution-collapse breccia pipes	Stable marine platform sediments	Breccia pipes developed from solution collapse within thick limestone/carbo-nate lithologies	Host rock in deposits in Arizona is Late Carbonife-rous to Late Triassic in age whereas ores are 260-200 Ma.	Karst-collapse breccia	Irregular ore bodies distributed in the breccia pipe. Breccia pipes themselves 30-200 m in diameter and up to 1000 m deep.	Pyritisation, dolomitisation, calcitisation, silicification, desilicification, Mg-depletion (dedolomiti-sation), gypsum/anhy-drite formation and bleaching	Fractured, permeable rock within breccia pipe is an important control for the loci of the uranium ore. In USA, Nevada, conduits for the mineralising fluids have been speculated to be either sandy horizons or structures.	Uranium mineralisation, which was introduced into the pipes by ascending groundwater and was deposited in response to changes in temperature and/or pressure or to changes in chemical environment, occurs in the interstices between breccia fragments and in fractures in the annular ring that separates the breccia-filled column from the surrounding wall rock.	Small resources (300-2,500 t) with grades between 0.20-0.80% U_3O_8 Mean grades and tonnages for the deposits in Arizona are 0.56% U_3O_8 and 0.23 Mt ore	Stream sediment data: anomalous enrichment in Ag, As, Ba, Cd, Co, Cr, Cs, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sr, U, V, Y, Zn, Zr, and REE; indicator elements are Ag, As, Co, Cu, Ni, Pb, and Zn Geophysical data: Electrical conductivity and magnetic petrophysical properties of the pipes are significantly greater than from unbrecciated rocks Spatial: collapse features recognized by concentrically inward-dipping beds, circular concave topography, circular patches of brecciated and/or bleached or iron-stained rock	• Orphan Lode, EZ-2, Pigeon, Arizona, USA	No known examples • *Breccia pipes in Franklinian Basin?* • *Carbonates in central East Greenland?*	Dahlkamp 1990 Fayek 2013 Finch 1992 & 1993 IAEA 2009

Uranium deposit type	**Com-modities (bypro-ducts)**	**Subtypes**	**Description**	**Tectonic setting**	**Geological setting / depositional environment**	**Age of minerali-sation**	**Host / associated rock types**	**Deposit form**	**Alteration** [bullet-numbers refer to subtypes]	**Ore controls**	**Genetic model**	**Typical grades/tonnages** [bullet-numbers refer to subtypes]	**Exploration signatures** [geochemical and geophysical]	**Global examples** [bullet-numbers refers to subtypes]	**Greenland examples** *[in italics potential areas]*	**References**
D11 **Phospha-te/phos-phorite deposits**	U (Sc, REE)	1. Organic (bedded) phosphorite deposits 2. Minerochemical (nodular) phosphorite deposits 3. Continental phosphorite deposits	Sedimentary phosphorites of marine origin contain low concentrations of uranium in fine-grained apatite.	At the transition zone between shelf and the deeper basins, along passive margins or in intracratonic platform or stable shelf basins	Marine environment; in sedimentary basins with access to upwelling, phosphate-rich seawater, characterized by high levels of organic activity, slow rates of sedimentation and warm climates.	Proterozoic to Tertiary	Phosphorite (18-40% P_2O_5, principally apatite with 70-200 ppm U, up to 800 ppm U) horizons within interbedded marine muds, shales, carbonates and sandstones.	Controlled by the shape of the host sedimentary rocks; generally sub-horizontal horizon. Broad regional extent.	Characteristic bluish-white weathering colour	Stable marine basins, access to upwelling, phosphate-bearing seawater, slow rate of sedimentation. Diagenetic enrichment and sedimentary reworking may be locally important for concentrating the phosphate. Appears to have formed within 40° of latitude north or south of the palaeoequator.	The uranium enrichment in marine phosphorite is thought to occur through the extraction of uranium from seawater and syngenetic incorporation into cryptocrystalline fluorcarbonate apatite. Slow rates of deposition permit longer exposure of apatite grains, which allows uranium from seawater to replace calcium in the apatite. Depositional processes involve mixing or upwelling of deep, cold seawater and warm ocean currents on shallow shelf waters.	Phosphorite deposits are low grade (concentrations are 0.005-0.3% U_3O_8) and high tonnage (4000 to ~50,000 t). Uranium is recovered as a byproduct of phosphate production. Where phosphoric acid is produced, uranium is sometimes extracted as a by-product; e.g. in Florida.	Geochemistry data: anomalous high P, N, F, C, and U Geophysical data: anomalously high radioactivity	• Santa Quiteria and Itataia, Brazil • New Wales, Florida (pebble phosphate) • Uncle Sam, Land Pebble District, USA • Gantour, Morocco • Al-abiad, Jordan • Melovoe deposit, Kazakhstan	No known examples	Fayek 2013 IAEA 2009 Dahlkamp 1993
D12 **Black shale deposits**	U (Cu, Cr, Mo, Mn, REE, V, P)	Based on the organic substances with which the uranium is associated two subtypes of black shales are distinguished: 1. Humic/kolm in alum shale (Ranstad type) 2. Bituminous/sapropelic black shale (Chattanooga type)	Syngenetic, uniformly disseminated uranium onto organic or clay rich particles in organic-rich, pyritic marine shale with thin coalified, phosphatic and/or silty intercalations	The formations that host uraniferous black shale at Ranstad deposit, Sweden, were deposited in shallow, partially closed epicontinen-tal basins within a tectonically stable terrane.	Black shales with a low rate of deposition under brackish to normal marine salinities and anaerobic, strongly reducing conditions	All ages(?); although older black shales may have been metamor-phosed causing the uranium to be mobilized.	Black shale	Stratiform beds, fairly uniform thickness (few to tens of metres) and geographically extensive (several hundred to 10,000 km^2). High concentra-tions are confined to beds (cm to m thick) that are rich in organics, particularly humic-coaly material. If phosphate nodules are present, they normally contain more uranium than the surround-ding shale.		Organic material present	Syn-sedimentary disseminated uranium adsorbed onto organic material	Low to medium grade (0.005 to 0.2%) and tonnage of 300 to above 1,000,000 t of U	Anomalous trace elements of U, Mo, Ni, V, As and Sb are typical for carbonaceous shale	• Ranstad, Sweden • Estonia • Chattanooga, USA • Chanziping deposit, China • Gera-Ronneburg deposit, Germany	No known examples • *Triassic-Permian black shales in central East Greenland* • *Shales in Franklinian Basin*	Fayek 2013 IAEA 2009

Uranium deposit type	**Com-modities (bypro-ducts)**	**Subtypes**	**Description**	**Tectonic setting**	**Geological setting / depositional environment**	**Age of minerali-sation**	**Host / associated rock types**	**Deposit form**	**Alteration** [bullet-numbers refer to subtypes]	**Ore controls**	**Genetic model**	**Typical grades/tonnages** [bullet-numbers refers subtypes]	**Exploration signatures** [geochemical and geophysical]	**Global examples** [bullet-numbers refer to subtypes]	**Greenland examples** *[in italics potential areas]*	**References**
D13 **Metamor-phite deposits**	U (Th, Cu, REE)	1. Strata-bound deposits 2. Structure-bound deposits a) Monometallic veins b) Polymetallic veins c) Marble-hosted phosphate i) Black ore in Na-metasomatised episyenite and marble with coffinite, hydrothermal zircon and organic matter ii) Pink ore; massive collophanite and cryptocrystalline hydroxyapatite (collophane) veins and stockwork in marble, gneiss and episyenite	Metamorphic uranium deposits formed directly from metamorphic skarn processes and related hydrothermal fluids in (mostly) uraniferous sediments or volcanic rocks (no direct evidence for mineralisation post-dating metamorphism). For the strata-bound types: the source of the uranium is metamorphosed sediments or phosphorite-rich rocks.	Regional metamorphic and deformation events e.g. associated with orogenic events	Uranium is remobilized and deposited in mid- to lower crustal levels during regional metamorphism and deformations associated with e.g. orogenic events.	All time periods, but probably most relevant for Archaean to Proterozoic orogenic events	Meta-sediments and/or meta-volcanics	Large irregular zones with disseminated uranium	Skarn-type alteration (e.g. garnetisation)	Skarn formations before the uranium enrichment and structural controls (fault/shear zones) on the loci for the mineralisation seem to be important factors that control the ore formation. Possible role of a redox control on chemical localisation of ore by conversion of Fe^{2+}-rich clinopyroxene-rich skarn host to Fe^{3+}-rich secondary garnet 'skarn' and uraninite-allanite ore. Alternatively, fluid pressure dropping as a consequence of fracturing of the host skarn may have triggered fluid unmixing, or fluid mixing, leading to ore precipitation.	The uranium mineralisation is a product of chemical and physical interaction between regional metamorphic/hydrothermal fluids and pre-existing calcic skarns. E.g., at Mary Kathleen uranium deposit in Australia the ore skarns were produced by contact metasomatism around the 1740 Ma Burstall Granite, whereas the allanite-uraninite ore formed under amphibolite-facies conditions, late during deformation phase of the *c.* 1550–1500 Ma Isan orogeny.	Highly variable in size (200-200,000 t) with low to medium grades (0.05-0.50%)	Geophysical data: anomalous radioactivity	1) • Forstau, Austria • Nuottojarvi. Lampinsaari, Finland 2.a) • Schwartzwalder, USA • Ace-Fay-Verna, Canada • Kamyshevoye Kazaksthan 2.b) • Shinkolobwe, DRC • Port Radium, Canada • Jaduguda, India 2.c) • Itataia, Brazil • Zaozernoye, Kazakhstan	No known examples • *Ammassalik Mobile Belt*	Fayek 2013 IAEA 2009 Oliver et al. 1999
D14 **Uranifero us coal and lignite deposits**	U (coal, lignite, Mo, As)	1. Stratiform-syngenetic lignite-coal deposits 2. Mixed stratiform/frac-ture-controlled epigenetic lignite-coal deposits	Elevated uranium in beds and seams of lignite/coal and in clay/sandstone adjacent to lignite	Intracratonic basins, rift and graben basins, strike-slip basin (oceanic, continental and continental margin settings) and foreland and foredeep basins along continental margins. Buried and later uplifted deltaic and alluvial plain environ-ments (lower part) and associated marine environ-ments.	Accumulation of organic matter, with a slow rate of clastic sedimentation, in a fresh- water fluvial and/or lacustrine environment with few or no marine incursions; and marginal-marine swamp shoreline (paralic) settings. Lake, delta, swamps, shoreline and vegetation mats. Conversion of organic matter to coal with burial and the attendant increase in temperature and pressure.	Carboni-ferous and later periods of coal and lignite formation	Lignite/coal, and in clay/silt and sandstone immediately adjacent to lignite	Thin beds of uranium-bearing lignite		Formation of coal and lignite is controlled by 1) primary deposition of plant material in fresh-water to marginal-marine environments characterized by slow sedimentation rates; 2) burial with the attendant increase in temperature and pressure to convert the organic matter to coal. For the formation of uranium-enriched coal/lignite it is believed that the presence of a source rock for the uranium and circulating groundwater that is able to leach and transport the uranium is of importance.	Uranium mineralisation in lignite in North Dakota is ascribed to a combination of 1) source rock with ash layers of highly anomalous volcanic ash, 2) leaching of the source rock by groundwater, 3) passage of uranium-bearing groundwater through sandstone aquifers adjacent to, or partially comprised of, lignite beds. When water passes through the lignite beds metals (uranium and molybdenum) are precipitated by sorption and by formation of metallo-organic compounds or complexes.	Uranium grades are typically very low (20–60 ppm to 0.1%), but some layers are enriched in uranium with values above 0.1% U Mined uranium-enriched lignite from North Dakota is reported to contain 0.25% U_3O_8. Tonnage from small to large (100-50,000 t)	Geophysical data: anomalous radioactivity. Geochemistry: coal and lignite showing enrichment in uranium.	• Serres Basin, Greece • North and South Dakota, USA • Koldjat and Nizhne Iliyskoe deposits, Kazakhstan • Melovoe, Russian Federation • Freital, Germany	No known examples • *Coal occurrences in Nuussuaq Basin* • *Coal occurrences in northern East Greenland*	Fayek, 2013 IAEA 2009

Uranium deposit type	Com-modities (bypro-ducts)	Subtypes	Description	Tectonic setting	Geological setting / depositional environment	Age of minerali-sation	Host / associated rock types	Deposit form	Alteration [bullet-numbers refer to subtypes]	Ore controls	Genetic model	Typical grades/tonnages [bullet-numbers refers subtypes]	Exploration signatures [geochemical and geophysical]	Global examples [bullet-numbers refer to subtypes]	Greenland examples *[in italics potential areas]*	References
D15 **Carbonate**	U (Cu, Pb, Zn, Ni)	1. Strata-bound carbonate deposits 2. Cataclastic carbonate deposits 3. Karst deposits (palaeokarst)	Uraninite occurring in intraformational fold and fractures	Sedimentary carbonate platform along passive continental margin	Palaeokarst formation, including karstification		Sediment-filled solution breccia within clay- and/or organic-rich carbonate /limestone. Ore at the Sanbaqi palaeokarst-hosted uranium deposit in south China occurs predominantly in carbonaceous pelitic micrite and fossiliferous micrite with inter-bedded silty micrite and biosparite.	Ore bodies are varied in morphology and include stratiform, stratabound, lenticular, hopper-shaped, nested and irregular bodies.				Small to large in size (100 to >72,000 t) with low to high grade (0.03-1%)		1) • Tumalappalle India 2) • Mailuu-Suu, Kyrgyzstan • Todilto District, USA 3) • Tyuya-Myuyun, Kyrgyzstan • Pryor-Little Mountains district, USA	No known examples • *Karsts in Franklinian Basin?* • *Carbonates in central East Greenland?*	Fayek 2013 IAEA 2009
Other: By-product from copper processing	U Cu	Uranium mineralisation occurs in low concentrations (50–200 ppm) in many metalliferous deposits												By-product from concentrates derived from processing of copper ores at: • Palabora, South Africa • Bingham Canyon, USA • Singbhum district, India	No known examples	Fayek 2013 IAEA 2009

ISBN 978-87-7871-376-6

GEOCENTER
DENMARK

Geocenter Denmark is a formalised cooperation between Geological Survey of Denmark and Greenland (GEUS), Department of Geoscience at Aarhus University and the Geological Museum and Department of Geosciences and Natural Resource Management at the University of Copenhagen.

MiMa report 2014/1

An evaluation of the potential for uranium deposits in Greenland

The exploration for uranium in Greenland has been dormant for approximately 30 years, but in 2013 new Greenlandic legislation opened up the country for uranium exploration and mining. This report outlines the potential for uranium deposits in Greenland. The selection of areas of interest for uranium exploration is based on available geological information and the classification of uranium deposits proposed by the International Atomic Energy Authority. The most prospective types of uranium deposits in Greenland are sandstone deposits, unconformity-related deposits, quartz pebble conglomerate deposits, vein deposits, intrusive deposits, volcanic deposits, and metasomatite deposits.

Based on current geological information, the geographic area with the highest potential for uranium deposits is South Greenland. In this region the strongest candidate deposits are hosted in the Gardar intrusive complex and the sandstones of the psammite zone. West Greenland hosts several carbonatite intrusions; the available data suggests that the Sarfartoq and Qaqarssuk intrusions have an especially high potential for uranium.
In North-West Greenland sediments of the Thule Supergroup provide an interesting target for exploration as sandstone or basal unconformity-type deposits. Central East Greenland hosts Mesozoic sandstones and a variety of intrusive complexes, volcanic rocks and veins that also make strong targets for uranium exploration.

This report gives a detailed overview of all areas that host potential uranium deposits and includes a description of all known uranium occurrences in Greenland.

Center for Minerals and Materials (MiMa) is an advisory centre under the Geological Survey of Denmark and Greenland.
MiMa provides knowledge on mineral resources and supply chains, from production to recycling.

De Nationale Geologiske Undersøgelser
for Danmark og Grønland (GEUS)
Geological Survey of Denmark and Greenland

Øster Voldgade 10
DK-1350 Copenhagen K
Denmark

GEUS is a research and advisory institution in the Danish Ministry of Climate, Energy and Building