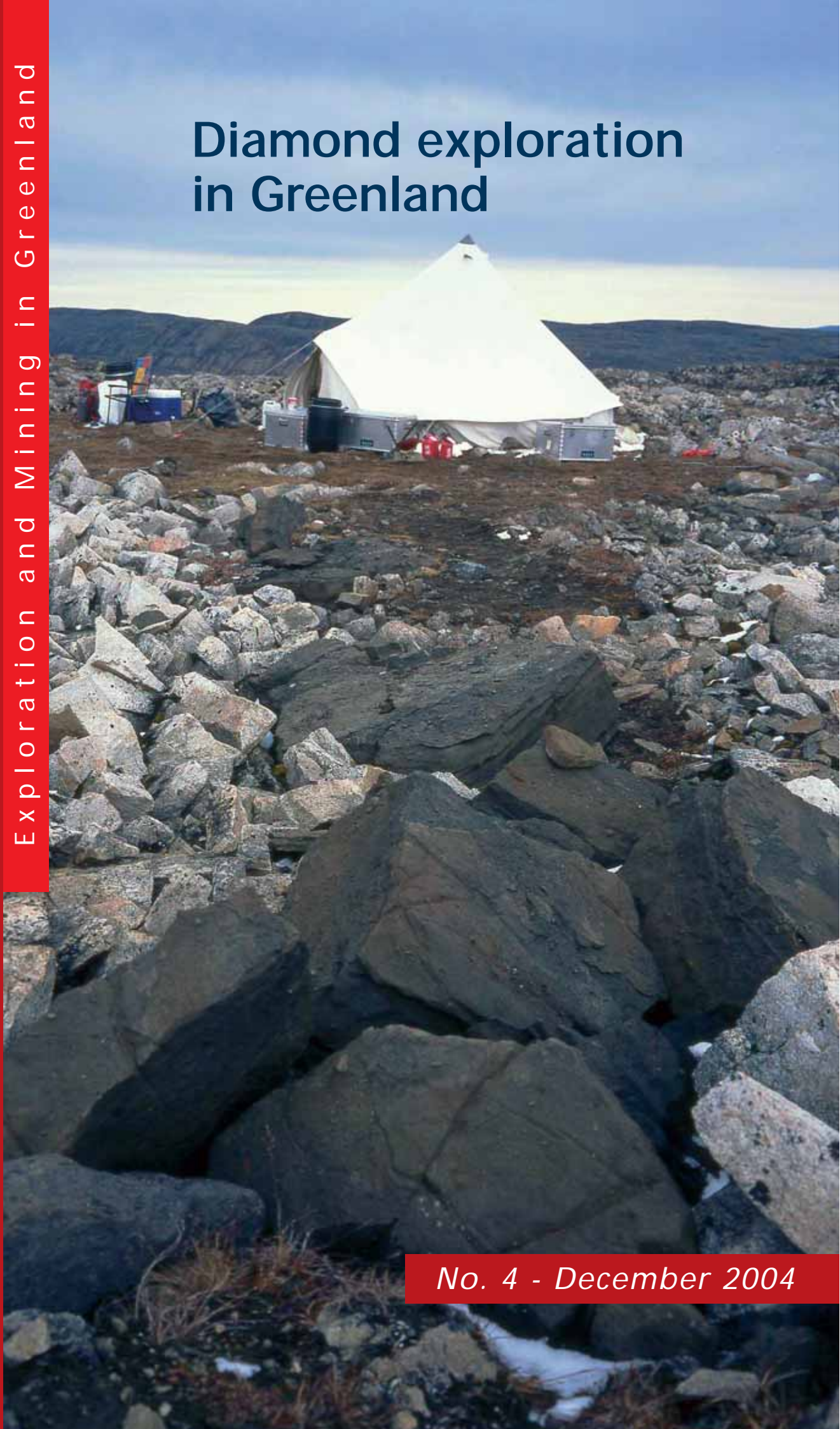




Diamond exploration in Greenland



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More than 1000 observations representing in situ kimberlitic dykes are now known in West Greenland, of which 2/3 are found within a major alkaline province in the region from 65°N to 67°N. To date, approximately 900 diamonds have been reported from kimberlitic rocks. The distribution of occurrences appears to partly reflect the uneven degree of investigation of different areas, and partly the fact that the rocks often occur in swarms. The commercial exploration carried out in West Greenland during the period 1992–2004 has mainly focused on the major alkaline province. The investigations of the remaining part of southern West Greenland have been of a more regional character



Outcrop of a 1 m wide kimberlitic dyke in the Maniitsoq area.

Exploration history

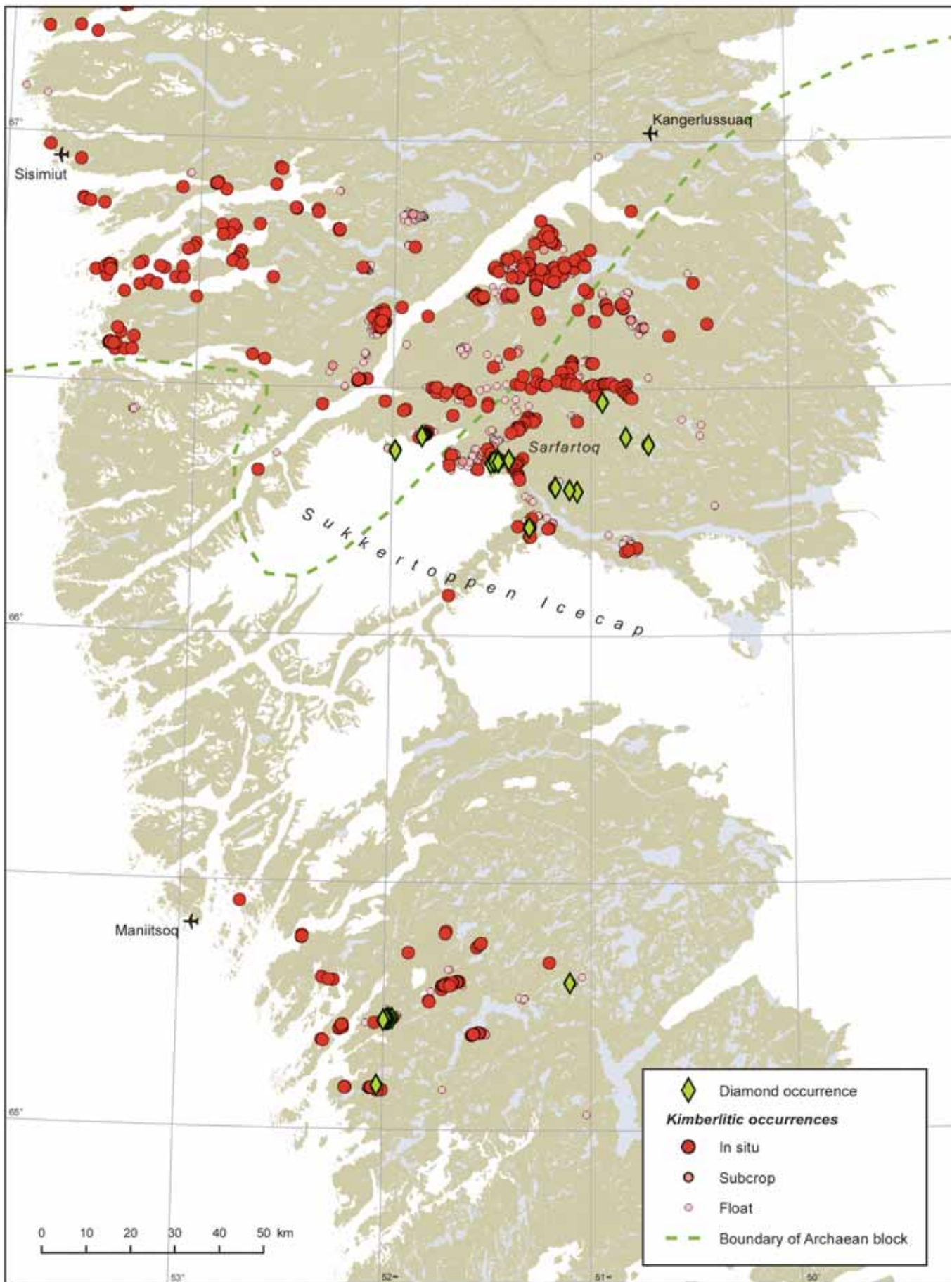
Greenland has seen several campaigns of diamond exploration since the early 1970s. Inspired by reports of kimberlite dykes at several locations in southern West Greenland, an exploration company investigated occurrences in the Pyramidefjeld area north of Ivittuut and recovered

two microdiamonds and one macrodiamond from kimberlitic samples. Early regional kimberlite prospecting covering large parts of West Greenland resulted in two microdiamonds extracted from bulk stream sediment samples from the broad Sarfartoq valley.

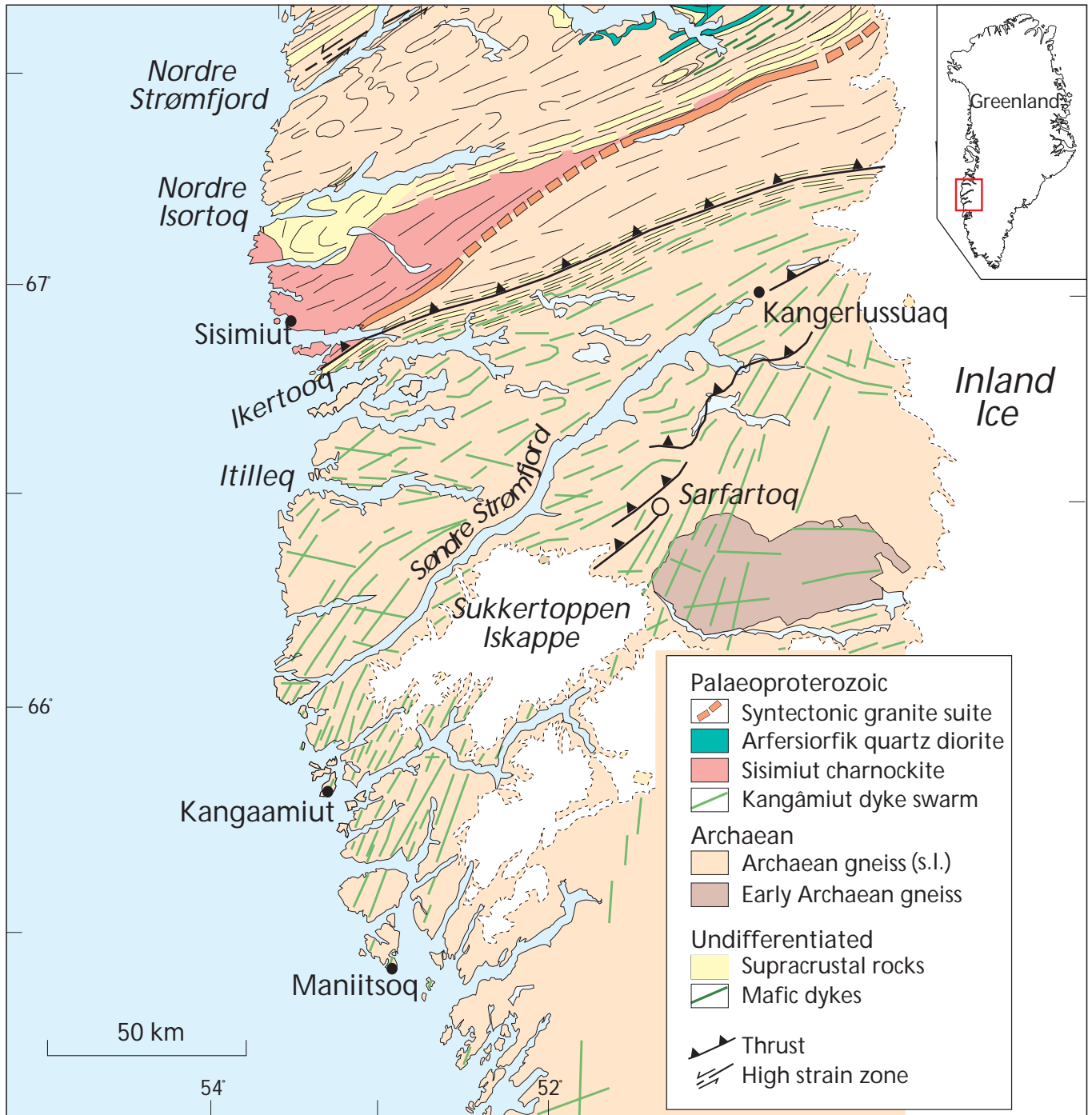
Field campaigns from 1994 onwards have mostly been dedicated to regional till and stream sediment sampling programmes with a view to locate kimberlite indicator minerals. Next followed airborne magnetic and electromagnetic surveys and drilling on frozen lakes for possible diatremes.

Highlights of recent diamond exploration

- 1995 Investigations in South-West Greenland, partly on previously reported kimberlites and diamond finds
- 1996 Regional till and stream sediment programmes initiated for the whole of the Archaean block of southern West Greenland
Microdiamonds from boulders, E of Maniitsoq
Helicopter-borne geophysics in the same area
- 1997 Helicopter-borne and ground geophysics in the Maniitsoq–Kangerlussuaq region
Diamond drilling for possible kimberlite diatremes under frozen lakes, same region Greenland's first diamonds reported from in situ kimberlite dyke, E of Maniitsoq (16 macros and 25 micros from a 792 kg sample)
- 1998 Helicopter-borne geophysics in the Maniitsoq–Kangerlussuaq region
Diamond drilling for possible kimberlite diatremes under frozen lakes, same region, including an 18-hole programme of which 14 holes intersected kimberlite
Reports of numerous new kimberlitic occurrences, several with 'unique' diamond indicator mineral chemistries
Microdiamonds from several boulder and dyke occurrences SW of Kangerlussuaq 474 microdiamonds and 5 macrodiamonds from mini-bulk samples of large kimberlitic boulders from suspected sill
- 1999 Ground geophysics in areas of the latest diamond finds
Helicopter-borne geophysics in the Maniitsoq–Kangerlussuaq region
- 2000 Extensive indicator mineral analysis programme for samples from areas SW of Kangerlussuaq
Field activities limited to follow-up on positive indicator mineral results
- 2001 Diamond drilling for kimberlites SW of Kangerlussuaq. A very large kimberlitic dyke (20 m wide and 5 km long) reported. Government research in the Sisimiut area
- 2002 Field activities limited to brief reconnaissance by one company. Government research and mapping in the Kangerlussuaq area.
Airborne hyperspectral survey in the Sisimiut–Kangerlussuaq area
- 2003 Field exploration and reconnaissance by a couple of companies. Government testing for diamond content of kimberlitic occurrences in the Sarfartoq–Maniitsoq area. Release of diamond testing results (124 micros, 4 macros) from the Sarfartoq–Maniitsoq area
- 2004 Government research in the Kangerlussuaq–Maniitsoq area. Company release of diamond testing results (111 micros, 9 macros) from "Garnet Lake" in the Sarfartoq area



Map of till and stream sediment sample localities in West Greenland



Geological map of the Sisimiut-Kangerlussuaq-Maniitsoq region.



Kimberlitic boulder with various xenoliths, the Sarfartoq area.

The first diamonds from in situ kimberlitic dykes were reported from the area east of Maniitsoq in 1997. One 792 kg sample of a large dyke yielded 25 microdiamonds (<0.5 mm) and 16 macrodiamonds (all <1 mm).

Focus then shifted north to the Sarfartoq region, where the largest number of microdiamonds recovered from a single kimberlitic occurrence came from a sub-cropping sill that returned 474 microdiamonds and 5 macrodiamonds. Another striking discovery was of a very large dyke that is traceable by geophysical methods over a length of 5 km with a width of 20 m confirmed by two inclined drill holes. In 2002, the Geological Survey of Denmark and Greenland (GEUS) and the Greenland Bureau of Minerals and Petroleum (BMP) conducted an airborne hyperspectral survey over the Sarfartoq region in order to assess this remote sensing technique for detecting kimberlitic rocks and weathering material associated with them.

Survey fieldwork in 2001 and 2002 has been focused on the spatial distribution of kimberlitic dyke rocks in areas with limited previous information, and detailed studies on mantle xenoliths from the kimberlitic dykes. In 2003, GEUS and BMP collected

1-tonne samples of three kimberlitic dykes for testing the diamond content by caustic fusion dissolution, and for determination and characterisation of their indicator mineral populations and chemistries. This test added 124 microdiamonds and 4 macrodiamonds to the database. One microdiamond was from a hitherto untested dyke of the Sarfartoq swarm. The two remaining dykes tested (one from the Sarfartoq region and one from the Maniitsoq region) were known from previous work to be diamondiferous, but previous tests were inadequately documented. Concurrently, research on selecting further targets is conducted including a comprehensive age dating programme, petrography and studies on regional uplift and thermal history of West Greenland.

Geological setting

Southern West Greenland hosts a major alkaline province with a variety of ultramafic alkaline rocks. The alkaline province includes swarms of dykes described as kimberlites and lamproites. These rock types are widely distributed in the Sisimiut–Sarfartoq–Kangerlussuaq region, as well as the region just south of Sukkertoppen Icecap. Lamproitic dykes in

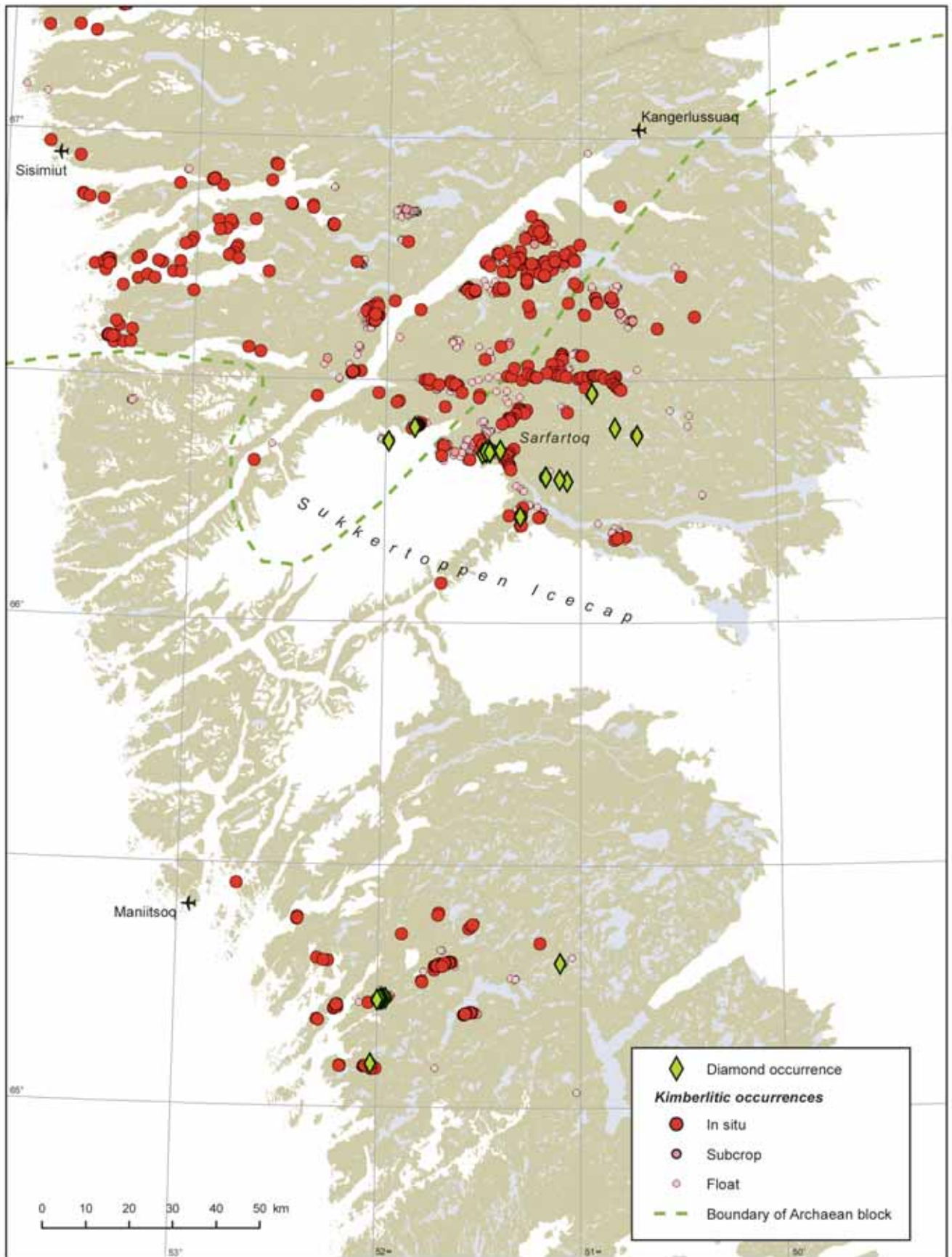
the Sisimiut region are around 1200 Ma old and the kimberlitic dykes in both the Sarfartoq and Sisimiut regions have ages of 600 Ma. A precise spatial relationship between the intrusive events resulting in kimberlitic rocks and the 600 Ma Sarfartoq carbonatite complex has not been established. The dykes have earlier been interpreted as cone-sheets related to the carbonatite complex.

South of Sisimiut, remnants of an Archaean alkaline complex have been located, perhaps comparable in age to the at least 2600 Ma old Tupertalik carbonatite complex near Maniitsoq. The 170 Ma Qaqaarsuk carbonatite complex, located in the area east of Maniitsoq, represents the youngest alkaline igneous event. At Fossilik in the vicinity of the Qaqaarsuk complex a small diatreme contains fragments of fossiliferous Ordovician limestone set in a matrix of carbonatitic-ultramafic breccia tuff.

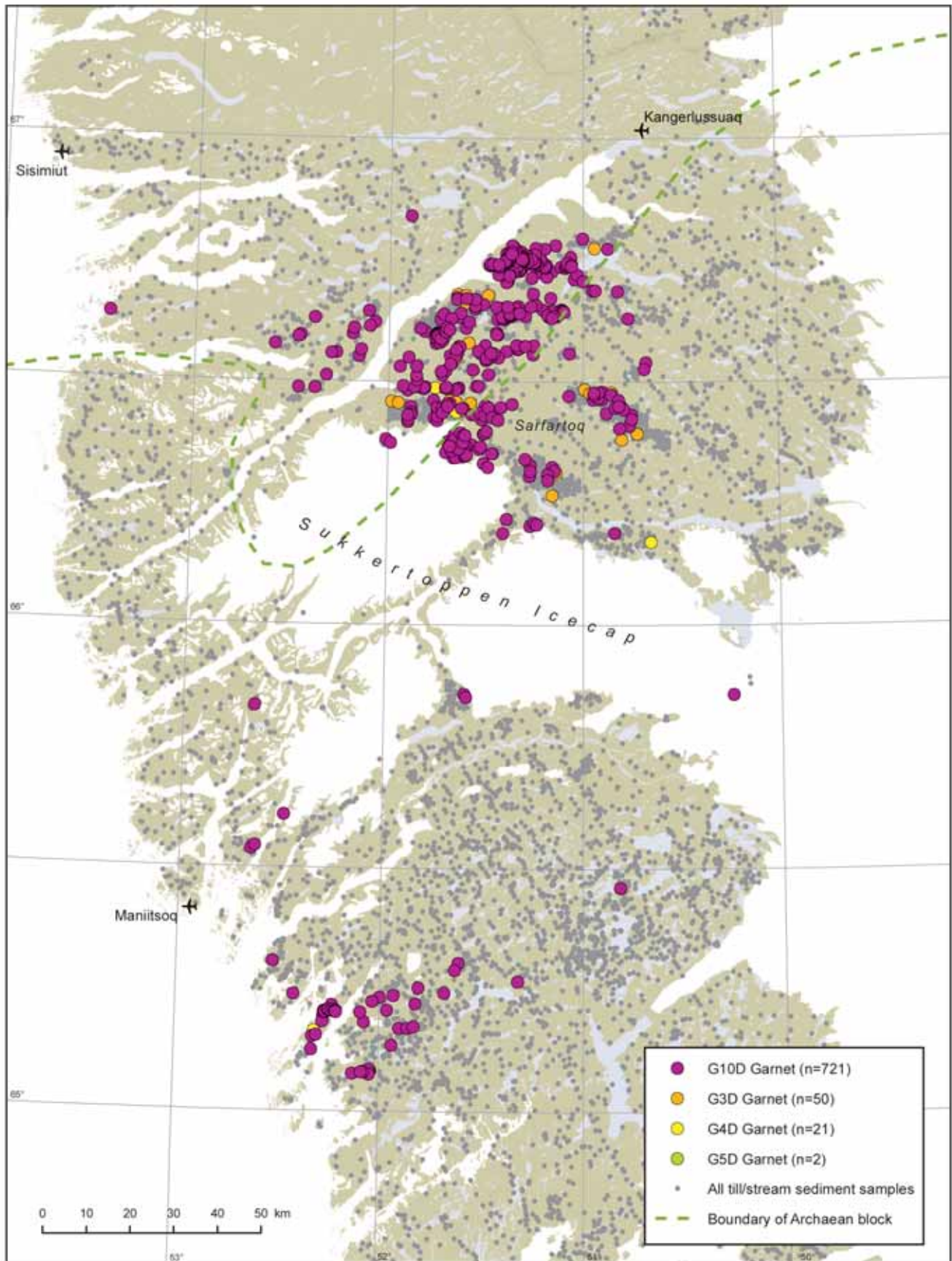
The alkaline province of West Greenland may host several clusters of kimberlitic dykes and sills. Dykes occur at distances of up to 40 km S, 35 km N, 50 km W and 30 km E of the carbonatite complex, and commonly appear to be controlled by pre-



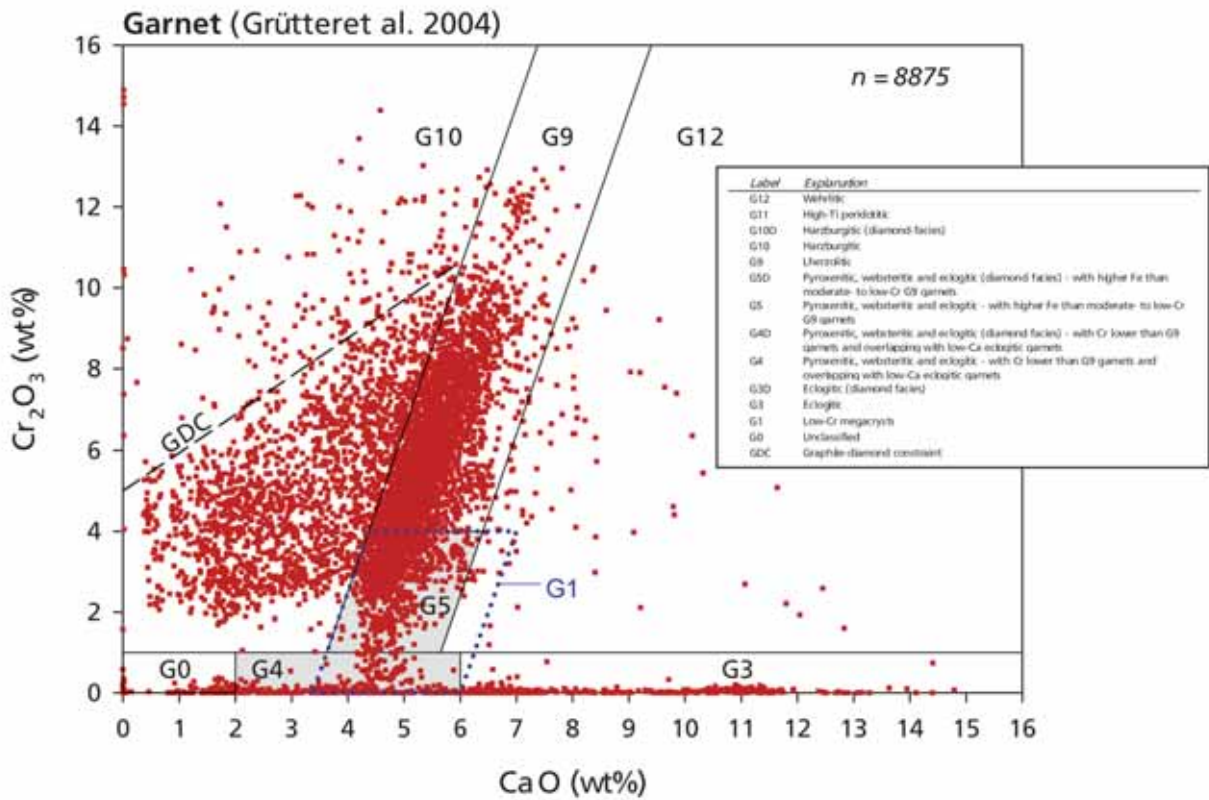
Ecolitic xenolith from a kimberlitic dyke, the Maniitsoq area.



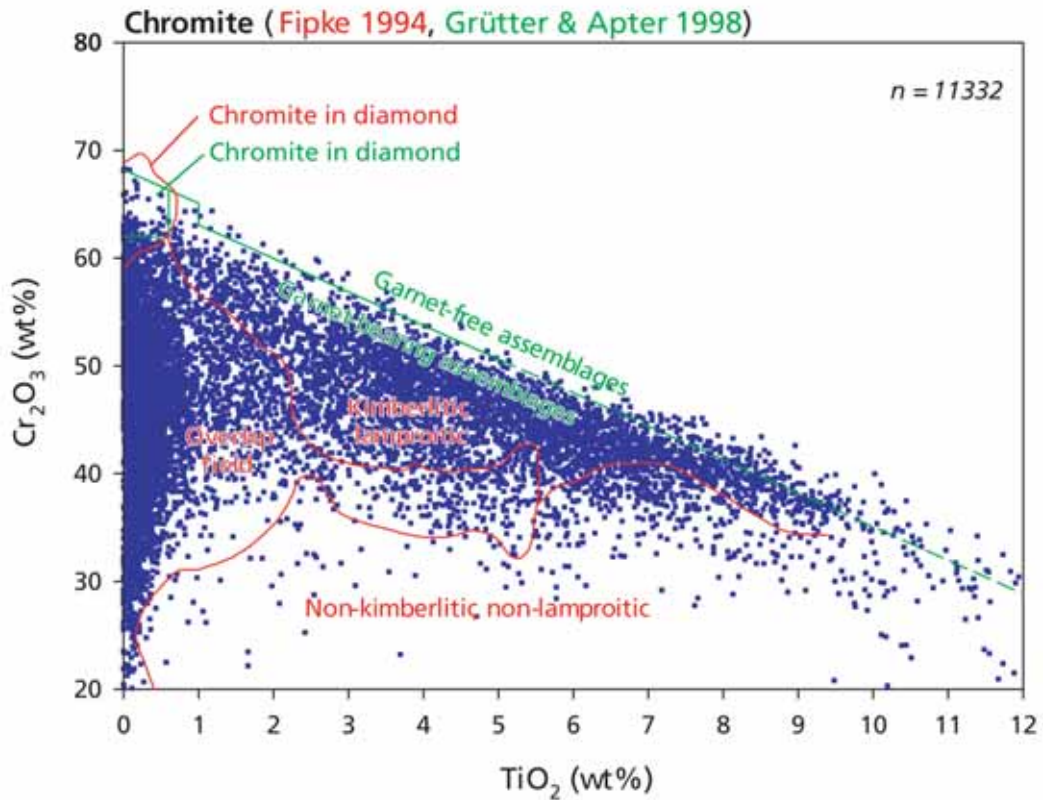
Map of kimberlitic and diamond occurrences of the West Greenland alkaline province.



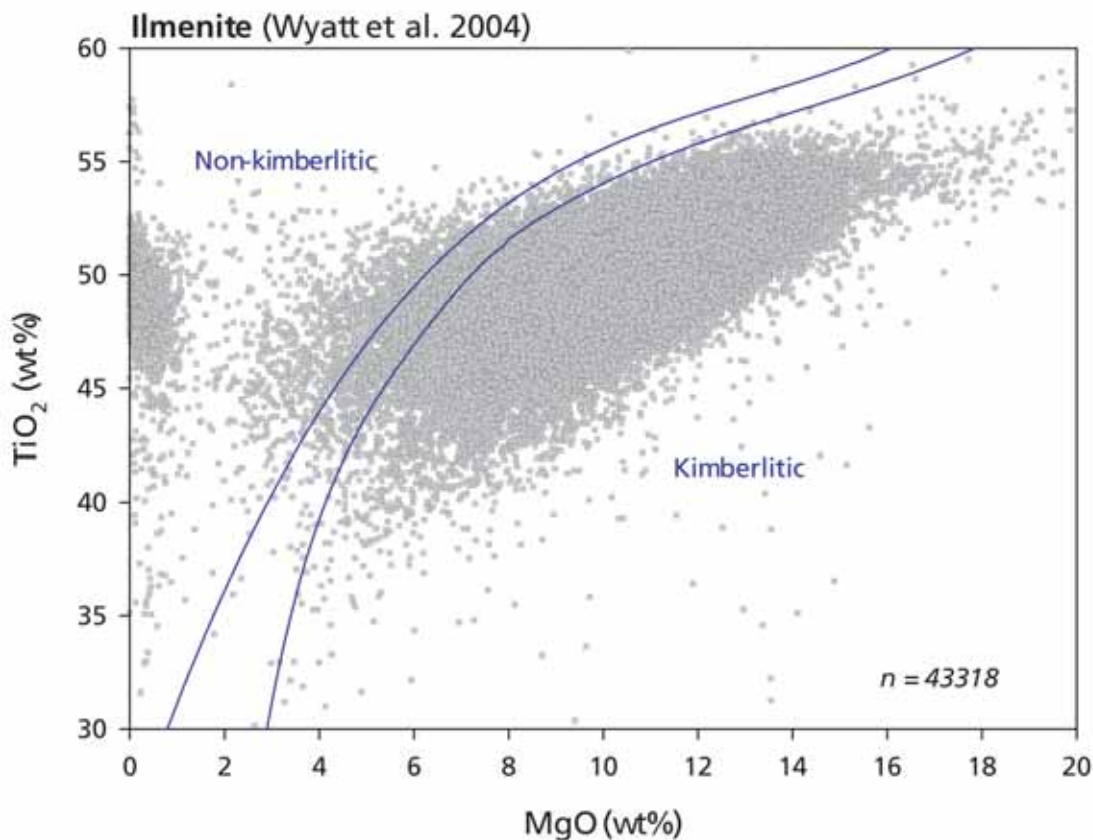
Map of selected diamond facies garnets of the West Greenland alkaline province.



(8a) Diagram of all garnet classes from indicator mineral picking (for explanation, see page 11).



(8b) Diagram of all chromite classes from indicator mineral picking (for explanation, see page 11).



existing joint systems or concordant with the enclosing gneiss.

The kimberlitic intrusions are often flat-lying sheets, rarely over 1 m thick, and traceable for a few tens of metres, while others are subvertical, 1–2 m wide, and traceable for 2–3 kilometres. The dykes often contain numerous mantle xenoliths ranging in size from a few millimetres to several decimetres. Ubiquitous kimberlitic or lamproitic boulders ranging in size from a few centimetres to 2 metres across are often concentrated in clusters or trains that may number hundreds of boulders, and be many hundreds of metres long.

The ultramafic alkaline rocks in the region NW of the Palaeoproterozoic deformation front still remain to be proven diamondiferous. As an encouragement for further exploration in this region it is noted that

the area covered by the Torngat orogen – the Canadian counterpart to the Nagssugtoqidian orogen – has been shown recently to host diamondiferous kimberlitic dykes. Additionally it can be mentioned that recent diamond exploration in the neighbouring Baffin Island, Nunavut, has revealed a number of very promising prospects in a geological environment very much like that of West Greenland.

Mantle xenoliths in kimberlitic rocks

Mantle xenoliths are present in many of the West Greenland kimberlitic dykes. A majority of the xenoliths encountered the Sisimiut–Kangerlussuaq region have peridotitic or pyroxenitic compositions and they range in size from less than 1 cm to a maximum of about 50 cm. In the

Diagram of all ilmenite classes from indicator mineral picking (for explanation, see page 11).

Maniitsoq region the typical xenolith assemblage also includes rocks of eclogitic composition with sizes of up to 10 cm.

The different xenolith types and their distinct mineral compositions illustrate the heterogeneous character of the West Greenland lithospheric mantle, even within a single kimberlitic dyke of limited extent. Temperature and pressure calculations suggest that the xenoliths from some kimberlitic dykes were derived from a depth interval of at least 49 to 69 kbar, corresponding to approximately 150–215 km. This implies vertical zonation of the mantle lithosphere with depleted and metasomatised zones beneath the Archaean craton. The P–T relations of the



Outcrop of kimberlitic dyke with various xenoliths, the Maniitsq area.

xenoliths suggest they were all derived from within the so-called diamond window.

Kimberlitic occurrences and indicator minerals from till samples

Three clusters of dykes have been recognised within the province. The Sisimiut swarm, consisting mainly of 1287 Ma lamproitic and 587 Ma kimberlitic dykes have a generally vertical E-W to SE-NW striking orientation. The Sarfartoq swarm consisting mainly of 615 Ma kimberlitic dykes has variable orientations, but with many dykes in a N-S trend. The 600 Ma kimberlitic dykes of the Maniitsq swarm have orientations in a predominantly ENE-SSW direction.

Many kimberlitic dyke orientations follow the trends of the Palaeoproterozoic Kangamiut dolerite dykes in reworked as

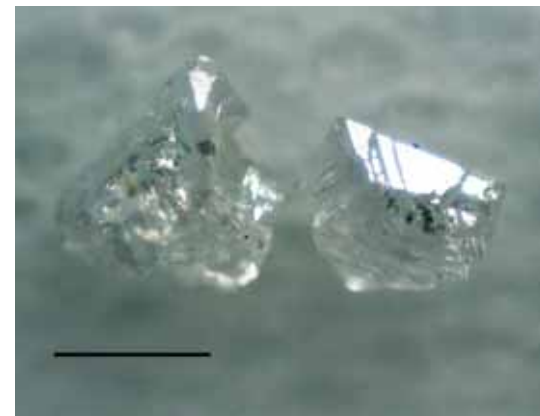
well as unworked parts of the Archaean basement. Another example is an apparent predominance of north-south dykes in a corridor reaching far beyond the Sarfartoq complex, e.g. the newly discovered very large 5 km long and 20 m wide dyke. Information from magnetic field data lend support to the hypothesis that kimberlite emplacement may be controlled by such structures of more regional character.

The exploration in Greenland has been focussed on indicator minerals such as peridotitic and eclogitic garnets (pyrope), chromite, ilmenite and chrome-diopside, using experience from Arctic Canada. An overview of the more than 15.000 sites sampled and the approximately 100.000 indicator minerals analysed are displayed on maps and diagrams. Exploration companies have conducted the sampling since 1995 and results have now been made

available to new users through a major Survey compilation report with accompanying data DVD.

Obvious diamond potential

Most of the approximately 900 diamonds reported to date are from just two areas,



Microdiamonds from a kimberlite dyke in the Maniitsq area. Scale 0.5 mm.

Diamond indicator minerals

Diamond indicator minerals are picked from till and sediment samples and from in situ kimberlitic dykes. The diamond facies indicator mineral classes are grouped and displayed according to accounts by:

Grütter, H.S. & Apter, D.B. 1998: Kimberlite- and lamproite-borne chromite phenocrysts with 'diamond-inclusion'-type chemistries. 7th International Kimberlite Conference, Cape Town, 13–17 April, 1998. Extended abstracts, 280–282.

Grütter, H.S., Gurney, J.J., Menzies, A.H. & Winter, F. 2004: An updated classification scheme for mantle-derived garnet, for use by diamond explorers. In: Mitchell, R.H. et al. (eds): Selected Papers from the Eighth International Kimberlite Conference. Volume 2: The J. Barry Hawthorne Volume. *Lithos* 77, 841–857.

Fipke, C.E., Gurney, J.J. & Moore, R.O. 1995: Diamond exploration techniques emphasizing indicator mineral geochemistry and Canadian examples. Geological Survey of Canada, Bulletin 423, 86 pp.

Fipke, C.E. 1994: Significance of chromite, ilmenite, G5 Mg-almandine garnet, zircon and tourmaline in heavy mineral detection of diamond bearing lamproite. In: Meyer, H.O.A. & Leonardos, O.H. (eds): Proceedings of the Fifth International Kimberlite Conference 2. CPRM Special Publication 1/B Jan/94, 366–381. Rio de Janeiro: Companhia de Pesquisa de Recursos Minerais.

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both located in the unreworked Archaean craton. It should be remembered that only a small fraction of the kimberlitic outcrops has been diamond tested so far. All in situ diamond occurrences fall within areas outlined by the diamond-favourable indicator minerals from till and stream sediment samples. On a local scale, however, kimberlite tracing using indicator minerals from till samples is not straightforward,

probably due to complex glacial dynamics. The most diamond-favourable indicator mineral assemblages occur far beyond the areas with known diamonds. This observation, together with a regional structural control, suggests that the potential appears to exist on either side of the boundary between reworked and unreworked Archaean basement.



Outcrop of the contact zone of a 20 m wide kimberlitic dyke near the Kangerlussuaq airport.

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Panorama of the GEUS diamond survey base camp 2003 in the Maniitsoq area.

Front cover photograph:

Field camp near a kimberlitic dyke (1 m) outcrop in the gneiss basement near Kangerlussuaq.

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