DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2008/51

Petrographic Atlas for ultramafic lamprophyres and kimberlites, southern West Greenland

Explanatory notes

T. F. D. Nielsen, K. Secher, F. A. P. Sauerberg,
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G E U S

Contents

Preamble

The Petrographic Atlas presents basic information on kimberlite and ultramafic lamprophyre occurrences in regions of diamond exploration in southern West Greenland. The atlas includes explanatory notes with a general introduction to the geology of the regions of diamond exploration and the occurrences of kimberlite and ultramafic lamprophyre, digital summary information and petrographic images.

The explanatory notes include short chapters on the historical perspective on the investigation of ultramafic lamprophyre dykes of possible kimberlitic affinity in West Greenland, the setting of dykes, general characteristics, and classification criteria, together with a presentation of the digital information. The atlas is restricted to areas in southern West Greenland between 67º30' and 63ºN, and to kimberlite and ultramafic lamprophyre lithologies. Lamproite and lamprophyre occurrences are not included. The dyke rocks are classified as kimberlite, transitional ultramafic lamprophyre, and ailikite on the basis of groundmass parageneses and the compositions of groundmass phlogopite, spinel and ilmenite.

The occurrences of kimberlite and ultramafic lamprophyre included in the atlas are 550-600 Ma old. The temporal relationship with the Sarfartoq carbonatite complex suggests that 550-600 Ma old magmatism in southern West Greenland illustrate the relationship between kimberlite, ultramafic lamprophyre, and carbonatite melts.

Kimberlite and ultramafic lamprophyre dykes in southern West Greenland: a historical perspective.

Early investigations: 1960-1990

Dykes composed of kimberlite *sensu strictu* and ultramafic lamprophyre with kimberlitic affinity in terms of megacryst and xenolith assemblages occur throughout the Archaean and Proterozoic terrains in West Greenland (Fig. 1). Such dykes have been recorded and sampled since the 1960´es by the Geological Survey of Greenland (GGU) and collaborating university groups. The many records of dykes with a possible affinity to kimberlite were made during regional mapping of the Archaean and Proterozoic basement in southern West Greenland and South-West Greenland. Concurrently with the mapping programme mining and exploration companies conducted general exploration in large parts of Greenland and recorded many occurrences of dyke rocks with possible kimberlitic affinity.

More detailed description of occurrences, mainly in the Sarfartoq and Sisimiut areas, and in South-West Greenland were presented, e.g., by Walton and Arnold (1970), Andrews and Emeleus (1971, 1975), Goff (1973), Upton and Thomas (1973), Emeleus and Andrews (1975), Scott (1977, 1979, 1981), Larsen (1980, 1991), Larsen et al. (1983), Thy et al. (1987). The term kimberlite was used for dyke rocks with megacrysts and/or xenoliths assemblages common to kimberlite *sensu strictu*. Many dykes referred to as “kimberlitic” are characterised by large proportions of olivine mega- and/or macrocrysts.

All of the pre-1991 records of dykes between 67°30’ and 64ºN with a possible affinity to kimberlite and a possible interest for diamond exploration are compiled and reviewed in Larsen (1991). The listed occurrences formed the basis for a more detailed investigation (Mitchell et al., 1999), who concluded that many of the dyke rocks described as kimberlite or referred to as “kimberlitic” should be re-classified to ailikite or melnoite, in accordance with empirical definitions given by Mitchell (1995) and subsequently by Tappe et al. (2005). Melilite has not yet been recorded among the occurrences of ultramafic lamprophyre and kimberlite, and ailikite is the preferred term for most of the dyke rocks hitherto referred to as kimberlite

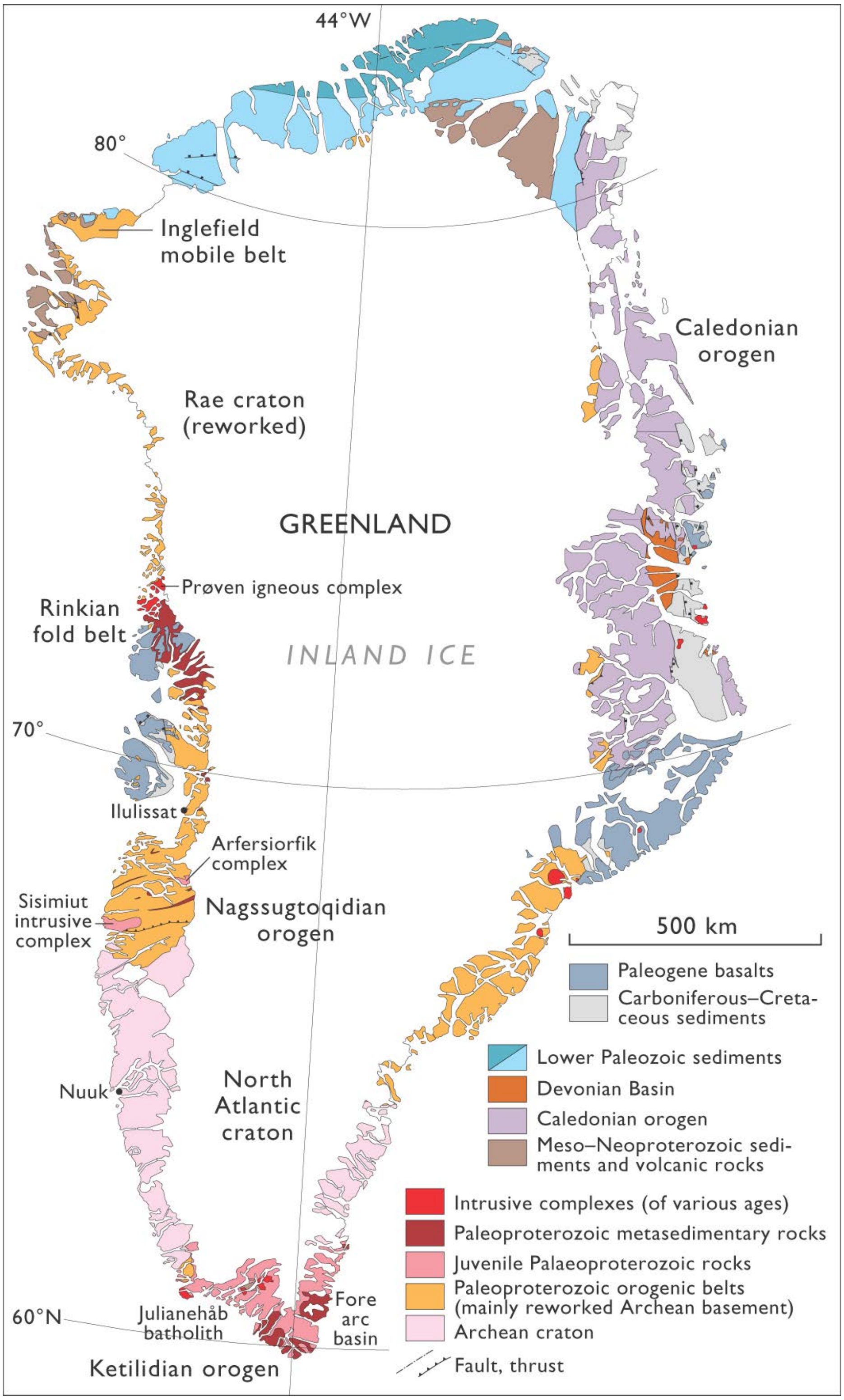

Figure 1: Geological map of Greenland with the Archaean and Proterozoic terrains in West and South-West Greenland (Lahtinen et al., 2008).

Only few diamond tests were performed prior to the 1990´es. Diamond was recorded in "kimberlitic" occurrences at Pyramide Fjeld in South-West Greenland and in sediment samples from the Fiskenæsset area (see Jensen et al., 2004a for a review).

Recent investigations: 1994-present

Despite the problematic classification of the dykes in the Sisimiut and Sarfartoq region, the compilation of known occurrences and the bulk rock chemistry in Larsen (1991) helped prompt new and intensified exploration for "kimberlitic" occurrences and targets for diamond exploration in the Archaean and Proterozoic terrains in West Greenland from Disko Bugt (70ºN) to Qaqortoq (61°N). All the non-confidential information obtained during the exploration campaigns in the late 90´es and first years of this century are compiled in Jensen et al. (2004a).

The new wave of exploration focussed on the paragenetic and chemical variation in indicator minerals, followed by airborne geophysics, field investigations, and drilling of possible targets (see Jensen et al., 2004a). Many new occurrences were registered, but pipes were not identified despite an intensive search. All occurrences are in the form of dykes, some with so-called blows. The activity resulted in the first record of diamond-bearing *in situ* dyke rock (for review, see Jensen et al., 2004a). The results of exploration and the conducted diamond tests gradually focussed the interest to the southern Sarfartoq region, and most or a significant part of the exploration has since been concentrated in this area (e.g., Hutchison, 2005, 2008). Based on systematic drilling, geophysical investigations, and diamond test, a dense media separation (DMS) pilot plant was established at the Garnet lake prospect by Hudson Resources Ltd. The largest (>2.5 ct) gem quality diamonds found in Greenland originate from the Garnet lake prospect (Hutchison, 2005, 2008, Hutchison & Frei, 2008).

The re-classification of the dyke rocks to ailikite questioned the diamond potential in southern West Greenland. More detailed information on the nature of the magmatism was needed and a number of research projects were initiated by Bureau of Minerals and Petroleum (Greenland) and the Geological Survey of Denmark and Greenland. The projects include: (1) systematic sampling from known occurrences, (2) search for new occurrences on the basis of geochemical maps and indicator mineral anomalies (e.g., Steenfelt et al., 2008), (3) development of remote sensing tools in the search for new occurrences (Tukiainen & Thorning, 2004), (4) age of the magmatism (e.g., Secher et al, 2008), (5) nature and structure of the lithosphere (P and T estimates and geochemical characteristics (Sand 2007; Sand et al, 2008a), (6) regional trends in the compositions of the melts (Nielsen et al., 2006, 2008), (7) detailed investigations of the composition and petrology of individual dykes (Nielsen & Jensen, 2005; Nielsen and Sand in press), and (8) diamond content in representative dykes (Jensen et al., 2004b). A general overview is given by Sand et al. (2007)

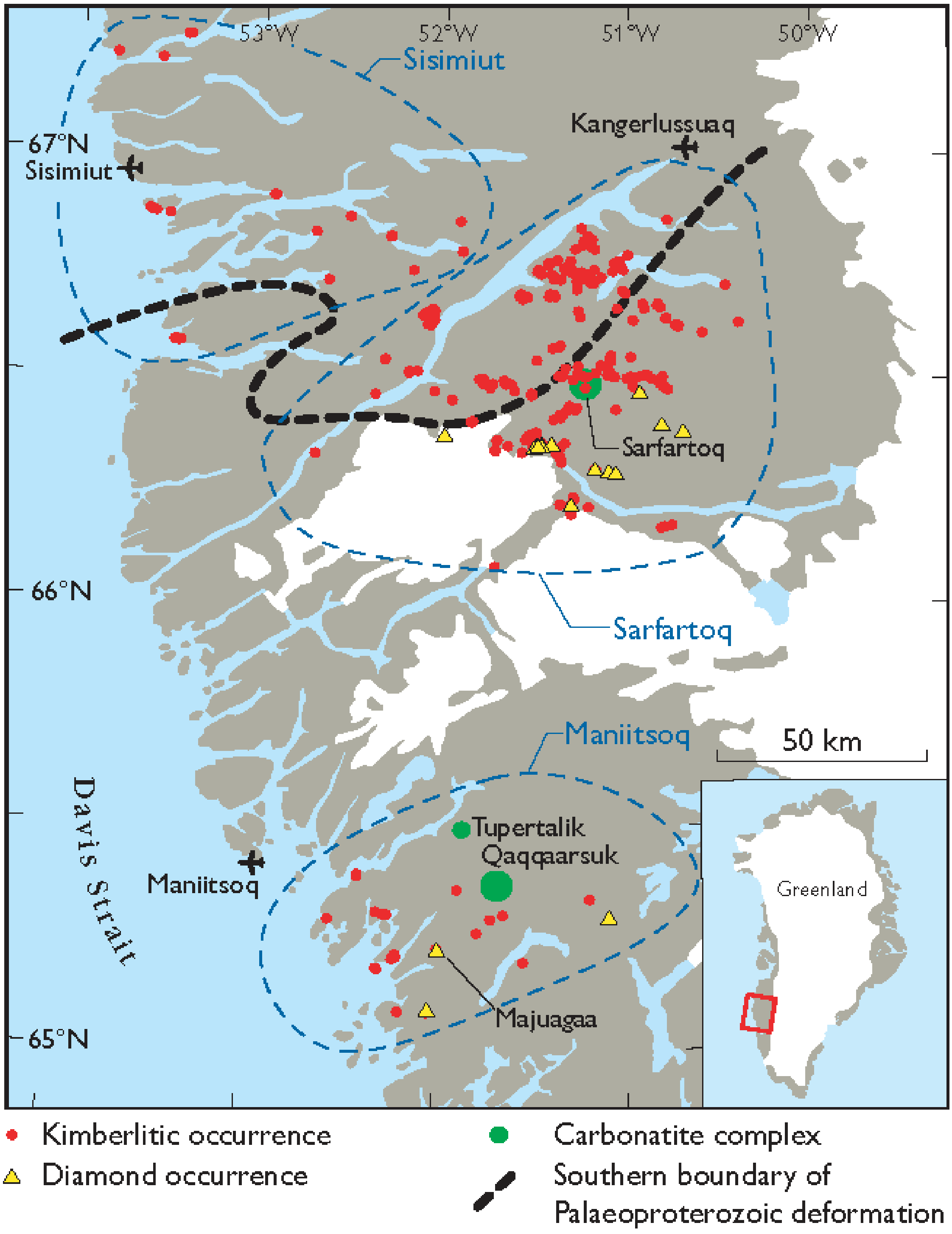

Fig. 2: Occurrences of kimberlite and ultramafic lamprophyre dykes and carbonatite complexes in southern West Greenland between 64°45' and 67°30'N. The Sisimiut, Sarfartoq and Maniitsoq regions are delineated. Also shown is the boundary between the Archaean core in the south and the deformed Archaean in the foreland to the Nagssugtoquidian orogen.

Introduction to the geology of diamond exploration areas in southern West Greenland

The areas in southern West Greenland between 63° and 67º30'N comprise the northern part of the Archaean core of Greenland and to the north the Paleoproterozoic terrains of the Nagssugtoquidian orogen in West Greenland (Fig. 1). Within this area is defined three broad regions of ultramafic lamprophyre and kimberlite dyke emplacement: (1) in the south the Maniitsoq region in preserved Archaean terrain, (2) to the northwest the Sisimiut region hosted in reworked Archaean terrain, and (3) the Sarfartoq region between the two and in the transition between non-deformed and the deformed Archaean crust of the Nagssugtoquidian foreland (Fig. 2).

The Archaean craton

The Archaean craton in West Greenland records a long and complex evolution with gneiss enclaves up to ca. 3.9 Ga old (for a review, see Hölttä et al., 2008). It is contiguous with the Nain province in Eastern Canada. The current understanding is that Archaean core comprises a series of terrains (Fig. 3). It is interpreted to be a deep mid-crustal section in crust formed in an arc-type geodynamic setting common to Archaean cratons (Hölttä et al., 2008). The northern part of the craton is referred to the Akia terrain. In the south, the Akia terrain comprises a 3.2 Ga old granulite facies core surrounded by supracrustal units and a younger suite of granitic gneiss (Nûk orthogneiss, ca. 3 Ga old). The Akia terrain is also the host of a large, now fragmented, layered, and ultramafic to mafic igneous complex, and a suite of norite intrusions (Secher, 1983).

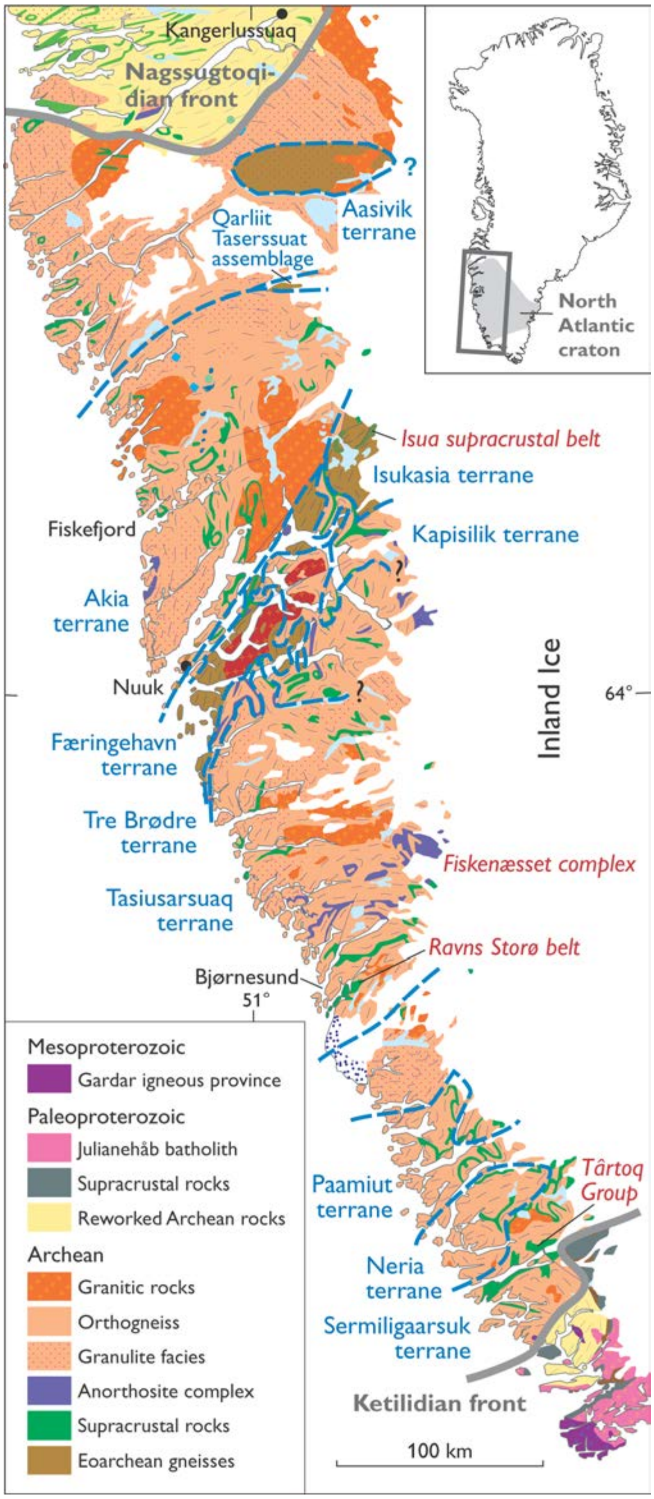

Figure 3: Geological map of the Archaean craton in West Greenland showing the subdivisions into terrains and the borderzone to the foreland of the Nagssugtoquidian orogen in the north (After Hölttä et al., 2008)

Large parts of the northern Akia terrain in the Maniitsoq area are dominated by the Finnefjeld orthogneiss complex. The Finnefjeld gneiss is a complex of large, rather homogeneous, deformed, and dominantly tonalitic intrusions. They are dated to ca. 3.05 Ga (Garde, 1997). The lithologies of the Finnefjeld gneiss appear never to have reached granulite facies metamorphic conditions. The Finnefjeld gneiss is the host rock for many of the kimberlite dykes of the Maniitsoq region.

The Paleoproterozoic Nagssugtoquidian orogen

In the Palaeoproterozoic the Archaean craton was subjected to emplacement of the NNE trending Kangamiut dyke swarm (2.04 Ga), rifting, followed by seafloor spreading, and subsequent collision in a full Wilson cycle (for a short introduction, see Lahtinen et al., 2008). The current model for the formed Nagssugtoquidian orogen recognises a suture zone to the north of the main areas of ultramfic lamprophyre and kimberlitic dykes (Fig. 4). The suture is suggested to be south-dipping and to extend south and under the Nagssugtoquidian foreland areas of the Sisimiut and Sarfartoq regions.

The pre-rifting Kangamiut dyke swarm is an important marker for southward thrusting and deformation onto the Archaean foreland. In the most southerly Maniitsoq regions the Kangamiut dykes are undeformed. A NE-SV trending boundary through the central Sarfartoq region marks the transition from undisturbed Archaean core to Archaean foreland subjected to Paleoproterozoic southward thrusting and deformation. Northwest of the boundary the Kangamiut dykes are rotated to E-W orientations, flattened, and often boudinaged. In the Sisimiut region, further to the NW, all the Kangamiut dykes are affected by the Nagssugtoquidian deformation.

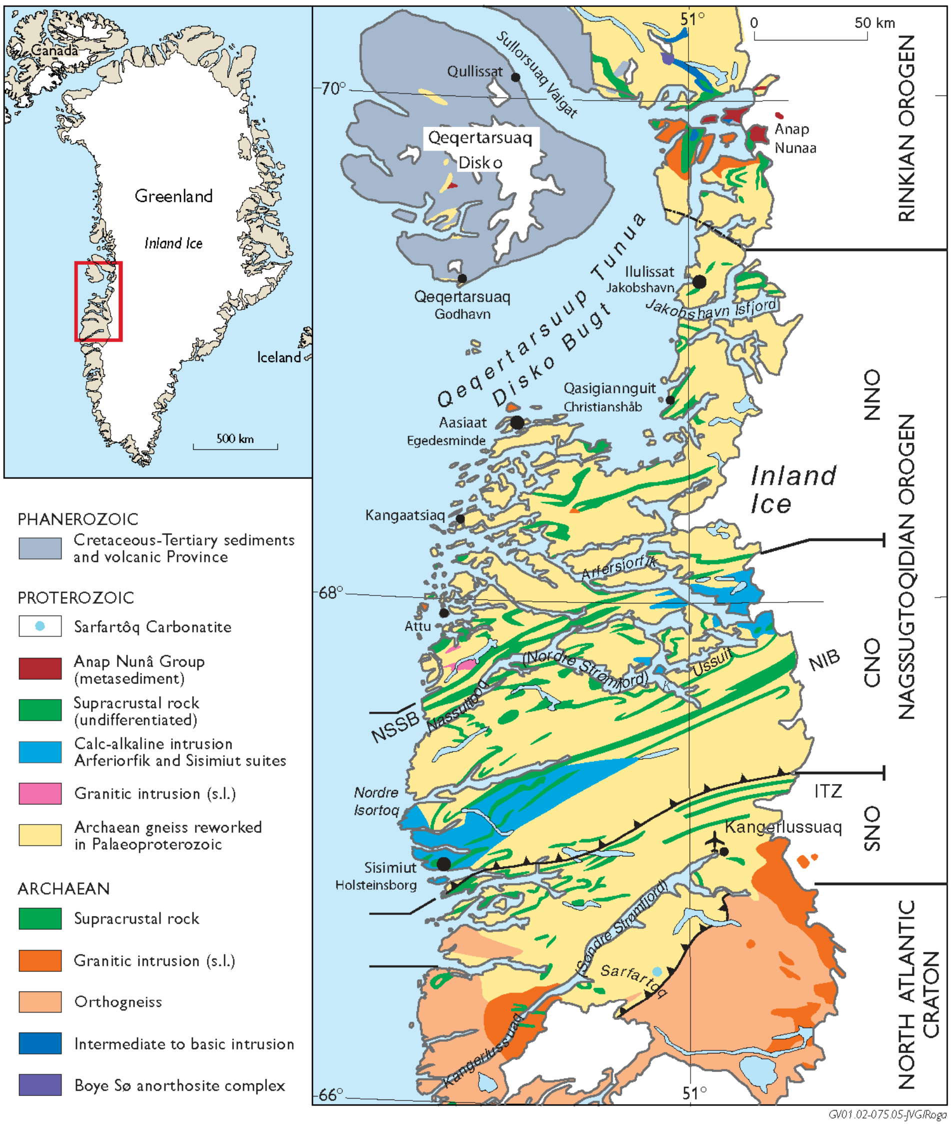

Figure 4: Regional map of the Nagssugtoqidian orogen. SNO, CNO and NNO refer to the southern, central and northern parts of the Nagssugtoqidian orogen. ITZ is the Isortoq thrust zone, NIB the Nordre Isortoq Belt, and NSSB the Nordre Strømfjord steep belt. The suture zone is suggested to be located centrally in the CNO (e.g., van Gool & Marker, 2007).

Carbonatite, kimberlite and ultramfic lamprophyre magmatism

Long-lived carbonatite and ultramafic alkaline magmatism affected most of West Greenland (for review, see Larsen et al., 1983). Central carbonatite complexes (Fig. 5) and swarms of lamprophyres, ultramafic lamprophyres, and lamproites give ages from ca. 3 to 0.16 Ga. A characteristic is the repeated emplacement of carbonatite in central complexes, suggesting a long-lived carbonate-rich source, a source that also can be traced in orthogneiss as well (Steenfelt et al., 2006). The dykes included in this atlas were all emplaced 550-600 Ma ago (Secher et al., 2008) and they are contemporaneous with the Sarfartoq carbonatite complex (Secher & Larsen, 1980) in the Sarfartoq region.

Fig. 5: The red-weathering core of magnetite-rich carbonatite of the Sarfartoq carbonatite complex.

The occurrence and setting of kimberlite and ultramafic lamprophyre dykes in southern West Greenland.

The occurrences of ailikite and kimberlite dykes in southern West Greenland are for both historical and petrographic reasons divided into three broad regions, the Sisimiut, the Sarfartoq and the Maniitsoq regions (Fig. 2). The dyke rocks are generally carbonate-rich and easily mechanically eroded. In coastal areas and rugged terrain the dykes generally hide in gullies filled with boulders of the host rocks and kimberlite or ailikite. In most cases, however, in situ samples can be collected along the length of the dykes. On high plateaus the dykes are often not exposed, but revealed by trains of kimberlitic boulders. Such occurrences are referred to as sub-crop occurrences.

The Sisimiut region

The Sisimiut region in the northwest hosts a swarm of 550-600 Ma old ailikite dykes and a swarm of 1200 Ma old lamproite dykes (Fig. 6; Secher et al., 2008). The region was for many years the better known region of lamproite and “kimberlite” dykes (e.g., Scott, 1981, Thy et al., 1987). In these early studies the 550-600 Ma old dyke rocks were referred to as “kimberlite”, but should with the current definitions be referred to as ailikite (Mitchell et al., 1999; Tappe et al., 2005).

The ailikite dykes of the Sisimiut region generally trend E-W, only with few exceptions. They are near vertical, up to 2m wide, discordant to the host gneiss, and may be followed for >1km (e.g., Scott, 1981). Little reaction is observed between dyke and host. The dykes commonly show internal contacts and multiple emplacement of magmatic pulses. Some dykes may have central parts with abundant rounded mantle xenoliths.

Fig. 6: 1200 Ma old lamproite dyke from Safanguaq in the Sisimiut region

The Sarfartoq region

The large number of “kimberlitic” dykes in the Sarfartoq region was first documented by Larsen (1991). As for the Sisimiut region, all investigated dyke rocks are re-classified to ailikites (Mitchell et al., 1999) or rock types transitional between ailikite and kimberlite (Nielsen et al., 2008). The dated dyke rocks and the Sarfartoq carbonatite complex divide in three magmatic events at 600, 580 and 560 Ma. (Secher et al., 2008).

The dykes of the Sarfartoq region show variable orientations (Jensen et al., 2003). The intrusive bodies may be near vertical or inclined dykes, or flat-lying sheets. N-S strike predominate the occurrences in the central and northern parts of the region, whereas most occurrences in the south-western part of the region strike ENE-WSW to ESE-WNW (Jensen et al., 2003).

Fig. 7: Ultramafic lamprophyre dyke with football size garnet-lherzolite xenolith from the Sarfartoq region.

Attempts to model the emplacement of the Sarfartoq dykes as a cone sheet type structure related to the Sarfartoq carbonatite complex have failed. The dykes of the Sarfartoq region vary considerably in width from veins and dykelets to wide and irregular near vertical intrusions with widths up to 20m. As in the Sisimiut region, the dykes are discordant to the host gneiss, undeformed and commonly composed of several pulses of melt. So-called “blows” are in several cases observed along or near dykes.

The dykes of the Sarfartoq region show a large petrographic range. In general, Sarfartoq ailikite samples are characterised by a more carbonate-rich matrix and lesser contents of phlogopite compared to those of the Sisimiut region. Megacrysts, macrocrysts and mantle xenoliths appear to be more abundant and larger in size. One ailikite dyke is crowded with football-size mantle xenoliths (Fig. 7).

Thin carbonate-rich dykes with no megacrysts, macrocrysts, or xenoliths form a special suite of dykes in the Sarfartoq region. They have very little or no macroscopic phlogopite and were initially referred to as kimberlite *sensu strictu* (Larsen, 1991). However, a detailed investigation of the compositions of groundmass phases led Mitchell et al. (1999) to the conclusion that these dykes represent carbonate-rich melt from an ailkite parent.

The Maniitsoq region

Although some dyke rocks in the Maniitsoq region were recorded as kimberlite, the systematic investigations were first initiated in the mid-1990´es. New dykes and swarms of dykes are found in the on-going exploration and investigations. All dated dykes from the Maniitsoq region are ca. 560 Ma old, and contemporaneous with the youngest period of magmatic activity in the Sarfartoq region and the Sarfartoq carbonatite complex (Secher et al., 2008). The Maniitsoq dykes conform in their appearance and macroscopic petrography with hypabyssal kimberlite (Nielsen and Sand in press). The classification as kimberlite (hypabyssal kimberlite, *sensu strictu*, Mitchell in press) is confirmed by the paragenesis and composition of the groundmass phases (Nielsen et al., 2008). Compared to dykes of both the Sisimiut and the Sarfartoq region, the Maniitsoq region dykes are macroscopically very poor in phlogopite and carbonate-rich.

Fig. 8: The Majuagaa kimberlite dyke SE of Maniitsoq (see Nielsen and Sand in press for details). The dyke is 2 m wide and hosted in Finnefjeld gneiss.

In contrast to the Sarfartoq region, the Maniitsoq occurrences are mostly steep dykes and trend ENE-WSW. The dykes may be several km long and reach width of app. 2m. They may form swarms of parallel dykes. They are, as in the Sisimiut and Sarfartoq regions, discordant to the host gneiss. No or very limited reaction is observed between dyke and host rock. The contacts appear in many cases chilled. In contrast to the dykes of the Sisimiut and Sarfatoq regions the Maniitsoq dykes appear more often as single pulse intrusions. Megacrysts, macrocrysts and mantle xenoliths are common.

Classification principles

The characteristic megacrysts and macrocrysts phases of the kimberlite are olivine, clinopyroxene, orthopyroxene, ilmenite, chromite, and red to purple and orange garnet commonly with a well developed kelyphite rim. The megacrysts and the macrocysts are the most easily identified components of kimberlite. In early investigations of the Greenland occurrences, dyke rocks with mega- and macrocrysts assemblages characteristic of kimberlite were classified as kimberlite or "kimberlitic". However, as concluded in Mitchell (1995), kimberlite intrusions can not be classified on the basis of megacrystic and macrocrystic minerals. The basis for the classification of the dyke rocks is the composition of the transporting melt, as constrained by the groundmass paragenesis and the composition of the groundmass phases determined by electron micro probe.

Kimberlite or ailikite

The empirical distinction between groundmass paragenesis in kimberlite *sensu strictu* and ultramafic lamprophyres such as ailikite and melnoite is based on the presence or absence diagnostic minerals.

By definition kimberlite melt does not crystallise clinopyroxene (Mitchell, 1995, Tappe et al., 2005). Most of the West Greenland samples investigated in Mitchell et al. (1999) and most samples of dykes from the Sisimiut and Sarfartoq regions are clinopyroxene-bearing. Consequently, and confirming the conclusion of Mitchell et al. (1995), none of the occurrences in the Sisimiut and Sarfartoq regions can be classified as kimberlite. The dyke rocks are in broad terms ultramafic lamprophyre, i.e., alikite or melnoite (Mitchell et al., 1999). No melilite has been recorded to date and the occurrences in the Sisimiut and Sarfartoq regions previously classified as kimberlite or referred to as "kimberlitic" are re-classified to ultramafic lamprophyre, sub-type ailikite.

In contrast, clinopyroxene is in general not found in the groundmass of dyke rocks from the Maniitsoq region. In combination with characteristic compositions of the groundmass phlogopite, spinel and ilmenite (Nielsen et al., 2008), the dyke samples from the Maniitsoq region are classified as kimberlite (*sensu* hypabyssal kimberlite, Mitchell in press).

The distinction between ailikite and kimberlite is, however, not clear-cut. Samples from several occurrences have parageneses and compositional characteristics transitional between kimberlite and ailikite. A continuum may exist between the two. In consequence, the suite of dyke rocks from the Sisimiut, Sarfartoq and the Maniitsoq region is on the basis of the petrographic observations and the compositions of groundmass phases empirically divided into kimberlite, ailikite, and “transitional ultramafic lamprophyre” (Trans-UML, transitional between the two) .

Groundmass of Maniitsoq kimberlite

Kimberlite groundmass has no clinopyroxene, perovskite is in most cases rare and only found as rims on spinel, and phlogopite is rare, transparent and slightly greenish and never zoned to tetraferriphlogopite. The phlogopite shows a very limited zonation in Fe and Ti, but have Ba-rich margins and rims. Mg-rich ilmenite and spinel form euhedral crystals and contain more than 20 wt% MgO and have low Mn-contents. The composition of spinel is in the field of Mg-rich “magmatic trend 1” spinel of *bona fide* kimberlite (Mitchell, 1995, Nielsen et al., 2006). The composition of ilmenite is in the Mg-rich end of the compositional field of groundmass ilmenite in kimberlite. The carbonate content (calcite and dolomite) is high, relative to primary serpentine. The combined characteristics of the groundmass phases warrant the classification of these dyke rocks from the Maniitsoq region as kimberlite. An example of the southern West Greenland kimberlite is sample 491713 from the Majuagaa dyke (Fig. 9; Nielsen & Sand, in press).

Fig. 9: The Majuagaa kimberlite dyke (GGU 491713). The kimberlite consists of macrocrysts and a groundmass. Macrocrysts include olivine, garnet with kelyphite rims (centre), ilmenite, altered orthopyroxene and clinopyroxene. The matrix consists of fragments of disintegrated macrocrystic olivine in a groundmass of carbonate and serpentine with euhedral ilmenite, spinel, and very minor translucent and light greenish phlogopite.

The Maniitsoq kimberlite samples show a range in composition. Some carry abundant late-crystallising perovskite, ilmenite is resorbed and mantled, spinel is only moderately Mg-rich. The composition of phlogopite is enriched in Ti and Fe and marginal to the compositional field of groundmass phlogopite of *bona fide* kimberlite (Mitchell, 1995). This type of kimberlite suggests the existence of a continuum of compositions between kimberlite *sensu stricu* and ailikite.

Groundmass of Sarfartoq and Sisimiut ailikite.

Clinopyroxene, phlogopite, and perovskite are a common phases in the groundmass of the studied samples of ailikite (Fig. 10). The phlogopite is brown or light-brown with distinct Ba-poor margins and rims of tertraferriphlogopite. Perovskite often forms euhedral crystals. Ilmenite is only preserved if armoured by spinel, and is regarded xenocrystic. Euhedral spinel, as well as armoured ilmenite, are less Mg-rich in ailikite compared to those of kimberlite (Nielsen et al., 2008). Barite is a common mineral in the groundmass of ailikite.

Fig. 10: The Paternoster ailikite from the northern Sarfartoq region. Compared to the Majuagaa kimberlite (Fig. 9) the ailikite is phlogopite-rich. Phlogopite occurs in all sizes and is always rimmed toward tertraferriphlogopite. Olivine is largely xenocrystic. Macrocrysts of ilmenite are resorbed. The groundmass consists of carbonate, serpentine, phlogopite, euhedral spinel including chromite, apatite, clinopyroxene and occasional barite.

Compared to that of kimberlite, ailikite groundmass appears in general to have less carbonate and more primary serpentine. An example is the so-called Paternoster dyke in northern Maniitsoq region (GGU 444206). Detailed descriptions of southern West Greenland ailikite are found in Scott (1981) and Mitchell et al. (1999).

Groundmass of Sarfartoq Trans-UML

Groundmass minerals of Trans-UML commonly show compositional heterogeneity. In the some areas of the thin sections, phlogopite can be almost colourless and without rims or margins, and in other areas light brown and zoned to tetraferriphlogopite. Some phlogopite grains may show strong Ba-enrichment (up to 11 wt% BaO). The euhedral groundmass spinel may show compositional trends similar to those of ailikite, but in addition have population of Mg-rich spinels (Nielsen et al., 2008). The proportion of late crystallising clinopyroxene is low, compared to ailikite. The heterogeneity and the common record of multiple compositional trends for groundmass minerals may be indicative of mixing of pulses of contrasting composition. An example of a Trans-UML is the Garnet Lake “kimberlite” (Hutchison 2005, 2008b) and the Panersiviup Qulaa occurrence (GGU 444281) in the northern part of the Sarfatoq region (Fig. 10).

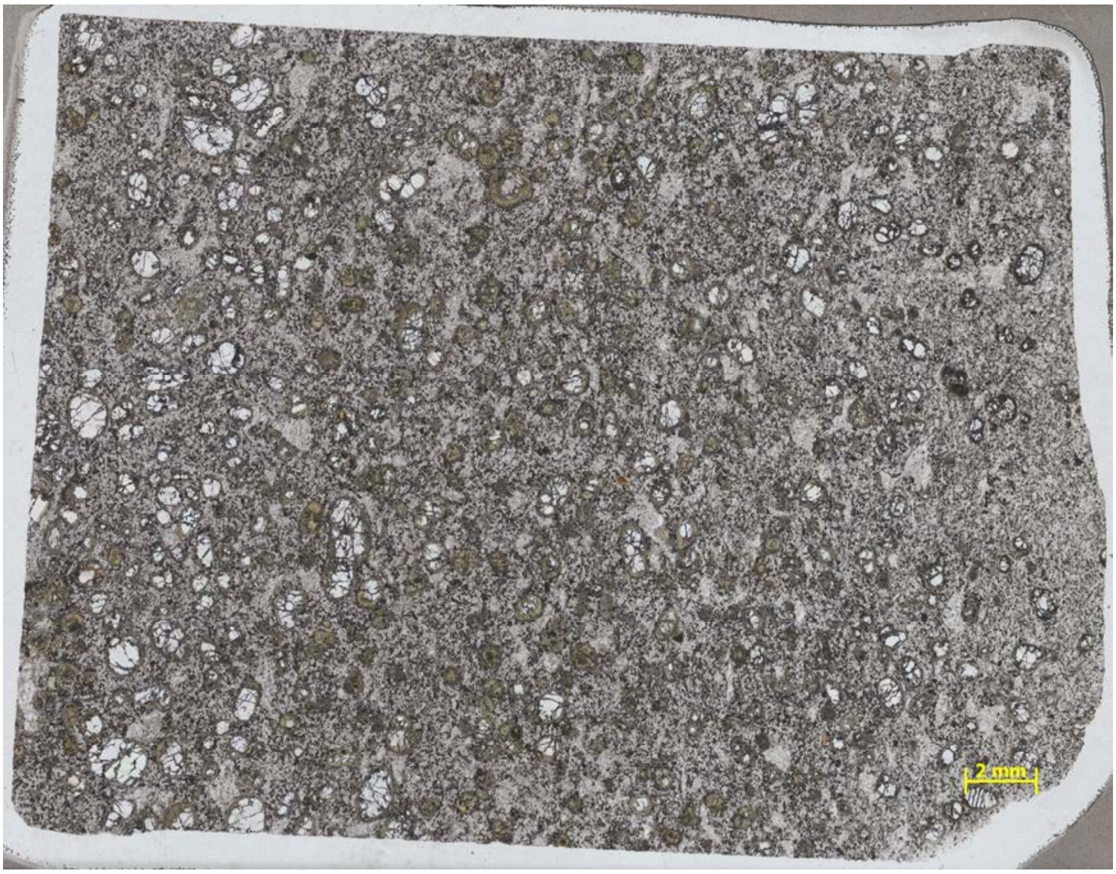

Fig. 11: The Panersiviup Qulaa Trans-UML from the northern Sarfartoq region.

The digital information

Summary information on all petrographically investigated and imaged samples will be made available in digital format in the form of an access database and a picture gallery. The digital information forms the basis for the development of a user friendly digital environment, to which can be linked further information such as bulk rocks chemistry, electron microprobe data for minerals, results of diamond test, etc.

The access database

The access database contains all basic information for the identification of the investigated and imaged samples including basic petrographic observations.

Sample identification

The individual sample is identified as a thin section of a given sample. The thin section is identified by the sample number (GGU number, e.g. 491713) and possible suffix. There may be more than one thin section from a sample. The number of the thin section, rather than the sample number is used because of the heterogeneity of kimberlite and ultramafic lamprophyre. A single sample may, as well as the dyke occurrence it originates from, be the result of multiple intrusion.

Locality

Together with the geographical coordinates, each locality is identified by the name given to the individual dyke or blow, and the region in southern West Greenland. Longitude and latitude information varies in precision. Compared to present-day sample localities collected by GPS, older sample localities have been read from sample maps and errors in the geographical coordinates can be significant.

Petrographic information

The petrographic information is restricted to observations necessary for the classification of the samples. Following the currently used classification criteria and the application of these to the West Greenland occurrences (Nielsen et al., 2008) the main focus is on the fundamental characteristics of groundmass clinopyroxene, phlogopite, ilmenite, spinel and perovskite. In the database is included information on megacryst, macrocryst, and phenocryst (rare) from description of hand specimens and observations made in the described thin section. It is emphasised that the information on megacrysts and macrocrysts may not be representative. The same applies to the xenolith assemblage of the occurrences. The xenoliths form a separate study, and only observations made during the study of the selected thin section are included.

Diagnostic groundmass characteristics: Following Nielsen & Jensen (2005) and Nielsen et al. (2008), the groundmass paragenesis and the characteristics of the groundmass phases allow distinction between kimberlite, ultramafic lamprophyre (ailikite) and transitional ultramafic lamprophyre intermediate between these two.

The characteristics that separate kimberlite from ailikite as well as transitional ultramafic lamprophyre is the absence of groundmass clinopyroxene and perovskite crystals, and the presence of euhedral ilmenite and minor pale, greenish, phlogopite without well-defined rims. In contrast, the groundmass of ailikite is commonly rich in euhedral perovskite (crystals), has late crystallising clinopyroxene. Ilmenite is mostly absent, whereas phlogopite is abundant and rimmed by distinct brown or red rims of tetraferriphlogopite.

Commentary: As described in the explanatory notes the suite kimberlite – transitional ultramafic lamprophyre – ailikite may be a continuum. The classification is therefore not simple and the commentary gives the reasoning for the classification of the sample as represented by the studied thin section.

Printed report

A download from the access database includes the basic information described above. In addition the printed report will include a plain polarized image and an image with crossed Nicols (see below) with hotlink or similar to the image database. Examples of print-outs are given in the appendix.

The digital images

To ensure high resolution, the digital images were acquired using a Zeiss Axioskop Pol 40 ® microscope equipped with an atomised high precision X-Y stage, and an Axiovision ® software package. A custom made sample holder was used to maintain focus during operation. The obtained images are mosaics resulting from a number of individual images, a number dependent on the magnification of the used lens.

Mostly, a 2.5X lens was used to avoid creation of files too large for the hardware attached to the camera of the microscope. Two images were acquired, one in plain polarized light and one with crossed Nicols

The digital images are processed using the Axiovision ® digital procession software of Carl Zeiss. The images are saved as *zvi*-files (format in Axiovision) and for common use as *jpeg*-files, varying in size between 5 and 10 Mbytes. The images can also be saved as *tif*-files (c. 40 Mbytes) by reprocessing the primary images in the *zvi*-file format.

The observable resolution in the acquired images depends on the setting of the screen and the programme used for the viewing of the *jpeg* files. Groundmass grains down to the size of 100 micron can be viewed in the mosaic images with the correct settings of screen and imaging programme. Higher resolution can be obtained by using the individual images that compose the mosaics.

Colours in the viewed images also depend on the settings of the screen and the software used. It is recommended to use a software product that allows correction of illumination and contrast to ensure the best reproduction of the images.

Acknowledgements

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Appendix

Examples of digital print-outs from the petrographic database.

Ultramafic lamprophyre, carbonate rich

Thin section 265373

Locality name	Sarfartoq Valley	Latitude	66.50179
Region	Sarfartoq south	Longitude	-51.52691

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☑		Groundmass serpentine	☑
Groundmass perovskite	☐		Groundmass olivine	☐
Groundmass phlogopite	☑	Pale green	Groundmass opx	☐
Marked phlogopite rims	☐		Groundmass cpx	☑

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☑		Macro/mega cpx	☑
Macro/mega olivine	☑	Slightly altered	Macro/mega opx	☐
Macro/mega phlogopite	☑	Brown		
Marked rim color	☑	Pale		

Xenoliths

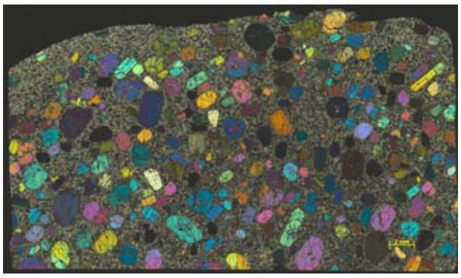
Xenliths observed	☑	Xenoliths not observed	☐

Comments: Olivine is rounded and mostly fresh. No perovskite.

plain

265373_PPL.JPG

Crossed Nicols



265373_CPL.JPG

Ailikite, segregation

Thin section 265815B

Locality name	Qôruluarqap kûa	Latitude	66.4813
Region	Sarfartoq south	Longitude	-50.79106

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☐		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims	Groundmass olivine	☐
Groundmass phlogopite	☑	Pale green	Groundmass opx	☐
Marked phlogopite rims	☐		Groundmass cpx	☑

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☐		Macro/mega cpx	☐
Macro/mega olivine	☑	Altered	Macro/mega opx	☐
Macro/mega phlogopite	☐			
Marked rim color	☐			

Xenoliths

Xenliths observed	☐	Xenoliths not observed	☑

Comments: Very carbonate- and oxide-rich segregation from ultramafic lamprophyre. Carbonate ocelli.

plain

265815b_PPL.JPG

Crossed Nicols

265815b_CPL.JPG

Tranultramafic lamprophyre

Thin section 311004

Locality name	Akuliarusinguaq	Latitude	67.20647
Region	northern Isortoq	Longitude	-53.5665

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☑		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐
Groundmass phlogopite	☑	Brown	Groundmass opx	☐
Marked phlogopite rims	☑	Red	Groundmass cpx	☐

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☐		Macro/mega cpx	☐
Macro/mega olivine	☑	Slightly altered	Macro/mega opx	☐
Macro/mega phlogopite	☑	Brown		
Marked rim color	☑	Red		

Xenoliths

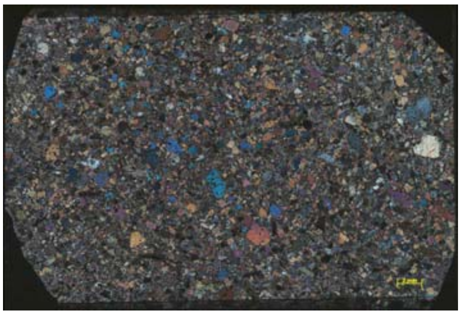
Xenliths observed	☑	Xenoliths not observed	☐

Comments: Gdm phlogopite and macro phlogopite appears to be the same, but there is a multigrain of phlogopite including one very big crystal.

plain

311004_PPL.JPG

Crossed Nicols



311004_CPL.JPG

Ailikite

Thin section 444206.1

Locality name	Qaassuup aasivii (Paternoster)	Latitude	66.7027563
Region	Sarfartoq north	Longitude	-51.27723285

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☐		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐
Groundmass phlogopite	☑	Brown	Groundmass opx	☐
Marked phlogopite rims	☑	Brown	Groundmass cpx	☑

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☑		Macro/mega cpx	☑
Macro/mega olivine	☑	Partly altered	Macro/mega opx	☐
Macro/mega phlogopite	☐			
Marked rim color	☐			

Xenoliths

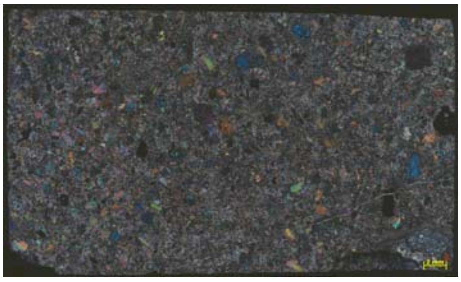
Xenliths observed	☑	Xenoliths not observed	☐

Comments: Clinopyroxene-bearing groundmass. Compositions of groundmass spinel and phlogopite suggests classification as ailikite. Ilmenite absent and perovskite common in the groundmass. Most olivine seems to be xenocrystic.

plain

444206.1_PPL.JPG

Crossed Nicols



444206.1_CPL.JPG

Ultramafic lamprophyre

Thin section 444218.1

Locality name	Qaassuup aasivii (Paternoster)	Latitude	66.7030513
Region	Sarfartoq north	Longitude	-51.27747962

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☐		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐
Groundmass phlogopite	☑	Pale brown	Groundmass opx	☐
Marked phlogopite rims	☐		Groundmass cpx	☑

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☐		Macro/mega cpx	☐
Macro/mega olivine	☐		Macro/mega opx	☐
Macro/mega phlogopite	☑	Brown		
Marked rim color	☑	Brown		

Xenoliths

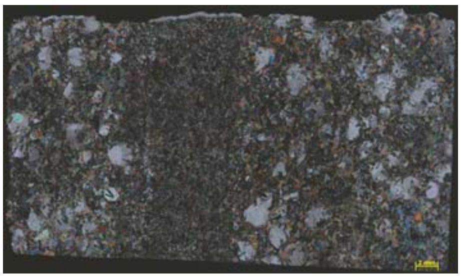
Xenliths observed	☐	Xenoliths not observed	☑

Comments: Concentration of late UML melt rich in carbonate, phlogopite and oxide grains. No olivine is observed. Many carbonate ocelli. Banded.

plain

444218.1_PPL.JPG

Crossed Nicols



444218.1_CPL.JPG

Ailikite

Thin section 444225

Locality name Kissavissat Qooruat (E), Francois

Region Sarfartoq south

Latitude 66.4871174

Longitude -50.97637483

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑	
Groundmass ilmenite	☐		Groundmass serpentine	☑	
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐	
Groundmass phlogopite	☑	Brown	Groundmass opx	☐	
Marked phlogopite rims	☑	Brown	Groundmass cpx	☐	

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☐		Macro/mega cpx	☐
Macro/mega olivine	☑	Altered	Macro/mega opx	☐
Macro/mega phlogopite	☑	Pale brown		
Marked rim color	☑	Brown		

Xenoliths

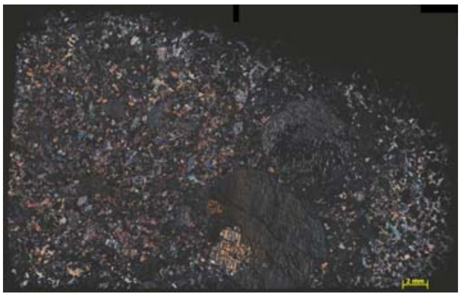
Xenliths observed ☑ Xenoliths not observed ☐

Comments: Macro phlogopite rimmed by TFP . Rims enclose spinel and perovskite.Most phlogopite appears crystallized in situ.

plain

444225_PPL.JPG

Crossed Nicols



444225_CPL.JPG

Calcite-rich transitional ultramafic lamprophyre.

Thin section 444281

Locality name	Panersiiviup Qulaa	Latitude	66.6861856
Region	Sarfartoq north	Longitude	-51.54693434

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☐		Groundmass serpentine	☑
Groundmass perovskite	☑	Rare crystals	Groundmass olivine	☐
Groundmass phlogopite	☑	Pale green	Groundmass opx	☐
Marked phlogopite rims	☑	Brown	Groundmass cpx	☐

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☐		Macro/mega cpx	☐
Macro/mega olivine	☑	Partly altered	Macro/mega opx	☐
Macro/mega phlogopite	☐			
Marked rim color	☐			

Xenoliths

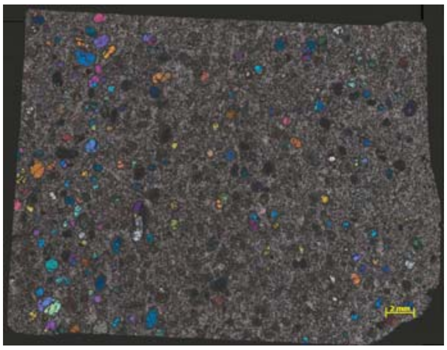
Xenliths observed	☑	Xenoliths not observed	☐

Comments: Oxide and carbonate rich. Perovskite rare, minor phlogopite. Some olivine cores preserved. Very minor clinopyroxene in groundmass. Calcite-rich transitional ultramafic lamprophyre. Degree of alteration of olivine varies throughout the thin section.

plain

444281_PPL.JPG

Crossed Nicols



444281_CPL.JPG

Ailikite

Thin section 483815

Locality name	Atanaligaarsuit (Anna)	Latitude	66.3879852
Region	Sarfartoq south	Longitude	-50.7141796

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☐		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐
Groundmass phlogopite	☑	Pale brown	Groundmass opx	☐
Marked phlogopite rims	☑	Brown	Groundmass cpx	☐

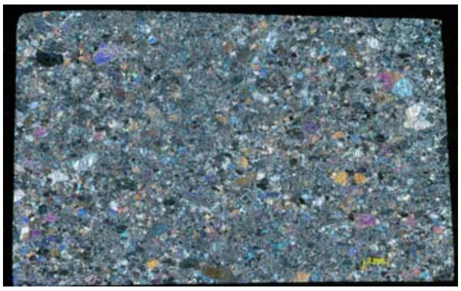
Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☐		Macro/mega cpx	☐
Macro/mega olivine	☑	Partly altered	Macro/mega opx	☐
Macro/mega phlogopite	☑	Brown		
Marked rim color	☑	Brown		

Xenoliths

Xenliths observed	☑	Xenoliths not observed	☐

Comments: Some alteration, many late calcite and serpentine rich veins.

plain	Crossed Nicols
	
483815_PPL.JPG	483815_CPL.JPG

Ailikite

Thin section 483824

Locality name	Kangerlussuup nunaa south	Latitude	66.7467156
Region	Sarfartoq north	Longitude	-51.18497467

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☐		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐
Groundmass phlogopite	☐		Groundmass opx	☐
Marked phlogopite rims	☐		Groundmass cpx	☐

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☐
Macro/mega ilmente	☑		Macro/mega cpx	☐
Macro/mega olivine	☑	Partly altered	Macro/mega opx	☐
Macro/mega phlogopite	☑	Pale brown		
Marked rim color	☑	Brown		

Xenoliths

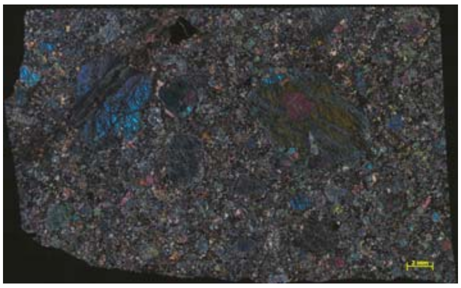
Xenliths observed	☑	Xenoliths not observed	☐

Comments: Rock is partly altered, Interstitiel and poikilitic macrocrystic phlogopite in the groundmass. Phlogopite has TFP rims. Occurrence of clinopyroxene in groundmass is not confirmed.

plain

483824_PPL.JPG

Crossed Nicols



483824_CPL.JPG

Kimberlite

Thin section 483838

Locality name	Timitta Tasersua east	Latitude	65.0850064
Region	Maniitsoq	Longitude	-52.06223011

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☑		Groundmass serpentine	☑
Groundmass perovskite	☑	Rims and crystals	Groundmass olivine	☐
Groundmass phlogopite	☑	Pale brown	Groundmass opx	☐
Marked phlogopite rims	☐		Groundmass cpx	☐

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☑
Macro/mega ilmente	☑		Macro/mega cpx	☑
Macro/mega olivine	☑	Slightly altered	Macro/mega opx	☑
Macro/mega phlogopite	☐			
Marked rim color	☐			

Xenoliths

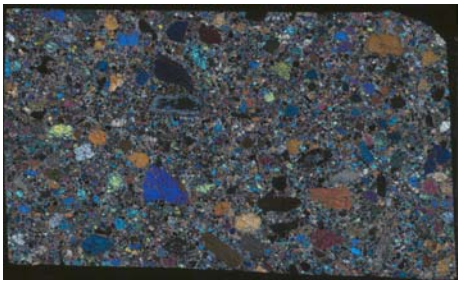
Xenliths observed	☑	Xenoliths not observed	☐

Comments: Macro phlogopite is grown from grm. The sample is classified as kimberlite on the basis of the compositions of groundmass spinel, ilmenite and phlogopite, but rare clinopyroxene in late vugs suggests a transitional character.

plain

483838_PPL.JPG

Crossed Nicols



483838_CPL.JPG

Kimberlite

Thin section 483861

Locality name	Qaamasoq	Latitude	65.2986155
Region	Maniitsoq	Longitude	-51.08086314

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☑		Groundmass serpentine	☑
Groundmass perovskite	☑	Rare rims	Groundmass olivine	☐
Groundmass phlogopite	☑	Pale green	Groundmass opx	☐
Marked phlogopite rims	☑	Brown	Groundmass cpx	☑

Macro/mega crysts

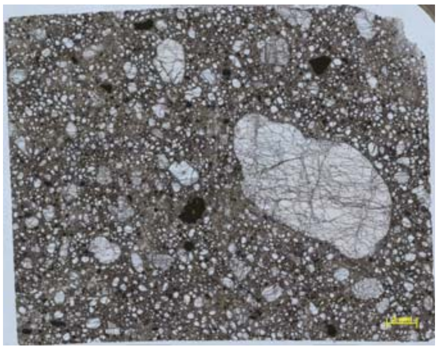
Macro/mega spinel	☐		Macro/mega_garnet	☑
Macro/mega ilmente	☐		Macro/mega cpx	☑
Macro/mega olivine	☑	Partly altered	Macro/mega opx	☑
Macro/mega phlogopite	☐			
Marked rim color	☐			

Xenoliths

Xenliths observed	☑	Xenoliths not observed	☐

Comments: Some olivines are eu-subhedral. Rutile needles. Based on the compositions of groundmass phlogopite, spinel and ilmenite the samples classify as kimberlite. Information about groundmass ilmenite is from microprobe.

plain



483861_PPL.JPG

Crossed Nicols

483861_CPL.JPG

Kimberlite

Thin section 491713

Locality name	Majuagaa	Latitude	65.2219465
Region	Maniitsoq	Longitude	-51.99618951

Groundmass

Groundmass spinel	☑		Groundmass Carbonate	☑
Groundmass ilmenite	☑		Groundmass serpentine	☑
Groundmass perovskite	☐		Groundmass olivine	☐
Groundmass phlogopite	☑	Pale green	Groundmass opx	☐
Marked phlogopite rims	☐		Groundmass cpx	☐

Macro/mega crysts

Macro/mega spinel	☐		Macro/mega_garnet	☑
Macro/mega ilmente	☑		Macro/mega cpx	☐
Macro/mega olivine	☑	Slightly altered	Macro/mega opx	☑
Macro/mega phlogopite	☐			
Marked rim color	☐			

Xenoliths

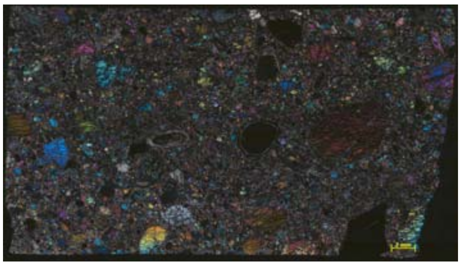
Xenliths observed	☑	Xenoliths not observed	☐

Comments: The groundmass contains no clinopyroxene. The sample is classified as a kimberlite on the basis of the compositions of groundmass ilmenite, spinel and phlogopite.

plain

491713_PPL.JPG

Crossed Nicols



491713_CPL.JPG

Transitional ultramafic lamprophyre

Thin section 491803B

Locality name	Eqalummiut nunaat (Alex)	Latitude	66.3015756
Region	Sarfartoq south	Longitude	-51.17703022

Groundmass

Groundmass spinel	[x]		Groundmass Carbonate	[x]
Groundmass ilmenite	[x]		Groundmass serpentine	[x]
Groundmass perovskite	[x]	Rims and crystals	Groundmass olivine	[ ]
Groundmass phlogopite	[x]	Pale brown	Groundmass opx	[ ]
Marked phlogopite rims	[x]	Red	Groundmass cpx	[ ]

Macro/mega crysts

Macro/mega spinel	[ ]		Macro/mega_garnet	[ ]
Macro/mega ilmente	[ ]		Macro/mega cpx	[ ]
Macro/mega olivine	[x]	Altered	Macro/mega opx	[ ]
Macro/mega phlogopite	[ ]			
Marked rim color	[ ]			

Xenoliths

Xenliths observed	[x]	Xenoliths not observed	[ ]

Comments: The sample contains no groundmass clinopyroxene but phlogopite is rimmed to tetraferriphlogopite. Compositions of gdm spinel and phlogopite suggests composition between kimberlite and ailikite. Information about groundmass ilmenit is from microprobe.

plain

491803b_PPL.JPG

Crossed Nicols

491803b_CPL.JPG