Investigating the diamond potential of southern West Greenland

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Southern West Greenland hosts a province of ultramafic alkaline rocks, including swarms of dykes traditionally described as kimberlites and lamproites (Larsen 1991; Jensen *et al.* 2002). Since the mid-1990s, commercial diamond exploration has been focused on the Sarfartoq region and the region south-east of Maniitsoq (Fig. 1), and has resulted in numerous reports of diamond-favourable indicator minerals from till sampling, finds of kimberlitic dykes, and recovery of diamonds from kimberlitic rocks.

A new digital compilation of company data released from confidential status (Jensen *et al.* 2003a) presents a comprehensive overview of exploration activities and results that have emerged since the Survey's first compilation of occurrences of kimberlitic and related rocks (Larsen 1991). The new compilation in a GIS (geographic information system) environment allows for refined assessment of the distribution, structural control and possible spatial and petrogenetic relationships that characterise the kimberlitic occurrences.

In 2003, the Geological Survey of Denmark and Greenland (GEUS) and the Government of Greenland's Bureau of Minerals and Petroleum (BMP) went further than has been customary in investigating the economic potential of specific sites. Four areas were temporarily closed to application for exploration licences, pending sampling and testing for diamond content of large samples of more than one tonne each from significant kimberlitic occurrences. Additional characterisation and research initiated on these and other occurrences include magnetic mapping, detailed petrography and studies of mantle xenoliths, as well as indicator mineral chemistry. An extensive programme to determine the ages of kimberlitic and related rocks was also initiated in 2003.

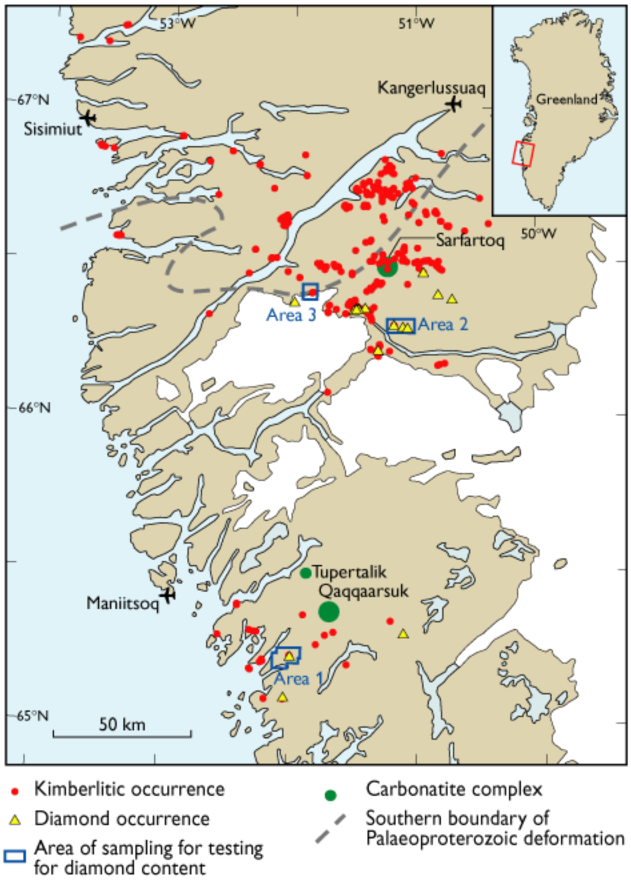

Fig. 1. Map of kimberlitic and diamond occurrences of the West Greenland alkaline province. Framed areas enclose the three kimberlitic occurrences sampled for determination of diamond content in 2003.

Distribution of kimberlitic occurrences

Alkaline ultramafic dykes in the Sisimiut–Kangerlussuaq and Sarfartoq regions intrude the border zone between the Archaean craton and the Palaeoproterozoic Nagssugtoqidian orogen (Fig. 1; Secher & Larsen 1980). The occurrences south-east of Maniitsoq mark the southernmost extent of the alkaline province.

The alkaline rocks of interest here have previously been described as kimberlites and lamproites (Larsen 1991; Jensen *et al.* 2002). This classification was questioned by Mitchell *et al.* (1999), who consider that they are not typical kimberlites, but unusual ultramafic lamprophyres in that they are sometimes diamondiferous. In the absence of petrographic data for many of the occurrences the broader terms 'kimberlitic' and 'lamproitic' are applied here.

Three clusters of dykes have been recognised within the province during the last 20–30 years (Larsen 1980, 1991; Scott 1981). The 'Sisimiut cluster', consisting mainly of 1214–1240 Ma lamproitic and *c.* 590 Ma kimberlitic dykes (Larsen & Rex 1992), is characterised by vertical E–W to SE–NW trends. The 'Sarfartoq cluster' has been described as a cone-sheet structure centred on the 600 Ma Sarfartoq car-

Fig. 2. Outcrop of one of the three kimberlitic occurrences from which more than 1000 kg of rock was collected (Area 1 in Fig. 1). Width of dyke approx. 1 m.

bonatite complex (Larsen 1980). The 600 Ma kimberlitic dykes of the 'Maniitsoq cluster' have more variable orientations.

The cone-sheet model for kimberlitic dykes around the Sarfartoq carbonatite complex was largely based on dyke orientations in a broad E–W-trending valley transecting the core of the complex. With new knowledge of hundreds of additional kimberlitic occurrences in the region presented in Jensen *et al.* (2003c), it now appears that other structural elements have controlled the emplacement of dykes. For example, some kimberlitic dykes follow the trends of the Palaeoproterozoic Kangâmiut dolerite dykes, as outlined by Escher *et al.* (1970, 1976), in reworked as well as unreworked parts of the Archaean basement. Another example is an apparent predominance of N–S-trending kimberlitic dykes in a zone reaching far beyond the Sarfartoq carbonatite complex. Information from magnetic field data lends support to the hypothesis that kimberlitic dyke emplacement may be controlled by structures of regional character (Jensen *et al.* 2003b, c).

Digital compilation of data

Exploration companies have produced a large volume of data relevant to diamond exploration, especially since 1994. The data include analyses of heavy minerals from till and stream sediment samples, dyke and boulder distribution maps, airborne and ground geophysical surveys, results of testing for diamond content of mini-bulk sampled dykes, drill logs, etc.

A GIS compilation of company exploration data now in the public domain (Jensen *et al.* 2003a) constitutes the most extensive overview of kimberlitic rocks and diamond occurrences in Greenland to date. The compilation contains scanned text and maps, and selected digital data from company assessment reports submitted to BMP in fulfilment of the standard terms for mineral exploration licences. A total of 146 company reports of relevance to diamond exploration, with a total of approximately 9250 pages of text, tables and maps, are included as PDF files. More than 53 000 tabulated analyses of indicator minerals from till and stream sediment are available, as are the details and results of drilling campaigns and tests for diamond content.

Fig. 3. Eclogitic xenolith in one of the dykes sampled for testing for diamond content (Area 1 in Fig. 1). Scale bar is 2 cm.

Diamond occurrences and indicator mineral chemistry

Most of the approximately 600 diamonds reported to date in Greenland are from just two areas, both located in the unreworked Archaean craton (Jensen *et al.* 2003a). Some 95% of the stones are classified as microdiamonds, i.e. smaller than the minimum size recoverable in operating mine plants – typically those passing a 0.5 mm screen. Another 20 microdiamonds from kimberlitic occurrences to the west of the Sarfartoq carbonatite complex were reported in late 2003 (Tuer 2003). The largest diamond from an *in situ* dyke reported to date is *c.* 1.7 mm in its longest dimension and has a weight of around 0.001 carat (1 carat = 0.2 g). Although microdiamonds do not constitute an economic resource, they are important to the characterisation of kimberlites and evaluation of diamond deposits (Rombouts 1995).

Nearly all of the reported diamonds have been recovered using caustic dissolution, a method that is usually adjusted to recover stones of all sizes down to around 0.1 or 0.15 mm. In addition, a few diamonds have been found in large stream sediment samples. Some occurrences have also been subjected to dense media separation tests for larger diamonds, where up to 11 tonnes of kimberlitic rock have been processed (Boucher 2000), but none of these tests have recovered any diamonds.

All *in situ* diamond occurrences lie within areas outlined by 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 the influence of complex glacial dynamics on the formation of the till deposits. The most diamond-favourable indicator minerals are distributed far beyond the areas with known diamonds. This observation, together with the postulated regional structural controls, suggests that the potential for diamonds is not restricted to the known occurrences. The potential appears to exist on both sides of the boundary between reworked and unreworked Archaean basement.

Testing of three kimberlitic occurrences for diamond content

In 2003, GEUS and BMP undertook sampling of three large occurrences of kimberlitic rocks for subsequent testing for diamond content using caustic dissolution.

Composite samples of approximately 1000 kg from each occurrence have been processed and examined for diamonds by a certified Canadian testing laboratory. Two of the occurrences are vertical dykes with a length of approximately 2500 m and a width of up to 2 m (Figs 2–4). The third occurrence is a shallow-dipping sill with a length of at least 500 m and a thickness of 1–2 m. The sill and one of the long dykes lie well within the unreworked Archaean craton, while the second long dyke lies a few kilometres inside the Palaeoproterozoic deformed region (Fig. 1).

The test resulted in 125 diamonds recovered from the sampled dyke in Area 1 (Fig. 1), two diamonds from the dyke in Area 2 and one diamond from the dyke in Area 3 (Jensen *et al.* 2004). The largest diamond recovered measures 0.74 × 0.63 × 0.54 mm, and the total weight of the 128 stones is 0.016 carat.

Fig. 4. Boulders of a 1.5 m wide and 2500 m long dyke sampled for testing for diamond content (Area 3 in Fig. 1).

Indicator minerals from the same three kimberlitic occurrences have been separated, picked and analysed by electron microprobe. The indicator minerals studied are sub-calcic pyrope, eclogitic garnet, chrome-diopside, chromite, ilmenite and olivine. The indicator mineral chemistry will be used in conjunction with the diamond determination results to assess the diamond potential of the occurrences. The mineral chemistry fingerprint of the *in situ* occurrences may have important implications for the interpretation of existing indicator mineral chemistry data from till and stream sediment samples.

Research in progress

The field work in 2003 included detailed magnetic mapping of the three occurrences using a proton magnetometer. Interpretation of the geophysical field data is ongoing.

Petrographic and geochemical characterisation of the kimberlitic occurrences has been largely neglected in previous investigations, and accordingly a comprehensive programme to systematically study and classify the groundmass, mantle xenoliths and indicator minerals of these rocks has been initiated.

An extensive programme to determine the age of these and many additional kimberlitic occurrences using the very precise U-Pb in perovskite method (e.g. Heaman *et al.* 2003) has been launched. Some phlogopite-rich rocks will be dated by the Rb-Sr method. A total of around 35 age determinations have been commissioned.

An updated version of the digital data compilation (Jensen *et al.* 2003a) planned for 2004 will include the results of the ongoing Survey testing and analytical work, as well as recently released company data, amounting to 3300 pages of text, tables and maps, 50 000 indicator mineral analyses, around 100 previously undescribed kimberlitic occurrences and a large volume of airborne geophysical data.

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