DISTRIBUTION AND MAGNETIC SIGNATURES OF KIMBERLITIC ROCKS IN THE SARFARTOQ REGION, SOUTHERN WEST GREENLAND

By Sven Monrad Jensen, Karsten Secher, Thorkild M. Rasmussen, Tapani Tukiainen, Johan Ditlev Krebs and Frands Schjøth

Geological Survey of Denmark and Greenland (GEUS), Denmark

INTRODUCTION

Southern West Greenland hosts an alkaline province with a variety of ultramafic alkaline rocks, including swarms of dykes traditionally described as kimberlites and lamproites. The classification of these rocks has been disputed by Mitchell et al. (1999) who consider them to be ultramafic lamprophyres. The term 'kimberlitic', however, is still in common use in Greenland and is applied in the following. The alkaline province has been a target for commercial diamond exploration since the mid-1990s, resulting in numerous reports of diamond-favourable indicator minerals from till sampling, finds of kimberlitic dykes, and recovery of both micro- and macrodiamonds from kimberlitic rocks. Geophysical data acquisition has been an integral part of the exploration activities. A new GIS compilation of company data in the public domain allows for refined assessment of the distribution, structural controls and possible spatial and petrogenetic relationships to contemporaneous alkaline magmatism.

GEOLOGICAL SETTING

The alkaline ultramafic dykes within the Sisimiut–Kangerlussuaq and Sarfartoq regions intrude the border zone between the Archaean craton and the Palaeoproterozoic Nagssugtoqidian orogen (Figure 1; Secher & Larsen 1980). This border is defined as the southern boundary of Palaeoproterozoic reworking of the Archaean basement gneisses. The Nagssugtoqidian orogen is a 300 km wide belt of predominantly Archaean gneisses which were reworked during Palaeoproterozoic orogenesis (van Gool et al. 2002). The reworking has affected the Palaeoproterozoic Kangâmiut dolerite dykes, which were intruded into the Archaean basement prior to deformation and are now highly strained and boudinaged north of the boundary.

The dykes have been interpreted as cone-sheets centred on the 0.6 Ga Sarfartoq carbonatite complex (Larsen 1980). Lamproitic dykes in the adjacent Sisimiut region are around 1.2 Ga old, and the kimberlitic dykes in both the Sarfartoq and Sisimiut regions have ages of around 0.6 Ga (Larsen & Rex 1992).

The Sarfartoq region has the largest concentration of kimberlitic dyke and boulder occurrences within the West Greenland alkaline province (Larsen 1991, Jensen et al. 2002).

DISTRIBUTION OF KIMBERLITIC ROCKS

New observations suggest that the region may host several clusters of kimberlitic dykes and sills (Figure 2), whereas earlier compilations highlighted occurrences in the vicinity of the carbonatite complex. 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-existing joint systems or concordant with the enclosing gneiss. The 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 many hundreds of metres. 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.

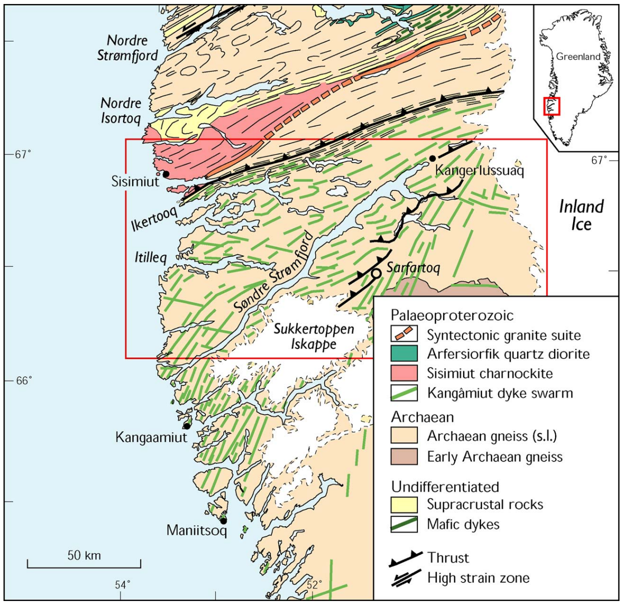

Figure 1: Geological map of part of southern West Greenland with the study area outlined in a red frame (Jensen et al. 2002).

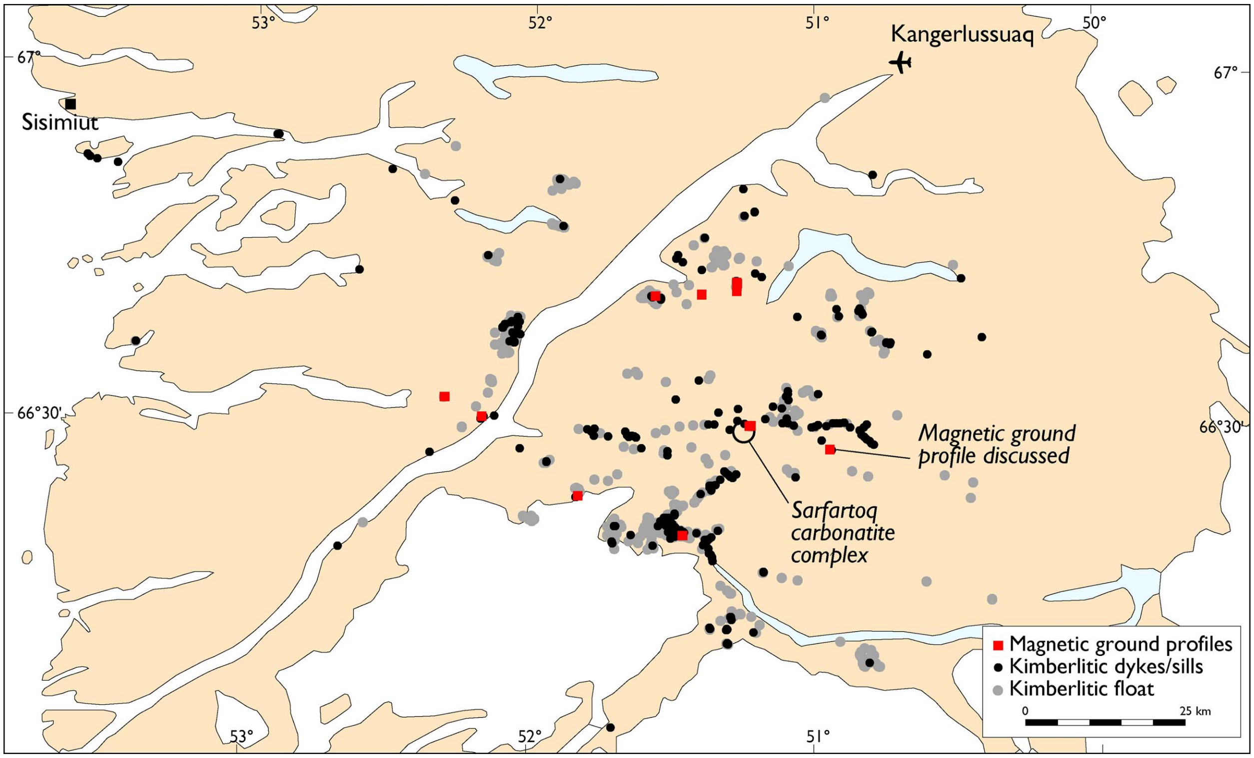

Figure 2: Distribution of kimberlitic occurrences and magnetic profiling localities in the study area. Data from Jensen et al. (in press). Several occurrences north of Sarfartoq are at present covered by confidentiality and are not shown.

GEOPHYSICAL CHARACTERISTICS

Geophysical data are available from a large number of surveys. The airborne surveys include magnetic, electromagnetic, radiometric and hyperspectral data. A number of ground surveys with magnetic and electromagnetic measurements have been carried out. Utilisation of the geophysical data in the search for kimberlitic rocks is determined by survey parameters such as line distance and ground clearance and partly by their petrophysical properties in relation to the host rocks.

MAGNETIC DATA

Three types of magnetic data are available from:

- Regional airborne surveys with a line separation of 500 m and a nominal altitude of 300 m
- Detailed surveys with flight line separation 100–200 m and nominal sensor altitude 30 m
- Ground measurements

The regional data cover the entire ice-free area of West Greenland south of 72°20'N, whereas the detailed surveys have been performed in selected areas only. Most of the ground measurements have been made as follow-up on previous airborne surveys and geological mapping.

Magnetic total field data from the regional survey are shown in Figure 3. A pronounced SW–NE trending magnetic boundary divides the unreworked and Palaeoproterozoic deformed Archaean rocks. Gneisses in the unreworked Archaean craton have very variable, and often high, magnetic susceptibilities, and the Palaeoproterozoic Kangâmiut dolerite dykes here have more uniformly high susceptibilities (average $50 \cdot 10^{-3}$ SI units); in contrast, both gneisses and dolerites are largely demagnetised in a 2000 km^2 zone of the Palaeoproterozoic deformation front (average $5 \cdot 10^{-3}$ SI units).

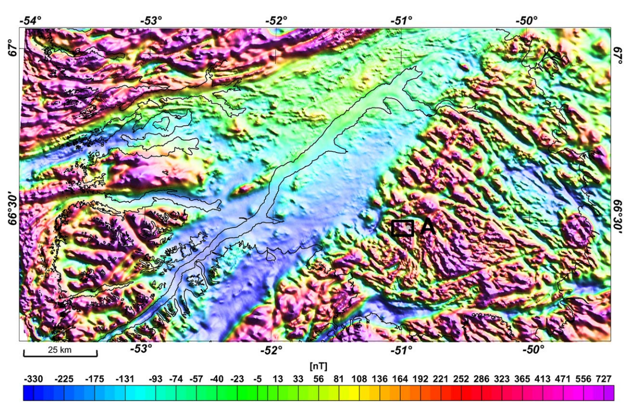

Figure 3: Magnetic total field data from the regional airborne survey of the study area. Area A is discussed in detail below.

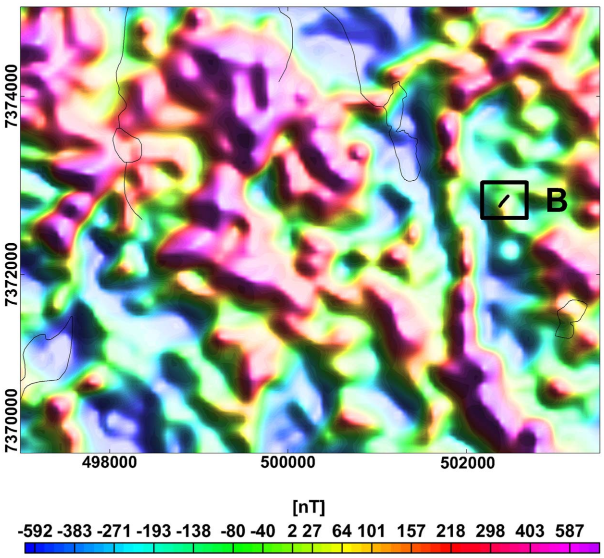

Figure 4: A subset of the magnetic total field data from a detailed helicopter-borne survey (Johnson 1997), corresponding to area A in Figure 3. The location of the ground profile is shown as a SW–NE trending line within area B. Co-ordinates in metres (UTM, zone 22); width of view c. 6 km

Kimberlitic and lamproitic dykes often have higher magnetic susceptibilities (average $80 \cdot 10^{-3}$ SI units) than their host rocks throughout the region, and in both the Archaean and Palaeoproterozoic areas lend themselves to detailed proton magnetometer profiling. Profiles over a number of dykes and two small suspected blows or 'pipe-like' bodies have been used in precise mapping of heterogeneities within the intrusions and modelling of their dimensions and orientations.

Experience from two airborne magnetic surveys in the Palaeoproterozoic illustrates the detectability of kimberlitic rocks at different scales of investigation. A helicopter-borne survey with a sensor ground clearance of 30 m and 200 m line spacing clearly outlines a 5 km long and 20 m wide kimberlitic dyke in the Palaeoproterozoic region; the dyke is not distinguishable in the data from a regional fixed-wing survey at 300 m terrain clearance and 500 m line spacing.

Application of magnetic methods is more difficult in the Archaean than in the Palaeoproterozoic area. An example is given from a helicopter-borne survey (Johnson 1997) in an area where a ground magnetic profile is available for comparison. The magnetic field variations are shown in Figure 4. The location of the ground magnetic profile is marked as area B.

The data from the helicopter-borne survey have been analysed by using a technique presented by Thurston et al. (2002). This technique is based on a transformation of the magnetic total field data into two source parameters, k_a and k_b, that characterise the sources. For a simple dyke model, both parameters are bell-shaped and have a local maximum above the edge of the dyke. For a sloping contact between two rock types, parameter k_b is zero whereas k_a is bell-shaped and has a maximum above the contact. The depth to and dip of the structures can be determined from k_a and k_b. The source parameters for area B are shown in Figure 5.

Estimation of depth to the sources did not give stable values along strike. This is attributed to a strong interference between different sources and deviations from the model assumptions. Although the technique fails to give stable estimates in this case, the transformation into source parameter functions is very valuable in the identification of near-surface structures.

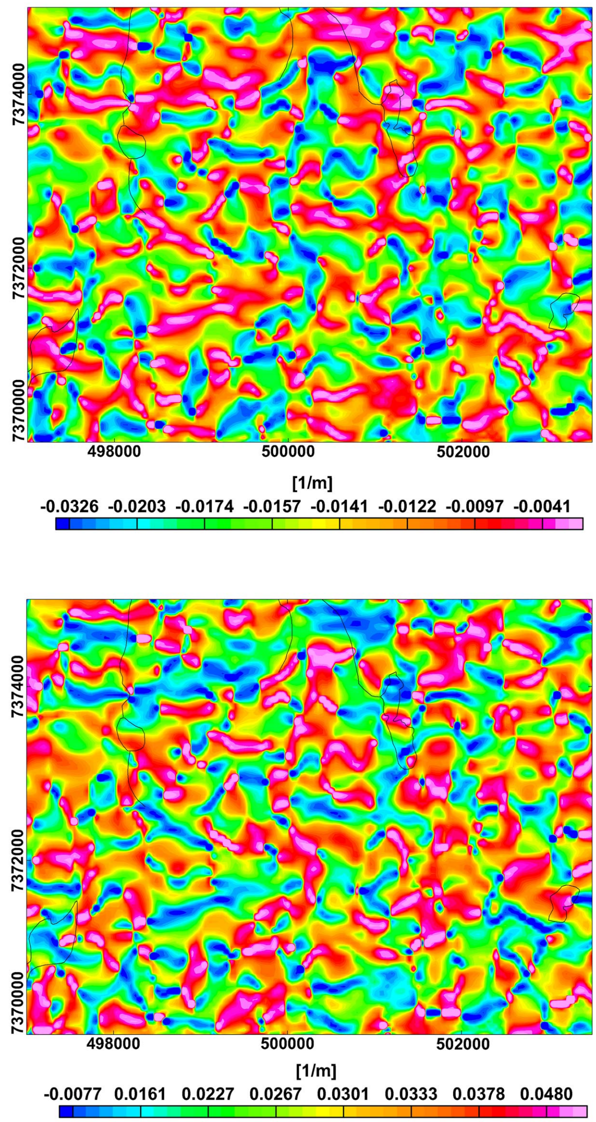

Figure 5: Source parameter k_a (top) and source parameter k_b (bottom), calculated from the magnetic field shown in Figure 4. Co-ordinates in metres (UTM, zone 22); width of view c. 6 km.

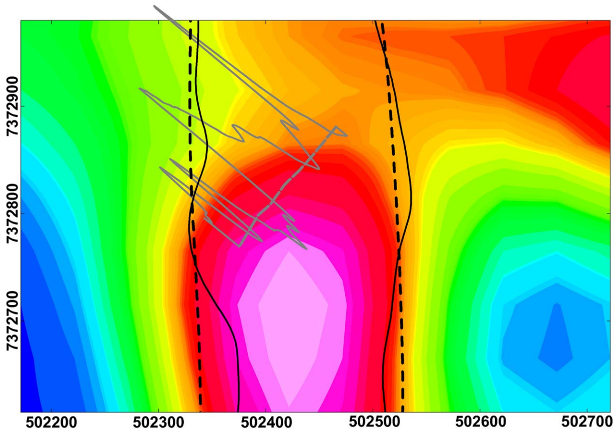

Figure 6: The data from SW–NE ground magnetic profile (grey) and the nearest line-data from the helicopter-borne survey (black). Dashed lines mark base levels and profile paths. Co-ordinates in metres (UTM, zone 22); width of view is c. 540 m.

The difficulties in applying the source parameter technique on data from the helicopter-borne survey can be understood by comparing with ground magnetic profiling (Figure 6). The ground profile indicates higher complexity in the sub-surface magnetic properties than can be inferred from the helicopter-borne data. The highest peak of about 2000 nT in the ground data corresponds to an exposed Kangâmiut dolerite dyke with a thickness of 3 m. The broad central peak corresponds to an observed kimberlitic dyke. Strong variations in the basement gneiss cause the two smaller peaks in the SW part of the profile. The helicopter-borne data do not allow discrimination of the different rocks in this case.

HYPERSPECTRAL DATA

Airborne hyperspectral (HS) data were acquired using a HyMap scanner covering an area of 8000 km^2 of the Sarfartoq region. Concurrently, approximately 30 kimberlitic and lamproitic occurrences were sampled and their spectral signature in the wave length region 350–2500 nm recorded. More than 1400 discrete spectra of the major lithologies, fluvial deposits and vegetation were measured. Rock samples from the visited sites were powdered and re-measured under laboratory conditions. All spectral data have been compiled into a spectral library. Figure 7 shows an example of the reflectance spectra of kimberlitic weathering material and basement gneiss.

The spectral library is currently being used to assist the development of image processing procedures for the mapping of the kimberlitic rocks using the airborne HS data. The intensity of chemical weathering is low in an Arctic glaciated terrain like West Greenland. Consequently, secondary minerals – normally easily detected by infrared imaging spectroscopy – are limited in amount and number. The high signal/noise ratio and spectral quality of the HyMap data may counterbalance the paucity of the secondary minerals when attempting to locate kimberlitic occurrences.

CONCLUDING REMARKS

The compilation of company and public data has given a new overview of the distribution of kimberlitic rocks in the region. The compilation can be used in targeting future diamond exploration, and as a contribution to the general understanding of the alkaline magmatic province.

Ground magnetic profiling shows significant lateral variation in magnetic properties within the dykes. The variability and the deviation from ideal homogeneous bodies have important implications for modelling and use of the data. Despite the complexity of describing the magnetic properties of the various rocks, the results from this study demonstrate that magnetic data are useful in identifying kimberlitic targets.

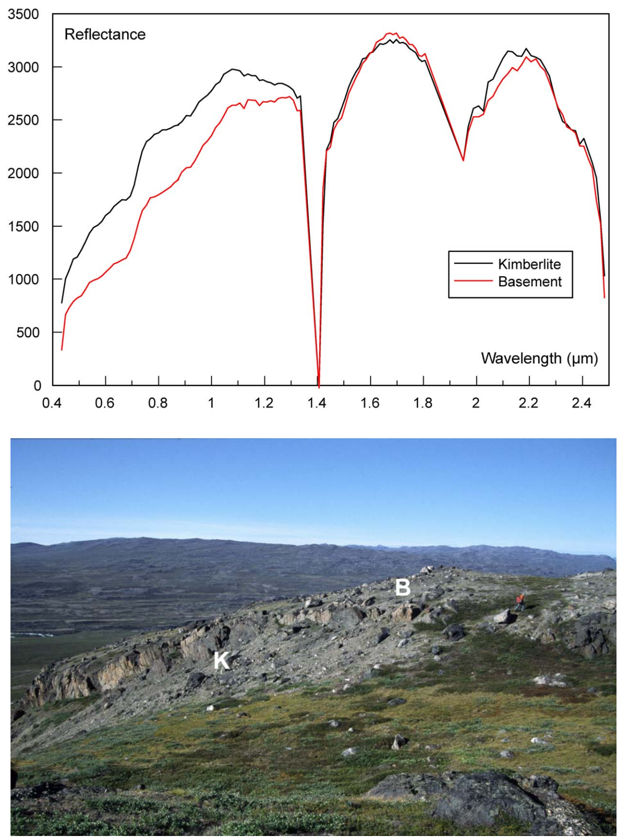

Figure 7: Top: HyMap reflectance spectra from a kimberlitic dyke occurrence. Bottom: Measured locality (K = kimberlitic weathering surface, B = basement). Person in red jacket for scale.

ACKNOWLEDGEMENTS

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Contact: SM Jensen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark, E-mail: smj@geus.dk