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Provinces of ultramafic lamprophyre dykes, kimberlite dykes and carbonatite in West Greenland characterised by minerals and chemical components in surface media

Agnete Steenfelt [a,*], Sven M. Jensen [b], Troels F.D. Nielsen [a], Karina K. Sand [c]

[a] Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK-1350, Copenhagen K, Denmark
[b] Intex Resources ASA, Munkedamsveien 45A, N-0250 Oslo, Norway
[c] Nano-Science Center, University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen Ø, Denmark

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ABSTRACT

This paper reports the results of studies undertaken to interpret the vast amount of chemical data for kimberlite indicator minerals in glacial overburden (ca. 96 000 grain analyses) acquired during diamond exploration within the Archaean craton of southern West Greenland. In particular, the studies and interpretations relate to the Neoproterozoic magmatic province, where abundant mineral grains from the diamond stability field have been recorded, but where the abundance and distribution patterns within the province were not readily understood in the light of known dyke distribution. Chemical data of indicator minerals from known dykes and from surrounding glacial overburden together with field observations allow us to conclude that the indicator minerals in the overburden are of local origin and that dyke emplacement patterns, local topography and glacial processes determine the efficiency of grain dispersal. Many new dyke occurrences were found during sampling and follow-up of kimberlite indicator minerals. Pronounced regional differences in the variation of chemical composition of indicator mineral grains from both overburden and rock are related to known differences in crustal lithology, magma compositions and lithosphere stratigraphy, and we argue that the latter is the main reason for chemical differences. The implication is that the mineral grains recovered from overburden samples, besides having proved their value in diamond exploration, contain much information of interest for investigations of the nature of the lithosphere.

1. Introduction

Kimberlite dykes (sensu lato) were discovered in Greenland in the late 1960s and the first microdiamonds were recovered from stream sediments in the early 1970s. By the 1980s over 500 dyke and sheet occurrences of ultramafic lamprophyre, kimberlite, and lamproite had been located. The Lac de Gras discovery in Canada in 1991 caused a revival of interest in Greenland as prospective ground for diamonds. At this time, the use of kimberlite indicator minerals (KIM) recovered from till had been successful in exploration for kimberlites in Canada (e.g. Fipke et al., 1995) and exploration companies commenced low density collection of samples of glaciogenic overburden (including both till and glaciofluvial deposits) and stream sediment all over the Archaean craton of SW Greenland (company reports listed in Jensen et al., 2004b). The samples were processed to obtain the non-magnetic heavy mineral fraction, from which grains of indicator minerals, including peridotitic garnet (pyrope), eclogitic garnet, chromite (chrome-spinel), picroilmenite, and chrome-diopside were picked. The distribution pattern of KIM bearing samples confirmed that the northern part of the Archaean craton was the most prospective and thousands of additional surface samples were collected at high density and processed in order to further narrow the location of potential diamond bearing occurrences.

The intensive exploration activities led to the discovery of many new occurrences of ultramafic lamprophyre and kimberlite (sensu lato) dykes carrying mantle xenoliths, and by the late 1990s the number of known occurrences had passed a thousand. Diamond tests have confirmed the diamondiferous nature of several occurrences.

The immense volume of data produced over the years by the exploration companies forms the basis for the present paper. We have conducted field work and mineral analyses to improve the interpretation of the surface data, and together with evidence gained from other investigations, we use this to tie the surface information to studies of magma generation and lithosphere properties.

2. Distribution of ultramafic lamprophyres and carbonatite in southern West Greenland

Swarms of ultramafic lamprophyre dykes and carbonatite complexes are known from a number of areas in Greenland. They range in age from Archaean to Palaeogene and the timing of their intrusion can be related to episodes of continental rifting (Larsen and Rex, 1992).

* Corresponding author. Current address: Vigdelsvegen 596, N-4054 Tjelta, Norway. Tel.: +47 51652861.
E-mail addresses: ast@geus.dk, agnete.steenfelt@gmail.com (A. Steenfelt).

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The four main regions, Sarfartoq, Maniitsoq, Tikiusaaq and Pyramidefjeld occur in the Archaean North Atlantic Craton in southern West Greenland (Fig. 1), and they are the results of Neoproterozoic (Sarfartoq and Maniitsoq) and Jurassic (Maniitsoq, Tikiusaaq and Pyramidefjeld) magmatism. It is characteristic that each magmatic event comprises both carbonatite and ultramafic lamprophyre (UML) dykes.

UML dykes in southern West Greenland have variably been termed kimberlites and kimberlitic rocks (e.g. Scott, 1981; Larsen and Rex, 1992), but according to recent classifications (e.g. Mitchell et al., 1999; Tappe et al., 2005) they are all UML dykes. It is argued (Nielsen et al., 2006, 2008) that dykes in the Maniitsoq region classify as carbonatite-rich kimberlite, but in this presentation dykes will collectively be termed UML for simplicity. Crater facies kimberlites or pipes have not been found anywhere in Greenland.

3. Data description and presentation

Chemical data based on chemical analysis of the less than 0.1 mm grain size fraction of stream sediment samples collected systematically at a density of 1 sample per 30 km^2 have been obtained from the entire Archaean craton (Steenfelt, 2001). The samples have been analysed for major and 30 trace elements, and the data sets have been quality controlled and calibrated to eliminate bias between analytical batches. The geochemical maps of niobium and phosphorus have been particularly helpful in mapping the extent of alkaline ultramafic and carbonatitic provinces.

Data on kimberlite indicator minerals (KIM) from glaciogenic overburden have been acquired over a large part of Precambrian West Greenland during diamond exploration and geochemical mapping by commercial companies and the Geological Survey of Denmark and Greenland (GEUS). Picked indicator minerals in these surveys comprise grains of peridotitic and eclogitic garnet, chromite, ilmenite, clinopyroxene (Cr-diopside), orthopyroxene and olivine. The data have been digitised, quality-controlled and presented by Jensen et al. (2004b). Overburden samples are from till and glaciofluvial deposits, and they are collectively called till in text.

Besides the picking results, i.e. determination of grain abundance for each picked indicator mineral in one to three grain size fractions of each sample, numerous grains have been analysed and plotted in discrimination diagrams to test their probable origin in terms of lithospheric depth and stratigraphy (see Jensen et al., 2004b).

On a regional scale, the UML-carbonatite magmatic provinces are clearly reflected in abundance patterns for KIM, here exemplified by peridotitic garnet (Fig. 1) and in stream sediment geochemical maps of niobium and phosphorus. The P-distribution, however, displays

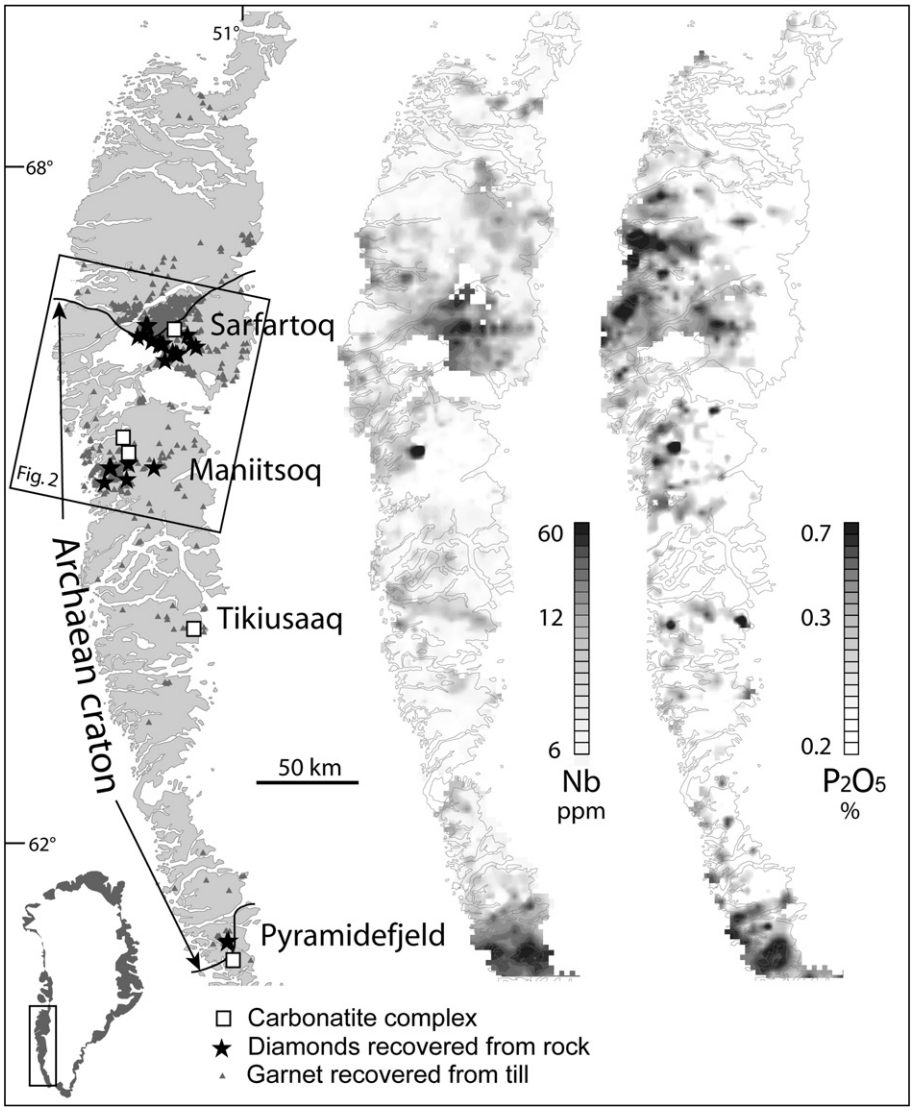

Fig. 1. Main UML-carbonatite provinces in Southern West Greenland, reflected by peridotitic garnet in till, and by Nb and P anomalies in stream sediment maps (contoured grids).