Emplacement patterns of kimberlites and ultramafic lamprophyres in an alkaline province located 64º – 67ºN in southern West Greenland – Evidence from 40 new robust age analyses

K. Secher[1], L.M. Heaman [2], T.F.D. Nielsen[1], S.M. Jensen[3], F. Schjøth[1], R.A. Creaser[2]

(1)Geological Survey of Denmark and Greenland, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

(2)Department of Earth & Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E3

(3)Intex Resources ASA, Munkedamsveien 45A, N-0250 Oslo, Norway

Introduction

Southern West Greenland hosts a major magmatic province comprising a variety of ultramafic alkaline rocks that occur as dyke swarms, sheets, and central complexes emplaced over a 1 b.y. time span. This alkaline province includes dykes described as ultramafic lamprophyres (UML), kimberlites and carbonatites. These rock types are widely distributed in the Sisimiut–Sarfartoq–Kangerlussuaq region, as well as the Maniitsoq region just south of Sukkertoppen Icecap. Renewed interest for primary diamond deposits in this province has been sparked by the recent discovery of diamond-bearing UML at Garnet Lake (e.g. Hutchison and Heaman, in press). Although the main periods of alkaline magmatism (Mesoproterozoic, Neoproterozoic and Jurassic) in the region had been established previously (e.g. Larsen 1980; Larsen 1991; Scott 1981) and reviewed by the Greenland Geological Survey (Larsen *et al.*, 1983; Larsen & Rex 1992), there is very little detailed understanding of the duration or temporal relationship between kimberlite, carbonatite and ultramafic lamprophyre within a specific period of magmatism (Nielsen *et al.*, 2008). For example, the spatial and temporal relationship between Neoproterozoic kimberlite and the Sarfartoq carbonatite complex has not been established (Secher & Larsen 1980, Sand *et al.*, 2007). In this study, more than 40 new high precision Rb-Sr phlogopite and U-Pb perovskite/pyrochlore ages from this province were determined.

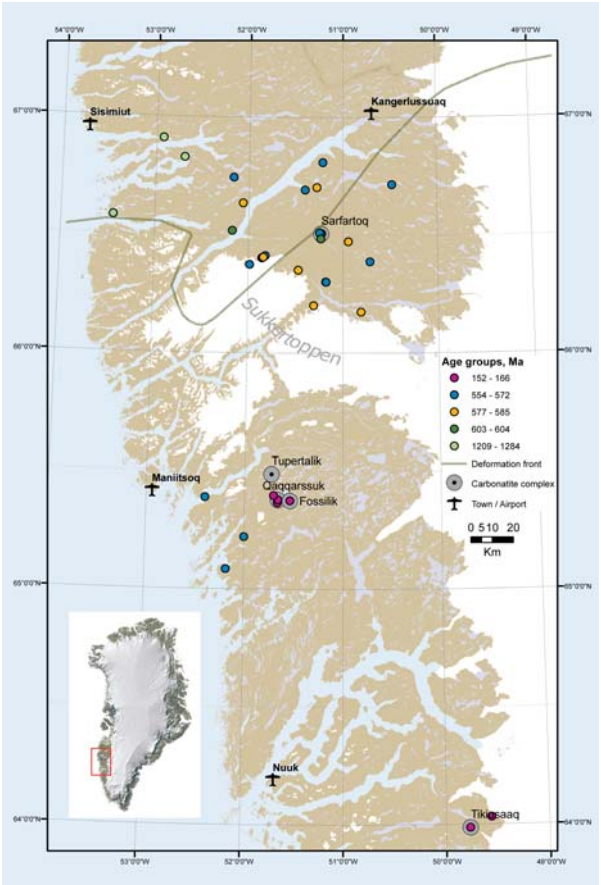

Fig 1. Map of dated occurrences of the West Greenland alkaline province.

Geological Setting

The UML, kimberlite, and carbonatite bodies located in southern West Greenland are represented by several clusters of dykes, sheets and sills. They occur as flat-lying sheets, rarely over 1-m-thick, and traceable for a few tens of metres, or as subvertical dykes, 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 (Sand *et al*,. 2008). Dykes occur frequently within distances of up to 50 km of carbonatite complexes, and commonly appear to be controlled by pre-existing joint systems or concordant with the enclosing gneiss. The dyke clusters in the Maniitsoq area have a dominant 080º orientation. The Sarfartoq dyke clusters, however, are more variable in orientation but with a predominance of N–S trending dykes. The Sisimiut dykes are dominated by orientations in the 090–100º range. The oldest carbonatite in the region is the 3000 Ma Tuper-

talik carbonatite sheet located near Maniitsoq (Bizzaro *et al.*, 2002).

Geochronology

U-Pb Methods

U–Pb dating was performed on 37 samples. Most of these samples were processed through standard crushing and mineral separation steps including the use of a jaw crusher, disk mill, Wilfley Table, Frantz Isodynamic separator and heavy liquids (methylene iodide). Perovskite isolated from 34 samples generally occurs as tiny (<80 microns) brown cubes or fragments. The perovskite chemical composition is consistent with matrix perovskite from UML and related rocks with low to moderate uranium contents and moderate Th/U (3.81-21.71). One observation from this study is that perovskite is very rare in calcite-kimberlites from the Maniitsoq region. U-Pb dating has also been carried out on a few pyrochlore grains isolated from the Sarfartoq carbonatite complex. The selected perovskite and pyrochlore fractions were dissolved in acid, uranium and lead purified using anion exchange chromatography, and the isotopic composition of uranium and lead determined using a VG354 solid source thermal ionization mass spectrometer. All age uncertainties listed are quoted at two sigma.

Fig.2. Typical UML dyke (1 m) outcrop in the gneiss basement near Kangerlussuaq.

Rb-Sr Methods

A number of whole-rock samples of UML and kimberlite contain fresh, light brown phlogopite megacrysts suitable for dating using the Rb-Sr method. All phlogopite fractions were carefully selected using a

Fig 3. UML boulder with various xenoliths from the Sarfartoq area.

binocular microscope to avoid alteration and any adhering kimberlitic matrix. All fractions were given a gentle HCl leach to remove entrained carbonate. Isotopic analysis was performed using a Sector54 Thermal Ionization Mass Spectrometry. All analyses were corrected relative to an average $^{87}Sr/^{86}Sr$ value of 0.71025 obtained in the lab for the SRM987 Sr standard.

Age Results

Based on more than 40 new robust U-Pb perovskite/pyrochlore and Rb-Sr phlogopite ages as well as previous geochronology, five distinct periods of magmatism are recognized in the Sisimiut, Sarfartoq and Maniitsoq regions of southern West Greenland; Mesoproterozoic ultramafic lamprophyres (1284–1203 Ma; n=5), three episodes of Neoproterozoic carbonatite, ultramafic lamprophyre and kimberlite magmatism at 603 Ma (n=2), 585–577 Ma (n=9), and 572–555 Ma (n=16), and a younger Jurassic event dominated by carbonatite and UML magmatism at 166–155 Ma (n=6).

Discussion

Neoproterozoic Magmatism

The three periods of Neoproterozoic magmatism in the Sisimiut, Sarfartoq and Maniitsoq regions are dominated by ultramafic lamprophyres, some of which are transitional into kimberlites. The calcite kimberlites appear to be constrained to the ~560 Ma event in the Maniitsoq region. This study has shown that calcite kimberlite, ultramafic lamprophyre and carbonatite magmatism is synchronous and an integral part of the latest stage of Neoproterozoic rifting, as indicated by a new 565 Ma age of the Sarfartoq complex. In addition, ultramafic lamprophyres transitional into kimberlite of the 580 and 560 Ma events in the Sarfartoq region (e.g.

the Garnet Lake occurrence), as well as carbonate-rich kimberlites of the 560 Ma event in the Maniitsoq region (e.g. the Majuagaa dyke) are macrodiamond-bearing. The calcite-kimberlite of the Majuagaa dyke is discussed in detail by Nielsen & Jensen (2005) and Nielsen & Sand (in press).

At present, there is no indication that the Neoproterozoic ultramafic alkaline rocks in the region NW of the Paleoproterozoic deformation front are diamondiferous (Jensen & Secher 2004; Jensen *et al.*, 2004). However, similar Neoproterozoic magmatism in the Torngat orogen, the Canadian counterpart to the Nagssugtoqidian orogen, has recently been shown to host diamondiferous UML dykes (Tappe *et al.*, 2004; in press). There is a striking similarity in the age, duration of magmatism, composition, and evolution of UML/carbonatite/kimberlite magmas in both West Greenland and the Torngat orogen (Tappe *et al.*, 2004; in press) and together these provinces were formed during the initiation of continental rifting and opening of the Iapetus Ocean at about 615 Ma.

Jurassic Magmatism

The youngest alkaline magmatism in West Greenland is dominated by the 165 Ma Qaqqaarsuk carbonatite complex and associated UML dykes (166 Ma), located in the area east of Maniitsoq. At Fossilik, in the vicinity of the Qaqqaarsuk complex a coeval small diatreme contains fragments of fossiliferous Ordovician limestone set in a matrix of carbonatitic-ultramafic breccia tuff. The study also revealed a slightly younger age for the recently discovered 155 Ma Tikiusaaq carbonatite complex and a suite of UML dykes east of the town Nuuk. This occurrence of Jurassic magmatism marks the southern edge of the alkaline province (Steenfelt *et al.*, 2007). So far, the Jurassic magmatism has not been shown to be diamondiferous. A more detailed investigation of the youngest alkaline dyke rocks in West Greenland (Mesozoic to Palaeogene) has recently been reported (Larsen 2006).

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