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The newly discovered Jurassic Tikiusaaq carbonatite-aillikite occurrence, West Greenland, and some remarks on carbonatite–kimberlite relationships

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ABSTRACT

We discuss mineral chemistry data and report ten high-precision U–Pb (zircon, baddeleyite, pyrochlore, and perovskite) and Rb–Sr phlogopite ages for the newly discovered Tikiusaaq carbonatite intrusion and associated ultramafic dykes from the North Atlantic craton, West Greenland. At Tikiusaaq, massive dolomite-calcite carbonatite sheets intruded an 2×3 km area along a ductile shear zone between ca. 158 and 155 Ma. The accompanying carbonatite and carbonate-rich ultramafic silicate dykes were emplaced between ca. 165 and 157 Ma in close proximity to this carbonatite centre utilizing pre-existing brittle fractures. The deep volatile-rich magmatism at Tikiusaaq forms part of a larger Jurassic alkaline province in southern West Greenland and represents the earliest manifestation of rifting processes related to the opening of the Mesozoic–Cenozoic Labrador Sea Basin.

Although the ultramafic silicate dykes macroscopically resemble hypabyssal kimberlites, they are identified as kimzeyite-bearing monticellite aillikites (carbonate-rich ultramafic lamprophyres) using a modern mineralogical–genetic classification. The overlapping emplacement ages of the carbonatite sheets and aillikite dykes, along with the carbonate-rich nature of the latter, suggest a genetic relationship between these magma types. The aillikites carry garnet peridotite xenoliths and have mineralogical characteristics of primitive magmas such as highly forsteritic olivine (up to Fo_{90} mol%) and Cr-rich spinel (up to 46 wt.% Cr_2O_3) microphenocrysts; whereas the carbonatite sheets reveal a higher degree of differentiation such as Fe-rich dolomite compositions (up to 9 wt.% FeO). The initial findings reported here from Tikiusaaq suggest that a link between these magma types by an increasing degree of partial melting of a common carbonated upper mantle peridotite source region, as commonly envisaged for the compositionally similar Sarfartoq complex, is untenable. Rather, proto-aillikite magma may be parental to the dolomitic carbonatite sheets, but the nature of the carbonate separation mechanism(s) is presently not understood.

1. Introduction

Ever since Brøgger (1921) first proposed the magmatic origin of carbonatites, scientific interest in this magma type has outweighed its volumetric significance. Many studies have highlighted the important role of the various associated alkaline silicate rock types in carbonatite magma petrogenesis and this diversity appears to reflect that carbonatite magma is produced in a number of ways (Bell, 1998; Mitchell, 2005; Woolley and Kjarsgaard, 2008). Aillikites — *or carbonate-rich ultramafic lamprophyres* — are among the rarest and compositionally most extreme magma types associated with carbonatites (Rock, 1986; Mitchell et al., 1999; Tappe et al., 2005). They are characterized by abundant primary groundmass carbonate and strong SiO_2 undersaturation; in some cases aillikites modally grade into carbonatites (Malpas et al., 1986; Mitchell et al., 1999; Tappe et al., 2006). The absence of a wide compositional gap between carbonatites and aillikites contrasts with virtually all other known carbonatite–alkaline silicate rock associations; this rather gradational nature has been ascribed to an increasing degree of partial melting of carbonated peridotite, i.e., a primary melting relationship (Dalton and Presnall, 1998; Mitchell et al., 1999; Mitchell, 2005; Woolley and Kjarsgaard, 2008; Foley et al., this issue). However, there is no a priori reason why these continuous gradations could not result from magmatic differentiation as discussed in Larsen and Rex (1992) and Tappe et al. (2006).

Southern West Greenland is one of the key regions where the carbonatite–aillikite association occurs (Larsen and Rex, 1992; Mitchell et al., 1999; Upton et al., 2003; Tappe et al., 2005) and glacially abraded bedrock exposures offer splendid opportunities for studying its nature.

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However, some important petrogenetic aspects of this relationship are still not fully understood due to; (1) the lack of high-precision emplacement ages for both carbonatite and aillikite phases from an individual occurrence, and (2) the uncertainty about whether the carbonatites represent near-primary liquids or liquids produced by secondary processes such as fractional crystallization and immiscibility, or are not liquid compositions at all. An additional complicating factor to unravelling petrogenetic links between carbonatites and aillikites — or ultramafic lamprophyres (UML) in the broadest sense — is that the latter are too often confused or lumped together with kimberlites (Emeleus and Andrews, 1975; Alibert and Albarede, 1988; Bizzarro et al., 2002; Gaffney et al., 2007; Hutchison and Heaman, 2008), which simply ignores their distinct volatile composition and alkali contents (Kjarsgaard et al., this issue). This has led unnecessarily to over-emphasis of carbonatite–kimberlite relationships and provoked extreme ideas such as kimberlites are merely peridotite-contaminated carbonatites (Nielsen and Sand, 2008; Patterson et al., this issue). The dilemma becomes most obvious in paraphrasing Dalton and Presnall (1998) that the Sarfartoq complex of West Greenland, which is a classic carbonatite-aillikite occurrence, is the best natural analogue of their experimentally produced carbonatitic–kimberlitic melt continuum.

In this paper we report results on the age, geology, and mineralogy of the newly discovered West Greenland 'Tikiusaaq' carbonatite complex and its accompanying ultramafic dyke rocks (Steenfelt et al., 2006; Steenfelt et al., 2007). Based on the mineral assemblage (e.g., presence of kimzeyite) and mineral compositional trends (e.g., spinel and phlogopite) the ultramafic dyke rocks are more akin to type aillikites from Aillik Bay in Labrador, North Atlantic craton (NAC) than to archetypal Kaapvaal and Slave craton kimberlites. Our high-precision U–Pb and Rb–Sr age data demonstrate that carbonatite and aillikite magmatism at Tikiusaaq was contemporaneous with and occurred as a distal effect of rift initiation in the developing Labrador Sea Basin during the Middle Jurassic. The prime goal of this paper is to lay the groundwork for further detailed petrological studies on the Tikiusaaq intrusion that will certainly enable us to more rigorously test prevailing ideas about petrogenetic links between carbonatites, aillikites, and the alleged kimberlites in areas of rifted cratonic lithosphere.

2. Carbonatite-aillikite magmatism of southern West Greenland

The Archean and Paleoproterozoic crust of southern West Greenland (Fig. 1a) has been repeatedly subjected to mantle-derived

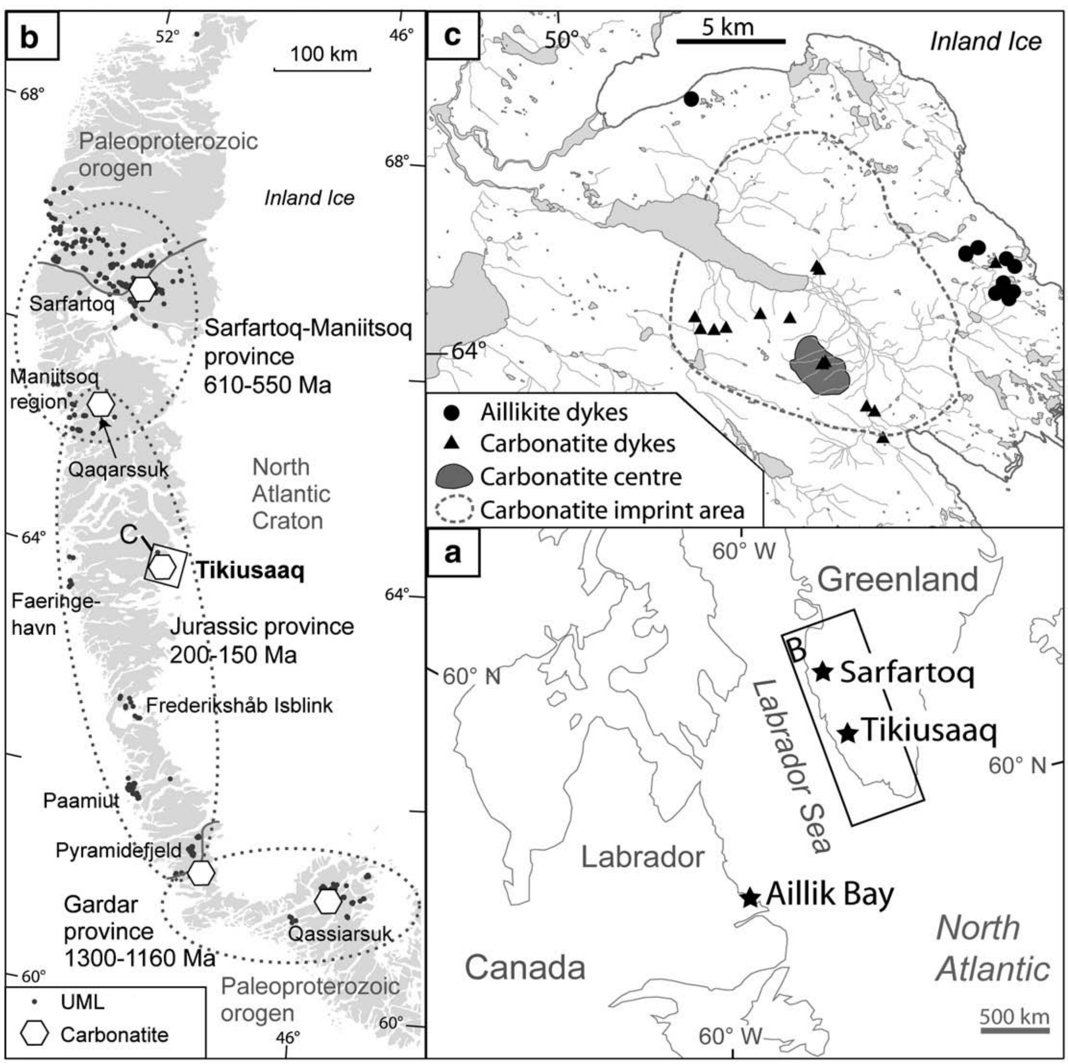

Fig. 1. Location of the newly discovered Tikiusaaq carbonatite-aillikite occurrence in southern West Greenland. (a) Tikiusaaq location in the greater North Atlantic cratonic region including the aillikite type locality at Aillik Bay in Labrador. (b) Distribution of carbonatite-aillikite occurrences across southern West Greenland. Symbols for carbonatites are not to scale. Note that the Jurassic carbonatite-aillikite province (200–150 Ma) occurs in the central part of the North Atlantic craton; whereas the Neoproterozoic (610–550 Ma) and Mesoproterozoic (1300–1160 Ma) carbonatite provinces are confined to the craton margins in the north and south, respectively. (c) Outline of the Jurassic Tikiusaaq carbonatite intrusion and associated aillikite dykes at 64°N close to the inland ice margin. A sample list is provided in Electronic Annex 2.