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Baddeleyite and zircon U–Pb ages from the Kærven area, Kangerlussuaq: Implications for the timing of Paleogene continental breakup in the North Atlantic

Paul Martin Holm [a,*], Larry M. Heaman [b], Lise E. Pedersen [a]

[a] Geological Institute, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen, Denmark
[b] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada T6G 2E3

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Abstract

We report U–Pb zircon and baddeleyite age results for two mafic units in the Kangerlussuaq area which are part of the Paleogene East Greenland igneous province; the Kangerlussuaq macrodyke, which represents a feeder to some flood basalts, and the nearby Kærven Gabbro. Baddeleyite from the macrodyke yielded a concordant age of 54.7±0.4 (2σ)Ma and this is among the most precise age determinations from the province. This age is interpreted to reflect the time of emplacement. The macrodyke belongs to a swarm of dykes emplaced perhaps in a failed arm during continental rifting, and the age predates the completion of continental breakup at the end of emplacement of the Plateau Basalts of the East Greenland eruption sequence. Geochemically the macrodyke is correlated with the Milne Land Formation lavas. The magma experienced slight crustal contamination. Based on the age and geochemistry of the macrodyke, the age of the Skaergaard intrusion and Skrænterne Formation lavas, an age span of 1–2 Ma is confirmed for the extrusion of the entire Plateau Basalts. U–Pb analysis of zircon from the Kærven Gabbro yields an age of 53.0± 0.3 (2σ)Ma. The Kærven Gabbro was intruded after extension had ceased in the area and we suggest that the post plateau basalt magmatism did not take place at a distinct later time, but instead that igneous activity continued for some time at a lower rate. Slightly fractionated HREEs indicate that the Kærven Gabbro magma was extracted at relatively shallow levels in the mantle.

Keywords: East Greenland; Continental breakup; U–Pb dating; Baddeleyite; Zircon; Kærven

1. Introduction

Datings of the magmatic events accompanying continental rifting are essential to constraining the geological details of continental breakup. In central East Greenland the continental margin is thought to have been modified extensively at the time of the first activity of the Iceland hotspot (Brooks, 1973; Burke and Dewey, 1973; Vink, 1984; White and McKenzie, 1989; Saunders et al., 1997; Tegner et al., 1998a).

The major magmatic events occurred in (1) an early phase (61–57 Ma) of the Lower Basalts, and (2) the main phase 56–54 Ma of the Plateau Basalts of the Blosseville Kyst (Storey et al., 1996), and (3) several mafic intrusions (Tegner et al., 1998b), minor basalts at the NE of the Blosseville Kyst (Peate et al., 2003), and some offshore lavas (Tegner and Duncan, 1999) were

* Corresponding author.
E-mail address: paulmh@geol.ku.dk (P.M. Holm).

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emplaced 50–47 Ma ago. The continental breakup has been correlated with the second phase of volcanism. However, to explain in detail the transition from continental to oceanic setting, age information on the geological events during the continental breakup must have a much higher temporal resolution than the 2 Ma duration of the breakup history, and such data are still sparse.

South of the Blosseville Kyst, uplift in the Eocene (Brooks, 1979) and glaciation in the Pleistocene have led to the removal of the Paleogene volcanic cover and exposure of related intrusive rocks. Evidence for massive intrusive activity is present along the Kangerlussuaq Fjord as central complexes and dykes many of which are large and parallel to the fjord (Brooks and Nielsen, 1982). The fjord has been modelled as a remnant of a failed arm of a triple junction (Brooks, 1973; Burke and Dewey, 1973; Karson and Brooks, 1999), the two other arms along the continental margin are parallel to the present coastline. This study attempts to show the relationship between major dyke intrusions and extension in the fjord area and the evolution of the volcanic succession of the continental flood basalt province associated with continental breakup.

Because of the relatively short duration of the major magmatic events, high-precision age determinations are required to resolve the sequence of events in sufficient detail so that the process of continental breakup can be better understood. Obtaining reliable age determinations for basaltic rocks can be problematic. The ages for most young mafic volcanic rocks are determined using the K/Ar or $^{40}Ar/^{39}Ar$ techniques but the robustness of these systems can be limited by low concentrations of the parental potassium isotope, as well as contamination with radiogenic isotopes from 3 Ga old continental crust. The U–Pb method on baddeleyite and zircon is ideal for this purpose. U–Pb baddeleyite dating in particular is a robust chronometer because it has high uranium contents, low common lead and is relatively rare in crustal rocks so it is relatively immune to crustal contamination (Heaman and LeCheminant, 1993). We present baddeleyite and zircon U–Pb ages from one of the major fjord-parallel dykes and the Kærven Gabbro.

2. Geological setting and sample locations

Lavas and plutons of Paleogene age are exposed in East Greenland between 66° and 75°N. Continental flood basalts occur continuously in part of the area 68–71°N (Pedersen et al., 1997) and on the shelf along the entire stretch of coastline (Holbrook et al., 2001). In the North Atlantic Igneous Province two main magmatic episodes are recognised (Storey et al., 1996; Saunders et al., 1997). Volcanic rocks of the early phase (61–57 Ma) (Storey et al., 1996) in the Kangerlussuaq area include the Urbjerget Formation lavas (Hansen et al., 2002) and possibly the Lower Basalts (Nielsen et al., 1981), and were erupted onto the Archaean basement or Cretaceous–Paleocene sediments (Nielsen et al., 1981). This volcanism has been correlated with either an early pulse of the Iceland plume (Hansen et al., 2002) or with plume impact (Storey et al., 1996; Tegner et al., 1998b). The main event at 56–54 Ma (Storey et al., 1996) is the extrusion of the Plateau Basalts (or middle series) of the Blosseville Kyst and the Prinsen af Wales Bjerge, as well as the Skaergaard intrusion and the Sorgenfri Gletscher Sill Complex (Pedersen et al., 1997; Tegner et al., 1998b). The magmatic history has been correlated with either continental breakup (Storey et al., 1996; Tegner et al., 1998b) or a second magmatic pulse of the Iceland plume (Hansen et al., 2002). The Plateau Basalts have been divided into four formations: the basal Milne Land Formation, the Geikie Plateau Formation, the Rømer Fjord Formation and the upper Skrænterne Formation (Pedersen et al., 1997). The younger magmatic phase at 50–47 Ma in the Kangerlussuaq area is represented by several plutons along the coast and has been correlated with the passage of the Iceland plume axis beneath the eastern margin of the Greenland craton (Tegner et al., 1998b).

A dyke swarm parallel to the coast intensifies towards the coastline (Nielsen, 1978; Klausen and Larsen, 2002; Hanghøj et al., 2003). Nielsen (1978) grouped the coast-parallel tholeiitic dykes into THOL-1 emplaced before rifting and development of the coast-parallel flexure (Wager and Deer, 1938). The subsequent THOL-2 group is a swarm of subalkaline dykes radiating inland from the mouth of Kangerlussuaq which were formed at the same time as the Skaergaard intrusion before the coastal flexure was fully evolved (Nielsen, 1978, Brooks and Nielsen, 1978).

In the coastal area of Kangerlussuaq Fjord, the Kræmer Ø macrodyke (Nielsen, 1978; Momme and Wilson, 2002) is an example of the swarm of basaltic dykes intruded along the fjord. Along the middle reaches of the fjord the many dykes (>10% of crust in the Mudderbugt area) can be equally divided into fjord-parallel dykes and dykes with other directions. The intensity of dykes diminishes dramatically north of Kærven (Fig. 1). We report on two of the large fjord-parallel NNW–SSE striking dykes occurring on 'Ryggen' between Mudderbugt and Kærven with widths from 30 to ca. 200 m. These macrodykes are all tholeiitic