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From volcanic plains to glaciated peaks: Burial, uplift and exhumation history of southern East Greenland after opening of the NE Atlantic

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ABSTRACT

In southern East Greenland (68–70°N), voluminous flood basalts erupted onto a largely horizontal lava plain near sea level at the Paleocene–Eocene transition when sea-floor spreading started in the NE Atlantic. Based on synthesis of geological observations, stratigraphic landform analysis and apatite fission-track analysis data in 90 rock samples, we show how three regional phases of uplift and exhumation subsequently shaped the present-day margin and controlled the discontinuous history of the Greenland ice sheet. A late Eocene phase of uplift led to formation of a regional erosion surface near sea level (the Upper Planation Surface, UPS). Uplift of the UPS in the late Miocene led to formation of the Lower Planation Surface (LPS) by incision below the uplifted UPS, and a Pliocene phase led to incision of valleys and fjords below the uplifted LPS, leaving mountain peaks reaching 3.7 km above sea level. Local uplift affected the Kangerlussuaq area (~68°N) during early Eocene emplacement of the Kangerlussuaq Intrusion and during late Oligocene block movements, that may be related to the detachment of the Jan Mayen microcontinent from Greenland, while middle Miocene thermal activity, coeval with lava eruptions, heated rocks along a prominent fault within the early Cretaceous to Paleocene Kangerlussuaq Basin. The three regional uplift phases are synchronous with phases in West Greenland, overlap in time with similar events in North America and Europe and also correlate with changes in plate motion. The much higher elevation of East Greenland compared to West Greenland suggests support in the east from the Iceland plume. These observations indicate a connection between mantle convection, changes in plate motion and vertical movements along passive continental margins.

1. Introduction

The geological record in southern East Greenland (68–70°N; Figs. 1, 2) provides unequivocal evidence that the margin subsided during and after breakup in the NE Atlantic at the Paleocene–Eocene transition. At that time, the voluminous Main Basalts (flood basalts) erupted onto a flat-lying lava plain, and there are marine incursions above and below them showing that the landscape was low-lying during the whole of the volcanic eruptions (e.g. Wager and Deer., 1939; Nielsen et al, 1981; Larsen et al., 1989, 2013; Pedersen et al., 1997; Larsen and Tegner, 2006). Subsidence must, therefore, have kept approximate pace with the outpouring lavas, and the land surface at the end of the eruptions must have been close to sea level (Nielsen and Brooks, 1981); see details in Bonow et al. (2014). The Main Basalts now make up the summit of Gunbjørn Fjeld – the highest mountain in Greenland (3.7 km above sea level, a.s.l.) – and there has thus long been consensus that the elevated margin of southern East Greenland formed after breakup (e.g. Brooks, 1979, 1985, 2011; Bott, 1987; Larsen, 1990; Larsen and Marcussen, 1992; Larsen and Saunders, 1998).

This is interesting in a broader perspective because the East Greenland margin shares characteristics with many elevated, passive continental margins (EPCMs) around the world (e.g. Brazil, Norway and SE Australia; see Japsen et al., 2012a; Green et al., 2013), which are commonly assumed to represent permanent highs (e.g. Persano et al., 2006, 2007; Swift et al., 2008; Nielsen et al., 2009, 2010; Sacek et al., 2012). One characteristic aspect of EPCMs is the presence of elevated plateaus cut by deeply incised valleys. Such plateaus are well known in East Greenland (Fig. 3; Ahlmann, 1941; Brooks, 1979, 1985, 2011; Pedersen et al., 1997; Bonow et al., 2014, in a paper parallel to the present), and Bonow et al. (2014) showed that the surfaces forming these plateaus represent peneplains that were graded to base level sometime after breakup and subsequently uplifted to their present elevations. Another characteristic that the East Greenland margin shares with other EPCMs, is found offshore where post-breakup strata are tilted and truncated by erosional unconformities towards the coast (Fig. 1; Larsen and Saunders, 1998; Japsen and Chalmers, 2000; Hamann et al., 2005). The specific conditions in southern East Greenland thus supports the notion of Japsen et al. (2012a) that EPCMs are not permanent highs, and that their characteristic present-day morphology is unrelated to rifting and continental breakup.

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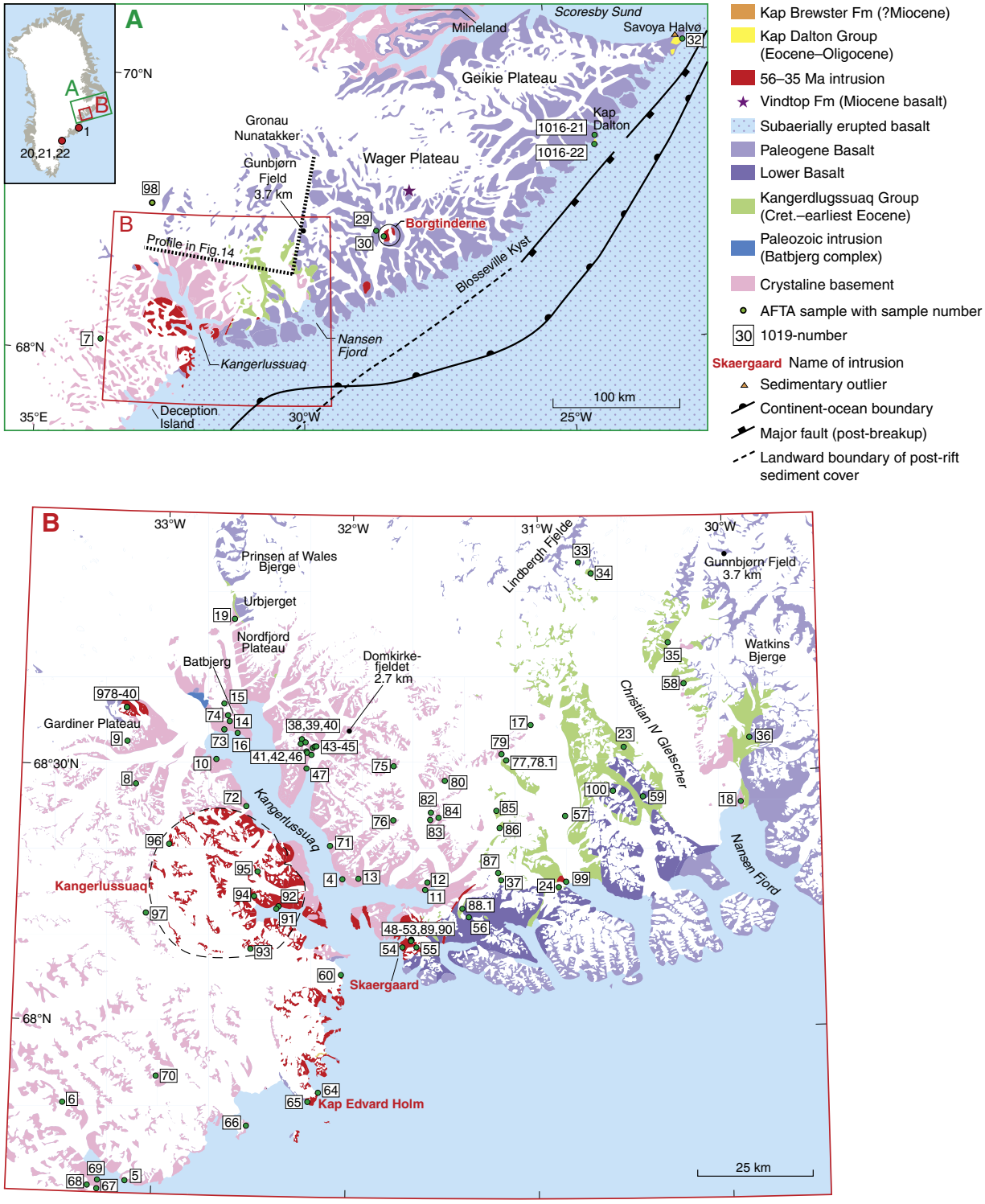

Fig. 1. Geology of southern East Greenland and location of AFTA samples. A. Scoresby Sund to Kangerlussuaq. B. The Kangerlussuaq area. Cretaceous strata in the Kangerlussuaq Basin are absent NE of Christian IV Fault (below Christian IV Gletscher; Larsen and Whitham, 2005). AFTA samples are indicated with sample numbers (those without prefix are GC1019-). Locations of three samples that are not included in Geotrack report GC1019, are also shown (978-40, 1016-21, -22). Locations of two VR samples analyzed for this study are also shown (1019-78.1, -88.1). Samples 1019-20, 21, 22 are from Kap Møsting, ~63°N and sample 1019-1 is from Kangertittivatsiaq, ~66°N. Map based on Henriksen et al. (2009) and modified after Larsen and Saunders, 1998; Larsen et al., 2002, 2005a,b; Nøhr-Hansen and Piasecki, 2002; Storey et al., 2004, 2007; Tegner et al., 1998, 2008).

The timing of the uplift of the East Greenland margin, however, remains unclear, and the driving forces are consequently difficult to assess. Brooks (1985) and Bott (1987) argued that the high elevation in the area developed after the Oligocene–Miocene transition, whereas Larsen and Saunders (1998) summarized the results of ODP Leg 152 and concluded that the main uplift of the margin is post-volcanic, and that the crustal exhumation accelerated in the mid-Tertiary. Ahlmann (1941) argued that the high-level plains in East Greenland were formed in post-basalt times and subsequently dissected after uplift, whereas Swift et al. (2008) thought that the main features of the landscape north of Scoresby Sund existed prior to breakup.