Using rock magnetics to resolve composite magmatic state fabrics: a case study from the Younger Giant Dyke Complex, South Greenland

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Introduction

Understanding the geometry of magma chambers plays a critical role in determining the igneous petrogenic processes that occur as intrusions cool. Quantitative fabric analysis methods, such as anisotropy of magnetic susceptibility (AMS), are routinely used to measure magma flow dynamics and determine the mechanism of magma transport and emplacement [1]. However, magma mushes typically experience multiple flow events; e.g. emplacement, convection and interstitial melt percolation [2]. There is thus a need to develop a more sophisticated approach to unravelling complex rock fabrics that record more than one magmatic state process.

This study uses the 1163 Ma Younger Giant Dyke Complex (YGDC) of South Greenland [3] as a case study. The YGDC is a series of giant gabbroic-troctolitic vertical sheet intrusions (locally up to 800 m wide) emplaced during a major rifting episode 1163 Mya as part of the Gardar Igneous Province. Here we assess the magmatic history of modally layered pods of the YGDC using novel rock magnetic data sets.

Rock magnetic techniques, such as in-phase AMS (ipAMS) and out-of-phase AMS (opAMS) are defined by distinct mineralogy and crystal populations [4]. Thus using several analyses in conjunction have the potential of recording separate processes within the same rock.

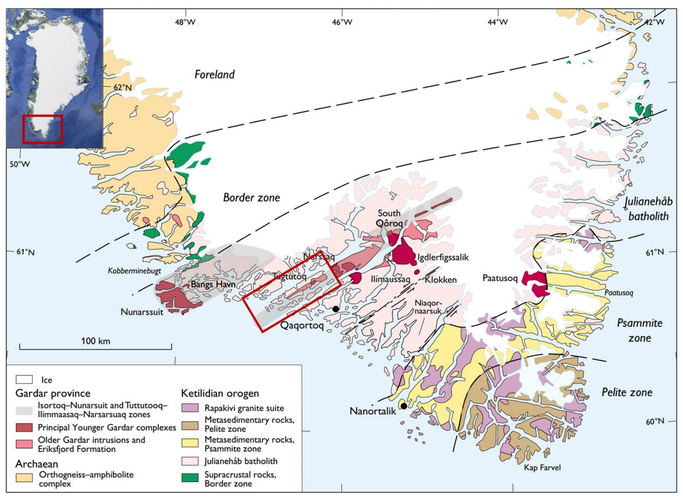


Figure 1: Regional context of the Gardar province. Tuttutooq island is highlighted by the red square. (Adapted from **[3]**)

Methods

- 156 orientated block samples were collected for rock magnetic analyses. T-X experiments were conducted on representative samples to constrain magnetic mineralogy. AMS and T-X were conducted on an AGICO KLY-5A Kappa Bridge at the M3Ore Lab.
- Magnetic remanence characterization experiments were conducted using an AGICO LDA-5 and JR6A at the M3Ore Lab.

Petrographic Observations

- At the dyke margins, 50 m of unfoliated gabbro (Fig. 3d) transitions across 2 m to a foliated troctolite. Foliation is defined by the alignment of plagioclase, parallel to the (010) faces. Layers dip concentrically inwards to a central point and are sub horizontal at the center of the dyke (Fig 2, 3e).
- Imbricate structures and ripple textures are observed in the plagioclase framework, and indicate a top-towards-centre of basin shear.
- Melt segregate lenses occur within the micro-gabbro as sheets perpendicular to host-rock contacts.
- No magmatic lineation is identified in the field.

AMS Results

ipAMS

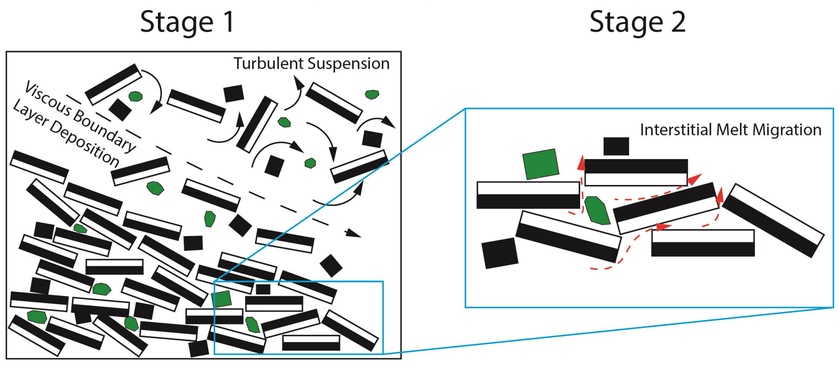
- 80% of ipAMS foliations within the foliated troctolite are oblate (Fig 4), and parallel to the orientation of plagioclase crystals. ipAMS is carried by cumulus Ti-magnetite (Fig 3c,f).
- 85% of ipAMS lineations plunge towards the centre of the basin, with deviations to N-S & E-W present in others (Fig 2).

opAMS

- opAMS preserves dominantly triaxial-prolate fabrics (Fig 4).
- Samples cross-cutting melt segregations within the marginal gabbro exhibit diferring in IP and OP AMS (e.g. 042, Fig 2).
- 75% of opAMS lineations plunge towards the centre of the basin, and steepen as ipAMS foliation shallow.

Interpretations

- Imbricate and ripple structures invoke a dynamic flow origin of the foliation. This is supported by consistent ipAMS lineations towards the centre of the pod.
- There is a component of compaction observed in ipAMS (Fig. 4)
- opAMS may record single-domain magnetite clusters which occur along clinopyroxene (a purely interstitial) cleavage planes. (Fig 4)
- **We propose AMS is recording fabrics from two distinct flow events; 1) convection above the foliated pods, leading to viscous deposition in the boundary layer, 2) trapped interstitial melt then migrates around the framework due to post-depositional compaction.**



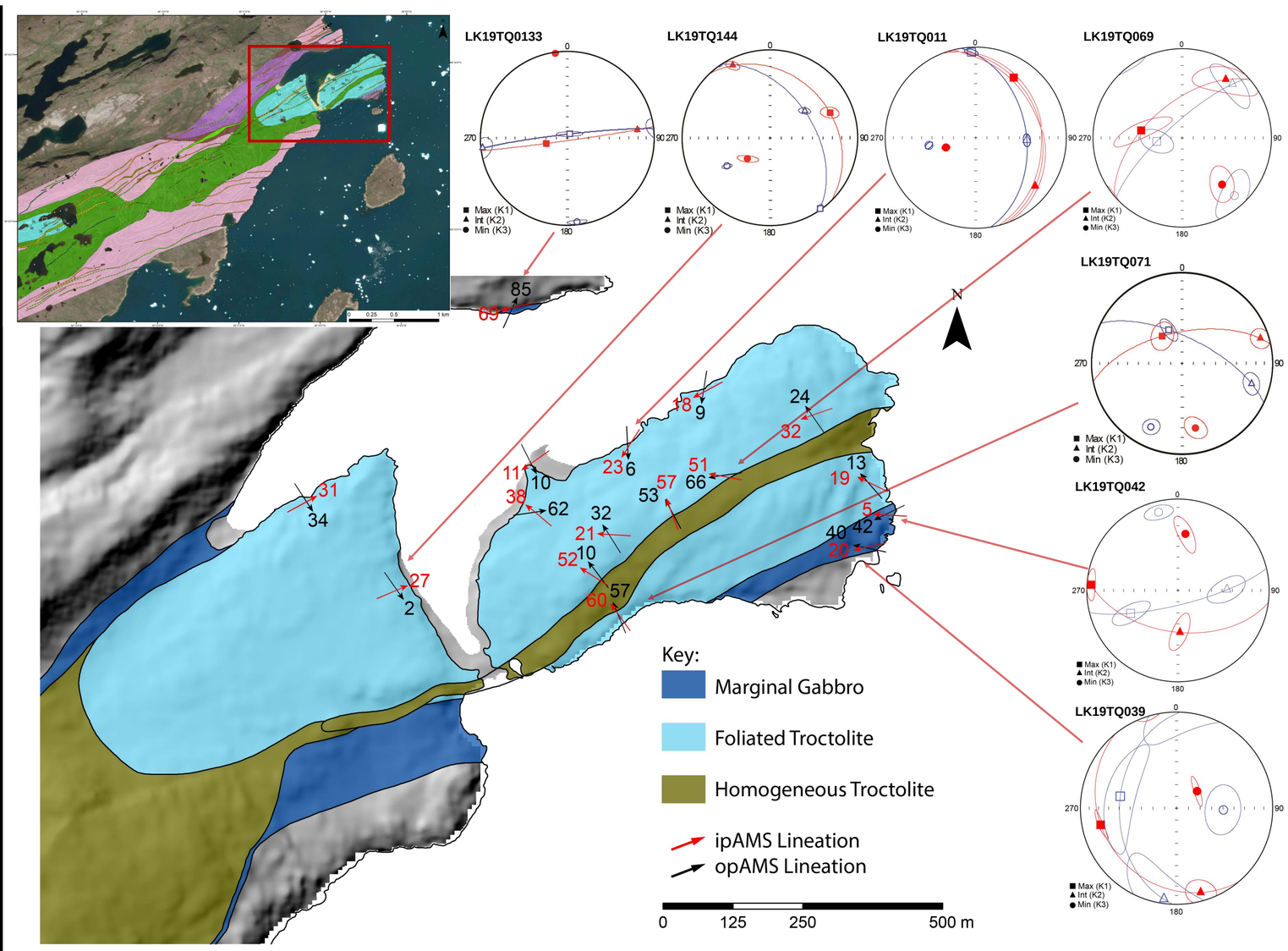
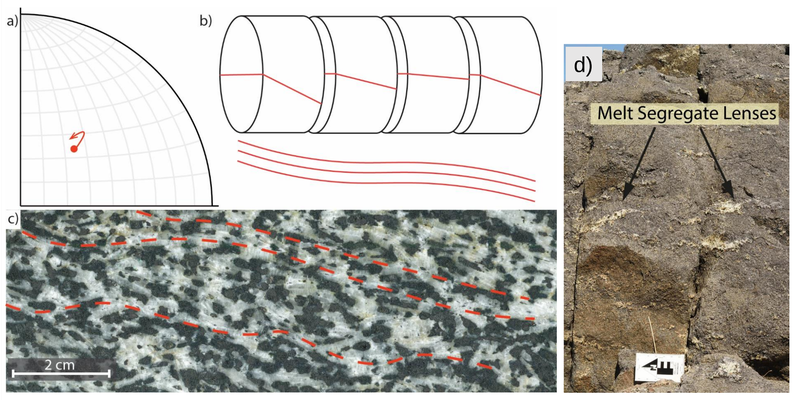


Figure 2: Geological map produced during fieldwork (Full map in top left), with magnetic lineations (K1 axes). ipAMS in red, opAMS in black. Select AMS results shown in stereonets (plotted great circles are magnetic foliations). In all, ipAMS is in red and opAMS is in blue.



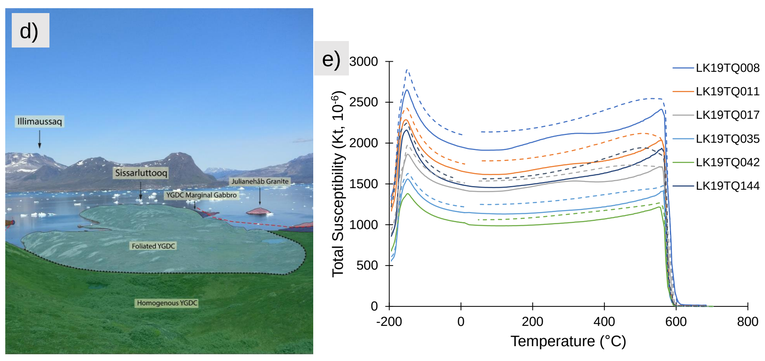
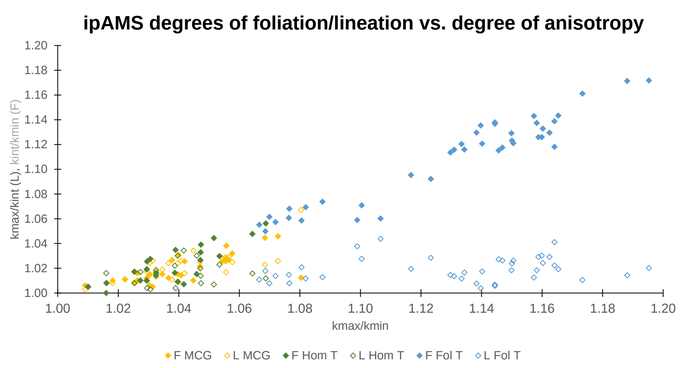


Figure 3: **a)** Southern hemisphere stereonet of ipAMS K3 (pole to foliation) of samples cored along ripples within the foliated troctolite. **b)** Cartoon of cored samples with individual foliations drawn in red, reconstructed below. **c)** Block image scan of rippled and imbricate textures in foliated troctolite**. d)** Marginal gabbro, with melt segregate lenses pervasive perpendicular to contact (N arrow 10 cm long), **d)** View of Sissarluttooq basin looking NE. **e)** In-phase susceptibility-Temperature results of select samples. Notice the Verwey transition (near -140 °C) and curie temperatures of 540-560 °C are indicative of low-Ti titanomagnetite as the dominant magnetic carrier in all samples.



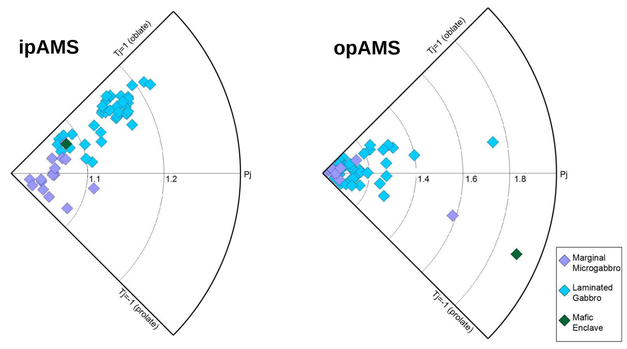


Figure 4: **Top:** ipAMS degrees of lineation and foliation plotted against degree of anisotropy. Notice the deviation between lineation and foliation in the foliated troctolite samples, suggesting a component of pure shear flattening (i.e. compaction).

Bottom: Shape of ellipsoid (Tj) – Pj polar plots of both ipAMS and opAMS (following method from **[5]**).

References

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