A whole-rock data set for the Skaergaard intrusion, East Greenland

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Abstract
We report a compilation of new and published whole-rock major and trace element analyses for 646 samples of the Skaergaard intrusion, East Greenland. The samples were collected in 14 stratigraphic profiles either from accessible and well-exposed surface areas or from drill core, and they cover most regions of the intrusion. This includes the Layered Series, the Upper Border Series, the Marginal Border Series and the Sandwich Horizon. The geochemical data were obtained by a combination of X-ray fluorescence and inductively coupled plasma mass spectrometry. This data set can, for example, be used to constrain processes of igneous differentiation and ore formation.

Tabular abstract

| Geographical coverage | The Skaergaard intrusion occupies a c. 11 × 8 km outcrop area of layered gabbroic rocks at Uttentals Sund, Kangerlussuaq area, East Greenland. Located at c. 68°9′ N and 31°41′ W. |
| Temporal coverage | Palaeogene (c. 56.0 Ma) |
| Subject(s) | Cosmochemistry and geochronology, economic geology, geochemistry, igneous rocks and processes |
| Data format(s) | Major and trace element compositions reported in an Excel spreadsheet. |
| Sample collection & analysis | Samples (n = 646) taken from surface outcrops and drill cores were analysed by X-ray fluorescence and inductively coupled plasma mass spectrometry (ICP-MS). The samples are stored and curated at: Aarhus University (surface samples from the Layered Series and Upper Border Series); Geological Survey of Denmark and Greenland (surface samples from the Layered Series); Natural History Museum of Denmark, University of Copenhagen (drill core samples) and the Harker Collection of the Sedgwick Museum, University of Cambridge (Cambridge 1966 drill core and surface samples of the Marginal Border Series). |
| Parameters | Major and trace element whole-rock compositions. |
| Potential application(s) for these data | This data set can, for example, be used to constrain processes of igneous differentiation and ore formation. |

Data collection
To examine the petrology and ore bodies of the Skaergaard Intrusion, East Greenland, we have collected hundreds of samples during six field expeditions between 1993 and 2017. In addition, we have collected samples from drill core material housed at the Natural History Museum of Denmark from drill core material housed at the Natural History Museum of Denmark.
Palladium and gold mineralisations have been identified in the LS (Andersen et al. 1968; Naslund 1984; Hoover 1989; McBirney 1996; Irvine et al. 2004). The processes resulting in igneous differentiation and ore formation in opposite positions relative to gravity (e.g. McBirney 1995).

**Sample profiles**

The stratigraphic profiles (n = 14) are summarised in Table 1 and illustrated in Figs 1 and 2. The profiles cover most regions of the intrusion and were collected either from accessible and well exposed surface areas or from drill core. The details of the sample profiles are described in Supplementary Data File 2.

**Sampling strategy**

The sampling was directed to obtain mainly average rock compositions in systematic stratigraphic sections. Additional samples of outcrop features such as gabbropegmatites, subzone boundaries and layered structures were also included, for example, the ‘wavy pyroxene rocks’ and colloform banding of the MBS (Humphreys & Holness 2010; Namur et al. 2013). The sample positions were recorded by GPS and altimeter readings (Supplementary Data File 1). For LS and UBS, the stratigraphic thicknesses were calculated relative to the local strike and dip of layering as described previously (Tegner et al. 2009; Salmonsén & Tegner 2013) and are listed in Supplementary Data File 1. Within the limitations of outcrops, we aimed to sample at regular stratigraphic intervals. For LS and UBS, the average stratigraphic interval was 12 ± 13 m (1 s.d.). For MBS, the lateral distance from the contact is recorded and the average spacing between samples was 18 ± 6 m (1 s.d.; Holness et al. 2022).

**Calculation of fraction of melt remaining (F)**

The box-like appearance of the intrusion with onion-ring distribution of zones and subzones (Fig. 2) implies that stratigraphic thickness, and mass proportions are not proportional (Nielsen 2004). Based on mass proportions estimated for each subzone in the floor, wall and roof series (Nielsen 2004), the mass fraction of melt remaining in the chamber, F, can be estimated for subzone boundaries. For the ‘reference profile’ of LS, a second-order polynomial was fitted to subzone boundaries to relate F to stratigraphic height (h) and given below as equation 1 (Tegner et al. 2009):

\[
F = 1.091 \times 10^{-7}H^2 - 5.9064 \times 10^{-4}H + 0.7678
\]

The F values for the 90-10 and 90-23 drill core samples were also estimated using equation 1 and tied to the ‘reference profile’ at the H of the UZa/b boundary.
Fig. 1 Geological map of the Skaergaard intrusion and adjacent host rocks. The rocks that solidified at the floor (Layered Series composed of Lower Zone, LZ, Middle Zone, MZ, and Upper Zone, UZ), walls (Marginal Border Series, MBS) and roof (Upper Border Series, UBS) are shown. Also shown are the approximate locations of 14 sample profiles (surface samples and drill cores) that are studied here. The sample profiles are numbered 1 to 14 and listed in Table 1. Further subzone abbreviations are in the text. Modified from McBerney (1989).
Similarly, the $F$ values for the samples of the Cambridge Core were estimated with equation 1, setting $H$ to zero at the LZa/HZ boundary (Holness et al. 2015). For UBS, $F$ values of subzone boundaries were fixed to the same values as for LS, and $F$ values of samples were related to stratigraphic height by linear interpolation (Salmonsen & Tegner 2013). Similarly for MBS, the $F$ values at subzone boundaries were assumed equal to those of LS, and the $F$ values of the samples were related to the distance between subzone boundaries by linear interpolation. Finally, in the sections crossing the SH, we assigned an $F$ value of zero to the sample with the lowest MgO content ($\leq 0.02$ wt%). The estimated $F$ values are reported in Supplementary Data File 1.

### Analytical methods

All samples were collected, prepared and analysed in the same way. From surface outcrops, we collected samples weighing 1–4 kg and avoiding alteration veins. The samples were trimmed for surface weathering by sawing, and an aliquot (100–400 g) was crushed to small aggregates (<2 cm) in a hydraulic steel press. This was followed by splitting, pre-contamination of a corundum shatterbox, cleaning and finally powdering of c. 30 g. The drill core material was prepared in the same way with one exception. The powders of drill core 90-22 ($n = 51$) were prepared using a steel jaw crusher and a tungsten-carbide shatterbox. All samples were prepared at Aarhus University as described in Tegner et al. (2009).
Table 1  Overview of samples and sample profiles

<table>
<thead>
<tr>
<th>Name</th>
<th>Rock series</th>
<th>Subzones</th>
<th>No. of samples</th>
<th>No. of samples</th>
<th>No. of samples</th>
<th>No. of samples</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference profile a</td>
<td>[1] Layered Series</td>
<td>LZA, LZA, LZC, MZ, UZA, UZB, UZC</td>
<td>138</td>
<td>135</td>
<td>2</td>
<td>1</td>
<td>Tegner (1997); Tegner et al. (2009); Thy et al. (in press)</td>
</tr>
<tr>
<td>Dobbert Gletscher</td>
<td>[3] Layered Series</td>
<td>HZ, LZA</td>
<td>8</td>
<td>8</td>
<td></td>
<td></td>
<td>This study</td>
</tr>
<tr>
<td>90-10 drill core</td>
<td>[4] Layered Series</td>
<td>MZ, UZA, UZB</td>
<td>81</td>
<td>81</td>
<td></td>
<td></td>
<td>This study</td>
</tr>
<tr>
<td>90-23 drill core</td>
<td>[5] Layered Series</td>
<td>UZA, UZB, UZC</td>
<td>87</td>
<td>87</td>
<td></td>
<td></td>
<td>This study</td>
</tr>
<tr>
<td>NW Basistoppen</td>
<td>[6] Layered Series/Upper</td>
<td>UZC, SH, UZC`</td>
<td>21</td>
<td>12</td>
<td>9</td>
<td></td>
<td>This study</td>
</tr>
<tr>
<td>Skaergaard Bay</td>
<td>[11] Upper Border Series</td>
<td>HZ<code>, LZA</code>, LZB`</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td>This study</td>
</tr>
<tr>
<td>Total no. of samples</td>
<td></td>
<td></td>
<td>646</td>
<td>624</td>
<td>20</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

aReference profile consists of surface samples from Uttental Plateau, Kraemer Ø, Pukugryggen/Forbindelsegletscher, West Basistoppen, and drill core 90-22. bNumbers labelled in Fig. 1. LZ: Lower Zone. MZ: Middle Zone. UZ: Upper Zone. HZ: Hidden Zone. SH: Sandwich Horizon.
The major and trace element data were obtained by a combination of XRF at Aarhus University and ICP-MS at the University of California, Davis and AcmeLabs as described in Tegner et al. (2009), Thy et al. (in press) and Tegner et al. (2019), respectively. Concentrations of FeO were determined by titration with potassium dichromate. The mass lost on ignition (LOI) was determined by heating the powder in air in a muffle furnace at 950°C for 3 h. The values obtained for certified reference materials, BHVO-1 and BIR-1, are reported in Supplementary Data File 3. XRF analyses of BHVO-1 and BIR-1 (n = 53–63) demonstrate that the relative variation of repeated analyses is less than 4.5% (1 s.d./average value) for most major element oxides. However, in BIR-1, the relative variation is higher (14%) for K$_2$O, which has a relatively low concentration (0.027 wt%; Jochum et al. 2016). For the trace elements measured by XRF, the relative variation of the transition metals (V, Cr, Ni, Cu, Zn) and Sr are within 5%. In BHVO-1, the relative variation is moderate for Rb, Y, Zr, Nb and Ba (4–12%) and higher for Ce (20%). In BIR-1, which is depleted in these elements relative to BHVO-1 (Jochum et al. 2016), the relative variation of repeat analyses is somewhat higher for Rb, Y, Zr and Nb and Pb (7–28%) and much higher for Ba and Ce. The accuracy or relative deviation from the preferred values for BHVO-1 is within 11% for all oxides and trace elements. Similar values were obtained for the accuracy of BIR-1, except for Rb, Nb and Ce, which have sub-ppm preferred values.

In conclusion, the XRF data can generally be viewed as accurate down to a few ppm. Repeat ICP-MS analyses of standards at AcmeLab (n = 14) and University of California (n = 6) deviate less than 7 and 18%, respectively, from the preferred values for all trace elements reported in this study (Supplementary Data File 3).

**Data description and main features**

The bulk compositions of cumulate rocks, such as those reported here, represent a mix of accumulated liquidus crystals (cumulus) and interstitial material (intercumulus) derived from crystallisation of interstitial melt (Wager et al. 1960; Irvine 1982). The present data set thus tracks changes in the compositions...
Acknowledgements

We are grateful to the Danish Lithosphere Centre for supporting field work in 2000. Platina Resources were accommodating during the 2008 and 2011 field seasons. The Geological Survey of Denmark and Greenland (GEUS) helped with field logistics in 2017. Platina Resources Ltd. are thanked for access to drill core material. We thank C. Kent Brooks for inspiring this project. We are indebted to Jakob K. Keiding for help with field work, sample preparation and discussion. We also enjoyed assistance and company in the field from Jens C.Ø. Andersen, Olivier Namur, Anja K.M. Fonseca and Joel A. Simpson. Sidsel Grundvig, Ingrid Aaes and Jette Villesen, Aarhus University, are thanked for help with sample preparation and X-ray fluorescence analyses. We thank two reviewers, Rais Latypov and Howard Naslund, as well as Kerstin Saalmann for careful editorial handling.

Additional information

Funding statement

This work was supported by funding from Danish National Science Research Council (CT, TFDN), the Danish National Research Foundation (TFDN, CEL, CT), the Carlsberg foundation (CT), Aarhus University (CT, LPS), the UK Natural Environment Research Council (MBH, MCH), the US National Science Foundation under Grant Number NSF-EAR-0208075 (CEL), the UK Royal Society International Joint Project (MBH, CT).

Author contributions

CT: Conceptualisation, Data curation, Funding acquisition, Investigation, Methodology, Supervision, Visualisation, Writing – original draft.
LPS: Investigation, Methodology, Writing – review and editing.
MBH: Conceptualisation, Data curation, Funding acquisition, Investigation, Methodology, Writing – review and editing.
CEL: Investigation, Conceptualisation, Funding acquisition, Methodology, Writing – review and editing.
MCSH: Investigation, Methodology, Writing – review and editing.
PT: Investigation, Methodology, Writing – review and editing.
TFDN: Investigation, Conceptualisation, Funding acquisition, Methodology, Writing – review and editing.

Competing interests

The authors declare no competing interests.

Additional files

Three additional files, including the data set, a description of sample profiles and analytical precision and uncertainty are available at https://doi.org/10.22008/FK2/HOWW6F.

References


