Geological mapping using airborne thermal hyperspectral data in Antarctica

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Antarctica is a unique and geographically remote environment. Field campaigns in the region encounter numerous challenges including the harsh polar climate, steep topography, and high infrastructure costs. Additionally, field campaigns are often limited in terms of spatial and temporal resolution, and particularly, the topographical challenges presented in the Antarctic mean that many areas remain inaccessible. For example, despite more than 50 years of geological mapping on the Antarctic Peninsula, there are still large gaps in coverage, owing to the difficulties in undertaking geological mapping in such an environment. Hyperspectral imaging may provide a solution to overcome the difficulties associated with field mapping in the Antarctic.

The British Antarctic Survey and partners collected the first known airborne hyperspectral dataset in the Antarctic in February 2011. Multiple spectrometers were simultaneously deployed imaging the visible, shortwave and thermal infrared regions of the electromagnetic spectrum. Additional data was generated during a field campaign in January 2014, with the deployment of multiple ground spectrometers collecting data in coincident visible, shortwave and thermal infrared regions.

In arid areas, such as polar or desert regions, sparsely developed vegetation cover can allow for detailed spatial mapping of mineral outcrops using a three step processing chain; (1) determine the number of endmembers in the image, (2) extract the endmembers and (3) determine the fractional abundance of the endmembers using spectral mixture analysis produce abundance maps. Here we present preliminary results of this processing chain applied to a target area to discriminate local igneous rocks (e.g. granite, granodiorite, dolerite) using hyperspectral thermal infrared data.

American Society of Photogrammetry and Remote Sensing
Imaging & Geospatial Technology Forum
Tampa, Florida, USA.
May 4th – May 8th 2015.

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Overview & Rationale

In Antarctica, despite over 50 years of geological mapping on the Antarctic Peninsula, there are still large gaps in coverage. Hyperspectral data could provide a cost- effective alternative to time-intensive, expensive field mapping techniques.

A successful campaign by the British Antarctic Survey (BAS), ITRES Research Ltd., and DRDC Suffield acquired the first known airborne hyperspectral data from Antarctica in 2011. Multiple spectrometers were simultaneously deployed imaging the visible, shortwave and thermal infrared regions of the electromagnetic spectrum. A recent field campaign deployed ground spectrometers to collect complementary spectra in the same wavelength ranges to aid in the airborne data analysis.

In arid areas, such as polar regions, sparsely developed vegetation cover can allow for detailed spatial mapping of mineral outcrops using a three step processing chain; (1) determine the number of endmembers in the image, (2) extract the endmembers and (3) determine the fractional abundance of the endmembers using spectral mixture analysis to produce abundance maps.

Here we present preliminary results of this processing chain applied to a target area from Anchorage Island, close to the British Antarctic Survey's main operating base (Rothera) to discriminate local igneous rocks (e.g. granite, granodiorite, dolerite) using hyperspectral thermal infrared data.

Study Area & Data

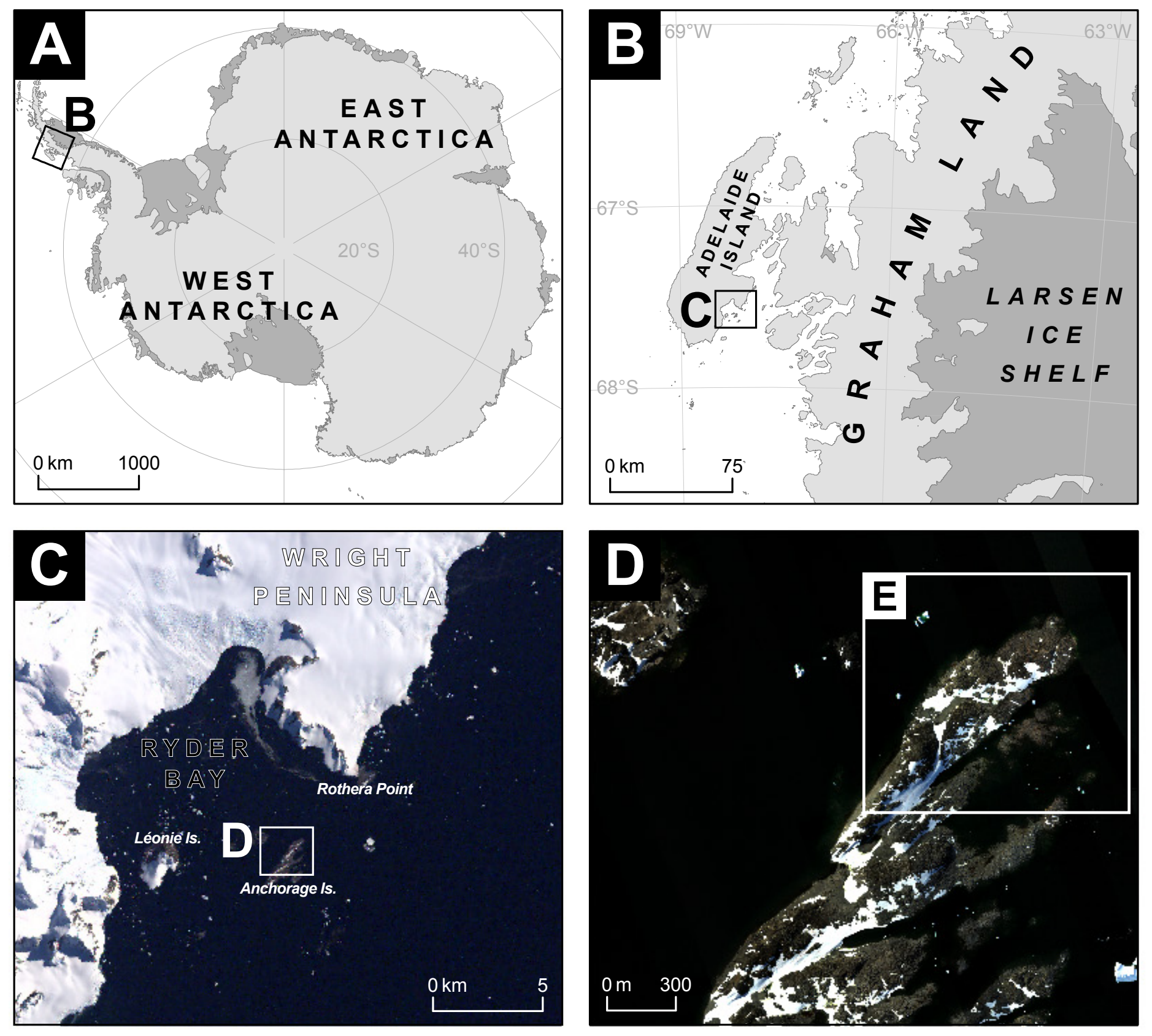


Figure 1. (A) the context of Adelaide Island within Antarctica; (B) the context of Adelaide Island and the Antarctic Peninsula; (C) the Ryder Bay area (with a Landsat colour image) showing extent of the study area (Box labelled D); (D) CASI hyperspectral colour composite image of Anchorage Island, where box (E) shows the extent of the area of interest in the North West of Anchorage Island.

In 2011 three ITRES sensors imaging the visible near-infrared (CASI), shortwave infrared (SASI) and thermal infrared (TASI) were deployed in a BAS aircraft (above).

In 2014 a field campaign collected spectral measurements in the same wavelength ranges (below).

Geological Context

The area of interest contains igneous rocks from the Adelaide Island Instrusive Suite (AIIS). An emplacement age in the range 45-52 Ma has been determined by U-Pb (zircon) geochronology.

The AIIS is typically granodiorite-tonalite, with minor dolerite dyke intrusions. In the area of interest a stoped block (around 25m²) of pink megacrystic granite is present with a high quartz content (~20%).

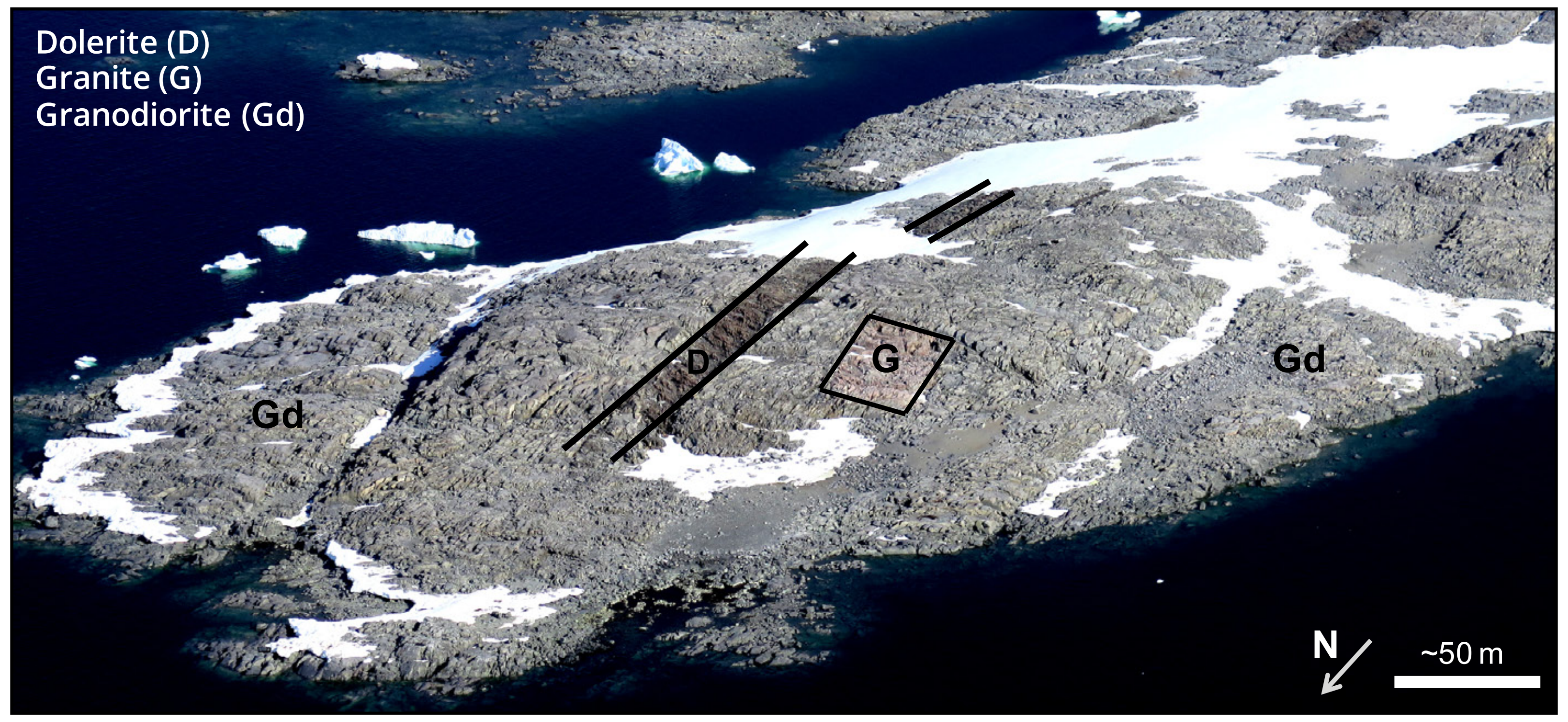
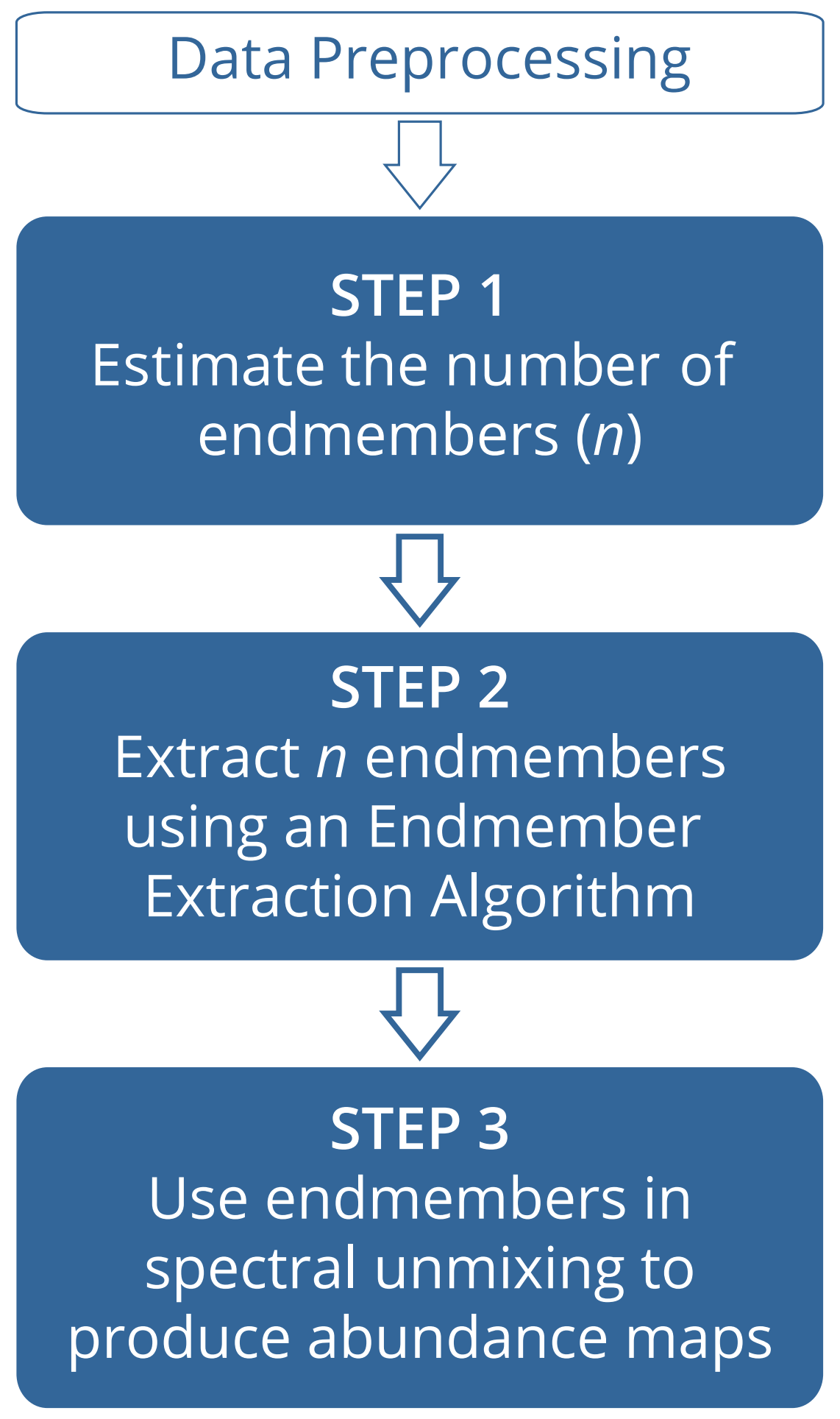


Figure 2. Geological schematic map of the North Western section of Anchorage Island. Interpretations are based on field observations, indicating the locations of granodiorite, the granite block and dolerite dyke.

Methodology



Data Preprocessing

STEP 1
Estimate the number of endmembers (*n*)

STEP 2
Extract *n* endmembers using an Endmember Extraction Algorithm

STEP 3
Use endmembers in spectral unmixing to produce abundance maps

Here we consider only the thermal infrared (TASI) data. The data has 32 spectral bands in the range of 8 µm to 11 µm, with a spectral resolution of around 100 nm and ground resolution of 1 m.

The data was atmospherically corrected and temperature emissivity separation was carried out using the Normalized Emissivity Method. Noise removal using the Minimum Noise Fraction (MNF) and empirical corrections were applied to correct for calibration issues caused by the extreme operating conditions in the Antarctic.

The three step automated processing chain (left) was then applied; Virtual Dimensionality [1] was applied at Step 1 and Vertex Component Analysis [2] at Step 2, followed by Fully Constrained Unmixing [3] at Step 3. The results were interpreted with respect to the field spectral data and observations.

Results & Discussion

Preprocessing was required to improve the quality of the TASI imagery prior to further analysis. Figure 3 (right) shows the results.

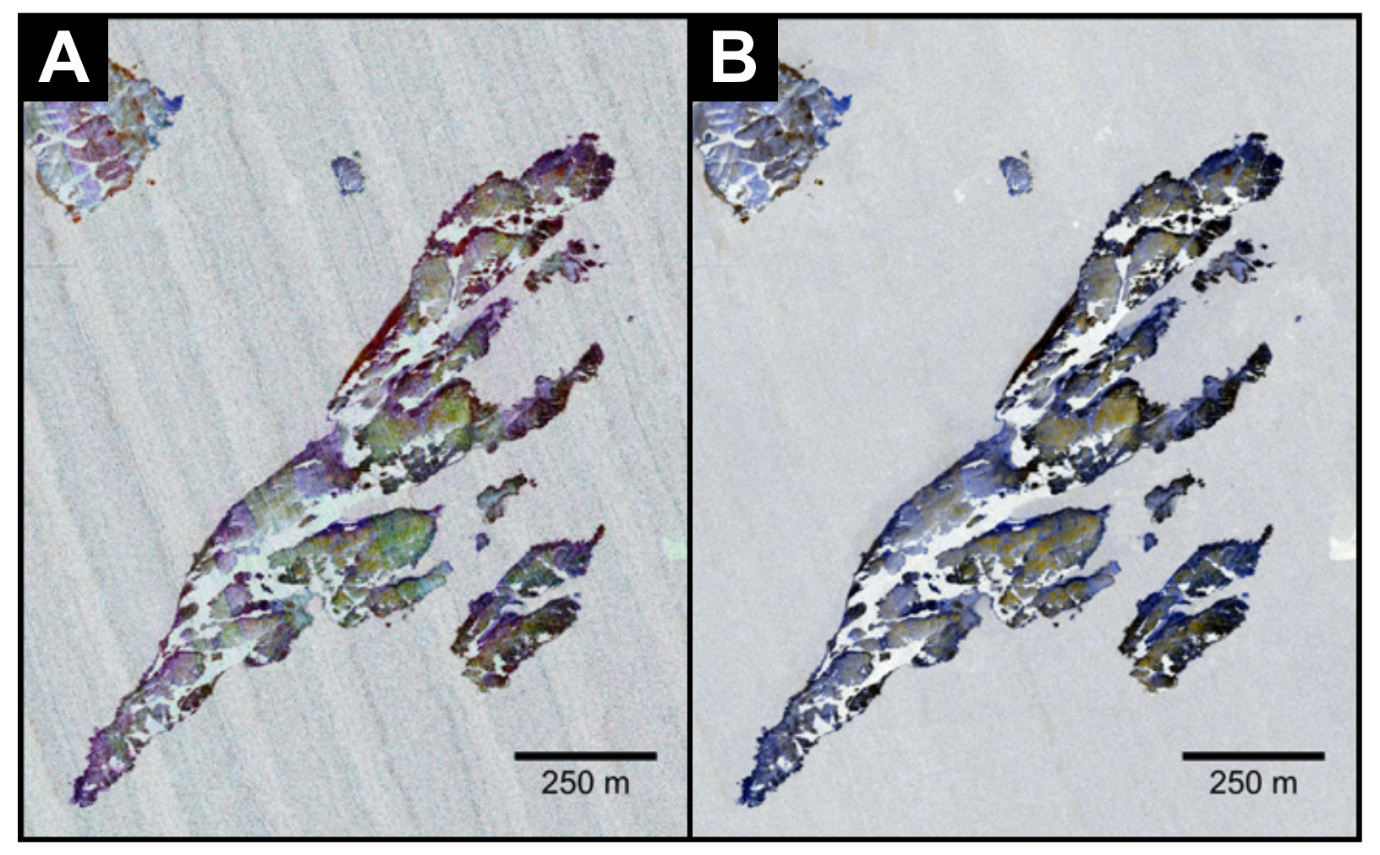
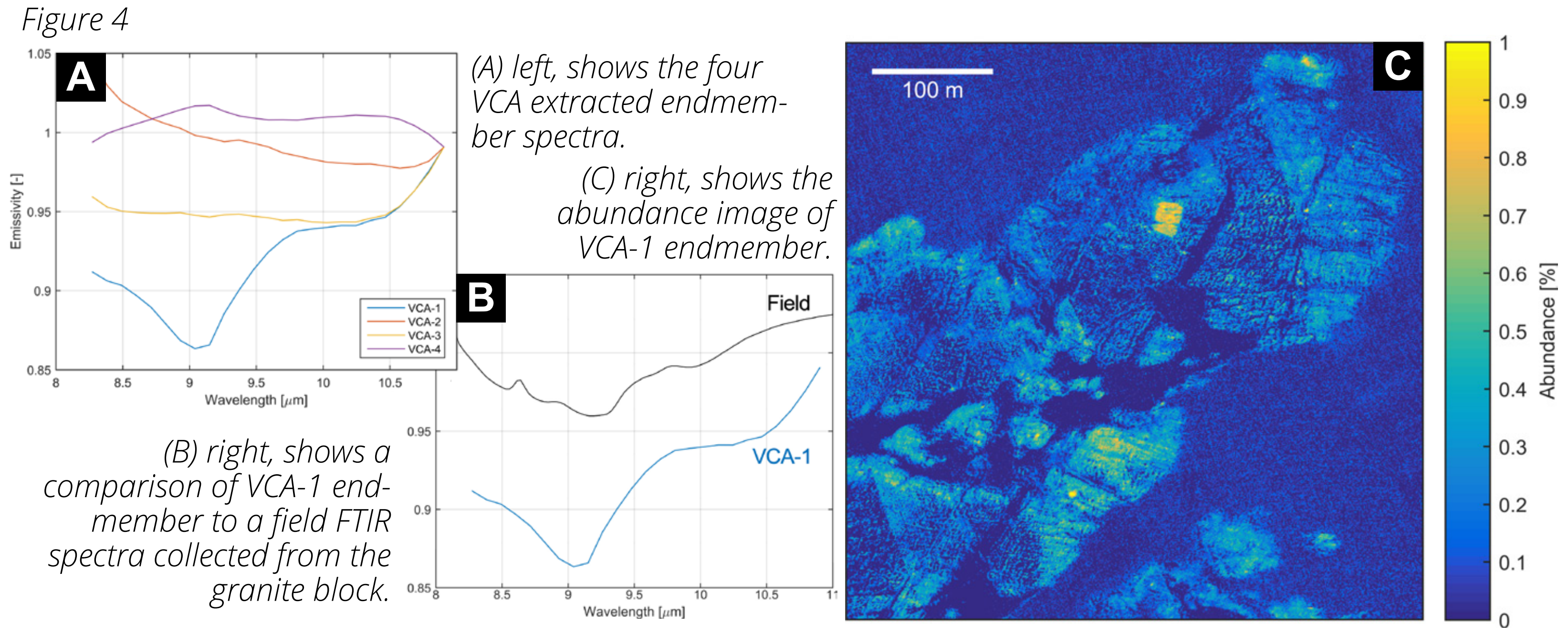


Figure 3. (A) TASI false colour (RGB bands 10.6 µm, 9.8 µm and 8.9 µm) image before preprocessing. (B) TASI false colour emissivity image after atmospheric correction, noise removal, temperature emissivity separation and an emissive empirical line correction.

Step 1 of the processing chain identified four endmembers in the image. The four endmembers were subsequently extracted (Step 2) and umixed (Step 3). The endmember spectra are shown below in Figure 4A.

Figure 4



(A) left, shows the four VCA extracted endmember spectra.

(C) right, shows the abundance image of VCA-1 endmember.

(B) right, shows a comparison of VCA-1 endmember to a field FTIR spectra collected from the granite block.

Only one of the endmembers could be reliably identified by comparison to field spectral data (Figure 4B), representing the stoped granite block. No endmembers corresponded to the dolerite dyke. The lack of distinct spectral features prevented reliable identification of the remaining endmembers.

Conclusions

A three step automated processing chain was applied to hyperspectral thermal data from Anchorage Island, Antarctica. The technique was capable of extracting an endmember associated with a megacrystic granite block of high quartz content but unable to reliably identify other igneous rocks (granodiorite and dolerite).

References & Acknowledgments

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The hyperspectral data was collected during an airborne survey funded by the UK Foreign and Commonwealth Office (FCO). M Black is funded by a Natural Environment Research Council (NERC) PhD studentship in conjunction with the British Antarctic Survey and the University of Hull (NERC Grant number NE/K50094X/1). Fieldwork was supported by AFI Grant CGS-86 and NERC FSF Loan No. 675.0613.

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