How is continental crust built? A study of how fault zone deformation controls vertical transport of magma during crustal growth in Fiordland, New Zealand

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ABSTRACT

Subduction zones are sites where converging tectonic plates focus and channelize magma in the process of forming continental crust. Transpressional deformation in these settings is a key process that vertically moves this magma to build the continent (Buritica et al., 2019), but it is unclear how shear zones (localized areas of strain) help move melt across rheological (strength) boundaries. The George Sound Shear Zone (GSSZ) in Fiordland, New Zealand, is a crustal-scale shear zone that has accommodated the upward channeling of magma across a rheological boundary separating plagioclase-rich lower crust from quartz-rich middle crust (Fig. 1). In the GSSZ, it is unknown how strain is kinematically accommodated as a response to magma flow and why there is strain localization in the middle crust. To understand how rock fabrics are formed by this process, I will analyze deformation microstructures in the GSSZ at this rheological boundary (Fig. 1). I hypothesize that strain is localized within quartz in the middle crust, and the monoclinic strain geometry of quartz deformation is kinematically compatible with deformed plagioclase of the lower crust of the GSSZ.

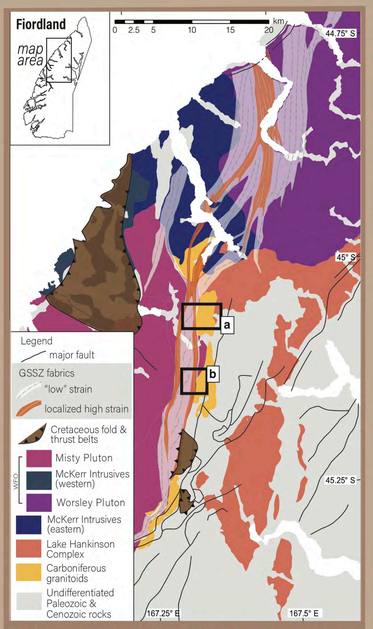

Figure 1. Simplified geologic map of the GSSZ in western Fiordland. Inset maps show locations of (a) Mary Peaks and (b) Myth Tarn. (modified from Lindquist, MS thesis 2020)

BACKGROUND

- Long-lived arc magmatism at the edge of Gondwana (Fig. 2) is responsible for:
  - the emplacement of several plutons into the lower & middle crust (Allibone et al., 2009)
  - a crustal-scale network of transpressional shear zones which played a role in vertically transporting magma (Buritica et al., 2019).
- The GSSZ is the deepest and largest of these shear zones, transecting the Worsley pluton (lower crust) and the Misty pluton (middle crust) (Klepeis et al., 2004; Schwartz et al., 2017).
- This project focuses on the structural analysis of rock samples from middle-crustal exposures of the GSSZ at Mary Peaks and Myth Tarn in Fiordland, New Zealand (Fig. 1).
- These locations were selected as they mark where the GSSZ:
  1) acts as a rheological boundary between the dioritic Misty Pluton and granitic host rocks, and
  2) where it narrows in width compared to its lower-crustal counterparts.

METHODS

- We will be conducting petrographic analysis (Fig. 4) along with creating EBSD orientation maps for Crystallographic Vorticity Axis (CVA) analysis, to reveal vorticity within the middle crust of the GSSZ
- By analyzing dispersion axes for all minerals in a sample (i.e., bulk vorticity axis), our work will shed light on how strain is accommodated by a variety of mineral strengths
- A connection between the bulk vorticity axis and macroscopic fabrics (i.e., foliation and lineation) will be useto understand:
  - The geometry of deformation
  - correlation between sample vorticity and regional scale deformation

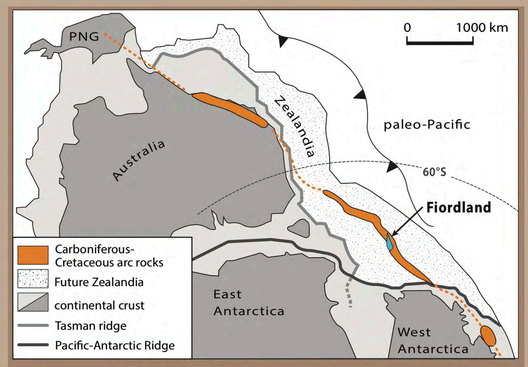

Figure 2. Reconstruction of supercontinent Gondwana ~100 Ma showing distribution of arc rocks and the future landmass Zealandia (Lindquist, MS thesis 2020)

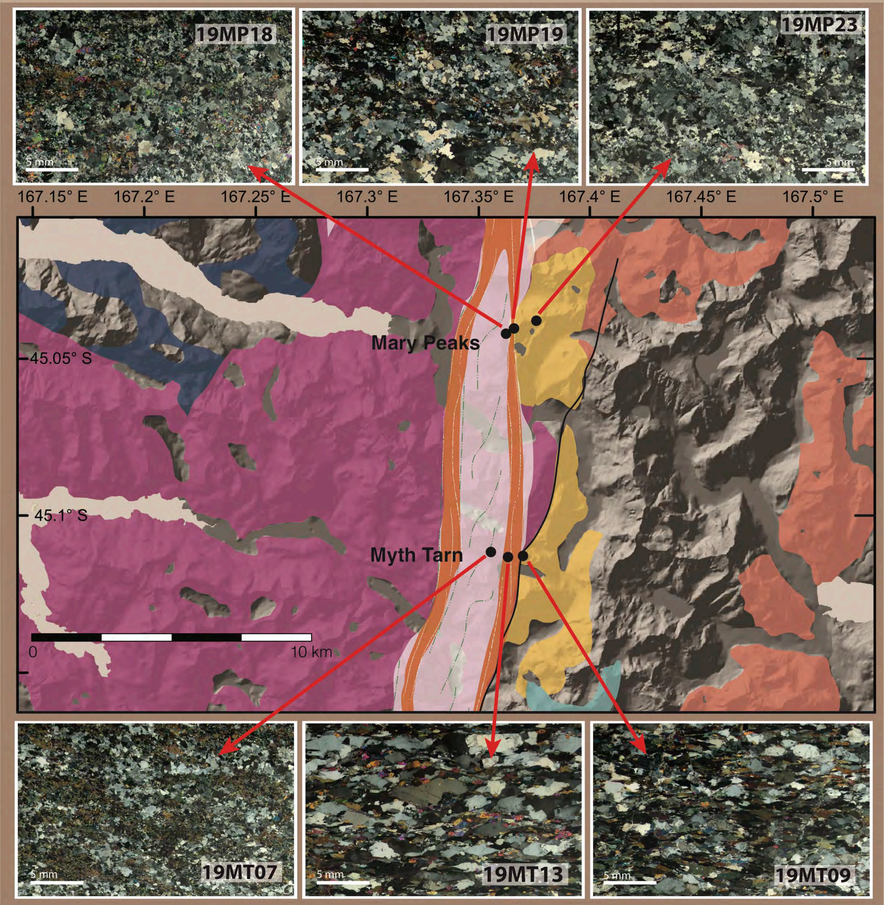

Figure 4. Geologic map of the Mary Peaks and Myth Tarn regions.The GSSZ acts as a rheological boundary between the margin of the Misty Pluton (diorite) and the Large Granite. Photmicrographs of samples show representative fabrics of the low strain, high strain, and deformed granites. Modified from Lindquist, MS Thesis (2020).

HOW EBSD WORKS

- Detector collects backscattered electrons (BSEs) after being ejected from the sample
- The BSEs reflection creates a pattern unique to each mineral and every crystal lattice to create an orientation map (Fig. 3)

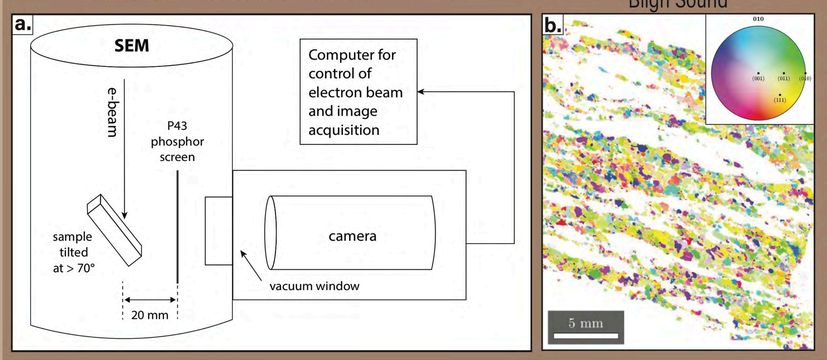

Figure 3. (a) Schematic diagram of how EBSD functions using a scanning electron microscope (SEM) (modified from Swapp, 2021). (b) Example of an orientation map produced from lower-crustal rocks of the GSSZ (Page, MS in progress). Produced via EBSD; the color scale is determined by the position of miller indices of plagioclase. This is an example of what we will be obtaining for our microstructural analysis.

PRELIMENARY RESEARCH

- Prelimenary petrographic analysis of selected samples shows variations in deformational fabrics across the strain gradients at both locations (Fig. 4)

19MT07
- hbl, plag, qtz, bt, ep
- rough foliation; randomly oriented bt, ep
- fine-grained, amoeboid plag

19MT13
- plag, bt, ep
- plag is control: elongated, pinched, def. twins
- defined foliation; dextral shear sense

19MT09
- hbl, qtz, kspar, plag, minor ep
- weakly foliated, several fractures

19MP18
- qtz, plag, hbl, kspar, bt, some ep
- qtz is control: GBM, SGR
- deformation twins in plag, bt + hbl aggregates

19MP19
- qtz, biotite, hbl, kspar, ep
- qtz is control: GBM, sub-grains, chessboard extinction
- aggregates of bt + hbl + ep

19MP23
- qtz, plag, kspar, bt
- qtz is control: GBM, deformation bands, SGR
- non-foliated, very fine-grained

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