Quantifying the Effects of Shear Strain on Melt Distribution and Permeability

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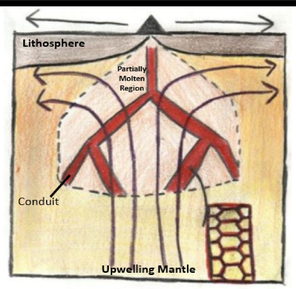
Introduction

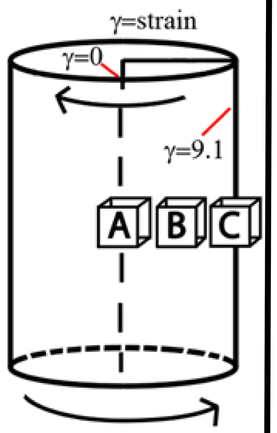


- Beneath mid-ocean ridges, divergent plates cause mantle upwelling inducing partial melt
- Melt separates from solid and moves to the surface by porous flow (Kelemen et al., 1997)
- Transportation rate affects geochemistry and geophysical processes.
- Affected by permeability and melt migration
- Porous flow through grain-scale networks (Miller et al., 2015)
- Stress-driven melt channelization
- Network of melt-rich bands in anisotropic systems
- Homogenous porous flow
- Power-law relationship when interconnect melt networks form:

$$k = \frac{\phi^n d^2}{c}$$

- Permeability sensitive to grain size and melt geometry
- Stress alters melt geometry

Sample



- Experimental Sample (C-Q0609A): San Carlos Olivine (90%) & MORB (10%)
- Deformed in torsion with confining pressure and temperature in gas medium deformation apparatus
- Developed stress-driven melt-rich bands
- Images obtained by x-ray synchotron microtomography (Qi 2018)

Hypothesis

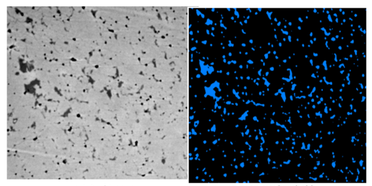
- Higher shear strain, melt will segregate into melt-rich and melt-poor regions

Lower shear strain
- Melt distribution more homogeneous

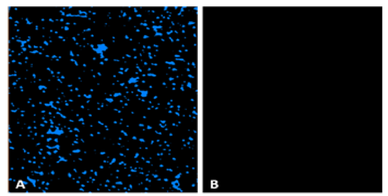
High shear strain
- Melt rich bands formed, different from melt-poor regions
- Change as a function of strain
- Anisotropic in melt geometry and permeability

Methods

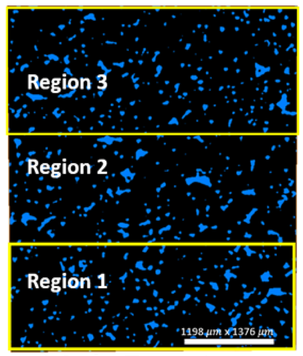
Low Strain



1. Noise Reduction

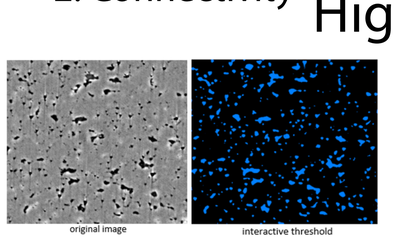


2. Connectivity



3. Melt Fraction

High Strain



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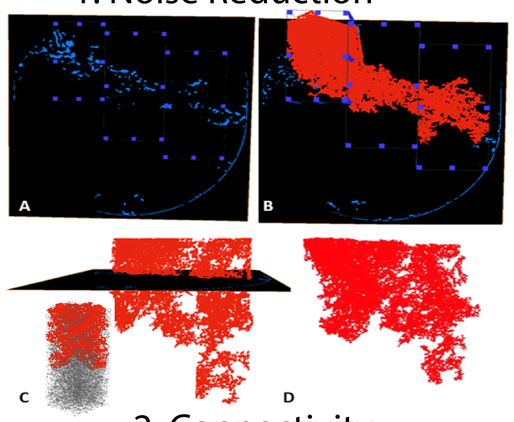
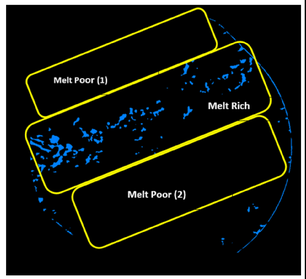


2. Connectivity



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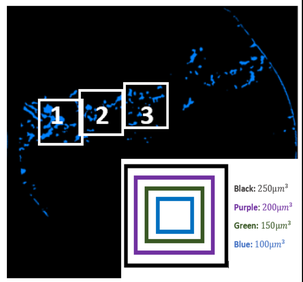
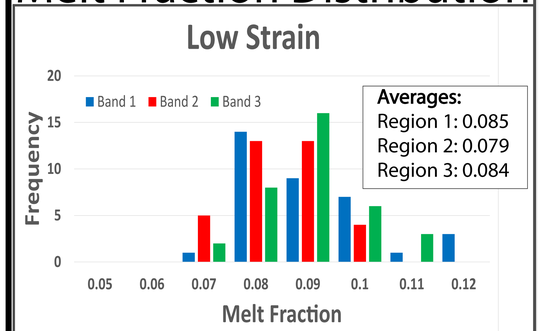


4. Permeabiliity

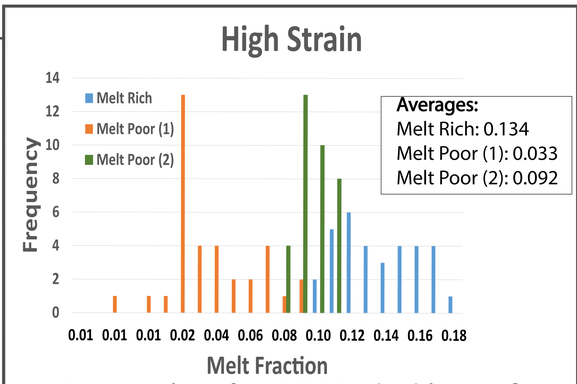
1) Various filters used to reduce noise and artifacts
2) Axis connectivity module to test for connected melt
3) Regions where melt fraction was calculated
4) Site locations with sizes that calculated permeability

Results

Melt Fraction Distribution

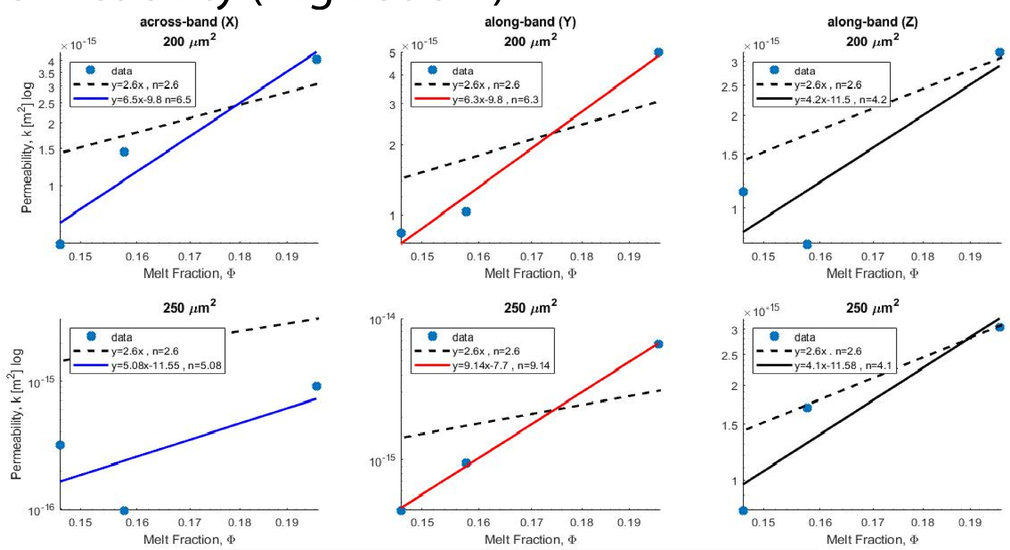


- ANOVA: p-value of 0.028 is significant at $p < 0.05$ and fail to reject the null hypothesis .
- Less heterogenous, more homogenous



- ANOVA: p-value of <0.00001 is highly significant at $p < 0.05$ so we fail to reject the null hypothesis
- More heterogenous, less homogenous

Permeability (High Strain)



- Permeability increasing as melt fraction increases.
- Higher slope values than dotted line (Miller 2014).

Conclusion

- Various image analysis tools on the X-ray synchrotron microtomography images
- Created a 3D melt distribution to form a digital rock and conduct virtual flow through experiments to calculate their permeability
- At low strain I found no connectivity, and the melt to be more homogenous and isotropic
- At high strain I found melt connectivity, melt to be more heterogenous and anisotropic, and a higher slope