QUANTITATIVELY DETERMINING STRESS ON MYLONITES FROM PATAGONIA, ARGENTINA

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WHAT IS A MYLONITE?

Definition: a fine-grained, foliated rock, commonly with poor fissility and possessing a distinct lineation (Nuendorf et al., 2011).

- Usually found in narrow, planar zones of localized ductile deformation
- They mark zones of concentrated stress
- Often inferred to indicate extensive simple shear, may also record pure shear or volume loss or both
- Formed by modification from plastic flows due to dynamic recrystallization (Winter, 2010)

MYLONITE APPEARANCE

- Usually very fine grained
- Well foliated – No cleavage
- Well developed fabrics due to grain size reduction from mylonitization

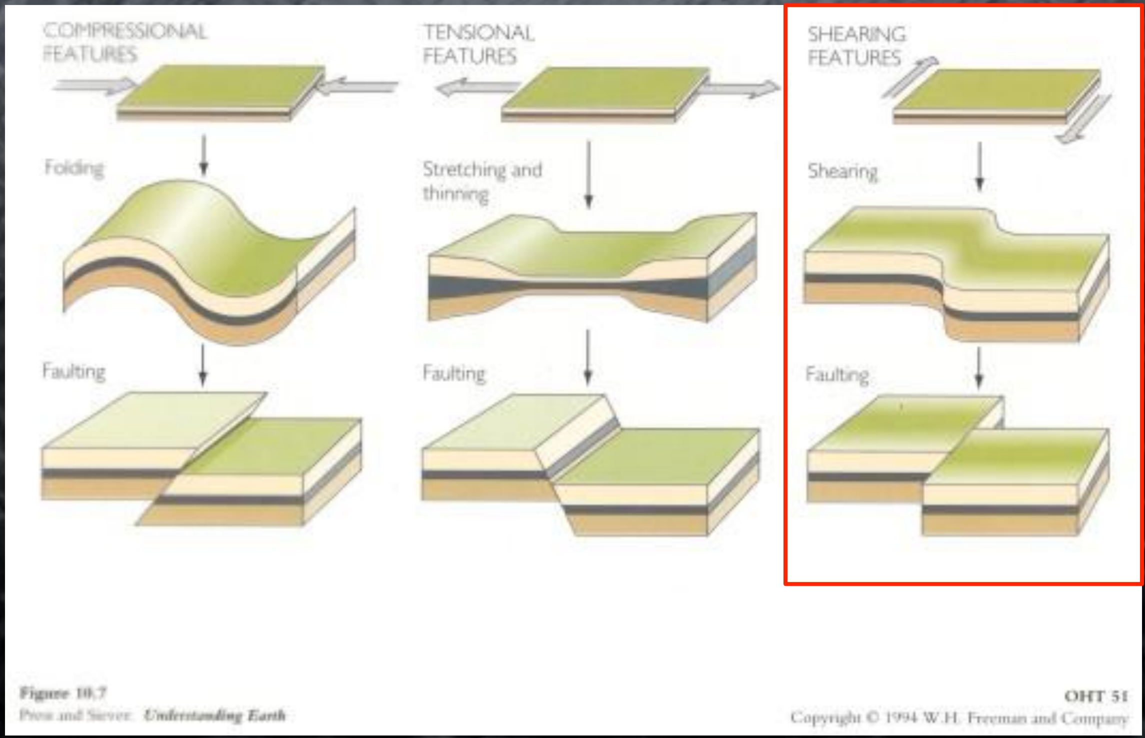
flexiblelearning.auckland.ac.nz

Wikipedia.org

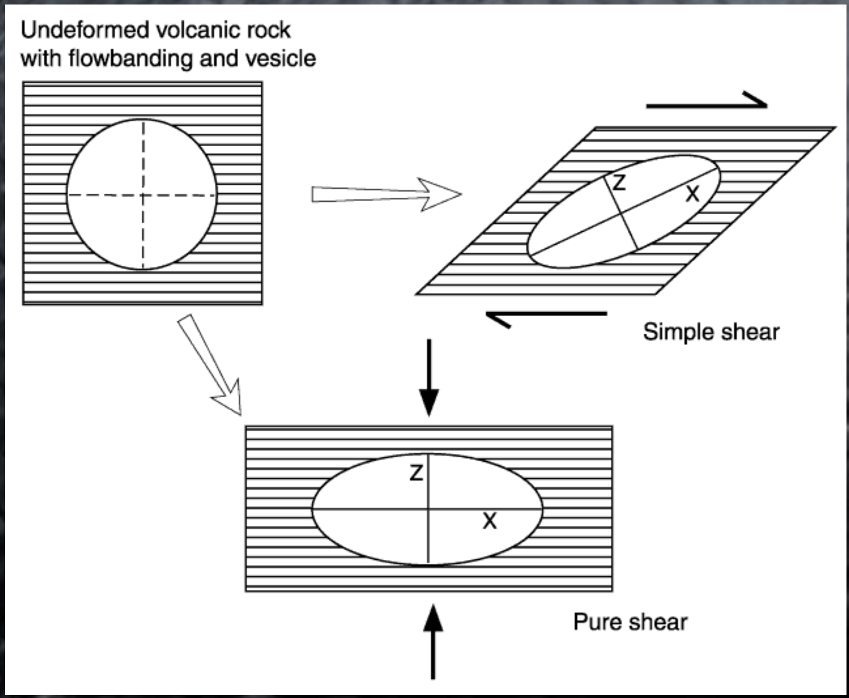
Feldspathic
Porphyroblast

users.monash.edu.au

SHEAR STRESS



PURE SHEAR VS. SIMPLE SHEAR



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TYPES OF MYLONITES

In Order of Increasing Metamorphic Grade:

Protomylonite - < 50% matrix

Mylonite – 50-90% matrix

Ultramylonite - > 90% matrix (highest shear)

Blastomylonite – warm enough that grains keep recrystallizing as they are sheared

GUIDING QUESTION

CAN YOU QUANTITATIVELY CALCULATE THE ORIGINAL STRESS ON A ROCK, BASED ON A MYLONITE IT LEFT BEHIND?

MYLONITES FROM PATAGONIA

- A COMPRESSIONAL GONDWANIAN OROGENIC EVENT OCCURRED
- THE COLLISION CAME FROM THE EAST
- LATERAL MOVEMENT POST INITIAL COLLISION TRIGGERED FORMATION OF MYLONITES

(Gregori et al., 2015)

METHODS

$$\dot{\varepsilon} = A(f_{H_2O})^p \sigma^4 \exp\left(\frac{-H_L}{RT}\right) \quad (1)$$

Equation 1: Flow law for dislocation creep in a quartz aggregate

- Dislocation Creep – Lines of defects/vacancies migrate through the crystal – can move far enough to create new grain boundaries
- Equation doesn't take into account grain size of the quartz

Equation Components:
E – Strain Rate
A – Material Parameter
F_{H2O} – Water Fugacity
P – Water Fugacity Exponent
σ – Stress
H_L – Molar Activation Enthalpy
R – Gas Constant
T – Temperature (K)

(Okudaira, 2012)

METHODS

$$\dot{\varepsilon} = \frac{64 \times 10^{12} b^3 D_G}{\mu k T d^2} \sigma^2 \exp\left(\frac{-H_G}{RT}\right) \quad (2)$$

Equation 2: Flow law for dislocation creep in quartz grains by grain boundary sliding

- Grain boundary sliding – crystals sliding past one another, occurs at high temperatures (Winter 2010)
- Takes into account 3-d grain size of quartz

Equation Components:
E – Strain Rate
b – Burgers Vector
mu – Shear Modulus of Quartz
K – Boltzmann Constant
T – Temperature
D – 3-d Grain Size of Quartz (m)
σ – Stress
H_G Molar Activation Enthalpy
D_G Pre-Exponential Factor
R – Gas Constant
T – Temperature (K)
(Okudaira, 2012)

METHODS

- Grain size (diameter) was calculated for deformed quartz grains in samples P5 and P6
- Then that number was multiplied by 1.7 to get the 3-d grain size
- The resulting number was plugged into equation 2

RESULTS FROM OKUDAIRA AND SHIGEMATSU

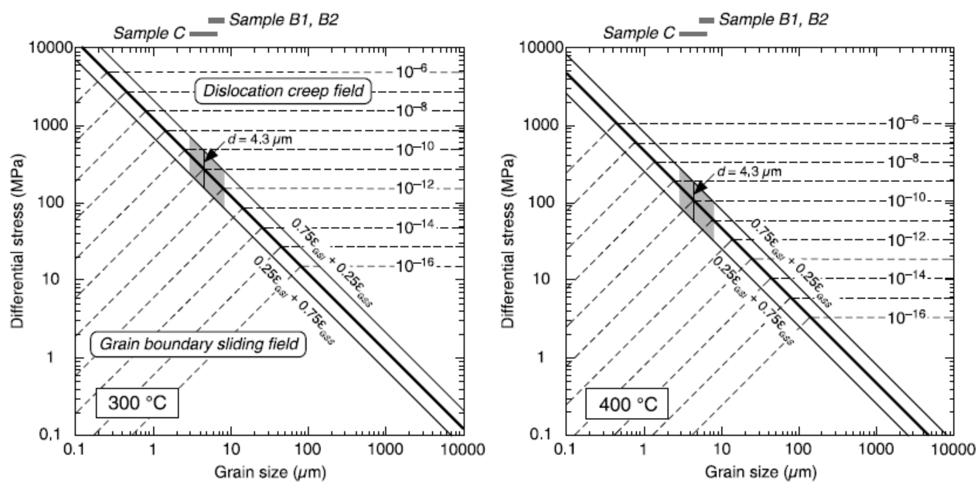
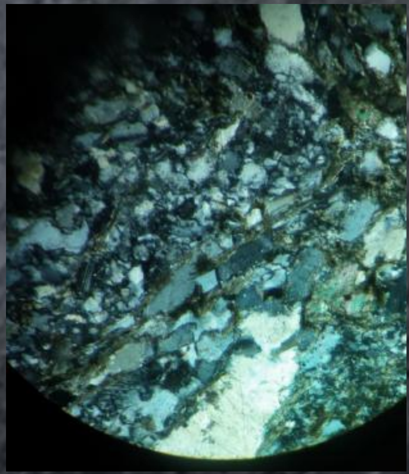


Figure 8. Flow stress versus grain size for a quartz aggregate at 300°C and 400°C for strain rates of 10^{-6} to 10^{-16} s^{-1}, showing the boundary between the fields of dislocation creep [*Hirth et al.*, 2001] and dislocation-accommodated GBS [*Gifkins*, 1976]. Horizontal bars at the top of each figure represent the grain sizes of quartz (1σ range) for samples B1, B2, and C, with stereological correction (see the text for details). For reference, the field boundaries are shown for the cases in which the relative contributions of GSI and GSS creep to the overall creep are $0.75\dot{\varepsilon}_{GSI} + 0.25\dot{\varepsilon}_{GSS}$, and $0.25\dot{\varepsilon}_{GSI} + 0.75\dot{\varepsilon}_{GSS}$. Shaded areas indicate the possible maximum ranges of grain sizes and resultant stresses.

(Okudaira, 2012)

Personal Results – Sample P5

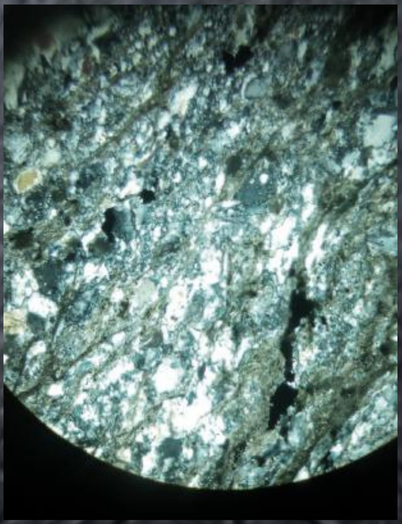
FOV: 2.0 mm



- Protomylonite
- Average deformed quartz grain diameter: 45 microns
- 3-d grain size = 45 microns x 1.7 = 76.5 microns
- Calculated Stress at 300° C, Strain Rate of 1.2 X10^{-11} s^{-1} : 228.4 MPa
- Calculated Stress at 400° C, Strain Rate of 1.2 X 10^{-11} s^{-1} : 52.0 MPa
- Changing the strain rate and temperature will change the stress values

PERSONAL RESULTS – SAMPLE P6

FOV: 2 mm



- Mylonite
- Average deformed quartz grain diameter – 10 microns
- 3-d grain size = 10 microns x 1.7 = 17 microns
- Calculated Stress at 300° C, Strain Rate of 1.2 X10 $^{-11}$ s $^{-1}$: 285.29 MPa
- Calculated Stress at 400° C, Strain Rate of 1.2 X 10 $^{-11}$ s $^{-1}$: 99.70 MPa

Conclusions

- My calculated stress values were similar to those calculated by Okudaira and Shigematsu.
- Therefore, grain size of deformed quartz in mylonites can be used to approximate the amount of stress that caused the deformation.

THANK YOU.