Mechanisms of Extensional Strain Localization: An Example from Cordilleran Metamorphic Core Complexes

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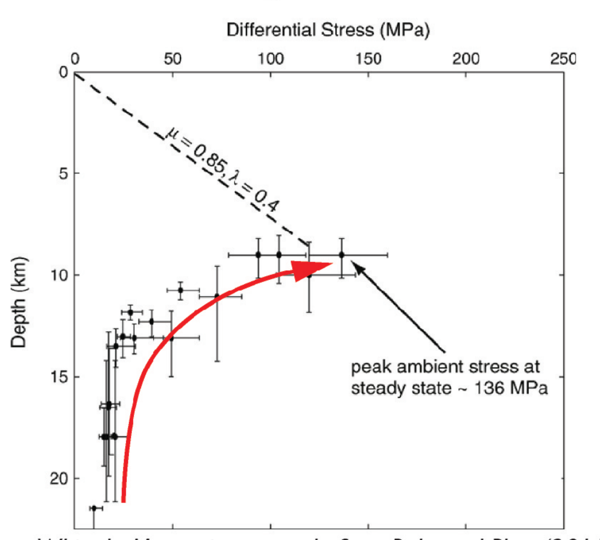
Motivating Questions

1) How do lithologic variations influence strain localization in extensional shear zones?

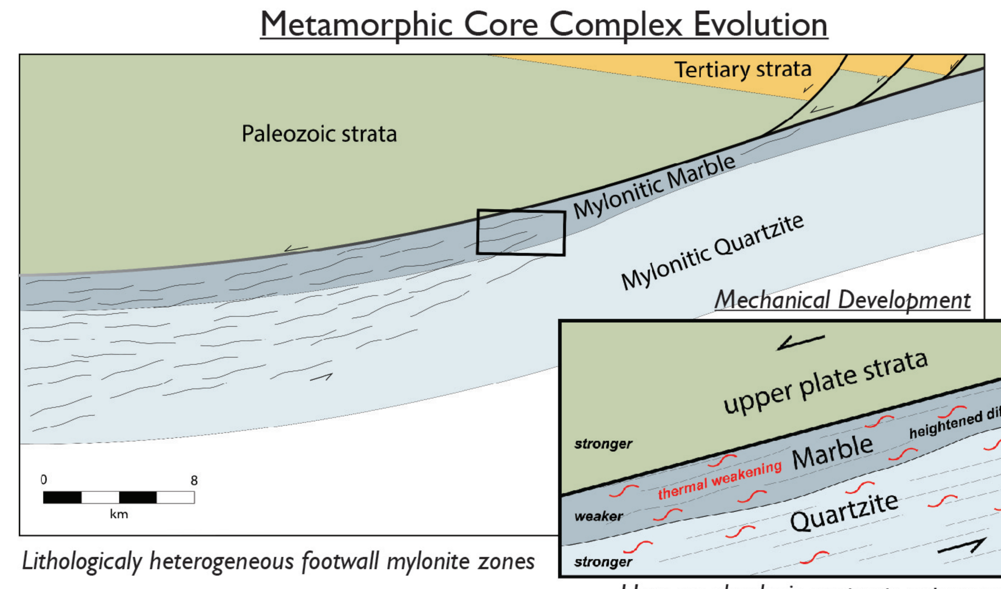
2) How does strain localization influence core complex evolution and extension rate?

Strength Evolution



Whipple Mountains example from Behr and Platt (2011)

Metamorphic Core Complex Evolution



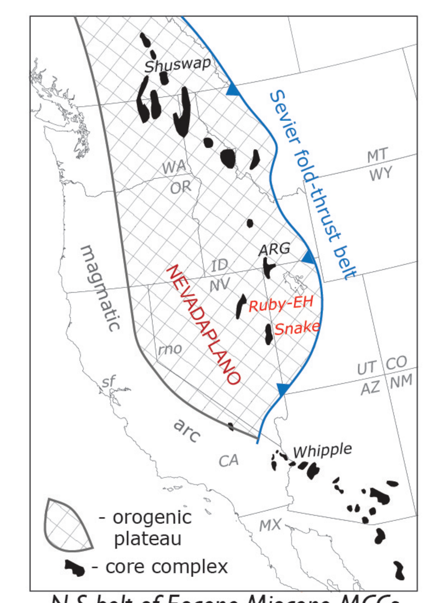
Lithologicaly heterogeneous footwall mylonite zones

How are rheologic contrasts expressed?

Extensional shear zones of the Basin and Range

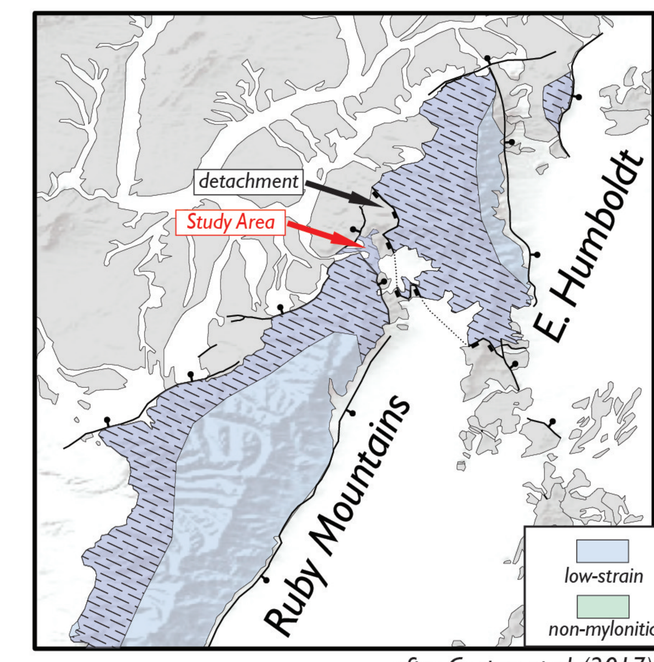
Cordilleran metamorphic core complexes are exceptional case study

North American Cordillera



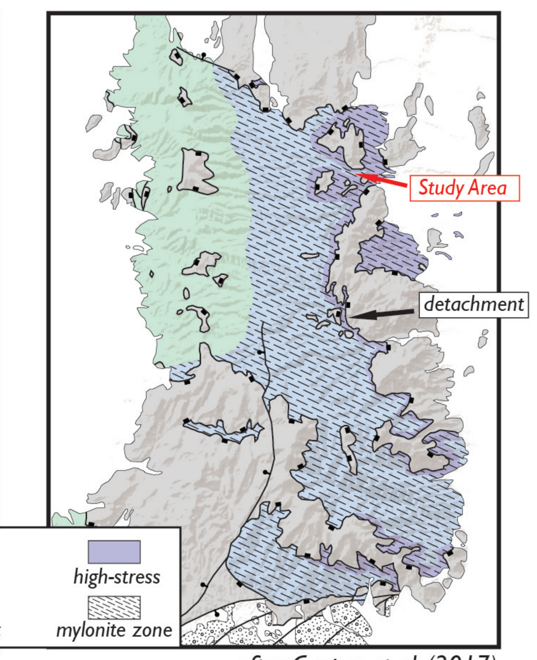
N-S belt of Eocene-Miocene MCCs after Whitney et al. (2013)

Ruby-East Humboldt MCC

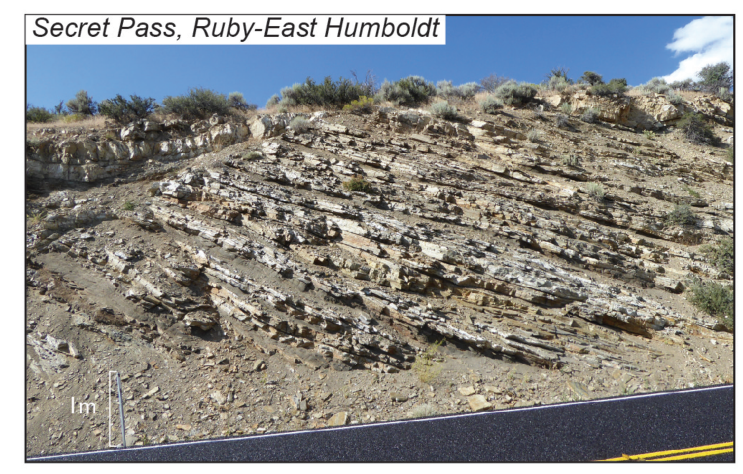


after Cooper et al. (2017)

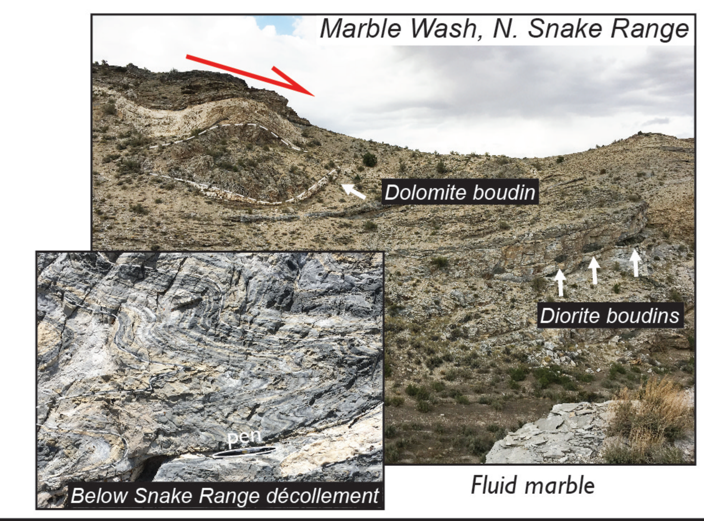
Northern Snake Range MCC



after Cooper et al. (2017)



Well foliated and lineated quartzite mylonite

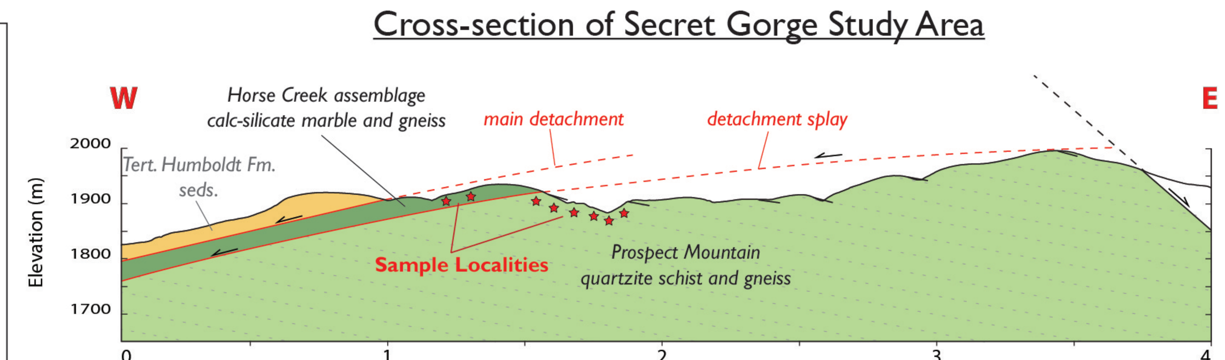


Fluid marble

Ruby-East Humboldt EBSD Analysis

- Peak metamorphism at 90-80 Ma (Hallett and Spear, 2015)
- Peak conditions: 3.5-9 kbar and 600-750 °C (Hurlow et al., 1991; Hallett and Spear, 2015)
- Onset of ductile extension at ~29 Ma (Wright and Snoke, 1993)
- Deformation T: ~ 450 - 650 °C (Hacker et al., 1990)
- Top-to-west unroofing complete in middle Miocene (Haines and van der Plujm, 2010)
- Main detachment underlain by detachment bounded slices of calc-mylonites

Cross-section of Secret Gorge Study Area

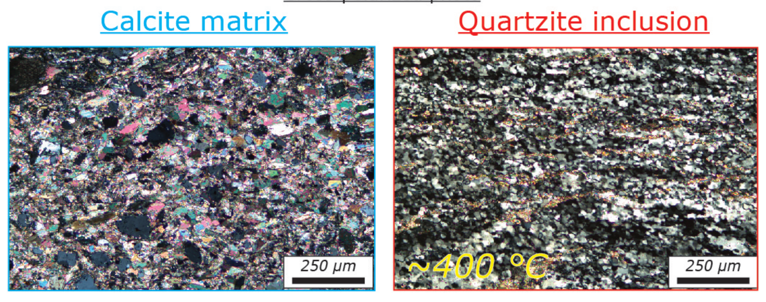


Calc-silicate marble

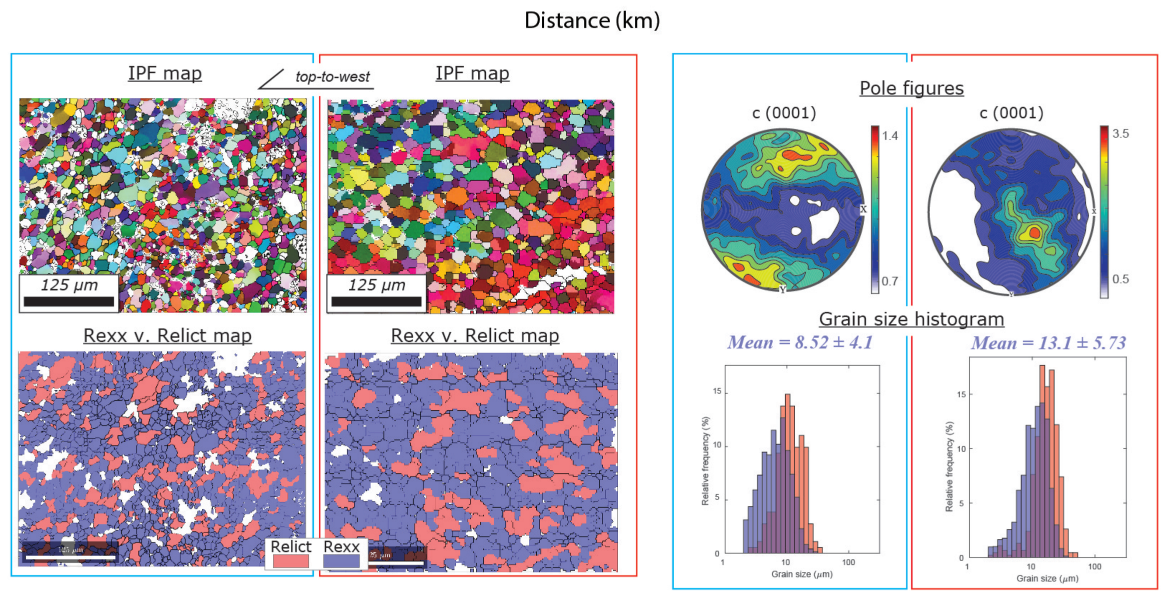
T = ~ 400 °C

Cross-polarized photo

Calcite matrix | Quartzite inclusion



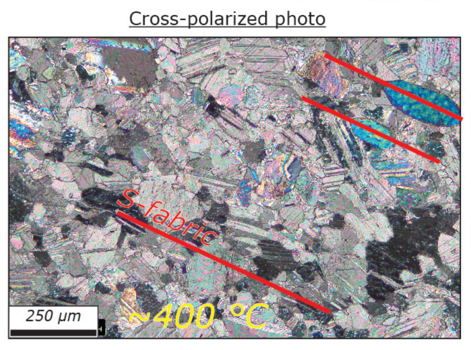
- No calcite twins
- Quartz SGR



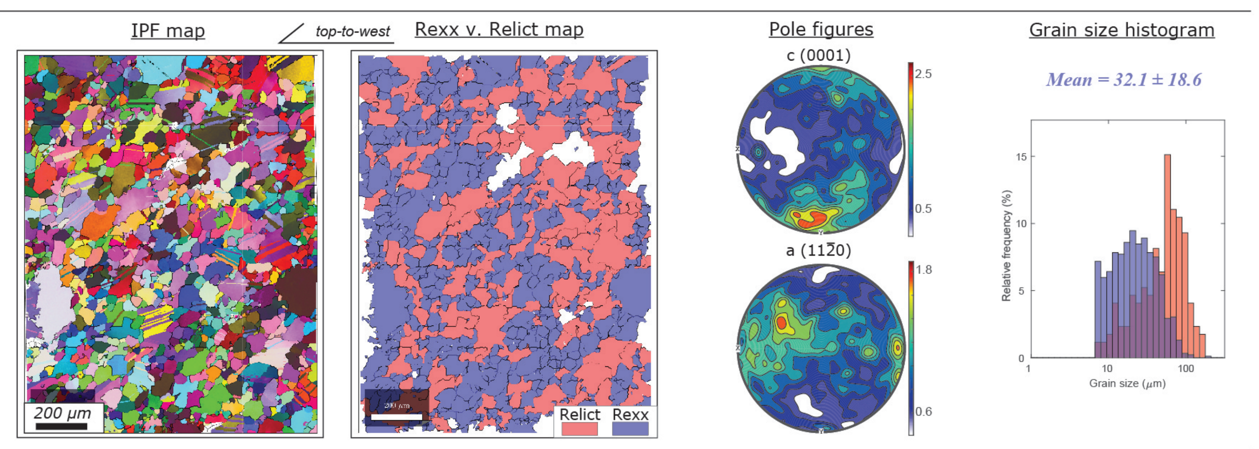
Calcite marble

T = ~ 400 °C

Cross-polarized photo



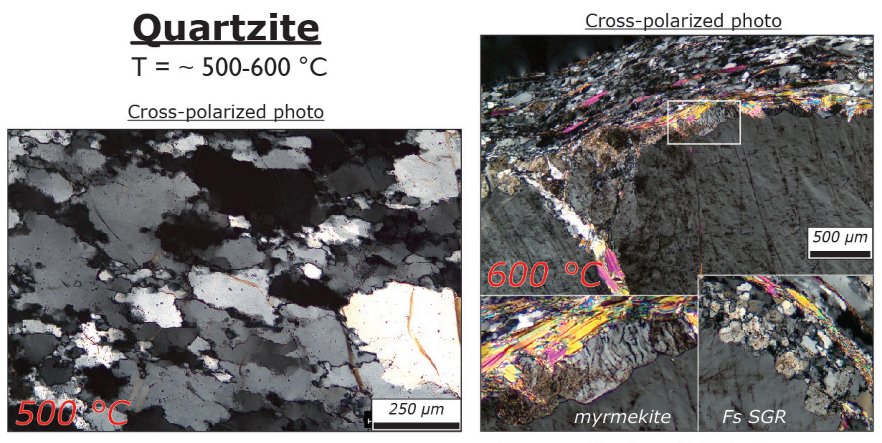
- Rexx calcite un-twinned
- Twinned grains record late-stage S-fabric



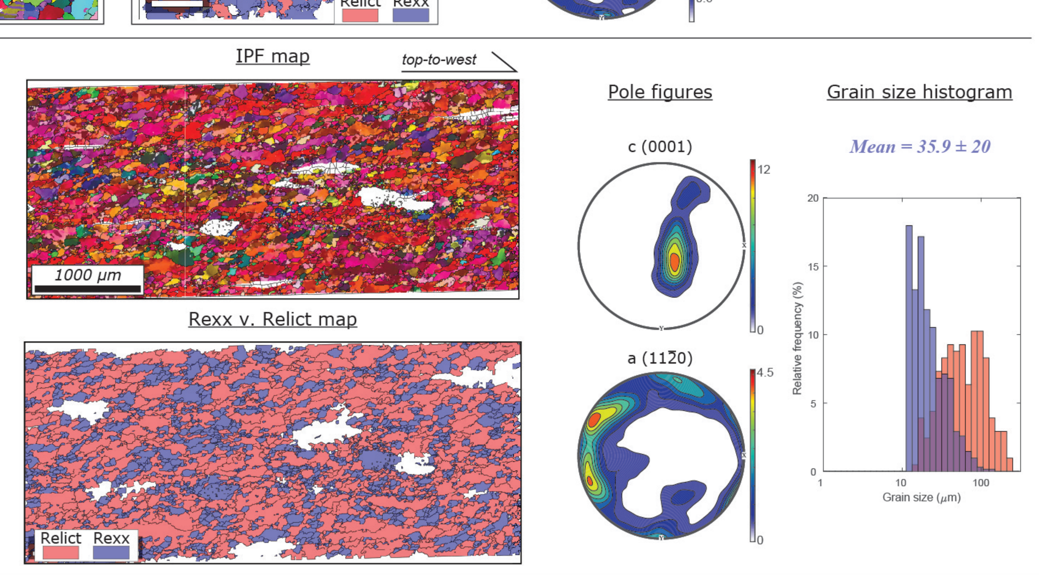
Quartzite

T = ~ 500-600 °C

Cross-polarized photo

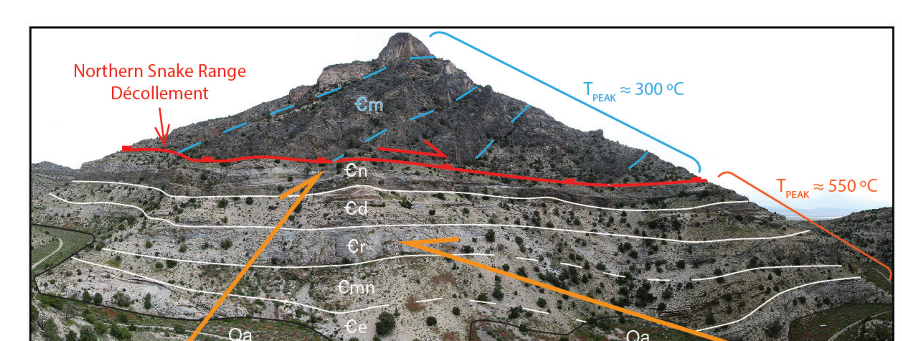


- Quartz SGR --> GBM
- Recrystallization of plagioclase
- Myrmekite development

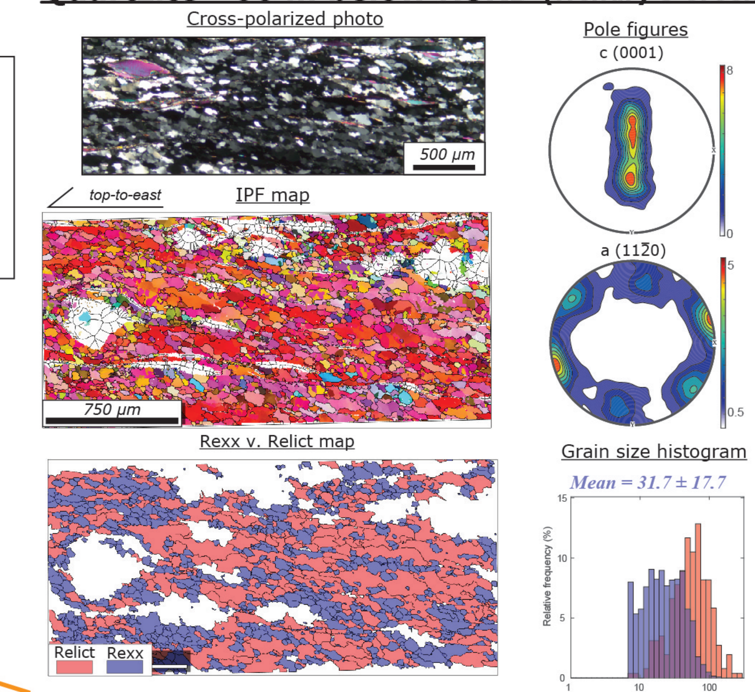


Snake Range EBSD Analysis

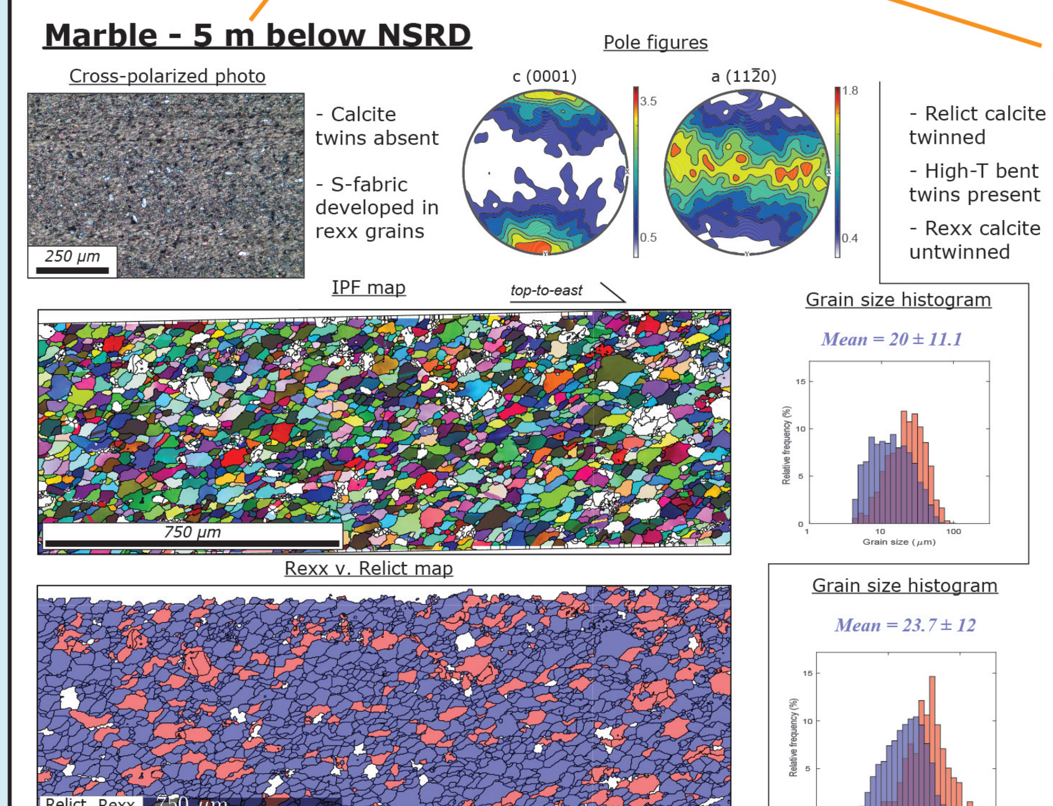
- Peak metamorphism at 88 Ma (Cooper et al., 2010a)
- Peak conditions: 6-8 kbar and 500-650 °C (Cooper et al., 2010a)
- Onset of ductile extension at 38 Ma (Lee et al., 2018)
- Deformation T: ~ 400 - 450 °C (Cooper et al., 2010b)
- Top-to-east unroofing complete at middle Miocene (Lee et al., 2018)



Quartzite - 60 m below NSRD (Hendry's Creek)



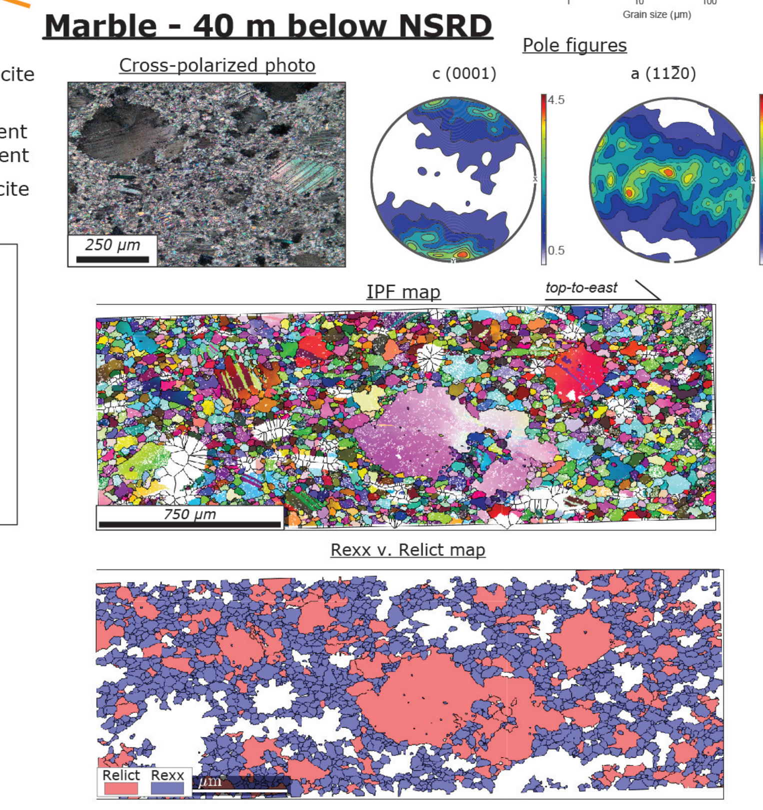
Marble - 5 m below NSRD



- Calcite twins absent
- S-fabric developed in rexx grains

Marble - 40 m below NSRD

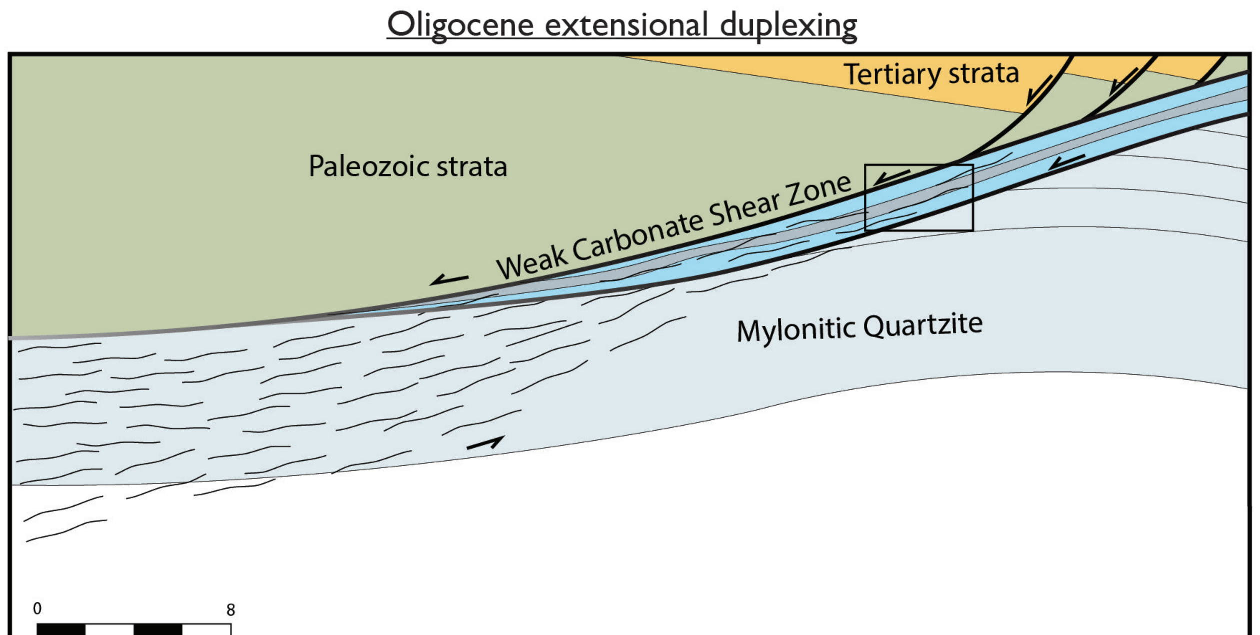
- Relict calcite twinned
- High-T bent twins present
- Rexx calcite untwinned



Strain Localization and Strain Rate Acceleration

- The Ruby-East Humboldt myolnite zone exhibits complex strain partitioning between quartzite pervasively intruded by leucogranite and a carbonate sequence intruded by diorite

Oligocene extensional duplexing

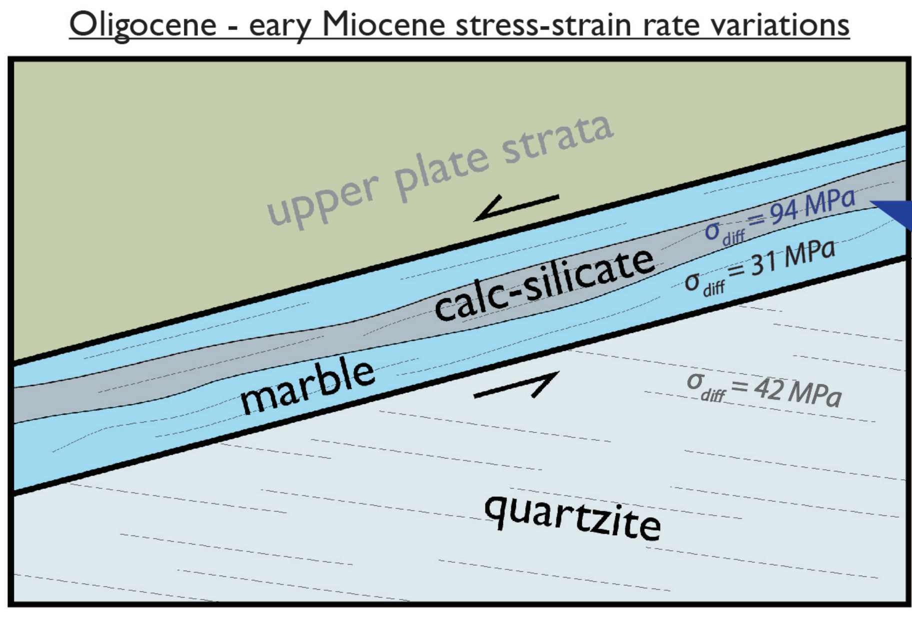


Shear zone evolution

- **Late Eocene - Oligocene** onset of mylonitization. Deformation at 500 °C recorded in quartzite mylonites
- **Oligocene** development of extensional duplex. Cooling to 400°C leads to rheologic contrasts favoring strain in the weak carbonate sequence.
- **Oligocene - early Miocene** high-strain deformation. Rheologic contrasts within carbonate shear zone leads to localized, high-stress high-strain rate zones.
- **Middle Miocene** deactivation of Ruby-East Humboldt detachment

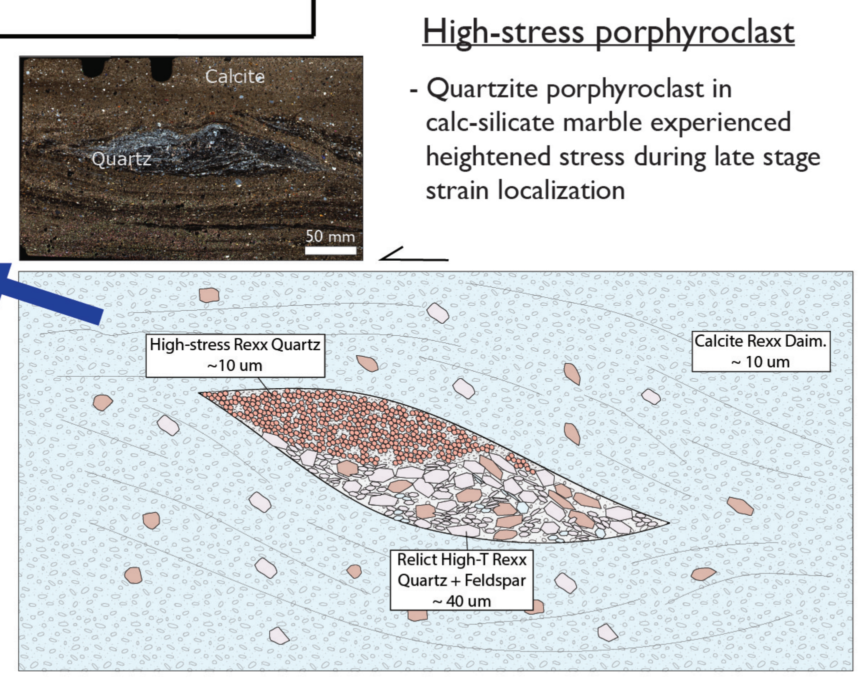
Based on thermochronology by: Dallmeyer et al., 1986; McGrew and Snee, 1994; Haines and van der Plujm, 2010;

Oligocene - eary Miocene stress-strain rate variations



High-stress porphyroclast

- Quartzite porphyroclast in calc-silicate marble experienced heightened stress during late stage strain localization

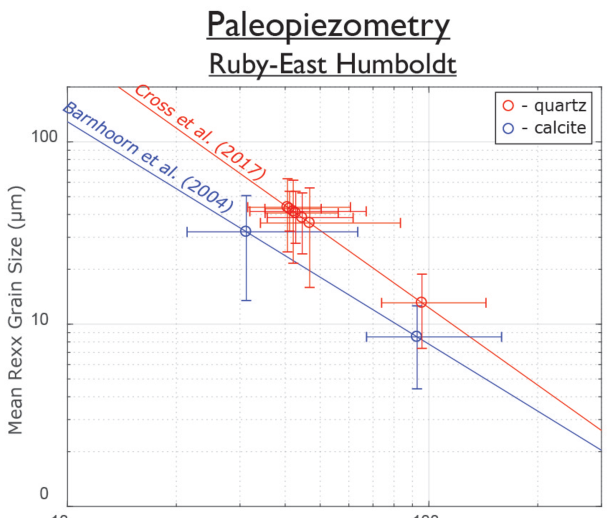


Rheologic influence on shear zone development

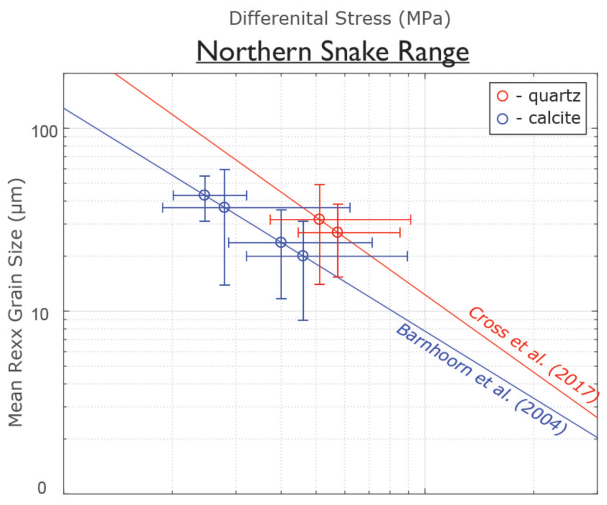
- Strain localization in weak carbonate rocks accelerates extension

Paleopiezometry

Ruby-East Humboldt



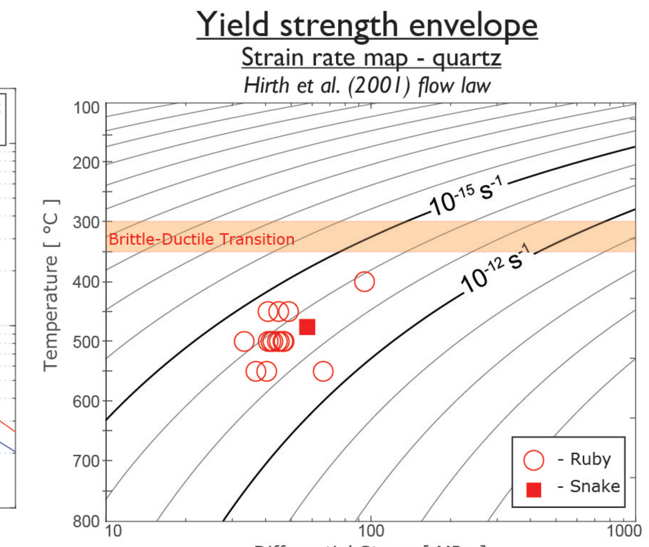
Northern Snake Range



Yield strength envelope

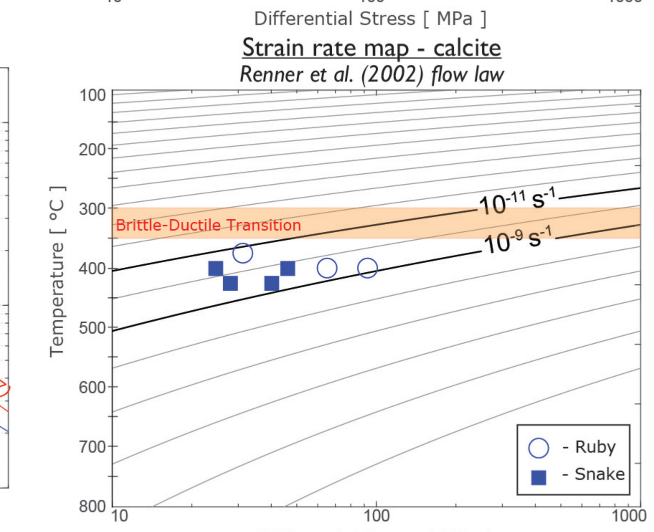
Strain rate map - quartz

Hirth et al. (2001) flow law

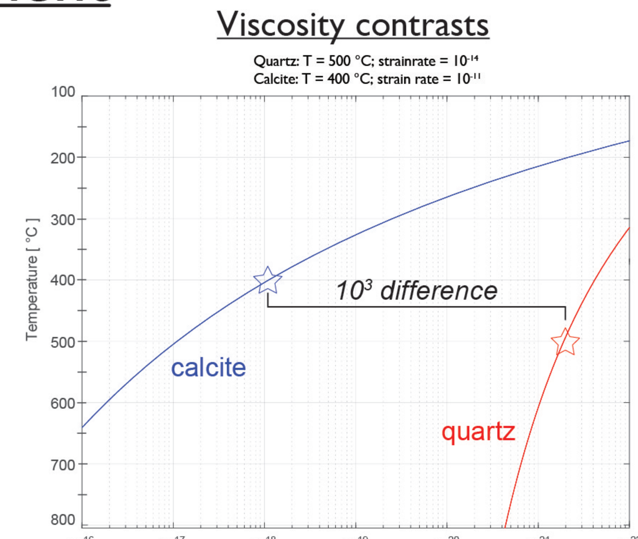


Strain rate map - calcite

Renner et al. (2002) flow law

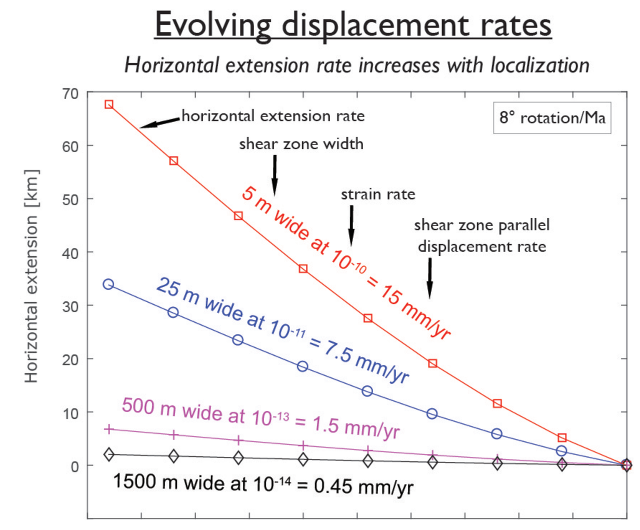


Viscosity contrasts



Evolving displacement rates

Horizontal extension rate increases with localization



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