DO INCREMENTALLY DEVELOPED SLICKENFIBERS RECORD ETS?

Observations from the Baraboo Syncline, WI, USA

Allison D. Jones, Laurel B. Goodwin, Philip E. Brown, Randolph T. Williams

December 10, 2019
DO INCREMENTALLY DEVELOPED SLICKENFIBERS RECORD ETS?
OBSERVATIONS FROM THE BARABOO SYNCLINE, WI, USA

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CAN QUARTZ SLICKENFIBERS PRECIPITATE ON ETS TIME INTERVALS?

PROBABLY NOT.

ALLISON D. JONES, RANDOLPH T. WILLIAMS, LAUREL B. GOODWIN, PHILIP E. BROWN

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WHERE WE ARE HEADED

01 Episodic Tremor and Slip (ETS)

02 Are quartz slickenfibers a record of ETS?

03 Is quartz precipitation fast enough?
EPISODIC TREMOR AND SLIP (ETS) AND WHY WE CARE

Characterized by:
- Occurrence near **seismic-aseismic transition**
- Near-lithostatic fluid pressures
- Repeats: weeks to a few years

Implications:
- May transfer stress to locked seismogenic zone
- Underlying deformation mechanisms are poorly understood
  - **Missing geologic record** of ETS

SLICKENFIBERS: A POSSIBLE RECORD OF ETS

- Irregularities in fault surface allow space to open during slip
- Slip increments delineated by planes of fluid inclusions
- Slip increments of ~20-40 μm = 3-30 kPa stress drops
- Identified in exhumed subduction zones at temperatures ~300-500ºC (Fagereng and Cooper, 2010)

Modified from Fagereng et al. (2011)
SEALING REQUIRES QUARTZ TO PRECIPITATE IN DAYS-YEARS

- Quartz growth rates would need to be **10-100 µm/year** to accomplish slickenfiber formation in ETS timescales.
- Near equilibrium, quartz growth rates are unlikely to exceed ~**10^-3 µm/year**
  - Too slow for ETS

Temperature (°C) vs. Quartz Growth Rate (µm/yr) graph with kinetic rate estimates and growth rates inferred for slickenfiber record of ETS.

Lander et al., (2008)
LARGE, RAPID DROPS IN FLUID PRESSURE MAY FACILITATE QUARTZ PRECIPITATION

Ujiie et al., (2018) propose a solution:

- Reducing pore fluid pressure could increase quartz supersaturation and growth rates
- Requires pressure drops of 160-240 MPa (lithostatic-hydrostatic)
WHY THE BARABOO SYNCLINE?

Marshak et al. (2016)
Quartz slickenfiber cut parallel to slickenline and perpendicular to fault plane
Secondary fluid inclusion planes **cross-cut and are cut by quartz subgrains and new grains**

- 25 ± 9 micron spacing; <5 micron inclusions
- Fluid inclusions could tell us something about **fluid pressure during slip increments**
Kaolinite + 2 quartz = pyrophyllite + water

- 280-330°C
- Near the seismic-aseismic transition
- ~12 km depth assuming geothermal gradient of 25°C/km
Secondary FIs will tell us something about the fluid pressure at the time of entrapment.

Two measurements:

- $T_h$: temperature at which the fluid homogenizes (minimum trapping temperature)
- $T_m$: temperature at which the inclusion melts after freezing (salinity estimation → density)
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FLUID INCLUSION ANALYSIS

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Two measurements:

- $T_h$: temperature at which the fluid homogenizes (minimum trapping temperature)
- $T_m$: temperature at which the inclusion melts after freezing (salinity estimation → density)
T_h and T_m are not significantly different ($p<0.10$) from sample to sample

- Median salinity $\sim 12$ wt.% NaCl equivalent
- Median density $\sim 0.98$ g/cm$^3$
Fluid pressure at entrapment \(~110-320\) MPa (95% confidence)

Evidence for \textit{overpressured fluids}
ENTRAPPED FLUID PRESSURES

- Removed any Th>330°C
- Excluded pressures outside of hydrostatic-lithostatic range:
  - For 280°C: 104-278 MPa
  - For 330°C: 123-330 MPa
PERMISSIBLE PRESSURE DROPS (ARE TINY)

- Randomly sampled 10,000 pairs of pressures; treat absolute value of the difference as pressure drop
- Permissible pressure drops:
  - Assuming 280°C: <135 MPa
  - Assuming 330°C: <160 MPa
IN SUMMARY

- Fluid inclusions constrain fluid to ~110-320 MPa during slickenfiber formation.
- Pressures inferred from fluid inclusions permit (but do not require) pressure drops.
- Pressure drops (if present) were not as large as previously predicted (maximum of ~160 MPa but likely much smaller).
  - Suggests quartz precipitation rates here may not be as fast as previously estimated.
  - Large lithostatic-to-hydrostatic pressure drops likely did not occur.
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References


