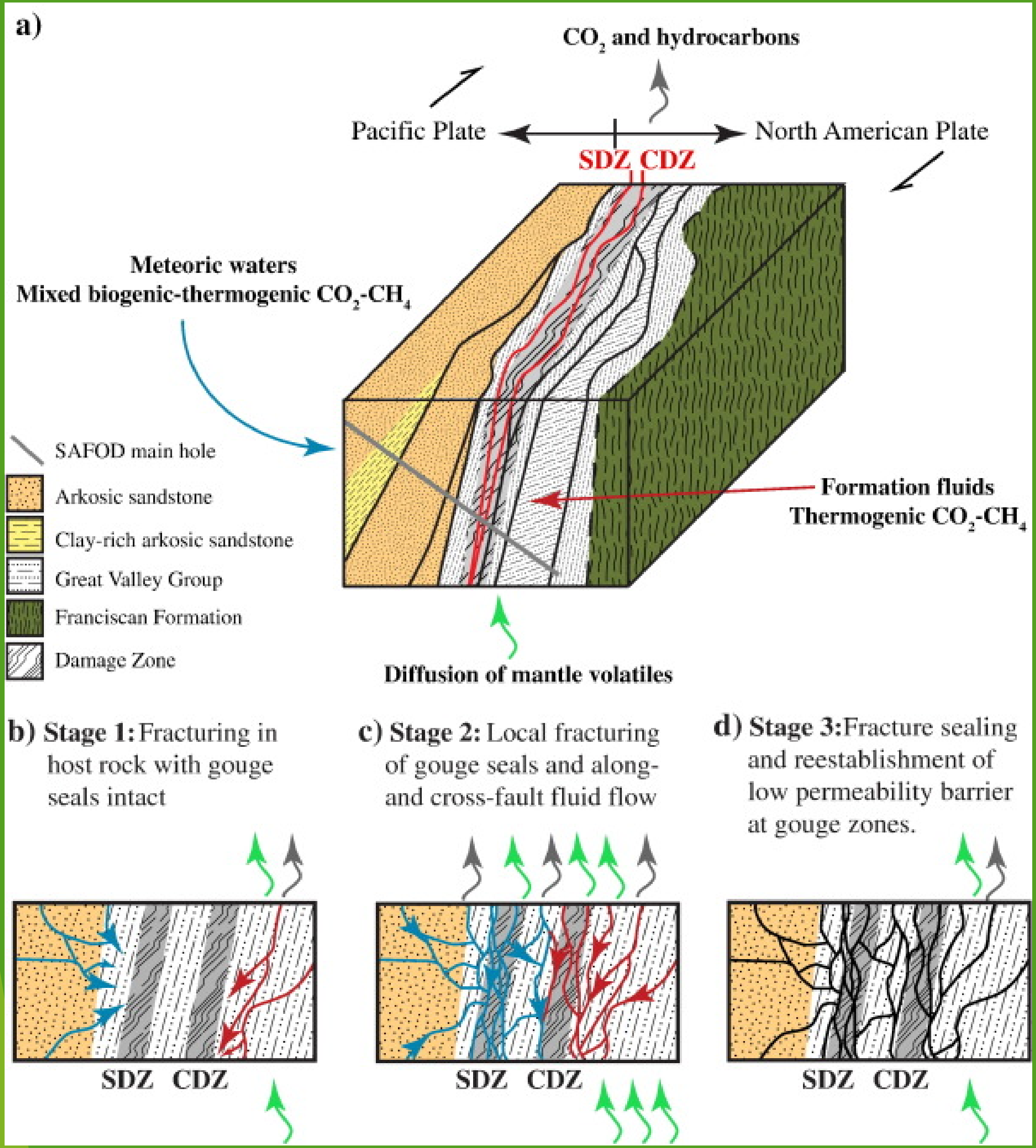
San Andreas Fault Analysis

The Influence of Temperature, Sliding Velocity, and Rock Composition at Depth On Fault Mechanics

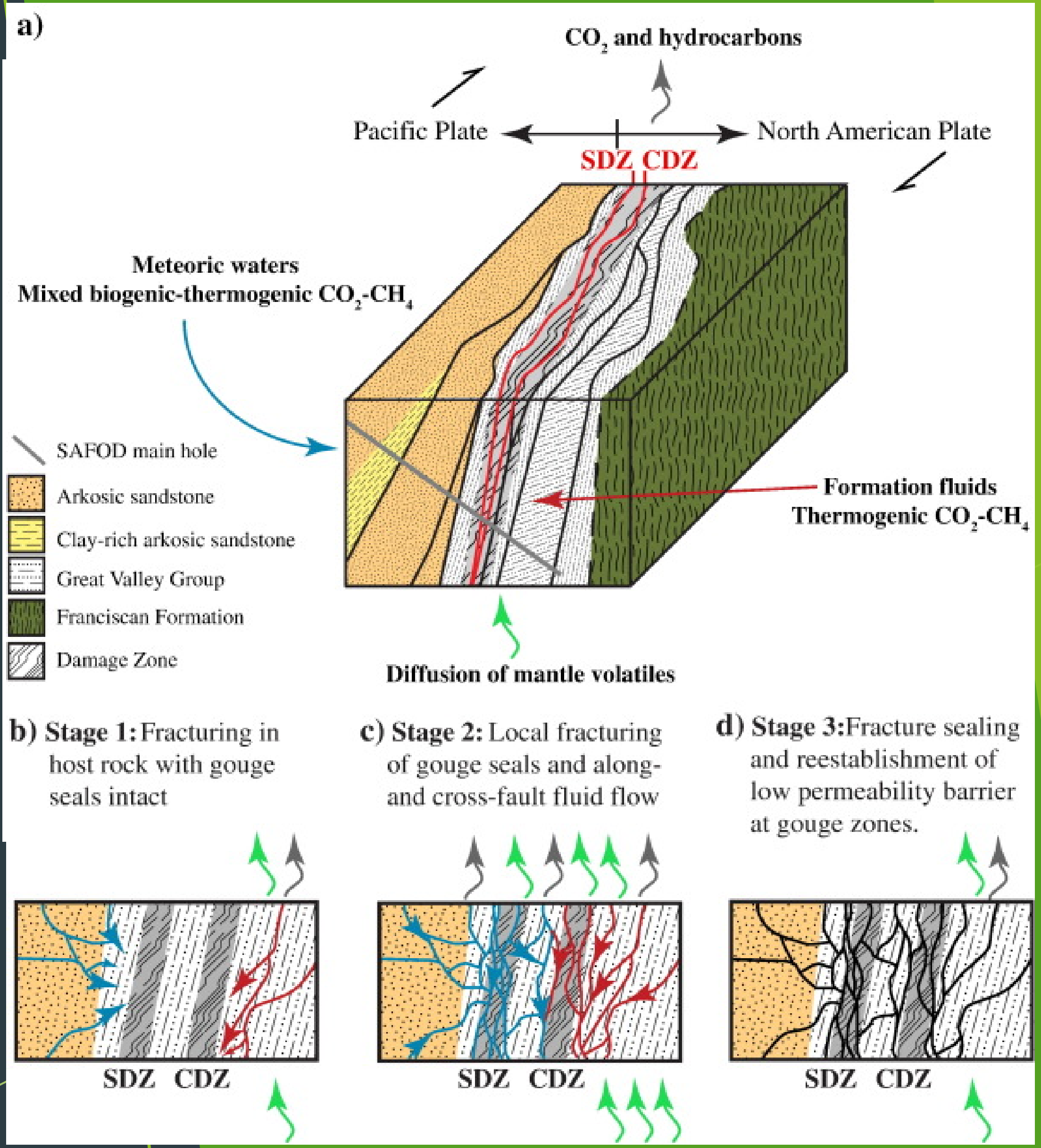
Background

- San Andreas Fault Observatory at Depth (SAFOD)
- Sample recovery of cores containing the two strands of foliated gouge where creep was identified: the central deforming zone (CDZ) and the southwest deforming zone (SDZ)
- Creep processes previously determined only sampled room-temperature data, not applicable to deeper portions of the seismogenic zone.
- Seek to evaluate fault gouges of different compositions, under different conditions.



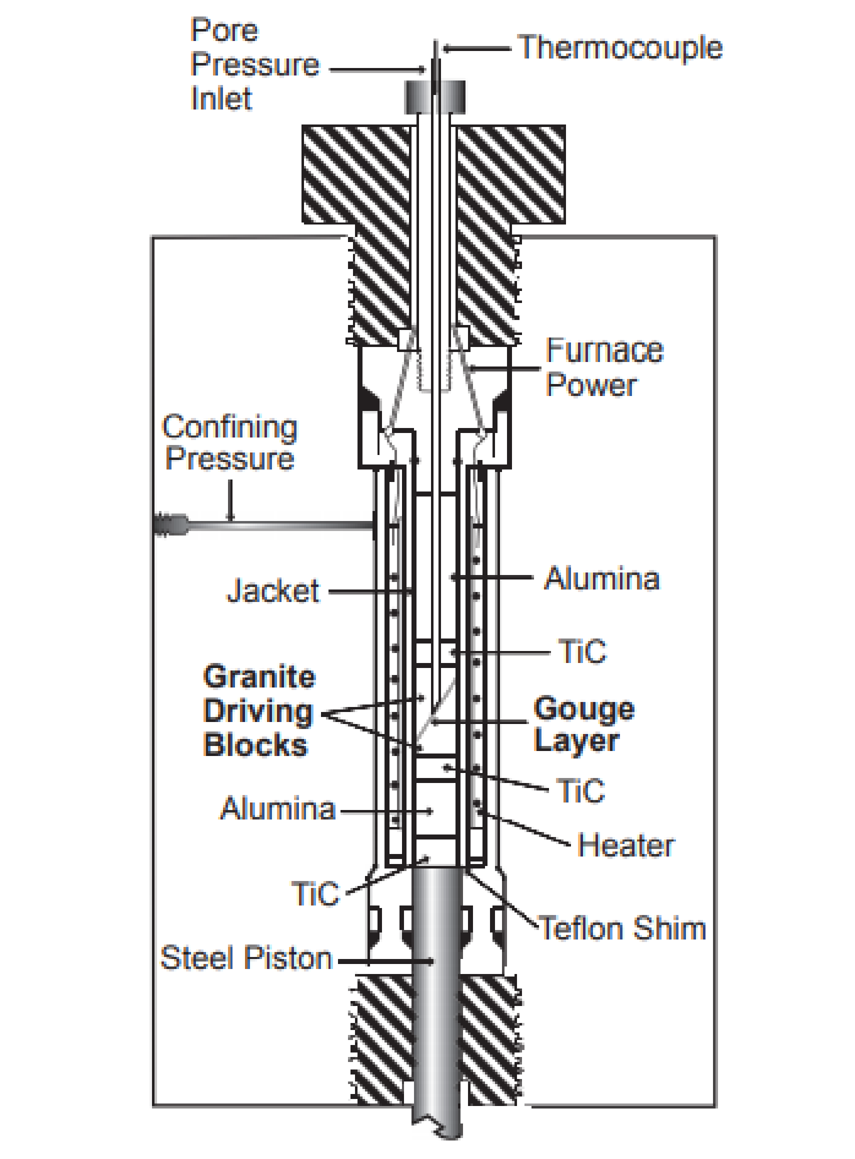
Methods

- New testing required to represent changes in coefficients of friction for rocks at deformation depth of over 3000m and high temperatures
- The study focused on the responses of four different materials to changes in temperature and velocity.
- Four samples were used to represent differences between fault mechanisms for the four major geological components of the SAF.
- Four synthetic gouges prepared from bulk rock specimens XRD analysis and known coring samples to simulate sliding behavior under varying conditions



Methods

- Triaxial friction experiments
- All experiments were run at 60 MPa pore-fluid pressure and 160 MPa normal stress, yielding a constant effective normal stress of 100 Mpa, at temperatures in the range 25-250 C and at axial velocities of 0.001-10.0 μm/s
- Each sample consisted of an initially 1-mm thick layer of gouge smeared along a 30º sawcut in a Westerly granite cylinder (19.1 mm diameter). The gouge was applied to the lower driving block as a thick paste prepared with the same synthetic “brine” approximating in situ groundwater chemistry at SAFOD
- Data compiled into plots of coefficient of friction, μ, versus displacement for the experiments conducted on the Great Valley, Franciscan, SDZ, and CDZ samples. To allow for direct comparison, the 250 °C strength data at two velocities are compared with those at 25-200 °C



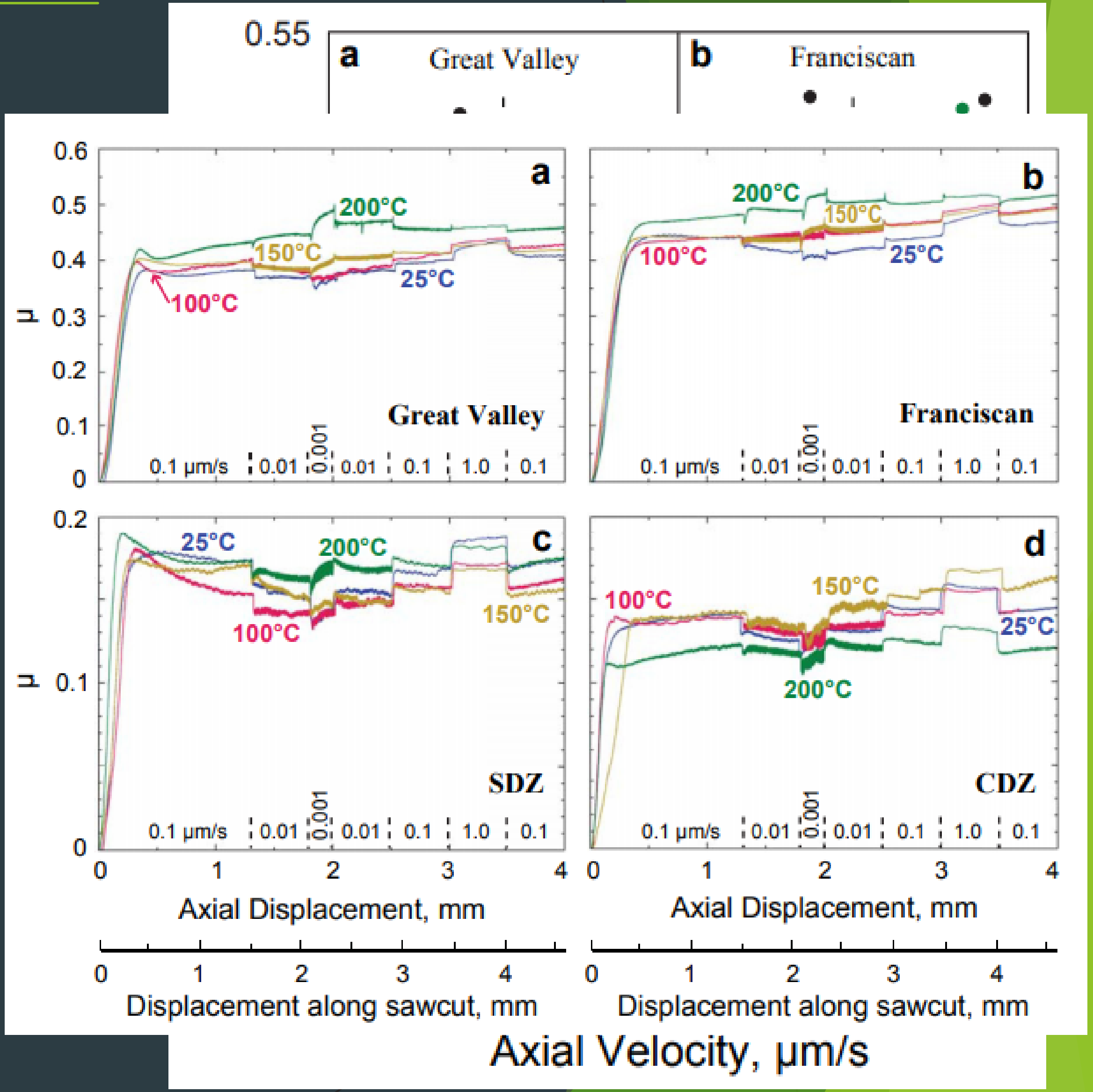
Effects of Temperature and Velocity

- The Great Valley sequence and Franciscan Complex samples are both characterized by modest increases in strength at T > 150 ℃ and a progressive change from purely velocity-strengthening behavior (creep) at T 100 ℃ to largely velocity-weakening behavior (locked fault) and stick slip at 250 ℃.

- Data shows difference in fault regimes at different temperatures

- The CDZ velocity data differ substantially from the Great Valley and Franciscan results.
    - there is no obvious correlation with either velocity or temperature.

- The SDZ, however, does show some similarities to the G.V. and Franciscan samples, in that μ decreases with decreasing velocity and increasing temperature



Conclusions

- Elevated temperatures cause CDZ, which is very weak and velocity strengthening at room temperature, to weaken further and remain velocity strengthening at higher temperatures (high temp = weaker + increased friction with increased velocity).
  - The heated CDZ data could explain the continued weakness and stable slip of the creeping section as a result of weakened clay mineral deformation

- In country rock the strengths increase progressively with increasing temperature above 150 ºC. The strengthening is accompanied by a transition from velocity-strengthening to velocity-weakening and stick-slip behavior.

- Determined that fault gouge at depth subjected to higher temperatures and different mineral assemblages is likely to behave as a locked fault.

- The differences between the CDZ's and the country rock's mineral compositions could prove to be the cause of differential fault movement mechanics along the SAF.

Future Analysis

- The likelihood that clay minerals are not present at T > 150 ºC in the fault makes the applicability of the higher temperature data uncertain, depending on its abundance and distribution in the fault.

- Future examination of exhumed shear zones of similar lithologic character may provide clues to the nature of the SAF creeping section at seismogenic depths.

Hydrothermal frictional strengths of rock and mineral samples relevant to the creeping section of the San Andreas Fault

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