Experimental and Geological Studies on Slip Process in the Deep Extensions of Seismogenic Faults

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Purpose

Large inland earthquakes can occur directly below the populated areas.

To understand the mechanism by which inland earthquakes occur.

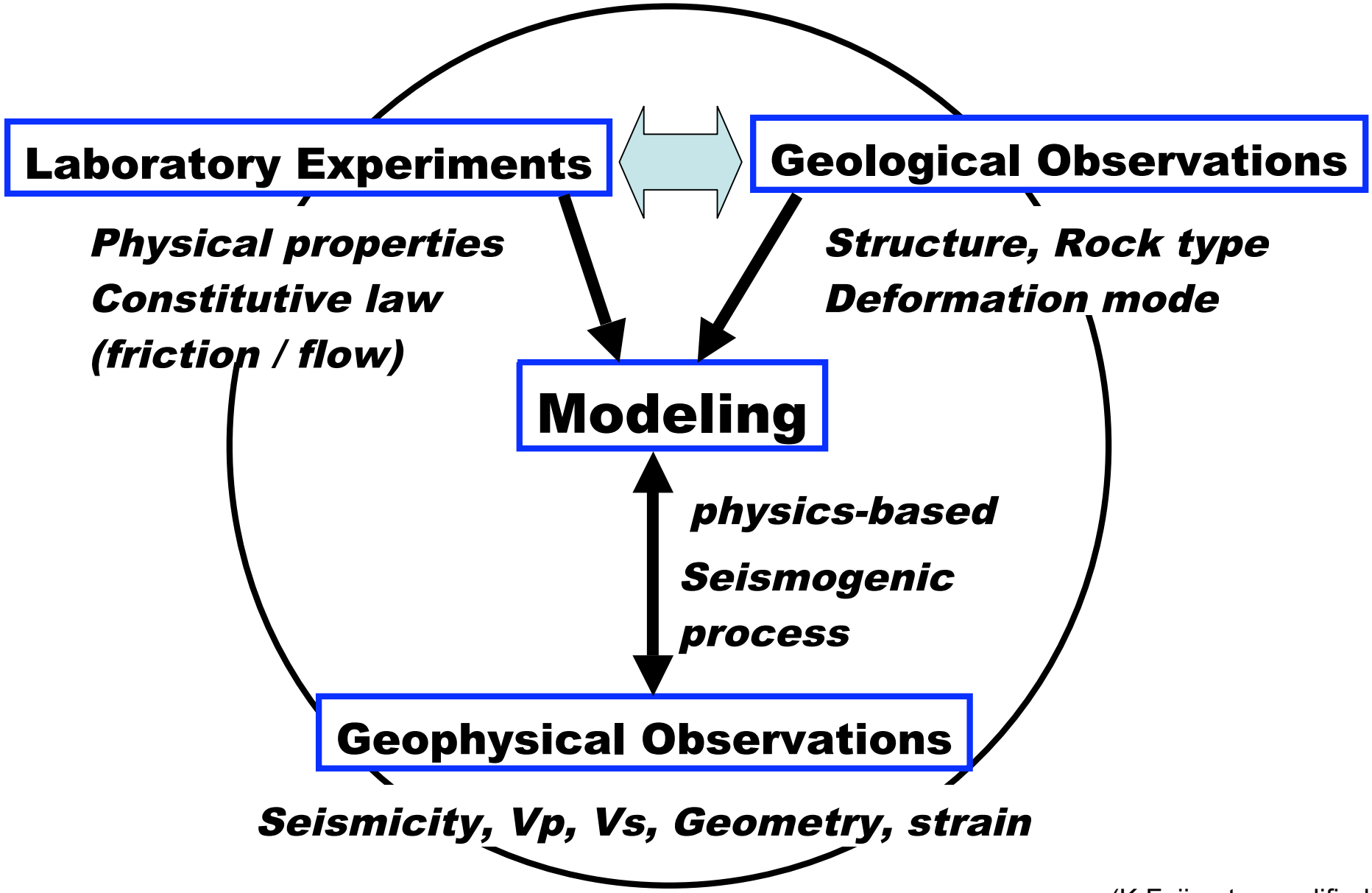
To establish physics-based forecast methods.

GSJ/AIST

(1) Geological studies on the exhumed fault zones.
(2) Geophysical measurements of natural fault materials from seismogenic zones.
(3) Laboratory studies under high-pressure and high-temperature conditions.

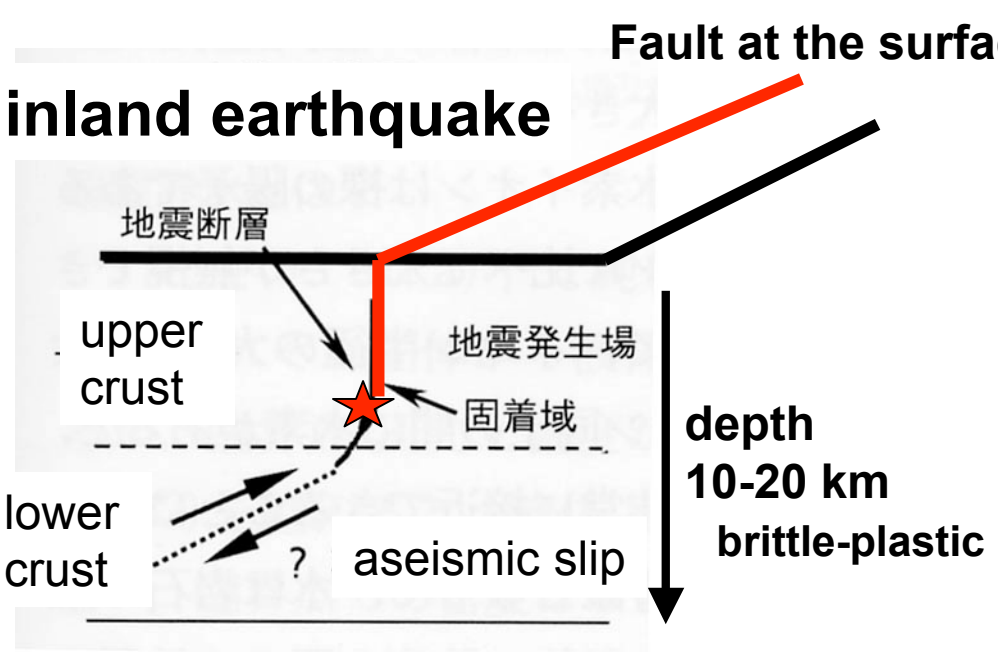
Outline

- Mechanical properties of the fault zone from brittle to ductile regime
- Gas-medium HPT apparatus developed
- Frictional properties of fault surface (mylonite)
- Frictional properties of gouge (feldspar, quartz)
- Effects of water, chemical reaction



(K.Fujimoto, modified)

Focal depth of strong inland earthquake



Conditions

High Pressure

High Temperature

Presence of water

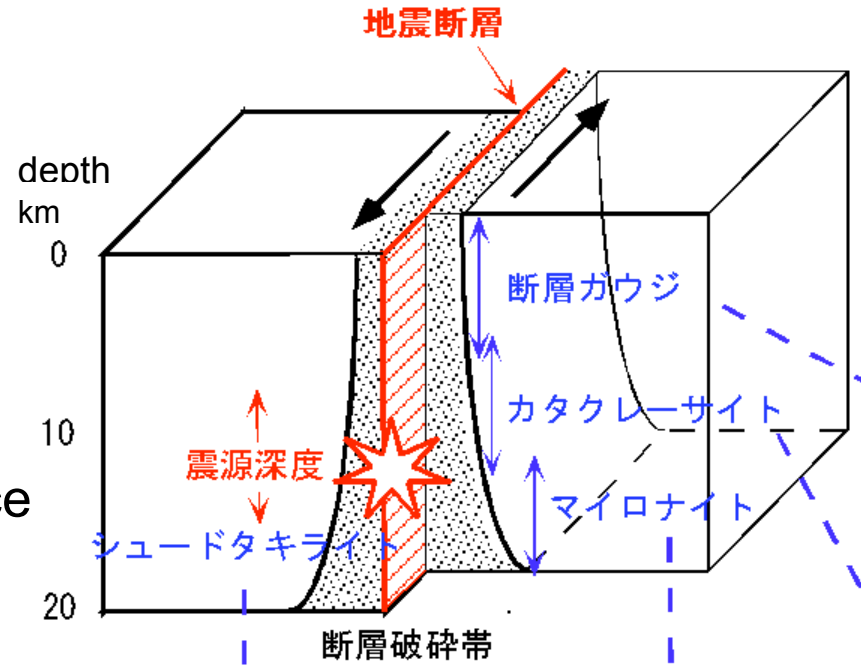
（1995 Kobe eq. photos by Masuda 1/22/95）

Geological studies on the exhumed fault zones

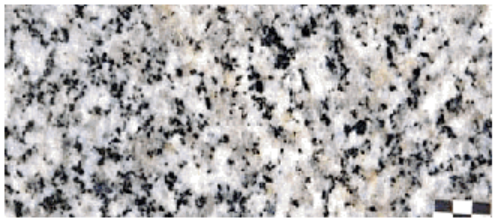
Seismogenic depth in the past

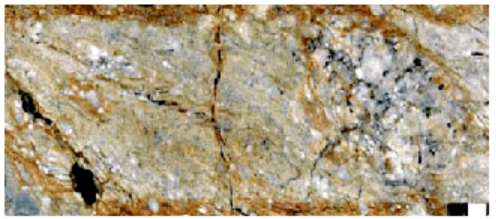
Now at the surface

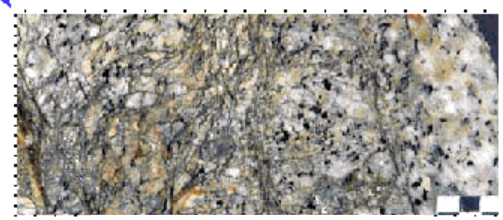
Geological observations



Unaltered country rock

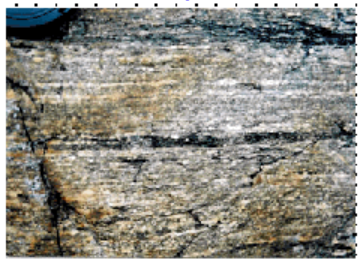






brittle fracture

pseudotachylite



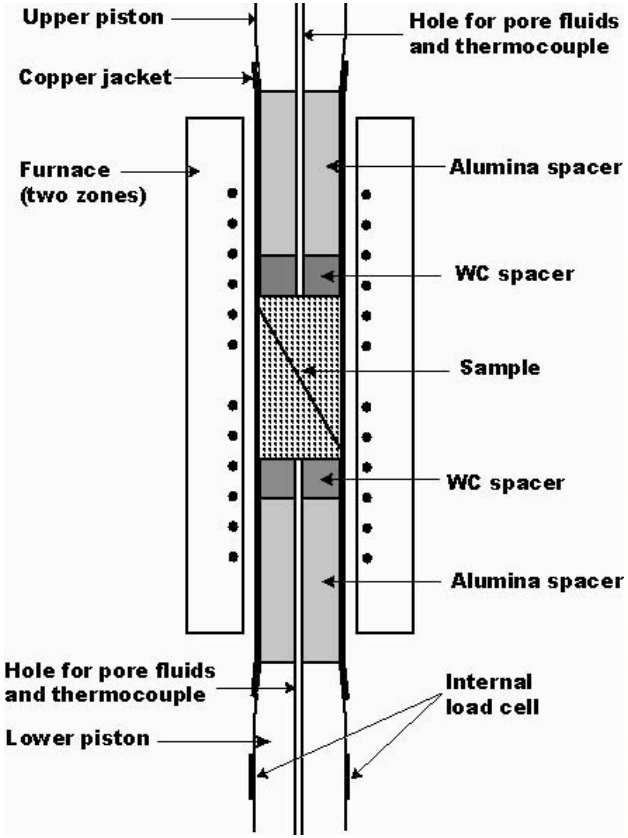
plastic deformation

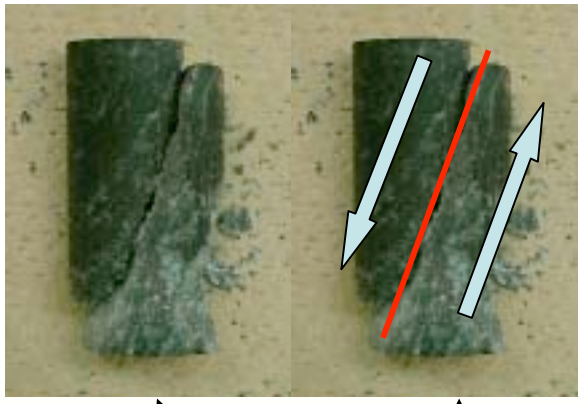
(K. Fujimoto, modified)

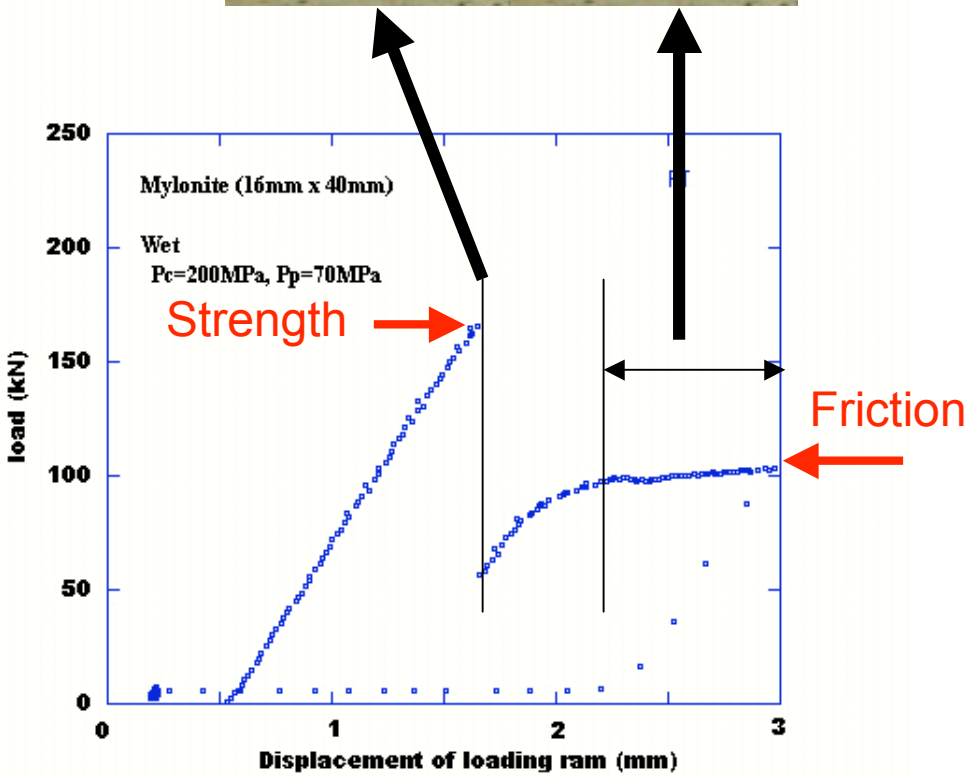
Gas-medium high-pressure and high-temperature apparatus (Geological Survey of Japan, AIST)

Max. Pc=200MPa (Ar-gas)
Max. Pp=200MPa (water or Ar-gas)
Max. T=800C
Deformation & fracture experiments, measurements of physical properties

Frictional properties of mylonite surface

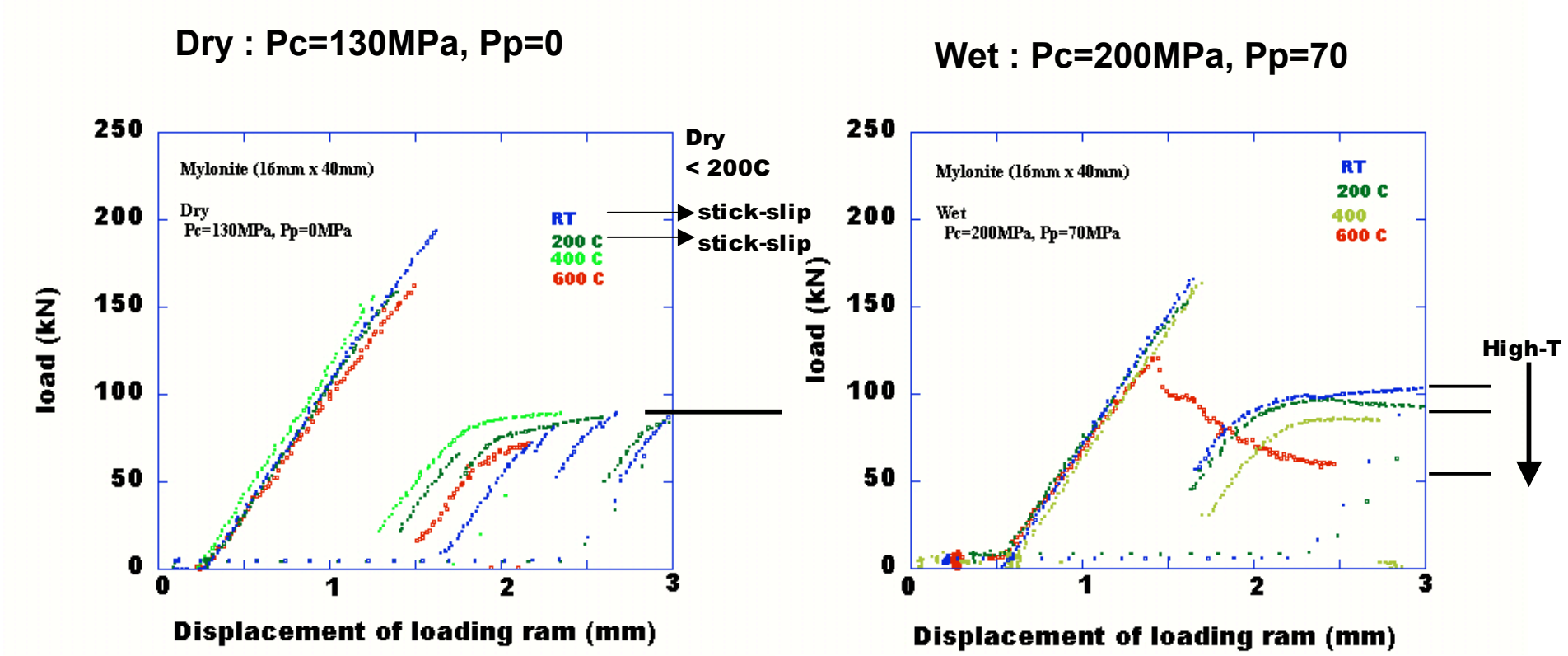






Dry: Pc=130MPa, Pp=0
Wet: Pc=200MPa, Pp=70MPa
（Effective Pc=130MPa）
Temperature:　RT to 600C

Frictional properties of mylonite surface



Friction of fault surface (mylonite)

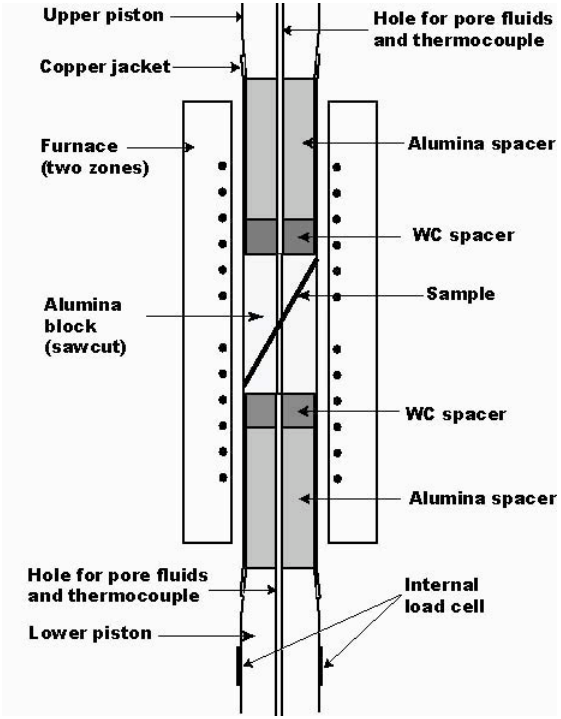
- Even under the same effective confining pressure, presence of pore water reduces the peak shear stress at 600C.
- In the dry condition (Pc=130MPa,Pp=0), stick-slip behavior observed less than 200C.
- In the wet condition (Pc=200MPa, Pp=70MPa), friction decreased as temperature increased.

Frictional properties of feldspar and quartz gouge

- Frictional properties of materials at the source region (5 to 20km, 100 to 350C)
- Frictional experiments, the physical properties of rocks using granite gouge.
- evaluate the physical properties of each minerals, feldspar and quartz (mica, biotite, clay minerals, …..)
- Feldspar (Ab, An) and quartz gouge

  (about 3 micron m diameter) H-T & H-P
- effects of water to the frictional coefficients

Frictional properties of fault materials

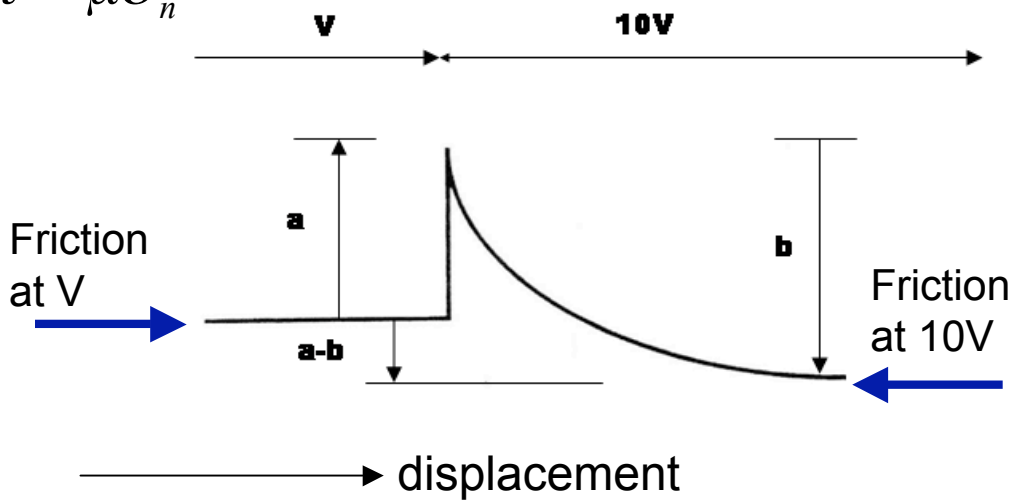


- Qz, Feldspar (Ab)
- Velocity-stepping test
  (V= 0.5μm/s, 5μm/s)
- Dry (Pc=150MPa, Pp=0)
- Wet (Pc=200MPa, Pp=50MPa)
- Temperature: RT to 600C

Rate- and state-variable friction law

$$\mu = \mu_* + a\ln(\frac{V}{V_*}) + b\ln(\frac{V_*\theta}{L}), \qquad \frac{\partial \mu_{SS}}{\partial[\ln V]} = a - b$$

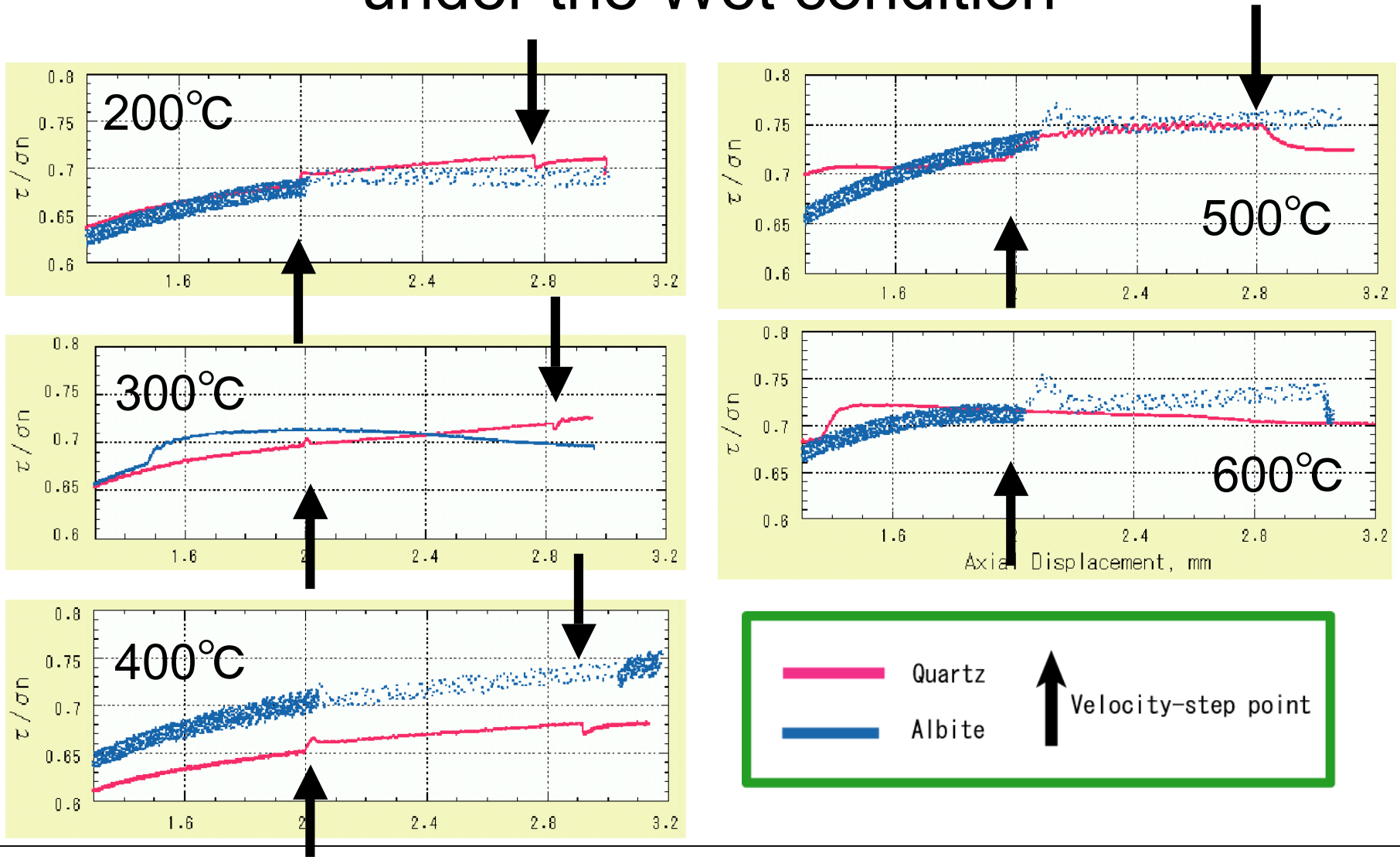
$$\tau = \mu\sigma_n$$



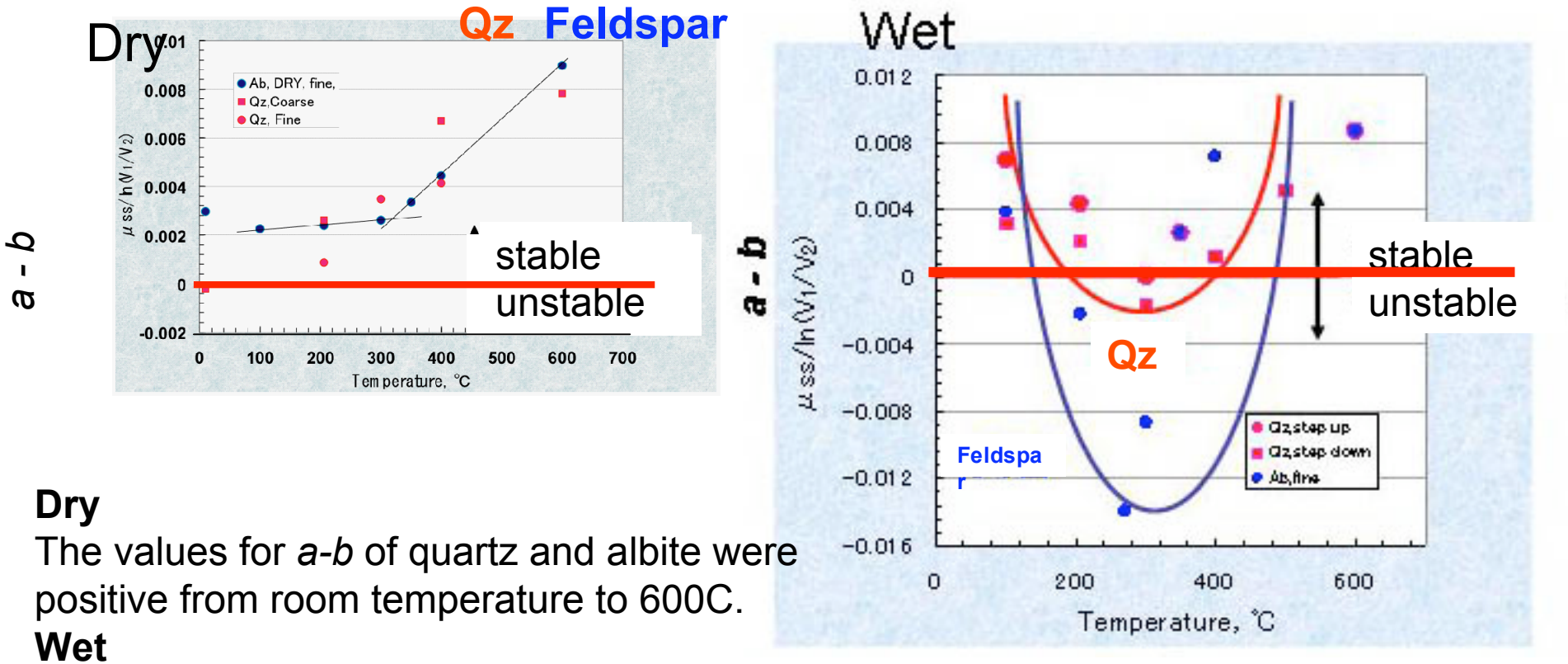
$a\text{-}b \geqq 0$ stable

$a\text{-}b < 0$ unstable

Frictional curves for feldspar(Al) and quartz under the Wet condition



a-b values for Qz & feldspar gouge



Dry

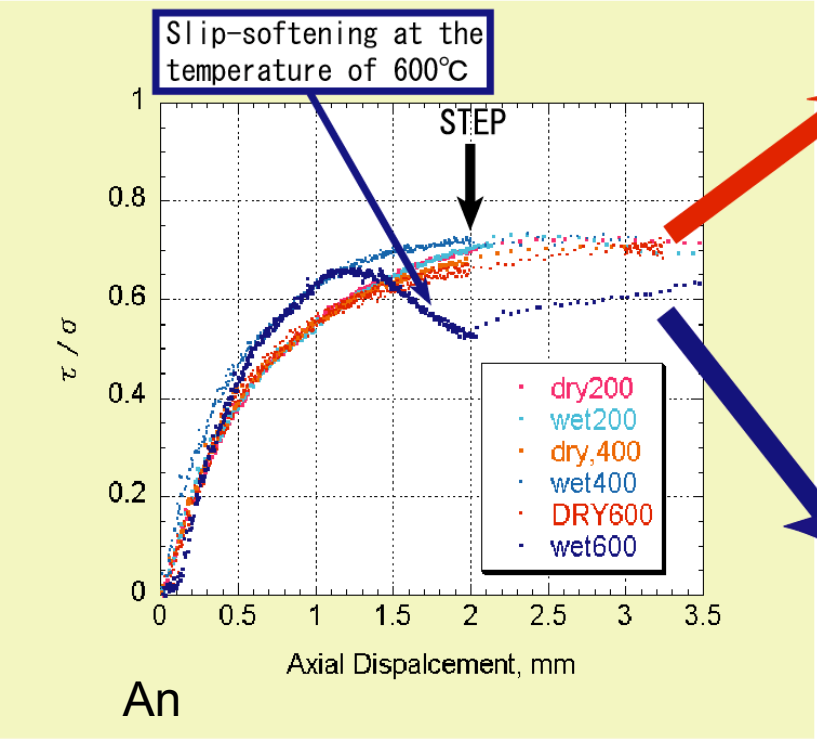
The values for *a-b* of quartz and albite were positive from room temperature to 600C.

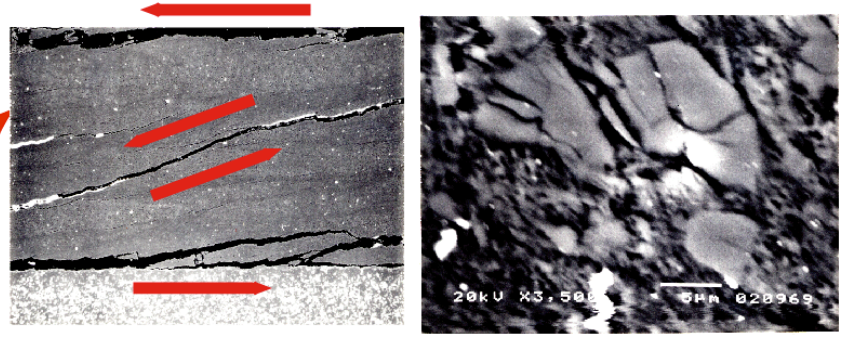
Wet

Qz: velocity weakening is seen at 300C (ca. 300C±50C)

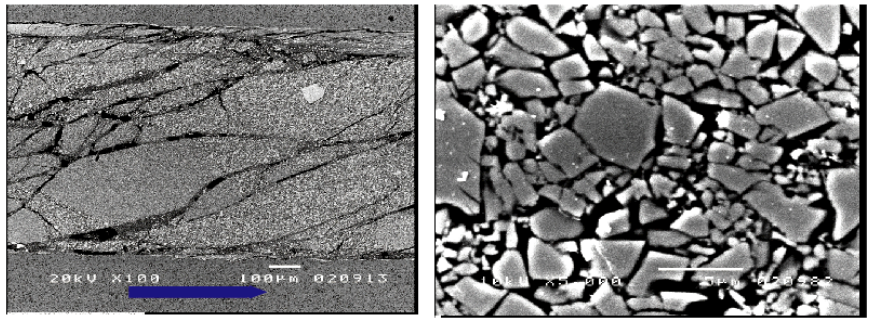
Feldspar (Ab): velocity weakening from 200C to 300C (ca. 200C to 350C)

Effects of chemical reaction at hydrothermal conditions





DRY Pc:150MPa, Pp:0MPa, T:600℃



Pc:200MPa, Pp:50MPa, T:600℃

WET

Conclusions

(1) Frictional properties of mylonite, feldspar, and quartz under high PT were obtained.

(2) Velocity weakening of feldspar is more apparent than that of Qz.

(3) Effects of chemical processes should be included in the future new constitutive laws.

We need physics-based, geologically realistic seismogenic models.

Laboratory studies with collaboration with structural geology are useful methods.