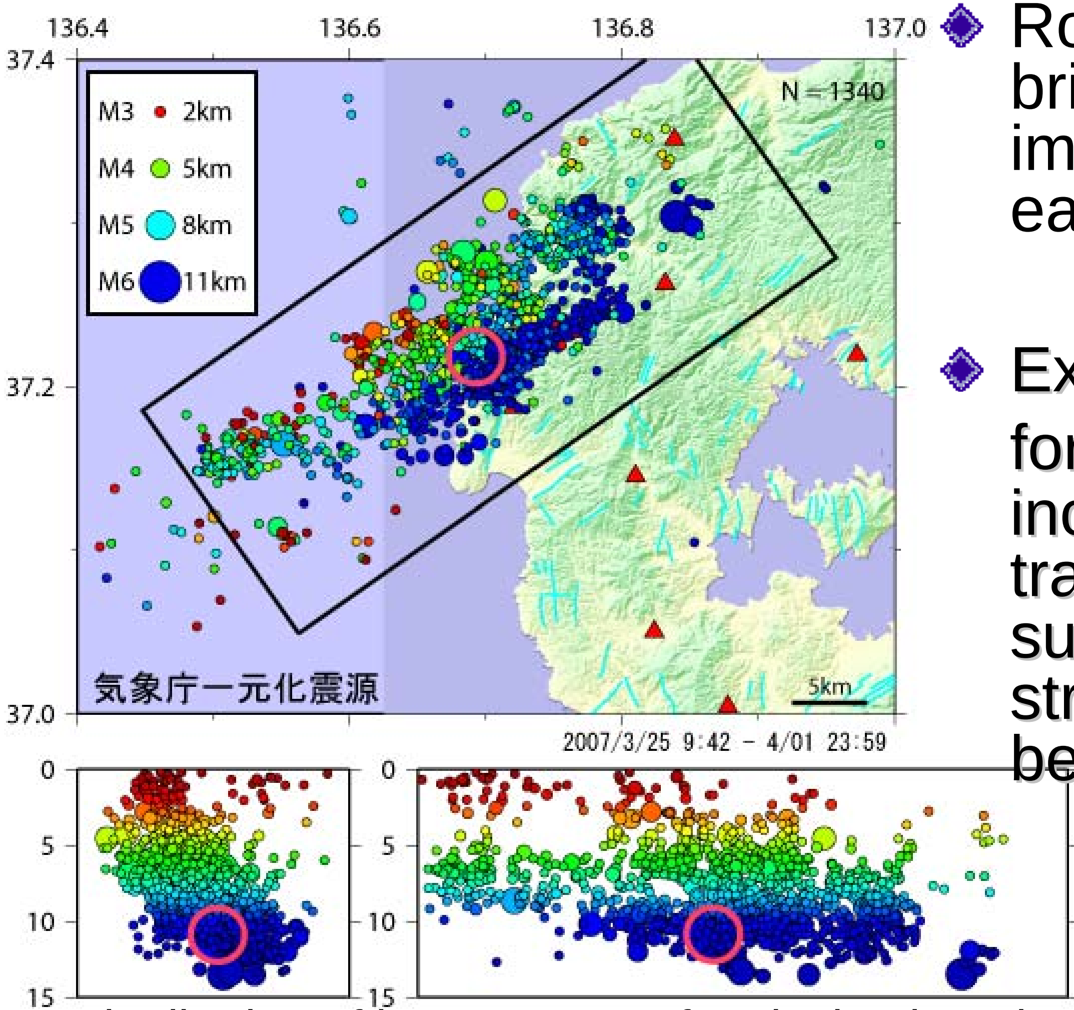
Heterogeneous localisation of plastic flow in the deepest part of a seismogenic fault:

insight from the Hatagawa Fault Zone, NE Japan

Norio Shigematsu (GSJ, AIST)

Occurrence of inland earthquakes

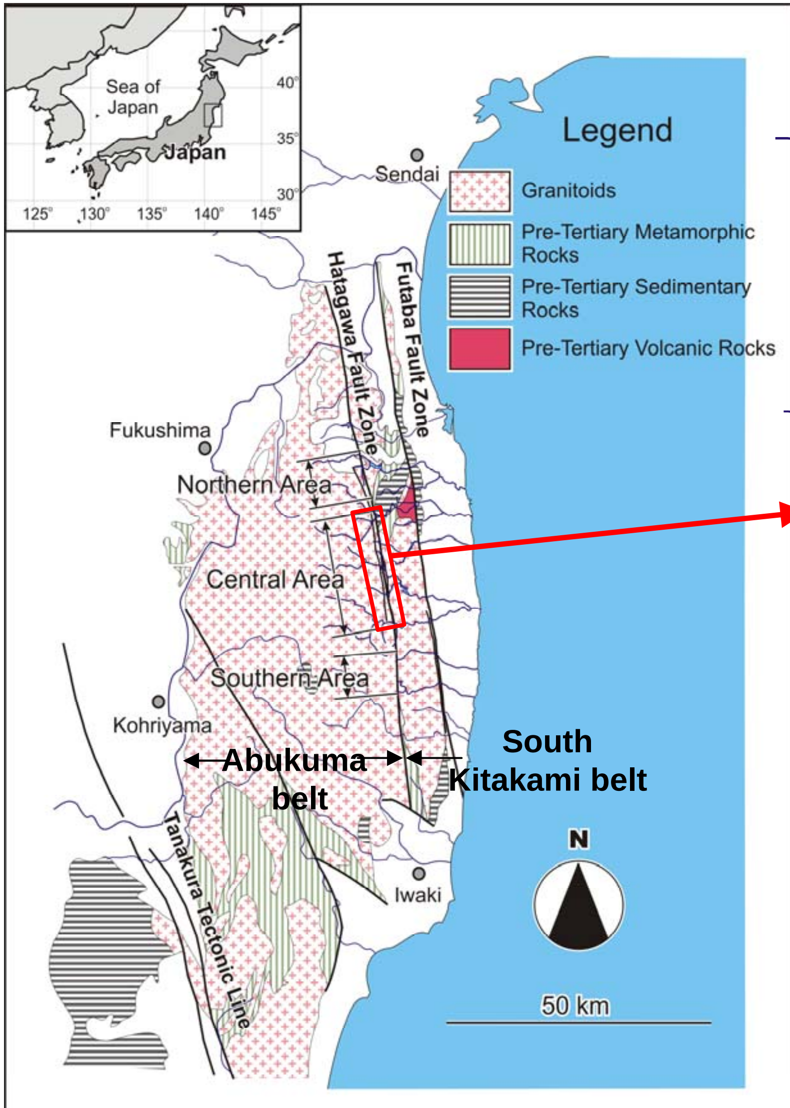


Distribution of hypocenters of mainshock and aftershocks for the Noto Earthquake 2007

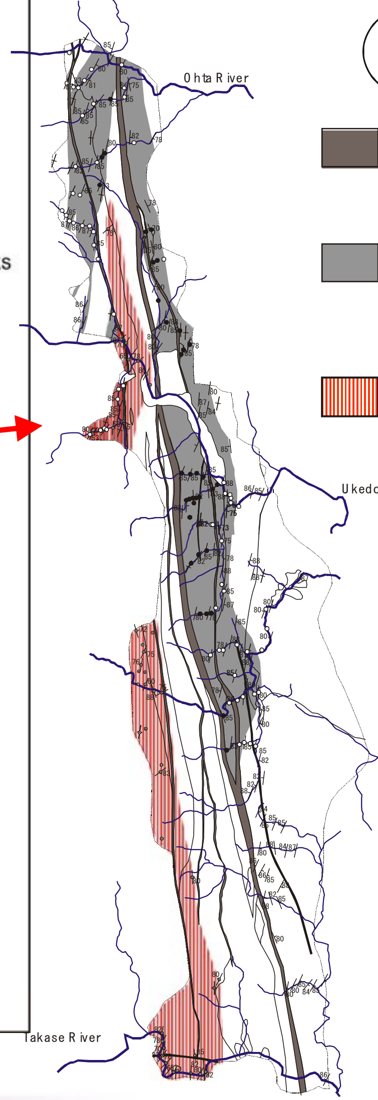
(From the web-site of the ERI of the University of Tokyo)

- Rock deformation under the brittle-plastic transition is important to understand the earthquake process.
- Exploring exhumed fault zones for which crustal sections including the brittle–plastic transition are exposed at the surface is an important strategy in understanding fault behaviour.

Hatagawa Fault Zone



Central Area

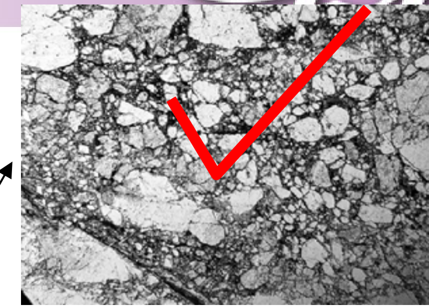


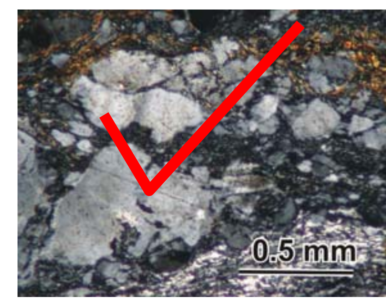
Cataclasite

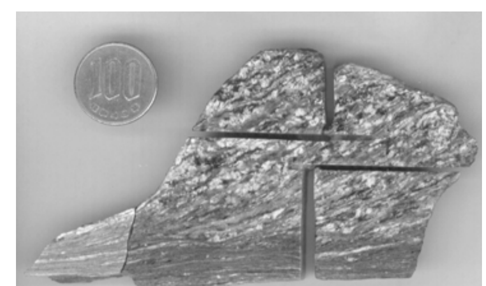
Mylonite with sinistral sense of shear

The area where small shear zones are developed

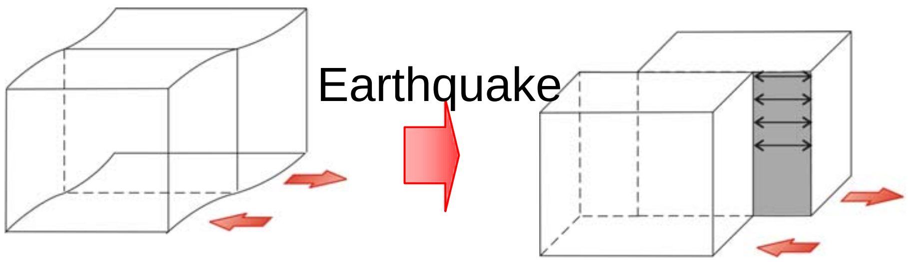
0 2
km

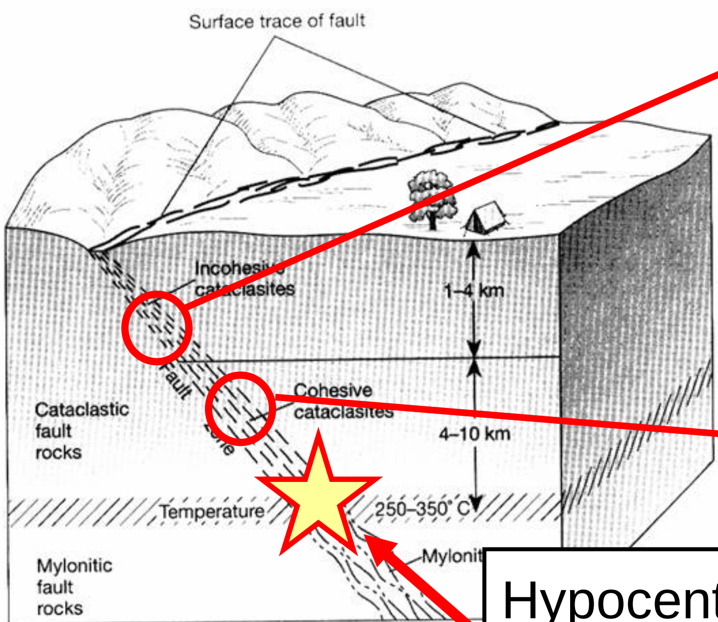






Fault rocks
(in the seismogenic zone)





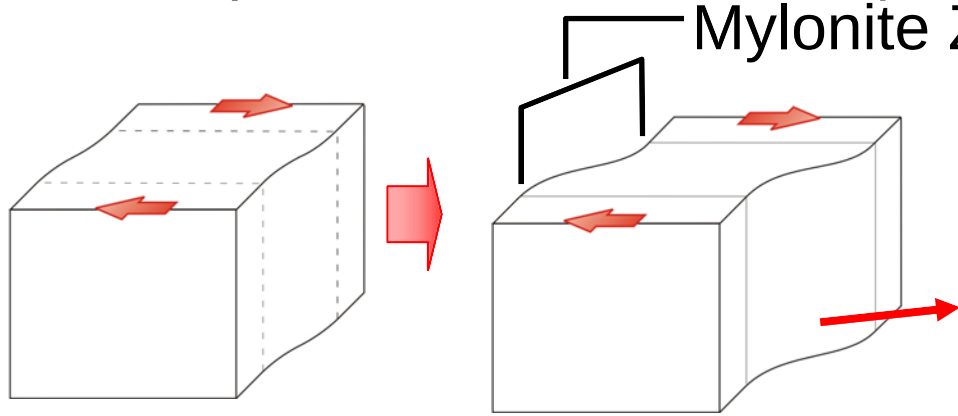
Hypocenter of large earthquake along active faults

Fault gouge (incohesive：MTL)

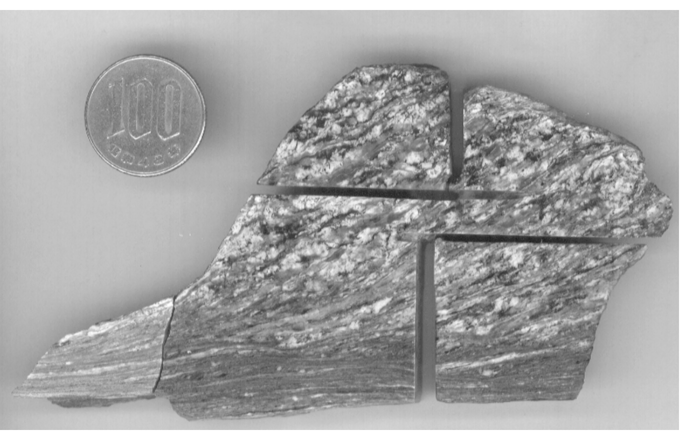
Cataclasite (cohesive：MTL)

Fault rocks

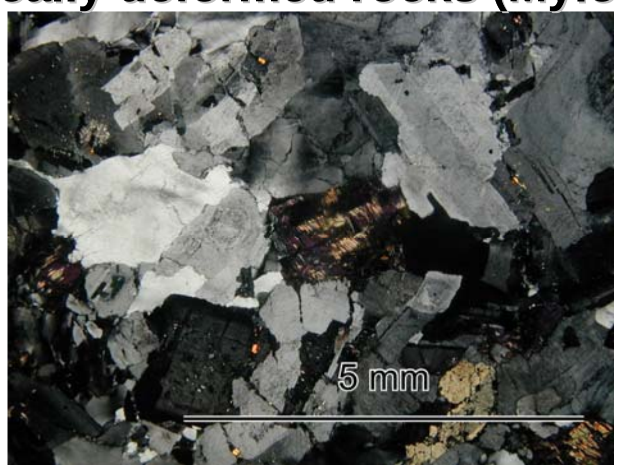
(under the temperatures above 300℃)



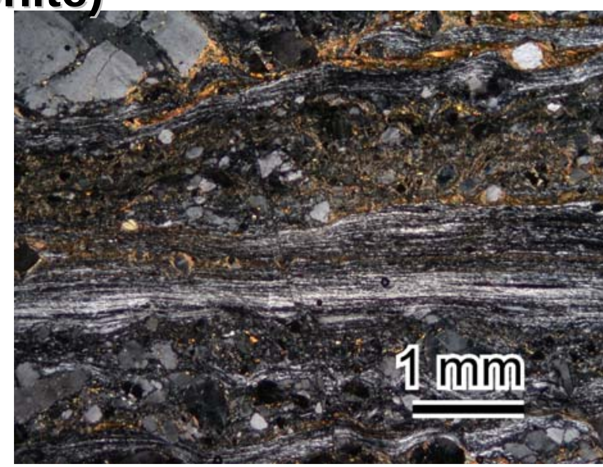
Plastically deformed rocks (Mylonite)



Small mylonite zone



Optical microphotograph of undeformed granite

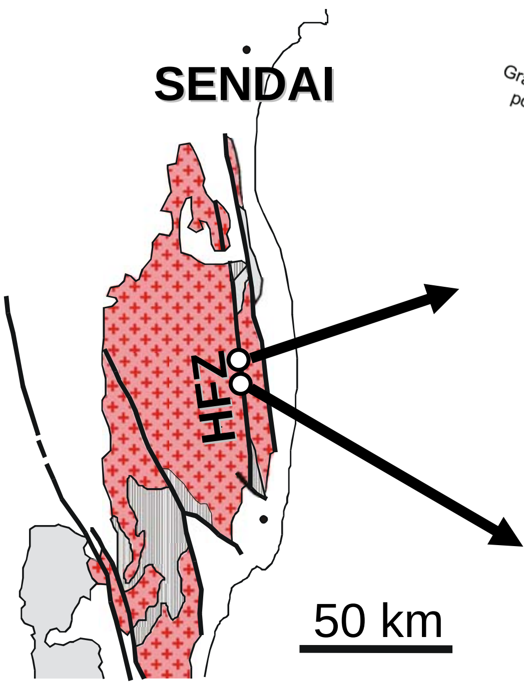


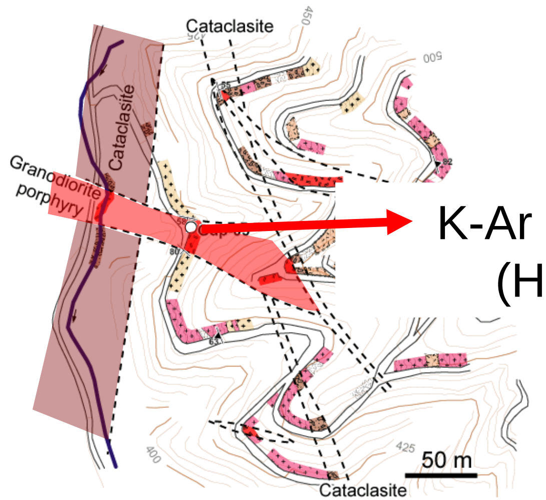
Optical micrograph of Granitic mylonite

To understand inland earthquakes → Boundary depth of cataclasite and mylonite

Cataclasite along the HFZ

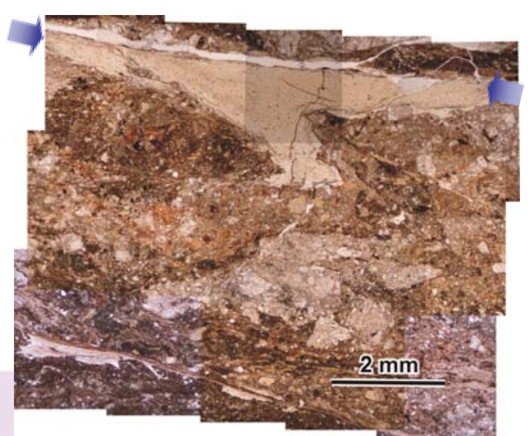
- The assemblage of altered minerals in the cataclasite indicates that the cataclasite zone was formed at temperatures above 220 ° C





K-Ar 98.1±2.5 Ma (Hornblende)

The activity had ceased by 98.1±2.5 Ma .

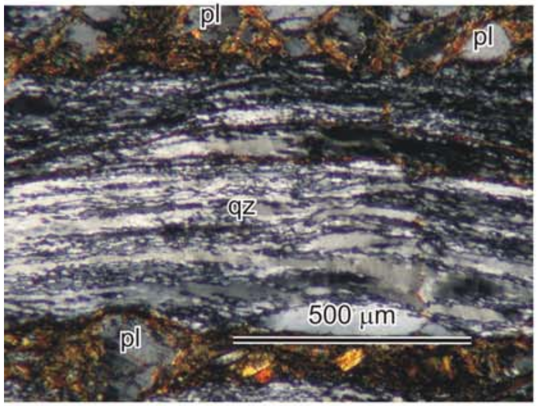


A repeating of earthquakes along the cataclasite zone.

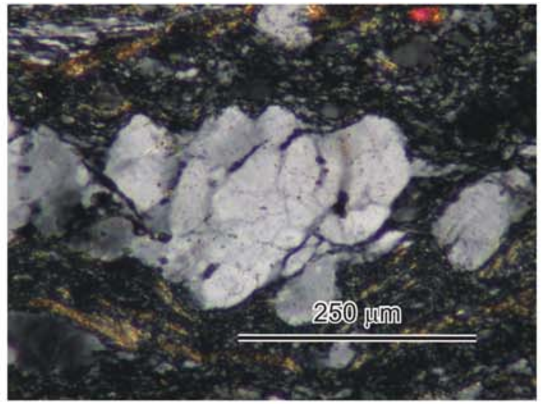
Fault Rocks along the HFZ (Mylonite)

Two types of Mylonite → Microstructures A and B

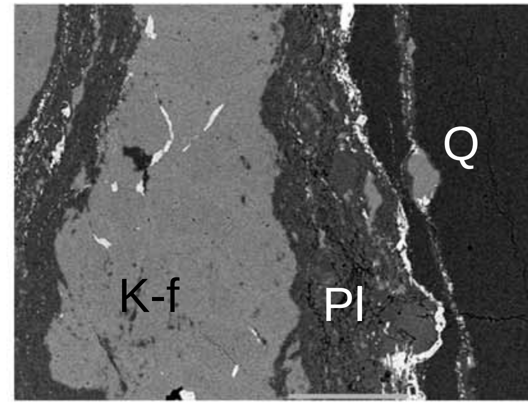
- *Microstructure A*



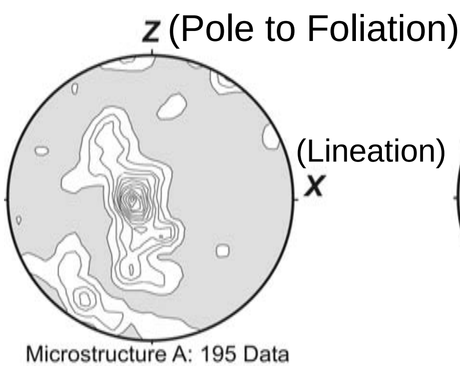
Quartz

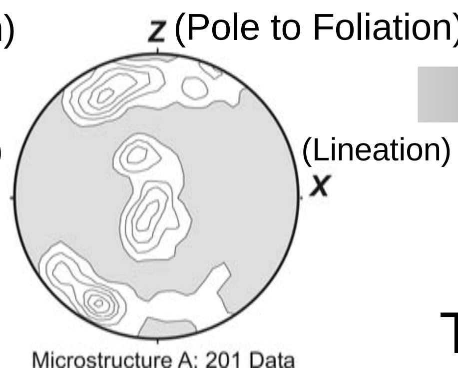


K-Feldspar Porphyroclast



Fine-Grained Matrix





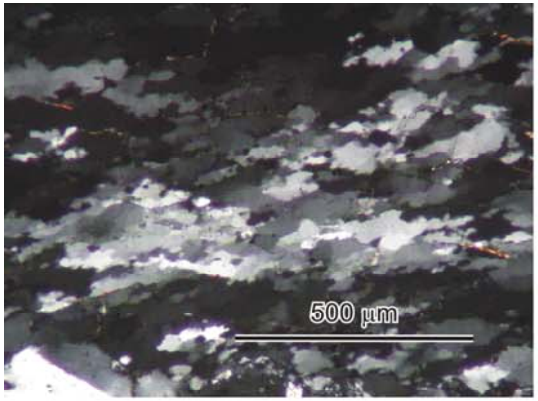
Pole Figures of quartz <c>

Lower temperature,
faster strain rate,
or
lower water activity.

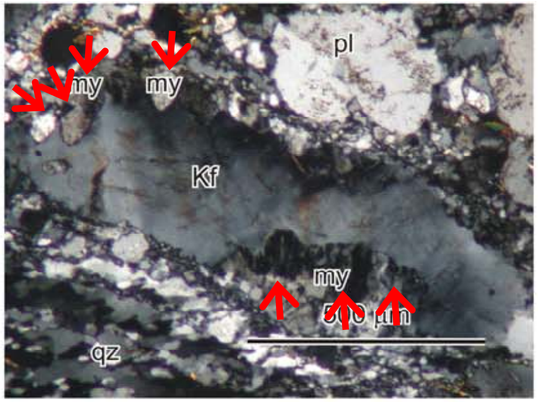
Two feldspar thermometry (Whitney & Stormer, 1977)

300～360 ºC

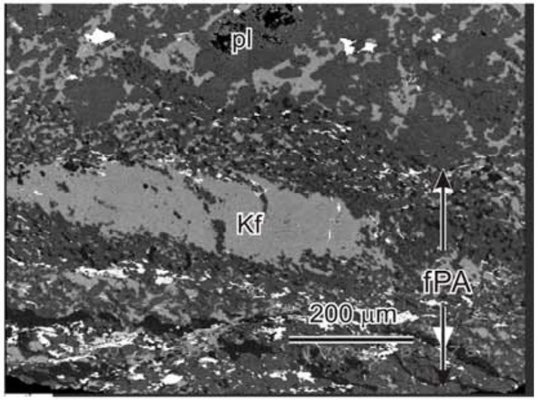
- *Microstructure B*



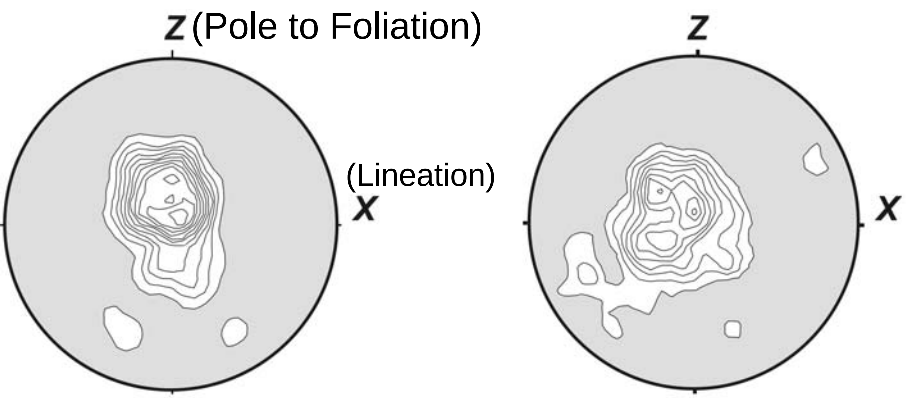
Quartz



K-Feldspar Porphyroclast



Fine-Grained Matrix



Microstructure B: 173 Data

Microstructure B: 200 Data

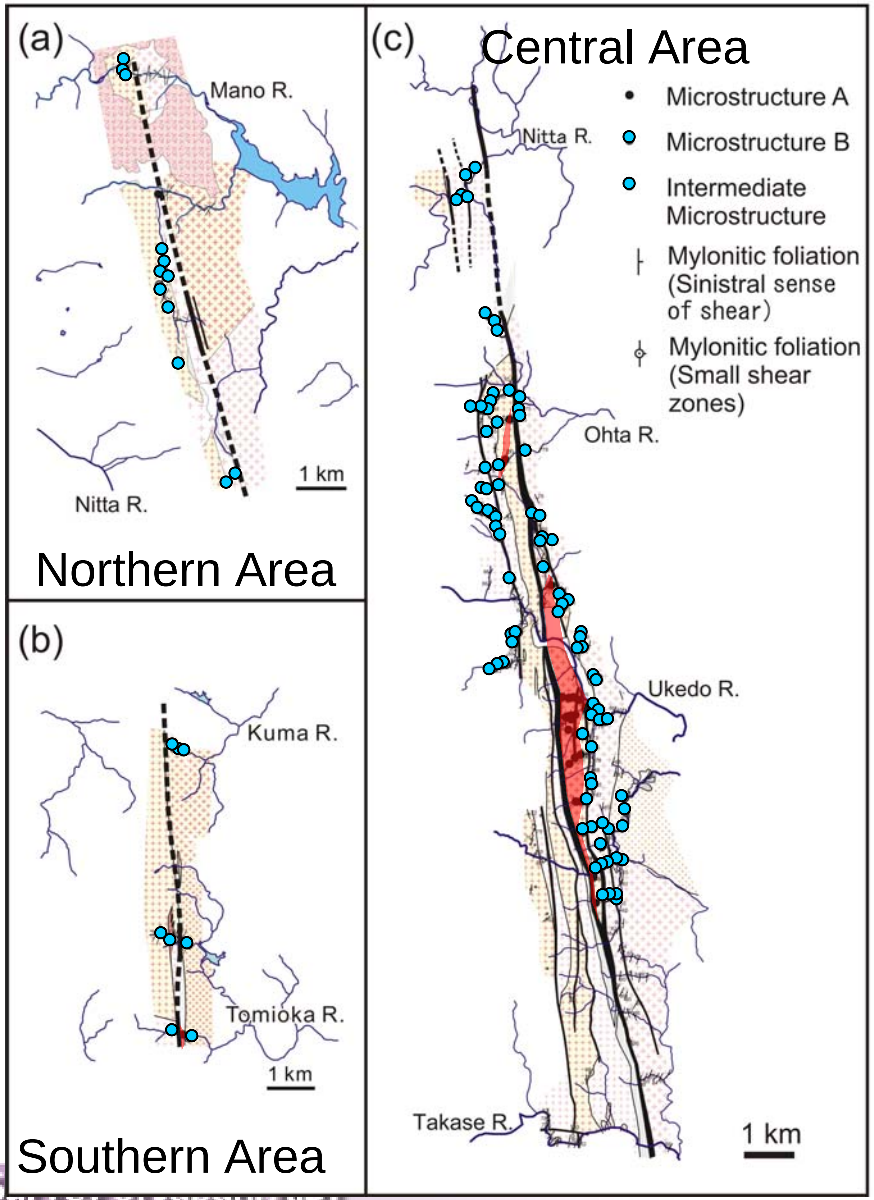
Pole Figures of quartz <c>

Higher temperature,
slower strain rate,
or
higher water activity.

Two feldspar thermometry

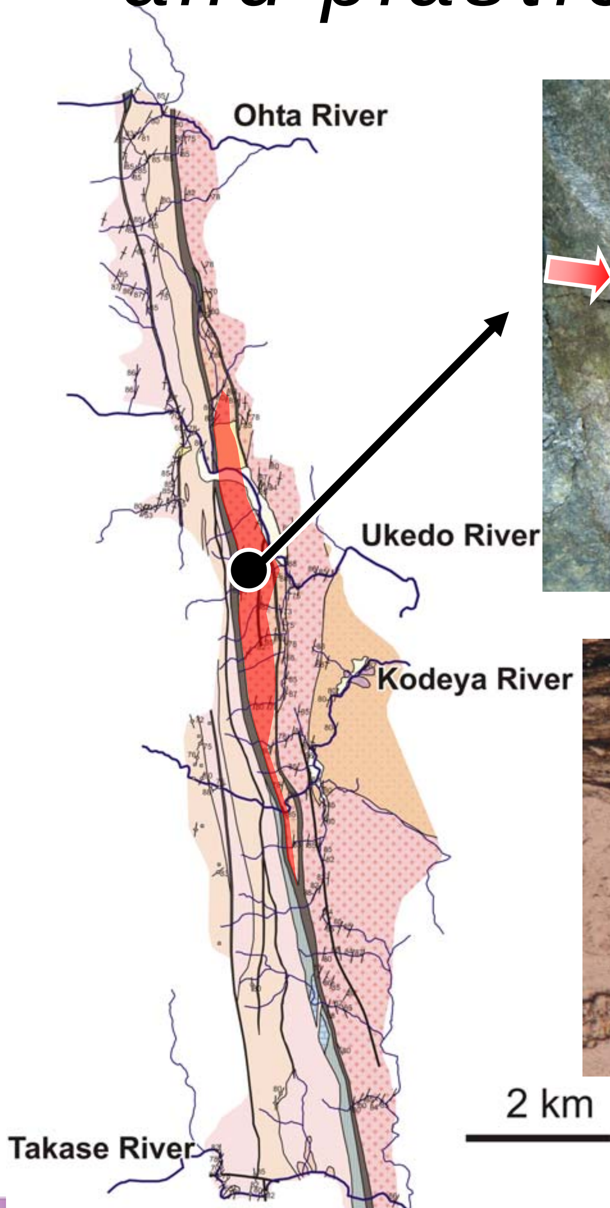
360 ~500 ºC

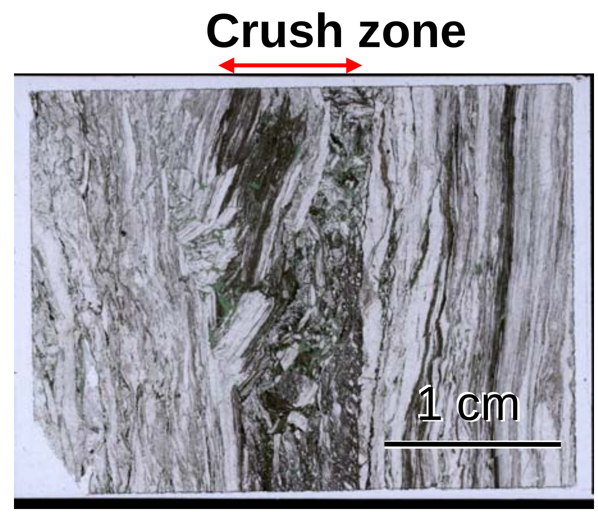
Outcrop extent of two types mylonite

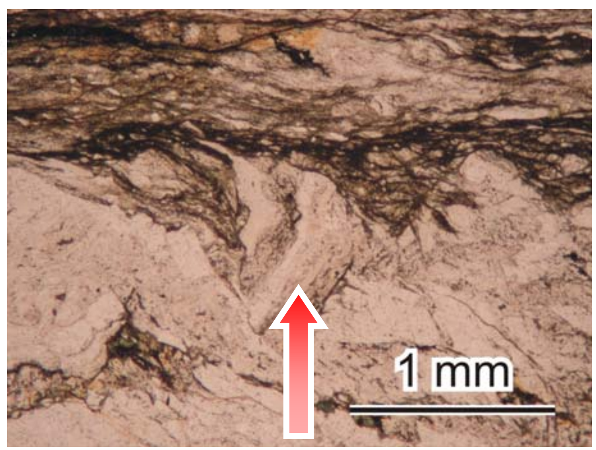


The outcrop extent of microstructure A

Association between fracturing and plastic deformation







subsequently plastically deformed fragment

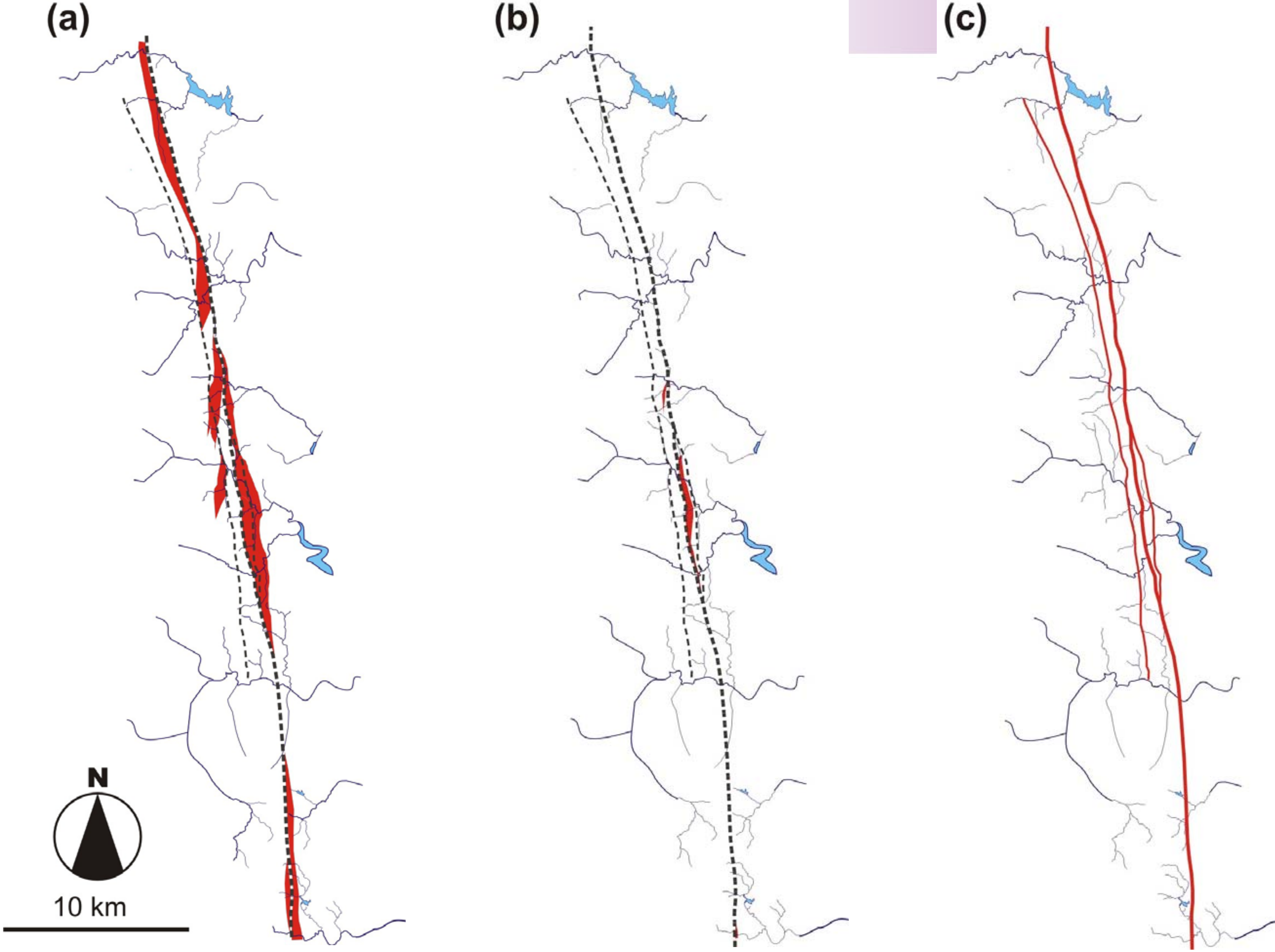
Outcrop extent of microstructure A

||

Deformed under the condition of brittle-plastic transiton

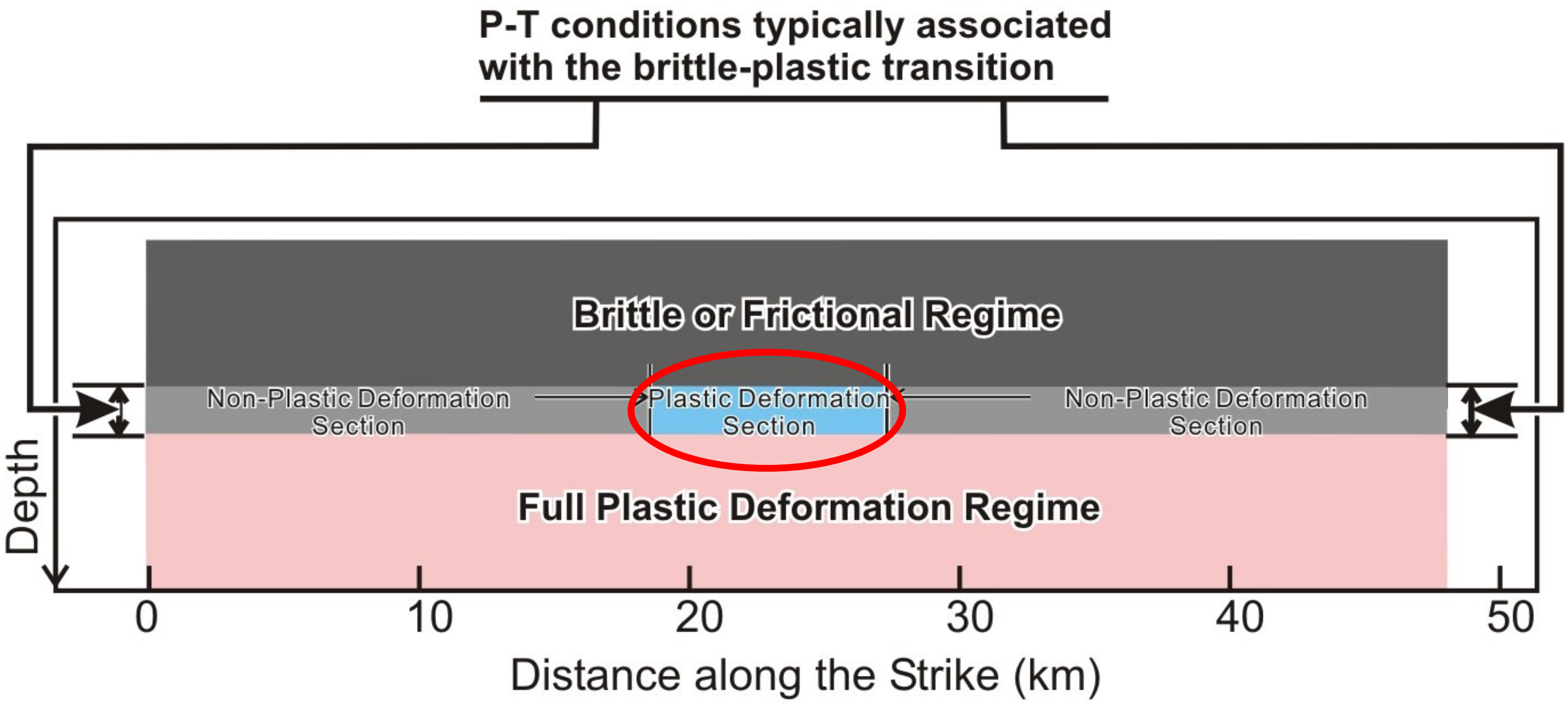
Final localised zones of plastic flow

History of displacement along the HFZ

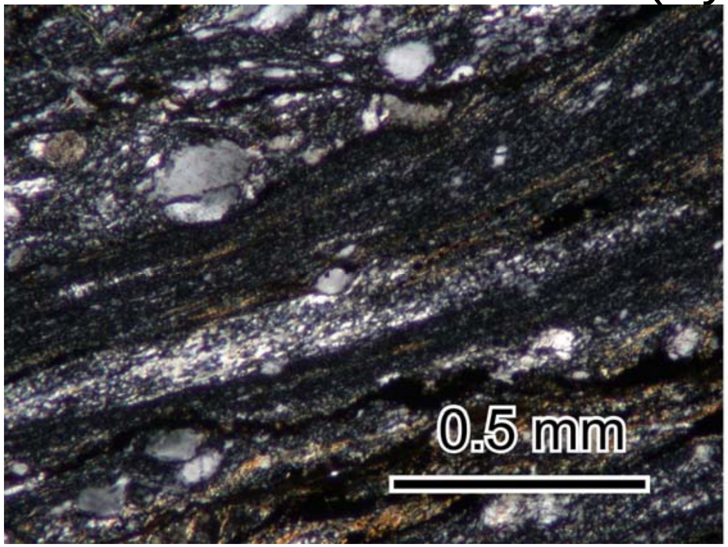


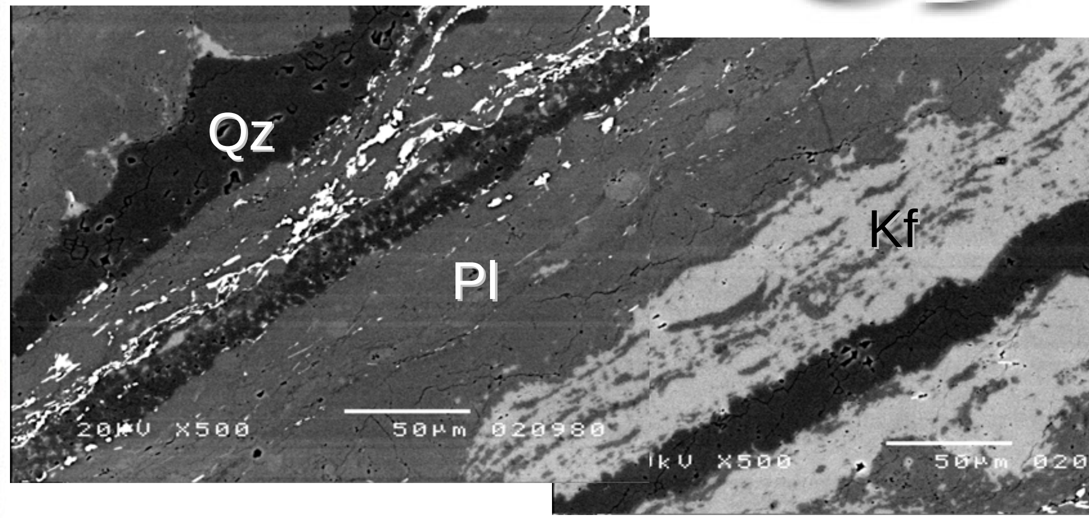
T=350～500℃ Brittle-plastic transition Brittle Regime

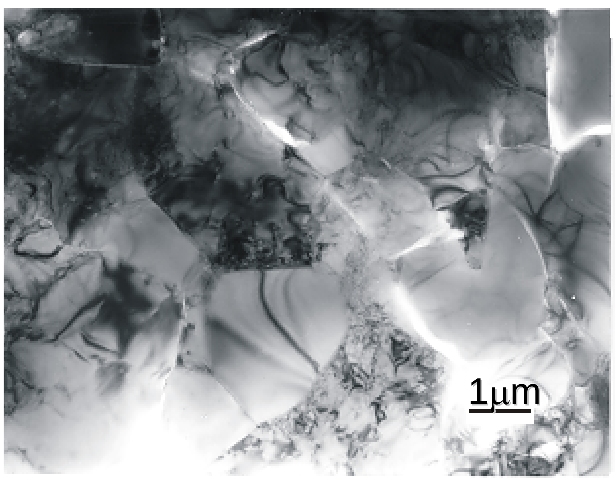
Cross-section of deformation styles

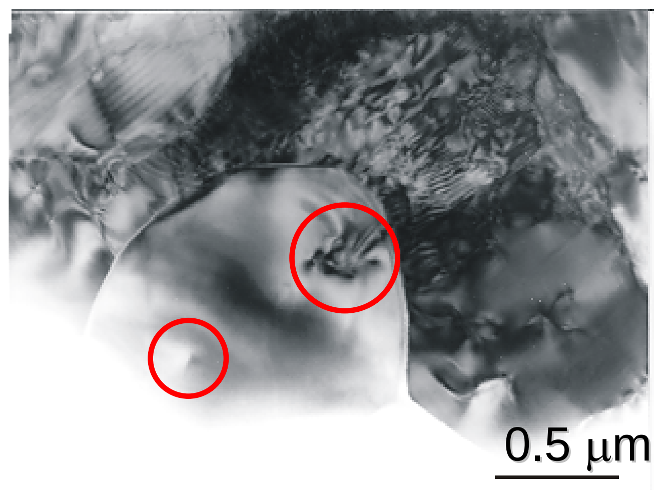


Deformation in the outcrop extent of microstructure A (Dynamic recrystallization of feldspar)





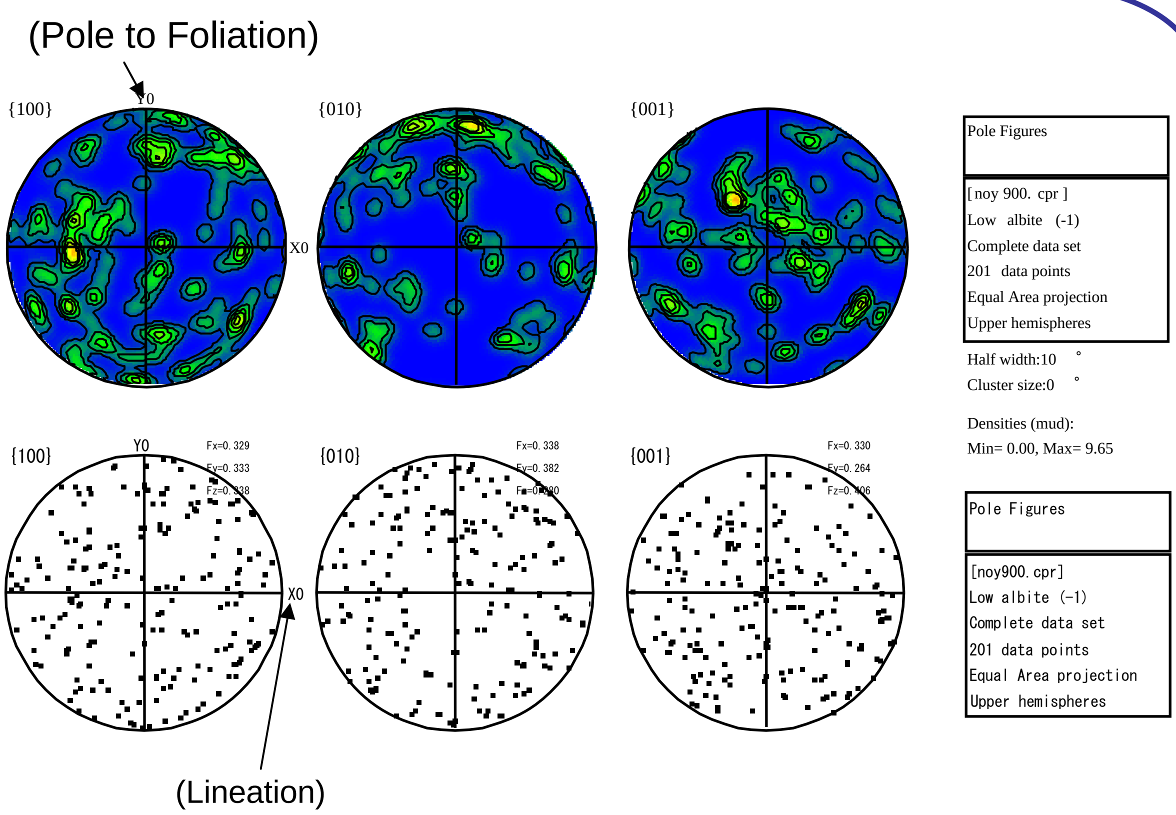




➡ Strain weakening

Localisation of deformation to the outcrop extent of microstructure A

Crystallographic Orientation of Feldspar



Crystallographic Orientations are random

Deformation by *superplasticity*

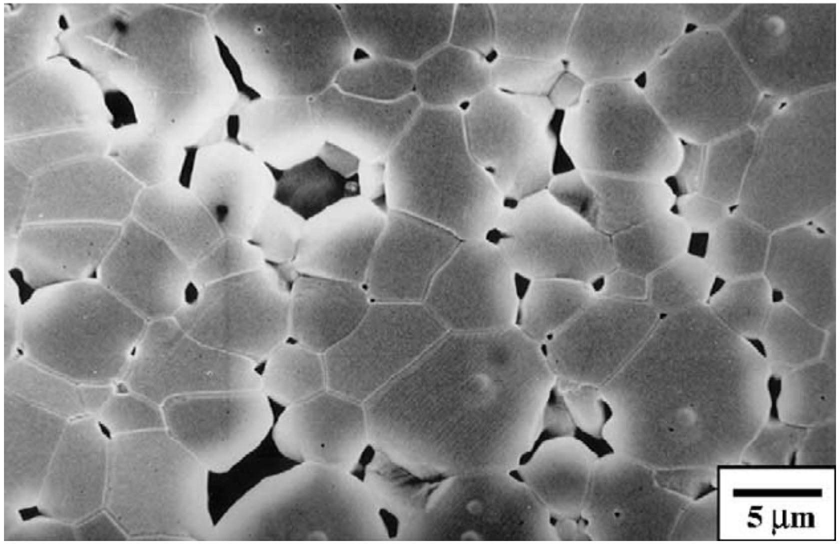
Association between fracturing and plastic deformation

Crush zone

- *Ductile Fracture*

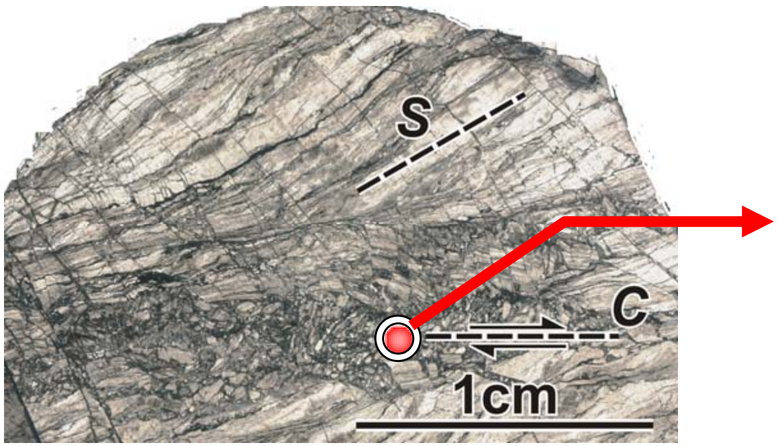
  Fracturing following the subjection of material to large plastic strain

Nucleation, growth and interlinkage of cavities



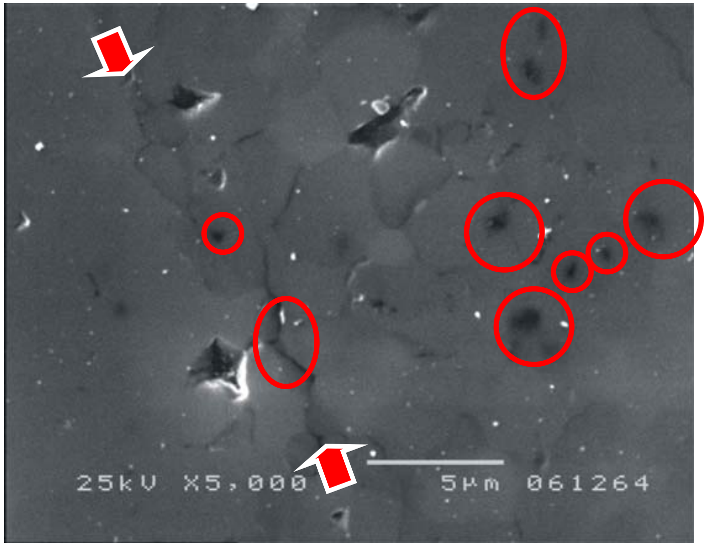
Cavitation during superplastic deformation of alumina
(Kottada and Chokshi, 2000; Chokshi, 2005)

Plastic deformation and fracturing of fine-grained feldspar *(Shigematsu et al., 2004)*



Shear zone including a crush zone along a shear band

- Fine grained feldspar within the shear band

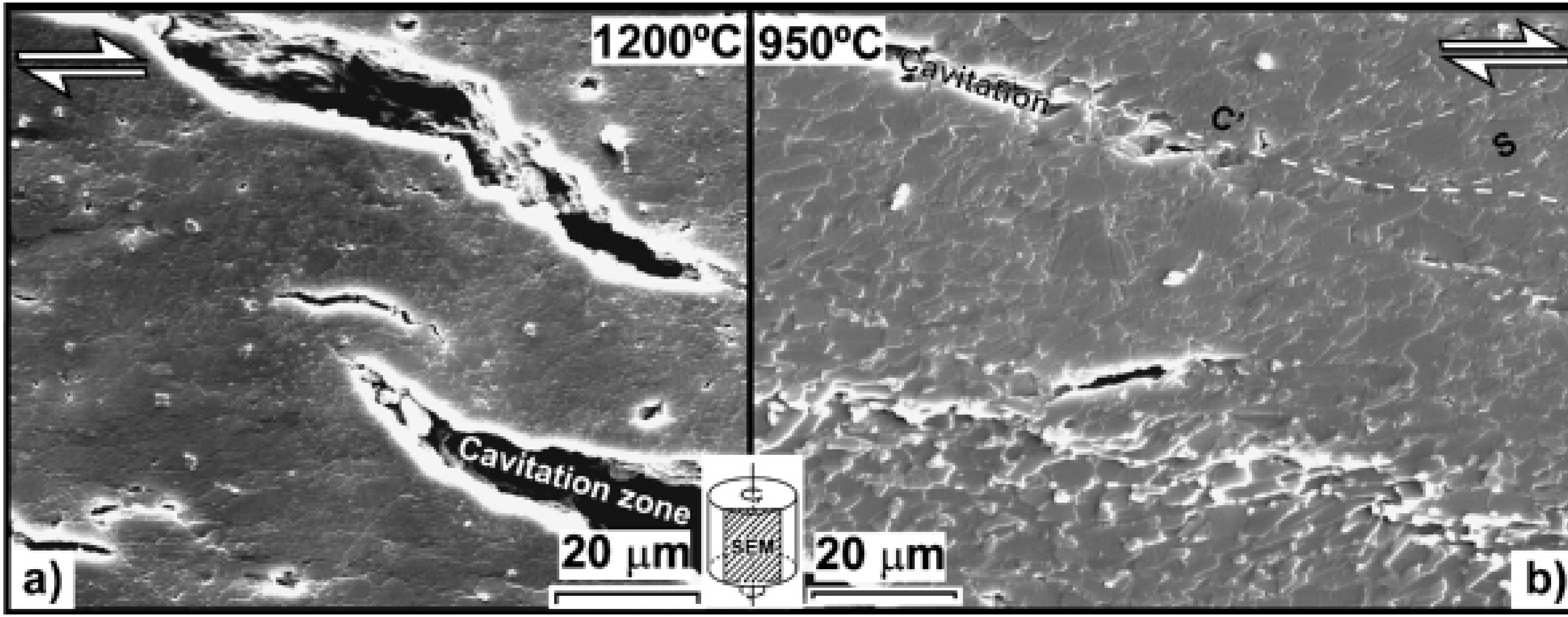


Secondary electron image of fine-grained feldspar. Cavities along grain boundaries are connected to form an intergranular fracture (arrows).

Fracturing during plastic flow of fine-grained feldspar

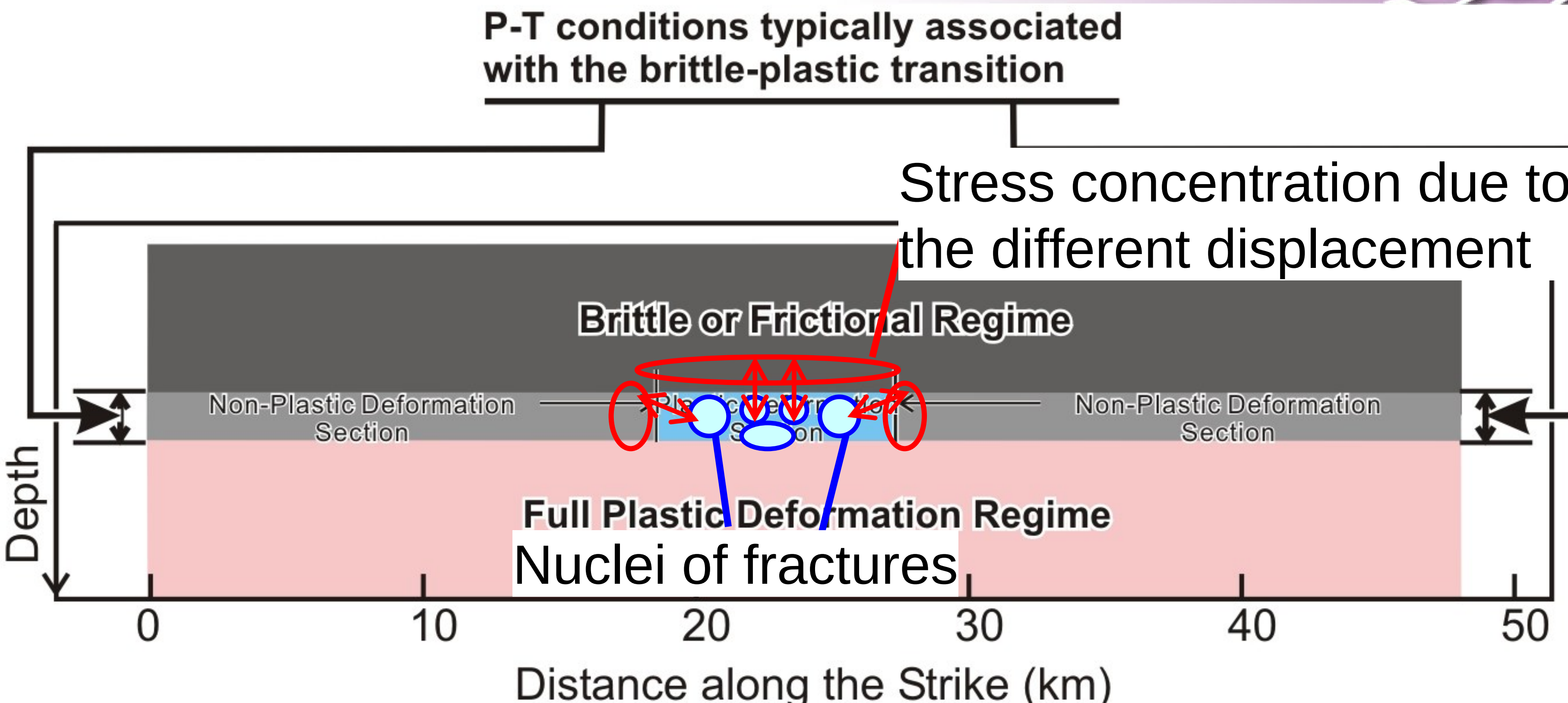
Fractures were nucleated during plastic deformation in the outcrop extent of microstructure A

Ductile fracture of fine-grained feldspar experimentally reproduced



Rybacki, et al., 2008 GRL35, L04304, doi:10.1029/2007GL032478

Large earthquakes along the HFZ



Outcrop extent of Microstructure A: Nucleation of fracture due to ductile fracture

Restricted plastic displacement in the outcrop extent of Microstructure A: → Stress concentration

Large Earthquakes

Summary

- Fault rocks formed in the B-D-T was exposed in a limited region along the HFZ, with a length of 6 km. Displacement by plastic flow occurred only in this restricted regions at the depth in the crust where P-T conditions were those of the brittle–plastic transition.
- The localisation of plastic flow to the region with a length of 6 km possibly resulted from strain weakening accompanied by the dynamic recrystallization of feldspar.
- The extreme strain localisation led to ductile fracturing of highly deformed fine-grained feldspar. It is likely that numerous fractures were nucleated in these rocks due to ductile fracture.
- Heterogeneous plastic displacement resulted in a significant stress concentration. Interaction between this stress concentration and fractures nucleated via ductile fracture possibly promoted the nucleation of large earthquakes.