Temporal change in permeability of an active fault zone after a large earthquake

– In the case of the Nojima fault, which is one of the 1995 Hyogoken-Nanbu earthquake faults –

[Kitagawa et al., 2002]

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A purpose of the Project

- Detection of a healing process of an active fault just after a large earthquake occurrence

Main purpose of this research

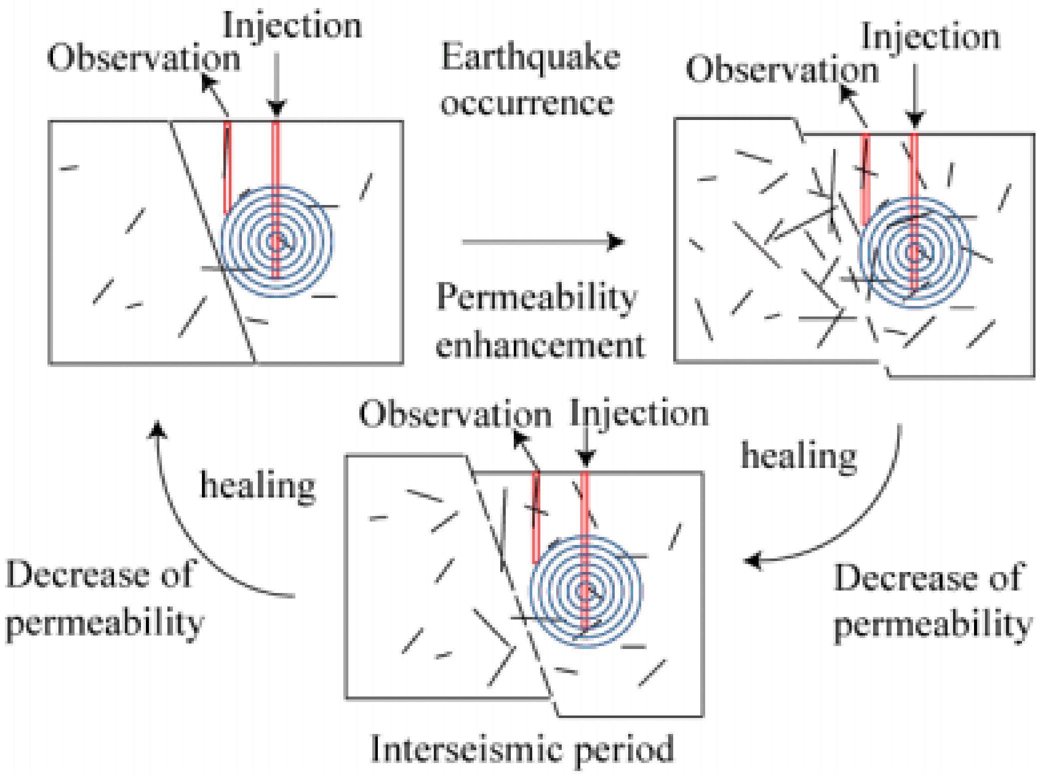
- Detection of a temporal change of a permeability of an active fault

Method [Shimazaki et al., 1998]

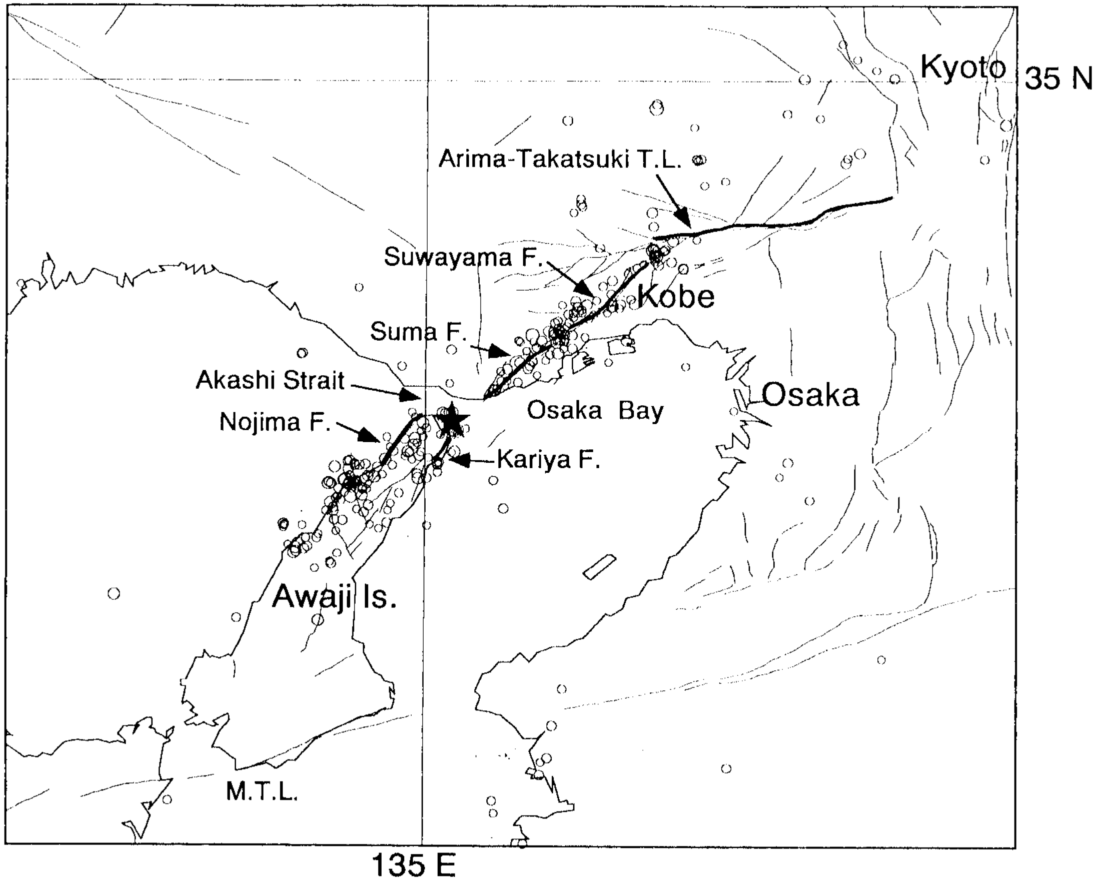
- In situ repeated water injection

Concept of the method

- Repeated measurement of a permeability of the fault zone and detection of its temporal change



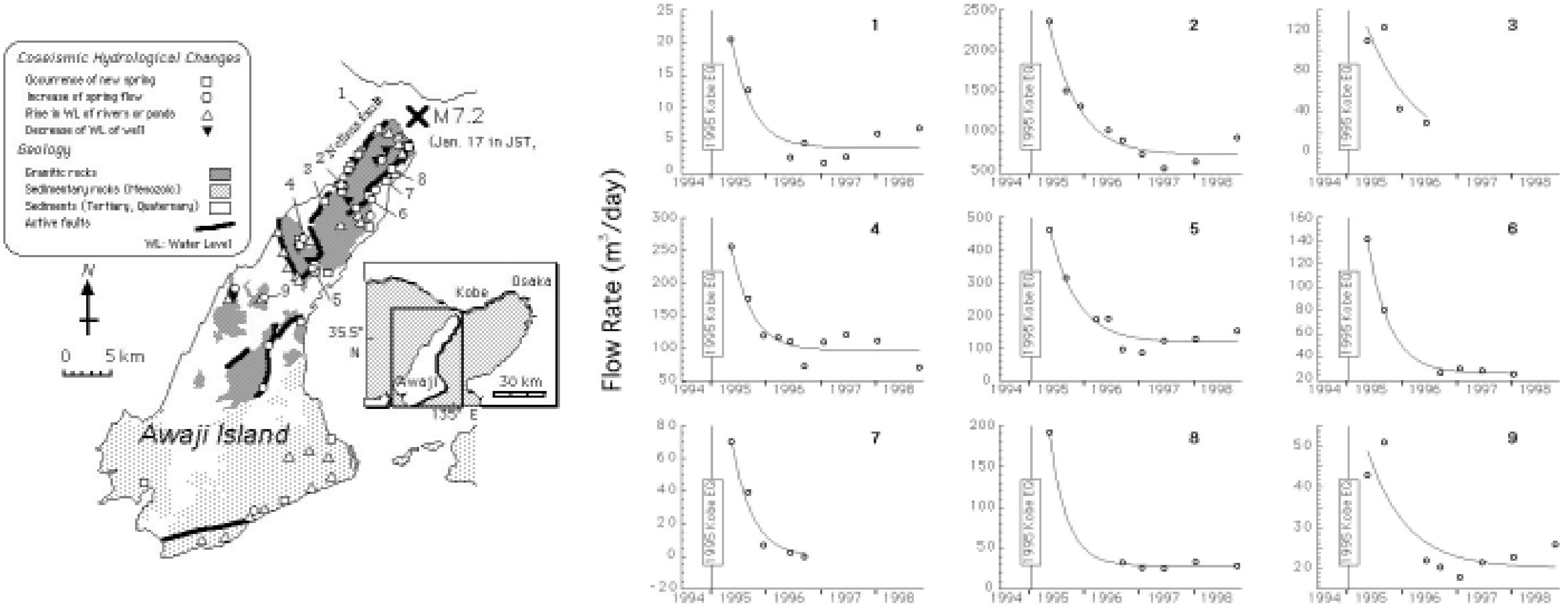
1995 Hyogoken-Nanbu earthquake



The Nojima fault had a right-lateral strike slip.

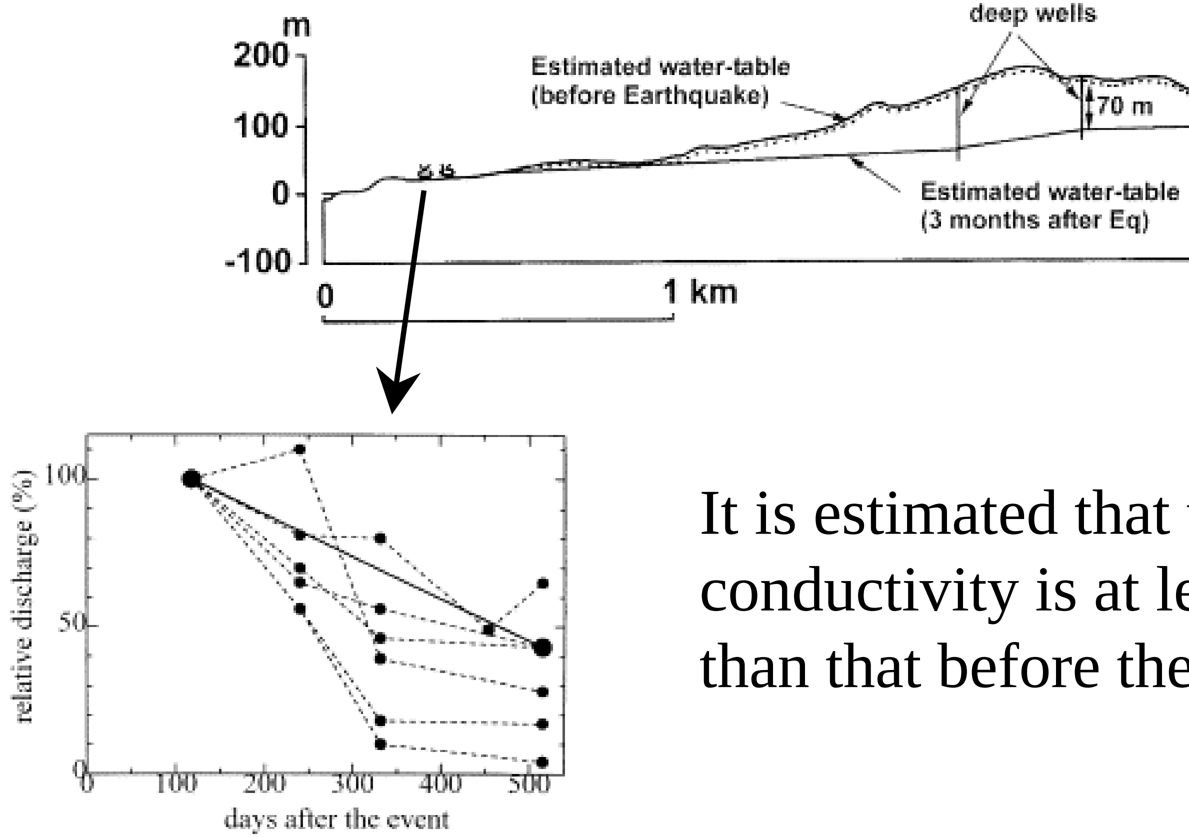
Hirahara [1996]

Estimation of a hydraulic diffusivity [Sato et al.,2000]



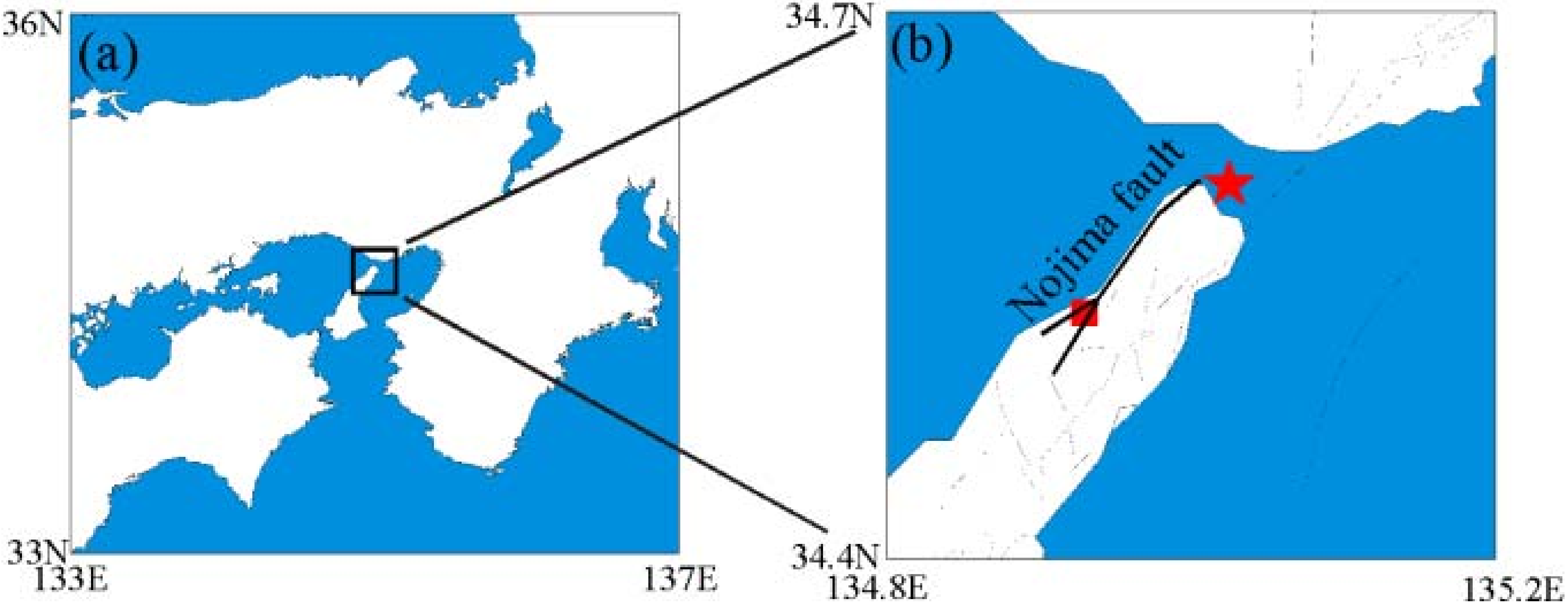
The range of enhanced hydraulic diffusivity is from 130 to 2300 cm^2/s.

Earthquake-induced permeability enhancement [Tokunaga, 1999]



It is estimated that the hydraulic conductivity is at least five times than that before the Earthquake.

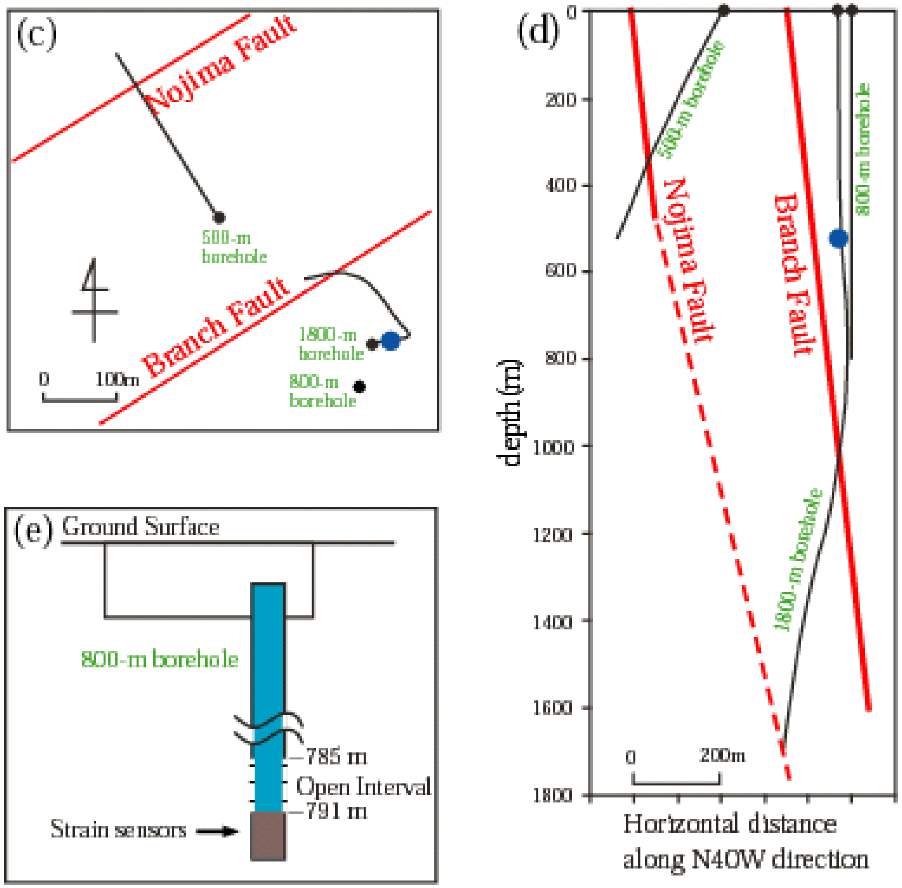
Observation site



■ : The site region

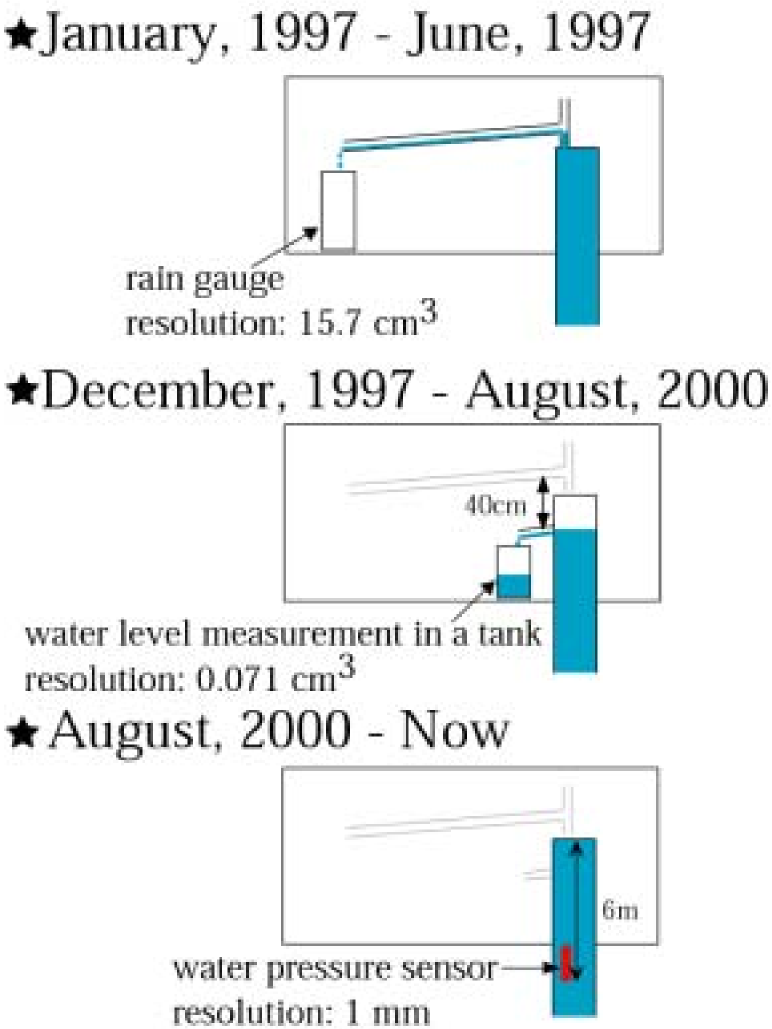
★ : The hypocenter of
the 1995 Hyogoken-Nanbu Earthquake

Outline of the observation boreholes



- This site is located near the southwestern end of the Nojima fault.
- The 800-m borehole has a open interval of 785 - 791 m depth.
- Water injected from the 1800-m borehole.

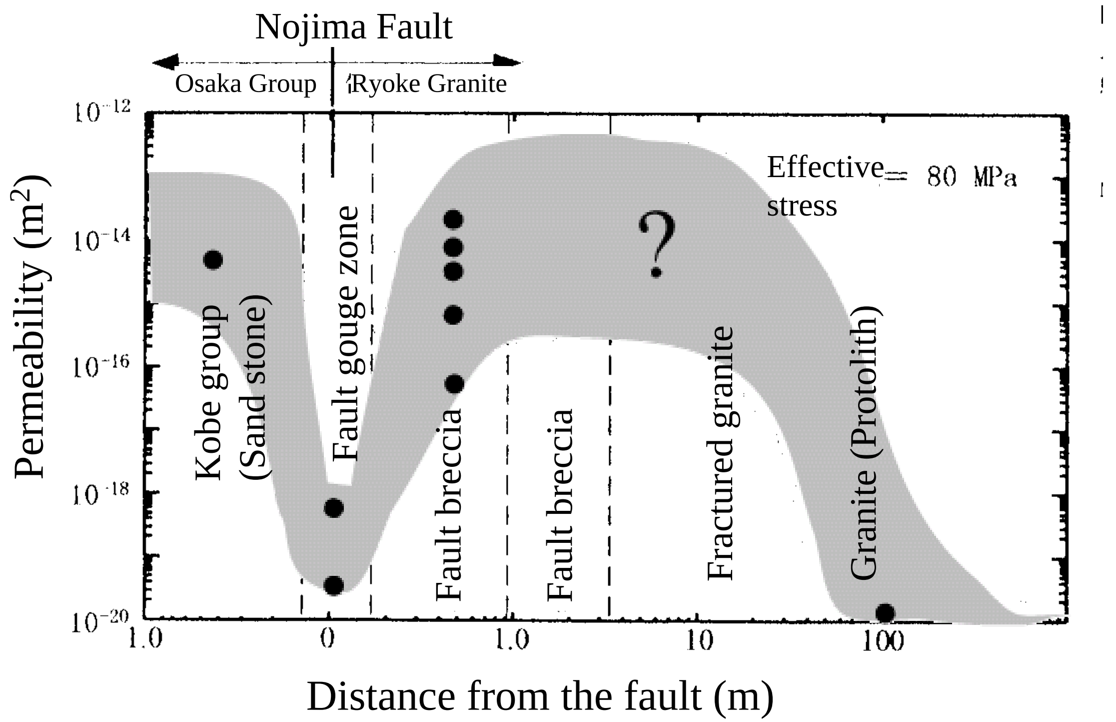
Observation method at the 800-m borehole



- Until August, 2000, discharge rate is observed.
- Since August, 2000, water pressure is observed.

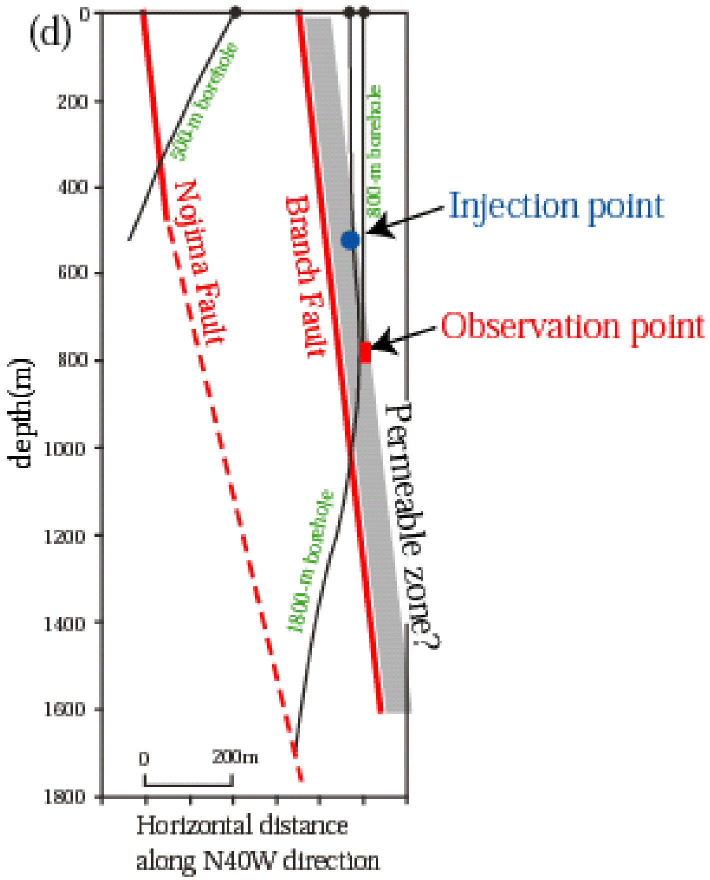
Hydraulic structure of the fault

Modified from Mizoguchi et al. [2000]



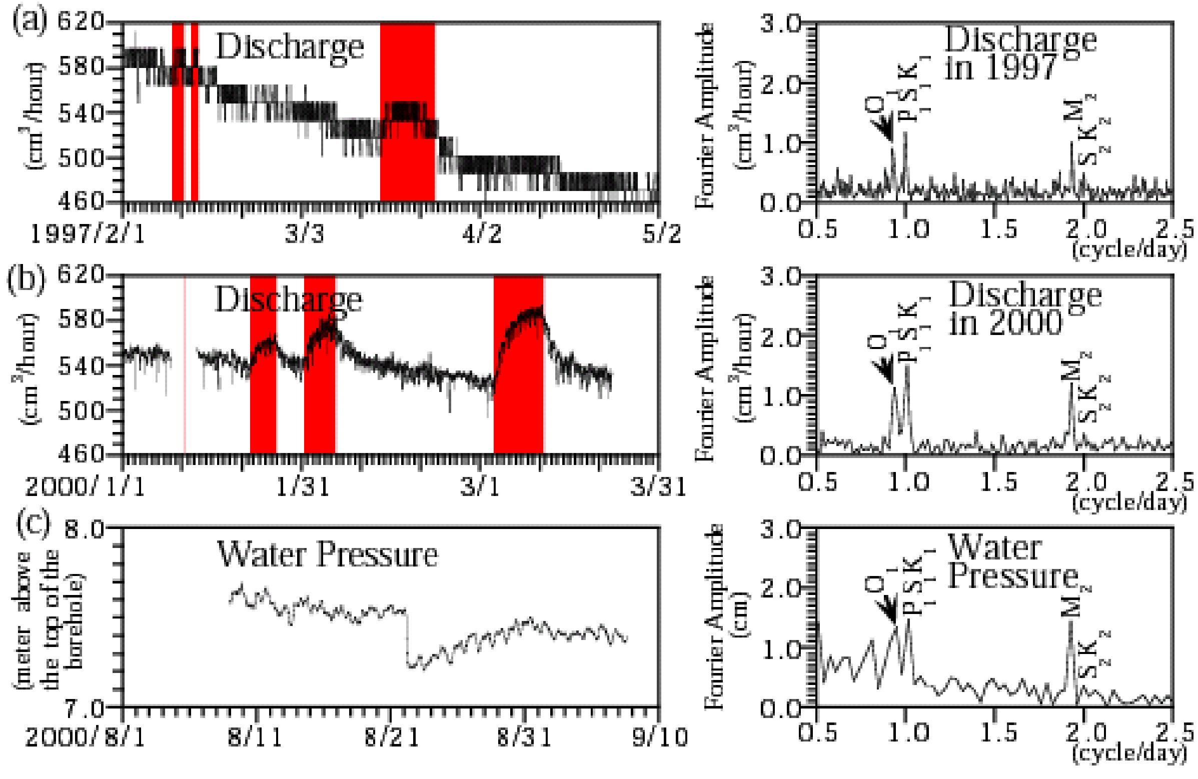
The width of permeable zone is several ten meters. The fault gauge zone and protolith are likely to be a impermeable zone.

Outline of the water injection experiments



- Water injected at the depth of 540 m of the 1800-m borehole.
- The observation point is 785 - 791 m depth of the 800-m borehole.
- Injection and observation points may be located in a permeable zone of the Nojima branch fault.

Observation result at the 800-m borehole



Discharge increased during the six water injection experiments.

Characteristics of the discharge changes

- The six water injection experiments increased the discharge of the 800-m borehole.
- The maximum of discharge changes in 2000 experiments is larger than that in 1997 experiments.
- The time until the increase of the discharge becomes stable in 2000 take longer than in 1997.

Estimation of the permeability Method: Numerical simulation

$$\frac{\partial H}{\partial t} = D\left(\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2}\right) + f(Q)$$

H: Head
D: Hydraulic diffusivity
f(Q): Injection factor
Q: Injection flow rate

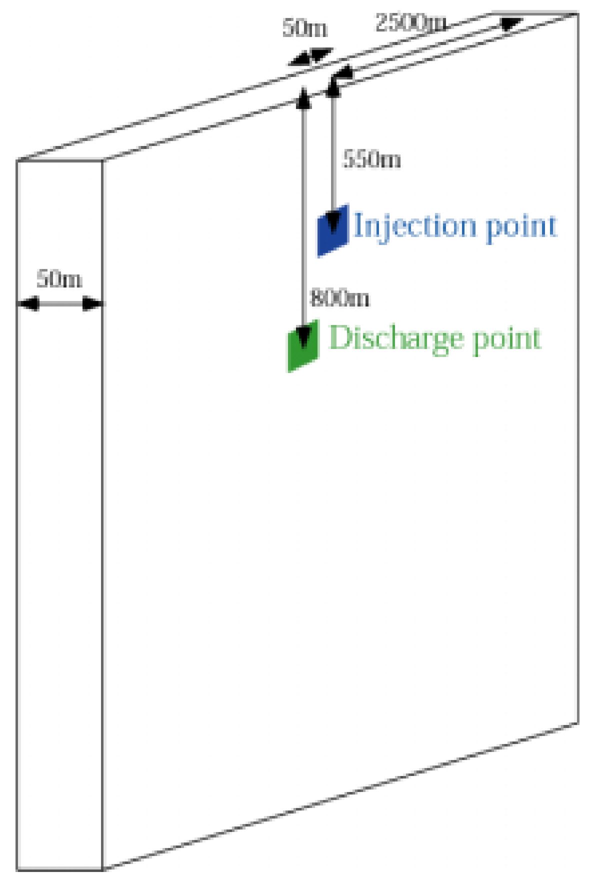
When the above equation is modified to a difference equation,

$$f(Q) = \frac{Q}{L^3 Ss}$$ at the injection point,

or

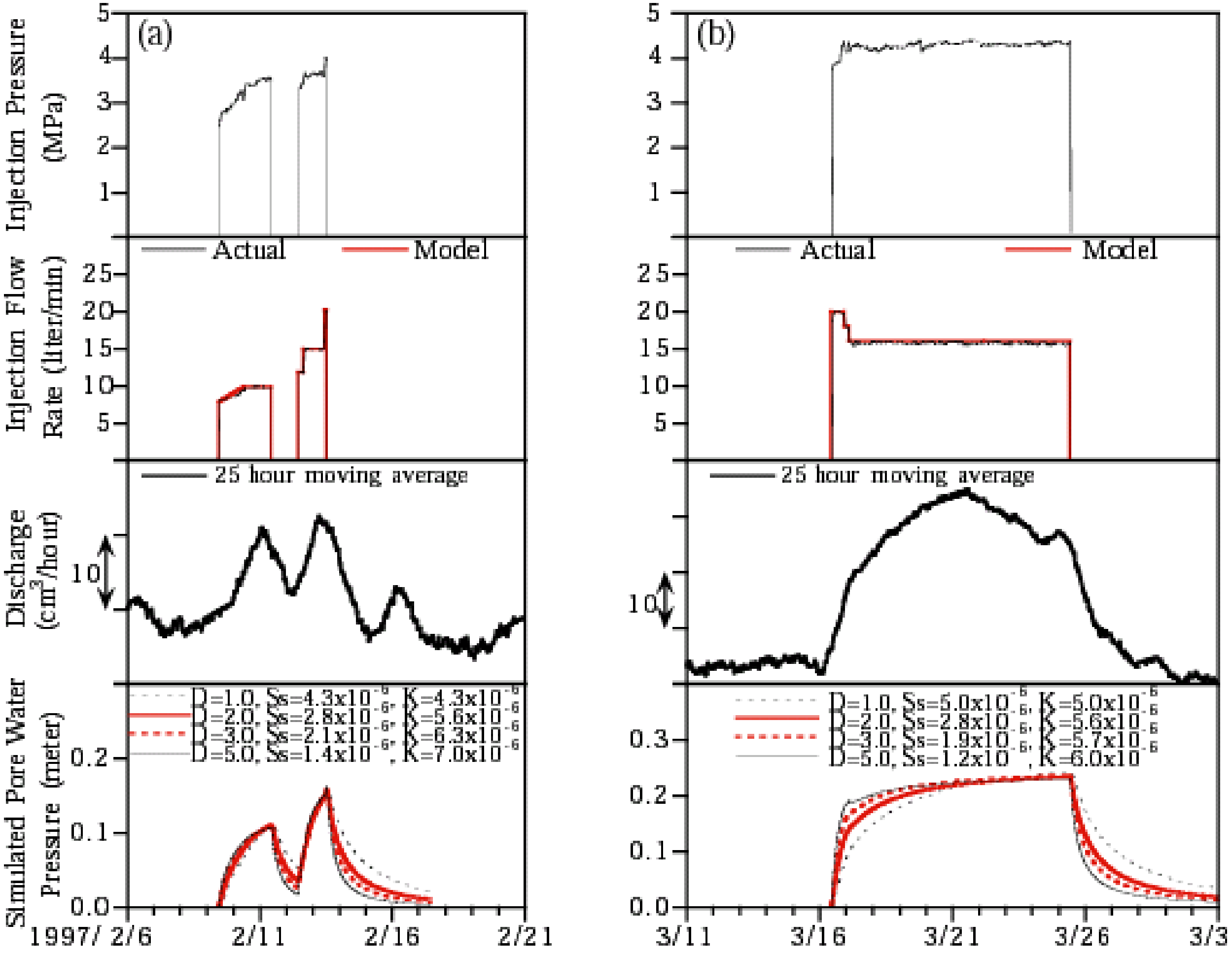
$$f(Q) = 0$$ at the others.

L: Grid size
Ss: Specific storage



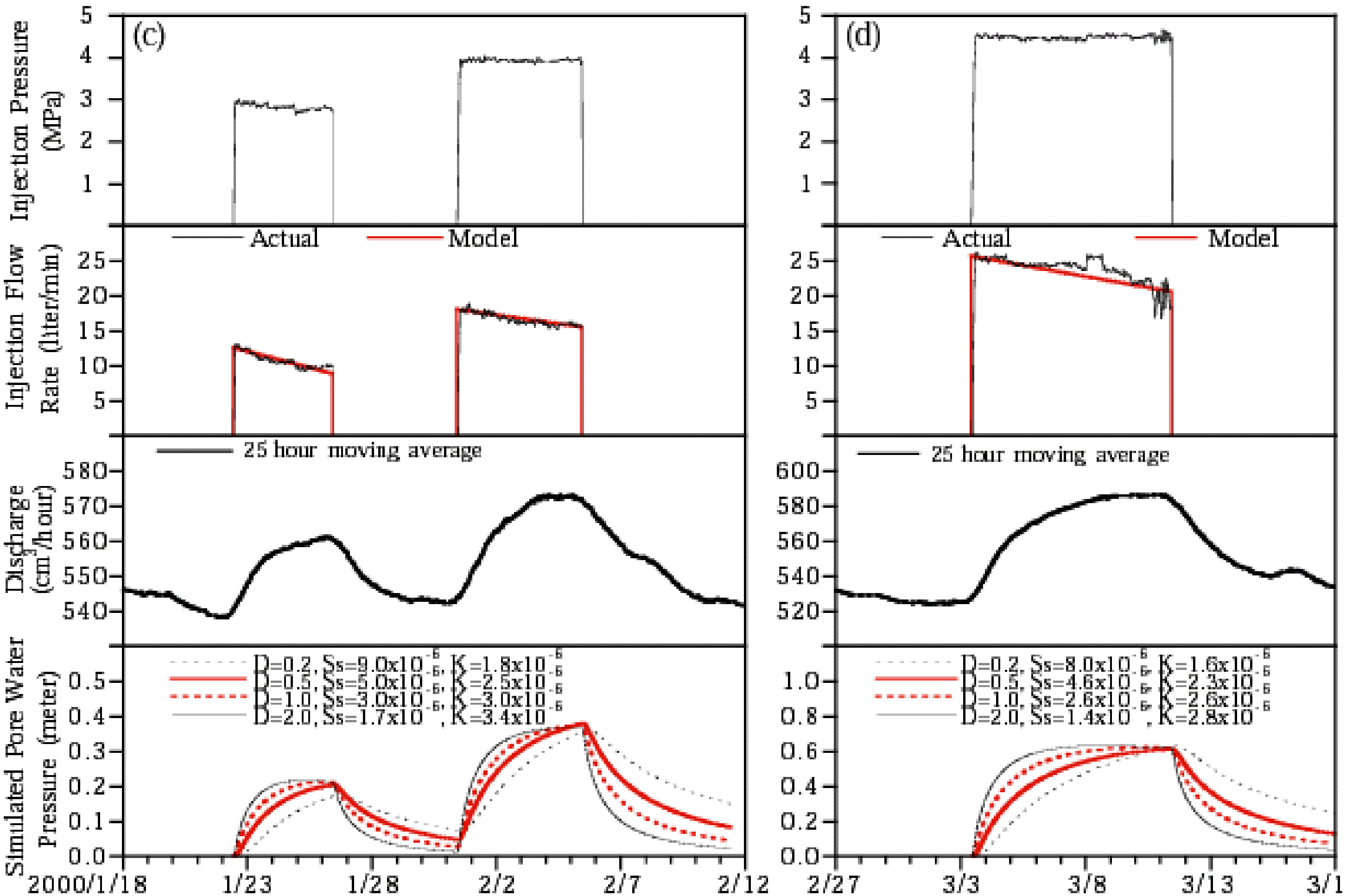
Result: case of the 1997 experiments

Estimated permeability is 5.6 – 6.3 m/s



Result: case of the 2000 experiments

Estimated permeability is 2.3 – 3.0 m/s



Conclusions

- The permeability of this site in 2000 became lower than that in 1997.
- This result shows that the macroscopic permeability of the damage zone of the Nojima branch fault decreased as time passed.
- Its temporal change is expected to be related to the healing process of a fault zone just after a large earthquake.

Reference

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