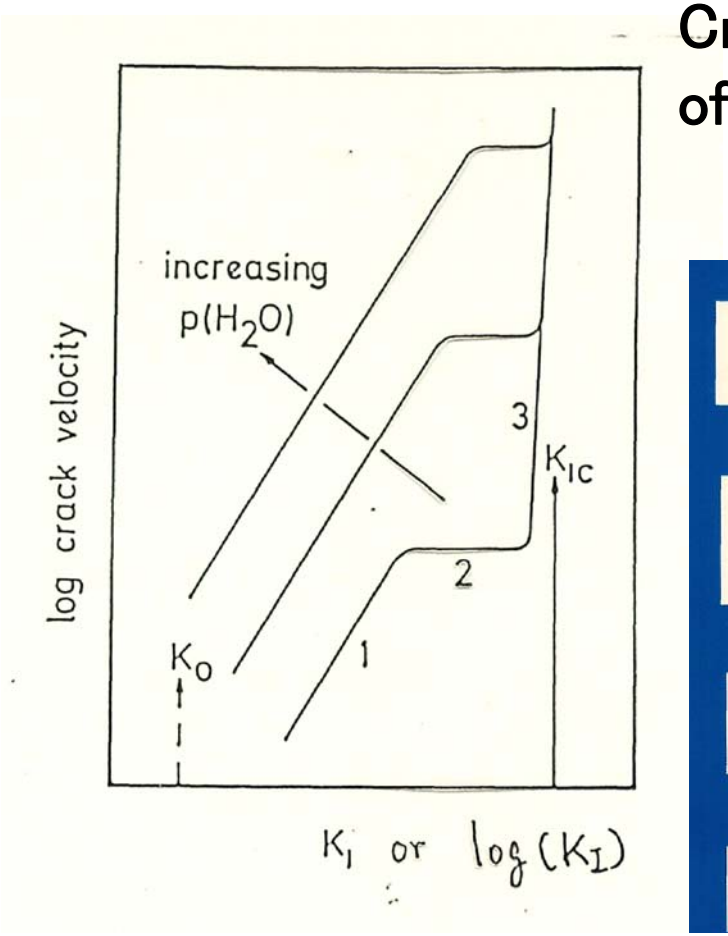
Stress Corrosion Cracking (Sub-Critical Crack Growth) and its Implication for Slow Slip

Osam SANO



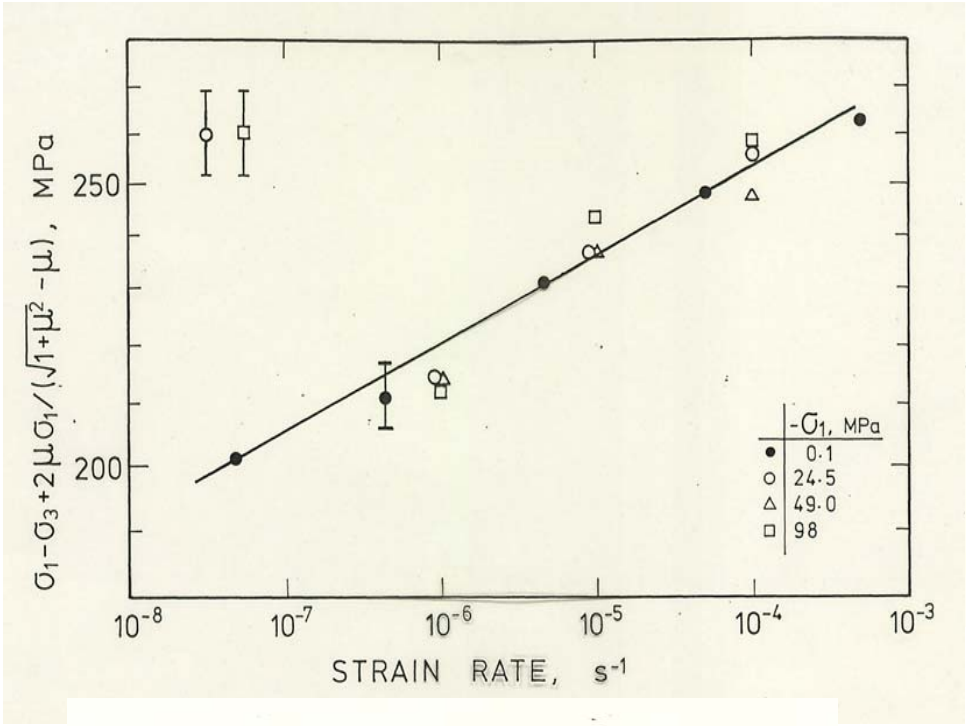
Cracks grow slowly even under critical state of stress, known as sub-critical crack growth.

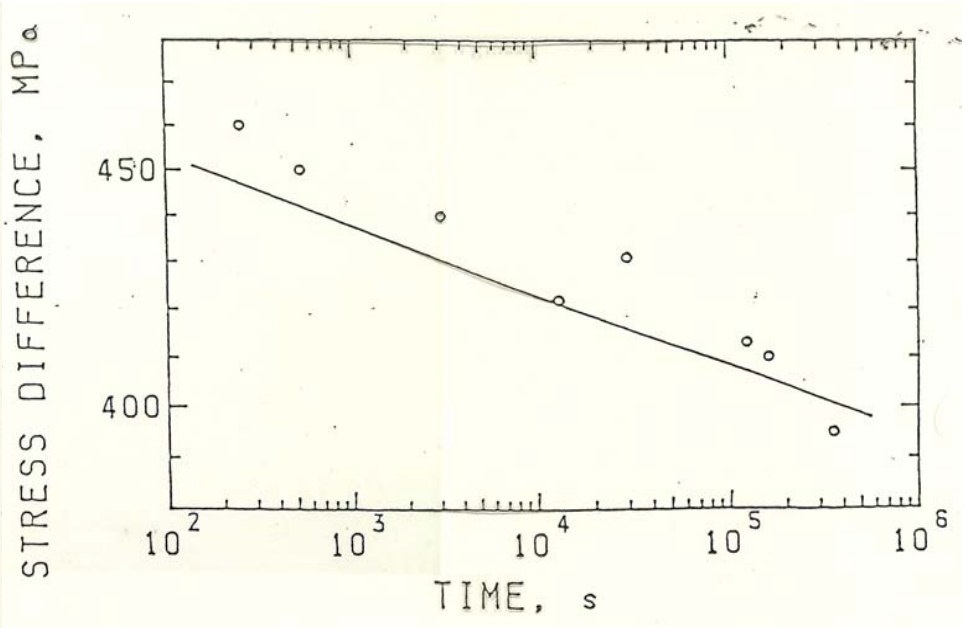
$[\equiv Si\text{-}O\text{-}Si\equiv] + H_2O \rightarrow \equiv SiOH + HOSi\equiv$

$V \propto K_I^{\,n} \exp(-E/kT)$

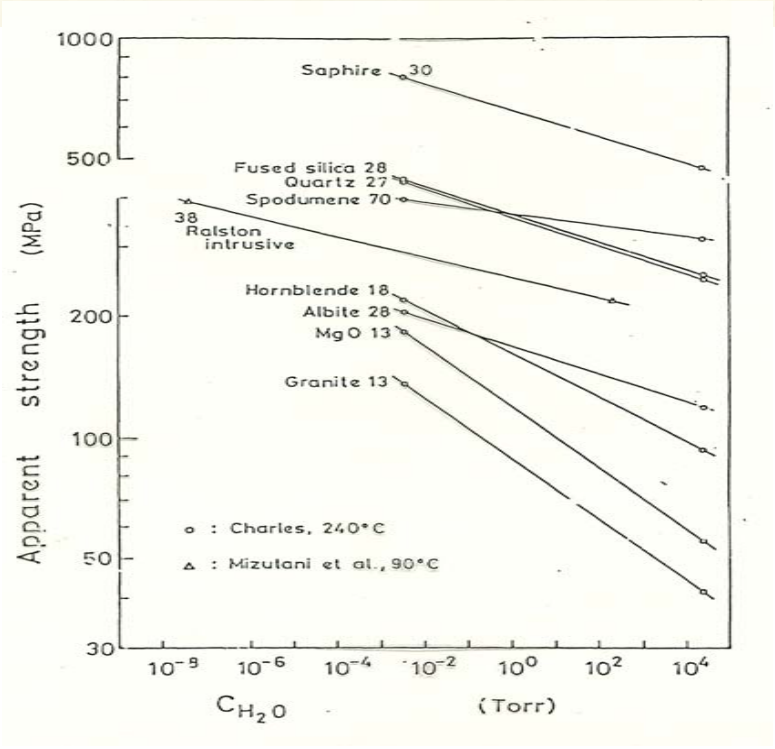
$V \propto \exp[-(E - \alpha K_I)/kT]$

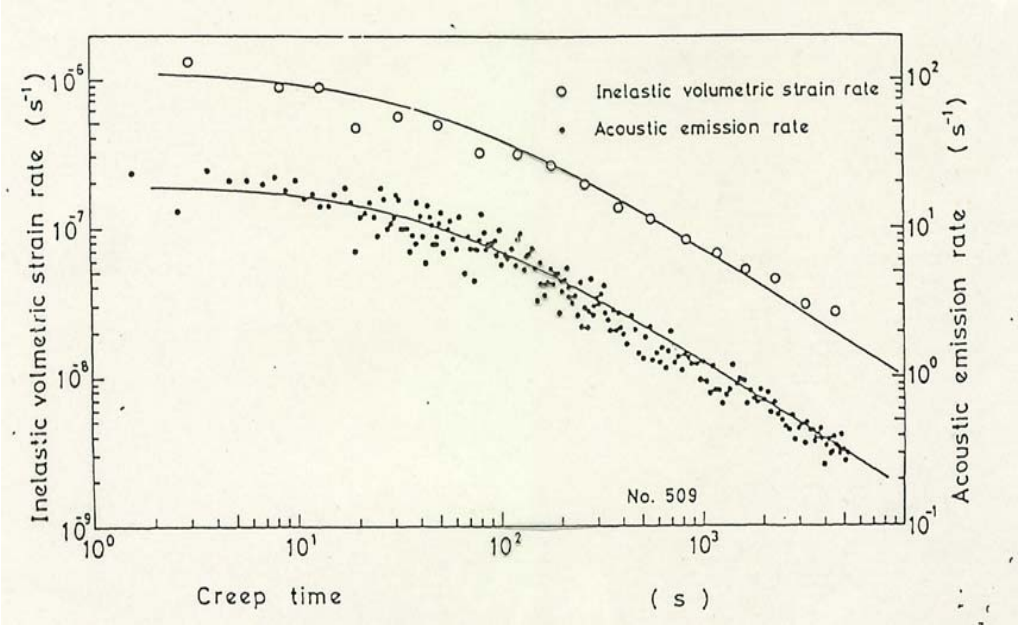
PURPOSE: 10^{-11}m/s or lower

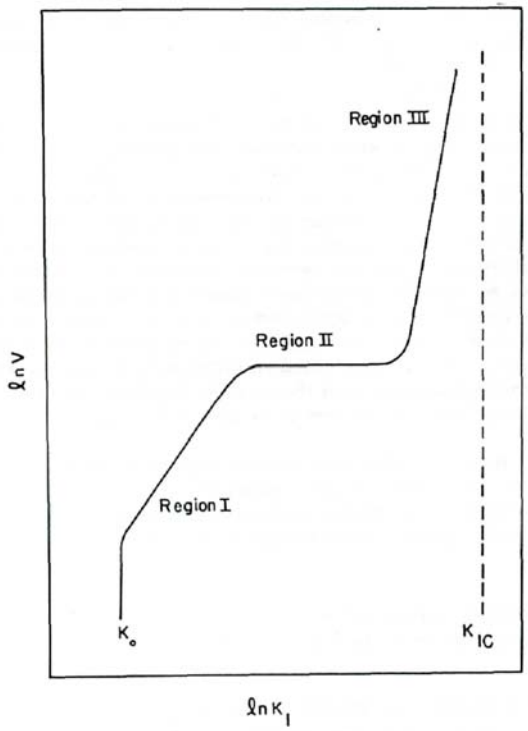




↑ Data by Kranz (1980) were re-plotted.







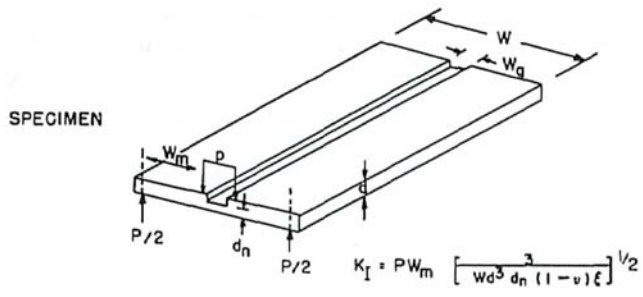
$$dC/dt = A_1 K_I^{\,n}$$

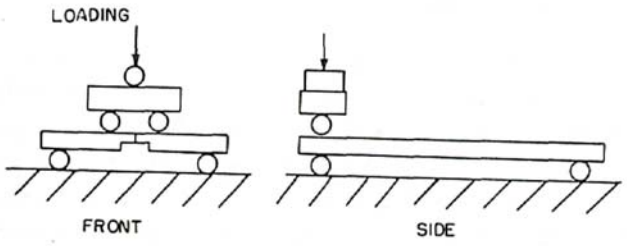
$$K_I = A_2 \sigma \sqrt{C}$$

$$dC/dt = A_1 A_2^{\,n} \sigma^{\,n} C^{n/2}$$

$$[C^{1-n/2} - C_0^{\,1-n/2}]/(1-n/2) = A_1 A_2^{\,n} \sigma^{\,n} t$$

$$C_0/(dC_0/dt) = (n/2-1)\, t$$





Three years are required for extension of one meter under constant velocity of 10^{-8} m/s. As K is proportional to the square of crack length, dc/dt will be accelerated.

Scaling? C_{max} for 10 MPa is 0.02 m. Is it OK?

C_{max} for 100 hPa is 19 km…

Gc = 60～100 J/m^2 for observed Kc.

82 days for C_0=1m, dC_0/dt=1e^{-8} m/s, or

1 m and 2 e−10 m/s for 3 years.

Arrest mechanisms?

$y = \lambda P = (Bc+D)P$

$dy/dt = BP\,dc/dt + (Bc+D)\,dP/dt$

(1) Constant Load

$dc/dt = (dy/dt)/BP$

(at constant dy/dt.)

(2) Constant dy/dt

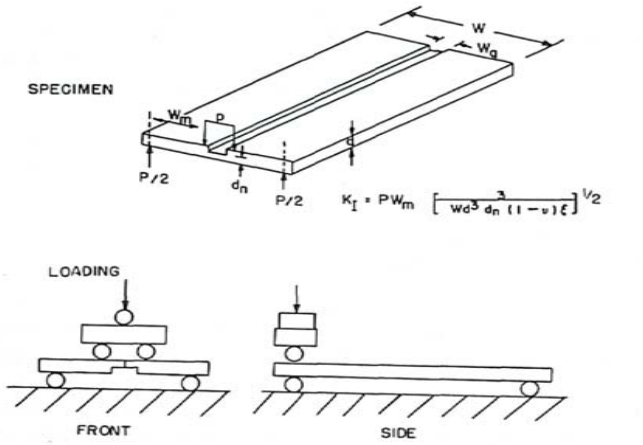
$dc/dt = (dy/dt)/BP$

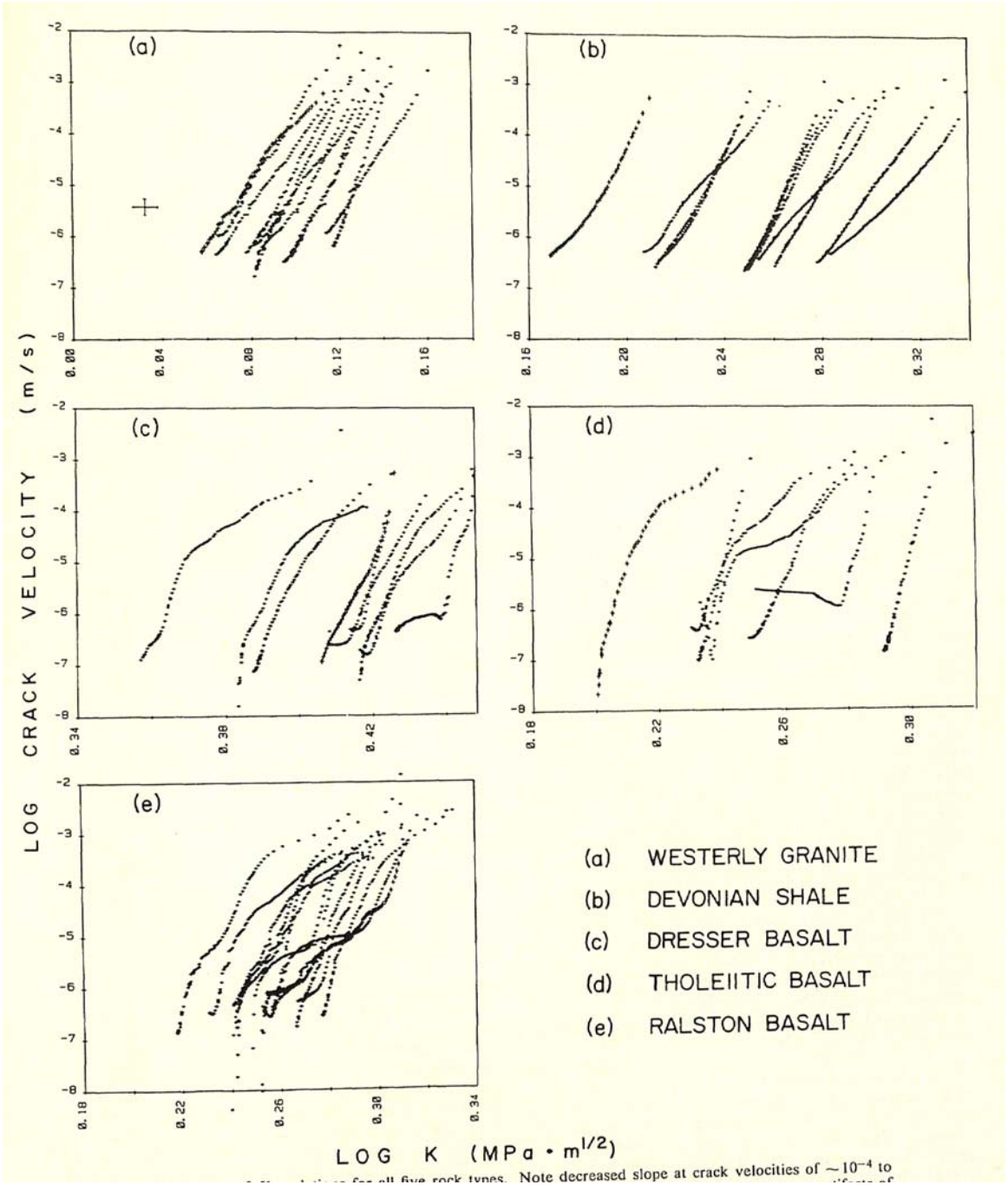
(at constant P).

(3) Constant y (Relaxation)

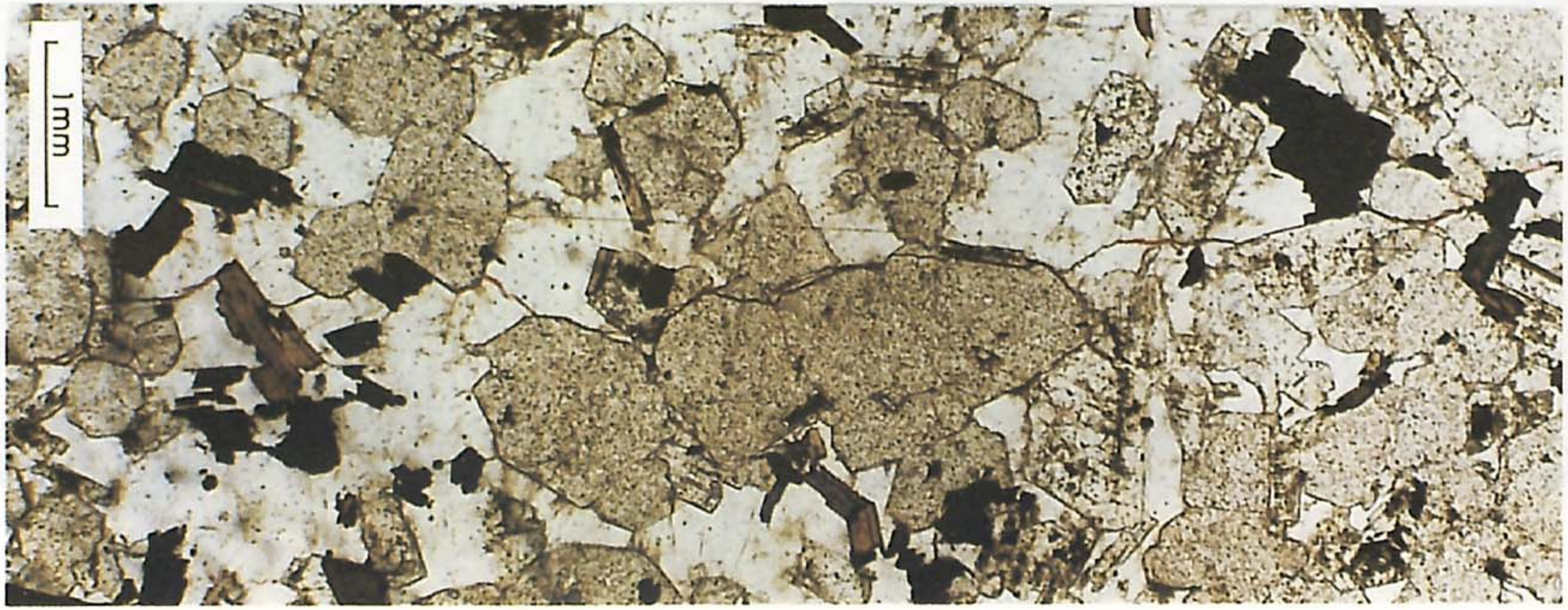
$dc/dt = -(P_i \lambda_i / BP^2)\, dP/dt$

(Red letters indicate observation)

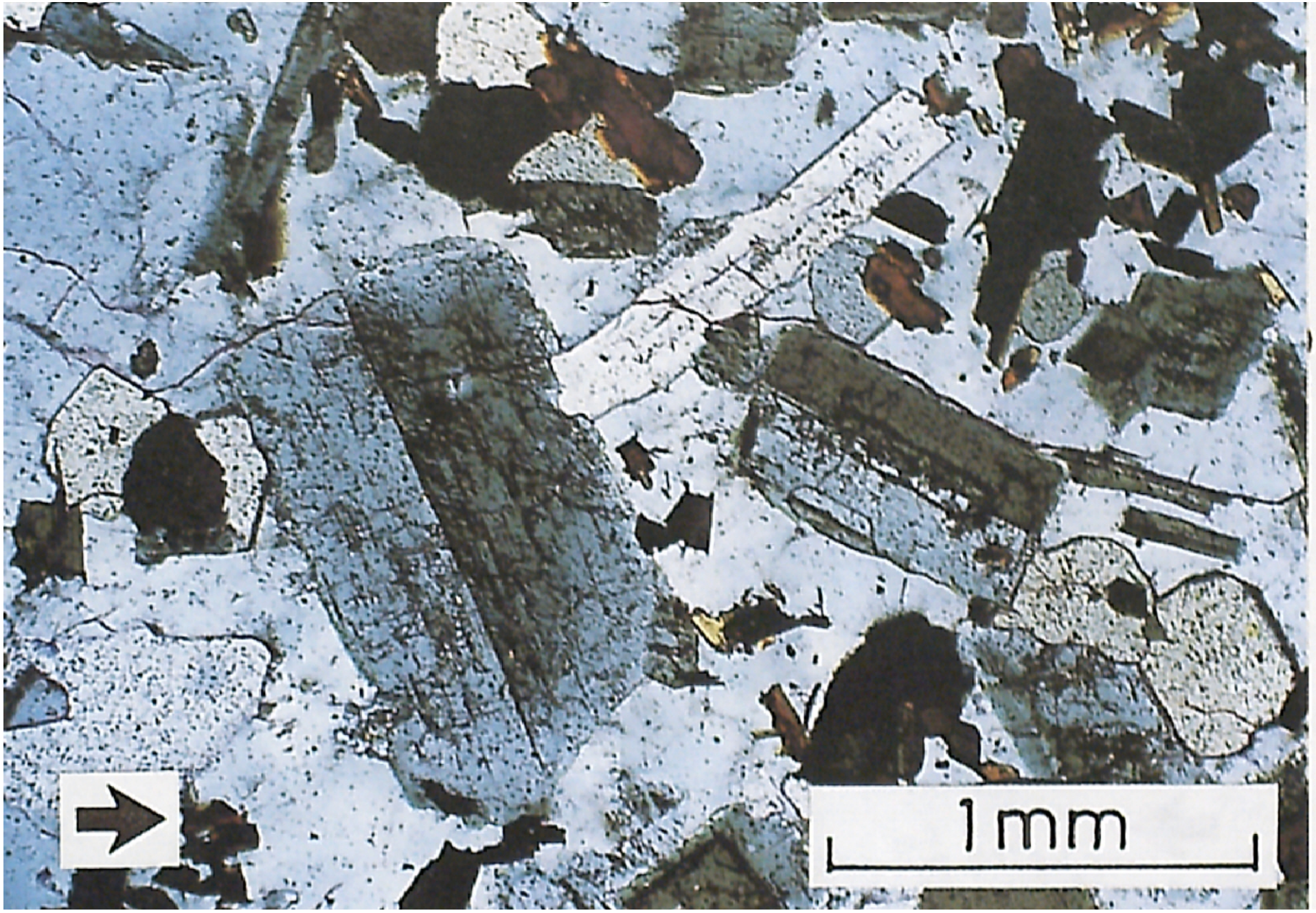


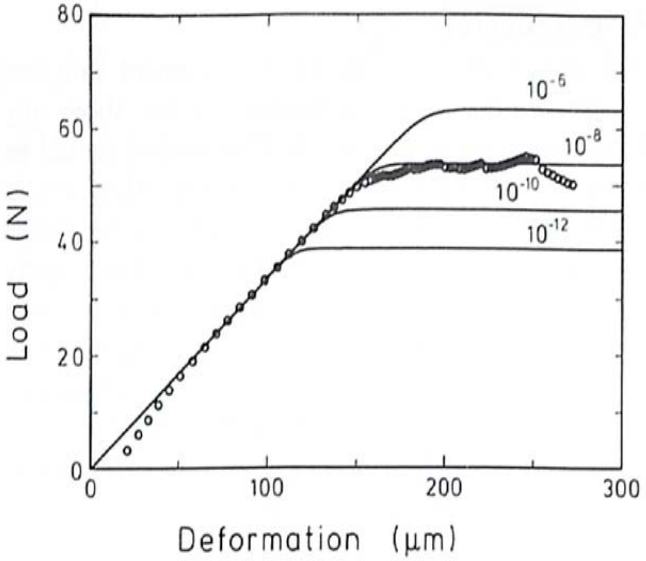


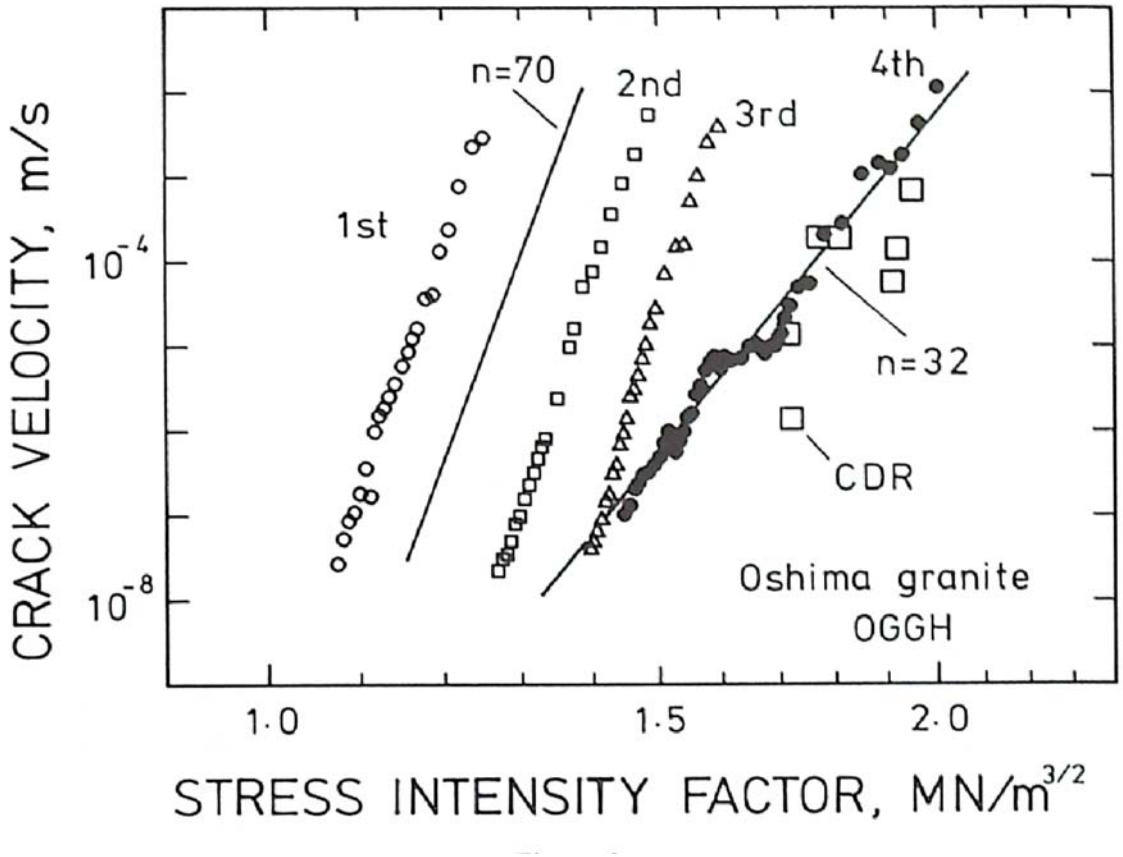
(After Swanson, J. G. R., 1984)

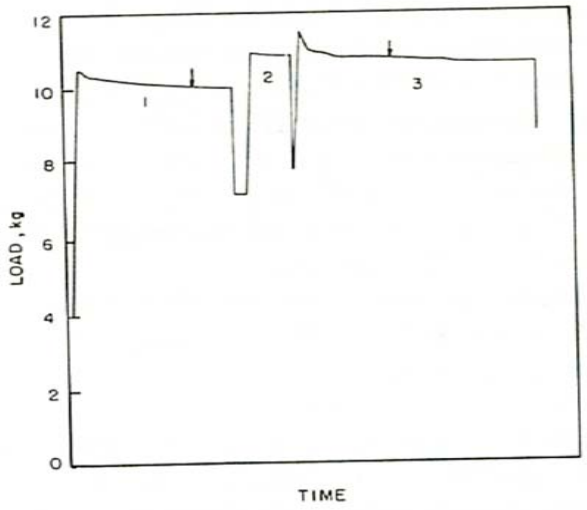

1mm


1mm


1mm

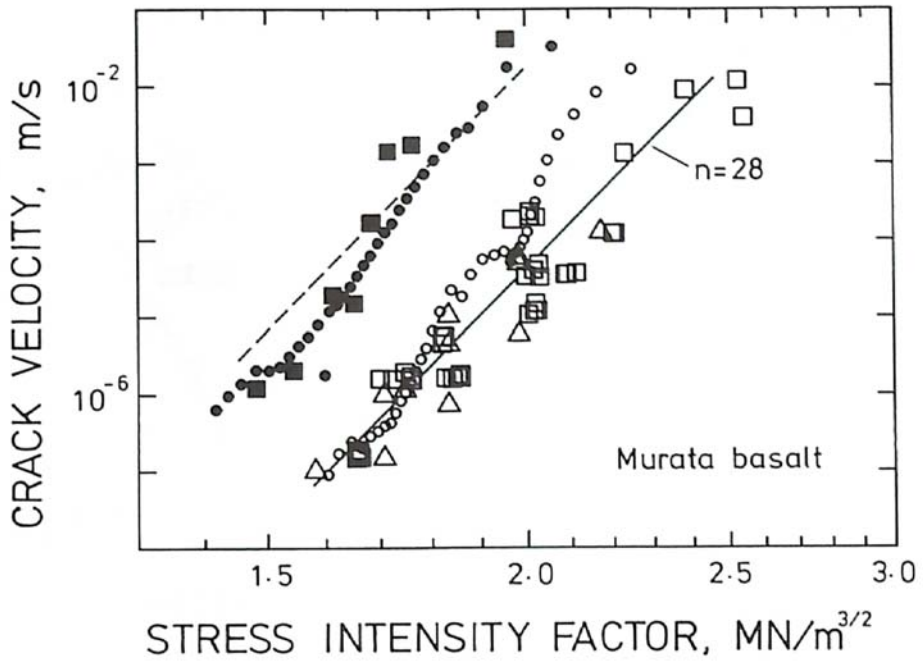


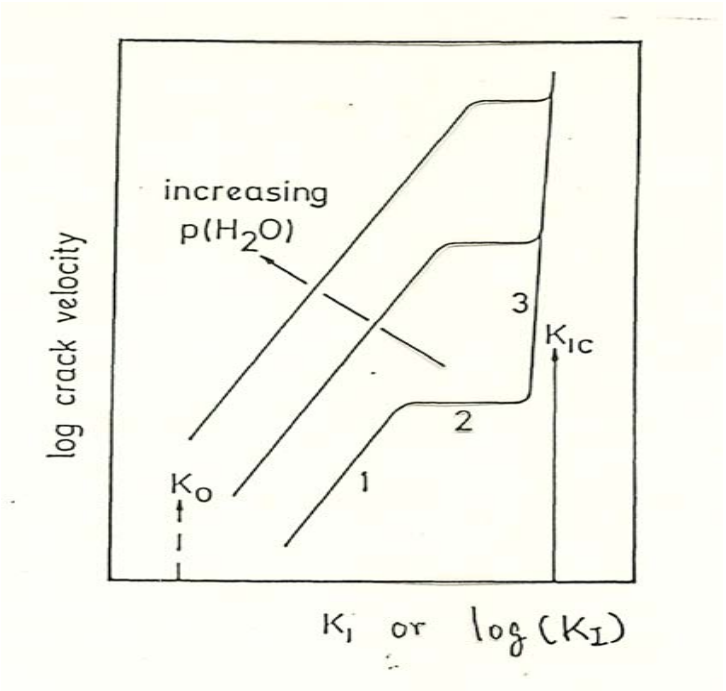


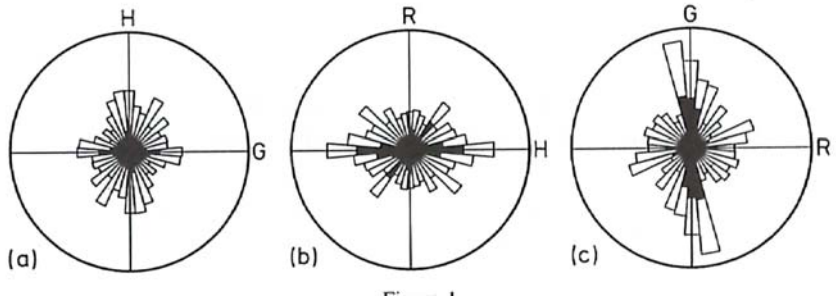


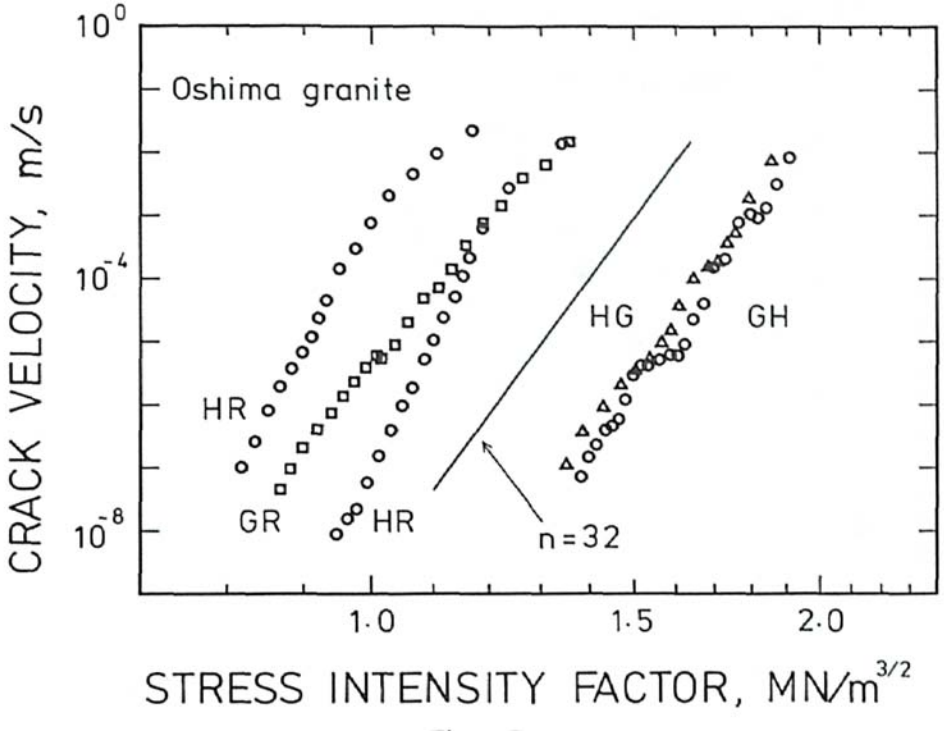
After Pletka et al. (1979).

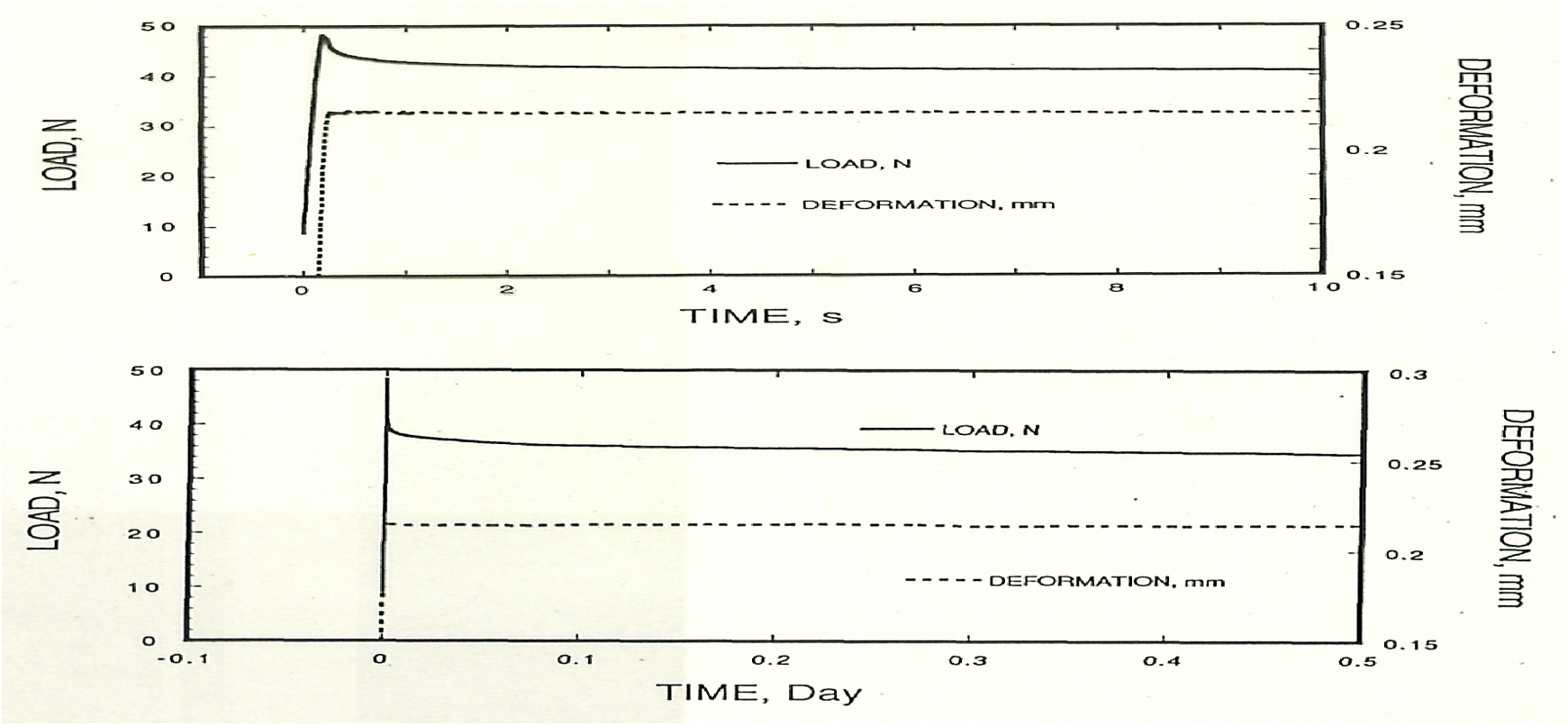
For rocks, load relaxation test has to be carried out under sufficiently large initial displacement. Sub-critical crack can easily be arrested or locked at barriers, or asperities.

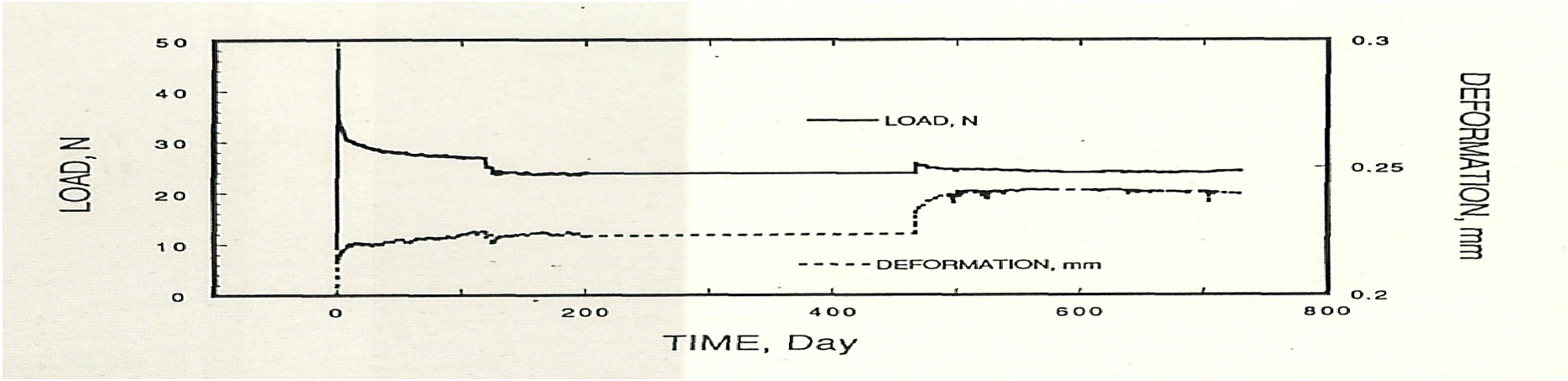

CRACK VELOCITY, m/s
10^{-2}
10^{-6}
n=28
Murata basalt
1·5
2·0
2·5
3·0
STRESS INTENSITY FACTOR, MN/m$^{3/2}$


increasing
p(H$_2$O)
log crack velocity
3
K_{IC}
2
1
K_O
K_I or log (K_I)


H
G
(a)
R
H
(b)
G
R
(c)

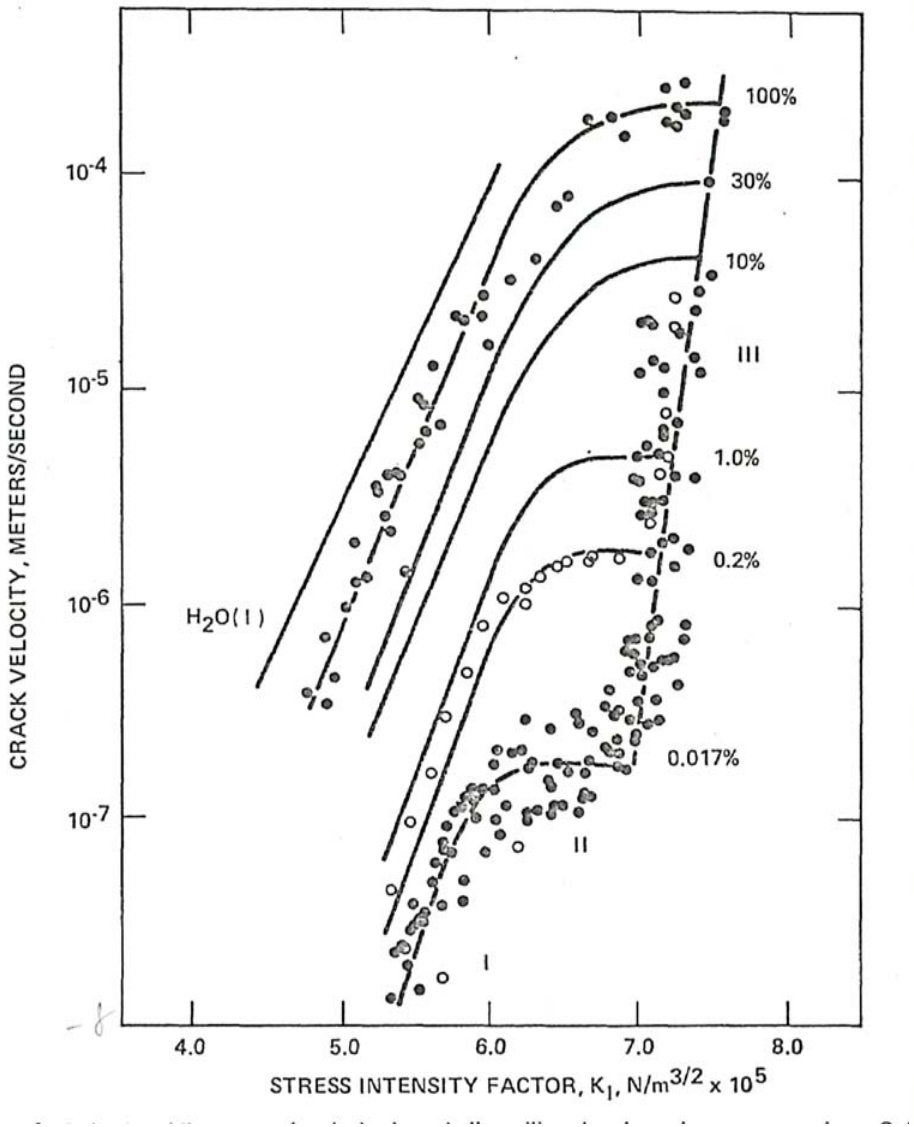

Oshima granite
CRACK VELOCITY, m/s
10^{0}
10^{-4}
10^{-8}
HR
GR
HR
HG
GH
n=32
1·0
1·5
2·0
STRESS INTENSITY FACTOR, MN/m$^{3/2}$



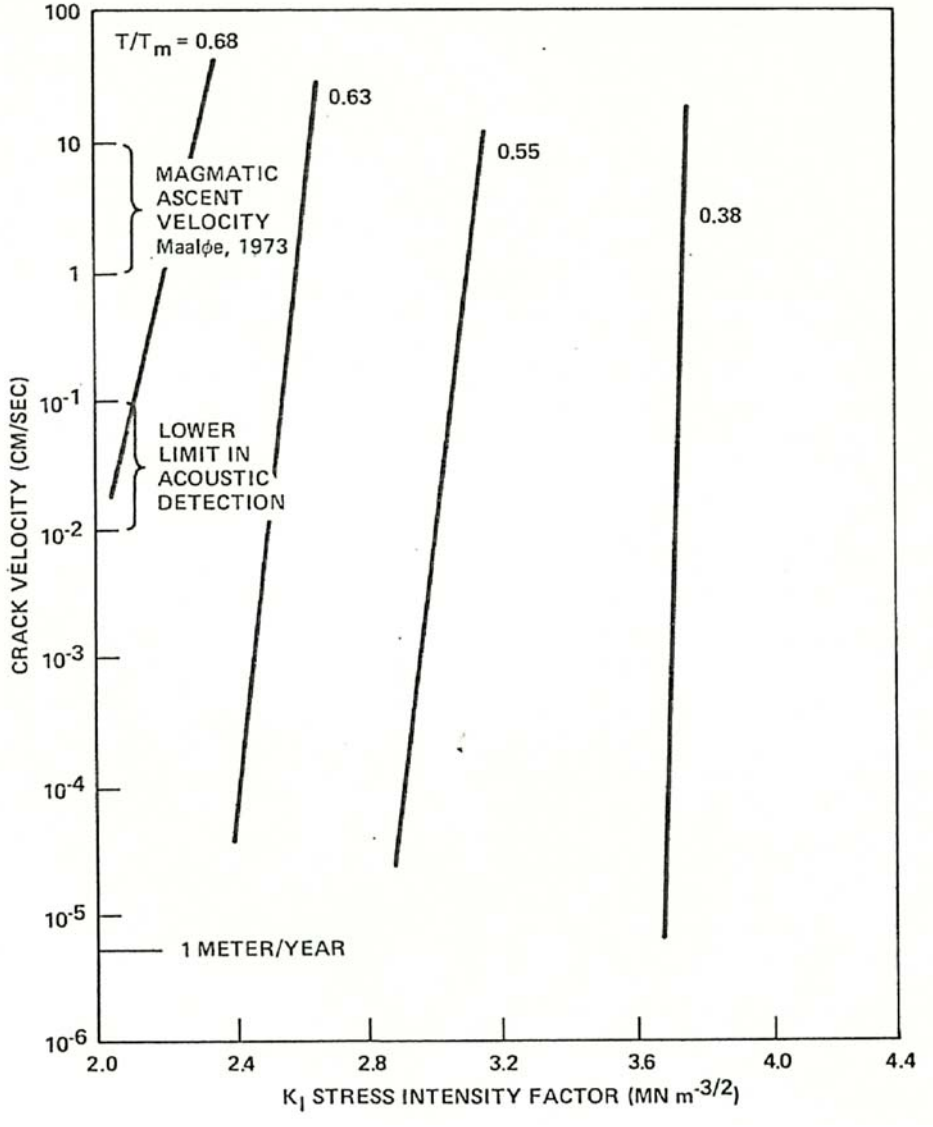


Memo: regarding to seismic effects on crack velocity, see Kerkhof, F., Proc. Int. Conf. Dynamic Crack Propagation, ed. Sih, Noordhoff Int. Publ., Leyden, 3-35, 1972.

We have to consider High temperature, high pressure and water.



After Wiederhorn (1967).



After Anderson and Grew (1979).