THE FAULT STIFFNESS AS THE KEY PARAMETER THAT CONTROLS EQ EFFICIENCY SCALING LAW

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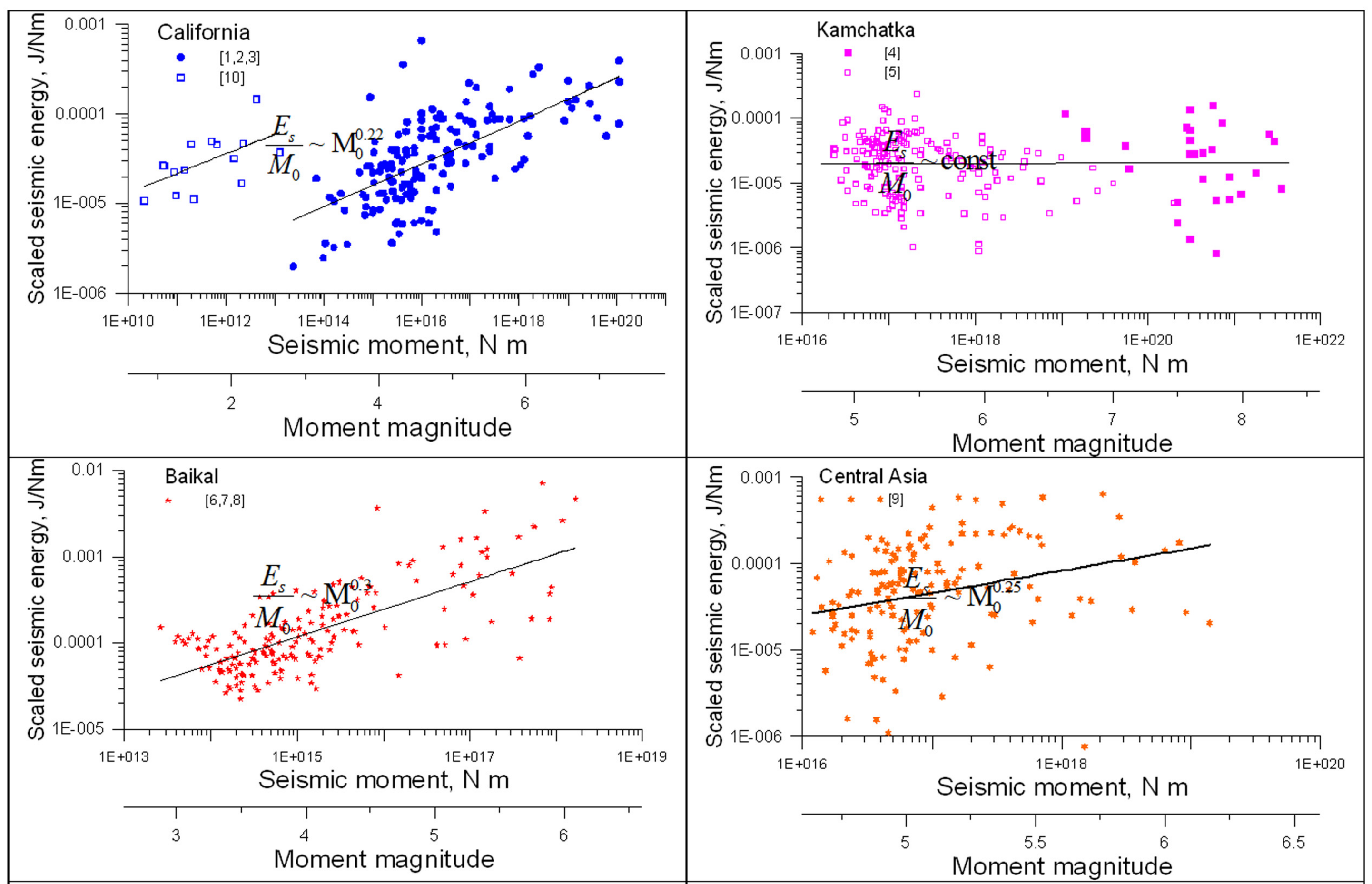
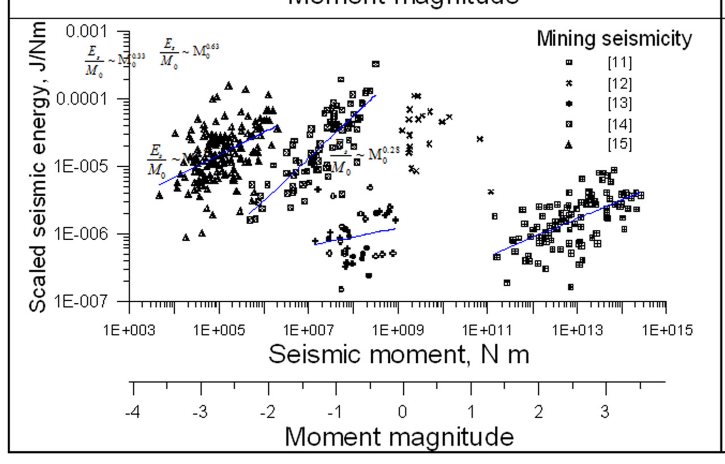
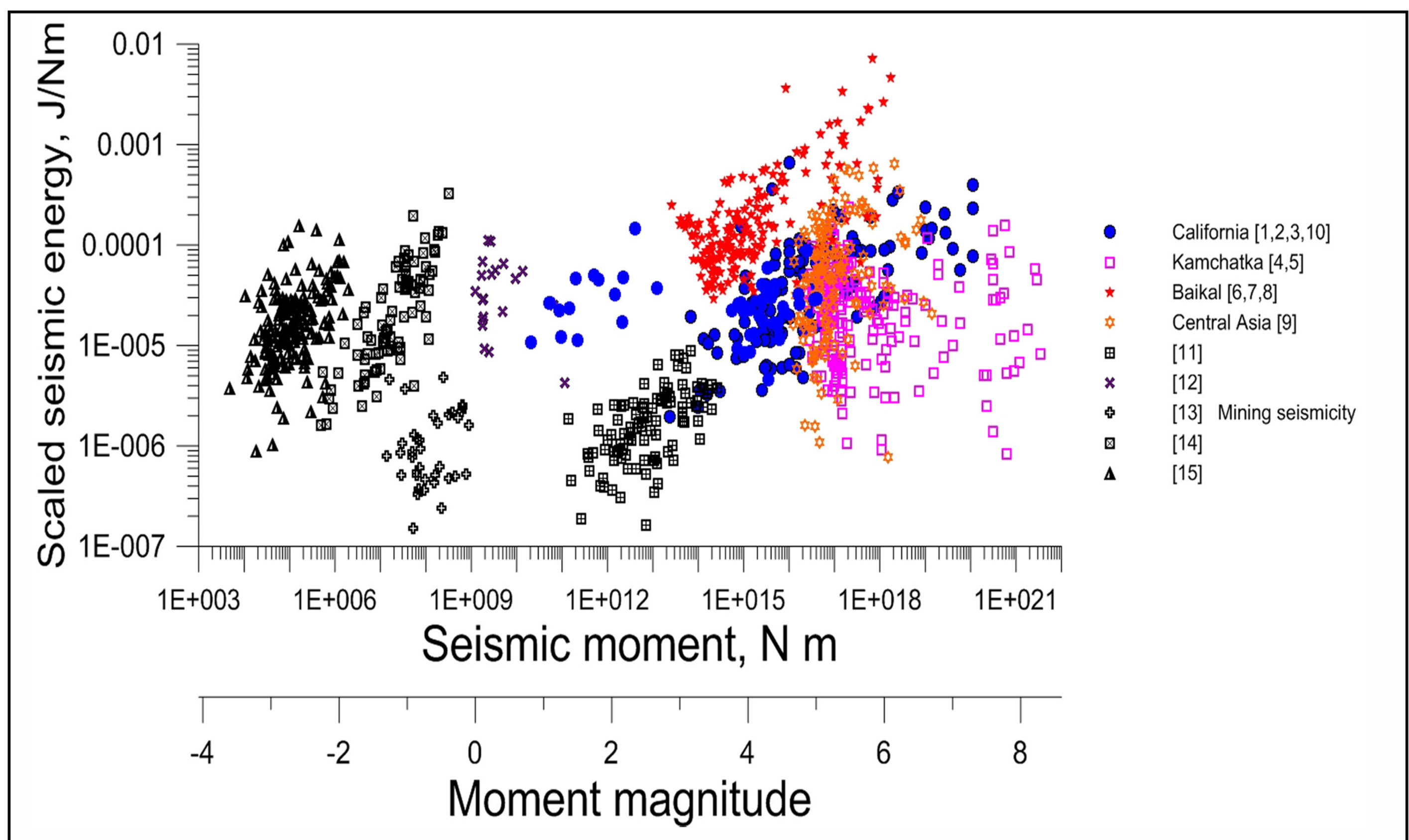




Scaled seismic energy vs EQ scale for some regions.

However, it is well known that consideration of individual rows of data often leads to the dependence of efficiency of radiation on the scale of event, even if the contribution of high frequency range of wave's spectrum to seismic energy is underestimated.

It is well known that earthquakes have different mechanical efficiencies. Fraction of the energy emitted in the form of seismic waves can vary widely. It is usually assumed that the tectonic earthquake seismic energy Es is of the order of a few percent of the total potential energy change ΔEe. However, in some cases this ratio differs significantly. So, tsunami earthquakes have the ratio Es/ΔEe one - two orders of magnitude lower, and for the so-called silent earthquakes Es becomes negligible. It is clear that the characteristics of radiated seismic waves are defined by the rapture velocity. The slower the rupture, the less energy is radiated in comparison to the scalar seismic moment M0.



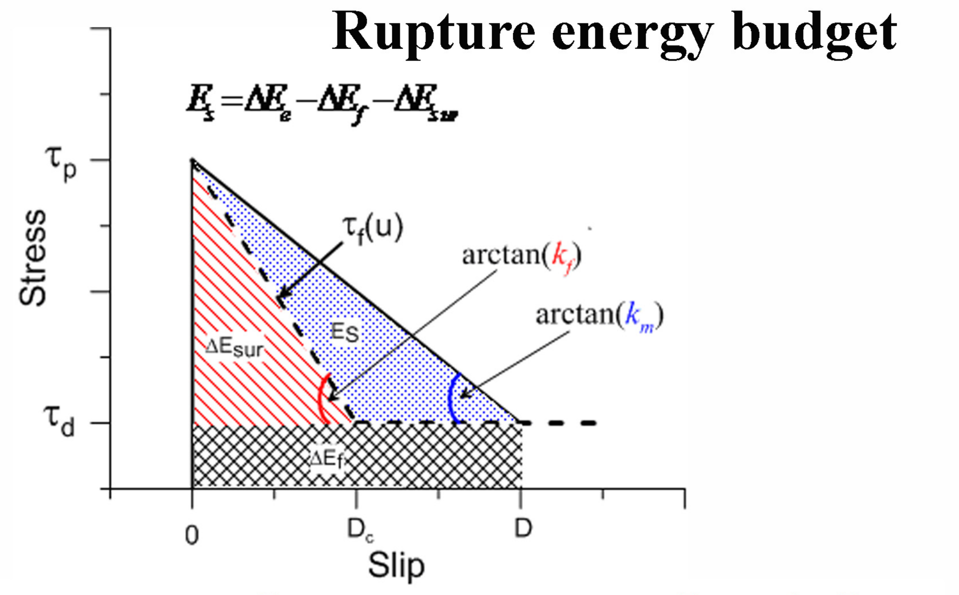
Scaled seismic energy vs EQ scale

If one changes the seismic moment by 19 orders of magnitude, almost all the data lie in the range Es/M0 ~ 10-6-10-3. Thus, in the full range of data, no dependence of this ratio on earthquake scale is detected, which corresponds to the self-similar medium with linear characteristics.

1 – (Kanamori et al., 1993); 2 – (Mori et al., 2003); 3 – (Mayeda et al., 1996);
4 – (Venkataraman, Kanamori, 2004), 5 –(www.emsd.ru/);
6 - (Dobrynina, 2011); 7 – (www.seis-bykl.ru/); 8 – (Kluchevsky, 2002); 9 – (www.kndc.kz
10 – (Ide, Beroza, 2001); 11 – (Domański, Gibowicz, 2008);12- (Yamada et al, 2007);
13 – (Oye et al. 2005); 14 – (Urbancic, Young, 1993); 15 –(Gibowicz et al., 1991)

- **What macroscopic parameters could be markers of the earthquake radiation efficiency?**
- **Is the specific slip mode at a particular location an inherent property of the fault, or determined by transient conditions?**
- **Is EQ efficiency the same in all magnitude ranges or there is some scaling law?**

Rupture energy budget



Seismic efficiency $\eta = \frac{E_s}{\Delta E_e}$. Radiation efficiency $\eta_R = \frac{E_s}{E_s + \Delta E_{sur}} = \frac{2\mu}{\Delta\tau}\frac{E_s}{M_0}$ (*Kanamori, Brodsky, 2004*). $\eta_R \geq \eta$. If $\eta_R \approx 1$, the breakdown zone is unimportant and friction-dominated failure occurs. If $\eta_R << 1$, the microscopic and macroscopic fracturing processes dominate.

Scaled energy $\frac{E_s}{M_0}$ is a convenient parameter to characterize radiation efficiency.

Radiation efficiency

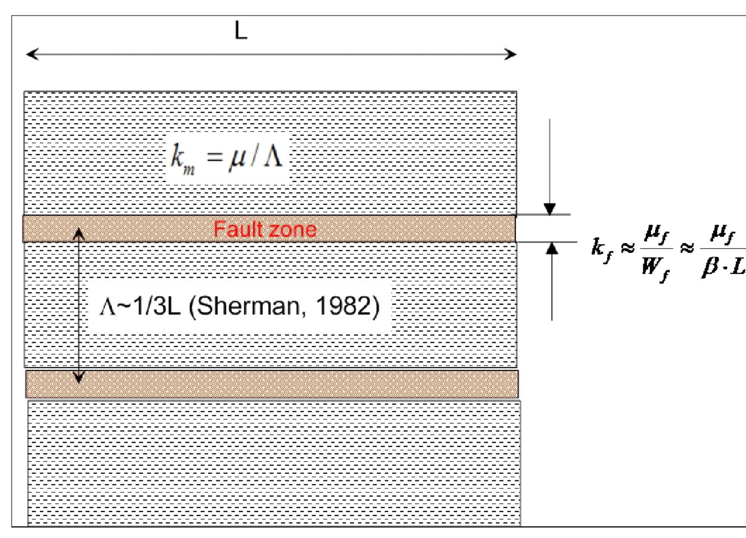
$$\eta_R = \frac{E_s}{E_s + \Delta E_{sur}} = \frac{2\mu}{\Delta\tau}\frac{E_s}{M_0} = \frac{D\cdot\Delta\tau - D_c\cdot\Delta\tau}{D\cdot\Delta\tau} = 1 - \frac{D_c}{D} = 1 - \frac{k_m}{k_f}$$

$$\Delta\tau = \tau_p - \tau_d \approx k_m \cdot D \approx k_f \cdot D_c$$

$k_m = \mu/\Lambda$ - stiffness of enclosing massif $\Lambda \approx \frac{1}{3}L$ (Sherman.1982)

k_f - fault stiffness

$$\eta_R \approx 1 - \frac{3\mu}{L\cdot k_f} \qquad (*)$$

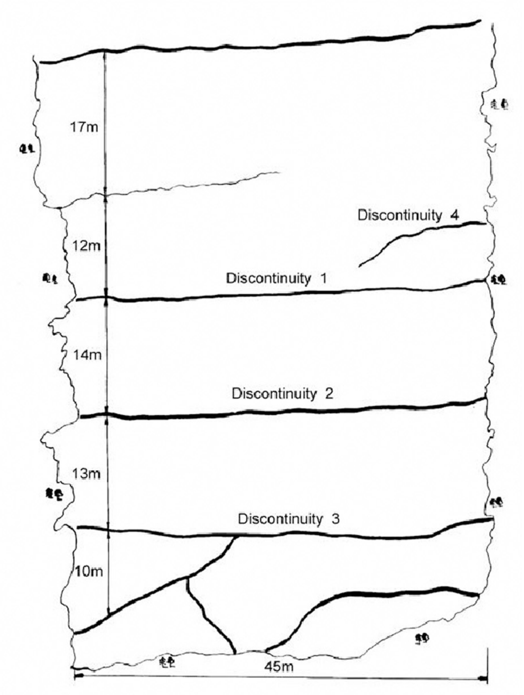


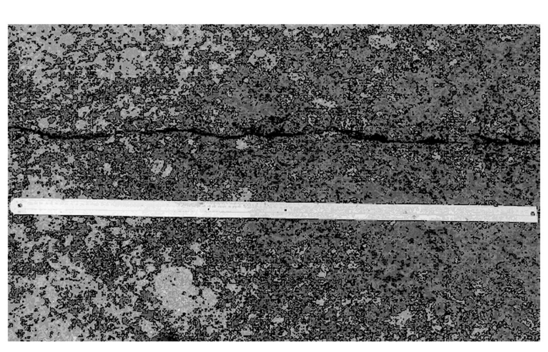
The simplest case

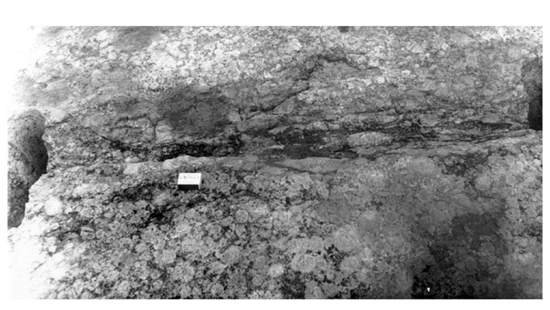
$k_f \approx \frac{\mu_f}{W_f} \approx \frac{\mu_f}{\beta\cdot L}$; $\beta \sim 10^{-3}$

From (*) $\eta_R \approx 1 - \frac{3\cdot 10^{-3}\mu}{\mu_f}$,

So, in the case of linear decrease of fault's shear stiffness with scale (self-similarity) the value of doesn't depend on the scale of event.

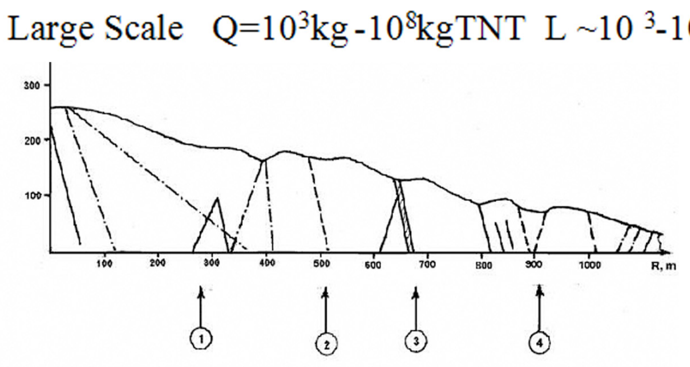


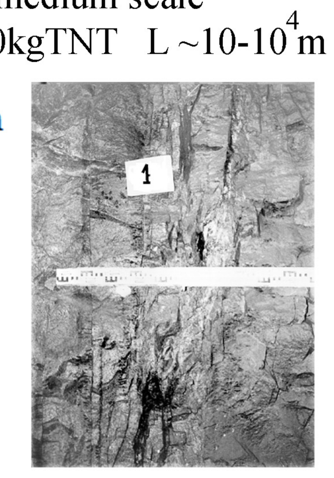


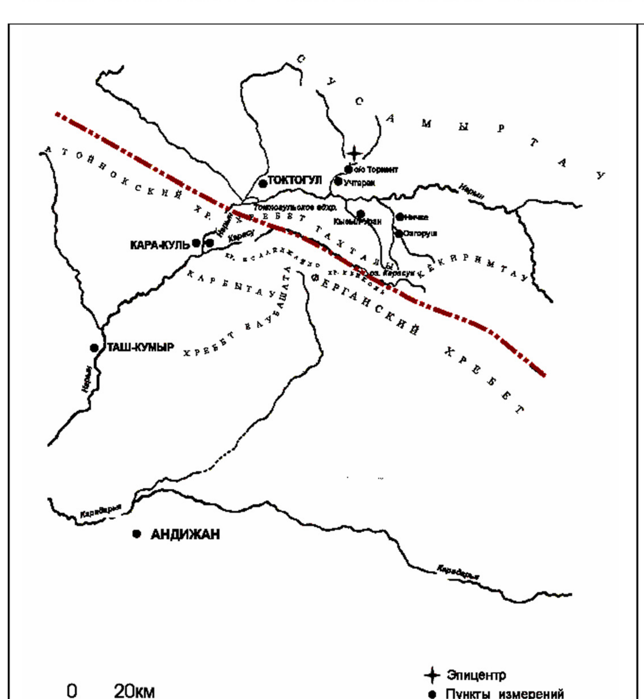


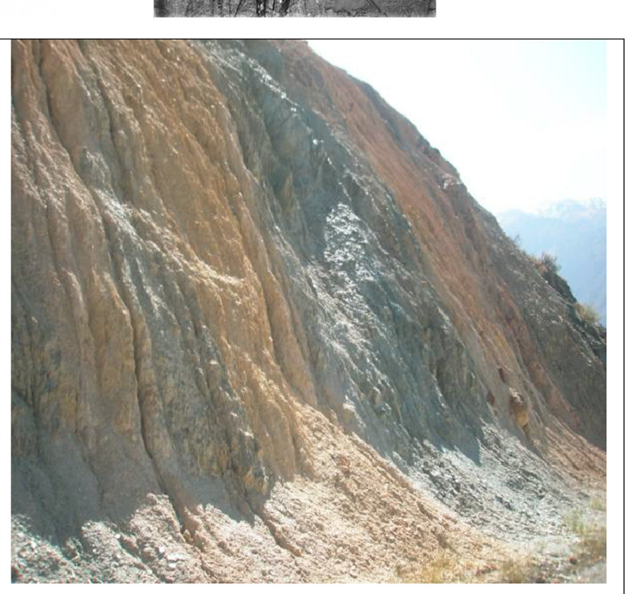
Small and medium scale
Q = 1g-100kgTNT L ~10-10[4]m

Large Scale Q=10[3]kg-10[8]kgTNT L ~10 [-3]-10[5]m



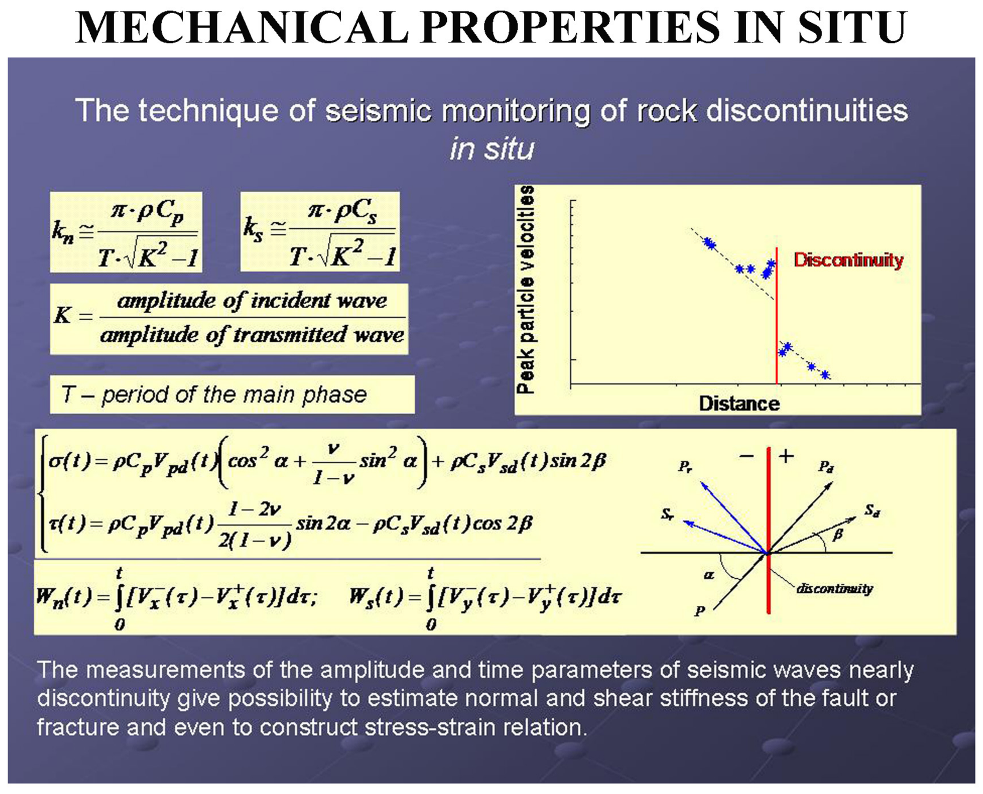


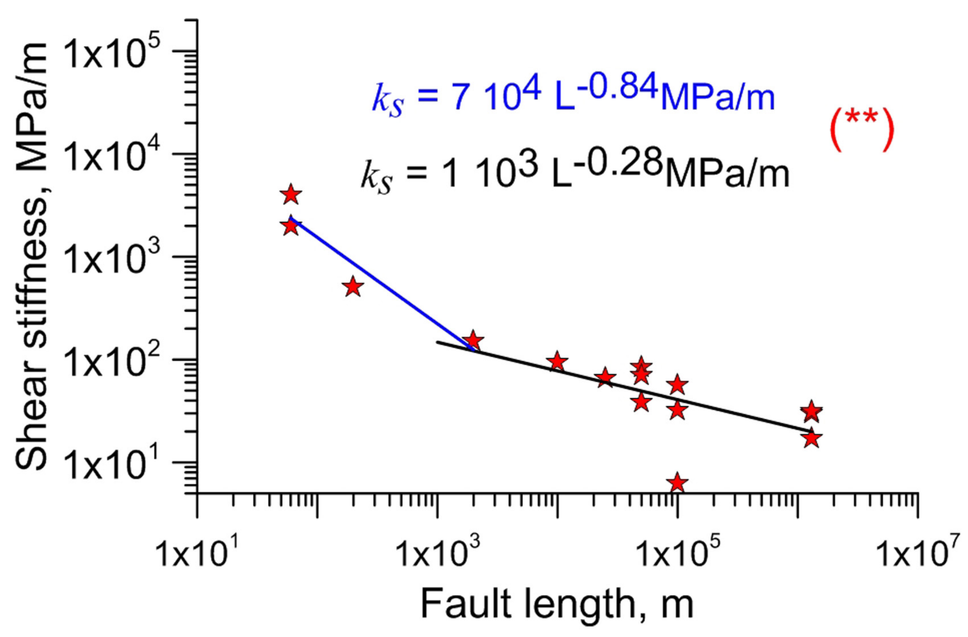




Giant Scale Q=10[5]kg-10[8]kgTNT L ~5 10[4]-5 10[6]m

STUDY OF REAL DISCONTINUITIES MECHANICAL PROPERTIES IN SITU

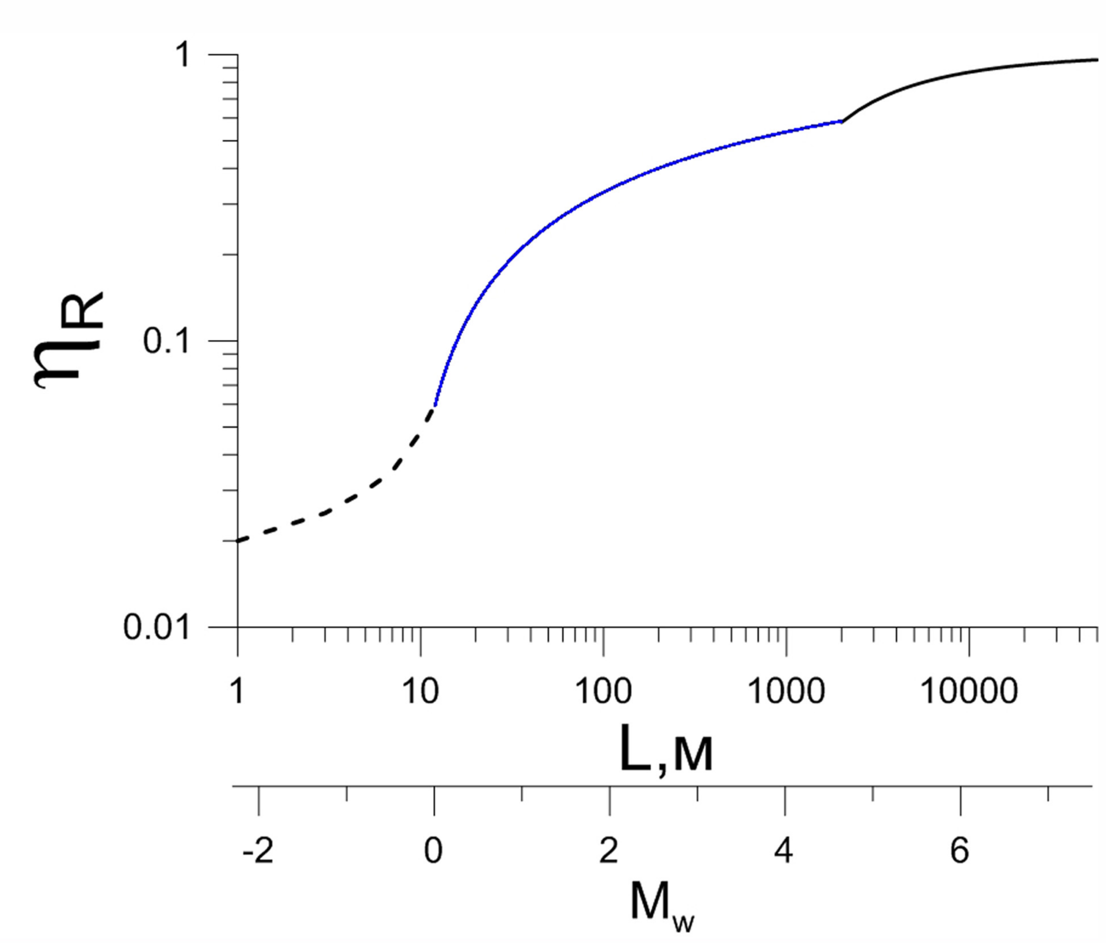




ESTIMATIONS OF RADIATION EFFICIENCY

From (*) and (**) radiation efficiency is:

$$\eta_R = \begin{cases} 1 - \frac{1.4}{L^{0.16}}, & 50м < L < 2000м \\ 1 - \frac{100}{L^{0.72}}, & L > 2000м \end{cases}$$



CONCLUSION:

- **Fault shear stiffness is the key macroscopic parameter that controls EQ radiation efficiency.**
- **The value of fault zone stiffness can be estimated in situ.**
- **The mode of sliding (normal EQ, low frequency EQ, very low frequency event, etc. is determined by the current fault zone mechanical properties rather than transient conditions.**
- **Fault shear stiffness scaling law set the tendency of increasing EQ radiation efficiency with the scale of events.**