An Analysis of the Dynamic Stress Drop and Rupture Velocity for Selected Seismic Events at Rudna Copper Mine

W. Dębski, B. Domański

Institute of Geophysics Polish Acad. Sci.

www.igf.edu.pl/d̃ebski

debski@igf.edu.pl

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Introduction

Rupture process can be characterized by a few parameters which describe kinematical and dynamical aspects of the rockmass breaking process.

- static stress drop
- apparent stress
- dynamic stress drop

Static stress drop

- Static (Brune) stress drop $[\sigma_0 - \sigma_1]$

$$\Delta\sigma_s = \frac{7}{16}\frac{M_0}{R^3}$$

Apparent stress

- Apparent stress

$$\sigma_a = \frac{\mu E}{M_0}$$

$$\sigma_a \approx 1/10\, \Delta\sigma_s \quad \text{(Rudna copper mine)}$$

Dynamic stress drop

- Dynamic stress drop $[\sigma_0 - \sigma_f]$

$$\Delta\sigma_f = \frac{M_0}{4\pi v_r^3 I} \left(1-\xi^2\right)^2 \frac{\mathrm{d}S}{\mathrm{d}t}$$

$$I = \int_0^T S(t)\,\mathrm{d}t$$

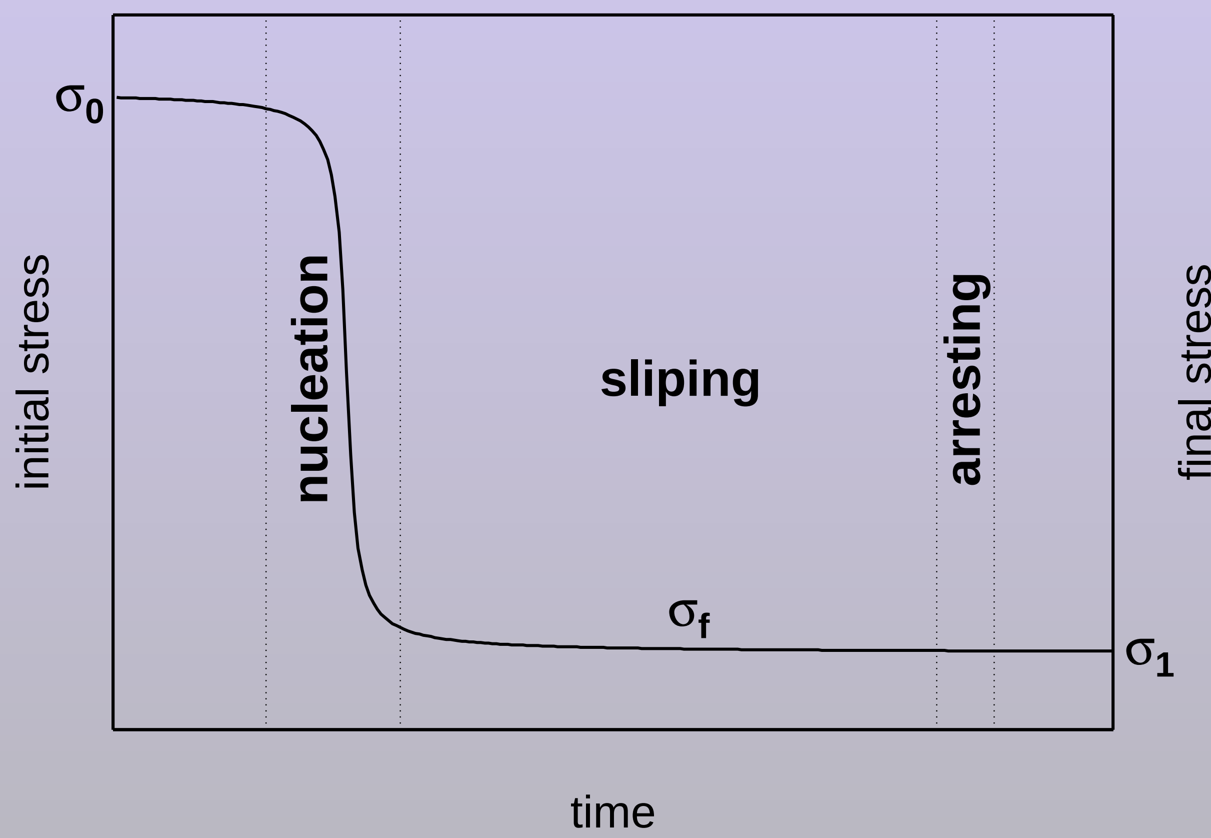
- Mo - seismic moment
- v_r - constant (assumption!) rupture velocity
- ξ - geometrical (directional) factor - assumed to be 0.75
- S - STF
- T - rupture duration time

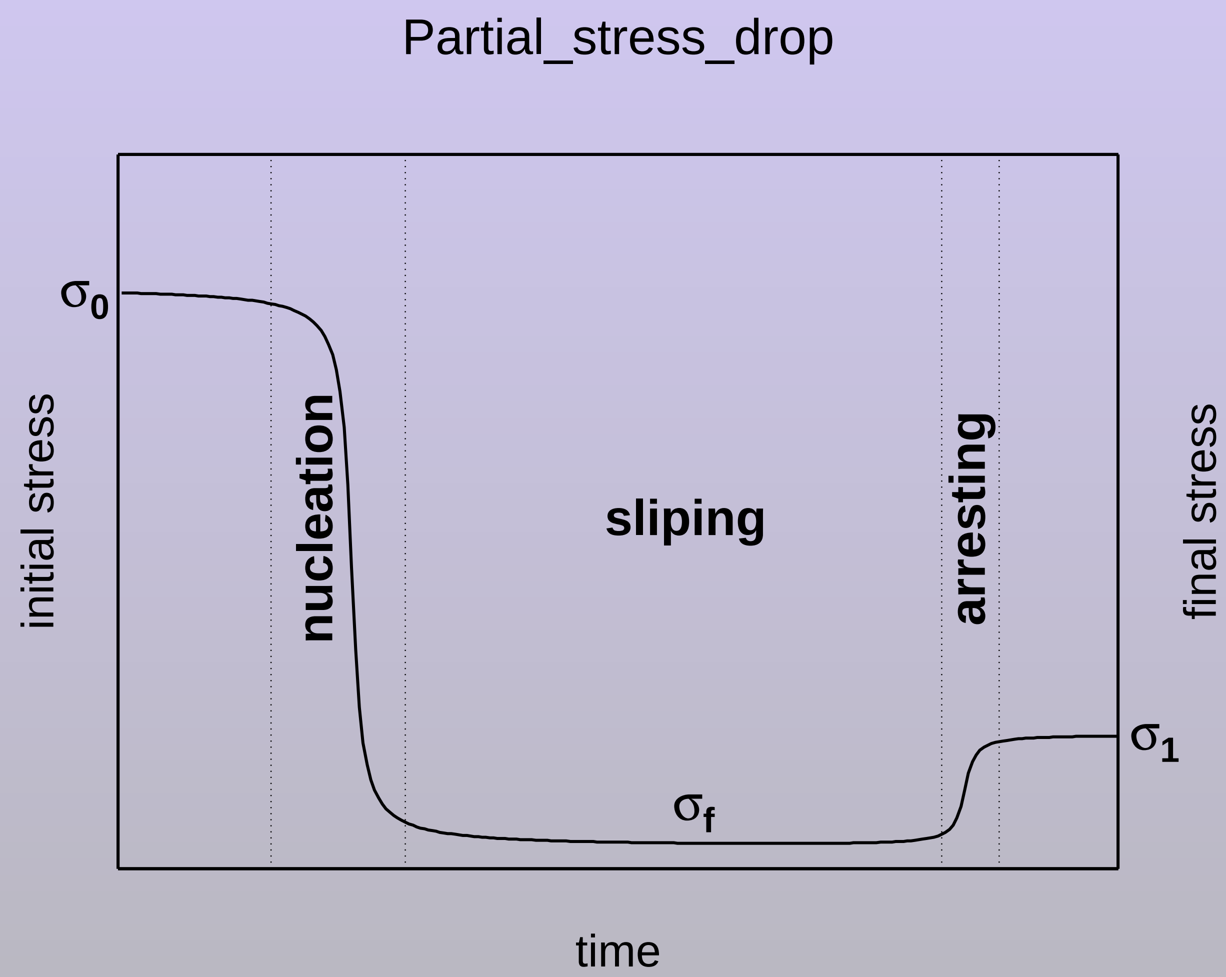
Partial stress drop/overshooting

$$\gamma_f = \Delta\sigma_f/\Delta\sigma_s = \frac{\sigma_0 - \sigma_f}{\sigma_0 - \sigma_1}$$

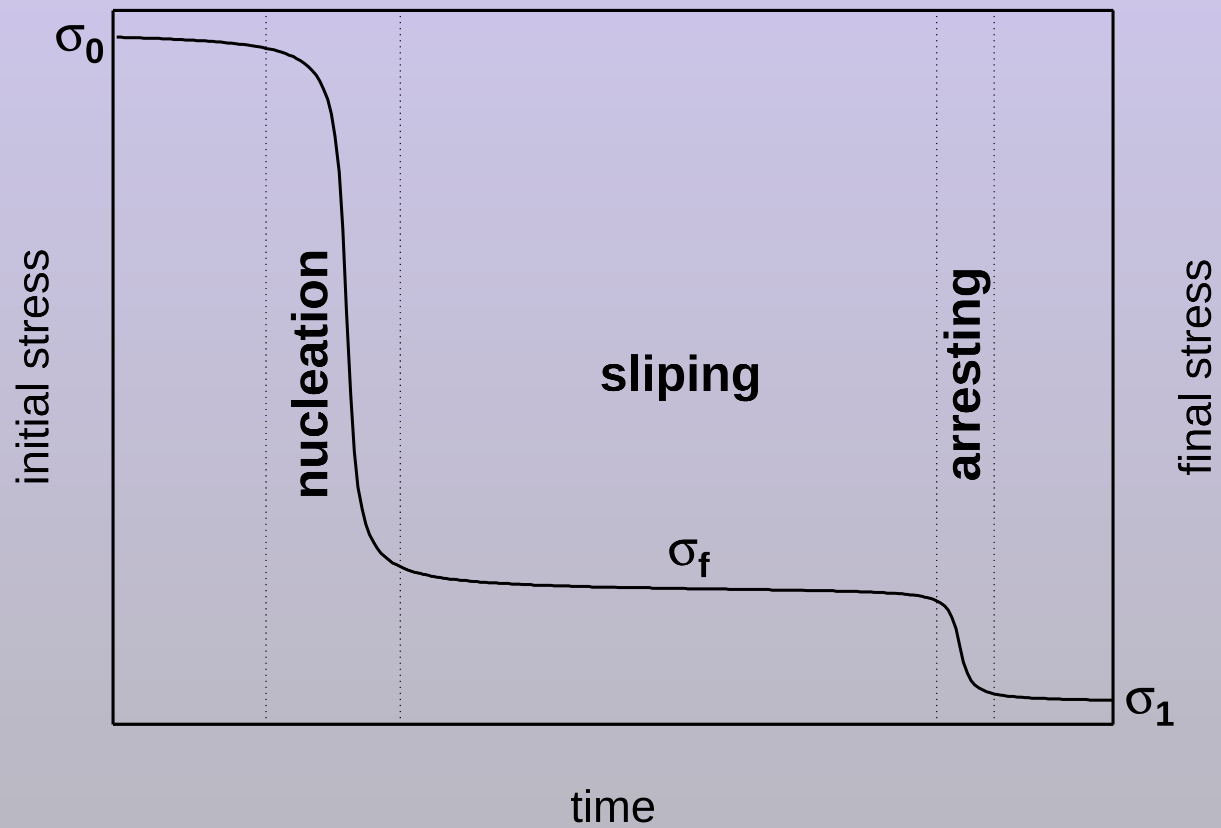
$$\gamma_f \quad \begin{cases} = 1 & \text{Orowan's model} & \sigma_f = \sigma_1 \\ > 1 & \text{partial stress drop} & \sigma_f < \sigma_1 \\ < 1 & \text{“overshooting”} & \sigma_f > \sigma_1 \end{cases}$$

Orowans_model



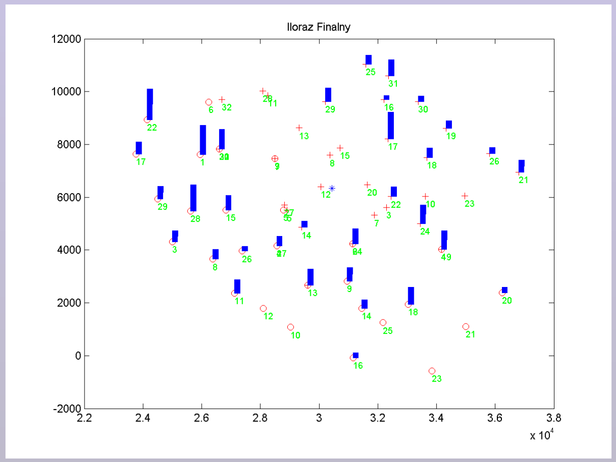

Partial_stress_drop
σ0
initial stress
nucleation
sliping
σf
arresting
final stress
σ1
time

Overshooting



Rupture velocity

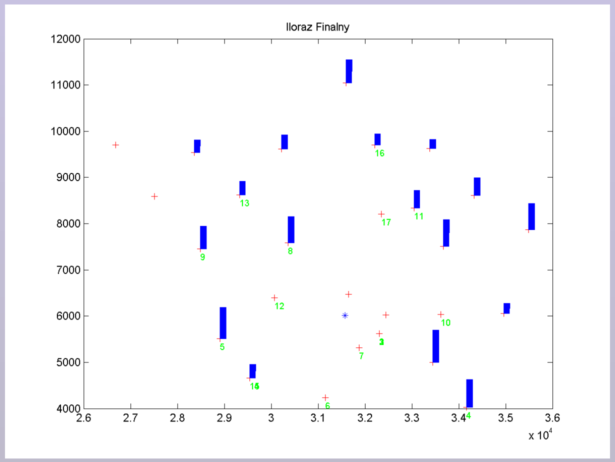
“circular type”



no visible directivity

$$V_r = 0.5 V_s$$

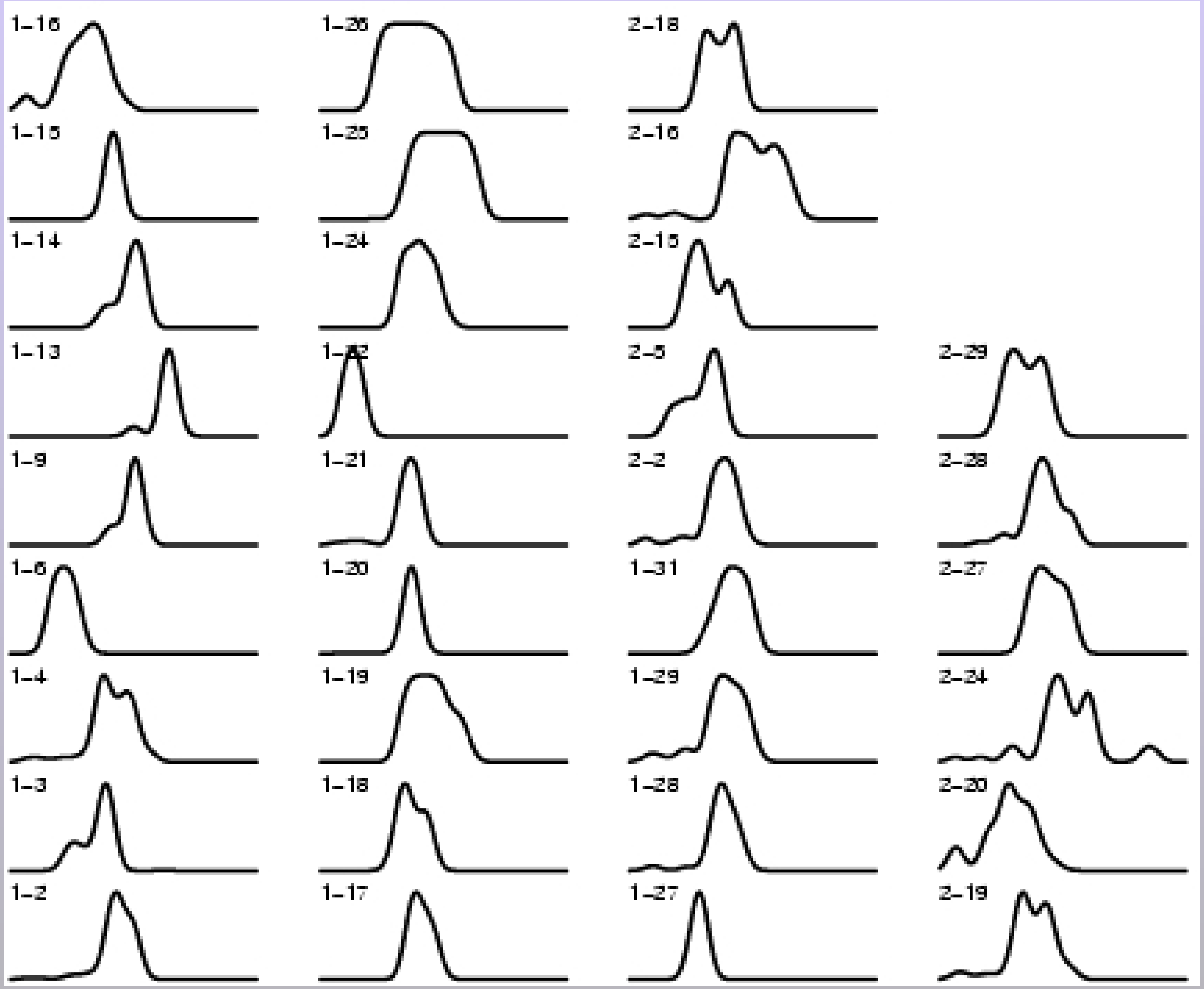
“unilateral type”



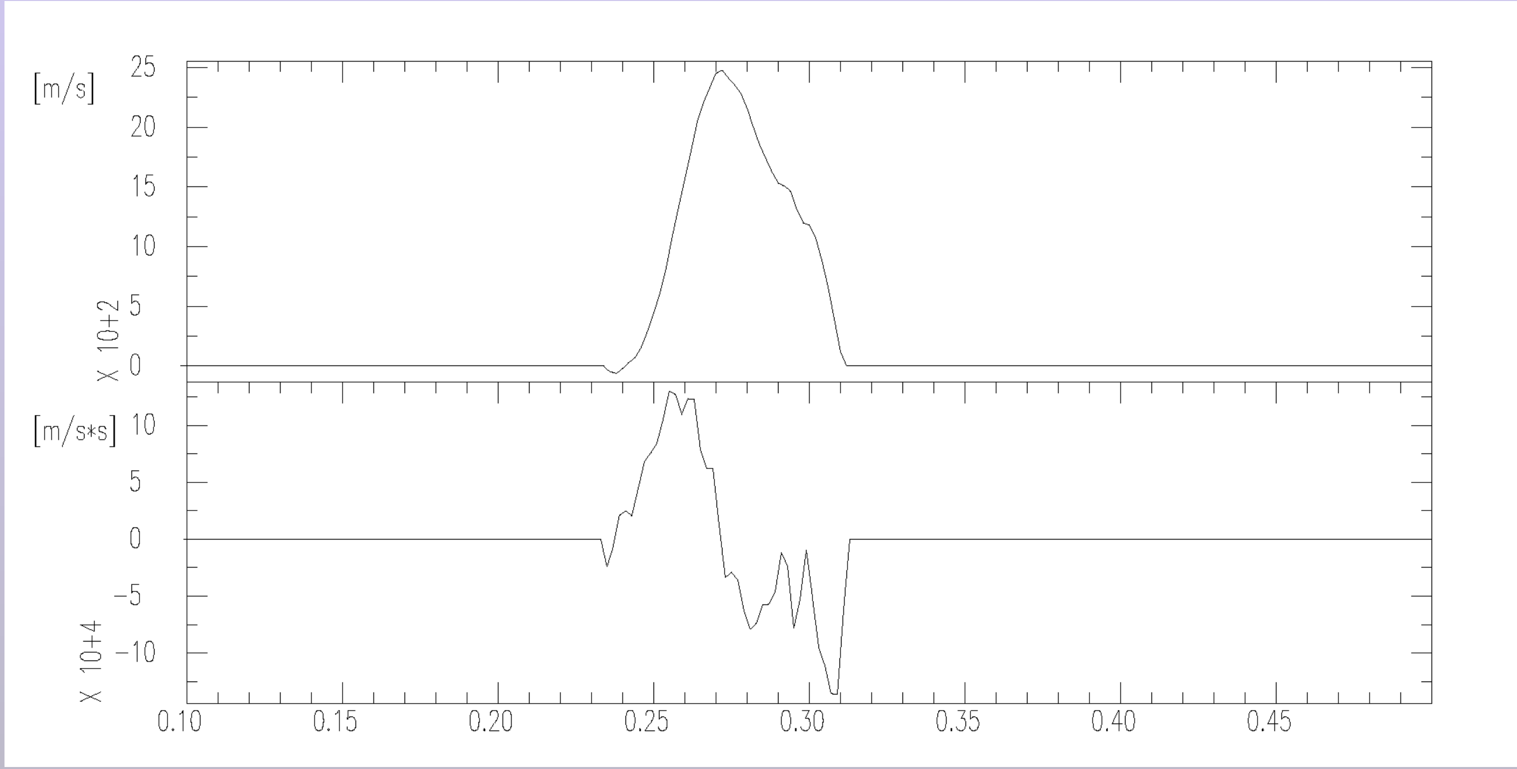
directivity of T distribution

$$T(\theta) = \frac{L}{V_r} - \frac{L}{V_P}\cos(\theta)$$

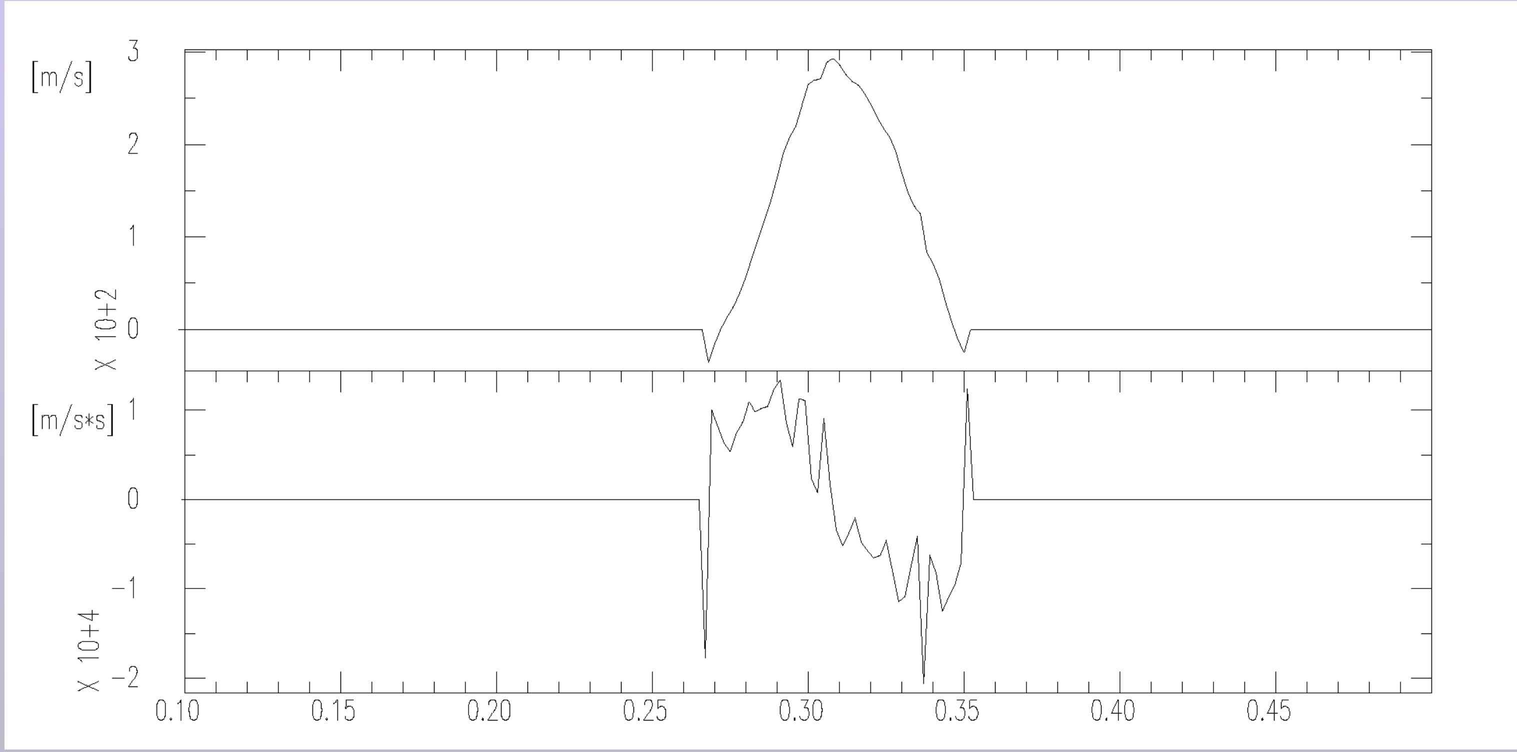
STF- spatial distribution



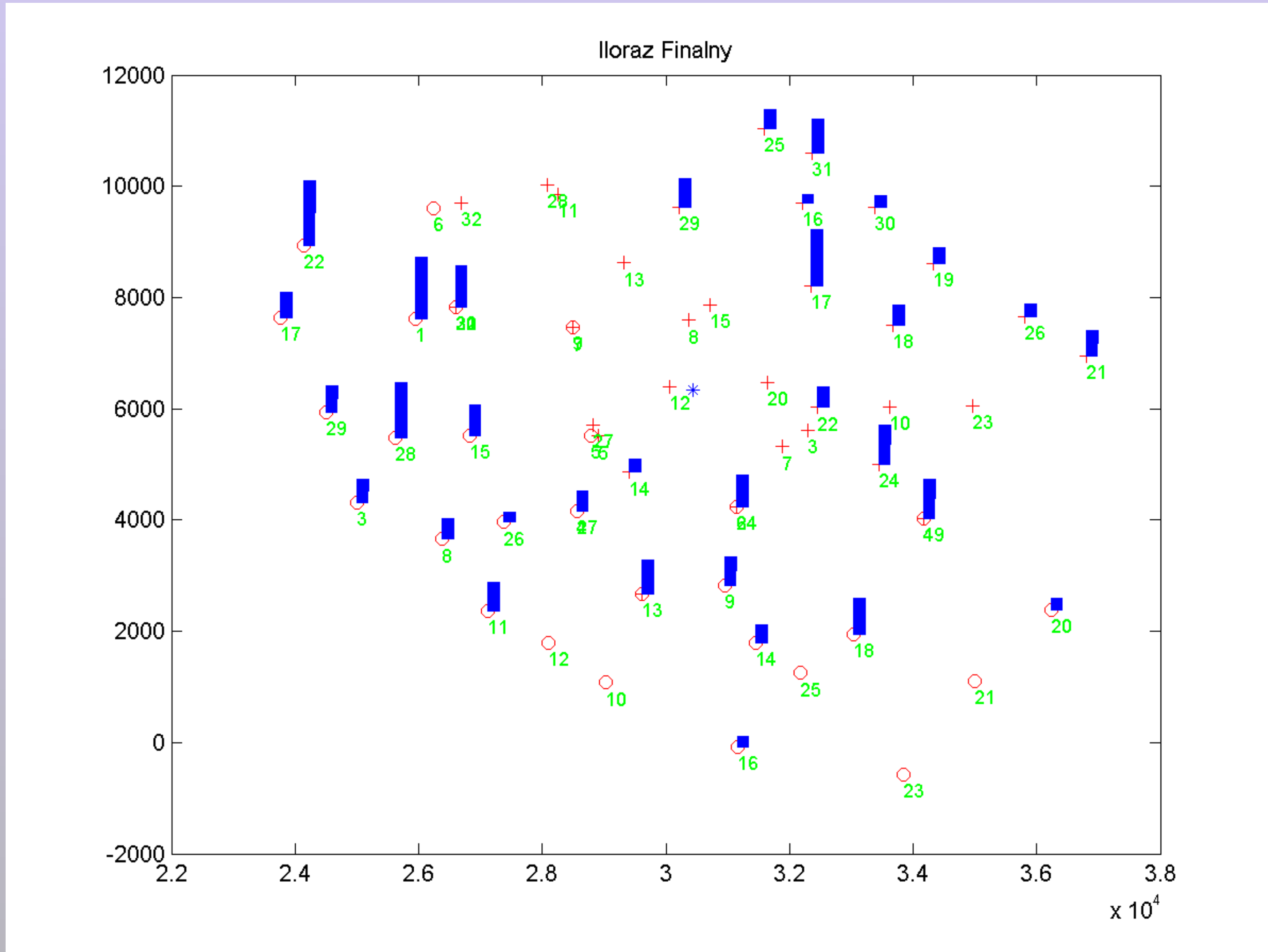
Source Time Function



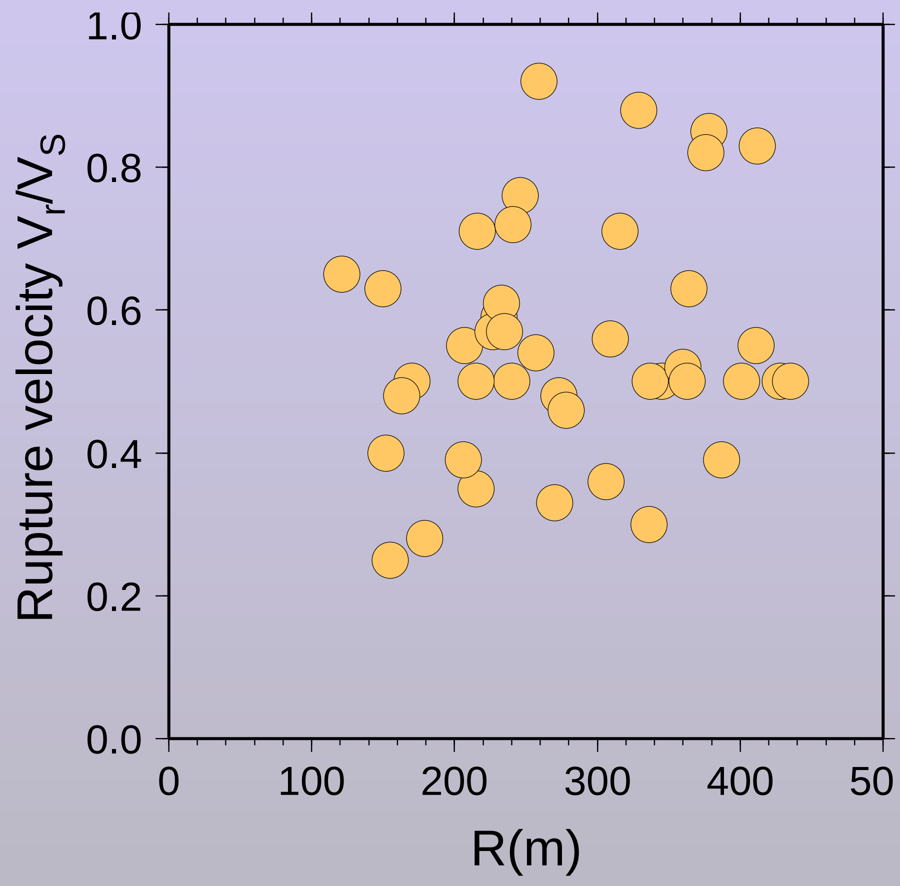
Source Time Function

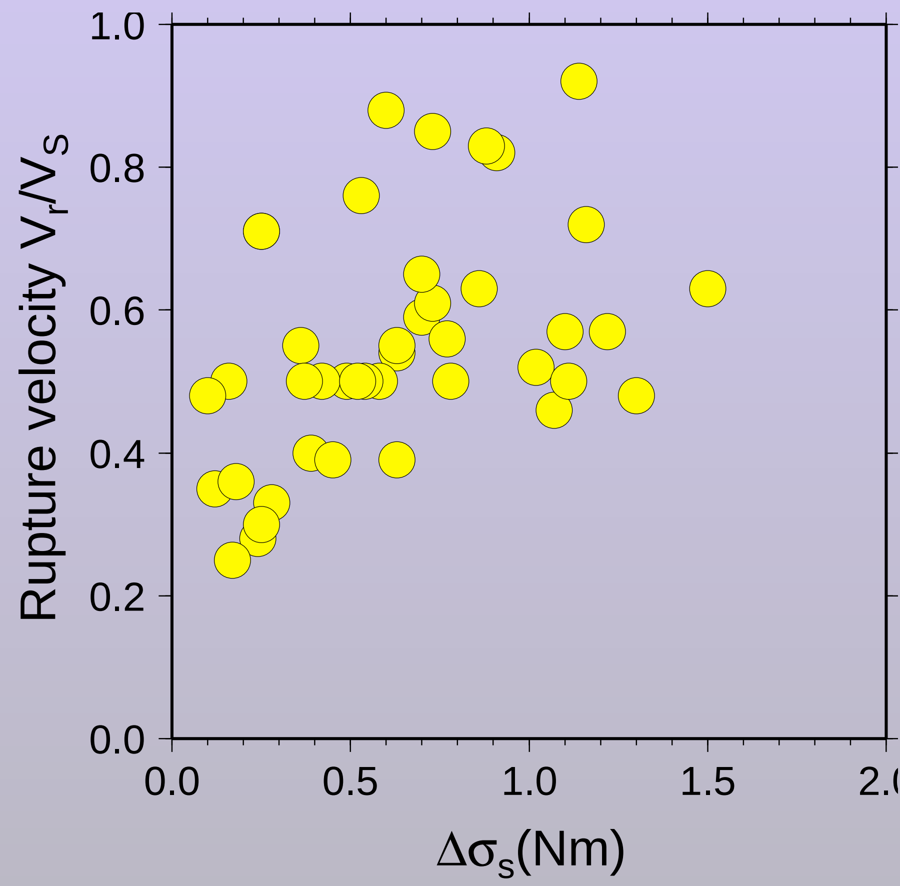


STW width - spatial distribution

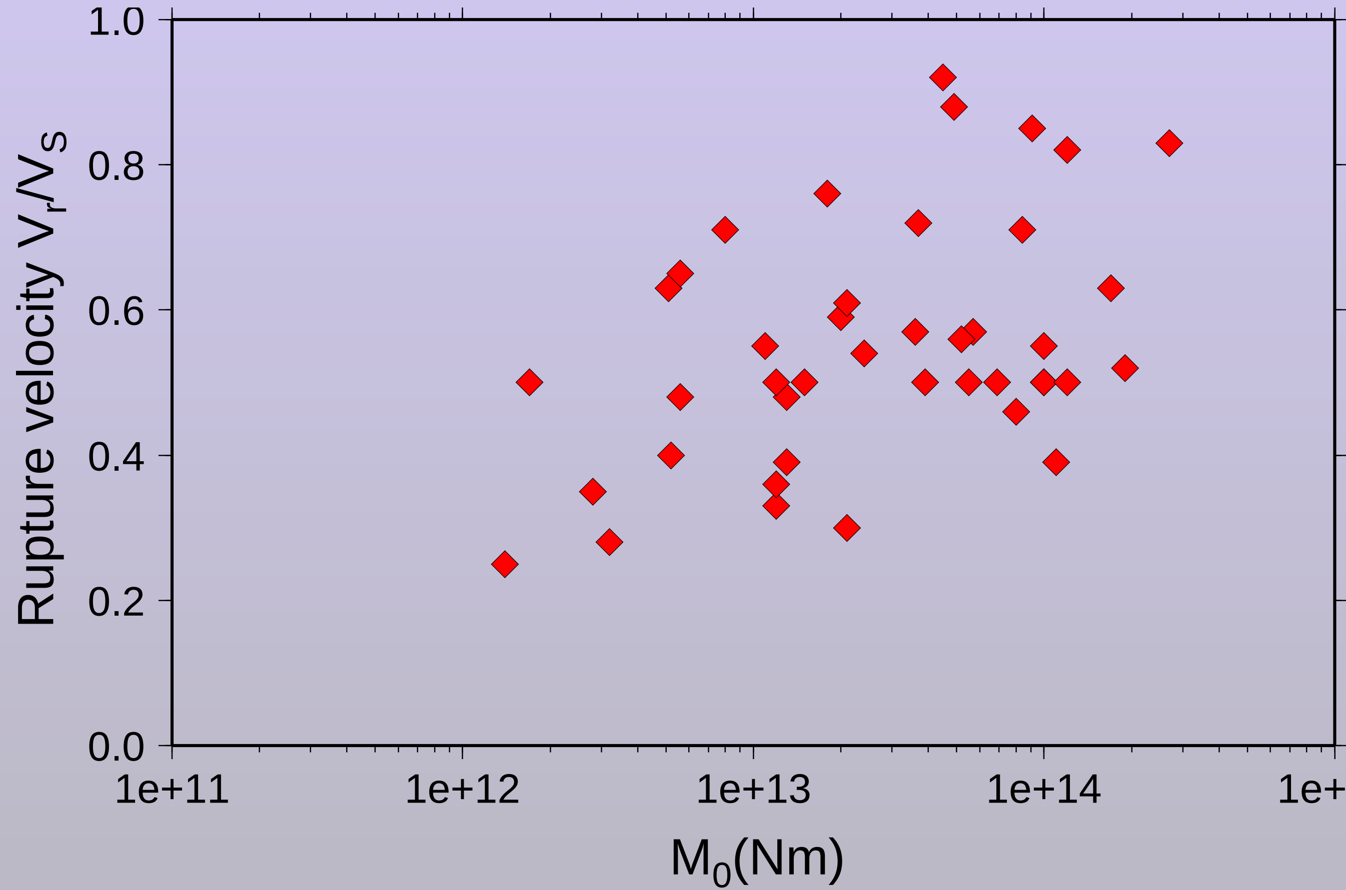


Rupture velocity

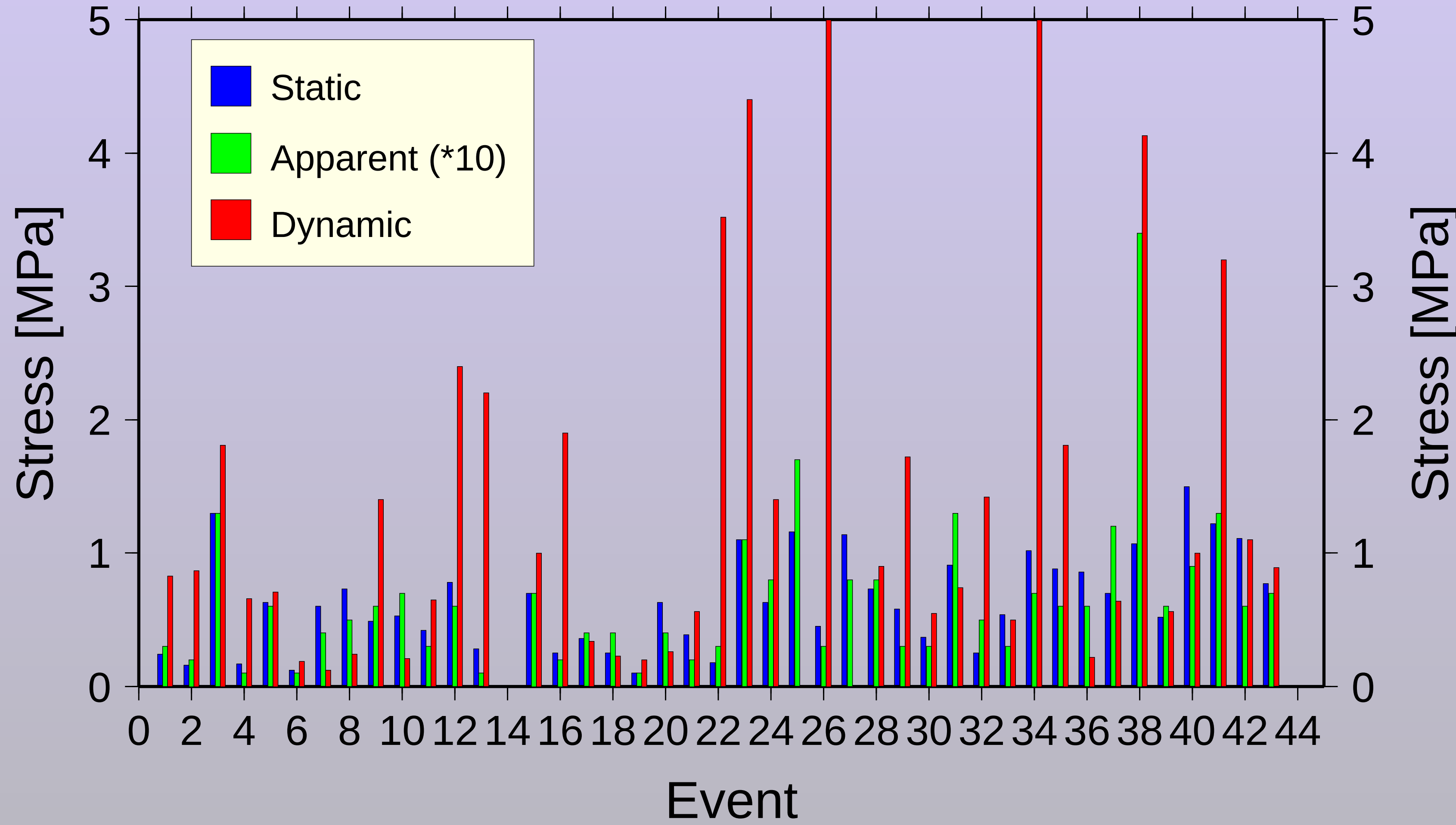




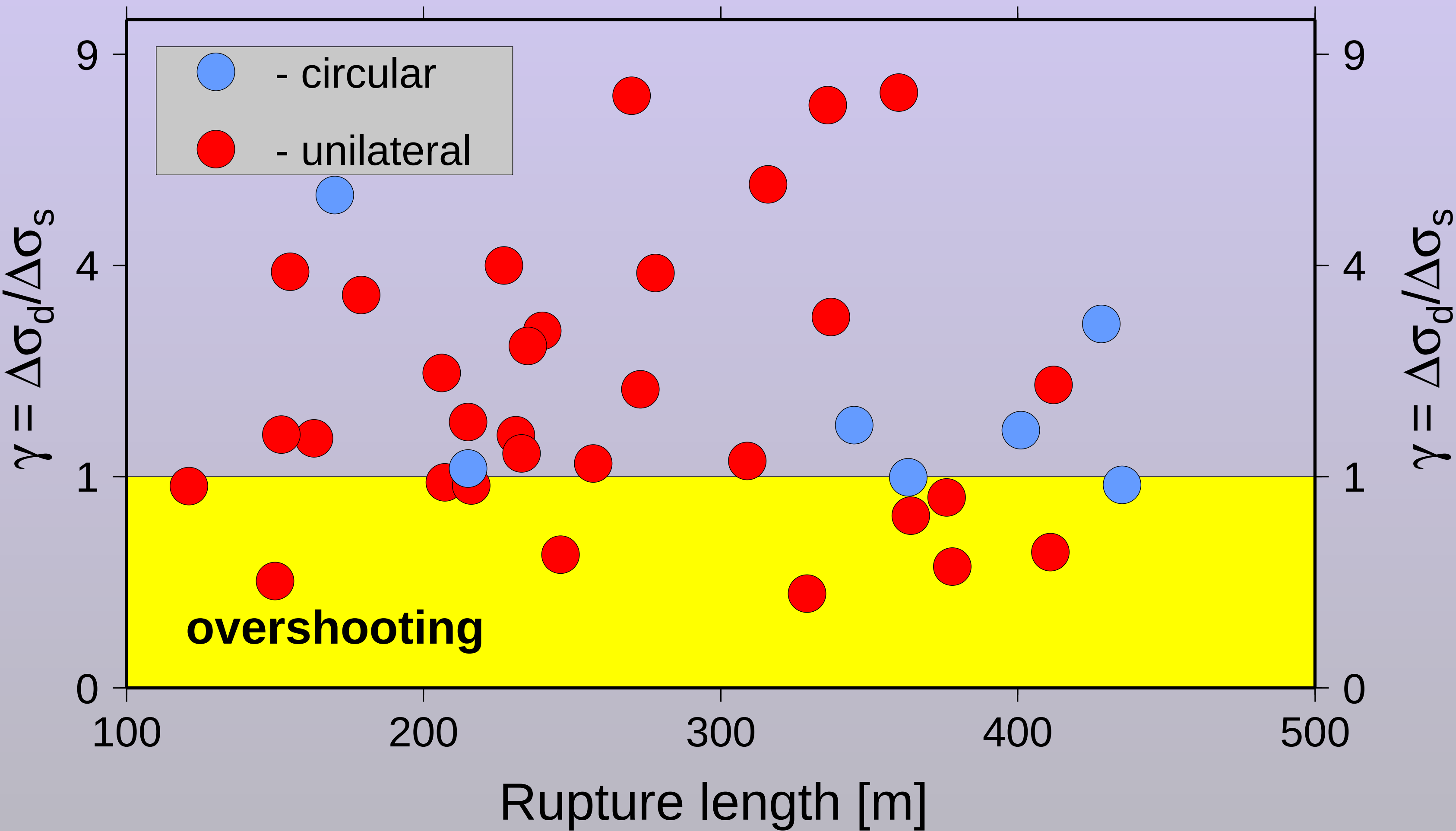
Rupture velocity



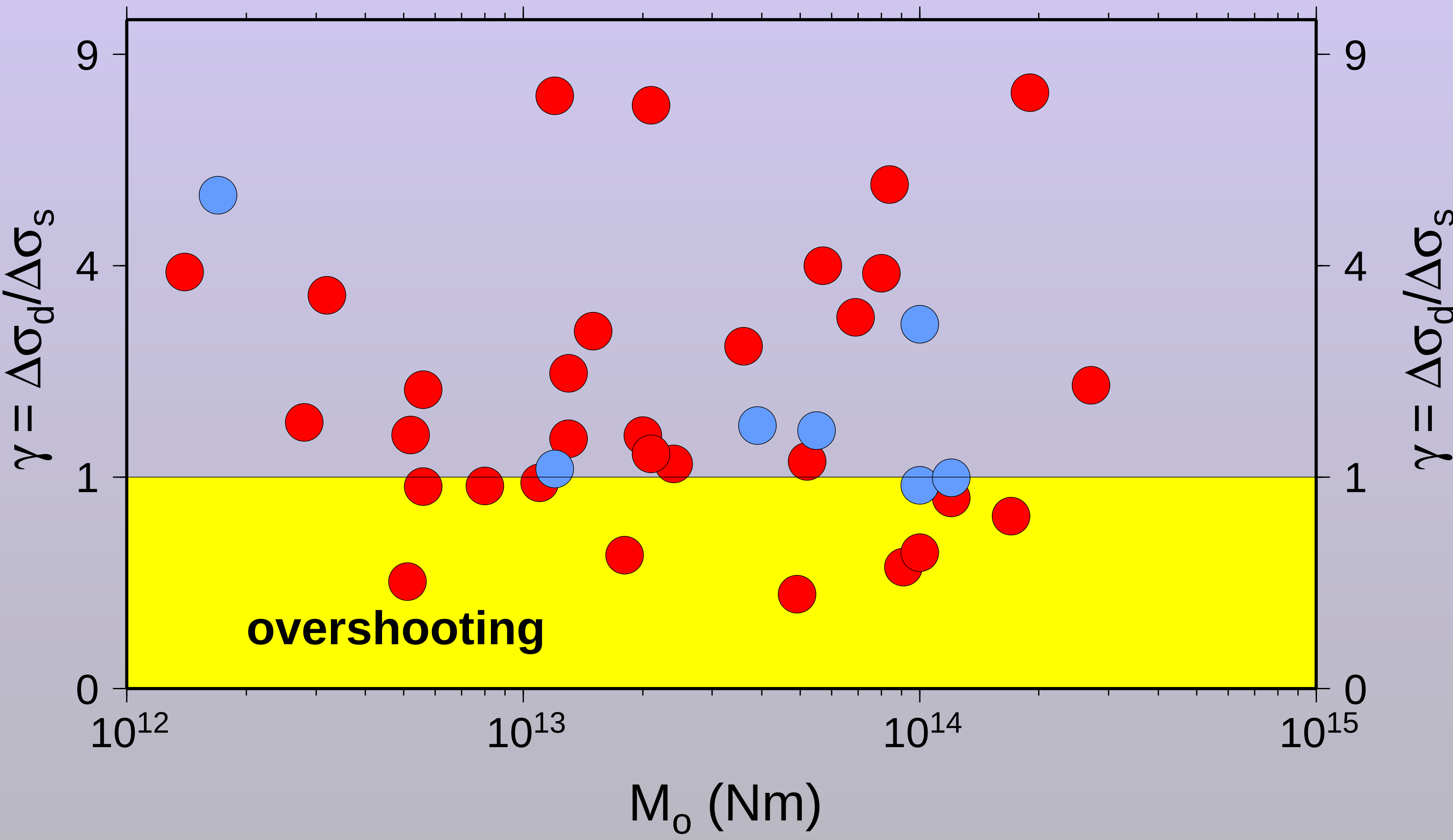
Stress estimates



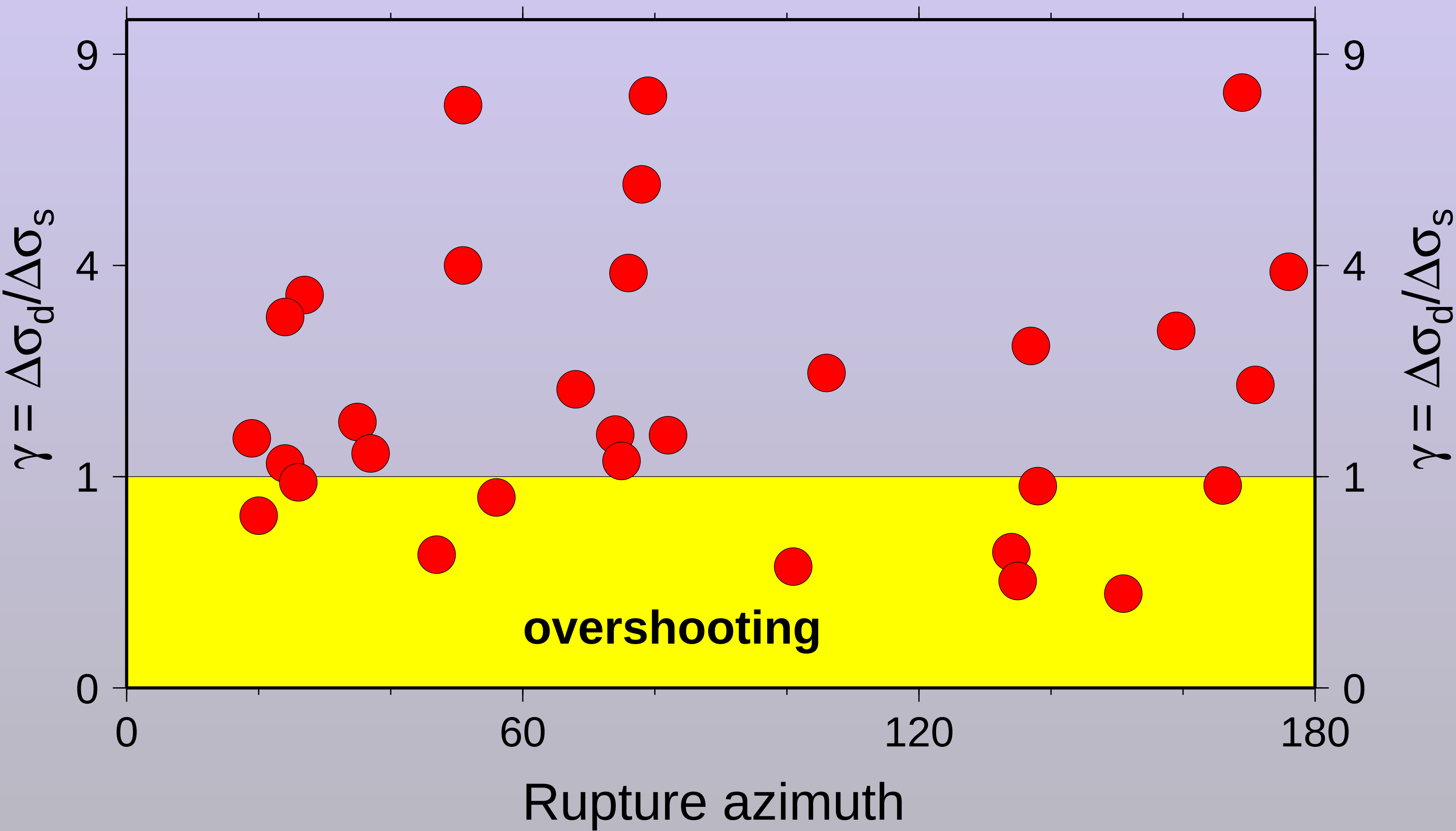
Correlations



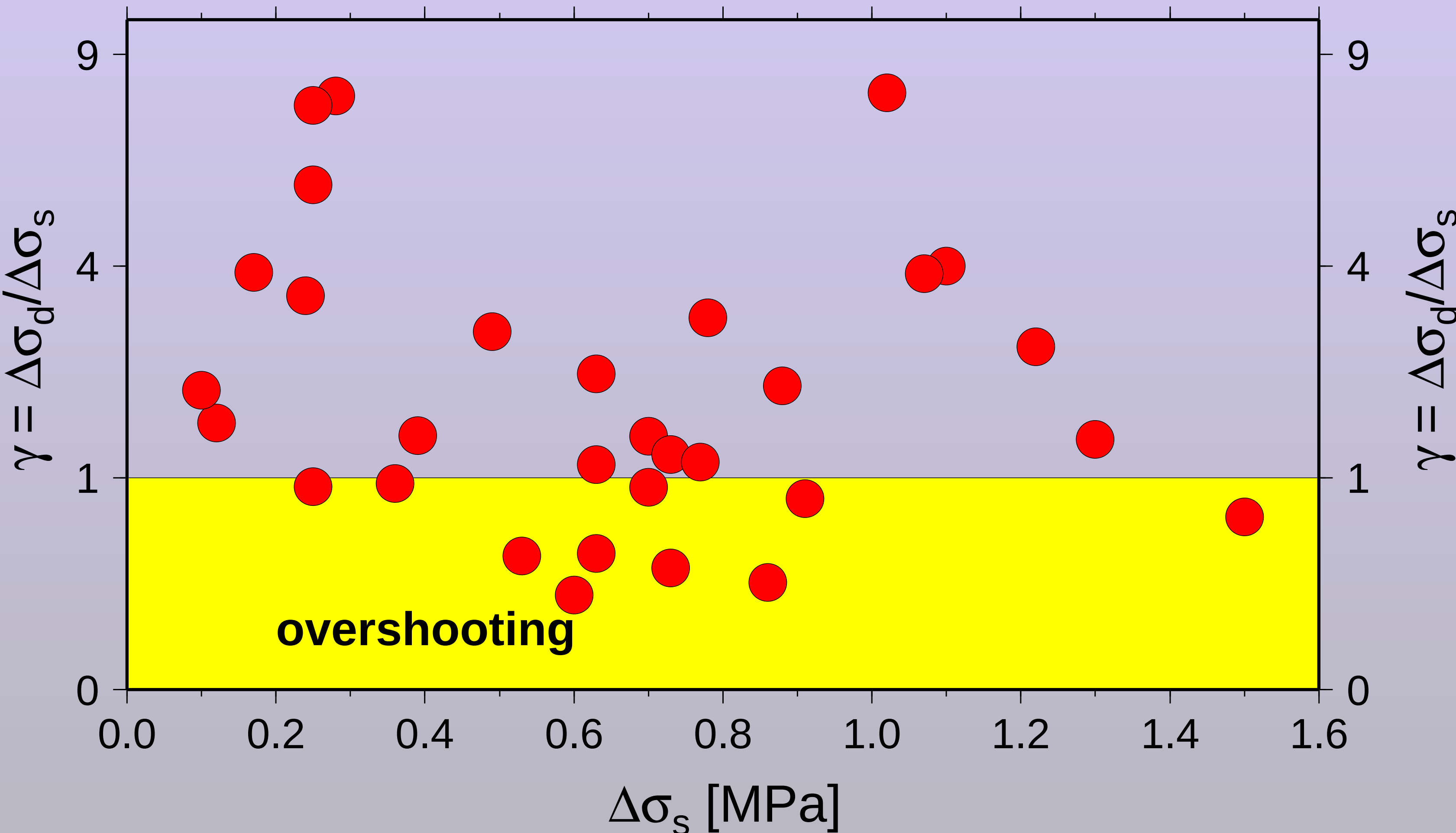
Correlations



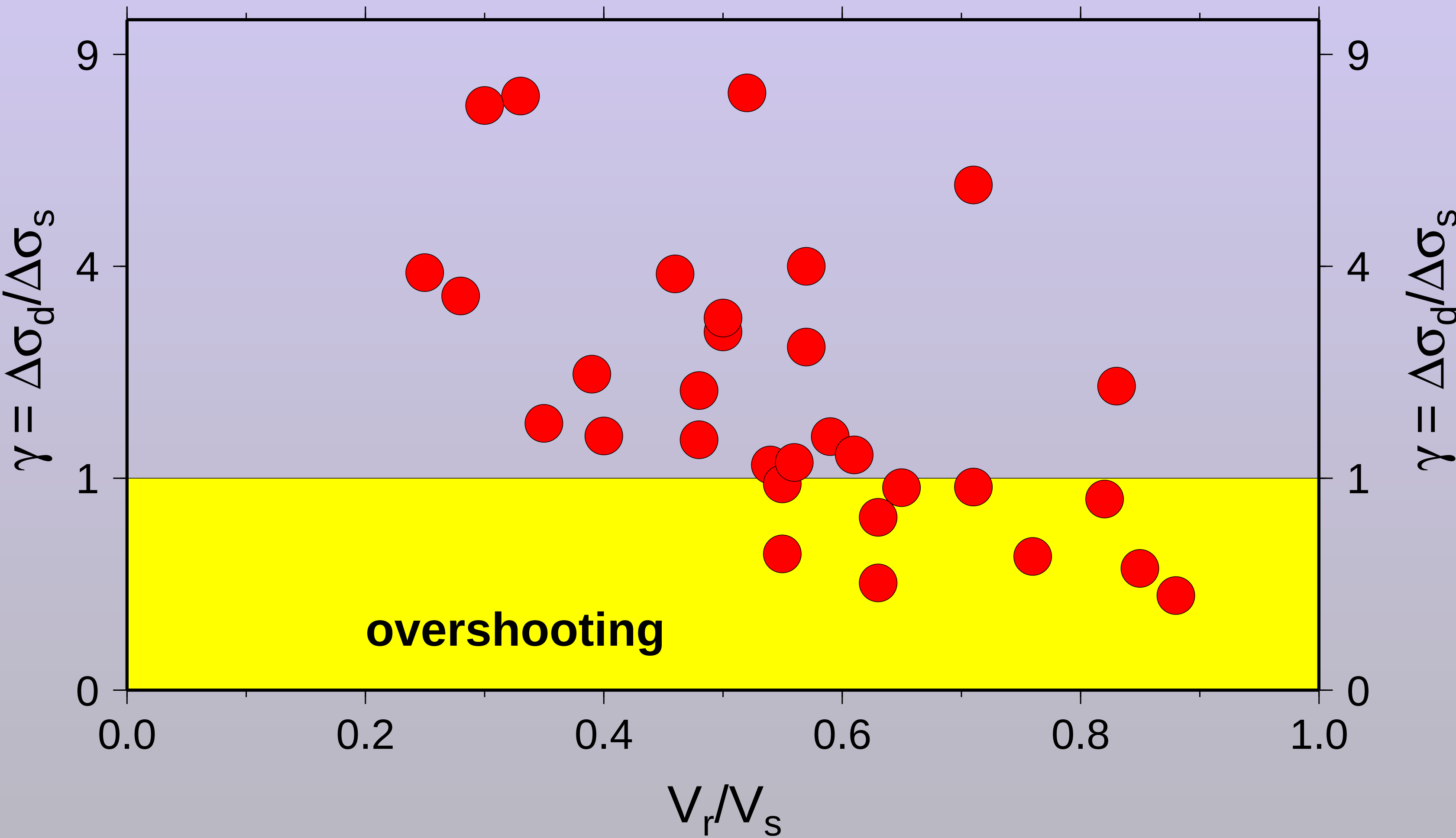
Correlations



Correlations

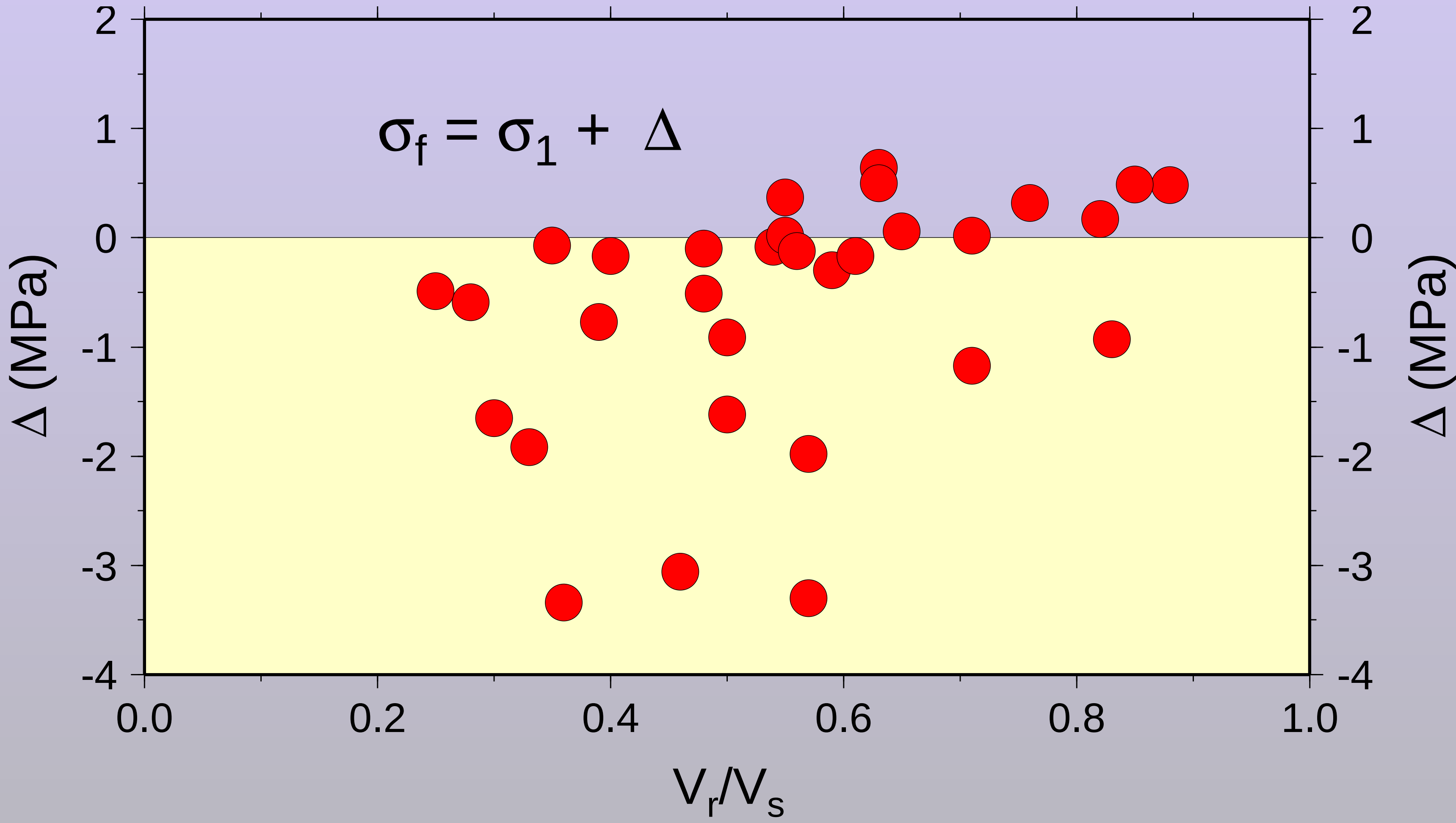


Velocity

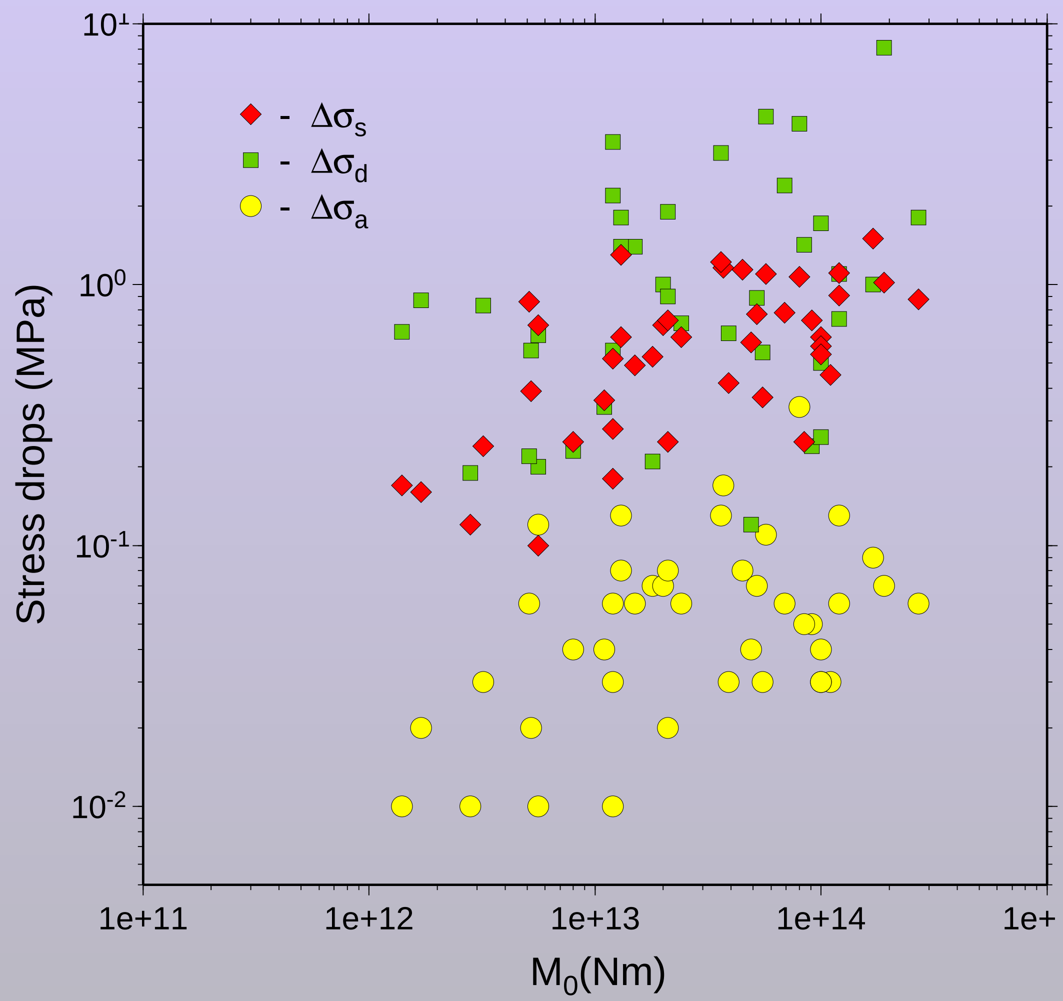


9
4
1
0
9
4
1
0
$\gamma = \Delta\sigma_d/\Delta\sigma_s$
$\gamma = \Delta\sigma_d/\Delta\sigma_s$
overshooting
0.0
0.2
0.4
0.6
0.8
1.0
V_r/V_s

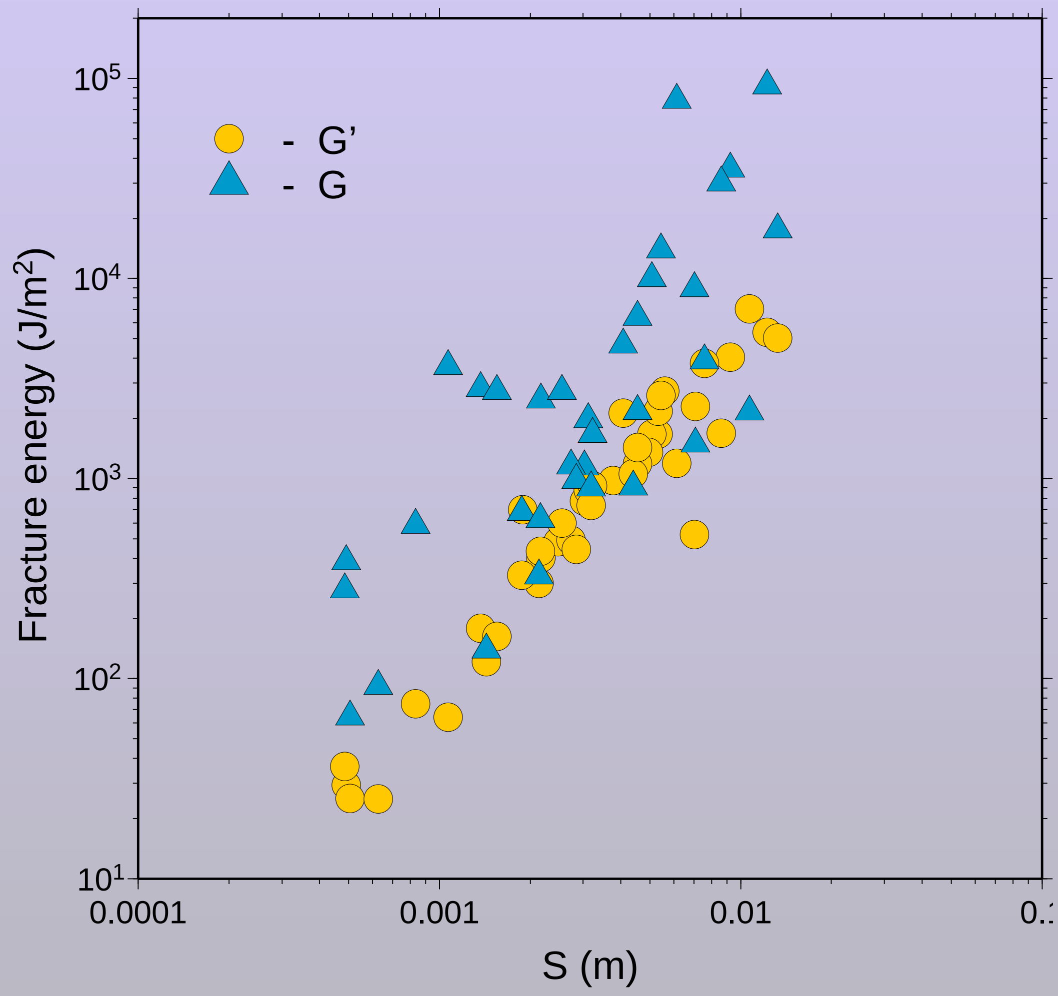
“Overshhoting” stress



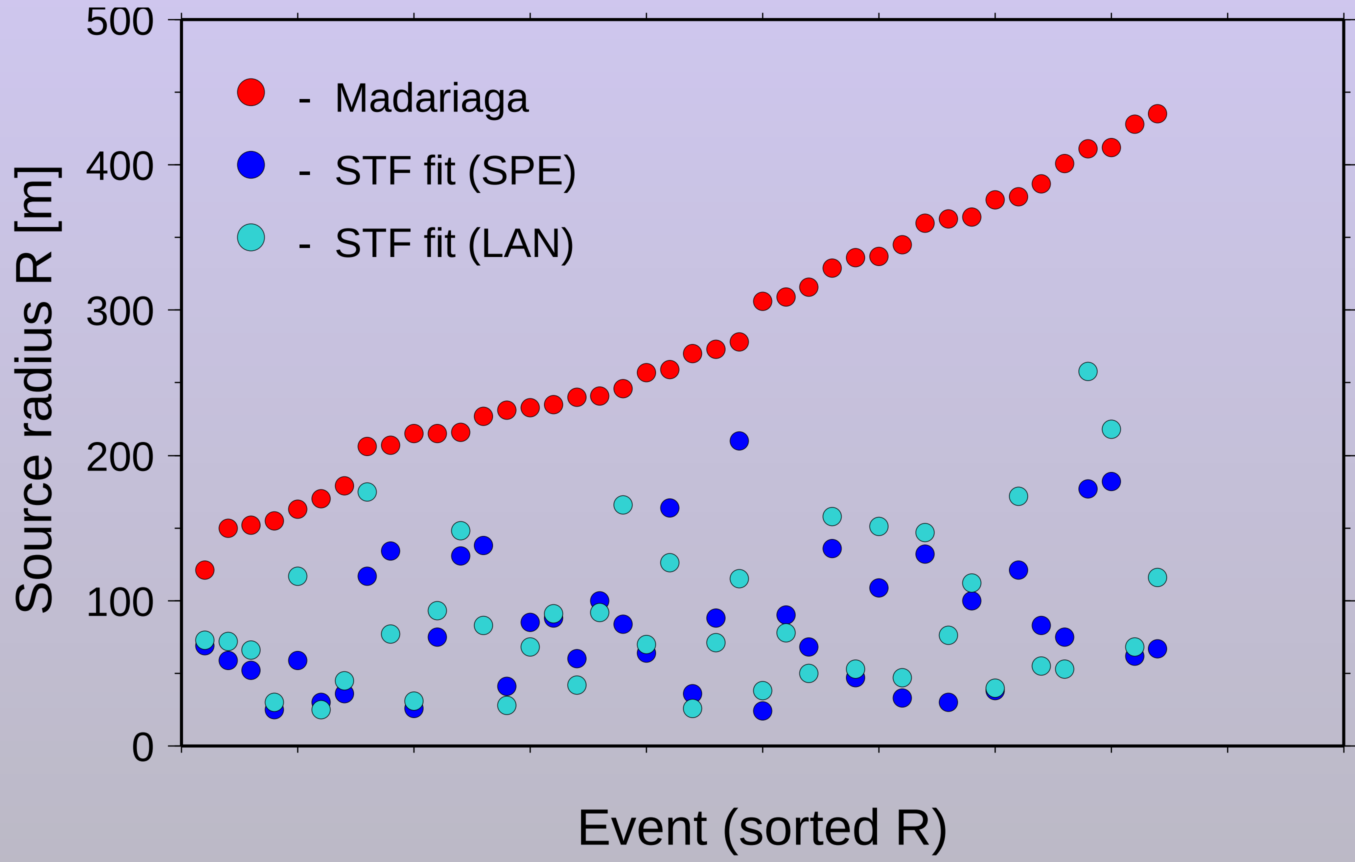
Scaling stresses with M_0



Fracture energy



Source size: Madariaga, Brune, or ...



Conclusions

- STF calculated via Empirical Green Function approach
- Spectral analysis provides static stress drop estimates
- Rupture velocity calculated from spatial distribution of the STF widths
- γ_f correlates ONLY with rupture velocity