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# Seismic Energy Partitioning Inferred from Pseudotachylyte-bearing Faults (Gole Larghe Fault, Adamello batholith, Italy)


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## Aim of this study

Partitioning of the earthquake energy between **fracture energy $E_G$** (energy required to create new rupture surface in the slip zone and a damage zone in the wall rock) and **frictional heat $E_H$** determines the features of the rupture propagation and the mechanical behavior of a seismic fault. The $E_G/E_H$ ratio cannot be inferred from seismological investigations. We propose to use the cataclastic microstructures associated with pseudotachylyte (solidified friction melt produced during coseismic slip) to constrain the $E_G/E_H$ ratio.

## Methods

**1.** We selected a pseudotachylyte-bearing fault, that records one single seismic rupture, from an exhumed fault exposed in the Adamello batholith (Gole Larghe Fault zone, Italy, Pan.1).

**2.** We estimated $E_H$ by energy balance calculations (Pan.2).

**3.** We estimated $E_G$ by:

3a. SEM and FE-SEM image analysis of fragmented plagioclase survivor clasts within the pseudotachylyte and fracture patterns in the host rock.

3b. Clast Size Distribution (CSD) and fracture density by computer-aided image analysis.

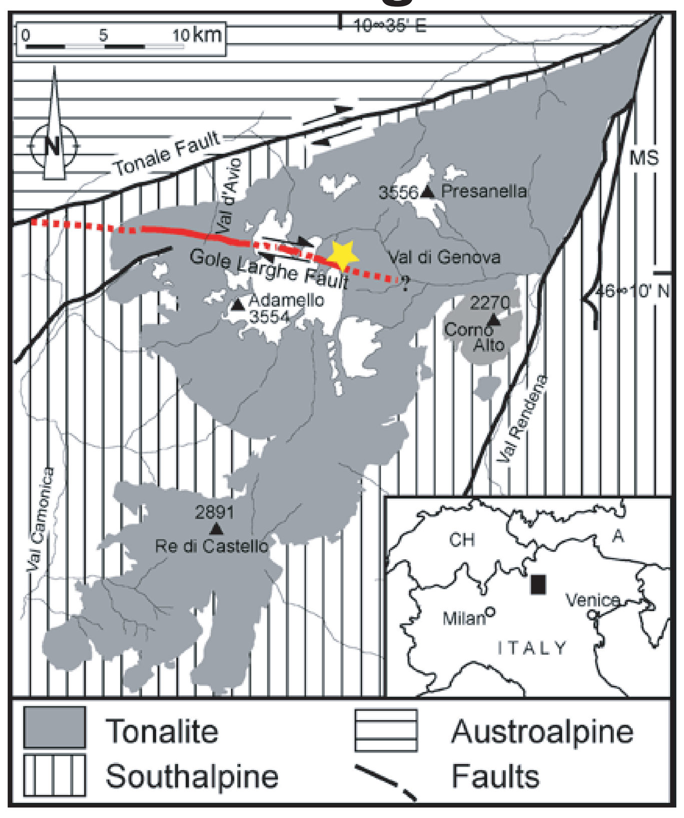
$E_G$, then, was determined by multiplying the seismically created new fracture surfaces for the specific surface energy (γ) of the rock-forming minerals (Pan.4).

## Results & Conclusions

The above estimates yield $E_H$ = 23.3 MJ m$^{-2}$ and $E_G$ in the range of 0.110-0.500 MJ m$^{-2}$.

We conclude that, for this local seismic energy balance estimate, **$E_G$ is negligible compared to $E_H$** (Pan.5).

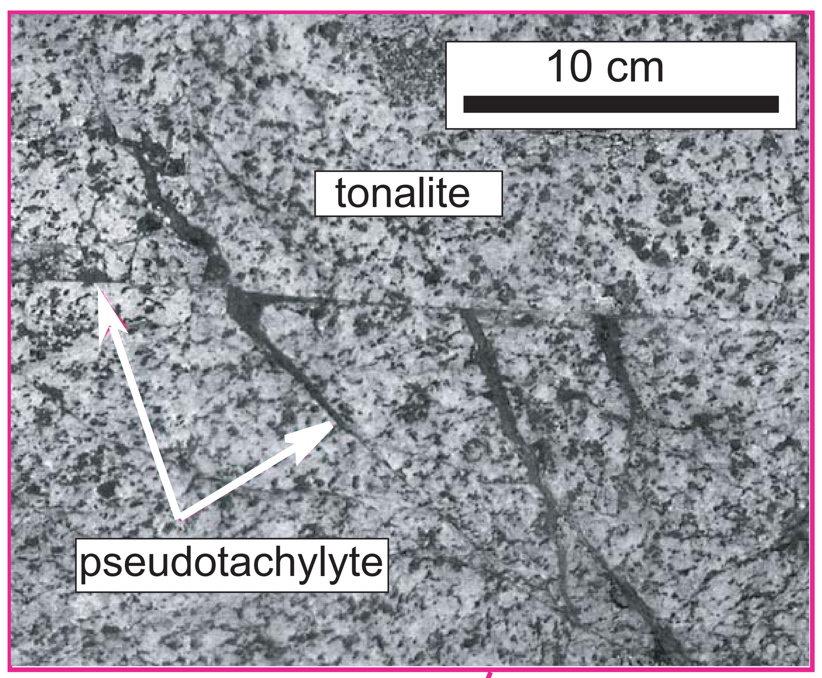
## Pan.1-Geological Setting




Geological map of the Adamello batholith (in gray). Location of the map (black box) is shown in the inset. The yellow star marks the studied area.

The Gole Larghe Fault is an E-W trending dextral strike-slip fault which crosscuts the Adamello tonalitic batholith (Italian Southern Alps). Ambient conditions during seismic faulting were 250<T<300 °C and 250<P<300 MPa (Ref. 1).

Pseudotachylyte-bearing faults exploited preexisting joints. Some of these faults record one seismic rupture (Pan.3)




## Pan.2-Estimate of $E_H$

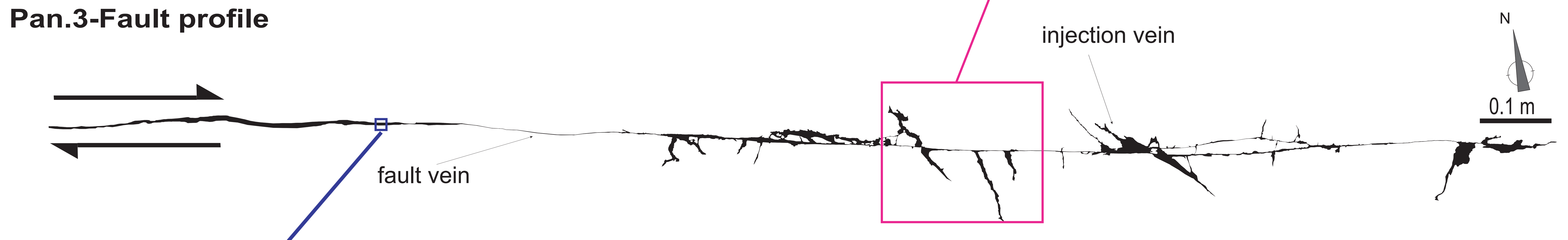
From Ref. 2:

$$E_H = [(1-\phi)\, H + c_P\, (T_m - T_{hr})]\ \rho\ 2w$$

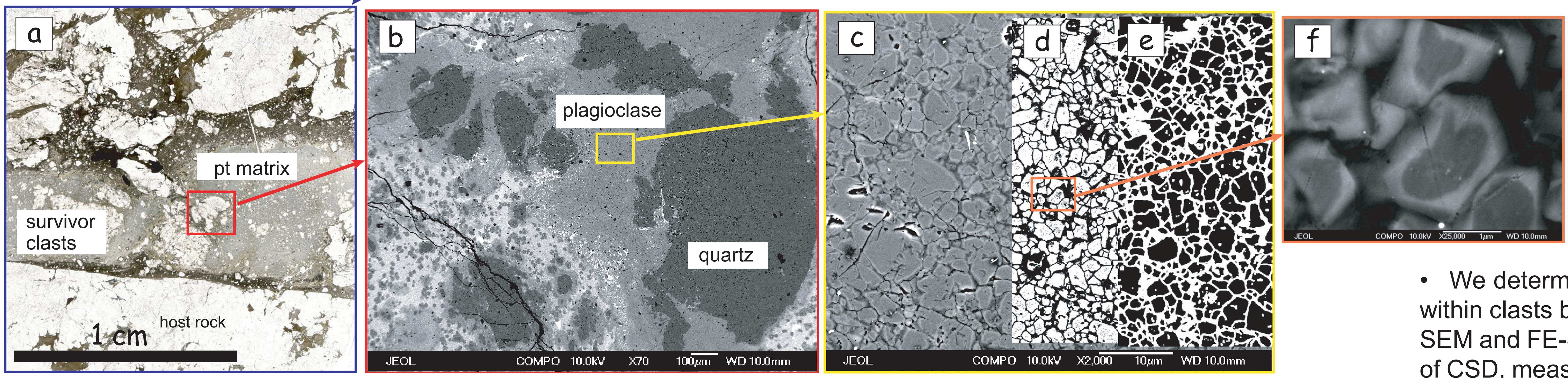
where $\phi$ = ratio clasts/pt matrix (0.2) (Fig.4a), $H$ = latent heat of fusion (3.28 10$^5$J kg$^{-1}$), $c_P$ = the specific heat (1180 J kg$^{-1}$ K$^{-1}$), $T_m$ = initial friction melt temperature (1723 K) $T_{hr}$ = host rock temperature (523 K), ρ = melt density (2350 kg m$^{-3}$) and $2w$ = average pseudotachylyte thickness. For the 5.9 10$^{-3}$ m thick fault shown in Pan.3:

$$E_H = 23.3 \text{ MJ m}^{-2}$$

## Pan.3-Fault profile

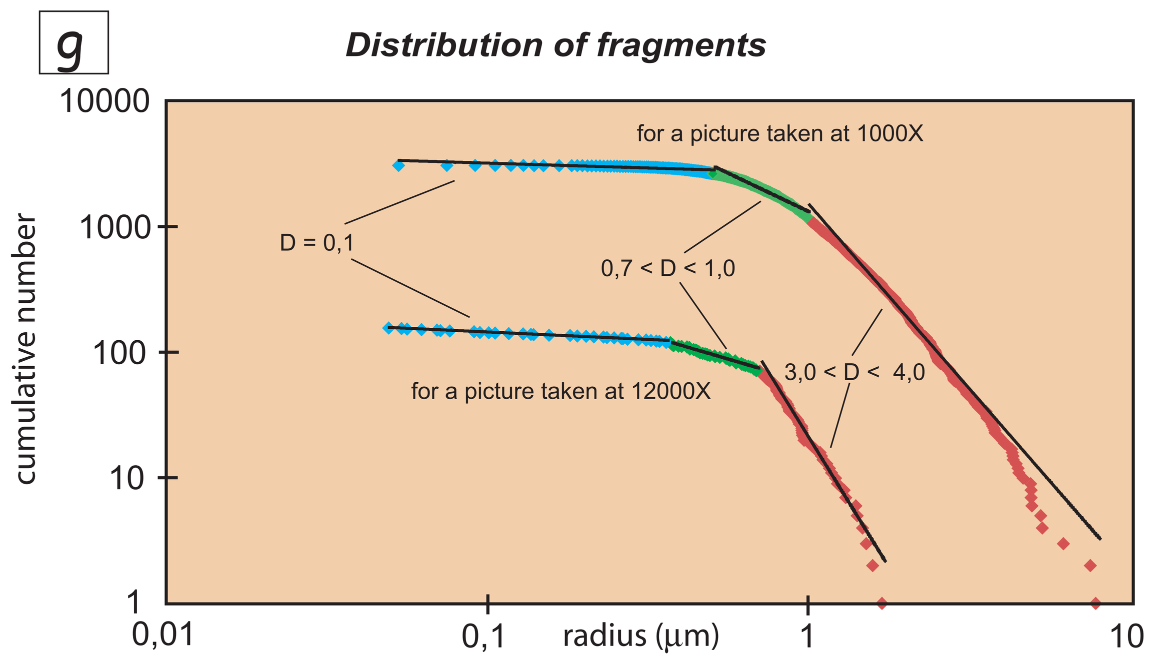


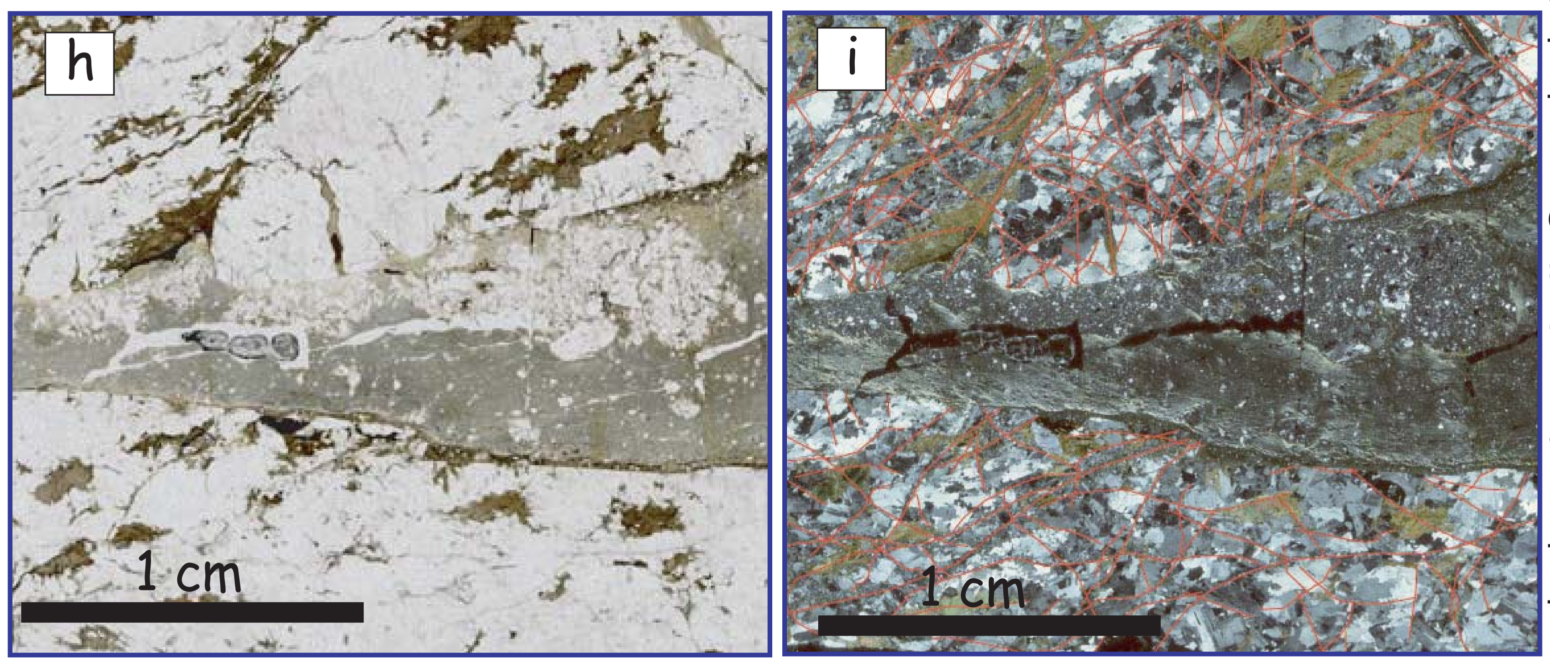

## Pan.4-Estimate of $E_G$




Plagioclase clasts (Fig.a) within pseudotachylytes display an internal fragmentation (Fig.c-f) that is absent in the host rock. Thus fragmentation occurred during the seismic rupture. Possibly, this fragmentation is the pristine structure produced during seismic rupture propagation and immediately obliterated by melting in the rest of the pseudotachylyte.

- We determined the fragment distribution (CSD) within clasts by computer-aided image analysis on SEM and FE-SEM images (Fig.c-f). Two examples of CSD, measured from images at different magnifications, are shown in Fig.g. The CSD is not fractal over the whole range of measured sizes r (0.05-100 μm). We identify three average "fractal" dimension: (i) D = 0,1 for 0.05 < r < 0.50 μm, (ii) D = 0.85 for 0.50 < r < 1.00 μm, (iii) D = 3.5 for 1.00 < r < 100 μm.




- We determined the fragment total surface per unit area (Sf) by assuming: (i) a spherical shape of the fragments and (ii) using the different D values for each grain size class. The Sf value is in the range 11000 and 50000.

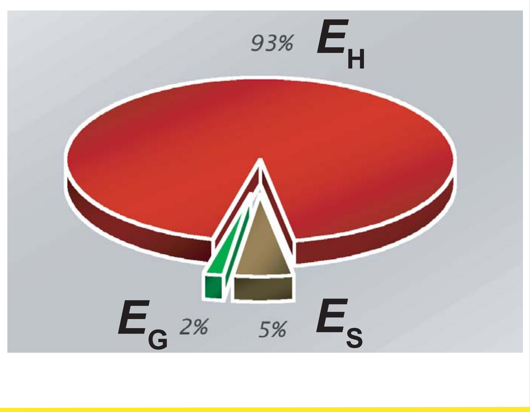
- We determined the fracture density in the host rock (Lf) on two orthogonal sections. The Lf values on the two sections are comparable. Whatever the assumption on the exact 3D geometry of fractures, the measured Lf values indicate that the host rock fracture surface is neglible compared to Sf.

Given $E_G$ = Sf *γ (Ref.3,4) and γ = 10 J m$^{-2}$ (Ref.5):

$$0.11 < E_G < 0.50 \text{ MJ m}^{-2}$$

## Pan.5 - Conclusions

Our study yields a local estimate of $E_G/E_H$ in the range 0.005-0.02. Assuming that the amount of energy radiated as seismic waves ($E_S$) represents the 0,1-10% of the total energy of an earthquake (Ref.6), we suggest the partitioning of $E_S$, $E_G$ and $E_H$ reported in the pie-diagram below for this local context.





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