Helmholtz Centre Potsdam
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CRC 1114 - Scaling Cascades in Complex Systems

Analogue earthquakes: A test bed for physical and statistical models?

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Introduction

There is a lack of insight into the long-term record of earthquakes and deformation accumulation because of the limited availability of information from historical events. Current explanations for deformation accumulation in fault networks rely on rate and state dependent (RSD) friction models. We want to explore the scaling relationships of seismically active fault networks by combining mathematical, numerical and analogue modelling. The successful reproduction of interacting faults showing correlation with earthquake statistics, short- and long-term deformation patterns, and lithospheric properties is our main goal.

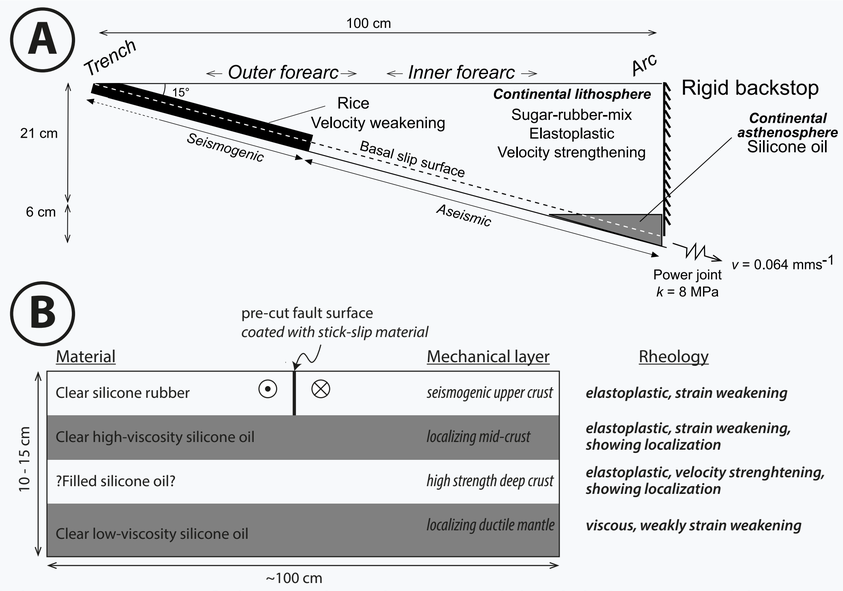
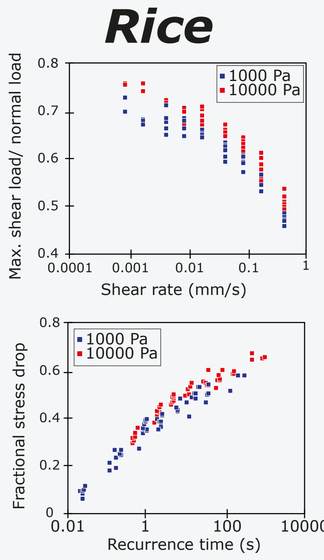


Figure 1: Schematic setup of the used analogue models. (A) Setup used by Rosenau et al. (2009), modelling creep on seismogenic faults in a subduction setting. (B) Work-in-progress model for a strike-slip setting following the numerical model of Gueydan et al. (2014).

Rice



Rocks

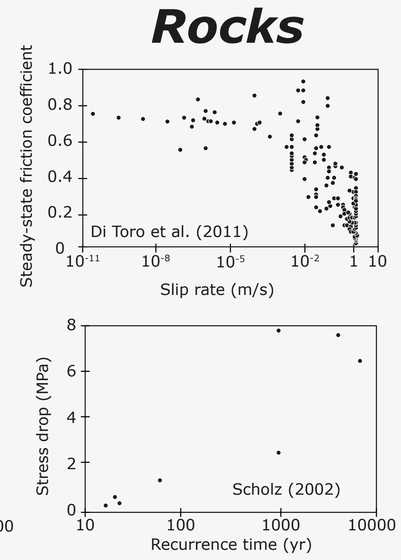


Figure 2: Frictional behavior of rice compared to rocks. The materials were tested using a Ring-Shear-Tester which allows the determination of frictional properties of granular materials at different normal loads and shear rates. Data by M. Rosenau.

State of the art

- Analogue materials show RSD frictional behavior.
- Periodic stress drops in the analogue models, combined with periodic slip events, are analogue earthquakes.
- Scaled moment magnitudes range from M_W=8 - 9.5.
- Analogue earthquakes feature aseismic creep during loading and mimicries of foreshock sequences.

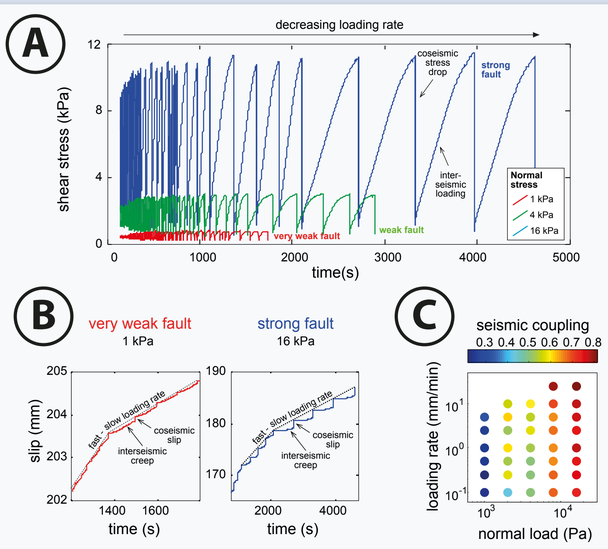


Figure 3: (A) Shear stresses for successively higher loading rates, the periodic stress drops represent analogue earthquakes. (B) slip along the fault measured by Particle Image Velocimetry. (C) Seismic coupling depending on loading rate and normal load (Rosenau et al., in prep.).

Rheology of silicone oils

- Silicone oils show a reduction of effective viscosity as shear rate increases, similar to the bulk lithosphere.
- Maxwell relaxation times are in the order of 10^{-1} s.
- Additives could enhance the scaling behavior of silicone.

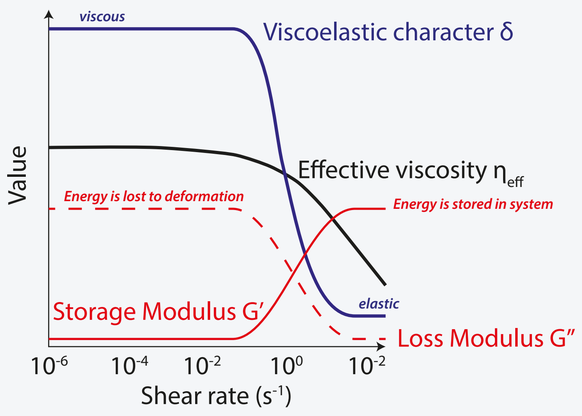


Figure 4: Schematic behavior of silicone oils under analogue modelling conditions. The parameters are used in polymer science to describe viscoelastic (VE) materials. VE-character δ shows the overall material behavior changing from viscous to elastic at high shear rates.

Outlook

- Combined analogue and physical modeling of strike-slip fault zones, coupled with high-resolution (space and time) measurement systems.
- Explore the recurrence behavior in the modelled systems.
- Quantify the role of asperities in strike-slip models.
- Transparent analog models will allow a 3D monitoring of stresses, strain, and displacements.

References

Di Toro, G.; Han, R.; Hirose, T.; De Paola, N.; Nielsen, S.; Mizoguchi, K.; Ferri F.; Cocco M. and Shimamoto, T. - Fault lubrication during earthquakes. *Nature*, **2011**, *Vol. 471, 494-498*.
Gueydan, F.; Précigout, J. and Montesi, L.G. - Strain weakening enables continental plate tectonics. *Tectonophysics,* **2014***, Vol. 631, 189-196.*
Rosenau, M.; Lohrmann, J. and Oncken, O. - Shocks in a box: An analogue model of subduction earthquake cycles with application to seismotectonic forearc evolution. *Journal of Geophysical Research*, **2009**, *Vol. 114*.
Rosenau, M. and Oncken, O. - Creep on seismogenic faults: Insights from analog earthquake experiments. *in preparation*.
Scholz, C. - The mechanics of earthquakes and faulting. *Cambridge University Press*, **2002**.

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