

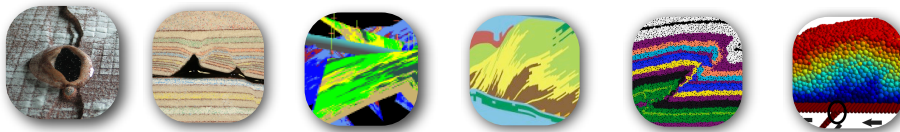
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# Barcelona

# GeoMod

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## **Organization**

GeoMod2018 is organized mainly by the Geomodels Research Institute (University of Barcelona) and the Institut de Ciències de la Terra Jaume Almera (ICTJA - CSIC). Specifically by:

Dr. Òscar Gratacós Torrà (UB)  
Dr. Oriol Ferrer García (UB)  
Dr. Daniel García-Castellanos (ICTJA-CSIC)

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Jacqueline Reber (Department of Geological and Atmospheric Sciences, Iowa State University, USA)  
Hemin A. Koyi (Department of Earth Sciences, Uppsala Universitet, Sweden)

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 Susanne Buiter (Geological Survey of Norway, Norway)  
 Guido Schreurs (Universität Bern, Switzerland)  
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- Analogue modelling of fault relay zones under biaxial extension ([Alba Peiro](#), Teresa Román-Berdiel and José Luis Simón)
- Simulation of normal faults using numerical models: the case of L'Aquila Fault ([Yuri Panara](#), Michelle Cooke, Giovanni Toscani, Cesare Perotti and Silvio Seno)
- Kinematic domain partitioning in passive margin salt basins: the myth of translational domain ([Zhiyuan Ge](#), Mattias Rosenau, Michael Warsitzka and Rob L. Gawthorpe)
- Controls on normal fault activity in the central Italian Apennines: Insights from thermo-mechanical modelling ([Anneleen H. Geurts](#), Ritske Huismans and Patience A. Cowie)
- Towards a comprehensive model of brittle faults at divergent plate boundaries – combining scaled analog models and high-resolution field data ([Michael Kettermann](#), Christoph von Hagke, Christopher Weismüller, Lisa Winhausen and Janos Urai)
- Structural characterization of salt-detached ramp-synclines and associated salt structures: results from 3D seismic interpretation obtained from analog modeling ([Maria Roma](#), Oriol Ferrer, Josep Anton Muñoz, Òscar Gratacós and Ken McClay)
- Coupling a frictional-cohesive cover and a viscous substrate in a discrete element model: first results of application to thick- and thin-skinned extensional tectonics ([Stuart Hardy](#))
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- Control of syn-tectonic sedimentation and décollement rheology in the geometry and evolution of the Kuqa fold-and-thrust belt (NW China). Results from analogue modelling ([Oriol Pla](#), Esther Izquierdo-Llavall, Eduard Roca, Oriol Ferrer, Òscar Gratacós and Josep Anton Muñoz)
- Interactions and feedback between tectonics, erosion and sedimentation during rifting: 2D and 3D thermo-mechanical models with surface processes ([Romain Beucher](#), Louis Moresi, Tristan Salles, Julian Giordani, Rebecca Farrington, Sara Moron-Pollanco and John Mansour)
- Effect of orographic precipitation on mountain denudation rate evolution ([Valeria Zavala](#), Sébastien Carretier and Stephane Bonnet)
- Landscape evolution from hillslopes to mountain ranges ([Liran Goren](#), Eran BenDror, Chen Gruber and Ron Nativ) (**keynote**)
- Erosion and sedimentation in the Var aerial catchment and submarine basin (Southern French Alps – Mediterranean) using Badlands ([Carole Petit](#), Tristan Salles, Yann Rolland and Guillaume Duclaux)
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- What controls sill formation: Insights from analogue models ([Giulia Sili](#), [Stefano Urbani](#) and Valerio Acocella)
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- Effect crustal heat production and mantle potential temperature on rifting and break-up: Insight from 2D and 3D modelling ([Laetitia Le Pourhiet](#) and [Julia Costa da Sousa](#))
- Factors controlling back-arc extension or overriding plate shortening – a numerical modeling study of ocean-continent subduction systems ([Sebastian Wolf](#) and [Ritske Huismans](#))
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- Backarc rifting behind narrow oceanic basins ([Zoltán Erdős](#), [Ritske S. Huismans](#) and [Claudio Facenna](#))
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- Fluid injection in single fractures: Induced seismicity and influence on the fracture slip regime ([Guillem Piris](#), [Enrique Gomez-Rivas](#), [Ignasi Herms](#), [Xavier Goula](#) and [Albert Grier](#))
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## Fluid injection in single fractures: induced seismicity and influence on the fracture slip regime

Guillem Piris<sup>1</sup>, Enrique Gomez-Rivas<sup>2</sup>, Ignasi Herms<sup>3</sup>, Xavier Goula<sup>3</sup> and Albert Griera<sup>1</sup>

<sup>1</sup>) Universitat Autònoma de Barcelona, Departament de Geologia, Bellaterra (Cerdanyola del V.), Spain

<sup>2</sup>) University of Barcelona, Department of Mineralogy, Petrology and Applied Geology, Barcelona, Spain

<sup>3</sup>) Institut Cartogràfic i Geològic de Catalunya (ICGC), Barcelona, Spain

albert.griera@uab.cat

S6 Geofluids and their influence on deformation

### Introduction

The so-called Enhanced Geothermal Systems (EGS) are characterized by a stimulation phase that aims to increase fluid flow and heat transfer between wells by increasing the permeability and transmissibility of the reservoir. This is achieved by injecting fluids at high-pressure in order to increase the apertures of existing fractures, enhance their sliding and/or generate new ones. However, this technique induces low-magnitude seismicity that occasionally results in damage at the Earth's surface. Numerical simulations able to reproduce the hydro-thermo-mechanical behaviour of geological reservoirs are an essential tool for the evaluation and forecasting of induced seismicity in such systems. In this study, the numerical code CFRAC (e.g. McClure, 2012) is used to systematically evaluate how the orientation of fractures with respect to the maximum compressive stress ( $\sigma_1$ ) influences seismicity, the injection rate and the fracture sliding behaviour.

### Results

The results show that three main seismic regimes can be distinguished. The first type are orientations that do not require a large fluid overpressure patch on the fracture before the onset and nucleation of a seismic event. A small perturbation of strength is enough to produce a critical load and fracture reactivation. The size of the rupture surface is larger than the size of the pressurised patch, and therefore, slip along the fracture can expand outside of the pressurised front leading to situations of uncontrolled rupture propagation. The fractures oriented between  $\alpha = 40^\circ$  and  $\alpha = 14^\circ$  follow this behaviour.

The second type of response is defined by fracture orientations that require longer injection times before the onset of fracture slip. In this case, the onset of dynamic slip requires that a large part of the fracture is first uniformly pressurised. Seismic events in this case are not located near the injection point, but into the pressurised front. They are characterised by high slip velocities and surface run-outs that can expand outside of the pressurised region, but are still able to produce rupture surface along the whole fracture distance. The fracture orientation ranges between  $5^\circ \leq \alpha < 14^\circ$  and  $40^\circ \leq \alpha \leq 45^\circ$ . Finally, a third case with the fracture oriented  $\alpha \leq 5^\circ$  can be defined. In this case, dynamic slip is not observed and fracture propagation is arrested due to the increase of the dynamic friction coefficient during the raise of the slip velocity. The accommodation of loading, and therefore the accommodation of a finite displacement along the fracture, takes place by means of slow motion events (i.e. low-magnitude seismicity) or by aseismic flow.

### References

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### Keywords

*Induced seismicity, EGS reservoir, discrete fracture, fluid injection.*

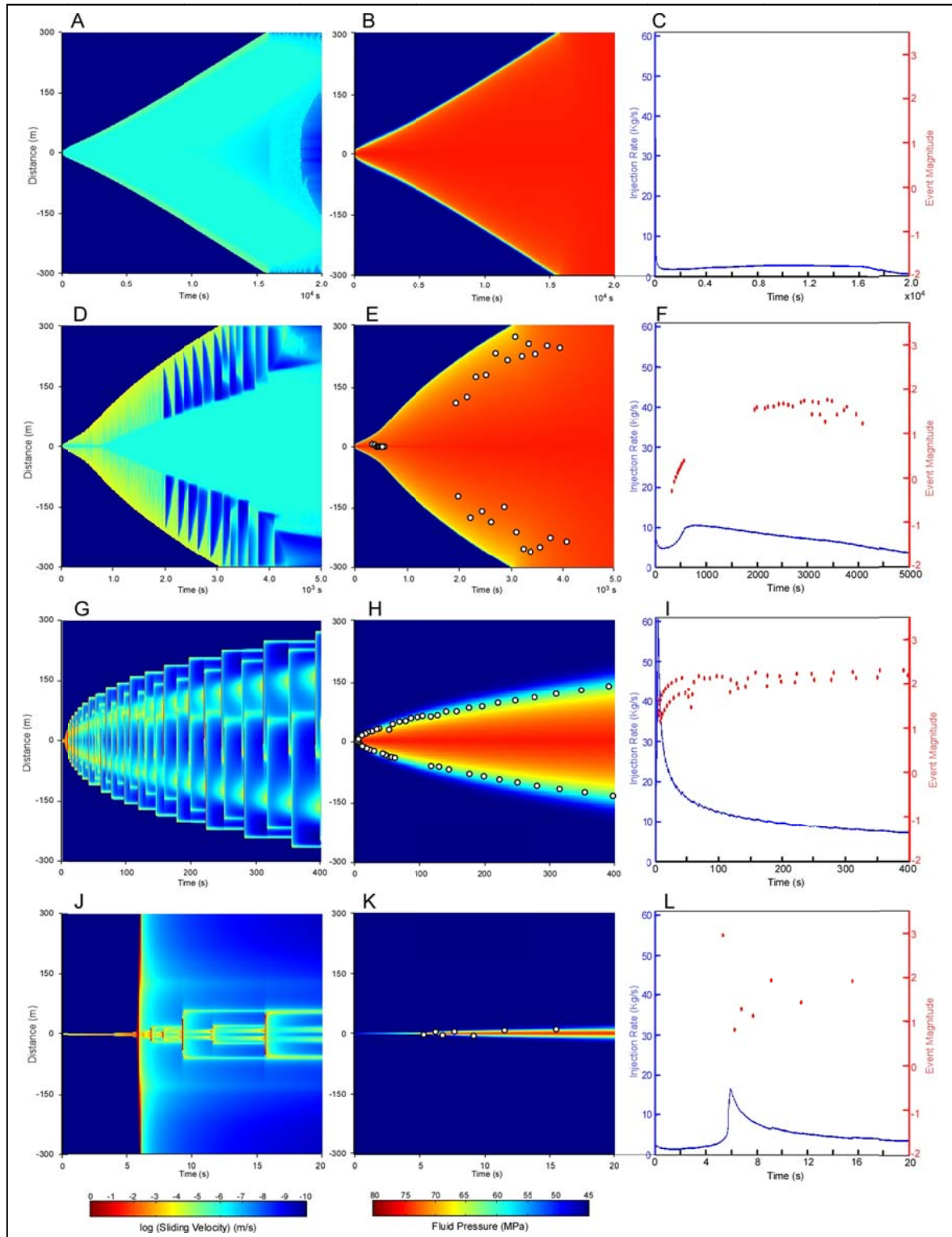


Figure 1: Sliding velocity (m/s), fluid pressure (MPa), injection rate (kg/s) and event magnitude evolution along fracture distance and time elapsed (s) for model  $\theta = 88^\circ$  (A-C),  $\theta = 86^\circ$  (D-F),  $\theta = 76^\circ$  (G-I) and  $\theta = 60^\circ$  (J-L). White points indicate hypocentre of seismic events. Fracture orientation ( $\theta$ ) was defined as the angle between the principal compressive stress  $\sigma_1$  and the fault normal.