Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

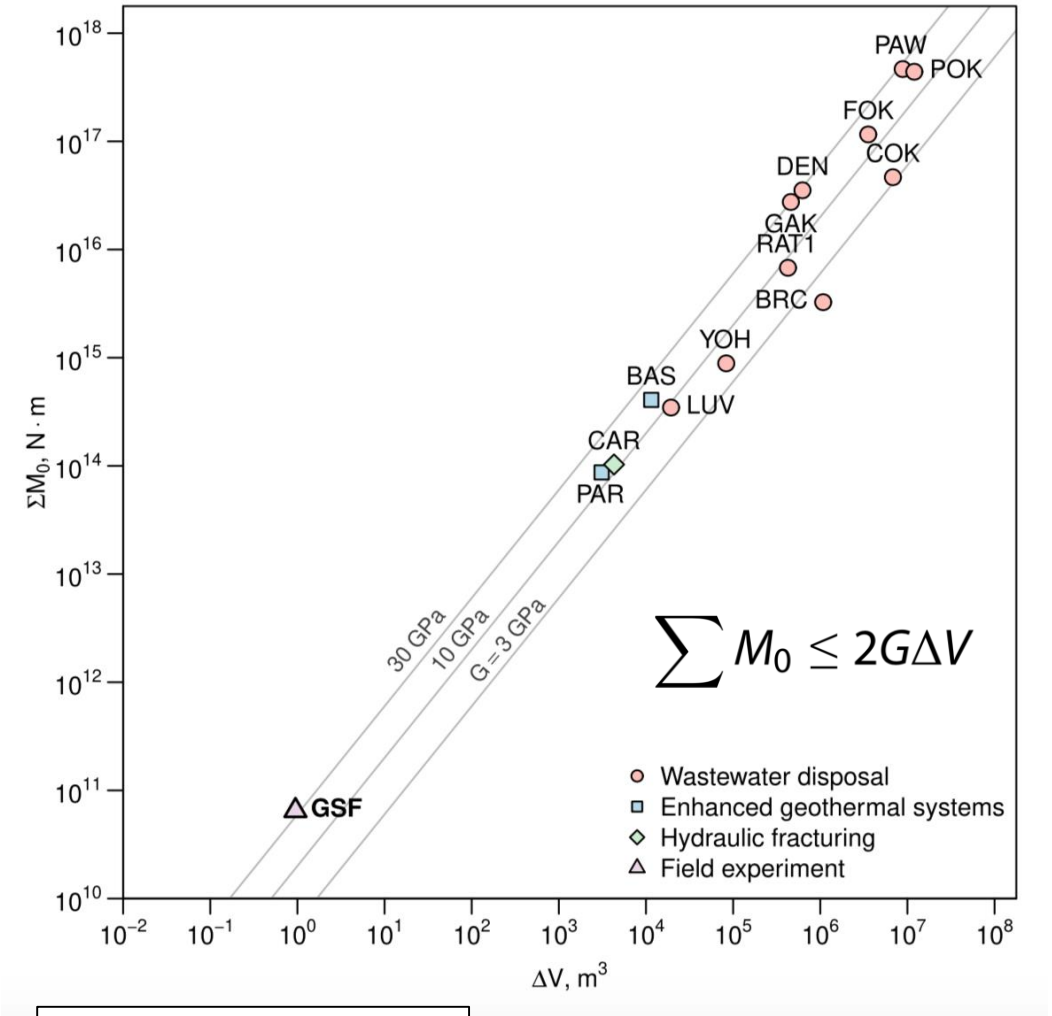
ETH zürich

Discussion on Induced Seismicity

Michael Manga & Antonio P. Rinaldi

4th Cargèse Summer School:
Flow and Transport in Porous and Fractured Media
Cargèse, Corsica (France), 06.07.2018

On the maximum magnitude of induced event



McGarr & Barbour, 2018

PAW=Pawnee, M_{max}=5.8
BAS=Basel, M_{max}=3.4
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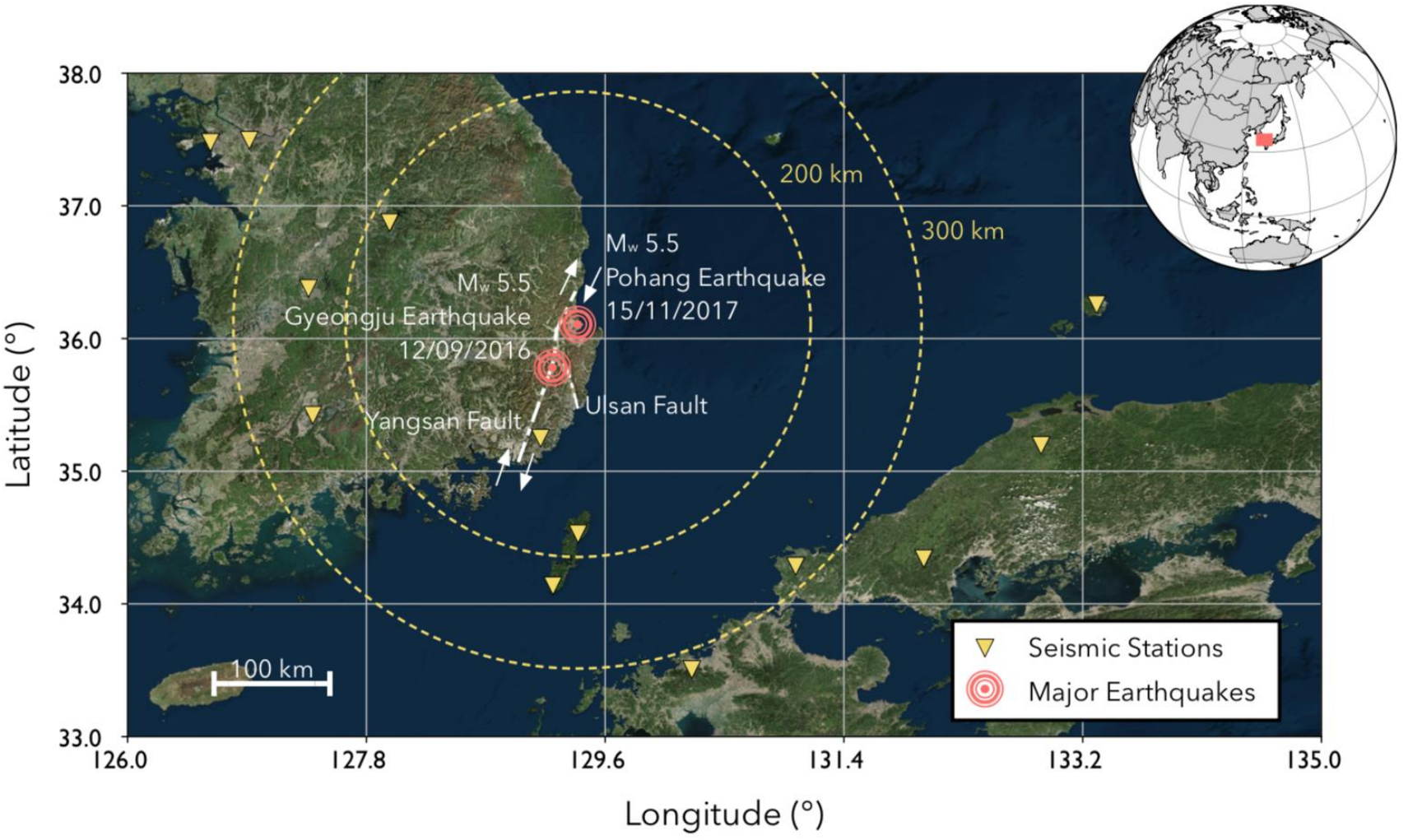
GFS=In-Situ experiment, aseismic

The case of Pohang, South Korea



Grigoli et al., 2018

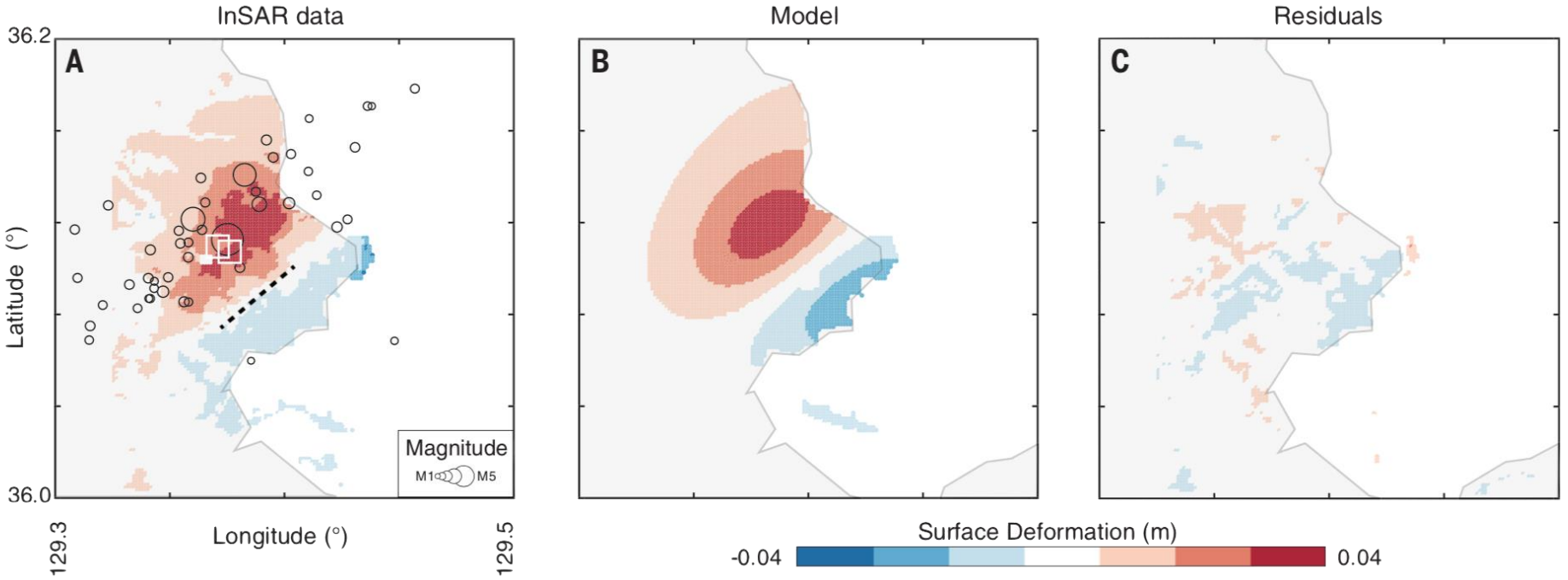
The case of Pohang, South Korea

Two papers recently published on Science raised the questions on caon earthquake being induced/triggered by injection activity.

- The "European" paper – Grigoli et al.
  - Independent analysis of seismicity from regional network and InSAR ground uplift.
  - Complex source mechanism
  - Analysis of Coulomb Failure Stress shows that little changes can be attribute to recent (one year before) seismicity

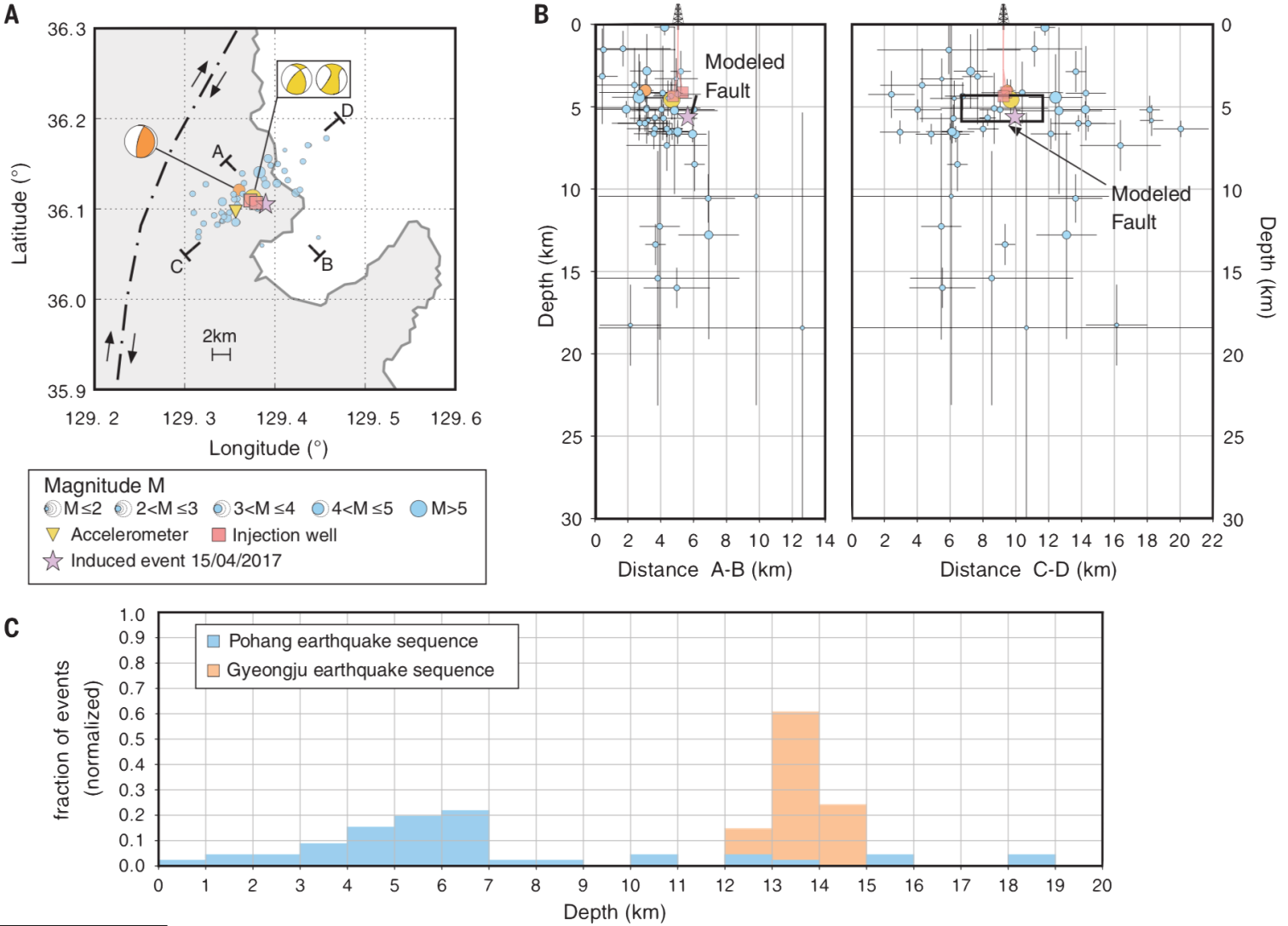
- The "Korean" paper – Kim et al.
  - Analysis of aftershocks using local network
  - Correlate net injected volume with seismicity

The case of Pohang
InSAR modeling



Grigoli et al., 2018

The case of Pohang regional network seismicity



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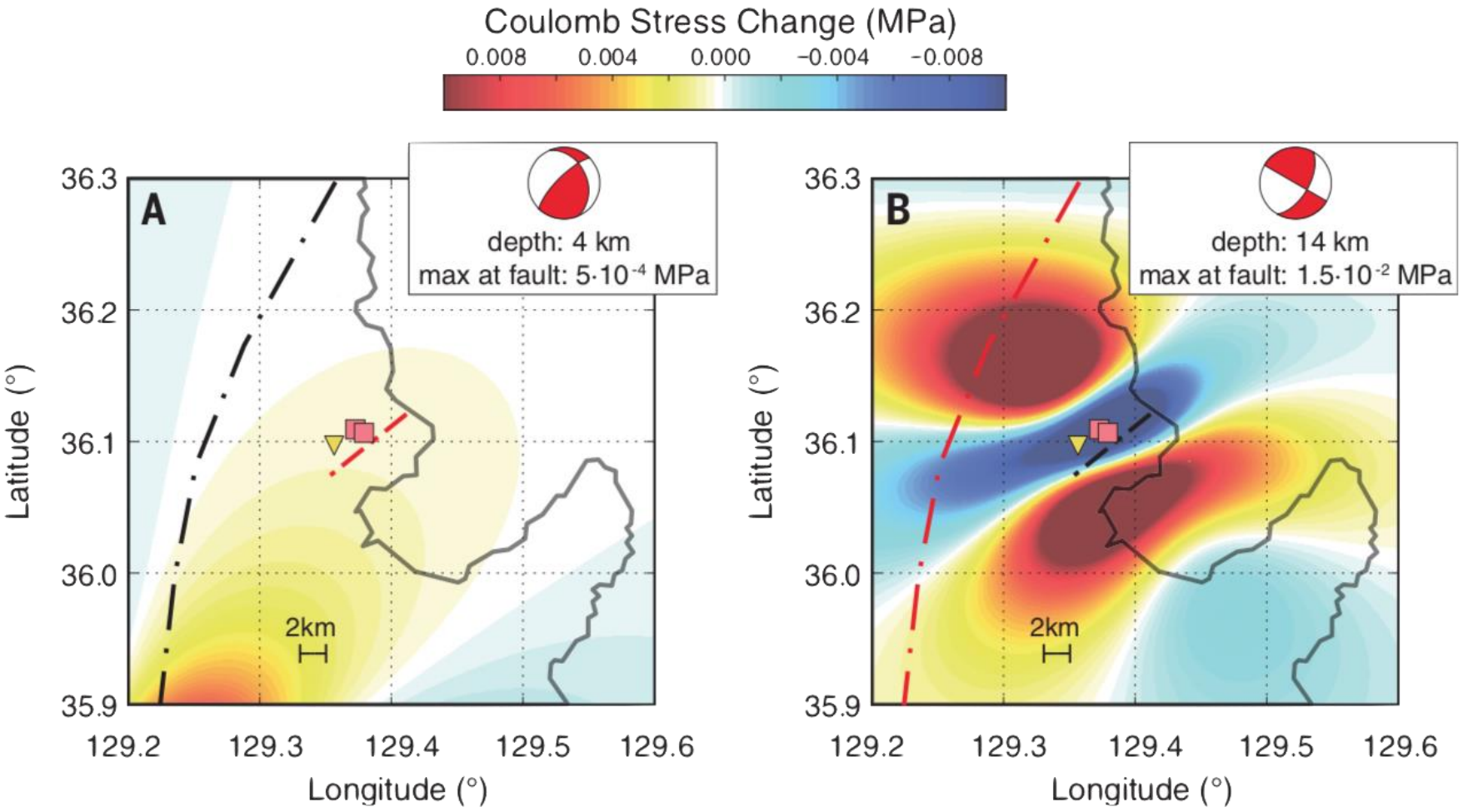
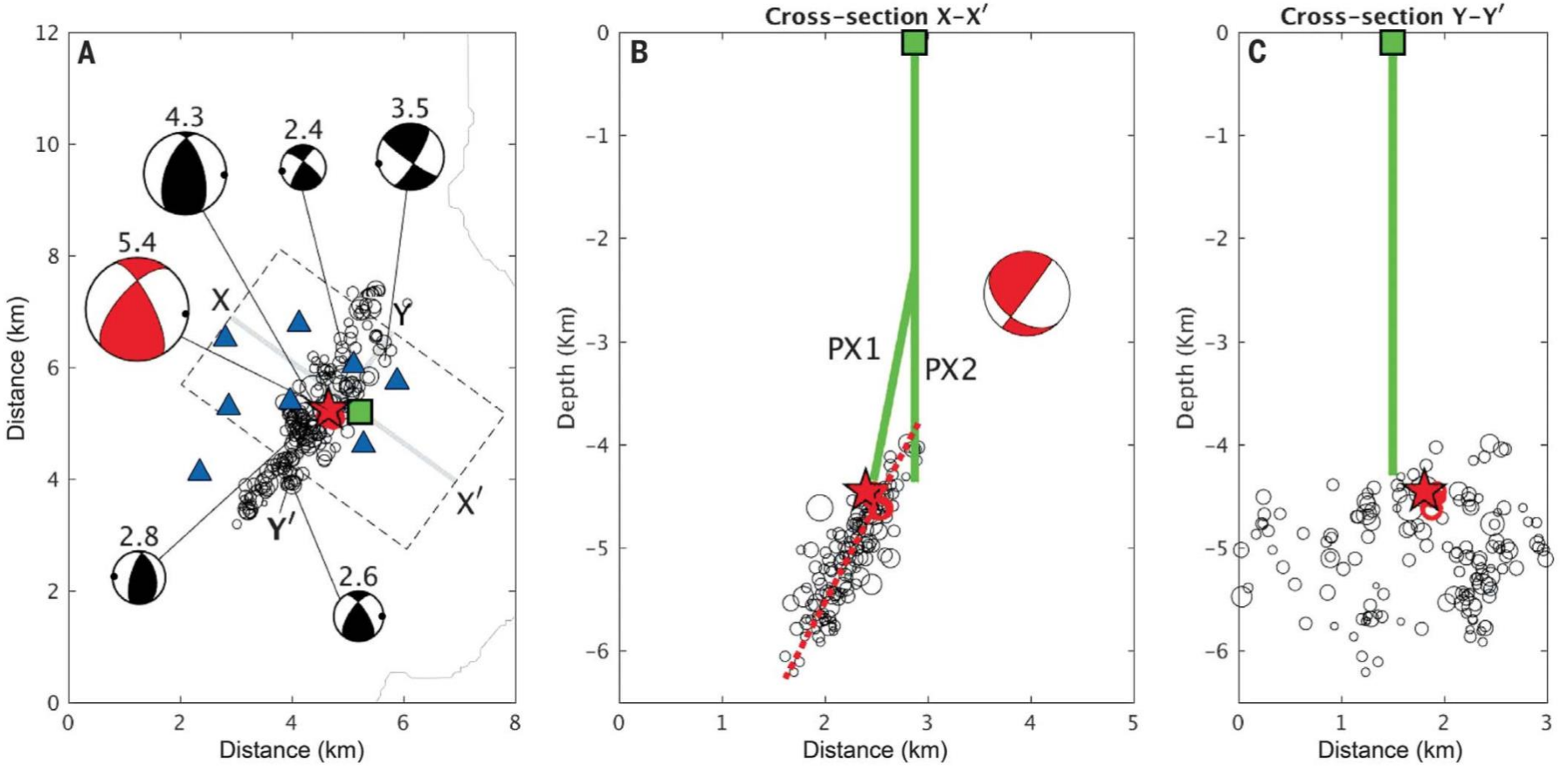
The case of Pohang
Coulomb Failure Stress



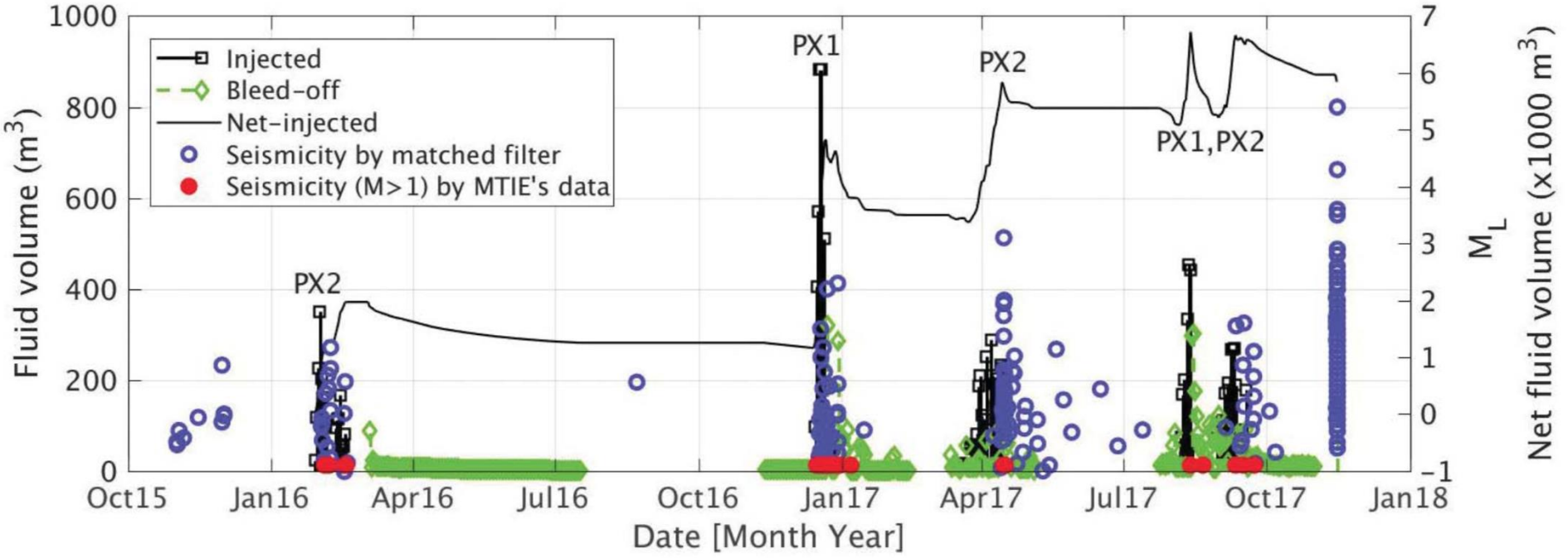
Grigoli et al., 2018

The case of Pohang local network seismicity



Kim et al., 2018

The case of Pohang injection activity and seismicity



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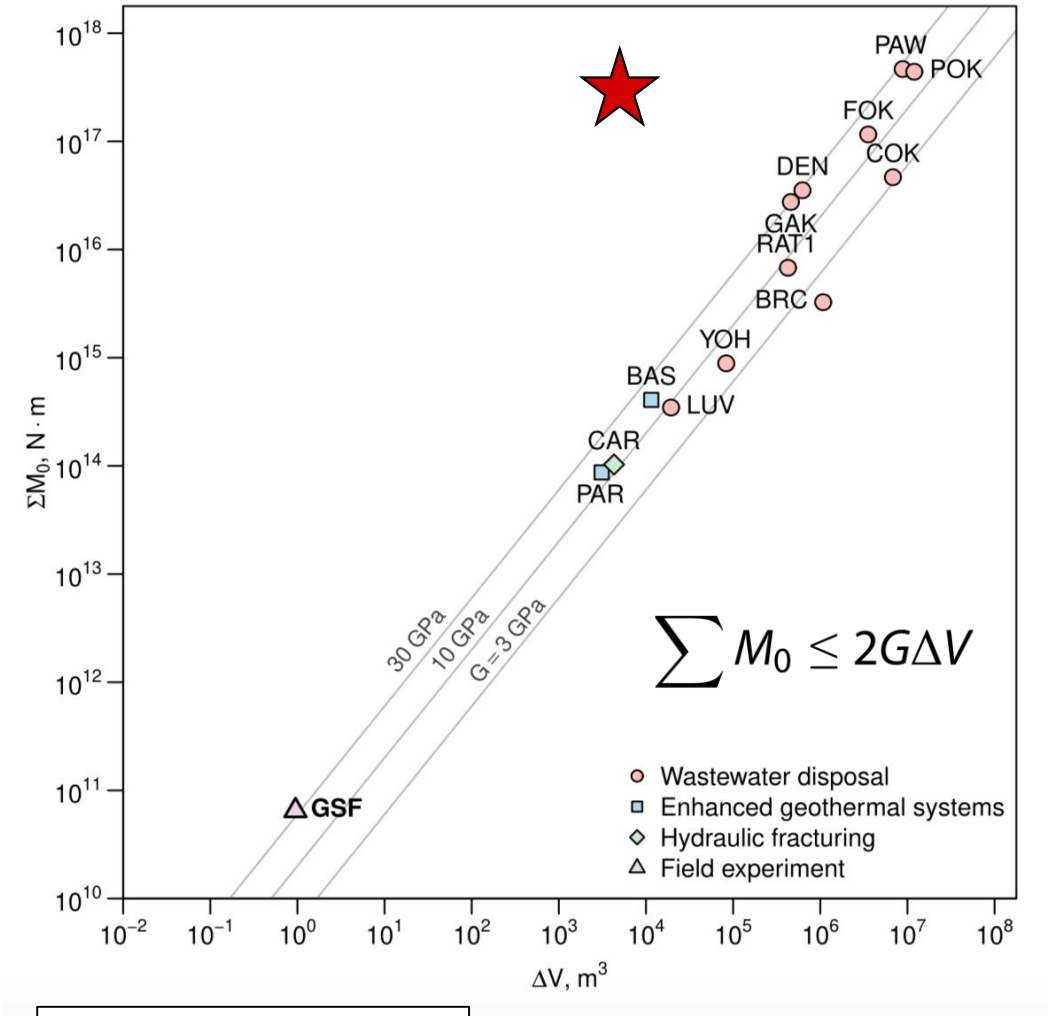

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Pohang, M_{max}=5.4(5.5)

St. Gallen Deep Geothermal System project timeline

2009 Feasibility study for geothermal project

2010 3-D seismic survey 270 km^2 (Heuberger et al., 2016)

2012 SED starts seismic monitoring

2013 Mar-Jul: Borehole drilling

Jul: Stimulation of Malm inducing ML 3.5 earthquake

Sep-Oct: Fishing for lost equipment and mud losses

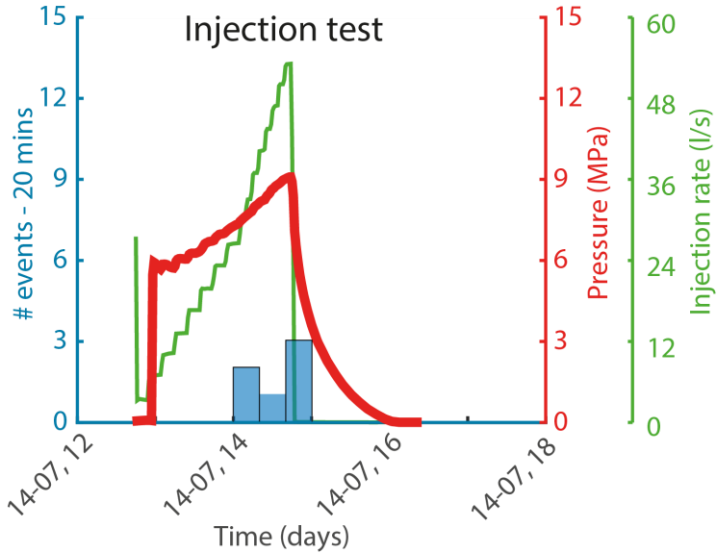
Oct: Production test (seismicity ceased)

since Nov: shut-in of well

2014 May: Geothermal project suspended

2013, Stadt St.Gallen / St.Galler Stadtwerke

The case of St. Gallen DGS
July 2013 – injection test



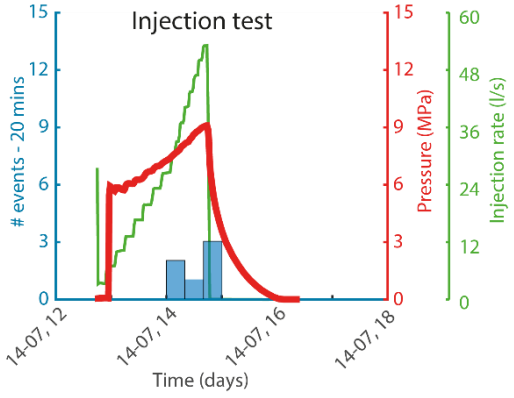
14 July

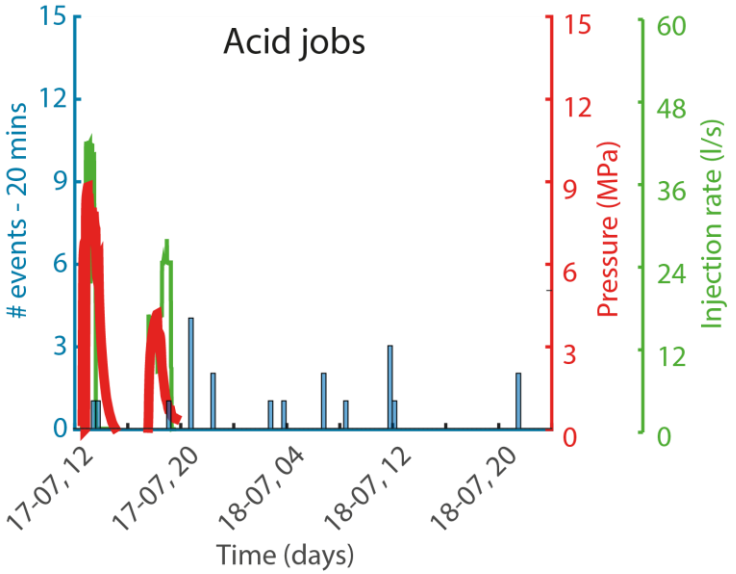
Injection test (175 m^3)

Time

Catalog of located events - Diehl et al., 2017
Pressures and injection rates - Wolfgramm (GTN), 2014

The case of St. Gallen DGS
July 2013 – acid jobs





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Acid stimulations (290 m^3)

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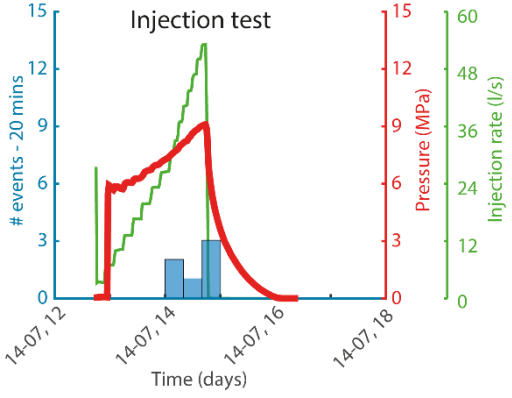
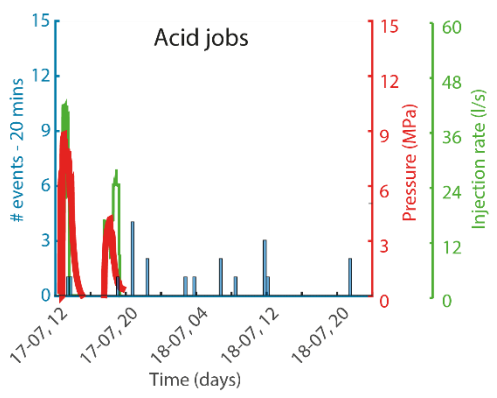
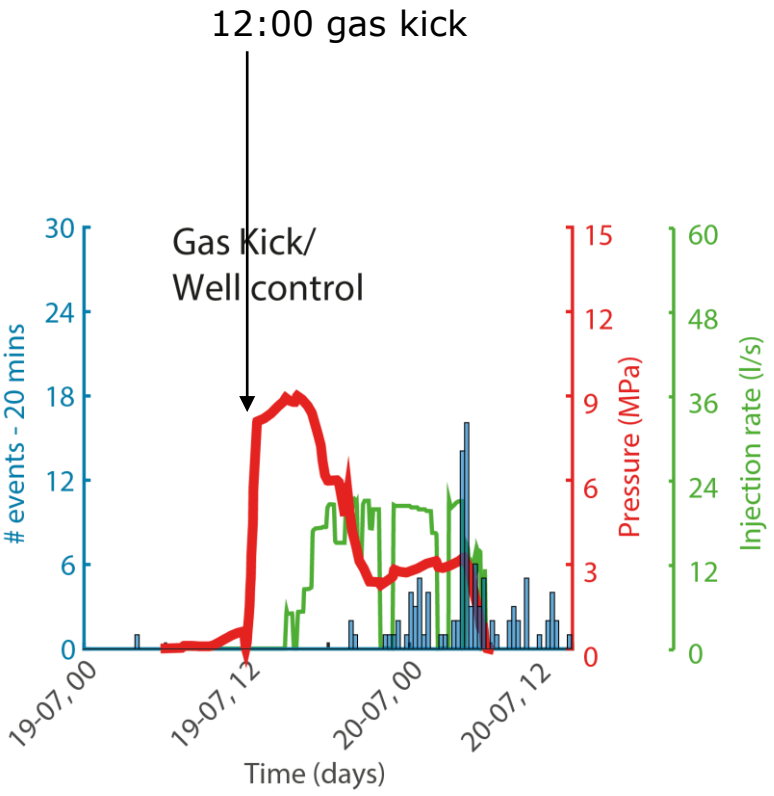
The case of St. Gallen DGS
July 2013 – gas kick and well control







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Gas kick and well control measures (700 m³)

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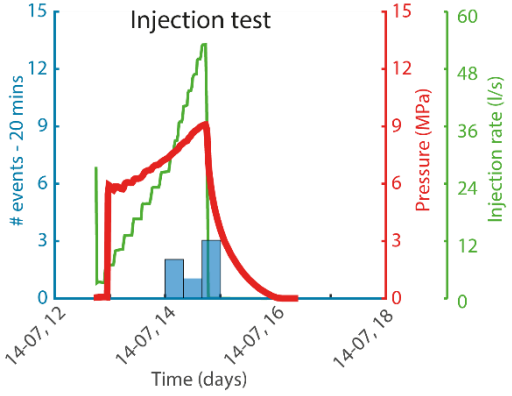

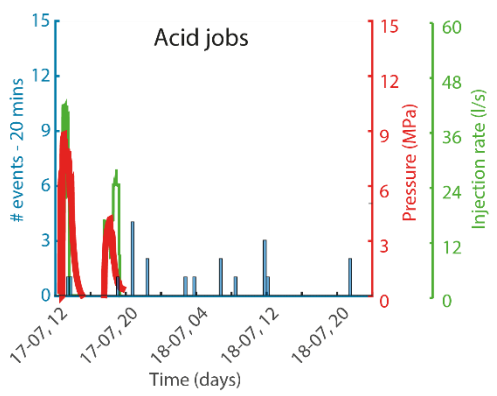

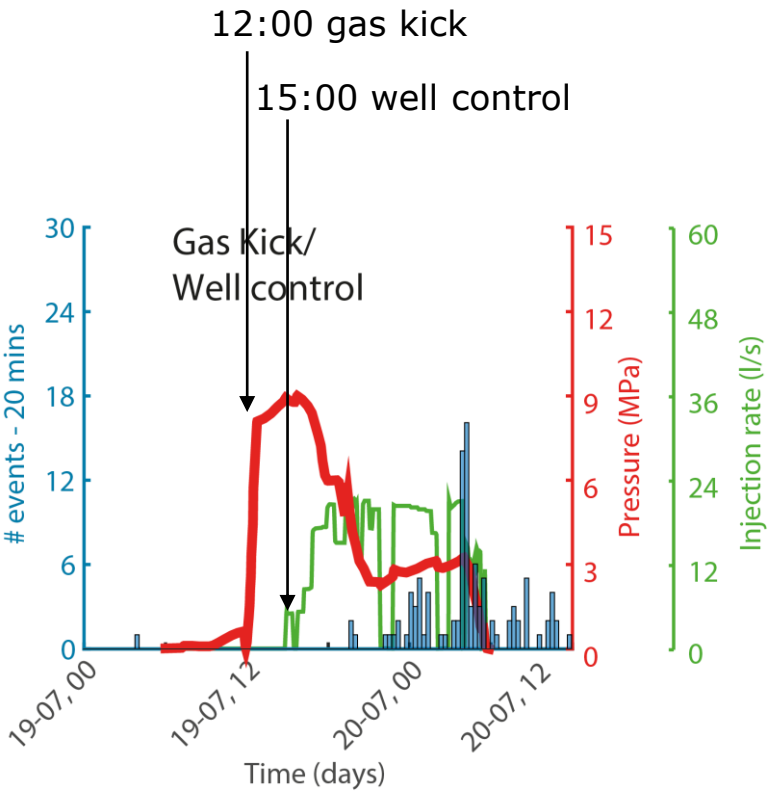

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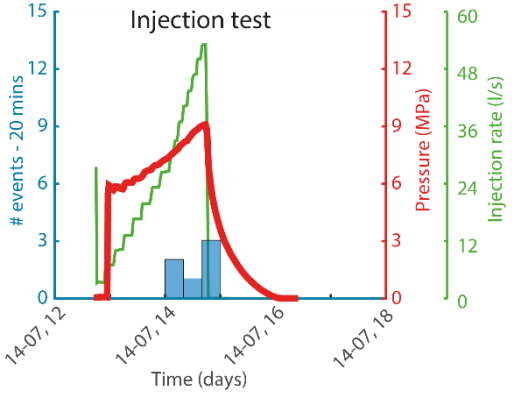

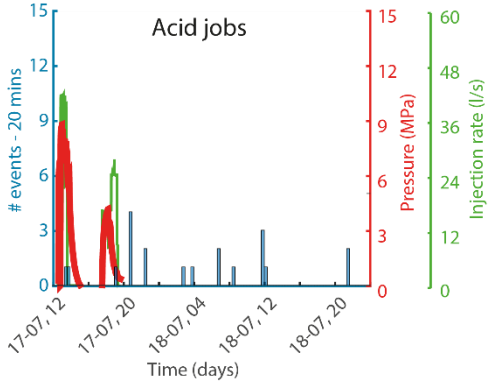

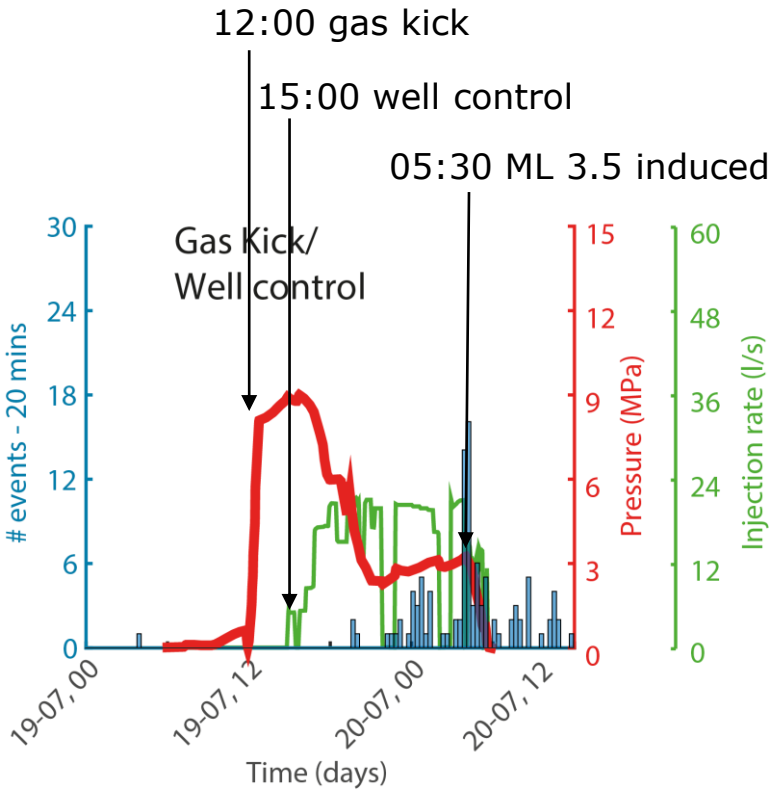

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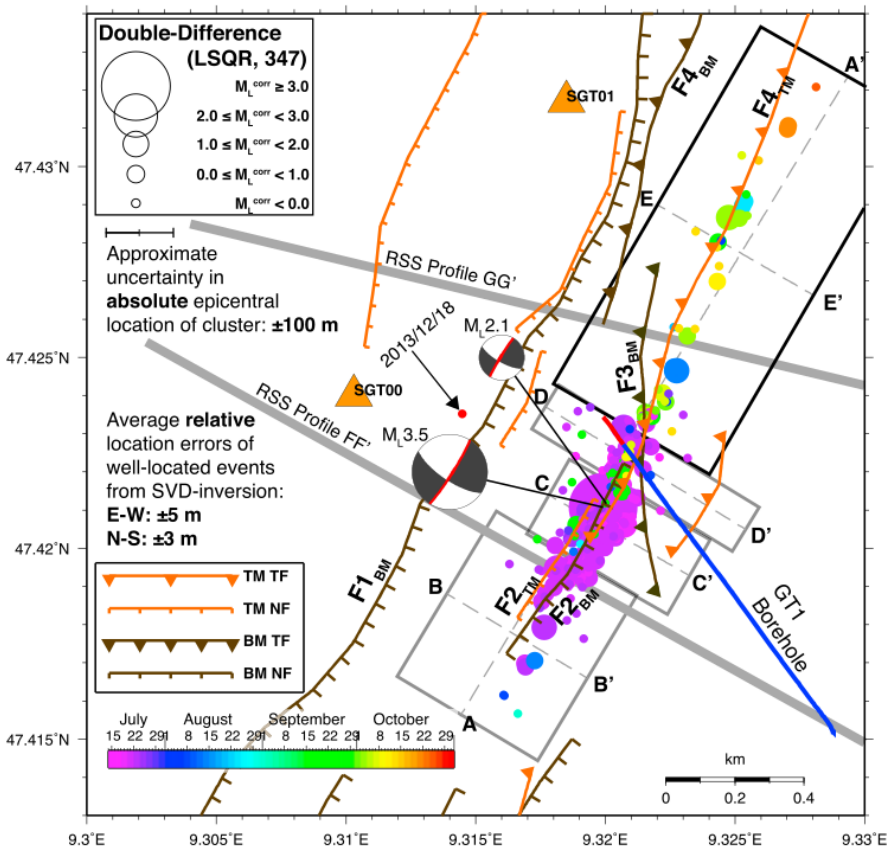
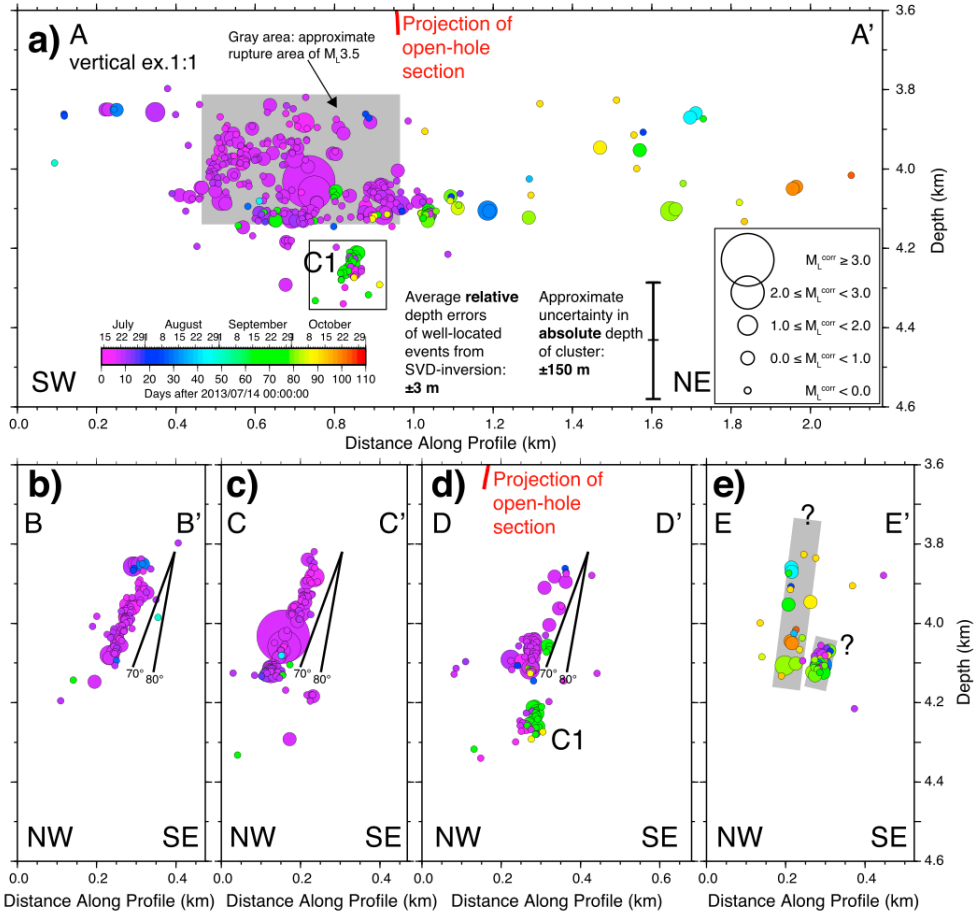
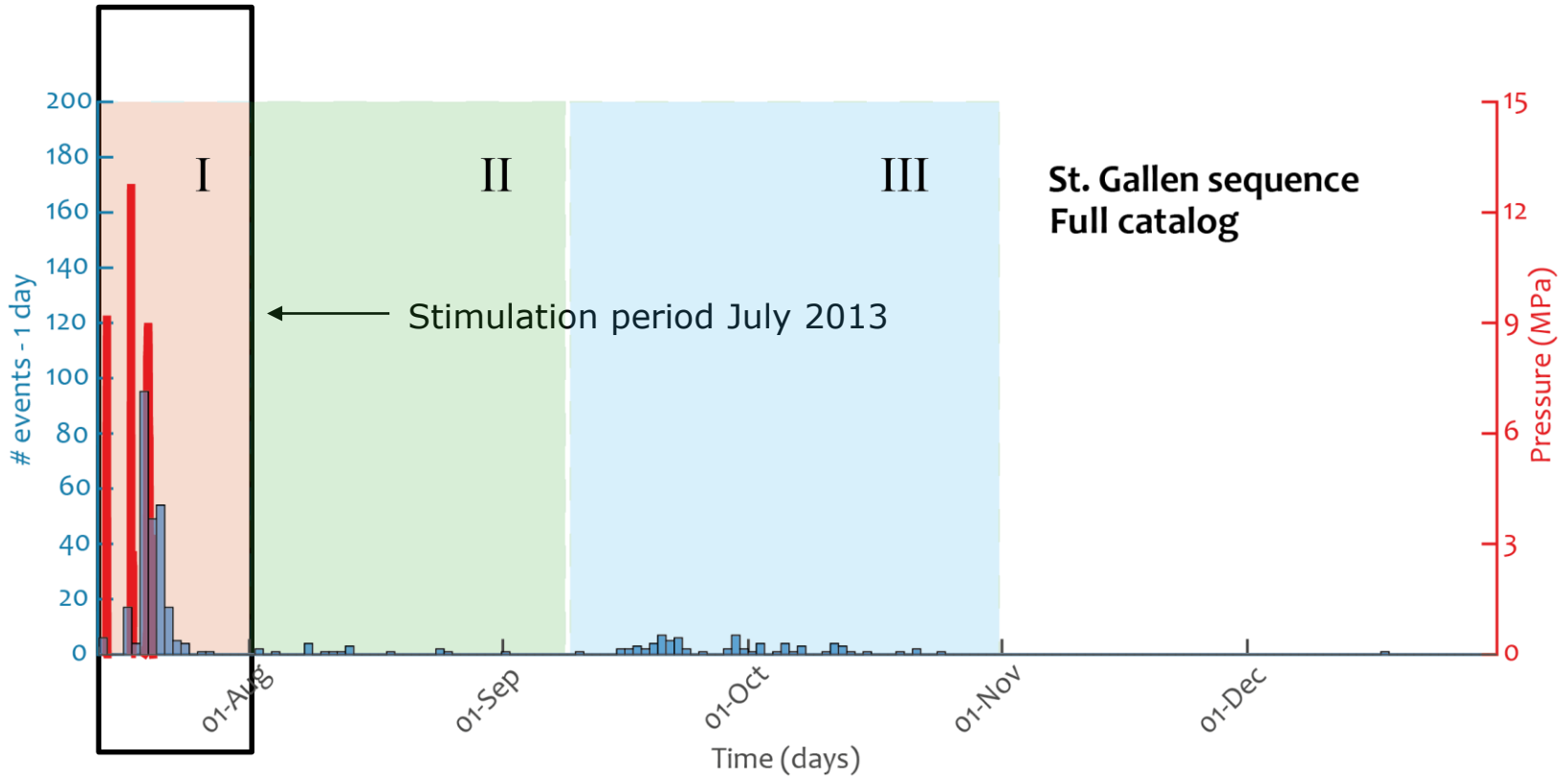
The case of St. Gallen DGS
Spatial distribution of seismicity





Diehl et al., 2017

The case of St. Gallen DGS
Temporal evolution of seismicity



Time

Catalog of located events - Diehl et al., 2017
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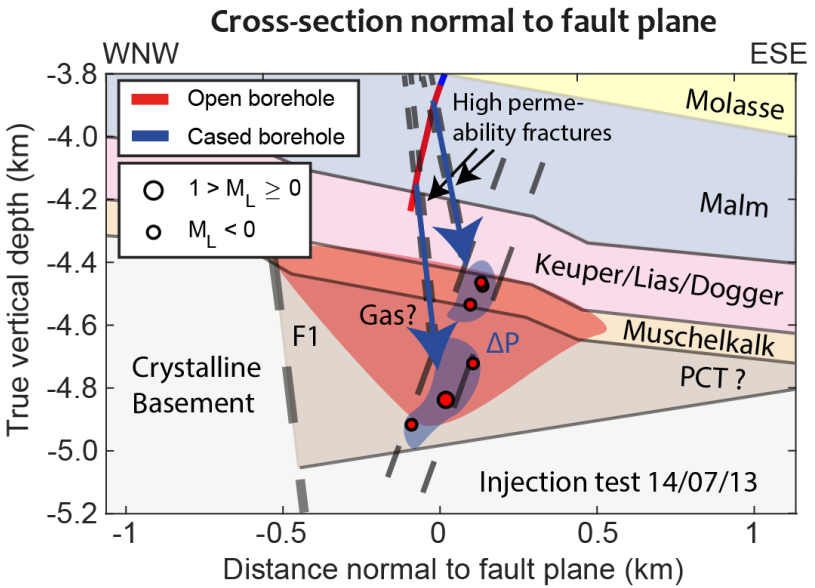
The case St. Gallen DGS
The conceptual model

Injection test (14 July) induces minor seismicity and opens up fractures



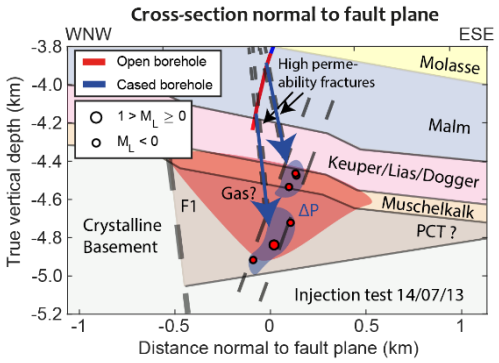
14 July

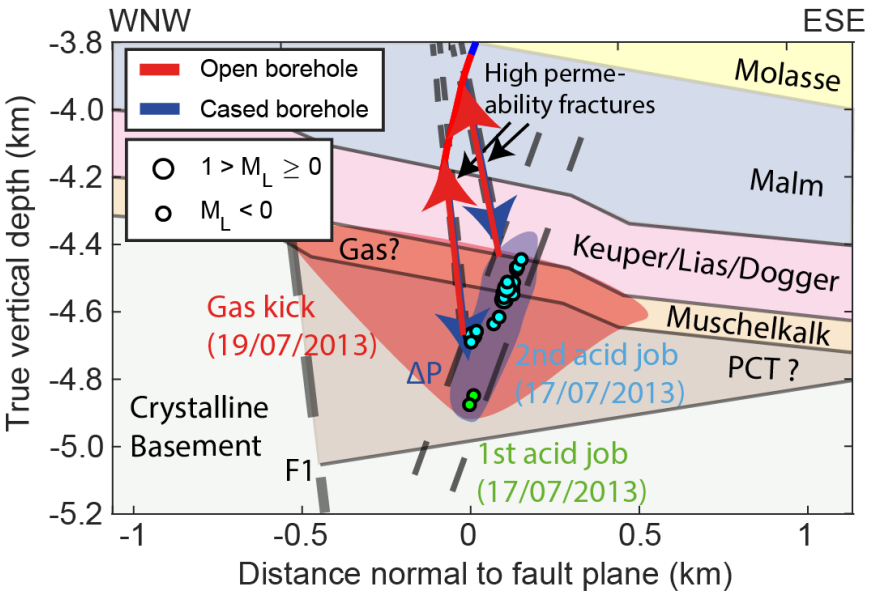
Injection test (175 m^3)

Time

The case of St. Gallen DGS
The conceptual model

Acid stimulations (17 July) induce further seismicity and increase fracture permeability so that gas can migrate upwards





14 July

Injection test (175 m^3)

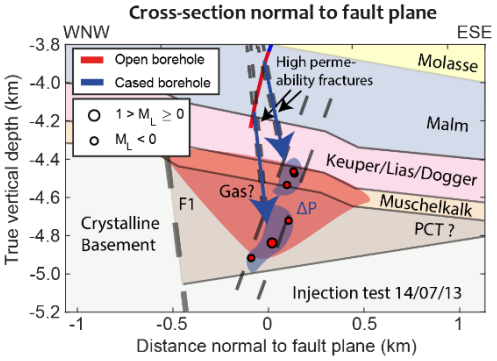
17-19 July

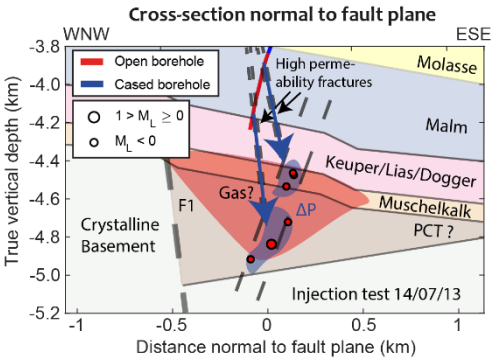
Acid stimulations and gas kick

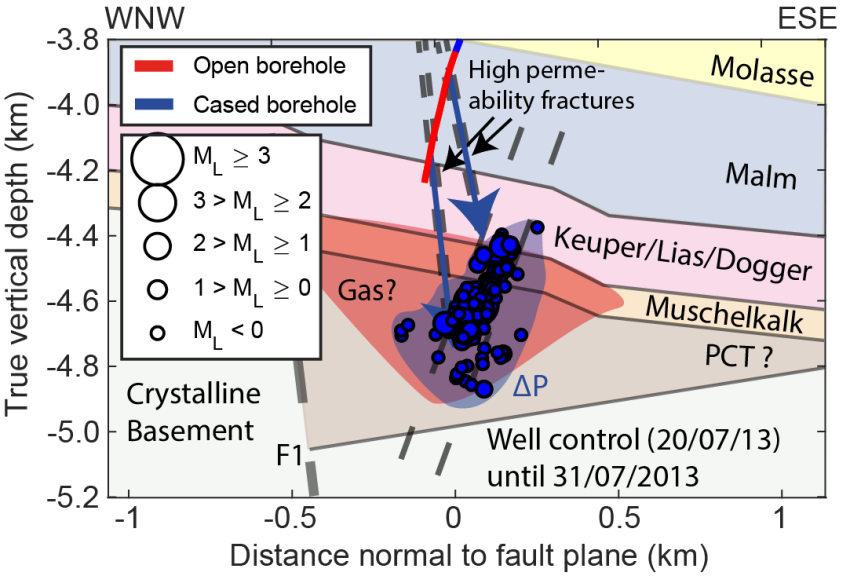
Time

The case of St. Gallen DGS
The conceptual model

Well control measures (700 m^3 injected) induces main sequence







14 July

Injection test

17-19 July

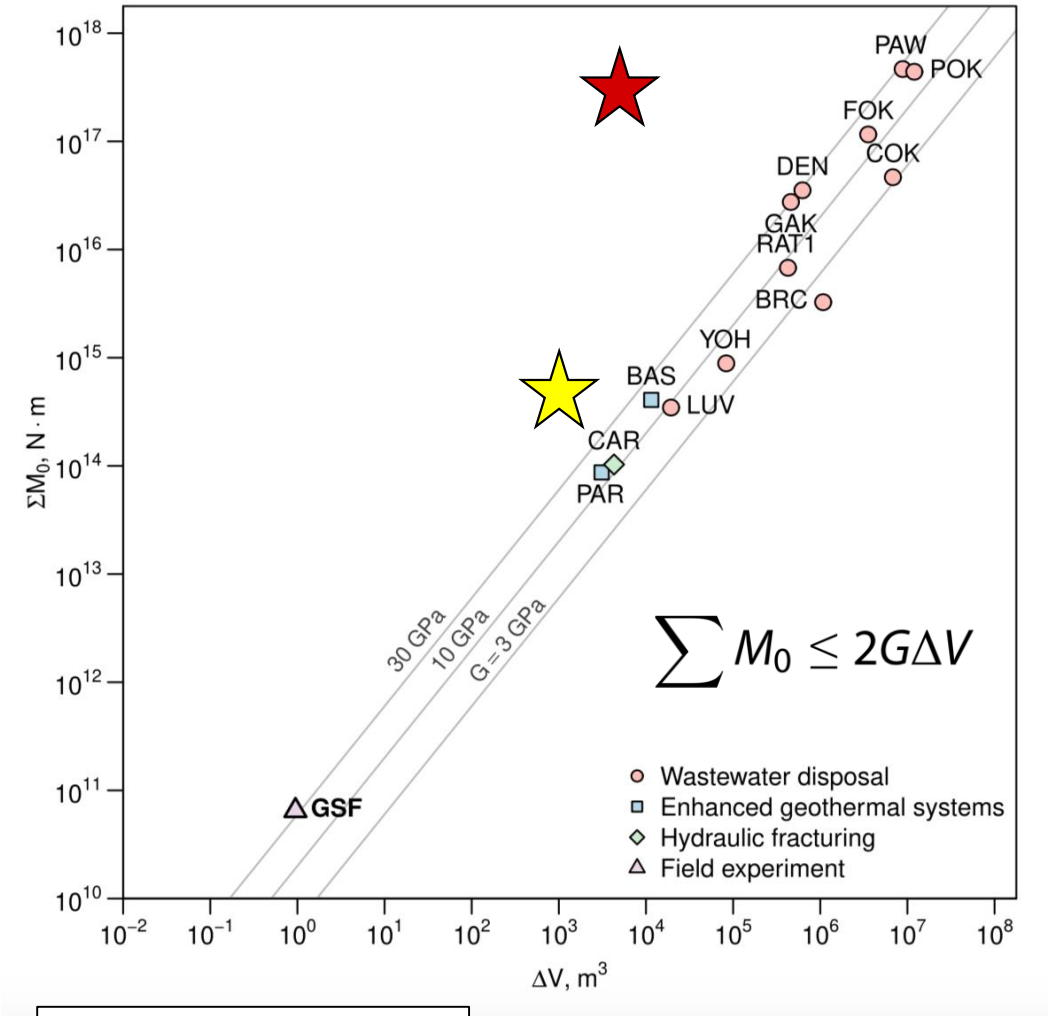
Acid stimulations and gas kick

20 July

Well control measures

Time

On the maximum magnitude of induced event



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