Seismicity monitoring

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Outline

Post-mining seismicity: lessons learnt by the PostMinQuake project

Post-mining seismicity monitoring: requirements, challenges and potential

Analysis of post-mining seismicity: the Gardanne, France, case study

Post-mining seismicity

Importance of post-mining seismicity

We recognise the importance of post-mining seismicity and warn to account for post-mining seismic hazard. Post-mining seismicity has been observed at all considered sites, with no exceptions, but with differences in temporal evolution, seismicity rates and magnitude range. In many cases post-mining seismicity occurred as a continuation of mining seismicity, with considerable overlap in terms of locations, depths and magnitudes.

The role of post-mining seismic monitoring

An adequate seismic monitoring is crucial to assess seismic hazard. Post-mining seismic monitoring setups are also heterogeneous, leading to different quality and completeness of seismic catalogs.

Post-mining seismic monitoring may suffer from the lack of underground seismic stations, requiring a network densification and/or re-adaptation to preserve adequate monitoring conditions.

Monitoring post-mining seismicity is challenging. How to design and optimize the seismic monitoring?

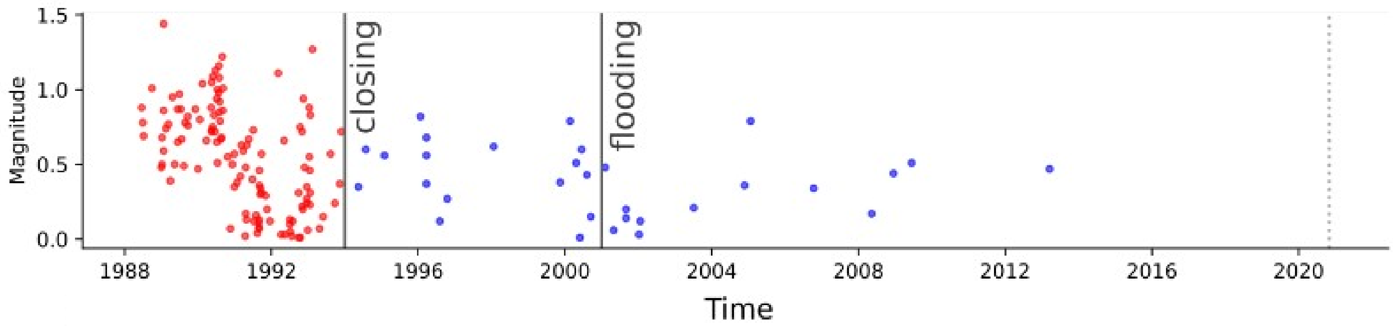
Building on the resolved characteristics of post-mining seismicity

Post-mining seismicity

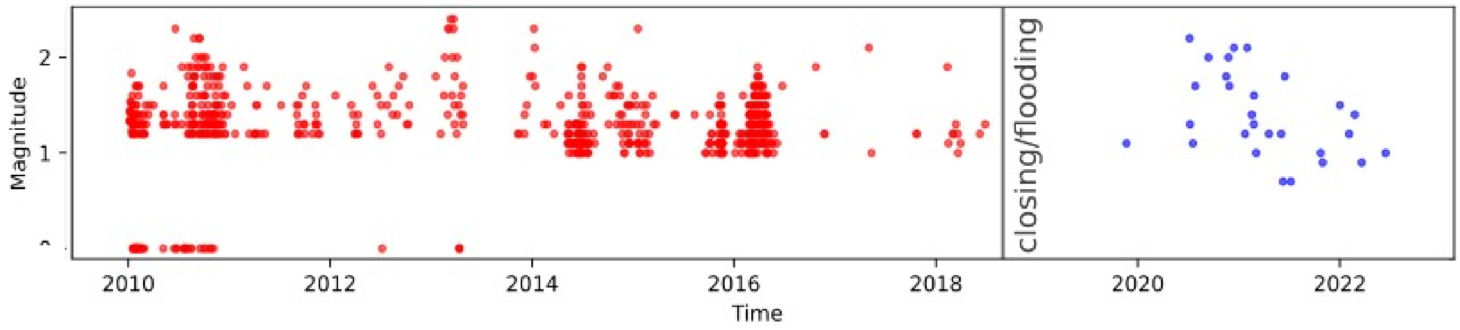
Seismicity rates

Quite heterogeneous, but are generally lower than corresponding active mining. At the Ostrava-Petrvald sub-basins and Hamm, seismicity rates dropped with the end of mining, while post-mining seismicity rates are higher at Ibbenbüren, alternating periods of high and low rates.

Ostrava-Petrvald



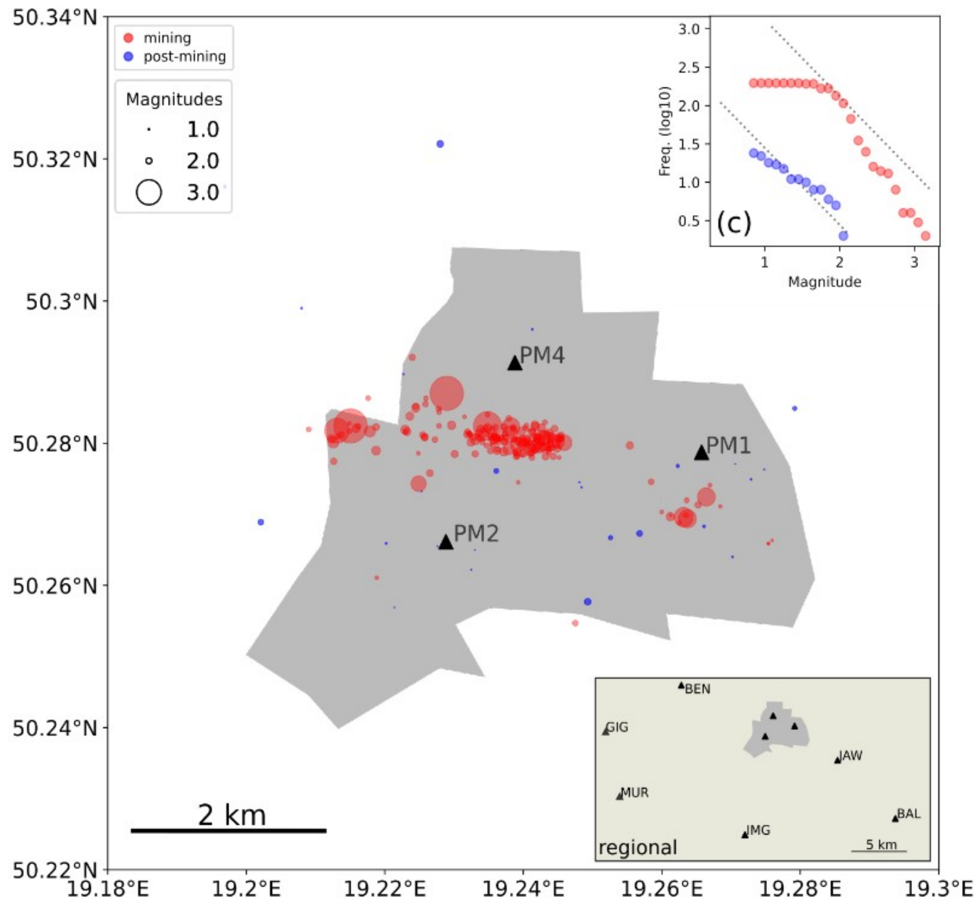
Ibennbüren



Post-mining seismicity

Locations

Post-mining seismicity located within or very close to the mine at all considered sites. Locations are often similar to mining seismicity (German and Czech sites), suggesting re-activation of fault structures. At the Polish site, however, the post-mining seismogenic volume is broader.

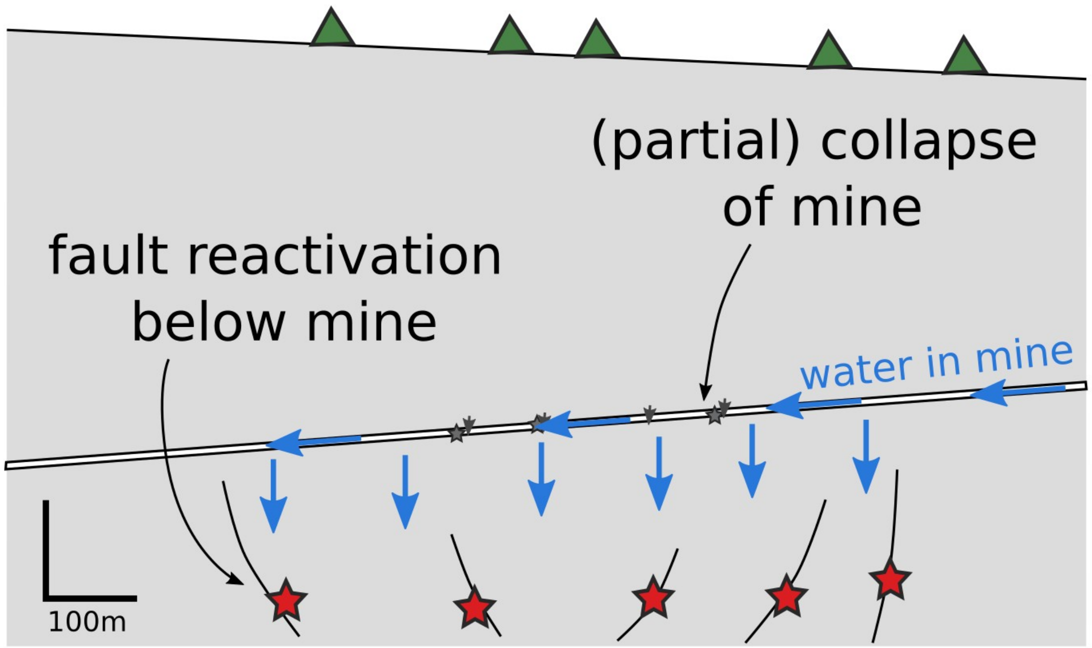


Kazimierz-Juliusz

Post-mining seismicity

Depths

The depth reported for post-mining seismicity is generally comparable to the depth of mining seismicity at the same mine. However, hypocentral depths of post-mining earthquakes are often poorly constrained, due to the lack of in-mine stations, hindering an accurate comparison. Accurate depths are important to distinguish between events located in the mine or related to deeper faults.



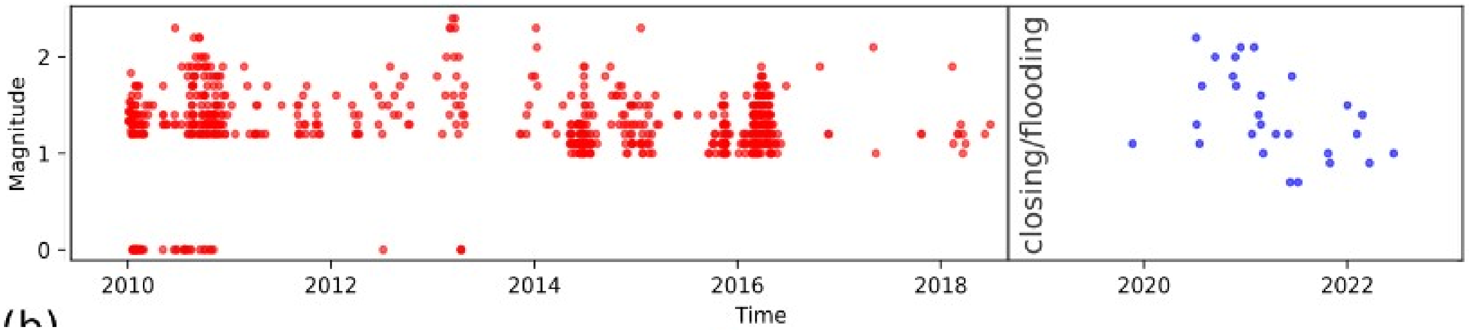
Gardanne

Post-mining seismicity

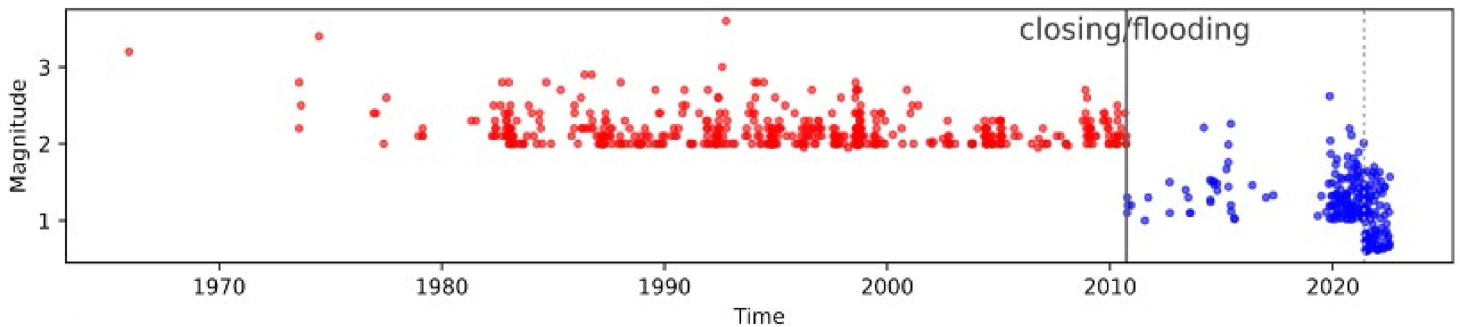
Magnitudes

Post-mining seismicity may reach comparable maximum magnitudes as induced during mining (Ibbenbüren). At the other sites, the post-mining maximum magnitude was, so far, slightly smaller (~0.5-1.0) than during mining. Routine magnitude assessment can be improved (Gardanne) to assure reliable magnitude estimates, a prerequisite for hazard analyses.

Ibbenbüren



Hamm

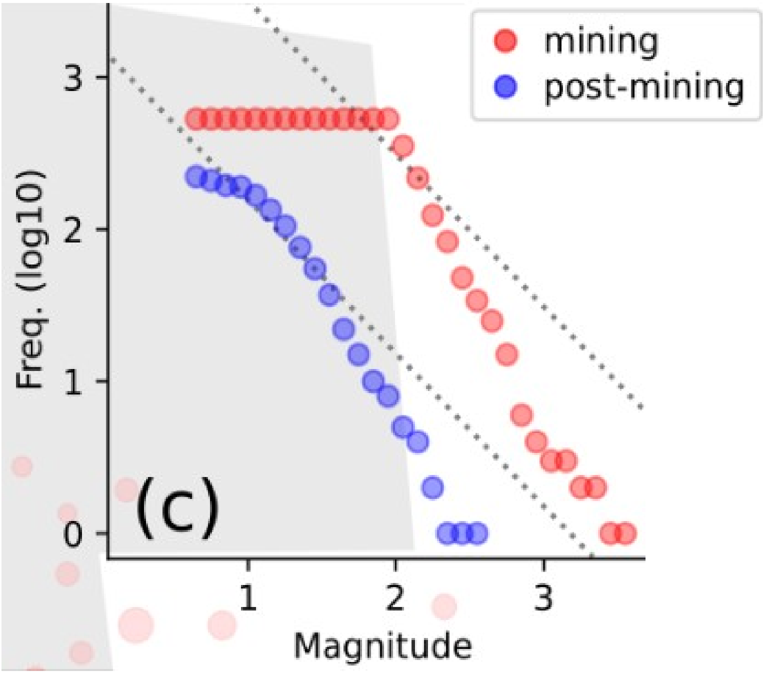


Post-mining seismicity

Spatio-temporal patterns and tatistics

Excluding sites with weak, low-rate post-mining seismicity (Ostrava-Petrvald, Kazimierz-Juliusz), post-mining seismicity appears clustered in space (Ibbenbüren, Gardanne) and/or time (Hamm, Gardanne). Spatial clusters of post-mining activities sometimes resemble the location of mining seismicity (e.g., Ibbenbüren), suggesting fault reactivation.

Hamm



Post-mining seismicity

Conclusions

Comparing post-mining and mining seismicity at various testbeds show significant differences

Post-mining seismicity occurs close to the mining areas, although not necessarily at the same locations and depths as mining seismicity

Mangitudes and seismicity rates may occassionally be comparable to those during mining

Post-mining seismicity processes may include fault reactivation, e.g. in response to flooding and pore pressure fluctuation, as well as failure in the mining overburden.

Since the role of mining flooding is relevant to drive seismicity, monitoring the water level should be included in support to seismic monitoring.

Post-mining seismicity monitoring

Requirements, challanges and potential

Requirements:

→ Ideally it should allow a comparable monitoring than during mining:
→ covering the entire mine volume
→ ensuring a similar detection performance and/or location accuracy

Challenges:

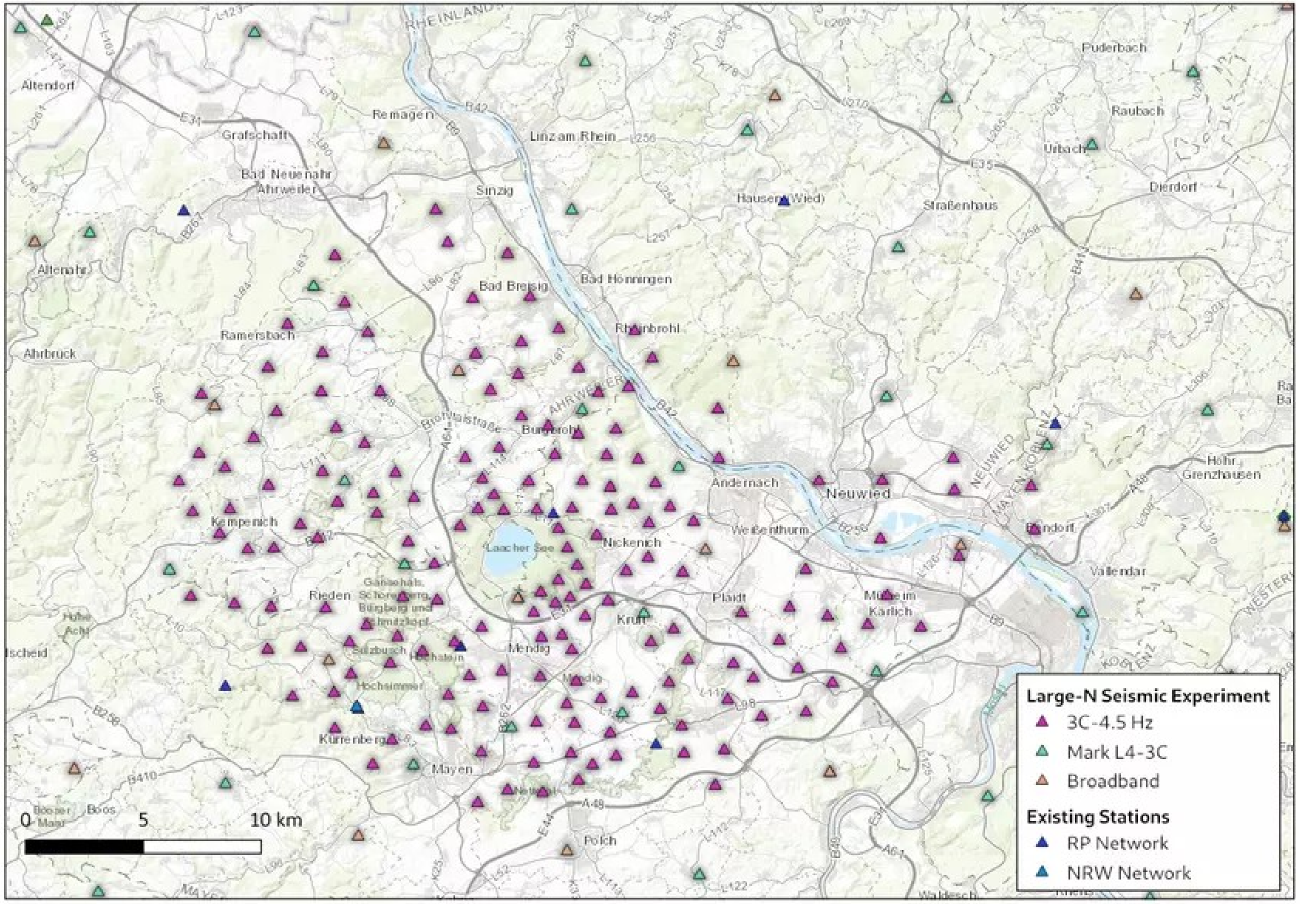
→ ensure comparable performance as during mining, but with no access to mining infrastructure (surface and/or shallow borehole)
→ low cost monitoring optmization

It should be supported by other geophysical monitoring:

→ seismic
→ surface deformation
→ underground water

Post-mining seismicity monitoring

Potential of surface seismic monitoring

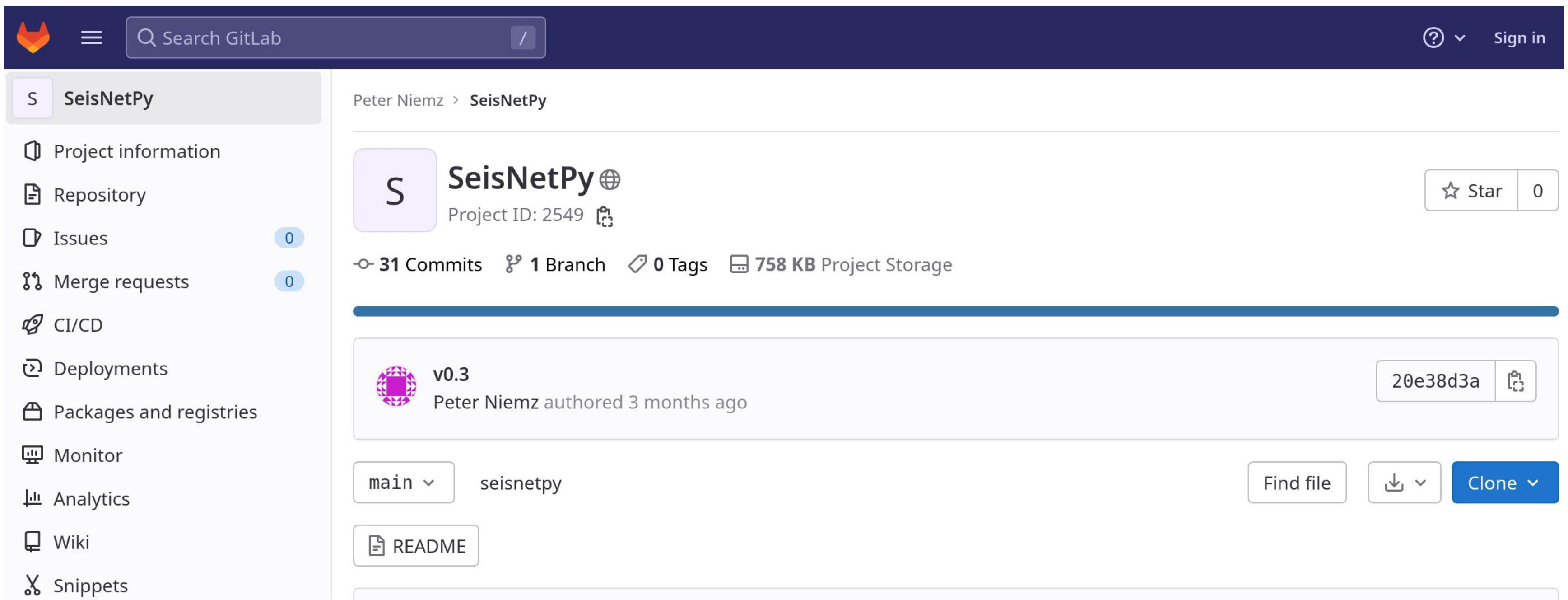


Large-N seismic monitoring in the Eifel region (source: GFZ Potsdam)

Post-mining seismicity monitoring

Optimization of surface seismic monitoring

SeisNetPy: an open tool for network optimization, targeting post-mining seismicity



Post-mining seismicity monitoring

Optimization of surface seismic monitoring

SeisNetPy: an open tool for network optimization, targeting post-mining seismicity

→ extended after Toledo et al. (2018), originally built for geothermal monitoring

→ open source, Python implementation

→ noise assessment using automated onlite, satellite-base land use maps

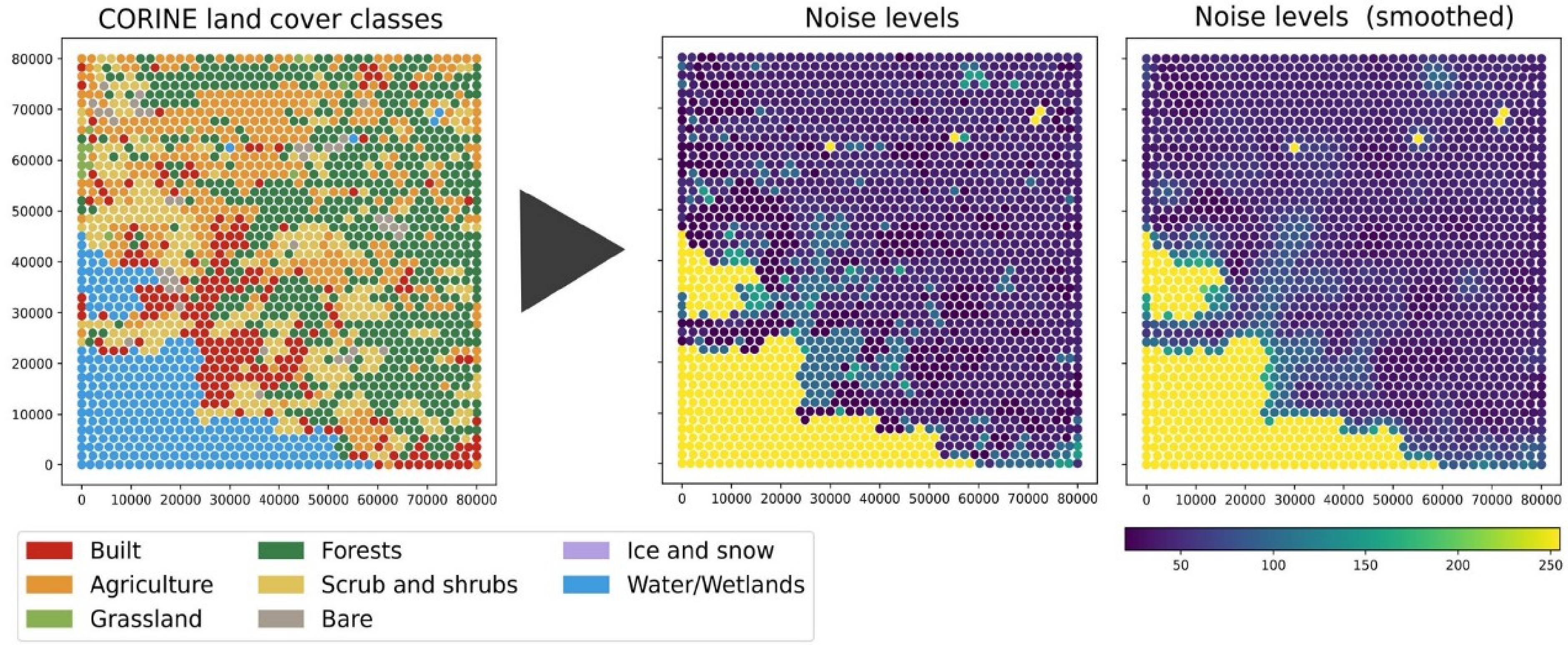
→ optimization for location, focal mechanism assessment or joint analysis

→ account for optimal network implementation or network extension

Post-mining seismicity monitoring

Optimization of surface seismic monitoring

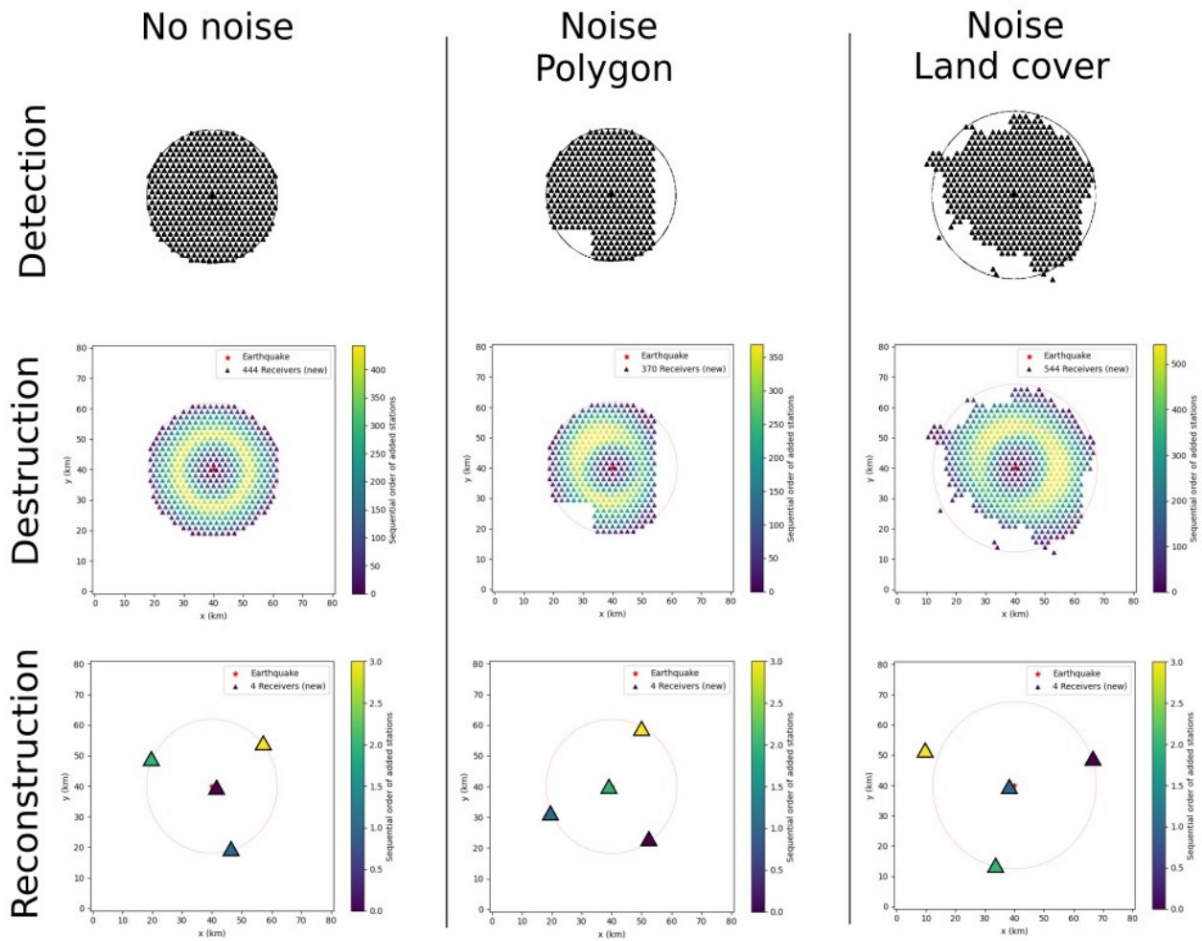
Accounting for land use as a proxy for seismic noise



Post-mining seismicity monitoring

Optimization of surface seismic monitoring

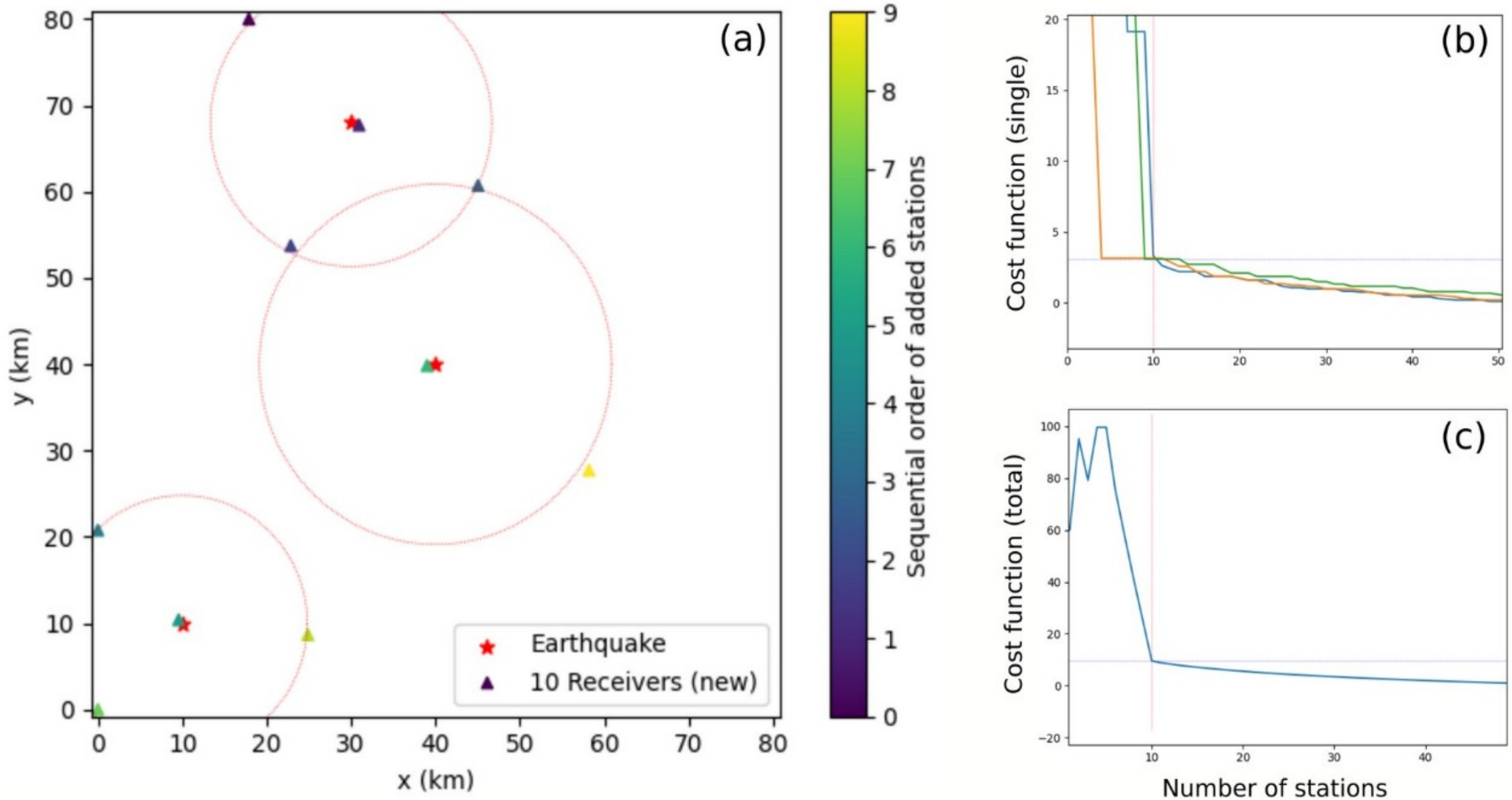
Example 1:
single earthquake
and different
noise / accessibility
constraints



Post-mining seismicity monitoring

Optimization of surface seismic monitoring

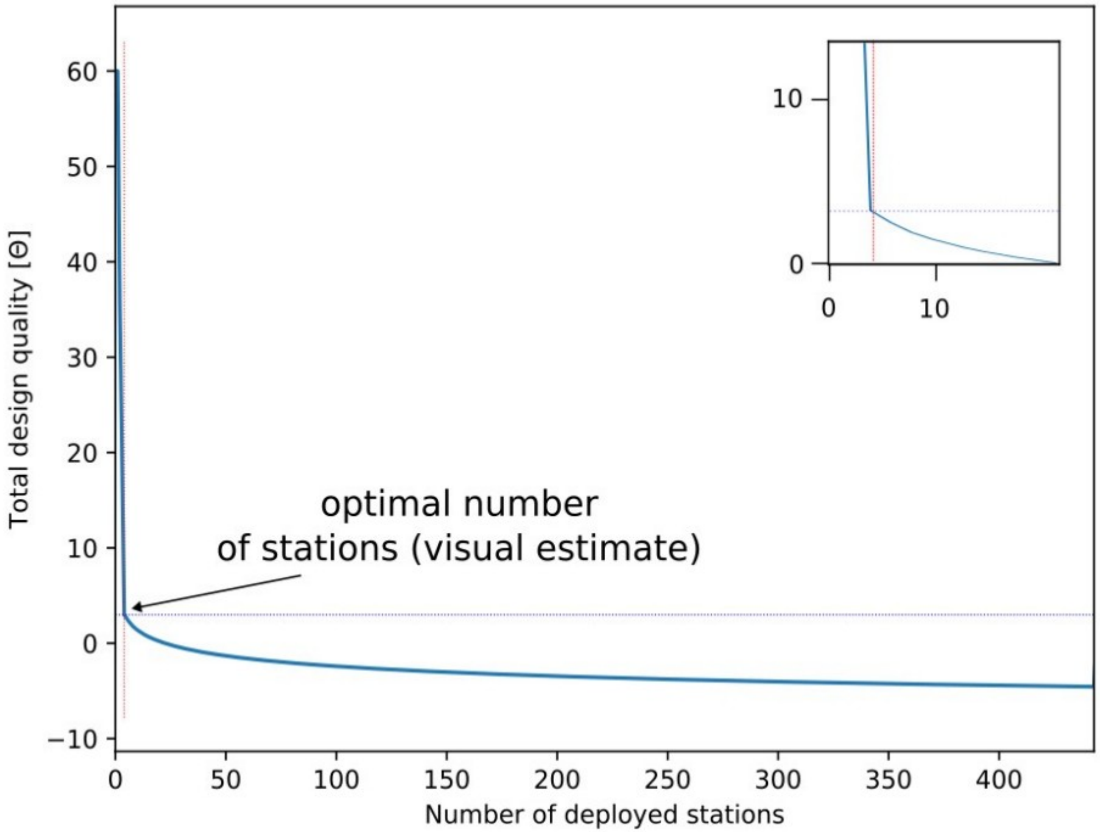
Example 2: 3 earthquake and 10 stations



Post-mining seismicity monitoring

Optimization of surface seismic monitoring

Example 3: Finding the optimal number of stations to newly install or to enhance a network

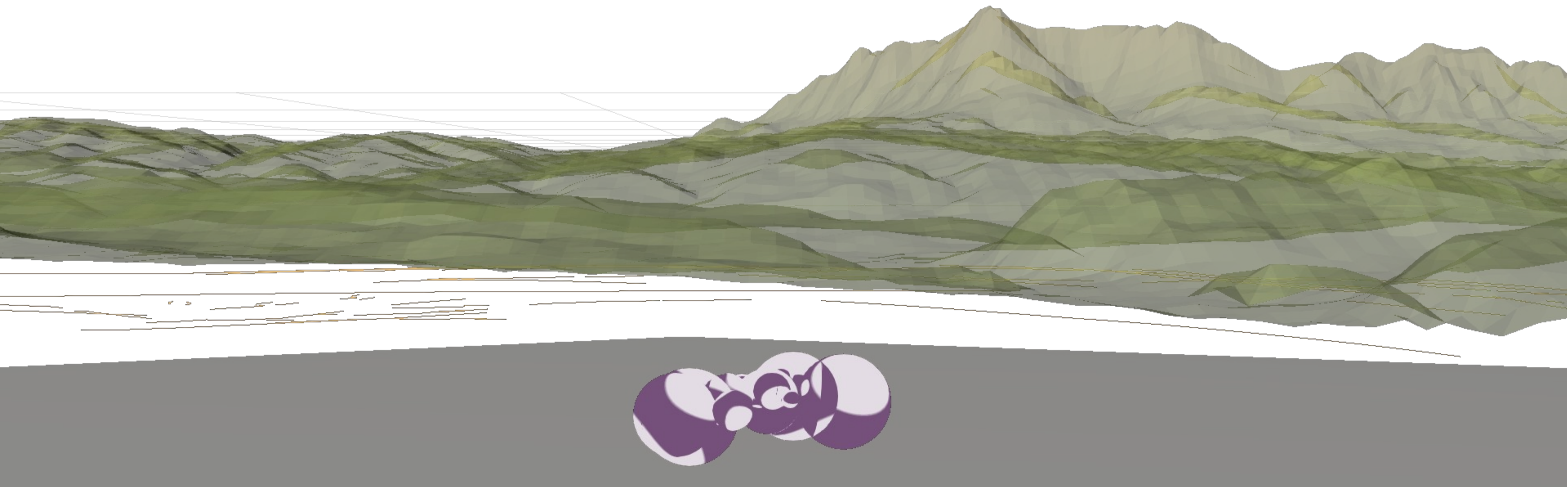


Analysis of postmining seismicity

The Gardanne, France, case study

A successful case study: seismic monitoring allows understanding post-mining seismic processes

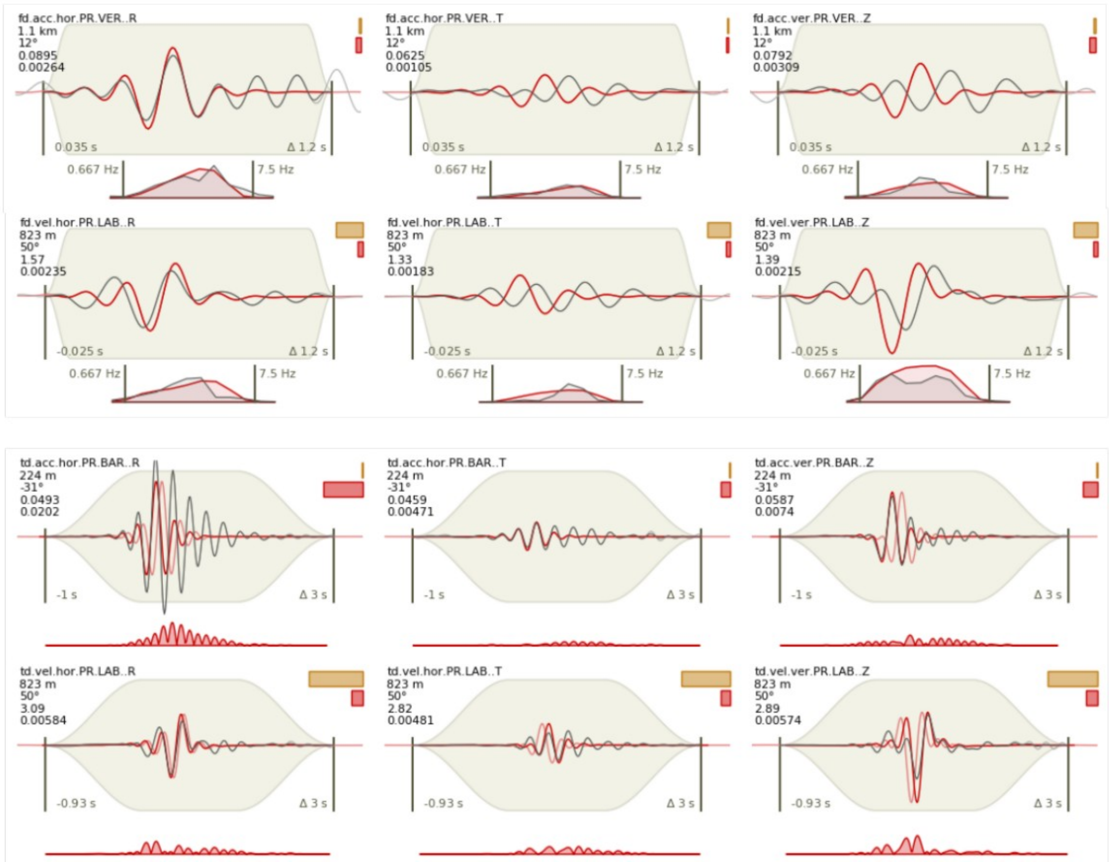
→ automated detection and location (Namjesnik et al. 2021)
→ moment tensor inversion (Heimann et al. 2018, Caputa et al. 2021)
→ waveform based clustering (Cesca 2020, Petersen et al. 2021)



Analysis of postmining seismicity

The Gardanne, France, case study

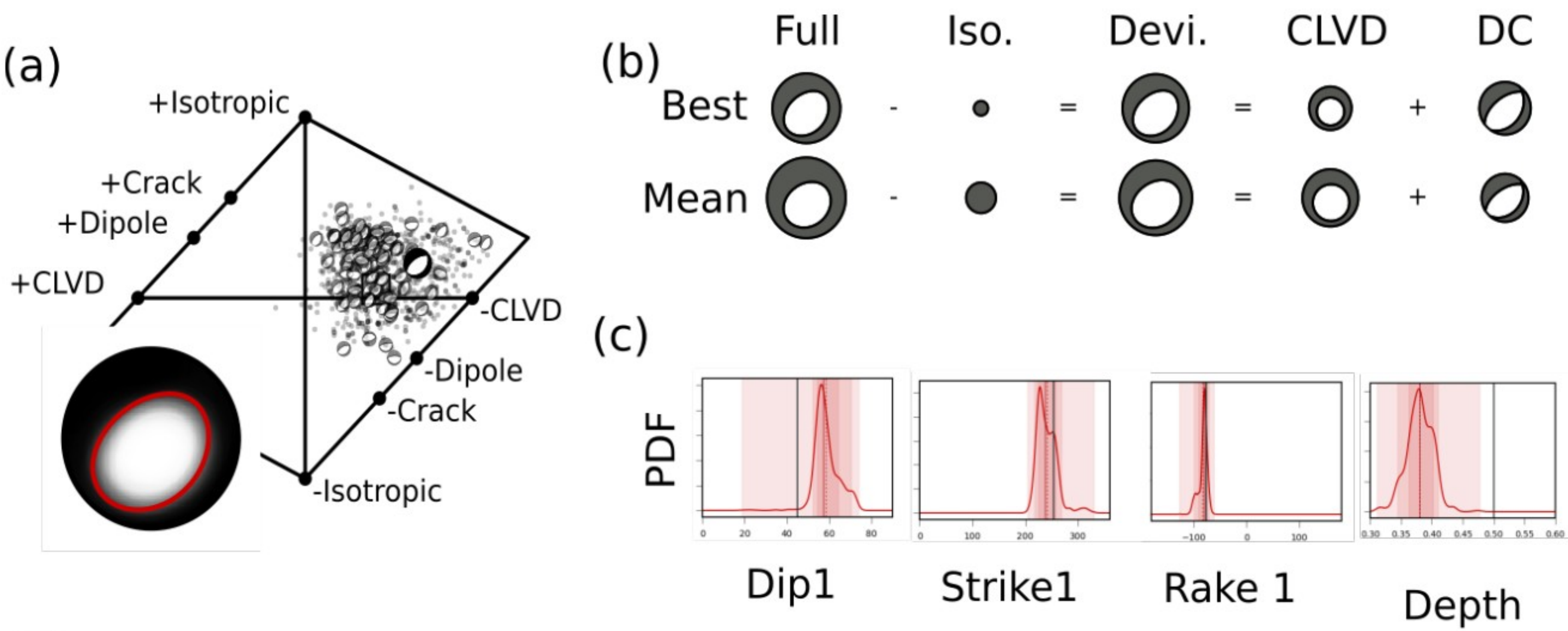
Moment tensor inversion by waveform and spectral fit…



Analysis of postmining seismicity

The Gardanne, France, case study

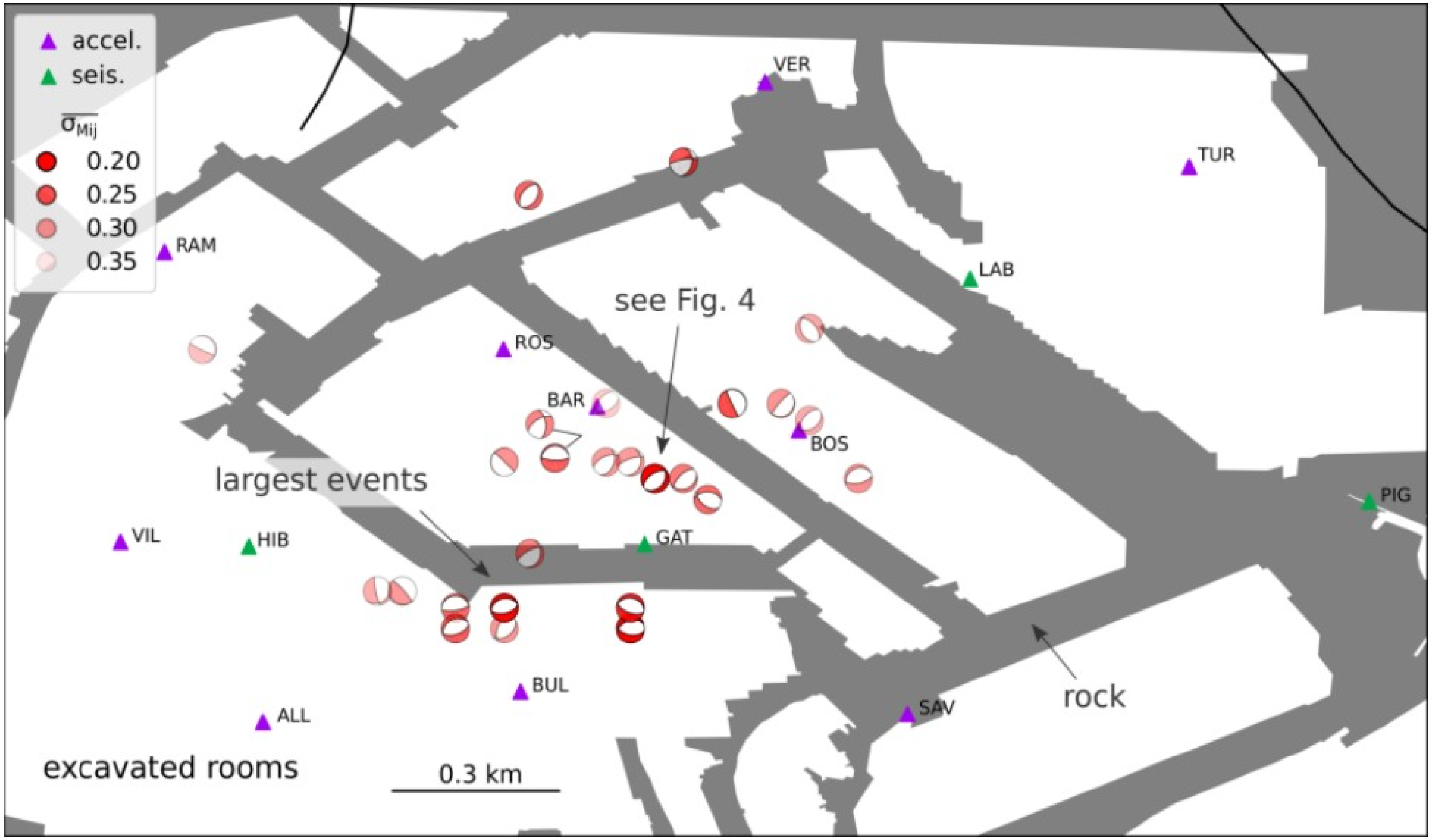
.. to derive the geometry of the rupture and rupture type (e.g. shear faulting, tensile crack, collapse).



Analysis of postmining seismicity

The Gardanne, France, case study

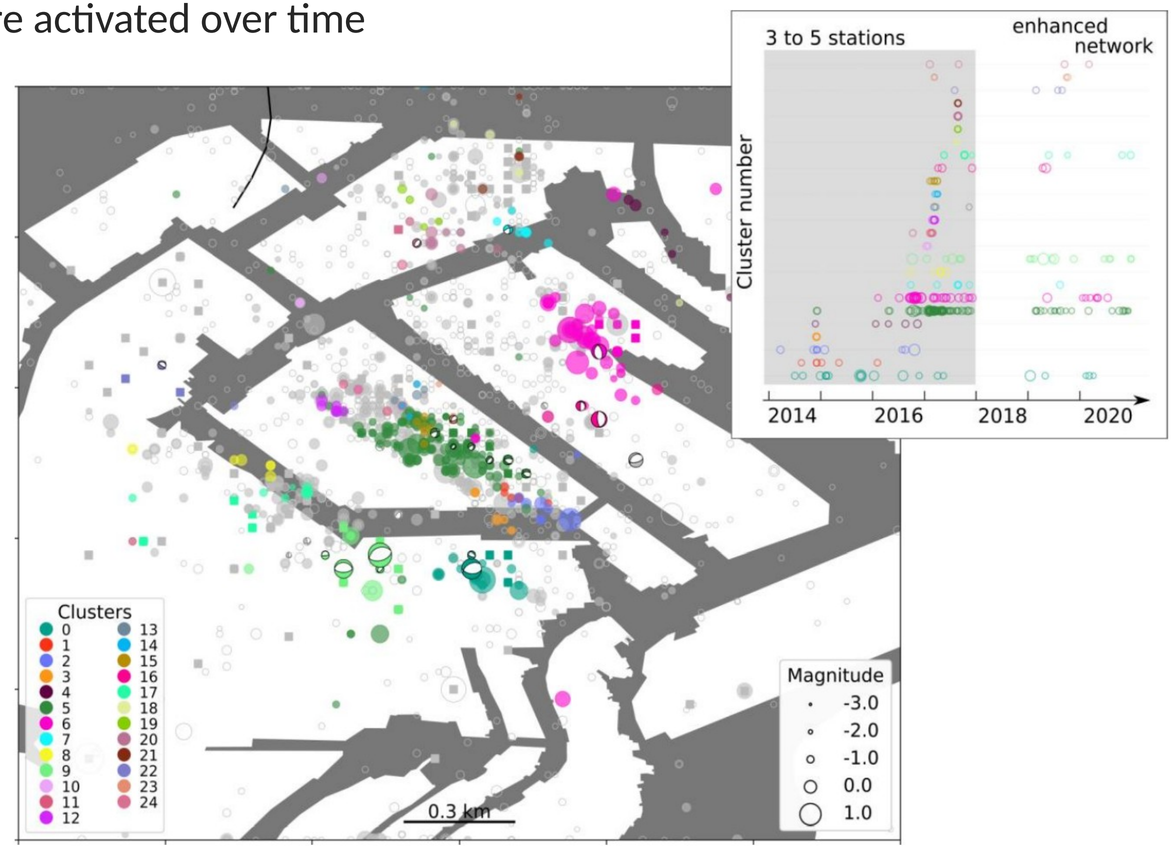
Provide information on rupture mechanics (note the higher resolution within the network)



Analysis of postmining seismicity

The Gardanne, France, case study

Combining moment tensor of large events with waveform similarity identifies clusters of similar events, which are activated over time



Thank you

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