Schatzalp workshop - Davos March 2017

On the variety of post-deformation phenomena in abandoned mining districts: Insights from seismic source analysis

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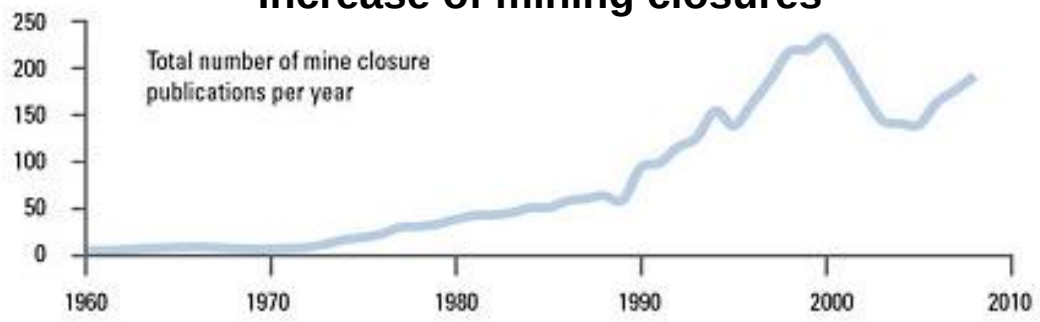
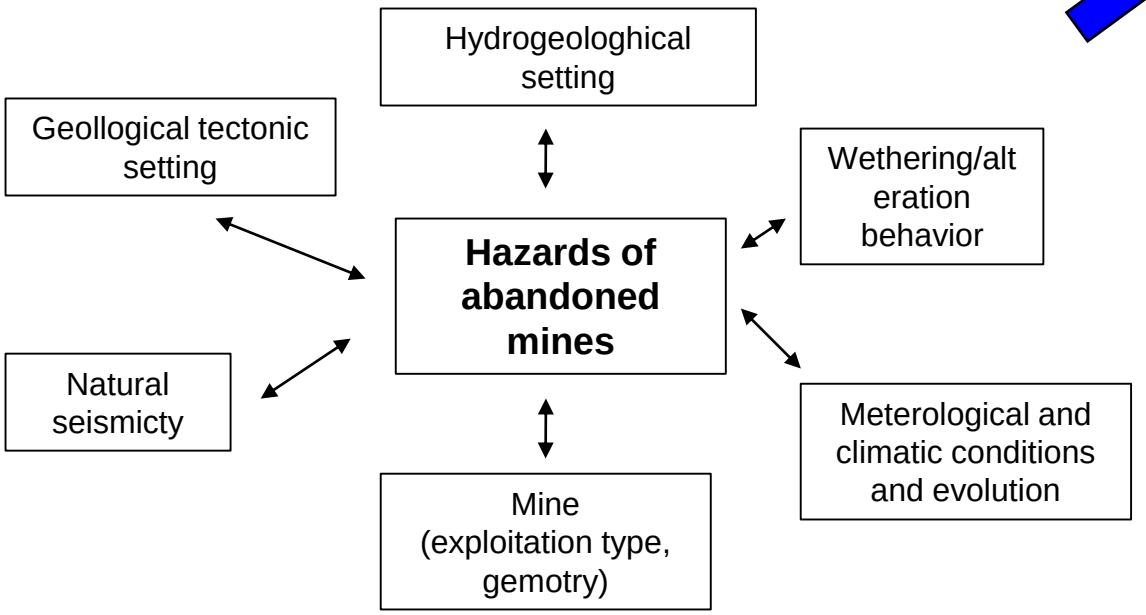
Challenges of hazard assessment in abandoned mine districts

Increase of mining closures



Source : SRK consulting

-> Imply strong **challenges** of **long-term hazard assessment** especially when get **flooded** (uncontrolled fluid extraction/injection experiment):



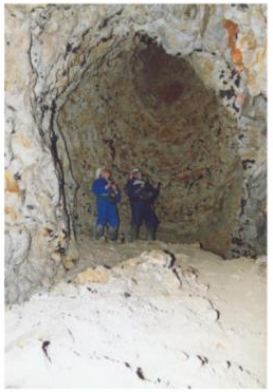
-> Most relevant hazards in terms of risk for local population

- Pollution/contamination hazard

- Hazard of ground and underground instabilities

1. Surface deformation: Landslides, sinkholes, subsidence (surface collapse hazard)

2. Underground limited deformation: Underground collapse, fault reactivation (seismic hazard)



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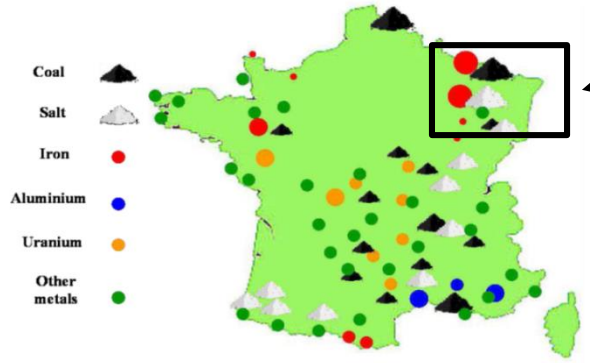
Surface deformation phenomena (Lorraine, NE France)

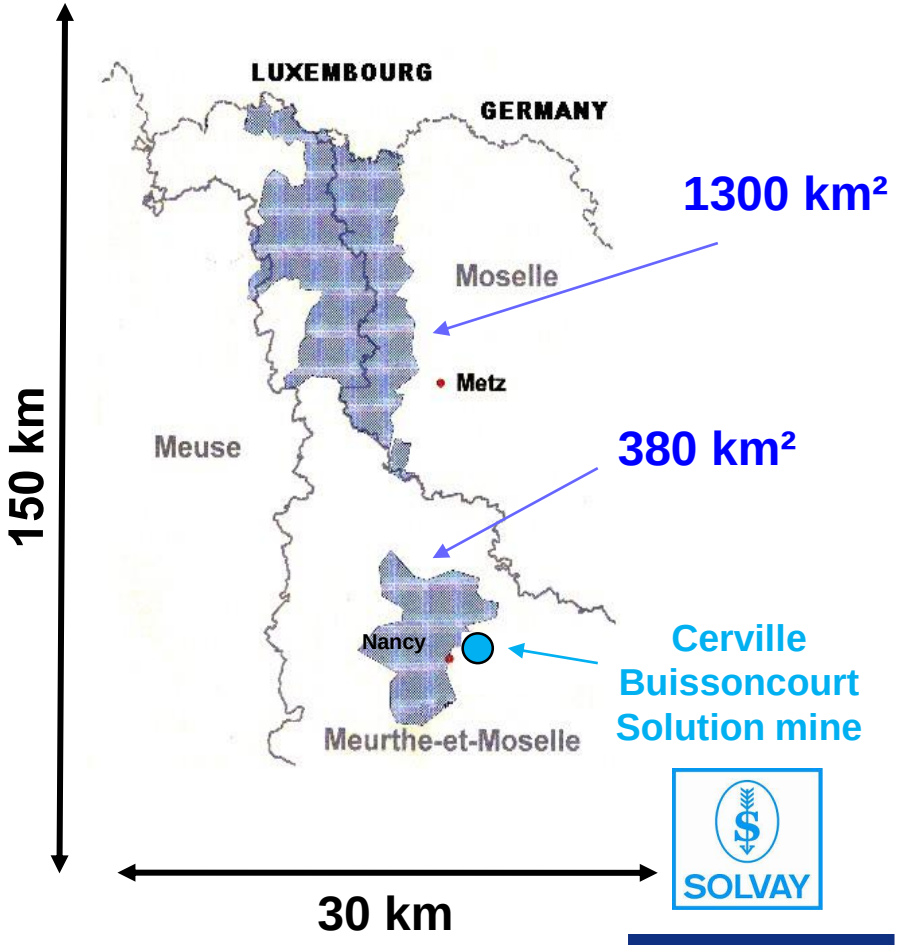
Post-mine deformation in Lorraine

Abandoned underground mines in France
=> Subsidence and surface collapses events



Catastrophic consequences, e.g.Auboué (1996):
70 damaged buildings, 150 family resettlements

Geotechnical monitoring of **non-reducible, high risk** zones
including microseismic survey



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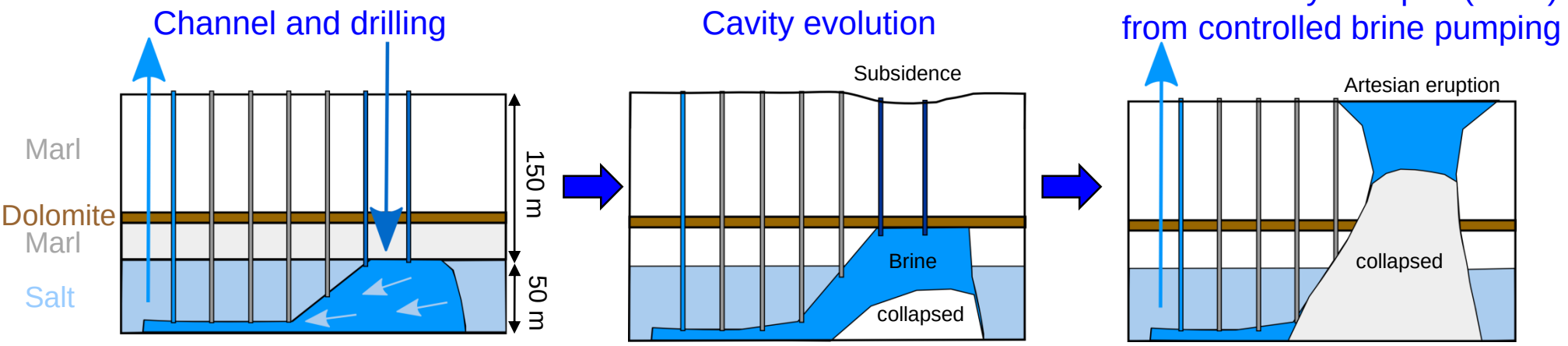
Cerville Buissoncourt experimentation site

Solution mining procedure

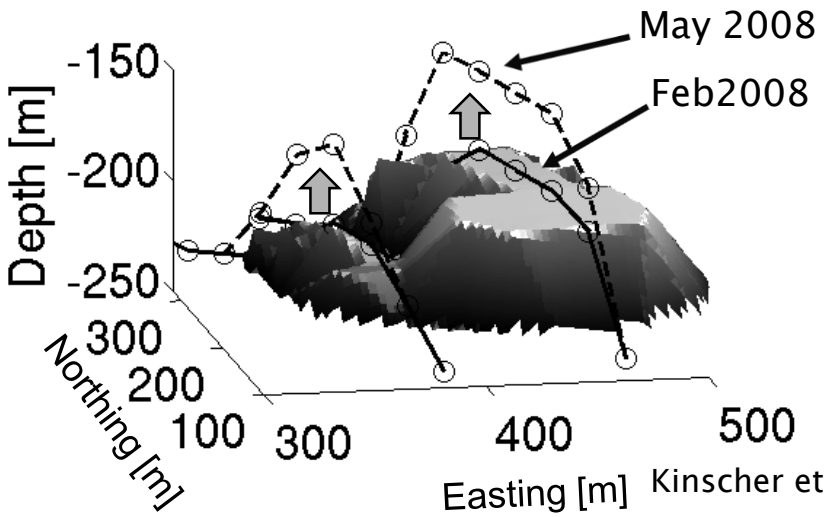


Monitoring

- In-situ **geotechnical** surveys: GPS, Extensometers, Tachemeter, Piezometer, Sonar, Gamma ray etc.
- **Microseismic** network

  ⇒ many 10k events

Cavity growth (2008)



Kinscher et al. 2015

Surface crater of final collapse (2009)

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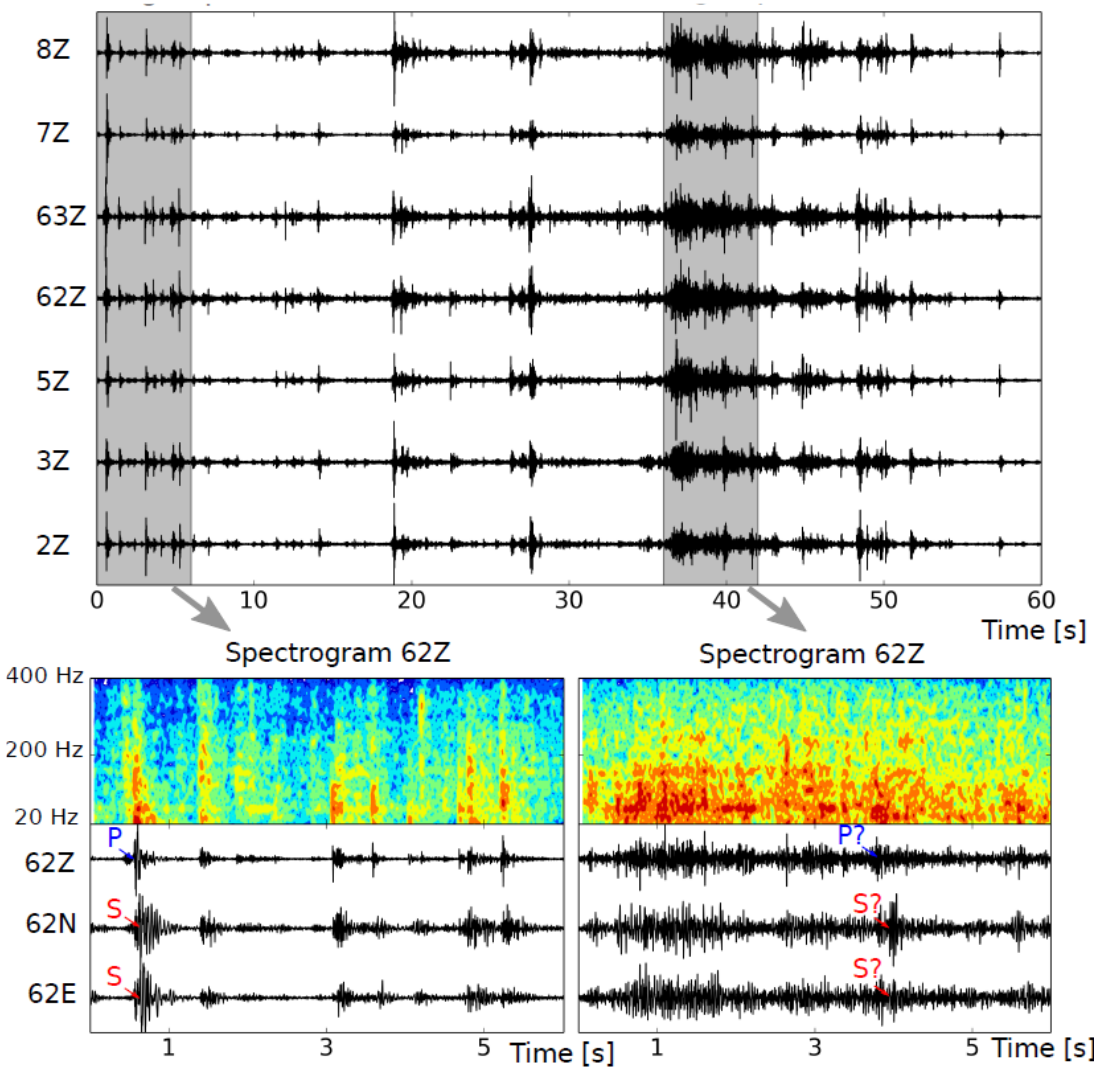
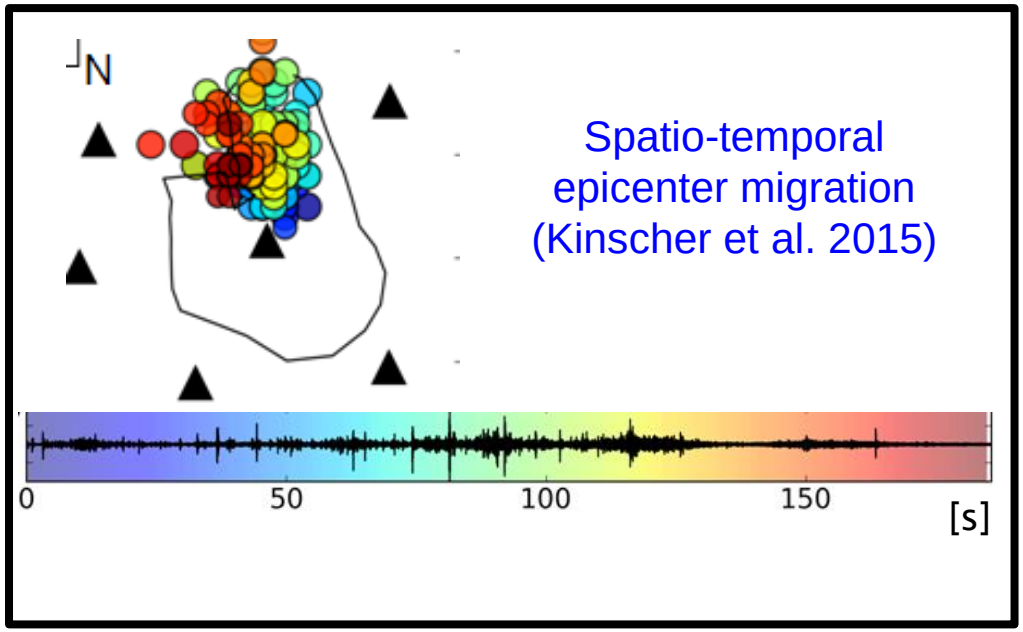
Cerville project: swarming events

Swarming example



-Complex swarming events with dense event superposition

-Swarming as a signature of
=> Progressive cavity roof failures (caving)



Spatio-temporal epicenter migration (Kinscher et al. 2015)

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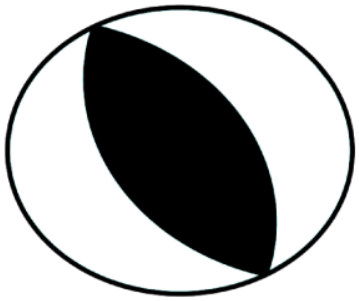
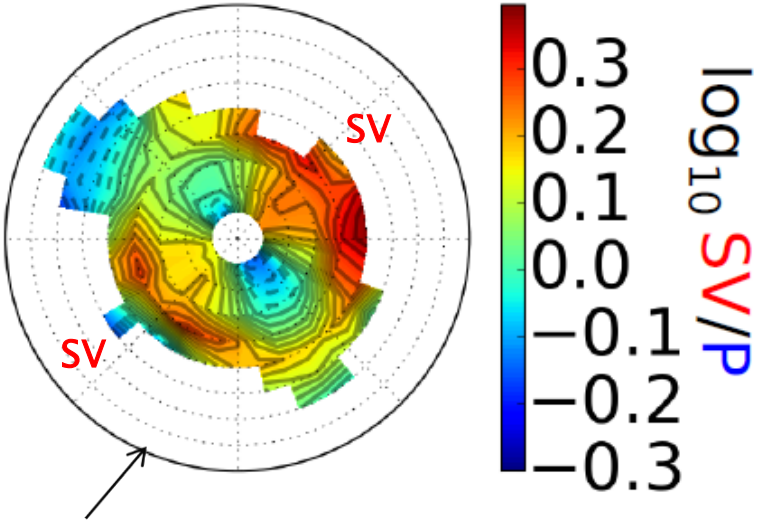
Cerville project: seismic source analysis

- Majority of events (> 80%) related to NW-SE striking thrust faulting mechanism (Kinscher et al 2016)

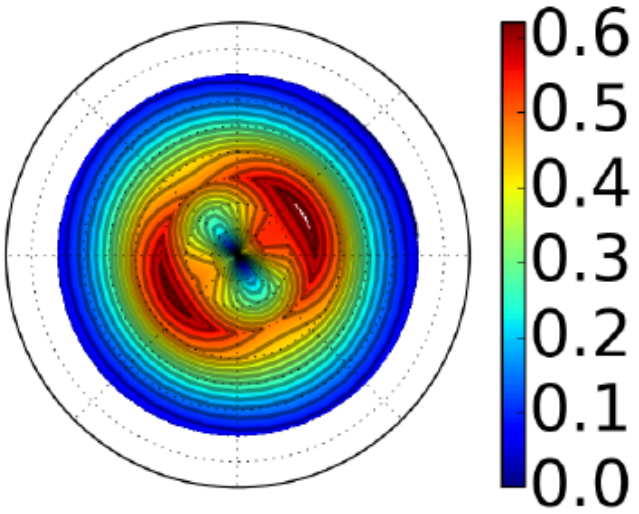


Observed
average amplitude ratios (30-90 Hz)
of 15,000 events

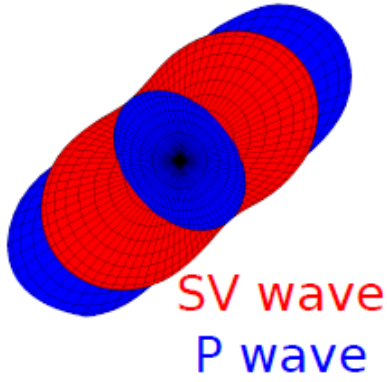


Station
lower
hemisphere

Synthtetics (dip-slip)
average amplitude ratios
strike 150; dip = 45°; rake=90°



Radiation pattern
NW-SE dip slip



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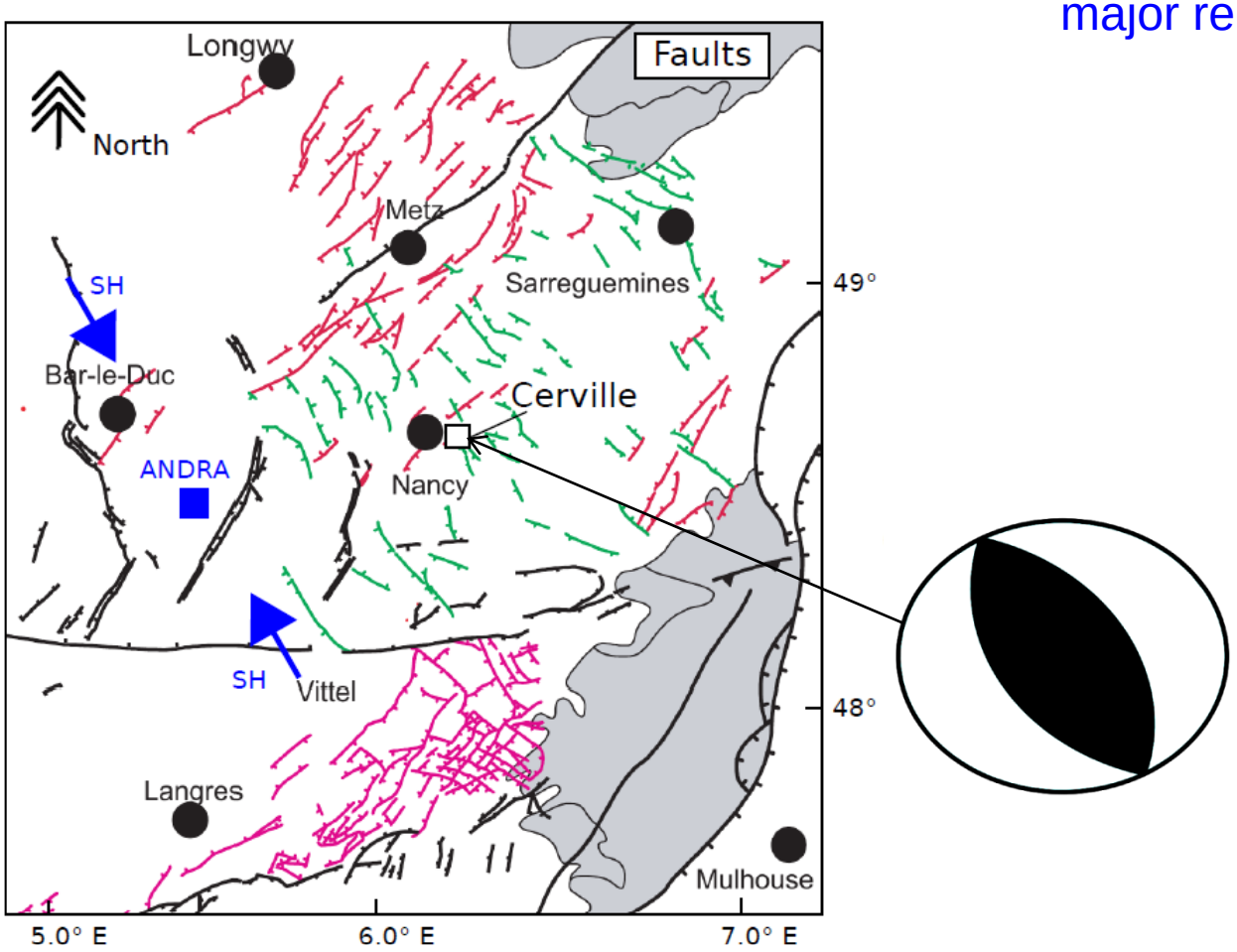
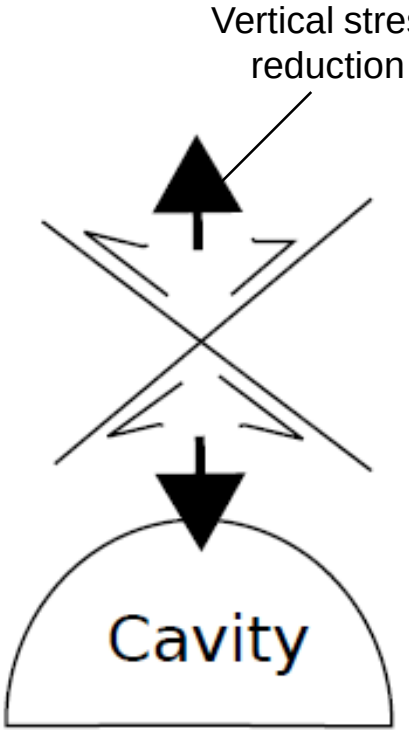
Cerville project: Reactivation of pre-existing heterogeneities ?

(a) Regional tectonic map after Andre (2003)



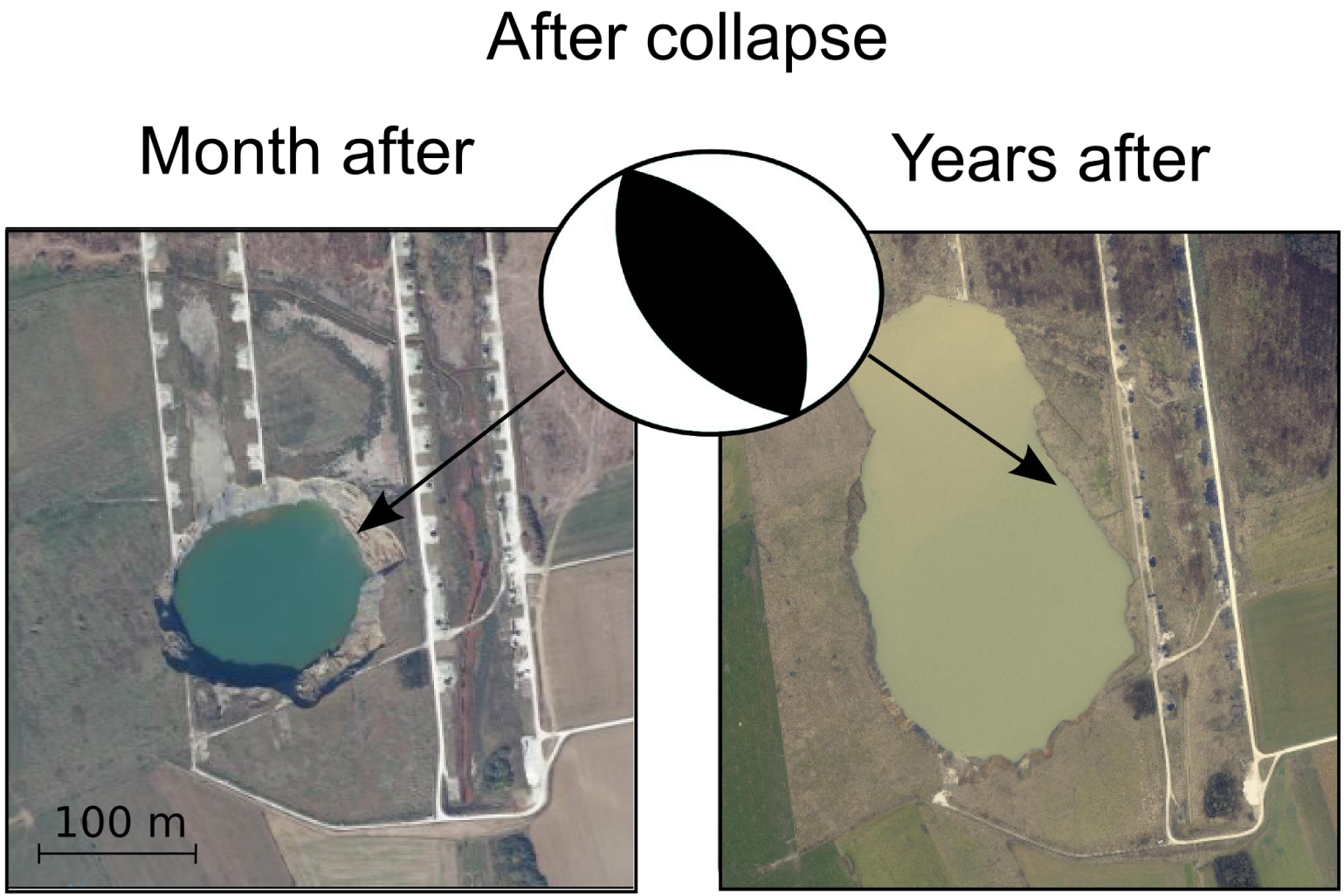
- **stability** in thrust fault orientation (NW-SE) fits to major regional geological structure orientations



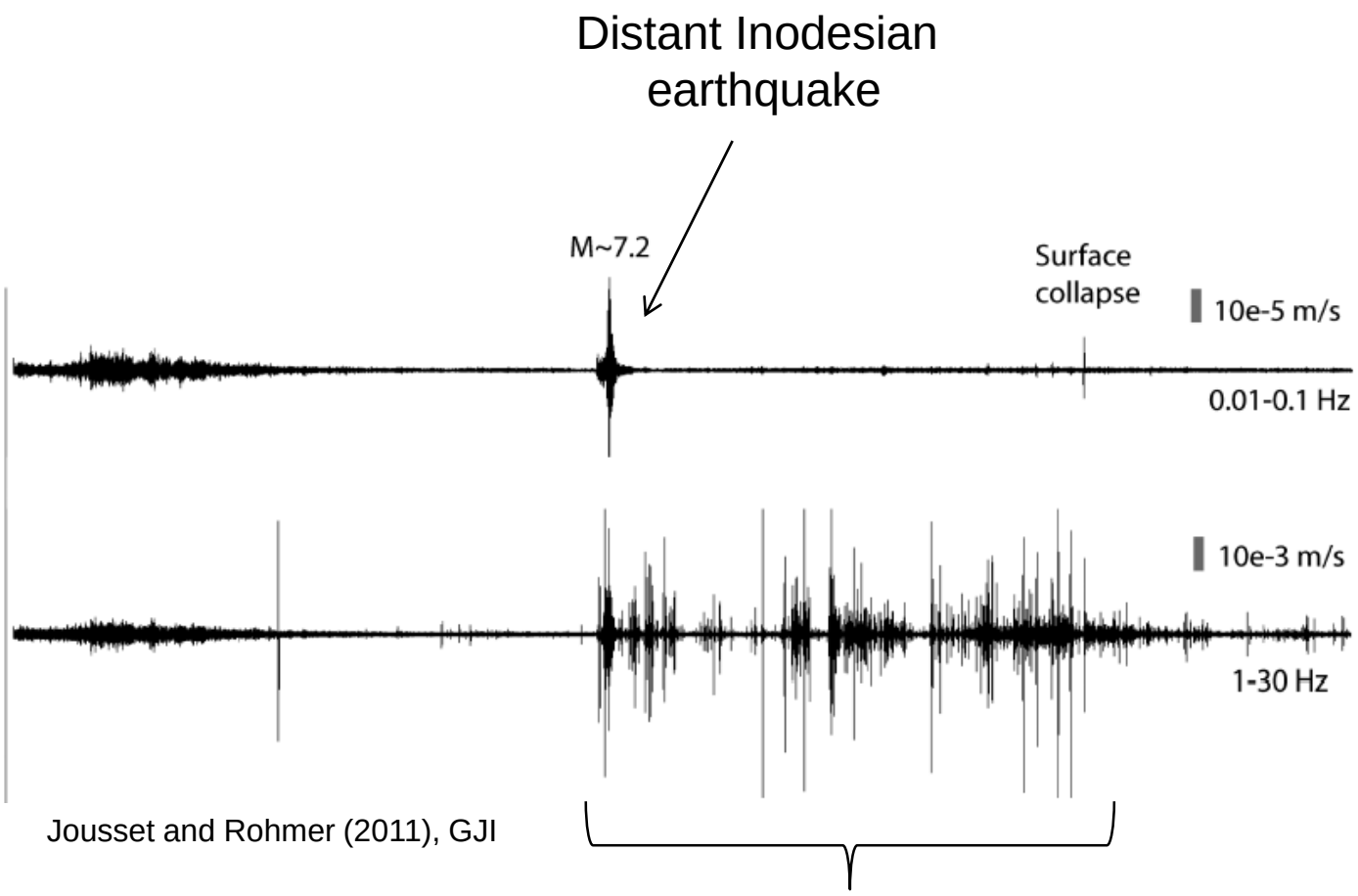
SH =max. horizontal stress (regional stress field)

Kinscher et al. 2016

Cerville project: Reactivation of pre-existing heterogeneities ?



Cerville project: triggering from distant earthquakes ?



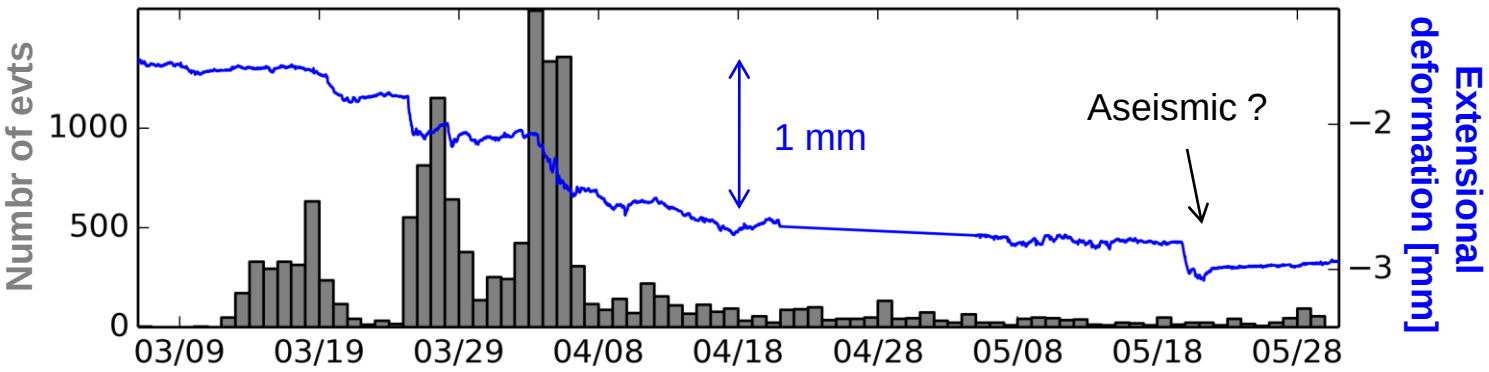
- Collapse related mircoseismic activty correlates in time with passage of wave trains (body and surface waves) of an Indonesian M7 quake

-Induced dynamic stress changes seem sufficient to trigger final rupture in overburden

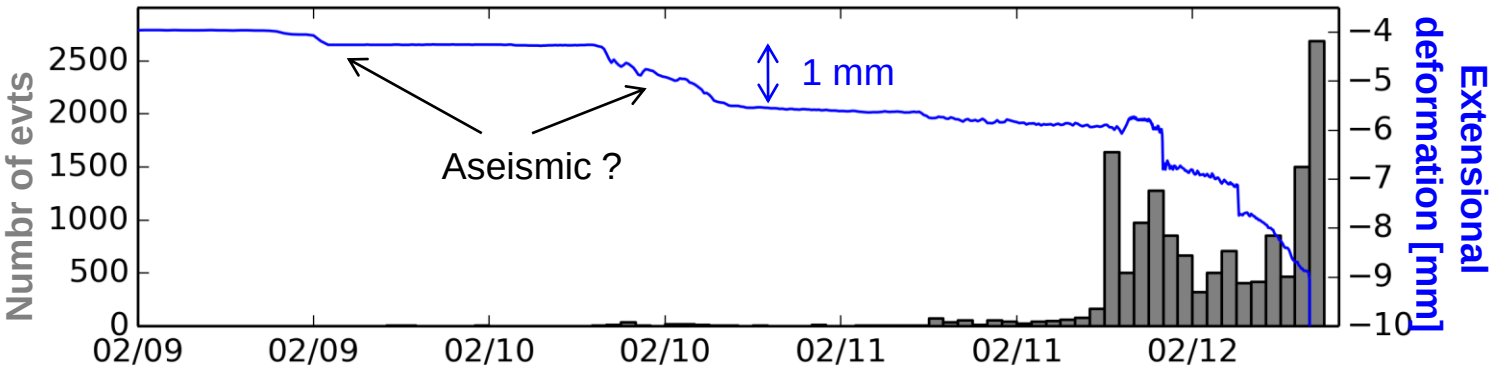
Cerville project: presence of aseismic processes ?

Microseismicity **VS** **In-situ extensometer data (overburden)**

Cavity growth (2008) : roof collapse



Final collapse (2009)



-Presence of aseismic processes ?
(stress memory ?)

-Aseismic processs may play an important role during surface collapsing/subsidence events

- 15 years seismic monitoring in Lorraine
=> 0 microseismic events!
=>Even though surface subsidence processes partially detected

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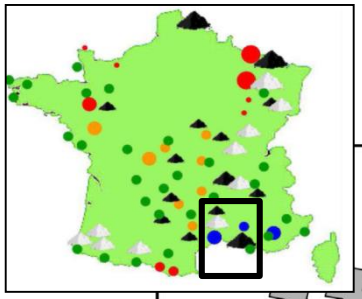
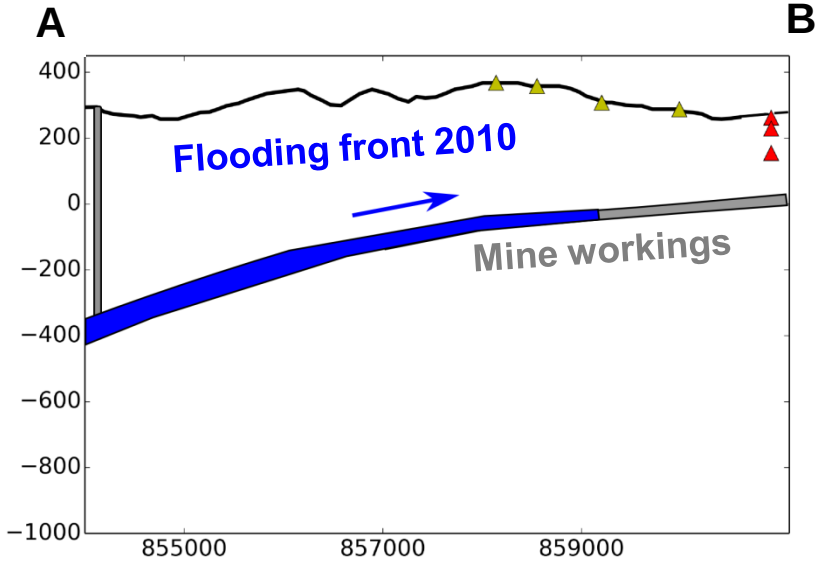
Underground deformation phenomena (Provence, SE France)

Gardanne coal mine, Provence SE France



Gardanne coal mine abandoned since 2003



-Repetitive swarming activity next to risk zone

-Since flooding front arrival 2010

-three major crisis in 2012, 2014, 2016-2017

-Strongly felt by population (IV-V) (especially during the last 4 months)

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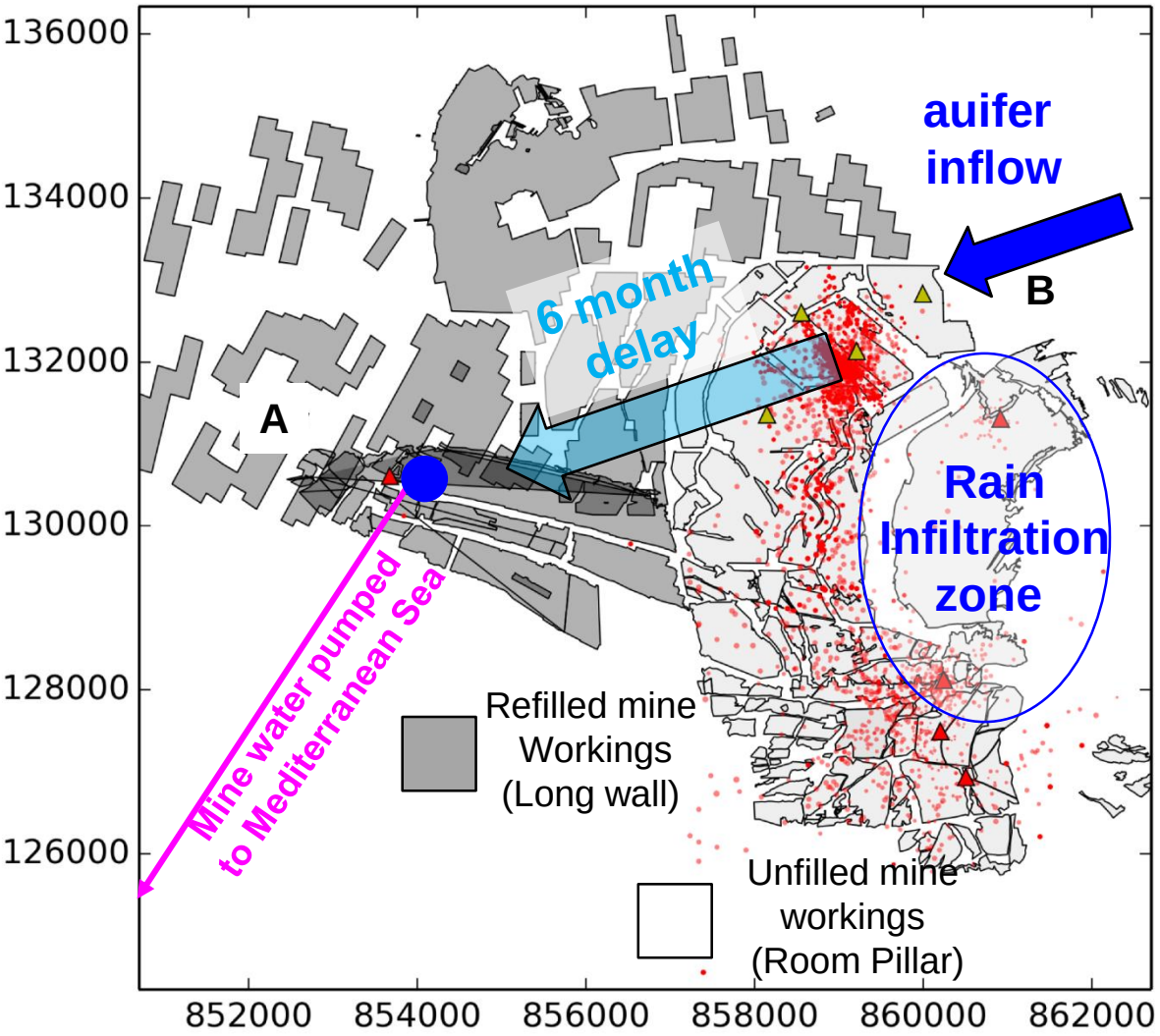
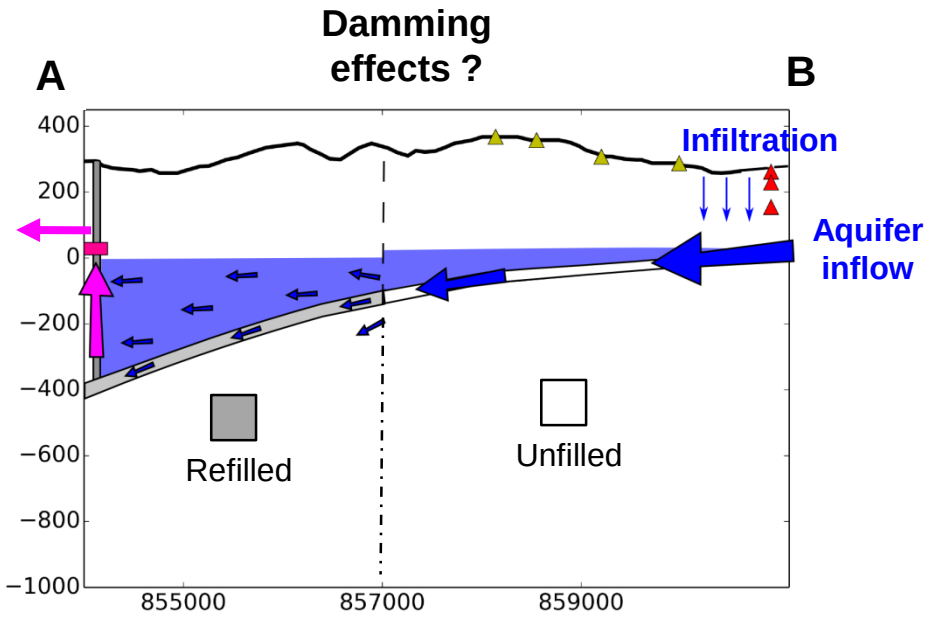
Gardanne coal mine: hydrological model





- Hydrological model suggest :
-> complicated flooding pattern
-> main water supplies from the east
-> take around 6 month to circulate

⇒No continuous flow in mine working ?
⇒ Damming effects ?

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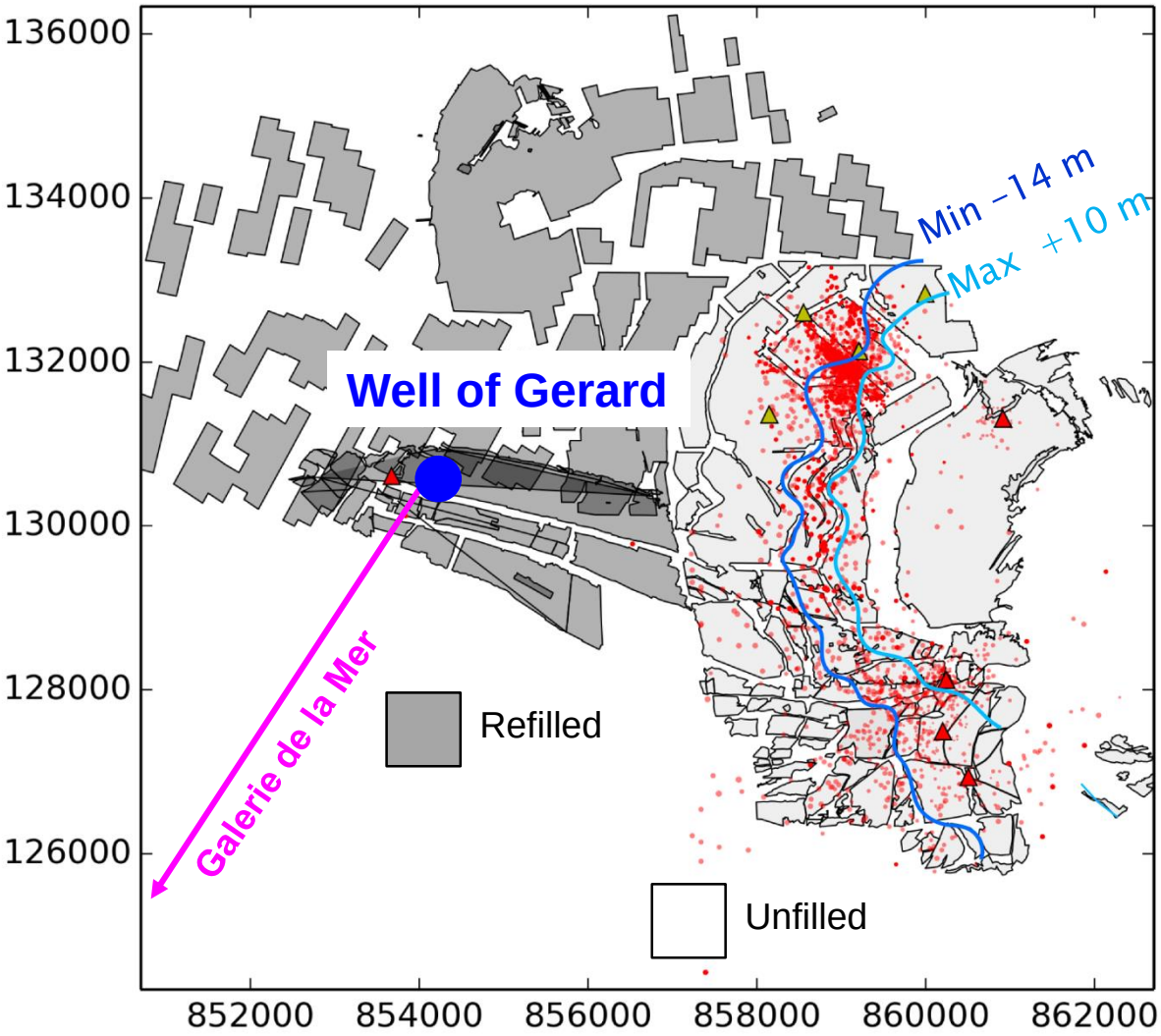
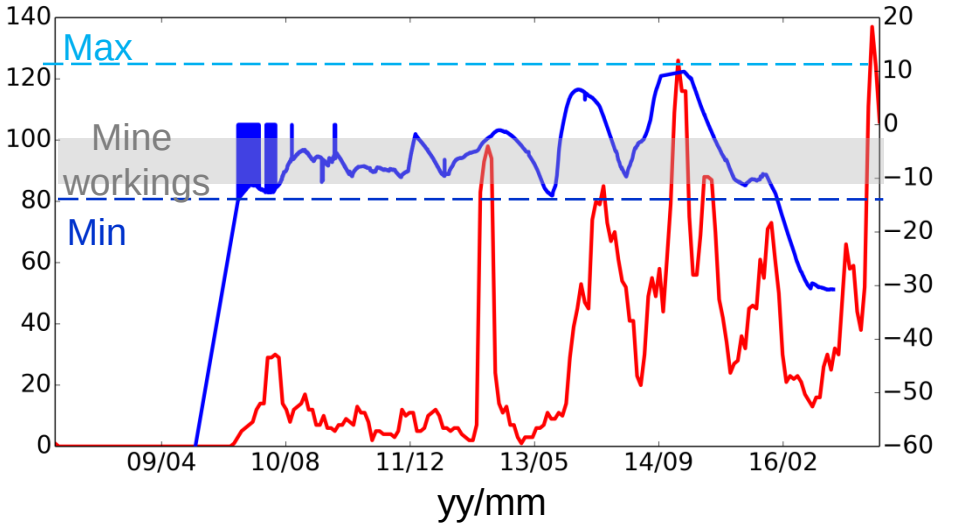
Gardanne coal mine: interaction seismicity vs mining water level



Ground water level Gerard well (6 month shifted)
VS
Nr Events **Seismicity since 2008** **[m] NGF**



- “shifted” Gerard well vs seismicity indicate:

-> correlation between flooding front arrival and beginning of seismic activity
-> seismicity correlate wiith seasonal water table variations

-> seismicity spatially constrained to flooding front and unfilled mine workings

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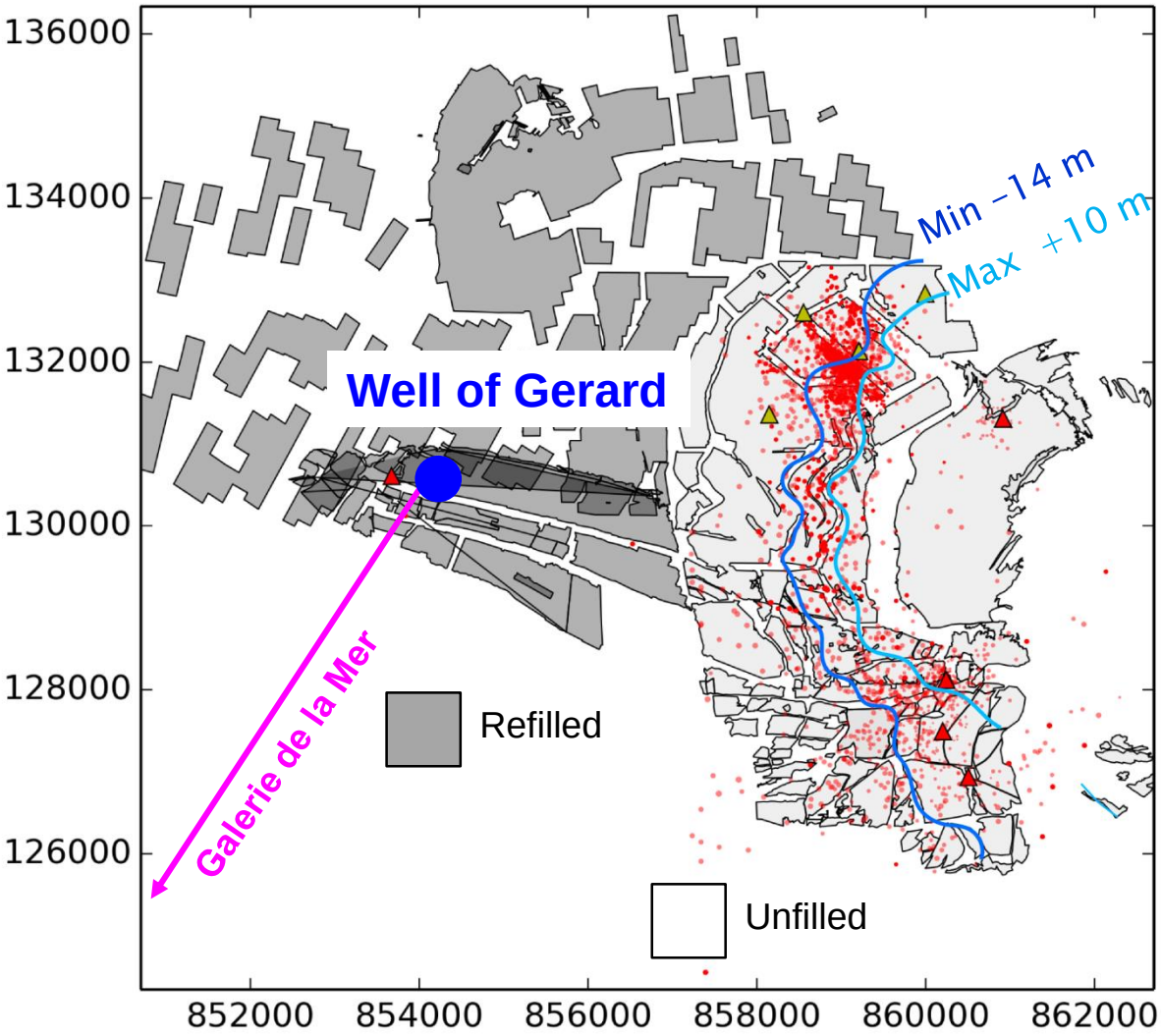

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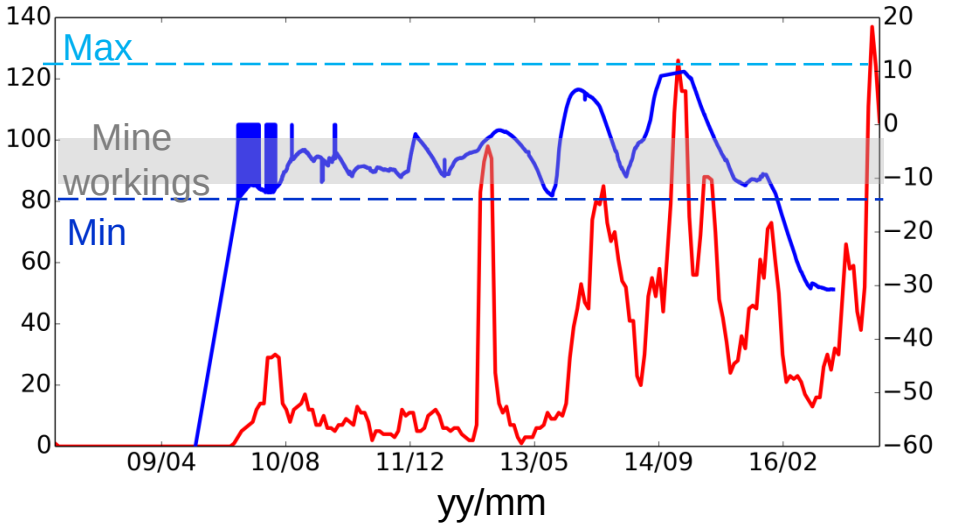

-> Simple water level threshold effect triggering seismicty ?

=> Local water level measurement required to understand triggering mechanism (pore pressure effect, elastic response of water column ?)

- part of ongoing investigation

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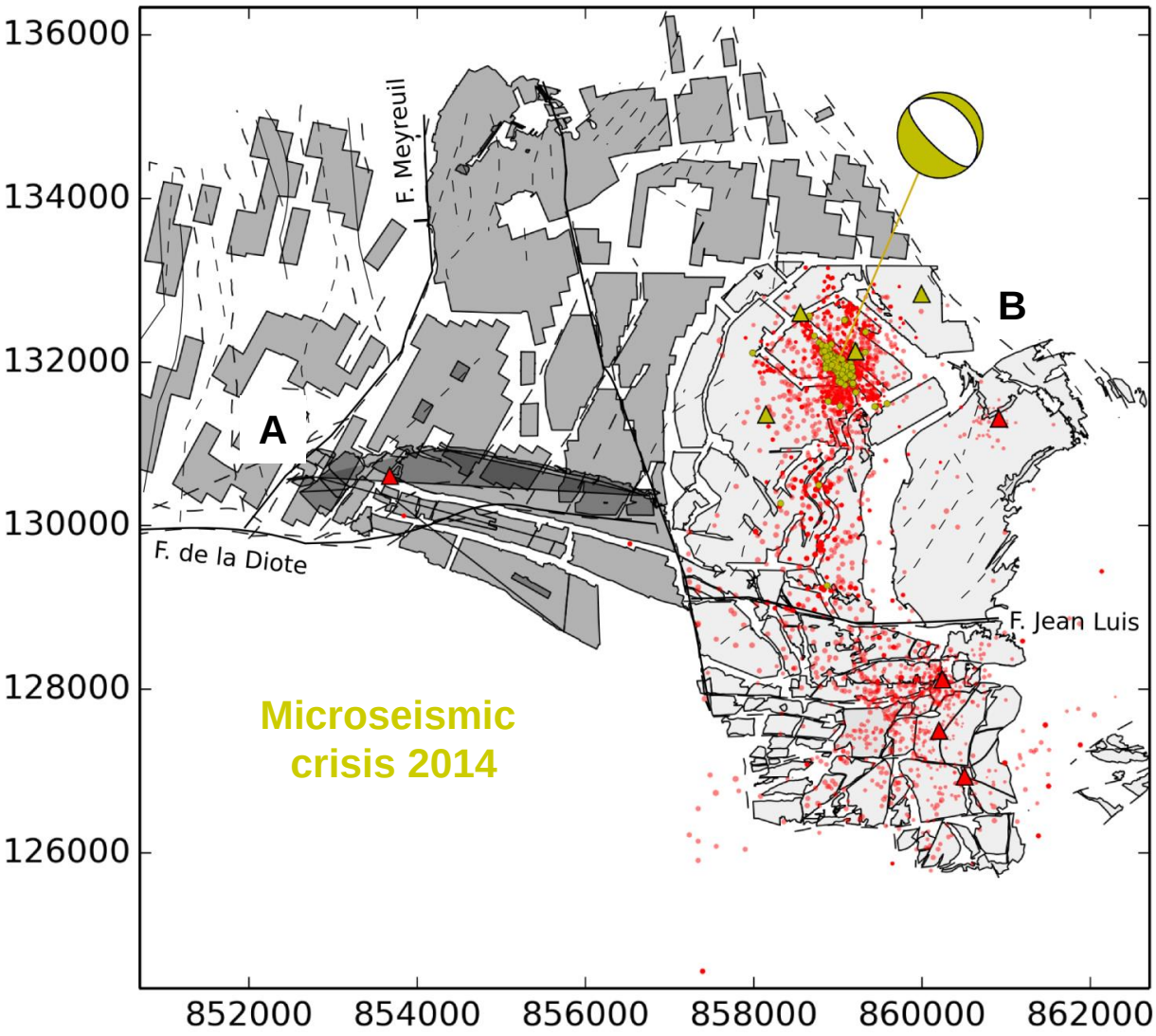
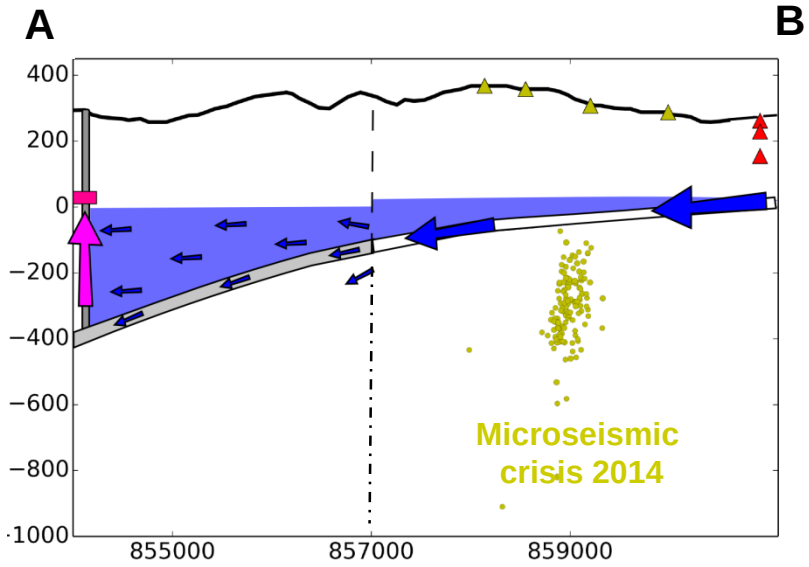
Gardanne coal mine: seismic source analysis





-Seismic source analysis of 2014 crisis indicated:
- seismicity seems located below mine working

-Source mechanisms dominated by NW-SE normal faulting

- Mw range between -1 – 1.7

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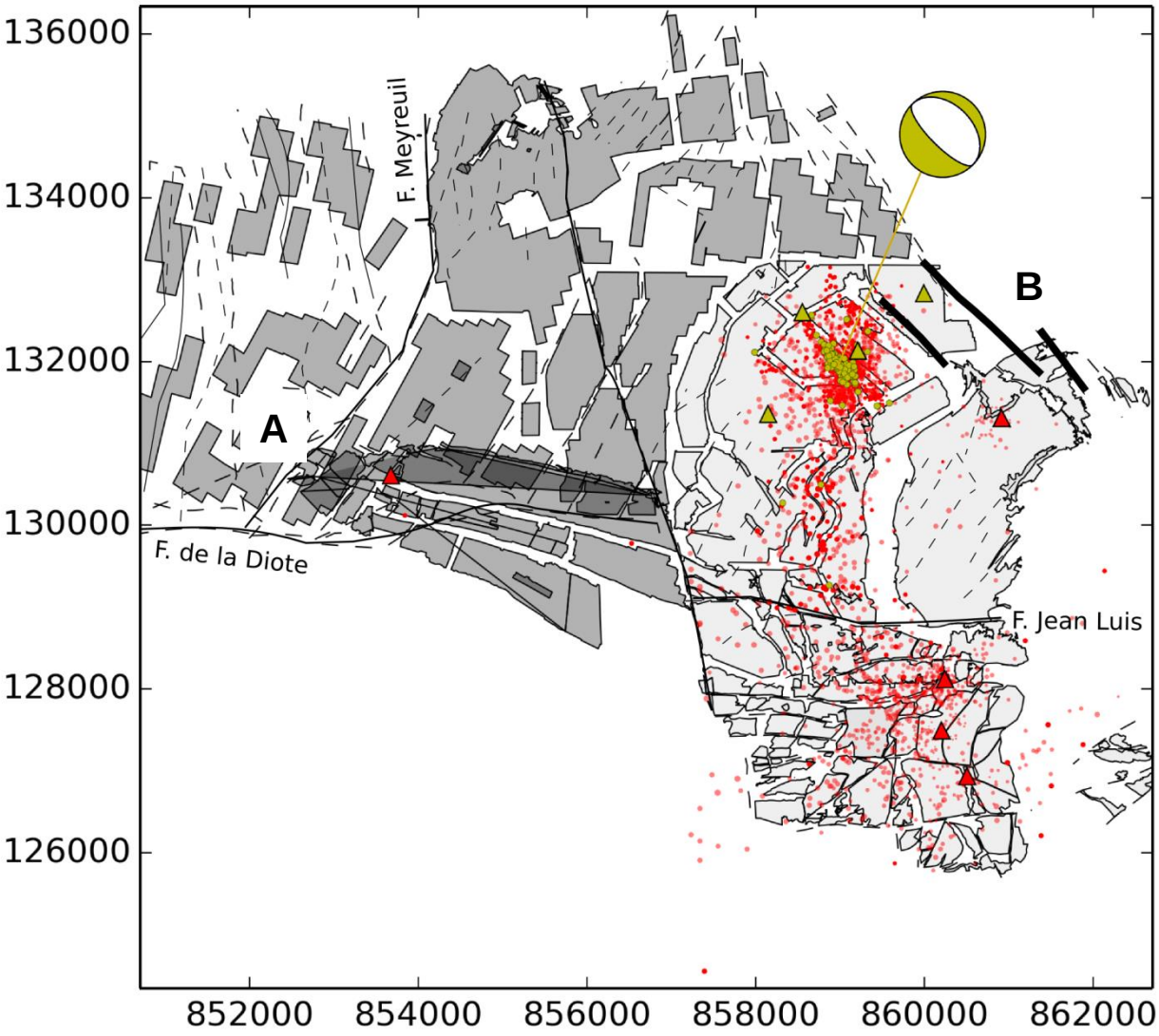
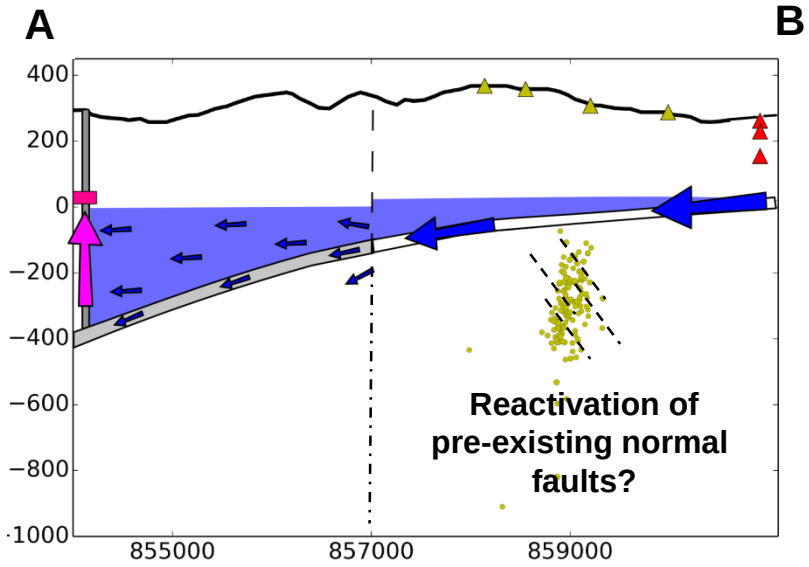
Gardanne coal mine: preliminary interpretation





- Results suggest :
-> Reactivation of network of preexisting normal faults

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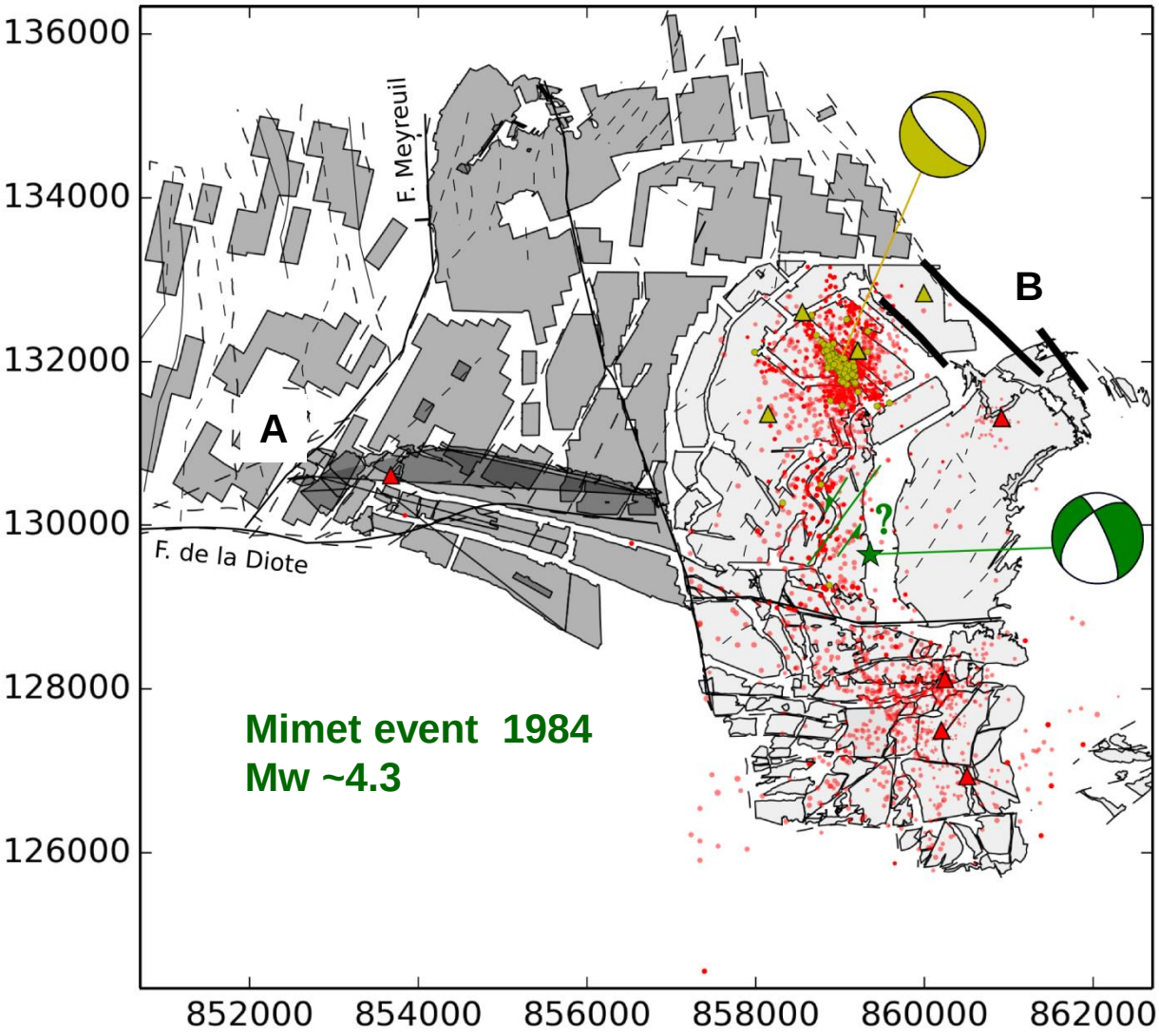
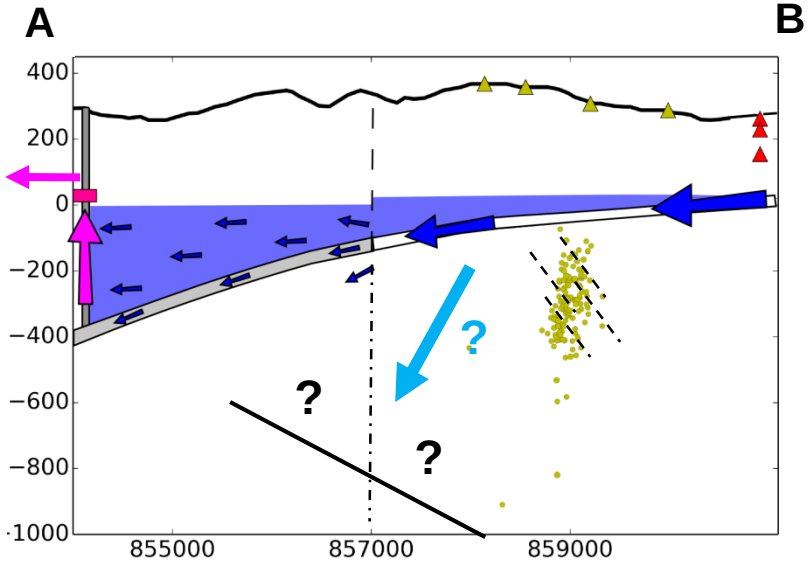
Gardanne coal mine: implication for seismic hazard assessment





- Region experienced M 4 events (1984)

- Necessity to include seismic hazard in to post-mining risk analysis

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Concluding remarks

Conclusion

Post-mining cases Lorraine :

- Dominance of surface deformation phenomena (aseismic?)

Insights to complexity of surface collapsing events from Cerville collapse experiment :

=> Interaction of local caving dynamics, preexisting structures, triggering from distant earthquakes and aseimsic processes

Insights to complexity of seismic hazard assessment related to underground deformation phenomena in Provence post-mining case:

=> Mine workings provoke modification of hydrological system reactivate faults whose activity seems today strongly linked to climatic/meteorological conditions

Another take away message…

To solve these challenges,

necessity to share knowledge and research
from different case studies and disciplines

Data integration to: Anthropogenic hazard platform

https://tcs.ah-epos.eu/

Thank you for your attention!

Data integration to: Anthropogenic hazard platform

https://tcs.ah-epos.eu/