Micro-seismic and leveling monitoring of a solution mining cavern collapse

From precursory signs to general collapse

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Context and Objectives of the Experiment

- Multi-partner research program about the management of in-use and abandoned salt mining concessions
  - partners : INERIS, BRGM, INPL and School of Mines of Paris
  - realized in collaboration with the mining operator SOLVAY
  - supported by the French Ministry in charge of Industry and Mines
- Objectives :
  - test a wide set of geotechnical and geophysical methods and evaluate their ability to detect early-warning signs of instability
  - improve understanding in brutal large scale collapse
  - provide useful feedback experience for operational monitoring

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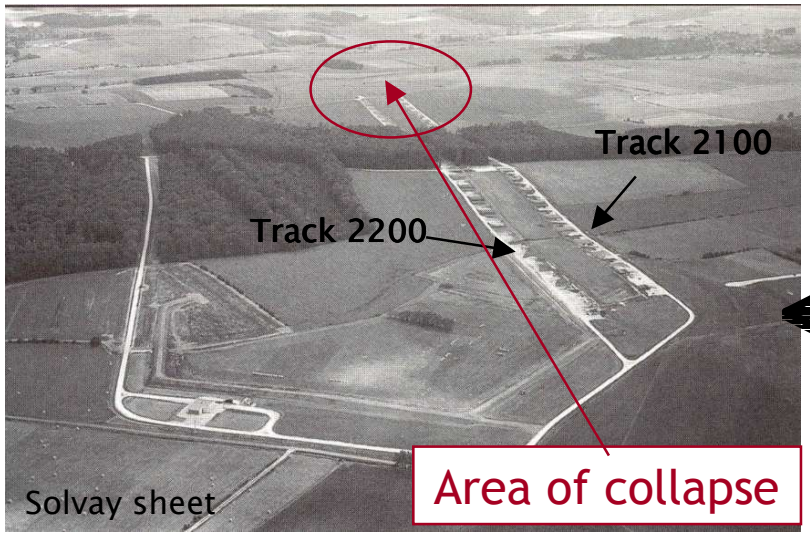
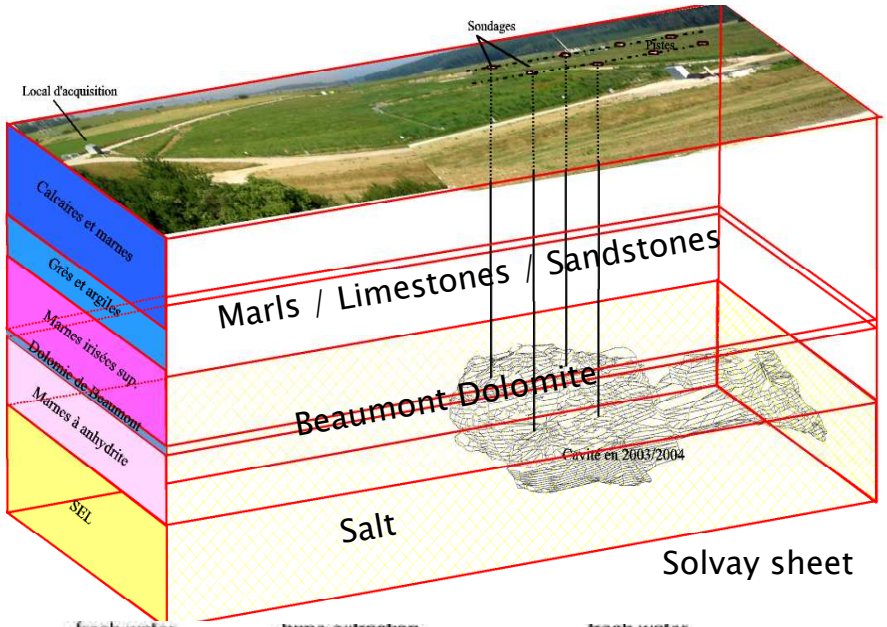
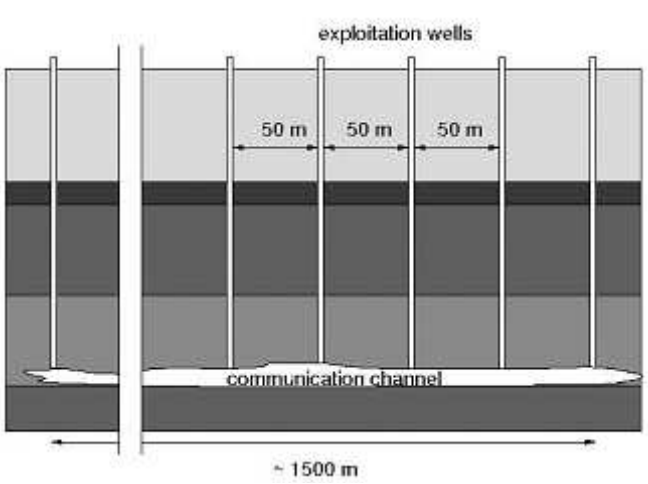
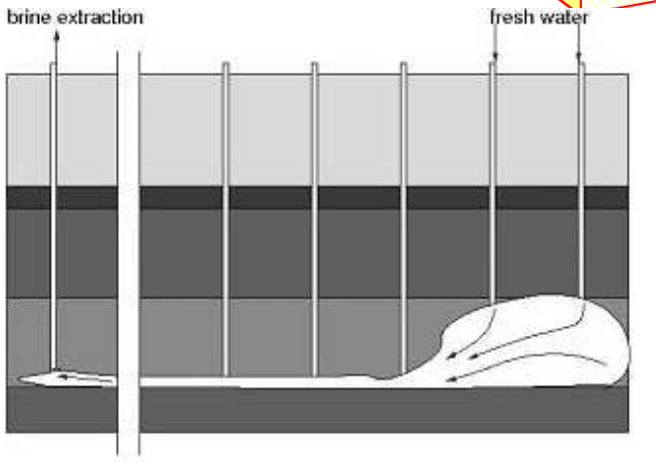
The Pilote site of Cerville-Buissoncourt - France

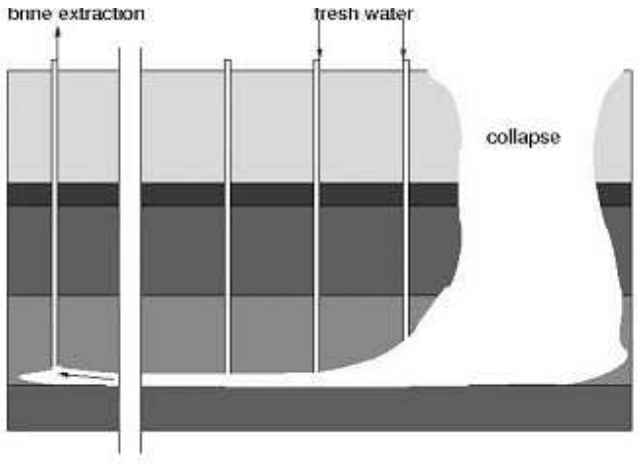
"channels and drillings" method



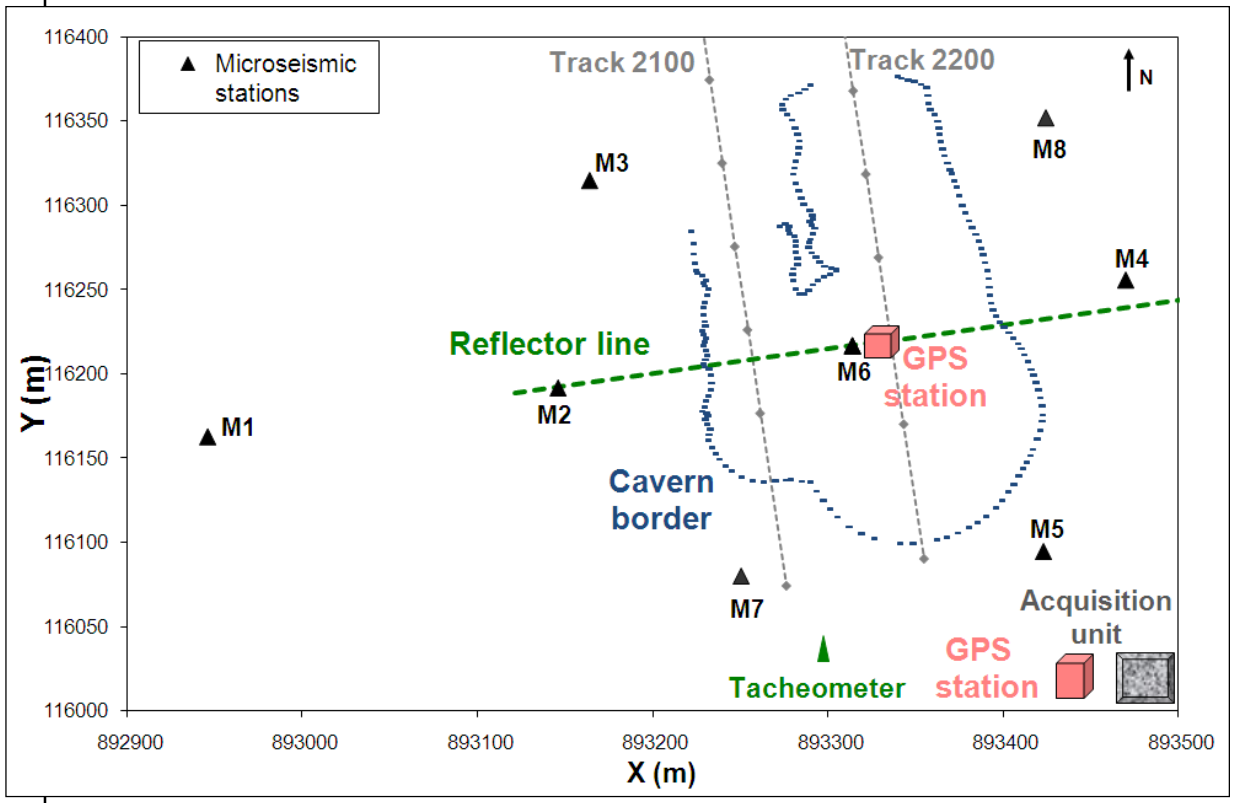


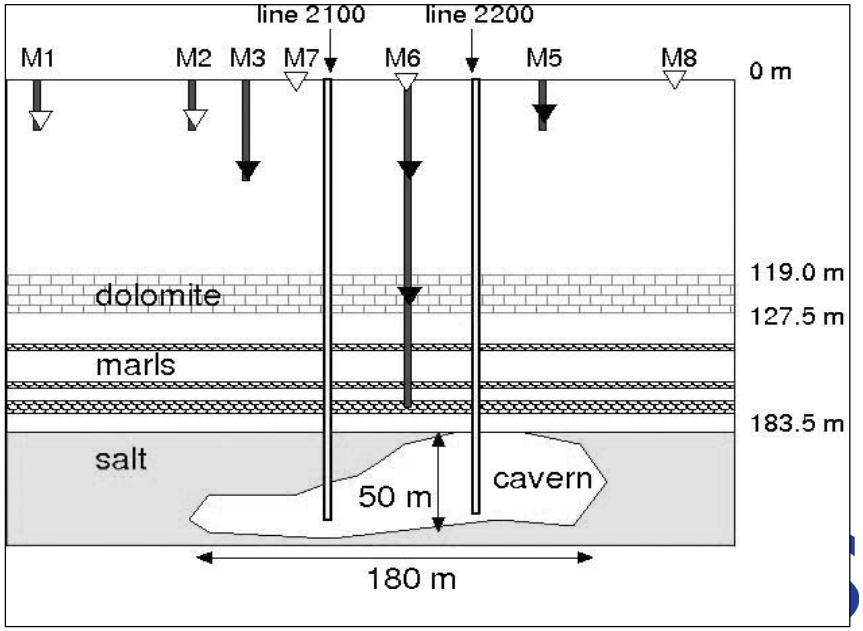






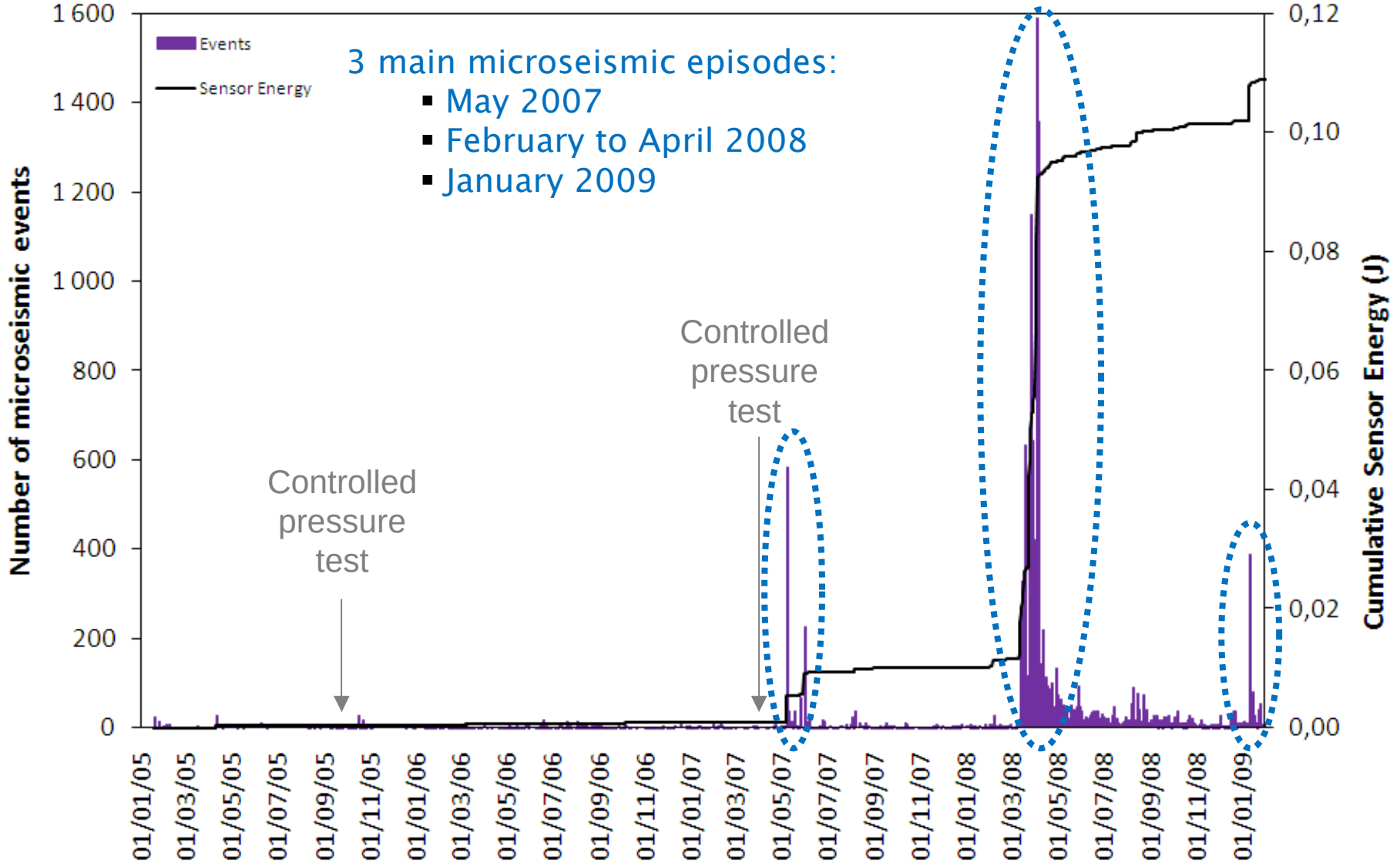
The multi-parameter monitoring system





- High resolution infra-red tacheometry (+/-5 mm)
- High resolution GPS - RTK measurements (1 measurement/second ; +/-5 mm)
- High resolution microseismic network (5 1D probes ; 4 3D probes ; 40-1000 Hz ; 8 kHz sampling)

Microseismicity between January 2005 and 2009



Microseismic data processing

- Microseismic data transferred in real time
- Automatic on-line data processing (SYTMIS software)
  - P-wave picking using an STA/LTA algorithm
  - Difficulties to achieve reliable automatic on-line S-wave picking, (far-field assumptions not always valid)

- 3-D location of events based on the non-linear inversion method (Lomax & Curtis, 2001)
  - Using a velocity model calculated from calibration blasts (3 layers; 0 -123 m 3000 m/s; 123 to 132 m, dolomite layer5000 m/s; below 4000 m/s)
  - Isolated microseismic events, good S/N, triggered on at least 6 probes
  - Location errors ~ 15 meters

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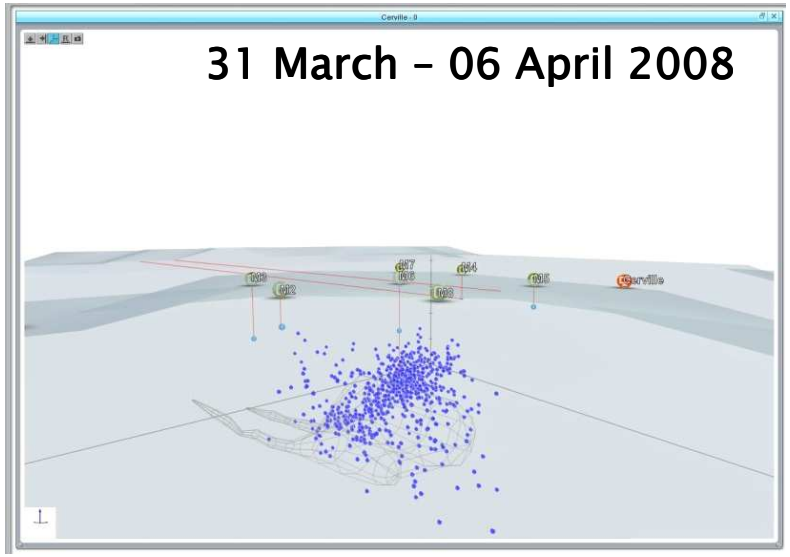
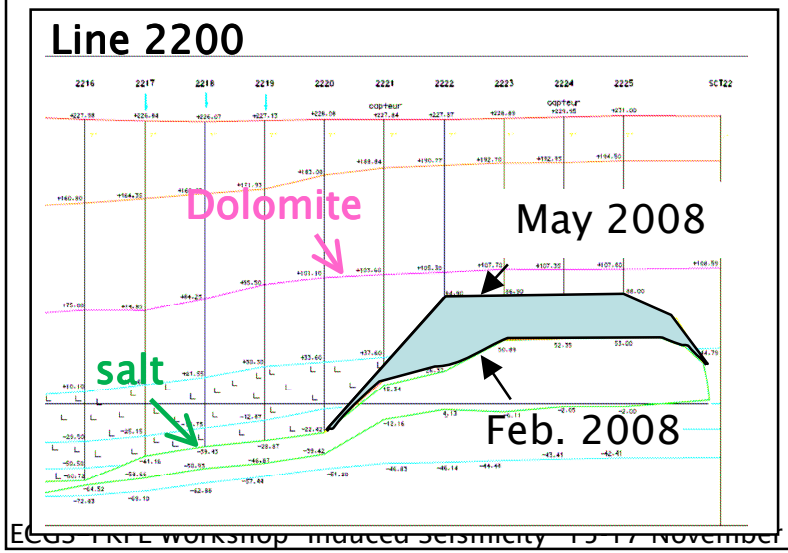
Microseismicity and Cavern Evolution between January 2005 and January 2009





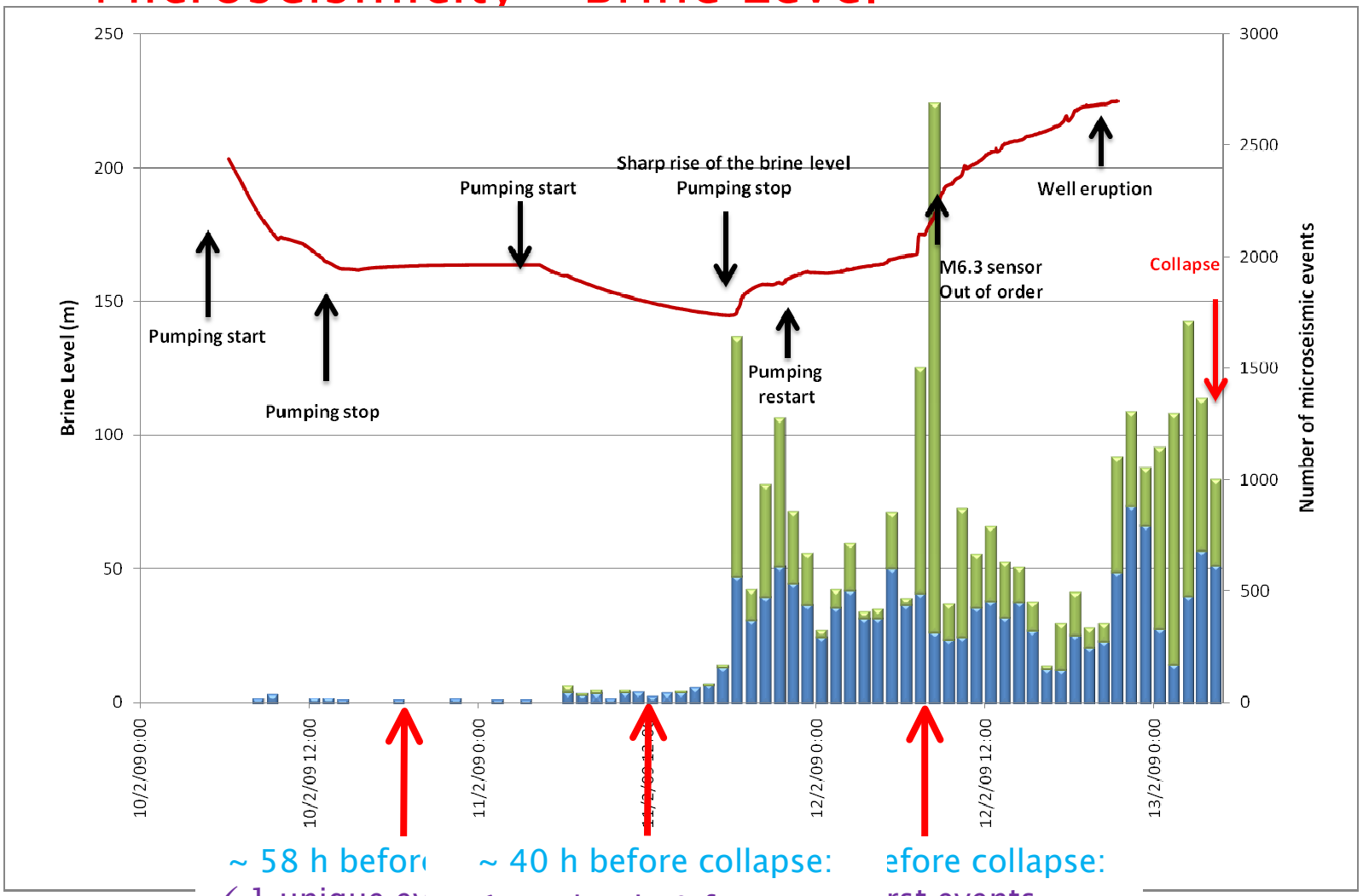
The microseismic activity:

- showed a vertical propagation of the dome cavern, indicating massive roof falls (~ 500 000 m3)
- correlated to brine pressure peaks
- occurred without any significant surface movement

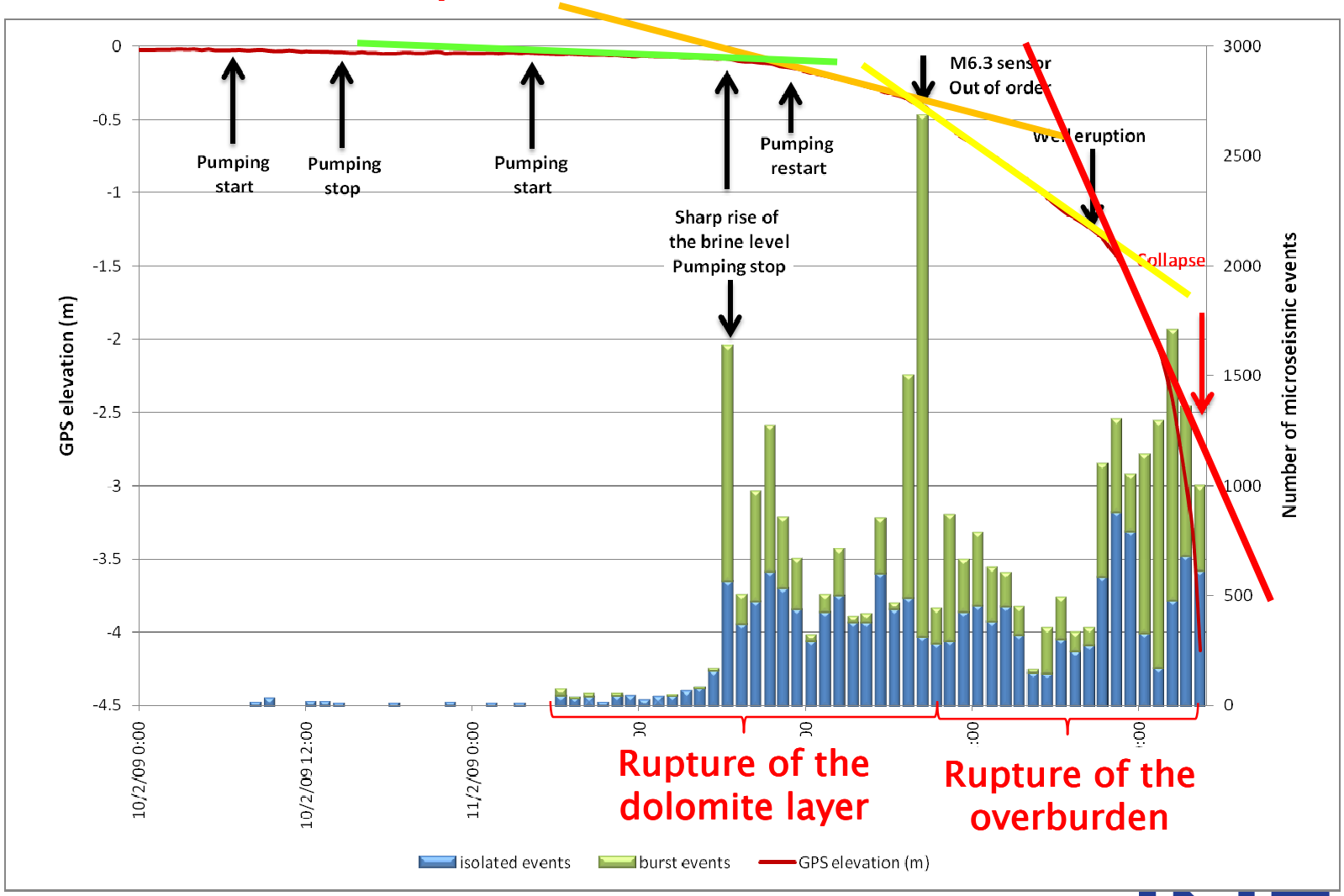
➔ The cavern had extended up to its critical size

- ➔ site access forbidden
- ➔ decision to trigger the general collapse by massive brine pumping – Feb. 2009

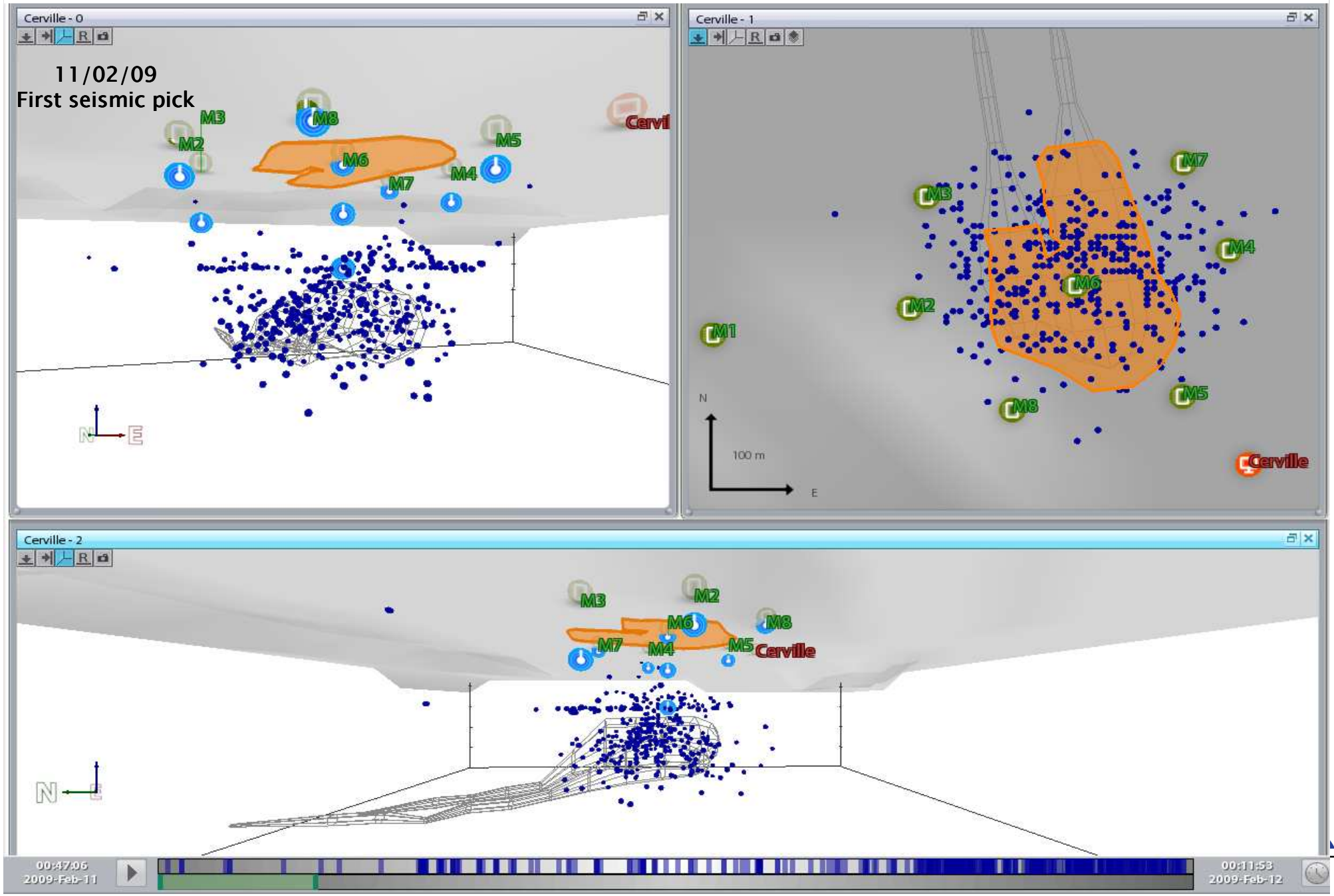
Data set of the Cavern Collapse
Microseismicity – Brine Level



Data set of the Cavern Collapse
Microseismicity – GPS elevation



Data set of the Cavern Collapse
Event location



Apparent b-value estimation

Gutenberg-Richter law,
approach from Amitrano et al. (2005)

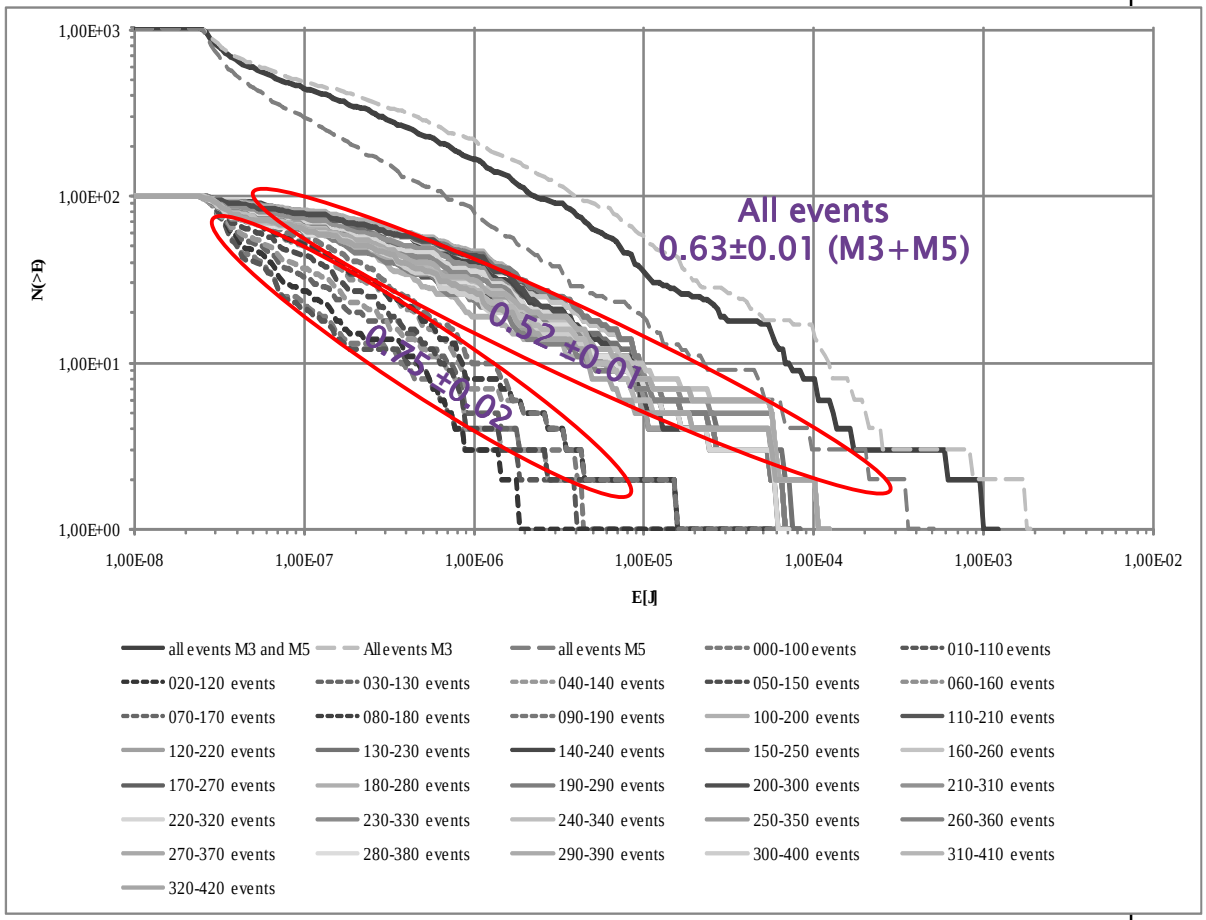
$$N(>E) \sim E^{-b}$$

- N(>E) is the number of events of energy larger than E
- b is the b-value

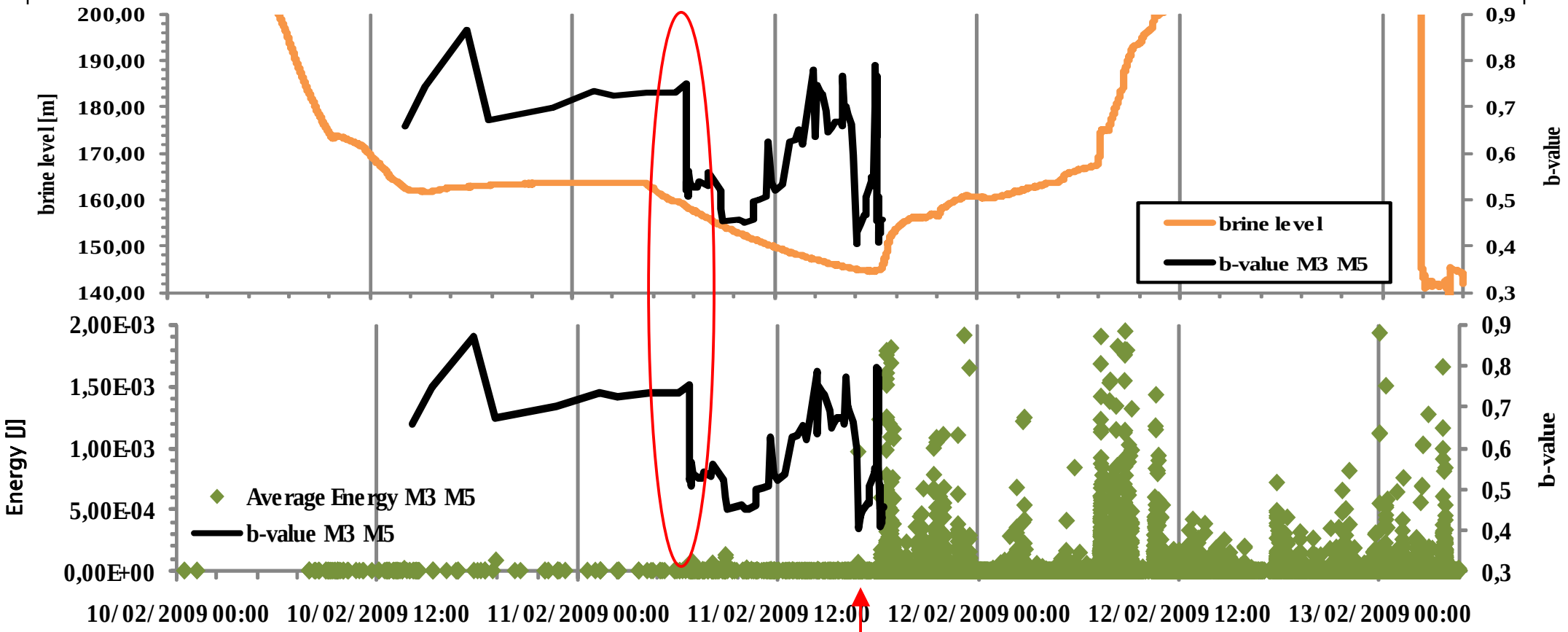
Hypothesis :

- Mean energy of 2 probes (M5, M3) located ~ 150 m of all recorded events

- Sample of event which occurs before the 1st seismic pick (sliding window 100 events, shifted by 10)



Apparent b-value / brine level & seismic energy



First Microseismic pick

Conclusion & perspectives

Unique database to:

- Identify precursors to collapse
- Describe the dynamic of rupture

On-going investigations:

- Identification of multiplets to improve location
- Calculation of the source mecanisms
  - traction / shear
- Processing and characterization of tremor type events
- Correlation with other available data
- Improve operational monitoring deployed on others mine context

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Thank you for your attention

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