Automatic full wave-form based monitoring at the deep Garpenberg metal mine

Kinscher, J.*, Palgunadi, K., Poiata, N., De Santis, F., Bernard, P., Klein, E.

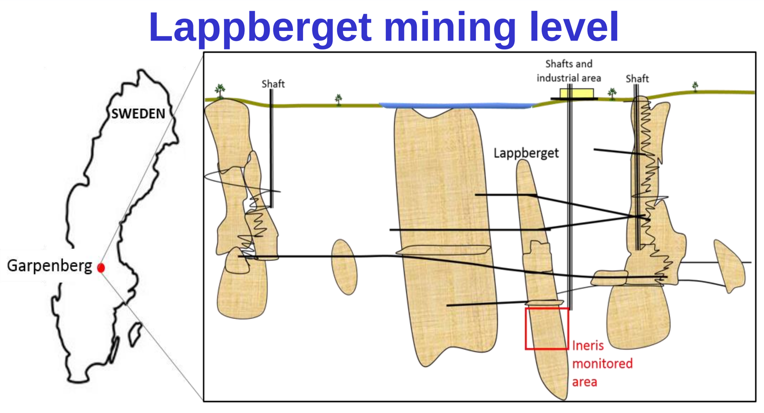
*Corresponding author:
Jannes-L.Kinscher@ineris.fr

Context

To improve prevention of seismic rockburst phenomena at the Lappberget level of the Garpenberg mine, Ineris and Boliden aim testing new methodologies for synchronized stress and seismic rockmass monitoring combined with geomechanic modelling ([2],[5],[6]).

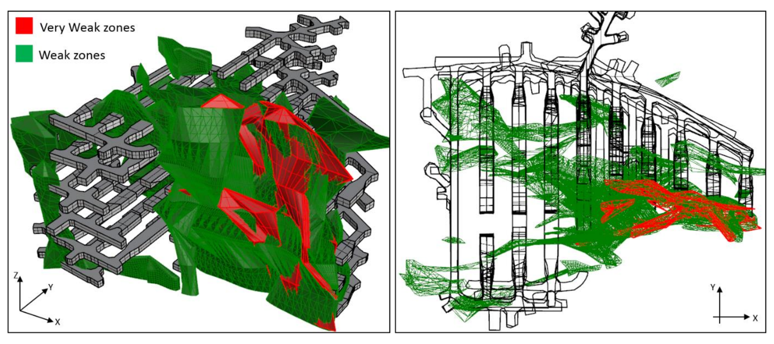
Garpenberg metal mine (Sweden)

Lappberget mining level

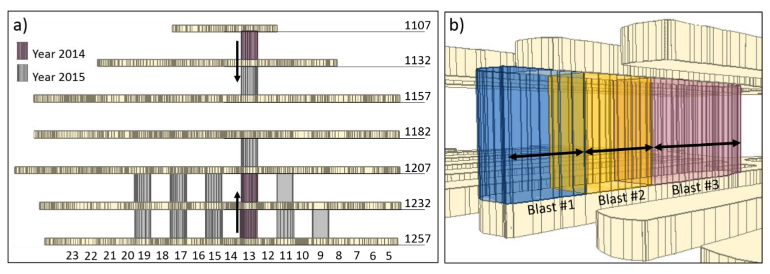


Geology and exploitation setting

Zones of weak materials (e.g. talc) [2]



Sublevel stoping mining with backfilling



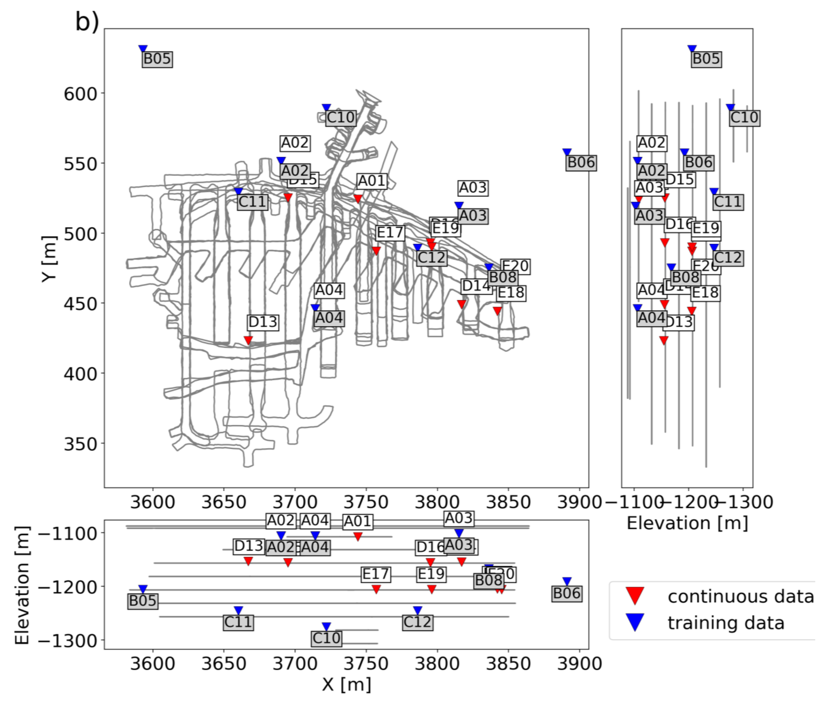
In this work, we present two recently developed seismic approaches supposed to significantly improve survey and understanding of seismic and aseismic rock response compared to classical monitoring approach in underground mines.

(1) The first approach is based on an automatic real-time detection and location work-flow using full wave forms that is able to deal with a wide range of mining noise sources and high sampling rate data (8 kHz).

(2) The second approach is related to matching and relocation of numerous seismic repeater occurrences probably linked to aseismic creep of weak rockmass materials in response to blasting.

Seismic monitoring network

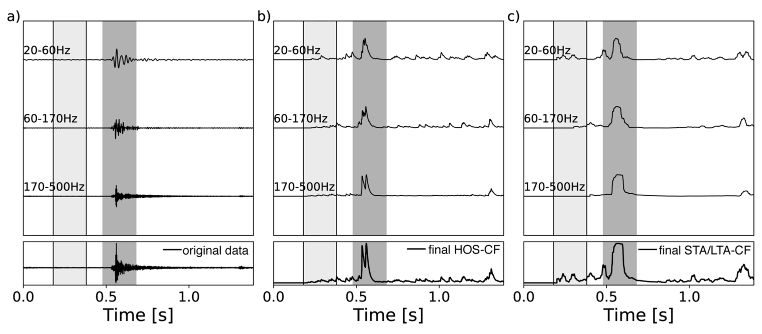
14 Hz geophones operating in triggered and continuous data recording modes



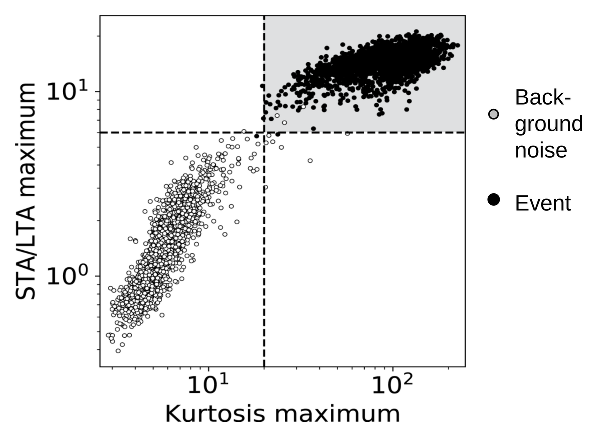
(1) Automatic detection-location for high sampling rate data in real-time

Processing workflow

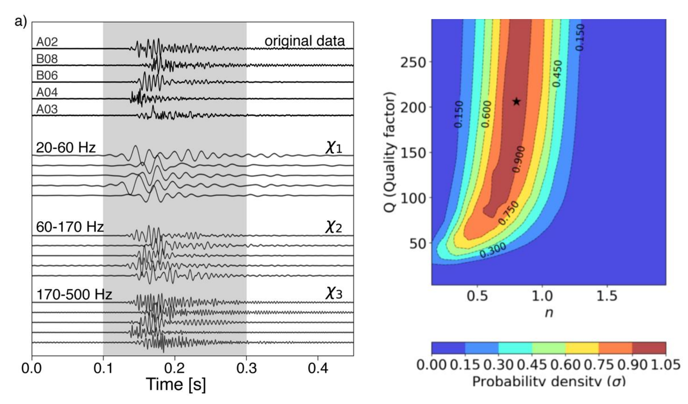
Stacked STA/LTA, Kurtosis (HOS) multiband based detection



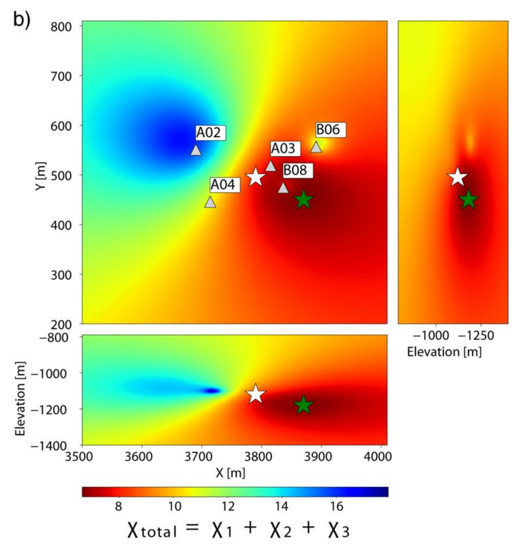
Event detection/ data volume decrease



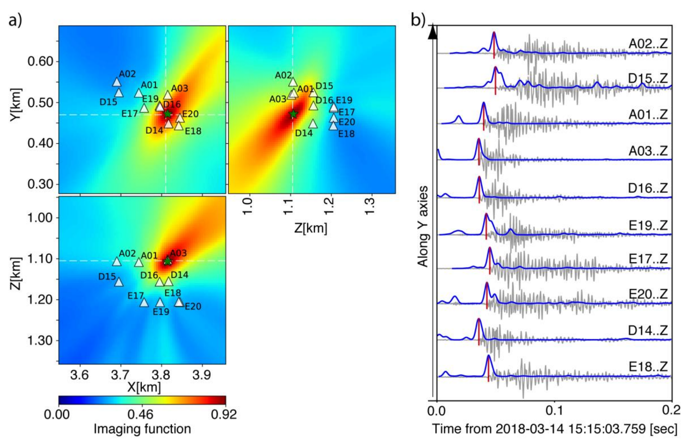
Multiband-amplitude based location [3]



First order location/real time catalogue

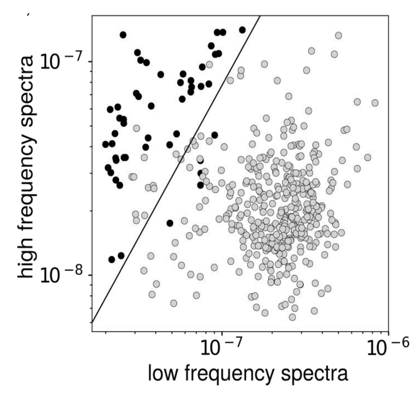


Precise BacktrackBB re-location [4]



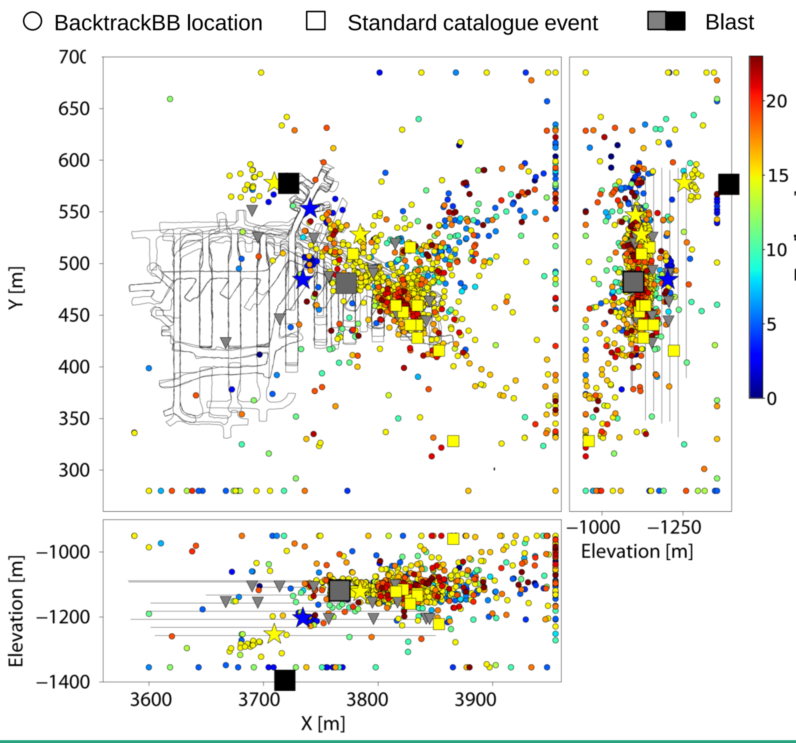
near real-time

Event pre-classification $f(A(f), M_L, f_{inst}, CF)$

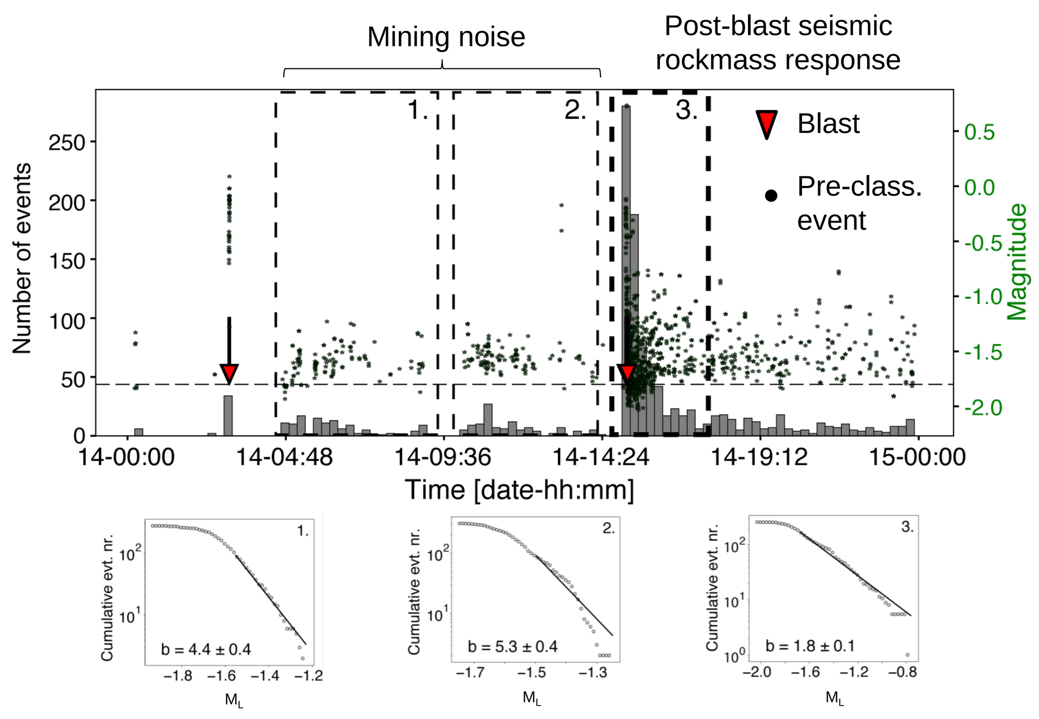


Example of real-time, spatio-temporal seismic rock response to blasting

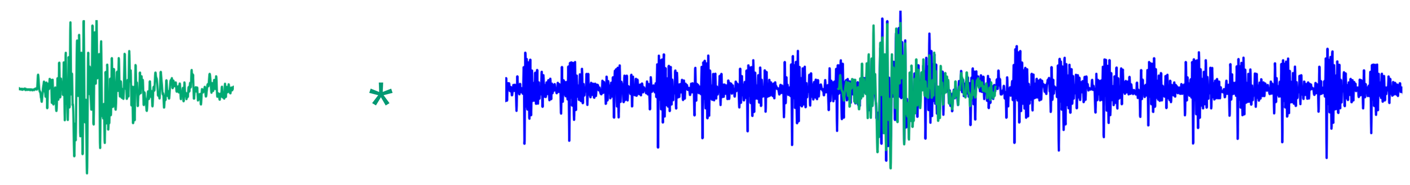
Spatial clustering in response to blasting



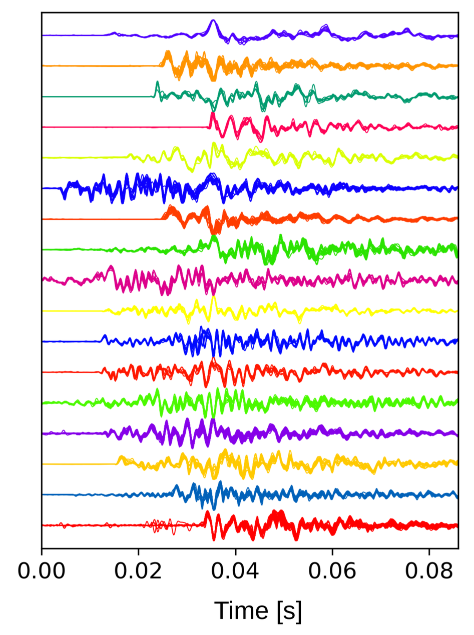
Real-time temporal clustering



(2) Matching seismic repeaters linked to weak rock mass creep



Aligned-stacked waveforms of seismic repeaters

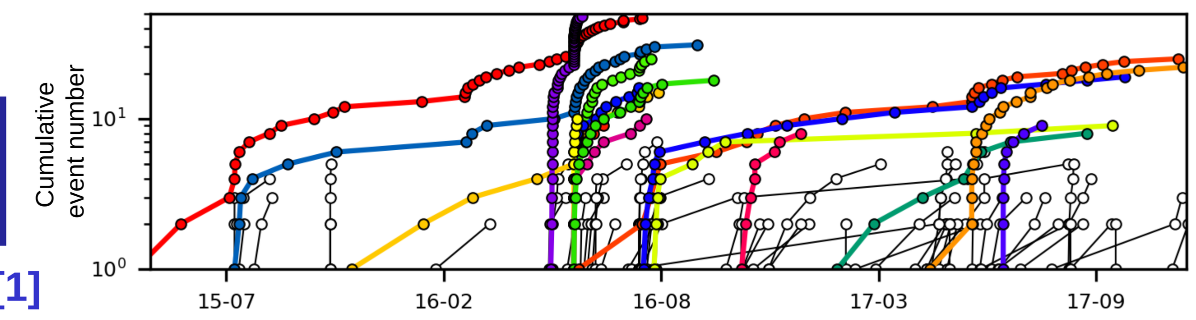


Analysis on seismic repeaters

Cross-correlation based template matching application showed presence of seismic repeaters (at least > 70 % of total data) with highly similar waveforms (C > 0.8). Repeaters occur mostly in response to blasting (near and far) in areas characterized by weak rock mass material, show typical Omori type decay and persist over periods from weeks to years.

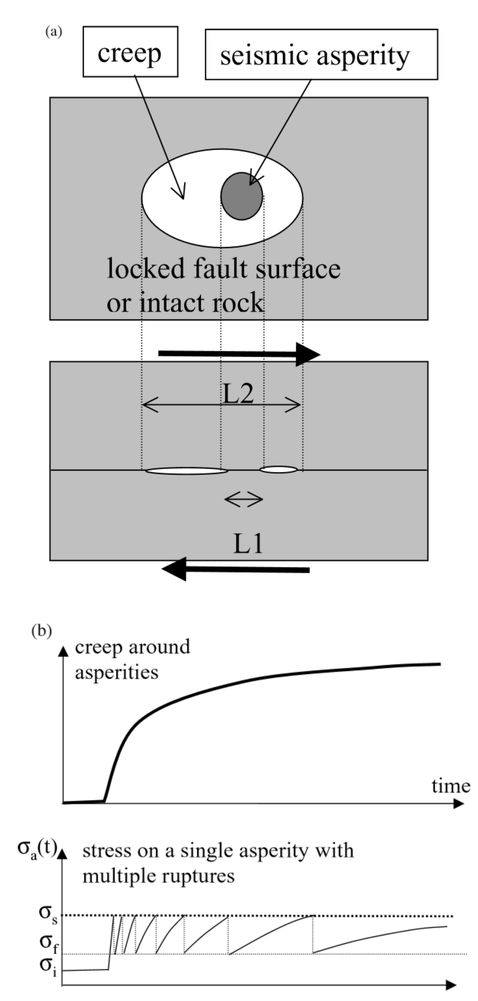
Most important families (> 7 events) have been relocated using ts-tp delays estimated from cross-correlation. Source mechanisms have been determined for ten groups by means of waveform inversion at 10-30 Hz using shearing DC model.

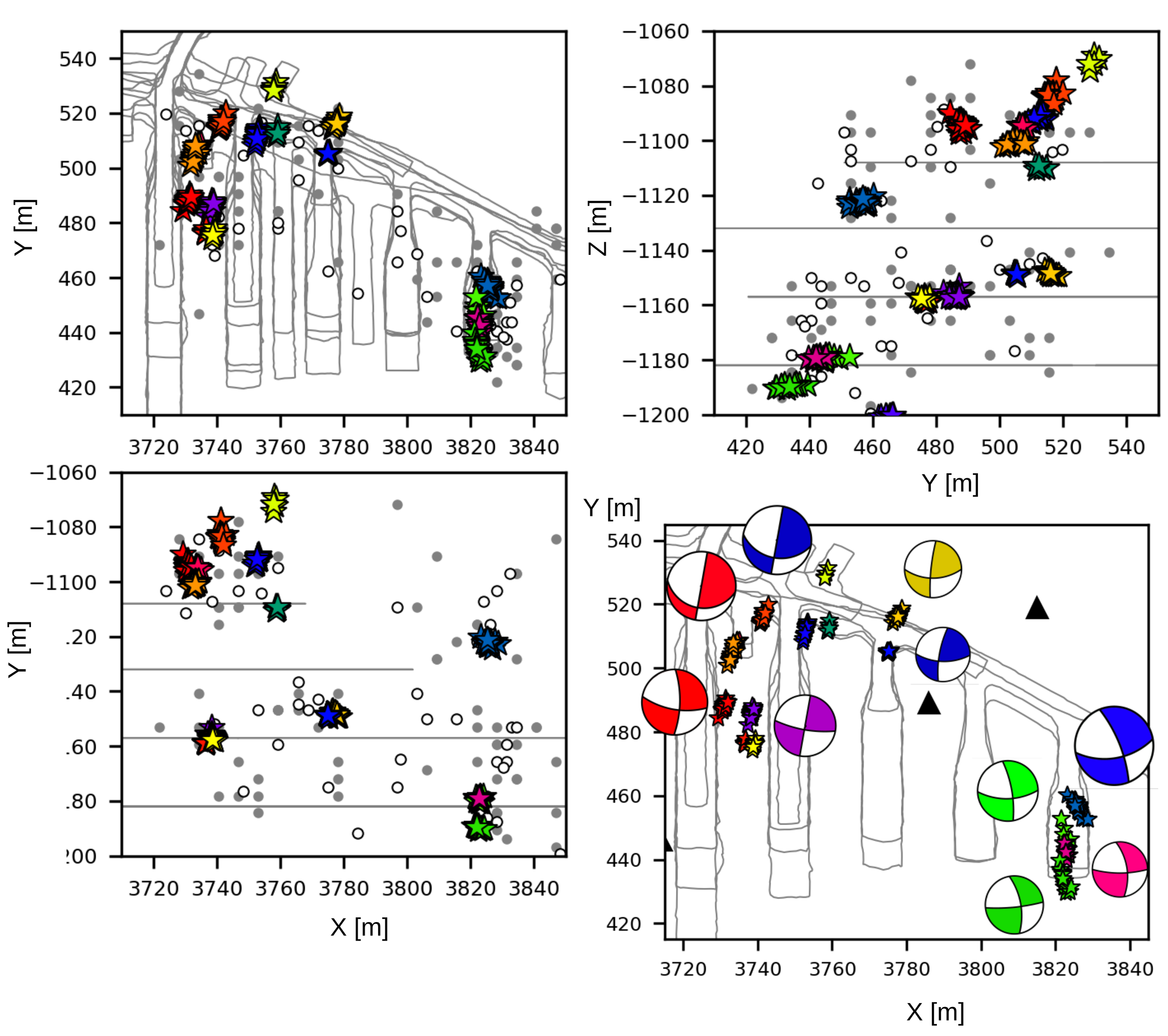
DD relocation and source mechanisms



Interpretation of seismic repeaters

Classical asperity model [1]





Repeaters are interpreted as repetitive ruptures on seismic asperities loaded by the surrounded aseismic creep of the surrounding weak rockmass in response to blasting. Relocation and source mechanisms show consistently that asperities seem to be composed by (sub)vertical segments, mainly 1-5 m in length, oriented N-S and associated with horizontal shearing. Source radii of individual events are widely larger than asperities. Some repeaters show cumulative slip in the order of cm, indicating presence of larger aseismic slipping structures (faults, talc lenses etc.)

References

[1] BOUROUIS, S., & BERNARD, P. (2007). Evidence for coupled seismic and aseismic fault slip during water injection in the geothermal site of Soultz (France), and implications for seismogenic transients. Geophysical Journal International, 169(2), 723-732..

[2] DE SANTIS F., CONTRUCCI I., KINSCHER J., BERNARD P., RENAUD V., GUNZBURGER Y. (2018) Impact of geological heterogeneities on induced-seismicity in a deep sublevel stoping mine. Pure and applied geophysics, Accepted

[3] KINSCHER, J., BERNARD, P., CONTRUCCI, I., MANGENEY, A., PIGUET, J. P., & BIGARRE, P. (2014). Location of microseismic swarms induced by salt solution mining. Geophysical Journal International, 200(1), 337-362.

[4] POIATA, N., SATRIANO, C., VILOTTE, J. P., BERNARD, P., & OBARA, K. (2016). Multiband array detection and location of seismic sources recorded by dense seismic networks. Geophysical Journal International, 205(3), 1548-1573.

[5] SOULEY M., RENAUD V., AL HEIB M., BOUFFIER C., LAHAIE F. NYSTRÖM A., 2018. Numerical investigation of the development of the excavation damaged zone around a deep polymetallic ore mine. International Journal of Rock Mechanics and Mining Sciences, 106, pp. 165-175.

[6] TONNELLIER A., C. BOUFFIER, V. RENAUD, P. BIGARRÉ, S. MOZAFFARI, A. NYSTRÖM, P. FJELLSTRÖM, 2016: « Integrating microseismic and 3D stress monitoring with numerical modeling to improve ground hazard assessment », Ground Support Symposium 2016, Lulea, Sweden.

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Towards advanced rockburst hazard monitoring

Approach (1) and (2) are currently implemented into Ineris cloud monitoring technology e.cenaris at Garpenberg mine to improve anticipation of nucleation phases of potential larger dynamic rupture and rockburst events and to monitor in detail the seismic and aseismic rock response. Indeed, approach (1) improves detection capacity by almost a factor 100 and provides reliable detection and location in (near)real-time even during periods of strong microseismic activity. The resulting increase of detected events in turn improves significance of statistical analysis in space and time and estimation of standard hazard parameters like the *b*-value of the Gutenberg Richter law, the *p*-exponent of the Omori law and gamma value of the inter-event times. In addition, ongoing works regarding semi-automatization of approach (2) (i.e. matching and relocation) provide the basis for monitoring of aseismic slip of weak rockmass in response to blasting and to provide advanced criteria for seismic hazard assessment as asperity density and interaction and to anticipate larger dynamic rupture potential.

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