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Post-mining risk management: lessons learnt from the microseismic monitoring of flooded iron-ore mines (Lorraine - France)

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The closure of mines has increased significantly since the last century and significant environmental problems can affect public safety and the sustainable development of the mining regions. These underground mines, are usually totally or partially flooded after mining shutdowns. The rock mass equilibrium is thus modified in an irreversible way and can produce geohazards like seismicity, subsidence, collapse, heaving ...
In France in the Lorraine region, decades of iron-ore mining from 1850 to 1997 have left vast underground cavities (40 000 km of galleries, 500 000 000 m3 of void) beneath or near urban areas. Several major collapses occurred in the southern part of this iron-ore basin in the 1990s, after the mine closure and the flooding of underground mine workings with serious damages to structures and infrastructures. Following these large-scale collapses, the French government initiated a strategy of post-mining risk management to prevent and control risks associated with these ground collapses. The high-risk zones are secured by reducing the vulnerability while the moderate risk zones are monitored for public safety purposes by using in situ monitoring. This monitoring relies mainly on real-time microseismic systems, to detect precursors to a rapid large-scale collapse. Data recorded are processing automatically and may generate alarm in case of abnormal evolution. Local authorities are informed, and evacuation can be triggered in case of danger for public safety.
After the progressive closing and then flooding of the northern iron basin ending in 2008, subsidence was observed in a town of the Lorrain basin in fall 2009. However, this local subsidence, with a low velocity of few centimeters per month, was not clearly detected by the borehole microseismic monitoring station located nearby. Only few microseismic events were recorded, which could not be unambiguously related to the beginning of the subsidence event. To better understand this lack of microseismic precursor, a geophysical investigation was launched. A calibration blast experiment was carried out from a remaining old underground access to characterise the wave propagation properties in this context.
The results of this study show strong anelastic attenuation of the seismic waves ($Q = 15 \pm 5$ on a frequency band ranging between 10 and 250 Hz for P wave) through the monitored overburden most likely related to the extensive fault system intersecting the study site. Moreover, robbed pillar extraction and flooding of the site may have induced a reduction of the mechanical properties of the overburden. These observations, added to a slow kinetics subsidence mechanism ($\sim$ cm/months) with little seismic energy release, may explain the lack of detected microseismicity during the subsidence event. In addition, low frequency microseismic events associated with the very slow subsiding movements might have not been detected by the used high frequency recording instruments, designed initially for rapid collapses ($\sim$ cm/hours). Following this experiment, a differential GPS was installed as well as inclinometers on the site to follow this progressive subsidence. Note that this slow subsidence does not presents any danger for public safety.