S30. Monitoring the Earth for Hazards: Integrating Geology, Geophysics, and Risk Assessment

Hydroseismograms from pressure devices in deep borehole within the Gran Sasso aquifer (central Italy) in earthquake hydrogeology studies

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This study explores, for the case study of the Gran Sasso Aquifer (GSA), the potential of high-frequency pore pressure monitoring (hydroseismograms) for enhancing the understanding of earthquake physics. This research has been developed within the Euratom funded ArtEmis Project and the HPC, Big Data and Quantum Computing - PNRR Project, funded by the European Union - Next Generation EU. Hydroseismograms, derived from a hydraulic pressure device (HPD) within deep, horizontal wells intersecting a major fault system inside the GSA, are compared with seismic data from the proximate seismic station, named GIGS, to gauge the HPD's earthquake detection capabilities. This distinctive setup, coupled with the HPD's 20 Hz data acquisition, provides a sensitive means for tracking both seismic events and pore pressure variations. The GSA's fractured-karst geology and its placement within a seismically active zone in Italy, alongside the Italian Institute of Nuclear Physics (INFN) underground lab (UL), establish an optimal setting for examining interactions between deep, saturated aquifers and earthquakes.

Based on monitoring data from May 1, 2015, to December 31, 2023 (continuous), the primary objectives were:

- Evaluating our HPD's performance in seismic detection and monitoring,
- Comparing the HPD's sensitivity against the GIGS seismic station,
- Comparing the HPD's sensitivity to comparable instruments in existing literature,
- To elucidate the different behavior of our HPD relative to analogous devices used by other researchers.

Here, HPD sensitivity is evaluated against the GIGS station. Therefore, sensitivity is here intended as conditional probability that a seismic event is detected by the HPD, given that it has already been detected by the GIGS. A statistical inferential method was employed, comparing HPD-detected events with GIGS-recorded events (1068) across varying magnitudes and distances. Key findings (Isaya et al., 2025):

- Mainly for far events, the identified detection threshold notably surpasses the “hard” detection limit for typical aquifers reported by Montgomery & Manga (2003), below which they observed no detections in a large dataset.
- It appears more effective than similar pore pressure sensors, even for deep events, although this analysis focused on far events due to a scarcity of near, deep earthquakes.
- Overall, our HPD exhibits substantially different sensitivity characteristics compared to analogous instruments documented in the literature.

These findings warrant further research into the not yet fully understood physics of hydraulic response to seismic events. This work highlights the potential of HPDs installed in deep boreholes for seismic monitoring and understanding the complex interplay between hydrological processes and seismic activity. Ongoing HPD monitoring will further investigate their role as a valuable tool for future seismic investigations and contribute to advancing earthquake science.

Isaya D. et al. (2025) - Hydroseismograms at Gran Sasso aquifer, central Italy, for earthquake hydrology studies. Sci. Rep., 15, 13162, https://doi.org/10.1038/s41598-025-96113-4.

Montgomery D.R. & Manga M. (2003) - Streamflow and water well responses to earthquakes. Science, 300(5628), 2047-2049, https://doi.org/10.1126/science.1082980.

pore pressure monitoring, seismic monitoring, hydroseismogram.

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