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Mini-seismic Methods for In-situ Rock Characterisation in Underground Facilities and Tunnels

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Summary

BGR developed a bundle of ultrasonic and seismic methods, which we call Mini-Seismic Methods (MSM), for a comprehensive in-situ rock characterisation. Methods are applied in single boreholes, between two or more boreholes, along or between drifts and as a combination of borehole and drift based methods. Furthermore, for the characterisation of evolution processes of rock parameters (e. g. EDZ/EdZ creation and sealing) targeted repetitions or long-term monitoring measurements are applied (Schuster et al. 2017). MSM are quick employable, robust and cheap tools which allow a reliable access to relevant basic geomechanical rock properties. For high spatial resolution boreholes are indispensable. MSM were applied in different potential host rocks for radioactive waste disposal in Europe. Piezoelectric transducers are used as receivers. As ultrasonic or seismic sources piezoelectric actuators and different impact tools are used. Transient recorders with up to 160 channels and up to 25 MS/s and dynamic ranges of 24 bit are used as recording systems.

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Exemplarily results gained in three different potential host rocks for radioactive waste disposal with three different emphasis are presented, namely (1) derivation of in-situ dynamic elastic rock parameters in crystalline rocks, (2) characterization with high spatial resolution of different clay formations and (3) determination of boundaries in rock salt formations.

(1) At the Grimsel test site a 70 m long inclined borehole was used for ultrasonic interval velocity measurements (IVM) in a granitic formation. With a 4 channel ultrasonic borehole probe the 70 m long borehole was measured in steps of 10 cm. Main results, like the vp-, vsv-, vdyn-, Edyn- and Gdyn-distribution, are compiled in Figure 1 (running averages over 3 points).

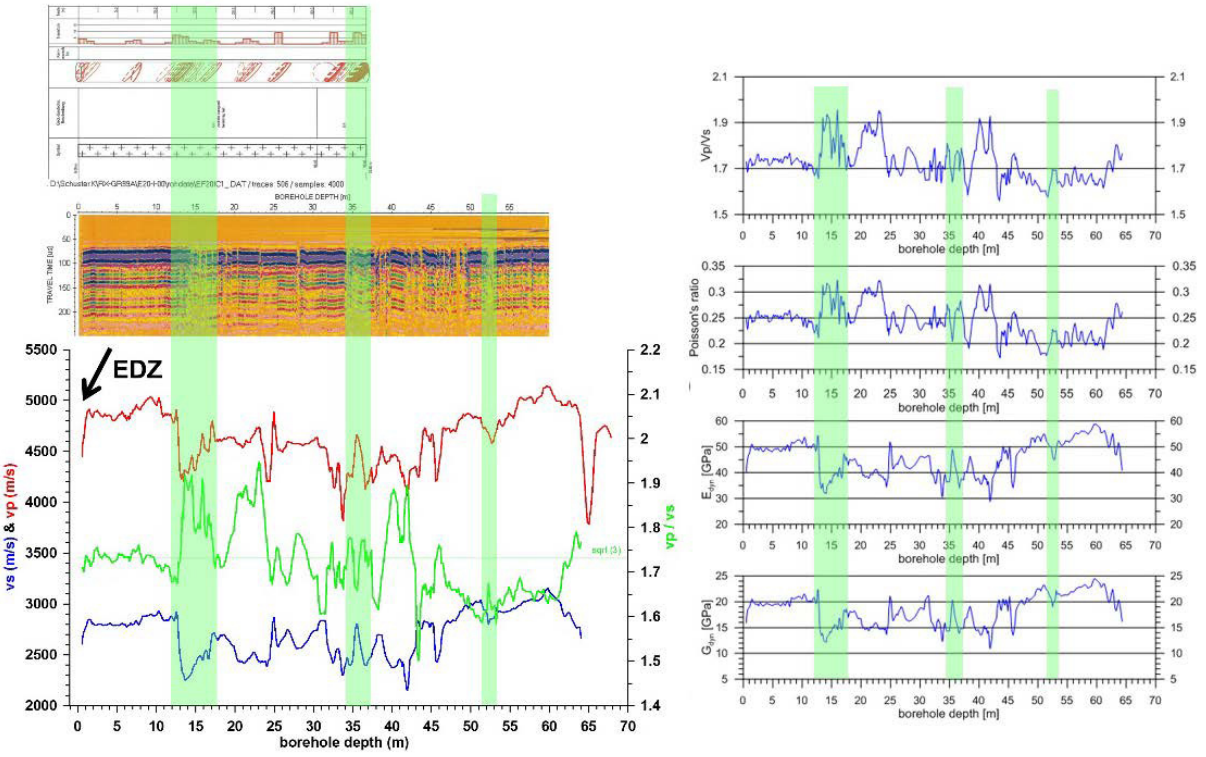

***Figure 1**: Results from IVM at the Grimsel test site (granitic formation). IVM were applied in steps of 10 cm. For some depth correlations with core mappings are highlighted.*

(2) In the frame of the Mont Terri rock laboratory extension which is planned for 2018 three boreholes of up to 70 m were drilled for a predictive investigation in the Jurassic Opalinus Clay, a clay which is of interest for the Swiss final repositories for radioactive waste. We used an 8 channel ultrasonic borehole probe with 5 cm distances between transducers. In Figure 2 the derived app. vpR2 is plotted. Note the high variability of vp (1200 m/s – 5200 m/s) and the high spatial resolution. Any of the "anomalies" (7 are marked exemplarily with red arrows) is in very good accordance with results from core mapping.

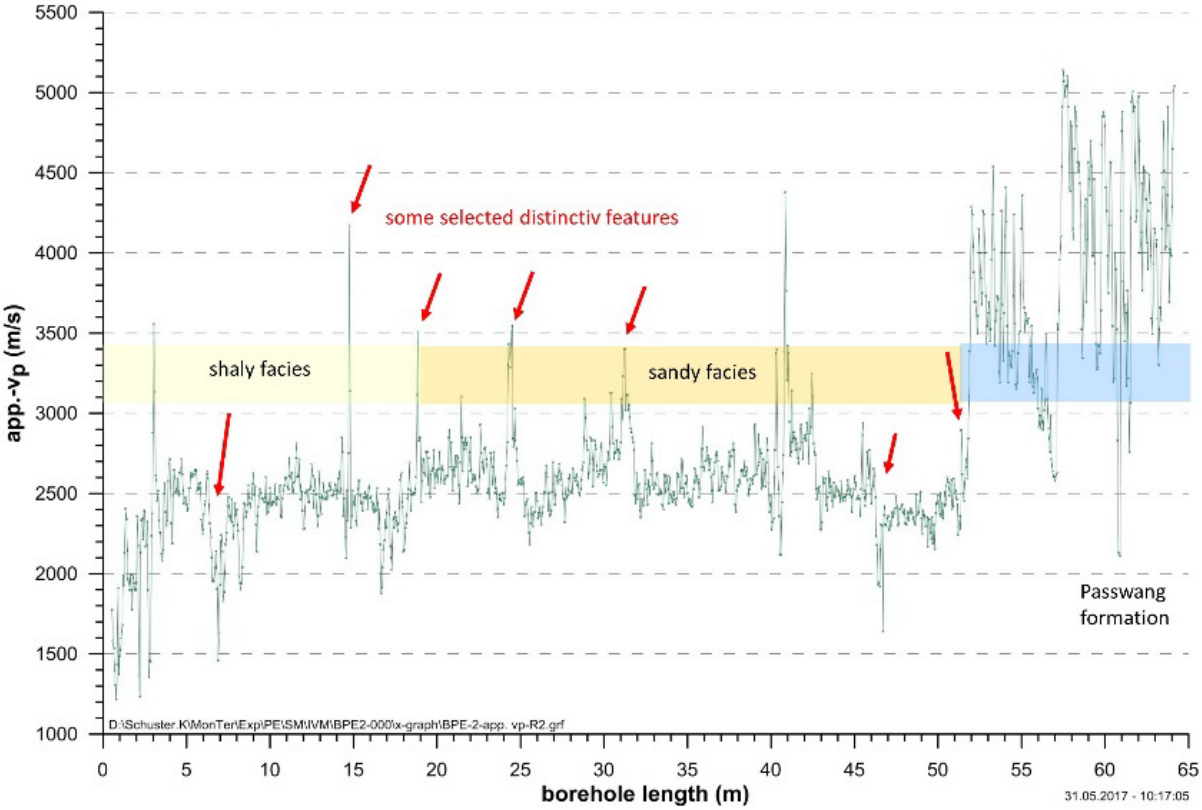

Figure 2 *app. vpR2 distribution (running average over 3 points) derived from IVM at the Mont Terri rock laboratory (Opalinus Clay) in steps of 5 cm. Indicated "anomalies" correlate well with core mapping data.*

(3) At the Morsleben repository for low- and medium-level radioactive waste (ERAM) at a depth of – 231 mNN seismic refraction / reflection measurements along a 330 m long drift were performed. 53 3-component piezoelectric transducers (X, Y, Z, 159 channels) were deployed at the side wall of a drift. A bolt firing tool was used as a seismic source. In all CSP-sections (SP at -20.5 m) very clearly the direct P- and S-wave first arrival phases are visible. In the wide angle range two reflections can be addressed, RX1 and RX2. With the help of a FD-ray tracing modelling in conjunction with the interpretation of several hodograms the strong reflection RX1 could be interpreted as a reflection from the salt table at a distance of 95 m. A spectral analysis gives usable signals in the range between 0.5 kHz and 5 kHz, what corresponds to seismic wave length between 9 m – 0.9 m for P-waves and 5.2 m – 0.5 m for S-waves.

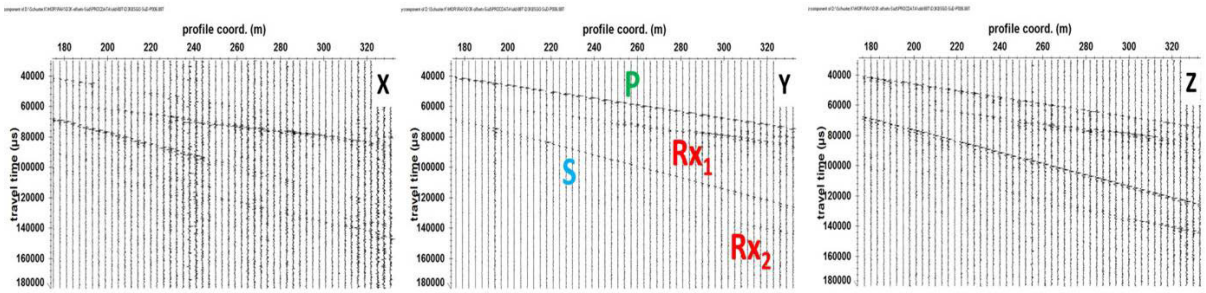

Figure 3 *CSP sections recorded with 3-component piezoelectric transducers (X, Y, Z). The wide angle reflection RX1 could be interpreted as a reflection from the salt table (FD-ray tracing and hodograms).*

Reference: SCHUSTER, K., AMANN, F., YONG, S., BOSSART, P., CONNOLLY, P., 2017. High-resolution mini-seismic methods applied in the Mont Terri rock laboratory (Switzerland). Swiss J. Geosci. 110,213-231, doi:10.1007/s00015-016-0241-4, open access: https://link.springer.com/article/10.1007/s00015-016-0241-4.