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Characterisation of carbonate rocks from near-surface cross-hole and reflection GPR investigations - A case study from southeast Zealand, Denmark

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Carbonates found in the near-surface of southeast Zealand, eastern Denmark, are analogous to deposits serving as groundwater and hydrocarbon reservoirs in the Danish region.

The study site is located in the Boesdal limestone quarry. A 20 by 20 m area of the bottom of the quarry was levelled using a bulldozer, and a grid of 100 MHz and 250 Mhz reflection profiles were collected to facilitate geological interpretation of structures in the uppermost part of the subsurface. Secondly, four 15 m deep boreholes were drilled in a square geometry with side lengths of 5 m. Core material was recovered from the boreholes for lithological control and to facilitate laboratory measurements of porosity and permeability. Cross-hole GPR data were collected between boreholes with 100 MHz Sensors&Software antennae. The distance between source and receiver antenna positions in the boreholes was set to 0.25 m.

Mounded features observed in the upper ca. 7 m of the subsurface imaged by the reflection GPR data are interpreted to represent bryozoan mounds similar to mounds mapped by others along cliff and quarry profiles close to our study site. Below the base of the mounds, the reflection signals become too weak to facilitate deeper imaging of the carbonates.

The section studied with the cross-hole data is water-saturated. Simple 1D modelling of the cross-hole data indicates a strong drop in GPR velocity at 7 to 8 m depth. Different 2D inversion strategies are tested for fine scale resolution of the inter-borehole heterogeneity. Sequential simulation strategies seem to be successful with respect to extracting well-defined correlation lengths and variance estimates of the velocity fluctuations. A strategy in which the intervals above and below 8 m depth are treated as separate heterogeneous media appears to be more successful in generating well-defined statistical parameters for the GPR velocity field of the subsurface than the typical strategy in which the total rock section covered by the cross-hole data is regarded as the same type of medium. Modelling strategies in which porosity data from the boreholes are included in the inversion algorithm are tested and compared to the results obtained using the more traditional approaches.

The GPR investigations may contribute to setting the framework for future fine-grained models designed to simulate fluid and gas flow in groundwater and hydrocarbon reservoirs.