Geophysical Research Abstracts
Vol. 15, EGU2013-8646, 2013
EGU General Assembly 2013

Efficient data analysis and travel time picking methods for crosshole GPR experiments

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High-resolution GPR crosshole experiments are conducted to resolve fine-scale anisotropy of chalk. Chalk plays important roles in groundwater production onshore Denmark and in hydrocarbon exploration in the North Sea, and chalk has previously been studied extensively with geological and geophysical methods. Future time-lapse GPR studies of different types of chalk aim at characterizing the flow characteristics of these economically important lithologies. In the framework of the current study, we have collected new crosshole GPR data from a site located in a former quarry in Eastern Denmark, where crosshole GPR experiments have been previously carried out.

Time-lapse GPR crosshole experiments involve the interpretation of large datasets organised in terms of transmitter or receiver gathers and hence call for efficient and robust data inspection and picking of first arrivals. To this end, we have developed a corresponding protocol for performing quality control and first-arrival picking for such data. The crosshole data considered in this study were acquired using 100 MHz borehole antennae from Sensors & Software. Each trans-illumination profile is produced by acquiring successive transmitter gathers. For each such gather the transmitter is fixed and the receiver is successively lowered in steps of 0.25 m. The thus obtained transmitter gathers each contain a total 57 traces.

After standard processing, the data are organized as a cube with the abscissa corresponding to the receiver position, the ordinate to the source position, and the vertical axis to the travel time. Using OpendTect (dGB Earth Sciences), this data cube is then displayed and inspected in a 3D environment, which allows for effective and efficient data analysis. Quality control and data editing of the individual transmitter gathers can be rapidly performed based on visualizing time slices or equal receiver positions with different source positions. The resulting final data cube is then amenable to first-arrival picking and/or to the application of state-of-the-art routines for 3D seismic interpretation, such as similarity check, dip-steering or meta-attribute analyses.

We believe that this approach to 3D representation and analysis of GPR crosshole data greatly improves consistency in travel time picking and reduces the time needed for the picking process. Moreover, the approach is well suited for generation of high quality input data for tomographic inversion with important implications especially for time-lapse studies where large amounts of data must be treated in a consistent manner.