Introduction

Detailed characterization of subsurface geological heterogeneities which control fluid flow and transport is still an unresolved challenge in the geoscience community. While surface geophysical methods have helped in obtaining large scale parameter distributions, the decrease of resolution with depth limits their application for delineating heterogeneities at high resolution. This limitation has encouraged the use of cross-hole geophysical techniques such as cross-hole seismic tomography. Cross-hole seismic tomography which involves measuring travel times of seismic ray paths between two or more boreholes in order to derive an image of seismic velocities between the wells offers an approach for characterizing geological heterogeneities at a high resolution. Its application range from near surface aquifer studies, geothermal, to deep oil and gas reservoirs (Sainkov et al 2005; Tselentis et al 2011). Becht et al., (2007), evaluated the use of cross-hole seismic tomography for high resolution aquifer characterization. In this study, we present a case application of cross-hole seismic tomography for a high resolution characterization of the Prakla-Seismos field test site. Detailed velocity distributions are correlated with available borehole geological data to better delineate subsurface heterogeneity which provide useful information for an improved groundwater flow and contaminant transport modeling in the area.

The PRAKLA-SEISMOS test site where the study was carried out is located North East of Hannover, North of Germany. The test site is characterized by Quaternary fine sand and coarse gravel, underlain by chalky clay. There are two wells at the test site, each having a total drilled depth of 100m, separated from each other by a distance of 90m.

Methodology

Cross-hole seismic tomographic surveys was carried out to reconstruct the P-wave velocity distribution between the two boreholes. Collection of Cross-hole seismic data was done with a down-hole sparker source SBS-42 and a hydrophone system BHC-2 (Geotomographie, Germany) using a 24-channel exploration seismograph SUMMIT II Compact (DMT, Germany), at a sampling rate of 1/16KHz and record length of 256ms. Shot Position spacing was 2m while the hydrophone spacing was 1m, resulting in over 1000 traces for each cross-hole survey, the data quality was excellent and allowed for manual picking of the First arrival times.

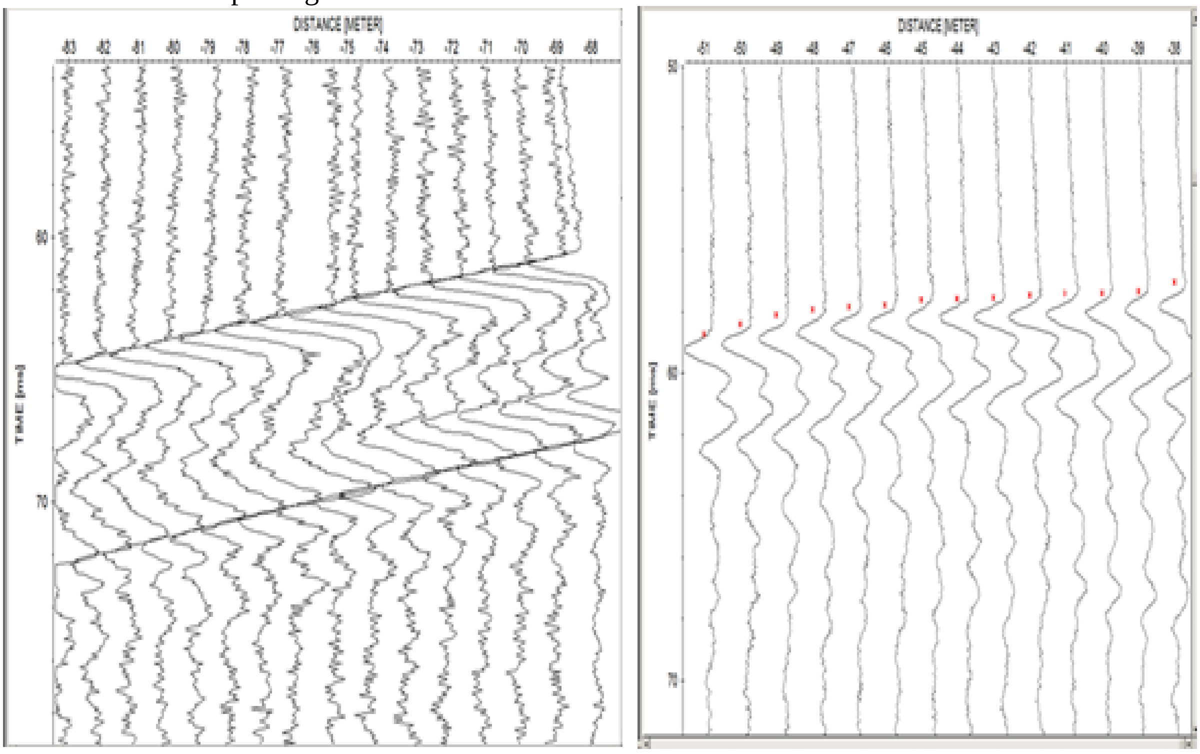

Figure 1. Showing the raw data (left), processed data (right) from the tomography test.

The travel times of the P waves were derived from the first-arrivals identified on the seismic trace for each shot-hydrophone pair and used with the known distance(s) between the shot/receiver boreholes to calculate the velocities (P) for each depth interval. Large number of p-wave travel times (more than a thousand) was recorded. Data were quality controlled and files formatted to fit to a tomography inversion software which calculates a 2D velocity image based on the 1D travel times.
After correctly picking of travel time for each seismic trace saved in different files, these record files were combined together using simple file joiner. TomoCheck was used to assign the true borehole geometry and also to check the quality of the picks.

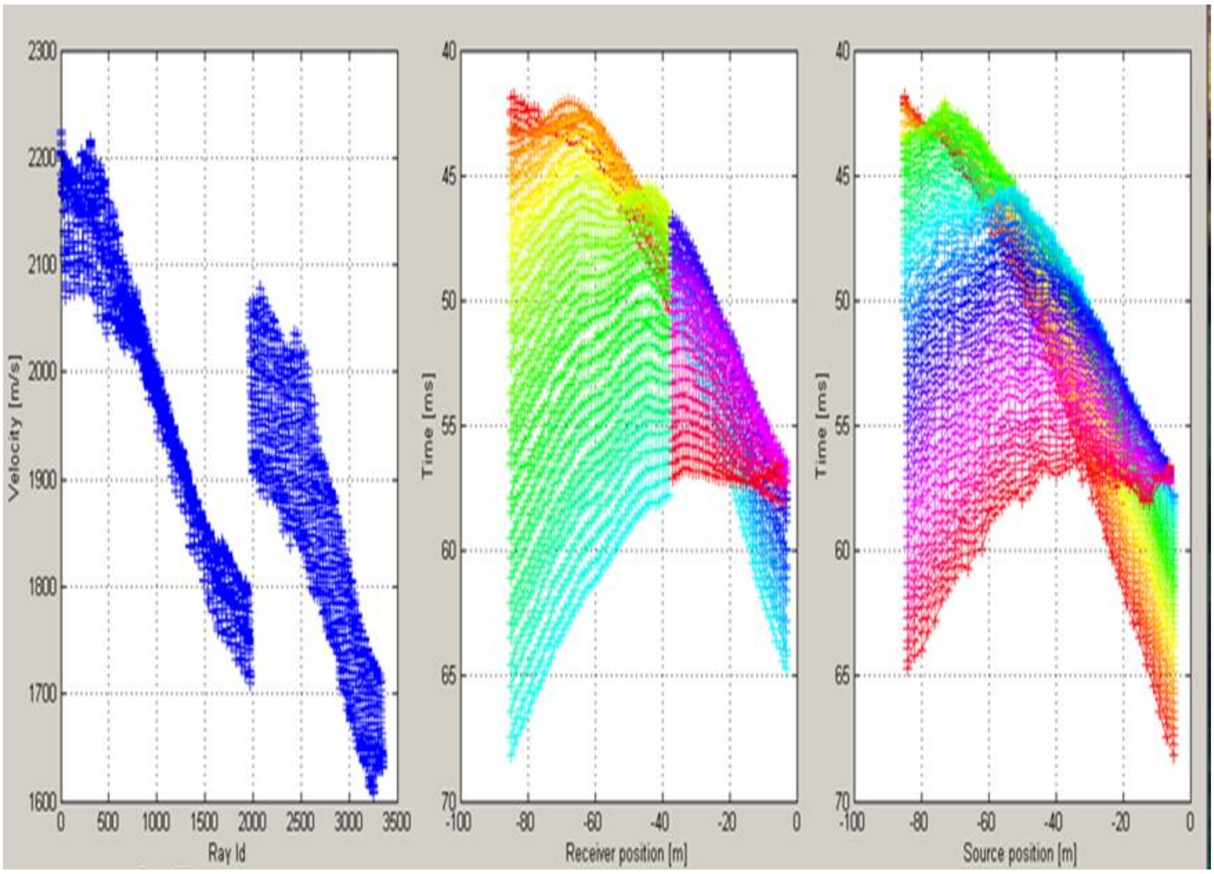

Figure2. Showing TomoCheck display for pick quality check. The smoothness of the curve is an indication that the picks were properly assigned.

Result

Tomographic Inversion was done using a software GeotomCG from Geotomographie, Germany. The inversion algorithm used is Simultaneous Iterative Reconstruction Technique (SIRT). The tomogram produced showed four distinct velocity zones, with velocity ranging from 1200-2400m/s, as shown in fig. 3 below. The first and lowest velocity zone, was observed at the depth of 6m-26m, and velocity range of 1700-1900m/s, with some patches which is an indication of heterogeneity. The second velocity zone was observed at the depth of 27m-40m, the third zone ranges from 40m-70m and the fourth zone was observed at depth of 70m and above. The p-wave velocity of water saturated sand

and gravel falls within the range of 1500-2000m/s, thus the result indicates that the aquifers of the study area lies within the velocity zones 1-3, with depth range of 6-60m. The result also shows some clear patches in the first and third velocity zone, this is a strong indication of heterogeneity in the structural composition of the aquifer materials. There is also significant variation in the velocity zones close to well B2 as compared to well B1.

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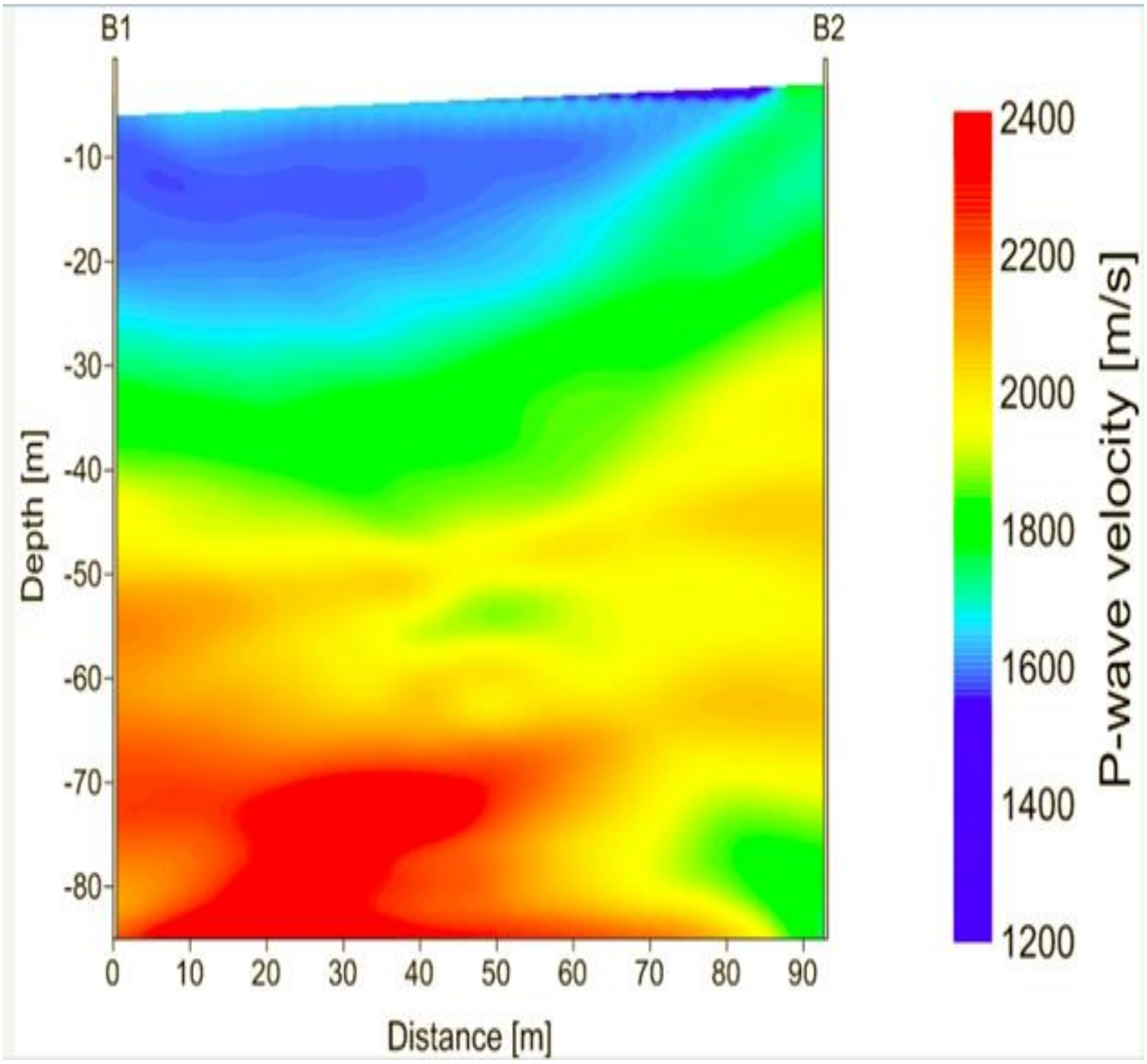

.Figure 3. Showing the velocity cross-section between the boreholes

Conclusion

The result Shows that the aquifers in the area lies between 6m – 60m as shown in the tomogram. It was also observed that borehole verticality is very important to improve the accuracy of seismic tomography data, this is indicated by the low velocity section at the bottom right near borehole B2, which is an error due to borehole deviation. This can be improved by measuring borehole deviations and correcting the data before final inversion. This work has shown that seismic tomography can be a useful tool for hydrogeological investigations because it provides additional information on aquifer heterogeneity such that could not be obtained from 1D borehole alone, thereby improving flow and solute transport modeling in the study area.

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