Geophysical Research Abstracts
Vol. 13, EGU2011-2192, 2011
EGU General Assembly 2011

Seismic attenuation imaging from full-waveform inversion: an onshore case study

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Here we demonstrate the potential of the visco-acoustic frequency domain full-waveform inversion (FWI) to reconstruct P-wave velocity and P-wave attenuation factor (Q_P) from the onshore seismic data. First we perform a sensitivity analysis of the FWI based on simple synthetic data. The relative sensitivity of the seismic data to the velocity and the attenuation factor is strongly dependent on the values of the attenuation in the medium. We show that both the velocity and the attenuation factor can be reliably reconstructed with a comparable resolution and without trade-off for sufficiently attenuating media and sufficiently-accurate velocity starting model by non-linear inversion. However, the imaging of the low wavenumber of the attenuation from the low frequencies can be unstable. Subsequently, we applied both the acoustic and visco-acoustic FWI to the real wide-aperture onshore seismic data with a strong footprint of attenuation that were recorded in the Polish Basin. We show how a heuristic normalisation of the data with offset allows us to remove the effect of the attenuation from the data and reconstruct a reliable velocity model in the acoustic approximation. Alternatively, visco-acoustic FWI allows us to reconstruct jointly both a reliable velocity model and a Q model from the true-amplitude data. We propose a pragmatical approach based upon seismic modelling and source wavelet estimation to infer the best starting homogeneous Q model for visco-acoustic FWI. We find the source wavelet estimation quite sensitive to the quality of the velocity and attenuation models used for the estimation. Consistent source-to-source wavelets obtained in the final visco-acoustic models and a very good match of the real and time-domain synthetic seismograms confirm validity of our results. We find the recovered velocity and attenuation models concordant with the expected lithology and stratigraphy in the study area. We link high-attenuation zones with the increased clay-content and a presence of the mineralized fluids.