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Seismic shear wave borehole tormography and the application of the curvelet transform to reflection seismic data

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2019-05
https://hdl.handle.net/10539/29588

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ABSTRACT

This thesis is comprised of two parts. In the first part, I show the application of seismic S-wave cross-borehole tomography in different geological environments and find optimal processing and interpretation flows adapted to different exploration questions. In general, S-wave tomographic imaging offers many additional parameter estimates and interpretational insight compared to P-wave tomography on its own. In the first case study, I show that prior to the construction of a large infrastructural project, cross-borehole P- and S-wave tomography can be effectively used to derive elastic parameters, and detect a large weak zone in highly weathered and karstic limestone. In the second case study, I used S-wave tomography, in conjunction with MASW and SCPT measurements, to improve an earthquake velocity model, by increasing the reliability of the near-surface S-wave velocity, and detecting zones of variable surface wave amplification. These two case studies were complemented with S-wave measurements in an overconsolidated clay environment, were different processing and interpretational capabilities of S-wave tomography were developed. One of the disadvantages of interpreting S-wave velocities, is the lower measurement accuracy of the S-wave traveltimes compared to P-wave traveltimes. To overcome this limitation, I propose a new method, whereby the less accurate S-wave traveltimes are structurally coupled to the more accurate P-wave traveltimes. This joint-inversion approach resulted in more accurate S-wave tomographic images, enhancing the interpretational capabilities. Further, I show that anisotropy plays an important role when interpreting S-wave data. Measurements with two directional sources produced differently polarised S-waves, which travelled at different velocities. The measurements show that S-wave anisotropy is far more severe compared to P-wave anisotropy, especially in a near-surface environment, and could be a reason for the reduction in accuracy, if an isotropic approach is taken. Parameters for a vertically transversely isotropic (VTI) medium were estimated by jointly inverting P- and S-wave traveltimes, which markedly improved the data fit and resolution of the tomographic images.

The second part of the thesis shows the benefit of enhancing legacy seismic data from the Kalahari-Karoo Basin, Botswana. The curvelet transform is employed to reduce noise, thereby enhancing the interpretational capabilities of the post-stack reflection seismic sections. I show that the reflection seismic method, and in particular re-utilising legacy data, is an invaluable tool to prospect for coalbed methane resources in Botswana.