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Characterization of azimuthal anisotropy in a natural fluid escape structure in the northern North Sea via wide-angle reflection-refraction travel-time tomography: Initial results

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In September 2017, we carried out the CHIMNEY controlled-source broadband seismic experiment around the Scanner pockmark in the northern North Sea. The objective of our experiment was to study natural fluid escape structures and pathways within the shallow sediments, which may be analogous to potential near-surface leakage pathways from reservoirs used for long-term storage of carbon dioxide. Scanner pockmark is located in waters of ∼150 m depth and consists in 900 m by 450 m oval-shaped seafloor depression of ∼ 22 m deep with two deep areas. It is formed by active methane venting. A diffuse seismic reflection anomaly, with bright spots indicating the presence of gas within the sediments, is located below this seafloor depression.

We deployed 18 ocean bottom seismometers (OBS) within and around the pockmark, and 7 OBSs on a reference site showing no evidence of subsurface fluid migration. We acquired multi-azimuth profiles using five different sources (Bolt airguns, GI-guns and surface and deep-towed sparker sources) that produced a multi-frequency dataset (20 to 6000 Hz). Shots were recorded with a sampling rate of 4 kHz on the OBSs and on two streamers.

Aligned vertical fractures and cracks are known to produce azimuthal anisotropy. We studied the azimuthal anisotropy (horizontal transverse anisotropy, HTI) within the Scanner pockmark and at our reference site, using the travel times of wide-angle refracted and reflected phases of the GI-gun source shot at 8 s interval at 4 kn. The resolution was assessed by checkerboard tests for various grid spacings and the spacing which recovered the smallest wavelength structure with realistic amplitudes was chosen for the inversion. The inversion was carried out into multiple steps: in the first step one-dimensional (1D) initial models of velocity and percentage and orientation of anisotropy were used and the dataset of ∼ 134,000 first arrival times were inverted in three dimensions (3D) with strong smoothing for both velocity and the anisotropy. The resulting 3D models were then averaged and used as 1D initial models for a second step with lower smoothing. Then reflected phases are included into the inversion with a layer-striping scheme, starting from the shallowest interface. The preliminary results show a low-velocity anomaly below the pockmark.