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Imaging the Alpine Fault: preliminary results from a detailed 3D-VSP experiment at the DFDP-2 drill site in Whataroa, New Zealand

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The plate-bounding Alpine Fault in New Zealand is an 850 km long transpressive continental fault zone that is late in its earthquake cycle. The Deep Fault Drilling Project (DFDP) aims to deliver insight into the geological structure of this fault zone and its evolution by drilling and sampling the Alpine Fault at depth. Previously analysed 2D reflection seismic data image the main Alpine Fault reflector at a depth of 1.5-2.2 km with a dip of approximately 48° to the southeast below the DFDP-2 borehole. Additionally, there are indications of a more complex 3D fault structure with several fault branches which have not yet been clearly imaged in detail.
For that reason we acquired a 3D-VSP seismic data set at the DFDP-2 drill site in January 2016. A zero-offset VSP and a walk-away VSP survey were conducted using a Vibroseis source. Within the borehole, a permanently installed “Distributed Acoustic Fibre Optic Cable” (down to 893 m) and a 3C Sercel slimwave tool (down to 400 m) were used to record the seismic wavefield. In addition, an array of 160 three-component receivers with a spacing of 10 m perpendicular and 20 m parallel to the main strike of the Alpine Fault was set up and moved successively along the valley to record reflections from the main Alpine Fault zone over a broad depth range and to derive a detailed 3D tomographic velocity model in the hanging wall.
We will show a detailed 3D velocity model derived from first-arrival traveltime tomography. Subsets of the whole data set were analysed separately to estimate the corresponding ray coverage and the reliability of the observed features in the obtained velocity model. By testing various inversion parameters and starting models, we derived a detailed near-surface velocity model that reveals the significance of the old glacial valley structures. Hence, this new 3D model improves the velocity model derived previously from a 2D seismic profile line in that area.
Furthermore, processing of the dense 3C data shows clear reflections on both inline and crossline profiles. Correlating single reflection events enables us to identify the origin of reflections recorded in the data and reveal their 3D character. This array data gives strong evidence for reflections coming from the side, possibly from the steeply dipping valley flanks.
Finally, the data will be processed using advanced seismic imaging methods to derive a detailed structural image of the valley and the fault zone at depth. Thus, the results will provide a detailed basis for a seismic site characterization at the DFDP-2 drill site, that will be of crucial importance for further structural and geological investigations of the architecture of the Alpine Fault in this area.