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Meter-Scale 3D Seismic Data for High-Resolution Site Characterization

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Summary

High-resolution 3D site characterization can deliver reliable quantitative property volumes of the subsurface when based on seismic data able to image meter-sized objects. Following the theoretical analysis of seismic wave propagation in the shallow sub-surface, we present case studies based on re-processing of 3D P-Cable seismic data. The case study of data re-processing from the Vestnesa Ridge west of Svalbard and the outer Vøring Basin show that P-Cable 2.5D and 3D data can provide decimeter- to meter-scale vertical resolution of the shallow subsurface. Collection of new 3D P-Cable data with optimized acquisition parameters will provide meter-scale horizontal and vertical resolution. Therefore, 3D seismic volumes will represent the framework for data interpretation, integration and inversion where in situ measurements can be propagated with minimal data interpolation.

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High-resolution 3D site characterization can deliver reliable quantitative property volumes of the subsurface when based on seismic data able to image meter-sized objects. Following the theoretical analysis of seismic wave propagation in the shallow sub-surface (Lebedeva-Ivanova et al., 2018), we present here two case studies based on re-processing of 3D P-Cable seismic data.

The first case study is based on a seismic data cube collected by the University of Tromsø in 2013 for monitoring methane hydrate systems and fluid flow phenomena on the Vestnesa Ridge west of Svalbard. The data acquisition configuration permitted a natural bin size of 3.125x6.25 m. Our high-frequency seismic re-processing workflow allowed to image the first tens of meters below the seafloor with one-meter vertical resolution. Deeper structures (down to ~100-200 m) were possible to image with 2-3 m vertical resolution due to high signal attenuation in the sediments. Data re-processing increased the level of details, including better definition of faults and imaging of 3D chimney structures throughout the upper hundred meters of the sub-surface.

The second case study is based on swath seismic data from the outer Vøring Basin. The data were re-processed as a 3D cube with a 6.25x6.25 m bin size, focusing on uplifting the high-frequency components. The sediments in this area are characterized by regular layering and low signal attenuation. These sub-surface properties allowed imaging of structures with decimeter- to meter-scale vertical resolution for the upper several hundred meters below the seafloor. The re-processed data show the directions of faults and potential fluid leakage structures within the 90 m-wide swath. Results of a seafloor seep sampling campaign in 2016 revealed oil indications at the fault termination where the re-processed line imaged soft anomalies likely related to fluid migration. In addition, seismic reflections at upper meters of the seismic section are consistent with lithological boundaries observed on ~3 m long the gravity core.

Our case studies show that re-processed P-Cable 2.5D and 3D data can provide decimeter- to meter-scale vertical resolution of the shallow subsurface. Collection of new 3D P-Cable data with optimized acquisition parameters will provide meter-scale horizontal and vertical resolution. Therefore, 3D seismic volumes will represent the framework for data interpretation, integration and inversion where in situ measurements can be propagated with minimal data interpolation. These results are crucial for geohazards assessment and overburden management by generating the best possible 3D ground model.

References

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