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Characterization of the Elmshorn salt diapir caprock by SH-wave reflection seismic and Full Waveform Inversion

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Both sudden and continuous subsidence of the earth's surface pose a geohazard to the population and infrastructure, especially in urban areas. In Northern Germany, sinkholes occur often at salt dome highs, where dissolution affects the caprock, creating mass deficits in the shallow subsurface. Gravitationally driven subsidence of the overburden subsequently leads to both slow and sudden deformations of the surface.

The city of Elmshorn, situated partly on the top of a shallow salt dome structure of nearly 30-40 m below surface, has to deal with such surface deformations which have been the motivation of several investigations in recent decades. Existing geologic data based on drillings has recently been extended by a shear wave seismic 2D profile grid, to support mapping of the spatial course of the salt structures and overlying sediments in high resolution, and to identify areas prone to subrosion more precisely. The seismic profiles were acquired using an Elvis shear wave vibrator (source signal: 20-160 Hz sweep) and a land streamer attached with 10 Hz horizontal geophones in 1 m spacing. High-resolution stacked sections of 0.5 m CMP spacing were generated using shot spacing of 2-4 m. The profile grid shows that the shear wave reflection methodology is suitable to image the heterogeneous caprock surface and the fine structure of the overlaying Quaternary sediments. Strong topographic variations in the caprock surface and strongly heterogeneous lithology of both caprock and overlying sediments occur over short lateral distances less than 100 m, reinforcing the requirements for a close-meshed profile grid. Different caprock lithologies can be distinguished by changes in reflectivity and wavelength. Further, derived physical parameters based on full waveform inversions enable the characterization of the caprock surface and the integrity of the overlying sediments to estimate areas affected by subrosion.

The results highlight the structural information capabilities of the shear wave reflection method for the investigation of subrosion-prone areas as well as the further potential of the methodology to improve the knowledge of subrosion process sequences.