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The structure and neotectonic evolution of the Osning Fault System in Germany derived from near-surface P- and SH-wave reflection seismics and retrodeformation modelling

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Neotectonic movements pose significant hazards and hold crucial scientific and social relevance, notably in seismic hazard assessment and subsurface utilization. In regions like northern Germany, a presumed aseismic region, understanding these processes remains limited because many faults are buried under sediments. Despite confirmed neotectonic activity, the specifics of these processes and associated structures remain largely unknown.

Improving our understanding of neotectonic activity requires investigations of recently-active fault zones, such as the Osning Fault System (OFS) in North Rhine-Westphalia, Germany. Using near-surface geophysics becomes crucial in this endeavour, which so far were not used at the OFS.

The OFS stands out as a site of recent and historical seismic activity, experiencing several large earthquakes over the past four centuries. Notably, major earthquakes in 1612 and 1767 with intensities ranging from VI to VII on the MSK scale, emphasize the seismic significance of the OFS. Unlike other faults in the region, the faults of the OFS reach the basement and the fault zone dips north-eastward. Furthermore, the former iceload from Scandinavia influenced the fault system by facilitating glacial isostatic adjustment, which subsequently enabled fault reactivation. The complex nature of the fault system spans various geological phases, prompting a comprehensive investigation approach to understand its regional neotectonic evolution.

Our geophysical and geological approach integrates high-resolution 2D P- and SH-wave reflection seismics and retrodeformation of previously-published cross-sections. This is complemented by surface geological maps and limited drilling information. Our aim is to identify and interpret fault geometry and kinematics.

While P-wave seismic surveys used for imaging of deep structures often lack high-resolution in the shallow subsurface, the integration of SH-wave reflection seismics compensates for this limitation, offering enhanced resolution, especially at the near-surface. The survey involved three P-wave profiles employing a hydraulically-driven vibrator vehicle and four SH-wave profiles utilizing an electro-dynamic micro-vibrator with varying source point spacing.

These seismic profiles successfully delineate fault structures within the Cretaceous formations, revealing previously unidentified extensions of the OFS. Although the P-wave profiles inadequately

image the Quaternary layers, there are indications that the faults extend into this formation. The SH-wave profiles, with their superior resolution in the near-surface due to lower wave velocities, confirm these assumptions, revealing further faulting and deformation features within the Quaternary sediments. Interpretation and fault imaging are further enhanced by full waveform inversion of P- and S-wave data, testing of different migration methods for the S-wave data, and seismic attribute analysis.

Retrodeformation and balancing of existing cross-sections and the interpreted seismic profiles allows the fault geometry and kinematics to be assessed. We determined which adjustments were necessary to make the profiles more geologically plausible. This combined geophysical and geological approach enabled a more comprehensive interpretation and understanding of the local fault geometry and the neotectonic evolution of the OFS.