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Explicit topographic expressions of neotectonic movements along the Tønder Graben structure, Denmark – an example of fault reactivation due to deglaciation

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The topography in southern Denmark is dominated by Late Glacial outwash plains surrounding remnants of older Saalian hills. The outwash plains were formed outside the Last Glacial Maximum (LGM) with a gently sloping surface averaging 1 m per 1.000 m. Formed in a proglacial environment the outwash plains have largely remained undisturbed by glacier ice and we would thus expect any topographic irregularities to relate to postglacial events. In that sense, the outwash plains constitute an ideal landform for identifying tectonic events during the late and postglacial periods. Irregularities in the present day glacial topography, such as kettle holes and other types of depressions are commonly linked to decay of dead ice. But this perception needs in many instances a further examination especially because of the recent availability of highly detailed LiDAR data.

The investigation area is situated above the Tønder Graben structure at the northern margin of the North German Basin. The Tønder Graben was formed along the WNW-ESE trending Rømø Fault Zone and mobilization of Zechstein salt added to the evolution of the graben. The Tønder Graben has caused a significant impact on the Mesozoic and Cenozoic sedimentary successions and is for instance clearly expressed as large elongate depressions in the Top Chalk surface.

On the larger scale, no clear signs of the outline of the graben structure can be seen in the present day topography to indicate movements during the Quaternary. However, when high resolution LiDAR data is investigated carefully signatures of neotectonic movements emerges on the outwash plain. Among these are morphological features such as: 1) Significant level changes along distinct lineaments, 2) frequent slope changes of neighboring areas, 3) 180 degree changes in dip direction and 4) presence of close lying polygonal areas with marked shifts in terrain level. All these morphological features are found right on top of the Tønder Graben. In addition to these smaller scale morphological features we also identify a large area of the outwash plain without the expected slope forming a large and unusual threshold in the surface.

Combined with information from boreholes and seismic data we relate the morphological irregularities to movements of the underlying Tønder Graben structure. Because we observe both negative and positive morphological features we propose that the tectonic movement within the graben has a strike-slip component. Based on dating of soil samples from depressions in the outwash plain the onset of the movements are constrained to around 9.000 years BP. We conclude that the deformation of the outwash plain is related to short-term reactivations of faults related to the Tønder Graben structure following the deglaciation.