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HAMBURG – A DYNAMIC UNDERGROUND (The HADU project)

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In urban regions with high concentration of built-up areas, industrial plants and traffic routes the knowledge of subsurface structures and a long term surveying of underground stability is of general interest. It is important to specify the structural style of underground deformation to estimate potential georisks in order to prevent serious damages. The deeper geological underground of the metropolitan region of Hamburg is characterized by salt diapir emplacements. Some of these diapirs reach up close to the surface. Long-term uplift and subsidence due to creeping salt movements caused deformations in the overburden Quaternary sediments. Locally groundwater penetration along cracks dissolved the evaporitic rocks and induced collapse-endangered cavities. During the last two centuries about 40 subcircular sinkholes have been formed in Hamburg's city zone. Sudden subsidence results in local collapse-earthquakes. Some active sinkholes cause visible damages at the surrounding buildings.

The objective of the interdisciplinary BMBF/Geotechnologien project: "**Hamburg – A dynamic underground (HADU)**" is to generate one comprehensive geological subsurface-model of the underground structure and dynamics of the metropolitan region of Hamburg. The involved sub-projects Geology, University of Hamburg (Analysis of surface and georadar survey of shallow subsurface structures) Geophysics, Universities of Potsdam and Hamburg (Ambient Seismic Vibrations) and Informatics, University of Hamburg (Information and Visualization Technology) will combine all new acquired data and obtainable information for the visualization of underground structures and an accurate geohazard assessment. It is planned to apply the developed workflow to other comparable metropolitan regions.

The specific aim of the **sub-project Geology** is a standardized detailed re-investigation and interpretation of underground structures in the metropolitan region of Hamburg. Our main targets are: (a) to reveal the formation of circular structures and their potential georisks and (b) detection of areas affected by recent salt-tectonics and / or former glacial processes and (c) surveying of ongoing local subsidence in the town of Lüneburg initiated by medieval salt-mining. Of general interest is the recognition of larger underground anomalies with respect to the subsoil stability.

(a) Several “sub-circular depressions” in Hamburg are *collapse-structures* (sinkholes) and have been formed by ongoing subrosion processes. Sudden collapses occur up to present times and sediment infillings show multiple deformation. Georisks of these areas are moderate to strong and damage of buildings might occur. Other circular structures represent former *kettle-holes*, bowl-shaped depressions, characterizing the resting or burial places of huge dead-ice blocks during the Pleistocene whose final melting away left a hole. During later infilling of sediments, the peat filling at the bottom of the hole will cause slight downbending of the layers due to compaction; the uppermost layers are almost undisturbed. These structures imply very low georisks. Both circular structures, either collapse features or former kettle holes are forming nowadays many small depressions (lakes) infilled by fossil soils and sands in the urban area of Hamburg. Thus origin and formation of the depressions are not always clear and controversial discussed. Ground penetrating radar surveying allows clear differentiation whether the depressions are collapse structures or kettle-holes.

(b) Surface and shallow subsurface deposits are represented by a variety of undeformed and deformed glacial, interglacial and recent clays, sands, and gravel and can be distinguished by different radar facies. Diapiric activity is reflected in the sedimentary record by variations in thickness of the deposits and changes in the drainage pattern. Reconstruction of the geometry of the glacial deposits reveals their formation and allows their differentiation from salt induced soft-sediment deformation.

(c) Man-made solution of salt over centuries in the Lüneburg salt diapir and natural dissolving by ground water induced a subsidence area in the western part of the city where many buildings were demolished. From 2002 and 2004 active subsidence reached about 20 cm/year. Basements dropped dramatically and sewer pipes broke off. With high-resolution ground-penetrating-radar profiling down to a depth of about 10m we detected the extension of the subsidence area and characterized the subsidence edges. Significant reflectors indicate pseudotectonic normal faulting. The reflectors demonstrate an increase of the dip angle from about 10° in the distal area of the circular structure up to 32° in its centre. Detailed 3D-GPR mapping of the subsurface allows to locate the subsidence edges defining the endangered zone. The development of a subsidence model permits the estimation of local georisks and leads to first steps of reconditioning to stop further subsidence in the built-up area.

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