Geophysical Research Abstracts
Vol. 15, EGU2013-10049, 2013
EGU General Assembly 2013

Cognitive 3D geological voxel modelling based on AEM and seismic data – a case from the southern part of Denmark

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The highly complex composition of the Quaternary and Tertiary near-surface deposits in Denmark is a challenging environment for 3D modelling. Geological elements like cross-cutting buried valleys, faults, glaciotectonic thrusts and folds, delta units and erosional unconformities are vital to identify and include in 3D geological models, but at the same time they all add to the complexity of the geological picture. Borehole data are rarely sufficient for the modelling; instead much more laterally dense data are needed. Airborne electromagnetic techniques therefore serve as perfect tools for providing an overview and spatial distribution of the geological elements and their composition. Such airborne surveys are perfectly supplemented by seismic data in order to map the stratigraphic framework within a model area. Translating airborne electromagnetic data to geology is a complicated task that requires a significant amount of geophysical and geological insight. It is necessary to implement thorough geological background knowledge in the interpretations while at the same time identify and acknowledge the inherent limitations of the method.

In an area covering 730 km2 across the border between Germany and Denmark a combination of an airborne transient electromagnetic survey (3200 line km performed with the SkyTEM system) and a 38 km high-resolution 2D seismic survey has proven very successful for mapping geological elements like the above-mentioned. Although the south-westernmost part of the study area is saturated with saltwater and the TEM data therefore are influenced by increased electrical conductivity, the geology is still revealed here. Geological interpretations are supported by a high number of pre-existing seismic sections originating from hydrocarbon exploration and borehole data, though most of the borehole data and several of the seismic sections have very poor quality. A couple of new 300-m deep exploration boreholes have been drilled in order to obtain high quality sediment samples and down-hole geophysical logs.

A comprehensive geological overview and understanding of the area is gained by integrated and cognitive interpretation of the geophysical and geological data enabling a detailed and reliable 3D geological model to be built. The model covers the area on the Danish side of the border. In order to address the detailed information from the SkyTEM data, the model has been constructed as a voxel model combined with surfaces representing layer boundaries and unconformities. Lithofacies and interpretation uncertainty attributes have been added to each voxel. Geostatistic inversion has been used to distribute lithological parameters to voxels in the most complicated areas of the model (areas with glaciotectonism). Experiments with octree modelling giving a high resolution with a limited number of voxels have also been performed. The final 3D model is primarily intended to serve as an input for groundwater flow modelling. The voxel model will therefore be supplemented by another attribute, hydraulic conductivity.