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Anisotropic 3D – Pre-stack Seismic Depth Migration - a spatially reliable data source for planning and operating of salt caverns

Bernward Otto
Wintershall Holding, Kassel, Germany

Abstract

In the course of the construction of a new salt cavern gas storage facility next to the village of Jemgum (Southern Permian basin, northern Germany) the companies astora and VNG, owners of the asset, commissioned a detailed geological site characterization of the Jemgum - Rhaude salt canopy to Wintershall Holding at an early stage of project planning in 2009. Therefor a reprocessed 3D seismic volume of good data quality (anisotropic 3D controlled beam pre-stack depth migration combined with 3D gravity modeling) was made available and provided the key primary data source for seismic interpretation and subsequent structural subsurface model building.

In order to accelerate the two processes a new segment-based interpretation workflow in a first instance had to be developed to overcome the well-known multi-z-value restriction inherent to any seismic horizon interpretation system. Based on these polygonal segments the salt interface mesh has then been reconstructed using the ball pivoting (BPA) algorithm (Cignoni et al., 2008). In a blind test the same set of polygonal segments has been used to reconstruct the salt interface a second time by applying the discrete smooth interpolation (DSI) algorithm instead (Mallet, 2002). This allowed to quantitatively compare the resultant salt interface meshes and assess spatial modeling uncertainties due to application specific implementations.

In contrast to pseudo 3D salt models based on 2D seismic data the resultant structural depth model provided an accurate and highly sampled three-dimensional spatial foundation of high confidence. In addition to its value at project planning stage the subsurface model enabled drilling depth prognoses of key strata with average prediction errors of ± 4 m (just one seismic depth sample; roughly half a drill string) which facilitated the optimization of drilling costs. Eventually the accuracy of the subsurface static depth model got proven by five blind wells not taken into account during seismic processing and structural modeling. Drilling results of ten new salt cavern wells further confirmed a high spatial reliability of the resultant depth model.

Apart from now knowing the salt interface in detail state of the art seismic analysis allowed to determine rock mechanic key parameters like cap rock thickness, its spatial variation as well as salt tectonic overprint. Seismic opacity blending furthermore made it possible to identify intra-salt seismic anomalies, most probably Zechstein anhydrite stringers, which again have been taken into account while positioning the caverns. RGB blending of spectrally decomposed seismic cubes in addition allowed to unravel stratigraphic anomalies within the shallow overburden (mid-Miocene fluvial system) as well as in the deeper parts of the salt canopy next to the allochthonous basis of Zechstein salt. Finally the detailed subsurface characterization provided new insights into the development of this complex salt canopy consisting of two Kuh-E-Namak - style salt glaciers which joined over geological times.

Beyond more academic considerations this paper also discusses the real added value of above mentioned 3D analysis methods on cavern planning, drilling operations as well as its long term impact on running of salt cavern facilities.

Key words: 3D seismic, 2D seismic, Pre-stack Depth migration, Anisotropy, Spatial uncertainties, Salt modeling, Ball pivoting algorithm, Discrete Smooth Interpolation algorithm, Segment-based workflow, Surface reconstruction, Meshes, Seismic attributes, Trace curvature, Negative Second Derivative, Spectral decomposition, Added value, Cavern planning, Salt canopy, Salt glaciers, Miocene, Fluvial system, Zechstein, Germany, Lower Saxony basin, Jemgum, Rhaude, Visualization, RGB blending, Opacity tuning, Decision support