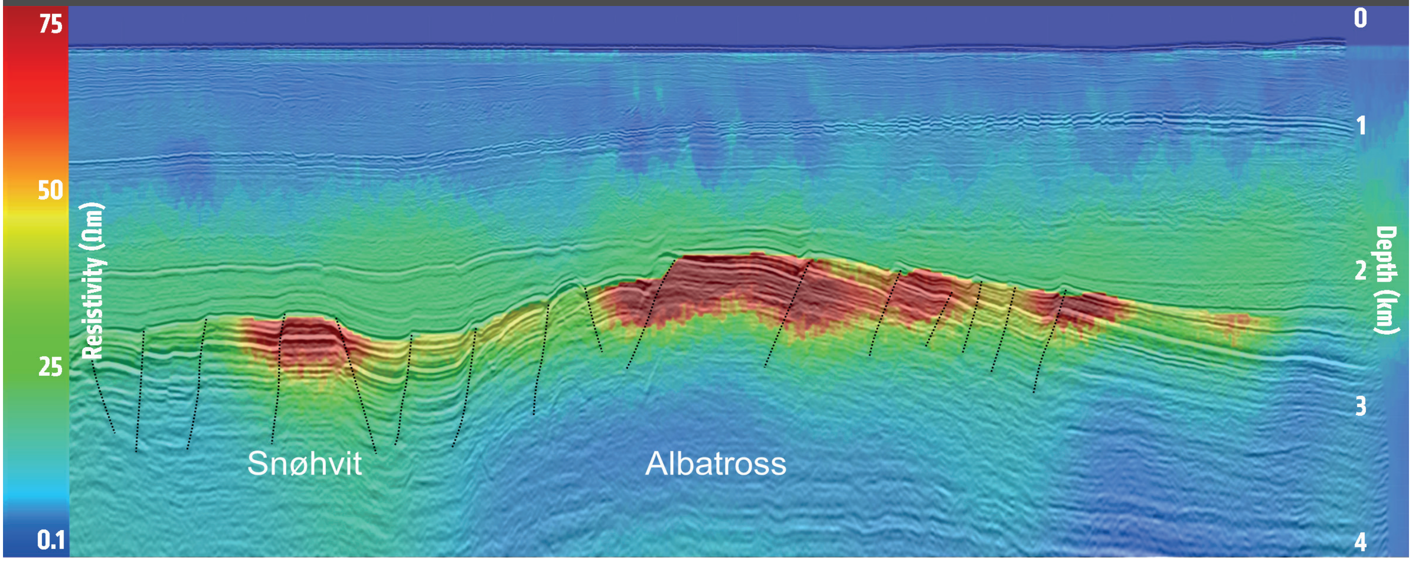
TechNote

Towed Streamer EM



Towed Streamer EM — Processing and Inversion

Towed Streamer EM data is monitored on board the vessel in real time as it is acquired. Once a sail line is complete offline QC is conducted, including a 1D QC inversion of every shot acquired. The EM field deliverable is denoised, navigation merged data, and this is delivered to both the customer and PGS' EM imaging team for 2.5D and 3D anisotropic inversion which is performed onshore.

Onboard and Real Time QC

Onboard QC and processing is standard during EM surveys, the processing flow is minimal and only involves denoise, deconvolution and a navigation merge, the output of which are the frequency responses - the EM field deliverable. These frequency responses are delivered to the customer in both MultiClient and proprietary EM surveys, enabling third party inversion of the data and a more open approach to data analysis than has been common in the past.

Inversion Codes

The inversion process is employed in order to get directly from frequency responses to sub-surface resistivity mapped with depth. A number of codes have been shown to be able to invert Towed Streamer EM data, both open source and proprietary. PGS uses the 2.5D code (MARE2DEM) to generate unconstrained and guided resistivity sections, this was was developed through the Scripps Seafloor Electromagnetic Methods Consortium and is freely available for oil companies to use. As EM acquisition is a volume sounding technique, PGS is also able to invert frequency responses acquired with a line spacing of <1.5 km into a 3D resistivity volume, delivering both horizontal and vertical resistivity, as well as anisotropy. iTEM is PGS' proprietary Gauss-Newton 3D inversion code which can invert datasets from large scale 3D surveys accurately and efficiently. iTEM has weak start model dependence and delivers rapid, stable convergence. It is particularly well suited to EM inversion through the provision of compensation

KEY BENEFITS

- Rapid turnaround / data delivery enables timely decision making in the context of brief exploration license periods
- Better exploration decision making through confidence in interpretation
- Improved understanding of the subsurface – improves chances of drilling success

EM Processing and Inversion Workflow	
Feasibility Study	Pre-survey work - Illumination studies, target recoverability,optimization of survey parameters.
Acquisition Support	Assistance with onboard data processing during acquisition.
QC of Deliverables	Generation and review of key data attributes.
Unconstrained Inversion	Conducted onshore, data driven,no assumptions made-1D half-space inversion ➡2.5D ➡3D
Guided Inversion	Initial seismic and EM integration requires some assumptions / knowledge about geological setting Structured grid / cut smoothness constraints across boundaries / add bounds on resistivity
Integration / QI	Further integration with seismic data / qualitative interpretation requires an amount of knowledge of geological setting

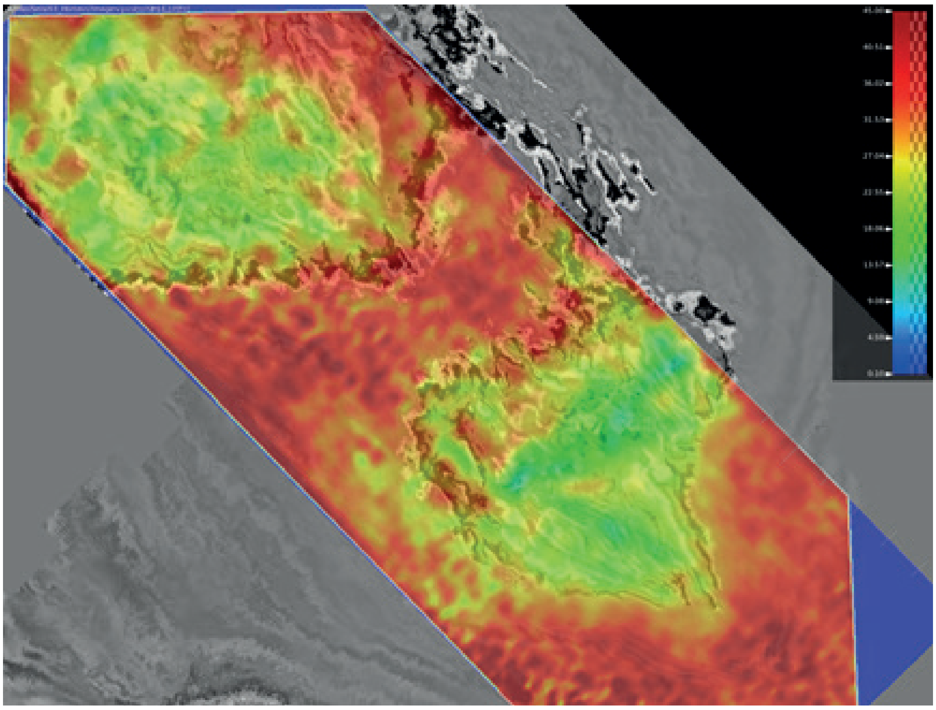
for exponential attenuation of the EM field, which removes the need for additional weighting.

Quantify Uncertainties and Derisk

To ensure confidence in the anisotropic inversion results PGS delivers 2.5D and 3D resistivity sections and volumes along with the frequency responses. Misfit data is also provided giving a statistical measure of how well the inversion results fit the measured data. Appropriate weights can then be assigned to EM data in the exploration workflow. Typical misfit values for unconstrained anisotropic inversion are in the range of 2-4 %.

Unconstrained to Seismically Guided Inversion

Performing unconstrained inversion of the EM data determines the subsurface resistivity and extracts the maximum amount of information from the data before introducing any constraints on the solution. PGS starts the 2.5D inversion process with a single value assigned to a homogenous half space. Due to the density of data acquired when using Towed Streamer EM, varying this initial value doesn't have a significant effect on the final output of the inversion. The only significant impact on varying this starting value is the number of iterations the inversion has to run through before it reaches the final model, the closer the initial value is to reality, the fewer the number of iterations required. This reliable approach to the inversion process is just one of the advantages of the significantly higher volume of data acquired using Towed Streamer EM.Seismically guiding the inversion allows anticipation of a significant change in subsurface resistivity at a specified boundary, usually one or more seismic horizon(s). This enables a higher resolution, seismic and EM integrated product to be produced, further increasing the understanding of the subsurface and dramatically derisking a frontier area when compared to using seismic alone.



Example vertical resistivity depth slice generated using iTEM – Area shown is ~5 000 sq. km in the Barents Sea Southeast