Electrical resistivity and anisotropy trends across the Barents Sea

Michelle Ellis*, Lucy MacGregor, Slim Bouchrara, and Amanda Geck Alvarez

Electrical anisotropy has a strong effect on controlled source electromagnetic (CSEM) data, and understanding this effect is key in ensuring robust survey design and well constrained data analysis. Electrical anisotropy can also provide key information that can be used to understand regional variations in rock physics properties as well as provide possible indications of geological drivers in an area, such as uplift. Despite the importance of anisotropy, until recently there have been no systematic studies of this parameter and how it varies with geology, lithology and setting. RSI's two year ERA project, built on our atlas of rock physics, addressed this deficiency, by examining regional trends and underlying controls of resistivity and resistivity anisotropy in the Barents Sea.

There are over a hundred exploration wells in the Barents Sea. Of these, eighteen which are in the public domain coincide with CSEM surveys acquired by EMGS and made available for the project. The bulk horizontal and vertical resistivity (and hence anisotropy) in major stratigraphic intervals around each of these wells was determined from the CSEM using a 1D stratigraphically constrained inversion approach. Other physical property information (velocity, porosity etc.) at each location was obtained from RSI's rock physics atlas. This atlas contains fully conditioned and modelled well log data. Well log data was averaged in each formation, to allow direct comparison with the CSEM results.

The results confirm the presence of high electrical anisotropy in the Barents Sea area, and show clear trends both geographically and with formation age. Figure 1 shows resistivity maps for the Kolmule formation. Resistivity increases towards the north of the Barents Sea. However anisotropy does not display the same regional trend. Cross plot analysis and rock physics modelling indicates that there are three mechanisms controlling the resistivity and anisotropy in the Barents Sea sediments. Porosity and pore fluid resistivity unsurprisingly are primary controls on the overall bulk resistivity. Alignment of the pore space and grains controls anisotropy in the shale dominated formations. This alignment is caused by the burial of the sediments. The subsequent 'freezing in' of the alignment during uplift, which affects the vertical resistivity to a greater extent than horizontal, results in an increase in anisotropy. This is illustrated in Figure 2, which shows how anisotropy and resistivity vary with maximum burial depth for the Kolmule formation. Clay content of the sediments has an effect on the resistivity and anisotropy but to a lesser degree than expected.

This work has led to a better understanding of the relationship between geophysical observations and the underlying physical properties of the rocks in this area. The results have also highlighted tantalizing correlations between electrical and elastic parameters. Whilst not causal, these suggest that at least some of the underlying controls on electric and elastic anisotropy are the same. As a result in future it may be possible to predict elastic anisotropy from the electrical equivalent. By constraining anisotropic parameters we can enhance our interpretation of the subsurface, build better surveys, produce more accurate feasibility studies and improve reservoir characterization.

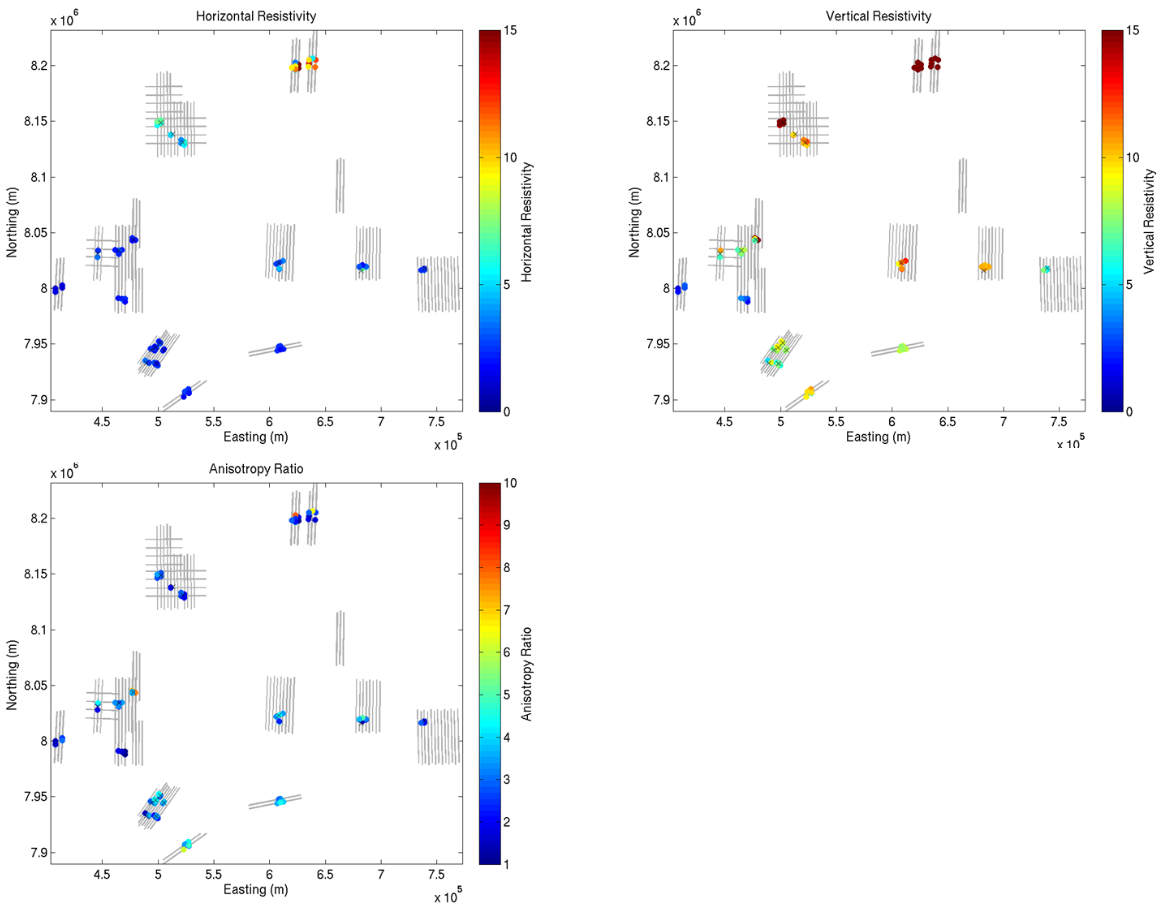

Figure 1. Maps of variation in electrical properties derived from CSEM data, for the Kolmule formation. Upper left plot is horizontal resistivity, upper right plot is vertical resistivity and bottom plot is anisotropy ratio. Each dot on the maps represents an inversion result for one arm of a CSEM receiver. Figure from Bouchrara et al., 2015, 85th Annual Meeting, SEG, Expanded Abstracts.

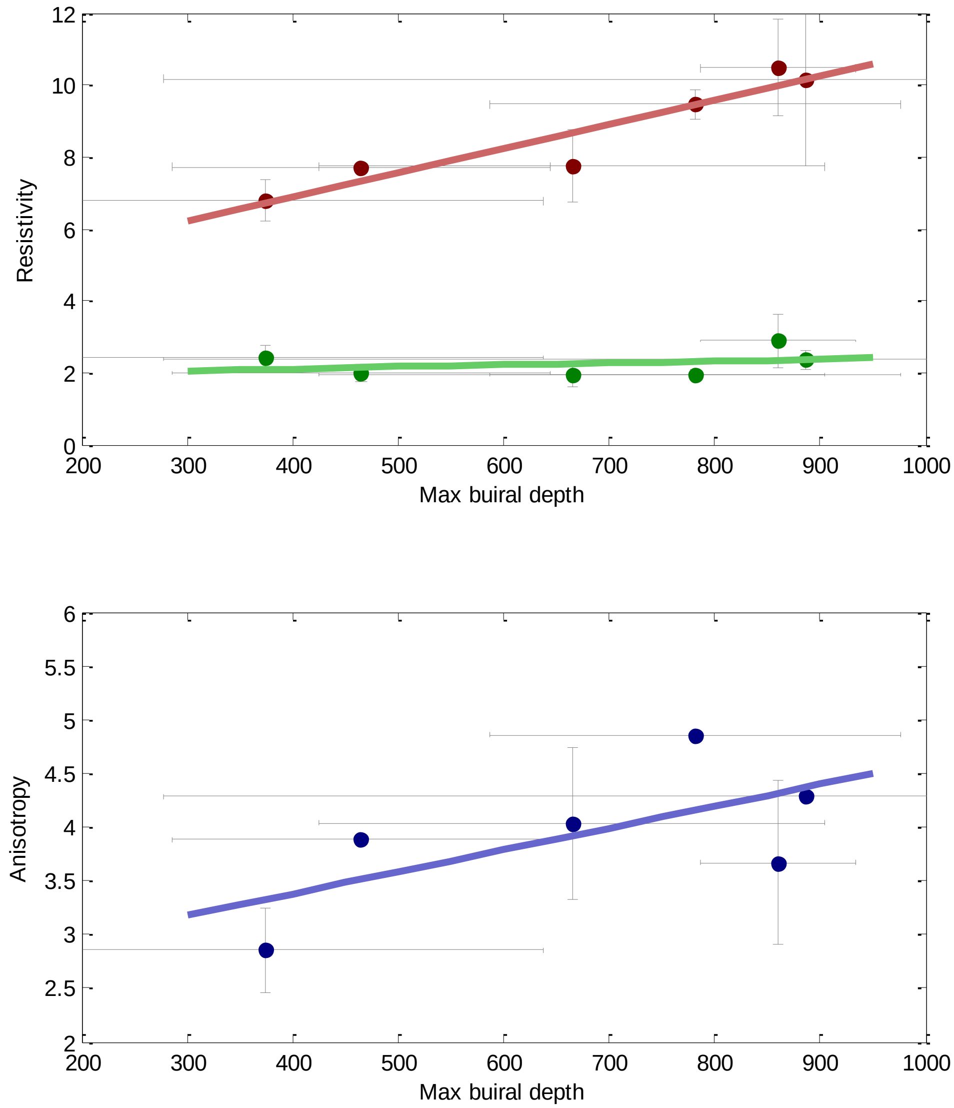

Figure 2. Top - Relative maximum burial depth versus horizontal resistivity (green) and vertical resistivity (red). Bottom - Relative maximum burial depth versus anisotropy (right) derived from the CSEM for the Kolmule formation.