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Gas hydrate occurrences in the Danube Delta, Western Black Sea: Results from 2D and 3D controlled source electromagnetics

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Marine controlled source electromagnetic (CSEM) data have been collected over gas hydrate targets in the Danube Delta off the coasts of Bulgaria and Romania in early 2014 during voyage MSM35 on R/V Maria S. MERIAN. The cruise was part of the German SUGAR Project, a joint venture project with the goal to study submarine gas hydrates as a source of methane. Within European waters the Black Sea is one of the most prospective hydrocarbon areas. Thick sedimentary basins, the existence of an extended gas hydrate stability zone and the observation of multiple bottom simulating reflectors (BSR) in the western part indicate a huge gas hydrate potential in sandy sediments. Low pore-water salinities between 1 and 4 ppt have been observed in borehole data at depths below $\sim$30 mbsf, and are attributed to sea level low stands in the past.

2D and 3D CSEM data sets have been collected over one of the channel levee systems of the Danube Delta fan. High-resolution 2D and 3D seismic, and OBS data are available in the same target area providing structural information and porosity profiles from seismic velocity data. Analysis of subsets of the 3D CSEM data reveal pore-water salinities around 4 ppt for the shallow sediment section, thus are not as low as suggested by the borehole data.

The inversion of both 2D and 3D CSEM data sets reveal highly anomalous resistivities within the gas hydrate stability field. We believe that high gas hydrate saturations are the likely cause, as low pore-water salinities are not sufficient to explain the high resistivities, seismic data indicate no clear gas migration pathways through the stability field, nor do hydro-acoustic data show areas of gas seepage which are confined to the landward edge of the stability field.

Estimates of the gas hydrate saturation are commonly derived from Archie's Law, and strongly depend on the proper choice of input parameters. We apply porosities from seismic velocity profiles, pore-water resistivities derived from salinity and temperature profiles, and Archie coefficients a, m, and n derived from laboratory studies with various sands and porosities. Gas hydrate saturation estimates vary between 20 and 60 % due to the wide range of input parameter, but are generally higher than estimates from seismic velocity data, an outcome also observed in other gas hydrate areas.