Nonlinear inversion algorithms for the controlled-source electromagnetic data

A. Abubakar[1], T.M. Habashy[1], Y. Zhang[2], V. Druskin[1], L. Knizhnerman[3] and D. Alumbaugh[2]

The marine controlled-source electromagnetic (CSEM) technology has attracted much attention for its capability in directly detecting thin hydrocarbon reservoirs. The approach is based on comparing the electric field amplitude as a function of the source-receiver offset with a similar measurement for a non-hydrocarbon bearing reservoir. The presence of hydrocarbon raises the amplitude of the measured electric field indicating the existence and to some degree determining the horizontal extent of the hydrocarbon zone; however with this approach it is difficult to know the reservoir's depth and shape. A more rigorous approach to address this type of application is the full nonlinear inversion. In this presentation we present two rigorous nonlinear inversion algorithms.

The first method is the so-called pixel-based inversion (PBI). In this approach the investigation domain is subdivided into pixels, and by using an optimization process the conductivity distribution of the investigated domain is reconstructed. The optimization process uses the Gauss-Newton minimization method augmented with various types of regularization. This PBI approach has demonstrated its ability to retrieve reasonably good conductivity images. However, the reconstructed boundaries and conductivity values of the imaged anomalies are still not adequately resolved. Nevertheless, the PBI approach can provide some useful information on the location, the shape and the conductivity of the hydrocarbon reservoir.

The second method is the so-called parametric inversion algorithm (PIA), which uses a priori information on the geometry to reduce the number of unknown parameters and to improve the quality of the reconstructed conductivity image. This PIA approach can be also used to refine the conductivity image that we obtained using the PBI algorithm. The PIA also adopts the Gauss-Newton minimization method. The parameters that govern the location and the shape of an anomaly include the depth and the location of the user-defined nodes for the boundary of the region. The unknown parameter that describes the physical property of the region is the conductivity.

We will show some inversion results of synthetic and field data to illustrate the PBI and PIA approaches. We further show that by combining both inversion algorithms we arrive at a better interpretation of the controlled-source electromagnetic data.

[1] Schlumberger-Doll Research
[2] Schlumberger, USA
[3] Central Geophysical Expedition, Russia