FAST PRACTICAL INVERSION OF MULTI-WELL INDUCTION RESISTIVITY MEASUREMENTS

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ABSTRACT

A number of three-dimensional (3D) simulators of borehole logging measurements have been developed during the last two decades for oil-industry applications. These simulators have been successfully used to study and quantify different physical effects occurring in 3D geometries. Despite such recent advances, there are still many 3D effects for which reliable simulations are not available. Furthermore, in most of the existing results only partial validations have been reported, typically obtained by comparing solutions of simplified model problems against the corresponding solutions calculated with a lower dimensional (2D or 1D) numerical method. In addition, three-dimensional simulations are rarely employed for the real-time inversion of borehole resistivity measurements due to their elevated computational cost. The lack of 3D simulation results (as opposed to 2D results) is due to major difficulties encountered when solving geometrically challenging problems. Namely, for mesh-based methods (Finite Elements, Finite Differences, Boundary Elements, etc.), the size of the system of linear equations becomes excessively large to be solved in real (logging) time.

In this presentation, we describe a computer library for the inversion of induction resistivity measurements. The library approximates a given three dimensional (3D) transversely isotropic (TI) formation by a sequence of various one dimensional (1D) sections. The well trajectory is arbitrary and the method is suitable for any commercial logging devices with known antennae configurations, including tri-axial instruments. Moreover, it enables to simultaneously invert results acquired at different wells and/or with different logging instruments. Forward simulations are computed semi-analytically for a sequence of 1D reduced models where both borehole and mandrel effects are assumed negligible. The inversion method employs a gradient based Gauss-Newton algorithm. It requires no user expertise, as it automatically determines the weights, regularization parameter, *a priori* information, Jacobian matrix, inversion variable, and stopping criteria. Given one or various apparent resistivity logs, a description of the employed logging instrument, the well trajectory, and the formation model, the inversion library delivers: (a) a resistivity distribution over each layer that minimizes the misfit of the data, and (b) the corresponding error bars expressing the degree of uncertainty of the inverted results.

Numerical inversion results of challenging synthetic and actual field data confirm the high stability and superior approximation properties of the developed inversion algorithm. They also demonstrate that triaxial measurements provide significantly more stable inversion results than conventional Hzz-based measurements in several scenarios, including: (a) certain anisotropic formations, and (b) in the vicinity of a high-contrast resistivity interface that is never crossed by the logging instrument.

Because of the efficiency, flexibility, and stability of the inversion algorithm, it can be readily employed by formation-evaluation specialists for routine analysis and appraisal of complex LWD and wireline resistivity measurements acquired under general geometrical and geological constraints.