Nanoparticles for Electromagnetic Fields Enhancement in Cross Well Imaging of Subsurface

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During the past two decades there has been increasing interest in the cross well imaging of the subsurface for oil exploration applications. As more and more deviated and horizontal wells are drilled in an attempt to increase the oil production, the azimuthal symmetry no longer holds. Up to present, many numerical methods have been developed for the forward modeling of 3-D cross well logging, including the finite element method (C. Li, B. Xiong, and Y. Lv, Geophysical and Geochemical Exploration, 36, 585-590, 2012), stabilized biconjugate gradient fast Fourier transform method (BCGS-FFT) (Z. Q. Zhang, and Q. H. Liu, Trans. Geosci. and Remote Sens., 41, 998-1104, 2003) and extended Born approximation (H. Tseng and K. Lee, Twenty-Ninth Workshop on Geothermal Reservoir Engineering, 2004).

Typically, most of existing methods used in the forward and inverse modeling of subsurface features in well logging problems are based on the variations in the conductivity and/or electric permittivity but have ignored variations in the magnetic permeability. The capability of nanoparticles to increase the permeability contrast in the formation and in oil properties can be taken advantage of to enhance the signature of the received magnetic field. This further enhances the accurate localization of the oil reservoir and the oil recovery.

In this paper we investigate the forward modeling of the electromagnetic fields enhancement with nanoparticles for 3-D cross well logging. We first present the stabilized biconjugate gradient fast Fourier transform method (BCGS-FFT) for the forward modeling of 3-D cross well logging with both dielectric/conductivity and permeability contrasts. For N unknowns inside the computation domain, the computer memory requirement is $O(N)$ and the CPU time is $O(N\log N)$ in the BCGS-FFT methods, which is significantly more efficient than the traditional method of moments (MOM). For low dielectric/conductivity and permeability contrasts, the extended Born approximation is also presented in this paper, which further accelerates the computation speed compared with the BCGS-FFT method. Both methods have been validated with analytical results and are shown to be efficient for 3-D cross well forward modeling. Numerical simulations show that the enhanced secondary electromagnetic fields can be received by introducing the nanopartices as the magnetic contrast agent. This helps the further improvement of the accurate localization of the oil reservoir and the enhancement of oil recovery.