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Model response curves and surveying aspects in crosshole MMR

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Computational and instrumental advances within the domain of multi-dimensional modeling and magnetic-field sensing revived the idea of using magnetic-field measurements as a complement to standard geoelectrical methods. The magnetometric resistivity method (MMR) measures the magnetic field in response to an injected low-frequency electric current in the subsurface. As a step towards the implementation of MMR for crosshole imaging, this paper addresses various aspects of importance in crosshole MMR surveying. Results from synthetic model studies, which were performed in order to ascertain the most suitable data acquisition geometry, as well as results from a first field survey are presented. The model studies consider both the anomalous magnetic field of interest due to simple but relevant subsurface structures and the overlapping magnetic field due to current flow in the wires to and from the injection electrodes. Modelling of anomalous magnetic fields was performed using a newly developed 2.5D finite-element code. Magnitudes of the cable effect are calculated using a numerical implementation of a simplified form of Biot-Savart's law. Response characteristics according to single-borehole, cross-borehole, borehole-to-surface and surface current excitations are investigated. In-hole configurations are found to be most suitable as they combine sufficiently high anomalous field values, model curve characteristics advantageous for detecting subsurface structures, and low-level source-generated noise. The described field measurements involve

low-frequency (25 Hz) current injection in one borehole and total magnetic field measurements in another one. Data acquisition was realized using prototype field instrumentation, developed at the Central Institute for Electronics and three-axes Bartington fluxgate sensors. Measuring density is determined by constant electrode separation of 2.4 m and sensor separations of 0.8 m. In order to compensate for the arbitrary azimuthal positioning of the borehole sensors, we implemented an orientation correction that transforms all recorded data into a local coordinate system. Data reduction is based on normal and reverse current injections as well as on analytical estimates of the primary and normal magnetic fields. The processed data are qualitatively validated, based on a conductivity distribution obtained from the inversion of independently collected ERT data. Measured and modelled data show an overall good fit. Data interpretation benefits from the derived model curves and reveals that complementary information is obtained by analyzing ERT and MMR data. The described adaptation of MMR to near-surface crosshole imaging represents a step towards the development of the so-called Magneto-Electrical Resistivity Imaging Technique (MERIT) as a new tool for hydrogeophysical investigations. MERIT considers simultaneous acquisition and joint inversion of ERT and MMR data, and is expected to be capable of resolving subsurface structures better than ERT or MMR alone.