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Measuring and interpretation of three-component borehole magnetic data

C. Virgil (1), S. Ehmann (1), A. Hördt (1), M. Leven (2), and E. Steveling (2)

(1) Institute of Geophysics and extraterrestrial Physics, TU-Braunschweig, Braunschweig, Germany (c.virgil@tu-bs.de), (2) Institute of Geophysics, University of Göttingen, Göttingen, Germany

Three-component borehole magnetics provides important additional information compared with total field or horizontal and vertical measurements. The "Göttinger Bohrloch Magnetometer" (GBM) is capable of recording the vector of the magnetic field along with the orientation of the tool using three fluxgate magnetometers and fibre-optic gyros. The GBM was successfully applied in the Outokumpu Deep Drill Hole (OKU R2500), Finland in September 2008 and in the Louisville Seamount Trail (IODP Expedition 330) from December 2010 until February 2011, and in several shallower boreholes.

With the declination of the magnetic field, the GBM provides additional information compared to conventional tools, which reduces the ambiguity for structural interpretation. The position of ferromagnetic objects in the vicinity of the borehole can be computed with higher accuracy. In the case of drilled-through structures, three-component borehole magnetics allow the computation of the vector of magnetization. Using supplementary susceptibility data, the natural remanent magnetization (NRM) vector can be derived, which yields information about the apparent polar wander curve and/or about the structural evolution of the rock units. The NRM vector can further be used to reorient core samples in regions of strong magnetization.

The most important aspect in three-component borehole magnetics is the knowledge of the orientation of the probe along the drillhole. With the GBM we use three fibre-optic gyros (FOG), which are aligned orthogonal to each other. These instruments record the turning rate about the three main axes of the probe. The FOGs benefit from a high resolution ($< 9 \cdot 10^{-4}$ °) and a low drift (< 2 °/h). However, to reach optimal results, extensive data processing and calibration measurements are necessary. Properties to be taken into account are the misalignment, scaling factors and offsets of the fluxgate and FOG triplet, temperature dependent drift of the FOGs, misalignment of the fluxgate and FOG triplet in respect with each other, as well as start and end position of the probe with respect to Earth's reference frame.

Using the high precision gyro data, we can compute the vector of the magnetic anomaly with respect to the Earth's reference frame North, East and Downwards. Based on the comparison of several logs, the estimated precision is 0.8 ° in azimuthal direction and 0.1 ° in inclination. Additionally, the orientation information provided by the GBM is used to compute the borehole path with a relative accuracy better than 0.35 %.