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Characterization of magnetized ore bodies based on three-component borehole magnetic and directional borehole seismic measurements

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In the last decades magnetic prospecting using total field data was used with great success for localization and characterization of ferromagnetic ore bodies. Especially borehole magnetic measurements reveal important constraints on the extent and depth of potential mining targets. However, due to the inherent ambiguity of the interpretation of magnetic data, the resulting models of the distribution of magnetized material, such as iron ore bodies, are not entirely reliable. Variations in derived parameters like volume and estimated ore content of the expected body have significant impact on the economic efficiency of a planned mine. An important improvement is the introduction of three-component borehole magnetic sondes. Modern tools comprise orientation modules which allow the continuous determination of the tool's heading regardless of the well inclination and independent of the magnetic field. Using the heading information the recorded three-component magnetic data can be transferred from the internal tool's frame to the geographic reference frame. The vector information yields a more detailed and reliable description of the ore bodies compared to total field or horizontal and vertical field data. Nevertheless complementary information to constrain the model is still advisable.

The most important supplementary information for the interpretation of magnetic data is the knowledge of the structural environment of the target regions. By discriminating dissimilar rock units, a geometrical starting model can be derived, constraining the magnetic interpretation and leading to a more robust estimation of the rock magnetizations distribution. The most common approach to reveal the lithological setting rests upon seismic measurements. However, for deep drilling targets surface seismic and VSP lack the required spatial resolution of 10s of meters. A better resolution is achieved by using directed sources and receivers inside the borehole.

Here we present the application of three-component (3-C) borehole magnetic measurements in combination with directional three-component borehole seismic in the Kiirunavaara iron ore mine (Kiruna, Sweden), operated by Luossavaara-Kiirunavaara AB. In order to derive the 3-C borehole magnetic data we applied the "Göttinger Borehole Magnetometer" (GBM) while the directional 3-C seismic data was recorded using a Seismic Prediction While Drilling (SPWD) prototype, developed and operated by the Helmholtz-Zentrum Potsdam - Deutsches GeoForschungsZentrum (GFZ). Both tools yield information of comparable spatial resolution of 10s of meters, with a depth of investigation of $\sim$ 100s of meters. The high-resolution, directional seismic data was used to create a geometric model of the rock units in the vicinity of the borehole. Based on the structural information, a starting model for the interpretation of the magnetic data was derived, significantly reducing the ambiguity of the interpretation. Based on the magnetic properties and the seismic velocity, potential ore bodies are characterized. The results will help to develop next generation survey concepts, contributing to more efficient exploration and thus to a more economic use of resources.