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Induced polarization and transient electromagnetic surveys for the characterization of a graphite ore

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The prospection of electrical conductors and semi-conductors has been one of the classical applications of the induced polarization (IP) method, with recent laboratory studies permitting to gain a deeper insight into the parameters controlling the polarization response. However, the application of electrochemical models developed for laboratory measurements has been rarely taken into field-scale imaging data sets. To fill this gap, here we discuss IP imaging results collected in Zettlitz (Austria), a former quarry operated between 1855 and 1967 for the extraction of graphite, an electrical conductor. The general goal of the geophysical survey is to characterize the geometry and volume of the residual graphite at the site. To this end, frequency-domain IP imaging measurements were collected along 10 main transects using different geometries, with selected data sets collected in the frequency range between 0.25 and 1 Hz to gain information about the frequency-dependence of the electrical properties. As expected, initial measurements revealed a high IP response in the graphite-rich areas. Nevertheless, the high electrical conductivity of the materials resulted in low voltage readings and an important decrease in the signal-to-noise ratio for deep measurements; thus, significantly reducing the depth of investigation. To overcome this limitation, we conducted measurements at areas of interest using transient electromagnetic (TEM) soundings, which are favored by the high conductivity of the targeted graphite and permit a better delineation of the contact to the calcareous host-rock. Initial analysis of the TEM data revealed a poor consistency with the electrical models retrieved from the IP surveys. However, taking into account the IP effect within the inversion of the TEM data significantly improved the consistency in the subsurface models resolved by the different methods. In order to resolve for adequate parameters for the modeling of TEM signatures, IP measurements were also collected at relevant positions in the frequency-range between 0.01 and 10000 Hz, with a high accuracy electrical impedance spectrometer. Further IP measurements were also collected in rock samples in the laboratory to aid in the interpretation of the field surveys and to permit the numerical modeling of the electrical signatures using a recently proposed electrochemical model. Our results demonstrate that the combination of IP and TEM surveys provide an improved modeling of the field signatures and, thus, a better characterization of the site. Additionally, we discuss the applicability of existing empirical and numerical models for the quantitative interpretation of field surveys.