Application of the Debye decomposition approach to time domain induced polarization profiling data: an ore exploration example

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In hydrothermal and metasomatic deposits, gold is frequently accompanied by sulphide minerals of different grain size and shape depending on degree of alteration of host rocks. We applied Time Domain (TD) Induced Polarization (IP) method combined with Debye Decomposition approach (DDA) to profiling data, in order to map zonality of the altered rocks within Julietta porphyry gold-silver deposit (Magadan region, Russia).

Gold is presented in veins. The veins are of complex shape and are surrounded with halos of low temperature altered rocks (beresite) with a thickness from 10 to 100 m. The altered rocks are of similar mineralogical composition (quartz, calcite, sericite, peach, sulphides) but with different metallic particle amounts, size and aspect ratio, which corresponds to different alteration degree. The veins are hosted by volcano-sedimentary deposits mainly of andesite composition, which are penetrated by numerous small intrusions (from rhyolites to basalts).

We carried out TD IP profiling with a pole-dipole (A120M40N) arrays, and with commercial instrument Cycle-IP-2 (current wavelength form was 2 s on-time and 2 s off-times with pulses of opposite polarity). IP decays were measured from 0.03 to 1.3 s in time windows (0.005 s), which allowed us applying the DDA. We also used a conventional magnetic survey.

In addition to traditional chargeability, based on DDA, for each station, we obtained the relaxation time distribution (RTD), the total chargeability and the mean relaxation time. In the data analysis we used previously obtained petrophysical relationships between the total chargeability (M) and volumetric content of the sulphide particles (ξ):

$$M \approx k\xi \tag{1}$$

and between the mean relaxation time (τ) and the particle radius (r):

$$\tau \sim r^2 . \tag{2}$$

Figure 1 shows the traditional geophysical parameters (apparent resistivity, chargeability, and total magnetic field, Fig. 1a), the integral IP parameters obtained from DDA (total chargeability, mean relaxation time, Fig. 1b), RTDs typical of the studied area (Fig. 1c), and a geophysical model of the deposit (Fig. 1d).

Three types of altered rock were found (Fig. 1d). The first type is characterized by increased apparent resistivity values (1000 – 4000 Ωm), small values of the chargeability (1.5 %) and total chargeability (6 %), a monotonously decreased RTD. This geophysical signature is typical of quartz and quartz-carbonate zones with very small amount of sulphide minerals ($\xi \leq 1 – 1.5$ %), which is not detected by IP. These zones can be found by increased apparent resistivity values; however these values are also typical of small intrusions.

The second type shows values of the apparent resistivity, chargeability and magnetic field similar to those typical of host andesites. However, RTDs are characterized by large values at early time range (< 0.1 s). These values are produced by a relatively small amount (up to 3 %) of fine grains of sulphide minerals ($r < 0.1$ mm). Moreover, for this type of altered rocks the total chargeability increases up to 12 %. This geophysical characteristic is typical of silicification areas with quartz-carbonate veinlets and low amount of sulphides with small grain size. Zones of the second type can be mapped on the basis of the DDA parameters only.

The third type shows large values of the chargeability (5 – 6 %) moderate apparent resistivity values (1500 – 1800 Ωm) and decreased values of the magnetic field (which is a manifestation of high alteration degree). RTD shows increased values at late times (> 1 s), which is typical of large metallic grains (Eq. 2) or for the case of high aspect ratio of the grains. This

geophysical characteristic is typical of beresites (including pyrite, sericite, carbonate, quartz and illite), which contains veinlets (frequently with gold) with 2 to 7 % of pyrite, chalcopyrite and galena.

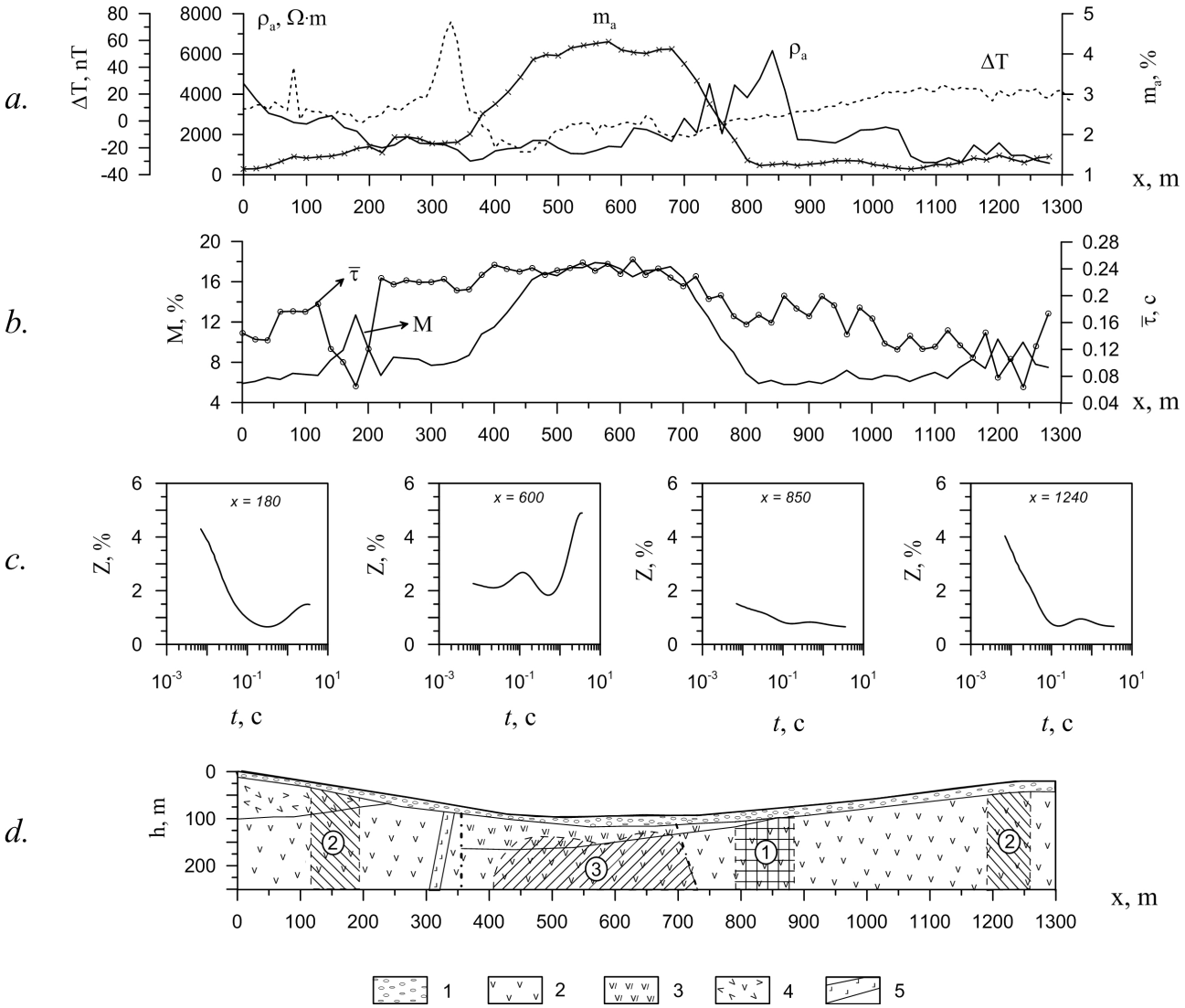

Fig. 1: Geophysical parameters along a line crossed altered rocks containing gold mineralization. a: apparent resistivity (ρ_a),chargeability (m_a) and total magnetic field (ΔT) distributions; b: total chargeability (M) and weighted average relaxation time (τ); c: typical RTDs, and geophysical model. 1 – Quaternary deposits, 2 – andesites, 3 – tuffs of andesites, 4 – porphyry andesites; 5 – andesite dyke.

Application of DDA to profiling data allows obtaining additional information comparing the standard processing procedure. One type of zones of altered rocks among three, which is economically important can be detected on the basis of RTD parameters only. The geophysical model (Fig. 1d) is confirmed by drilling results.