Interpretation of a clay rock's desaturation process with IP methods

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This study investigates the desaturation of a clay rock with Electrical Resistivity Tomography (ERT) and Induced Polarization methods used in time (TDIP) and spectral domains (SIP) in the experimental Underground Research Laboratory of Tournemire (Aveyron, France) which belongs to the French Institute of Radioprotection and Nuclear Safety (IRSN). The desaturation process is investigated from the older gallery (East-96), excavated in 1996, in the experimental test site over profiles concerning floors and walls of the gallery. The desaturation has interpreted by two approaches: (1) all electrical parameters and observations gathered for a profile including floor and walls (U profile, see Fig. 1) at a time of acquisition, (2) monitoring the Excavation Damaged Zone's (EDZ) evolution with ERT and TDIP methods during two different periods (June 2008 and February 2009) having different hygrometry values.

The East-96 gallery has no surface-coating (directly clay rock) and the investigated layer is an EDZ including fractures originated from mechanical stress release (new fractures, mm) and hydric modifications due to the ventilation of gallery (hydric fractures, mm) after the excavation. ERT and TDIP measurements were carried out with a Syscal Pro device (IRIS instruments) while SIP measurements were performed (46 mHz – 12 kHz) with the SIP FUCHS-II apparatus (Radic Research). To install electrodes, drillings with holes 12 ± 1 mm in diameter and with a depth of 5.0 ± 0.1 cm are realized. After that, the injection of wet bentonite into these micro-drillings is made. Non-polarizing $Cu/CuSO_4$ electrodes (6 mm in diameter) were used during injection and potential measurements. Figure 1 shows ERT and TDIP tomograms and the apparent imaginary conductivity spectra obtained from SIP measurements over the U profile. The inversion of the chargeability and the resistivity on U profile has been carried out with the software Res2Dinv from Geotomo (Loke and Barker 1996). We separated the collected data as North wall, South wall and ground into files and then the inversion is applied separately for each section.

Our study over the U profile of East-96 gallery show that hydric fractures on walls cause textural modification on the rock which are interpreted as a continuous layer with high resistivity (100 – 160 Ωm) and low chargeability (≤ 2 mV V^{-1}) values. While at the ground, where we observe new fractures, the EDZ is more important compared to wall's EDZ according to resistivity values. The different state of damage between gallery walls and ground can be related to anisotropy of the rock. Another explication of this difference on the damage can be explained by the work of Ramambasoa (2001). This author indicated that hydric fractures have a hydromechanic behaviour which is a function of ambient hygrometry. In summer (humid period), hydric fractures are closing, while in winter (dry period), hydric fractures are opening. New fractures associated with stress release do not show such kind of hydromechanical behaviour. In consequence, except the mechanical damage, ground seems to be subjected to desaturation process over the all year which amplifies the state of damage at this zone. Thus, new fractures allow desiccation of the clay rock though its cracked-air filled structure penetrating through the depth of the rock (Okay et al. 2013). A very sensitive parameter to water content (Ghorbani et al. 2009), the apparent imaginary conductivity spectra, obtained for a Wenner array C1P1 = 40 cm, also support this statement. Ground show the lowest polarization amplitude compared to gallery wall. Consequently, the lower amplitude of σ'' support the strongly desaturated state of ground compared to the gallery walls. As an another result, monitoring the EDZ's evolution with TDIP method during two different periods (June 2008 and February 2009) having different hygrometry show the change of resistivity and chargeability confirming Ramambasoa (2001) and the desaturation penetrating in deeper layers of the clay rock.

Finally, SIP tomography obtained from longitudinal profiles at ground show the desaturated state of clay rock with an emphasized visibility with increasing frequency (187, 375 and 750 Hz).

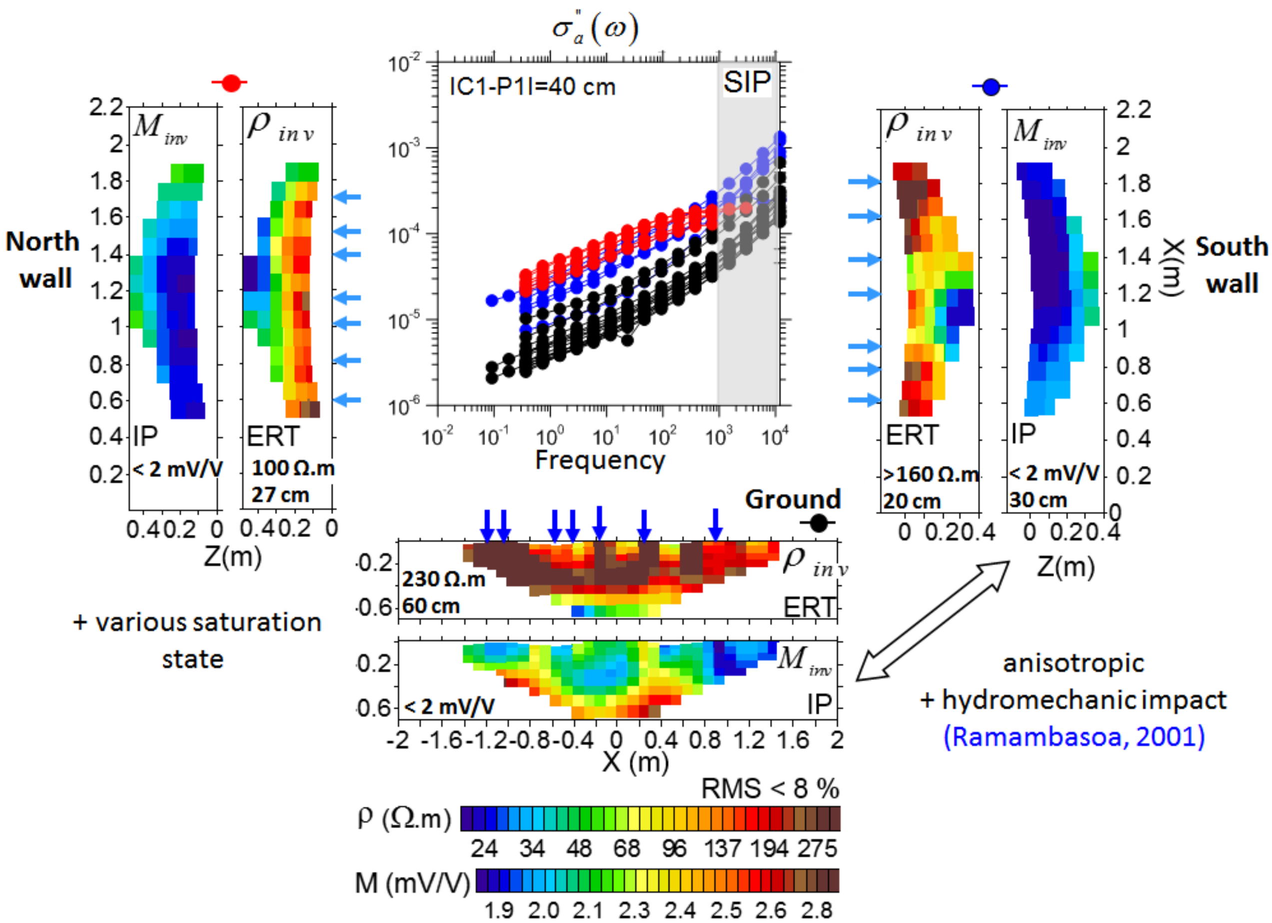

Fig. 1: Electrical resistivity and TDIP tomograms at the East-96 gallery U profile (concerning North wall, South wall and the ground) and the imaginary conductivity spectra. Each curve on the spectra indicates a measurement of a frequency range over a position on the U profile. This means that red curves interpret measurement on the North wall, blue curves interpret measurements on the South wall and black curves indicate measurements on the ground (all with Wenner array).

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