

Electrical Impedance Tomography in geophysics, application of EIDORS

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Introduction

The open-source collaborative software suite EIDORS (Adler and Lionheart, 2006), has been written primarily with a focus on medical imaging. This paper describes our work to adapt EIDORS for applications in geophysics. In geophysics, we apply EIT in order to image inner structures of geological objects since the rock resistivity can vary by several orders of magnitude depending on the rock nature, porosity and water content. The geometry of the electrode array consists most often in profiles of regularly spaced electrodes. And the geometrical factor is usually calculated to represent quickly the apparent conductivities, this allows to control the data quality in the aftermath of their acquisition. The distance between the electrodes defines the spatial resolution and the penetration depth. The spatial resolution of the method in geophysics is of the order of meters and the penetration depth can reach 500m.

We adapted the software EIDORS to inverse two sets of geophysical data. The first data set correspond to a study of the impact of excavations on clay properties in the Mont Terri underground rock laboratory. The second data set has been acquired on la Soufrière de Guadeloupe volcano to constrain the geometry of the hydrothermal system. EIDORS allows us to take into account the geometry of the electrode arrays and to make joint inversion of huge data sets in order to achieve a 3D tomography of the geological object. Moreover, the possibility of interaction with the EIDORS community allowed rapid development and answering of questions. This leads to a collaboration which aims at developing the geophysical applications of this free and open access software.

Applications

The Mont Terri project

The Mont Terri project (Switzerland), started with the observation of low humidity in the opalinus clay layer during the excavation. This rock presents useful properties of permeability suitable for nuclear waste storage. An underground rock laboratory has been constructed which welcomes experiments to characterise the mechanical behaviour of opalinus clay and follow the variations of its properties induced by the excavation or by a heating of the formation.

Three arrays of electrodes have been placed on rings around a gallery to follow the excavation damaged zone, Fig. 1. The gallery finite element model is computed from the positions of the electrodes to fix the gallery geometry, Fig. 2. Low conductivity areas are determined and interpreted as more damaged zones, Fig. 3 and 4. Repeated measurements on rings allow to perform a time monitoring which shows a reduction of the damaged zone. This confirms the auto-healing properties of the opalinus clay (Gibert *et al.*, 2006). The inversion of these data sets requires to take into account the circular geometry of the array and with parameters that can be different from those of the direct problem. We adapted EIDORS to fulfill these requirements since this software offers the possibility to choose the algorithm of the direct and inverse problems.

The study of la Soufrière de Guadeloupe volcano

The study of volcanoes with this method is also particularly interesting since hydrothermal

conduits can be characterized by high conductivities, regions with low densities can be interpreted as non altered rock and the regions with the lower densities may correspond to fractured areas. An array of electrodes has been set up on profile around and across the volcano, Fig. 5. The apparent resistivity shows a high conductivity zone under the volcano which may be interpreted as an area altered by the hydrothermal system. The data set reveals also that the volcano is highly heterogeneous and could be made of andesite blocks of cubic meter size whom interstices are filled with altered material and ashes, Fig. 6 (Nicollin *et al.*, 2006).

Contributions to EIDORS

The scale of a geological object is huge compared to a human body, however the mesh of the direct problem has to be fine in order to insure its precision. Moreover the resolution of the inverse problem requires a high number of iteration of the direct problem (hundreds of times). The direct problem must then be computed quickly. To decrease this time of computation we introduced an electrode “pivot” to make an artificial protocol of acquisition.

To reduce the number of inverse parameters, we defined a mapping in order to gather the direct problem elements into larger composite elements. The gathering of elements was defined following the resolution of the method : elements of the inversion further from the electrodes were made coarser than the nearer one. This proceeding accelerates the inversion and improve its robustness.

Developments required for geophysical tomography

Geological rocks present a high anisotropy in conductivity and it would be very interesting to develop models taking into account this particularity since its influence on the EIT reconstruction in three dimensions is significant (Nicollin *et al.*, 2010). It would be also valuable to introduce finite elements to EIDORS to better represent geophysical objects and eliminate eventual edge effects.

References

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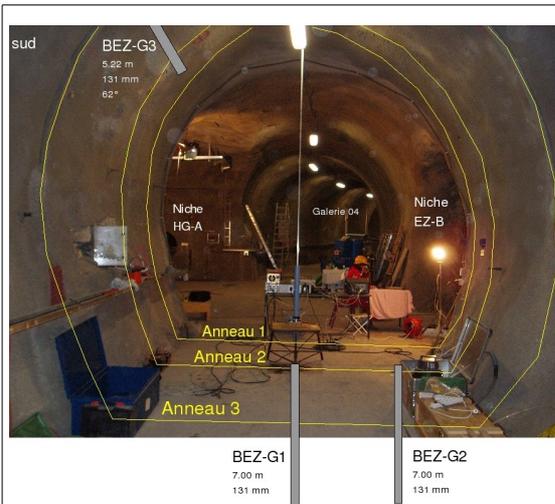


Figure 1 : Installations in the zone EZG-04 of the Mont Terri underground rock laboratory. The yellow rings represent the three rings of electrodes covered by concrete. Drills allow also

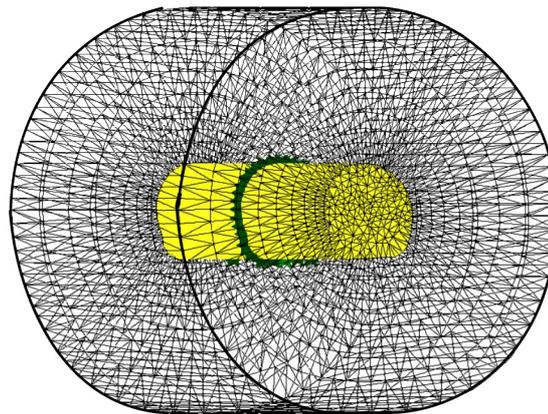


Figure 2 : Finite element model of the gallery. The green points represent the electrodes, the yellow zone corresponds to the gallery.

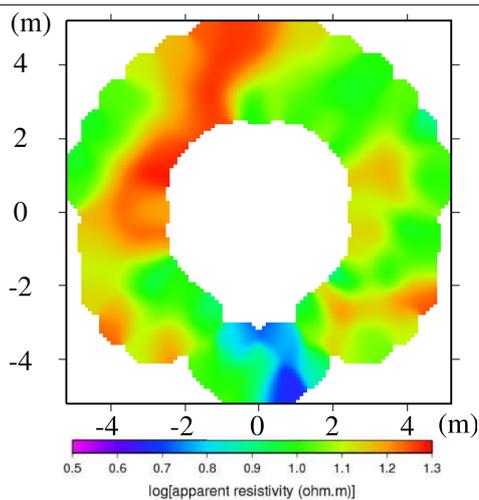


Figure 3 : Apparent resistivity measured on the second ring in March 2005. High resistivity areas enlighten the damaged areas.

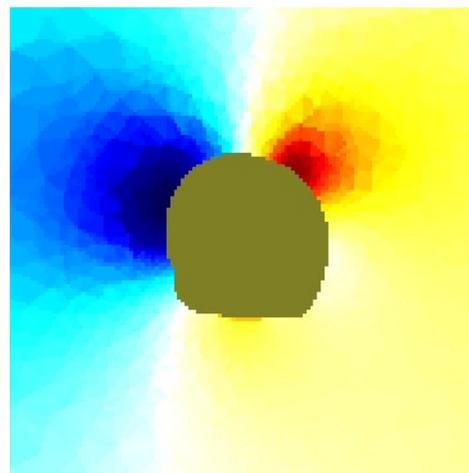


Figure 4 : Resolution of the inverse problem with EIDORS, the blue area correspond to a low conductivity zone.

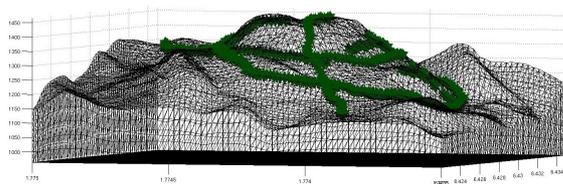


Figure 5 : Finite element model of la Soufrière de Guadeloupe volcano. The green points represent the electrodes.

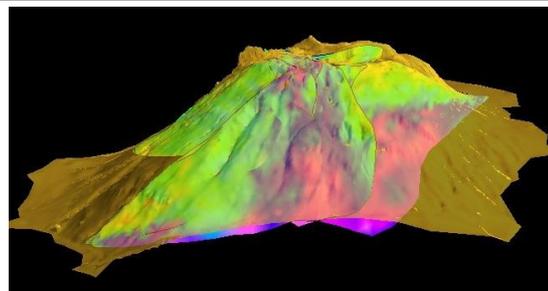


Figure 6 : Apparent resistivity of la Soufrière de Guadeloupe volcano. The pink area correspond to a high conductivity

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