POLARIS

LINEAR AND NON-LINEAR INDUCED POLARIZATION TO LOCATE LOW GRADE ORES AND STUDY THE IMPACT OF THEIR EXTRACTION ON THE ENVIRONMENT

Institut de Recherche pour le Développement
FRANCE

Project coordinator: André Revil, Institut des Sciences de la Terre (ISTerre), Université Grenoble Alpes, 38058 Grenoble, France
4 partners: ISTerre; G&E; UMMISCO; METIS

CONTEXT

POLARIS looks for a breakthrough in developing an imaging technique called induced polarization to locate critical metals (low grade ores plus W, Nb, Ta, Li, Sn, Be, Cs, Li, Sb, In, and Au) resources in the subsurface. High tech raw materials requires these metals and are of great strategic significance in relation to the overall resource balance of France and the European Union. There is an urgent need to reassess such mineralizations especially within the most promising European host, the Variscan Belt using ecologically-friendly approaches such as discussed in the 2018 ANR call. Induced polarization is a non- intrusive electromagnetic imaging technique looking at the low-frequency polarization of rocks occurring typically in the frequency band 0.001 Hertz-10 kHz. While the method is not new (first described in Schlumberger, 1920), its use has been limited because of the following gaps of knowledge: (1) lack of a fundamental unified theory of its causes for ore bodies, (2) non-linear induced polarization of mineralization is terra incognita with few exceptions, (3) a large dataset of experimental data looking at the effect of ore types, salinity, temperature, and non-linear effect is missing, (4) there is a gap between the way induced polarization is classically imaged and what could be done by merging more information.

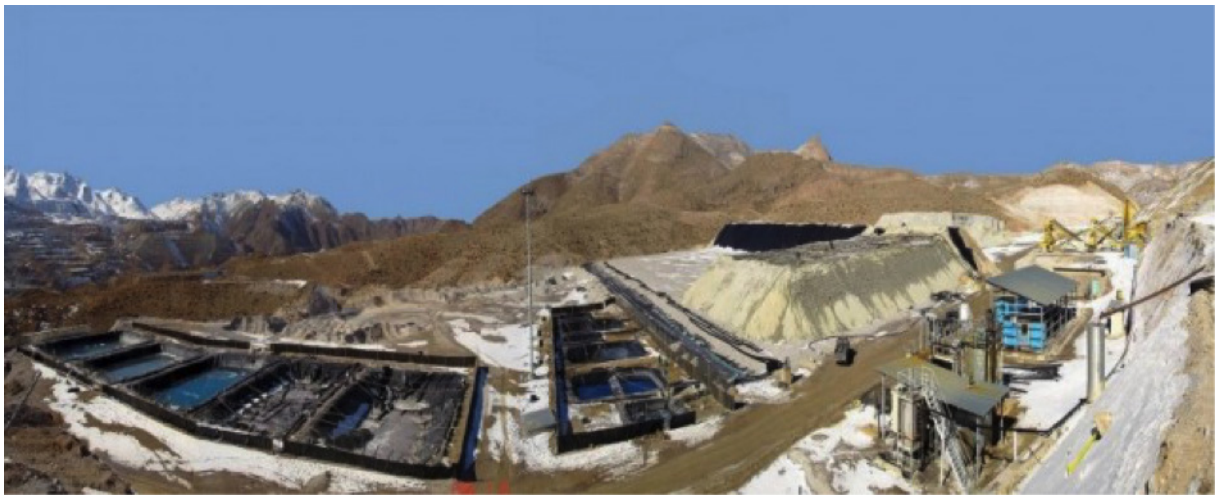

Figure 1: Heap bioleaching by MINTEK society in South Africa (courtesy Mintek)

OBJECTIVES

Our first goal is to go therefore further by unifying three types of polarization mechanisms for disseminated mineralized rocks occurring (1) in the bulk pore water, (2) at the surface of metallic particles (effect of redox active species and polarization of the electrical double layer), and (3) inside the metallic particles themselves. The second goal is to validate the theory in establishing a unique experimental database of 100 well-characterized samples with different types of mineralizations in various experimental conditions (temperature, salinity, strength of the electrical field, presence of redox active species) as well as to evaluate our ability to monitor extraction processes such as bioleaching. The third objective is to provide a breakthrough in our imaging capabilities built on recent advances made on (i) data merging and the use of prior information in a broad sense (through image guided inversion, geological and geophysical data merging) and (ii) new geophysical instruments that are built on radically new concepts. The overall goal of POLARIS is therefore to improve our fundamental understanding of the linear and non-linear electromagnetic responses of ore bodies in the frequency range (1 mHz-10 kHz) for a better interpretation of actively recorded electromagnetic signals in geosciences to locate ore bodies, discriminate between them, and offer new strategies to follow the environmental impact of their extraction.

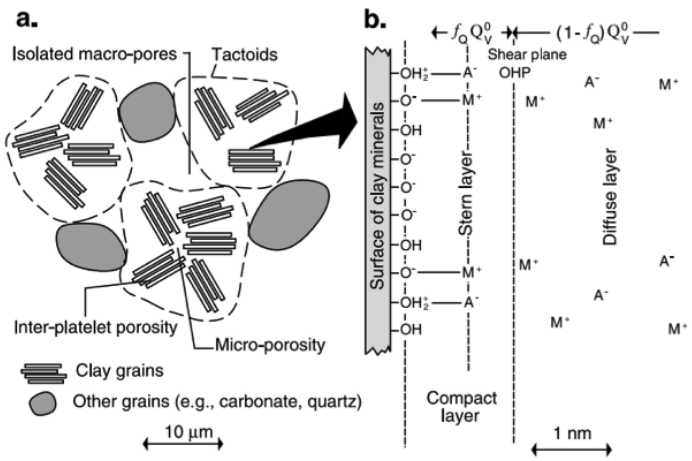

Figure 2: Understanding linear and nonlinear electrical polarization of the rock particle is the nano- to micro scale challenge of the project, to finally permit to up-scale the method to the field.

APPROACH

The present proposal in coupling theoretical, numerical and experimental methods has no analogues in France and, as far as we know, in the world. POLARIS can be considered as the first national project to study linear and non-linear polarization mechanisms of mineralized rocks of economic relevance for France and Europe. The results are expected to provide breakthroughs in the development of new non-intrusive geophysical imaging techniques to locate low grade ore bodies due to the increased sensitivity of the proposed method. Our goal will be to release our results in high impact factor journal (>2) (we forecast over 30 peer-reviewed publications during the course of this project). We plan to organize an international workshop at the end of the project with a special issue in Journal of Geophysical Research (IF=3.35).

Figure 3: Induced polarization investigation on the field

SPECIFIC CHALLENGE

Assessing the nonlinear complex resistivity natural porous medium response to propose new tools for soils/ground characterization including and low grade ore and metallic pollutions.

Providing improved tomography tools to monitor bio heap leaching efficiency on the field.

EXPECTED RESULTS

(1) Novel fundamental knowledge on the electromagnetic properties of mineralized rocks useable by a broad variety of end-users (from mining companies to environmental agencies such as ADEME),

(2) A unique platform in the world for the study of linear and non-linear induced polarization of these rocks.

(3) Validation of the models through the development of a unique experimental database.

(4) Development of breakthrough techniques to image the subsurface using information merging.

(5) Significant breakthroughs in unifying various polarization mechanisms into a single theory.

(6) Predictive numerical models and establishment of scientific recommendations for best practices in the study of low grade ore bodies imaging and the monitoring of their impact on the environment

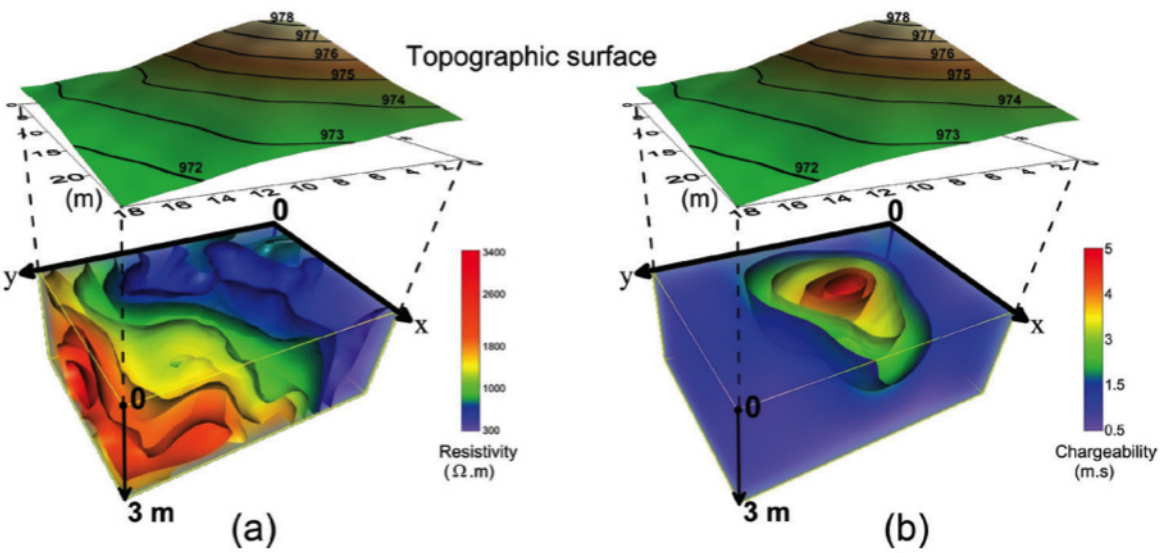

Figure 4: Example of 3-D complex electrical tomography. The changeability signal is independent of the resistivity image and provides the amount of polarizable particles embedded here into a slag heap.