

#### Contribution of multi-instrumental geophysics to determine the hydromechanical functioning of a deep-seated coastal landslide (Cirque des Graves, Normandy, France)

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#### ▶ To cite this version:

Guillaume Thirard, Benjamin François, Gilles Grandjean, Adnand Bitri, Yannick Thiery, et al.. Contribution of multi-instrumental geophysics to determine the hydromechanical functioning of a deep-seated coastal landslide (Cirque des Graves, Normandy, France). EGU General Assembly 2019, Apr 2019, Vienne, Austria. hal-02144697

HAL Id: hal-02144697

https://hal.science/hal-02144697

Submitted on 31 May 2019

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# Contribution of multi-instrumental geophysics to determine the hydromechanical functioning of a deep-seated coastal landslide (Cirque des Graves, Normandy, France) – EGU2019-2415

# 1 GENERAL CONTEXT AND ISSUE

The coastline of eastern Calvados (Normandy) is affected by four large deep-seated rotational-translational landslides. Those slopes instabilities took place because of the underlying lithology, composed by numerous sedimentary layers, in link with sediment inflows due to alternating between marine and colluvial deposits.

The "Cirque des Graves" is characterized by an important size (1 km x 500 m) and numerous stakes (villas & strategic road). Variations of groundwater level in the landslide body is setting Cenomanian chalk panels in motion, sinking on Albian sands and sliding on Oxfordian clays.

It is studied since the major acceleration of 1982, during which around 30 buildings were damaged [Maquaire, 1990]. Previous researches allowed to well constrain the functioning in regards to geomorphology, kinematic and lithology of the unstable area [Maquaire, 1990; Lissak, 2012; Lissak et al., 2013].

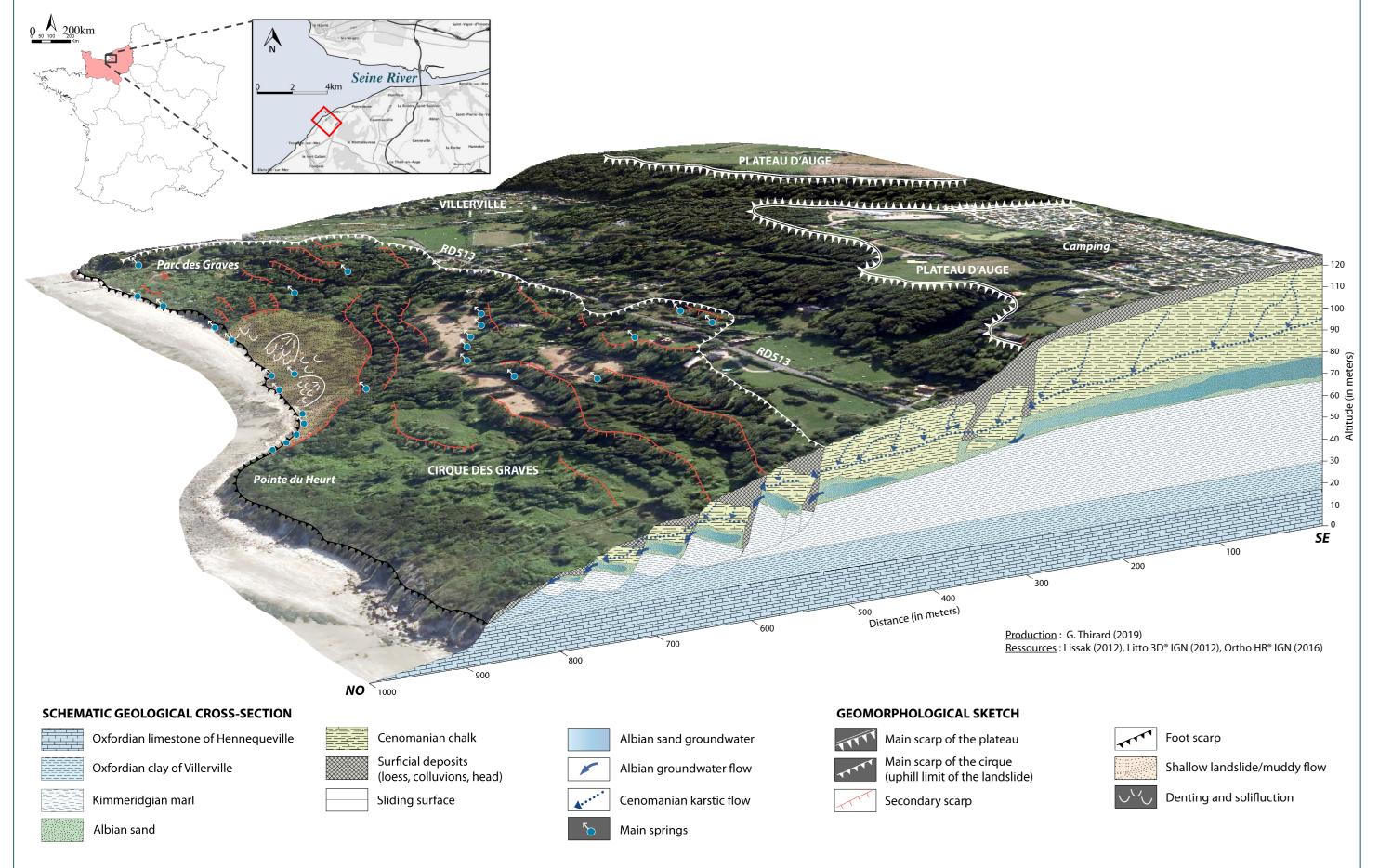


Figure 1. Conceptual geological and geomorphological functioning of the Cirque des Graves

A more robust knowledge is needed in regards with hydrogeological functioning. Furthermore, the middle zone (with major stakes), is structurally not as well defined as the eastern extremity.

Funded by the ANR RICOCHET project (ANR-16-CE03-0008), this research aims to improve this knowledge on the landslide structure and the groundwater flows, which requires the use of various geophysical methods.

# METHODS OF INVESTIGATION & OBJECTIVES

Three different geophysical methods were used to understand the internal morphostructure and its dynamics, especially in the middle zone:

1- Spontaneous Polarization (SP) to map the drainage paths, quantifying the natural electric potential (without information about the depth). From this data, we selected a profile with an interesting gradient in the middle of the landslide, for further analysis.



Figure 3 – Seismic streamer on the upstream-downstream profile



Figure 4 – Seismic in-vehicule source on the transverse profile

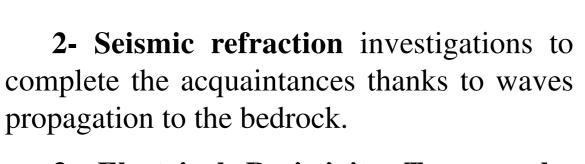


Figure 2. SP and GPS surveys during

the spontaneous polarization survey

3- Electrical Resistivity Tomography (ERT), for giving informations on shallow structures, lateral edges and water saturation.

SP was conducted in the entire landslide, while seismic and ERT investigations were focused on a cross-section comprising an interesting SP gradient.

## **3** SPONTANEOUS POLARIZATION SURVEY

This method allows to identify the main water flows in the structure of the landslide. Around 1,200 measurement points were acquired to realize a map of the electrical potential over this great landslide of 47 ha, using the electrofiltration method, adapted to porous environments [Aubert, 1997; Naudet, 2004].

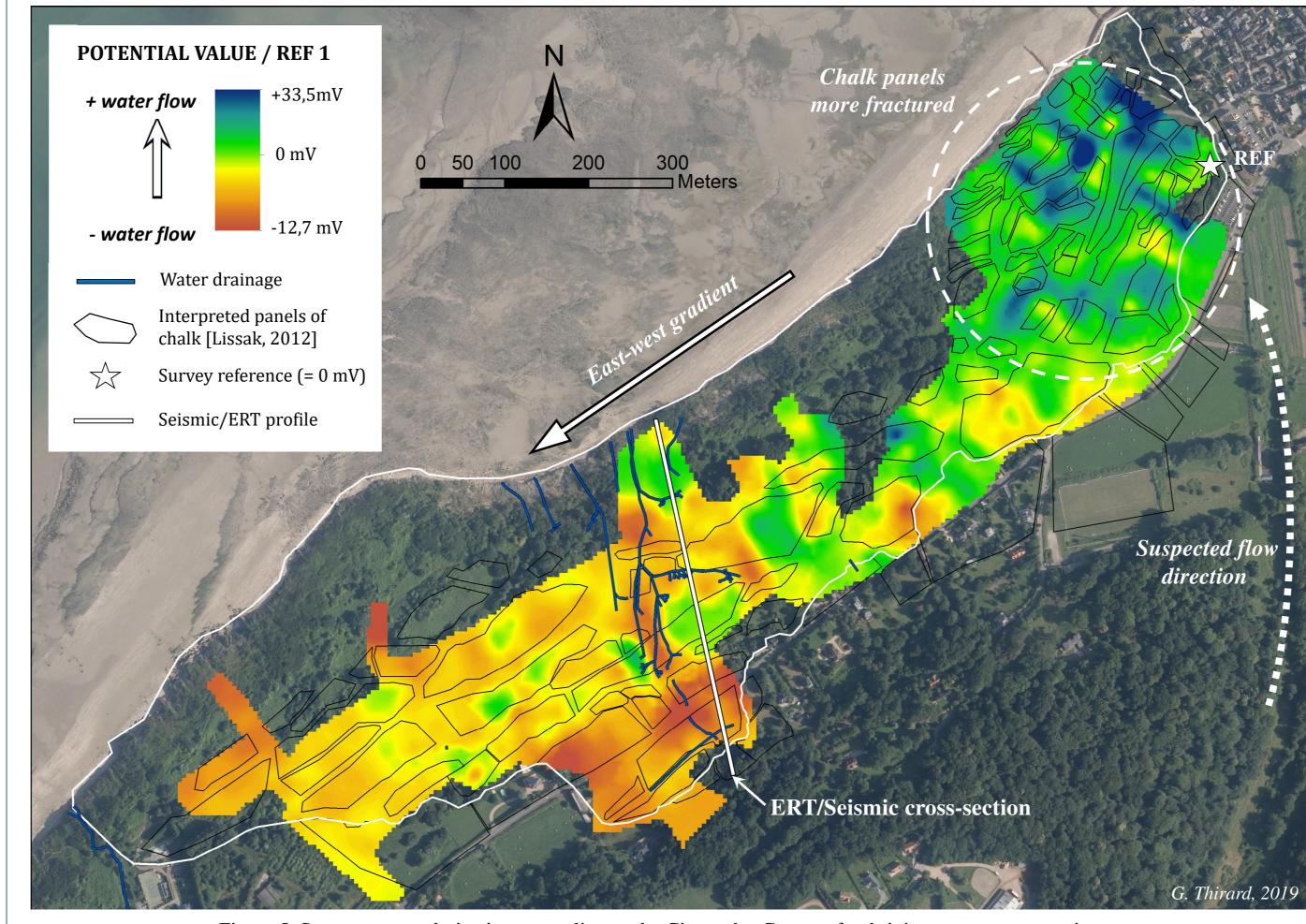


Figure 5. Spontaneous polarization anomalies on the Cirque des Graves after kriging measurement points

An east-west gradient and some discontinuities appear. Thanks to landforms analysis and previous **knowledge** on the morphostructural units, **three assumptions** can be made:

- 1- A link exists between very fractured chalk panels and an **intensive drainage** in the east part;
- 2- The dry valley located upstream of the east part is a **preferential path** for water inflows;
- 3- On the west half of the cirque, the lowest values corresponds to a drainage area of surface water and springs, which reduce infiltration and the electrical response in surface.

### 4 INTERPRETATION BY SEISMIC REFRACTION

Seismic refraction allows to constrain the interpretation in depth. The speed propagation of P-waves brings us an overview about the thickness of the layers. Seismic refraction is adapted for discriminating between loose and compact materials [Coulouma et al, 2012].

Two seismic sources were used depending on the possible accesses:

- 1- Double-hammer on an upstream-downstream cross-section;
- 2- More powerful in-vehicule source on an additional transverse profile for the deepest limits at the cross with the first survey.

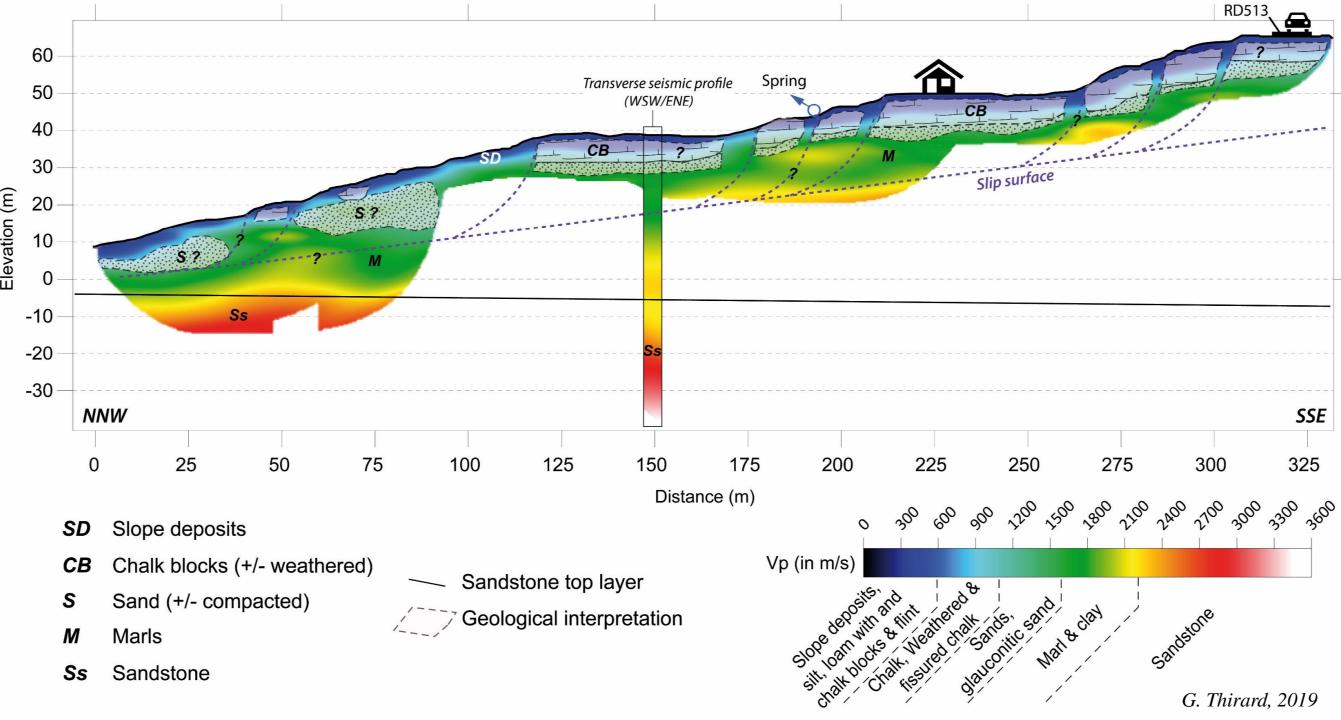


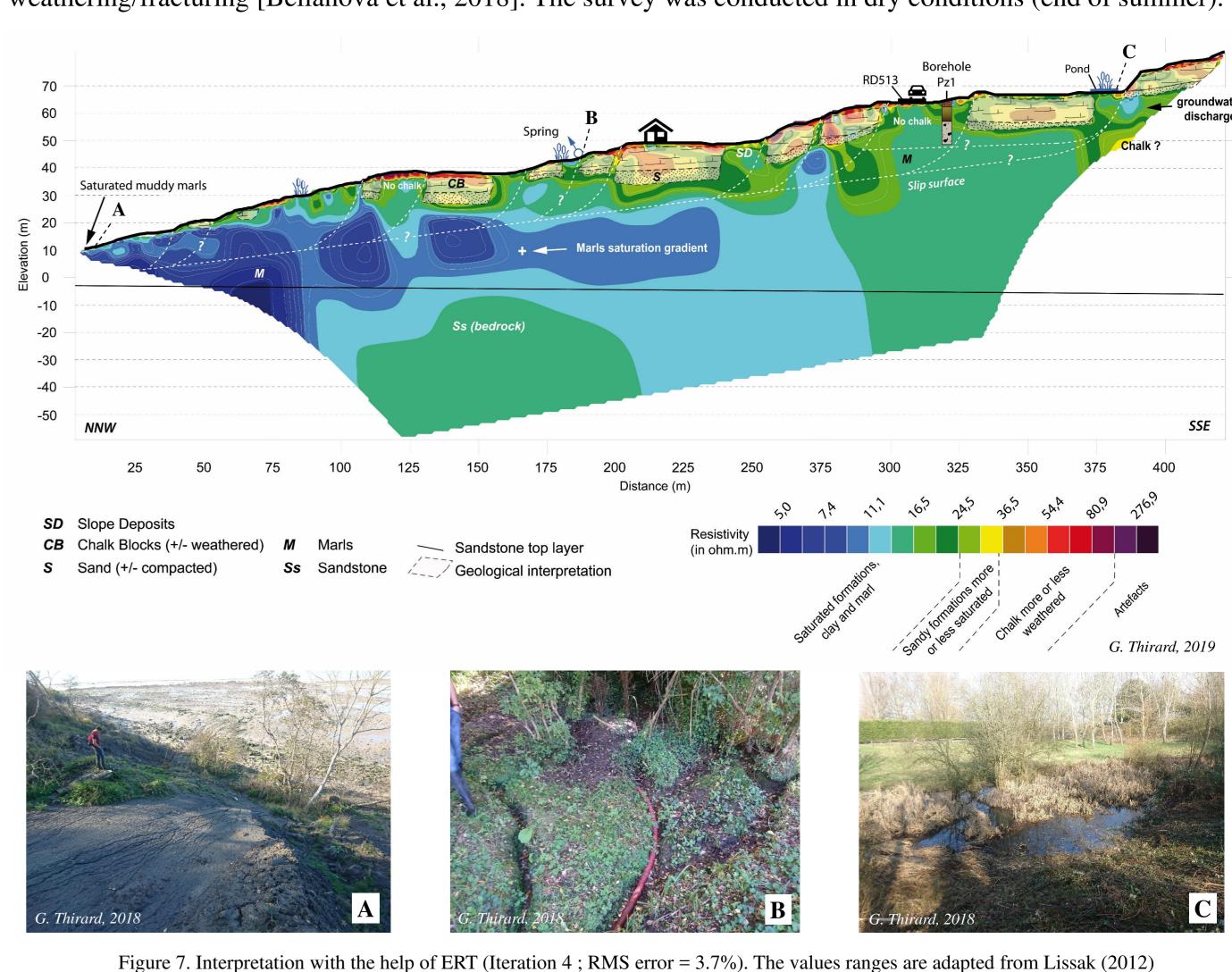
Figure 6. Interpretation of the lithostratigraphy with the help of seismic refraction (RMS error = 3.8% or 3.37ms) The values ranges are based on Lissak (2012)

### REFINEMENT OF THE MODEL BY ERT

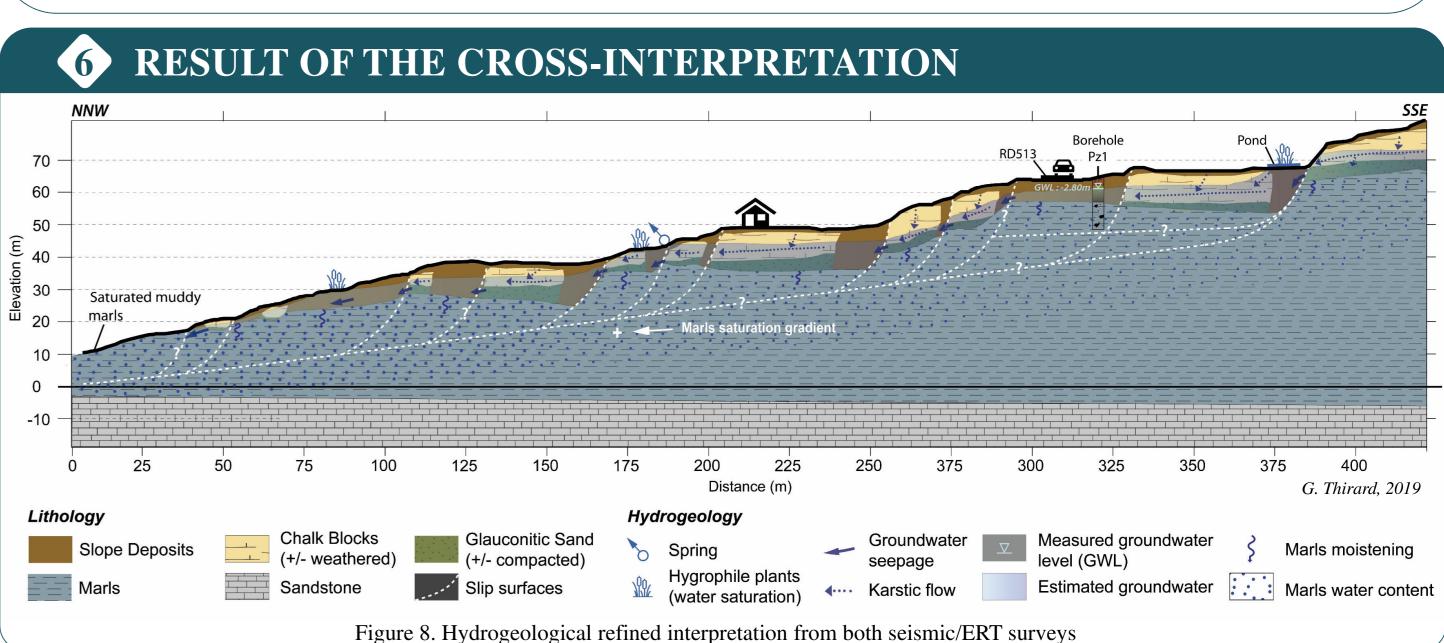
Two methods of data acquisition were combined for Electrical Resistivity Tomography (ERT) survey :

- 1- Dipole-dipole for the sub-surface;
- 2- Wenner-Schlumberger for the deepest structures.

ERT enables to get a better sight of the lateral limits and allow to identify the water content and rock weathering/fracturing [Bellanova et al., 2018]. The survey was conducted in dry conditions (end of summer).



(A) Marly mudflow at the foot of the landslide; (B) Springs nearby the seismic/ERT profile; (C) Pond at the bottom of the main scarp (water stagnation)



## 7 CONCLUSION & RESEARCH PERSPECTIVE

The three different geophysical methods **complement one another**:

- ☐ SP & ERT are completing each other on the hydrogeology knowledge (water flows, internal saturation);
- Coupling seismic and ERT surveys allows refining the structural model for depth and lateral bounds.

Through that work, the knowledge was clearly improved in many ways:

- ✓ Robust assumptions have been issued from the SP mapping about the groundwater preferential circulation at the landslide scale:
- ✓ SP & ERT results are linked, in particular on the upstream-downstream saturation gradient;
- ✓ The limits and thicknesses of chalk panels, sands and marls are now better-constrained in the middle of the Cirque des Graves thanks to both ERT/seismic surveys.

From these cross-geophysical data, numerical models will soon be conducted thanks to the hydromecanical software FLAC®, in order to confirm the hypothesis of functioning and define the boundary conditions of reactivation of this landslide.

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