Imagery down to one kilometer depth by airborne electromagnetics: New constraints for geological and hydrogeological modeling in volcanic contexts

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SUMMARY

We present an original approach to combine airborne magnetic data and five different airborne electromagnetics data sets going from 3 000 NIA up to 1 000 000 NIA magnetic moments (three different TDEM systems were used) in La Réunion island. A 3D geological model of the first kilometer bellow the Plaine des Fougères was built and then used for 3D hydrogeological interpretation.

Keywords: Airborne electromagnetics, Time Domain ElectroMagnetics, volcanic island, geological modeling

INTRODUCTION

To bring water to the northern part of La Réunion island (Indian ocean volcanic island), a new gallery will be drilled bellow the Plaine des Fougères and connected to the existing deep underground gallery called 'Salazie amont', covered by up to 1000 meters of volcanic materials. County council of la Réunion (CD974) has asked BRGM to produce a 3D geological model that will be used to create a 3D hydrogeological model, in order to prevent hydrogeological risks related to the drilling of highly permeable surrounding aquifers under high pressure. This work is presented in technical report by Peyrefitte et al (2022).

METHOD

A first airborne electromagnetics (AEM) survey was carried out in La Réunion island in 2014 using the SkyTEM 304 system. It resulted in the imagery of the first 300 m in depth over the whole Réunion island. A second survey was flown in 2021 over the Plaine des Fougères area, using the SkyTEM 306HP and the SkyTEM 312HP systems in order to extend the imagery, down to 1 000 m depth. During both AEM surveys, airborne magnetic data were also acquired. New deep bodies can now be imaged and mapped for geological or hydrogeological purposes. Figure 2 is an example of two South-North resistivity profiles in the same area, illustrating the gain in depth of investigation between SkyTEM 304 and SkyTEM 306HP systems. Combining both data sets, a high-resolution resistivity image of the Plaine des Fougères from the surface to 1000 meters depth was obtained. The processing methodology of AEM data is presented in Reninger et al (2020) and includes the use of the singular value decomposition and a manual editing of the residual noise. A joint smooth SCI inversion (Viezzoli et al, 2007) was run considering all the AEM data. Finally, a 3D resistivity model was created by the interpolation of the 304 and 306HP resistivity models for the near surface (the first 200 m) and the interpolation of 306HP and 312HP resistivity models for greater depths.

2D profile magnetic modeling was performed, using the resistivity model as background preliminary geometry and rock sample magnetic measurements to constrain the geological magnetic responses. Taking into account the volcanic history, 2D profiles constrained by both AEM and magnetic modelling lead to geologically realistic cross-sections (An example is presented in Figure 3). The resistivity model provides the overall geometry of volcanic layers and their alteration degree. Magnetic data allows refining the geological model in depth, highlighting distinct geological units within relatively homogeneous resistivity layers.

RESULTS

Combining all the previous 2D information, 3D geological modeling was carried out from -1000 m to 1500 meters above sea level. Figure 1 displays a result of the modelling, where we can see PN0 to PN4 formations, classified by increasing age, and information about their alteration or saturation in water.

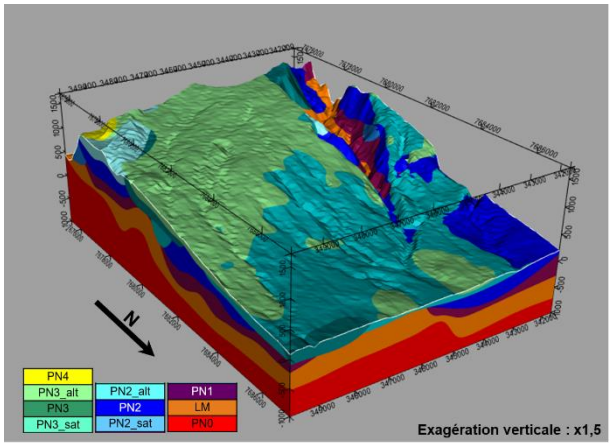

Figure 1: 3D geological model of the Plaine des Fougères.

This 3D model was then used for hydrogeological modelling in Visual KARSYS (Malard et al, 2018), in order to predict hydrogeological risk along several possible gallery routes.

CONCLUSION

Following an original approach consisting in the combination of high-resolution near surface and deep AEM surveys with aeromagnetic data and rock sample measurements, a realistic 3D geology was modeled down to 1000 meters depth. This made it possible to map the geometry of hydrogeological bodies within the first kilometer below the Plaine des Fougères in order to reduce the risk during the drilling of a deep gallery.

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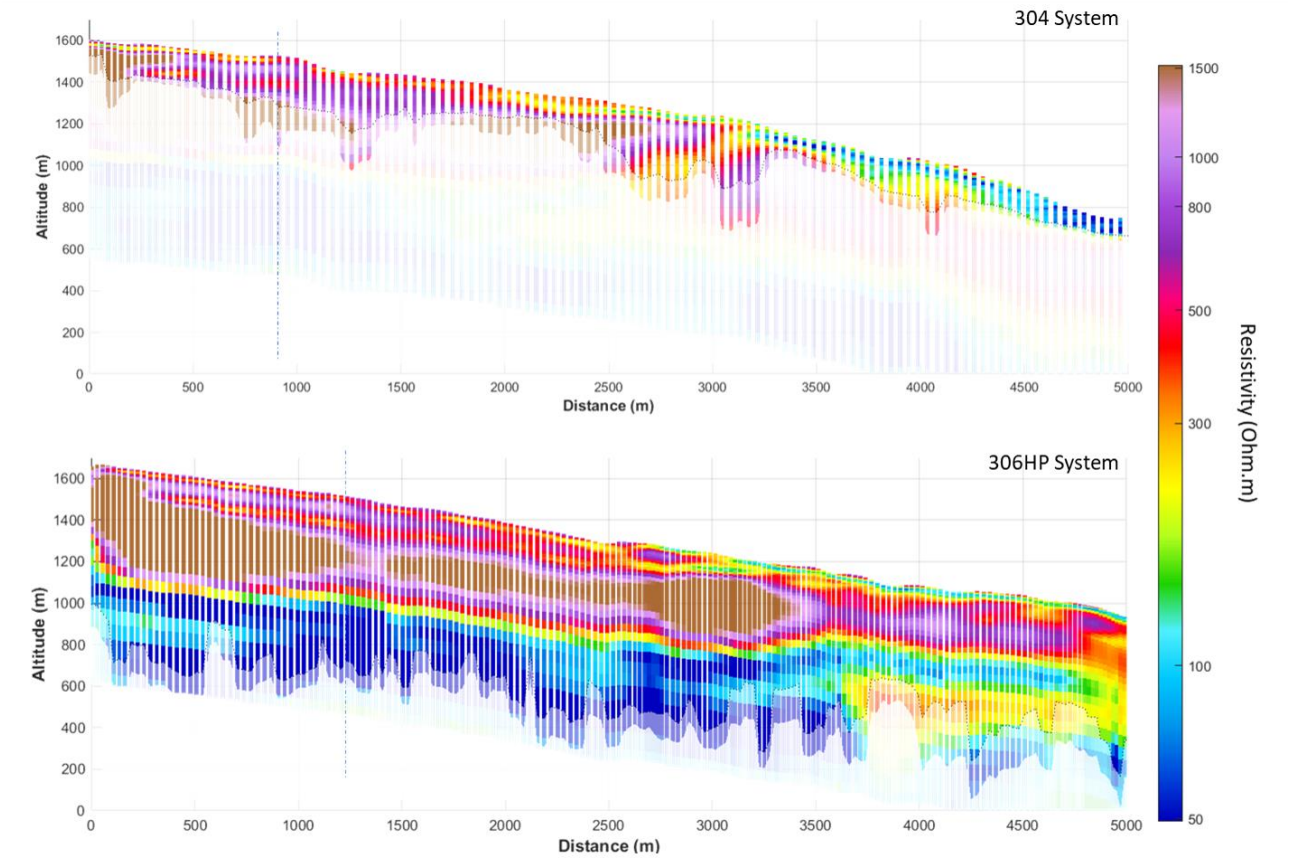

Figure 2: South-North resistivity profiles acquired with 304 (a) or 306HP (b) systems in the Plaine des Fougères area.

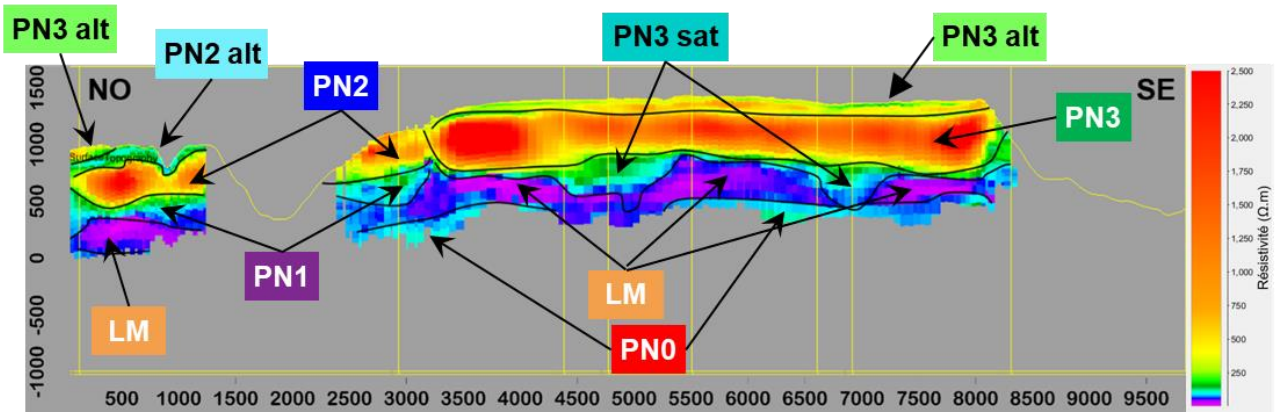

Figure 3: Example of an interpolated resistivity profile along the existing underground Salazie amont gallery, with geological interpretation. PN0 to PN4 represent old to recent volcanic formations.