Discontinuities detection using transmission electrical resistivity imaging

Nolwenn Lesparre[1], Justo Cabrera[1], Alistair Boyle[2], Bartłomiej Grychtol[3], Andy Adler[2]

1) IRSN, B.P. 17, 92262 Fontenay-aux-Roses Cedex, France. nolwenn.lesparre@irsn.fr 2) Carleton University, 1125 Colonel By Drive, K1S 5B6 Ottawa, ON, Canada. 3) Fraunhofer PAMB, Mannheim, Germany.

Introduction

In this study, we explore the interest of the presence of a regional fault crossed by a tunnel that allows us performing transmission measurements on a vertical plane between tunnel and surface. Protocols used involved classical Schlumberger and dipole-dipole measurements from which the resulting resistivity image is compared with the inversion of the whole data set containing in addition transmission measurements. As information collected about the medium resistivity distribution is spatially heterogeneous we apply a parametrization of the inversion problem based on sought values defined as pilot points. The interest in improving the resolution in depth for the resulting image by the use of transmission measurements is investigated by comparing image quality. The reconstructed image is interpreted in light of geological knowledge.

Measurements

Measurements were performed at the experimental platform of Tournemire (France) in order to image the regional Cernon fault. A such fault is susceptible to present a thickness larger than 10 m at the tunnel level. Resistivity data were acquired using classical protocols from the tunnel and by injecting current in transmission between tunnel and surface.

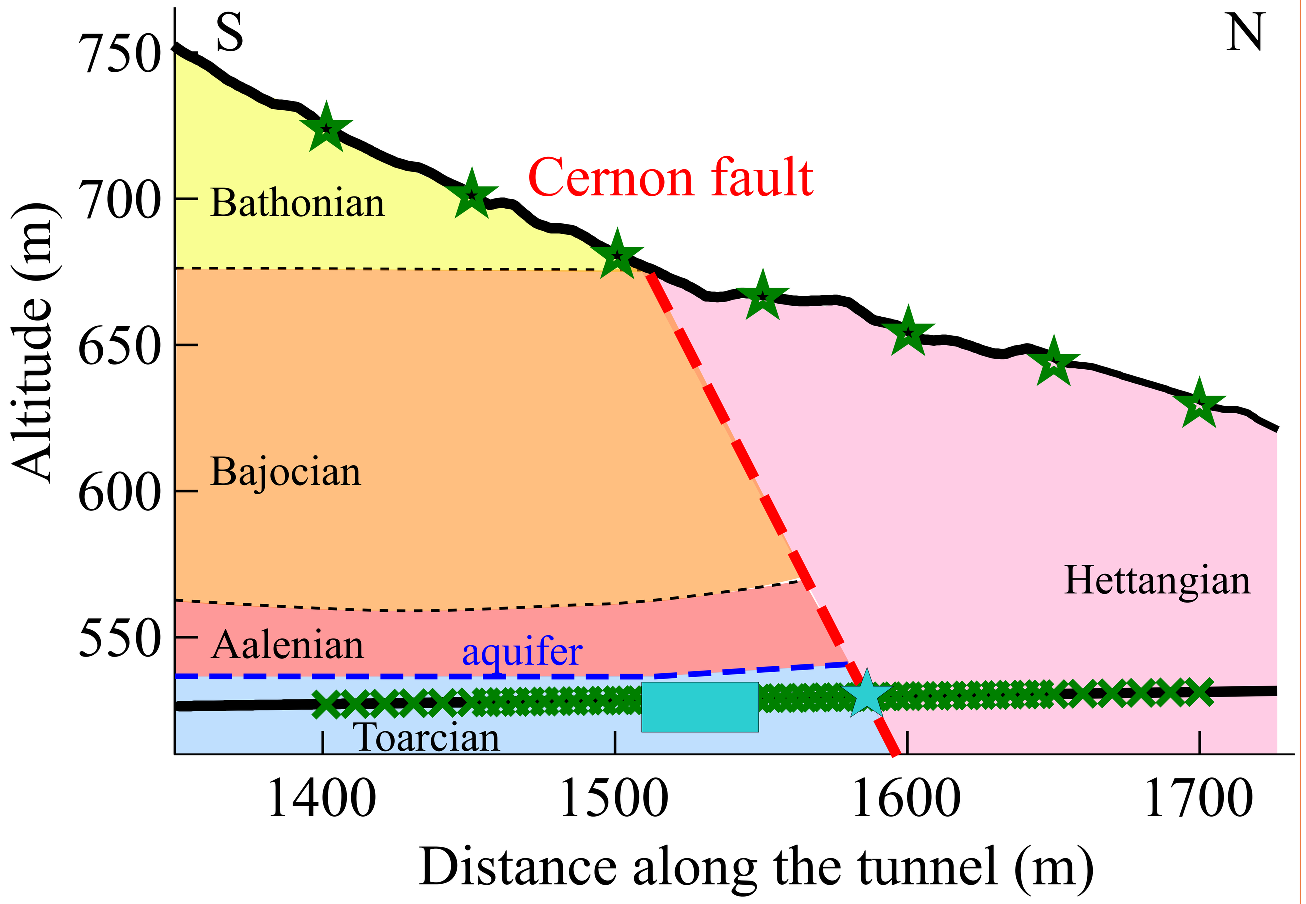

Figure 1: The green crosses and stars represent respectively electrodes in the tunnel and at surface. The blue star and rectangle represent respectively a water resurgence and a deformation zone.

Forward problem

The experiment is simulated using a 3D finite element model in order to seek the resistivity ρ distribution in the medium surrounding the Cernon fault. The forward problem is then solved with EIDORS as in [3].

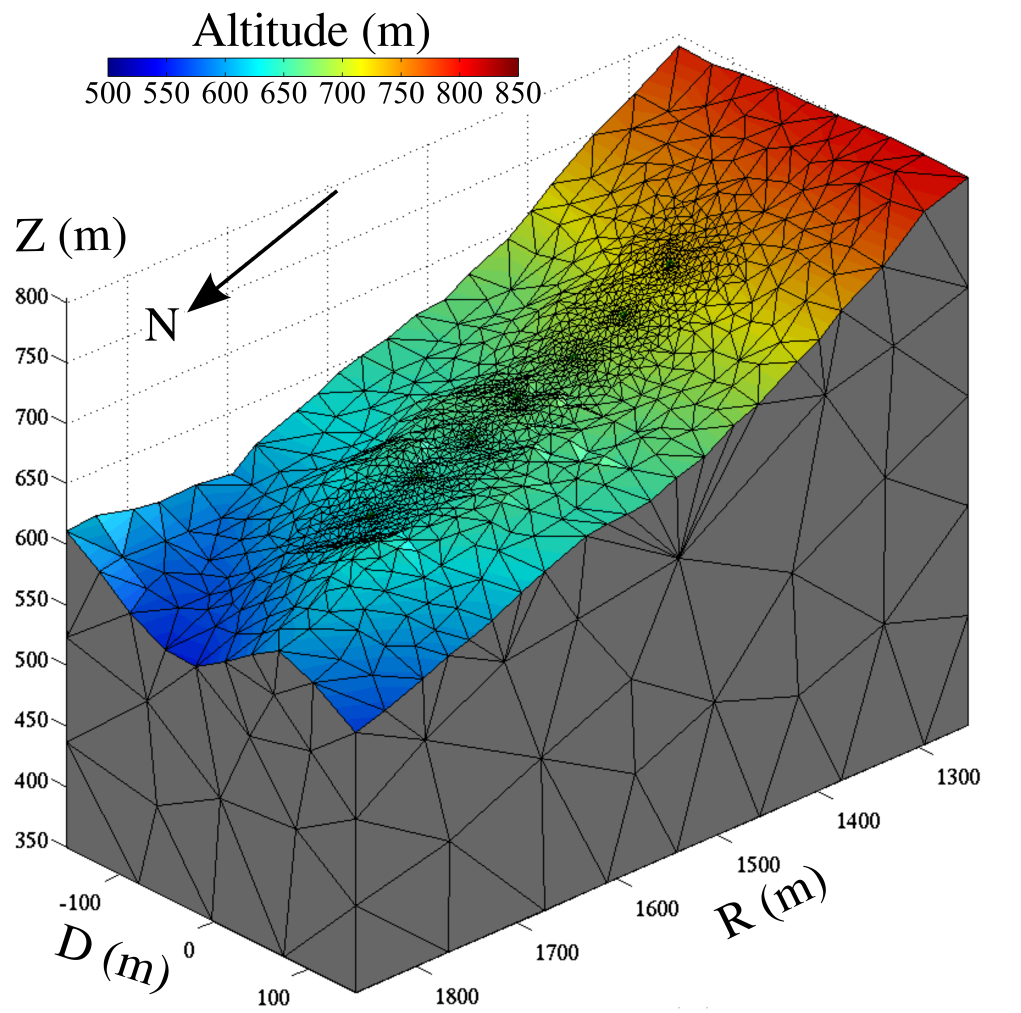

Figure 2: 3D Finite element model.

Sought parameters

Sought parameters are defined in 2D as pilot points [1]. An inversion is first performed to estimate ρ for a reduced number of pilot points to distinguish the main structures, the number of pilot points is then progressively increased until the number of the 2D grid's pixels is reached. Image resolution improves then gradually. Pilot points are located in the regions the most constraint by acquired data as determined by an analysis of the problem sensitivity.

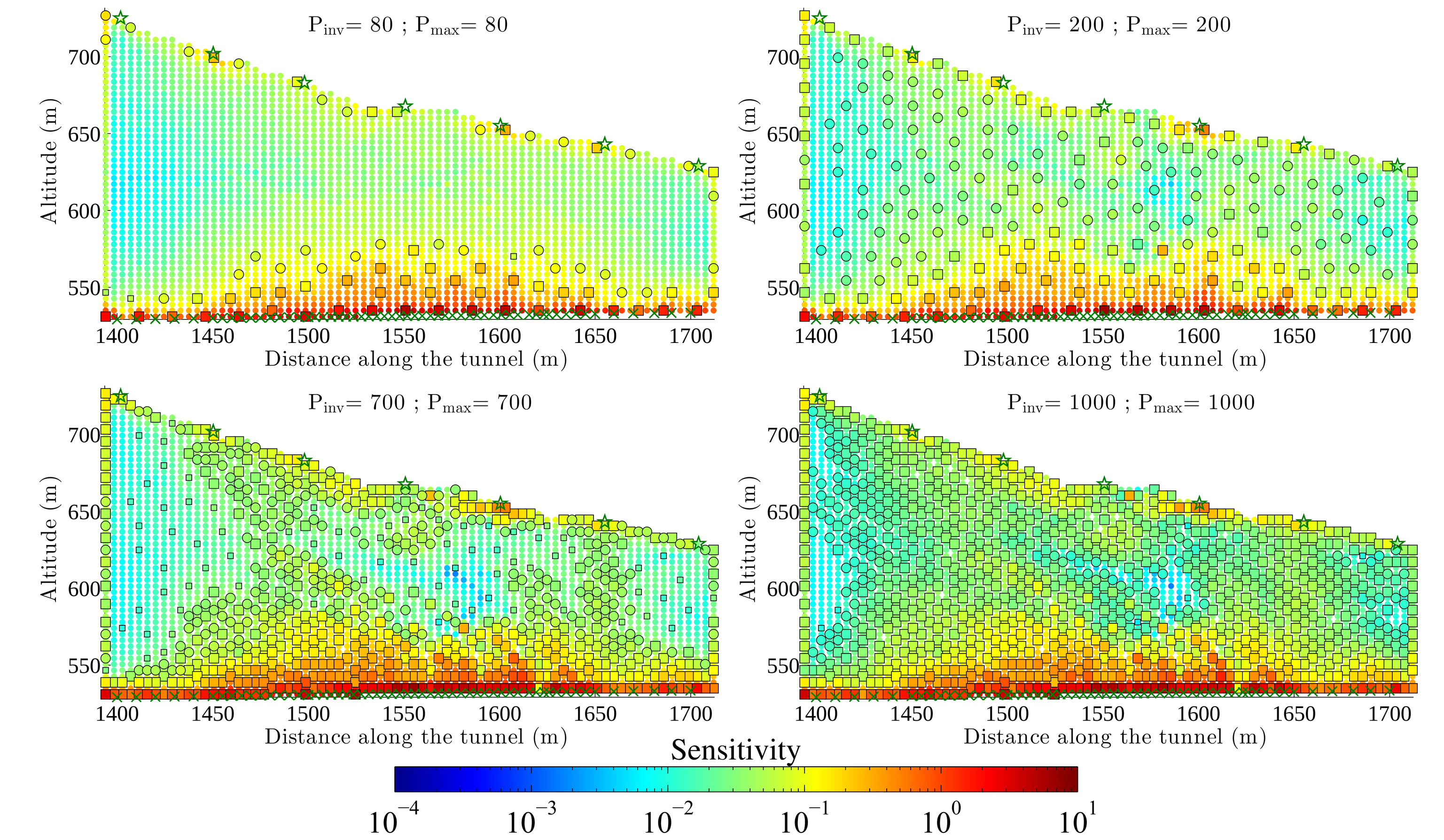

Figure 3: 2D sensitivity in the plane of the electrodes. Previous pilot points are represented by squares and new ones by circles.

Results

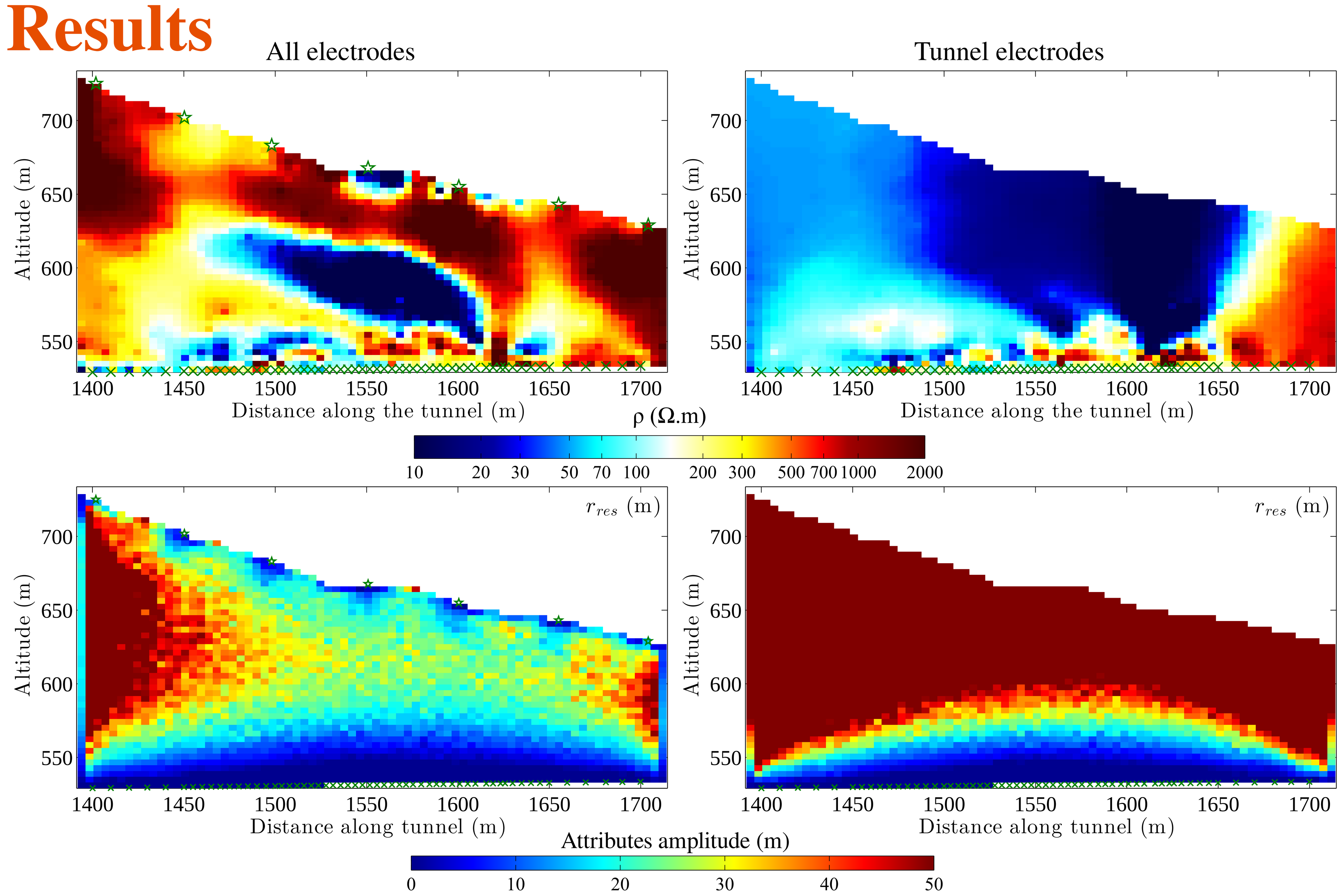

Figure 5: resulting image after inversion of the whole data set (left top) and with tunnel electrodes only (right top) and corresponding image resolution from Friedel analysis (bottom) [2].

Discussion

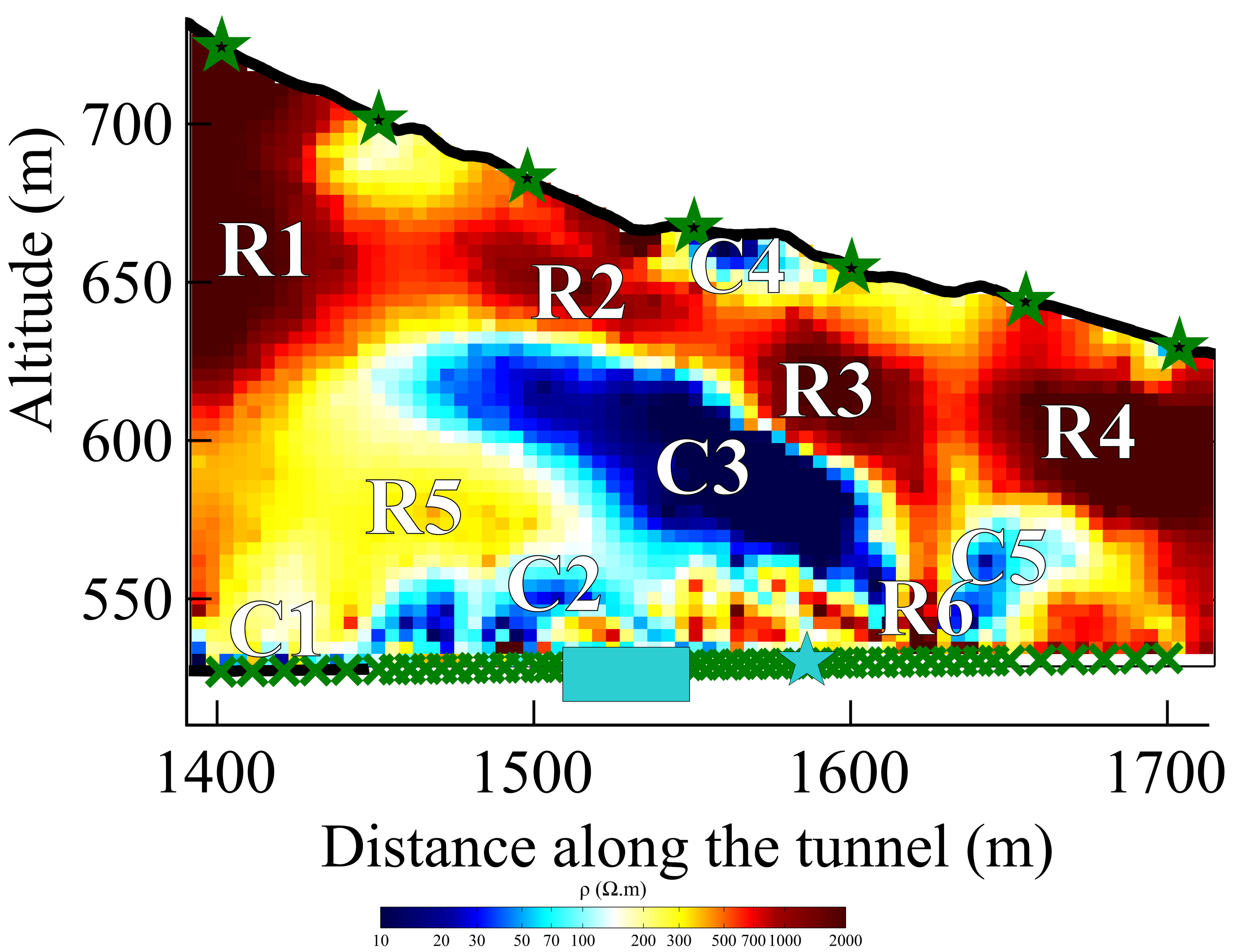

Figure 6: Interpretation of the resulting image.

The resulting image shows the medium hetrogeneity and reveals the destructuration around the fault zone. **Conductive zones**: C1 is interpreted by the presences of clays from the Toarcian formation close to the tunnel. C2 might correspond to a water saturated medium with water arising from the aquifer circulating above the Toarcian layer. C3 corresponds to a region of lower density and so the high conductivity might result from a fractured medium through which water is circulating. The lower resolution of the image on south (left side) does not exclude an extension of that conductive zone in the southern directions as water could circulate along the stratification of limestone rocks constituting the Bajocian layer. C4 is interpreted as a fractured medium perturbed by the fault and saturated by water. C5 might correspond to a damaged zone through which water is circulating. **Resistive zones**: R1 to R5 may reveal the presence of massive limestone layers sometimes interrupted due to the fault perturbation. R6 might reflect the presence of a karstic cave as observed from the tunnel.

Acknowledgements

The implementation of the experience benefited from the great help of B. Combes, E. Martinez, P. Desveaux and A. Julien. We also thank C. Courbet and P. Dick for fruitful discussions. The EIDORS open-source software is available at http://eidors3d.sourceforge.net. Financial support was provided by the IRSN through the experimental research project fund TOMUEX.

References

[1] Certes, C., de Marsily, G., 1991. Application of the pilot point method to the identification of aquifer transmissivities. Adv. Water Resour., 14, 284–300.
[2] Friedel, S., 2003. Resolution, stability and efficiency of resistivity tomography estimated from a generalized inverse approach, Geophys. J. Int., 153, 305–316.
[3] Lesparre, N., Grychtol, B., Gibert, D., Komorowski, J.C., Adler, A., 2014. Cross-section electrical resistance tomography of La Soufrière of Guadeloupe lava dome, Geophys. J. Int, 197, 1516–1526.