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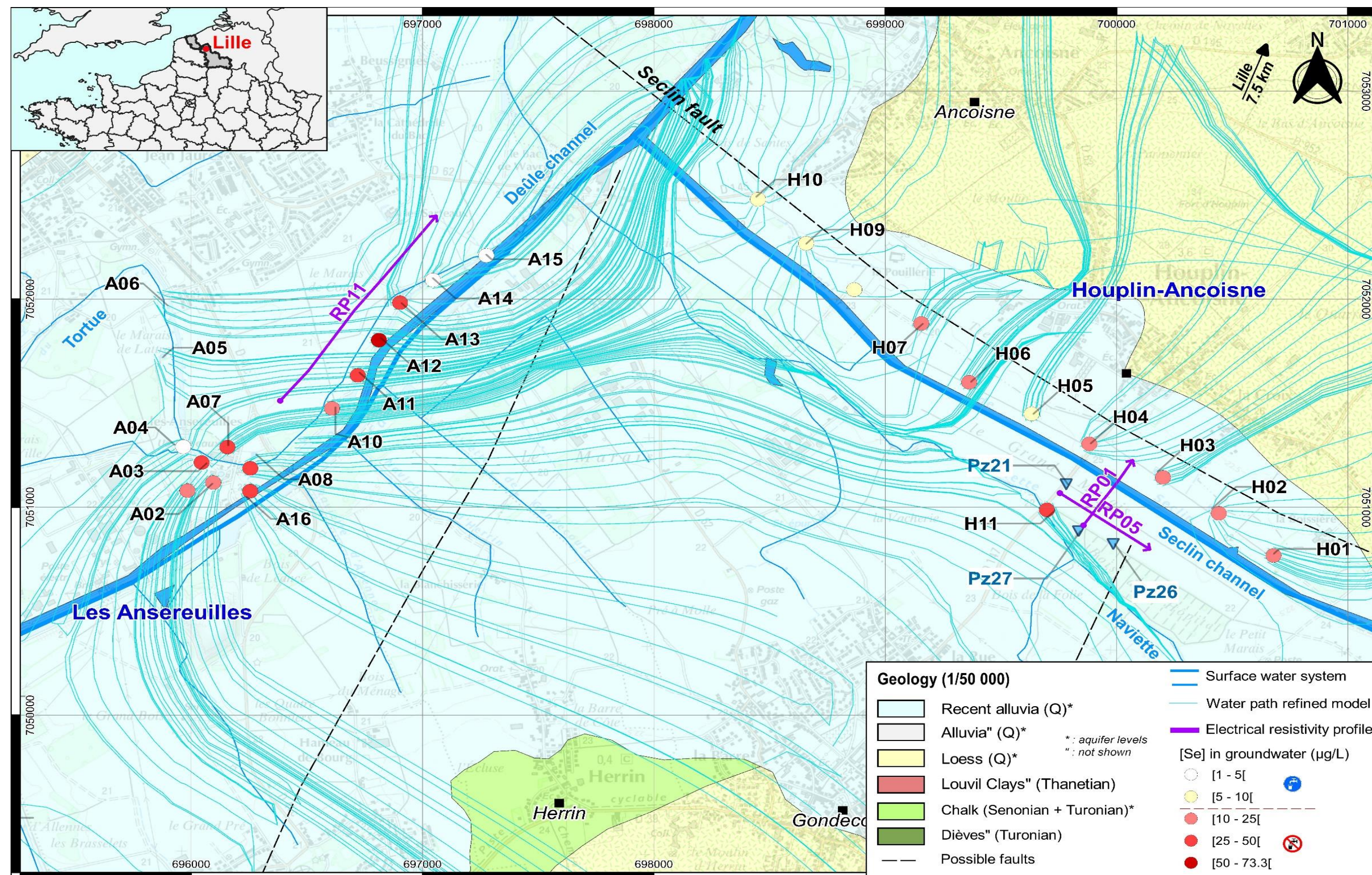
Enhanced geology of the Chalk aquifer (Northern France) from ERT imaging for hydrogeological purposes

Introduction

30% of the drinking water supplying the Lille European Metropolis originates from 2 well fields south of the city, named Les Ansereuilles and Houplin-Ancoisne which tap the Chalk aquifer

In recent years, a low recharge and a growing water demand have led to the decrease of the piezometric level of the Chalk aquifer. To preserve the sustainability of the well fields, exploitation volumes have recently been reduced.

Geology - Hydrogeology



High concentrations of undesirable elements as Se (Fig. 1), Ni, Co, As... locally affect groundwater (Cary et al., 2014) exceeding the French drinking-water limit values.

The Tertiary formations overlying the Chalk (Fig. 1), controls both the groundwater chemistry and the spatial distribution of natural contaminants, through the unconfined-confining groundwater status and the associated redox conditions (Cary et al., 2014; 2021).

Questions remain about the geometric and structural constraints of the main geological formations, e.g., what is the role of the Chalk heterogeneities in contaminant transfer (e.g. fracturing)?

We performed Electrical Resistivity Tomography (ERT) imaging to characterized the geometry of the Chalk aquifer.

Fig. 1 - Geological and hydrogeological map of part of the well fields of the Les Ansereuilles and Houplin-Ancoisne in the South of Lille metropolis. Selenium concentrations illustrate the geochemical contamination of groundwater (Bessière et al., 2015; Lacquement et al., 2004; Cary et al., 2021). Coord.: RGF93/Lambert 93.

We applied the ERT method to investigate the geological formations from the surface down to the "Dièves" (0-80 m depth, 5 m electrode spacing). Processing of resistivity data, including topography, was modeled by the interfaces from the 3-D geological model of the study area (Picot et Bourguine, 2010).

We present one resistivity profile (RP) in the Les Ansereuilles well field (RP11 from A10 to A15) and two in the Houplin Ancoisne one (RP1 and RP5) (Fig. 1). Thanks to the numerous drilling logs present along the resistivity cross-sections we propose the following interpretation scheme (Tab. 1):

Interpretation	Electrical unit
Sandy quaternary silts	R1 (30-35 ohm.m)
Quaternary alluvium	C1 (30-35 ohm.m)
Louvil clays	C1' (<5 ohm.m)
See next section	C2-R2
Weathered Chalk ?	C4 (~50 ohm.m)
Marls (« Dièves »)	C3 (<25 ohm.m)

Fig. 3 (right) - 2-D resistivity cross-sections along the RP01 (a) and RP05 (b) profiles in the Houplin-Ancoisne well field and along RP11 (c) in the Les Ansereuilles well field.

Tab. 1 - Geological interpretation scheme of the electrical units.

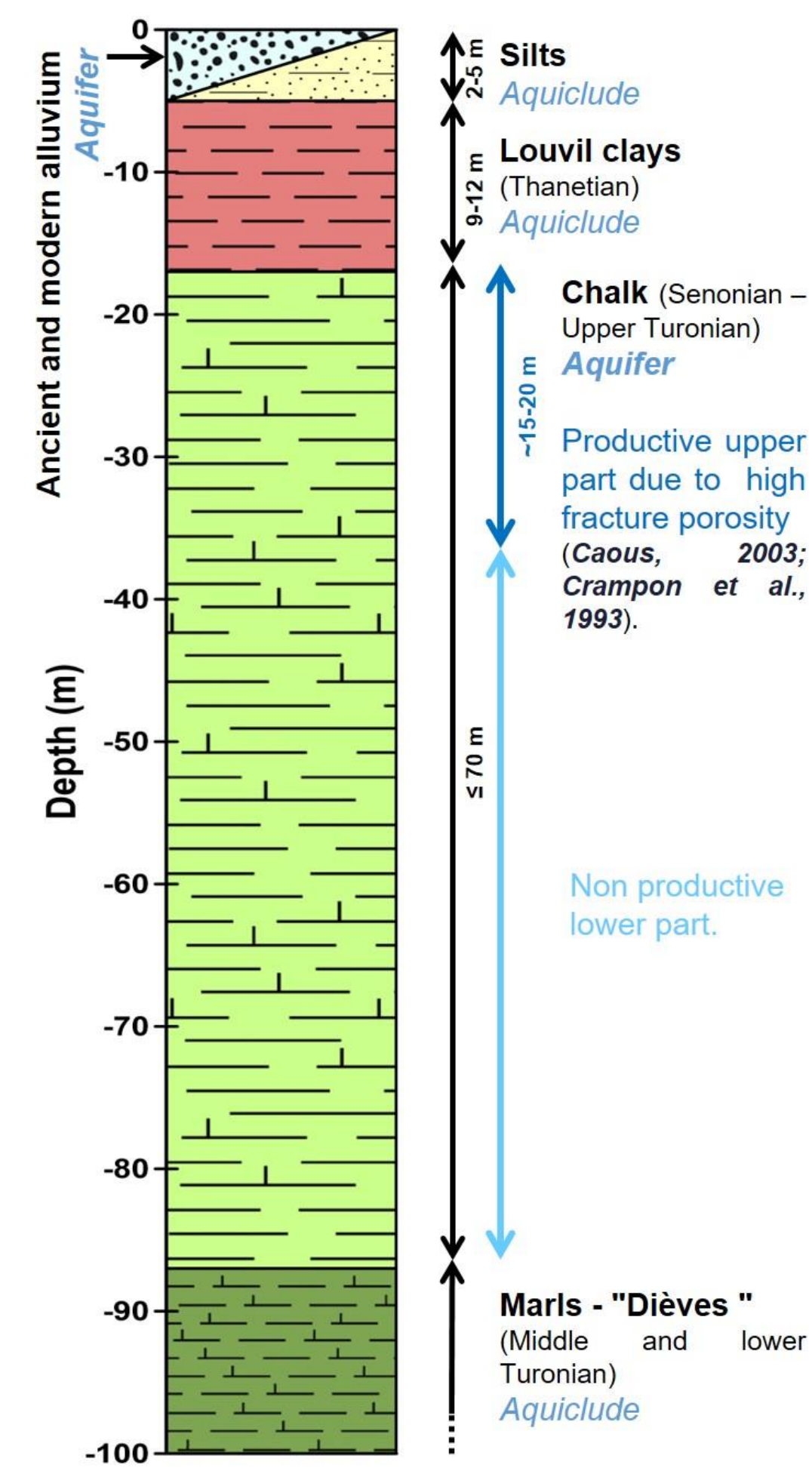
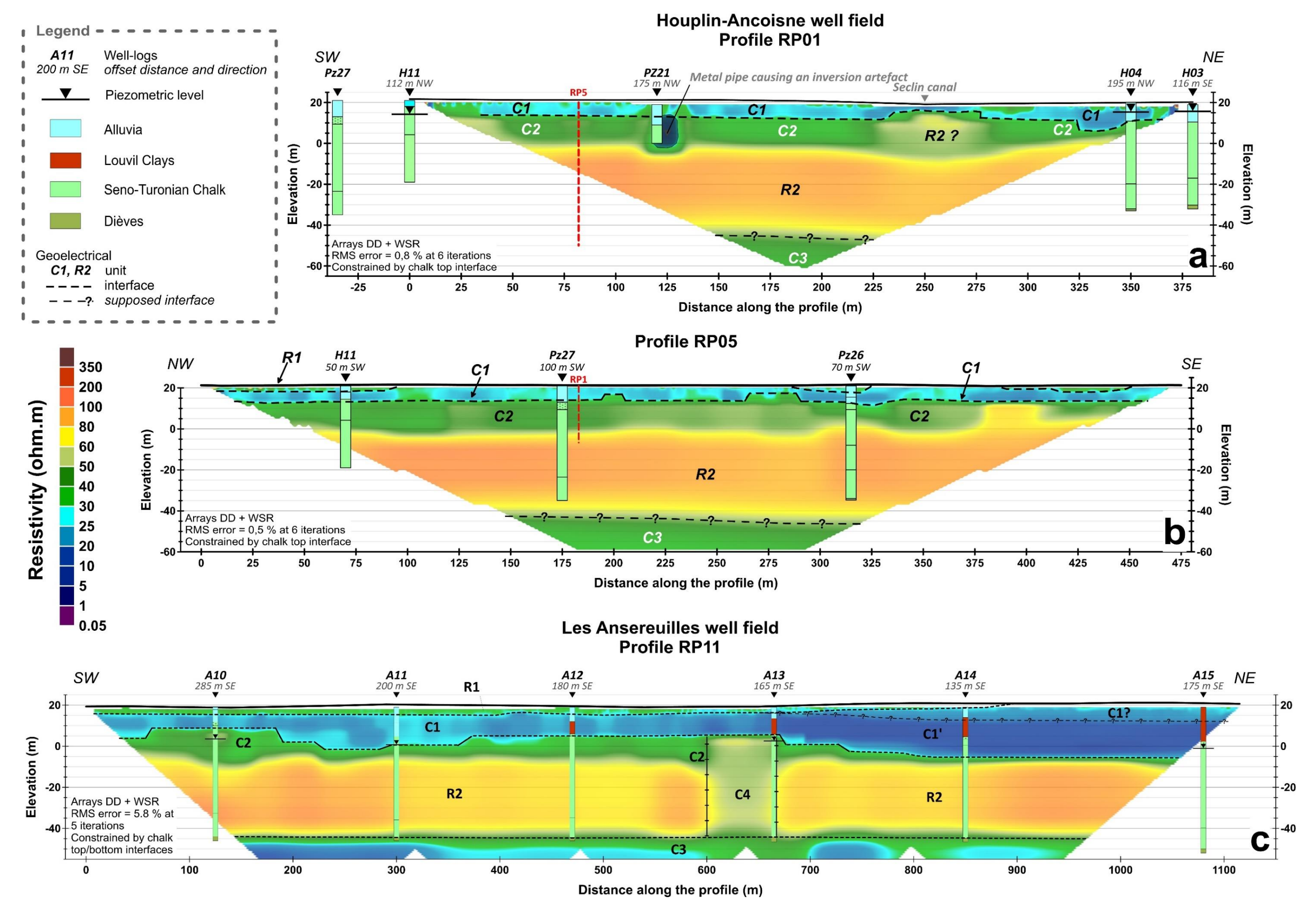


Fig. 2 - Synthetic geological and hydrogeological log of the studied area (Fig. 1).

Geophysical results

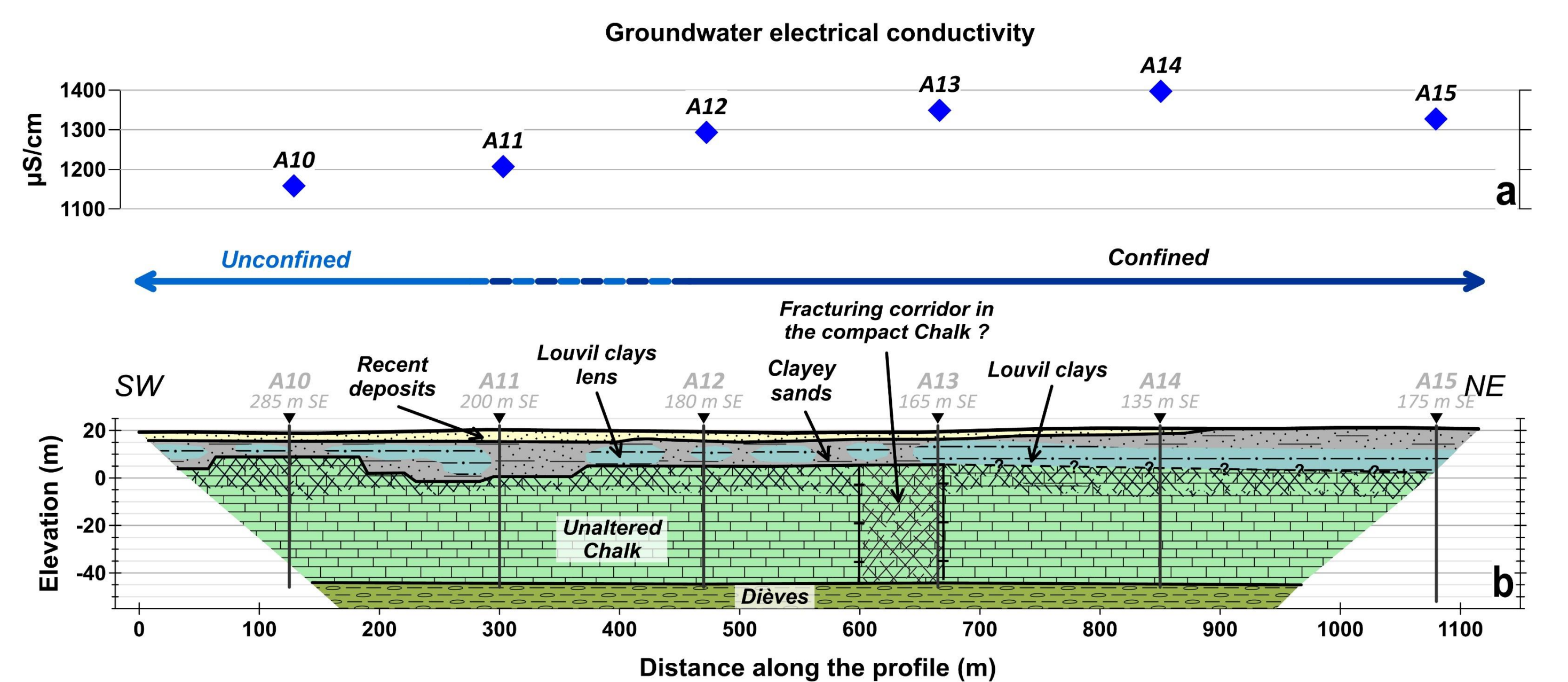


The Les Ansereuilles well field

In the Les Ansereuilles well field, ERT results clearly highlight the Chalk weathering profile (C2) to the SW of A13 (Fig. 4b). Beyond well A13, the C1' horizon thickens up to 15-20 m. A14 and A15 geological indications indicate that the clays are present only in the first seven meters of C1'. Below, C1' matches with the productive Seno-Turonian Chalk. Here, we explain this local very low conductivity of the Chalk by an increase of the interstitial water conductivity due to the presence of the above Louvil Clays (Fig. 4a; Cary et al., 2021).

The discontinuous presence of the Louvil Clays leads to a progressive confinement of the groundwater from the SW to the NE (Fig. 4b). The 60 m large more conductive zone observed inside the unaltered Chalk (C4) could represents a fracturing corridor that may issued from faults-associated alteration. Both the Louvil Clays and a potential weathered/fracturing corridor have strong implication on the recharge infiltration and the redox conditions and pollutants mobility (Cary et al., 2021).

Fig. 4 - Les Ansereuilles well field: max. groundwater electrical conductivity (a) and geological interpretation (b) of the RP11 resistivity cross-section (Fig. 3c).



A petrophysical origin of the double electrical signature of the Chalk aquifer?

The Seno-Turonian Chalk exhibits a different electrical signature between its conductive upper part (around 15 m thick) and its more resistive lower part.

Crampon et al. (1993) established that a double porosity characterizes the Chalk: (i) a globally and homogeneous matrix porosity and (ii) a fracture porosity due to weathering processes affects the top of the Chalk (around 20 m thick) is considered as productive whereas the lower part not.

A double porosity (matrix + fracture) characterizes the upper part of the Chalk. Such an open porosity, in a saturated environment, makes the electrical current flow easier because the interstitial fluid (i.e. water) preferentially carries it and tends to decrease the resistivity (Fig. 5). In the more compact an unaltered lower part of the Chalk the fracturing porosity decreases. There, we consider the only matrix porosity as a closed porosity that slows the electric current: the electrical signature appears more resistive.

According to this analysis, in the Chalk, the ERT results seems related to petrophysical properties of the rock and could allow to characterized the aquifer stratification which constitutes a key element for hydrogeological modeling.

Conclusion

In this study we (1) define a petrophysical-linked electrical signature of the Chalk that allows us to distinguish the productive and non-productive parts of the aquifer and (2) identify a fracturing corridor inside the unaltered Chalk and refine the geometry of the Louvil Clays in the Les Ansereuilles well field. The refinement of the geological structures enhances our understanding of the Chalk hydrosystem functioning that represents a key issue to guarantee the sustainable management of a water resource.

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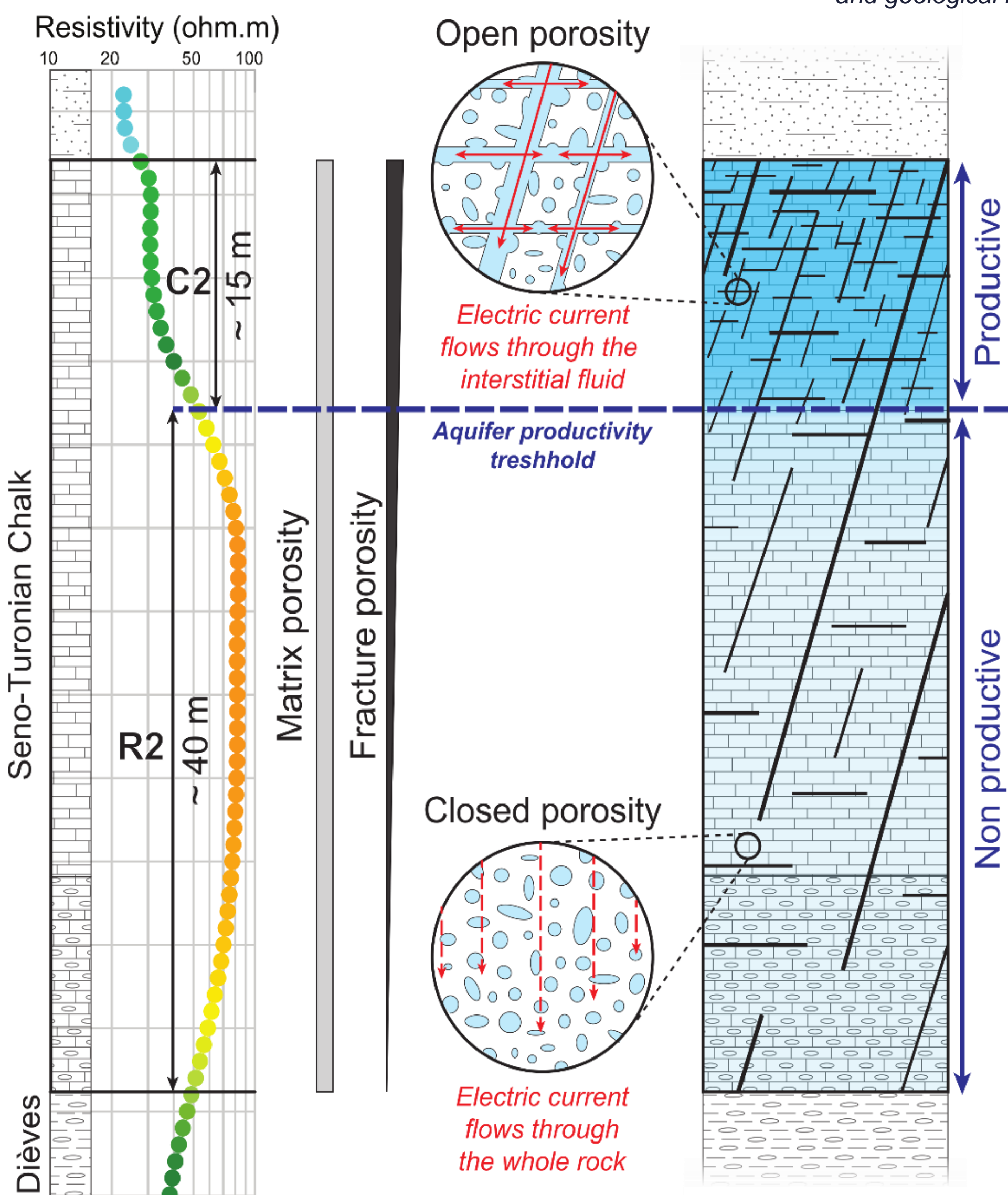


Fig. 5 - Schematic representation of the petrophysical-linked electrical double-signature of the Chalk observed in the well fields of the South of Lille metropolis.