Borehole siting in deeply weathered hard rock aquifers **using electrical resistivity**: the example of Benin, West Africa

C. Allé, M. Descloitres, JM. Vouillamoz, N. Yalo, F. Lawson, C. Adihou

Result obtained thanks to the **GRIBA project**

Abstract N°1853

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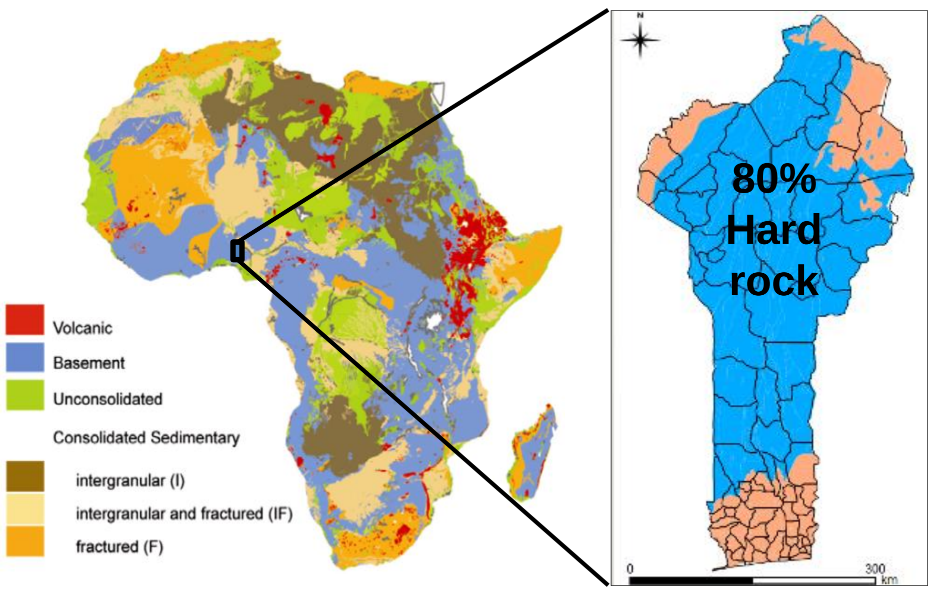
Introduction

- 80% of Benin surface area is underlined by hard rock

Africa **Benin**



Geological map
(Mc Donald et al., 2012)

Hard rock and sedimentary
rock location

Granite (Plutonic)

Shist (Metamorphic)

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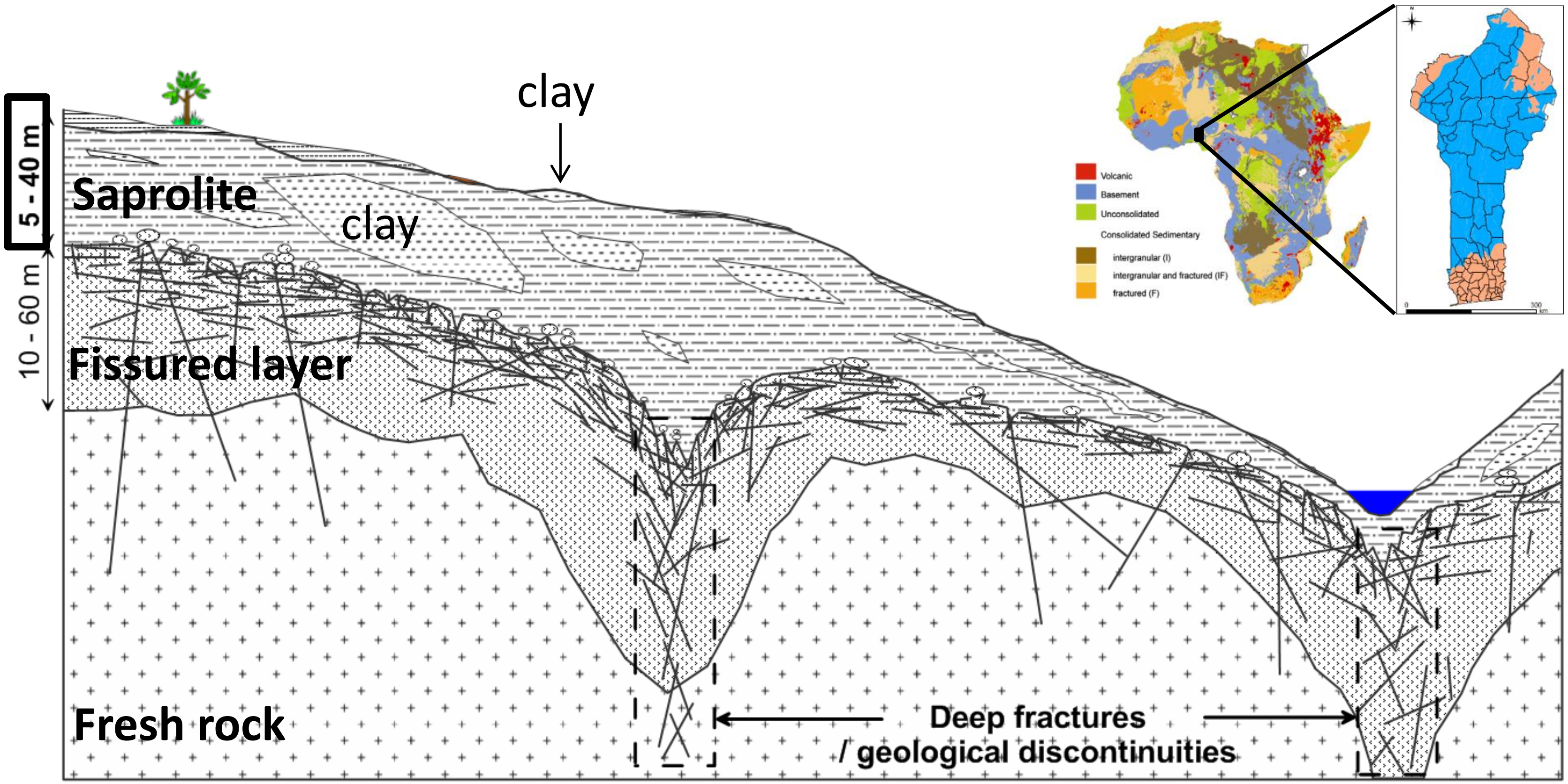
- ❑ 80% of Benin surface area is underlined by hard rock
- ❑ Model of hydrogeological compartment: **deeply weathered zone**



Conceptual model of hydrogeological compartment in tropical hard rock (adapted from Dewandel et al., 2011)

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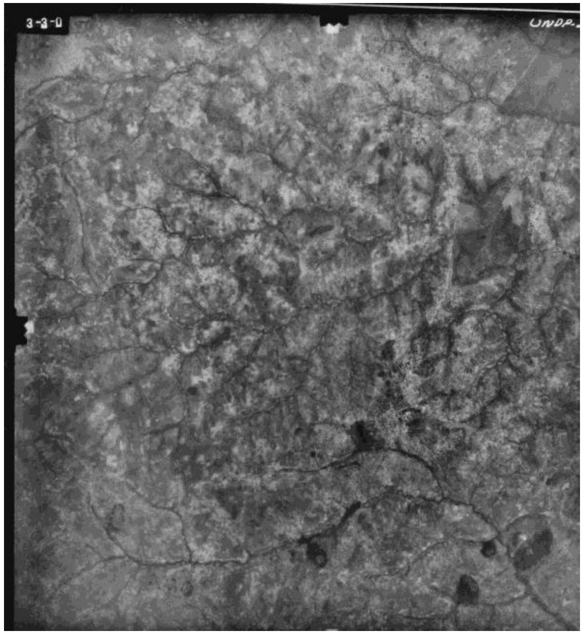
- **Boreholes siting:** based on a comprehensive procedure

Air photographs



Air photograph of Djougou

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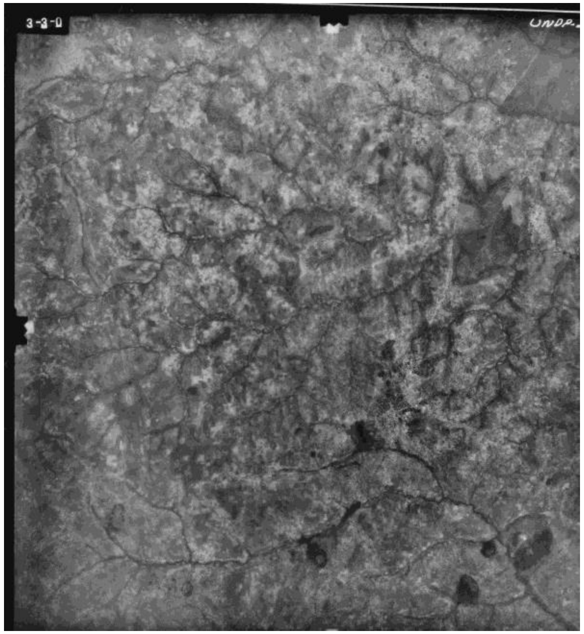
Air photographs + **Field inspection**



Air photograph of Djougou

Baobab (absorbent tree)

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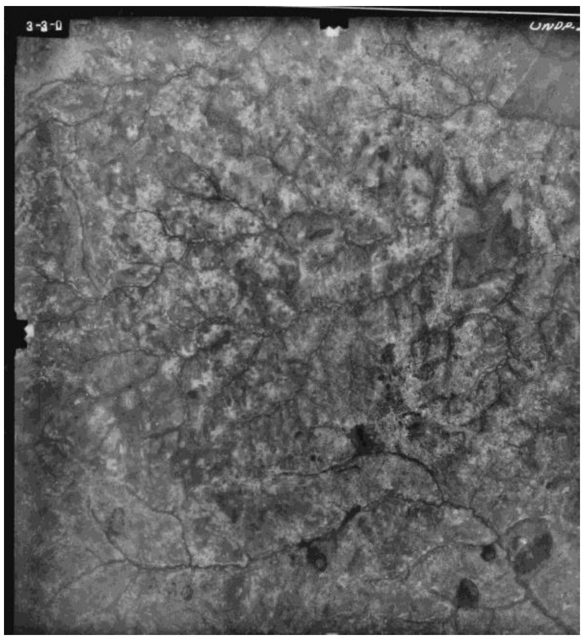
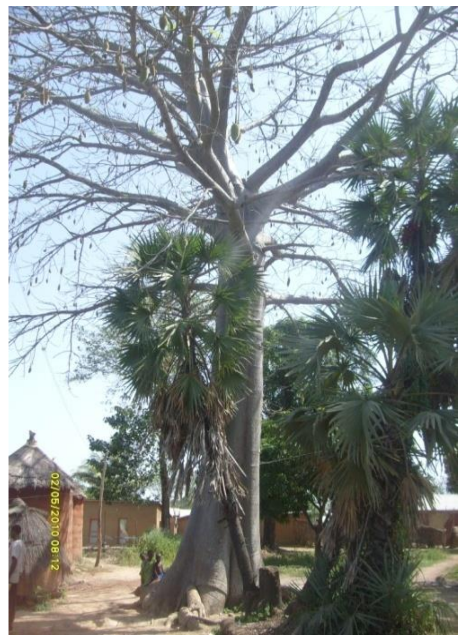
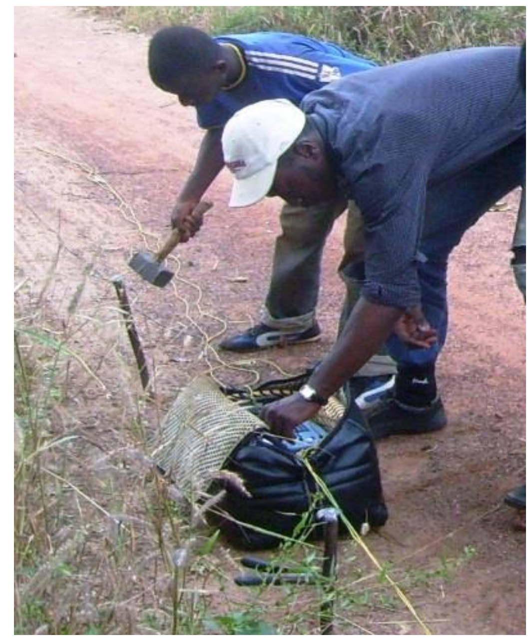
Air photographs + **Field inspection** + **Electrical geophysical survey**



Air photograph of Djougou



Baobab (absorbent tree)



Electrical profiling and sounding

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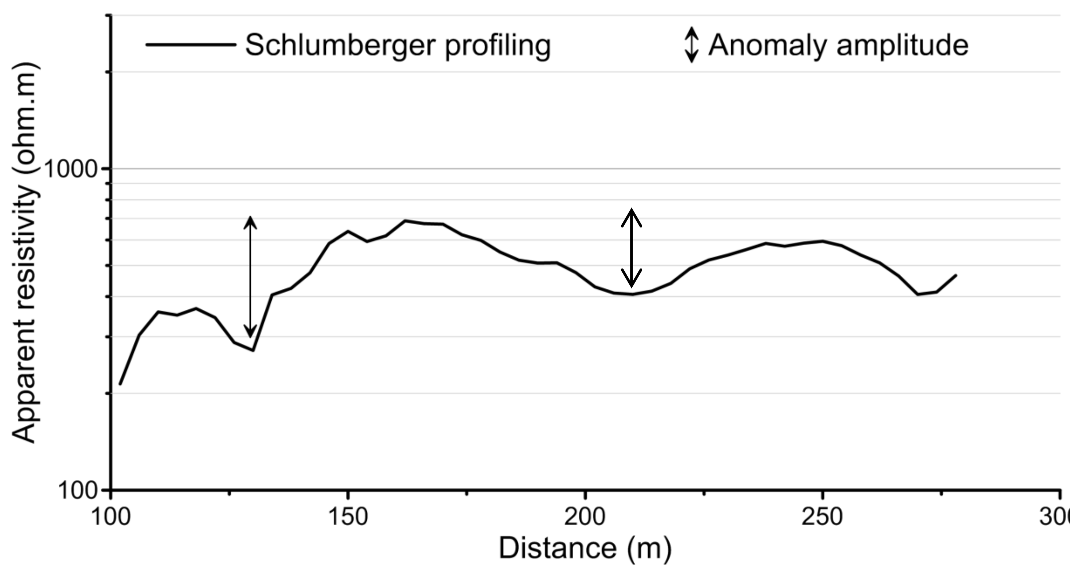
Classical techniques → **Electrical profiling** (EP)



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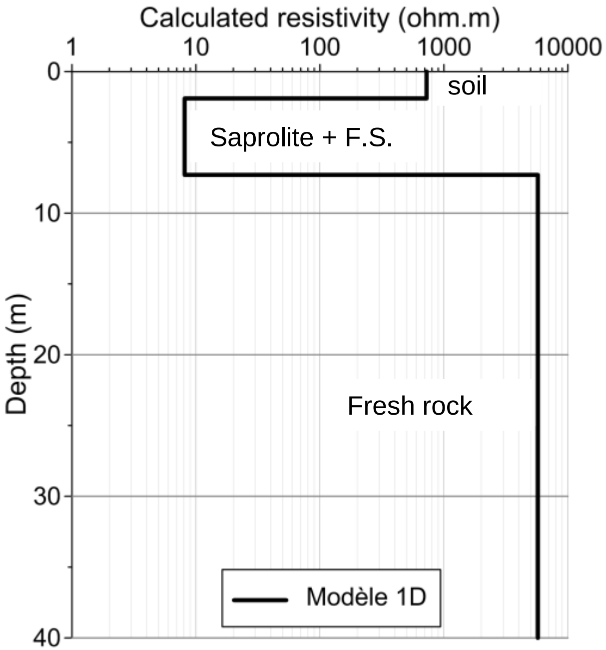
Classical techniques

Electrical sounding (ES)
Necessity of 1D hypothesis



Introduction

- 80% of Benin surface area is underlined by hard rock
- Model of hydrogeological compartment : **deeply weathered zone**
- **Boreholes siting:** based on a comprehensive procedure
- **40%** of the boreholes drilled are negatives (yield less than 0.7 m3/h)

Aim of study

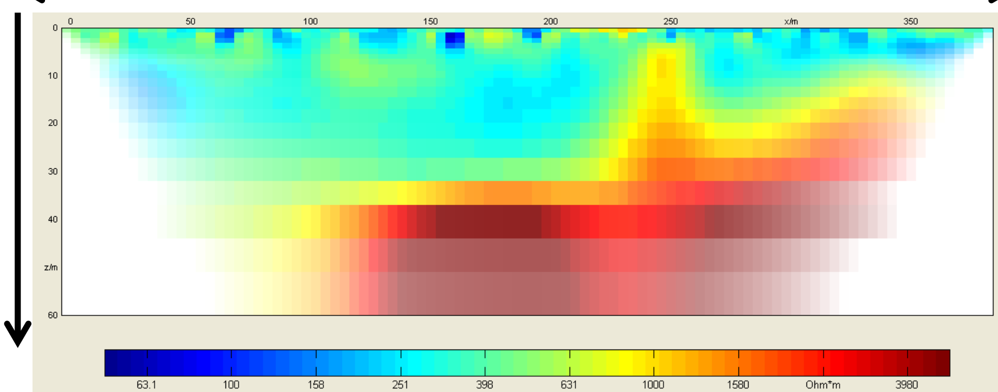
- **Review** the **classical techniques** and explore the **contribution** of **ERT** for borehole siting in **deeply wheathered hard rocks**

2D technique → **Electrical Resistivity Tomography** (ERT)

Resistivimeter multi electrodes

Distance

Depth



Electrical resistivity image

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Materials and method

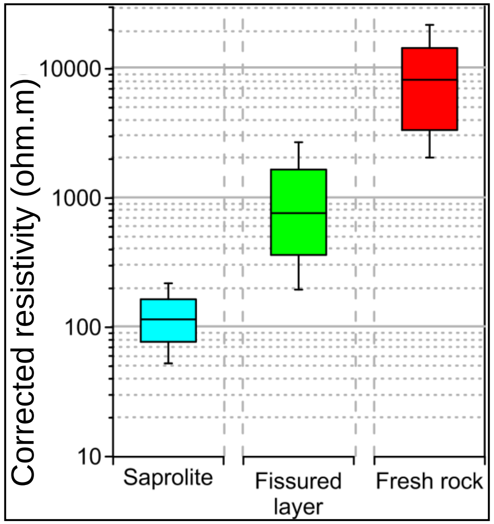
- **Numerical modeling** work to check the theoretical interests and limits of both the classical techniques and ERT

- **Field work** to verify the modeling result

Materials and method

❑ Numerical modeling

✓ **Resistivity range of compartment** (electrical logging on six sites)



Resistivity ranges for 6 sites

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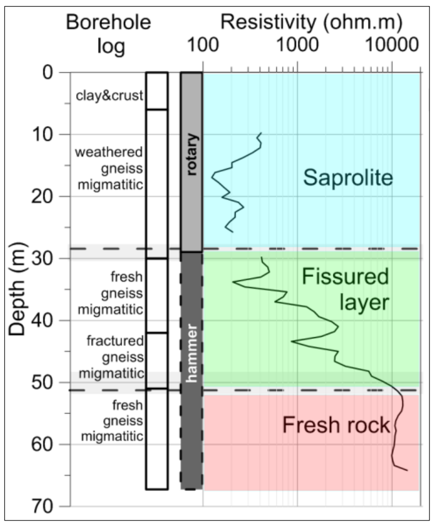

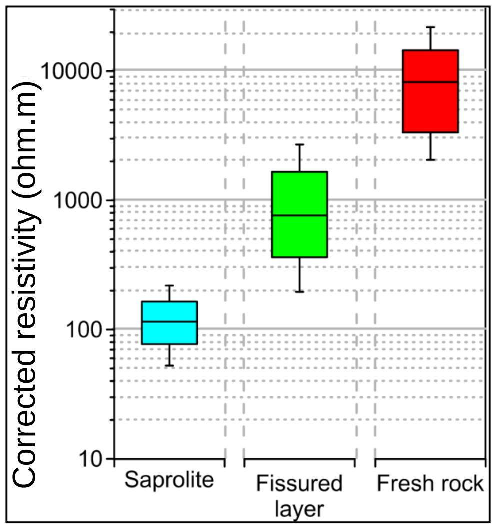

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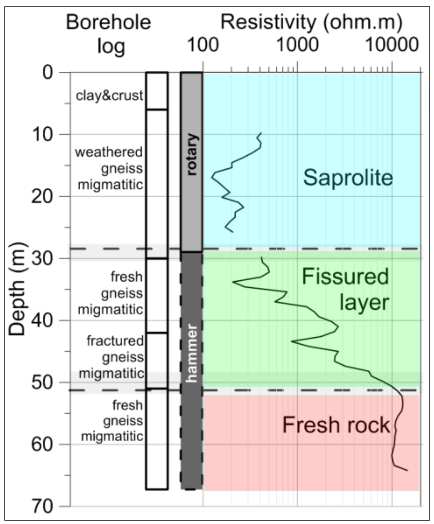
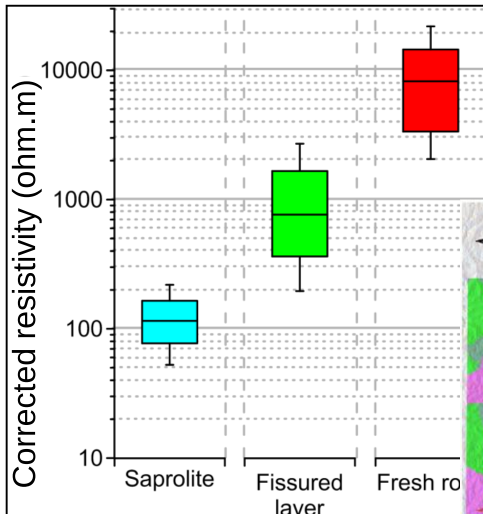
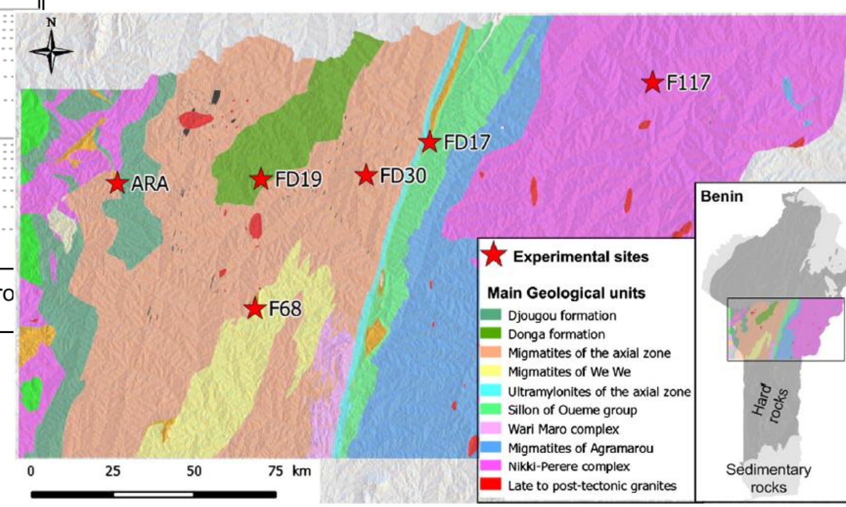




Resistivity ranges for 6 sites



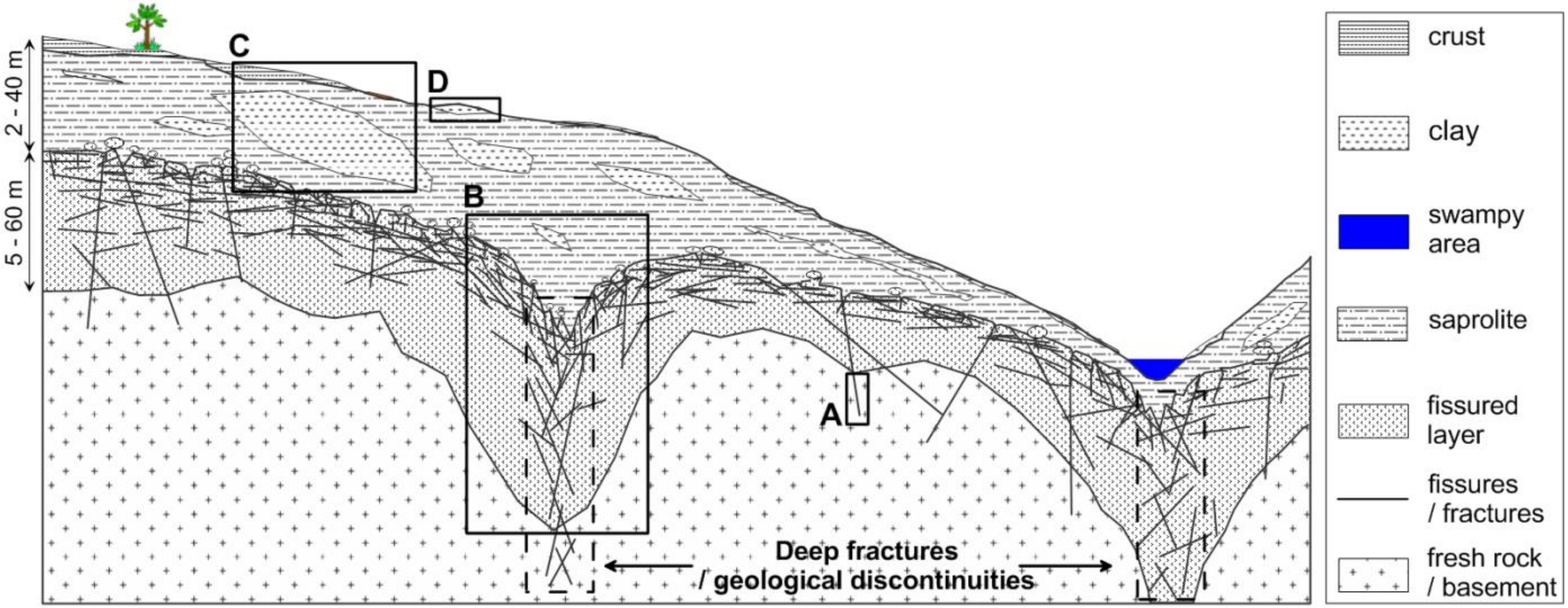
Location of the 6 experimental sites (Vouillamoz et al., 2014)

Materials and method

❑ Numerical modeling

- ✓ **Resistivity range of compartment** (electrical logging on six sites)
- ✓ Numerical models based on typical simplified geometries

(Resistivity ranges and **conceptual model of hydrogeological compartment**)



Conceptual model of hydrogeological compartment in wheathered hard rock (adapted from Dewandel et al., 2011)

Materials and method

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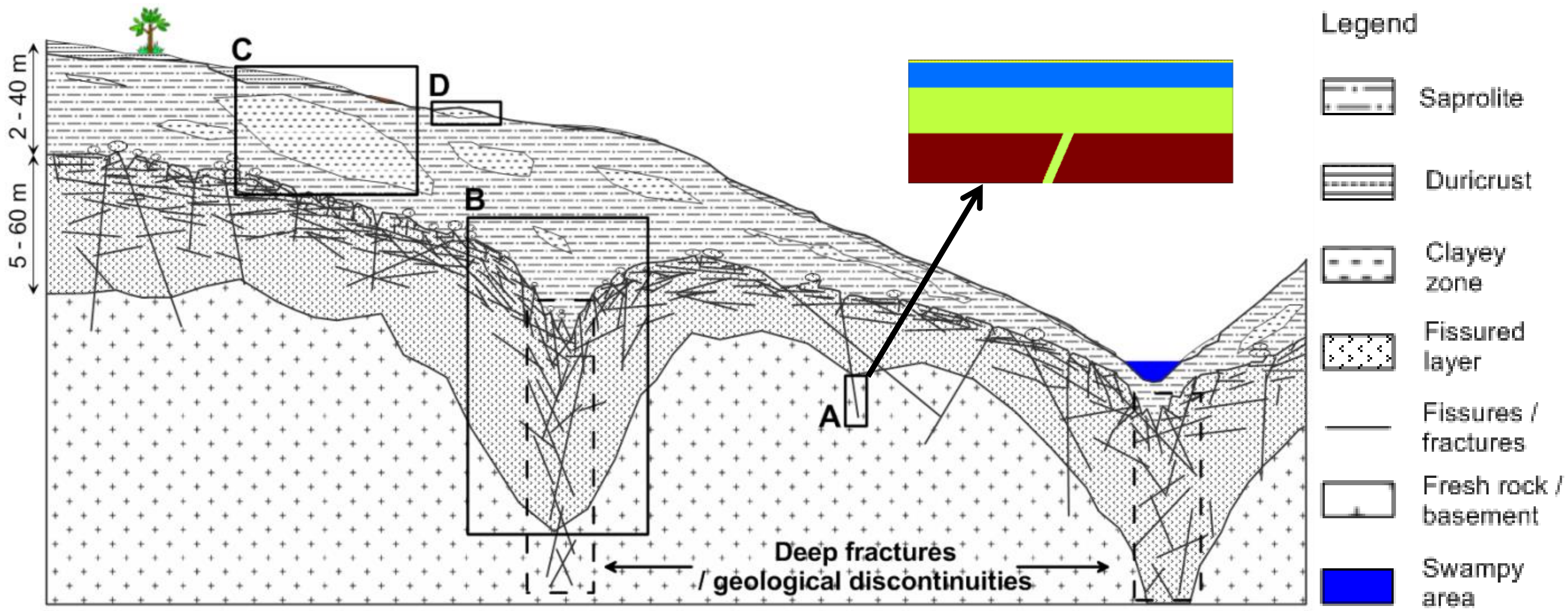

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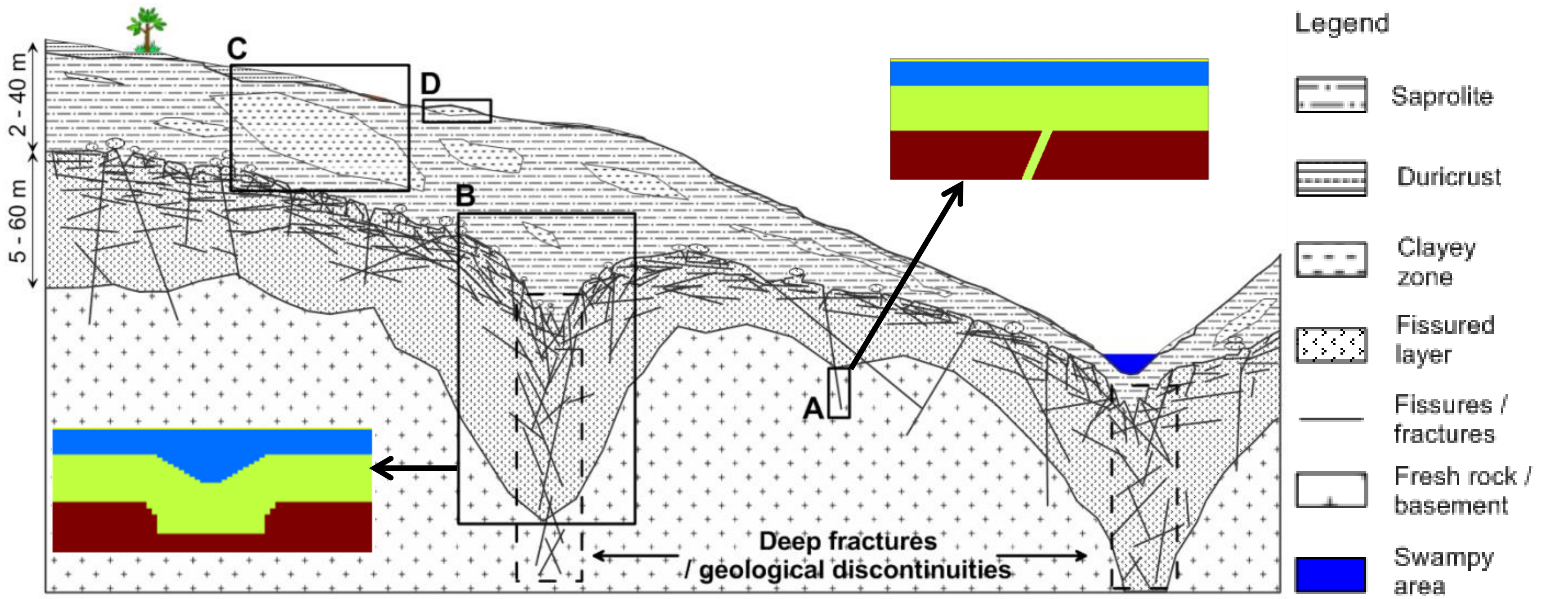

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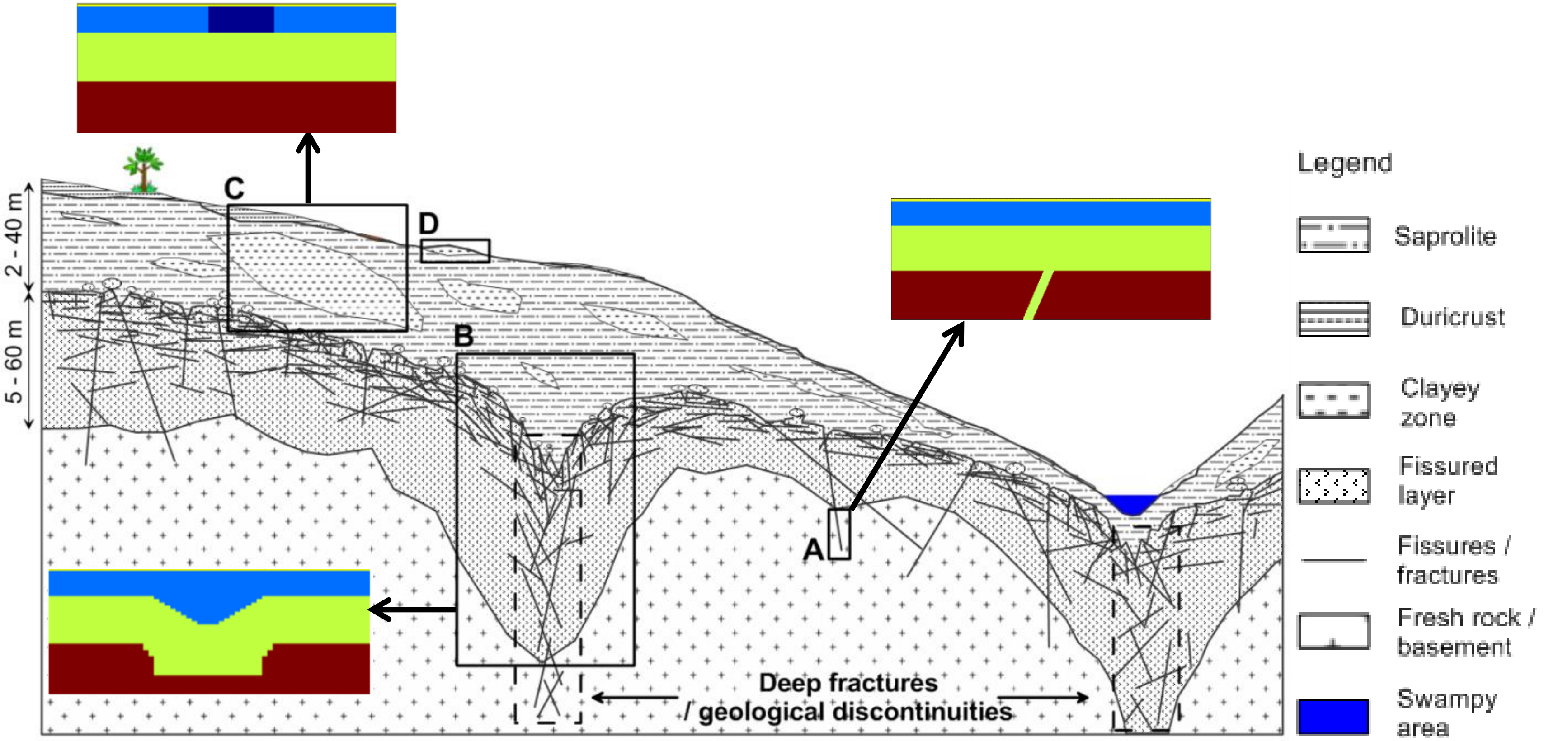

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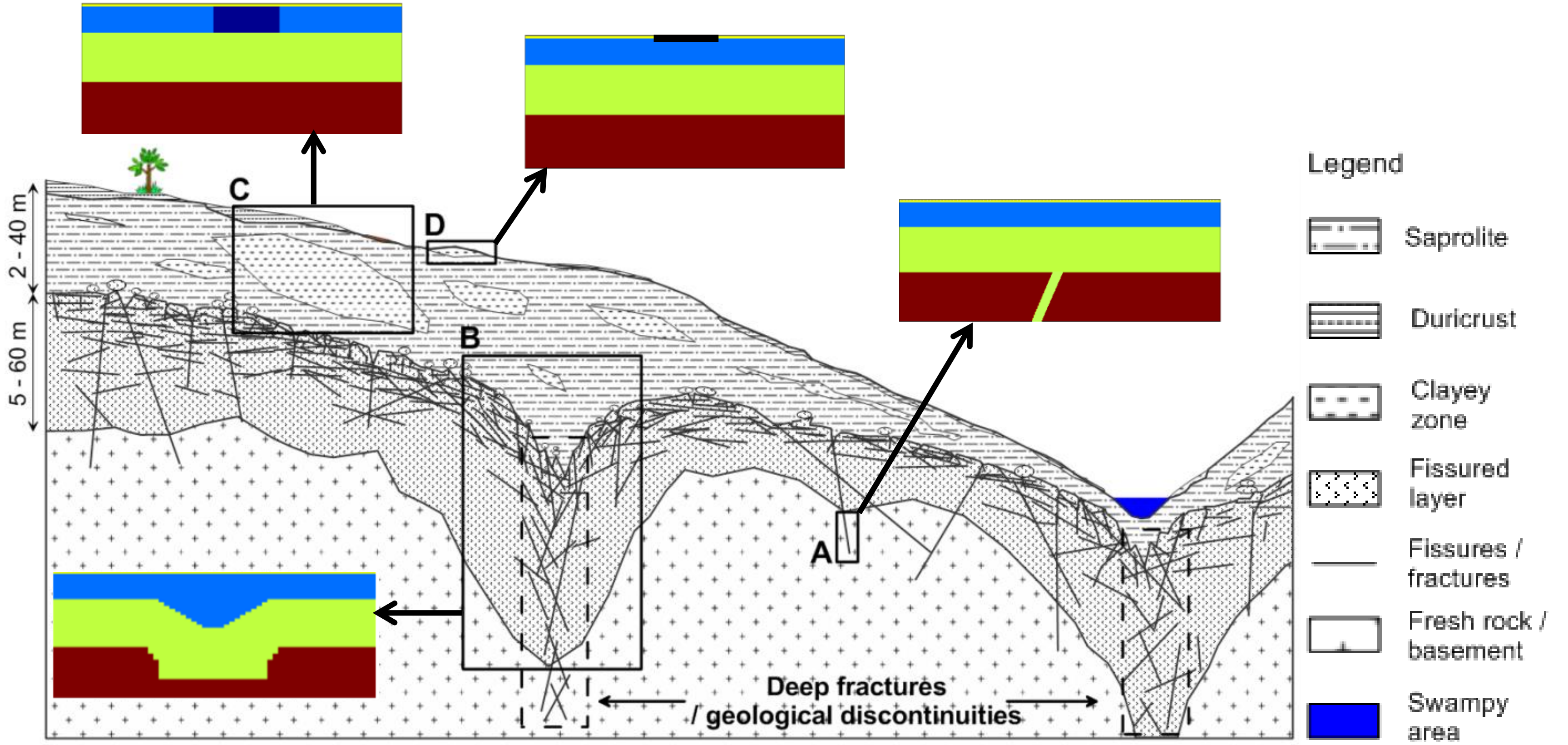

Conceptual model of hydrogeological compartment in wheathered hard rock (adapted from Dewandel et al., 2011)

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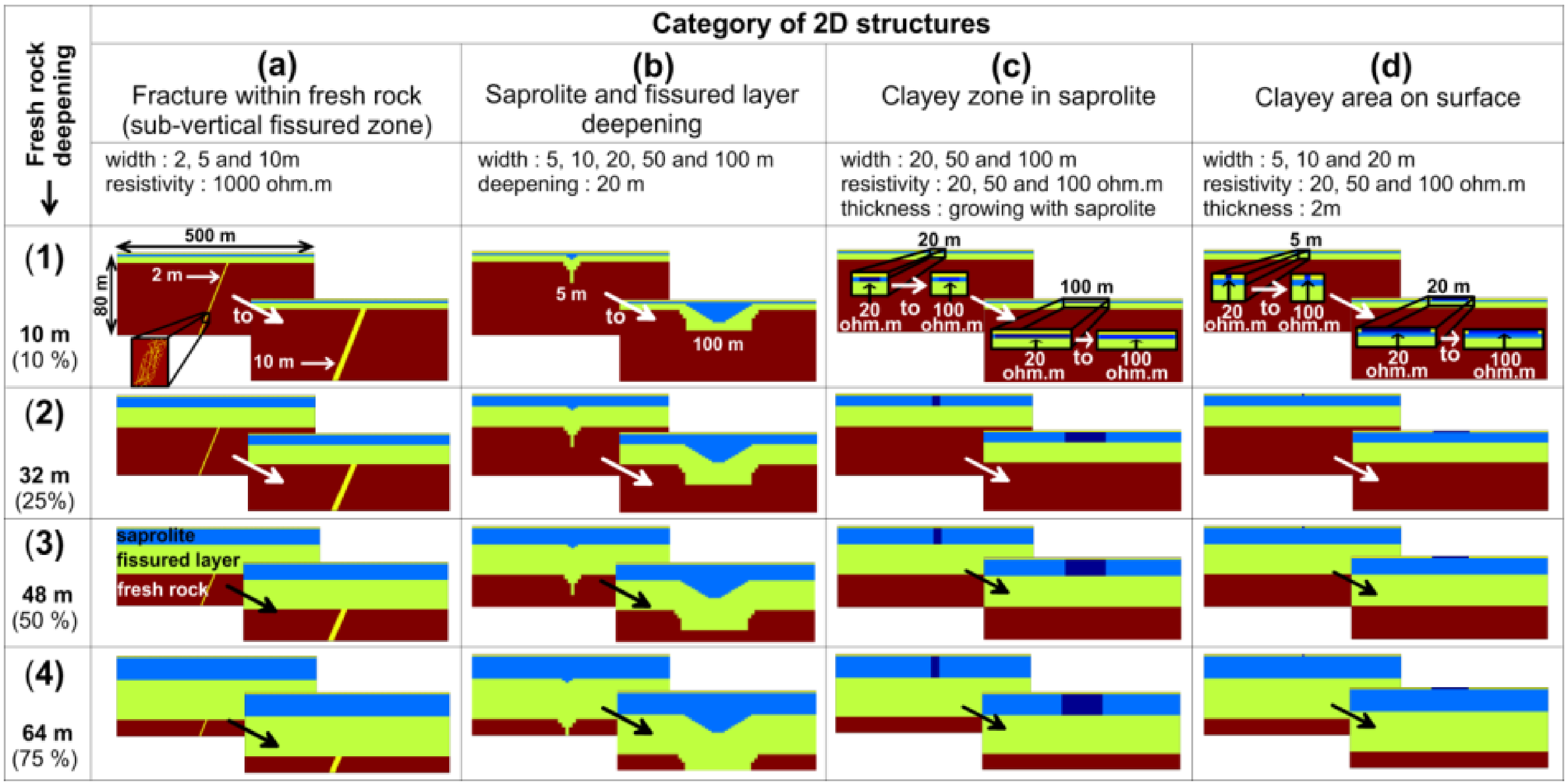
Materials and method

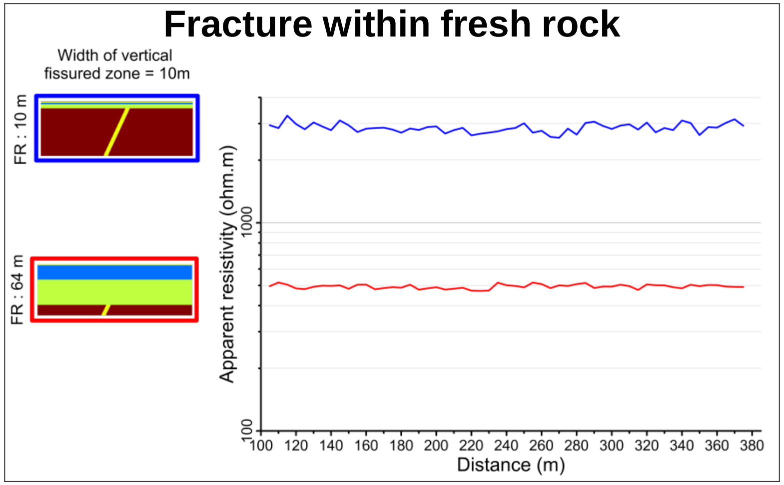
104 numerical models by varying

- resistivity; - width of the structure; - depth of fresh rock



Numerical models used for geophysical modeling

Results (Electrical profiling)



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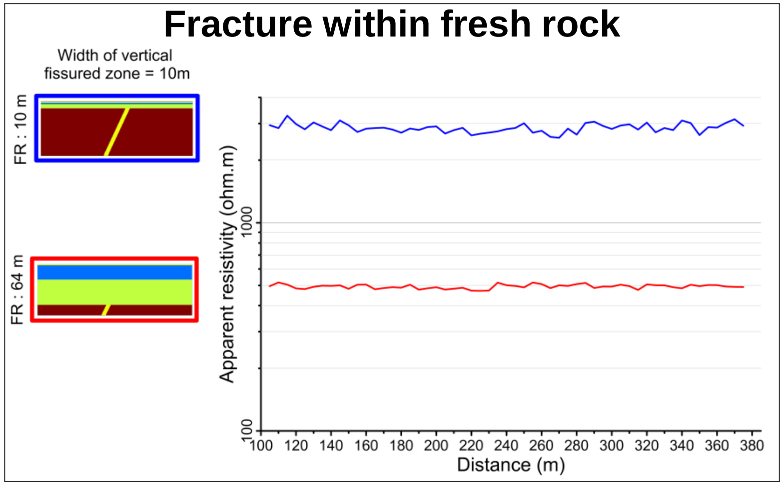
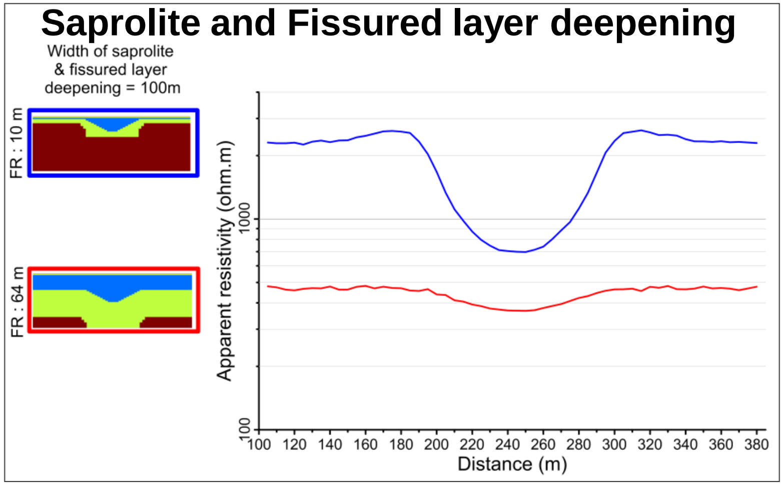
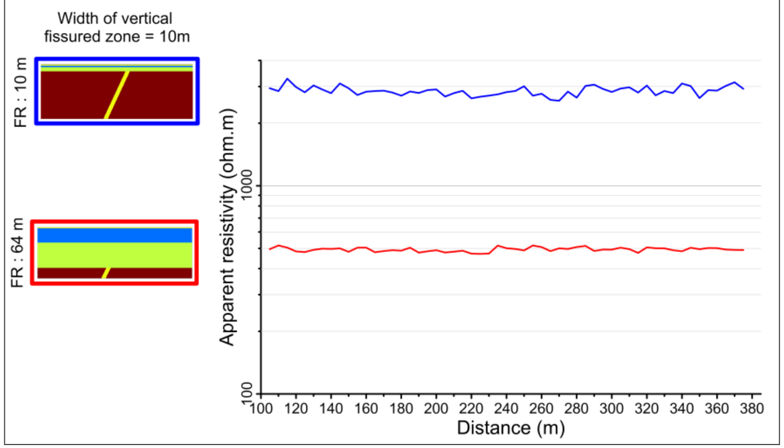


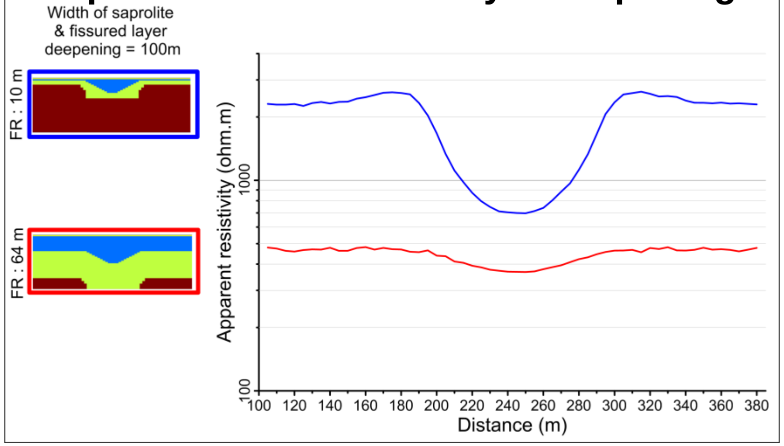


Results (Electrical profiling)

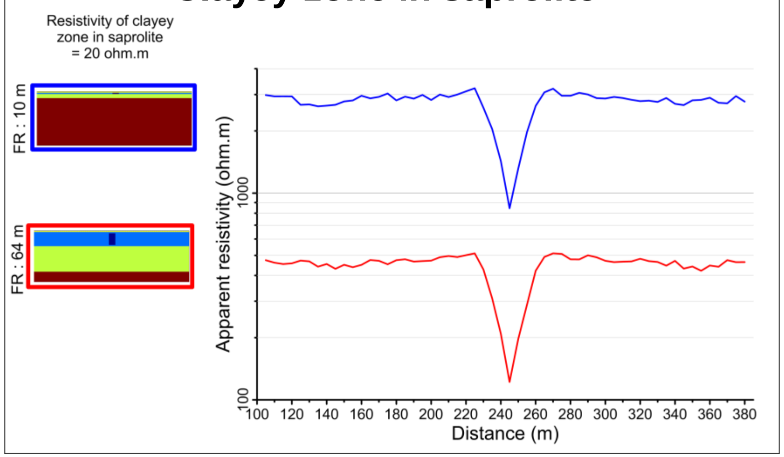
Fracture within fresh rock



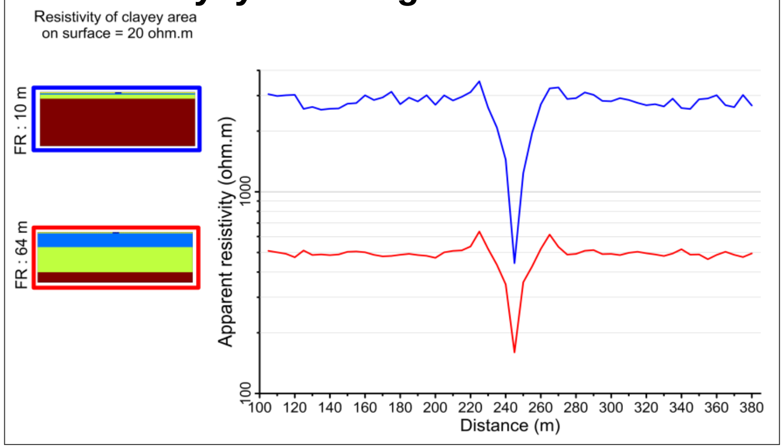
Saprolite and Fissured layer deepening



Clayey zone in saprolite

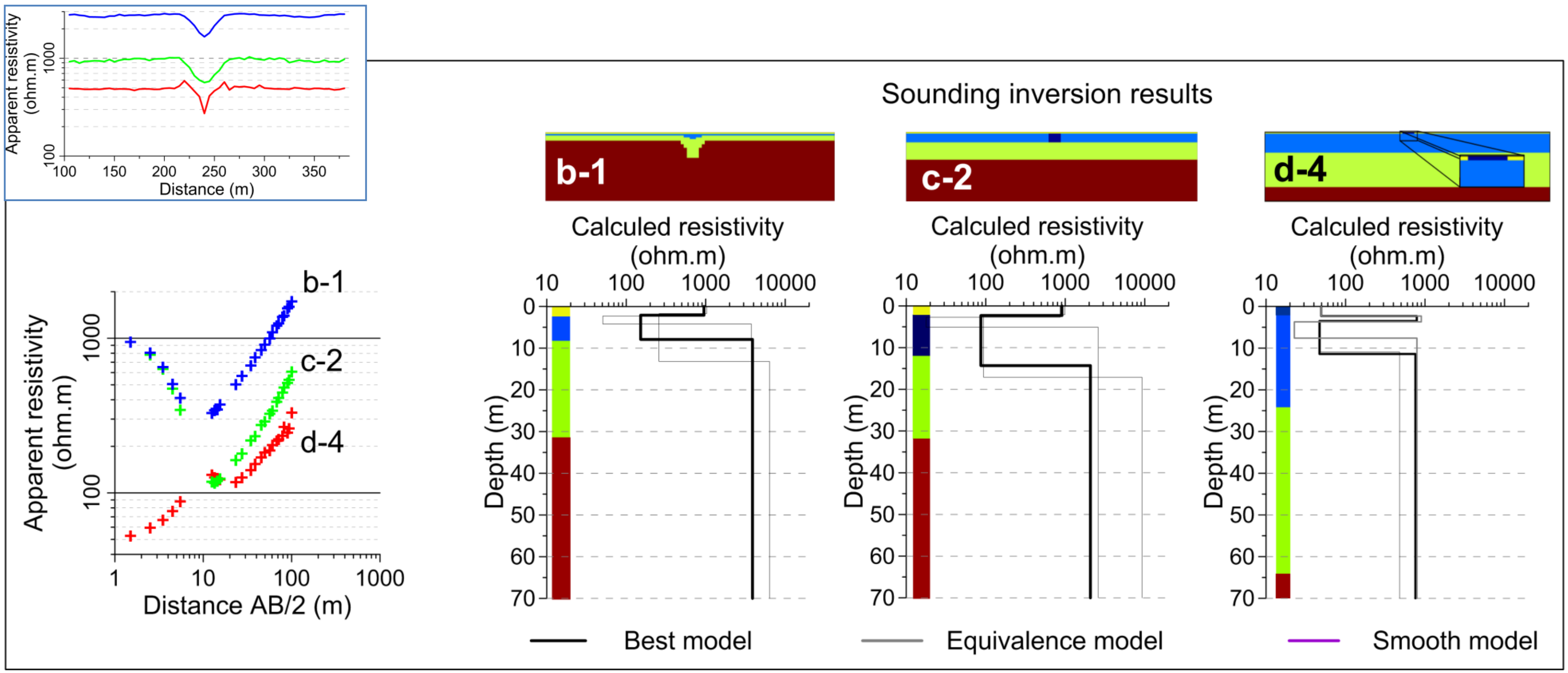


Clayey area at ground surface



Clayey zone in shallow surface is the main source of deflection on E. Profiling

Results (Electrical sounding)



ES have very limited interest in discriminating 2D geometries

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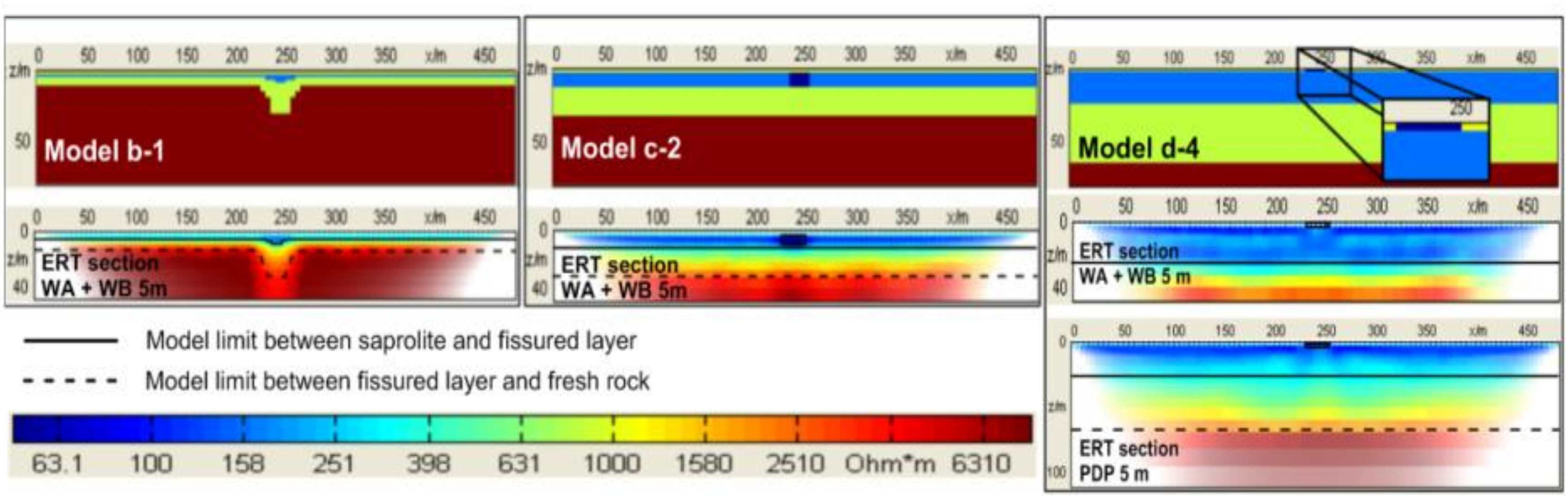
Results (ERT imaging)

❑ The 3 models (b1, c2, d4)

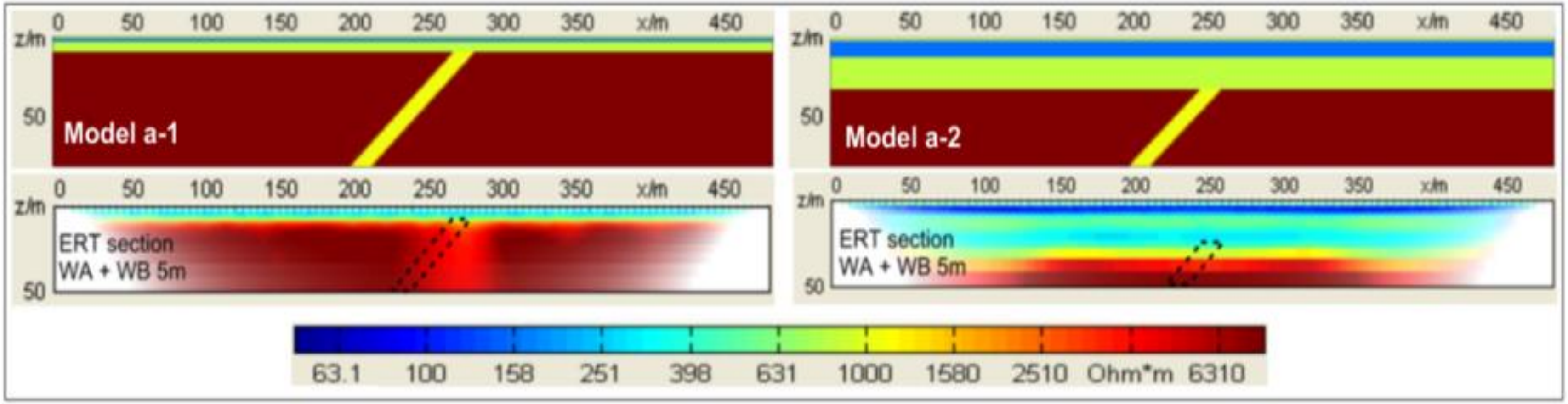


Results of ERT conducted on models 3 models

ERT discriminates the three models which not discriminated by ES

Results (ERT imaging)

❑ Fracture within fresh rock is not discriminated by ERT



Results of ERT performed on the structure of model A (10m width).

Beyond 10 m depth, ERT does not detect a fracture within fresh rock when the fracture is less than 10 meters width

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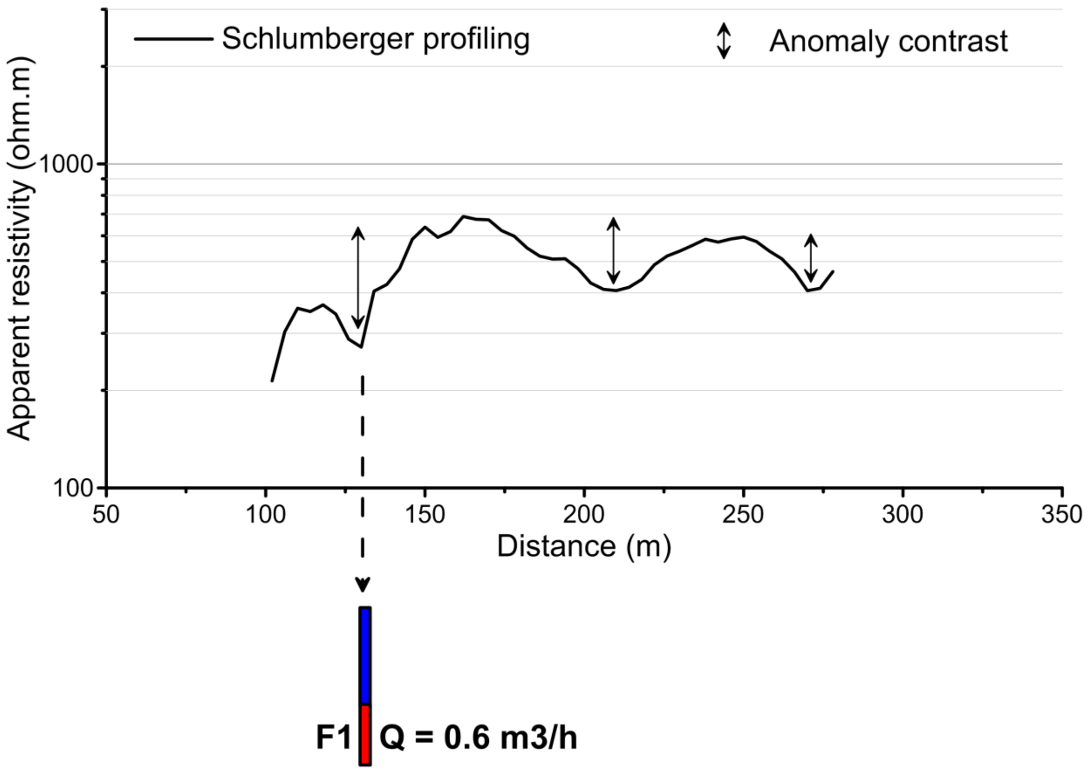
Results (Concrete field case)

SARE site



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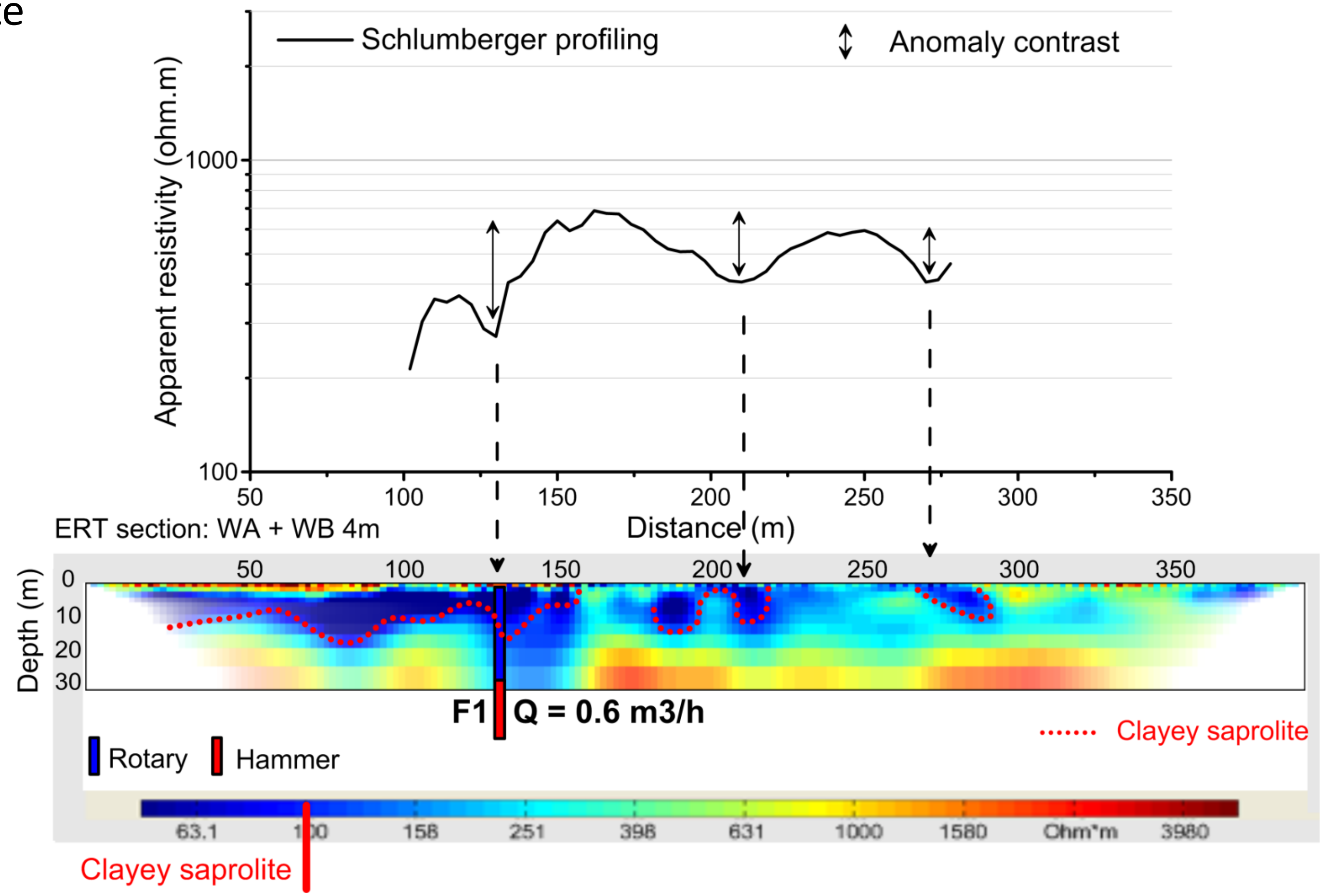

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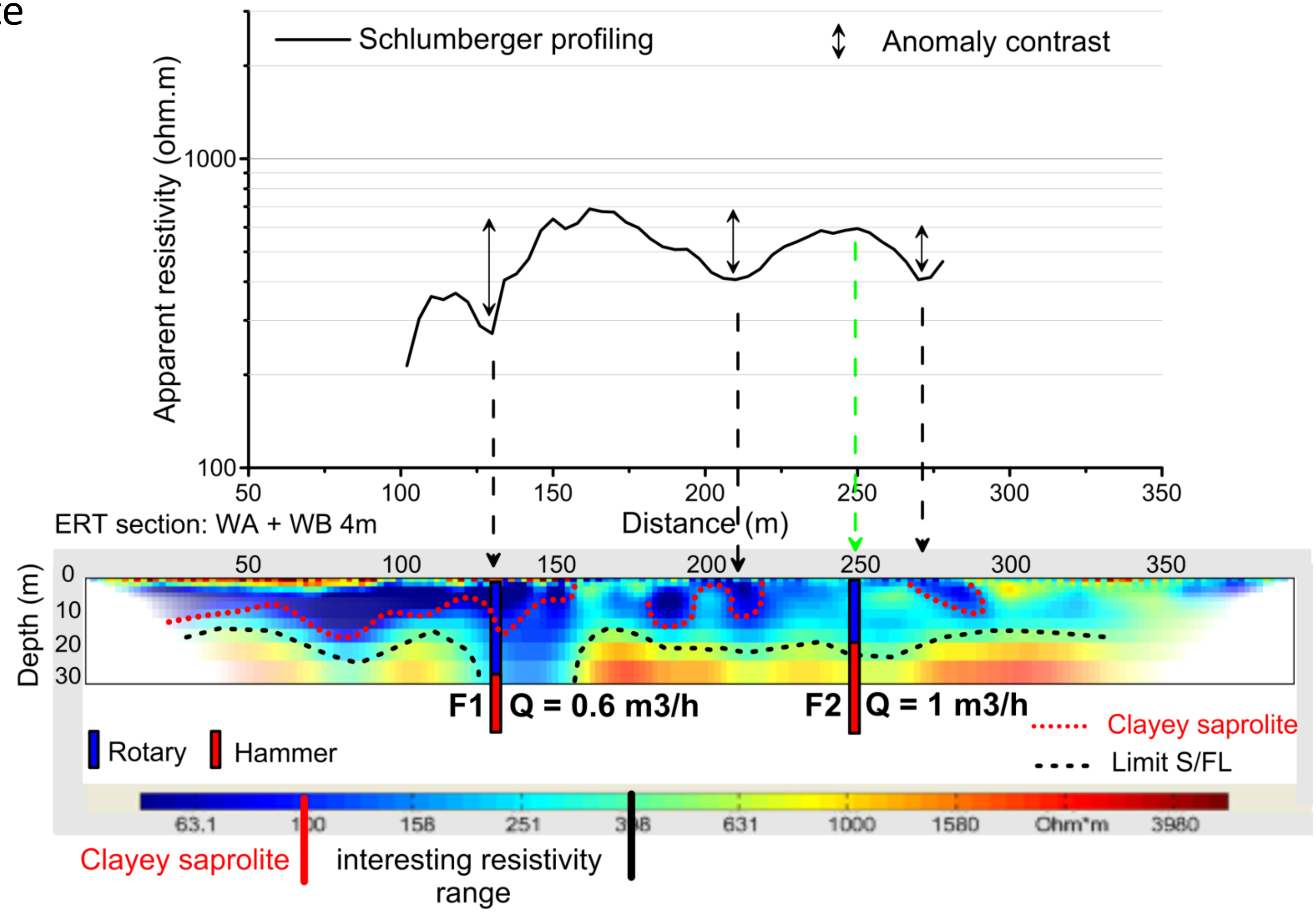

Conclusion

- **Deflection on EP** is often **produced by a clayey zone** in shallow surface

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- **Whatever the classical techniques or ERT**, **fracture** within fresh rock **is not detectable**

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- **ERT** gives **better resolution** of structures and compartment in this context

- **Whatever the classical techniques or ERT**, **fracture** within fresh rock **is not detectable**

For the boreholes siting in deeply weathered hard rock, **ERT is recommendable**, while **EP and ES should be abandoned**.

Thank you!