Robustness of the 2D-DC Resistivity Imaging method applied to dike survey : state of the art, limitations and outlooks

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31 August 2012

Paris, France

Summary

- **Electrical Resistivity Imaging**
  - **2D - ERI principle**
  - **Resolution study principle**
- **Dike survey by ERI**
  - **Limitations**
  - **Parametric study**
  - **Impact of the measurement error on R_M**
  - **InGEOHT 2D+ principle**
- **Case study**
  - **Presentation of the surveyed structure**
  - **Results**
- **Conclusion and Outlooks**

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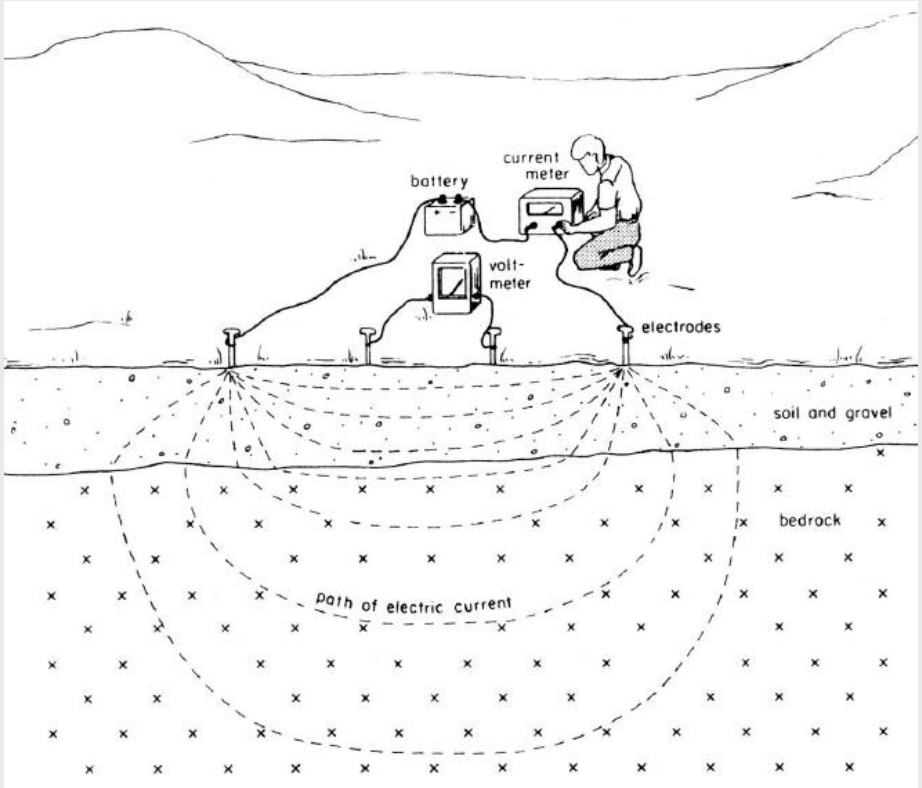
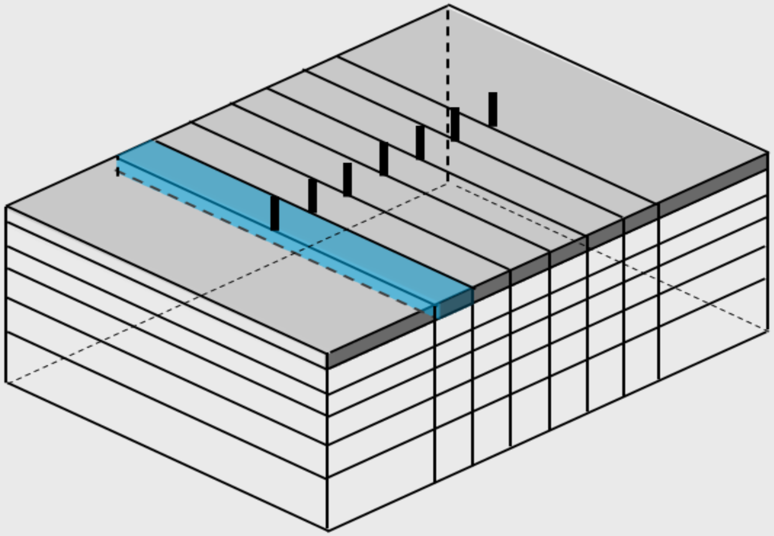
❑ Electrical Resistivity Imaging principle





Limitations:

- non-uniqueness of the solution
- depth of investigation

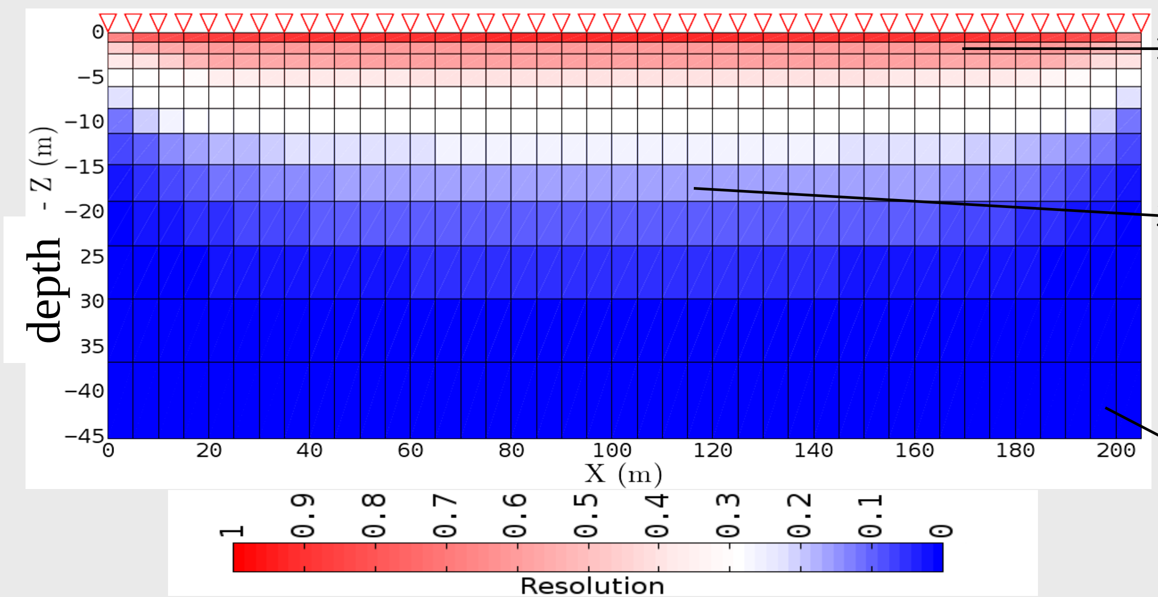
❑ Resolution study principle

$$R_M = (J^T W_d^T W_d J + \lambda C^{-1})^{-1} J^T W_d^T W_d J$$

Gives the capacity to invert uniquely each inversion cell (robustness of the solution)

R_M : Model Resolution Matrix
J : Sensitivity matrix
W_d : Matrix of data error
λ : damping factor
C : smoothing matrix

2D section



High robustness

Moderate robustness

Low robustness

❑ Resolution study principle

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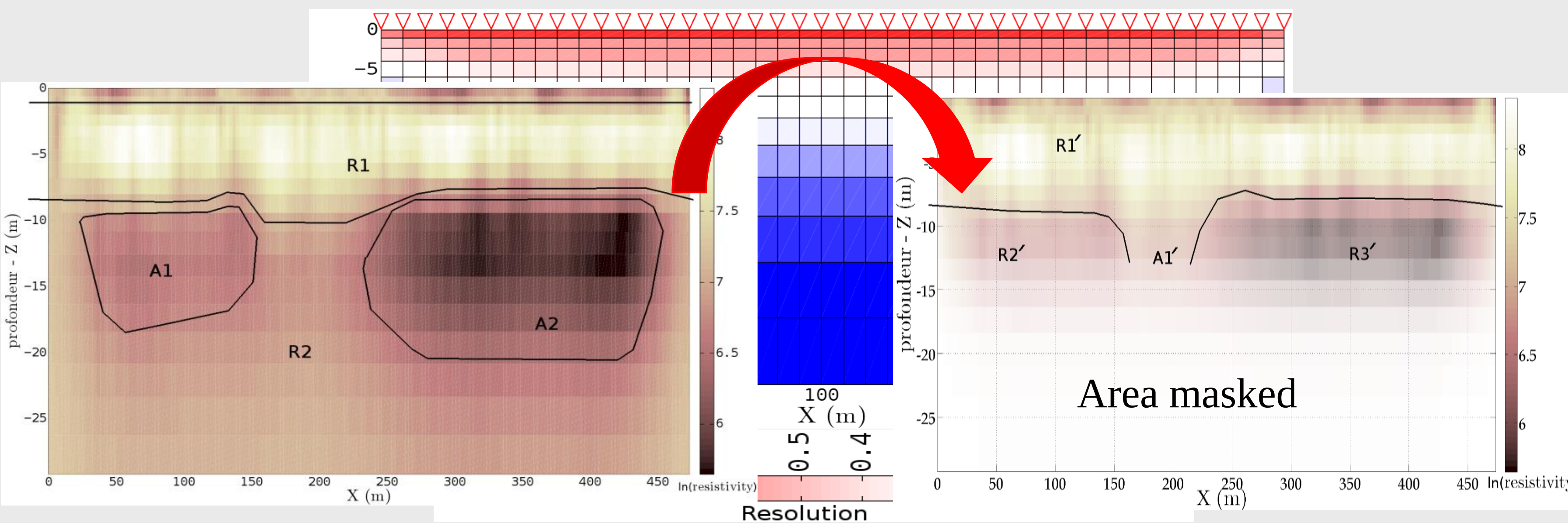

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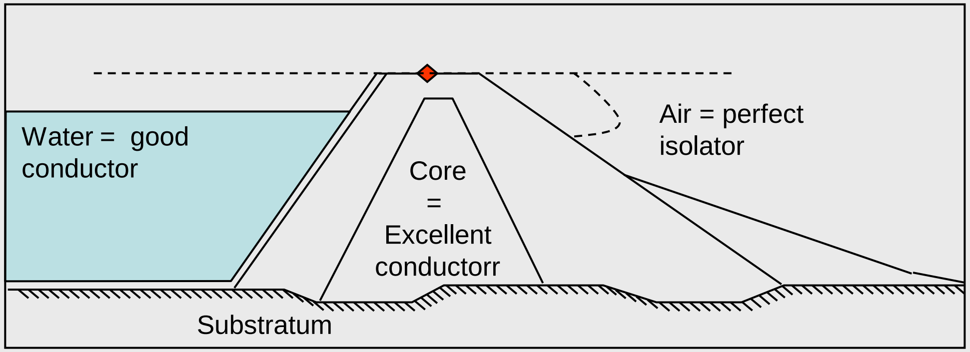
❑ Dike survey by ERI

- For cost effective reasons, surveys are performed longitudinaly

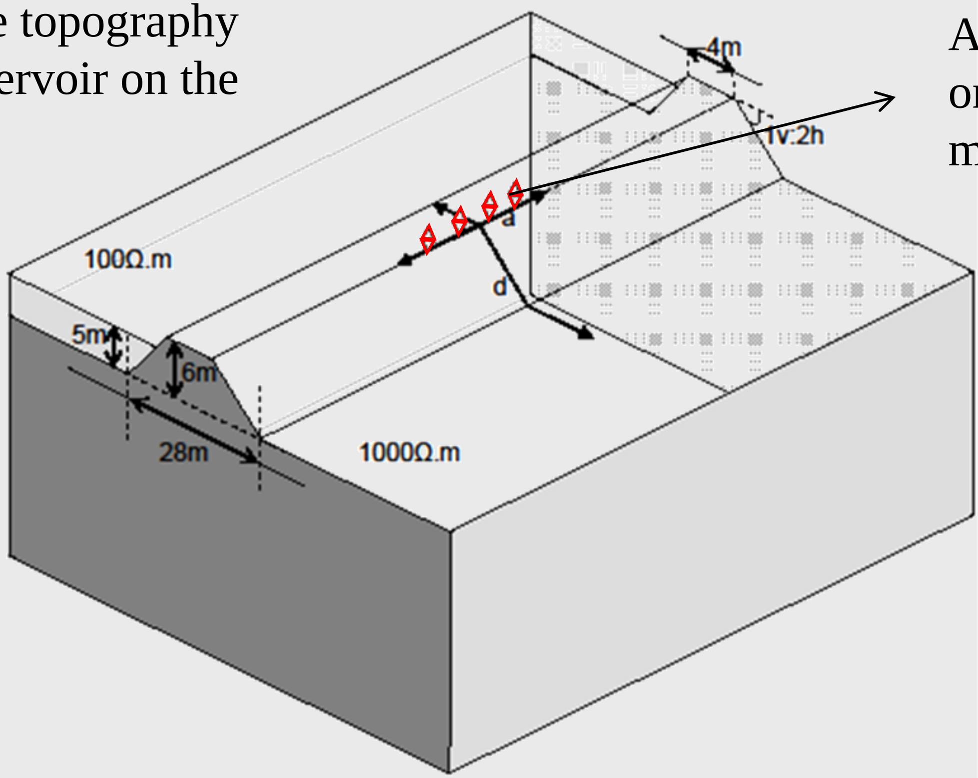


- For dike longitudinal surveys, 2D Hypothesis is completely wrong

Is the 3D behaviour of the dike composition has a significant impact on the measurement ?

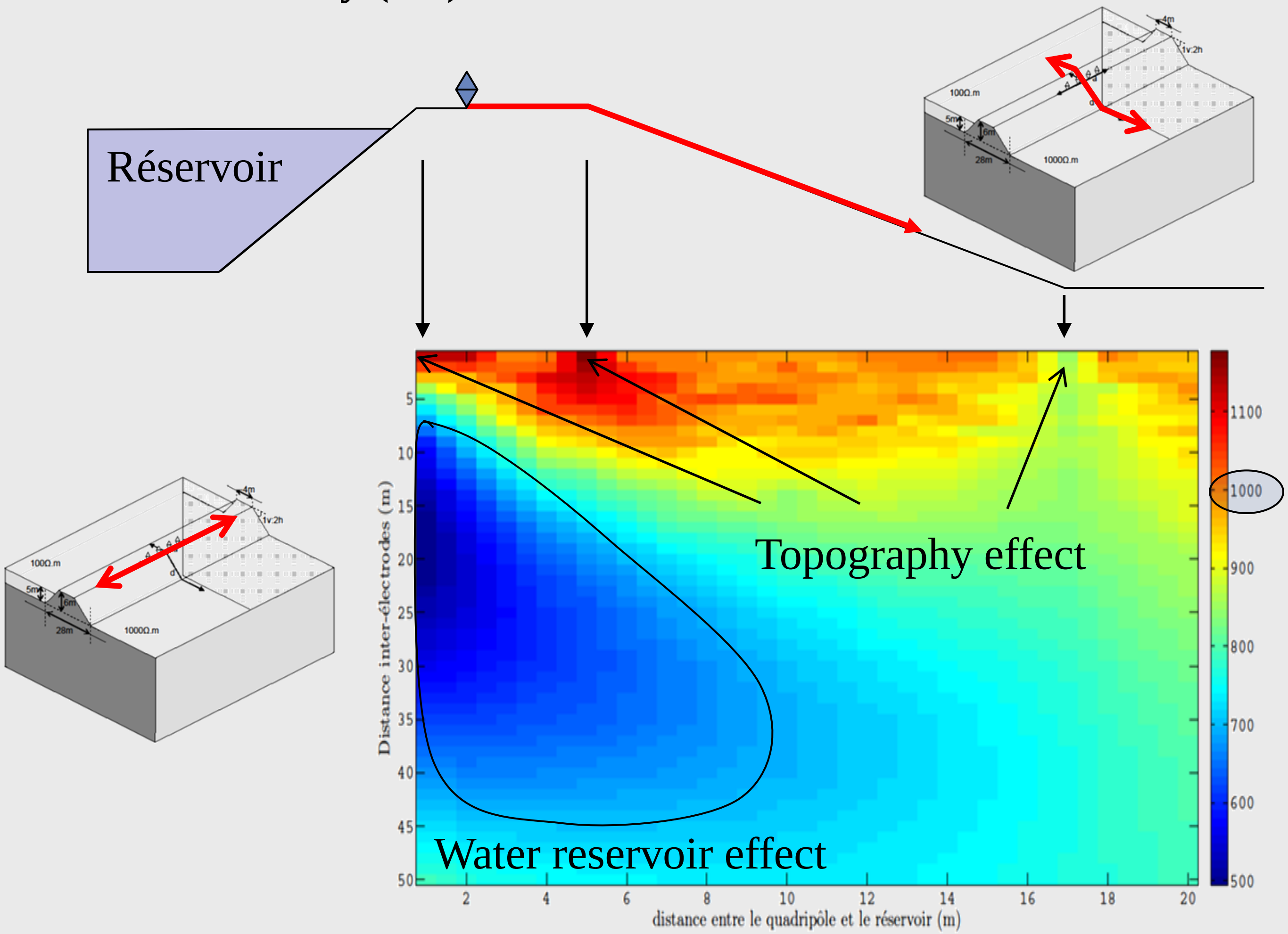
❑ Parametric study (1/2)

Test the effect of the topography and of the water reservoir on the measurement

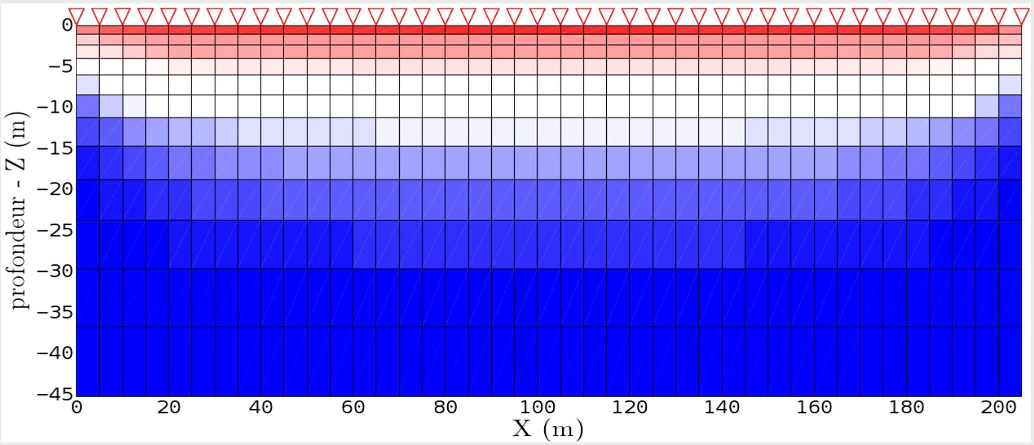


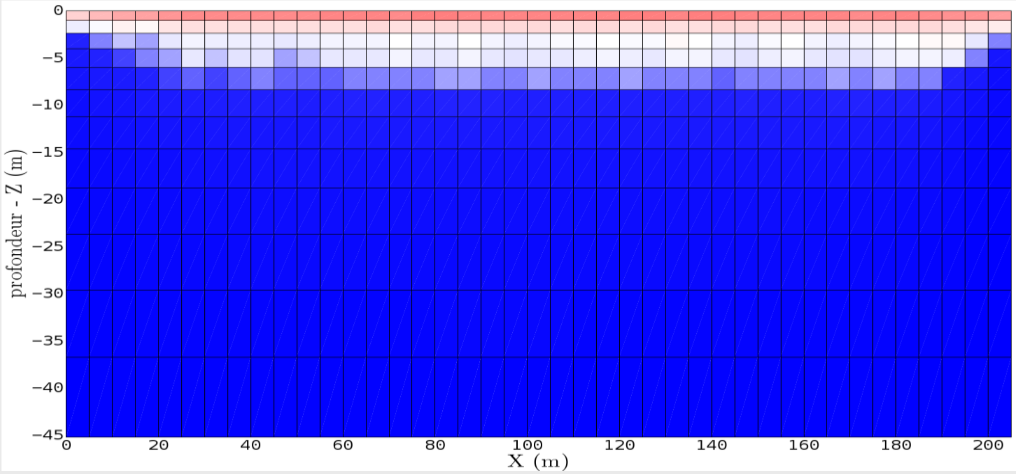
A quadripole is moved on the dike and a measure is simulated

❑ Parametric study (2/2)



❑ Impact of the measurement error on R_M



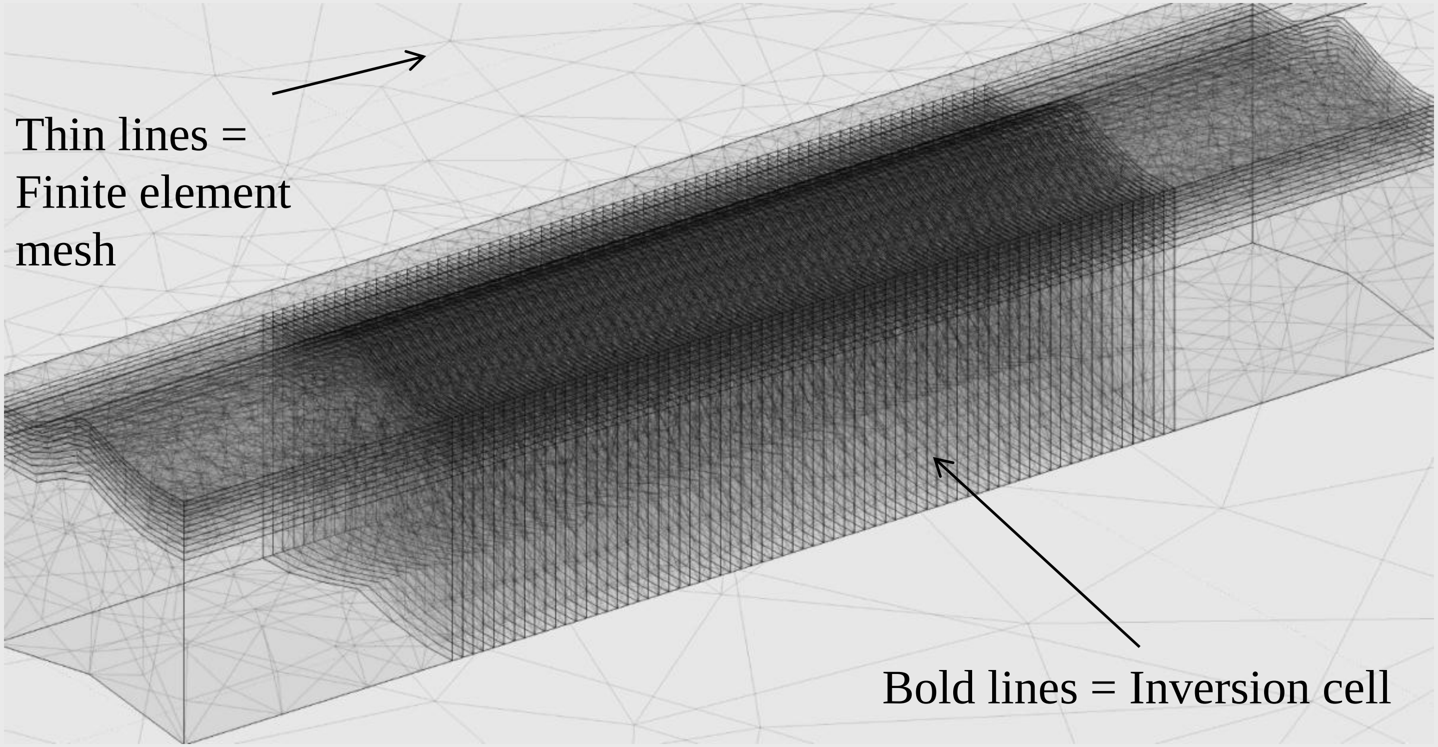


$$\boxed{R_M = (J^T W_d^T W_d J + \lambda C^{-1})^{-1} J^T J}$$

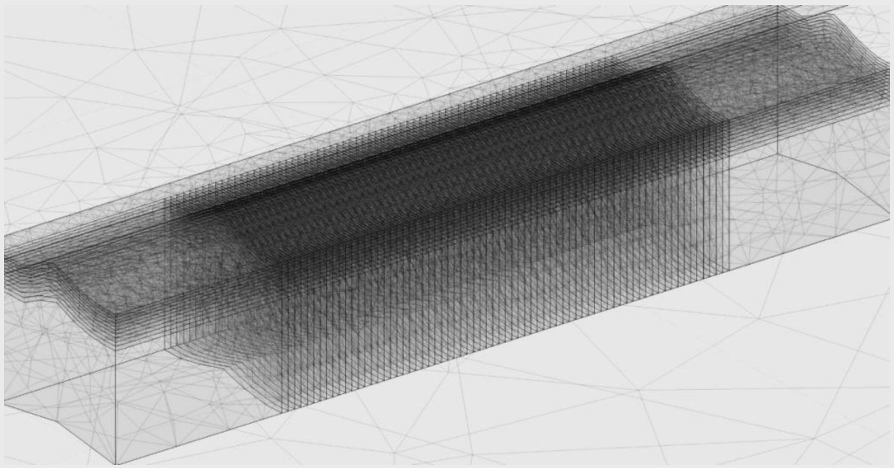
Conclusion : conventional resolution results over-estimate the robustness of an imaging result

❑ InGEOHT 2D$^+$

Principle : The topography and the water reservoir is explicitly defined in the inverse problem

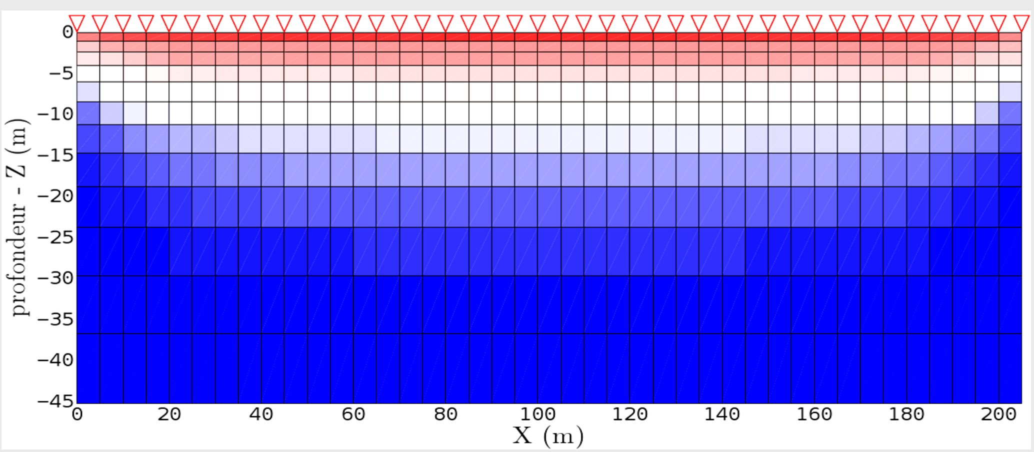


❑ InGEOHT 2D$^+$



The resolution and depth of investigation are not reduced.

R_M can now be used to improve the interpretation of 2D ERI longitunal survey on dike.



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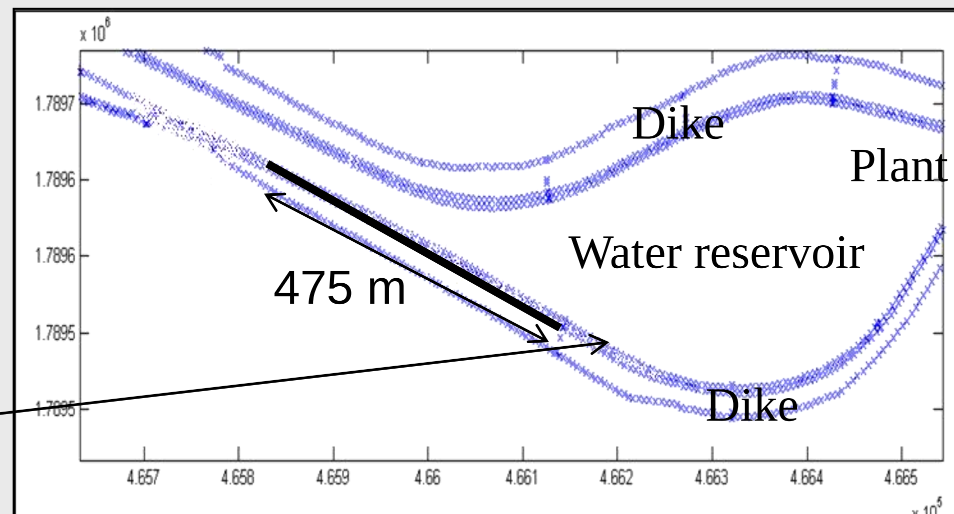
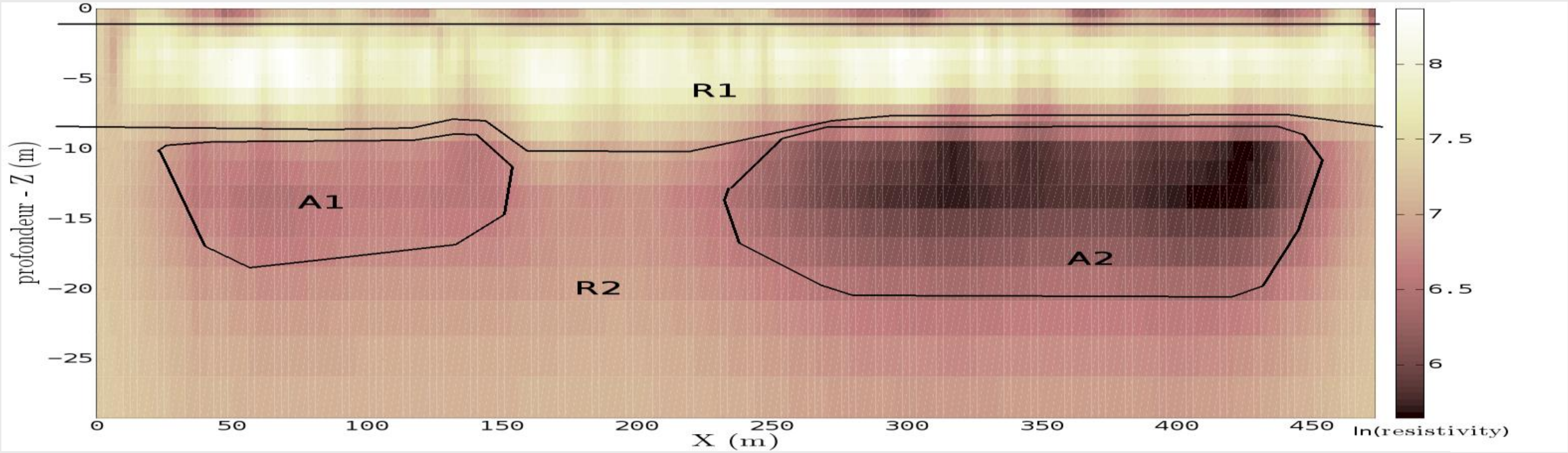
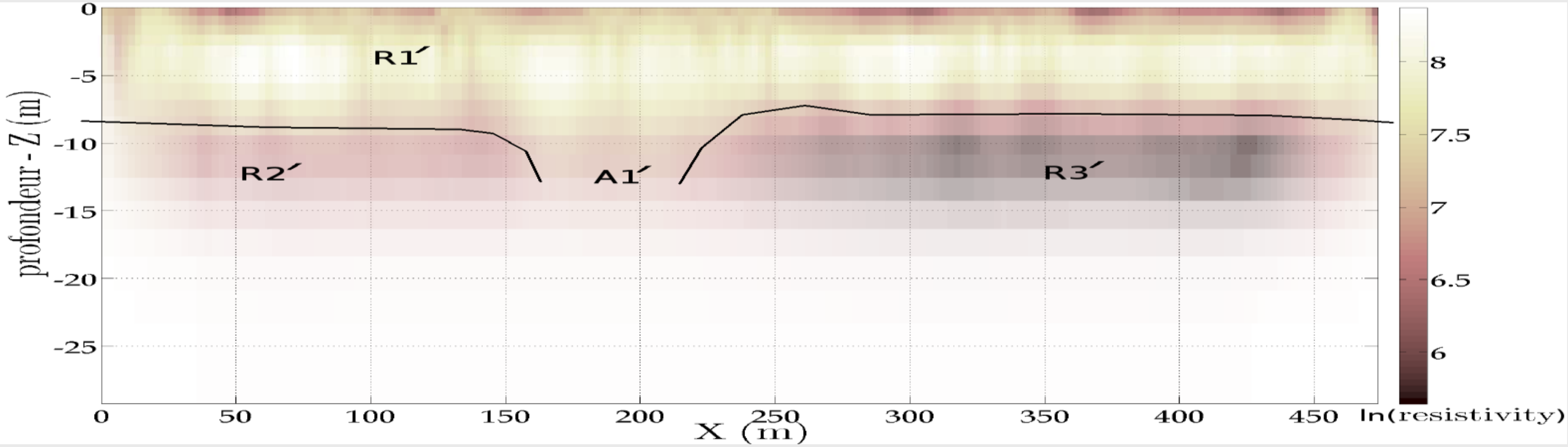
❑ Presentation of the survey

- Homogeneous
- Concrete facing (upstream side)
- Height of 6 to 7 meters
- 475 meters longitudinal survey (96 electrodes with 5 meters inter electrode spacing)
- Wenner Schlumberger acquisition protocol



❑ Results


R1
A1
A2
R2
profondeur - Z (m)
X (m)
ln(resistivity)


R1´
R2´
A1´
R3´
profondeur - Z (m)
X (m)
ln(resistivity)

Summary

❑ Conclusion & Perspectives

<u>In general :</u>

- An imaging result is non-unique $\longrightarrow$ Questions about the robustness

<u>For 2D ausculted medium:</u>

- R_M (conventional) can be used to help the interpretation of the result

<u>For 2D longitudinal survey of dikes :</u>

- Dike geometry has a strong effect on the measurement
- The error on the measurement has an effect on R_M and limit the depth of investigation
- Conventional depth of investigation are always over estimated
- New inversion algorithm can be used to overpass this limitation

THANK YOU FOR YOUR ATTENTION

InGEOHT 2D$^+$

- Gauss-Newton inversion algorithm
- 100 < number of inversion parameter < 10 000
- Minimisation of the objective fonction :

$$\Phi = \Phi_d + \lambda\Phi_m = \|\mathbf{D}(\vec{d}_{mes} - \Gamma(\vec{m}))\|_2^2 + \lambda\|\mathbf{C}(\vec{m} - \vec{m}_0)\|_2^2$$

- Φ_d : data objective function; Φ_m : model objective function
- λ : damping factor; **D** : Data error
- d_{mes} : vector of measured data; Γ : forward problem
- m : model ; m_0 : *a priori* model; **C** : smoothing matrix

$$\underbrace{(\mathbf{G}^T\mathbf{D}^T\mathbf{D}\mathbf{G} + \underbrace{\lambda\mathbf{C}_m^T\mathbf{C}_m}_{\text{Occam type regularisation of the Hessian}})}_{\text{Hessian}}\Delta\vec{m}_{i+1} = \underbrace{\mathbf{G}^T\mathbf{D}^T[\mathbf{D}(\vec{d}_{mes} - \Gamma(\vec{m}_i))]}_{\text{Gradient of the objective function}}$$