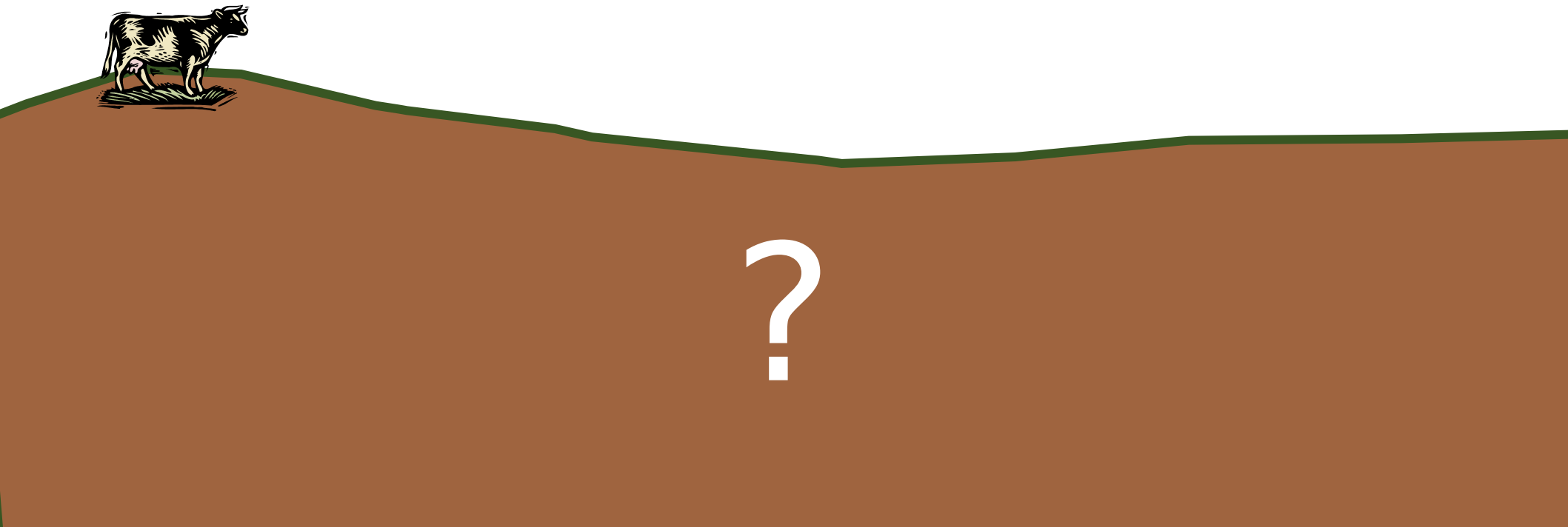
Integração de métodos geofísicos

Apresentação do curso e objetivos

PÓS::GRADUAÇÃO
DINÂMICA
DOS **OCEANOS**
E DA TERRA
UFF

Em um levantamento geofísico

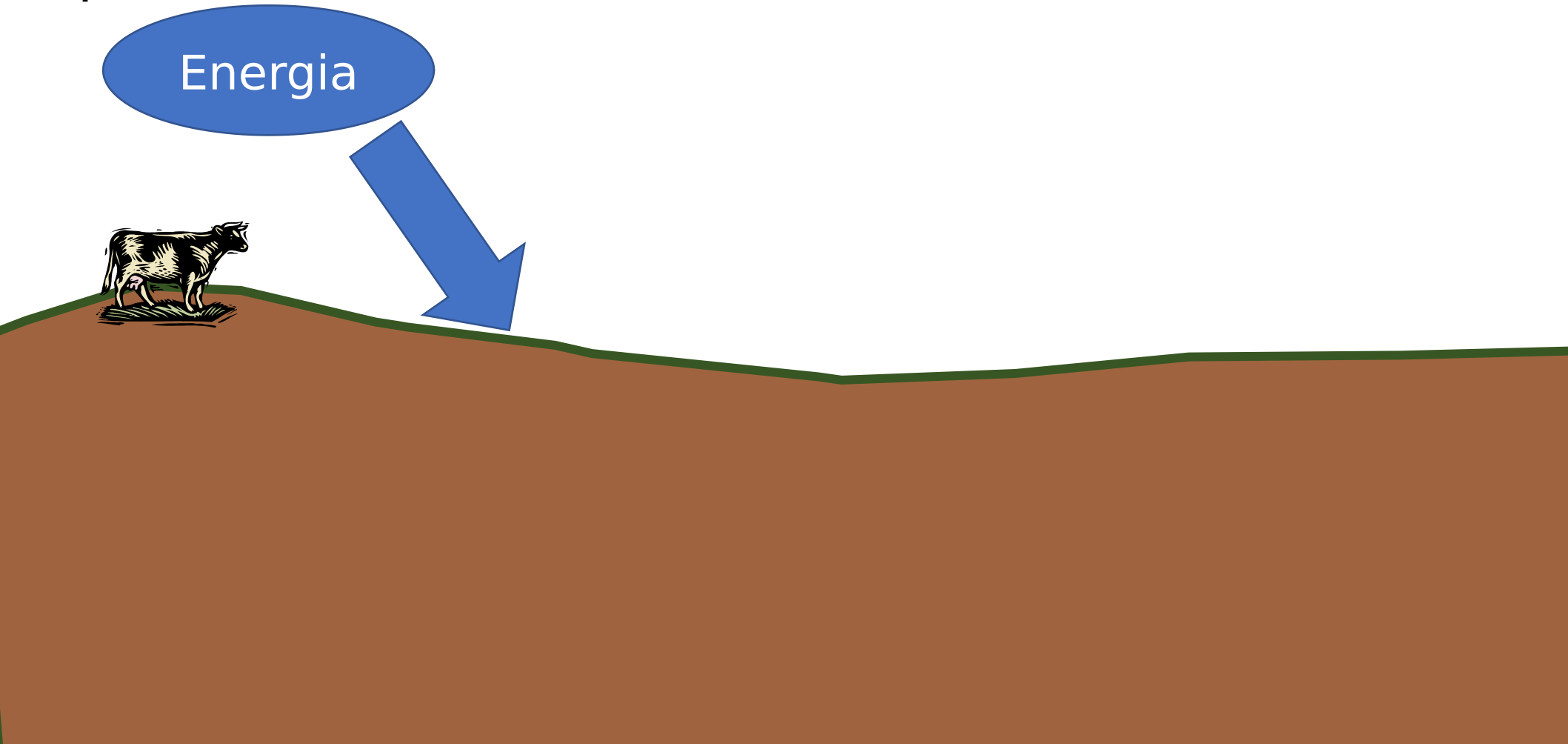
Determinar o que está embaixo da superfície



Determinar o que está embaixo da superfície

Energia

Determinar o que está embaixo da superfície



Determinar o que está embaixo da superfície

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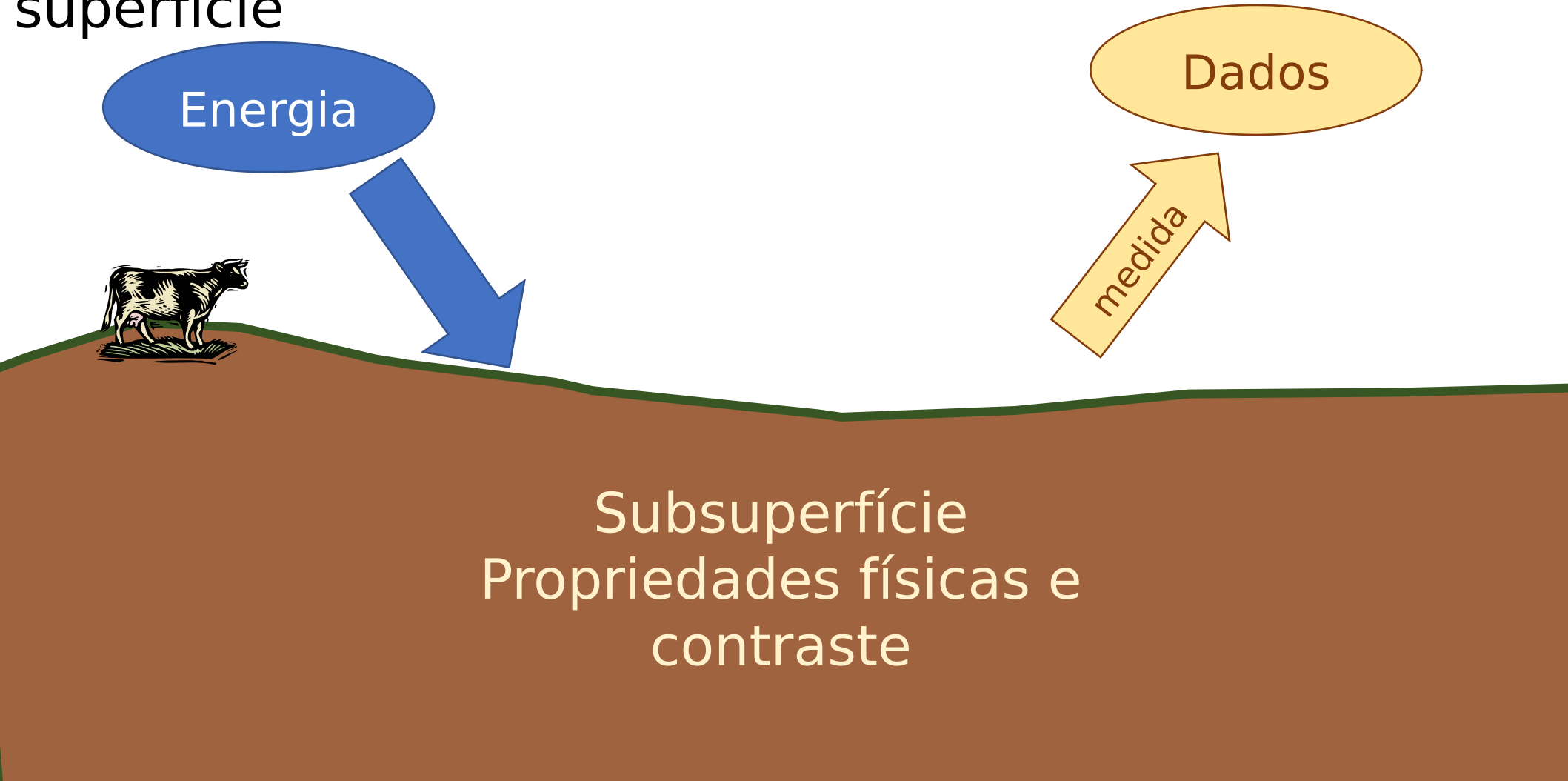


Os materiais da Terra podem ser caracterizados em termos de suas propriedades físicas.

Energia

medida

Dados

Subsuperfície
Propriedades físicas e contraste

Os materiais da Terra podem ser caracterizados em termos de suas propriedades físicas.

Os materiais da Terra podem ser caracterizados em termos de suas propriedades físicas.

Energia

Dados

medida

condutividade elétrica

permissividade dielétrica

permeabilidade magnética

densidade

magnetização

impedância acústica

Energia

Dados

medida

Contém informação das propriedades físicas da terra

condutividade elétrica

permissividade dielétrica

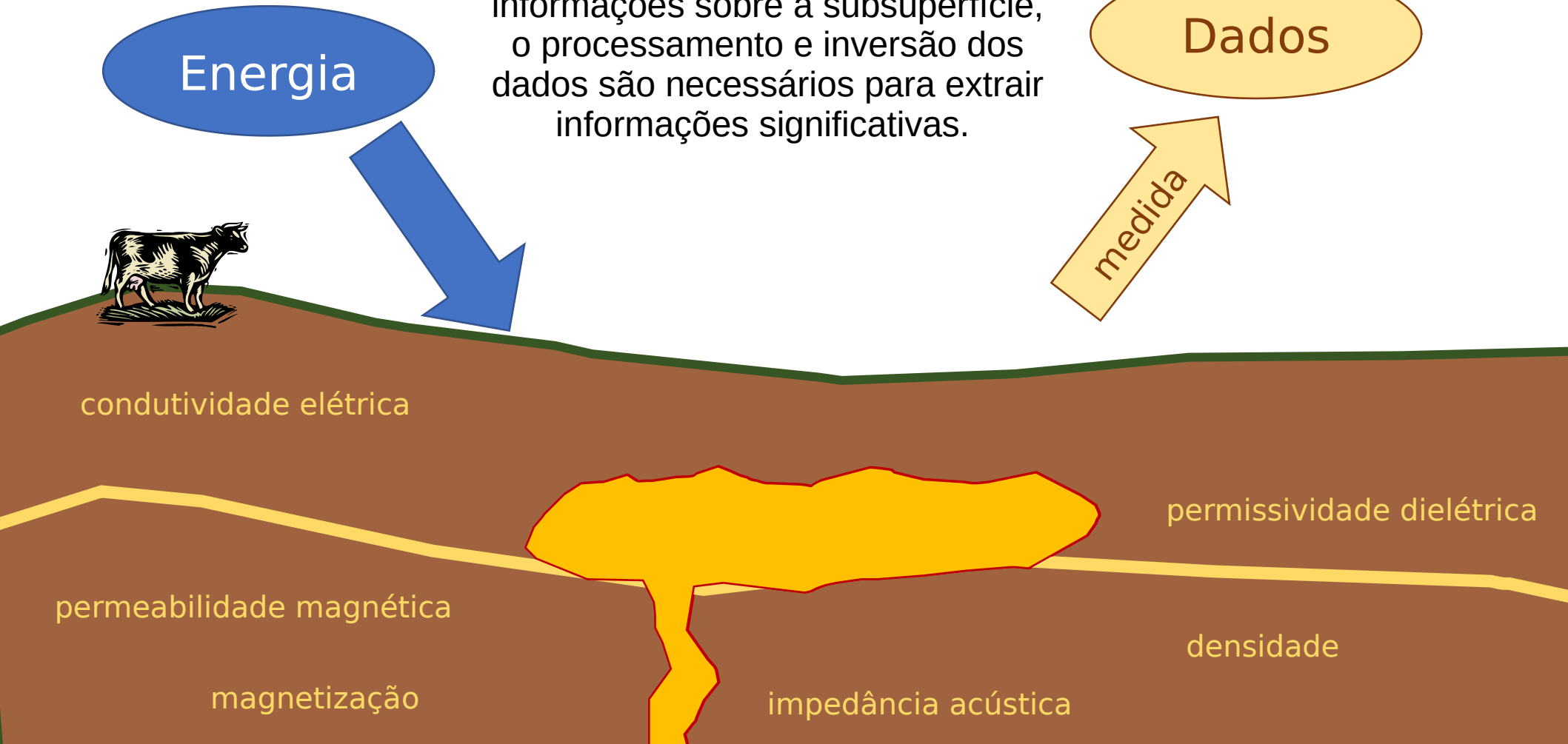
permeabilidade magnética

densidade

magnetização

impedância acústica

Embora os dados contenham informações sobre a subsuperfície, o processamento e inversão dos dados são necessários para extrair informações significativas.



Propriedades físicas

condutividade elétrica

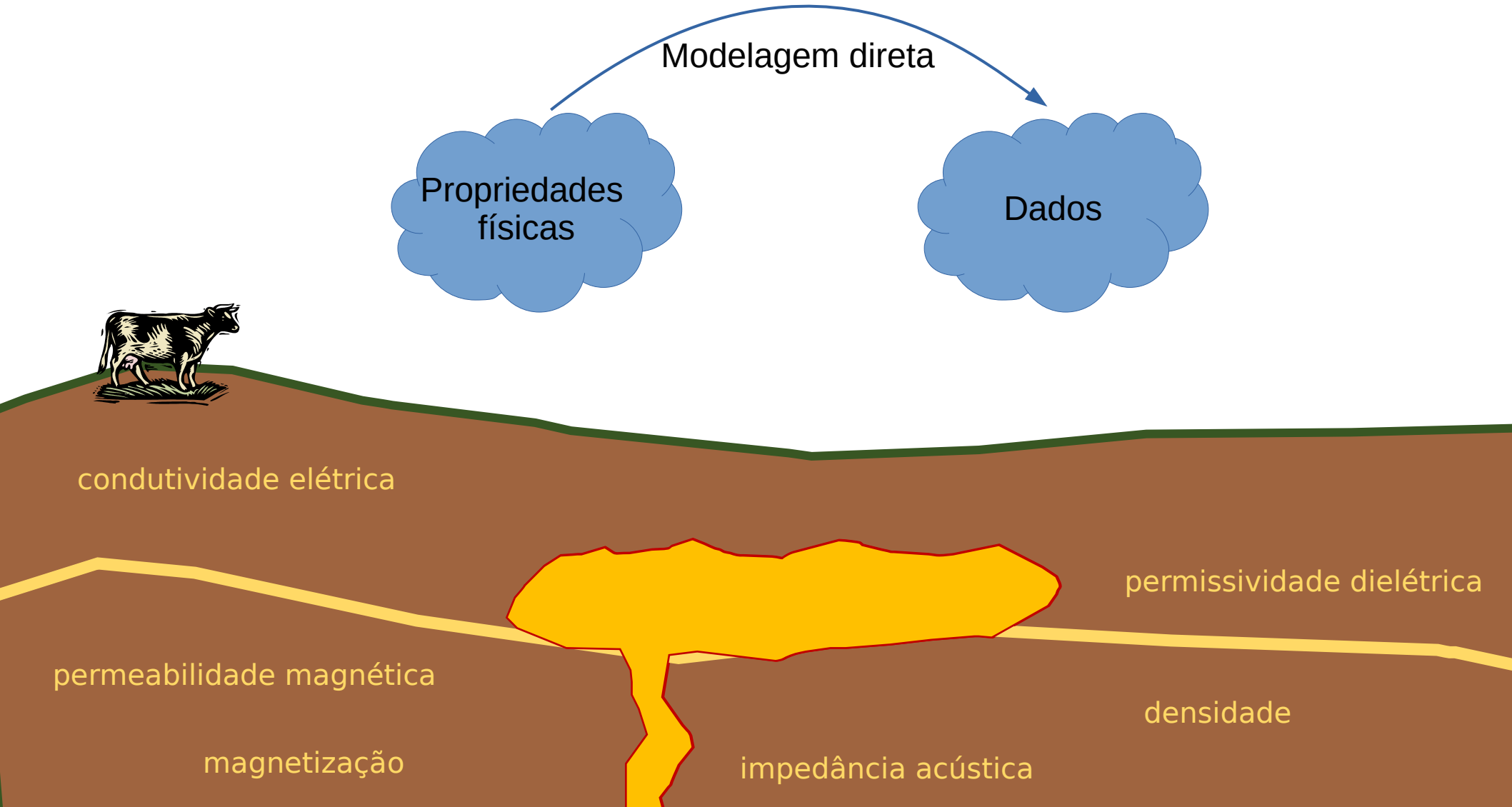
permissividade dielétrica

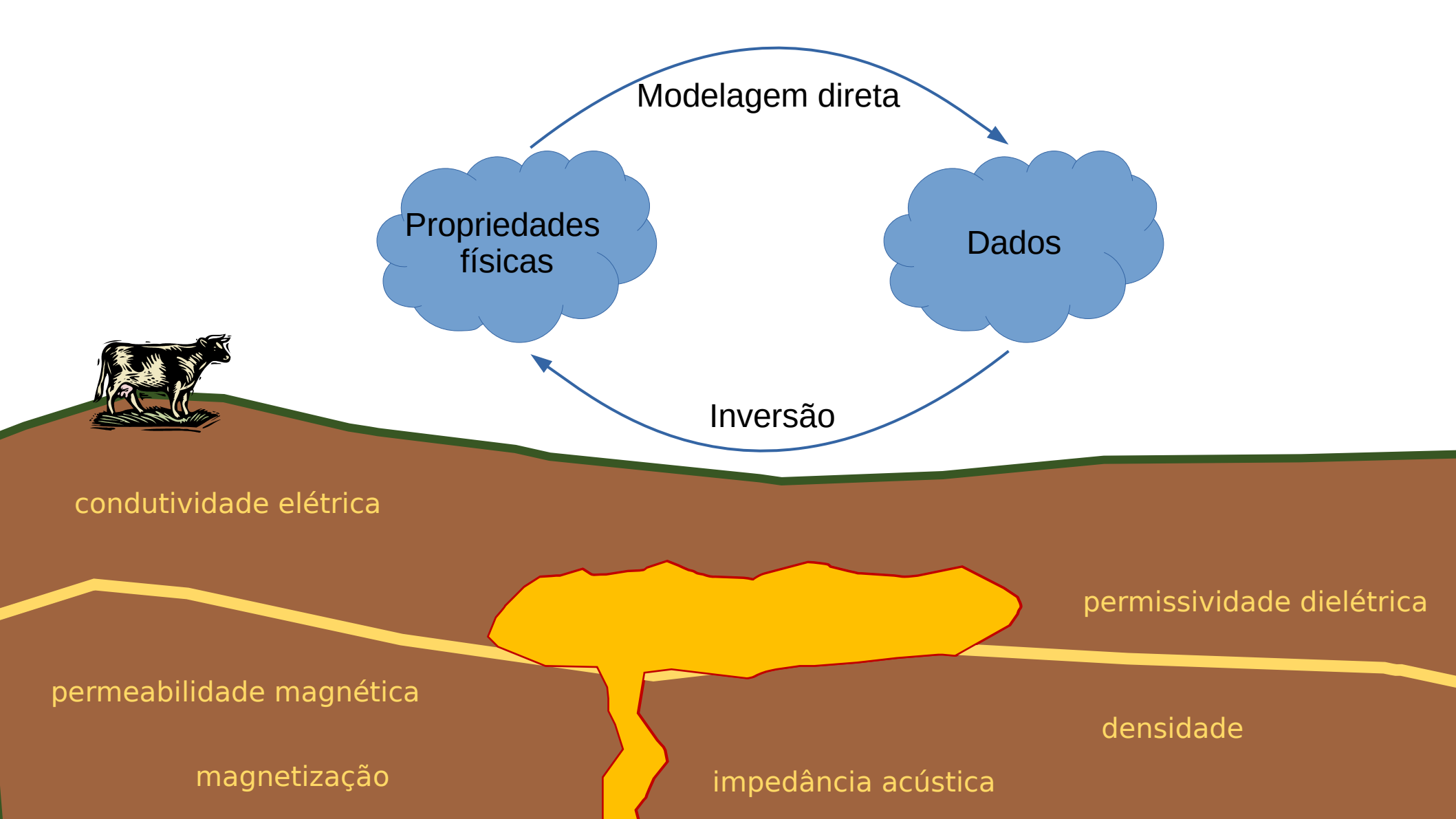
permeabilidade magnética

densidade

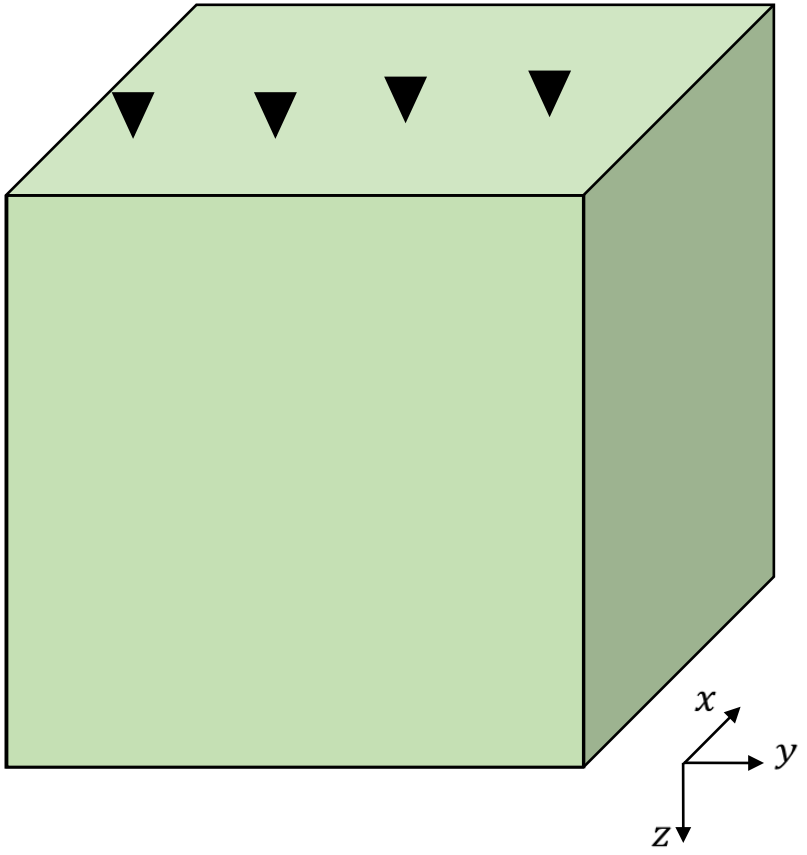
magnetização

impedância acústica

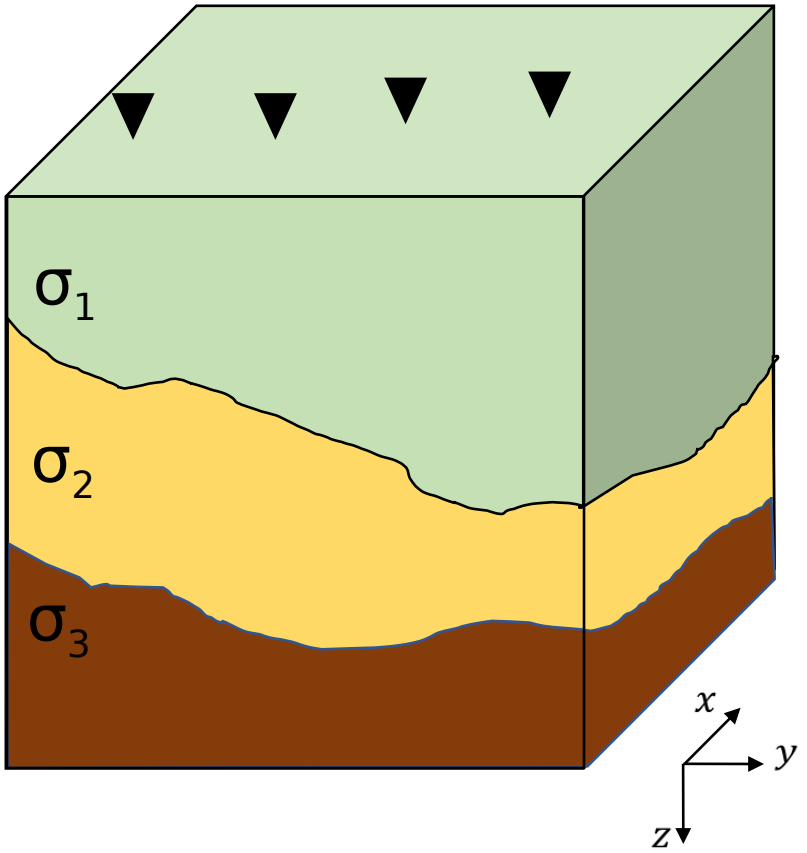

Modelagem direta
Propriedades físicas
Dados
condutividade elétrica
permissividade dielétrica
permeabilidade magnética
densidade
magnetização
impedância acústica


Modelagem direta
Propriedades físicas
Dados
Inversão
condutividade elétrica
permissividade dielétrica
permeabilidade magnética
densidade
magnetização
impedância acústica

Modelagem

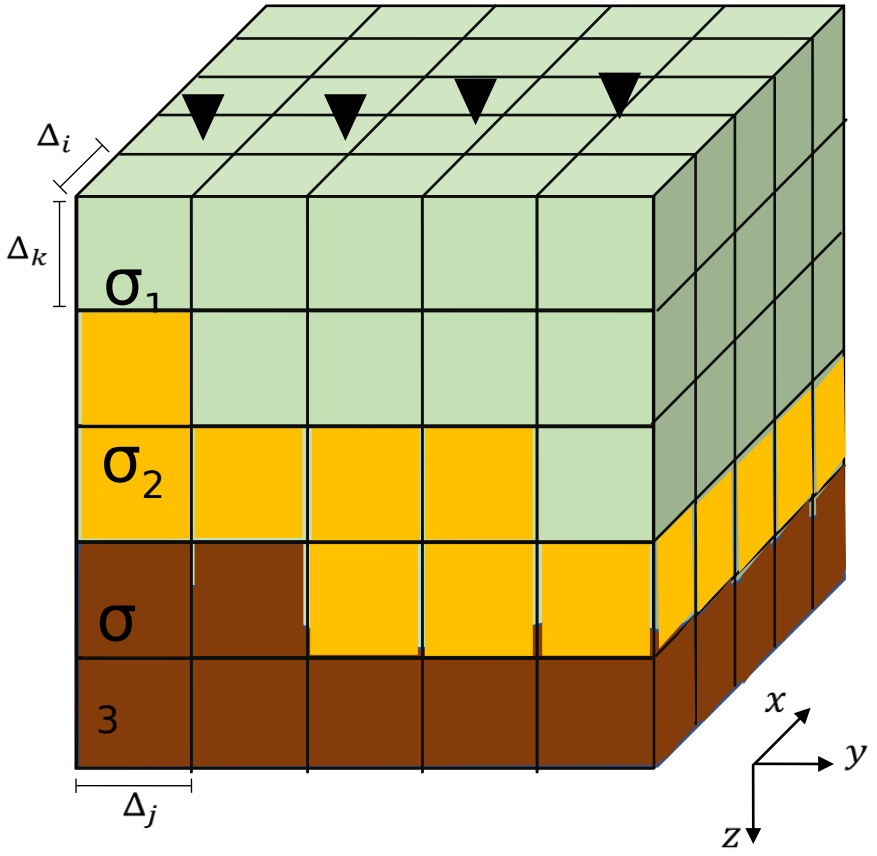


Modelagem



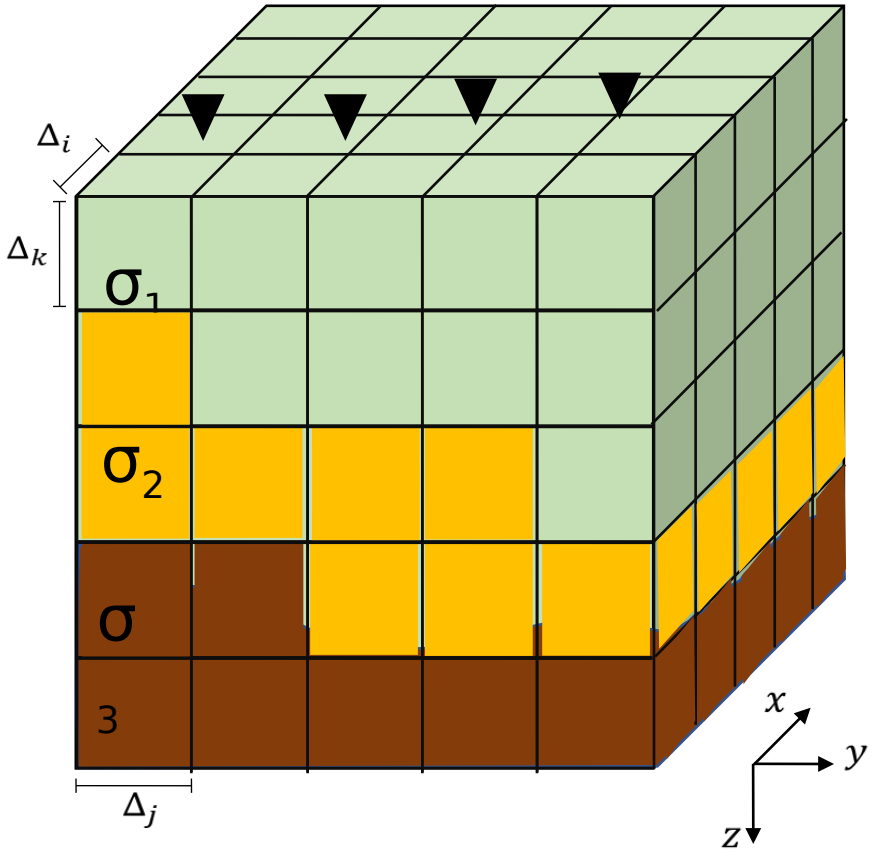
Modelagem

Diferenças Finitas



Modelagem

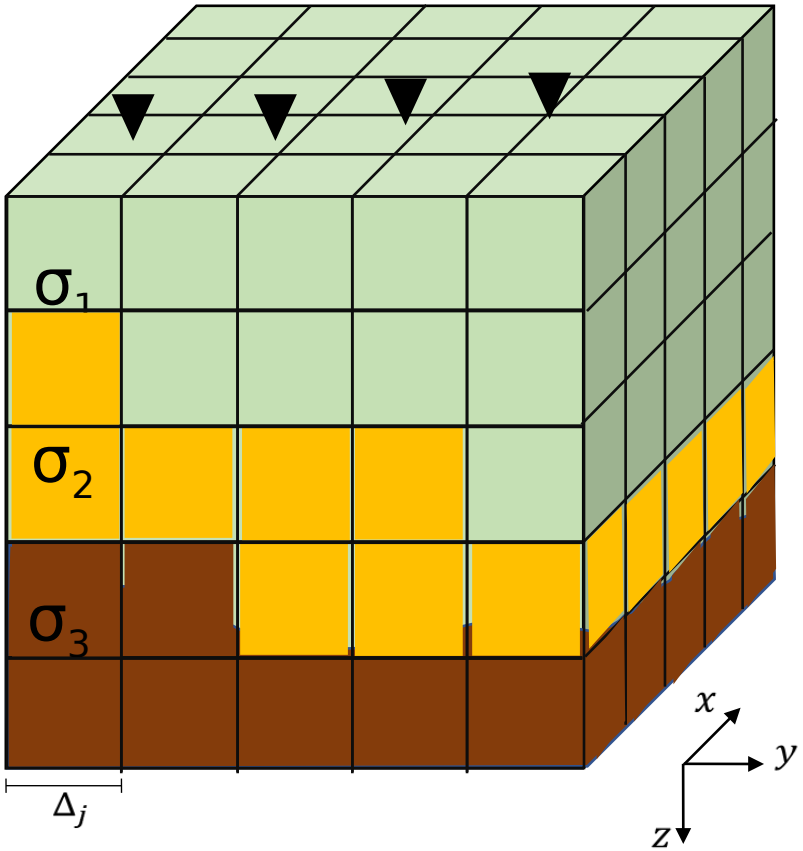
Dimensões e propriedades físicas conhecidas



Modelagem

Métodos EM

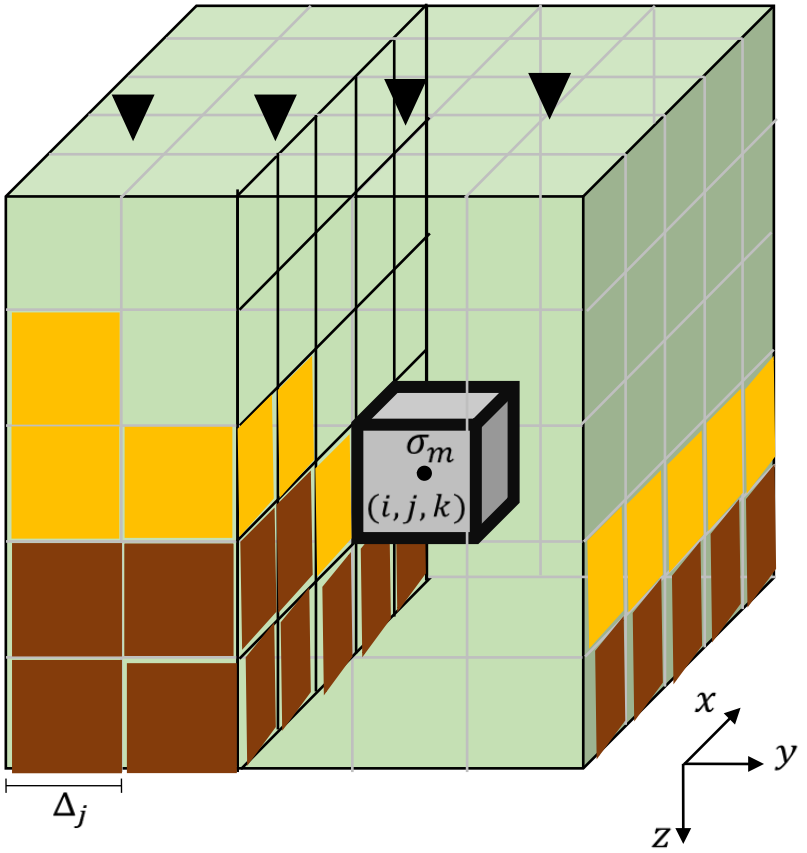
Vetor de parâmetros $\sigma = \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \vdots \\ \sigma_M \end{bmatrix}$



Modelagem

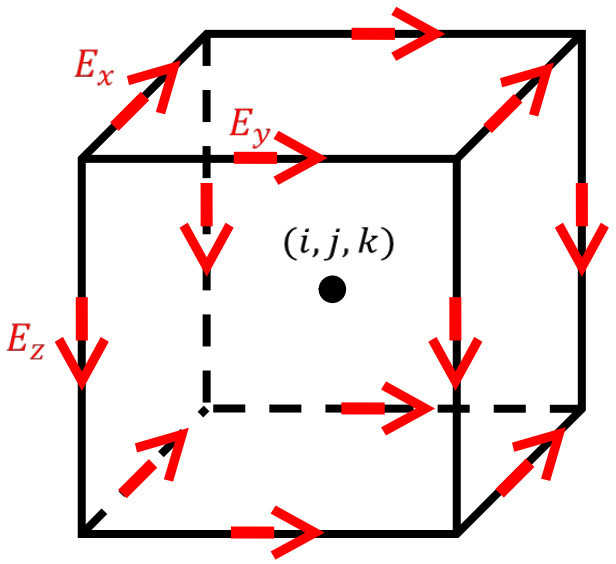
Métodos EM

Calcula-se o campo elétrico para cada prisma – simula-se a propagação dos campos EM em todos os prismas do modelo

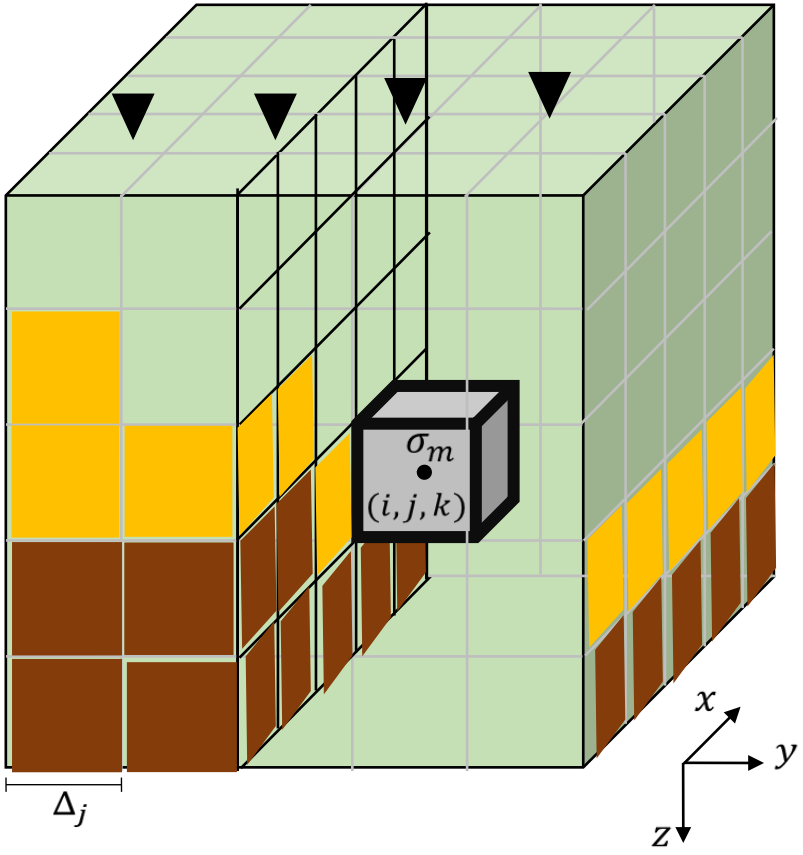


Modelagem

Métodos EM

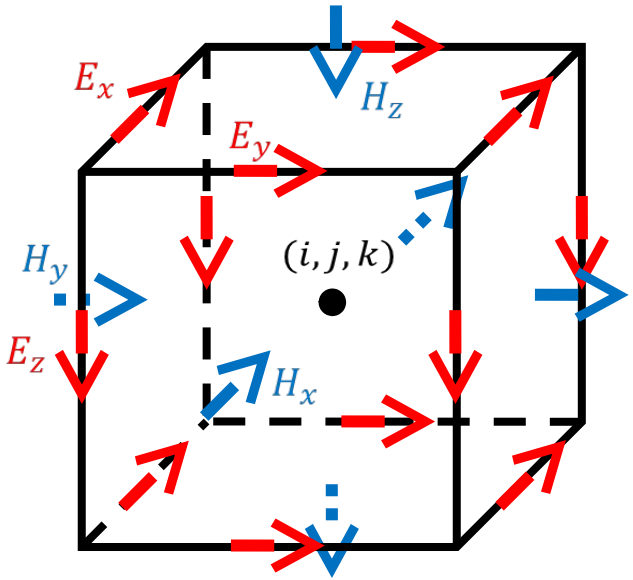


$$\nabla \times \nabla \times \mathbf{E} + i\mu\omega\sigma\mathbf{E} = 0$$



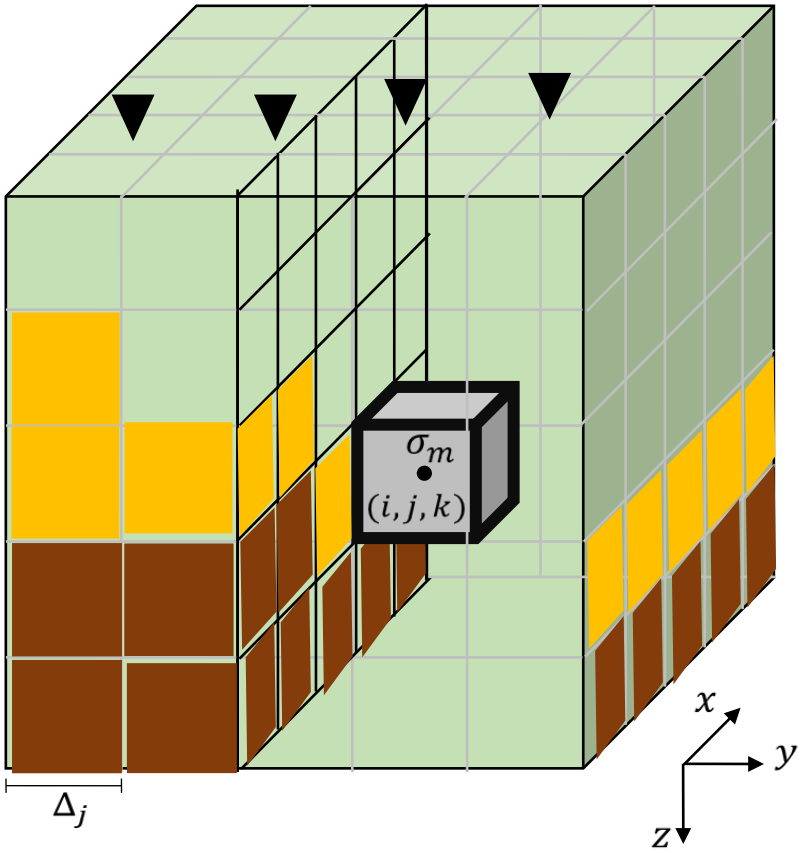
Modelagem

Métodos EM



$$\nabla \times \nabla \times \mathbf{E} + i\mu\omega\sigma\mathbf{E} = 0$$

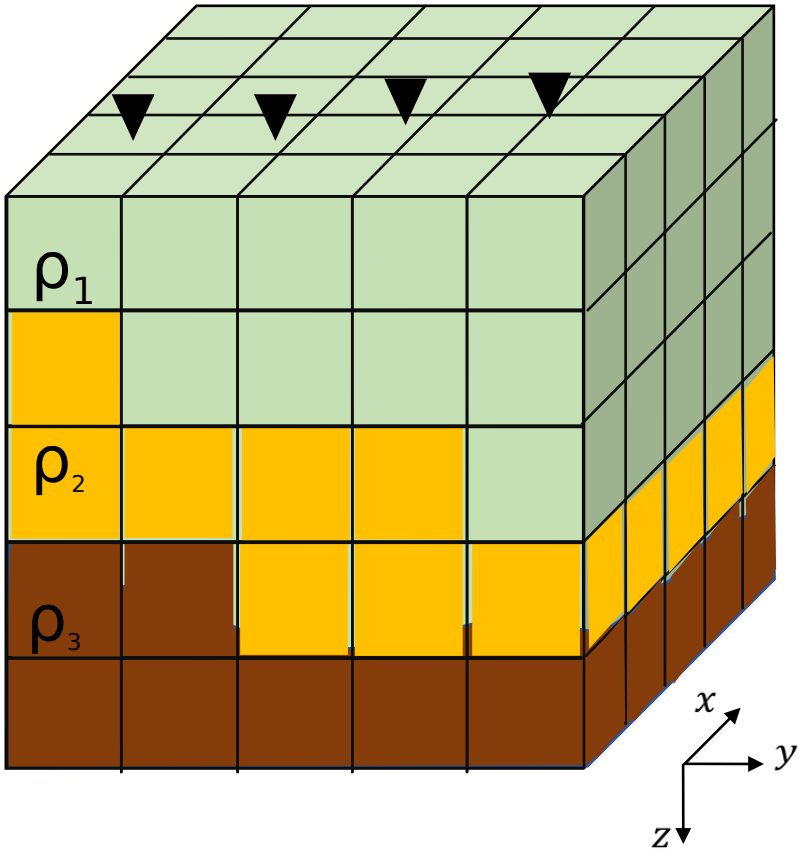
$$\mathbf{H} = (-i\mu\omega)^{-1}\nabla \times \mathbf{E} = 0$$



Modelagem

Métodos Potenciais

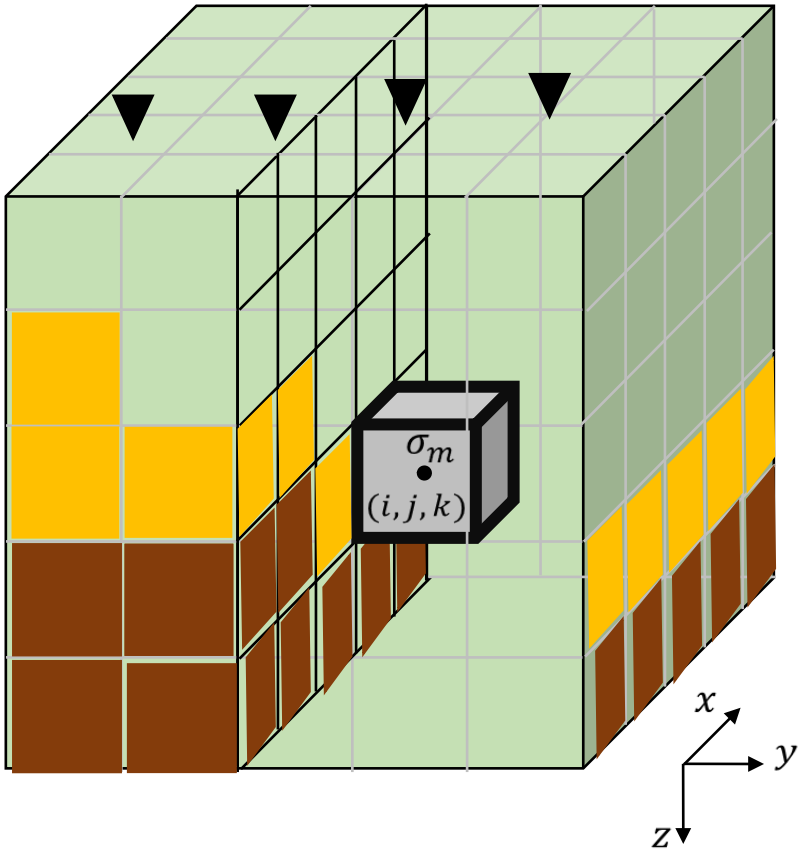
$$\boldsymbol{\rho} = \begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_M \end{bmatrix} \qquad \boldsymbol{m} = \begin{bmatrix} m_1 \\ m_2 \\ \vdots \\ m_M \end{bmatrix}$$



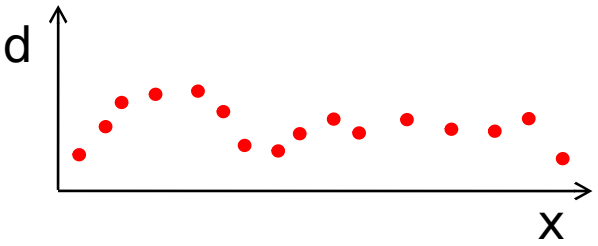
Modelagem

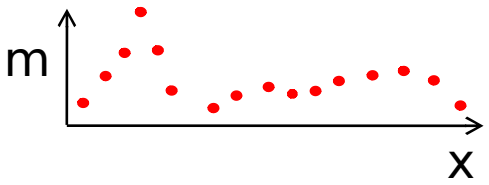
Métodos Potenciais

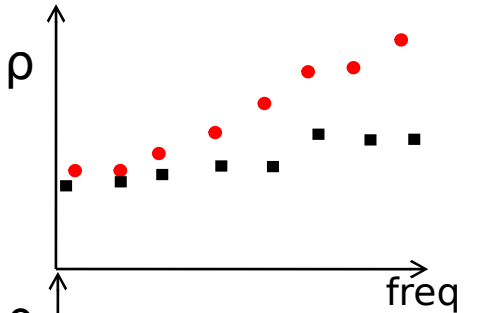
Calcula-se a soma do efeito gravitacional/magnético produzido por cada prisma nos pontos de observação

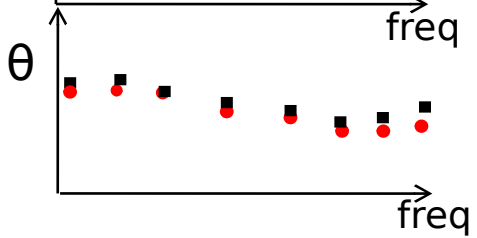


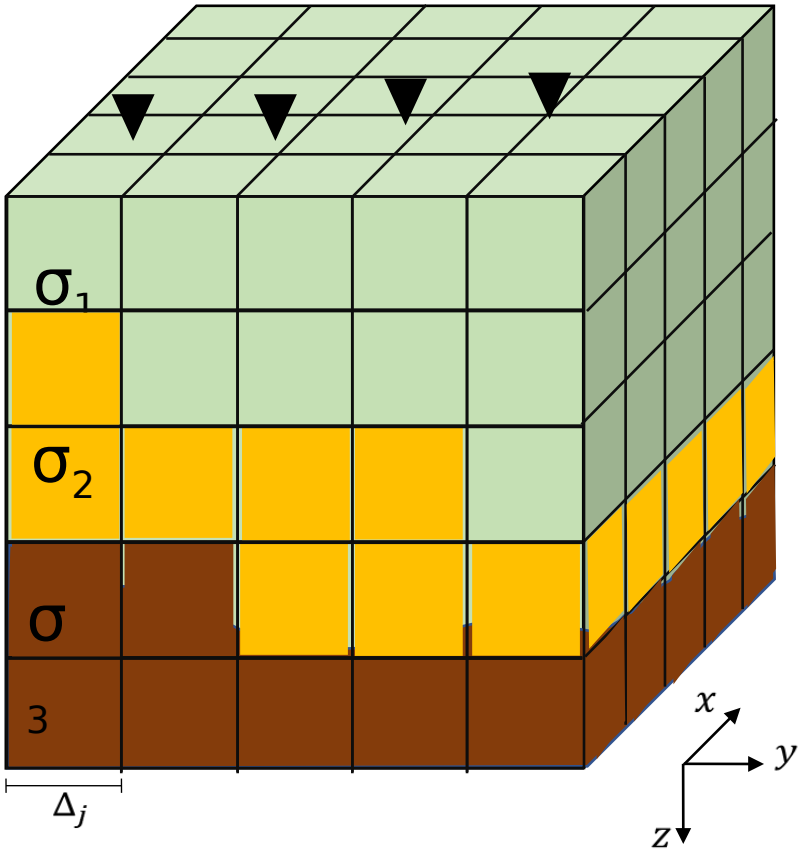
Modelagem



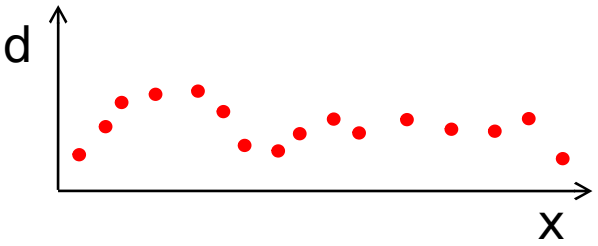


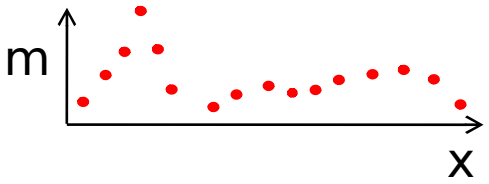


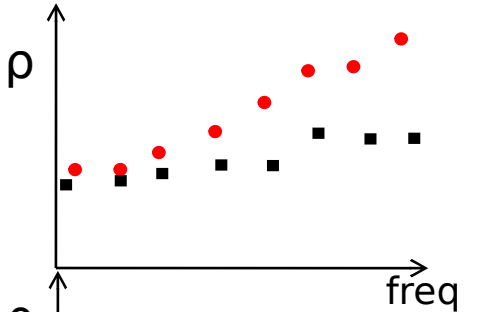


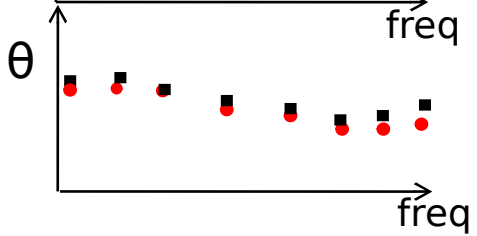


Modelagem

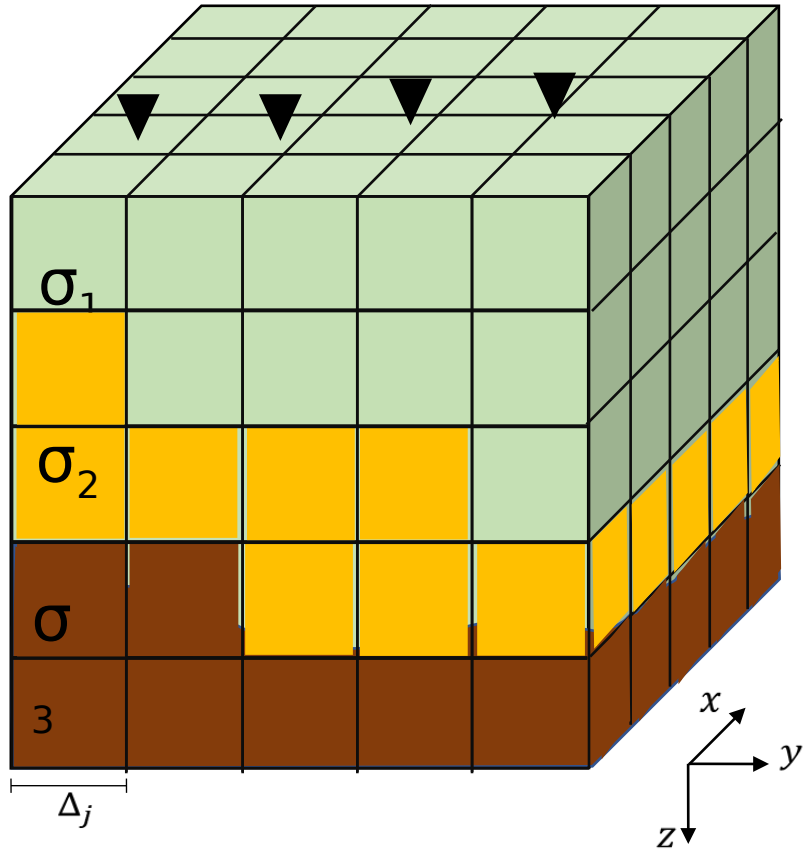


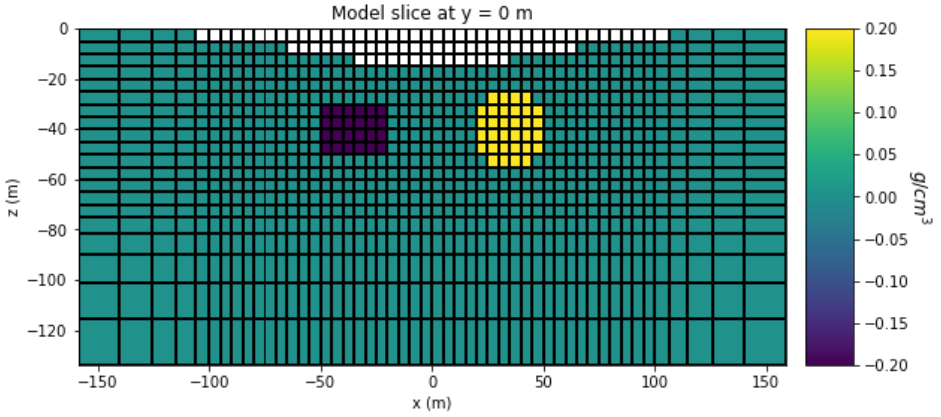


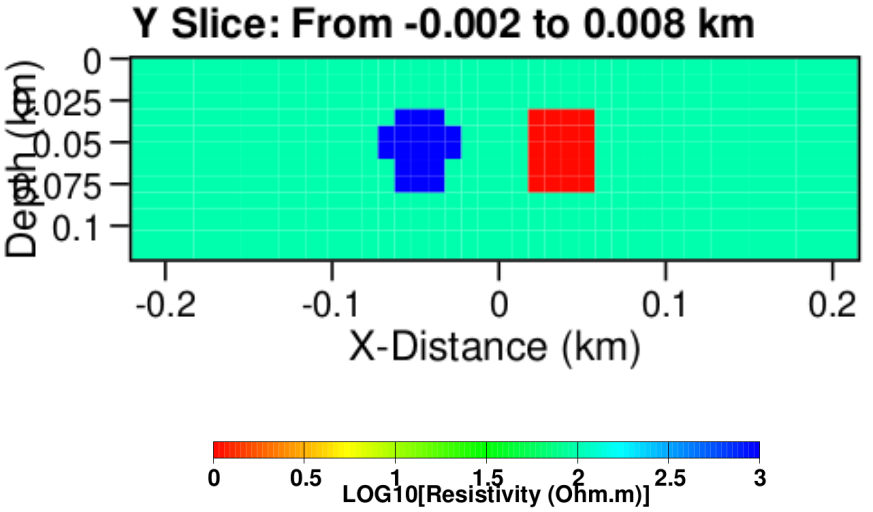


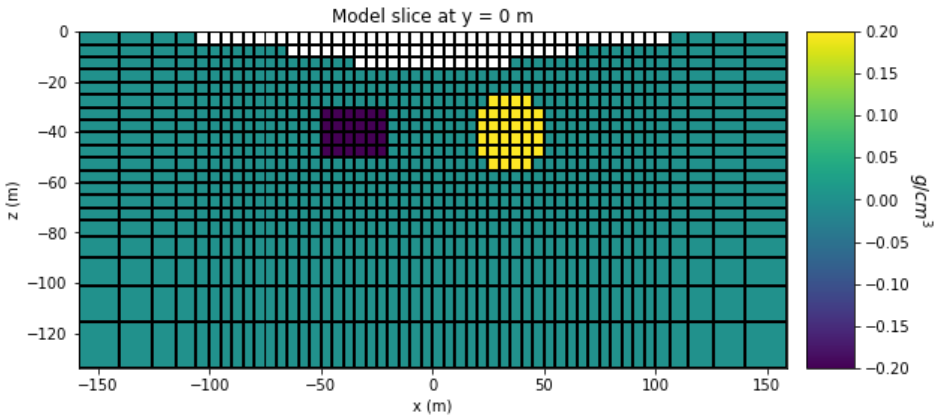


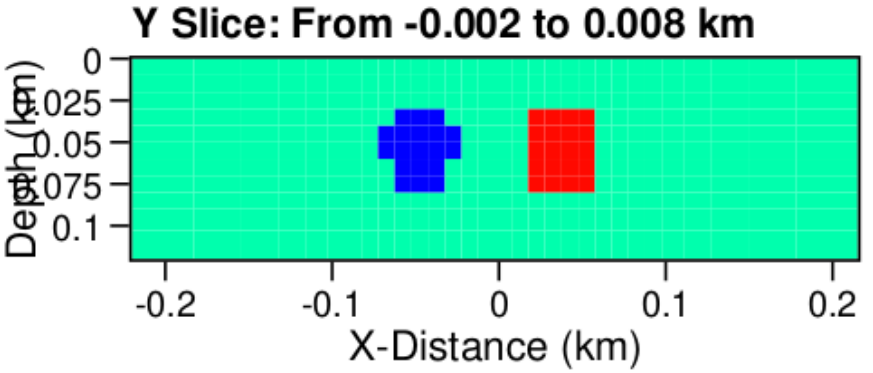
$$\boldsymbol{d^p} = \begin{bmatrix} d_1^p \\ d_2^p \\ \vdots \\ d_N^p \end{bmatrix}$$

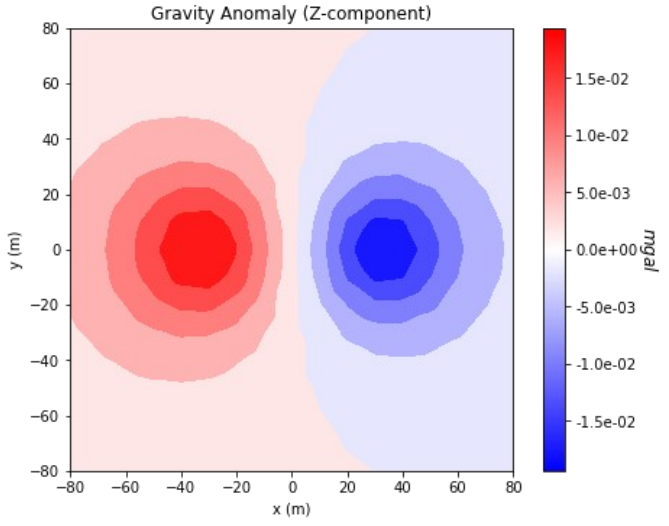


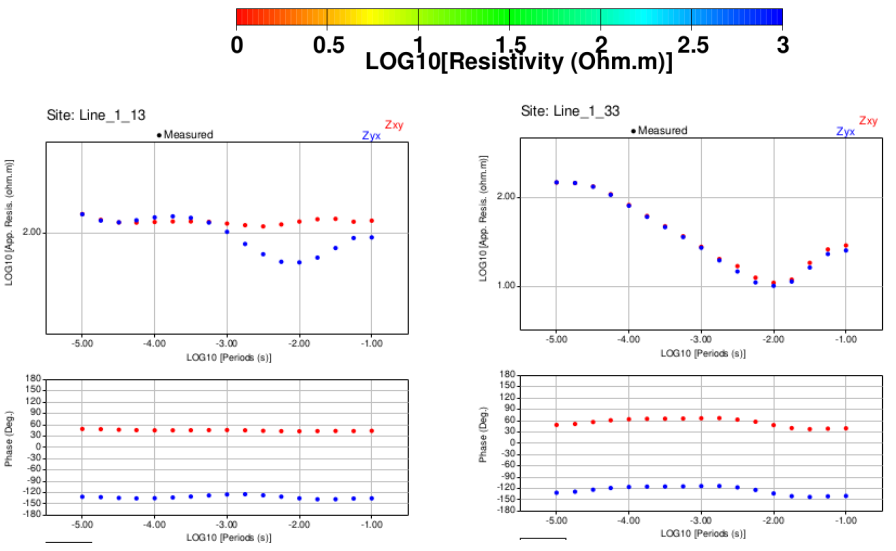

Model slice at y = 0 m
z (m)
x (m)
g/cm³


Y Slice: From -0.002 to 0.008 km
Depth (km)
X-Distance (km)
LOG10[Resistivity (Ohm.m)]

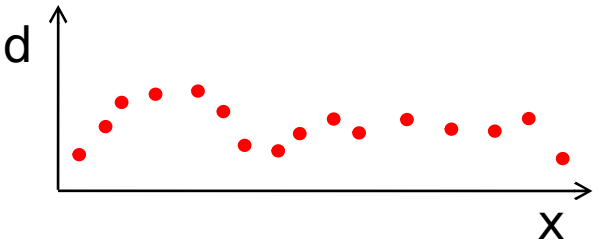

Model slice at y = 0 m
z (m)
x (m)
g/cm³

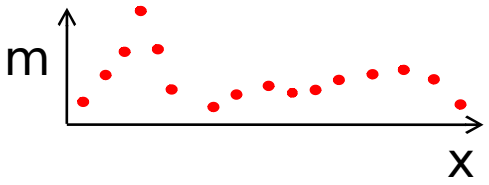

Y Slice: From -0.002 to 0.008 km
Depth (km)
X-Distance (km)

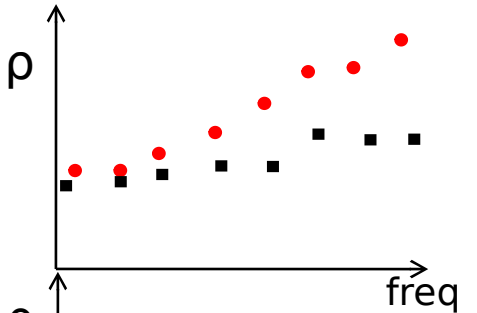

Gravity Anomaly (Z-component)
y (m)
x (m)
mgal

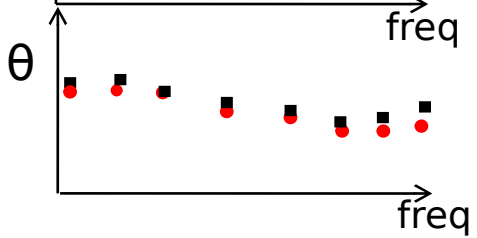

LOG10[Resistivity (Ohm.m)]
Site: Line_1_13
Site: Line_1_33
Measured
Zxy
Zyx
LOG10 [Periods (s)]
Phase (Deg.)

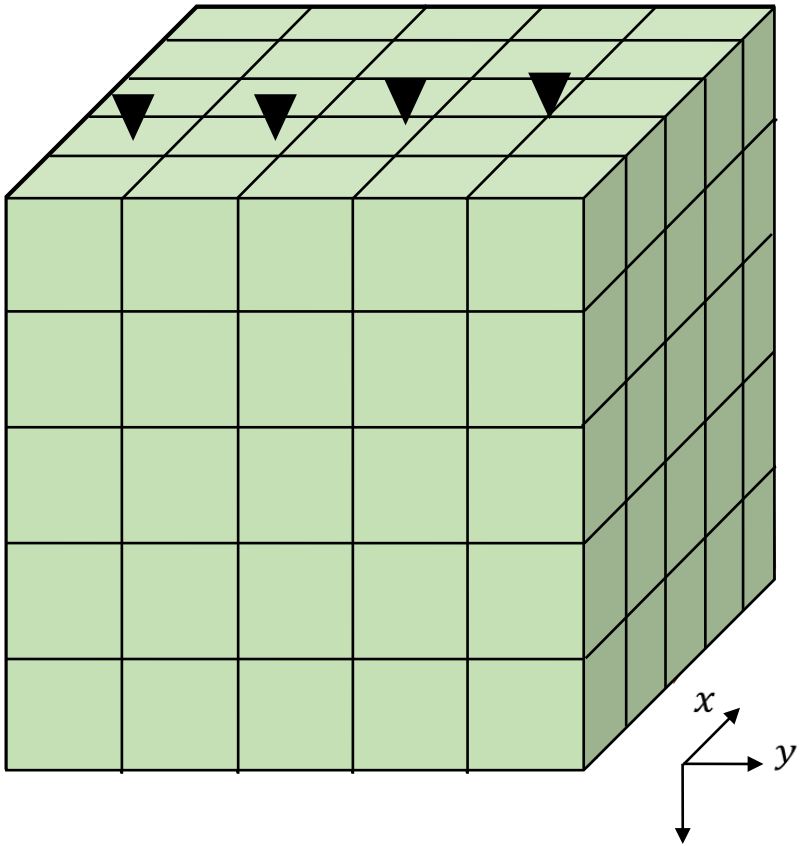
Inversão



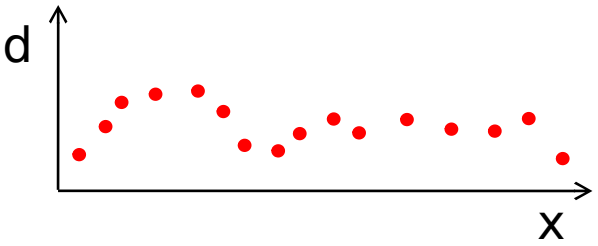


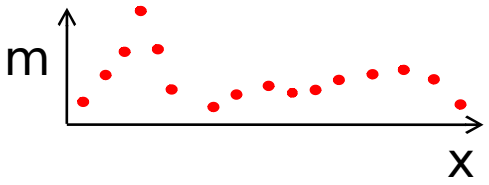


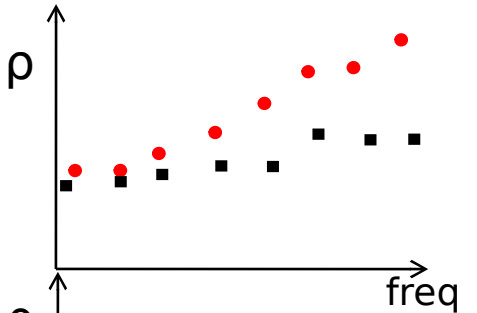


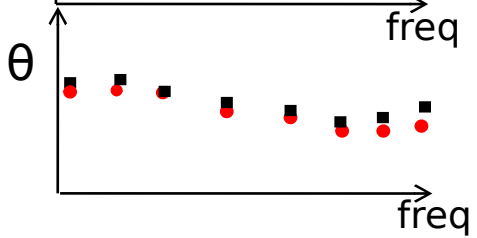


Inversão

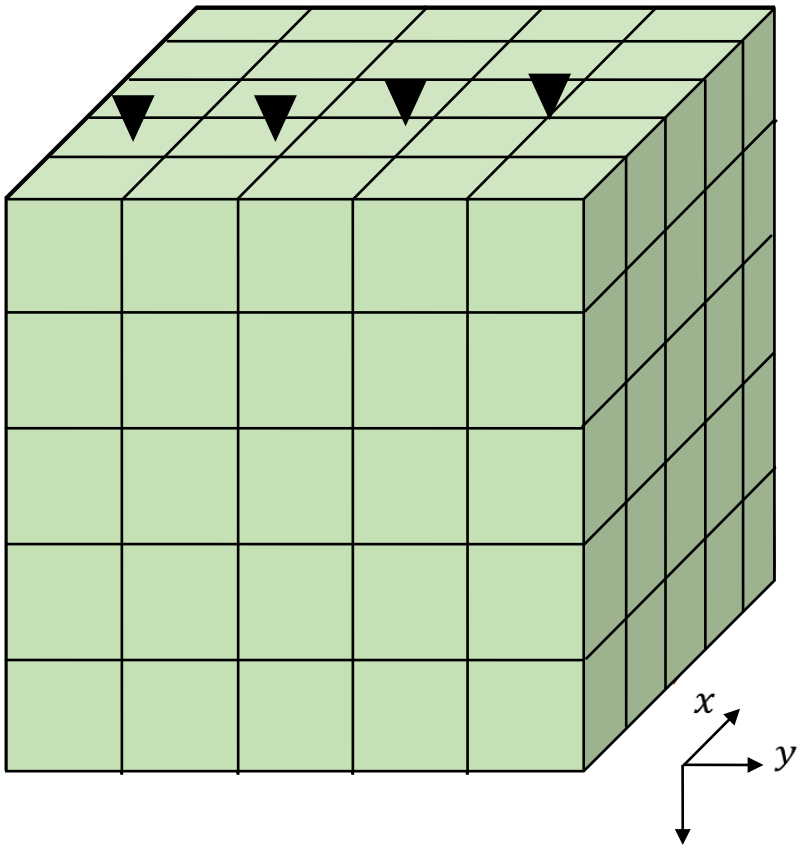




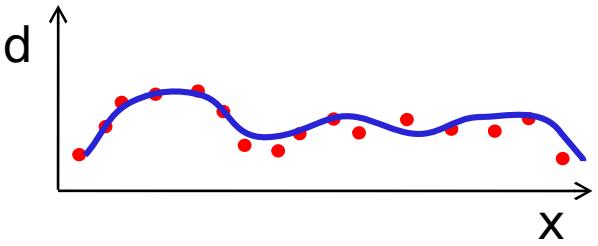


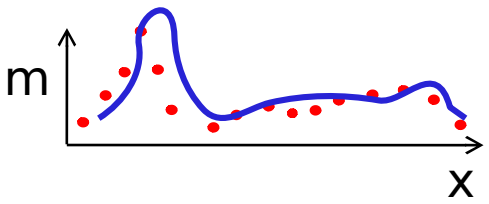


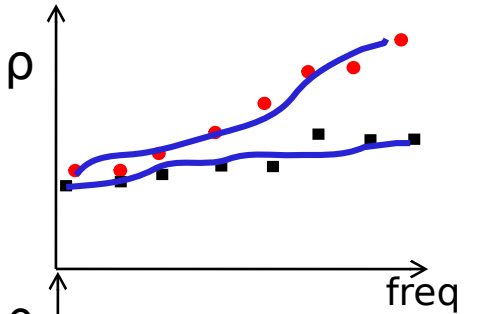
$$\boldsymbol{d} = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_N \end{bmatrix}$$

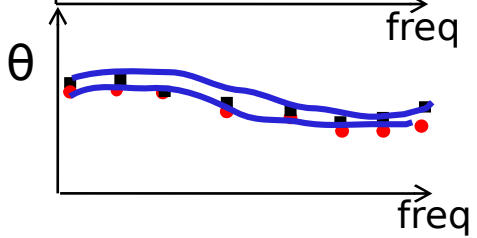


Inversão

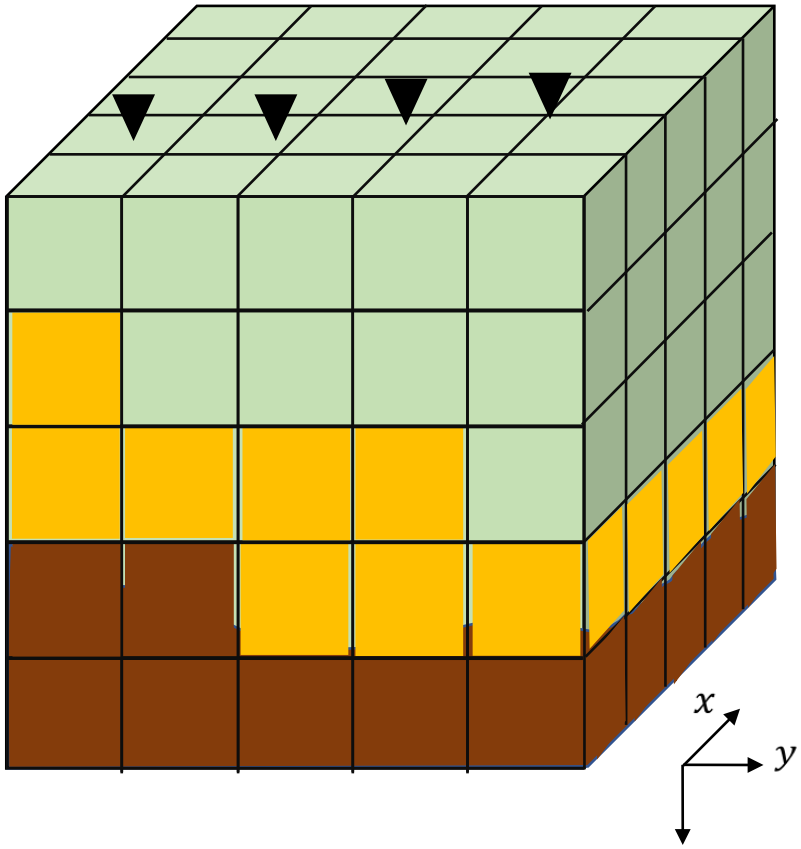








$$\boldsymbol{d} = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_N \end{bmatrix} \approx \boldsymbol{d^p} = \begin{bmatrix} d_1^p \\ d_2^p \\ \vdots \\ d_N^p \end{bmatrix}$$



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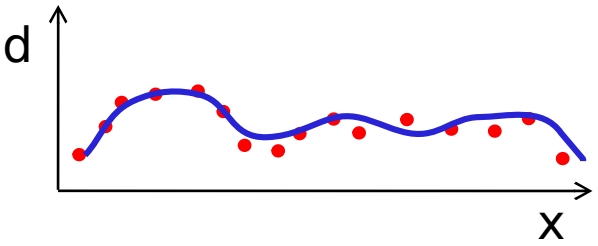

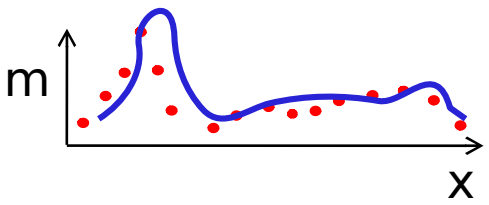

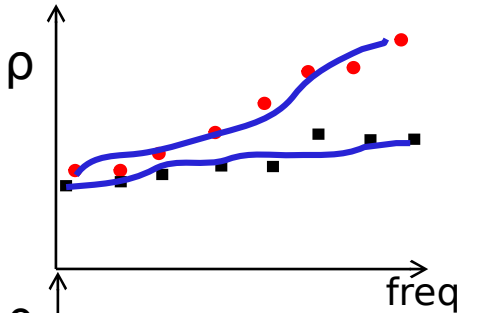

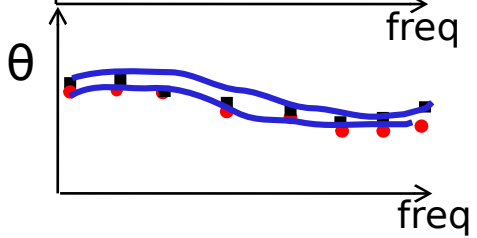

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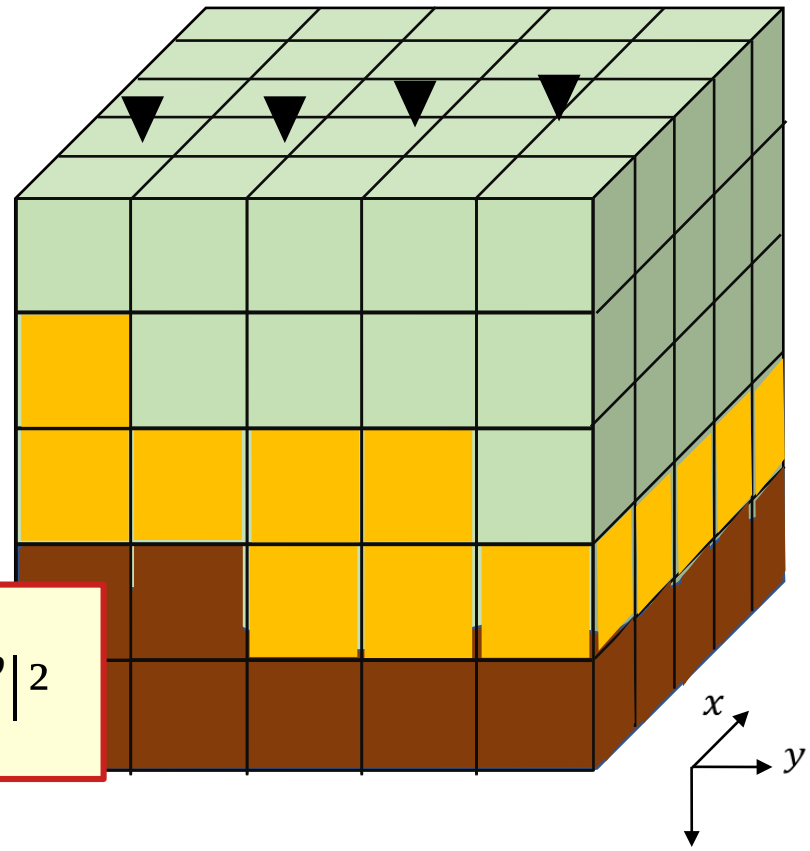
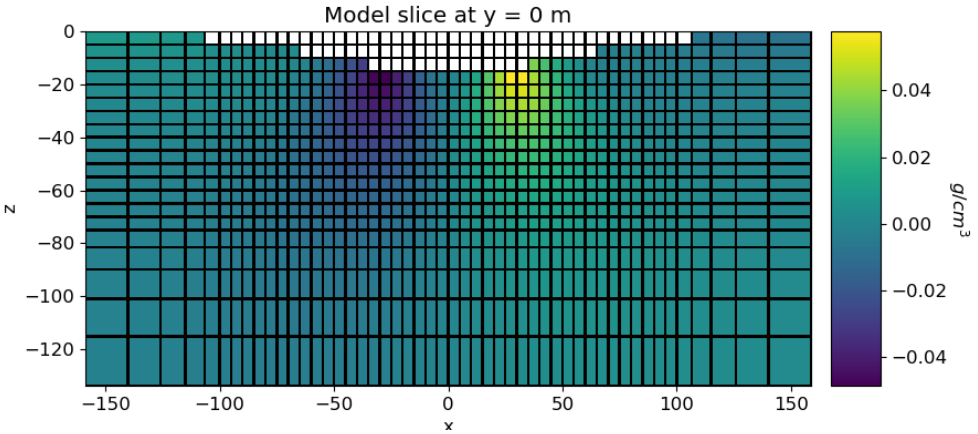
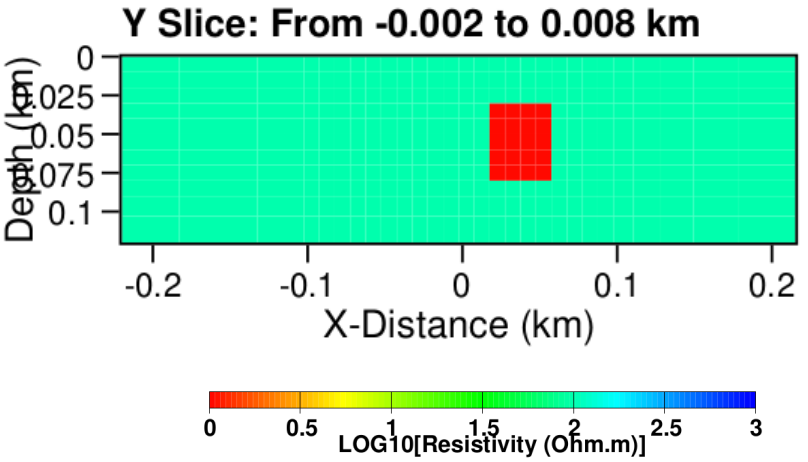
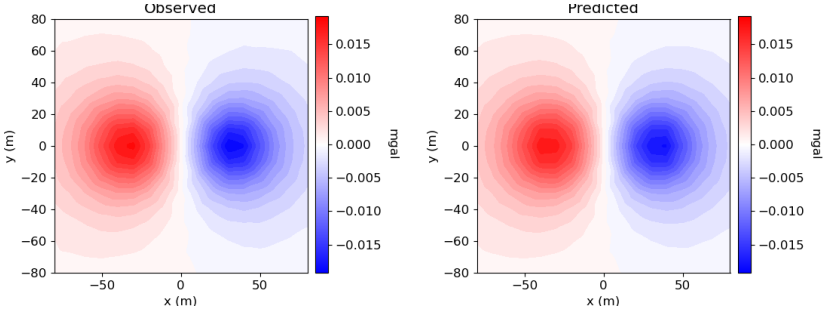
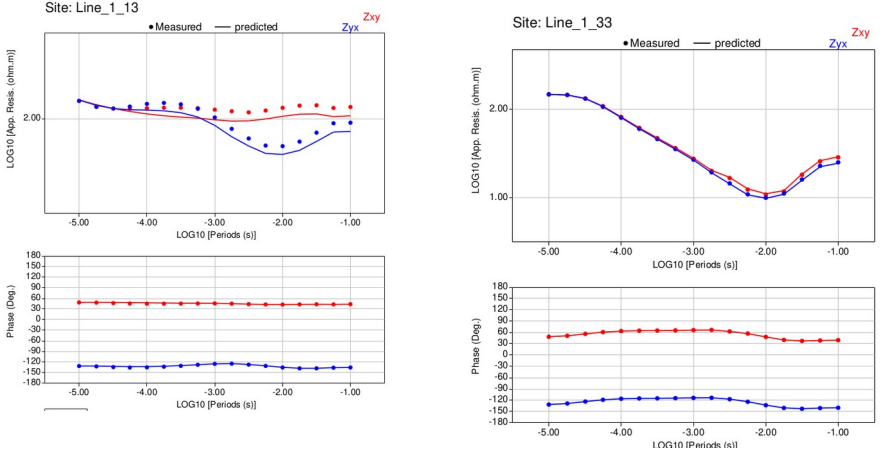
$$\Phi = \left| \boldsymbol{d^o} - \boldsymbol{d^p} \right|^2$$




Model slice at y = 0 m
z
x
g/cm3


Y Slice: From -0.002 to 0.008 km
Depth (km)
X-Distance (km)
LOG10[Resistivity (Ohm.m)]

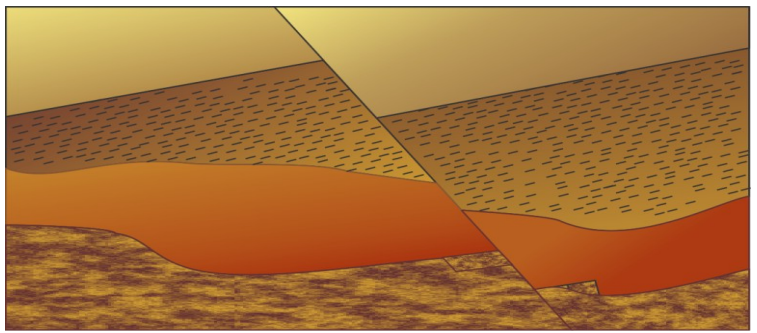

Observed
Predicted
y (m)
x (m)
mgal


Site: Line_1_13
Site: Line_1_33
Measured
predicted
Zxy
Zyx
LOG10 [App. Resis. (ohm.m)]
Phase (Deg.)
LOG10 [Periods (s)]

Sistema físico	Equações governantes	Grandeza física	Dados observáveis
Campo gravitacional da Terra	Lei da gravitação de Newton	Densidade	Campo gravitacional
Campo eletromagnético (na superfície)	Equações de Maxwell	Condutividade elétrica	Campo eletromagnético
Ondas sísmicas (de terremotos)	Equações da onda	Velocidade (densidade)	Velocidade da partícula

Qual a proposta da disciplina?

Qual a proposta da disciplina?

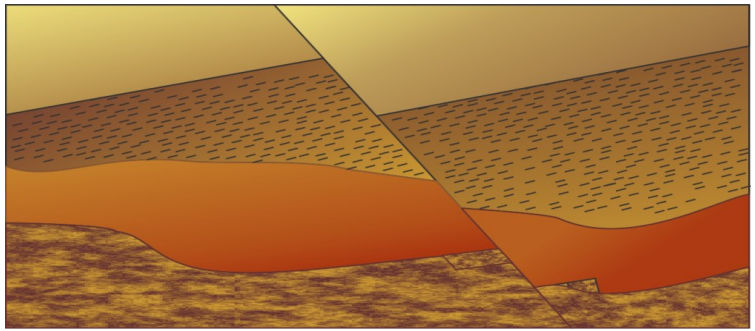


condutividade elétrica

impedância acústica

magnetização

densidade



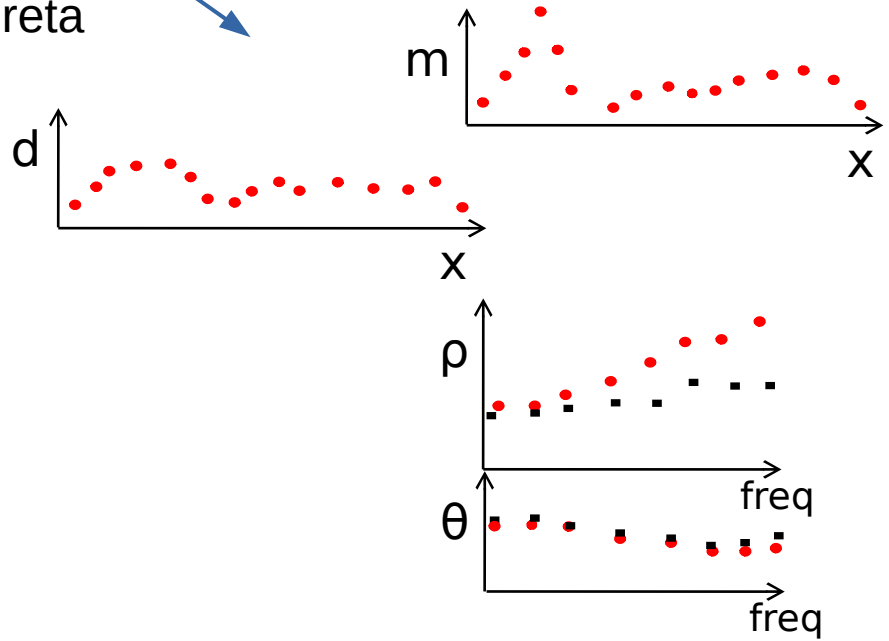
condutividade elétrica

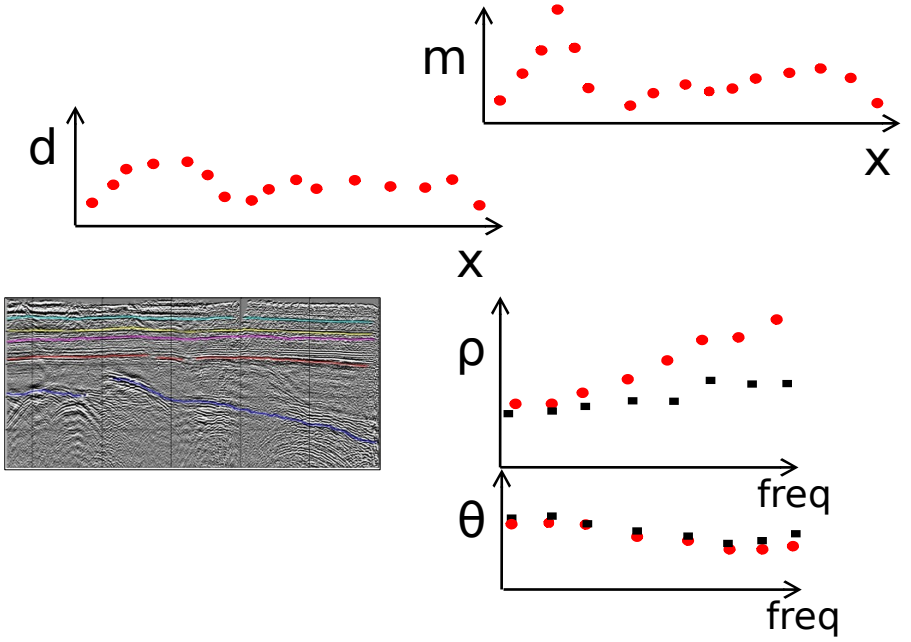
impedância acústica

magnetização

densidade

Modelagem direta




m
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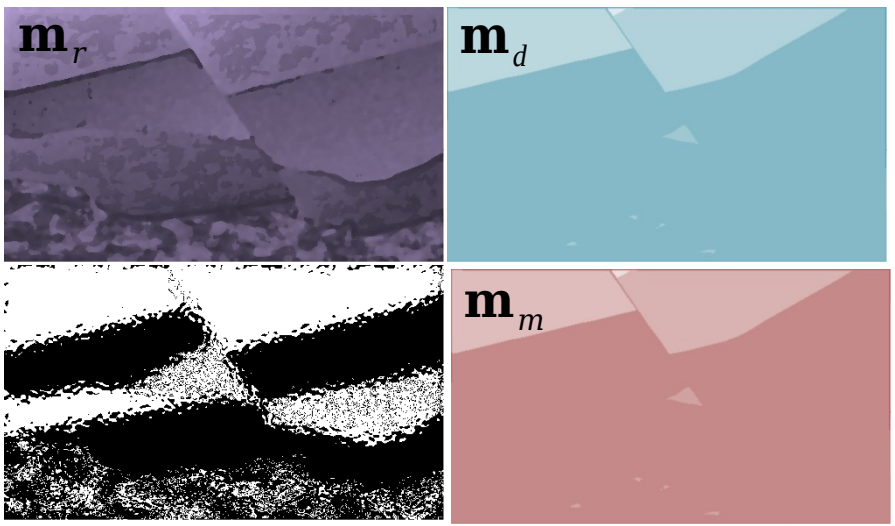
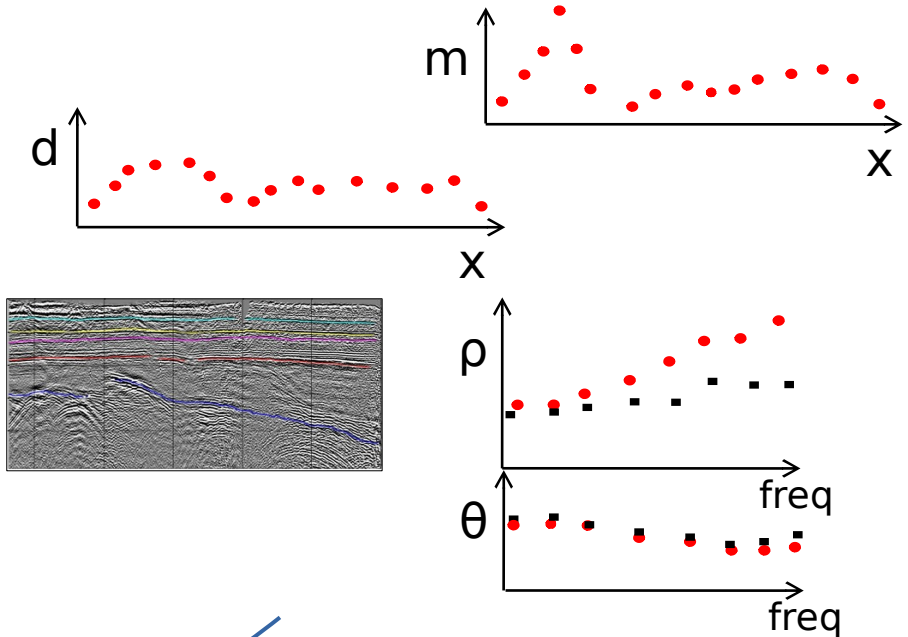
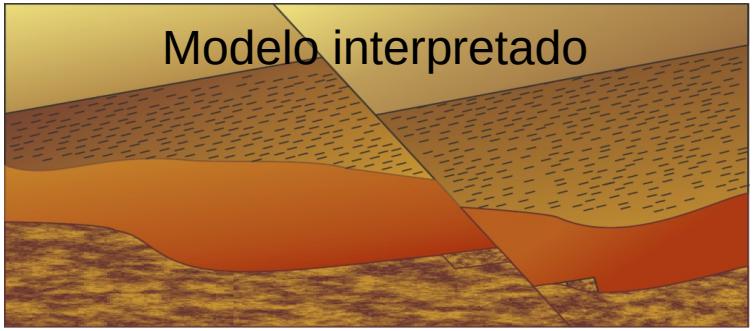
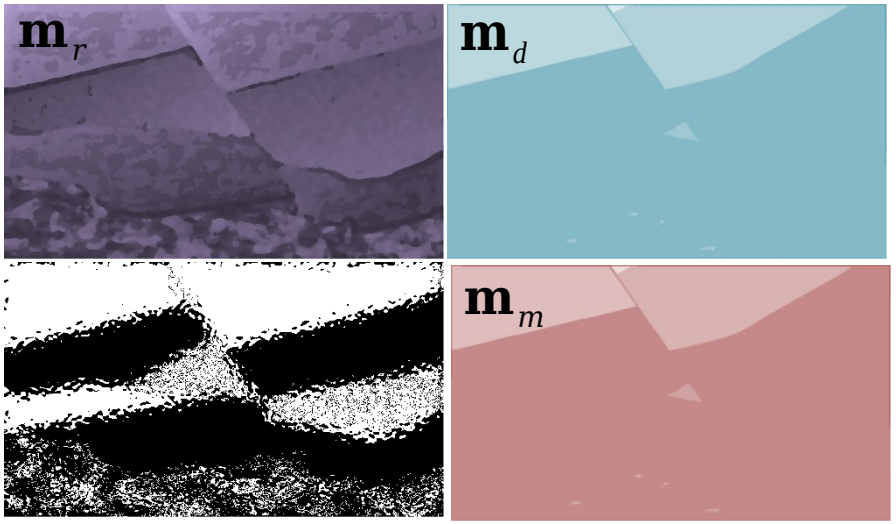
freq

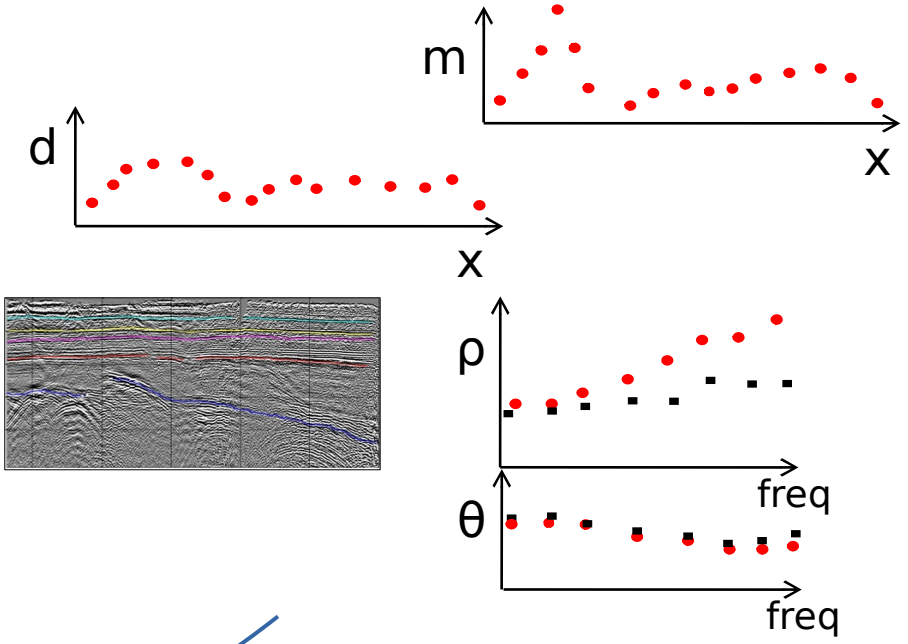




Inversão


Modelo interpretado


$\mathbf{m}_r$
$\mathbf{m}_d$
$\mathbf{m}_m$


m
x
d
x
ρ
freq
θ
freq

Inversão

CSEM, MT e gradiometria no Mar Vermelho

Exploration beyond seismic: The role of electromagnetics and gravity gradiometry in deep water subsalt plays of the Red Sea

Daniele Colombo[1], Gary McNeice[1], Nickolas Raterman[2], Mike Zinger[2], Diego Rovetta[1], and Ernesto Sandoval Curiel[1]

ABSTRACT

The Red Sea is characterized by thick salt sequences representing a seal for potential hydrocarbon accumulations within Tertiary formations deposited over deep basement structures. The Red Sea "salt" is characterized by halite concentrations embedded in layered evaporite sequences composed of evaporite and clastic lithologies. Salt complicates seismic exploration efforts in the Red Sea by generating vertical and lateral velocity variations that are difficult to estimate by seismic methods alone. In these conditions, the exploration challenges of independently imaging the subsalt section and provide enhanced velocity model building capabilities were addressed by a multigeophysics strategy involving marine electromagnetics (magnetotellurics and controlled source electromagnetics [CSEM]) and gravity gradiometry surveys colocated with wide azimuth seismic. Three-dimensional inversion of MT and CSEM is performed first with minimal a priori constraints and then by including variable amounts of interpretation in the starting models. The internal variations in the evaporitic overburden, the subsalt, and the basement structures are independently imaged by combined electromagnetic methods and confirmed by new drilling results. CSEM, in particular, provides unprecedented detail of the internal structures within the salt overburden while magnetotellurics provides excellent reconstruction of the base of salt and basement. Gravity gradiometry shows primary sensitivity to the basement and the corresponding 3D inversion provides density distributions structurally consistent with the resistivity volumes. The common-structure, multiparameter models obtained from 3D inversion deliver additional aid to seismic interpreters to further derisk exploration in the Red Sea and provide additional detail to depth imaging velocity models. The reciprocal consistency of the obtained results show promises for extending the work to more analytical integration with seismic such as provided by joint geophysical inversion.

Colombo at al 2013

CSEM e MT no Mar Vermelho

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Integração

EM (CSEM e MT)
Sismica
Gradiometria

CSEM e MT no Mar Vermelho

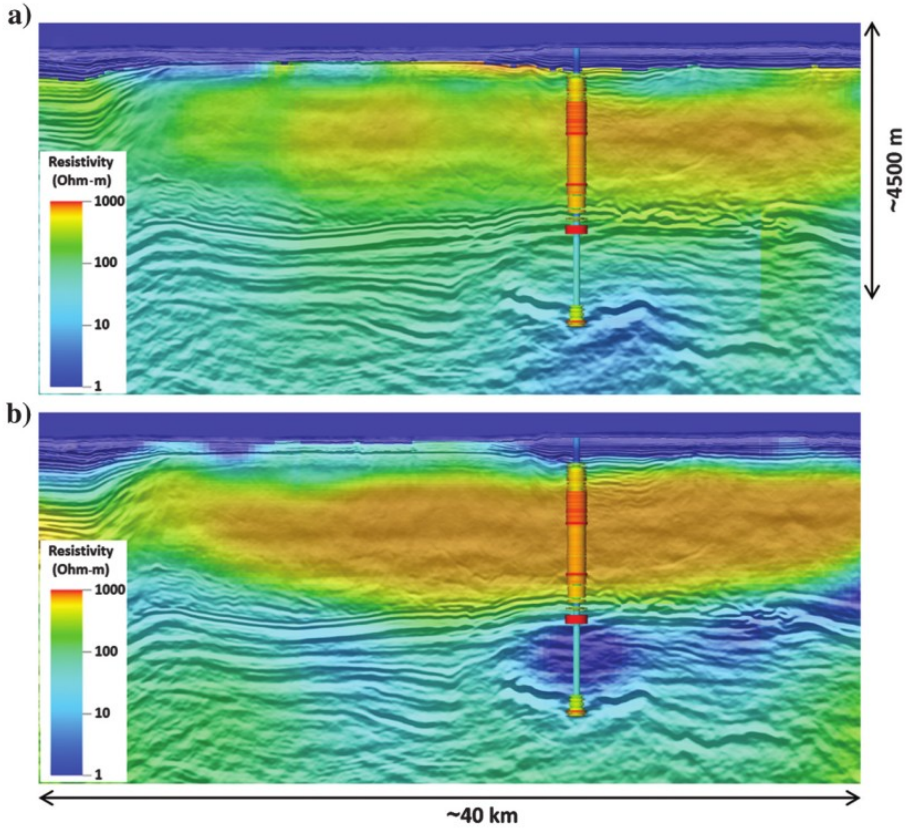
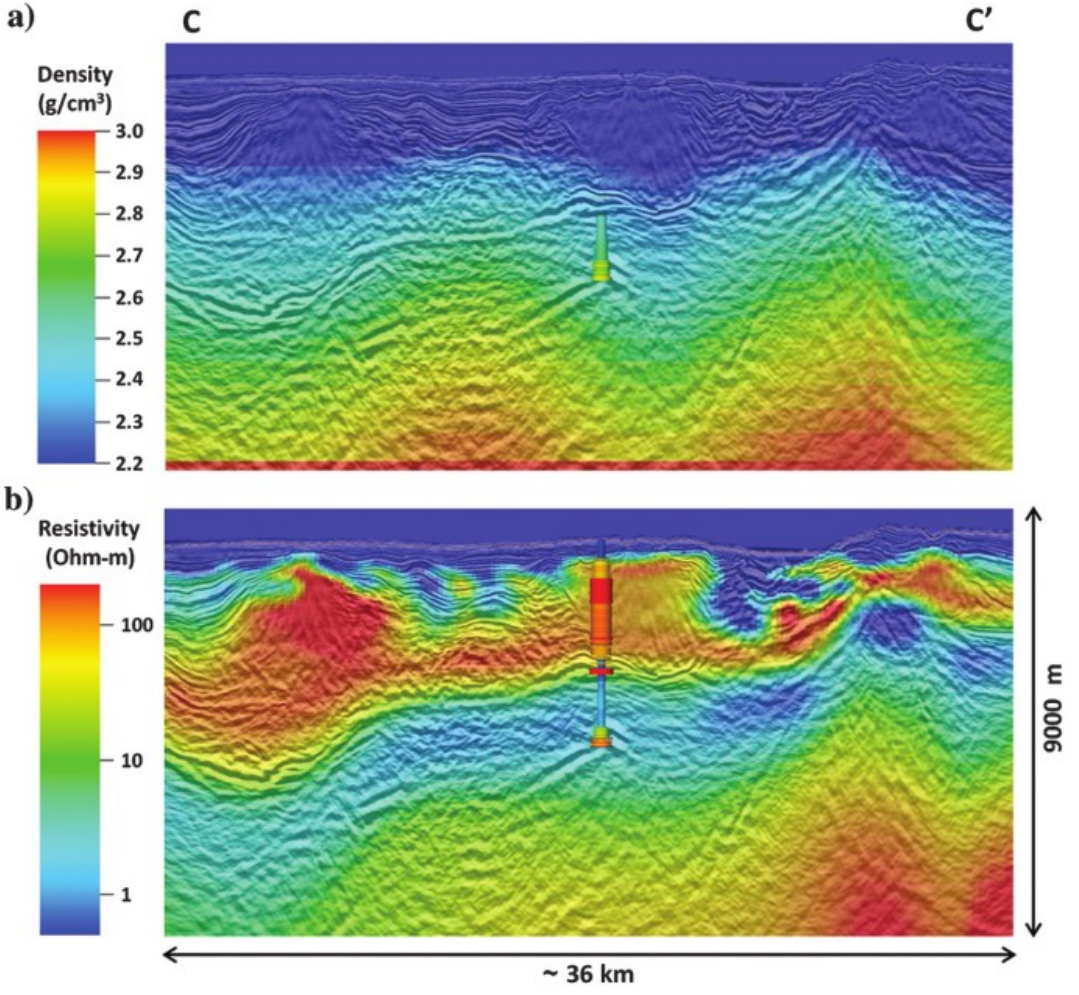


Figure 8. Data-driven 3D CSEM inversion in area 1 from different starting models: (a) half-space resistivity start model, i.e., below top LES; (b) start model is the 3D MT inversion model. In both cases, the background resistivity and the log use the same color scale.

Modelos CSEM fornecem informações sobre as camadas evaporaticas e sedimentos de subsal.

CSEM e MT no Mar Vermelho

Figure 17. Common structure model from area 1: (a) 3D gravity inversion showing primary sensitivity to the basement structures; (b) 3D CSEM inversion from the MT start model detailing the internal structures of the LES and halite.



Conteúdo

- https://github.com/florasolon/disciplina-integracao-geofisica

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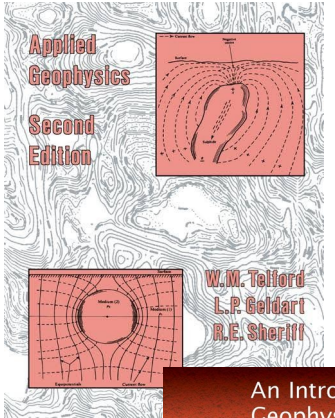

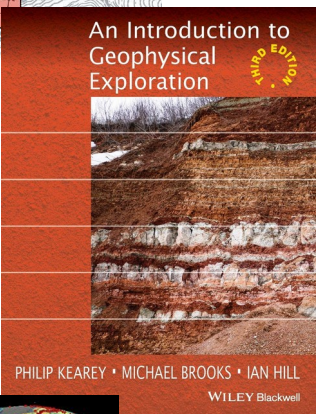

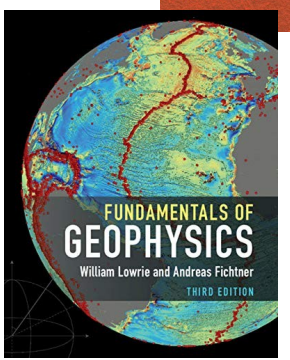

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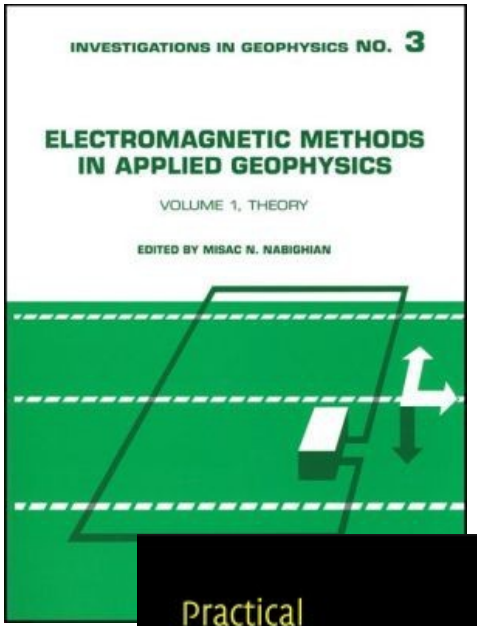

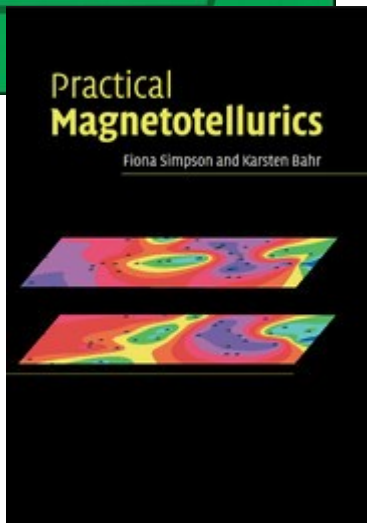

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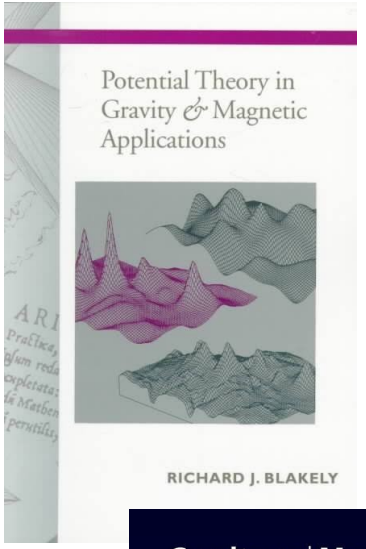

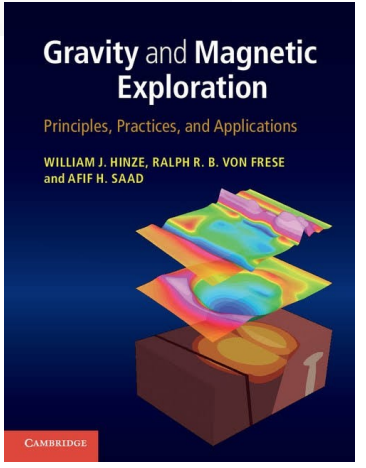

Avaliação

- Seminário - P1
- Tarefas ao longo do curso - pontos extras (pe)
- Projeto Final – P2

$$\text{Nota final} = \frac{(P1 + P2)}{2} + pe$$