Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Electrical Surveying
Part III: Self-potential method

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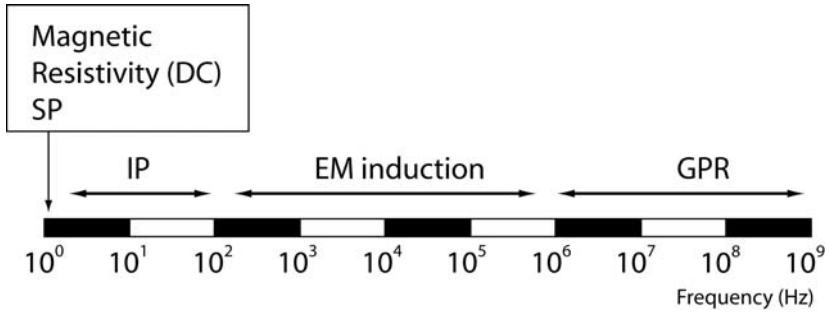
Introduction

Electrical surveying…



- Resistivity method
- Induced polarization method (IP)
- Self-potential (SP) method

Higher frequency methods (electromagnetic surveys):

- Electromagnetic induction methods
- Ground penetrating radar (GPR)

Self-potential method

The self-potential method makes use of natural currents flowing in the ground that are generated by electrochemical processes to locate shallow bodies of anomalous conductivity and water circulation

Application

- Exploration of metalliferous mineral deposits
- Detection of water circulation into the ground
- Monitoring dams or tank integrity

Structure of the lecture

1. Basic SP theory
2. Survey strategies and interpretation
3. Conclusions

1. Basic SP theory

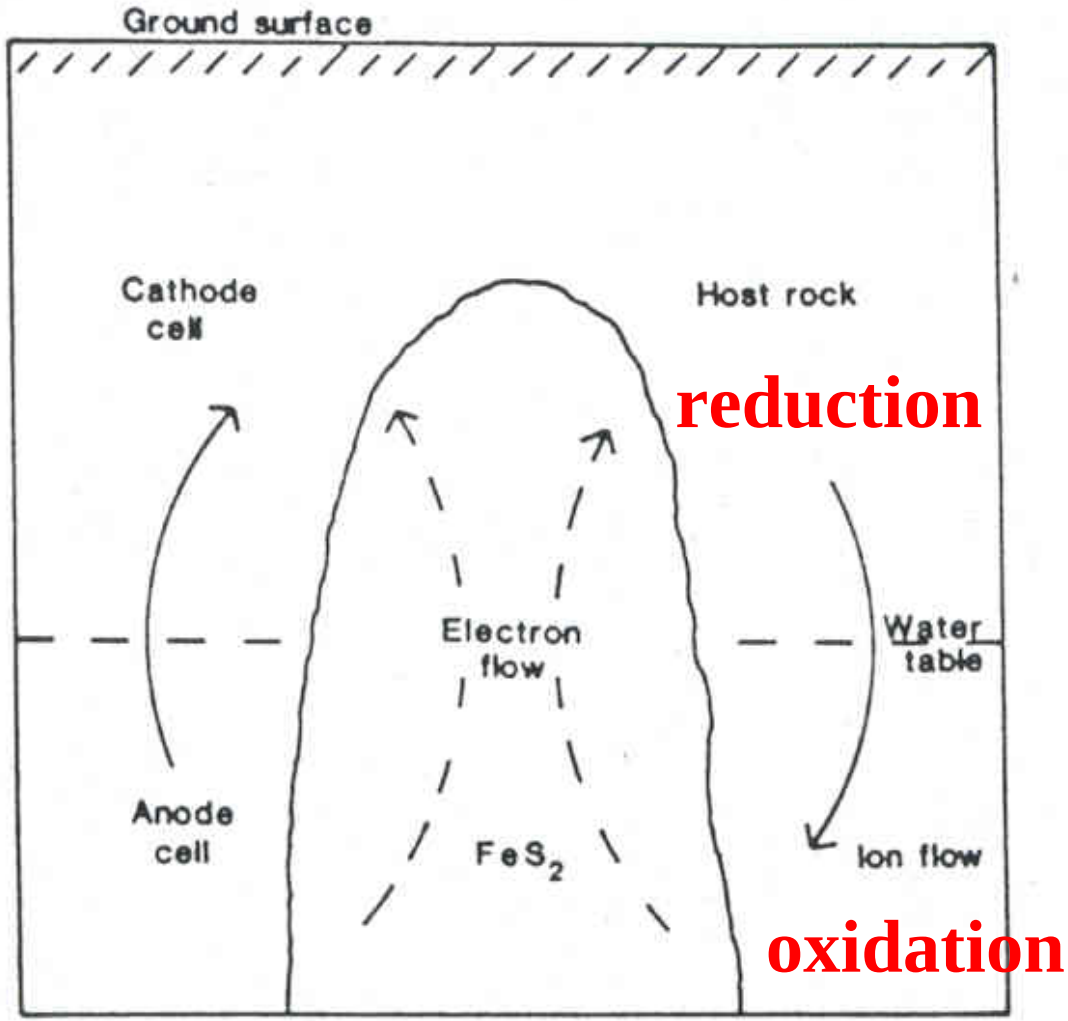
Basic theory

This is a method employing natural electric sources. Two natural potentials are mainly used in exploration geophysics:

- Electrokinetic (streaming) potential
- Mineralization potential

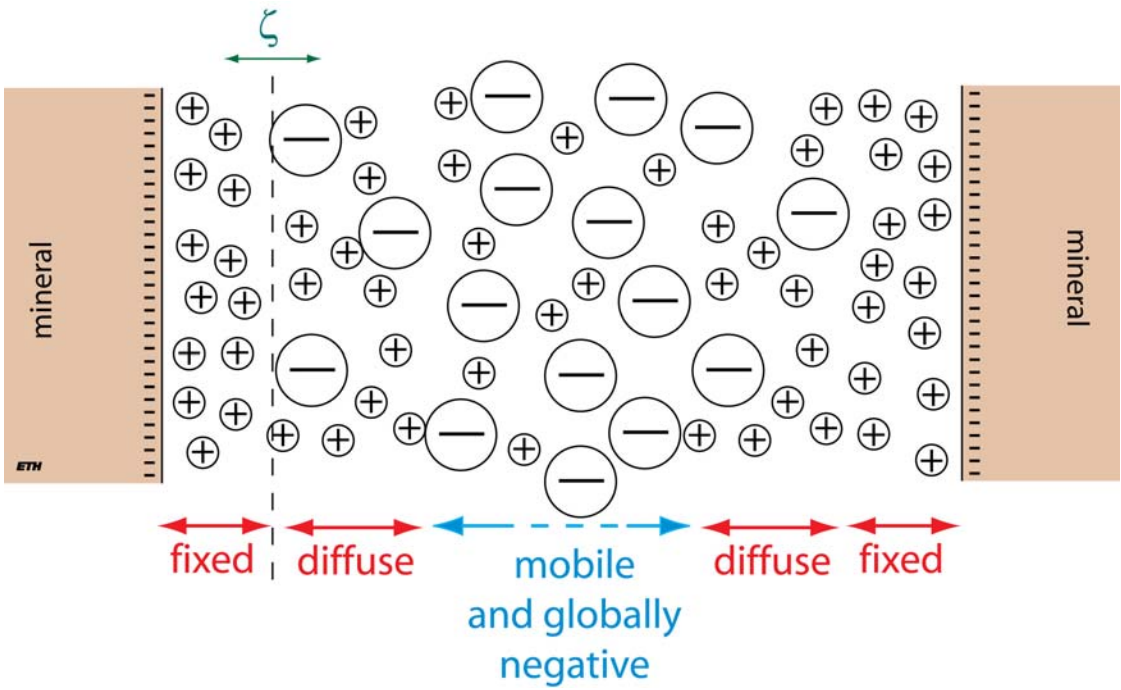
These potentials are expressed in V or mV

Mineralization potential



- Mining geophysics
- Negative anomalies often higher than 100 mV

Electrokinetic (streaming) potential



$$\Delta V = \frac{\zeta\, k}{\eta\, \sigma_w} \Delta P$$

- ζ potential between + and – layers
- k dielectric constant of the fluid
- η viscosity of the fluid
- σ_w conductivity of the fluid
- ΔP difference of pressure between the measuring points
- ΔV difference of potential between the ends of the passage

- Mainly used in hydrogeophysics
- Positive or negative anomalies often lower than 50 mV

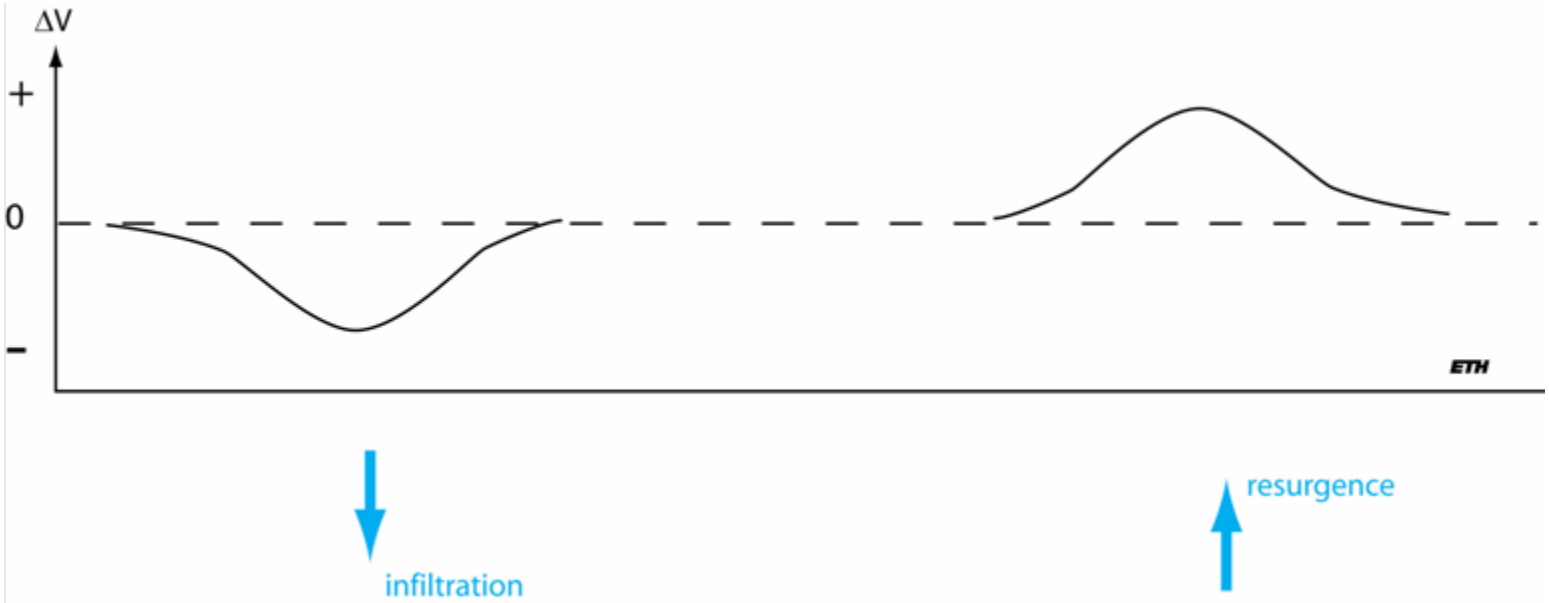
Electrokinetic (streaming) potential

$$C = \frac{\Delta V}{\Delta P} = \frac{\zeta\, k}{\eta\, \sigma_w}$$

C is often described as the coupling coefficient

- If the grain size decreases, *C* increases
- If the temperature decreases, *C* decreases
- If σ_w decreases, *C* increases
- Permeability has a complex effect on *C*.

Electrokinetic (streaming) potential



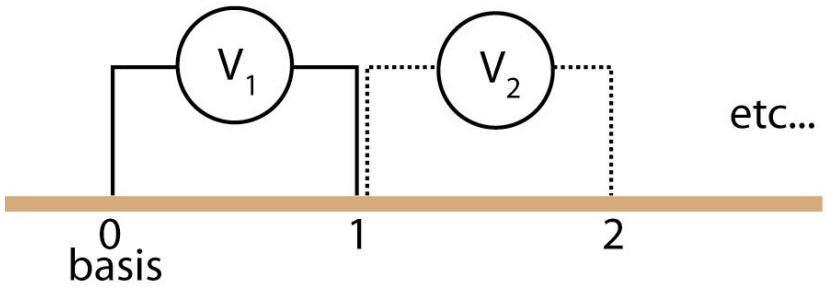
SP anomaly is positive where the hydrostatic pressure decreases (i.e. in the direction of the water flux).

If the flow is horizontal, then $\Delta P = \Delta h = 0$ and $\Delta V = 0$

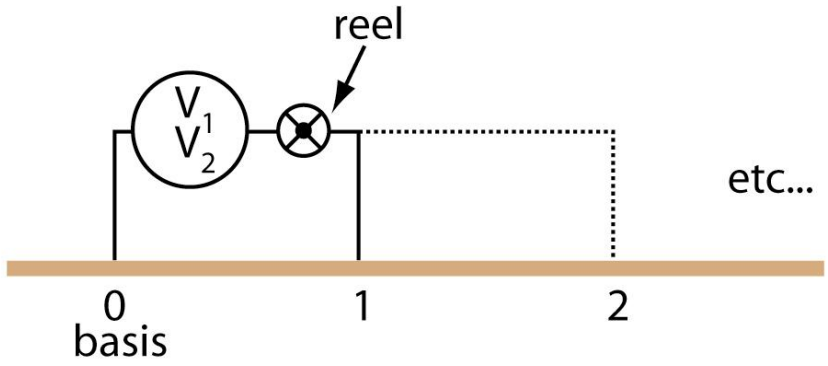
2. Survey strategies and interpretation

SP measurement

V : raw data
P : real potential values at the basis

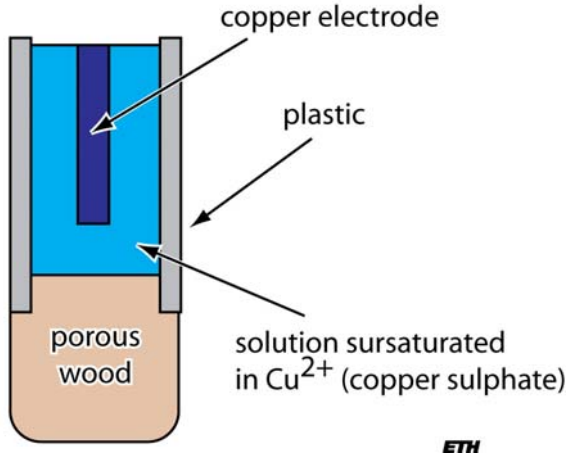


$P_1=V_1$
$P_2=V_1+V_2$
$P_n=V_1+V_2+...+V_n$



$P_1=V_1$
$P_2=V_2$
$P_n=V_n$
$P_{n+1}=V_{n+1}+P_n$ (for a new basis)

Non-polarizing electrode



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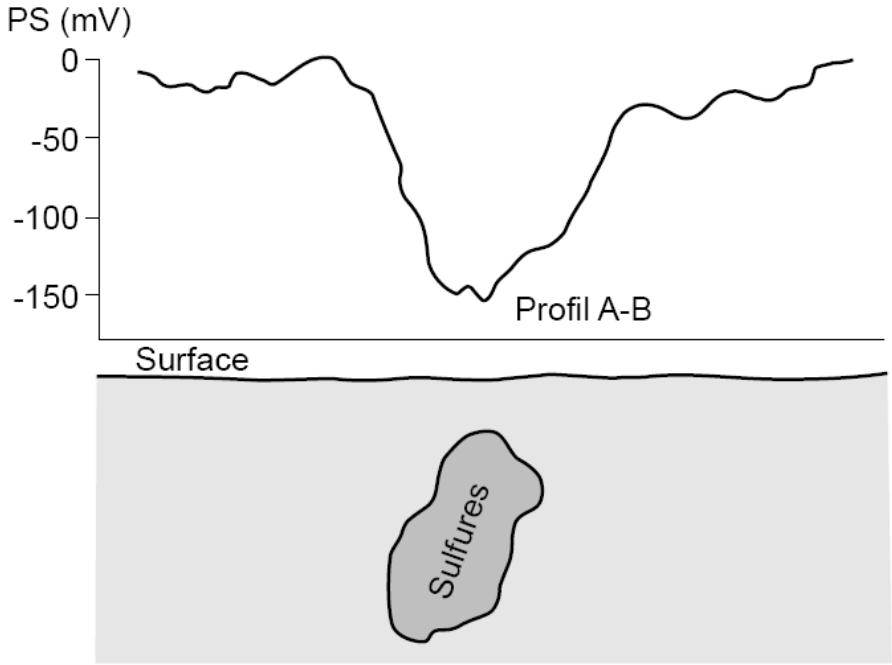
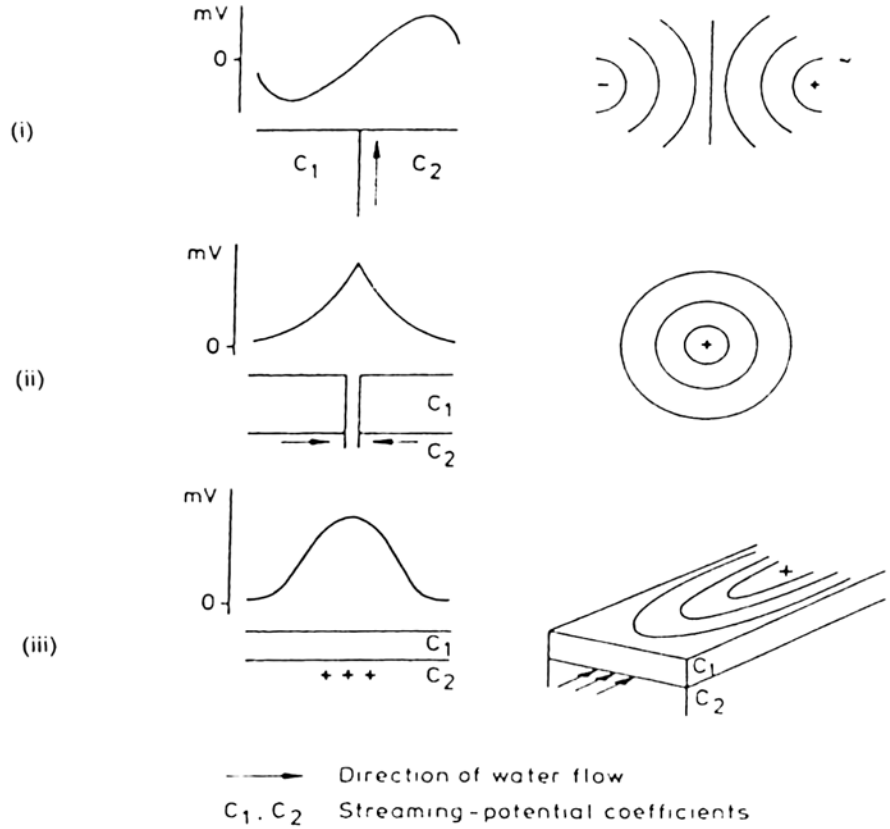
Interpretation

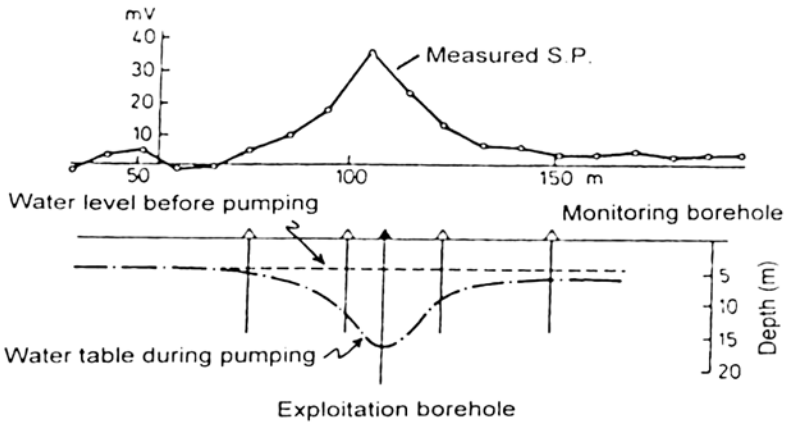
- Depth of investigation depends on the size of the mineralized body and the depth of the water table for a mineralization potential (generally shallow, < 30 m)
- Interpretation mainly qualitative (profile, map)
- Quantitative using dipole approximations for the polarized body (similar to magnetic interpretation)

Example of mineralization potential

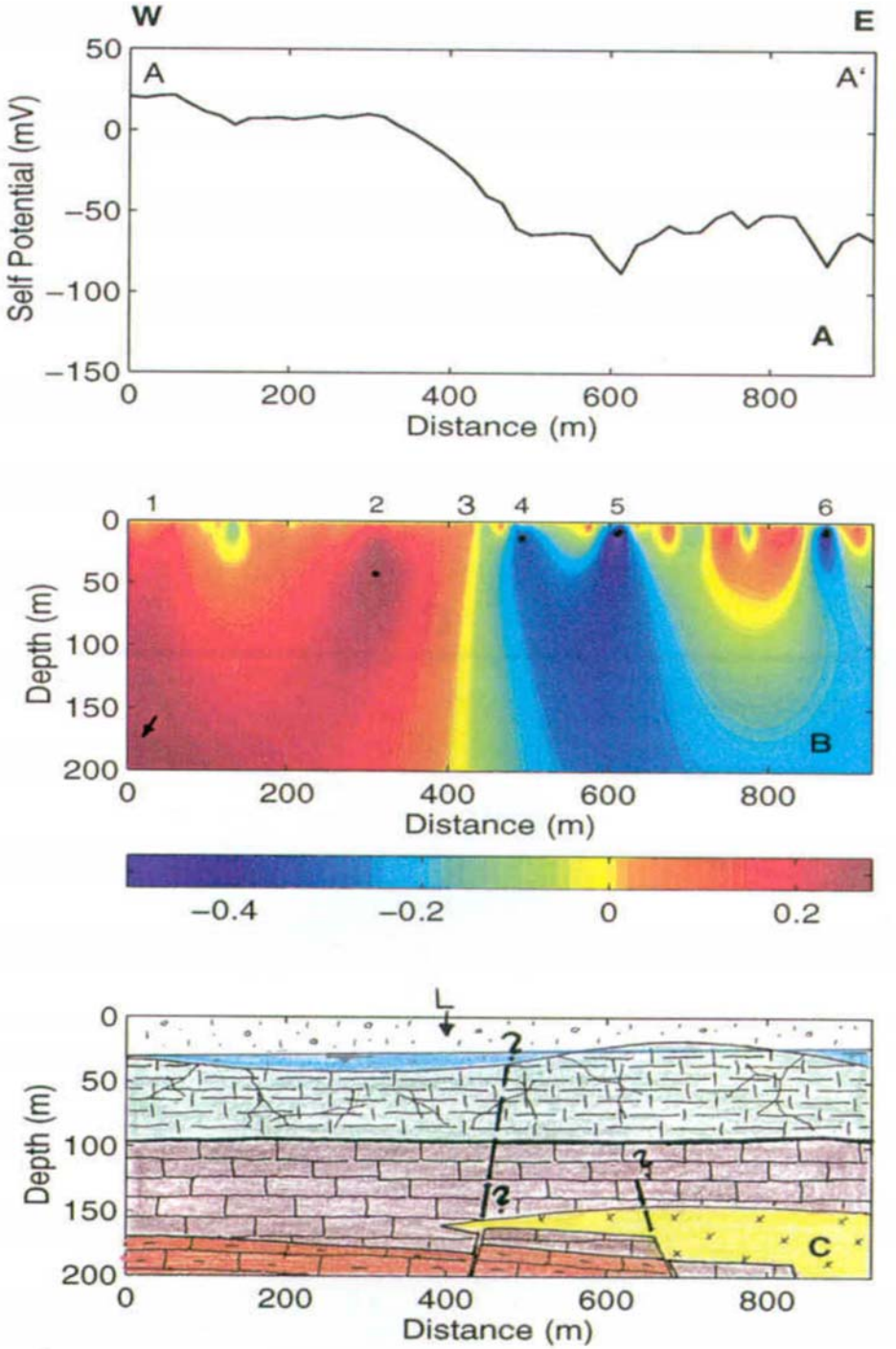


Examples of streaming potential

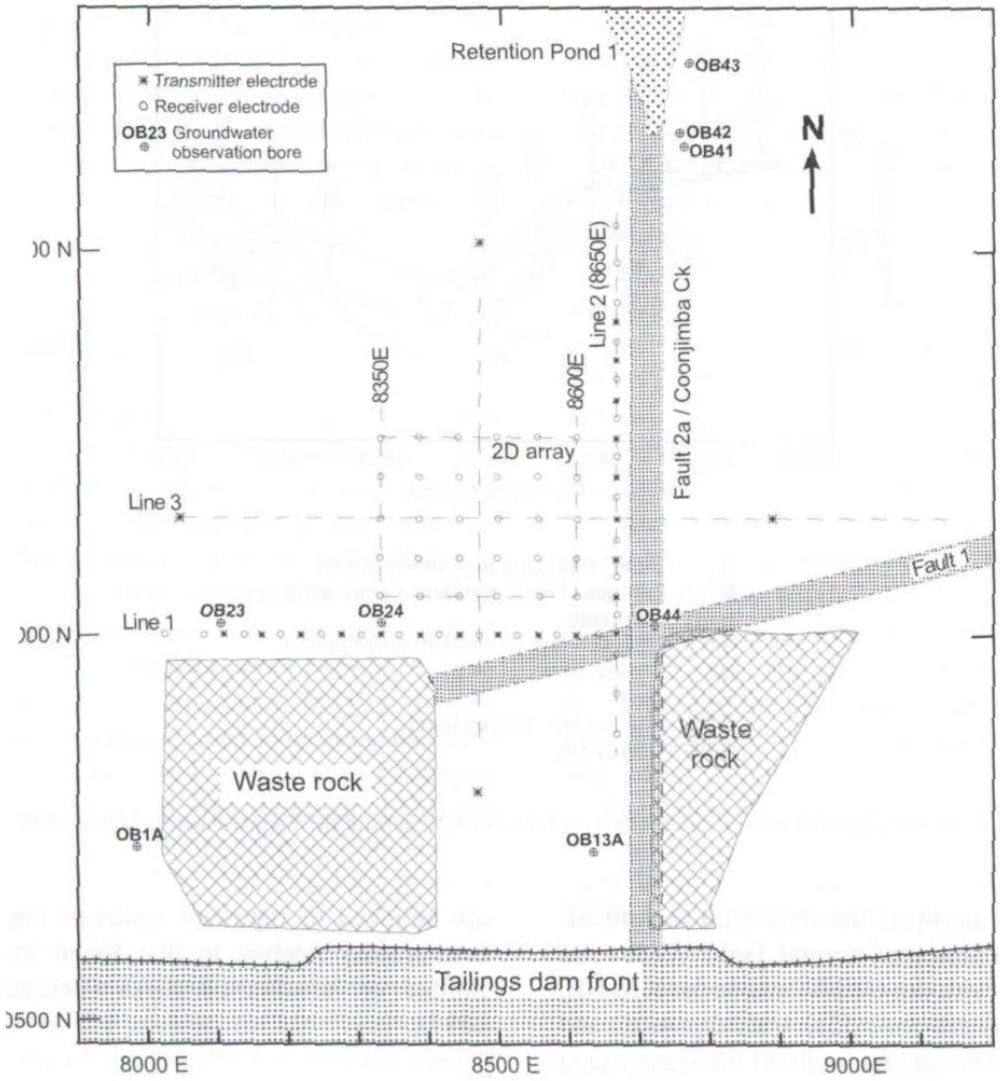




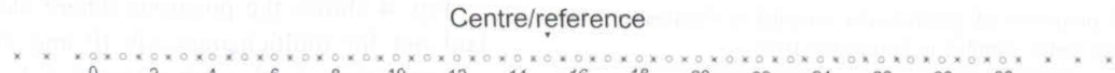
Geology


W
E
A
A'
Self Potential (mV)
50
0
−50
−100
−150
0
200
400
600
800
Distance (m)
1
2
3
4
5
6
Depth (m)
B
−0.4
−0.2
0
0.2
L
?
C

Waste deposits

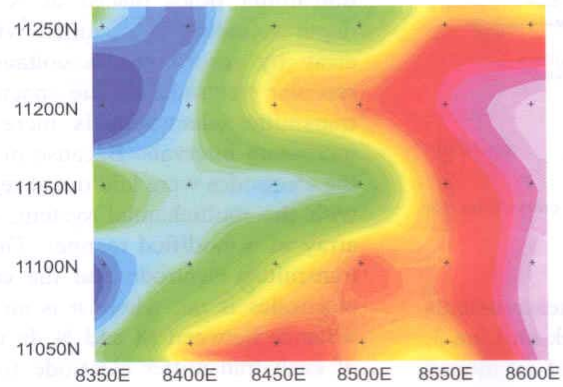


(a) The survey grid

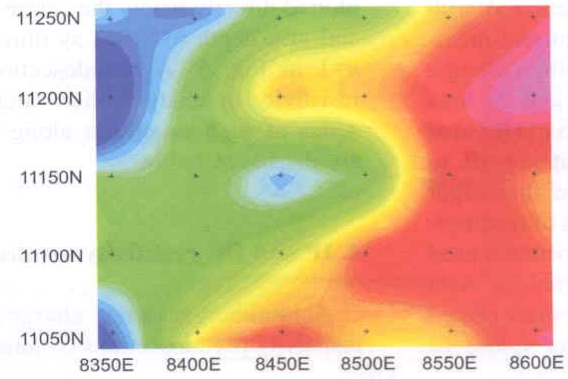


(b) Details of Line 3

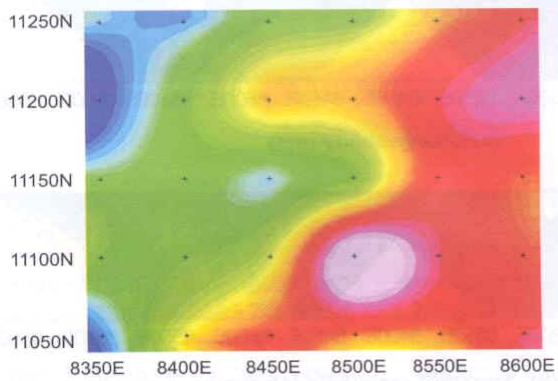
12:23pm, 23/10/98 (average of 10 sec data)

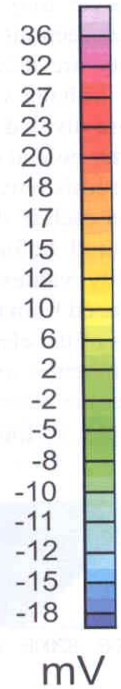


1:32pm, 23/10/98 (average of 200 sec data)

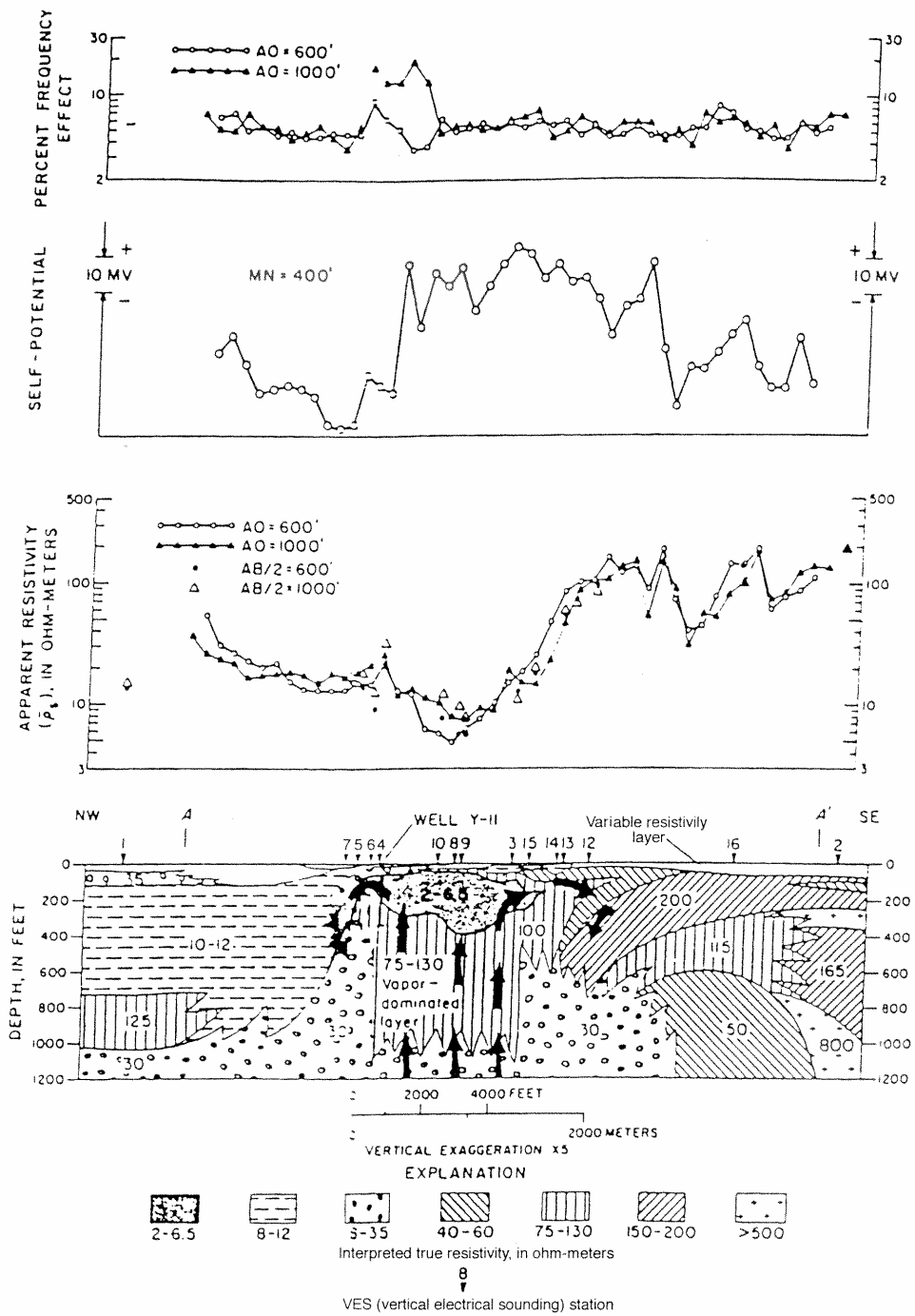


1:32pm, 26/10/98 (average of 600 sec data)





Geothermy


PERCENT FREQUENCY EFFECT
AO = 600'
AO = 1000'
SELF-POTENTIAL
10 MV
MN = 400'
APPARENT RESISTIVITY (ρ_a), IN OHM-METERS
AO = 600'
AO = 1000'
AB/2 = 600'
AB/2 = 1000'
NW
A
WELL Y-11
Variable resistivity layer
A'
SE
DEPTH, IN FEET
2-6.5
10-12
75-130
Vapor-dominated layer
100
200
115
165
125
30
50
800
2000
4000 FEET
2000 METERS
VERTICAL EXAGGERATION X5
EXPLANATION
2-6.5
8-12
5-35
40-60
75-130
150-200
>500
Interpreted true resistivity, in ohm-meters
VES (vertical electrical sounding) station

3. Conclusions

Advantages

- Survey simple
- Non expensive
- Allows for a rapid qualitative mapping of the underground
- Suitable for monitoring

Drawbacks

- Very sensitive to noise
- Physical aspects still not well understood
- Quantitative aspects still need to be developed