Near-surface Geophysics

hergarten.at/20S/Geophysics

Institut für Geo- und Umweltnaturwissenschaften

Geophysics Lab

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Institute of Earth and Environmental Sciences

Room: 01 008

Further Reading

Books: Main Fields of Geophysics

- Reynolds (2011): An Introduction to Applied and Environmental Geophysics. Wiley-Blackwell.
- Telford, Geldard and Sheriff (2010): Applied Geophysics. Cambridge University Press.
- Burger, Sheehan and Jones (2006): Introduction to Applied Geophysics. Norton & Company.

MATLAB Recipes

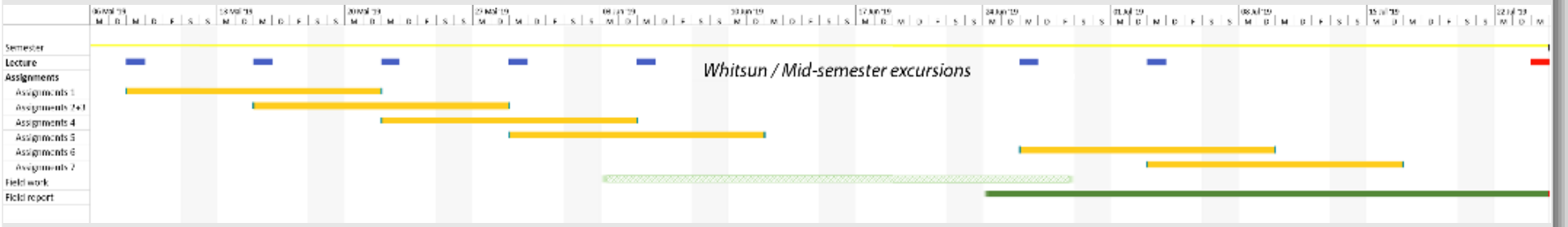
- Traut (2010): Matlab Recipes for Earth Sciences. Springer.

Additional scripts: Seismology

- Fundamentals of Ray Tracing by Rick Aster (2011): http://www.ees.nmt.edu/outside/courses/GEOP523/Docs/rays.pdf

Introduction

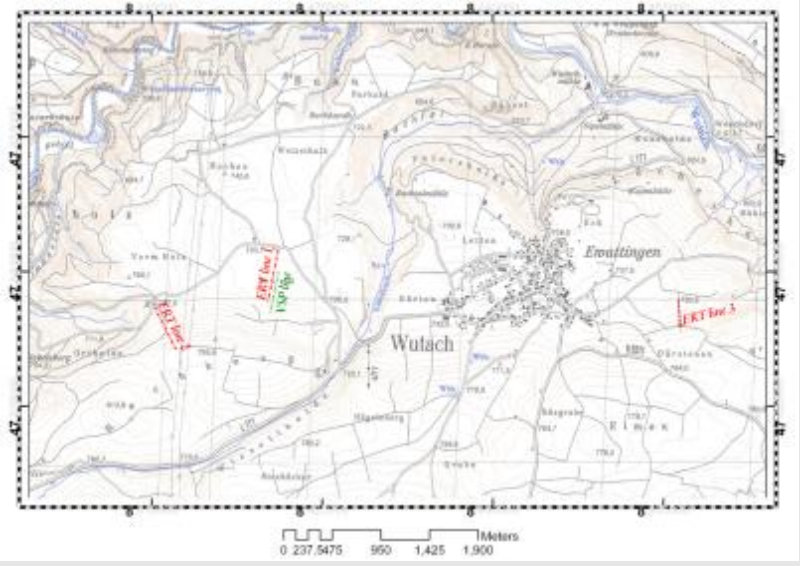
Structure

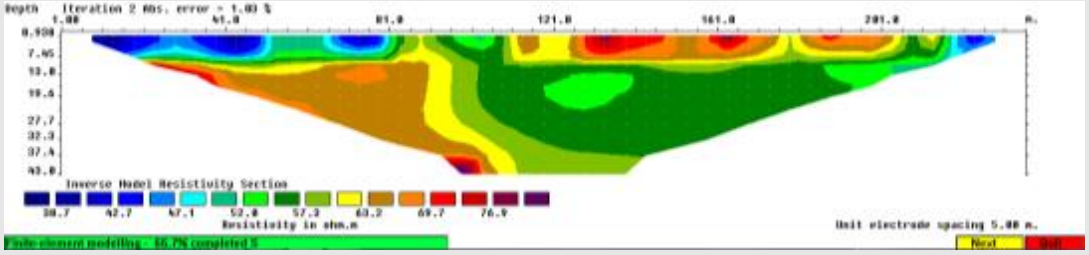


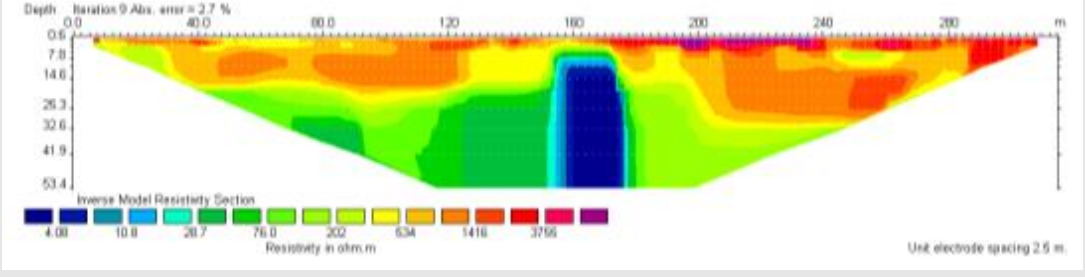
Component	Contribution
• 7 assignment sheets: 7 assignments + field report – usually 14 days for each assignment sheet – field report due end of July	60 %
• helping your classmates solving the assignments/solving on your own	10 %
• short test at the end of the semester	30 %

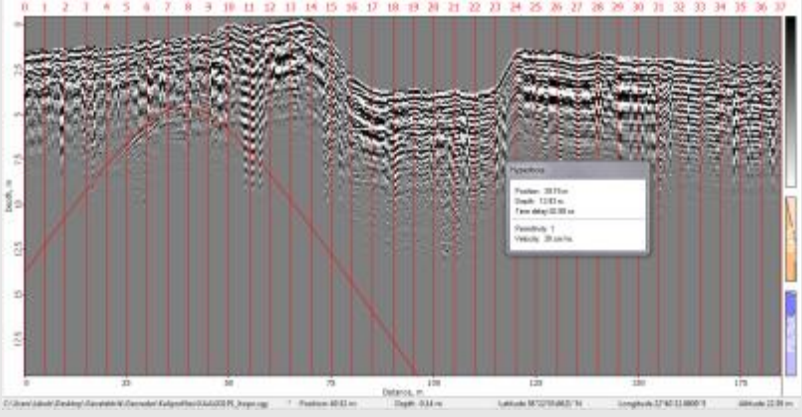
Introduction

Field exercise









- Wutach or Münstertal Valley
- 2 days in July
- 2 groups

Basic Terms

Disciplines of Geophysics

Investigation of the physical properties and processes related to the earth:

Solid earth: General geophysics

Hydrosphere: Oceanography, hydrology

Atmosphere: Meteorology, aeronomy

Geophysical Methods

Exploration of the subsurface (from the surface to the core) by measuring fields (e. g., gravity field, magnetic field)

- at the surface,
- in boreholes or
- from air.

Basic Terms

Inversion

- Geophysical measurements provide only indirect information on the subsurface properties.
- Inversion is the construction of a subsurface model from properties (fields) measured at the surface, in boreholes or from airborne systems.

Active and Passive Methods

Passive methods measure and analyze fields which are naturally supplied by the earth and their modification by the subsurface structure.

Active methods generate fields themselves and analyze their modification by the subsurface structure.

Basic Terms

Applied Geophysics

Application of geophysical methods in areas of relevance outside geophysical fundamental research, e. g.,

- exploration of resources
- groundwater
- residual waste
- archaeology
- mass movements

Types of Fields

Classification according to the Number of Field Components

Classification according to the number of field components:

Scalar fields, e. g., temperature, pressure

Vector fields, e. g., gravity, electric field, magnetic field

Classification according to the Type of "Propagation"

Potential fields, e. g., gravity, described by elliptic differential equations.

Diffusive fields, e. g., temperature, described by parabolic differential equations.

Wavefields, e. g., seismic waves, described by hyperbolic differential equations.

The most Important Geophysical Field Methods

Geothermics

Measurement of temperatures and thermal conductivities.

Passive Method

Radiometry

Measurement of the radiation of radioactive materials.

Passive Method

The most Important Geophysical Field Methods

Geomagnetics

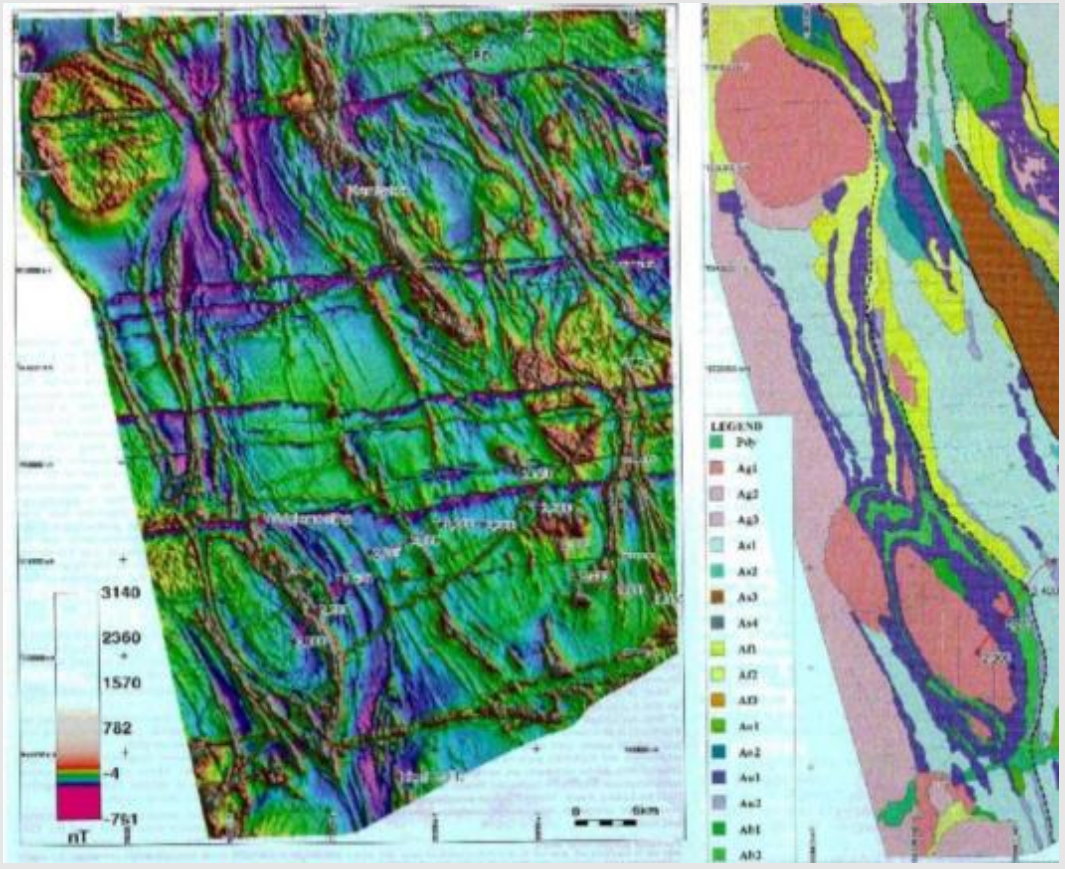
Measurement of the earth's magnetic field and its modification by the subsurface structure.

Passive method

- Target property: magnetic susceptibility
- Prospection and exploration of ore deposits
- Detection of residual waste
- Support of geological mapping
- Application is in principle simple, but is often disturbed by temporal variations of the earth's magnetic field.

The most Important Geophysical Field Methods

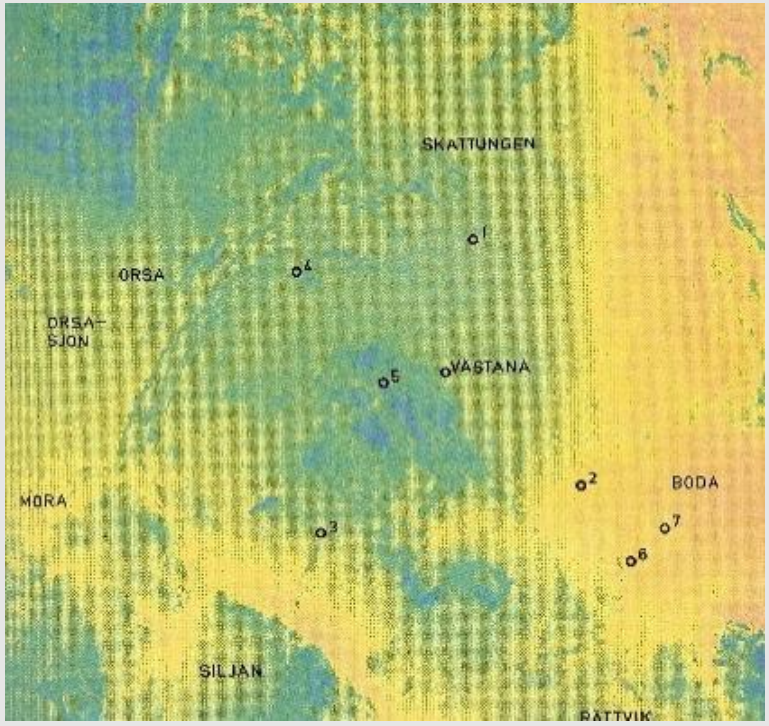
Geomagnetics

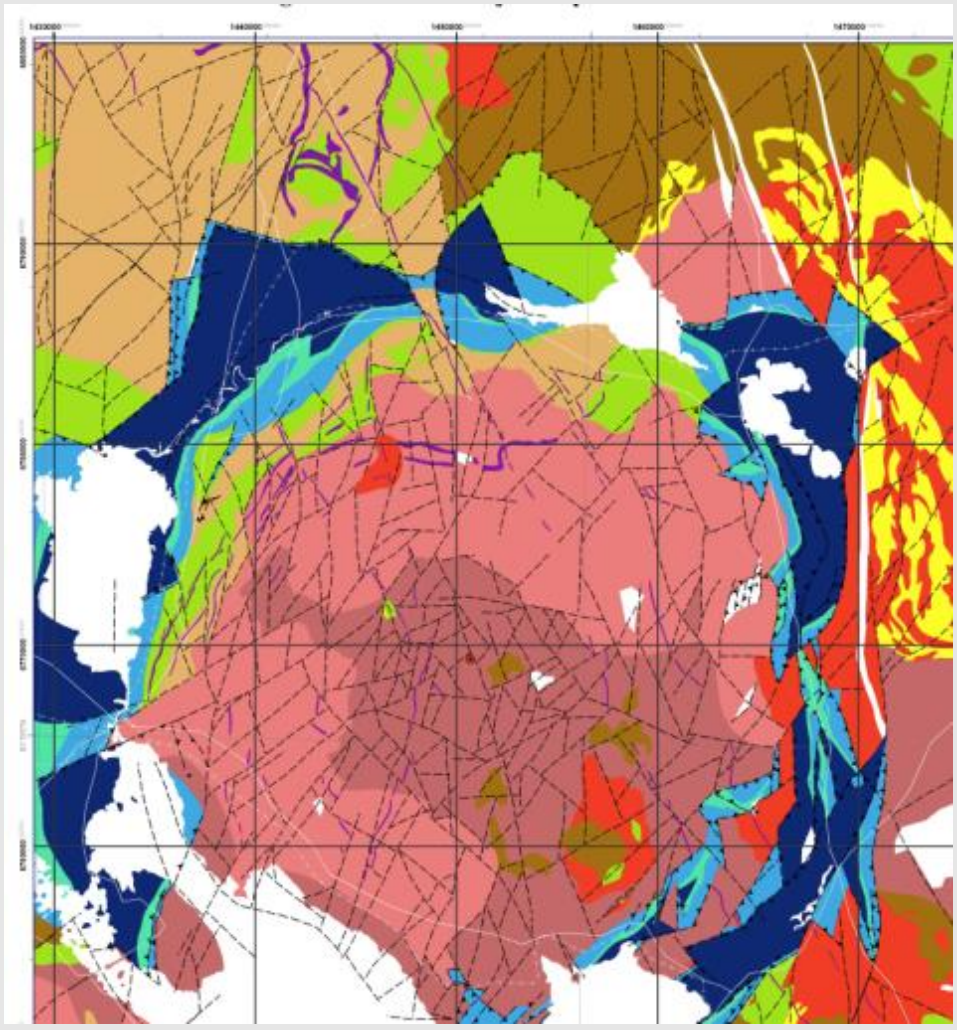


(middle) Aeromagnetic anomaly map, Western Australia.
(right) Lithological interpretation (House et al., 1999)

The most Important Geophysical Field Methods

Geomagnetics - Aeromagnetics

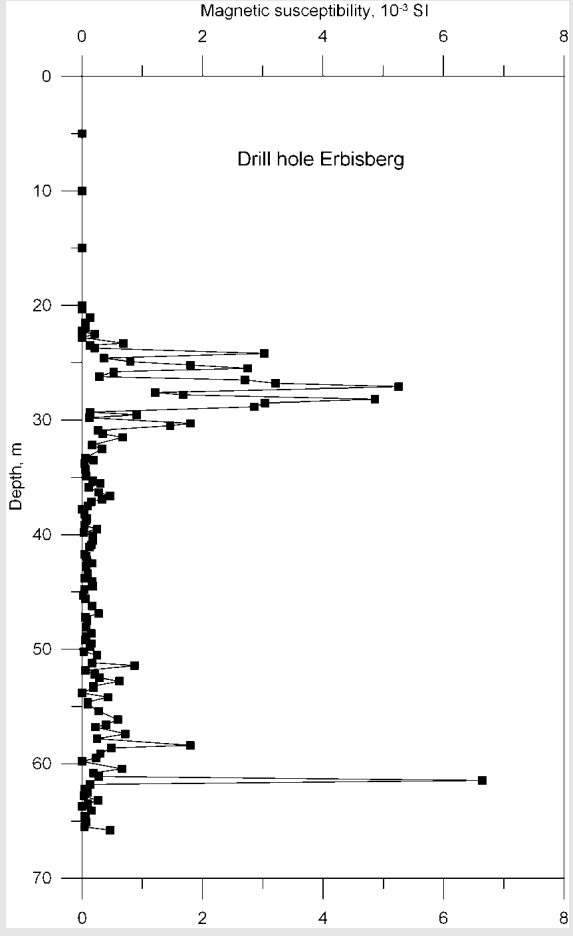




The most Important Geophysical Field Methods

Geomagnetics

- **Magnetic susceptibility** - as non in-situ method



The most Important Geophysical Field Methods

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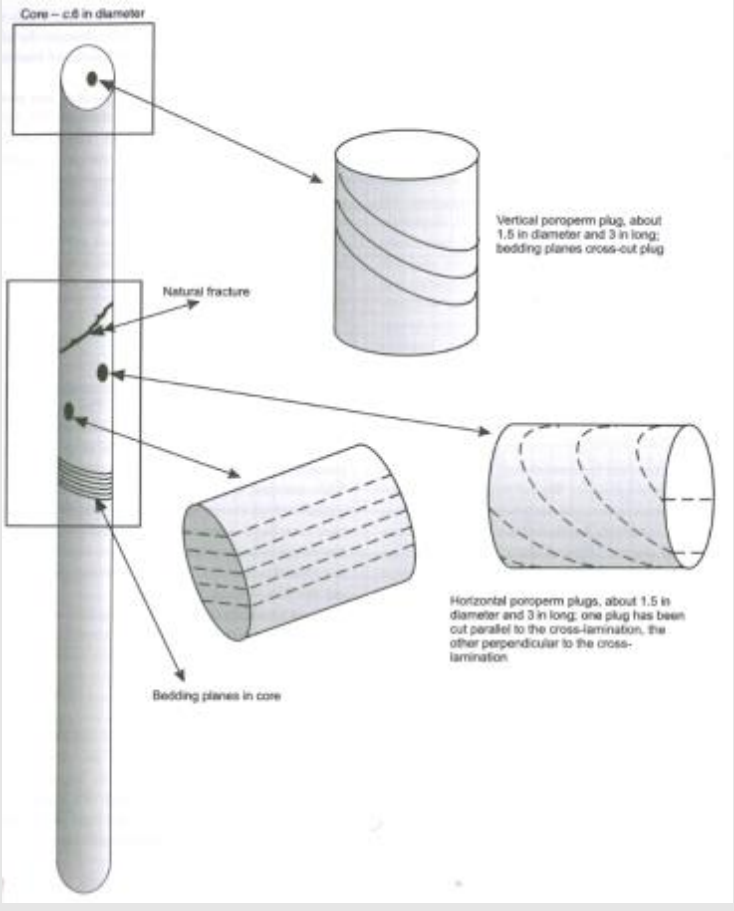
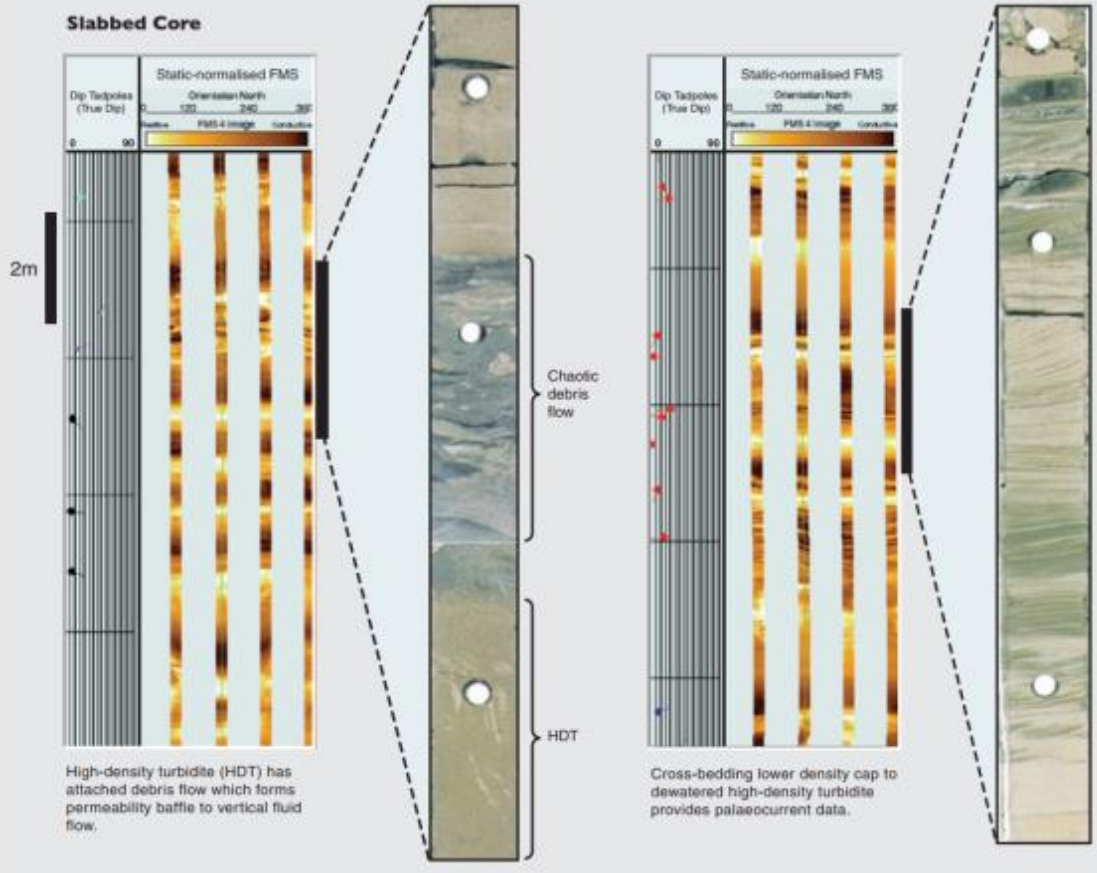




The most Important Geophysical Field Methods

Gravimetry

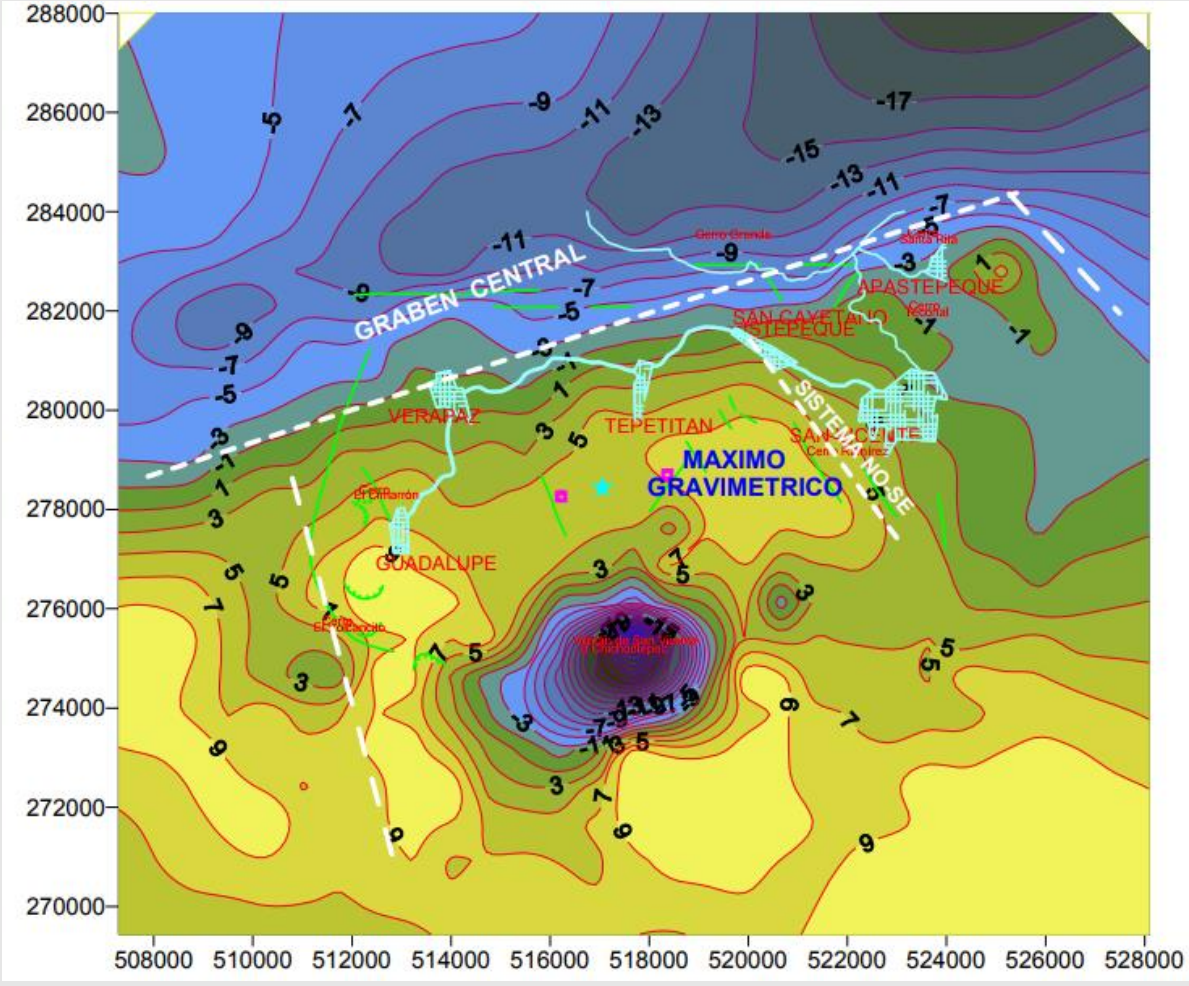
Exploration of the earth's natural gravity field

Passive method

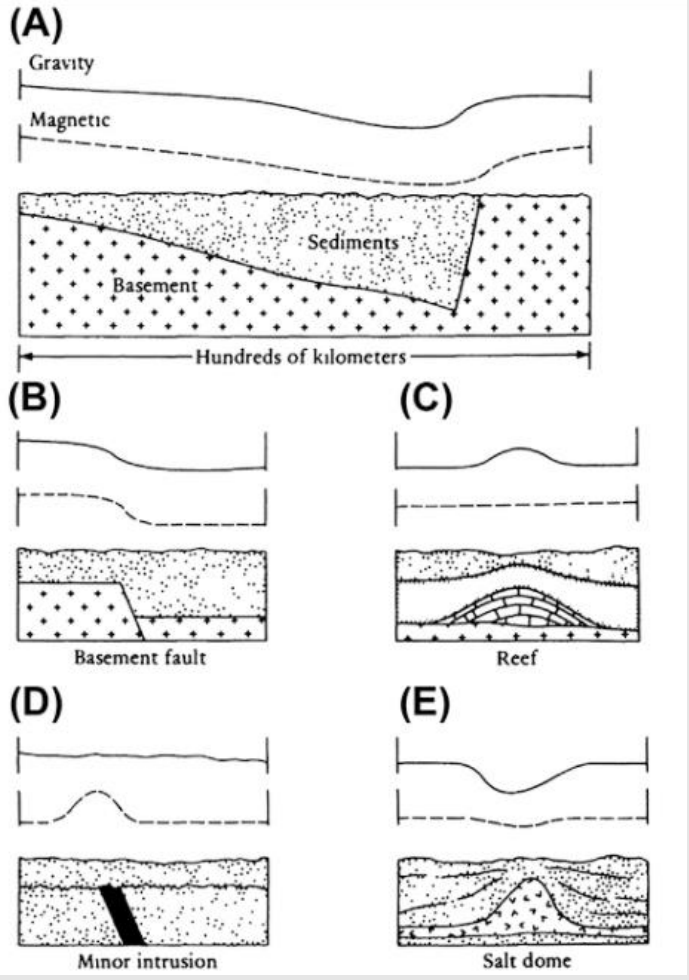
- Detection of excess mass of mass deficits in the subsurface.
- Very important for the exploration of resources (mainly heavy ores) and for investigating the deeper interior of the earth.
- Also very important in geodesy, e. g., the geoid or changes in surface elevation through time.
- Also suitable for the investigation of large-scale groundwater phenomena.

The most Important Geophysical Field Methods

Gravimetry



Bouguer anomaly map of the San Vicente geothermal area (Rivas 2009)



(Selley and Sonnenberg,1985)

The most Important Geophysical Field Methods

Seismology and Seismics

Propagation of mechanic waves in the subsurface

Seismology: Theory of wave propagation, exploration of the earth's interior with the help of seismic waves originating from earthquakes.

↓

Passive method

- Has provided the majority of our knowledge in the earth's interior.
- Rather fundamental research than applied geophysics.

Seismics: Exploration of the subsurface by means of artificial seismic waves (hammer stroke, weight dropping, explosives, vibration)

↓

Active method

The most Important Geophysical Field Methods

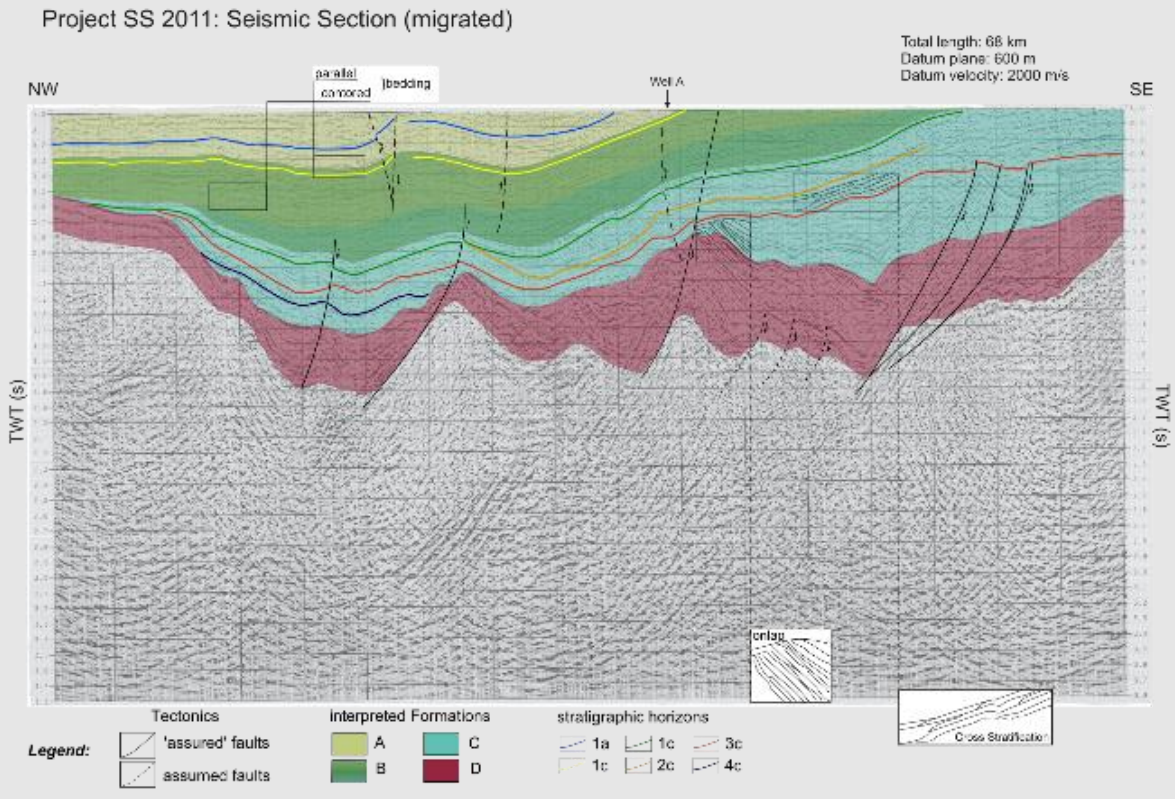
Seismics

Vibroseis
(source: Wikipedia)

alternatives – Weight drop (thumper), Dinoseis (explosion of propan-air mixture), Geoflex (explosive cable), earth-temperer

The most Important Geophysical Field Methods

Seismics



Reflexw

CWP SU

MADAGASCAR

- seismic processing

Petrel

GISMO

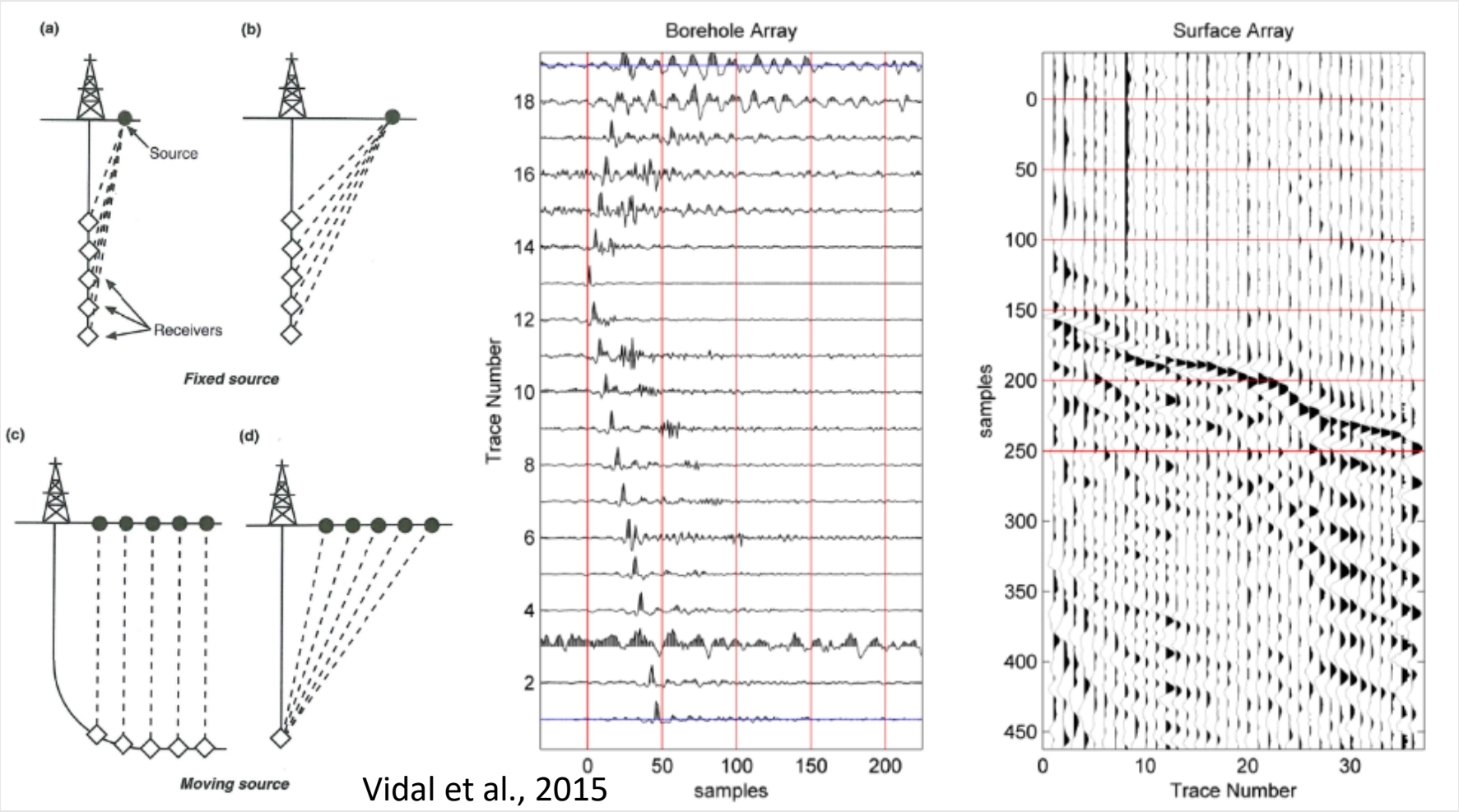
OpendTect

- multidimensional analysis

The most Important Geophysical Field Methods

Seismics

- **Sonic Log** - Vertical Seismic Profiling (VSP)



Vidal et al., 2015

The most Important Geophysical Field Methods

Electromagnetic Methods

Interaction of time-dependent electric and magnetic fields:

Low frequencies: Electromagnetic induction

High frequencies: Electromagnetic waves

Touchless field generation and reception by conductor loops, coils or antennas is possible

Particularly useful for airborne systems.

Frequency-domain methods: Long, sine-shaped signals

Time-domain methods: Short pulses

The most Important Geophysical Field Methods

Electromagnetic Methods

Very low frequency (VLF) method: Uses electromagnetic waves of existing powerful radio transmitters.

Passive (or parasitical?) Method

Magnetotellurics: Simultaneous measurement of electric and magnetic fields. Analyze the reaction of the electric field to changes in the earth's magnetic field.

Passive method

The most Important Geophysical Field Methods

Electromagnetic Methods

Ground-Penetrating Radar (GPR): Submits pulses of electromagnetic waves in the microwave band (about 1GHz) and records waves reflected at discontinuities.

Active Method

- High spatial resolution for the price of low penetration depth.
- Detects discontinuities in solids as well as sudden changes in water saturation.
- Main applications: Residual waste, ground investigation, archaeology, detection of land mines, groundwater exploration.

The most Important Geophysical Field Methods

Geoelectrics

DC geoelectrics (resistivity methods): Current is transmitted through the subsurface, and differences in the electric potential (voltage) are measured.

↓

Active method

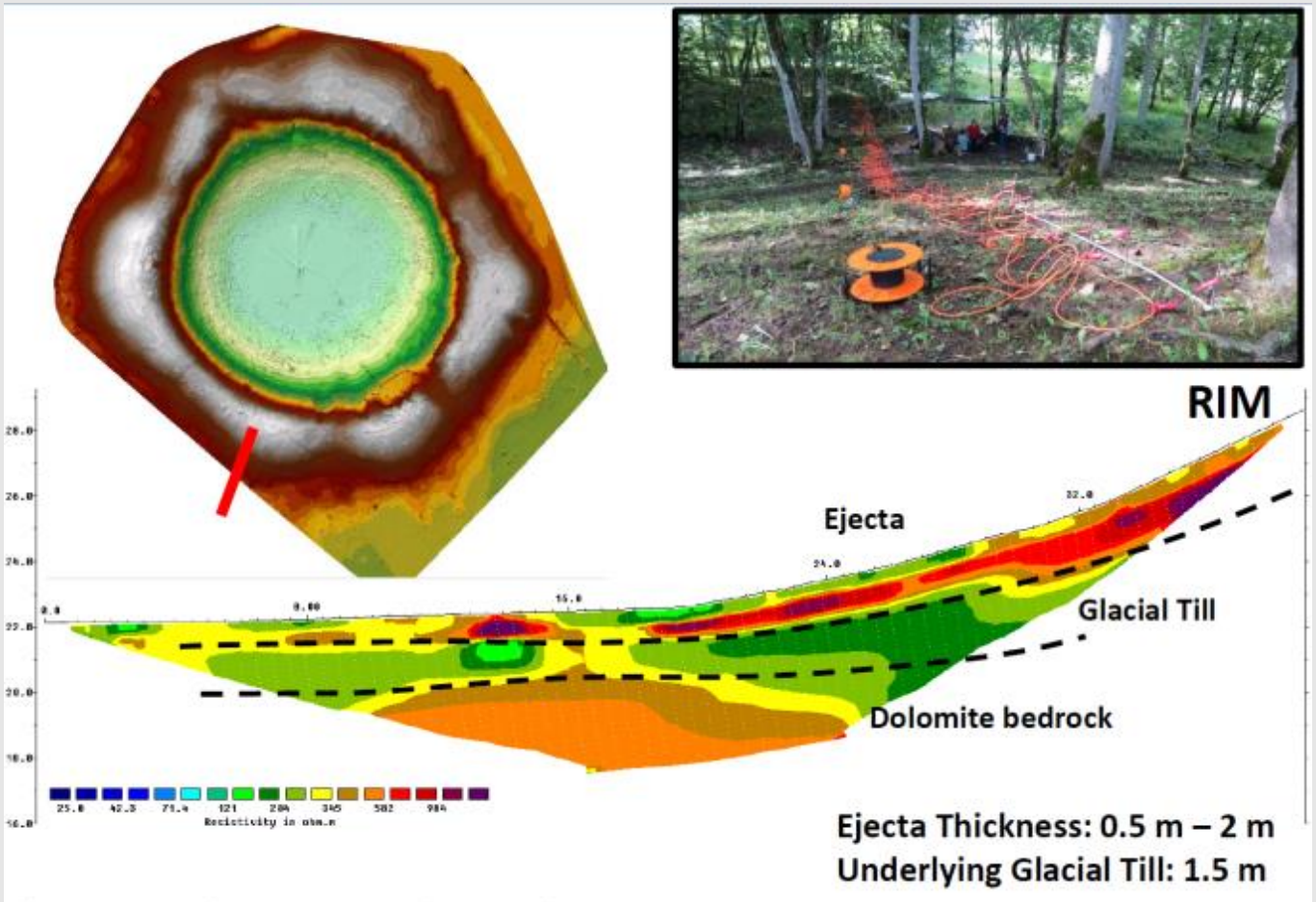
- Target property: Electrical conductivity or resistivity
- Conduction in porous media is governed by electrolytes in the porewater.

↓

Perhaps the most important geophysical method in subsurface hydrology.

The most Important Geophysical Field Methods

Comparison of GPR and ERT Profiles



The most Important Geophysical Field Methods

Geoelectrics

Induced polarization (IP): Measure the effect of switching the current on and off.

Active method

Sensitive to the presence of some ores and clay minerals.

Spontaneous potential (self-potential, SP) method: Measurement of naturally occurring electric potential differences.

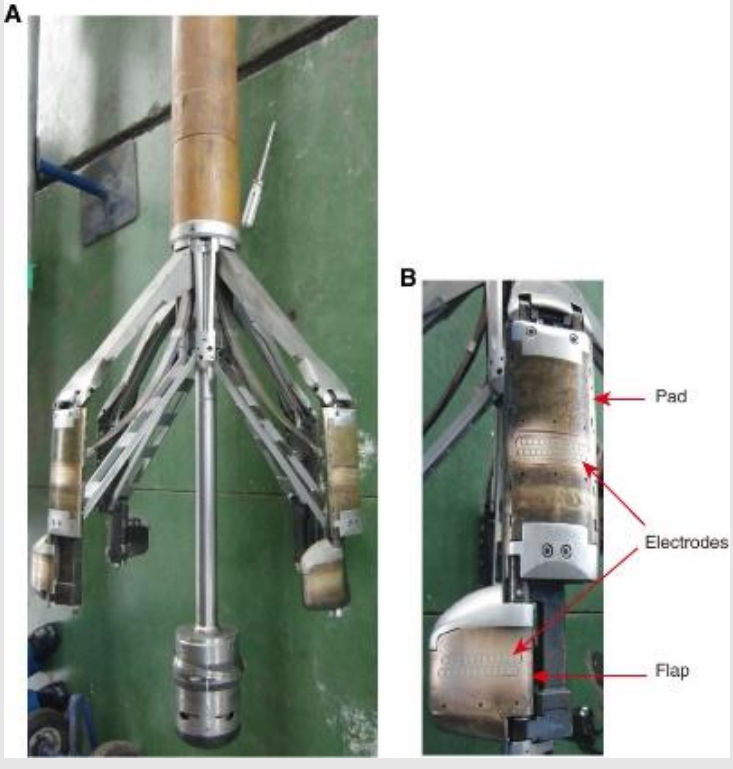
Passive method

Exploration of ore and graphite deposits and residual waste.

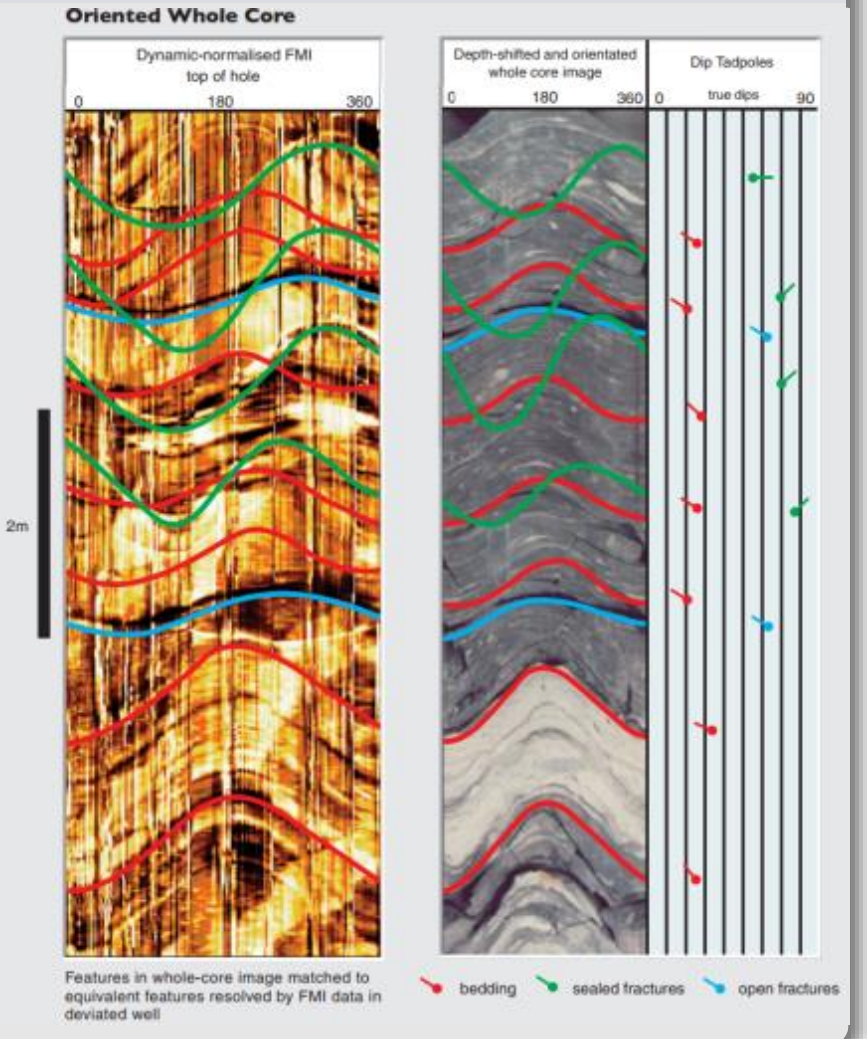
The most Important Geophysical Field Methods

Geoelectrics

- **Electric Resistivity / Induction Logs**
  FMI / FMs
  (Formation MicroImager/Scanner)



Schlumberger 2017



The most Important Geophysical Field Methods

Geoelectrics

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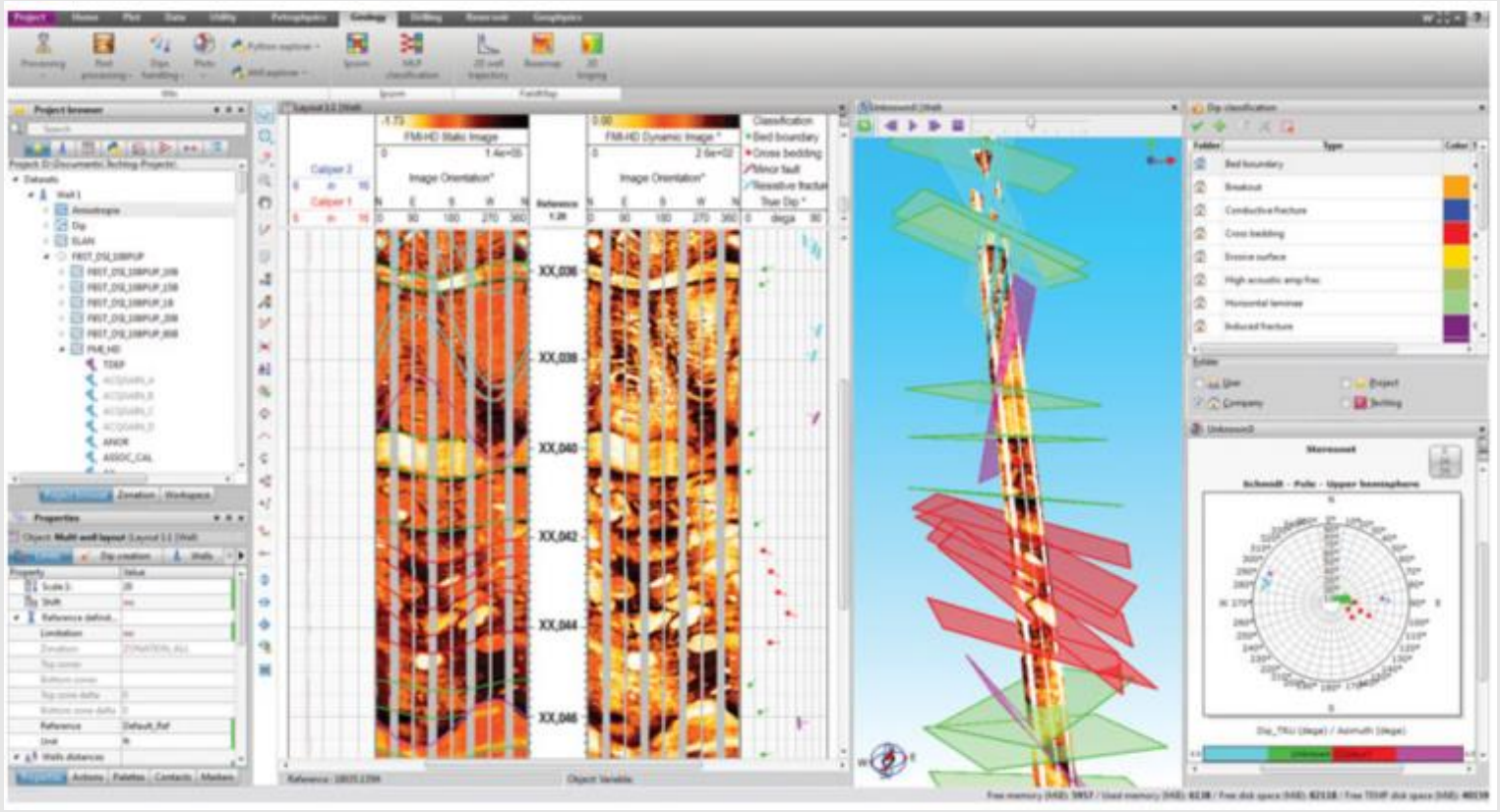
  FMI / FMS *(Formation MicroImager/Scanner)*



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The most Important Geophysical Field Methods

Comparison of GPR and ERT Profiles