Workpackage 1.02

Magnetotelluric theory and practice in geothermal exploration

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Development and use

This course was developed by drs. Wouter van Leeuwen from IF Technology in 2015 and 2016. For additional information on this course he can be contacted at w.a.vanleeuwen@iftechnology.nl.

The course material provides a theoretical background to and practical recipes for the magnetotelluric method for geothermal exploration as well as exercises applying the method to real world situations.

Abstract

Magnetotellurics is a non-evasive geophysical technique which utilizes the variations in the Earth's electromagnetic field to image the electrical resistivity structure of the subsurface. The MT method is utilized for research purposes and commercial activities such as deep crustal studies, exploration for mining and offshore hydrocarbon. In addition to these applications, MT has a long track record in the exploration of volcanic geothermal systems, which have a clear signature in resistivity models. In this course an introduction is given to the most important theory and assumptions used for the MT method.

Additionally, common causes for signal distortion and how to mitigate hem are discussed and a good-practice field procedure addressing key factors during data acquisition is presented. Furthermore strategies to assess the quality of a MT data set are introduced as are the main theoretical principles of MT data processing theory.

Finally, inversion (modelling)n and interpretation of the subsurface models derived from MT data are discussed.

It is the intention of this course that the participants are, after the successful completion of the course, able to explain others the the main principles of the MT method. Furthermore, they will know how to carry out MT fieldwork or simple modelling for geothermal prospecting and transfer this knowledge to others. To some extent, the participants will also be able to carry out a quality check on acquired MT data as well as assess the validity, reliability and accuracy of any resistivity model and its interpretation made on the basis of MT data.

Target group

Target groups are practitioners as well as trainers/ lecturers from academia.
The entry level of the target groups is at least of a bachelor in Earth Sciences (Geology, Geophysics, Geochemistry, etc.) level or comparable work experience or education

Content

After an introduction to geothermal systems and their exploration in general, the following topics are addressed during the course:

1. An introduction to magnetotelluric prospecting in geothermal exploration, in this Chapter the electromagnetic and magnetotelluric theory, factors affecting subsurface resistivity as well as the application of magnetotellurics in geothermal exploration are discussed.

2. The magnetotelluric transfer function provides in insight in how the subsurface resistivity structures are recovered from the magnetotelluric signal.
3. Distortion of the magnetotelluric signal. Here, possible factors and their mitigation measures negatively affecting the magnetotelluric signal are discussed.
4. In 'data acquisition' some practical tips and tricks regarding magnetotelluric surveying as well as methods to quality check and assess the recorded data are discussed.
5. The theory of data processing is introduced in the estimation of the magnetotelluric transfer function.
6. In 'inversion and modelling' a short overview of the basic concepts of the process of resistivity inversion modelling is given.
7. Geothermal interpretation of resistivity models provides some examples in which the resistivity response of some typical geothermal systems are discussed.

Learning outcomes

Knowledge the student has gathered and can reproduce by the end of this course comprises:

- magnetotelluric theory;
- properties of the magnetotelluric transfer function;
- causes of distortion of the magnetotelluric signal;
- basic concepts of magnetotelluric data processing and inversion.

By the end of this course, the student comprehends:

- the field procedures to maximize magnetotelluric data quality before and during acquisition;
- basic concept of the tools and techniques available for magnetotelluric data QA and QC

Futhermore, by the end of the course, the student is able to

- assess if a magnetotelluric field survey is properly designed and carried out;
- quality check the delivered magnetotelluric responses;
- run a 1-D and 2-D inversion of a magnetotelluric data set;
- assess the quality of a resistivity model and its geothermal interpretation.

Study load

Study load is defined as the amount of time needed by the student or participant to study the course. This includes all activities: self-study, following lectures, conducting assignments, practicals, field work, etc. Please fill in the following table:

Activity	**Number of hours**
Self-study of the materials and the assignments	8
Lectures	10
Supervised practicals	9
Project based learning	15
Report writing	4
Field work	16
Total	**62**

Course structure

This is a full-time course. In which we will work at least 8 hours. Since fieldwork is included there will be some long days. The 8 hours of self-study is meant for preparation of the course before start.
A typical course schedule is given in the following table.

Day 1	Morning Afternoon	Lectures and assignments on MT theory Lectures and assignments on geothermal exploration with MT
Day 2	Morning Afternoon	Lectures and assignments on magnetotelluric theory MT modelling exercises; lectures and assignments on MT theory
Day 3	Morning Afternoon	Field school Field school and MT data processing
Day 4	Morning Afternoon	Field school Field school and MT data processing
Day 5	Morning Afternoon	Lectures and assignments on MT data processing; MT data processing MT data inversion and modelling
Day 6	Morning	Resistivity model geothermal interpretation; closing

Teaching and learning methods

Activities conducted in the presence of a teacher:
Lecture: 20%
Individual assignments: 15%
Group practical: 20%
Field work: 30%

Individual activities:
Reading study material: 10%
Report writing: 5%

Assessment

Pre-test to test level of understanding of MT of the students before the course starts.
The learning progress of the students during the course is assessed as follows:

- After the lectures assignments are given and directly carried out during a supervised practical. The students are expected to hand in their answers to the exercises before the first lecture of the following day.
- The students are expected to hand in a short report (2-4 pages) at the end of day 5. This report should contain a describing of the survey carried out, including a simple QC, a report on the processing and the results of the inversion.

The quality of the material handed in will be judged by the lecturers and mentioned on the course certificate.

Study materials

- course reader (provided in advance of the course)
- hand outs of lecture power points
- assignments
- MT software

Teaching materials

- Power points
- Course reader
- Software and assignments + marking guidelines
- MT equipment