National Geothermal Academy 2019
Geothermal Geophysics Course Outline

National Geothermal Academy
University of Nevada, Reno

GEOL 457/657 Module 2: Geothermal Geophysics (2 credits)

Dates: June 17-21, 2019

Supported by the:

U.S. DEPARTMENT OF ENERGY

Instructors: Dr. Joe Batir, Prof. David Blackwell, Karen Christopherson, and Dr. Jeff Witter

Location: University of Nevada, Reno

Course summary

This course aims to teach geoscience and engineering students and professionals the fundamentals of geophysical techniques commonly used in geothermal exploration and resource development, specifically thermal geophysics, magnetotellurics (MT), gravity and magnetics. In addition to traditional lectures and group discussions, course participants will complete hands-on exercises throughout the week to consolidate their learning. The course is intended for outstanding undergraduates, graduate students, and professionals with backgrounds in geoscience, math, and/or engineering. All classes will be held at the University of Nevada, Reno's Redfield campus in south Reno. International and USA applicants are welcome.

1. Thermal Geophysics – Dr. Joe Batir and Prof. David Blackwell

Outline:

- Theory of Heat Diffusion
  - Basic derivation of the heat diffusion equation, the basis for Thermal Geophysics
- Basic Geothermal Systems Background
  - Crustal permeability characteristics
  - Types of geothermal resources - each will have a distinct difference in thermal regime and signature
    - Volcanic geothermal resources
      - Magma chamber models
    - Basin and Range geothermal resources
    - Unconventional geothermal resources
  - *Exercise* - Conceptual 2D Thermal Profiles
- Temperature Logging - A method to find and refine the geothermal system conceptual model
  - What is temperature logging
  - What can be seen in a temperature log
    - Thermal gradient, stratigraphy, fluid flow, etc.
  - Different potential errors in temperature logs - and corrections for said errors

        - Drilling disturbance
        - Terrain
        - Fluid flow
    - Different methods to log temperature
        - most common methods
            - 2 m (nominal) holes
            - Thermal Gradient holes (TG wells)
            - Slim holes
            - Production wells
            - Bottom Hole Temperature (BHT)
    - *Exercise* - Analyzing Temperature logs
        - Will include error identification
- Heat flow and subsurface thermal regime mapping - large scale thermal regime mapping to understand tectonics and find geothermal systems
    - How to calculate surface heat flow
        - What exactly are we calculating?
        - Why surface heat flow?
    - Thermal gradient from different temperature sources
    - Measurement of thermal conductivity
    - Radiogenic heat production
    - Mapping of surface heat flow
        - Calculating the potential error in the surface heat flow
    - Calculating subsurface thermal regime (Temperature-at-Depth) from the collected data
    - *Exercise* - Calculating heat flow and subsurface thermal regime

Learning outcomes:

At the end of this module, students will:

- understand how subsurface temperature and heat flow are measured, and how these data can be used to locate and characterize geothermal resources;
- appreciate the difference between convective and conductive temperature profiles in well data, and the implications for permeability and subsurface fluid flow;
- be able to calculate heat flow and geothermal gradients from downhole temperature datasets (logs and/or bottom hole temperatures) and be aware of the assumptions made in these calculations;
- understand how subsurface temperature and heat flow data can be used to develop a conceptual reservoir model.

2. Magnetotellurics – Karen Christopherson

Outline:

- History of MT
    - Formulation of the technique
    - First field trials
    - Developments over the past few decades

- Theory
    - Maxwell's Equations
    - Tensor components
    - Various computed parameters
- Source Fields
    - High frequency
    - Low frequency
- Acquisition
    - Equipment
    - Noise sources
    - Good field practices
    - QC of field acquisition
    - Planning of surveys
- Processing
    - Standard
    - Robust schemes
    - Decomposition techniques
- Interpretation
    - Review of data parameters (dimensionality, strike, good vs. bad data, cultural noise)
    - Selection of TE/TM modes
    - 1D forward and inverse modeling
    - 2D forward and inverse modeling
    - 3D inversion
- Applications and Case Histories

Learning outcomes:

At the end of this module, students will be able to:

- understand the basic physics involved in MT;
- know what the two key MT source fields are, and their behavior;
- define the basics of MT acquisition – what fields are acquired, how and why;
- realize the various ways to process MT data ;
- describe how the numerous MT parameters are utilized in MT interpretation ;
- distinguish between 1D, 2D, and 3D interpretation methods, and
- understand the steps and needs for completing a good MT field acquisition program and interpretation.

3. Gravity and Magnetics - Dr. Jeff Witter

Outline:

- What is gravity and magnetic surveying?
    - How is it useful for geothermal exploration?
- How is a gravity/magnetic survey done?
    - Ground vs. airborne
    - Instrumentation
    - Survey design – grid vs. lines, spacing? (*hands-on exercise*)

- Importance of physical rock properties
    - Density and magnetic susceptibility
    - How do you measure rock properties (hand samples vs. downhole logs?)
- What are the units of measurement?
    - Gravity (mGal) and magnetic (nT)
    - Density (g/cm^3) and magnetic susceptibility (SI)
- Gravity and magnetic data processing
    - Data reduction, QC, detection limits, errors
    - Gridding the data
- Interpretation in map form (*hands-on exercise*)
    - Gravity and magnetic plan maps (e.g. CBA, RTP)
    - Derivative maps (filtering, upward continuation, etc.)
    - The power of the color ramp…
    - The challenge of magnetic remanence
- Advanced Interpretation in 2D & 3D (*hands-on exercise*)
    - 2D profile gravity/magnetic forward modelling
    - 3D gravity/magnetic forward and inverse modelling
    - Non-uniqueness
    - Visualization and interpretation of 2D and 3D gravity/magnetic models

Learning outcomes:

At the end of this module, students will:

- understand the value and limitations of using gravity and magnetics for geothermal exploration;
- design a cost-effective, ground-based or airborne gravity/magnetic survey over a geothermal project area;
- gain an appreciation for processing, data reduction, QC, and gridding of gravity and magnetic data;
- confidently interpret the geological significance of major features on gravity and magnetic maps;
- understand the importance of rock properties in the interpretation of gravity and magnetic data;
- understand how 2D & 3D modelling and interpretation of gravity and magnetic data can be used to build geologic understanding;
- appreciate the differences between visualization, interpretation, and quantitative modelling of geoscience data, and
- know what software tools are available for gravity/magnetic data processing, modelling, & interpretation.