GEOL492.6: Geological Sciences Research

School year 2025/2026, Terms 1 and 2

Advanced analysis of geophysical field school data

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Problem

The goal of this course will be to analyse geophysical data acquired during geophysical field schools in 2025. This study will provide the student with opportunities to learn practical geophysical data processing and also to investigate two novel and advanced subjects. This course also will replace the data-analysis sections of the geophysical field class GEOL485.6 (no longer offered) and thereby fulfill requirements for professional engineering and geoscience registration (APEGS).

Of the nearly 20 datasets acquired during the Geological-Sciences and Engineering field schools in 2025, the student will look into two key datasets:

1) Seismic refraction datasets acquired at the UofS geophysical test site and near Petursson's Ravine in Saskatoon.
2) 3-D resistivity and induced polarization (IP) dataset acquired by DIAS at the geophysical test site during the field school in May.

Methods

General methods for data analysis of the above data were introduced in last year's course GEOL334 and continued in GEOL480 this year. These methods consist in transforming the recorded data files in various ways, performing inversion using commercial and free software, plotting the results and performing interpretation. In addition to these methods, the student will try out new ideas which have not been used for such data before. These ideas are summarized in the following subsections.

Resistivity dataset

For the 3-D resistivity dataset, the student will critically examine the assumption that the in a vicinity of a current injection point, the electric potential depends only on the distance $r = \sqrt{x^2 + y^2}$ as

$$\phi(x,y) = \frac{q}{2\pi r}, \tag{1}$$

where q is the charge induced by the source at the injection point. This relation is at the core of all existing resistivity and IP imaging and inversion methods. In particular, eq. (1) is used for defining the standard geometrical factors for the various types of electrode arrays used in resistivity/IP imaging.

In this study, the student will test relation (1) using DIAS DC resistivity dataset. Preliminary, as shown in GEOL487 data summaries, relation (1) is insufficient, and a two-parameter relation is needed. The student will try two alternative models for $\varphi(x,y)$:

$$\phi(x,y) = q\left(\phi_0 + \frac{1}{2\pi r}\right), \tag{2a}$$

and

$$\phi(x,y) = \frac{q}{2\pi r^{\nu}}, \tag{2b}$$

where ϕ_0 and ν are the new parameters (static induced potential per unit charge or geometrical spreading, respectively). In addition, both models (2a) and (2b) can be azimuthally-dependent, which can be caused by surface topography.

Equations (2a) and (2b) will be first tested for selected current source points within the dataset. If these results are deemed satisfactory and significant, we will attempt inverting for parameters ϕ_0 and/or ν for the entire dataset. This inversion would be analogous to "time field" inversion of refraction seismic data described in the next section. With time permitting and sufficient interest, the results of eqs. (2a) amd (2b) can be extended to IP data from the same DIAS dataset.

Seismic dataset

For seismic part of this project, the student will analyze the refraction profile we acquired on August 25 for the UofS Engineering field school near Petursson's ravine in NE Saskatoon. These data appear to be better than the refraction line the Geophysics field school data in May because they were acquired at quieter conditions. The expected near-surface structure consists of about 1-m layer of silt (presumably lower-velocity) underlain by glacial till and further by sand. At depths of 5-10 m within the sand, there should be a significant increase of seismic velocities due to an increase of water saturation (water table). The goals of refraction data analysis will be to constrain the depths and lateral variations of the silt-till-sand contacts and of the water table.

The data analysis will be started by conventional methods and extended with a relatively new method based on the concept of "travel-time fields" (Jhajhria and Morozov, 2013). The procedure will be as follows:

1) Stacking repeated shot records in order to increase the signal to nose ratio;
2) Identifying first and secondary arrivals in the records; identifying the direct waves and refractions;
3) Interactive picking of first-break travel times, possibly assisted by algorithms;
4) Spatial interpolation of first-arrival travel times to for a continuous "travel-time field" (TTF) surface in the (*midpoint-location*, s*ource-receiver-offset*) domain.
5) Using the TTF surface, derive common midpoint (CMP) travel-time curves at each midpoint location;
6) Using the CMP travel times, measure velocities of the subsurface layers and invert for their depths at different CMP locations.
7) Create plots of the travel-time picks, TTFs, and resulting cross-sections and variations of velocities.
8) Correlate results with images obtained by multinode resistivity imaging along the same line

Tools

Matlab/Octave programs implementing the above data analysis were created by I. Morozov during the M.Sc. study by M. Lepitzki (2022) and for the analysis of 2025 field school data. In this project, the student will revise and test these programs with the help of the supervisor.

Other commercial and academic software available in geophysics labs may also be used in this project: ProMAX and Vista (seismic displays, filtering, and arrival picking), GeoTomo (seismic arrival picking, near-surface modelling and inversion), Res2DInv (resistivity modelling and inversion).

Expected course outcomes

At the end of this class (May 2026), the student will:

1) Prepare an about 20-25 page research paper summarizing the results of both parts of this project.
2) Make a presentation to GEOL492.

The results from both research topics above could potentially lead to research papers in major international journals.

Work plan

In Term 1, we will work on the resistivity dataset, and in Term 2 – on the seismic dataset and final report.

It is expected that the student will work with the data and computer codes in close collaboration with the supervisor. We will conduct weekly meetings to discuss progress and review results.

Most data processing and numerical modelling will be conducted by using Octave software on Linux computer ‘neva’ in Rm. 111. Octave can be installed for free on any computer, and all data can be provided on an external USB drive, and therefore the work can also be conducted elsewhere.

Grading

Paper:	60%
Oral presentation:	25%
Computer scripts, plots, and test examples in electronic formats:	15%

References and recommended reading

Jhajhria, A., Morozov, I. B. (2013), Refraction-static analysis in 3-D by using time fields, Can. J. Expl. Geoph., 38, 12-21

Morozov, I. (2025), GEOL487 course materials on UofS Canvas

Reynolds, J. M. (2011) An Introduction to Applied and Environmental Geophysics, 2-nd ed, John Willey & Sons

Additional reading will likely be required in the course of the work.