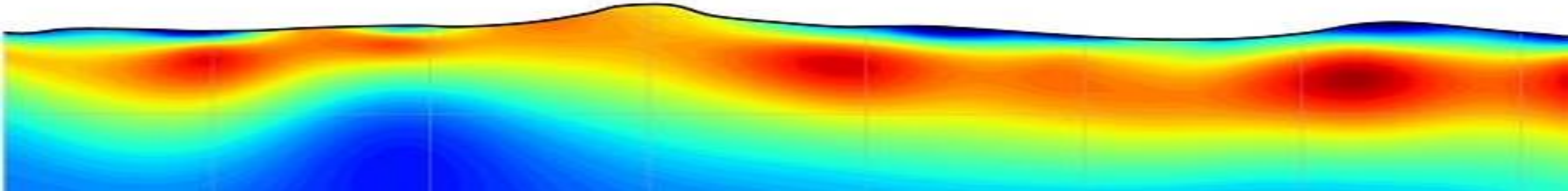
ESS302 Applied Geophysics II

Gravity, Magnetic, Electrical, Electromagnetic and Well Logging

Introduction

Instructor: Dikun Yang

Feb – May, 2019



Syllabus

- Instructor: Dikun Yang
  - PhD in geophysics, University of British Columbia, 2014
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  - Phone: 88018695
  - Email: yangdk@sustc.edu.cn
  - Web: sustech-gem.cn
  - Office hour: By appointment
  - TA: Yinchu Li (11849188@mail.sustc.edu.cn)

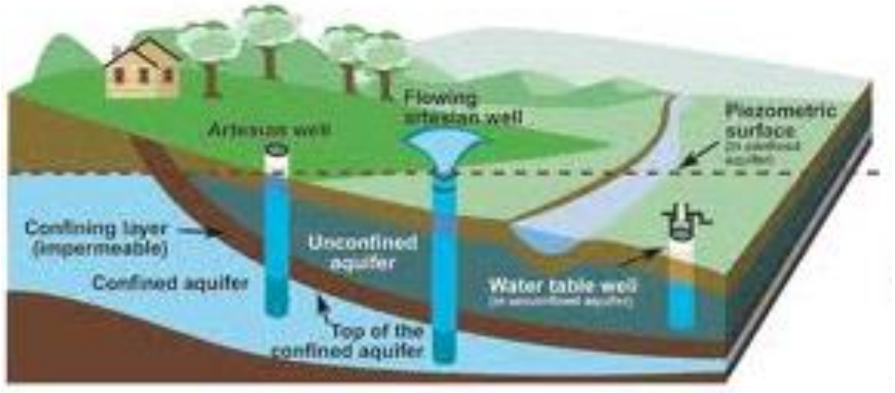
First some problems of relevance

Finding resources

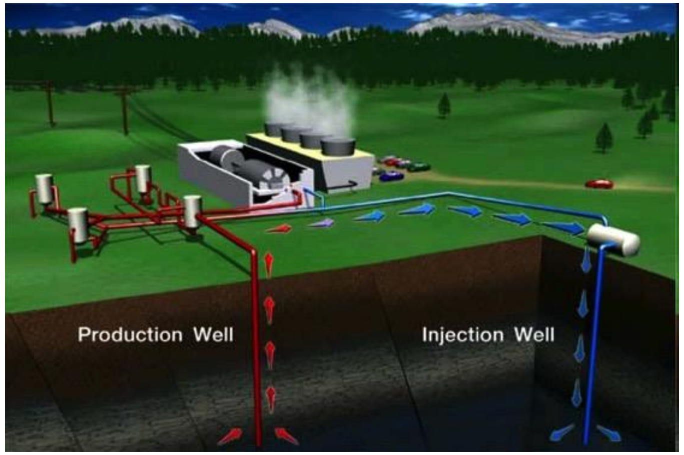
Minerals

Oil and gas

Groundwater



Geothermal

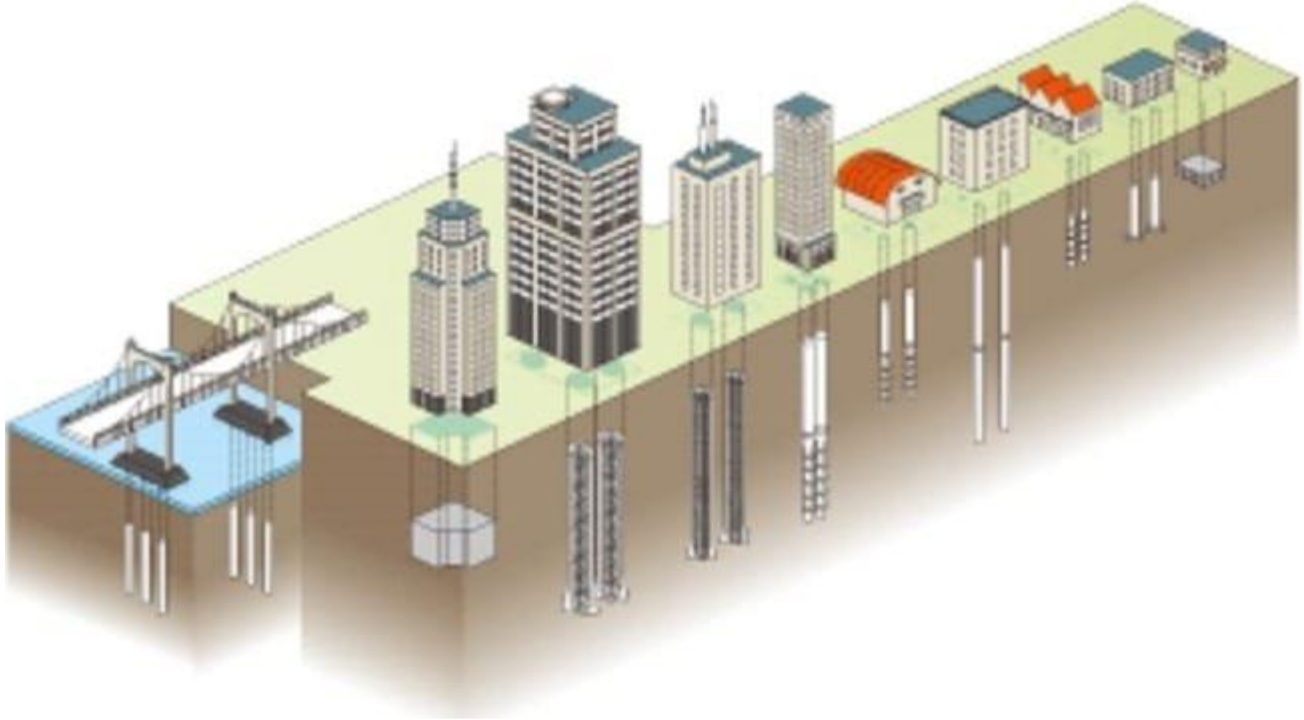


Natural Hazards

Landslide

Earthquakes

Geotechnical engineering



Foundation

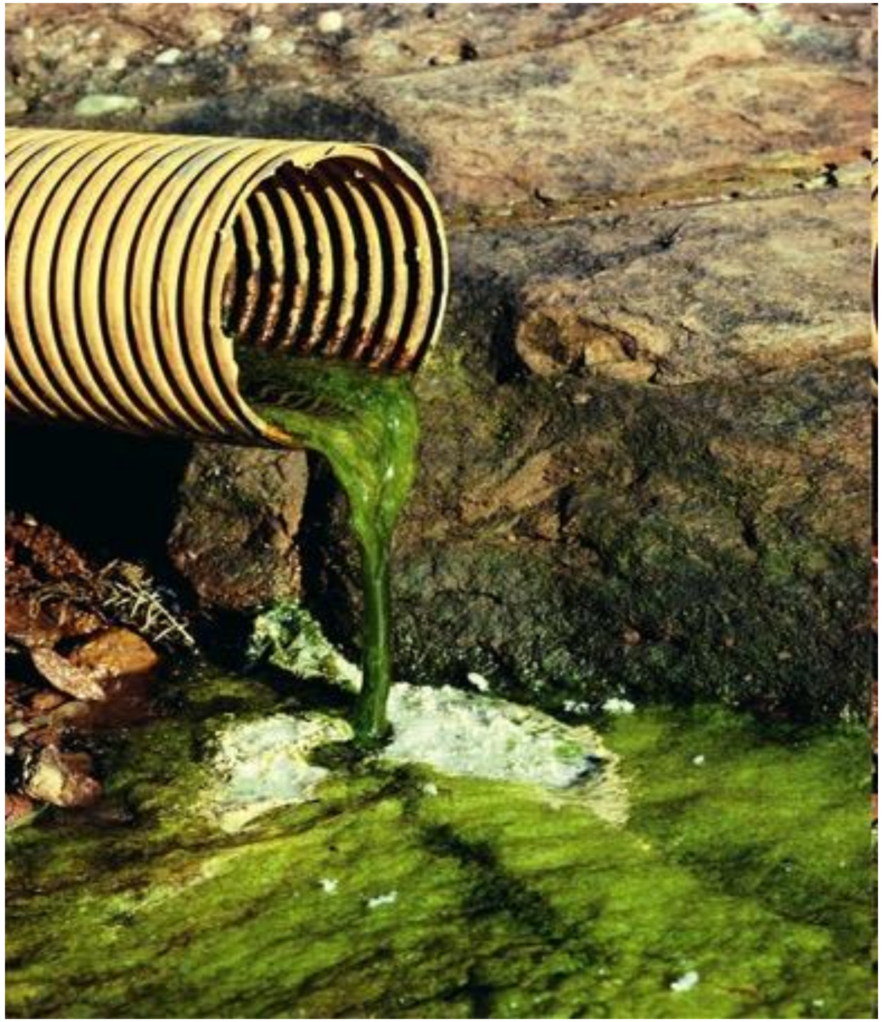
Tunneling

In-mine safety

Environmental

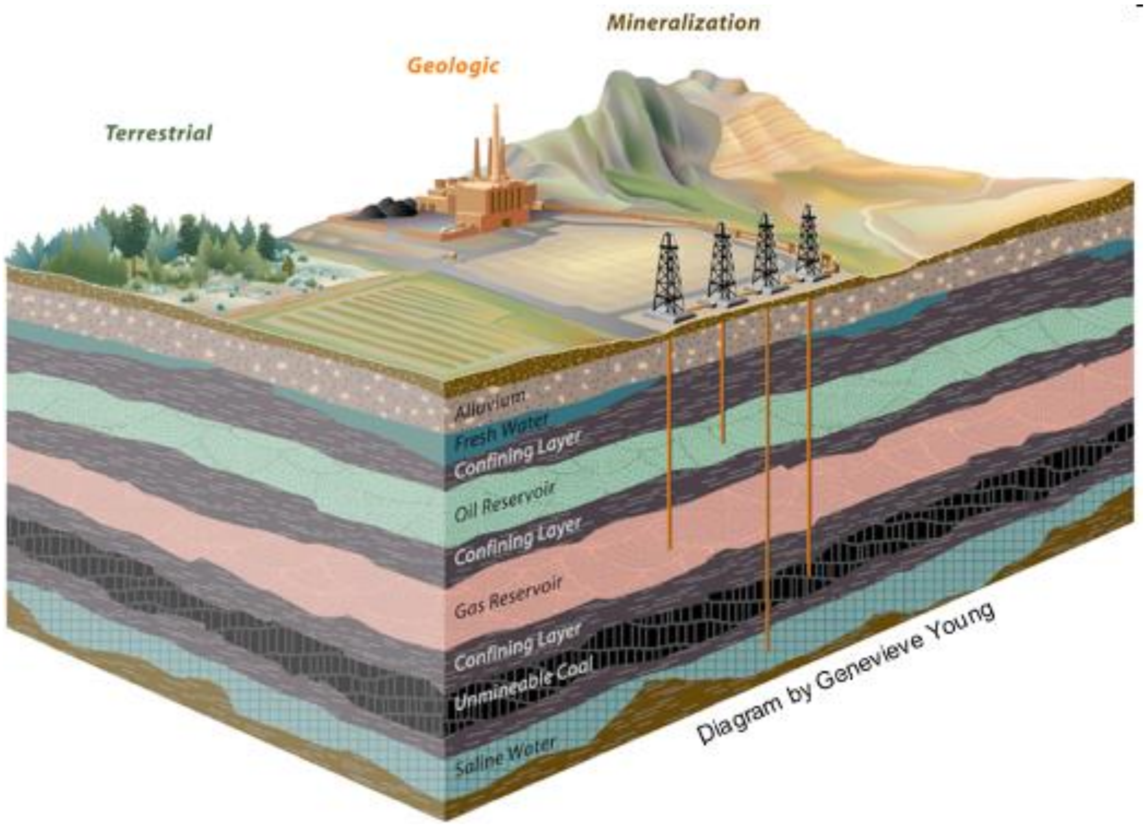
Unexploded ordnance (UXO)

Water contamination



Surface and underground storage

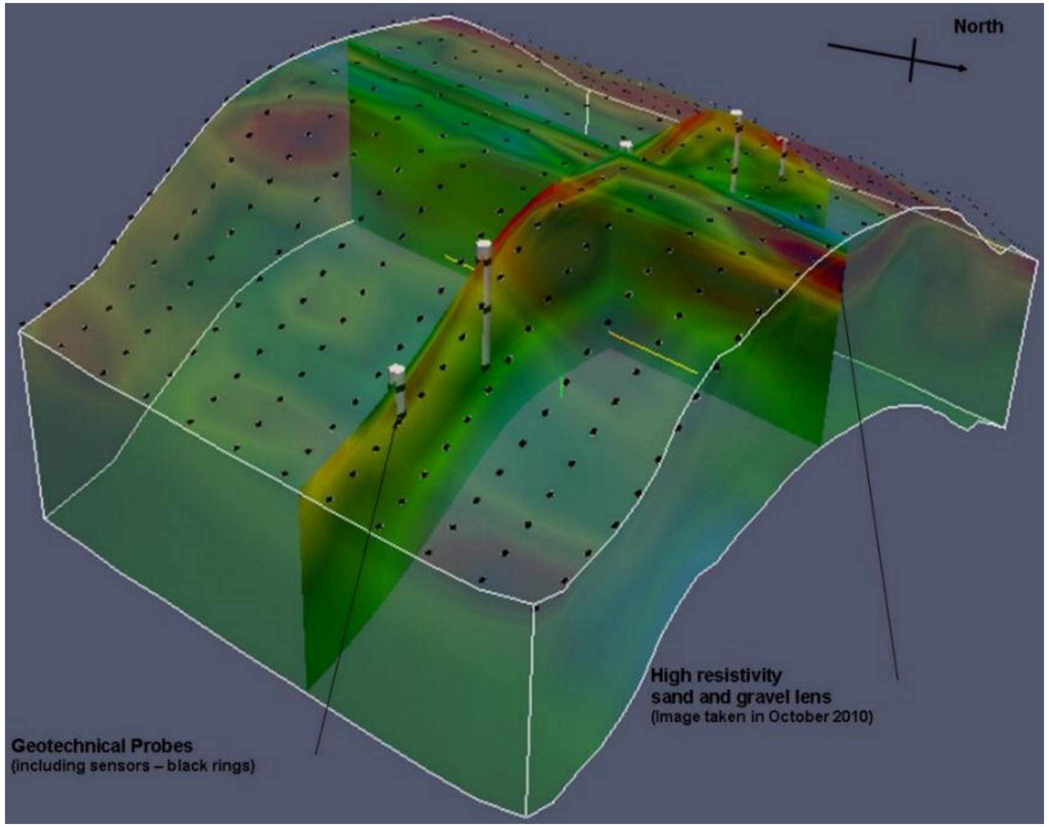
CO_2 sequestration



Underground fuel or water tank

What do these problems have in common?

- They all require ways to see into the earth without digging
- Geophysics is the only discipline that is devoted to this goal.



Syllabus

- Course description
  - Applied geophysics: Physical methods to characterize the subsurface
  - Applications: Finding objects buried underground/undersea for the purpose of resource exploration, environmental protection and engineering
  - Audience: Undergraduate students in geophysics
  - No equation derivations but how geophysics acts as a powerful tool in solving practical geoscientific problems.
  - Prepare students for either a professional career or further study in earth science.
  - ESS302: Non-seismic components of applied geophysics

Syllabus

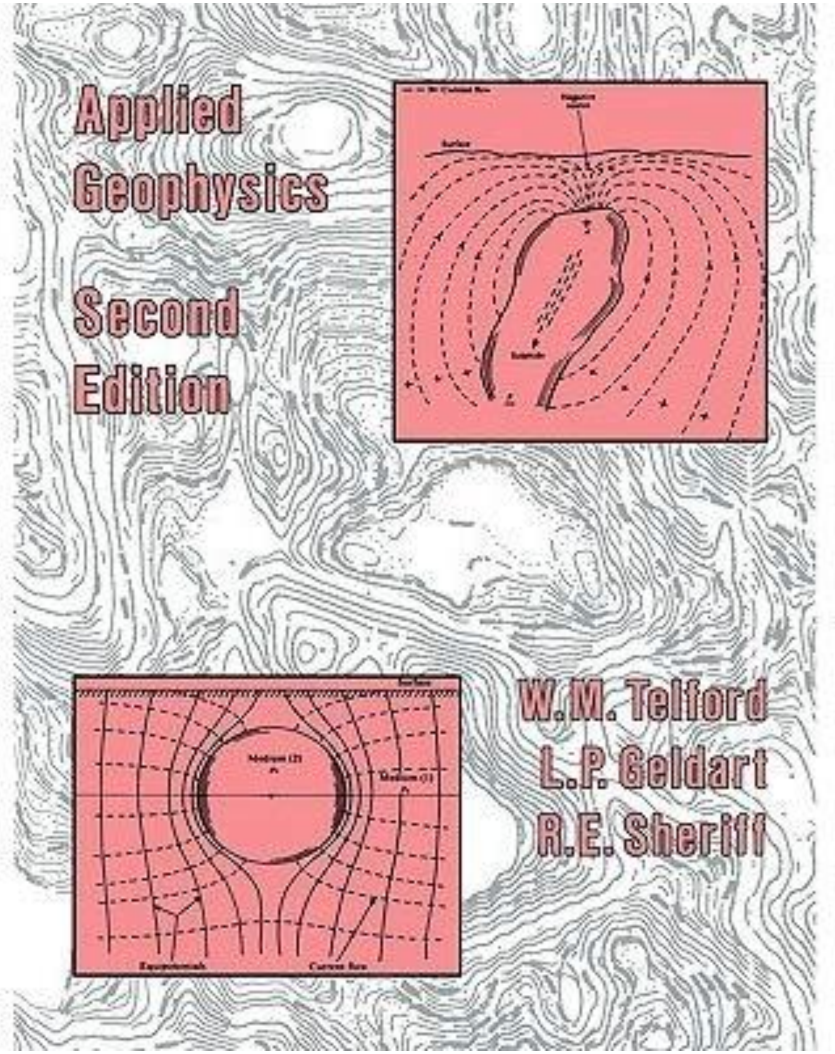
- Course Goals
  - Learn knowledge of geophysical exploration methods
  - Understand the earth in its physical properties
  - Make connections between equations and geoscientific problems
  - Being able to work with measured geophysical data
  - Being able to apply geophysical techniques in future work
  - Skill of acquiring new knowledge and critical thinking
  - Have fun with geophysics!

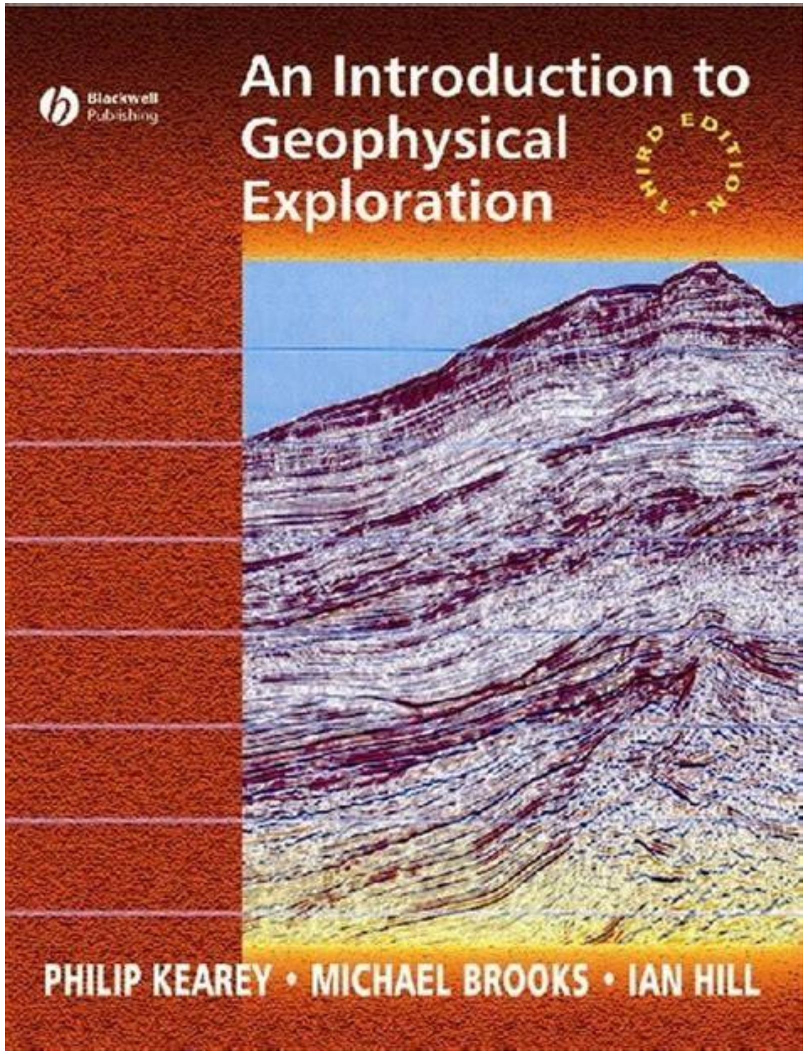
Syllabus

- Schedule and modules
  - Introduction: 2 hours
  - Gravity: 6 hours
  - Magnetics: 6 hours
  - Electrical: 6 hours
  - Electromagnetics (induction): 6 hours
  - Mid-term: 2 hours (April 19)
  - Electromagnetics (geo-radar): 4 hours
  - Well logging: 6 hours
  - Geophysical inversion: 4 hours
  - Integrated methods: 4 hours

Syllabus

- Resources
  - Textbooks





(Available in my office)

Syllabus

- Resources
  - Textbooks
  - eBooks, websites

GPG
0.0.1

Search docs

- Foundations
- Physical Properties
- Magnetics
- Seismic
- Ground Penetrating Radar
- Electromagnetic Methods
- DC Resistivity
- Induced Polarization
- Gravity
- Apps
- Lectures

Docs » Geophysics for Practicing Geoscientists

Edit on GitHub

Geophysics for Practicing Geoscientists

The GPG is a learning resource for applied geophysics and its applications to help solve problems of relevance to society including those in resource exploration, environmental applications, and geotechnical projects. Geophysical surveys and data are sensitive to physical property variations in the subsurface. These variations can be diagnostic for finding resources, tracking contamination or mapping geologic units. Application of a geophysical technique to help answer a geoscientific question requires that targeted physical properties be identified and appropriate geophysical surveys, processing and interpretation be carried out. The application of geophysics is consolidated into a Seven Step procedure that serves as a guiding template in every problem. In the GPG we discuss the physical principles for each type of survey and carry through with applications. The focus is on environmental, resource exploration and geotechnical problems but the concepts span a broad range of applications. The GPG is meant to be a resource for geoscientists, including those who are not specialists in geophysics, in particular geological engineers, geologists, and undergraduate geophysicists. The GPG is light on mathematical development but links to deeper levels of analysis are provided.

To ease readers' understanding in applied geophysics and its applocations, materials in GPG are integrated with the Jupyter apps. We strongly promote readers to use both text materials in GPG and apps together. By clicking below **binder** badge will show you list of the apps, and there you can run the app.

https://gpg.geosci.xyz
https://em.geosci.xyz

Syllabus

- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia

Not logged in Talk Contributions Create account Log in

Article Talk Read Edit View history Search Wikipedia

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
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About Wikipedia
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Recent changes
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Tools

What links here
Related changes
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Gal (unit)

From Wikipedia, the free encyclopedia

Not to be confused with gallon.

The **gal** (symbol: Gal), sometimes called **galileo** after Galileo Galilei, is a unit of acceleration used extensively in the science of gravimetry.[2][3][4] The gal is defined as 1 centimeter per second squared (1 cm/s^2). The **milligal** (mGal) and **microgal** (μGal) refer respectively to one thousandth and one millionth of a gal.

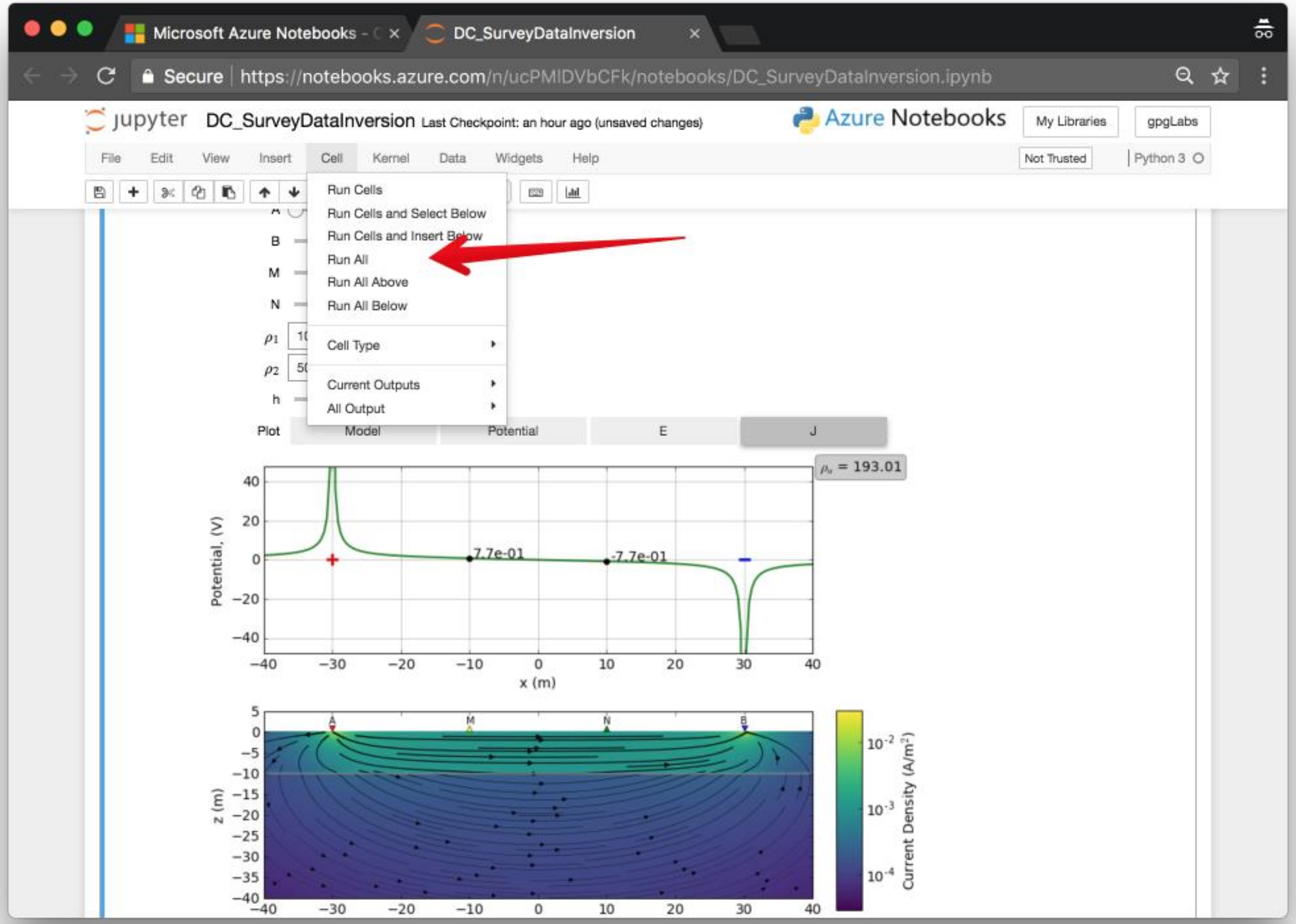
The gal is not part of the International System of Units (known by its French-language initials "SI"). In 1978 the CIPM decided that it was permissible to use the gal "with the SI until the CIPM considers that [its] use is no longer necessary".[3][5] However, use of the gal is deprecated by ISO 80000-3:2006.

The gal is a derived unit, defined in terms of the centimeter–gram–second (CGS) base unit of length,

Earth's gravity measured by NASA GRACE mission, showing deviations from the theoretical gravity of an idealized smooth Earth, the so-called earth ellipsoid. Red shows the areas where gravity is stronger than the smooth, standard value, and blue reveals areas where gravity is weaker. (**Animated version.**)[1]

Syllabus

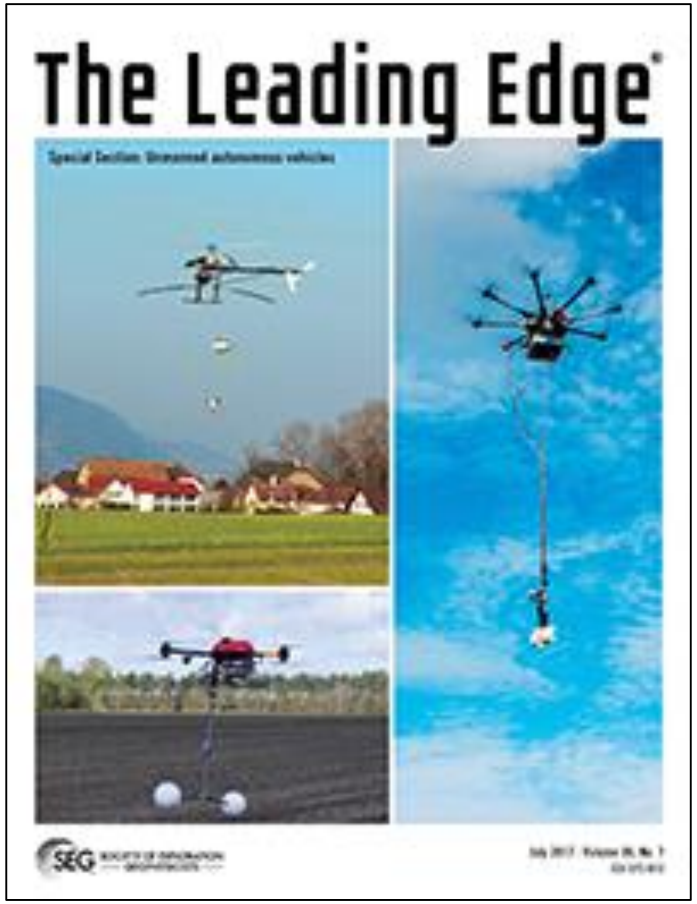
- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia
  - Interactive apps



(Python Jupyter notebooks)

Syllabus

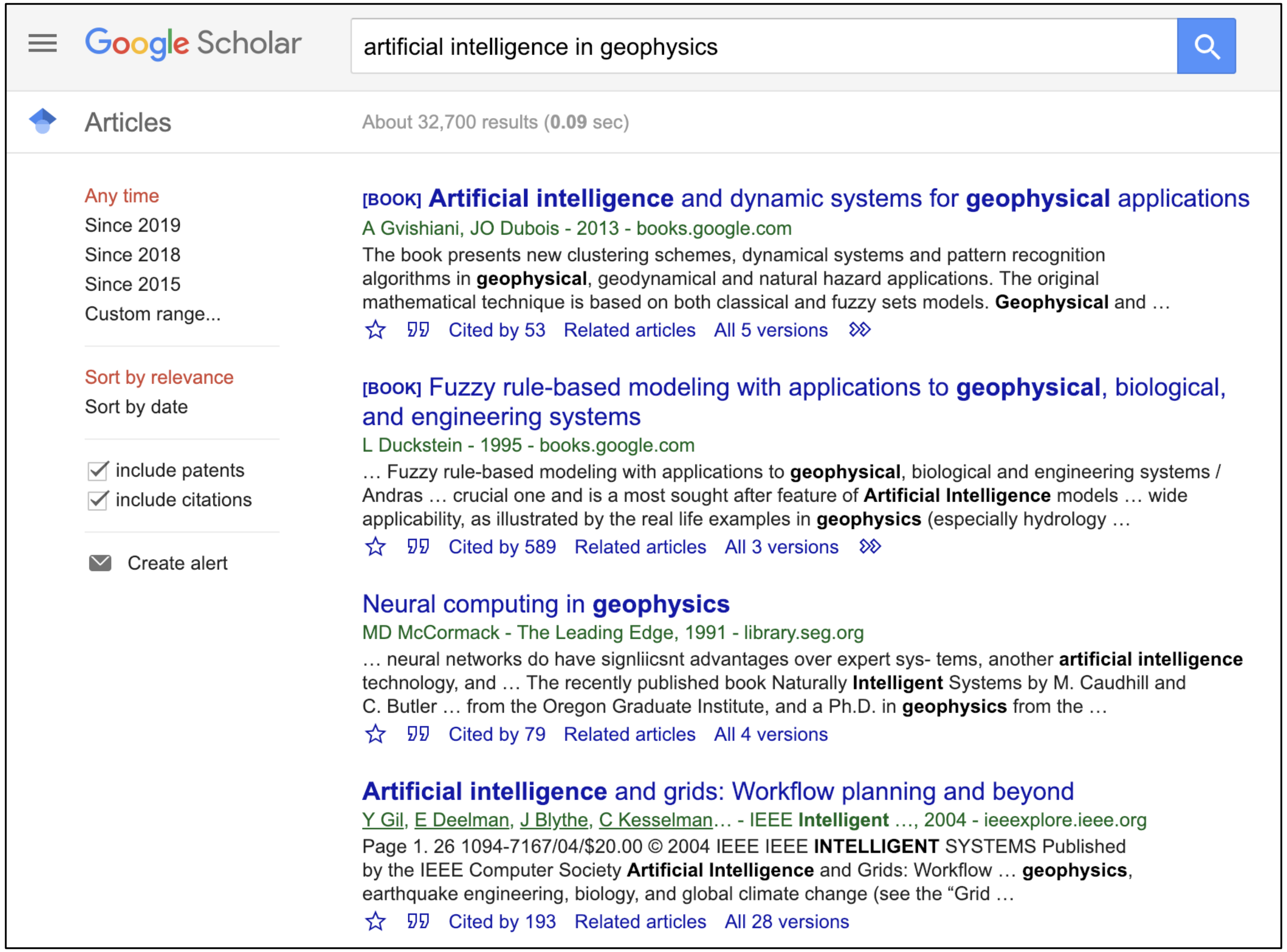
- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia
  - Technical publications



(Available online or in my office)

Syllabus

- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia
  - Technical publications
  - Google scholar



Syllabus

- Grades
  A. Classroom performance: 10%
  B. Assignments: 20%
  C. Mid-term exam: 30%
  D. Final exam: 40%

- Activities within each module
  - Lectures
  - Q&A
  - Discussion
  - Assignments
    - Interactive jupyter notebook apps
    - Light coding

Syllabus

- Term reading project
  - Choose a published technical article
  - Complete a fact sheet before the mid-term
  - Read the article throughout the term
  - Discuss the article with the instructor
  - Present your articles on the last day of class
  - Use the knowledge you learned in the final
  - Details on course website …

Example

Low-cost reservoir tomographs of electrical resistivity

William Daily, Abelardo Ramirez, Robin Newmark, and Kenneth Masica, Lawrence Livermore National Laboratory, Livermore, California, U.S.

The geophysics we describe here will sound different from what you have heard before, because it is different. It uses electric fields instead of seismic waves. It is not designed for exploration. It is a distant cousin of cross borehole seismic tomography, although it is quite different in terms of its application and results. Probably the most curious aspect is that it doesn't chase the holy grail of geophysics—high resolution.

What good could possibly come from a low-resolution, electrical geophysical tool? The answer is found in the paradigm gradually finding favor by oil executives and reservoir engineers: while finding and exploiting large new fields is important for long-term growth, improving recovery efficiency for existing resources also makes sense because developing a new field is increasingly expensive. As a result, secondary recovery methods are receiving increasing attention.

This shift in view requires a parallel shift in geophysics. Now geophysics needs to deliver useful information about field production using low-cost, long-term monitoring techniques that have minimum impact on production operations. Electrical resistance tomography (ERT) is ideally suited to these new goals. ERT is a method for tomographically reconstructing the electrical resistivity distribution in the subsurface using an array of electrodes. Typically, current is driven between two of the electrodes and the resulting voltage distribution is measured on the remaining electrodes. Repeating this with other pairs of current electrodes in the array makes it possible to sample the subsurface electrical properties in a manner that allows calculation of the spatial distribution of those properties. The electrical properties depend strongly on pore fluid content. Consequently, ERT is especially good at giving information on the movements of oil, water, and gas—the principal fluids of interest in a petroleum reservoir.

An important aspect of this method is that the *oil well casings themselves are used as very long electrodes*. Normally, ERT surveys are conducted using a large number of electrodes, each one short compared to the distance separating them. We are advocating just the opposite—that the electrodes, each a steel casing, be very long compared to their separation—and, as we shall see, this strategy produces some interesting benefits. We call this synthesis of ERT and very long electrodes, long electrode electrical resistance tomography or LEERT. Figure 1 shows this simple concept.

What are those benefits of LEERT? First, and probably most important, is the fact that the electrodes are already scattered throughout the reservoir. No new "monitoring" wells are needed. Any well casing can be used as an electrode that reaches to the depth of the formation of interest. This means that the capital cost for doing LEERT is very small. Considering that the cost of a monitoring well can be as high as a million dollars, this advantage can make the difference between a method being practical or impractical and thereby the difference between used or not used.

A second benefit is that the well casing can be used irrespective of what else the well is used for or what it contains. It may be a production well, an injection well, or even a monitoring well and still be used as an LEERT electrode. The only real restrictions are that the casing must be steel (no insulators like fiberglass) and in good electrical contact with the formation. If it is a production well, then production tubing need not be removed from the casing for it to be used as an electrode. Production can continue uninterrupted. This, in fact, can be another significant cost benefit. Similarly, if it is an injection or monitoring well, its original function is unaffected.

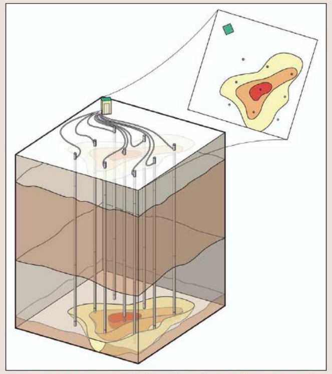


Figure 1. LEERT concept. The long electrodes used for imaging reach into the formation to be imaged.

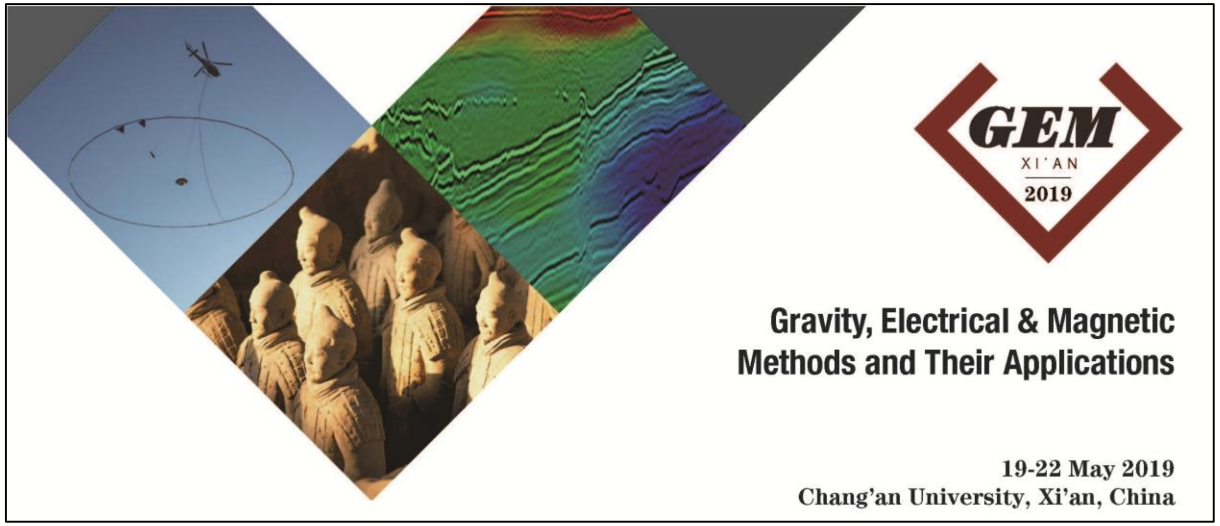
A third benefit is that LEERT requires minimal field personnel to operate, thereby minimizing survey costs. Moving sondes in boreholes for logging or crosshole tomography, or moving sources and receivers on the surface for reflection seismology, are time consuming and expensive operations. The cost of a 3D surface seismic survey can reach $1 million (or more). Conventional borehole geophysics is less expensive but has an upfront cost and a downtime cost—as mentioned above. In contrast, the steel casings used by LEERT are all connected to a central multiplexer and are chosen automatically as a current source or for voltage measurement by an appropriate switching algorithm. It's all done automatically and with no moving parts.

For any monitoring method, the time interval between surveys is generally limited by the survey costs and the reluctance to remove wells from production. In contrast, we will show how LEERT can be used as a truly long-term monitoring tool able to yield nearly continuous imaging, not limited by mobilization costs, survey costs, downtime costs, or demobilization costs. We will show how LEERT can provide on-demand, real-time continuous imaging.

Commonly used borehole techniques tend to have a narrow field of view. For example, borehole logging is focused on a narrow strip around the well bore. Similarly, seismic crosshole tomography is insensitive to all but a narrow region directly between the well bores. In contrast, LEERT is a global tool, meaning that it is sensitive to the 3D volume in which the well casings are embedded and can provide a view of hundreds of acres of producing formation.

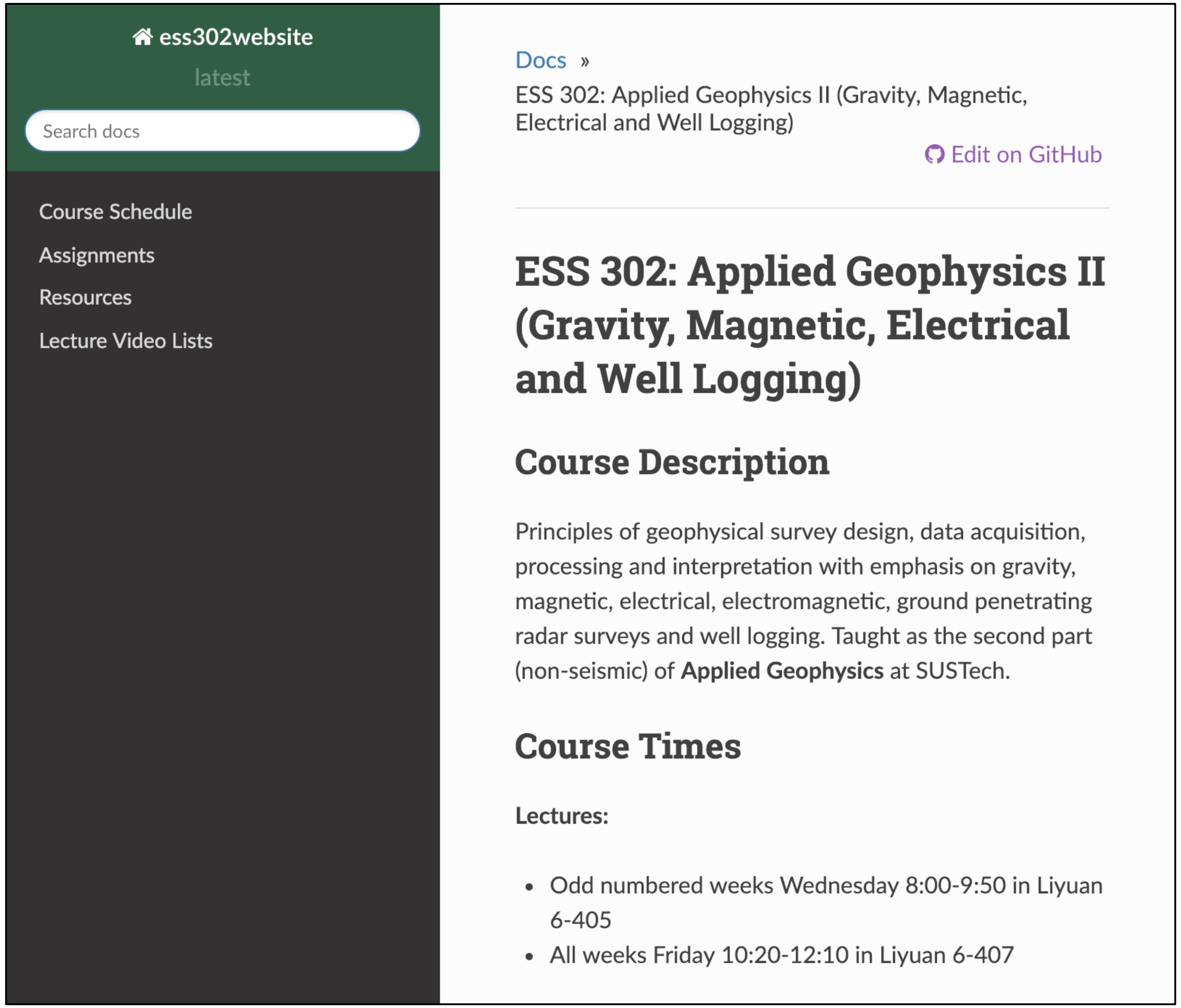
Syllabus

- Course Policies
  - Assignments turned in on time receive a 20% bonus
  - The top-ranked student before the final goes to GEM2019 in Xian



Syllabus

- Communication
  - Course website: primary source of information, including schedule, assignments, lecture slides and links to resources
  - Email
  - WeChat group



https://sustech-ess302.readthedocs.io

https://youtu.be/f1GeNljM0T8