



<http://disc2017.geosci.xyz/denver>



Thanks to...



Yaoguo Li + Volunteers



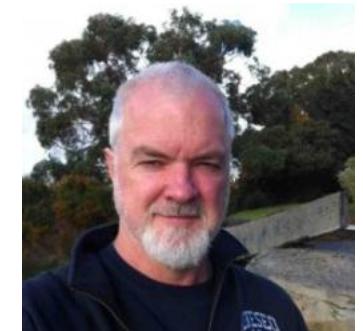
Andrei Swidinsky



Karen Christopherson



Misac Nabighian



Jeff Love

Thanks to...



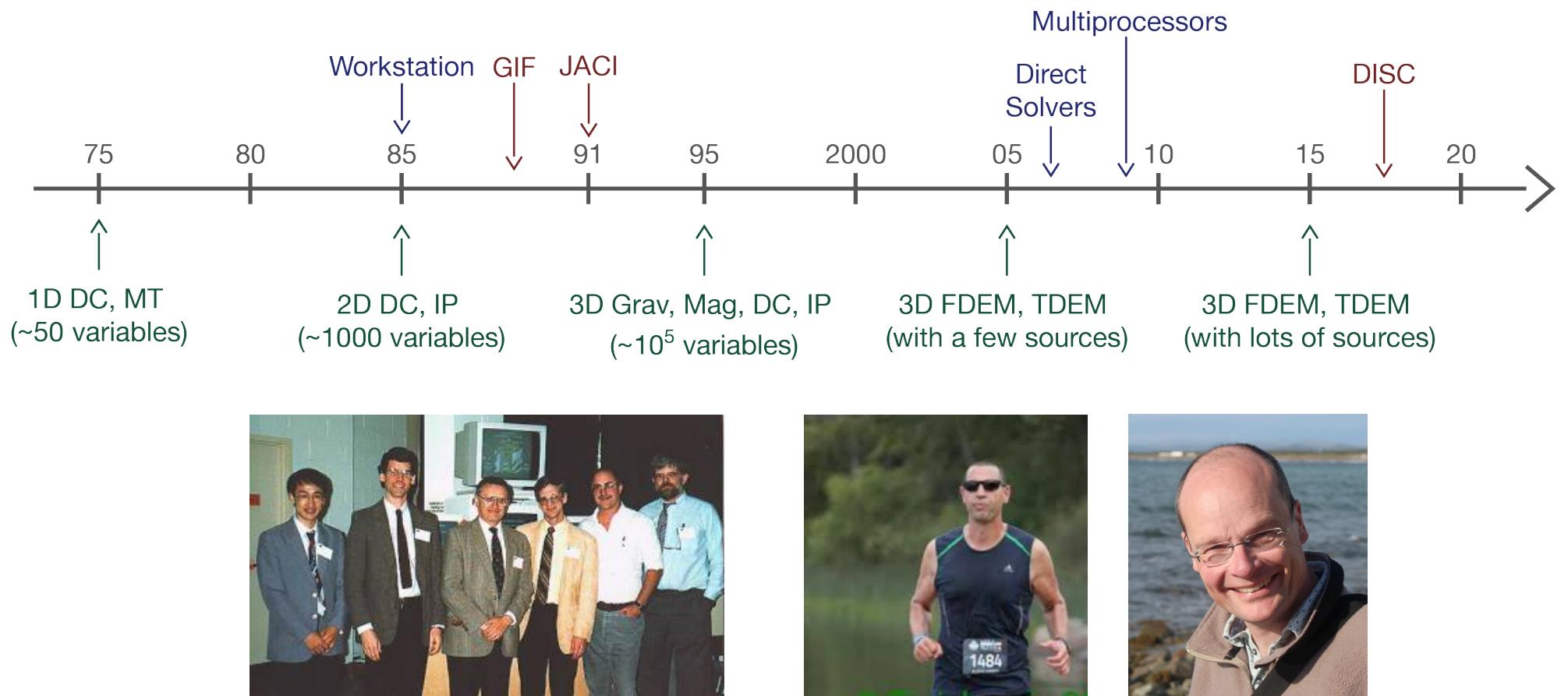
Student sponsorship



DISC Lab & support

Some Background

- Doug inspired by Bob Parker, Freeman Gilbert and George Backus:
The Geophysical Inverse Problem

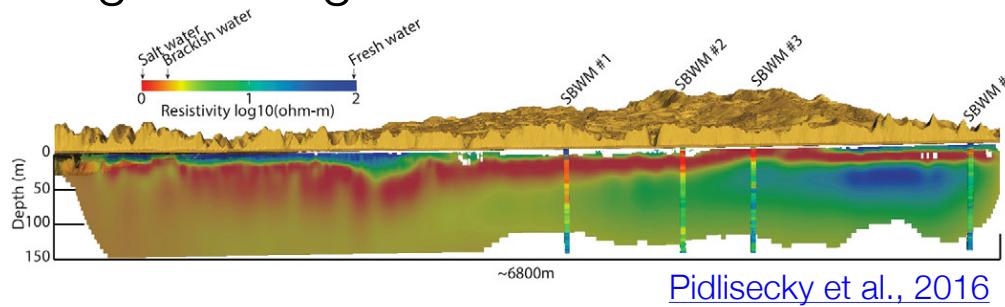


Result: Computing power + advances in inversion methodology
→ we can now solve most EM geophysics problems

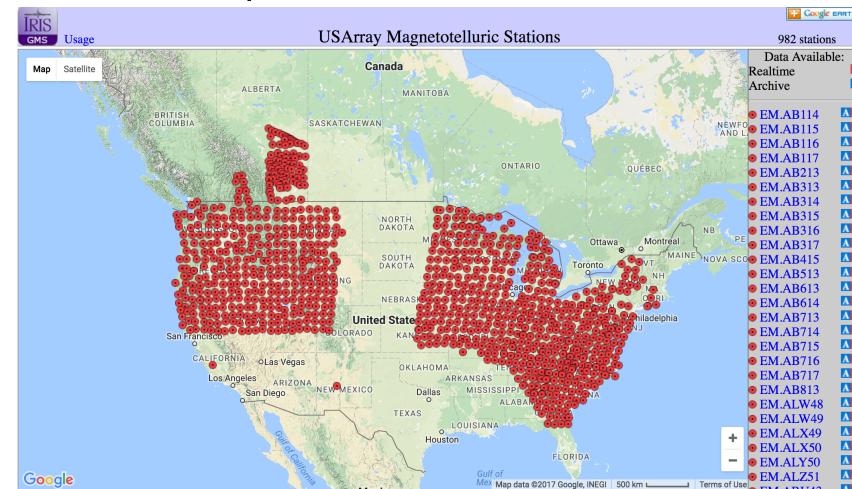
Instrumentation and Data

- The second major advance is in data acquisition
- Data with unprecedented data quality and quantity.

Large-scale ground water studies: California

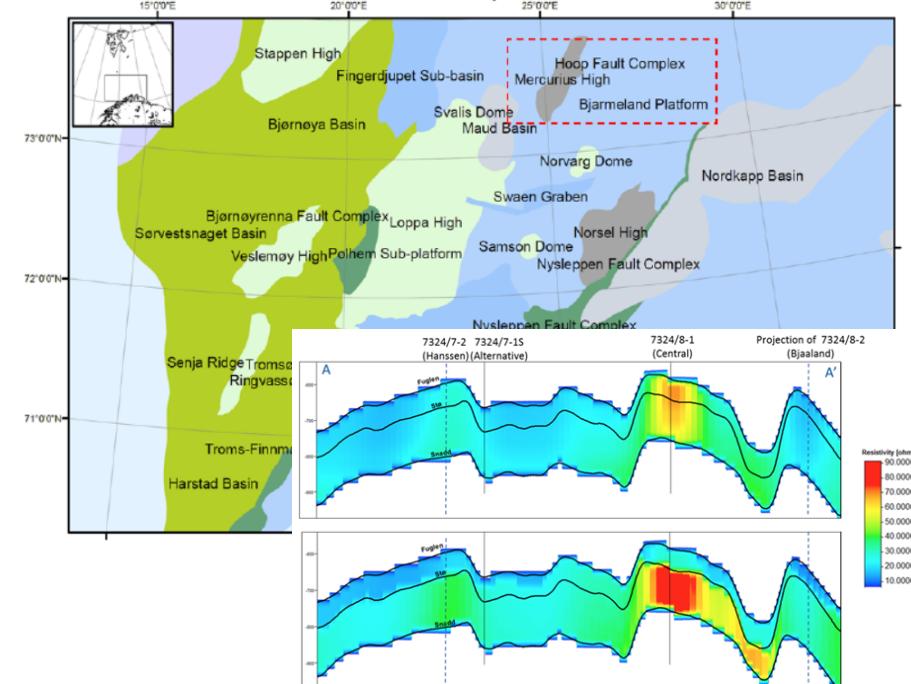


Earth scope: Continental Scale MT



Earth Scope

Offshore: Hydrocarbon De-risking



Alvarez et al, EM.GeoSci

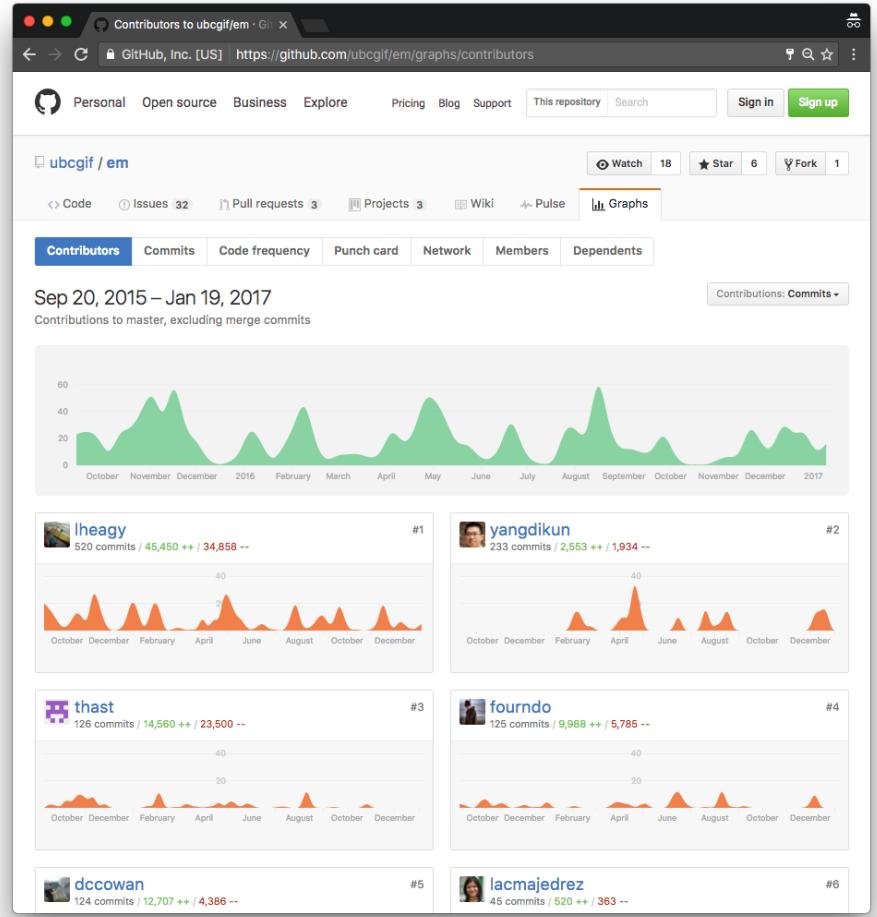
Web and Open Source Resources

- Open source development:
Software and resources
 - Collaborate
 - Share
 - Test changes
 - Interactive computing



Simulation and Parameter Estimation in Geophysics

<http://simpeg.xyz>



GitHub
versioning, collaborating



Travis CI
testing, deploy



Jupyter
interactive computing



Creative Commons
licensing, reuse



Python
computation

Many applications

Electromagnetics can be used for ...



We have the basic ingredients

- Application problems
- High quality data
- Ability to invert EM data sets
- Web tools to communicate

What are the roadblocks?

Roadblocks

In general, geoscientists...

- Don't realize that EM can play a role in solving the problem
- Don't understand the technique
 - Confusing terminology
 - Seems complicated and unintuitive

What is the connection between my problem and the physical properties?

So many types of surveys, how to choose?

- DC, frequency, time?
- Surveys in air on ground, downhole?
- What to expect for resolution?

Are there situations, similar to mine, in which EM has been applied?

Goal of DISC: Remove Roadblocks

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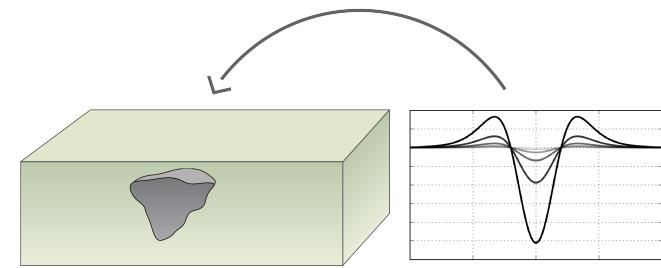
Are there situations, similar to mine, in which EM has been applied?

DISC can take advantage of a Perfect Storm

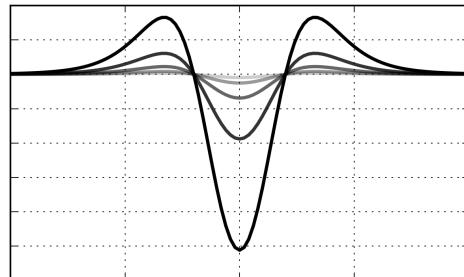
Problems



Inversion capabilities



High quality data

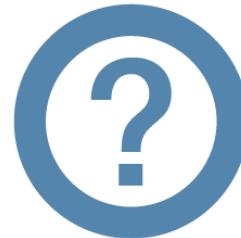


Web tools to communicate

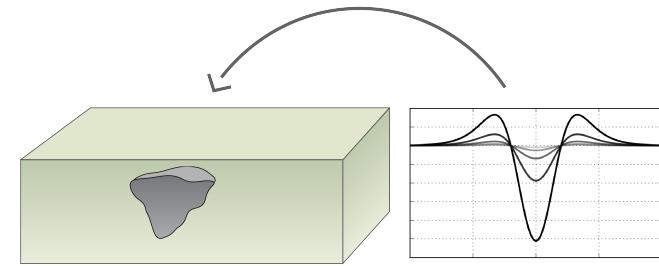


DISC can take advantage of a Perfect Storm

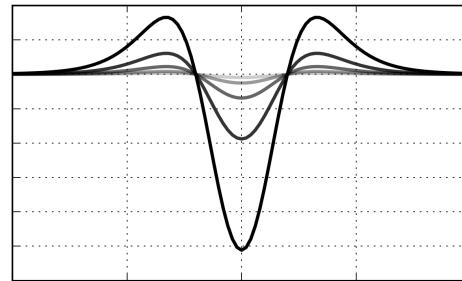
Problems



Inversion capabilities



High quality data



Web tools to communicate



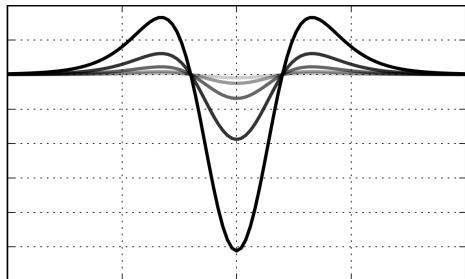
A good idea but missing an important ingredient ...

Talented Young Geoscientists

Problems



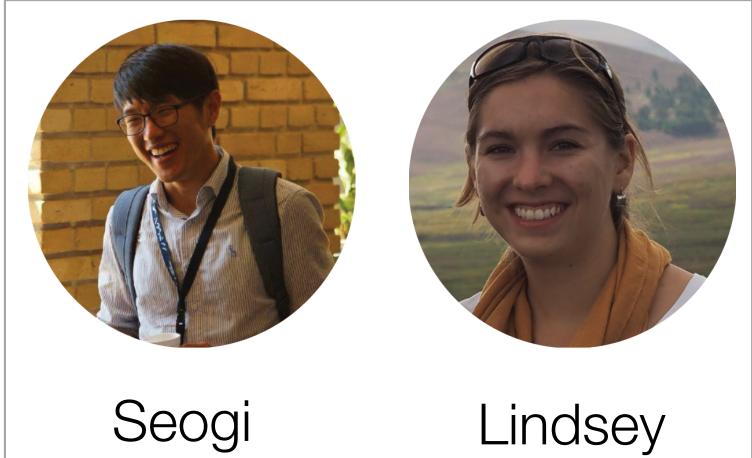
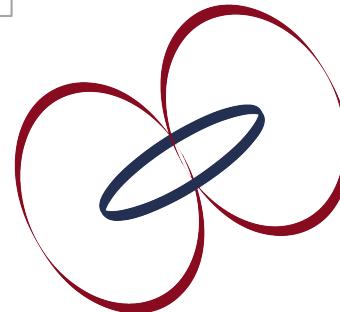
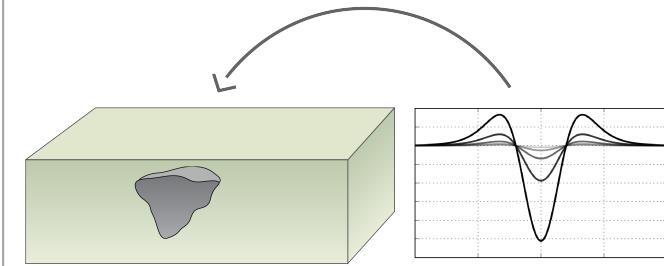
High quality data



Web tools to communicate



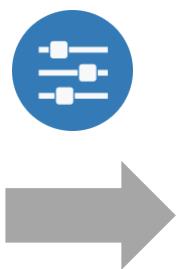
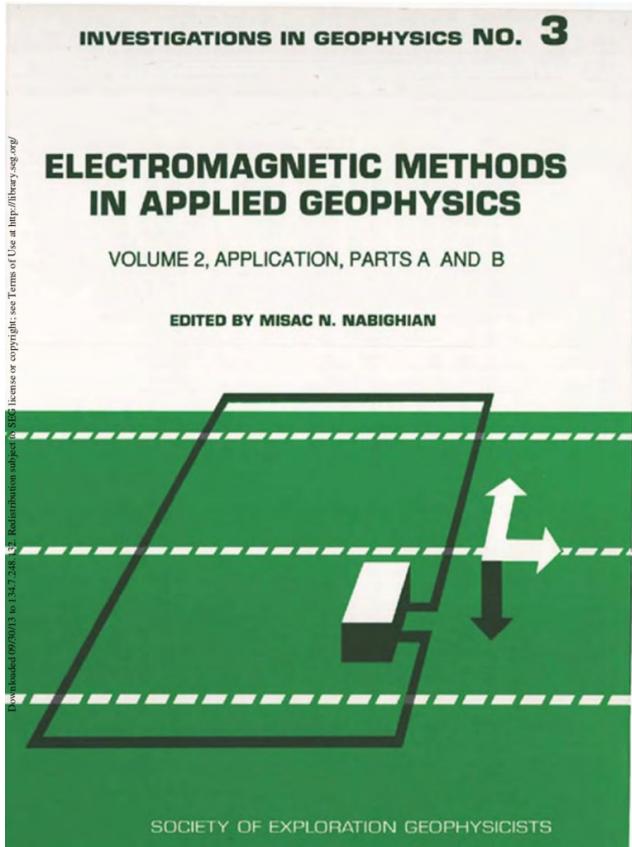
Inversion capabilities



Goals for the DISC

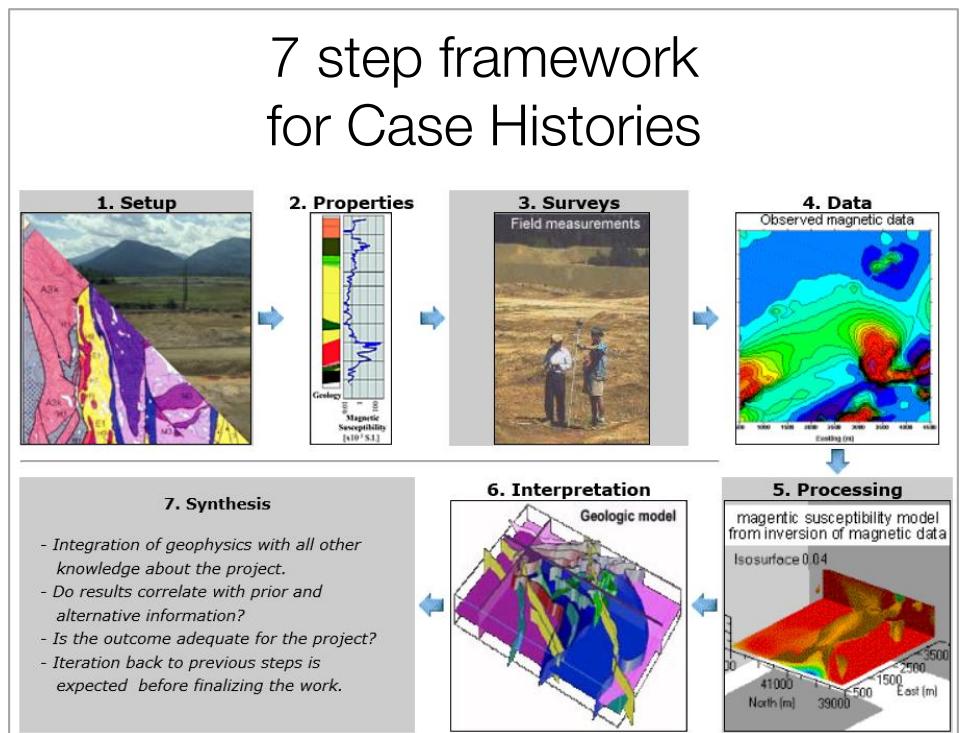
- Inspire
 - See the variety of potential applications
 - Illustrate effectiveness using case histories
- Build a foundation
 - Basic principles of EM
 - Exploration and visualization with interactive apps
 - Open source resource: <http://em.geosci.xyz>
- Set realistic expectations
- Promote development of an EM community
 - Open source software
 - Capturing case histories world-wide

Resources: EM.geosci



<http://em.geosci.xyz>

Resources: EM.geosci



Case Histories

Case histories provide the context for our development of educational and research material presented in em.geosci. Each case history focuses upon a particular problem to be solved and provides the motivation for working with particular surveys and shows the effectiveness of electromagnetics in answering the posed questions. For many people, a case history will be the entry point to this site. To facilitate transfer of knowledge we have developed a common framework (Seven Step Process) in which each case history is presented. Links are provided so that a reader can investigate fundamental aspects of EM, the survey, or interpretation. In some cases we are able to provide data sets and analysis/inversion software to enhance the user experience and to address important issues regarding reproducibility. Case histories for our initial launch of em.geosci are those that have been developed by past and present students at the Geophysical Inversion Facility. The titles, and EM systems used are provided below.

Gallery

Mt. Isa

- Mt. Isa
- Contributors
 - author: Dom Fournier
- Tags
 - geophysical survey: DC, IP
 - application: Mining
 - location: Australia

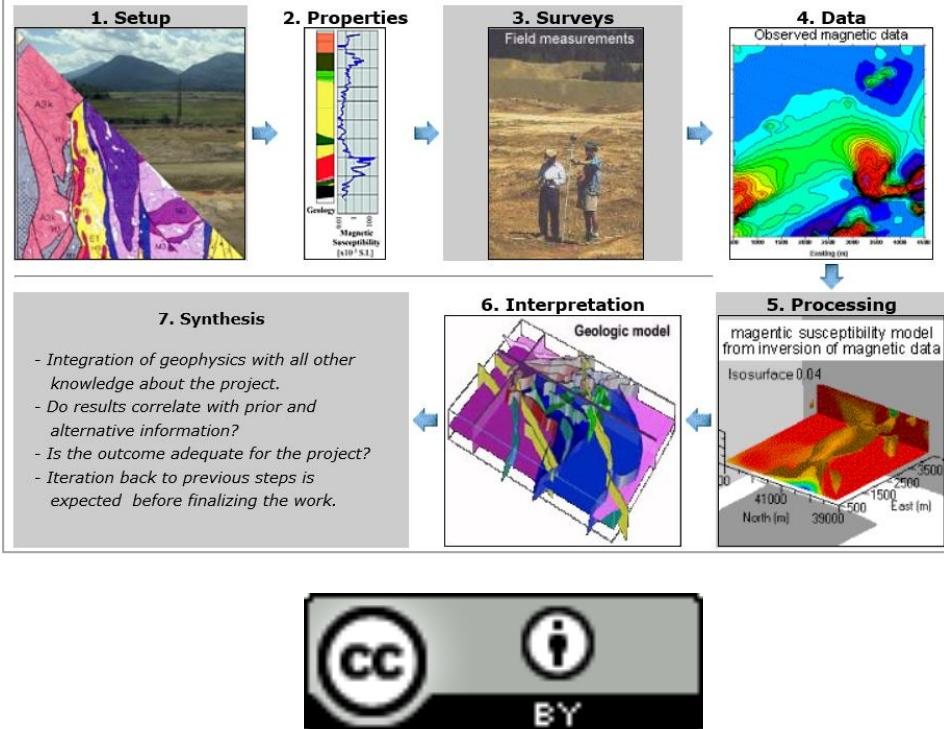
Bookpurnong

- Bookpurnong
- Contributors
 - author: Dikun Yang
- Tags
 - geophysical survey: Airborne FDEM, Airborne TDEM
 - application: Groundwater
 - location: Australia

<http://em.geosci.xyz>

Resources: EM.geosci

7 step framework for Case Histories



Edit on GitHub

Case Histories

Contributors
Introduction
Physical Properties
Maxwell I: Fundamentals
Maxwell II: Static
Maxwell III: FDEM
Maxwell IV: TDEM
Geophysical Surveys
Inversion

Case Histories

- Mt. Isa
- Bookpurnong
- Aspen
- Lalor
- Elevenmile Canyon
- Albany
- West Plains
- Furggwanghorn
- Norsminde
- Barents Sea
- Kasted
- The Balboa ZTEM Cu-Mo-Au porphyry discovery at Cobre Panama

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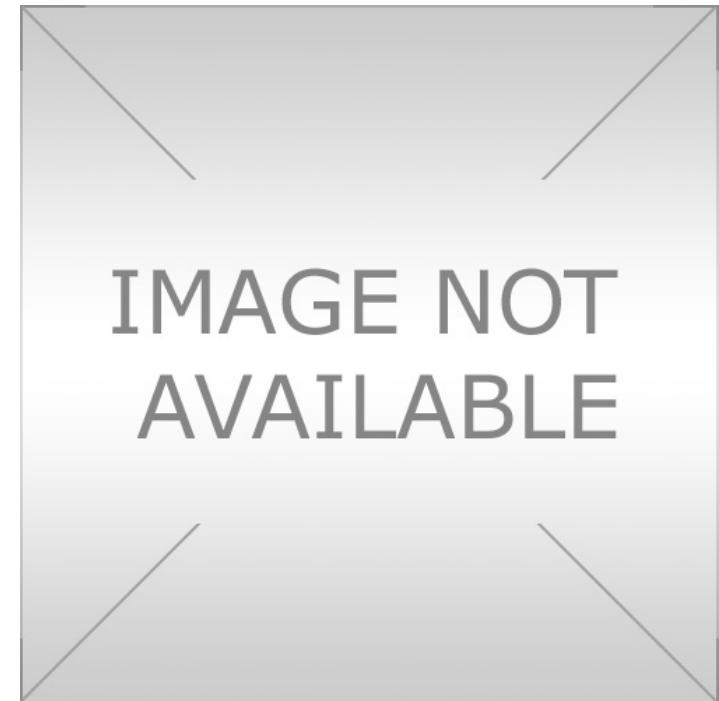
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Why Apps

$$\nabla \times \mathbf{e} = - \frac{\partial \mathbf{b}}{\partial t}$$

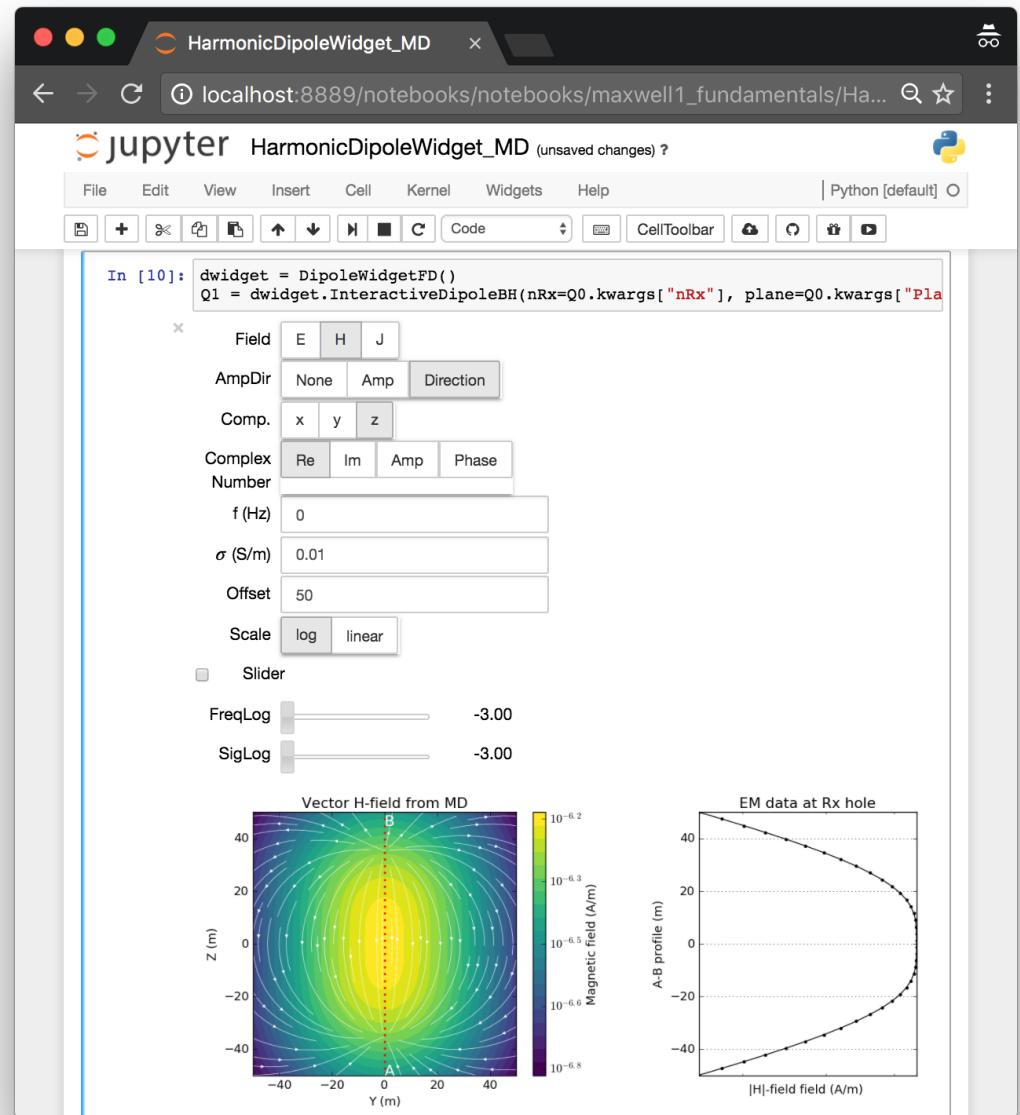
$$\nabla \times \mathbf{h} = \mathbf{j} + \frac{\partial \mathbf{d}}{\partial t}$$



<http://em.geosci.xyz/apps.html>

Why Apps

$$\nabla \times \mathbf{e} = - \frac{\partial \mathbf{b}}{\partial t}$$
$$\nabla \times \mathbf{h} = \mathbf{j} + \frac{\partial \mathbf{d}}{\partial t}$$



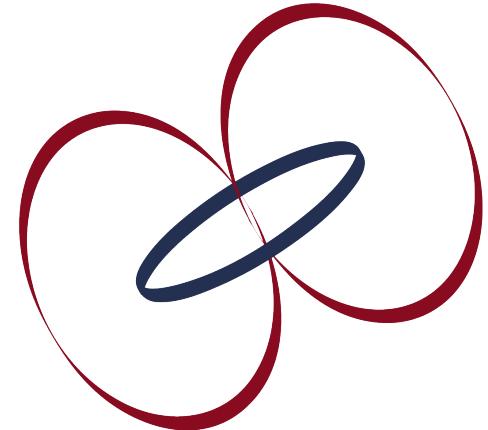
<http://em.geosci.xyz/apps.html>

How do we achieve our goals

- Connect to relevant applications
- Select a type of survey
- Use apps to explore and ask questions
- Show success in a case history

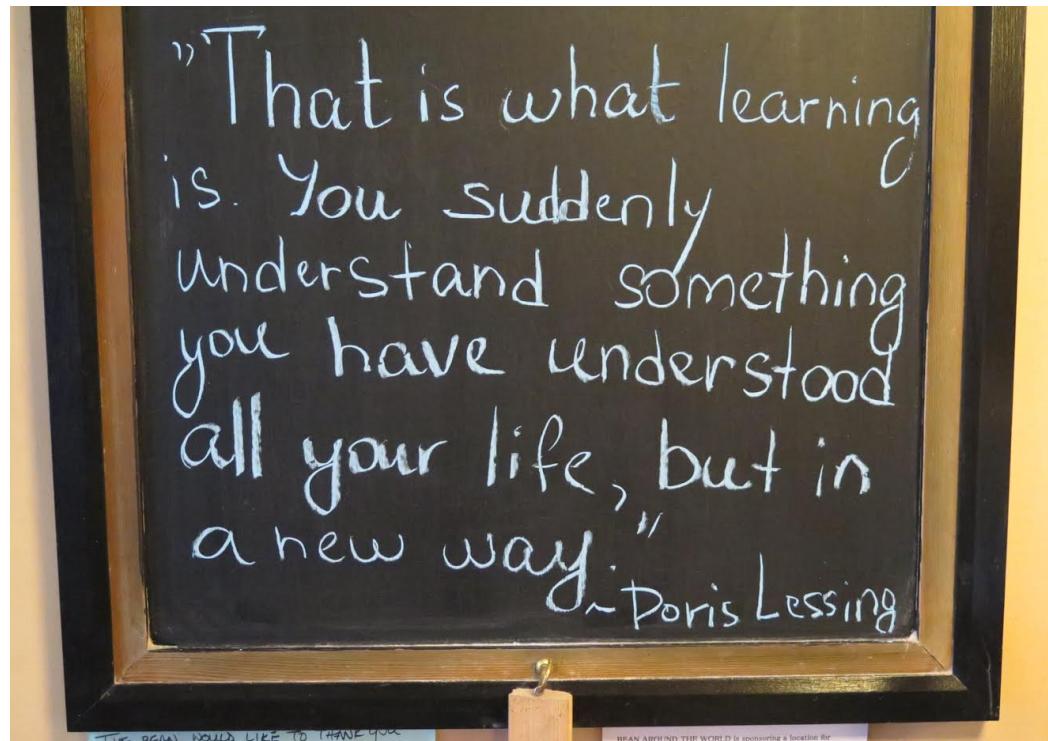
Agenda for today

- Introduction to EM
- DCR
- EM Fundamentals
- Inductive sources
 - Lunch: Play with apps
- Grounded sources
- Natural sources
- GPR
- Induced polarization
- The Future



A touch of realism

- Ambitious schedule
- Wide variety of backgrounds but hope there is something for everybody
- Not really targeting the experts but even them...



DISC is a 2-day event

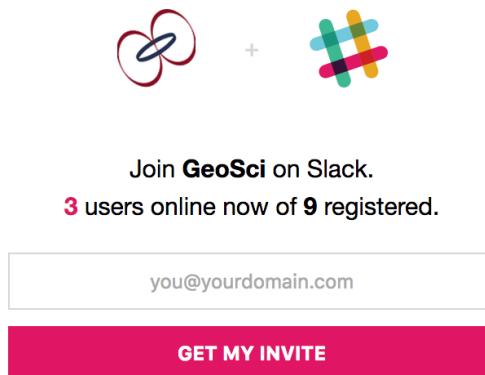
- SEG DISC Course (today)
 - Sponsored by SEG
- DISC Lab (tomorrow) (sponsored by GIF)
 - Capture “local” applications
 - Discuss and put them in a 7-step procedure
 - Share on the web
 - Sign up at <http://disc2017.geosci.xyz/schedule#denver>
- The tour:
 - 30 locations
 - Capture geoscience problems around the world
 - Connect geoscientists worldwide, build a community



Connecting & Contributing

- Today: Slack

- <http://slack.geosci.xyz/>



- Contributing:

- EM GeoSci
 - Case histories
 - Content
 - SimPEG
 - Software

A screenshot of a web browser showing two pages side-by-side. The left page is titled "Case Histories" and lists various geological and mining case studies such as Mt. Isa, Bookpurnong, Aspen, Lalor, Elevenmile Canyon, Albany, West Plains, Furggwanghorn, Norsminde, Barents Sea, Kasted, and The Balboa ZTEM Cu-Mo-Au porphyry discovery at Cobre Panama. The right page is titled "Case Histories" and provides a detailed description of the context for developing educational and research material, mentioning the Seven Step Process. It also includes sections for "Gallery" (with images of geophysical surveys) and "Bookpurnong" (with a detailed geological cross-section diagram).

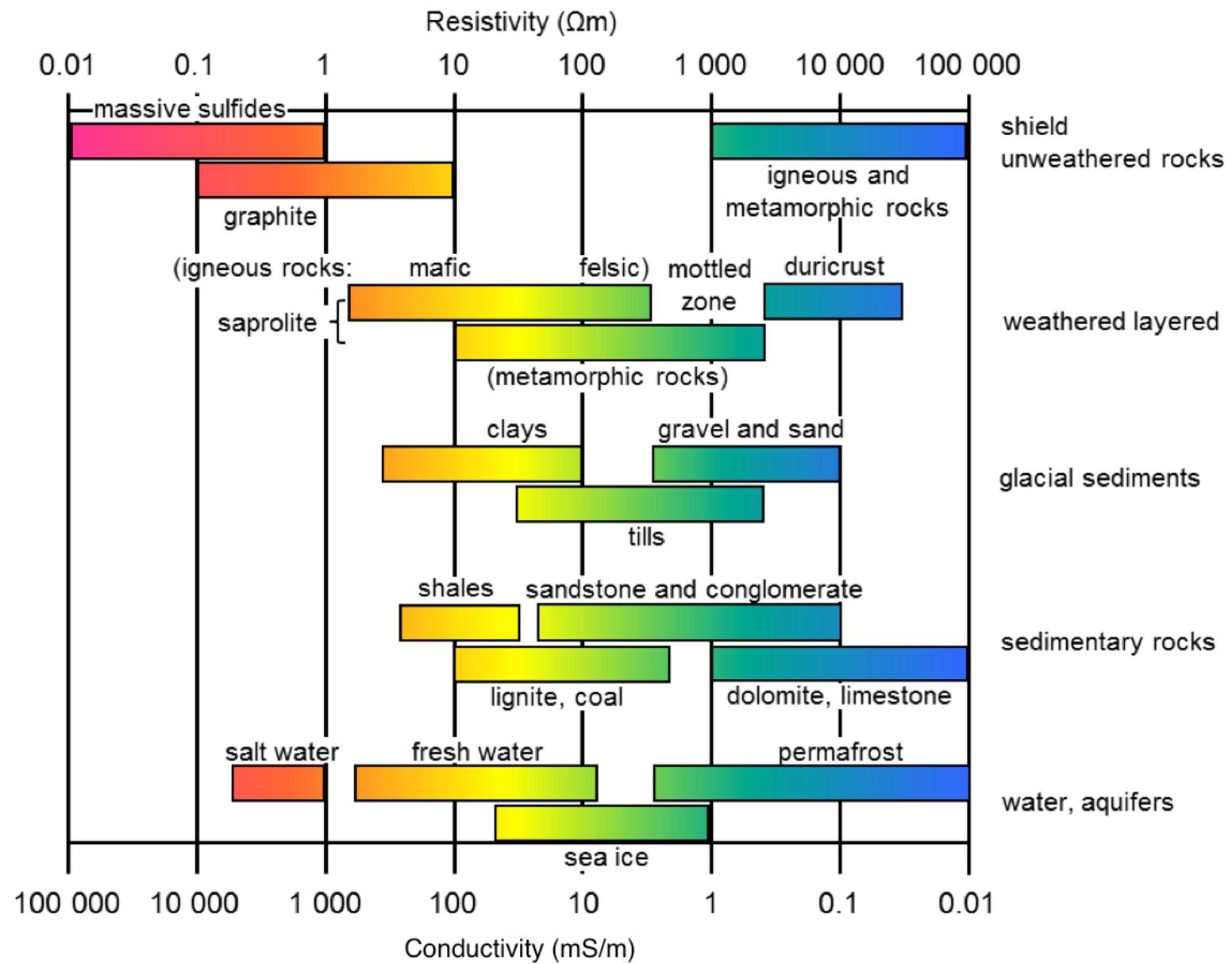
Introduction to EM



Three problems



Electrical Resistivity / Conductivity

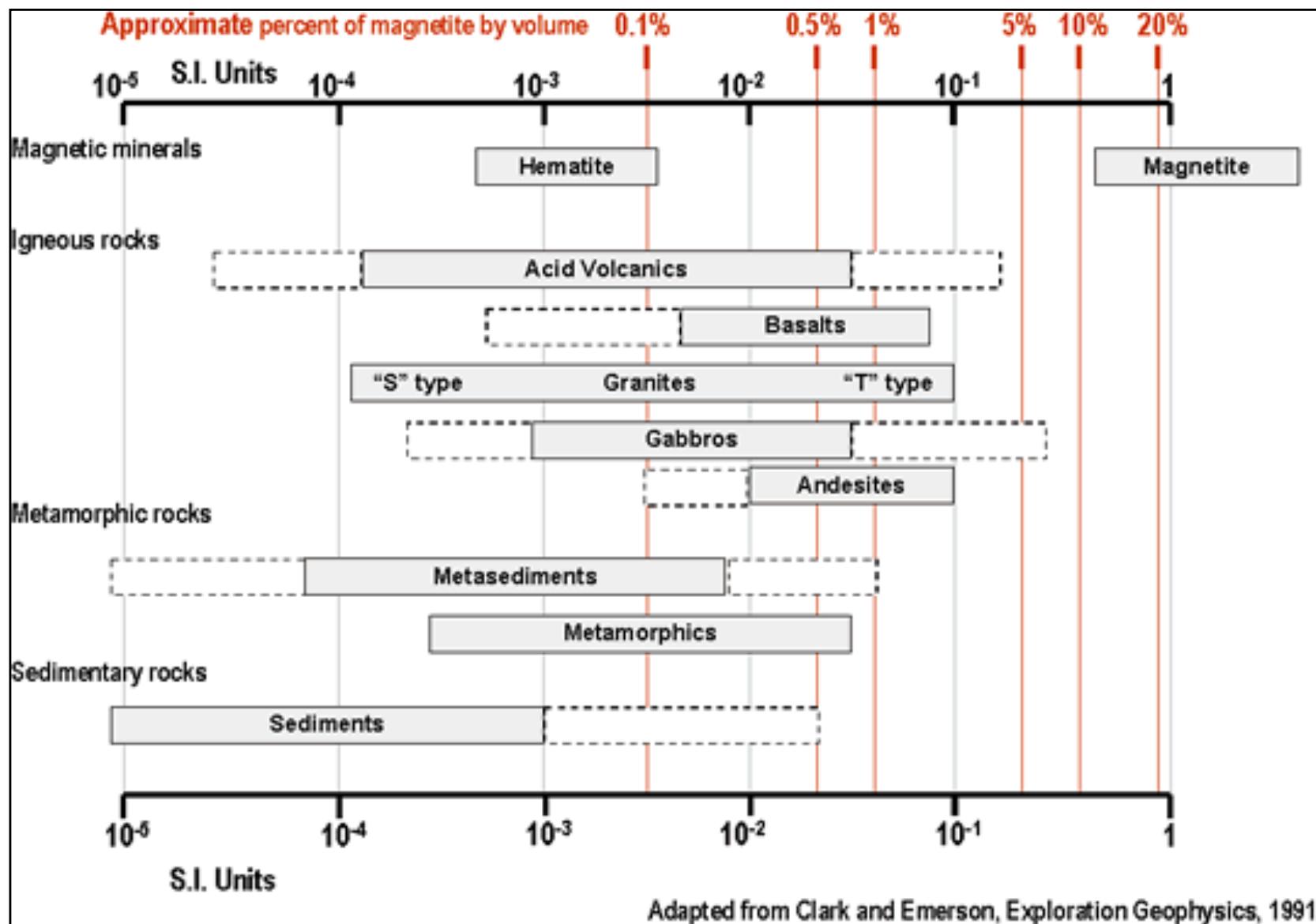


Dielectric constant

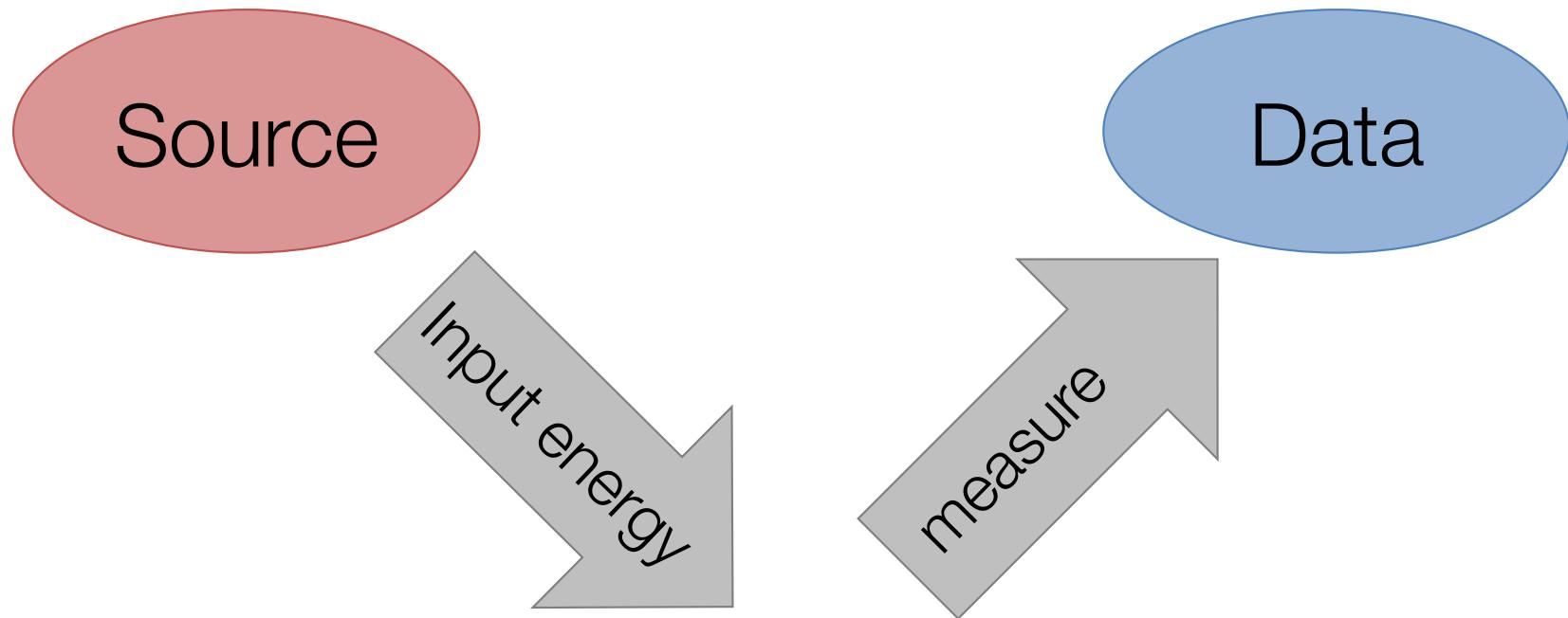


Material	Relative Permittivity	Conductivity (mS/m)	Average Velocity (m/ns)
Air	1	0	3
Fresh Water	80	0.5	0.033
Sea Water	80	3000	0.01
Ice	3-4	0.01	0.16
Dry Sand	3-5	0.01	0.15
Saturated Sand	20-30	0.1-1	0.06
Limestone	4-8	0.5-2	0.12
Shales	5-15	1-100	0.09
Silts	5-30	1-100	0.07
Clays	5-40	2-1000	0.06
Granite	4-6	0.01-1	0.13
Anhydrites	3-4	0.01-1	0.13

Magnetic Susceptibility



EM Survey & Physical Properties



Physical
Properties

$$\sigma, \mu, \varepsilon$$

Basic Equations

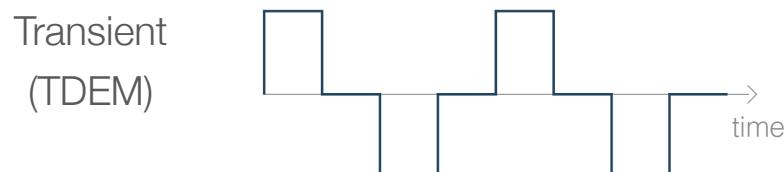
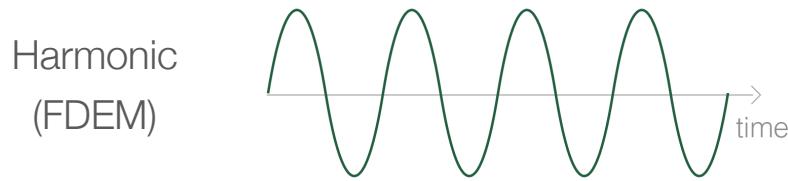
	Time	Frequency
Faraday's Law	$\nabla \times \mathbf{e} = - \frac{\partial \mathbf{b}}{\partial t}$	$\nabla \times \mathbf{E} = - i\omega \mathbf{B}$
Ampere's Law	$\nabla \times \mathbf{h} = \mathbf{j} + \frac{\partial \mathbf{d}}{\partial t}$	$\nabla \times \mathbf{H} = \mathbf{J} + i\omega \mathbf{D}$
No Magnetic Monopoles	$\nabla \cdot \mathbf{b} = 0$	$\nabla \cdot \mathbf{B} = 0$
Constitutive Relationships (non-dispersive)	$\mathbf{j} = \sigma \mathbf{e}$ $\mathbf{b} = \mu \mathbf{h}$ $\mathbf{d} = \epsilon \mathbf{e}$	$\mathbf{J} = \sigma \mathbf{E}$ $\mathbf{B} = \mu \mathbf{H}$ $\mathbf{D} = \epsilon \mathbf{E}$

* Solve with sources and boundary conditions

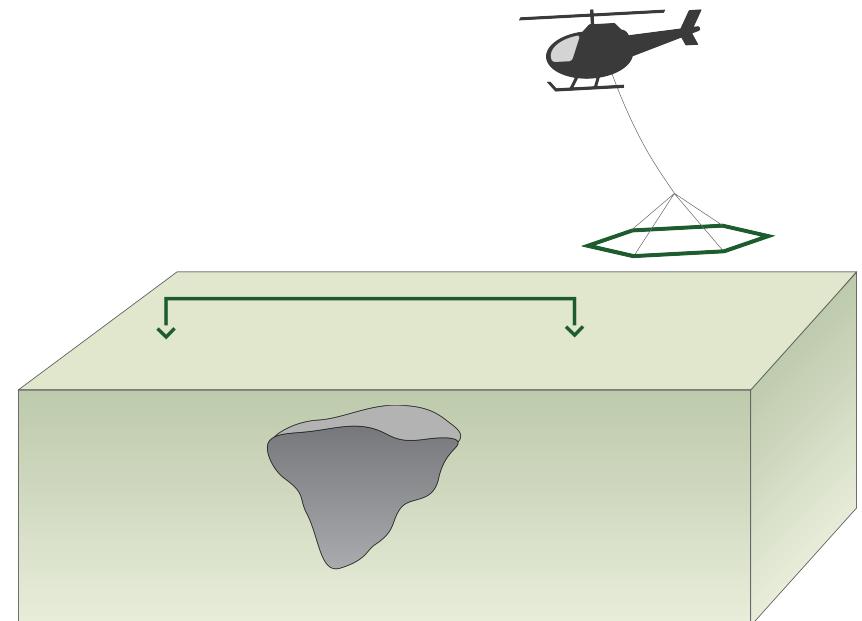
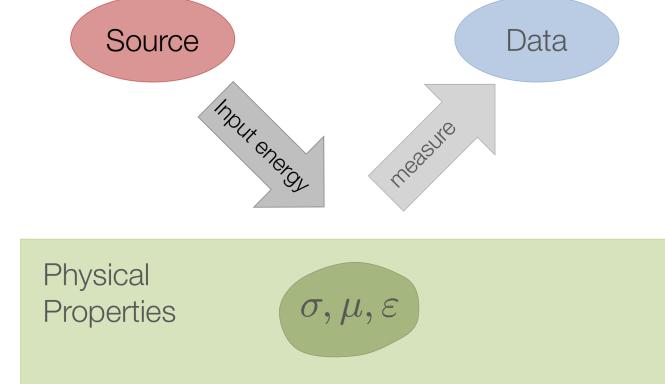
Electromagnetic Survey: Sources

- Type
 - Inductive
 - Grounded

- Waveform

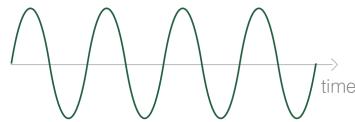


- Location
 - Airborne
 - Ground
 - Borehole

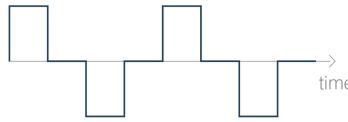


Electromagnetic Survey: Data

- Which field?

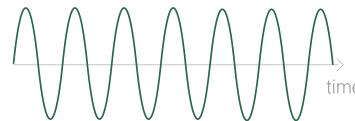
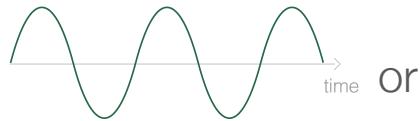


E, B



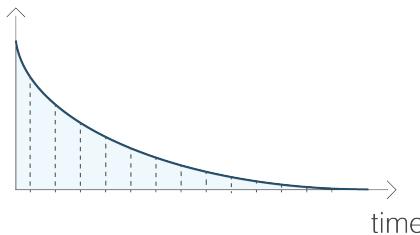
$e, b, \frac{db}{dt}$

- Which frequencies?



or

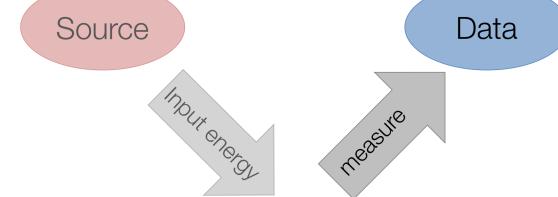
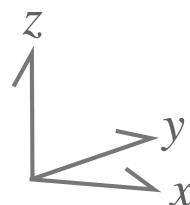
- times?



- Components?

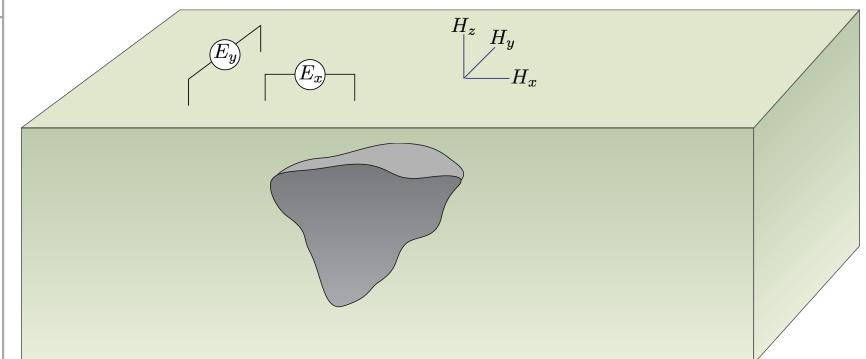
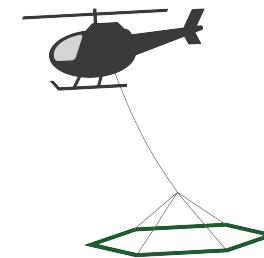
- Location?

- Airborne
- Ground
- Borehole



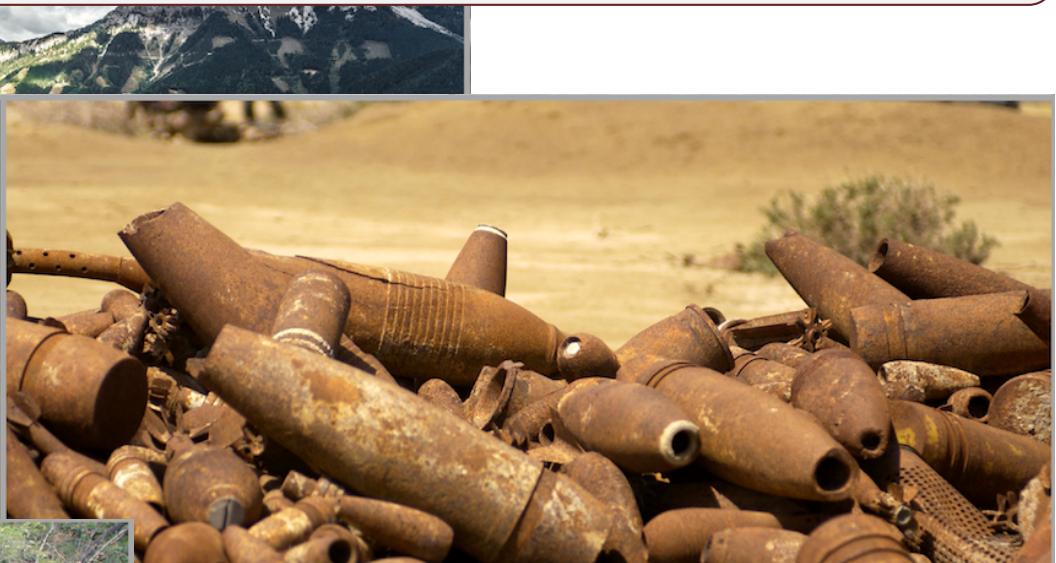
Physical Properties

σ, μ, ϵ



Three problems

Electrical conductivity is diagnostic for all three



Finding resources

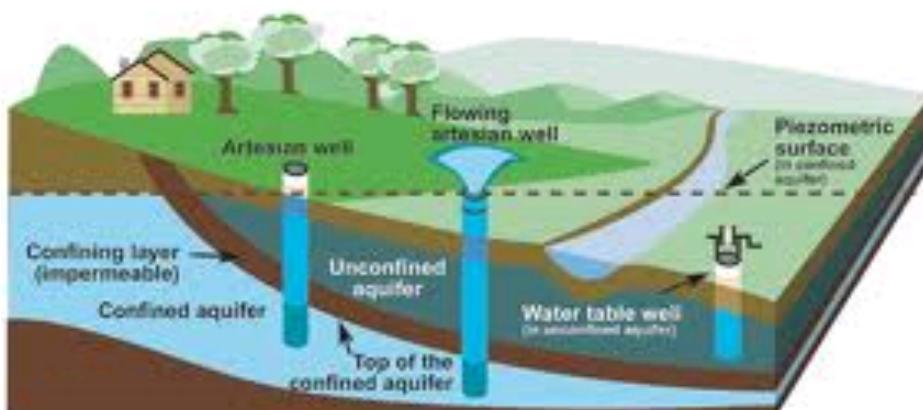
Hydrocarbons



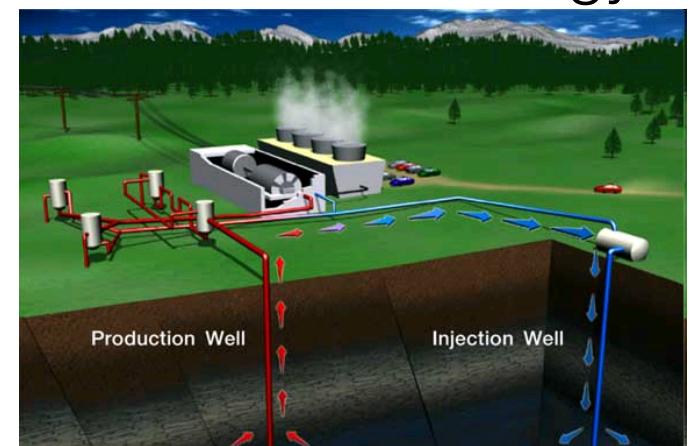
Minerals



Ground Water



Geothermal Energy



Natural Hazards

Volcano



Landslide



Tsunami



Earthquake



Geotechnical engineering

Tunnels and highways



In-mine safety



Slope stability

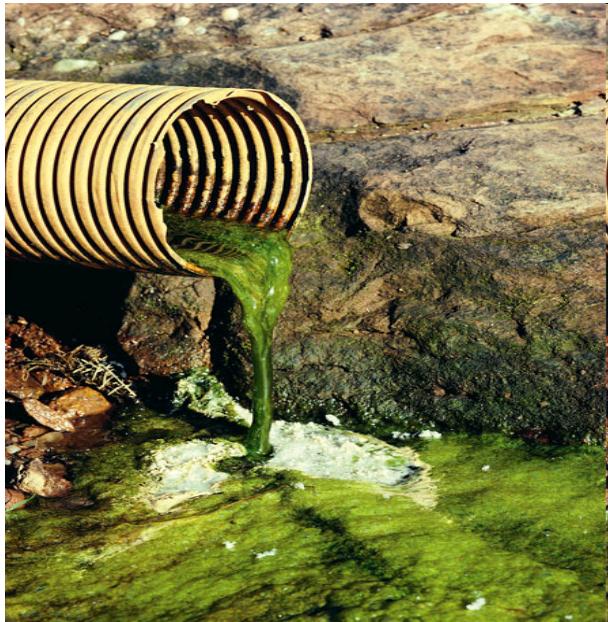


Subsurface voids

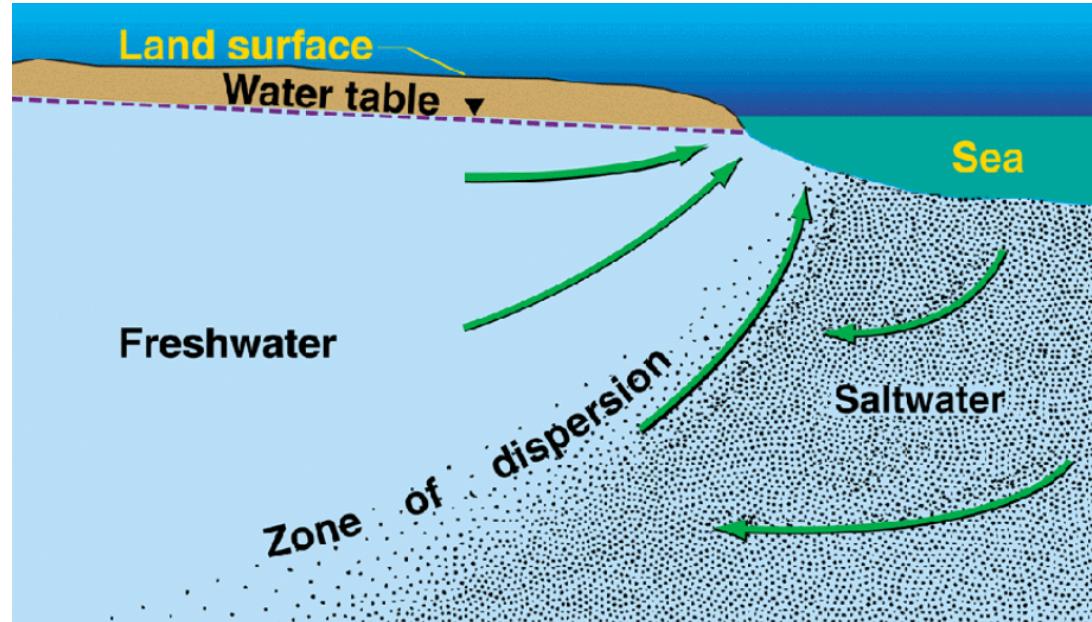


Environmental

Water contamination



Saline water intrusion

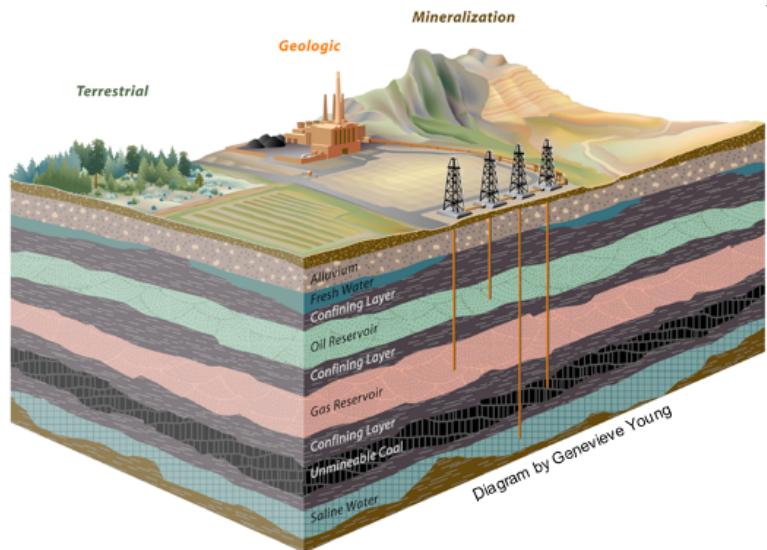


UXO detection

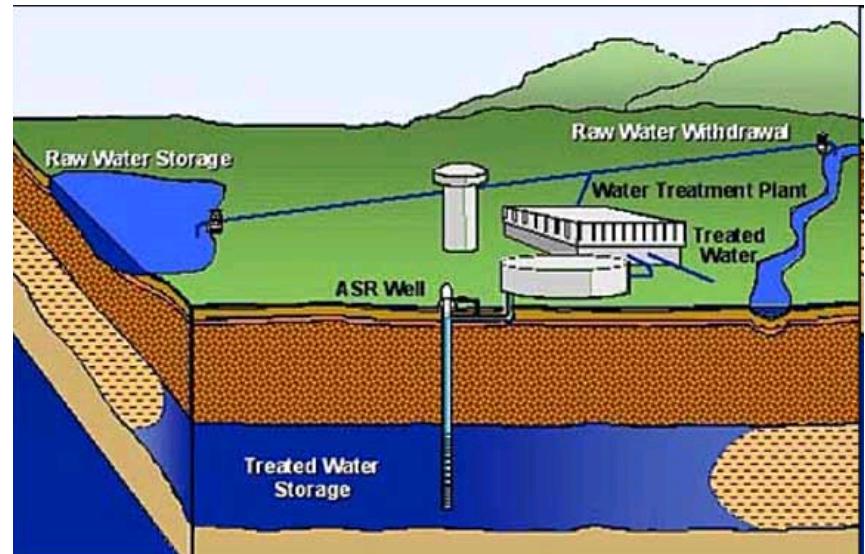


Surface or Underground Storage

CO₂ sequestration



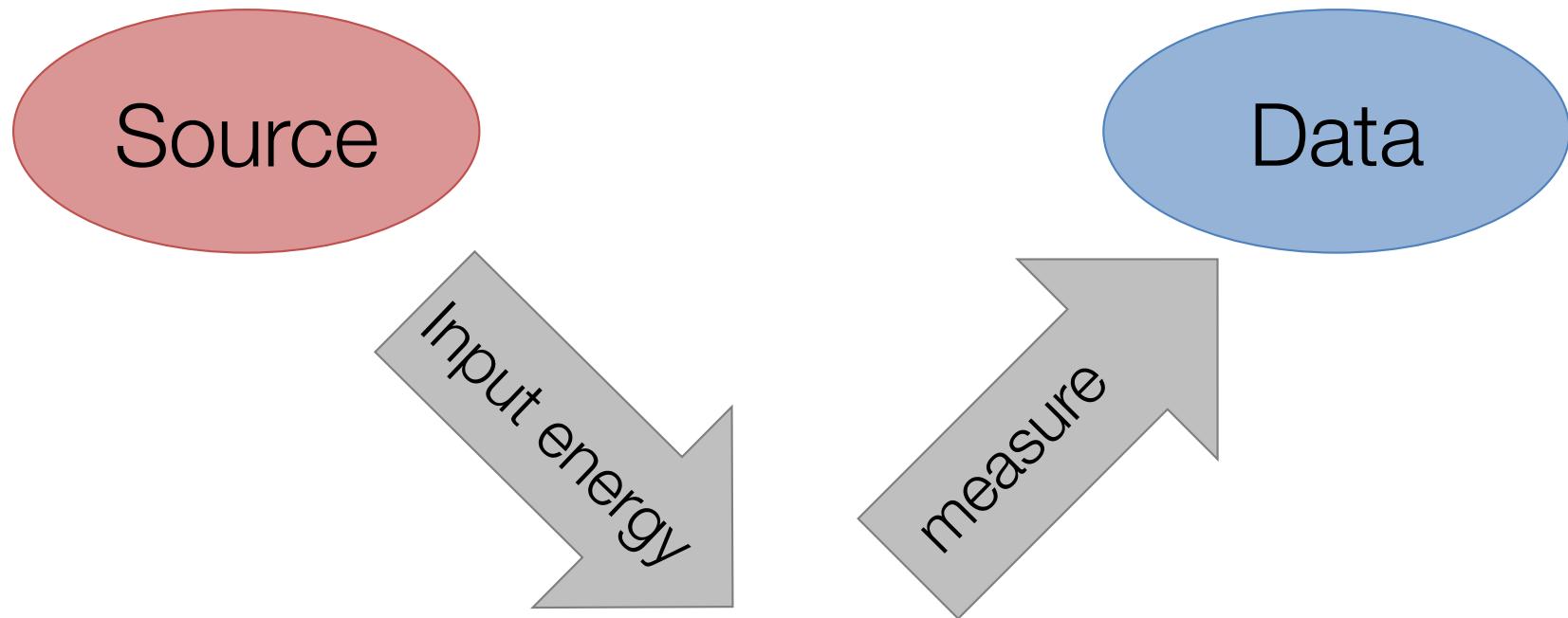
Aquifer storage and recovery



Industrial and radioactive waste



EM Survey & Physical Properties



Physical
Properties

$$\sigma, \mu, \varepsilon$$

End of Introduction

Next up



- Introduction to EM
- DCR
- EM Fundamentals
- Inductive sources
 - Lunch: Play with apps
- Grounded sources
- Natural sources
- GPR
- Induced polarization
- The Future

