DISC 2017

Electromagnetics Fundamentals and Applications

http://disc2017.geosci.xyz/vancouver

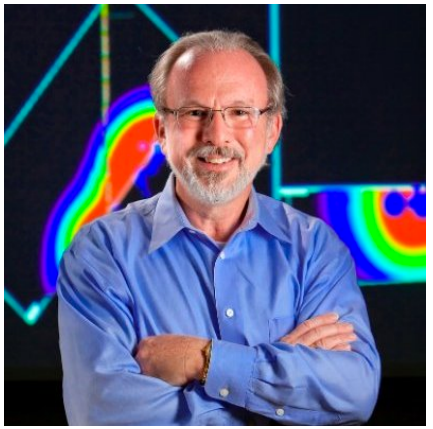
SEG SM SOCIETY OF EXPLORATION GEOPHYSICISTS

Thanks to…

Ross Polutnik

Dennis Woods

Peter Duncan



Vancouver Sponsors

Discovery International Geophysics

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GEOPHYSICS Science on Target

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BCGS
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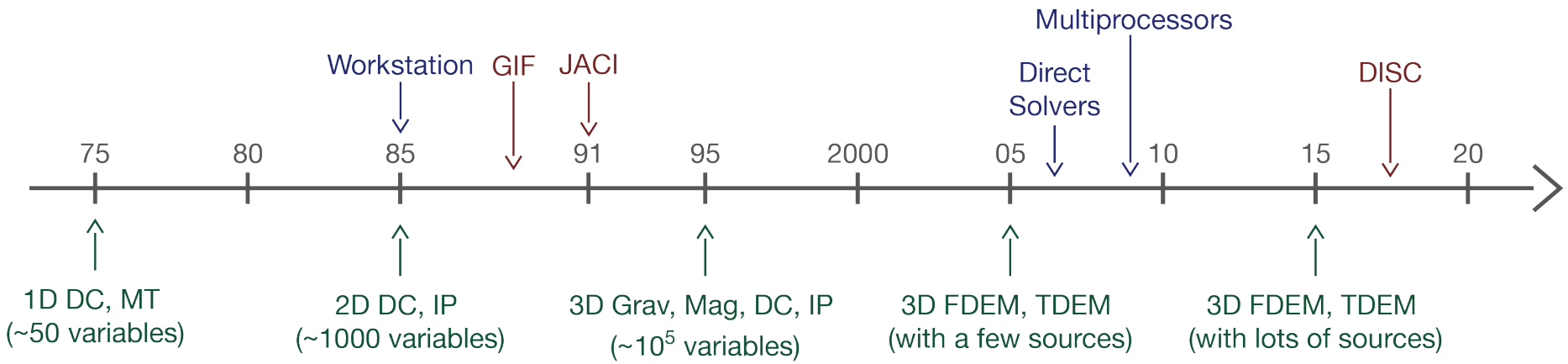
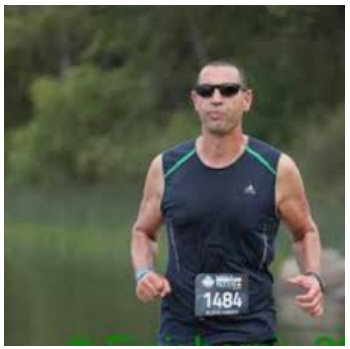
SEG FOUNDATION

Some Background

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



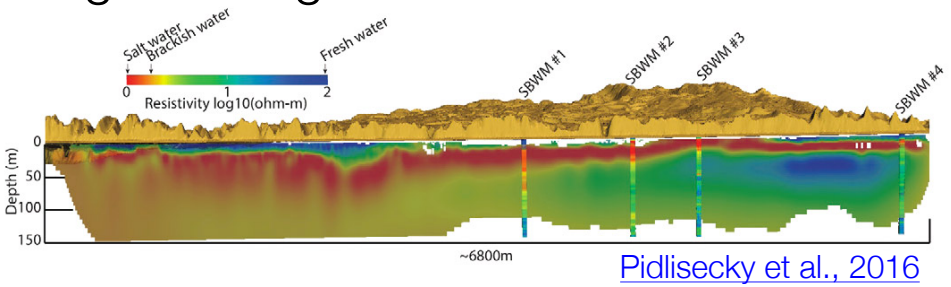


Result: Computing power + advances in inversion methodology
→ we can now solve most EM geophysics problems

Instrumentation and Data

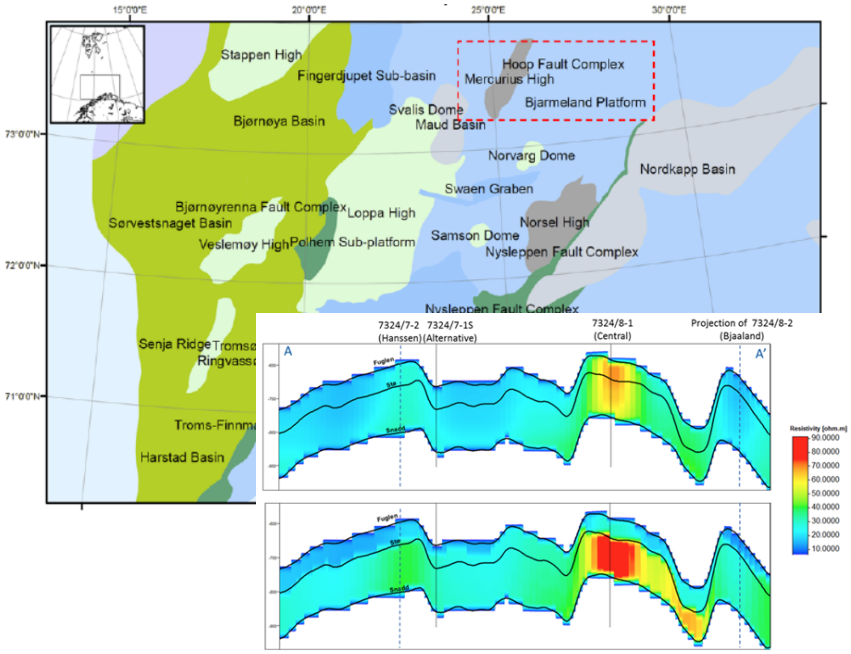
- The second major advance is in data acquisition
- Data with unprecedented data quality and quantity.

Large-scale ground water studies: California



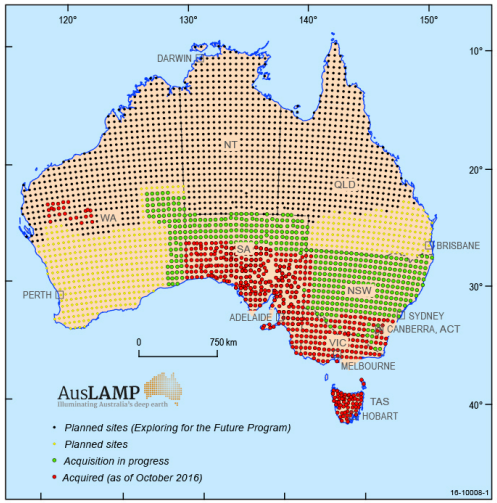
Pidlisecky et al., 2016

Offshore: Hydrocarbon De-risking



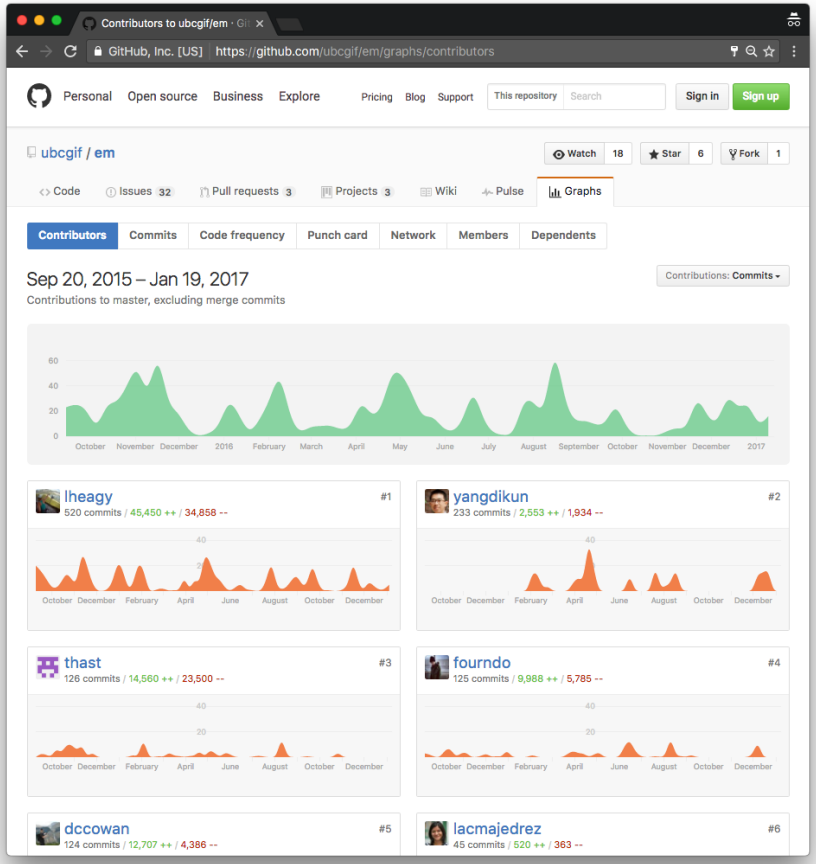
Alvarez et al, EM.GeoSci

AusLamp: Continental Scale MT



Web and Open Source Resources

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



simpeg

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 …


minerals


contaminants


water


geothermal


geotechnical


slope stability


hydrocarbons


unexploded ordnance

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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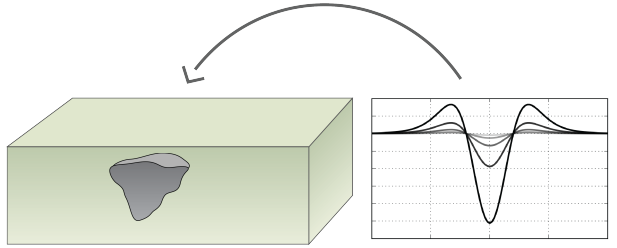
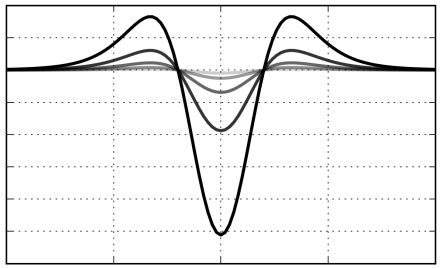
DISC can take advantage of a Perfect Storm

Problems

Inversion capabilities



High quality data

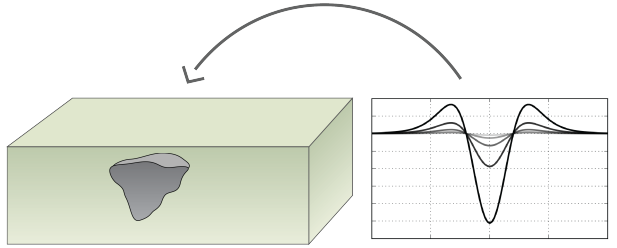


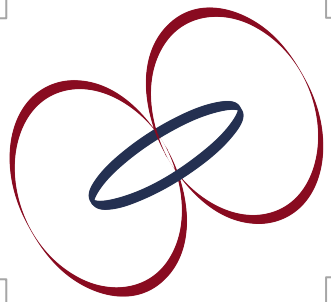
Web tools to communicate

DISC can take advantage of a Perfect Storm

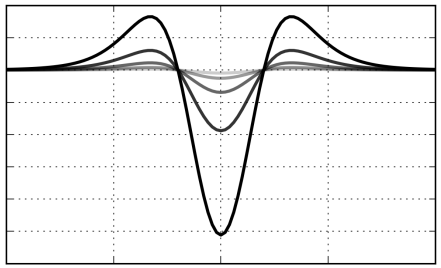
Problems

Inversion capabilities





High quality data



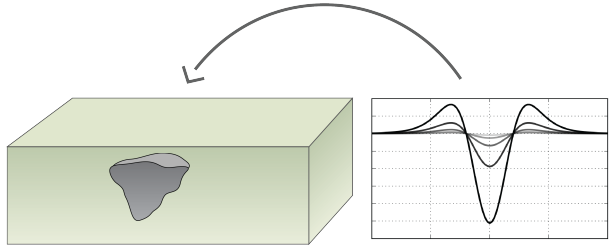
Web tools to communicate

A good idea but missing an important ingredient …

Talented Young Geoscientists

Problems

Inversion capabilities



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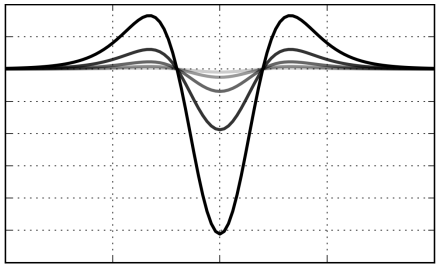


Web tools to communicate

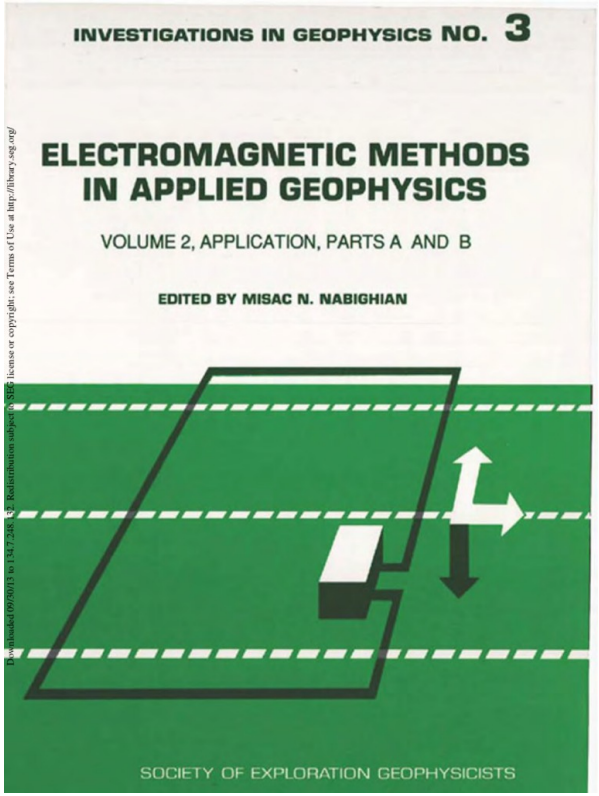
Seogi

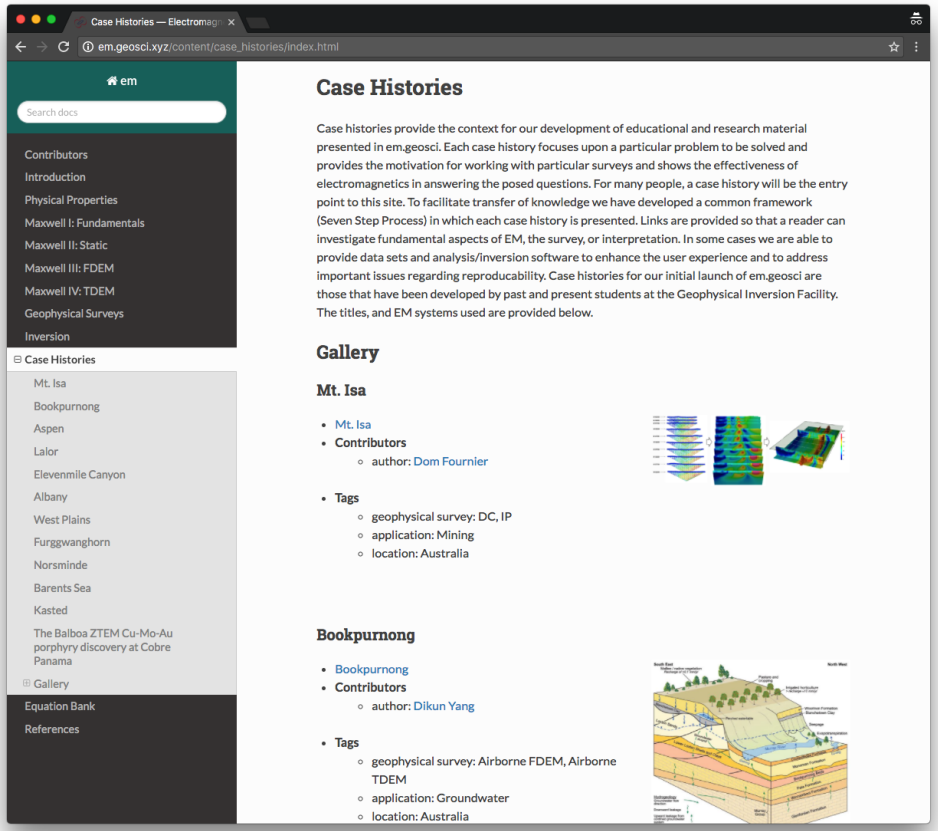
Lindsey

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

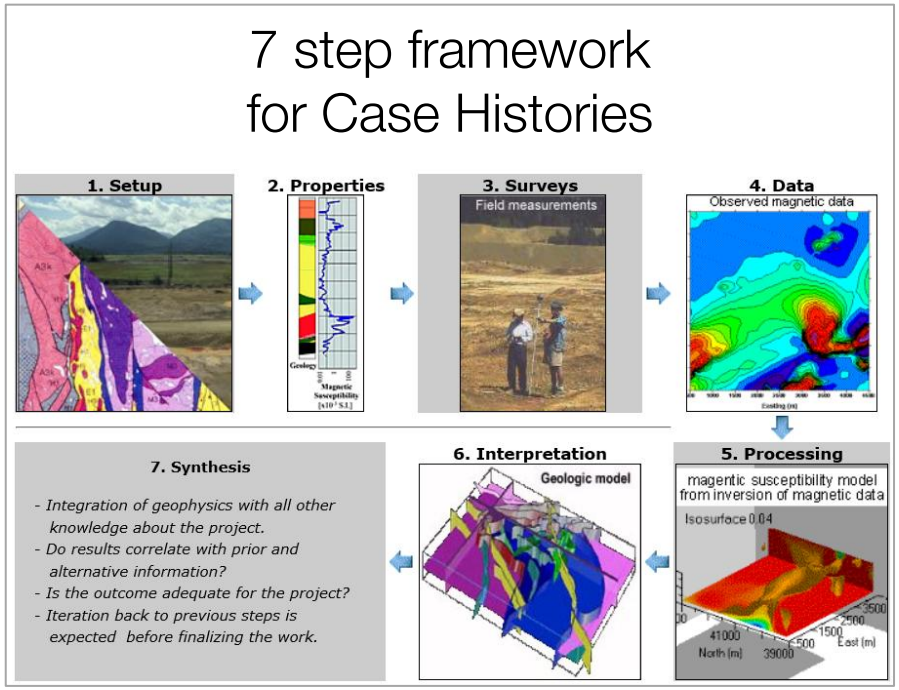
Resources: EM.geosci

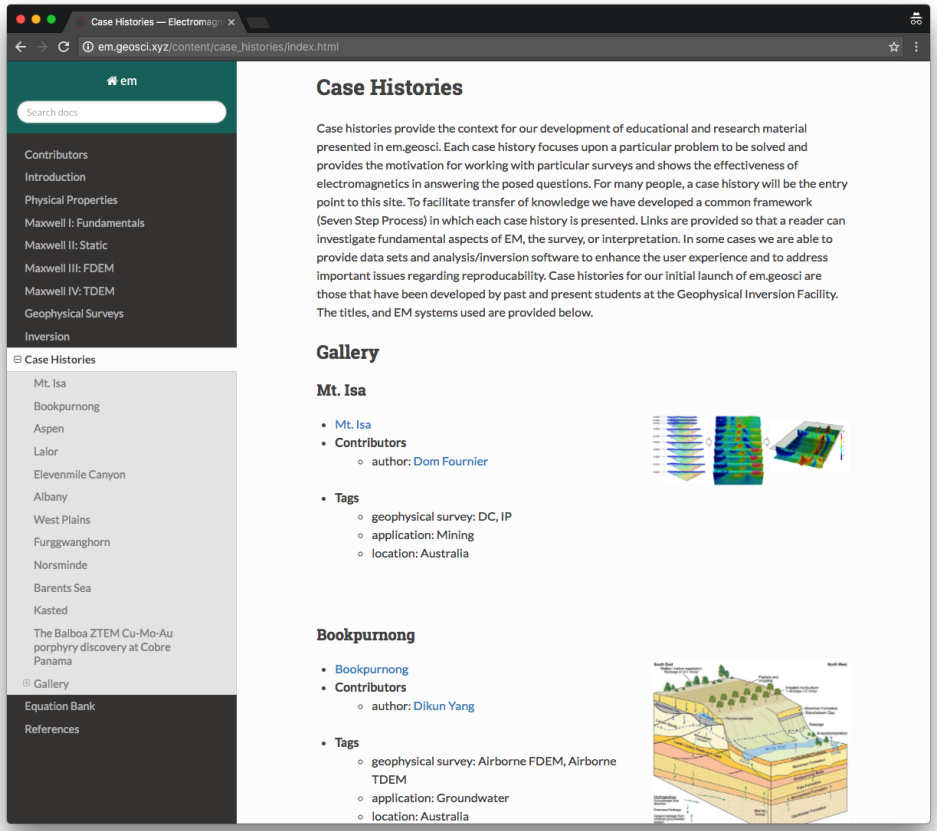




http://em.geosci.xyz

Resources: EM.geosci





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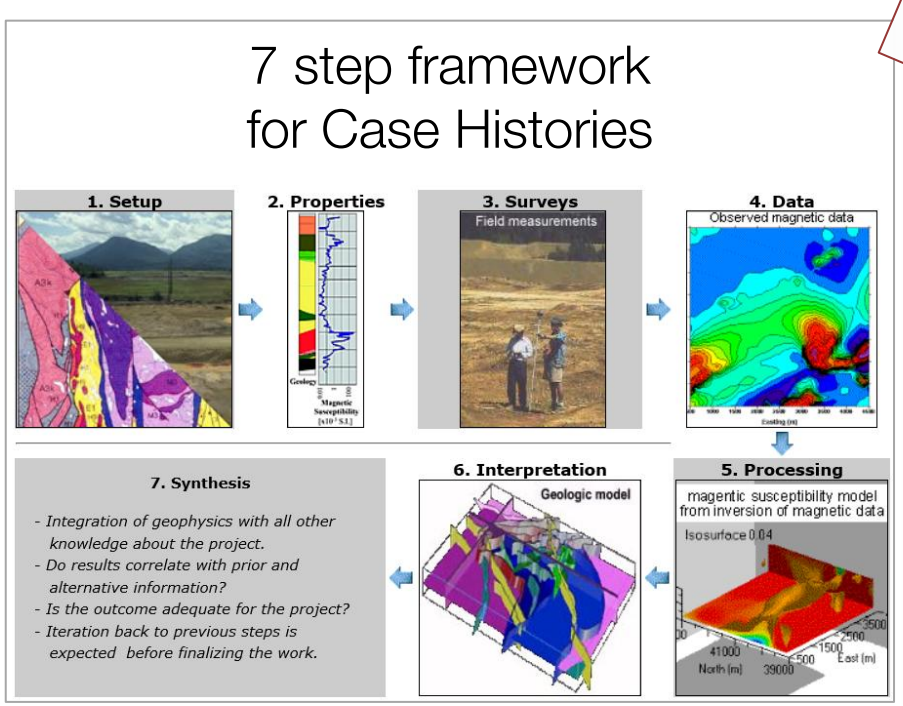
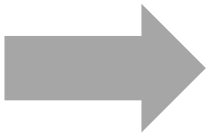


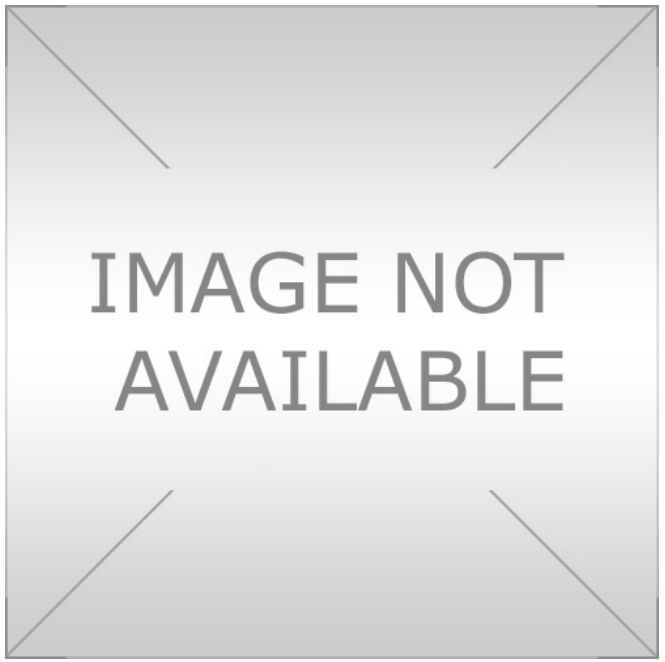
http://em.geosci.xyz

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

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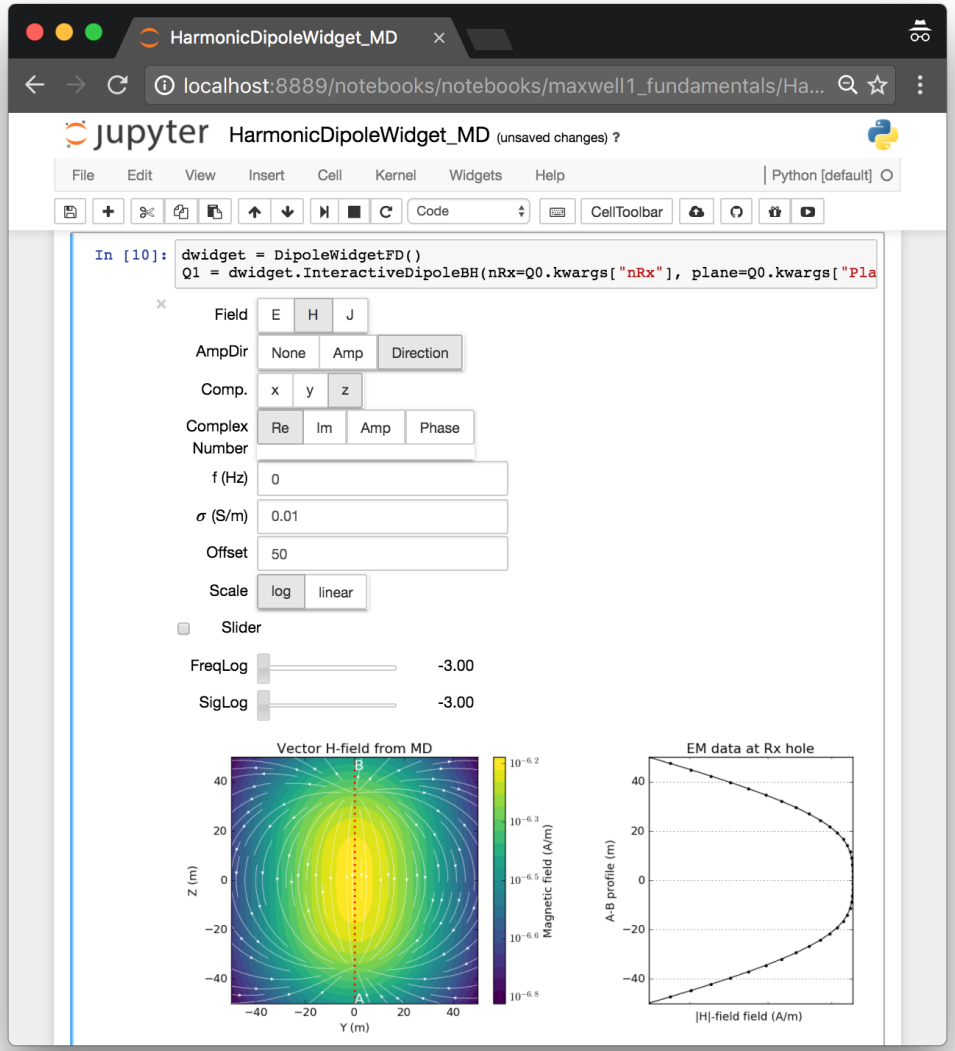
$$\nabla \times \mathbf{h} = \mathbf{j} + \frac{\partial \mathbf{d}}{\partial t}$$

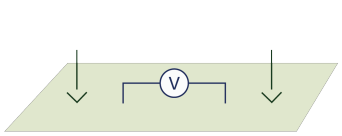


http://em.geosci.xyz/apps.html

How do we achieve our goals

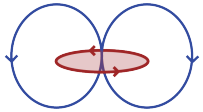
- Connect to relevant applications
- Select a type of survey
- Use apps to explore and ask questions
- Show success in a case history

Agenda for today

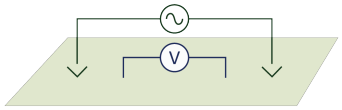


DC Resistivity

EM Fundamentals

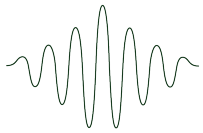


Inductive Sources



Grounded Sources

Natural Sources



GPR

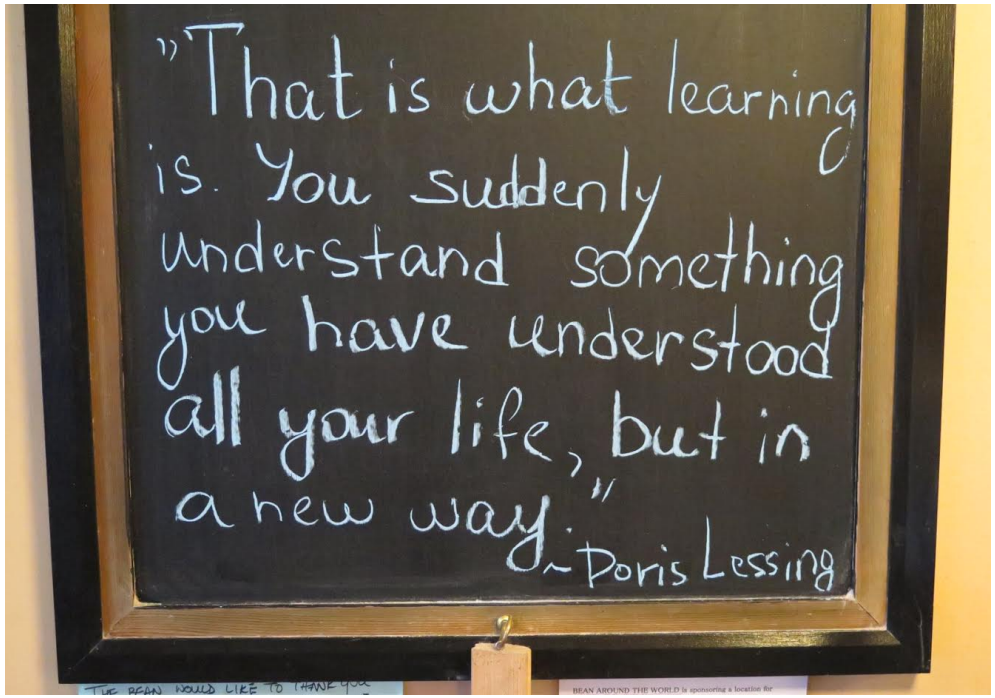
Induced Polarization

The Future

Lunch: Play with apps

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

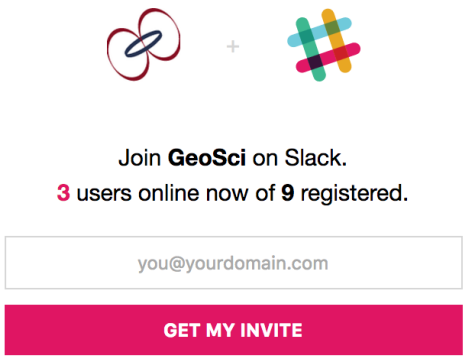
- SEG DISC Course (today)
  - Sponsored by SEG

- DISC Lab (tomorrow) (sponsored by GIF)
  - Capture “local” applications
  - Share on the web

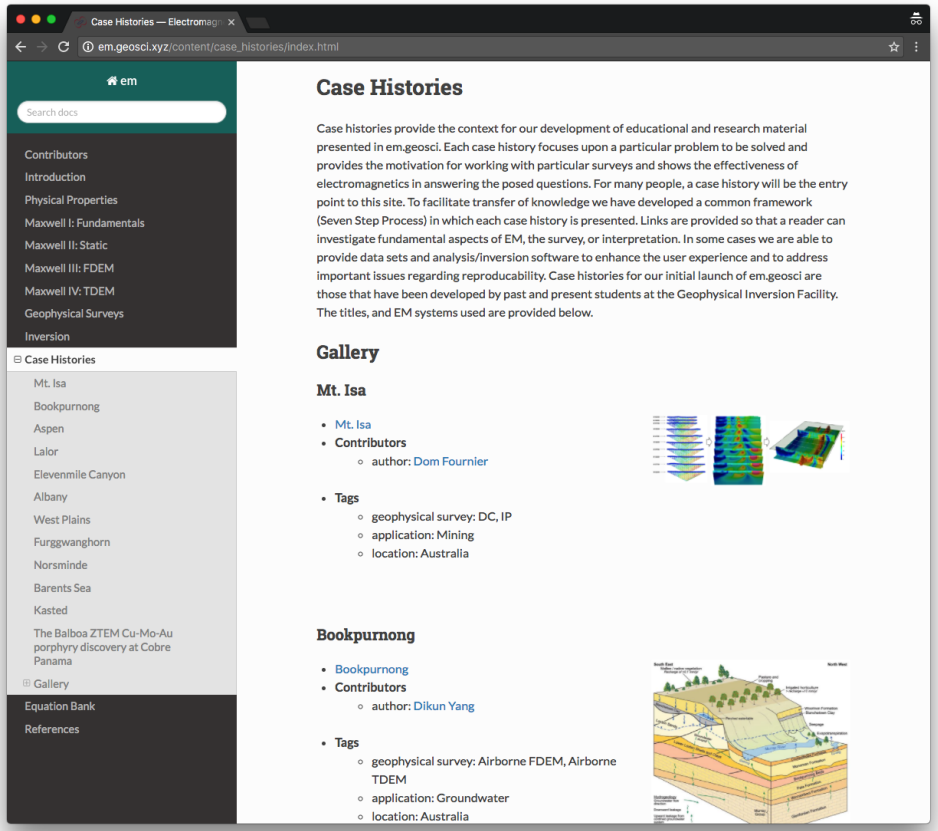
- The tour:
  - 30 locations
  - Capture geoscience problems around the world
  - Connect geoscientists worldwide, build a community

Connecting & Contributing

- Today: Slack
  - http://slack.geosci.xyz/



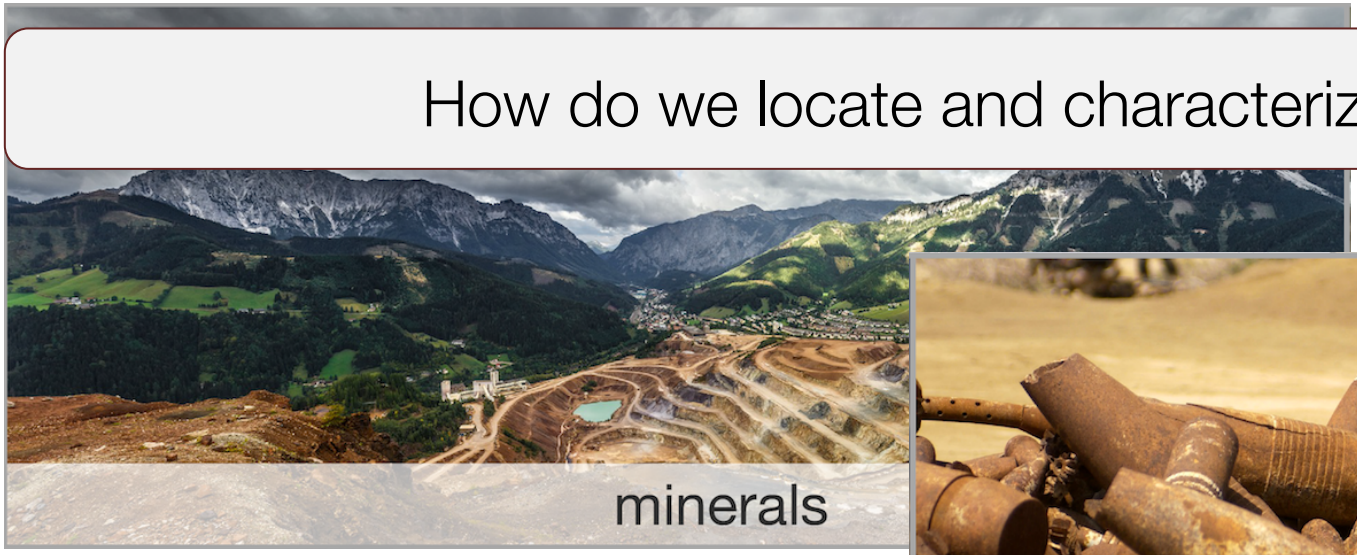
- Contributing:
  - EM GeoSci
    - Case histories
    - Content
  - SimPEG
    - Software



Introduction to EM

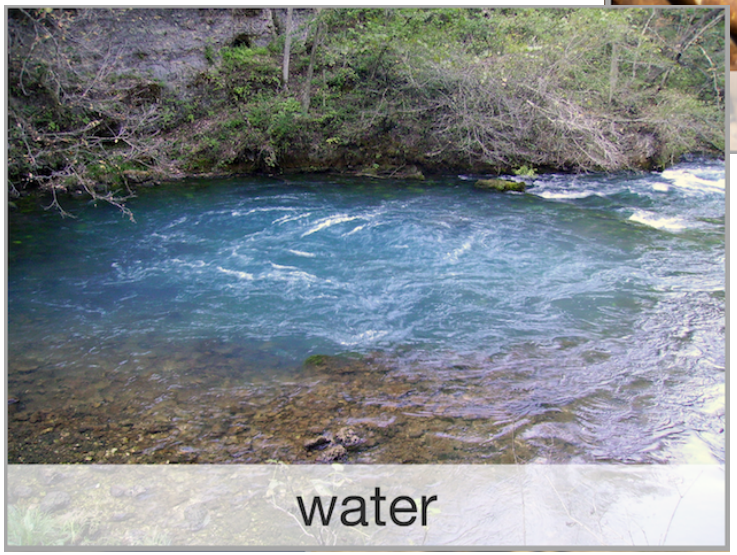
Three problems

How do we locate and characterize …



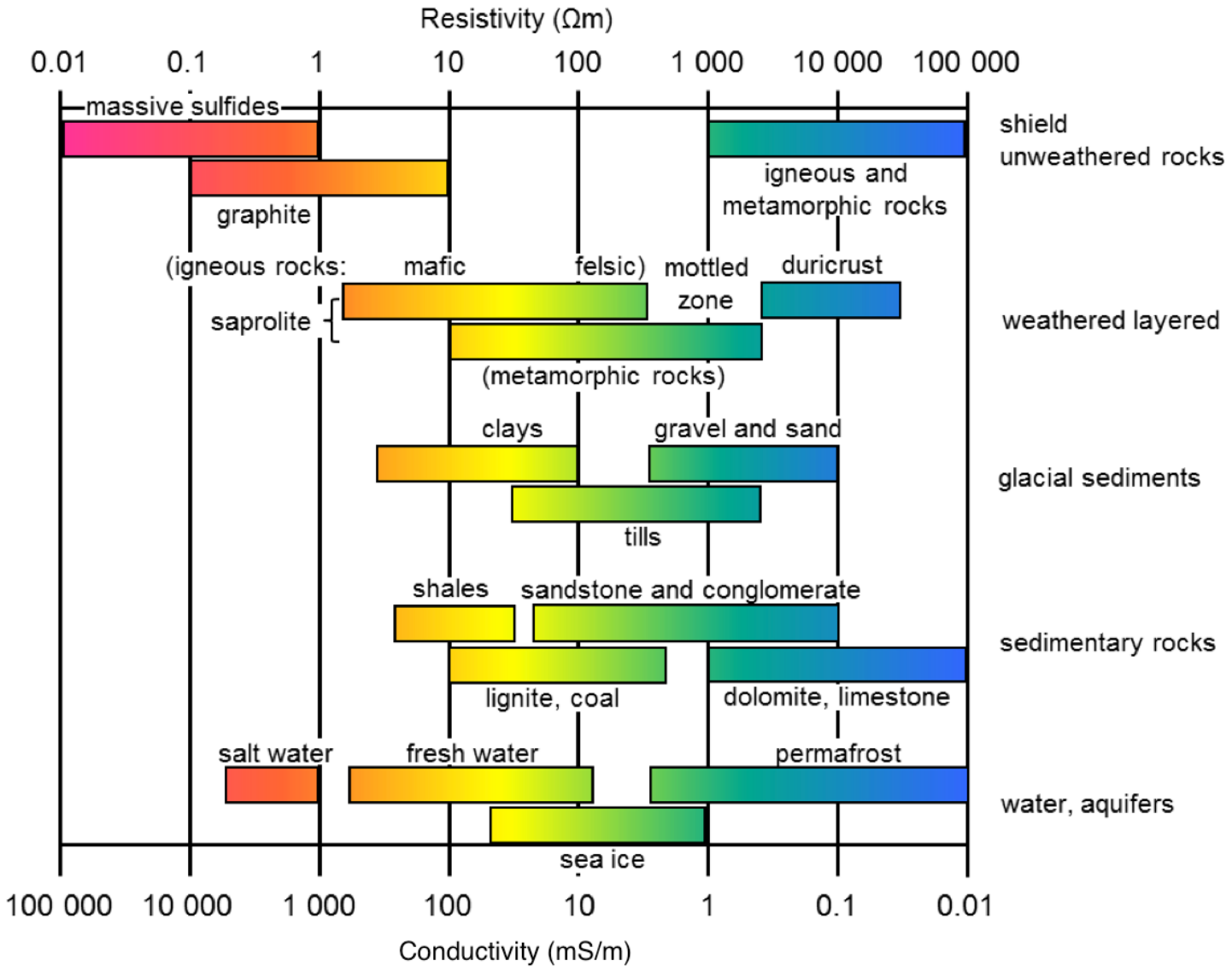
minerals

unexploded ordnance



water

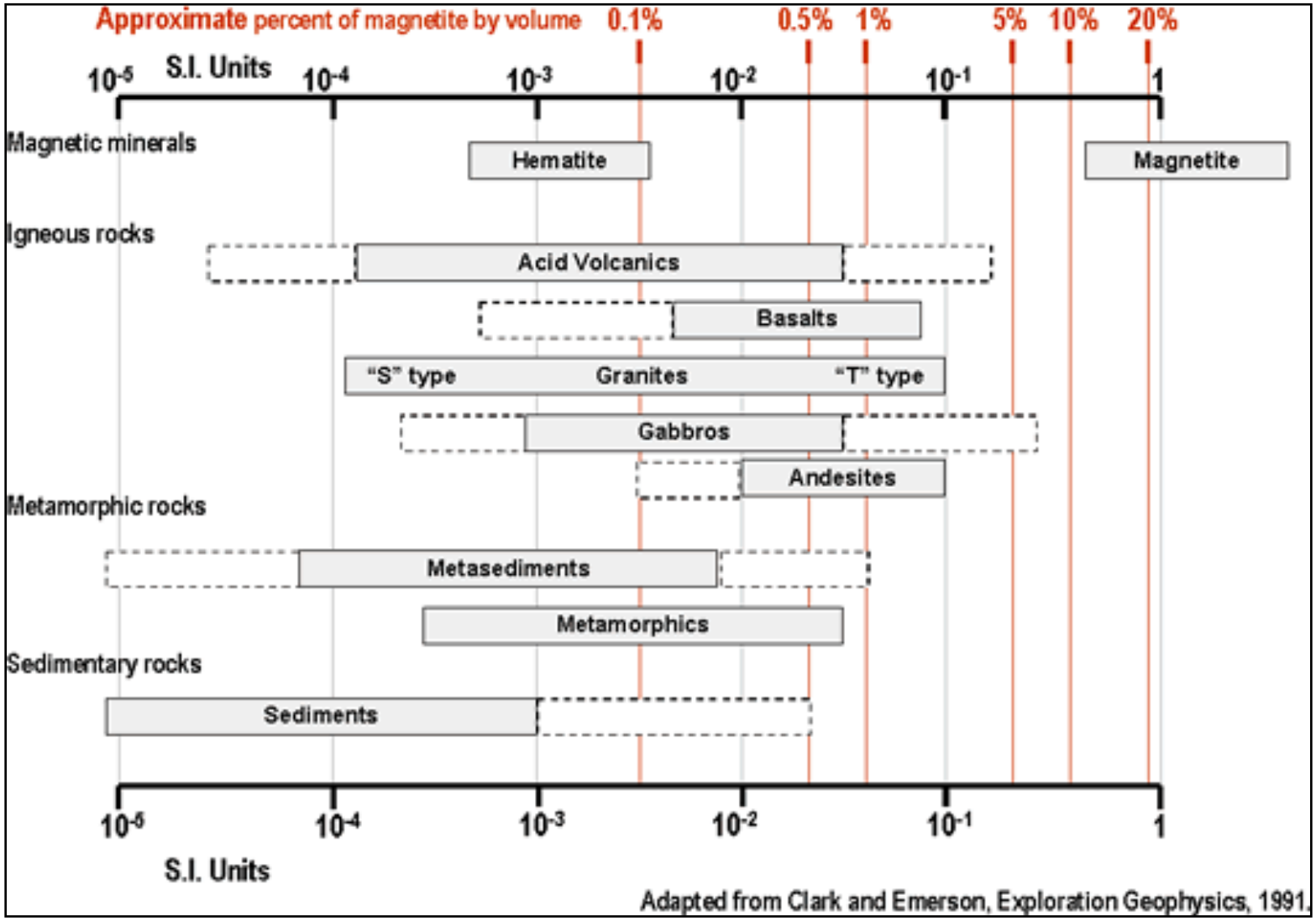
Electrical Resistivity / Conductivity



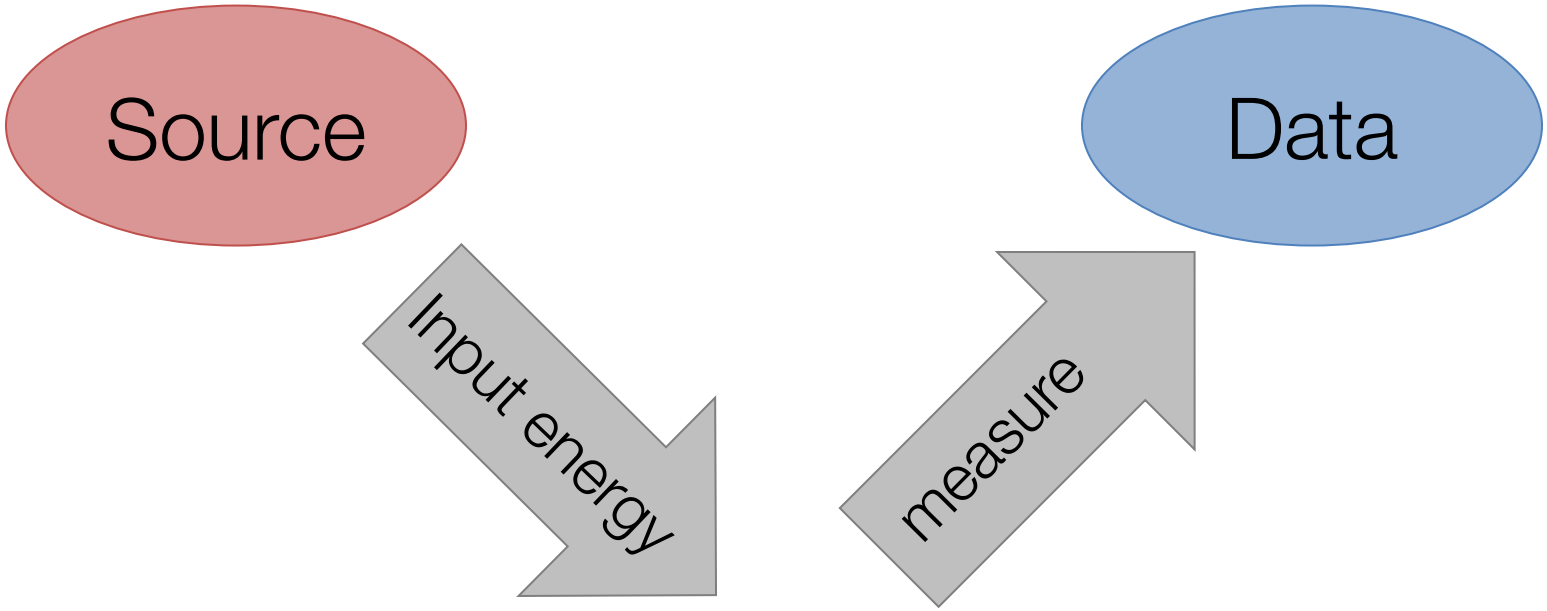
Dielectric constant

Material	Relative Permittivity	Conductivity (mS/m)
Air	1	0
Fresh Water	80	0.5
Sea Water	80	3000
Ice	3-4	0.01
Dry Sand	3-5	0.01
Saturated Sand	20-30	0.1-1
Limestone	4-8	0.5-2
Shales	5-15	1-100
Silts	5-30	1-100
Clays	5-40	2-1000
Granite	4-6	0.01-1
Anhydrites	3-4	0.01-1

Magnetic Susceptibility



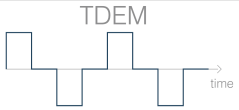
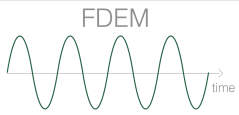
EM Survey & Physical Properties



Physical Properties

σ, μ, ε

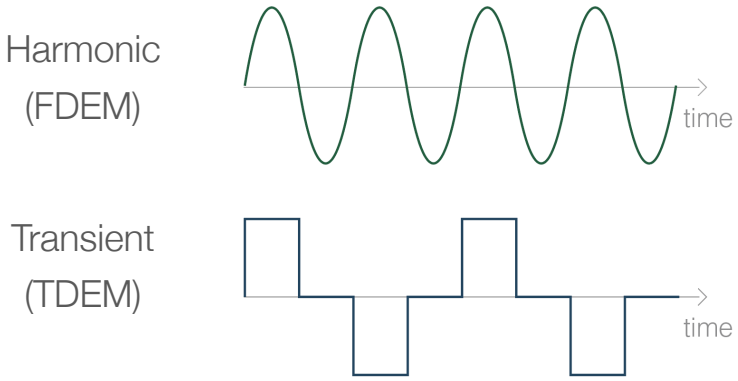
Basic Equations

	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)	$\mathbf{j} = \sigma\mathbf{e}$ $\mathbf{b} = \mu\mathbf{h}$ $\mathbf{d} = \varepsilon\mathbf{e}$	$\mathbf{J} = \sigma\mathbf{E}$ $\mathbf{B} = \mu\mathbf{H}$ $\mathbf{D} = \varepsilon\mathbf{E}$

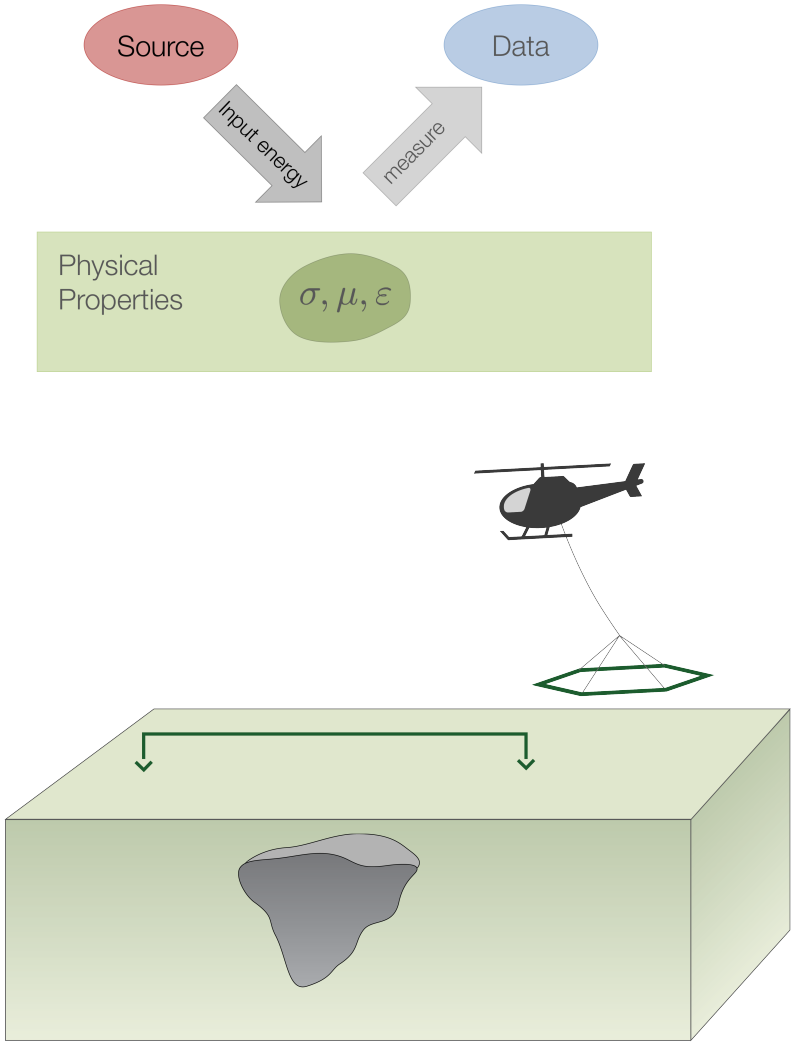
* Solve with sources and boundary conditions

Electromagnetic Survey: Sources

- Type
  - Inductive
  - Grounded
- Waveform

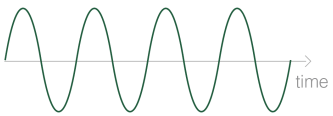


- Location
  - Airborne
  - Ground
  - Borehole

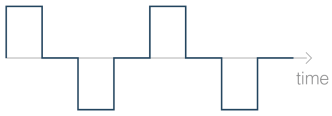


Electromagnetic Survey: Data

- Which field?

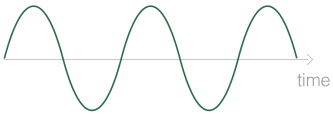


$\mathbf{E}, \mathbf{B}$

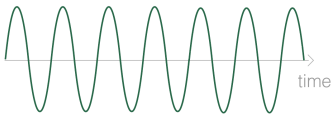


$\mathbf{e}, \mathbf{b}, \dfrac{d\mathbf{b}}{dt}$

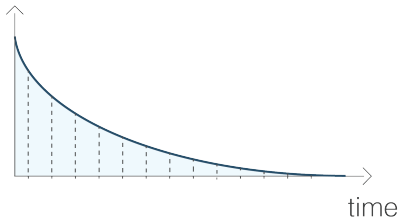
- Which frequencies?



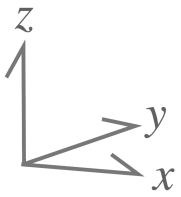
or

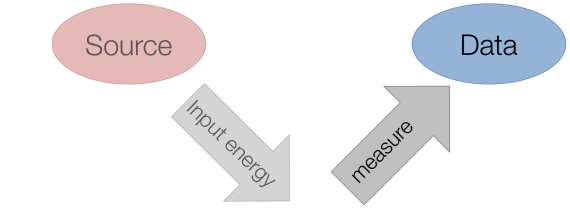


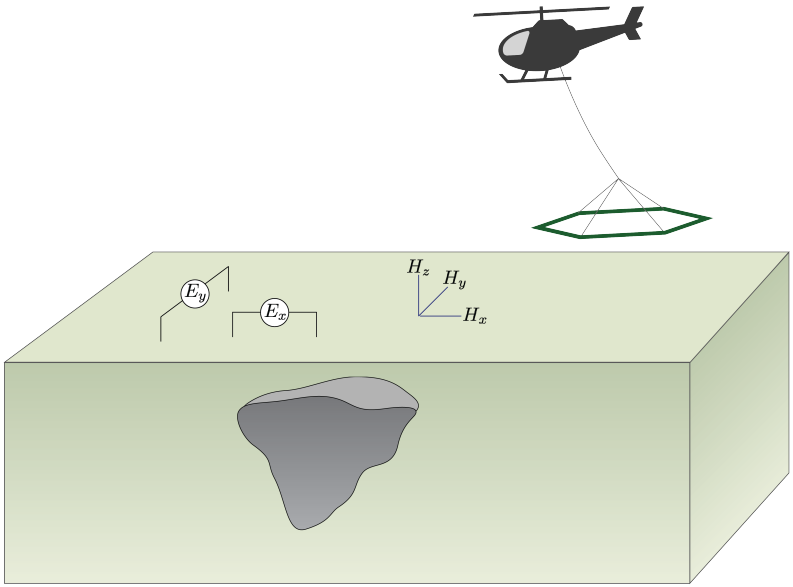
- times?



- Components?
- Location?
  - Airborne
  - Ground
  - Borehole

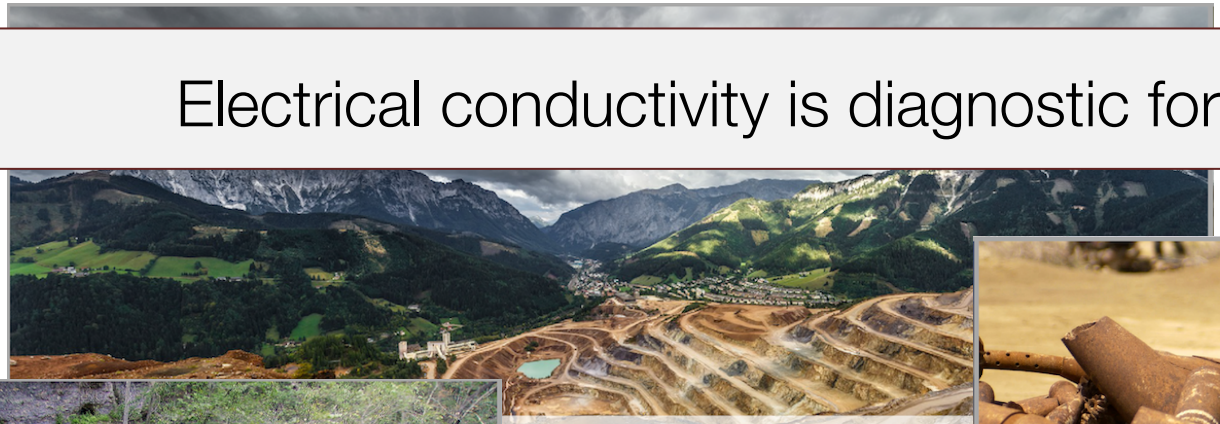




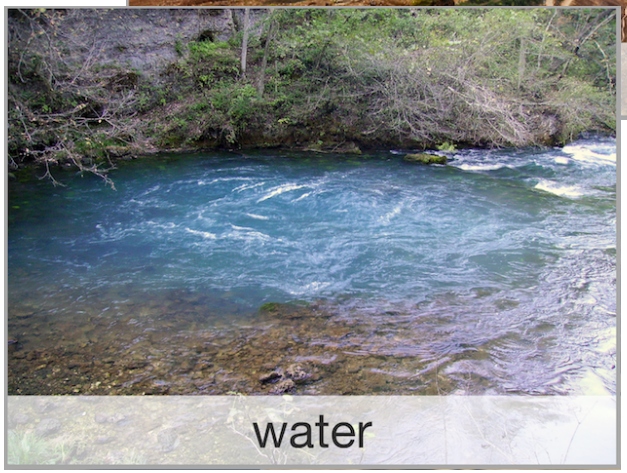


Three problems

Electrical conductivity is diagnostic for all three

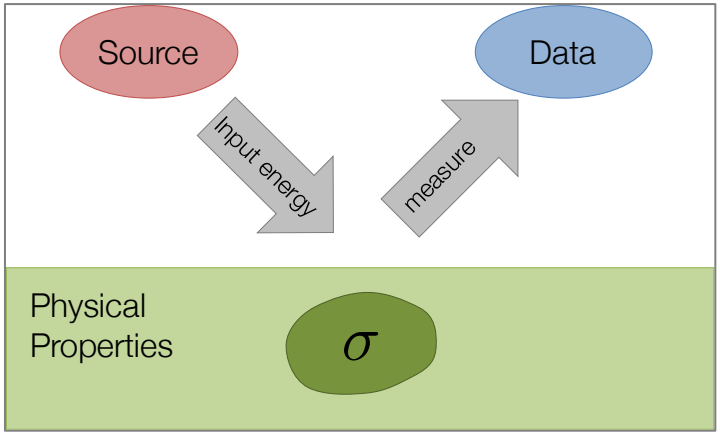


minerals



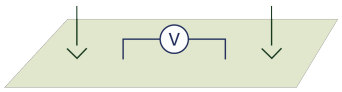
water

unexploded ordnance



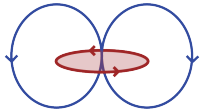
End of Introduction

Next up

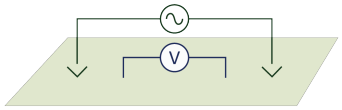


DC Resistivity

EM Fundamentals

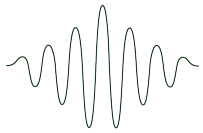


Inductive Sources



Grounded Sources

Natural Sources



GPR

Induced Polarization

The Future

Lunch: Play with apps