DISC 2017

Electromagnetics
Fundamentals and Applications

http://disc2017.geosci.xyz/bonn

SOCIETY OF EXPLORATION GEOPHYSICISTS

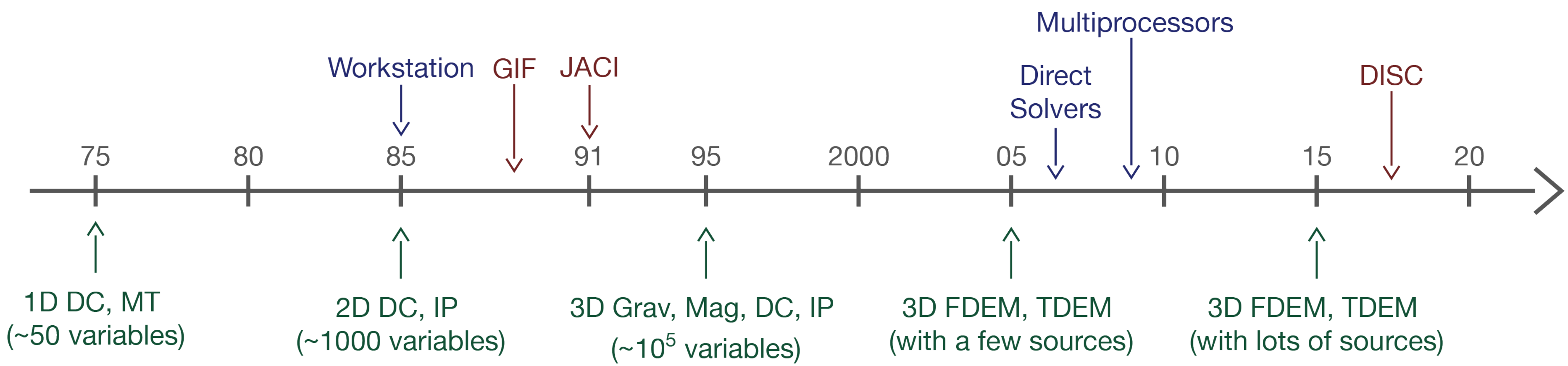
Thanks to…

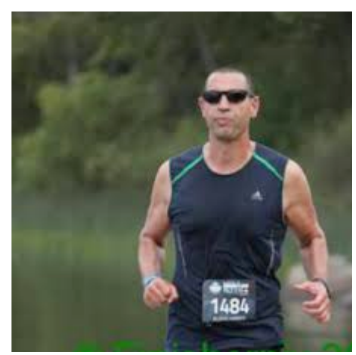
Andreas Kemna

Florian Wagner

Some Background

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



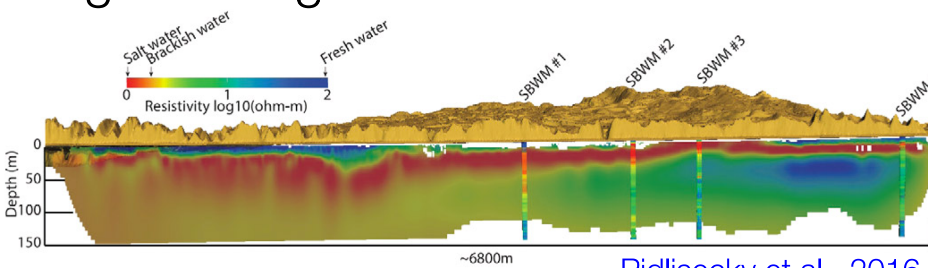


Result: Computing power + advances in inversion methodology
→ we can now solve most EM geophysics problems

Instrumentation and Data

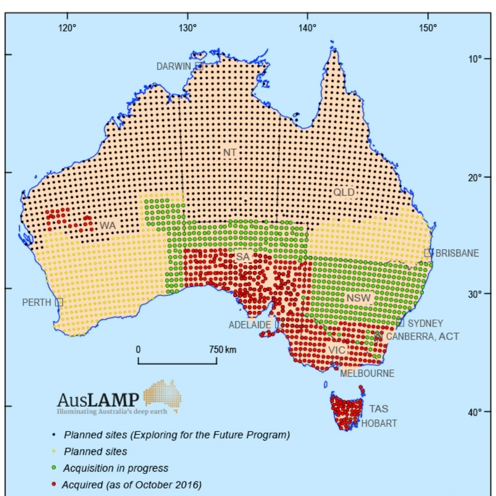
- The second major advance is in data acquisition
- Data with unprecedented data quality and quantity.

Large-scale ground water studies: California

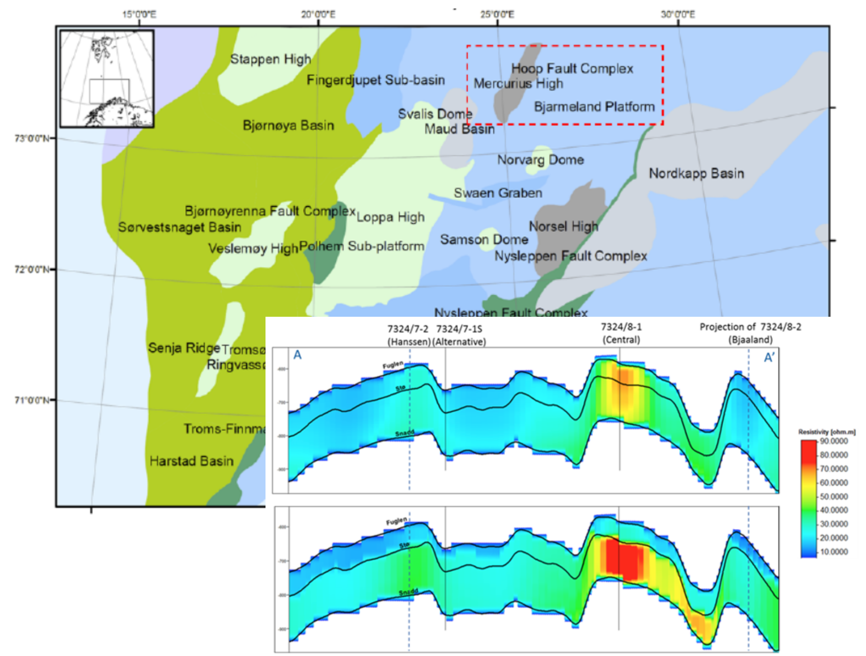


[Pidlisecky et al., 2016]

AusLamp: Continental Scale MT



Offshore: Hydrocarbon De-risking



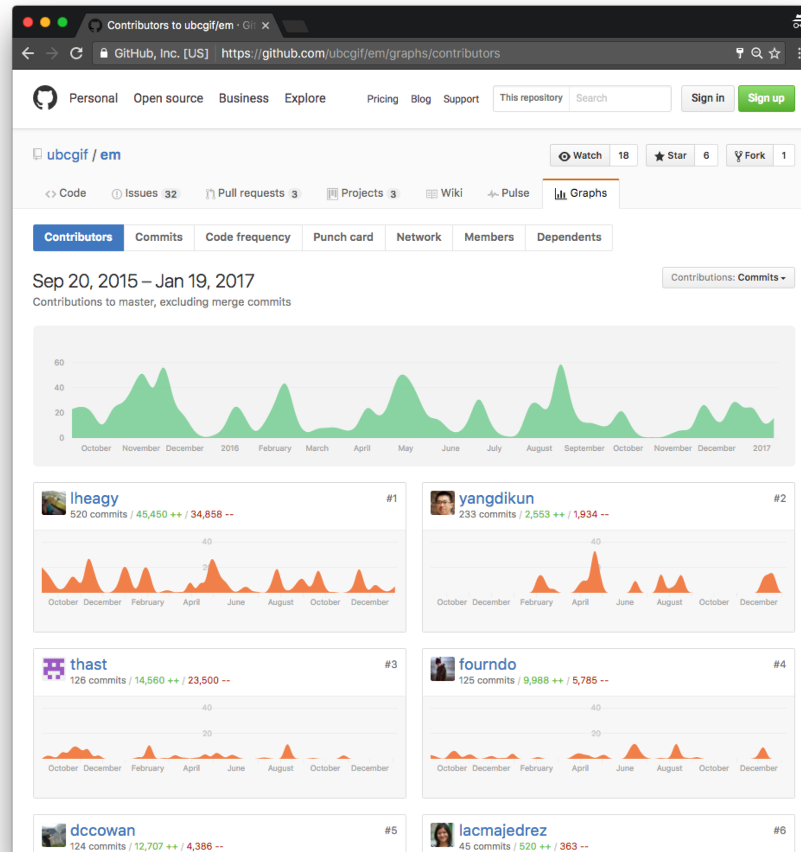
[Alvarez et al, EM.GeoSci]

Web and Open Source Resources

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

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 …

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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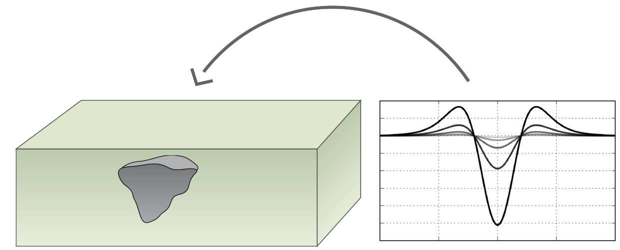
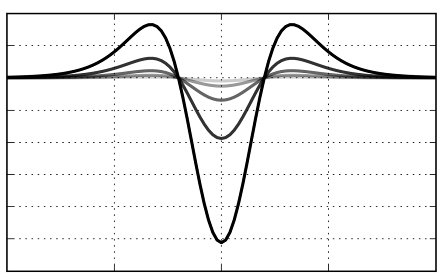
DISC can take advantage of a Perfect Storm

Problems

Inversion capabilities



High quality data

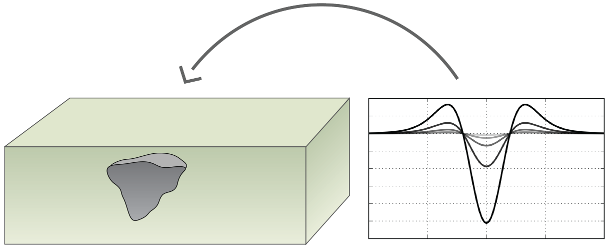


Web tools to communicate

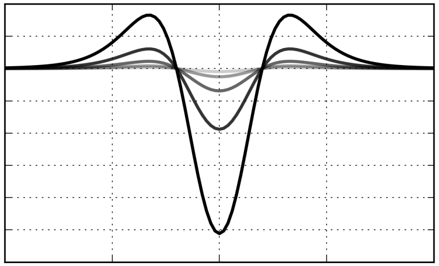
DISC can take advantage of a Perfect Storm

Problems

Inversion capabilities



High quality data



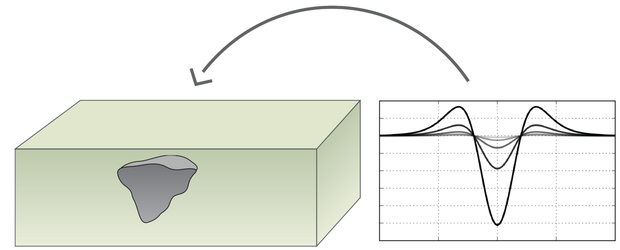
Web tools to communicate

A good idea but missing an important ingredient …

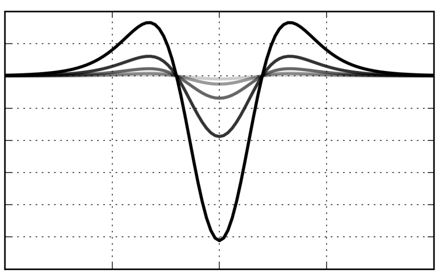
Talented Young Geoscientists

Problems

Inversion capabilities



High quality data



Web tools to communicate

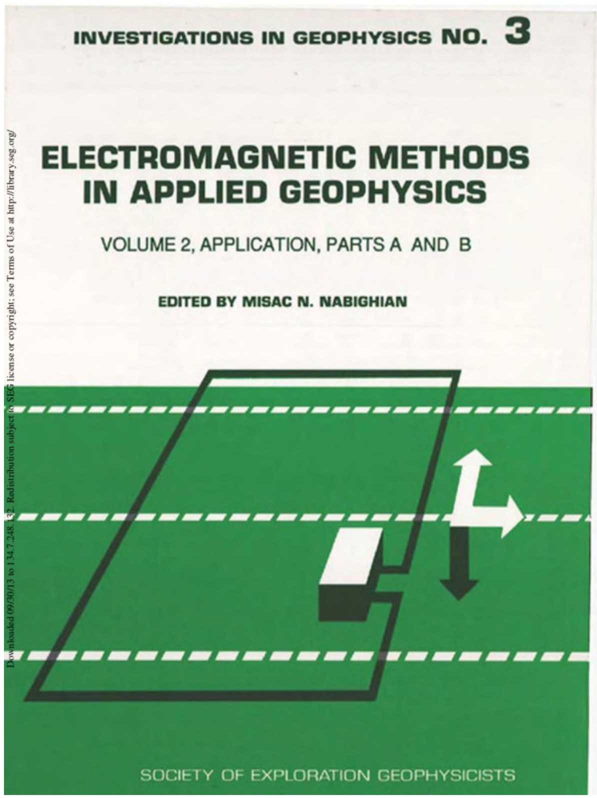
Seogi

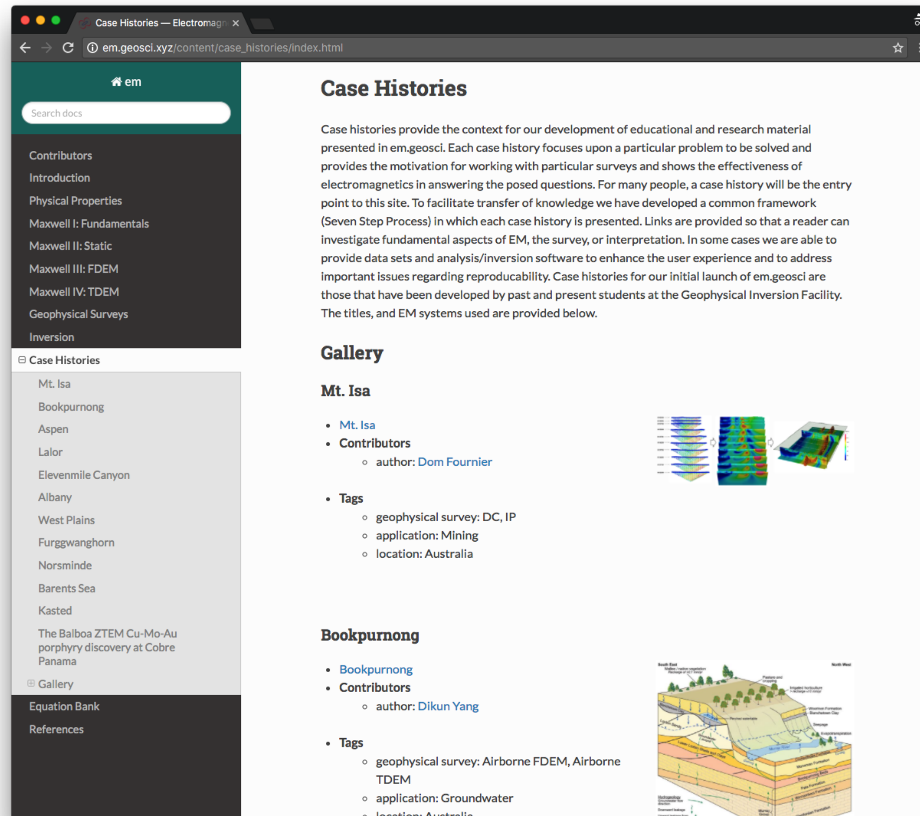
Lindsey

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

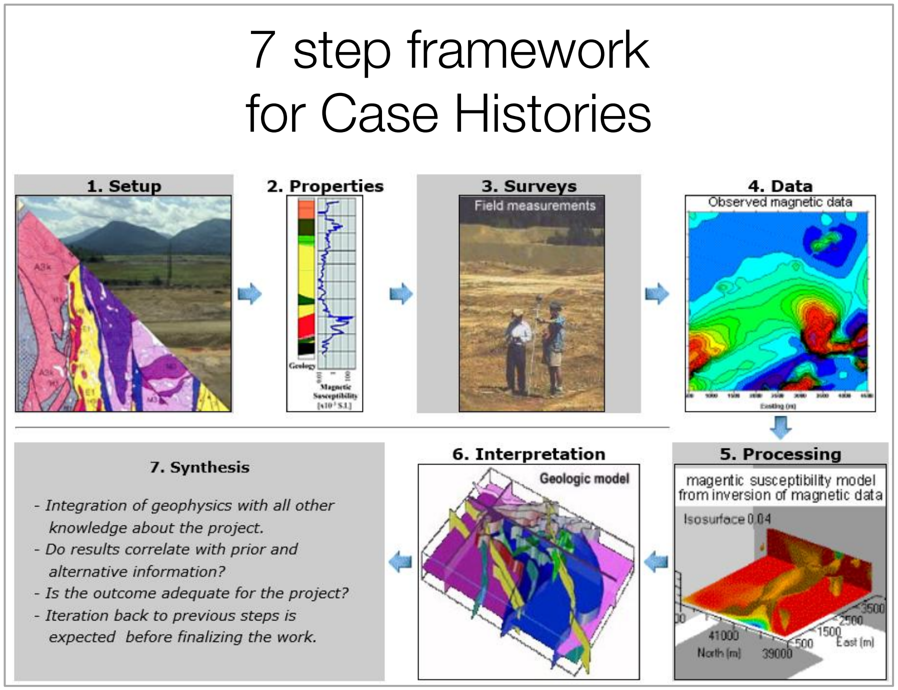
Resources: EM.geosci

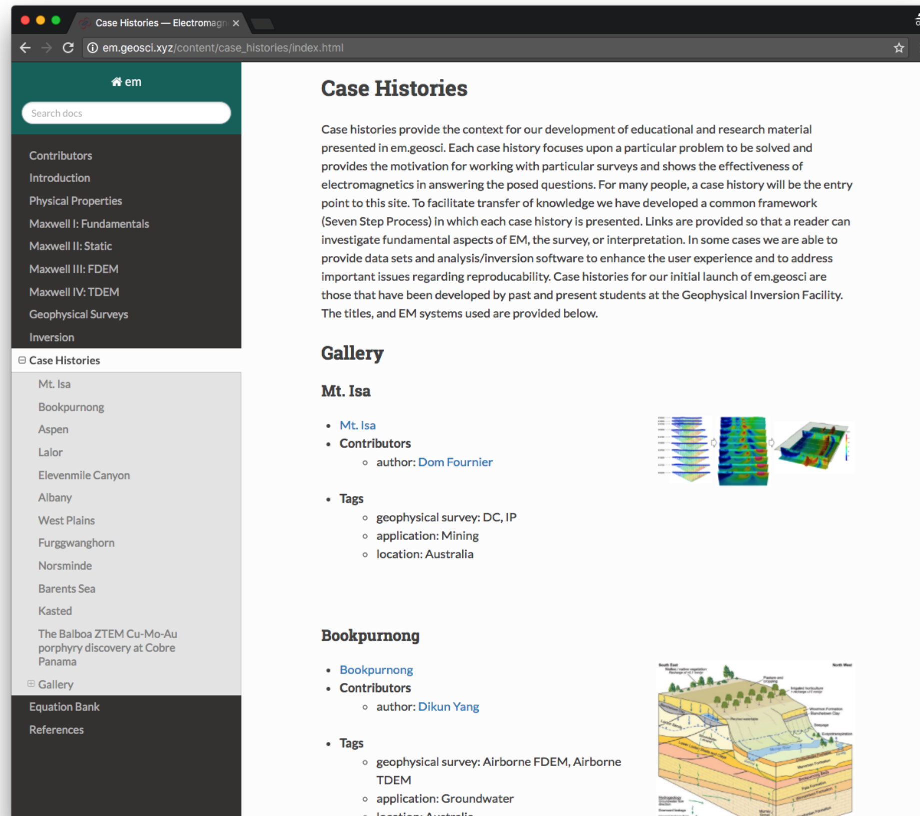




http://em.geosci.xyz

Resources: EM.geosci





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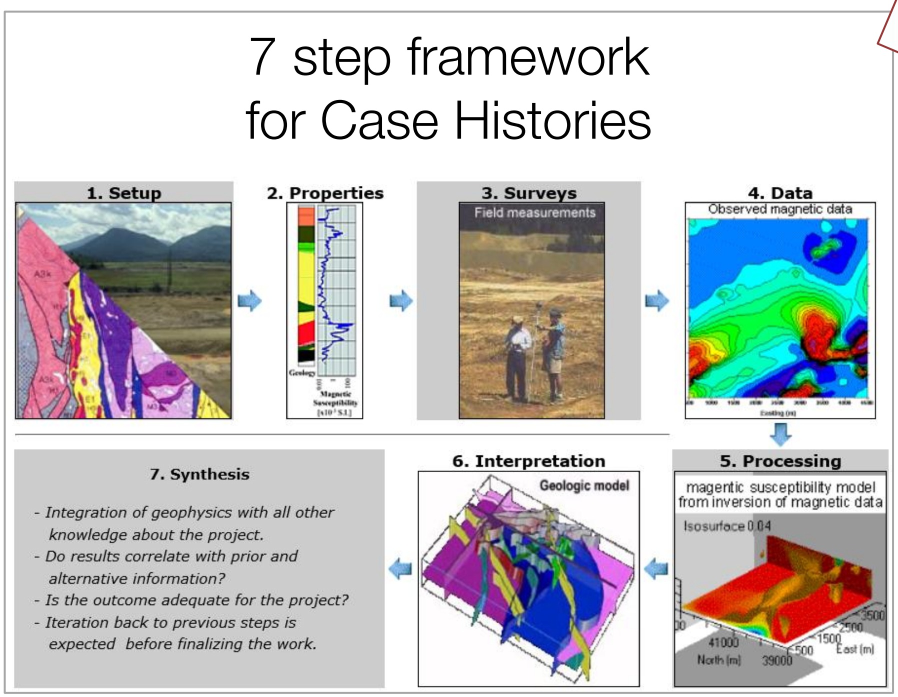
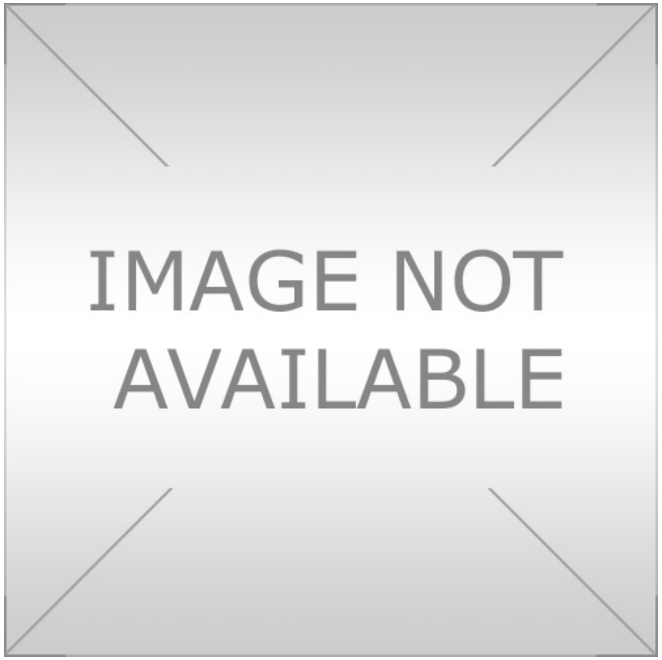


http://em.geosci.xyz

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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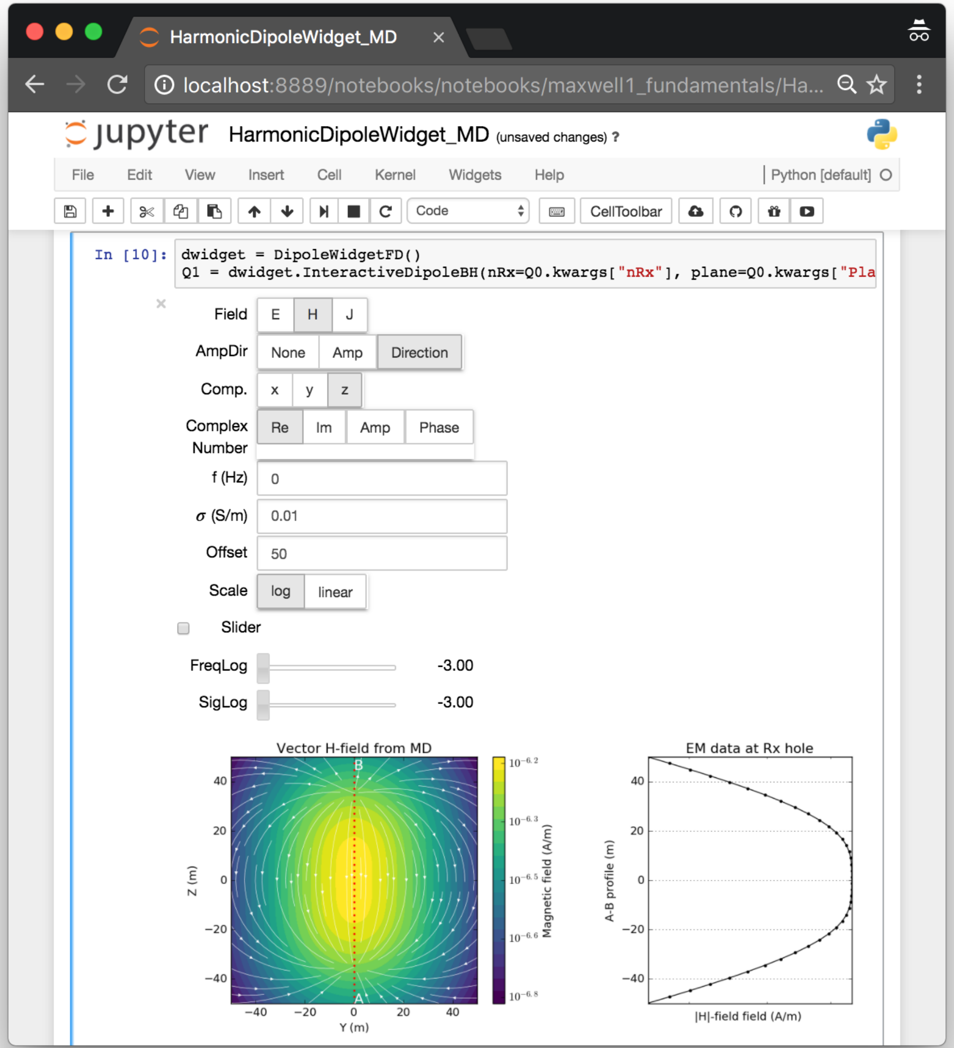
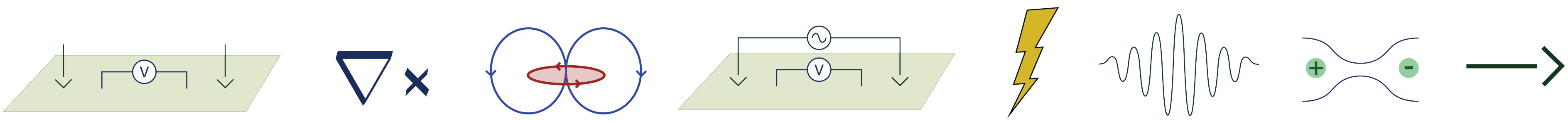


http://em.geosci.xyz/apps.html

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

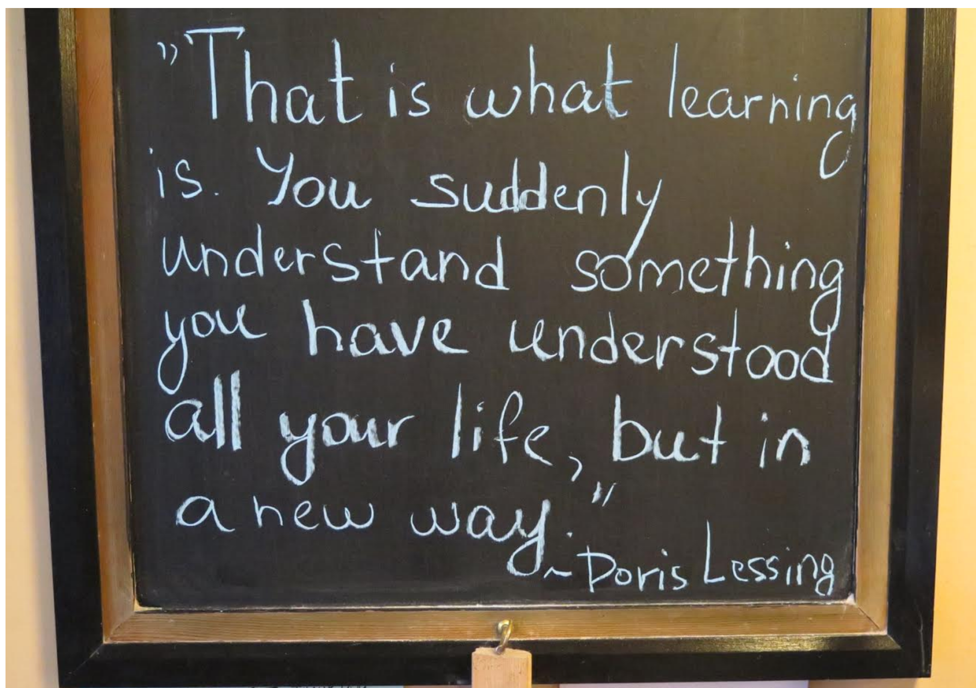


DC Resistivity | EM Fundamentals | Inductive Sources | Grounded Sources | Natural Sources | GPR | Induced Polarization | The Future

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…

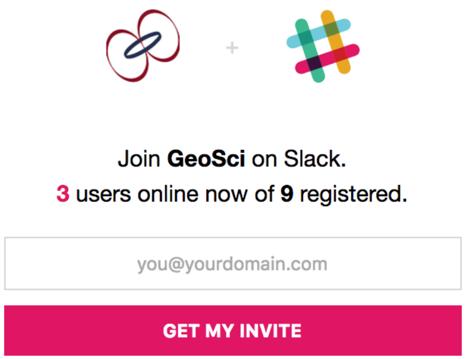


DISC is a 2-day event

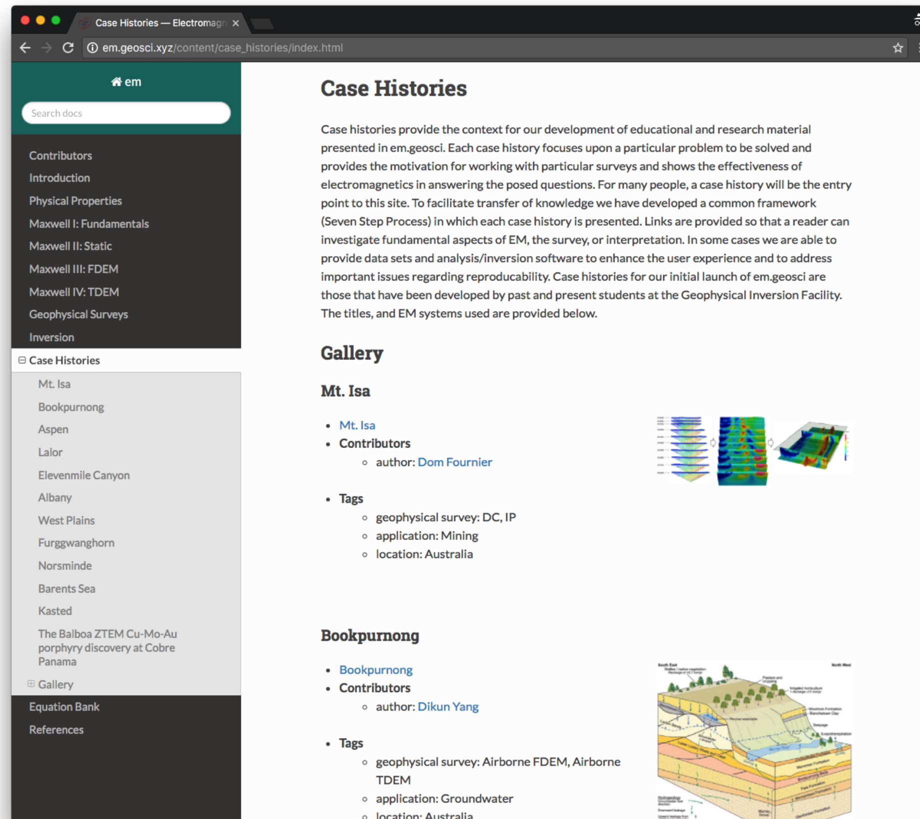
- SEG DISC Course (today)
  - Sponsored by SEG
- DISC Lab (tomorrow) (sponsored by GIF)
  - Capture “local” applications
  - Share on the web
- The tour:
  - 30 locations
  - Capture geoscience problems around the world
  - Connect geoscientists worldwide, build a community

Connecting & Contributing

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



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



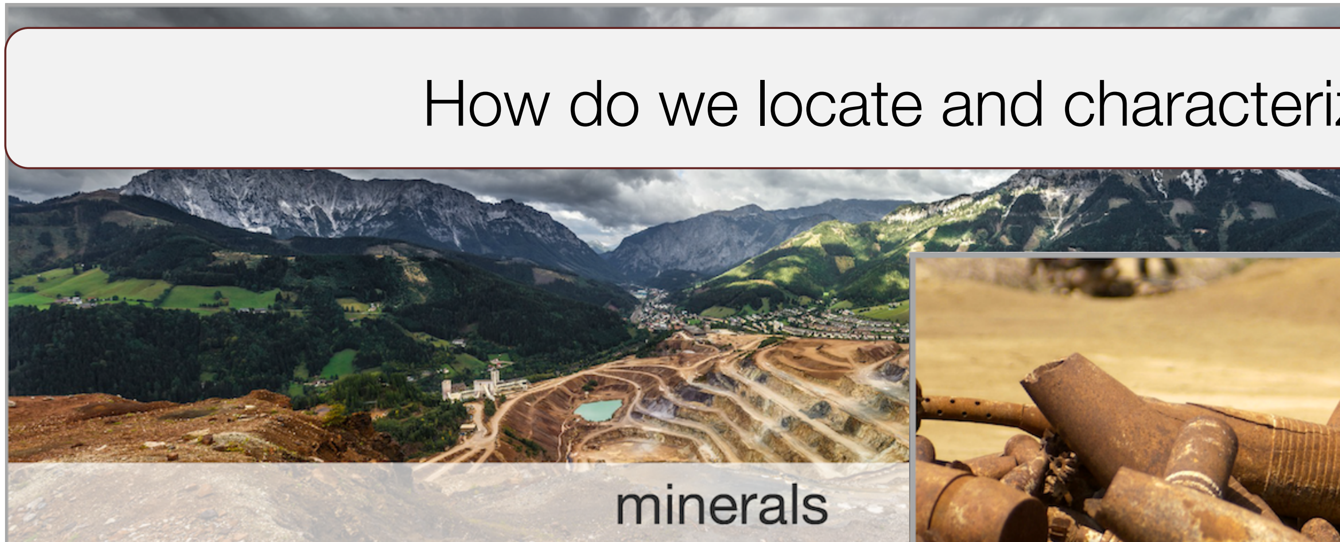
Introduction to EM

DISC 2017

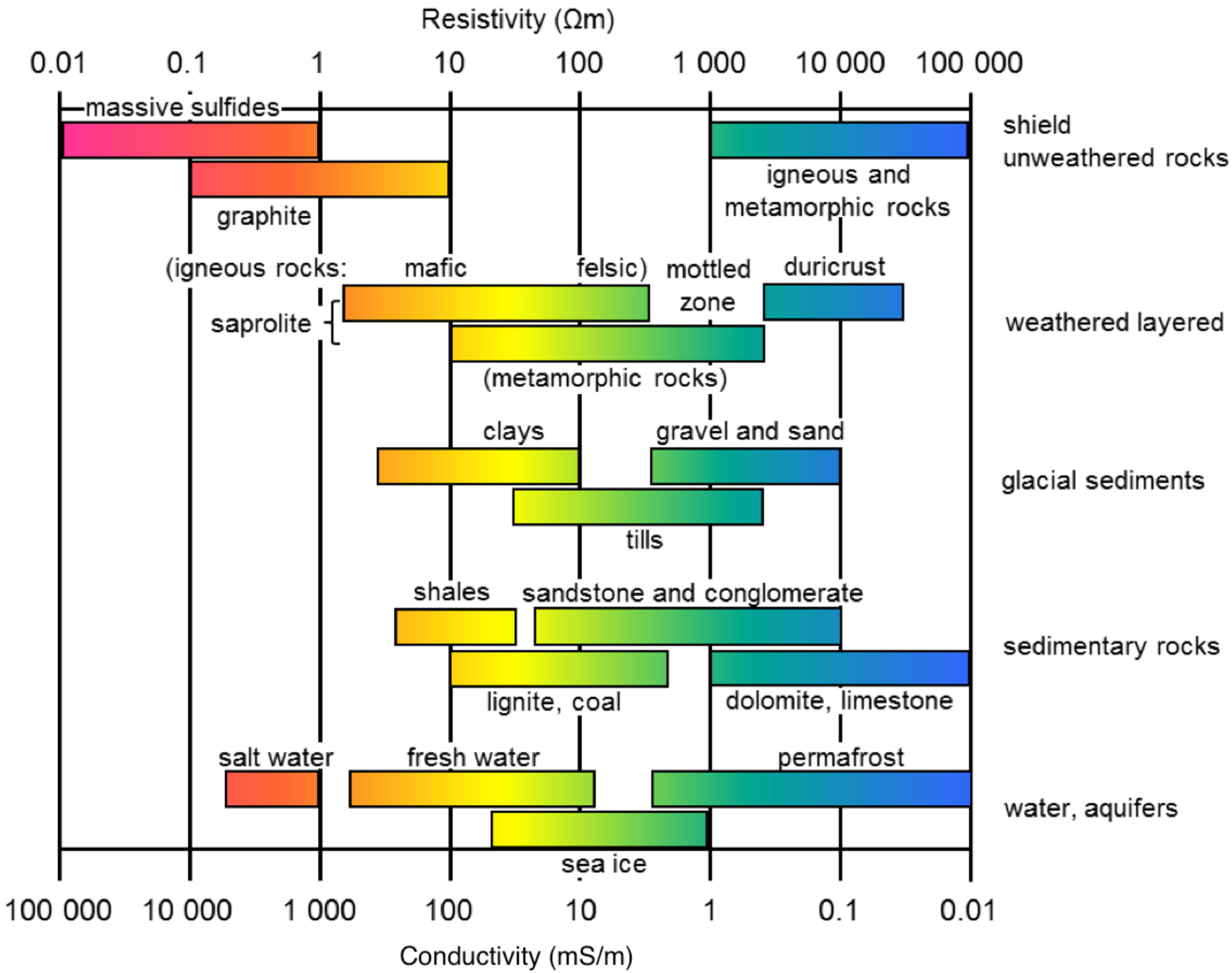
Electromagnetics Fundamentals and Applications

Three problems

How do we locate and characterize …



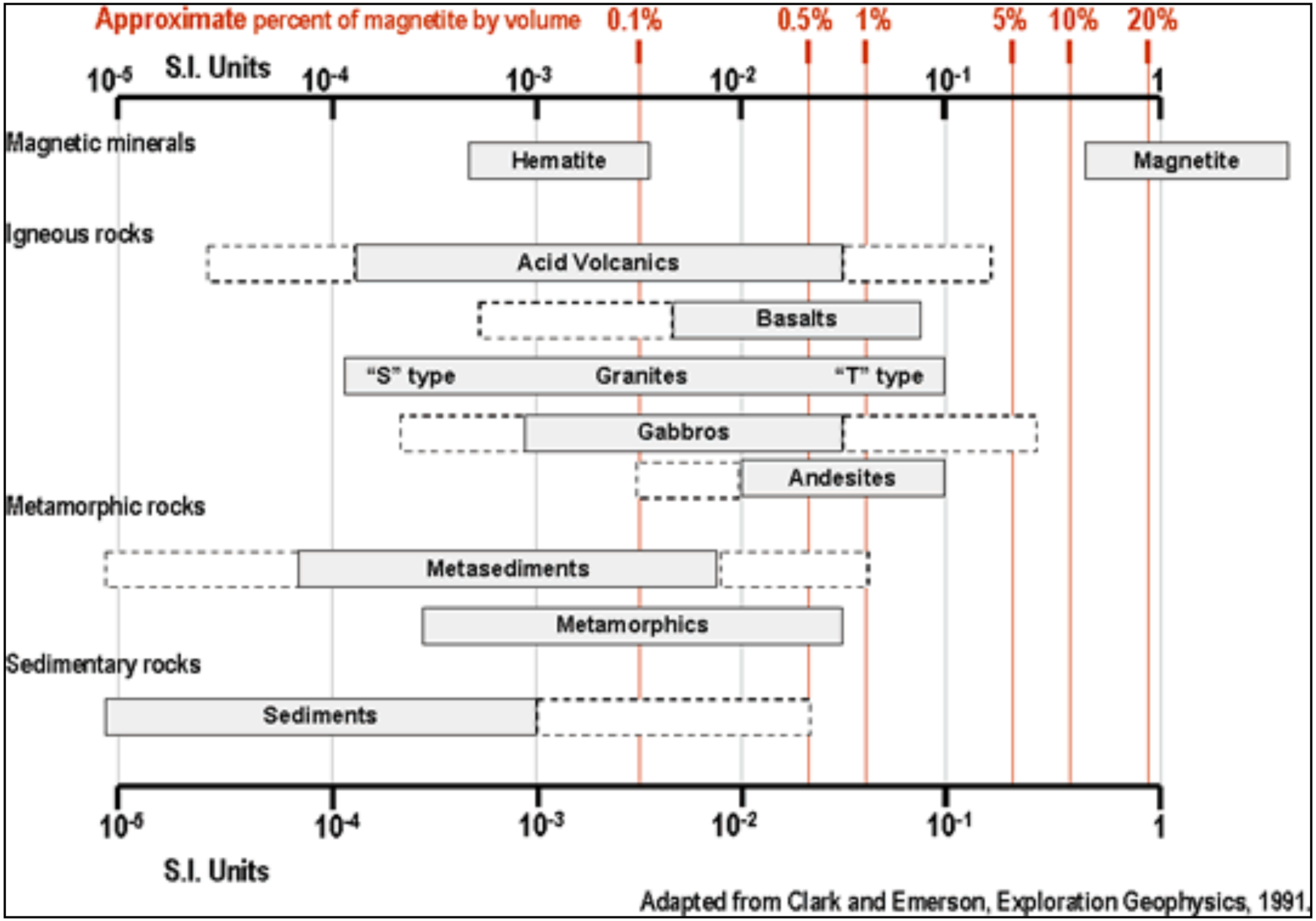
Electrical Resistivity / Conductivity



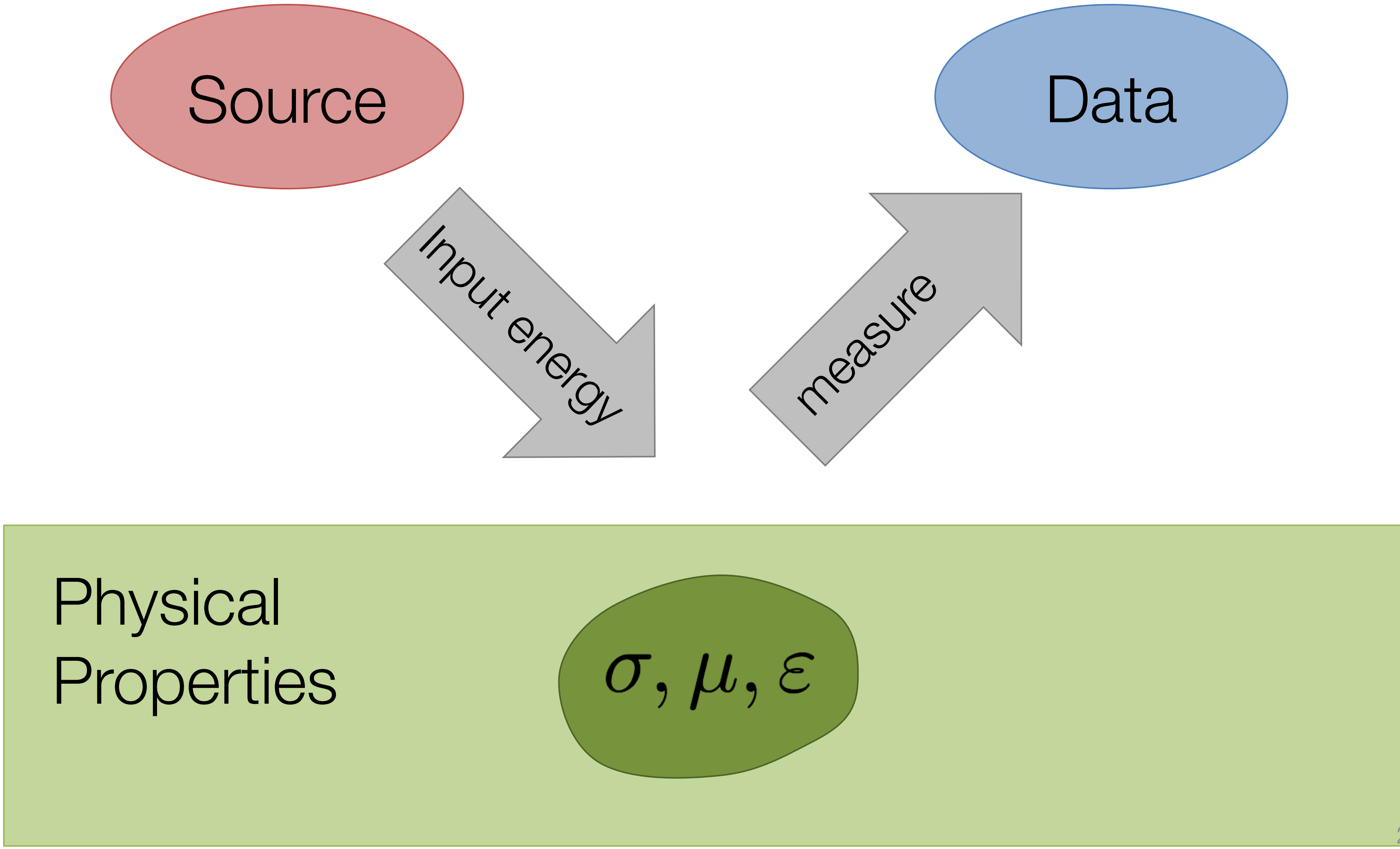
Dielectric constant

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

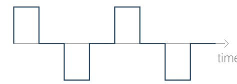
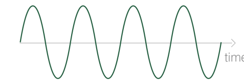
Magnetic Susceptibility



EM Survey & Physical Properties



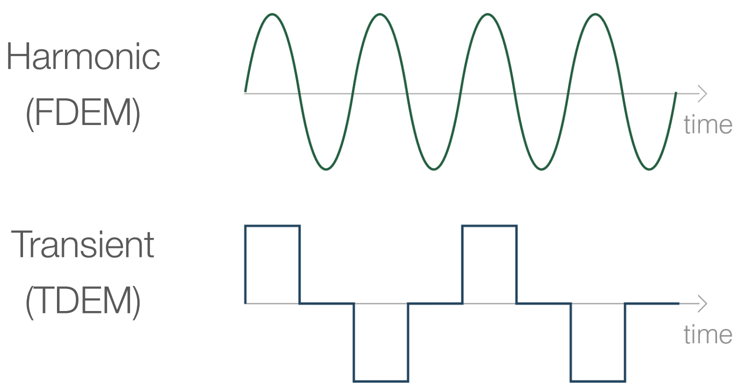
Basic Equations

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

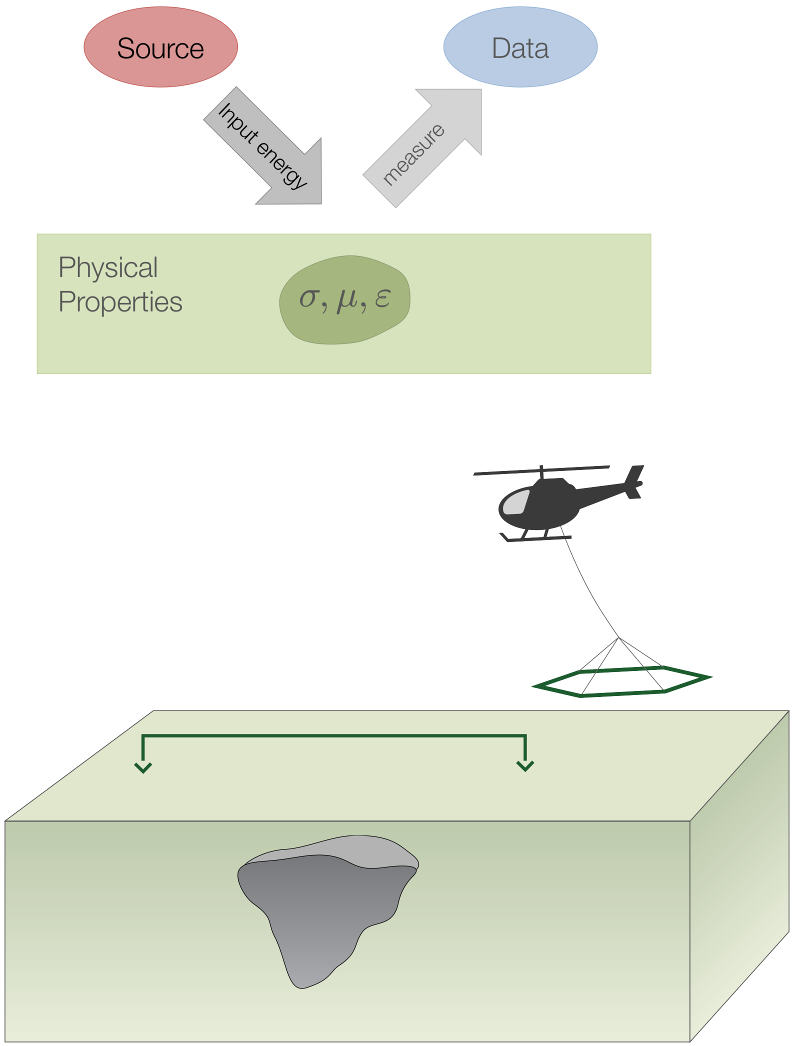
* Solve with sources and boundary conditions

Electromagnetic Survey: Sources

- Type
  - Inductive
  - Grounded
- Waveform

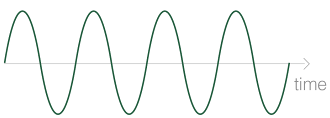


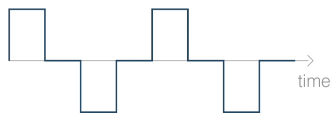
- Location
  - Airborne
  - Ground
  - Borehole



Electromagnetic Survey: Data

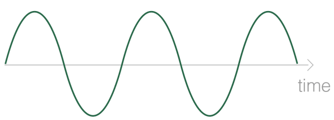
- Which field?



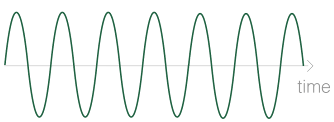


$\mathbf{E}, \mathbf{B}$ $\qquad$ $\mathbf{e}, \mathbf{b}, \frac{d\mathbf{b}}{dt}$

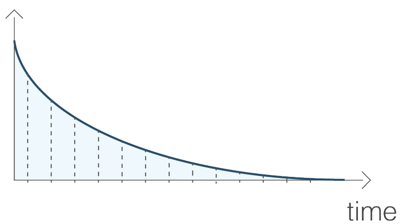
- Which frequencies?



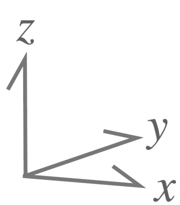
or

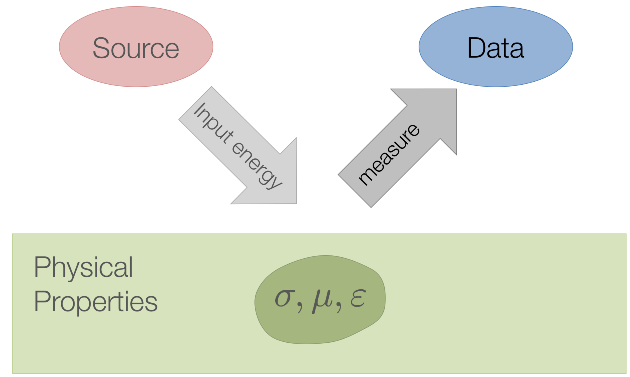


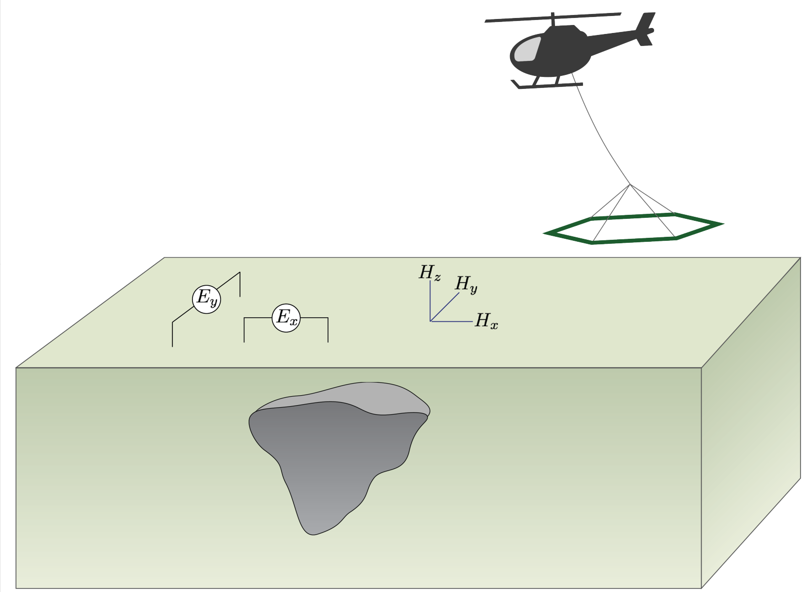
- times?



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

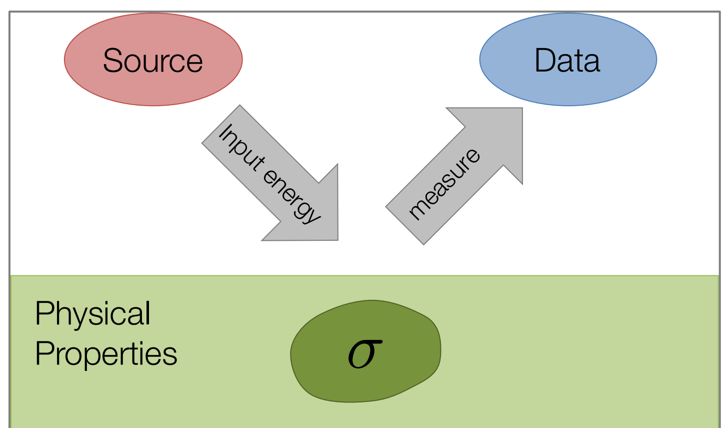






Three problems

Electrical conductivity is diagnostic for all three



End of Introduction