



DISC

2017

Electromagnetics
Fundamentals and Applications

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



SOCIETY OF EXPLORATION
— GEOPHYSICISTS —

Thanks to...

Mark Kneipp



Emma Brand

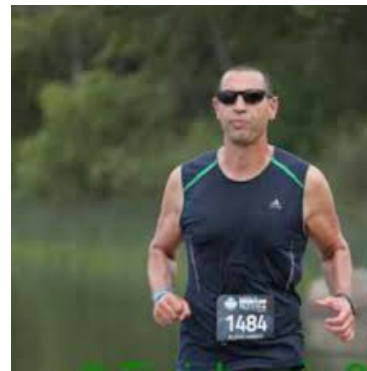
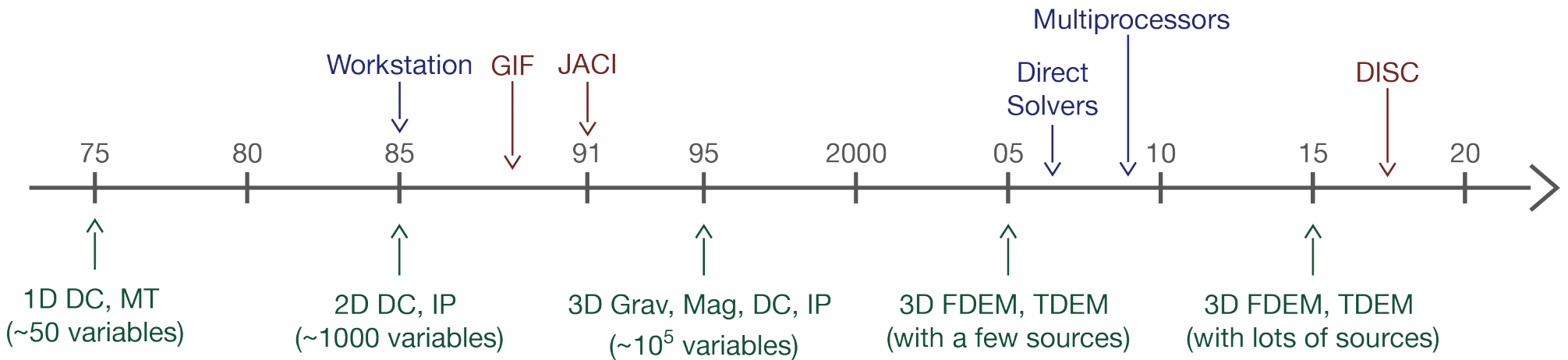


Australian Society of
Exploration Geophysicists



Some Background

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

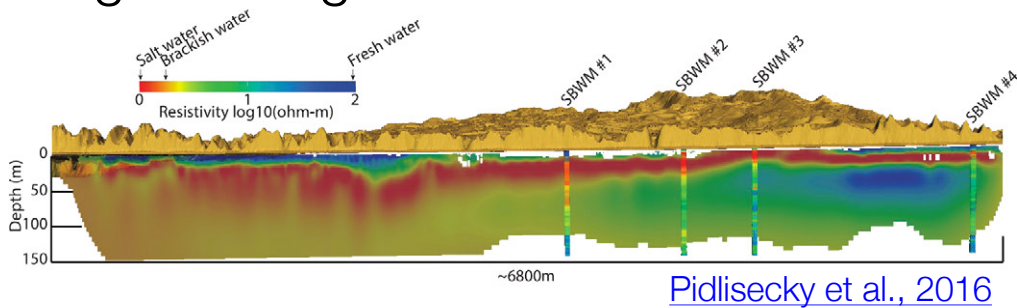


Result: Computing power + advances in inversion methodology
→ we can now solve most EM geophysics problems

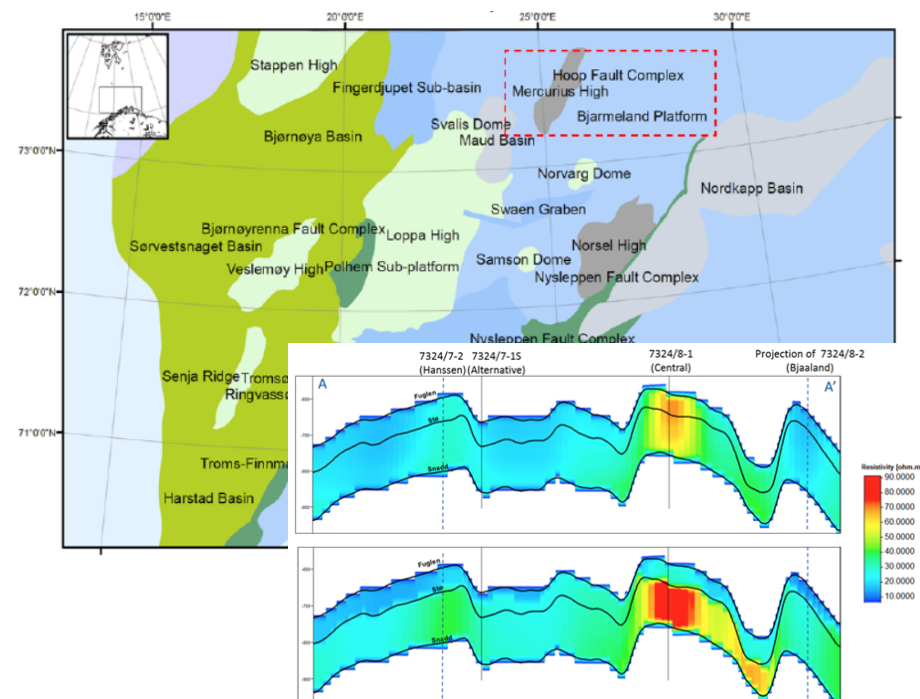
Instrumentation and Data

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

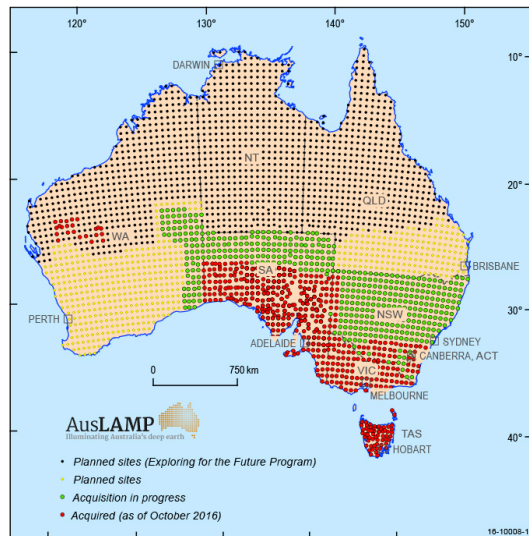
Large-scale ground water studies: California



Offshore: Hydrocarbon De-risking



AusLamp: Continental Scale MT



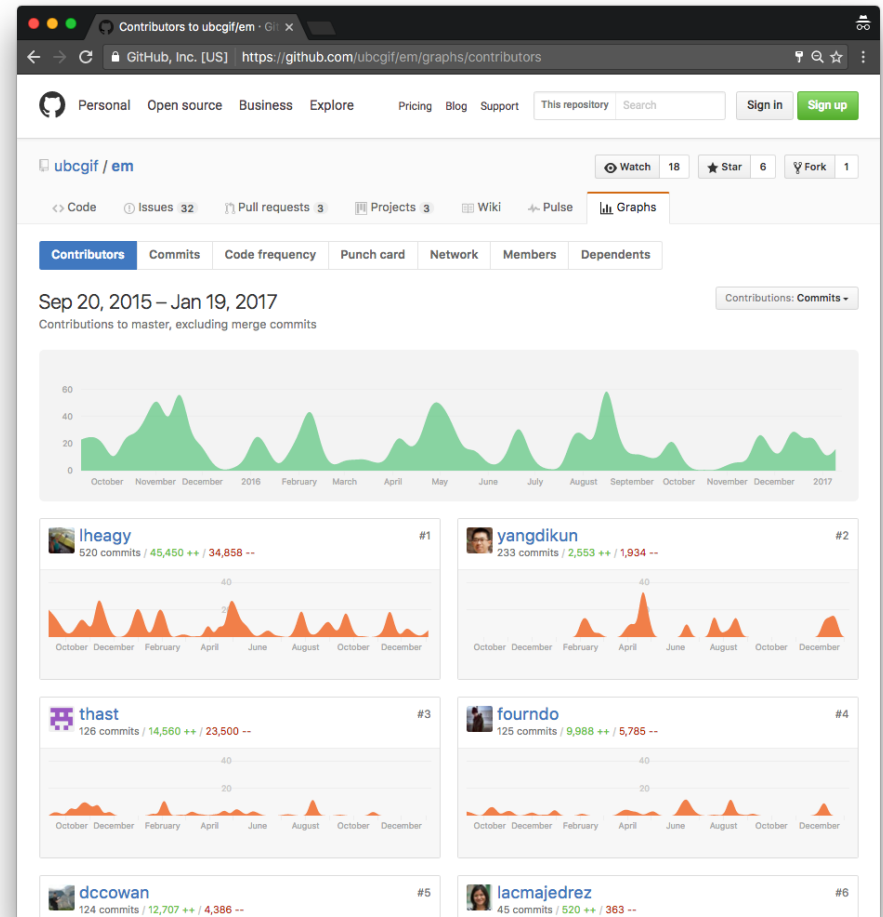
Web and Open Source Resources

- 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 ...



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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- Don't understand the technique
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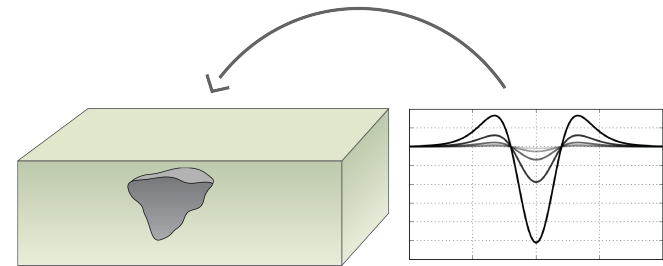
Are there situations, similar to mine, in which EM has been applied?

DISC can take advantage of a Perfect Storm

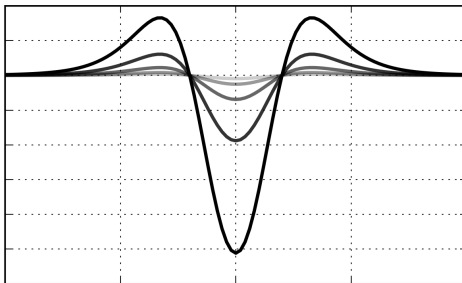
Problems



Inversion capabilities



High quality data



Web tools to
communicate

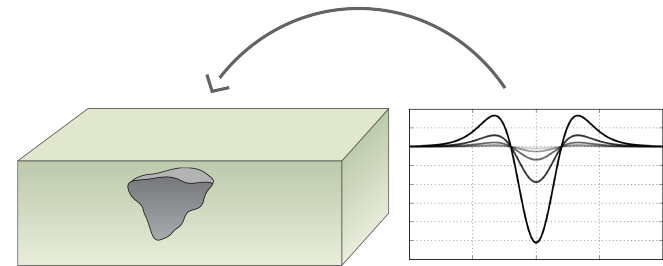


DISC can take advantage of a Perfect Storm

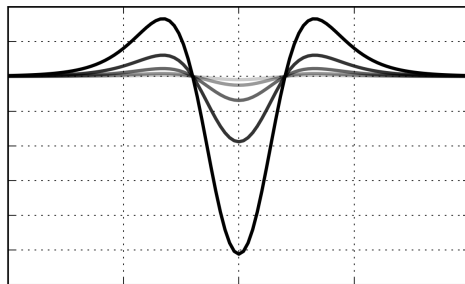
Problems



Inversion capabilities



High quality data



Web tools to
communicate



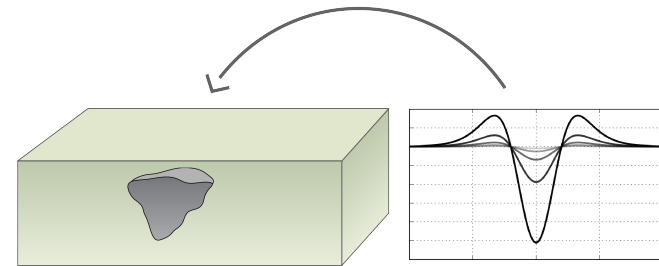
A good idea but missing an important ingredient ...

Talented Young Geoscientists

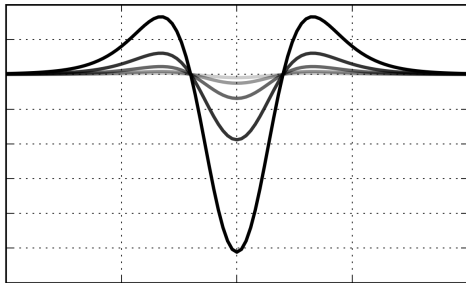
Problems



Inversion capabilities



High quality data



Web tools to
communicate



Seogi

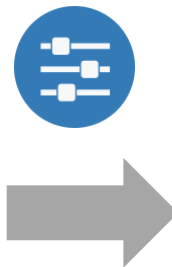
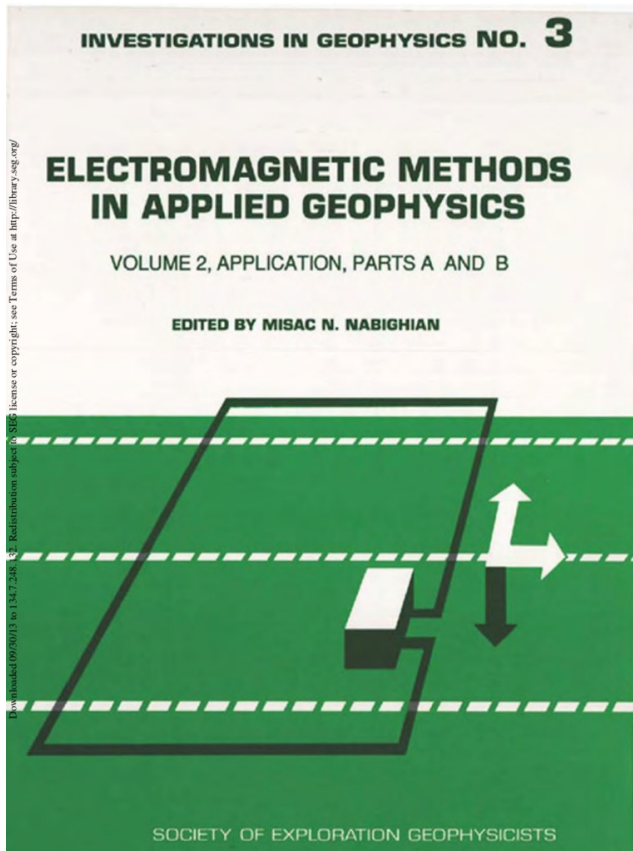


Lindsey

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

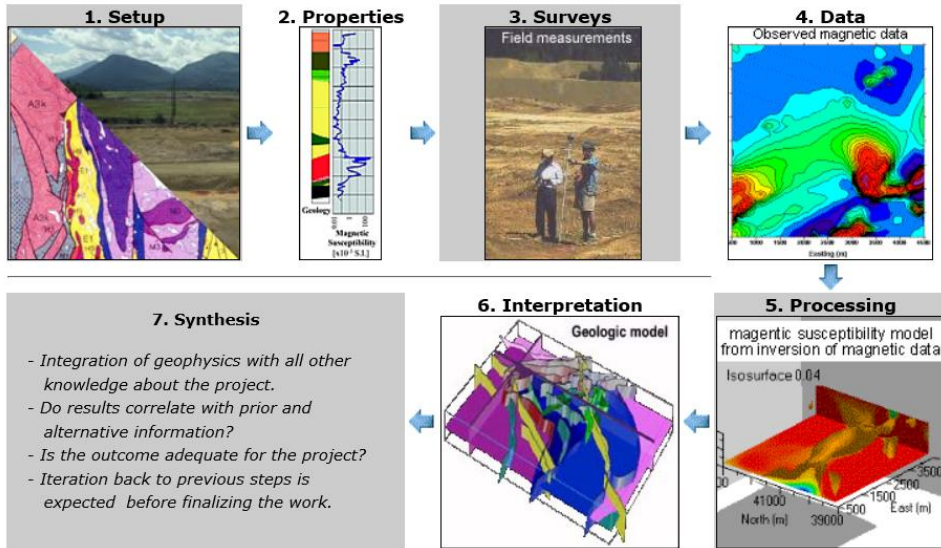


The screenshot shows the website "em.geosci.xyz" with the "Case Histories" section. The page has a dark green header with the "em" logo and a search bar. A sidebar on the left lists various categories: Contributors, Introduction, Physical Properties, Maxwell I: Fundamentals, Maxwell II: Static, Maxwell III: FDEM, Maxwell IV: TDEM, Geophysical Surveys, and Inversion. Under "Case Histories", there is a list of entries including 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 main content area is titled "Case Histories" and contains a paragraph explaining the purpose of case histories. Below this is a "Gallery" section with two entries: "Mt. Isa" and "Bookpurnong". Each entry lists contributors and tags. The "Mt. Isa" entry lists the author as Dom Fournier and tags include geophysical survey (DC, IP), application (Mining), and location (Australia). The "Bookpurnong" entry lists the author as Dikun Yang and tags include geophysical survey (Airborne FDEM, Airborne TDEM), application (Groundwater), and location (Australia). There are also small images related to each case history.

<http://em.geosci.xyz>

Resources: EM.geosci

7 step framework for Case Histories



Case Histories — Electromagnetics

em.geosci.xyz/content/case_histories/index.html

Case Histories

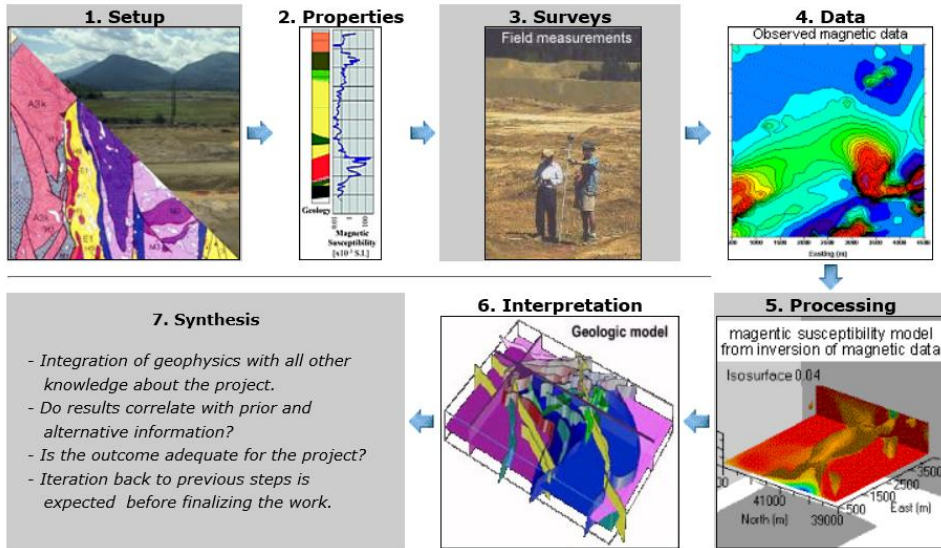
Case histories provide the context for our development of educational and research material presented in em.geosci. Each case history focuses upon a particular problem to be solved and provides the motivation for working with particular surveys and shows the effectiveness of electromagnetics in answering 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**
 - Contributors
 - author: Dom Fournier
 - Tags
 - geophysical survey: DC, IP
 - application: Mining
 - location: Australia
- Bookpurnong**
 - Contributors
 - author: Dikun Yang
 - Tags
 - geophysical survey: Airborne FDEM, Airborne TDEM
 - application: Groundwater
 - location: Australia

Resources: EM.geosci

7 step framework for Case Histories



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
 - Furggwanhorn
 - Norsminde
 - Barents Sea
 - Kasted
 - The Balboa ZTEM Cu-Mo-Au porphyry discovery at Cobre Panama
- Equation Bank
- References

Gallery

Mt. Isa

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

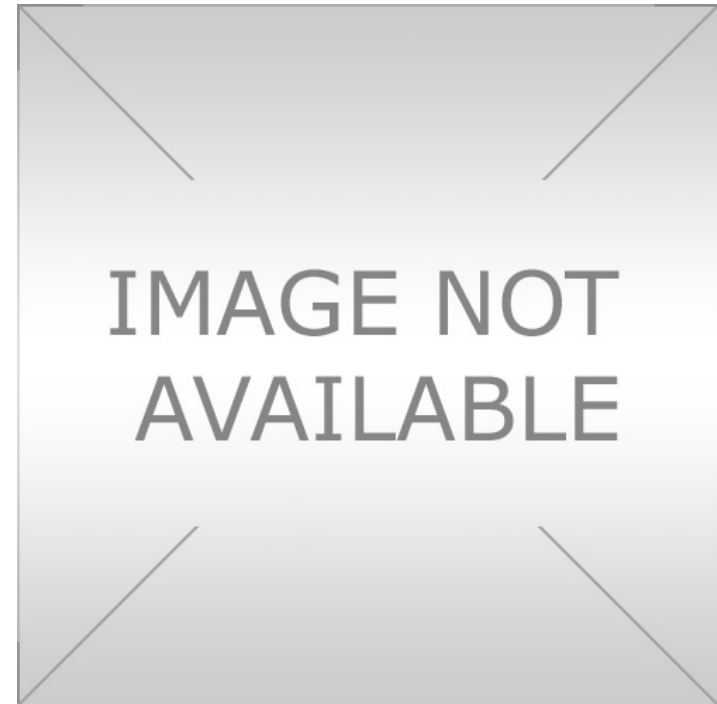
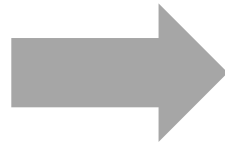
Bookpurnong

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

Why Apps

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

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

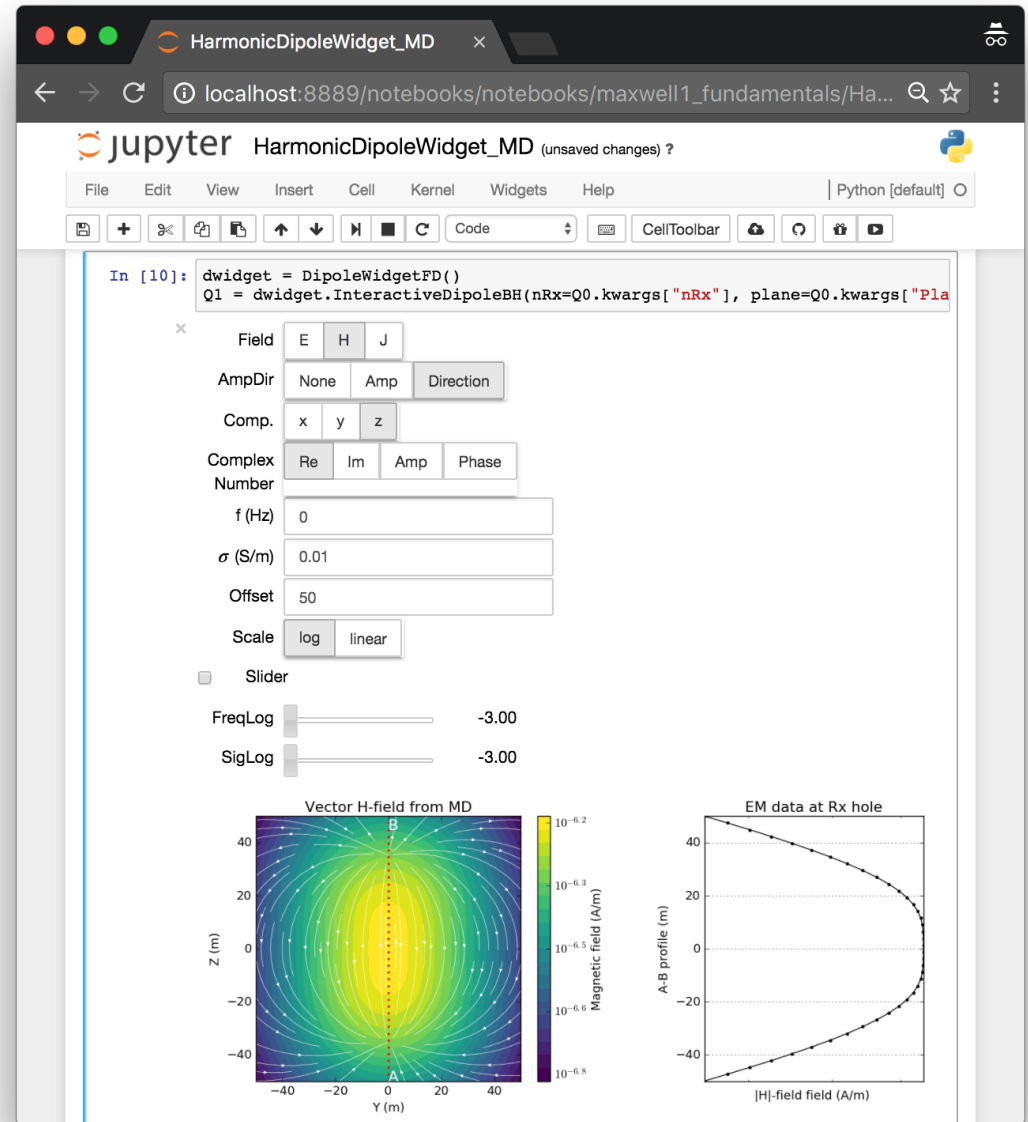
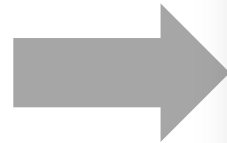


<http://em.geosci.xyz/apps.html>

Why Apps

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

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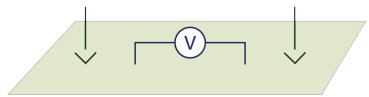


<http://em.geosci.xyz/apps.html>

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

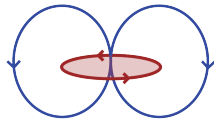
Agenda for today



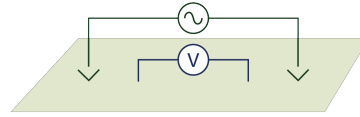
DC Resistivity



EM
Fundamentals



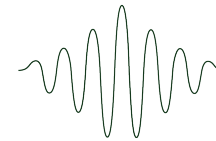
Inductive
Sources



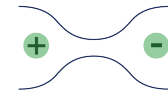
Grounded
Sources



Natural
Sources



GPR



Induced
Polarization

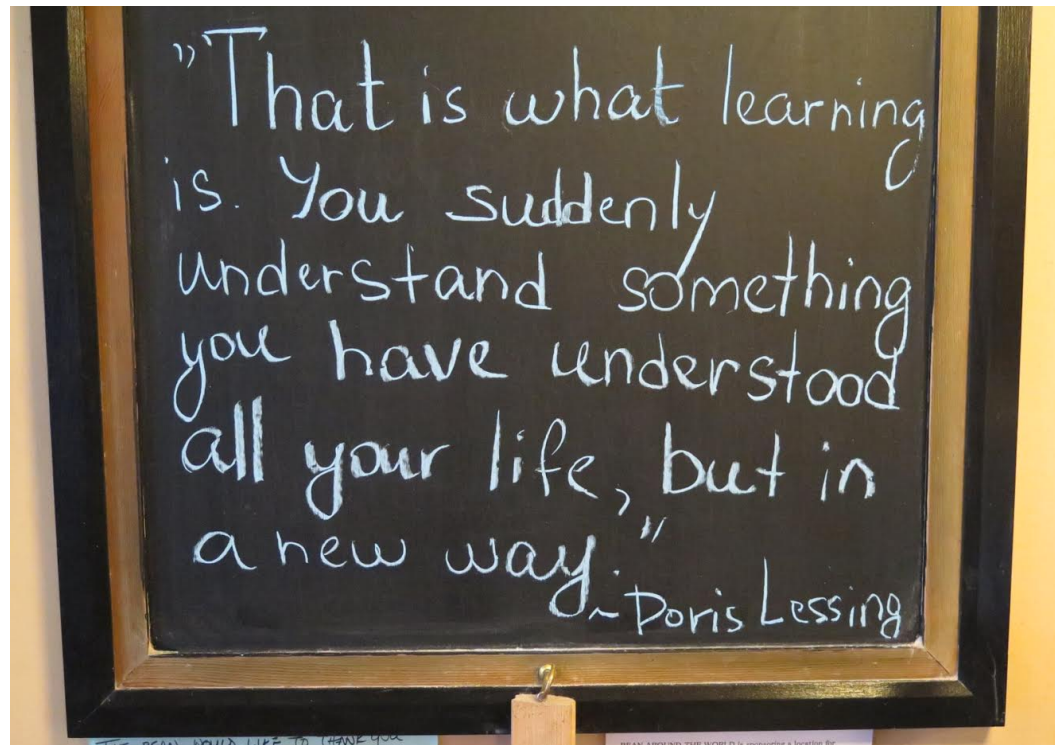


The
Future

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

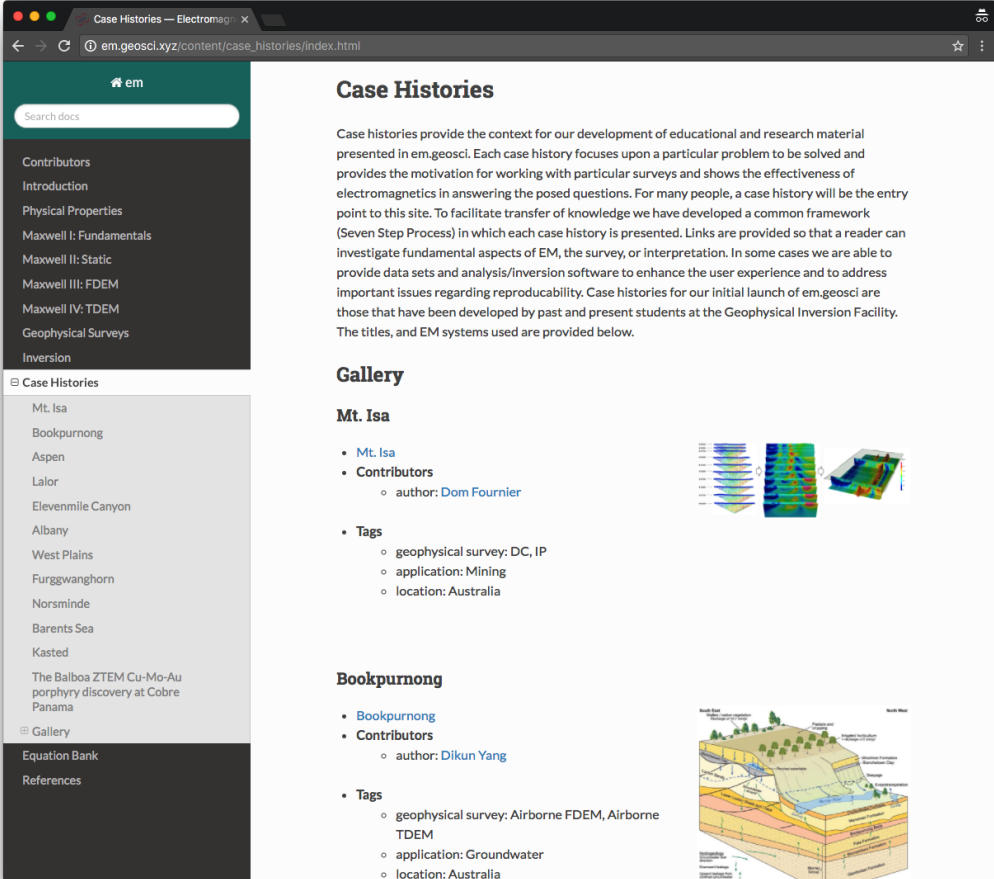
- Today: Slack
 - <http://slack.geosci.xyz/>



Join **GeoSci** on Slack.
3 users online now of 9 registered.

GET MY INVITE

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



The screenshot shows a web browser displaying the 'Case Histories' page on the em.geosci.xyz website. The browser's address bar shows the URL 'em.geosci.xyz/content/case_histories/index.html'. The page has a dark green header with the 'em' logo and a search bar. A sidebar on the left contains a navigation menu with categories like 'Contributors', 'Introduction', 'Physical Properties', 'Maxwell I: Fundamentals', 'Maxwell II: Static', 'Maxwell III: FDEM', 'Maxwell IV: TDEM', 'Geophysical Surveys', and 'Inversion'. Under 'Case Histories', it lists 'Mt. Isa', 'Bookpurnong', 'Aspen', 'Lalor', 'Elevenmile Canyon', 'Albany', 'West Plains', 'Furggwanhorn', 'Norsminde', 'Barents Sea', 'Kasted', 'The Balboa ZTEM Cu-Mo-Au porphyry discovery at Cobre Panama', and 'Gallery'. The main content area features a 'Case Histories' section with an introductory paragraph, followed by a 'Gallery' section. Two case histories are highlighted: 'Mt. Isa' and 'Bookpurnong'. Each entry includes a list of contributors and tags such as 'geophysical survey', 'application', and 'location'. To the right of the 'Mt. Isa' entry is a 3D visualization of a geological structure, and to the right of the 'Bookpurnong' entry is a cross-sectional diagram of a geological site.

Introduction to EM

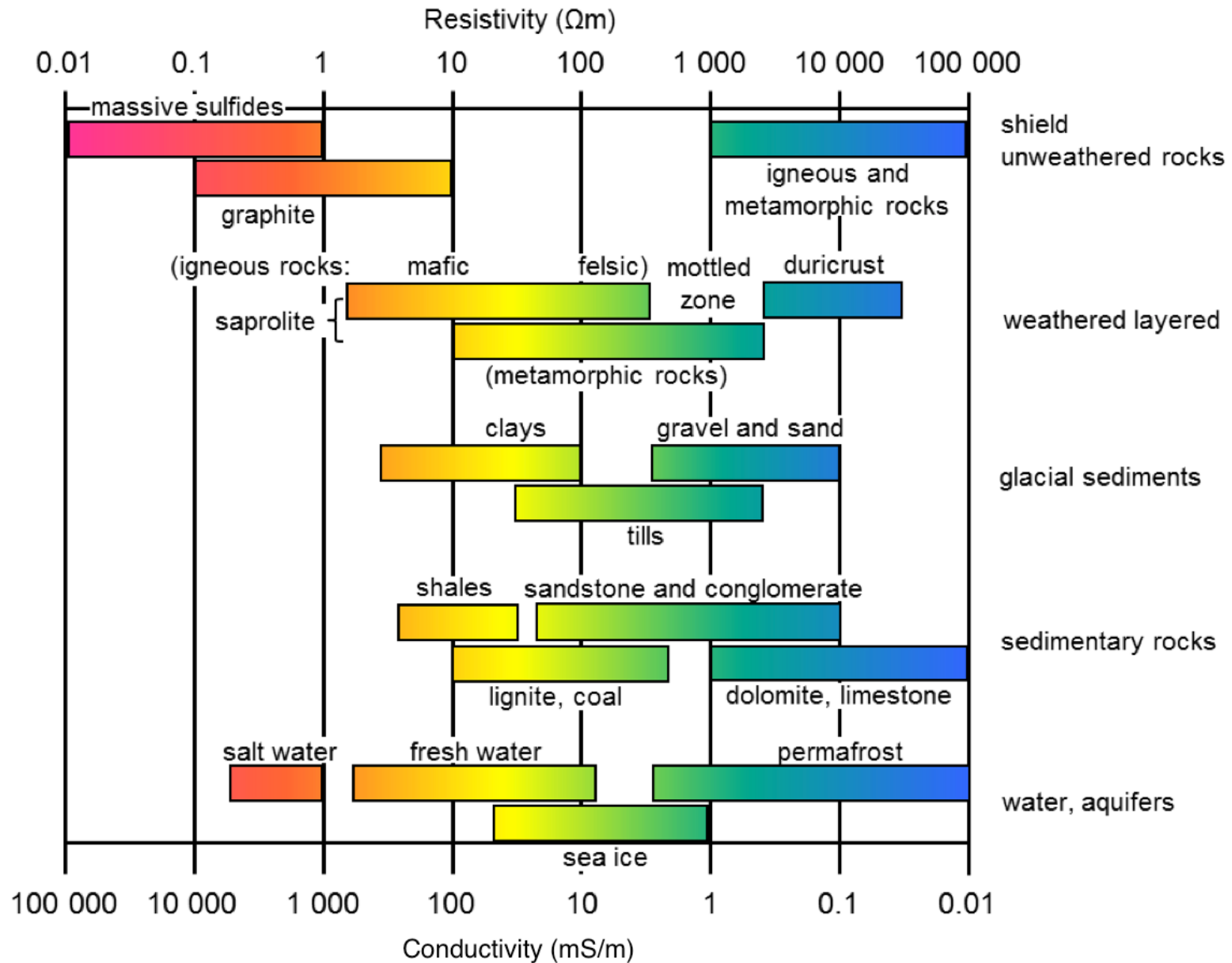


Three problems

How do we locate and characterize ...



Electrical Resistivity / Conductivity

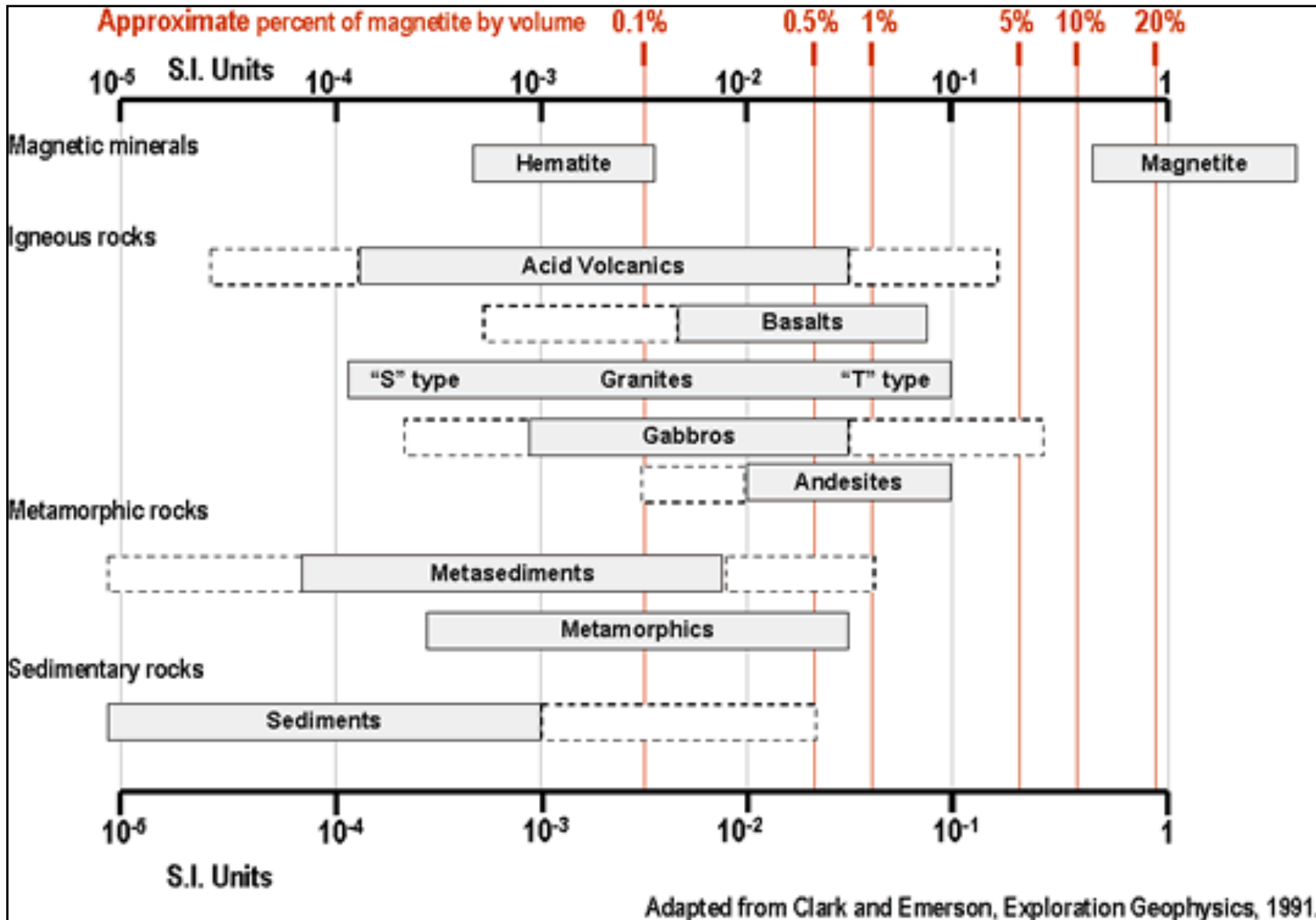


Dielectric constant

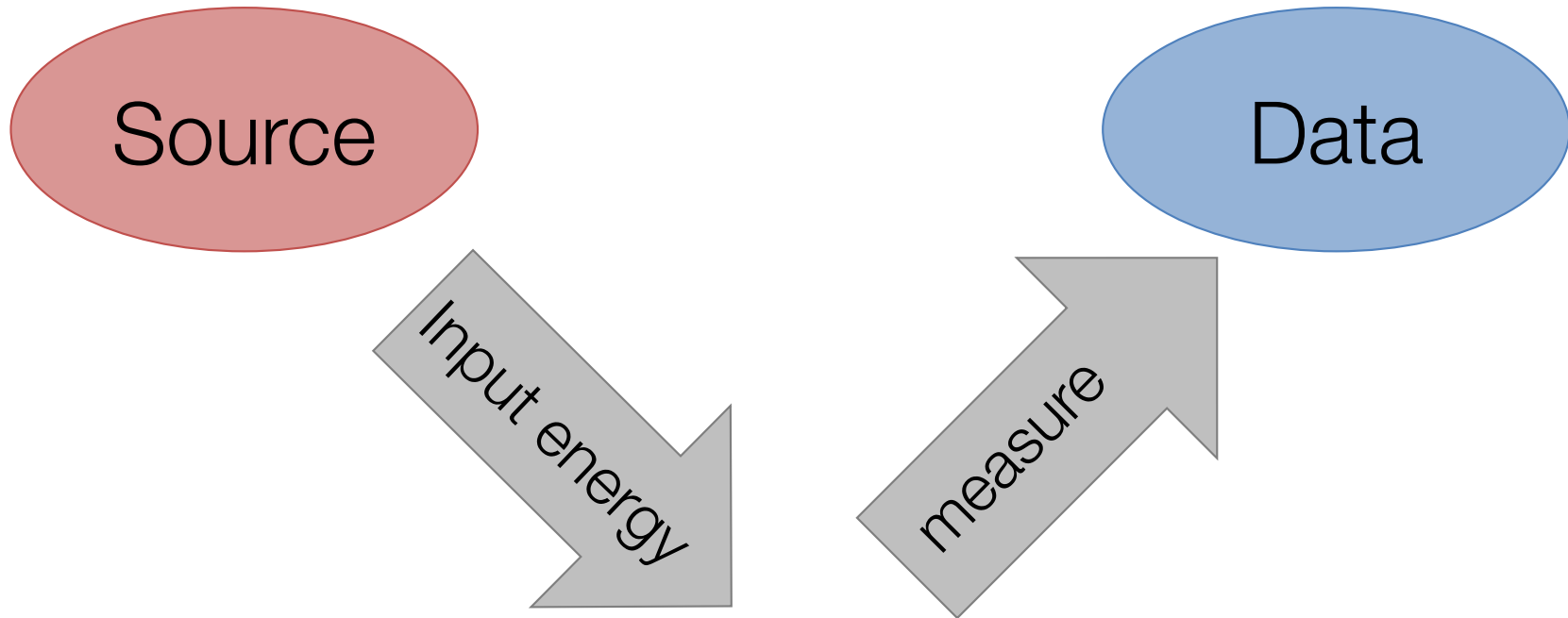
Material	Relative Permittivity	Conductivity (mS/m)
Air	1	0
Fresh Water	80	0.5
Sea Water	80	3000
Ice	3-4	0.01
Dry Sand	3-5	0.01
Saturated Sand	20-30	0.1-1
Limestone	4-8	0.5-2
Shales	5-15	1-100
Silts	5-30	1-100
Clays	5-40	2-1000
Granite	4-6	0.01-1
Anhydrites	3-4	0.01-1



Magnetic Susceptibility



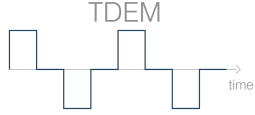
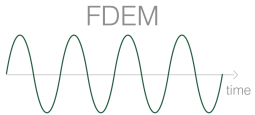
EM Survey & Physical Properties



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

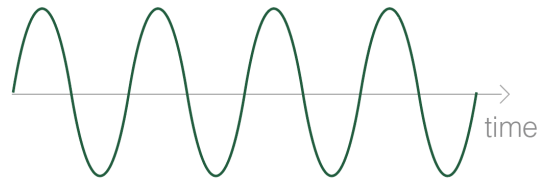
* Solve with sources and boundary conditions

Electromagnetic Survey: Sources

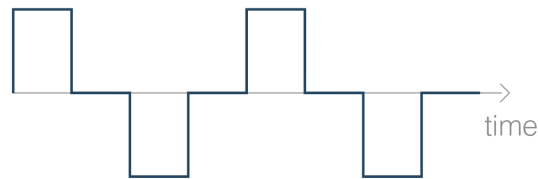
- Type
 - Inductive
 - Grounded

- Waveform

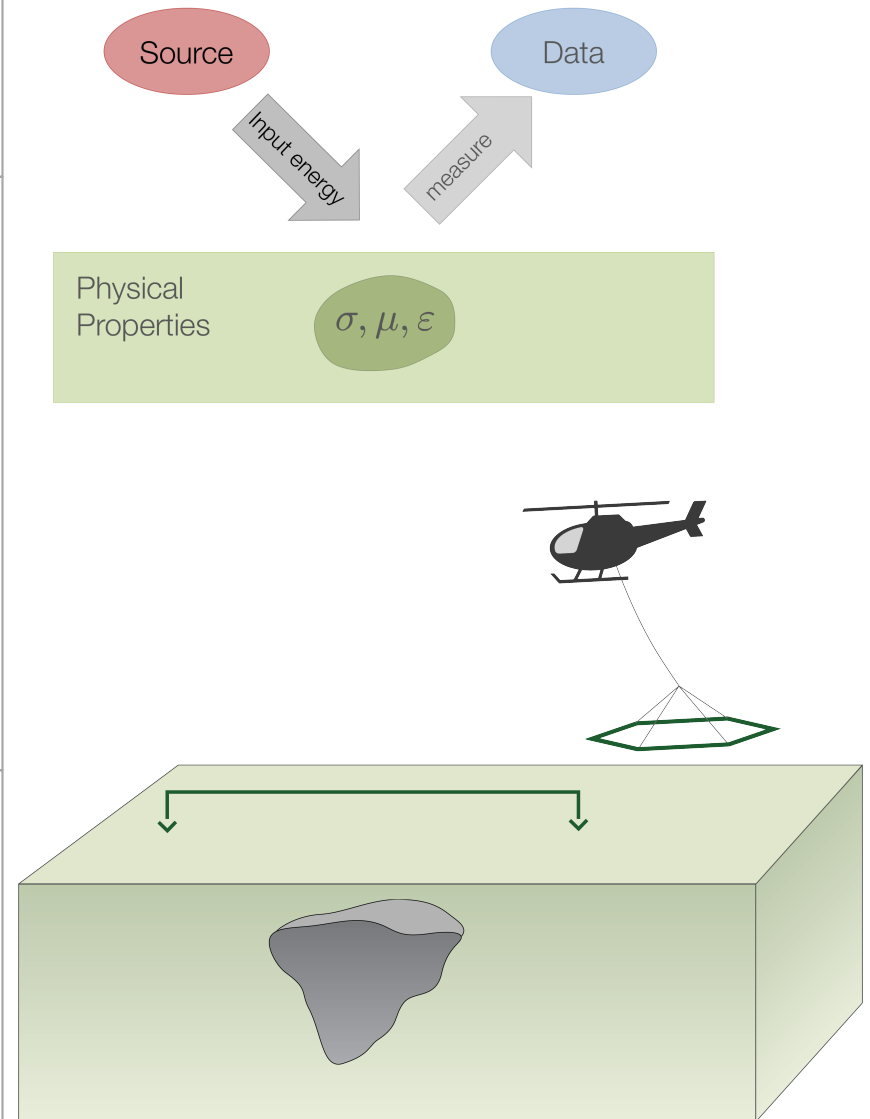
Harmonic
(FDEM)



Transient
(TDEM)

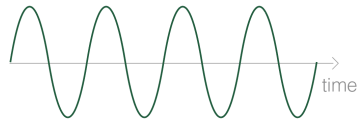


- Location
 - Airborne
 - Ground
 - Borehole

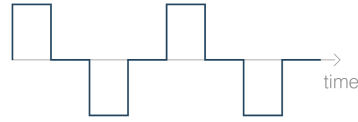


Electromagnetic Survey: Data

- Which field?



E, B

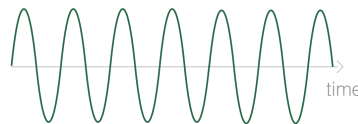


e, b, $\frac{db}{dt}$

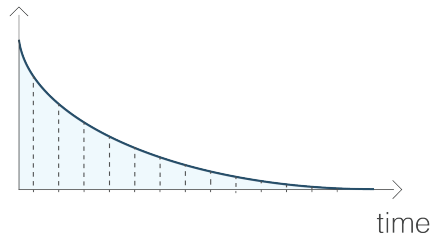
- Which frequencies?



or



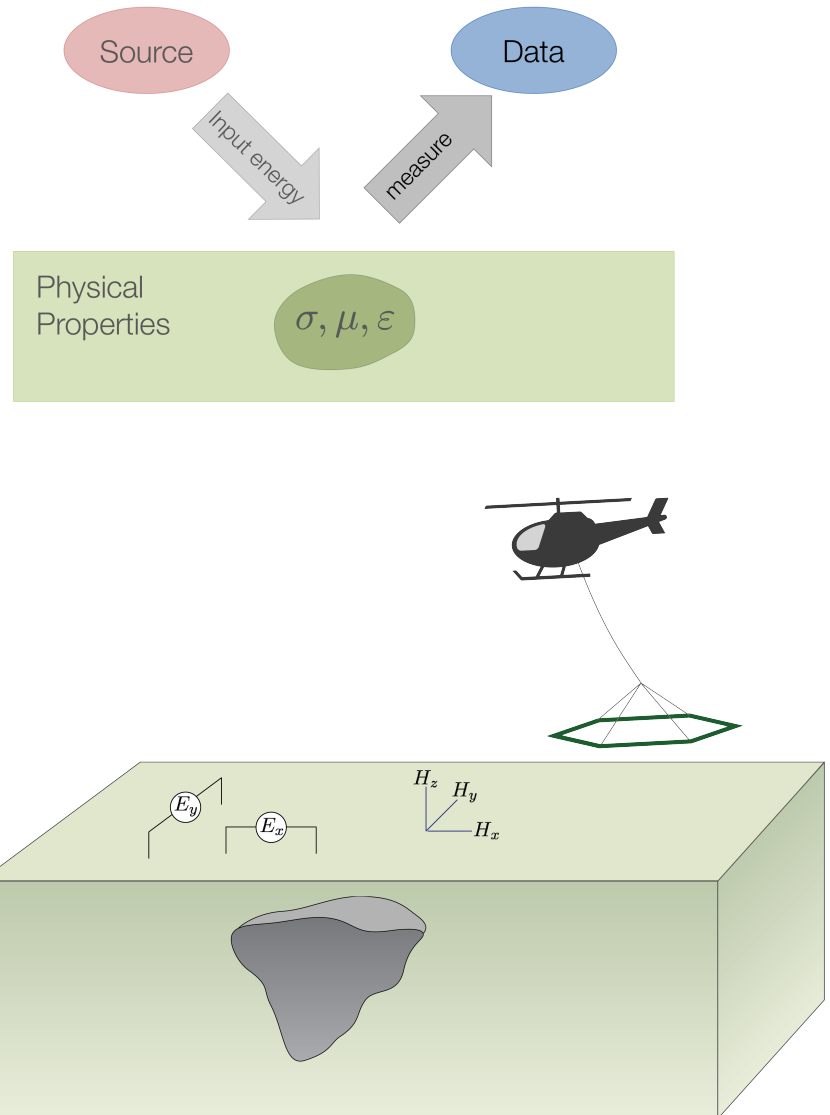
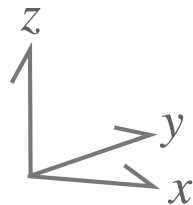
- times?



- Components?

- Location?

- Airborne
- Ground
- Borehole



Three problems

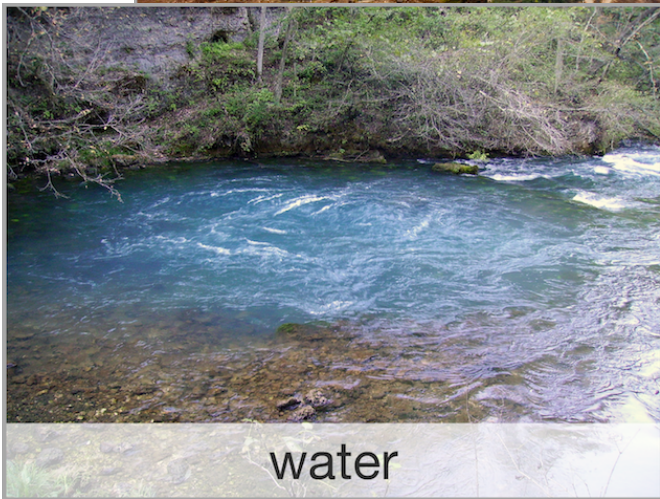
Electrical conductivity is diagnostic for all three



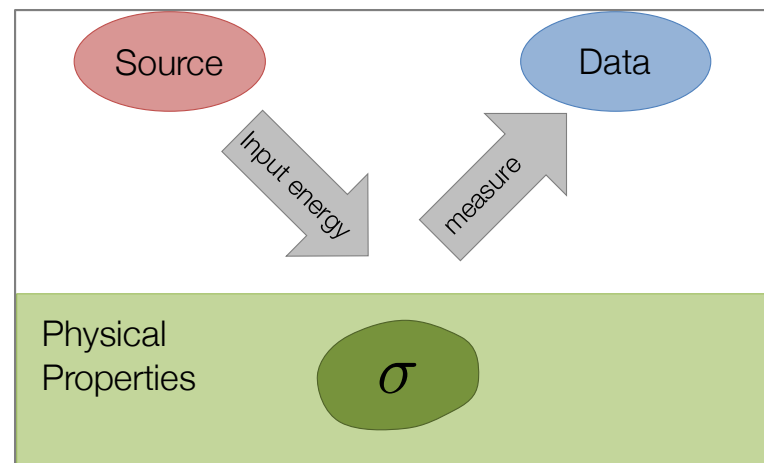
minerals



unexploded ordnance

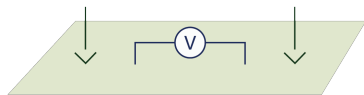


water



End of Introduction

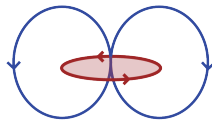
Next up



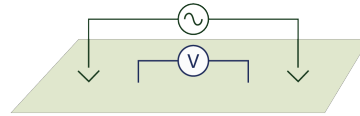
DC Resistivity



EM
Fundamentals



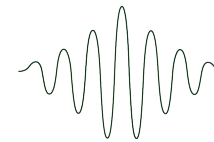
Inductive
Sources



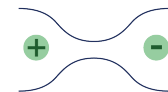
Grounded
Sources



Natural
Sources



GPR



Induced
Polarization



The
Future

Lunch: Play with apps