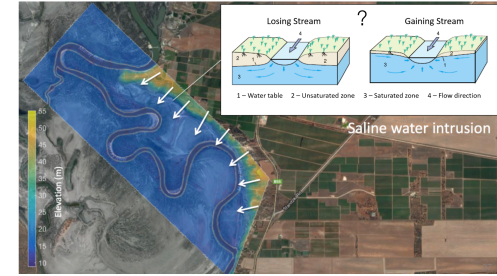
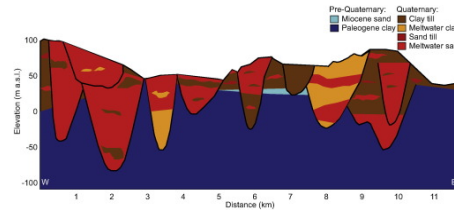
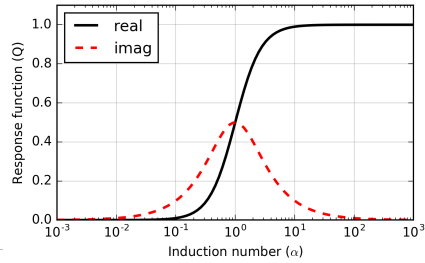
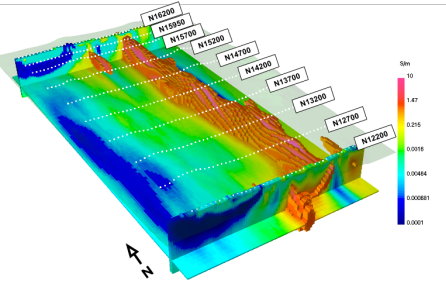


# Summary and the Future



# What have we covered?

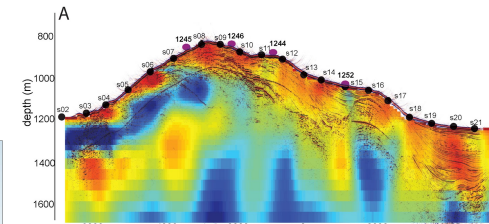
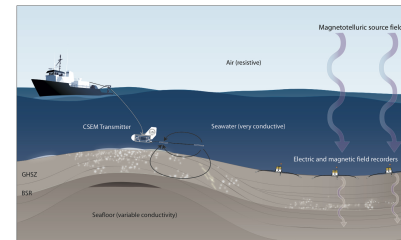
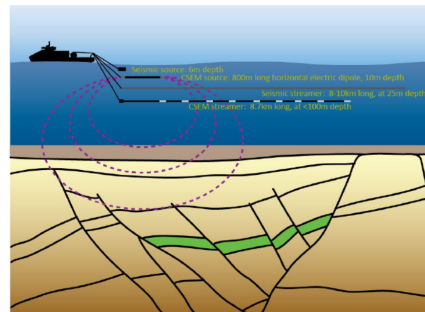
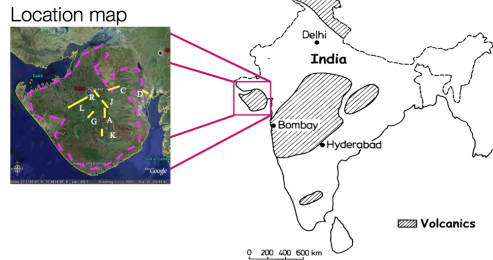


Kasted, Denmark:  
mapping  
paleochannels

Bookpurnong, Australia:  
diagnosing river  
salinization

Mt. Isa, Australia:  
Mineral Exploration

EM Fundamentals



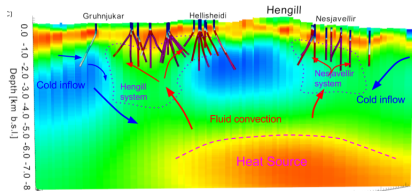
Barents Sea:  
Hydrocarbon de-  
risking

Oregon, USA:  
Methane Hydrates

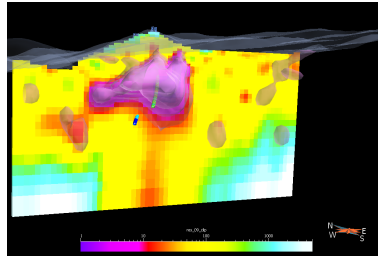
Deccan Traps, India:  
mapping sediment  
beneath basalt

Marine CSEM

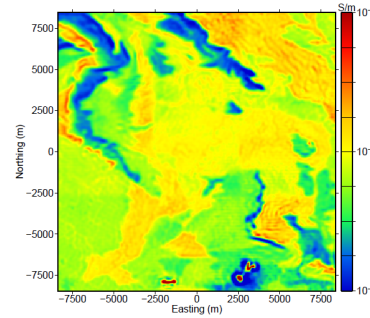
# What have we covered?



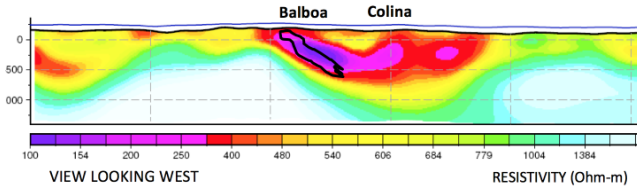
Iceland: characterizing geothermal systems



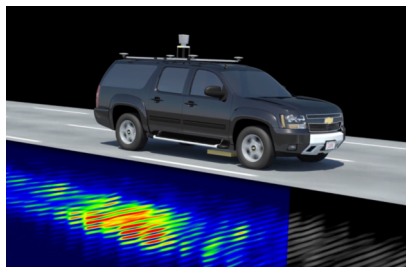
Santa Cecilia, Chile: Mineral Exploration



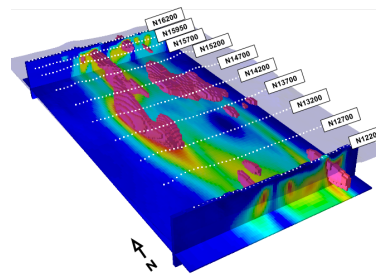
Noranda, Canada: Geologic Mapping



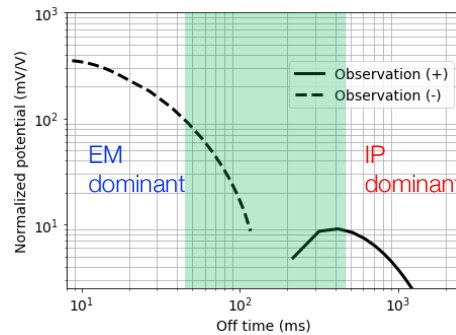
Balboa, Panama: Mineral Exploration



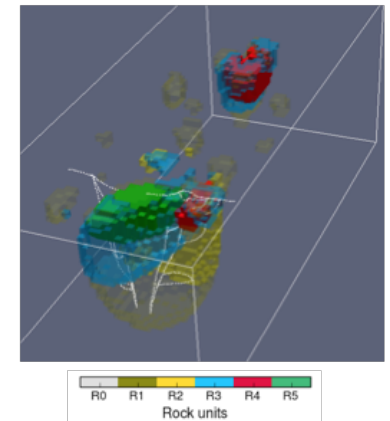
USA: Self-driving vehicles



Mt. Isa, Australia: Mineral Exploration



EM decoupling



TKC, Canada: Mineral Exploration

What does the future hold?

What does the future hold?

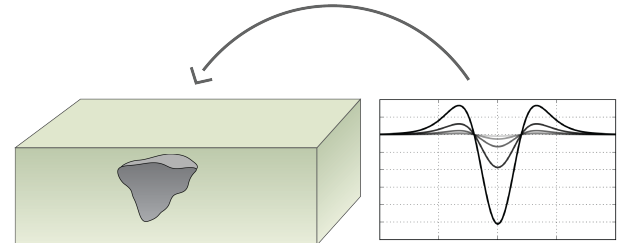


# What does the future hold?

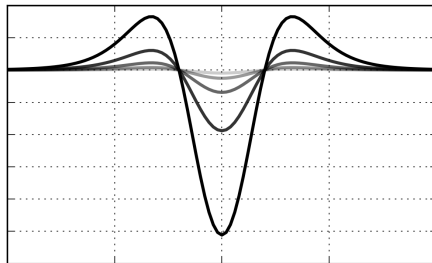
Problems



Inversion capabilities



High quality data



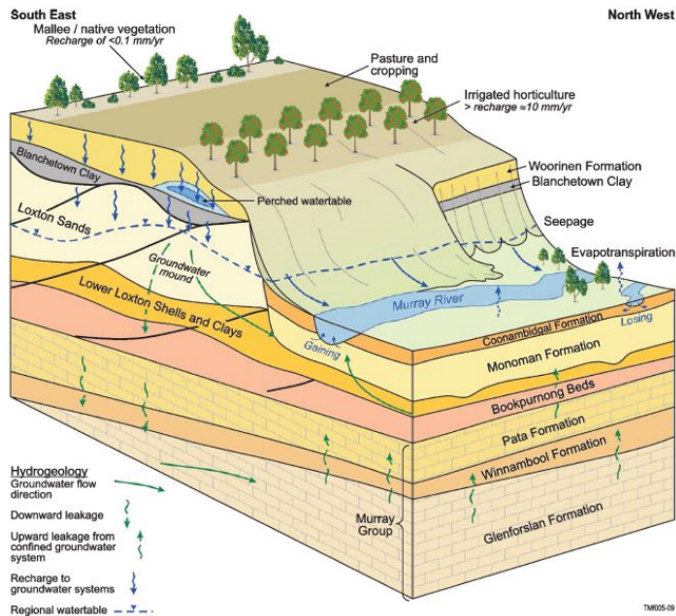
Web tools to  
communicate



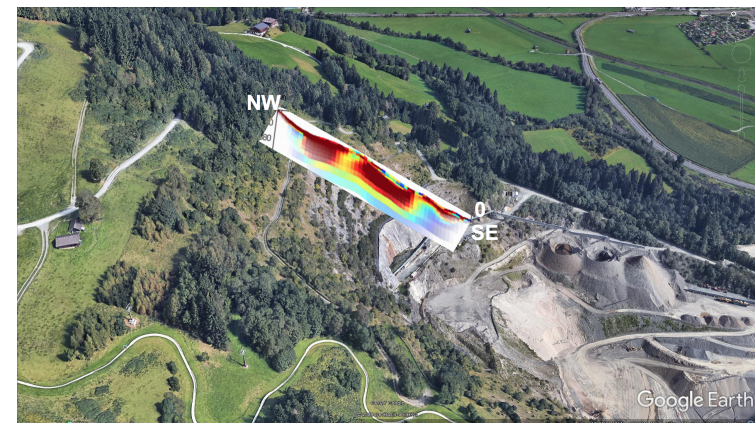
# The Future: Monitoring

- Dam integrity
- Slope stability
- Aquifers
- Coal seam gas
- Enhanced oil recovery

Mt. Polly tailings dam collapse



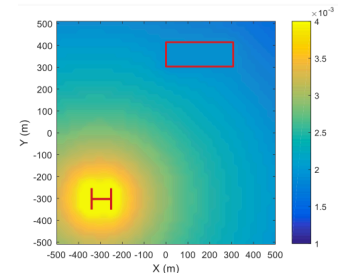
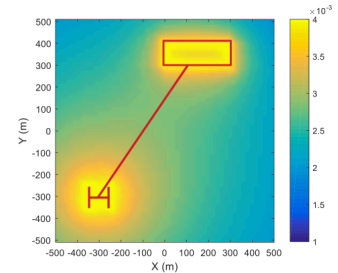
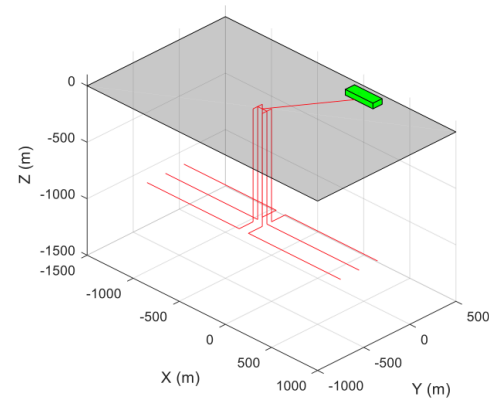
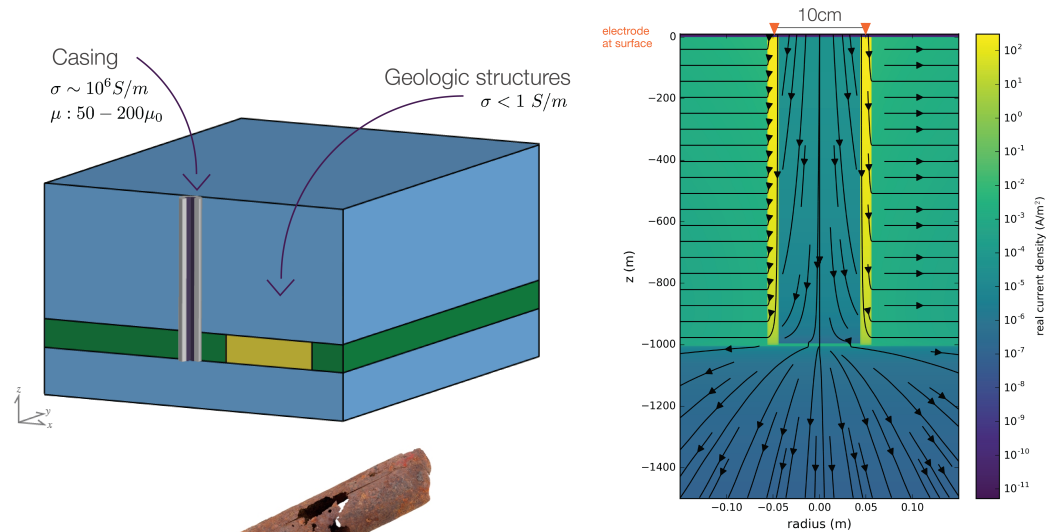
Water infiltration and slope stability



Florian Bleibinhaus

# The Future: Large Contrasts

- Conductivity contrasts
- Permeability contrasts
- eg. Steel Casing
  - Mechanism for getting current to depth
  - Challenges:
    - Scales
    - Physical properties



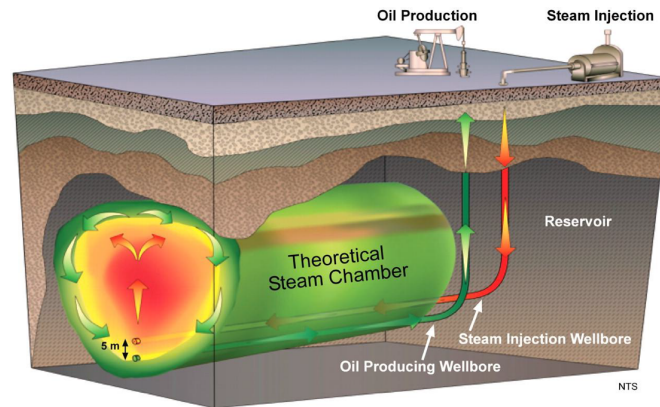
eg. Sudbury basin



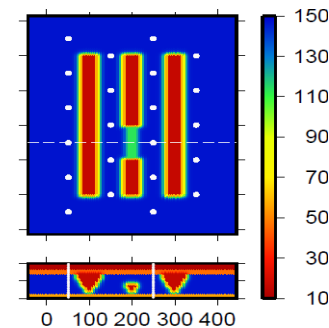
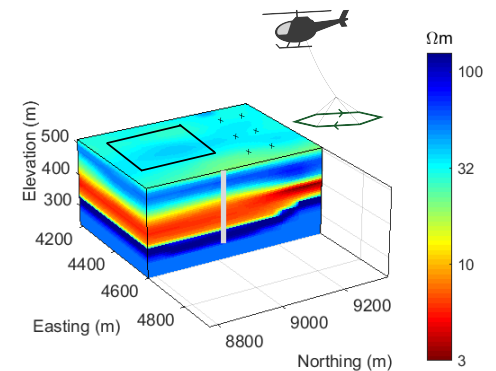
# Monitoring: Choosing the appropriate survey

Different EM surveys needed to answer different questions

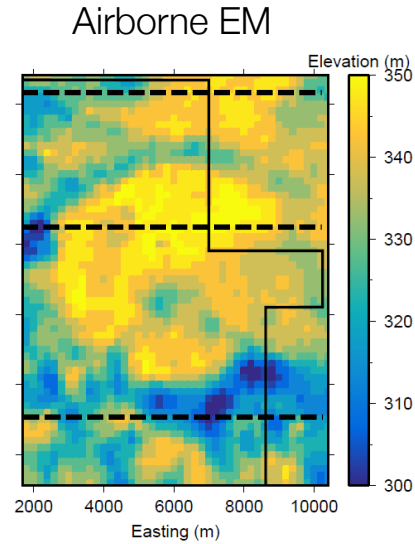
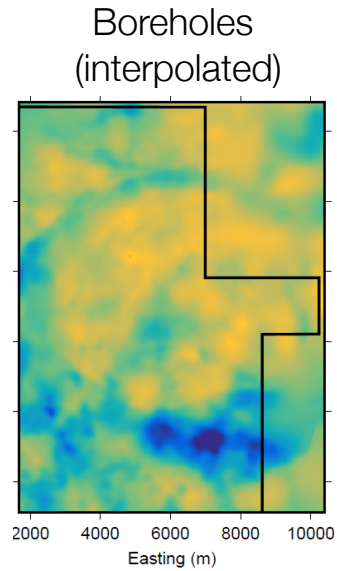
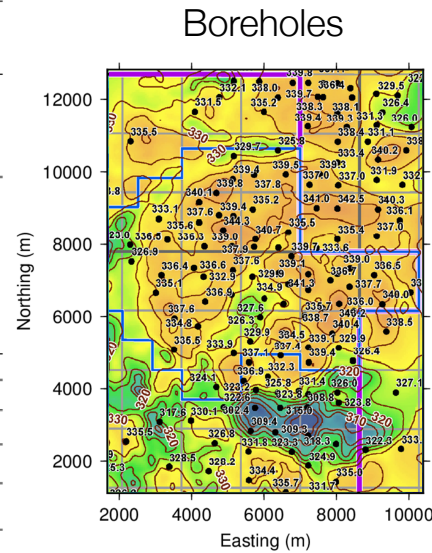
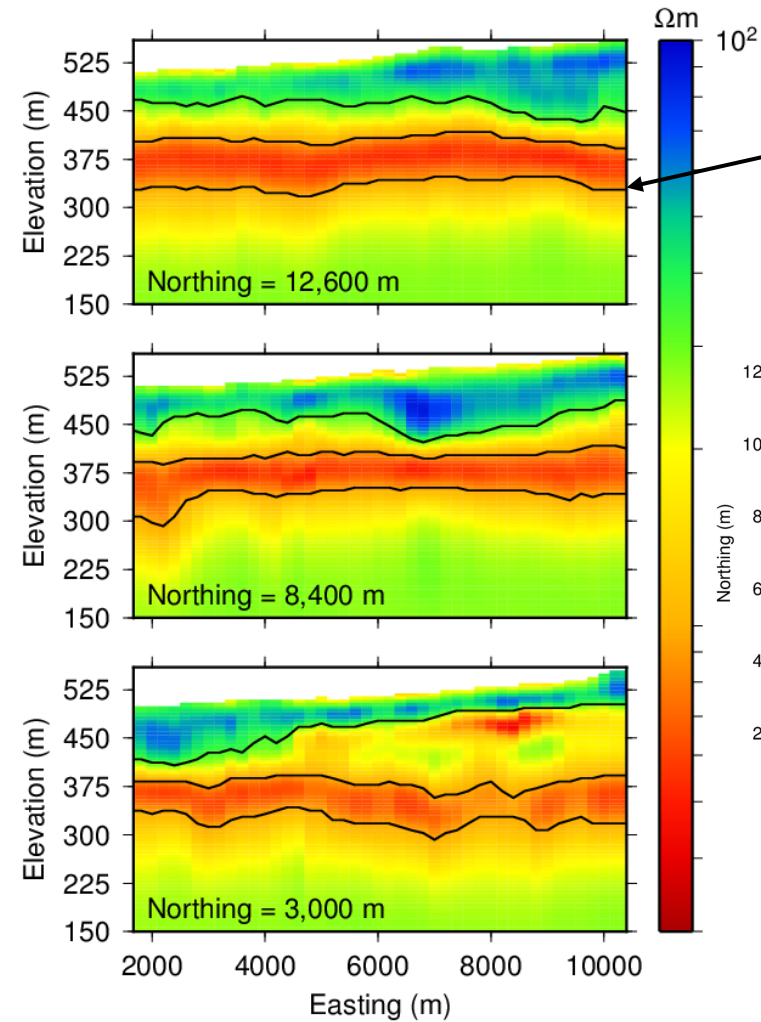
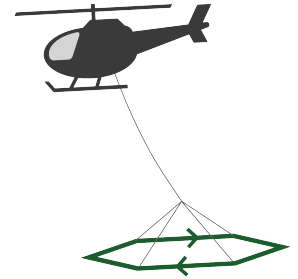
SAGD (Injection and monitoring steam flooding)



- Stage 1: Airborne reconnaissance survey
- Stage 2: Surface and borehole for pre-injection
- Stage 3: Monitoring array

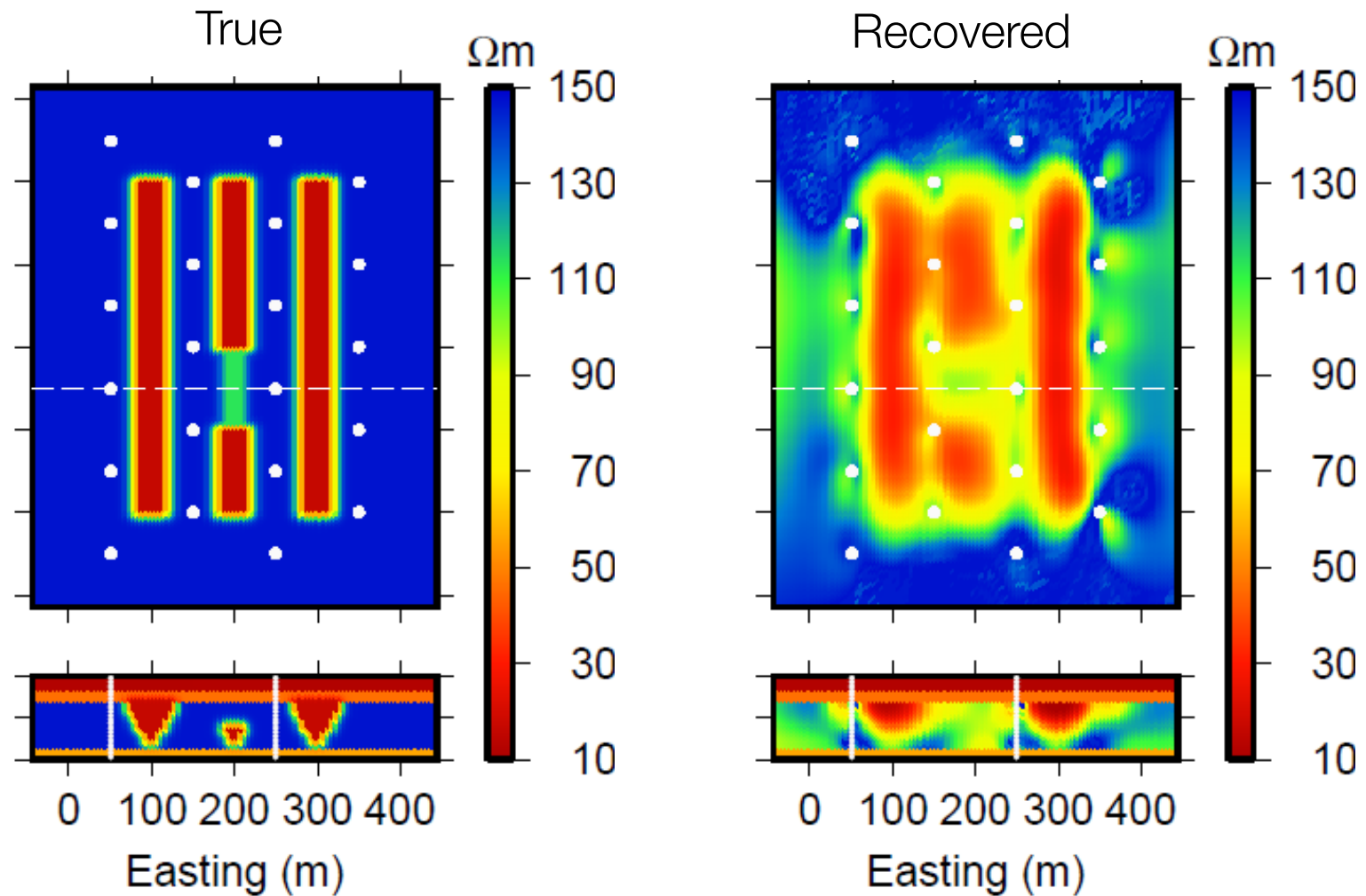


# Large scale reconnaissance (SAGD)



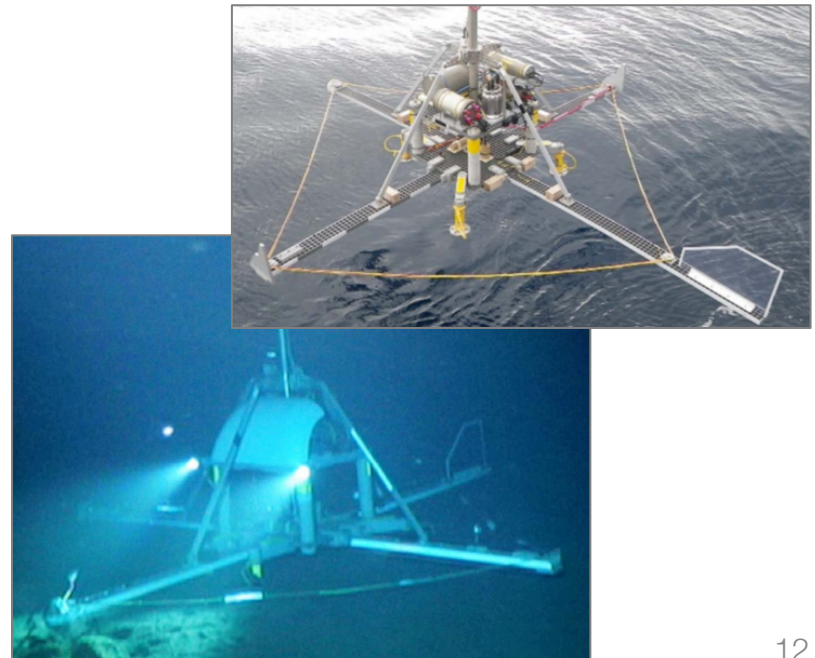
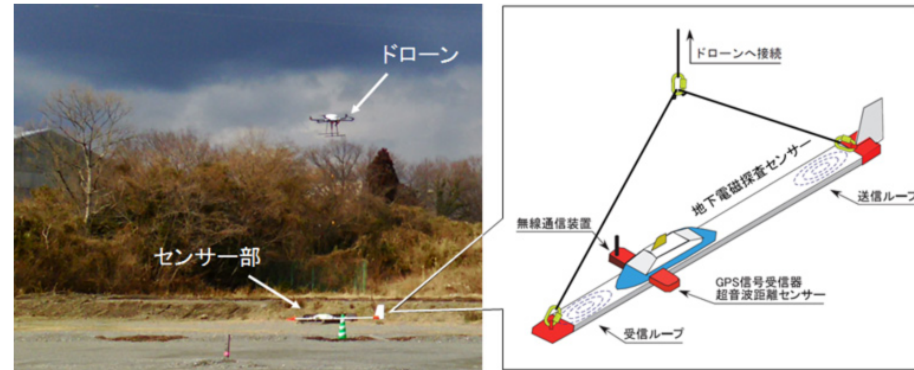
# Multi-stage EM for monitoring

Post-injection: surface sources, borehole receivers



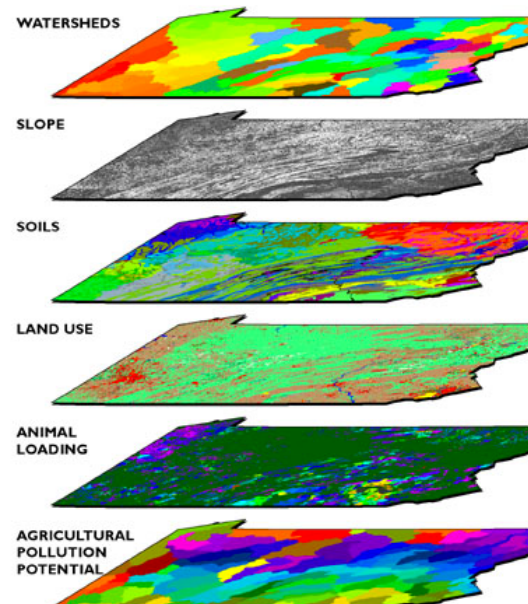
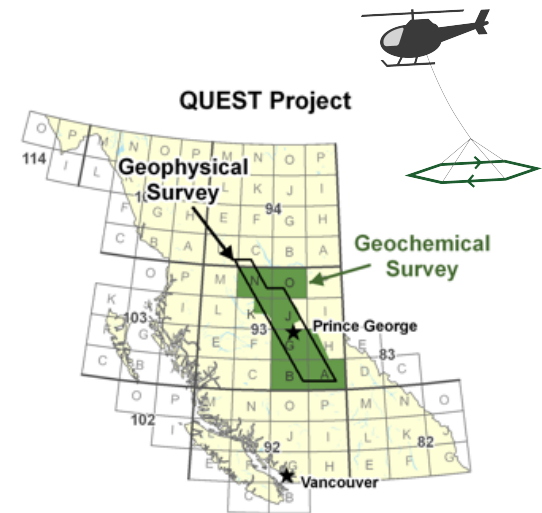
# The Future: High Quality Data

- Improved instrumentation
  - Lower noise
  - More power
  - Better control on transmitters and receivers
    - Current waveform
    - Filtering parameters
    - Position and orientation
    - Higher sampling rates
    - ...
- Data collection
  - Drones
  - AUVs
  - ROVs
- Mathematical modelling requires that we know all the details.



# The Future: Lots of Data

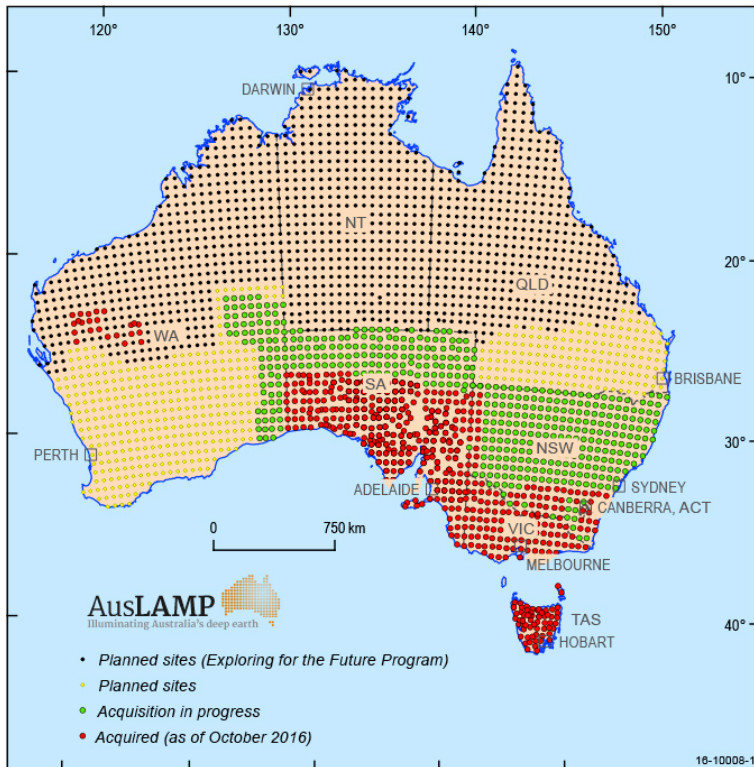
- Big data
  - Multicomponent receivers
  - Many transmitters, receivers
  - High sampling rates
  - Large areas
- Multiple types of data
  - geophysical surveys
  - Physical properties
  - Geochemistry
  - Geology
  - ...
- Machine learning



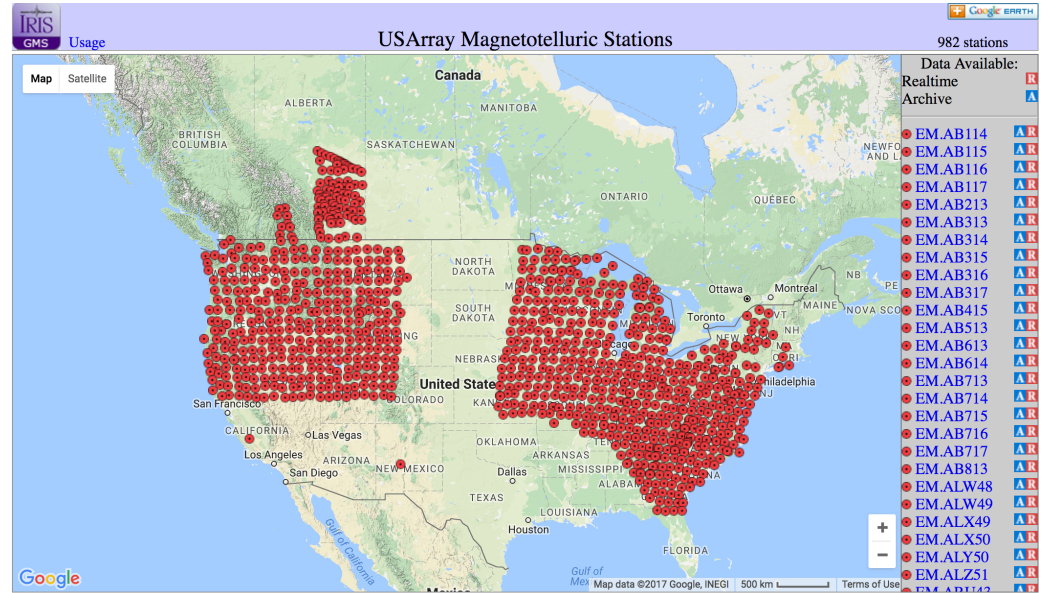


# The Future: Large Scale EM

## AusLamp

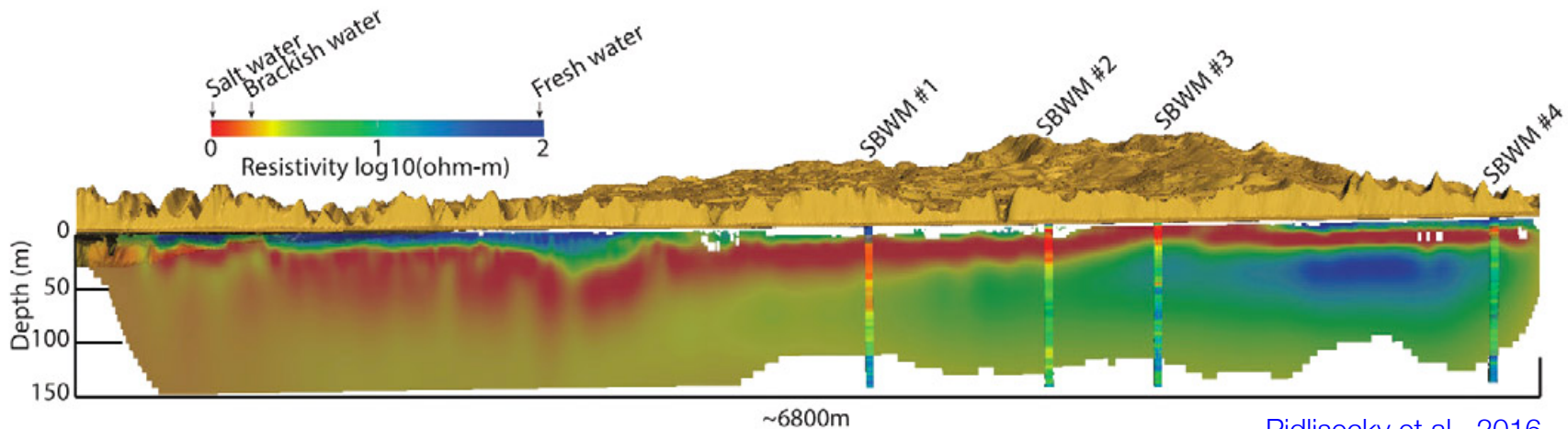
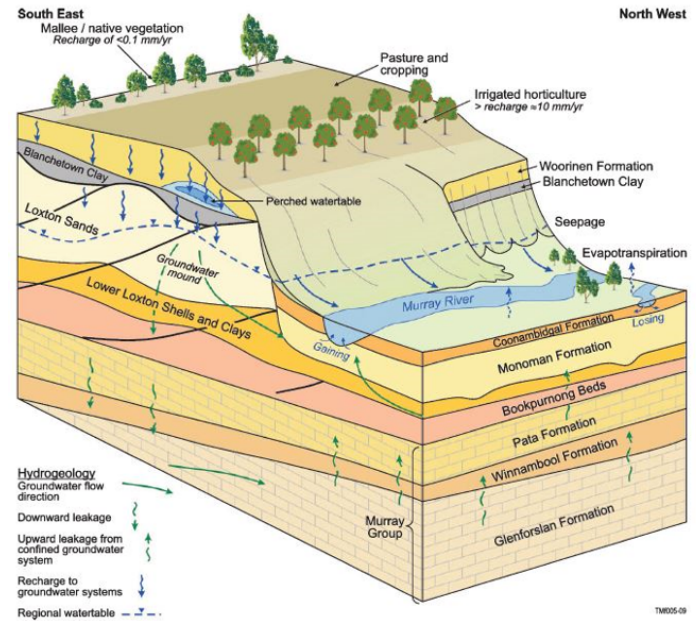


## Earth scope



# The Future: Water

- Finding and delineating water
- Aquifer monitoring and management
- Salt water intrusions
- Pollutants



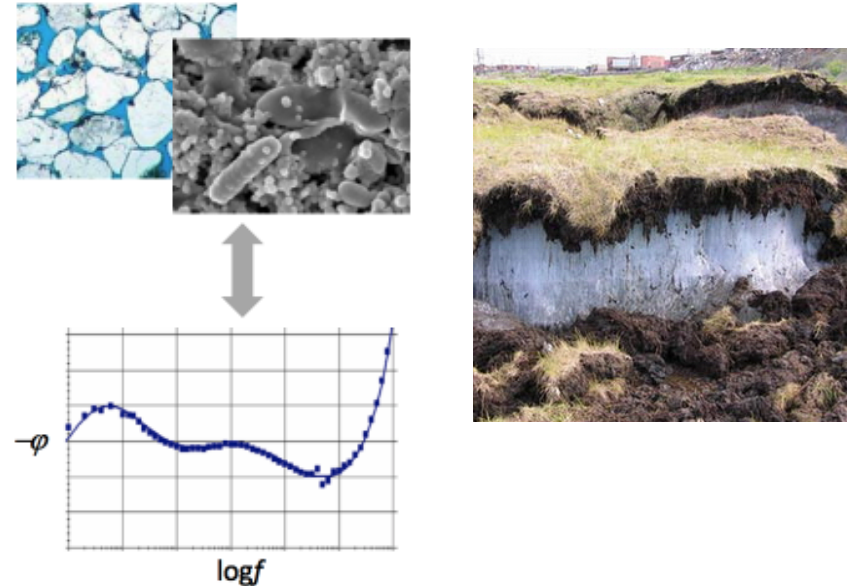
Pidlisecky et al., 2016



# The Future: Physical Properties

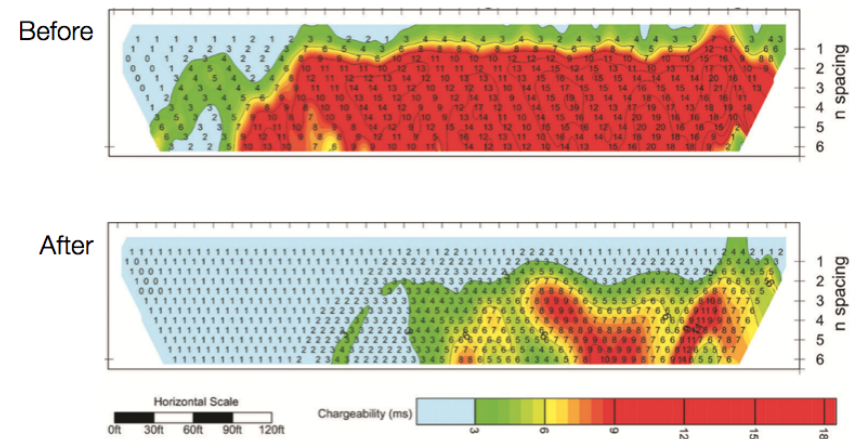
## Dispersive Conductivity (IP)

- Ice / water, permafrost
- Organic materials
- Bioremediation
- Hydraulic permeability
- Characterizing materials based on spectral IP response



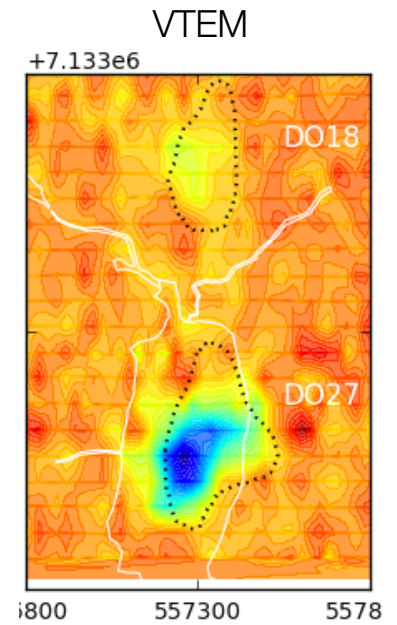
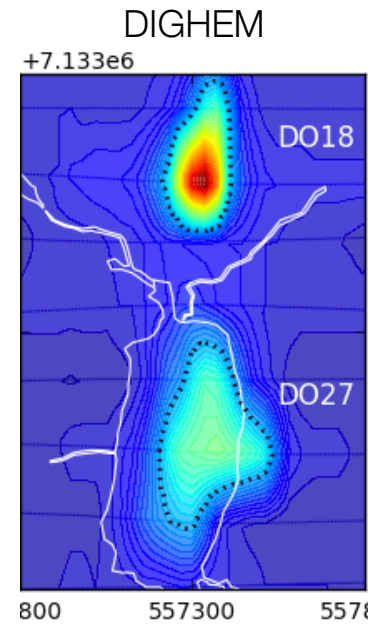
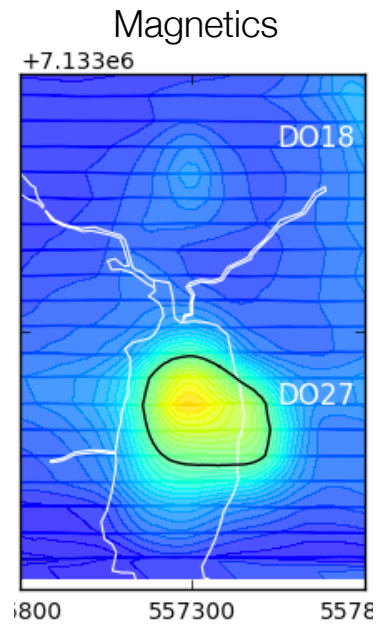
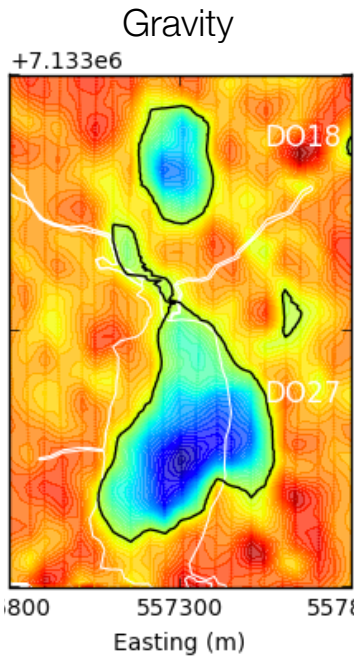
## Dispersive Magnetic Permeability (Viscous Remanent Magnetization)

- Soils
- Bioremediation (?)

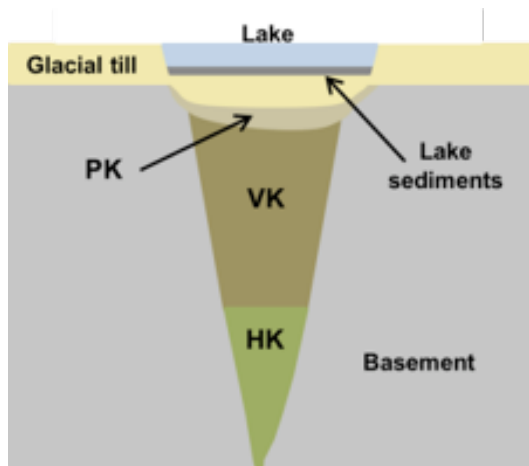


## Numerical Modelling

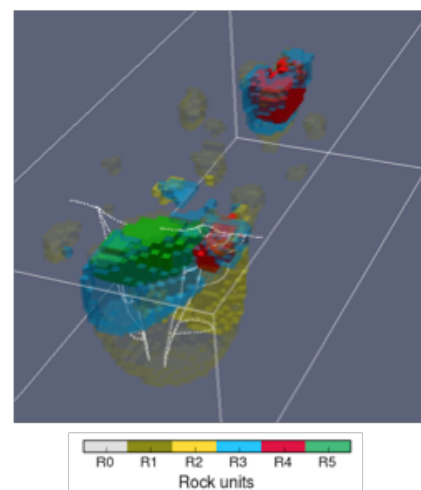
# The Future: Data Integration & Multi-physics



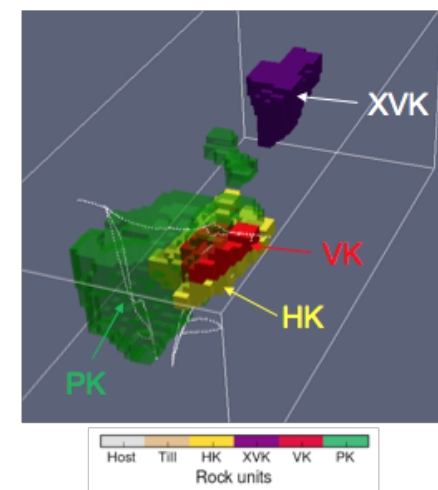
Kimberlite Model



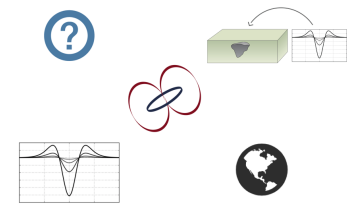
Rock Model from Geophysics



Rock Model from Drilling



# The Future: Modelling and Inversion

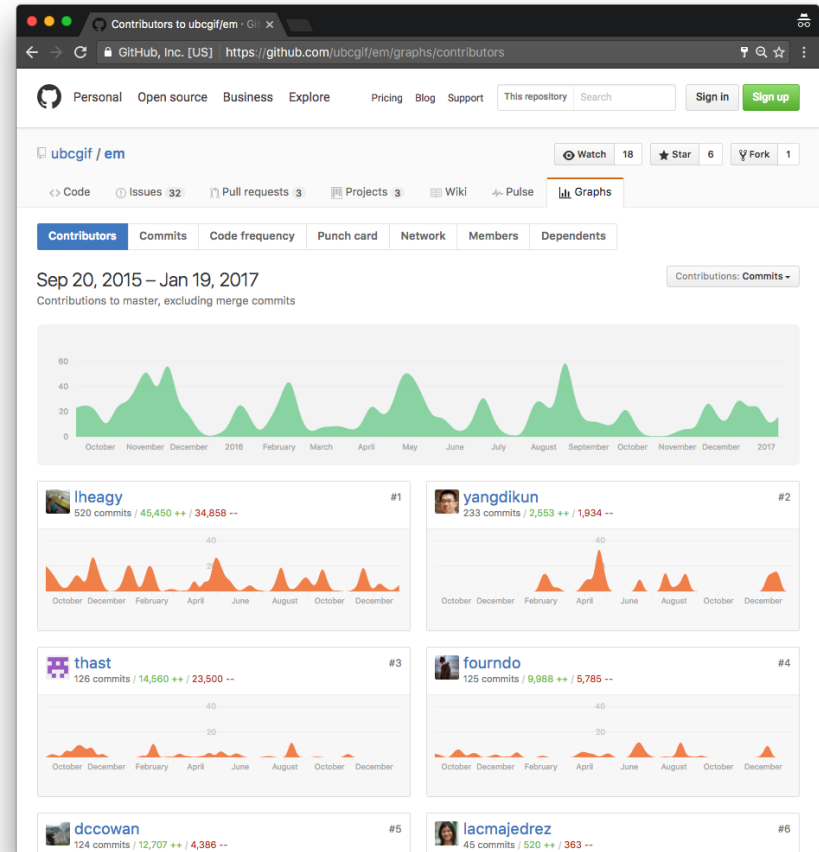


- HPC, Cloud computing
- Collaborative development
- Open source



Simulation and Parameter Estimation in Geophysics

<http://simpeg.xyz>



Github  
versioning, collaborating



Travis CI  
testing, deploy



Jupyter  
interactive computing

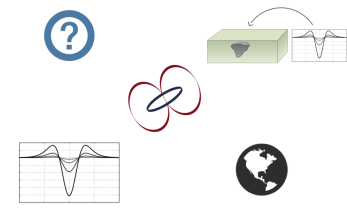


Creative Commons  
licensing, reuse



Python  
computation

# The Future: Modelling and Inversion

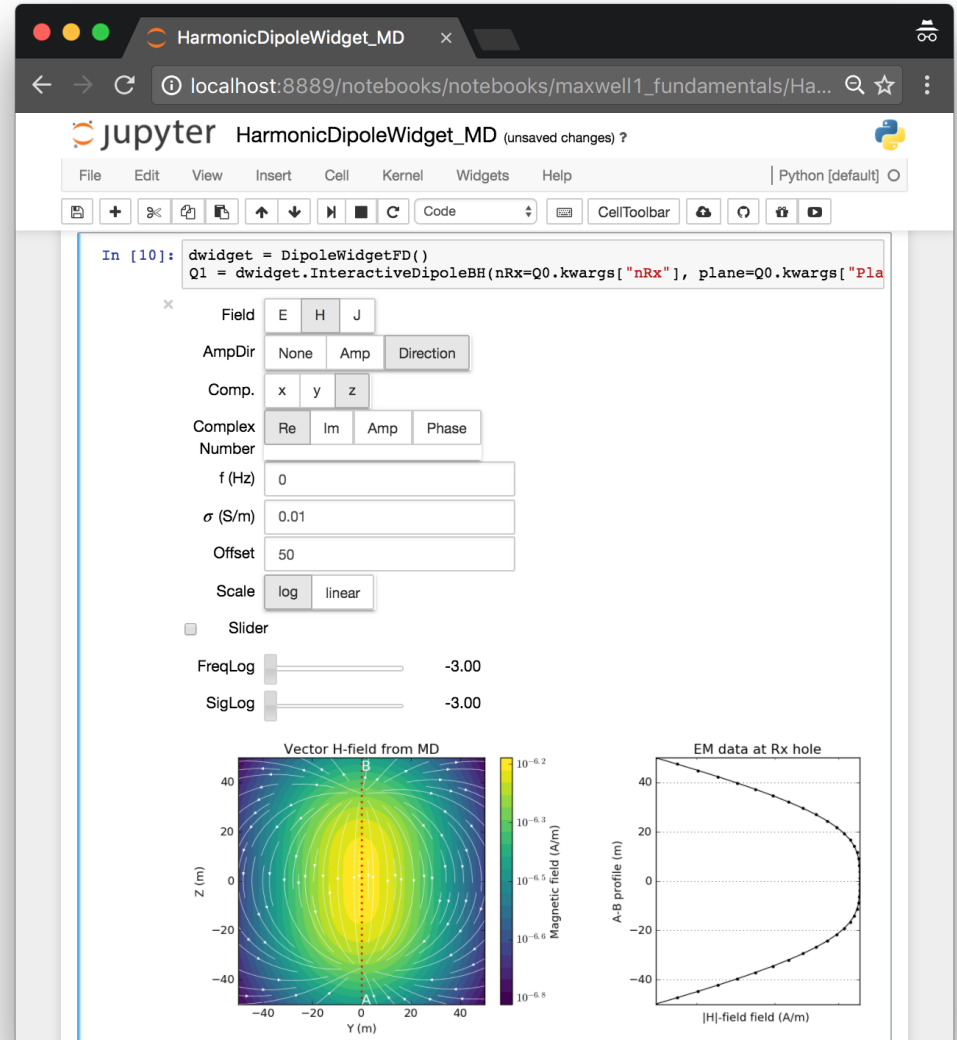


- Interactive computing
- Visualization

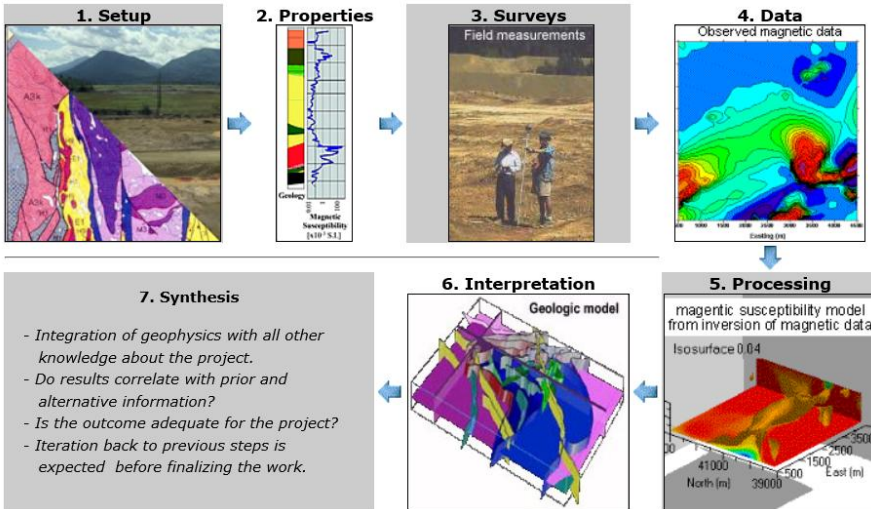
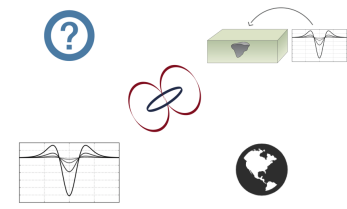
$$\nabla \times \mathbf{e} = - \frac{\partial \mathbf{b}}{\partial t}$$



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



# The Future: Collaboration



Case Histories — Electromag...  
em.geosci.xyz/content/case\_histories/index.html

em

Search docs

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

Gallery

Equation Bank

References

### Case Histories

Case histories provide the context for our development of educational and research materials 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

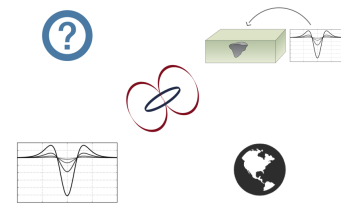
#### Bookpurnong

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



<http://slack.geosci.xyz>

# 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

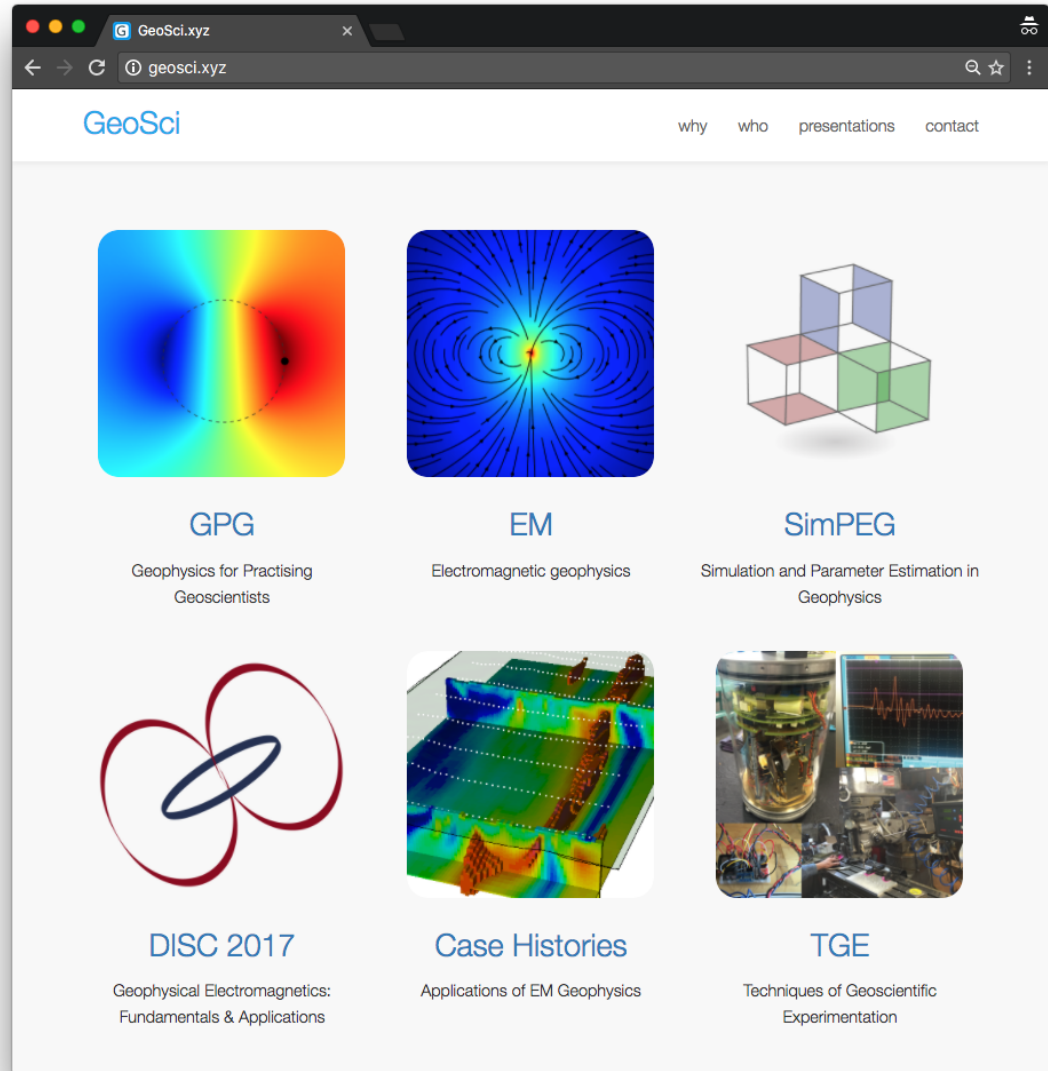
- GeoSci

<http://geosci.xyz>

- Web-textbooks
- Software
- Apps

- Apps:

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



# GIF DISC Team



doug



lindsey



seogi

## UBC GIF Team



Thibaut



Patrick



Rowan



Devin



Kris



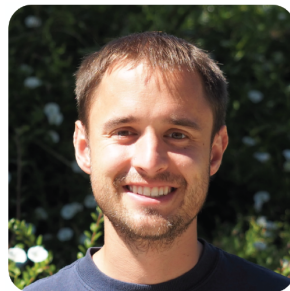
Sarah



Dom



Mike



Mike



Gudni



Dikun



# Join us tomorrow at DISC Lab

- Tell us what you are doing
- How EM is (or could!) play a role in the solution
- Continue the conversations
- Connect with other geoscientists
- Contribute to the development of a community

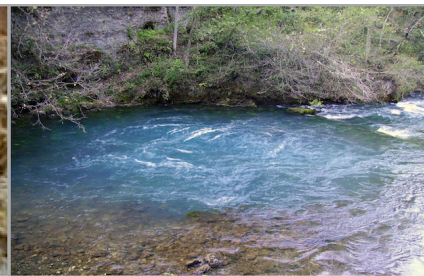
<http://disc2017.geosci.xyz>



minerals



contaminants



water



geothermal



geotechnical



slope stability



hydrocarbons



unexploded ordnance

# Thank You!

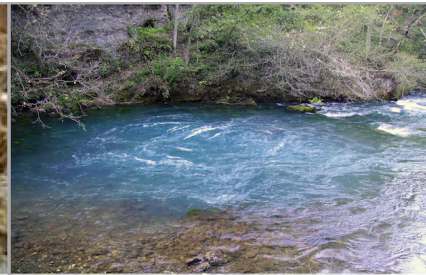
<http://disc2017.geosci.xyz>



minerals



contaminants



water



geothermal



geotechnical



slope stability



hydrocarbons

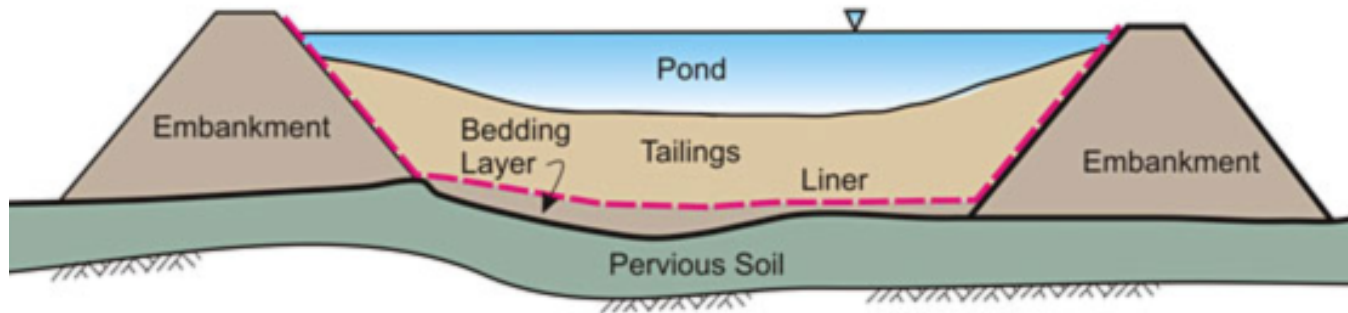


unexploded ordnance



# The Future: Monitoring

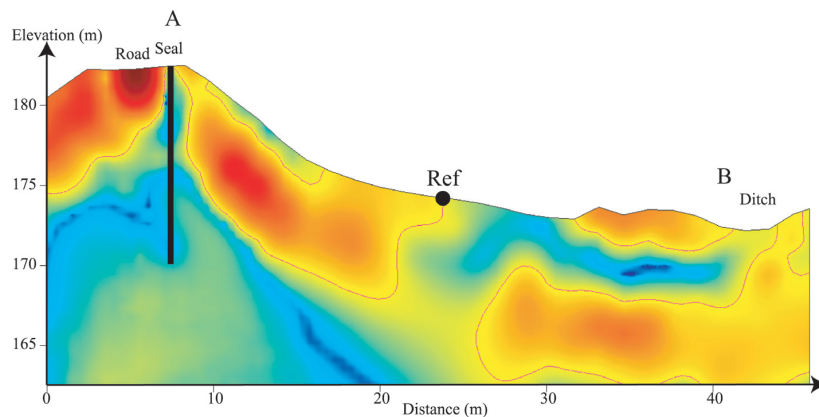
- Tailings Dam: How do we monitor?



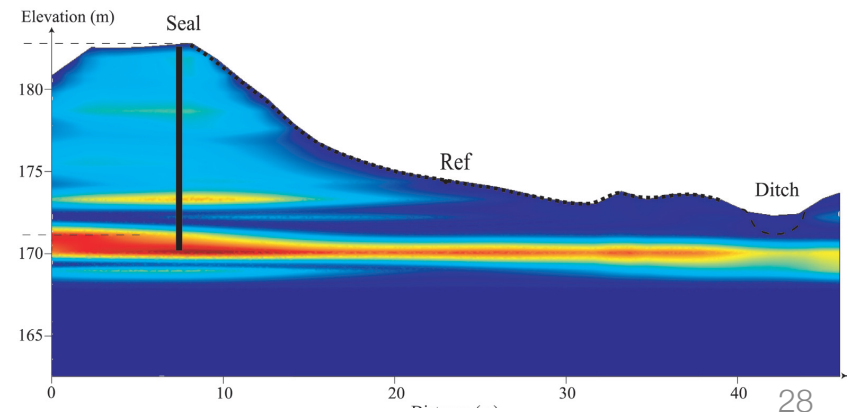
From the GARD Guide

- Self-potential and DC for monitoring Dam integrity

## Conductivity

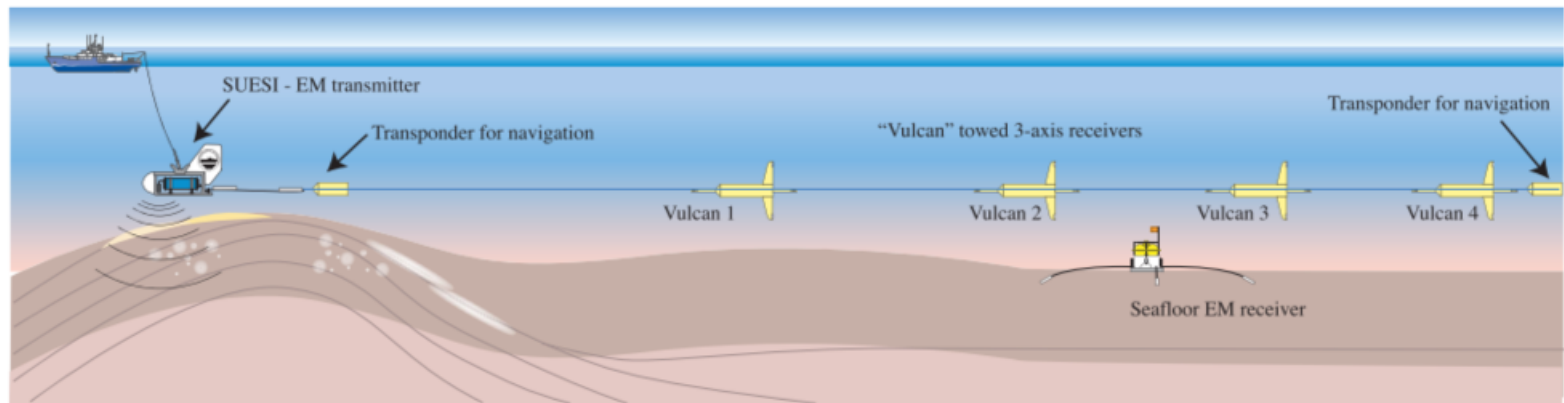


## Streaming current



# The Future: Marine EM

- Grounded source:
  - E.g. Vulcan system (towed + ocean bottom receivers)



Constable et al., 2016

- Inductive source:
  - E.g. Waseda Univ. (towed coincident loop; similar to AEM)

