The University of British Columbia Geophysical Inversion Facility



# EOSC 350 : Environmental, Geotechnical and Exploration Geophysics I

September 2016



http://gpg.geosci.xyz

## Outline:

- Introduction: Example problems
  - Environmental, geotechnical, resource exploration
- Geophysical surveys and data images
- Inversion
- Mineral exploration example
- Summary/discussion

# Environmental: UXO

- Military proving grounds
- Regions of conflict
- Avalanche control





http://www.centennialofflight.gov



http://www.nohowinc.com/

# Various types of UXO



## Environmental: How do we find UXO?





# Geotechnical: A Canadian potash mining



# Geotechnical problem

• Slide: water gushing into the mine



# Mineral exploration

• What do we have?







# Mineral exploration

- What do we want?
  - Subsurface structures and materials



Map of surface geology



## Solutions ... Geophysics



# Subsurface: Physical Properties and Contrasts

# Geophysics: Sources

- On the ground
- In the air
- Inside the earth

![](_page_10_Figure_4.jpeg)

![](_page_10_Picture_5.jpeg)

# Geophysics: Physical Properties

![](_page_11_Figure_1.jpeg)

-Density

- -Magnetic susceptibility
- -Electrical conductivity
- -Chargeability
- -Electrical permittivity
- -Elastic moduli

Important to have contrasts in physical Properties.

# Geophysics: Surveys and Data

- On the ground
- In the air
- Inside the earth

![](_page_12_Figure_4.jpeg)

![](_page_12_Picture_5.jpeg)

# How do we distinguish bodies?

- Characterize materials by physical properties:
  - Density
  - Magnetic susceptibility
  - Electrical conductivity
  - Chargeability
  - Electrical permittivity
  - Elastic moduli

![](_page_13_Picture_8.jpeg)

• If we know the physical properties then we might be able to answer our question...

# **Physical properties**

• UXO:

- Electrical conductivity and magnetic susceptibility

- Water (at potash mine):
  - Electrical conductivity: high if it has dissolved salt
- Minerals:
  - magnetic susceptibility (at Raglan)
  - electrical conductivity,
  - chargeability,
  - density

# **Environmental : Magnetic Survey**

![](_page_15_Picture_1.jpeg)

Ferrex

![](_page_15_Picture_3.jpeg)

![](_page_15_Picture_4.jpeg)

![](_page_15_Figure_5.jpeg)

TM4

# **Operational Task: Dig**

![](_page_16_Picture_1.jpeg)

![](_page_16_Picture_2.jpeg)

![](_page_16_Picture_3.jpeg)

# Geotechnical survey data (potash mine)

![](_page_17_Figure_1.jpeg)

![](_page_17_Figure_2.jpeg)

slide 18

### Two geophysical surveys along tunnels

n

100

110

120

Ground Penetrating Radar: Drill-holes with no water

![](_page_18_Figure_1.jpeg)

130

DISTANCE [METER]

<sup>140</sup> 143 m

Water found

148 m<sup>150</sup>

155 m 159 m<sup>160</sup>

Electrical Resistivity Model

EOSC 350 slide 19

0

163 m

# Our mineral exploration example

- Data: magnetic measurements.
- Image: map of anomalies in earth's field.

![](_page_19_Picture_3.jpeg)

![](_page_19_Picture_4.jpeg)

Map of surface geology

Image provides some information ... but not enough.

# Getting more from data ...

• Image provides some information but not enough.

![](_page_20_Figure_2.jpeg)

We want a "model" of subsurface materials. Invert the data

# What is Inversion?

![](_page_21_Figure_1.jpeg)

slide 22

![](_page_22_Figure_0.jpeg)

- fixed size and unknown value).
- Inversion: find values for cells such that data are explained.
- Use mathematical optimization theory.
- Difficulties:
  - Solution is non-unique.
  - Computationally demanding.

 $\kappa_1$   $\kappa_2$ 

**Physical property** 

distributions = MODELS

3D, and ~  $10^5$  cells

# Geophysical inversion is analogous to medical imaging

• We need a 3D image for pinpointing a target or making a final assessment.

Image of a brain based on MRI measurements.

![](_page_23_Picture_3.jpeg)

# Image of an ore body based on magnetic field measurements.

![](_page_23_Figure_5.jpeg)

# Viewing an inversion result

- 3D volume can be viewed many ways. Here:
  - Data on top
  - Pixels showing material property value: visible along the slice.
  - Isosurface:

hide all cells with values less than a chosen value.

![](_page_24_Figure_6.jpeg)

### Exploration at Raglan: Inversion image

### Invert data => 3D images of property distribution.

Total field aeromagnetic data

![](_page_25_Figure_3.jpeg)

![](_page_25_Figure_4.jpeg)

### Framework for Applied Geophysics: 7 Steps

- Setup: What is the question to be answered?
- What are the diagnostic physical properties?
- Choose survey and design data acquistion.
- Data collection
- Processing of field data
- Interpretation
- Synthesis

## Mineral Exploration: The "Cluny" copper/lead/zinc deposit

### **Physical Properties of the Rocks**

Rock unit	Conductivity	Chargeability
Adjacent shale	high	low
Host volcanic rocks	low-moderate	low
<ul> <li>Mineral zone:</li> <li>Siltstone containing (Cu, Pb, Zn)</li> <li>Galena, pyrrhotite, pyrite, sphalerite</li> </ul>	moderate	high

# Electrical survey: concept

![](_page_28_Figure_1.jpeg)

## Electrical survey: data

- Eight survey lines
- Two survey configurations.

### Data set #2:

Apparent conductivity, pole - dipole.

![](_page_29_Figure_5.jpeg)

### 3D conductivity model from 3D inversion:

![](_page_30_Figure_1.jpeg)

EOSC 350 Click image to see the <sup>31</sup>AVI movie

### IP data: what is being measured?

![](_page_31_Figure_1.jpeg)

Measurement is: *How easily does material retain charge.* 

![](_page_31_Figure_3.jpeg)

### 3D induced polarization

![](_page_32_Figure_1.jpeg)

slide 33

# 3D conductivity and chargeability: Cluny

### Volume rendered resistivity model

![](_page_33_Figure_2.jpeg)

#### Volume rendered chargeability model

![](_page_33_Figure_4.jpeg)

# Summary For Applied Geophysics

- Multi-disciplinary:
  - brings together mathematics, physics, computer science, geology, engineering into a single context.
- Requires team work and ability to communicate among different disciplines
- Two communication tools are:
  - Expressing problems in terms of physical properties
  - Images

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- Setup: What is the question to be answered?
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![](_page_36_Picture_0.jpeg)

![](_page_36_Picture_1.jpeg)

- Read the paper:
- "A Geophysical Journey around Ireland" by James Hodgson
- Download the TBL and complete it by evaluating one of the case histories in the paper. This is handed in at the beginning of the next class.

Upcoming events:

- Quiz involving "Foundations"
- Team exercise: Physical properties and case histories from Ireland.