

# A global snapshot of EM and inversion: my career so far

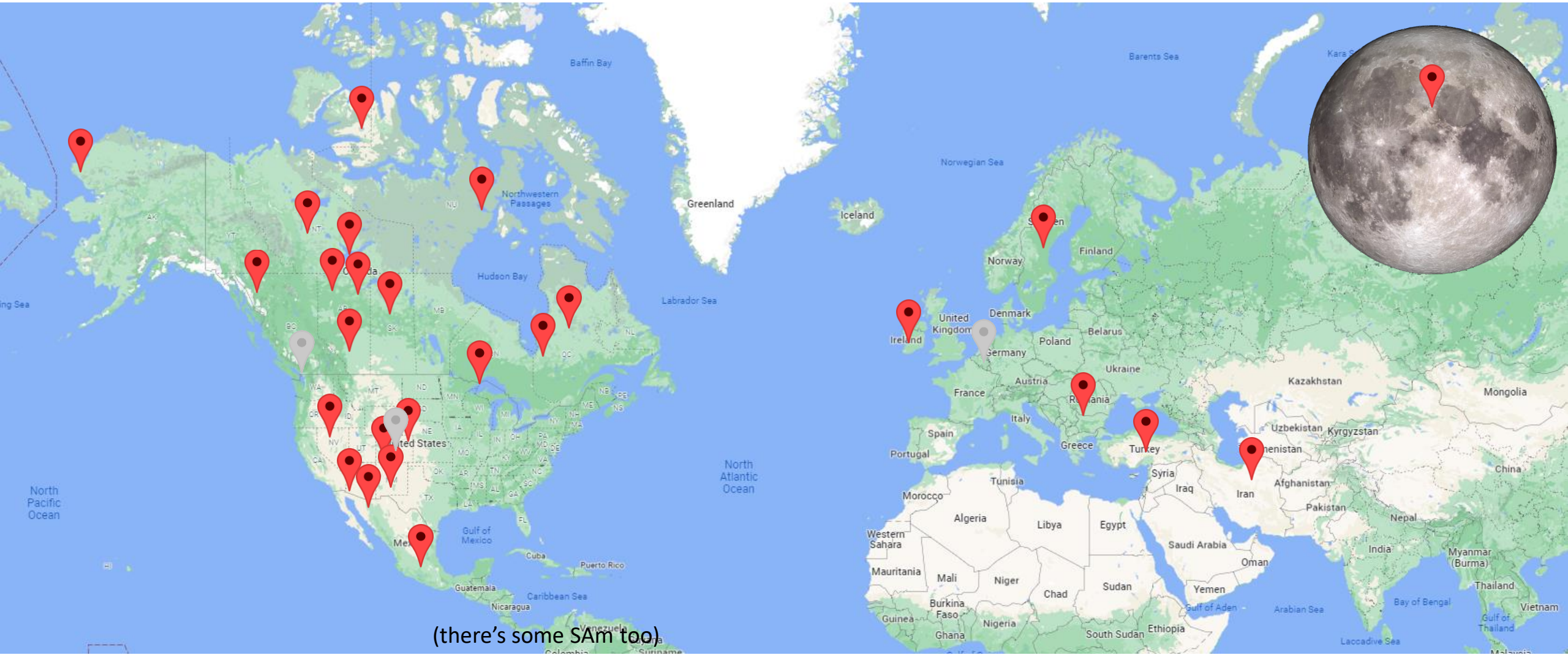
Sarah Devriese, PhD, P.Geol.

April 20, 2022

# Snapshot map

 Homes

 Selected projects



# Outline

- Timeline of career progression with snippets of projects
  - Stable downward continuation of PF data
  - 3D inversion of ZTEM data for geothermal exploration
  - 3D inversion of PF data for kimberlite exploration
  - 4D and airborne electromagnetics for steam chamber delineation
  - Re-evaluation of DCIP data at Red Chris

# The very early years

- Born and raised near Brugge, Belgium
- Immigrated to Colorado at age 10



# Colorado School of Mines

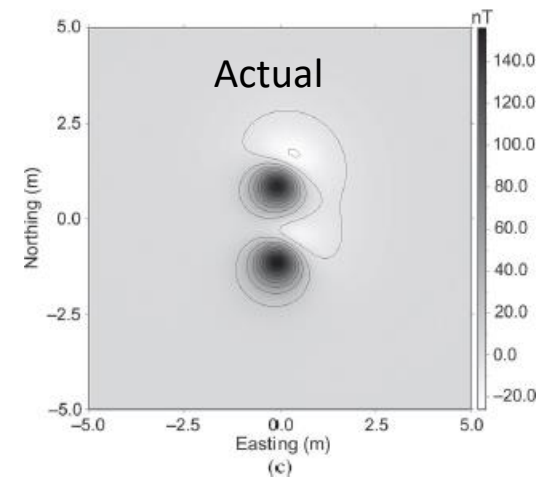
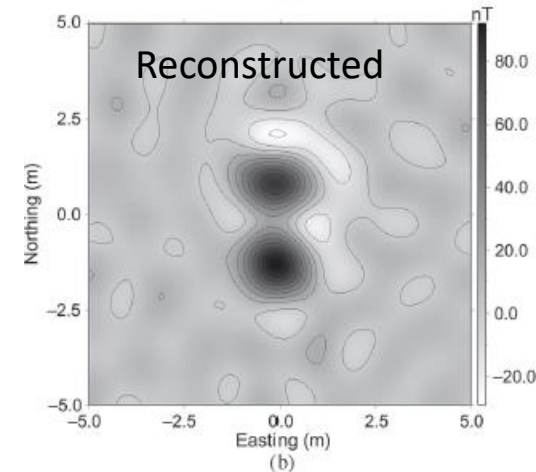
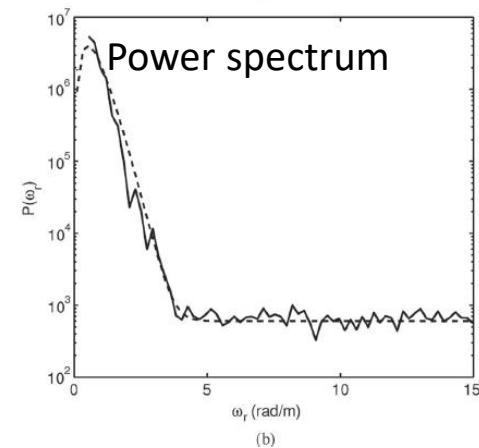
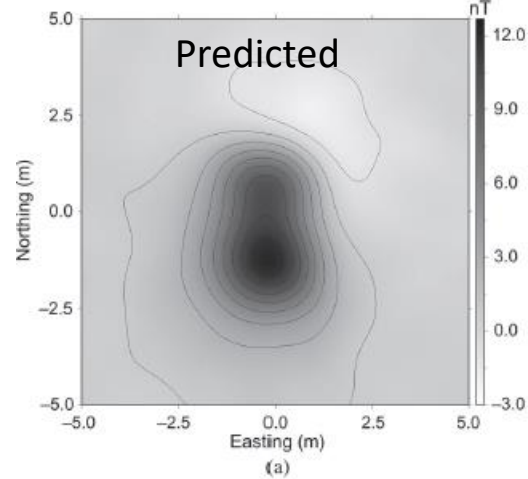
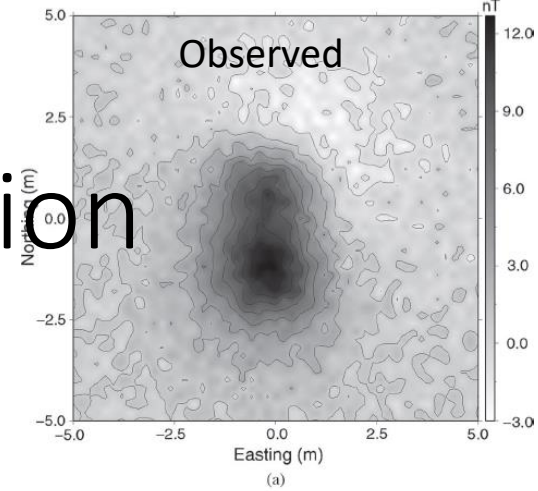
2006 - 2010

- Declared chemical engineer major for first year
- Immigration status prevented internships
  - Worked for free for a professor for a summer
  - Wrangled a technical internship into a course credit
  - Became a research assistant after getting a student visa; first peer-reviewed publication and hooked on inversions



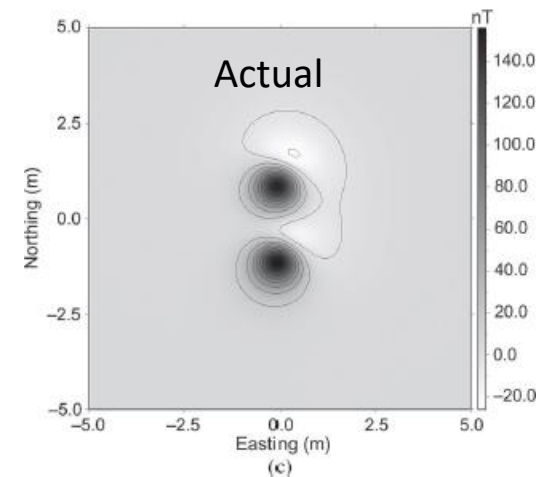
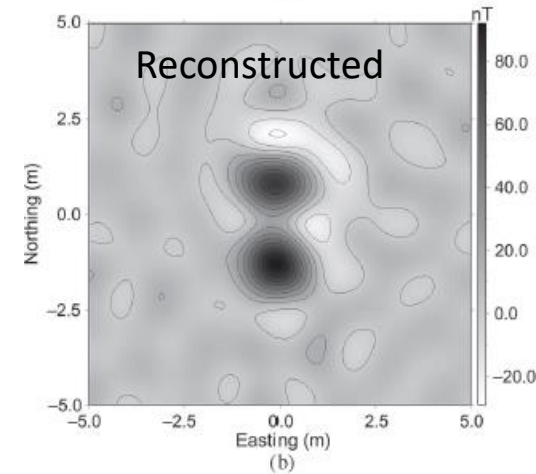
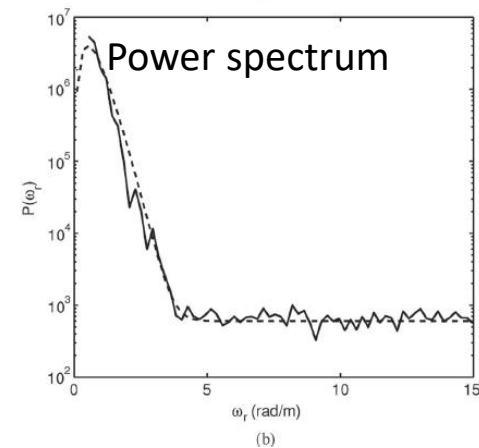
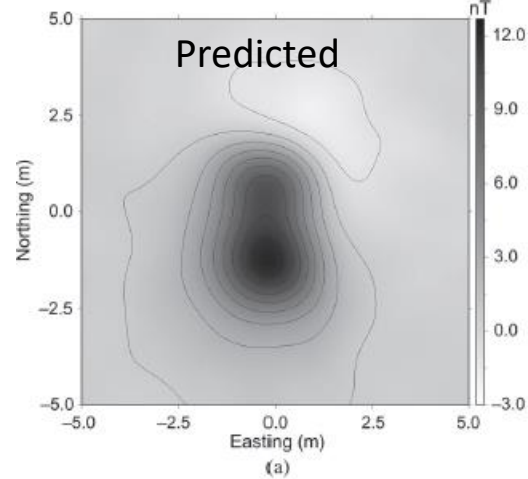
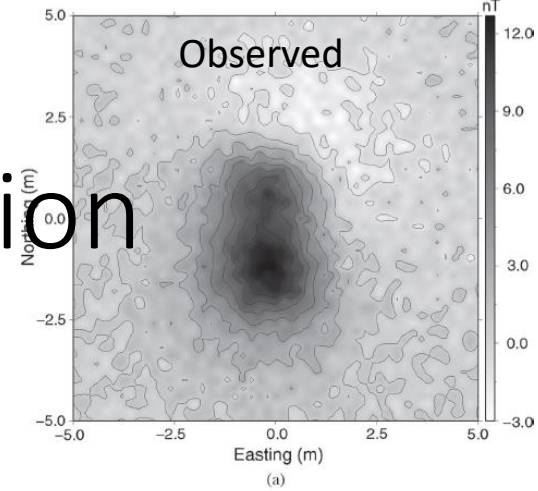
# Stable downward continuation

- Inversion approach to downward continuation, which incorporates the expected power spectrum of UXO anomalies
- Power spectrum preserves spectral properties while subduing amplification of high-frequency noise



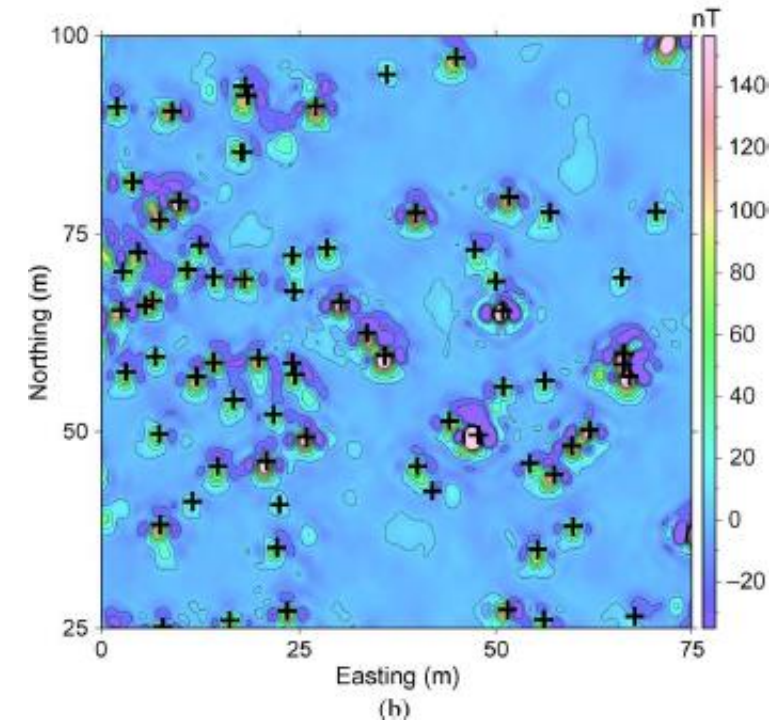
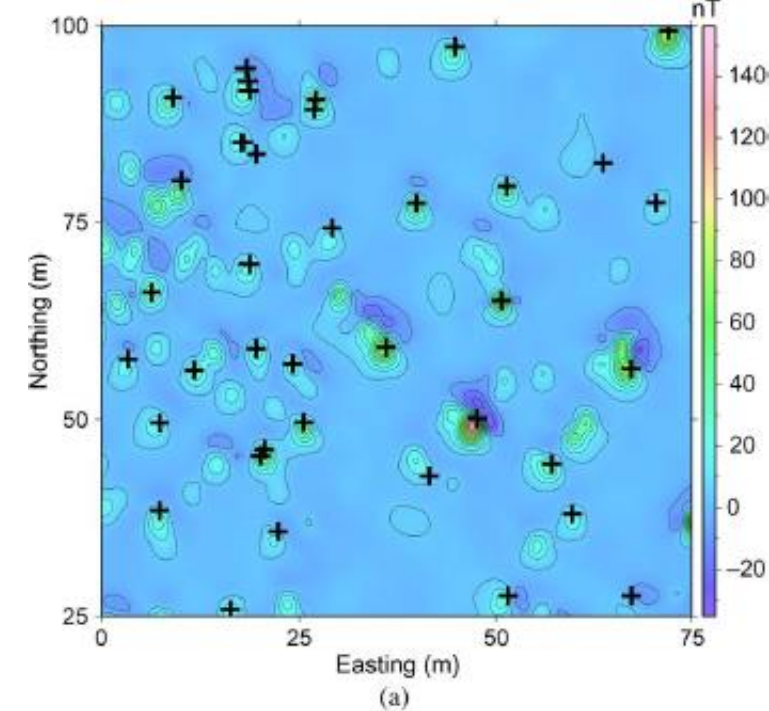
# Stable downward continuation

- Inversion approach to downward continuation, which incorporates the expected power spectrum of UXO anomalies
- Power spectrum preserves spectral properties while subduing amplification of high-frequency noise
- The result is the field reconstructed at a lower observation height without being dominated by noise



# Kirkland, NM example

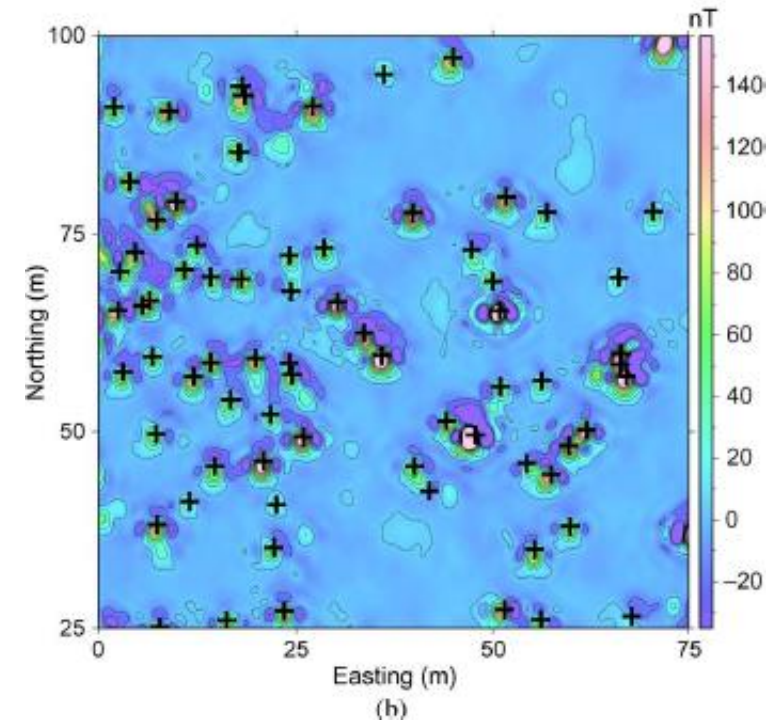
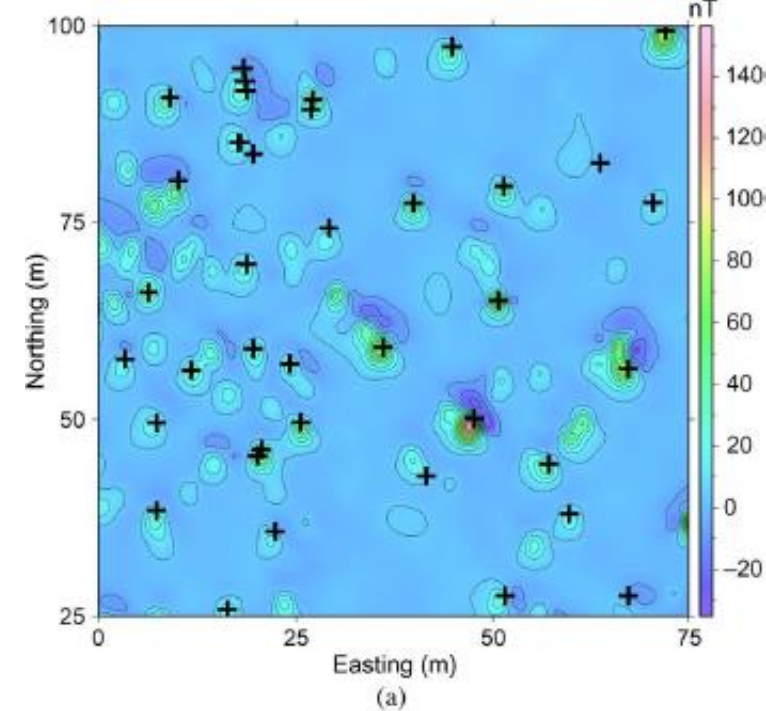
- 6500-acre demonstration area with a variety of UXO
- Heliborne magnetic data collected at 1-1.25 m height
- Automated Euler detection results picks up many UXO anomalies





# Kirkland, NM example

- 6500-acre demonstration area with a variety of UXO
- Heliborne magnetic data collected at 1-1.25 m height
- Automated Euler detection results picks up many UXO anomalies
- Data were stable downward continued by 1 m
- Rerunning the Euler detection algorithm results in far more identified UXO anomalies



# Other incredible projects



# Country-less summer 2010

- Student visa expired after graduating CSM in May, Canadian one not ready till August

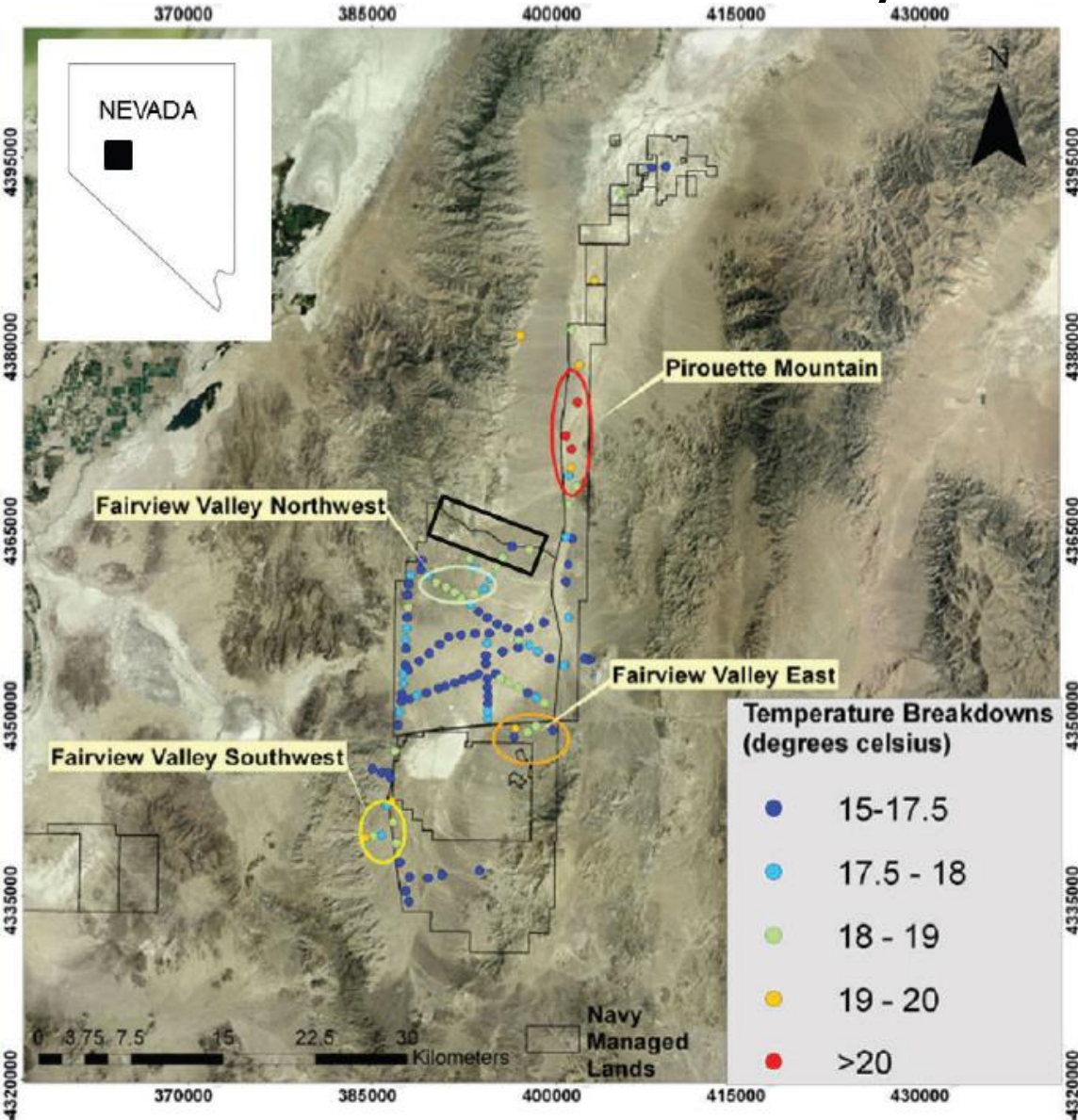


# University of British Columbia

2010 - 2016

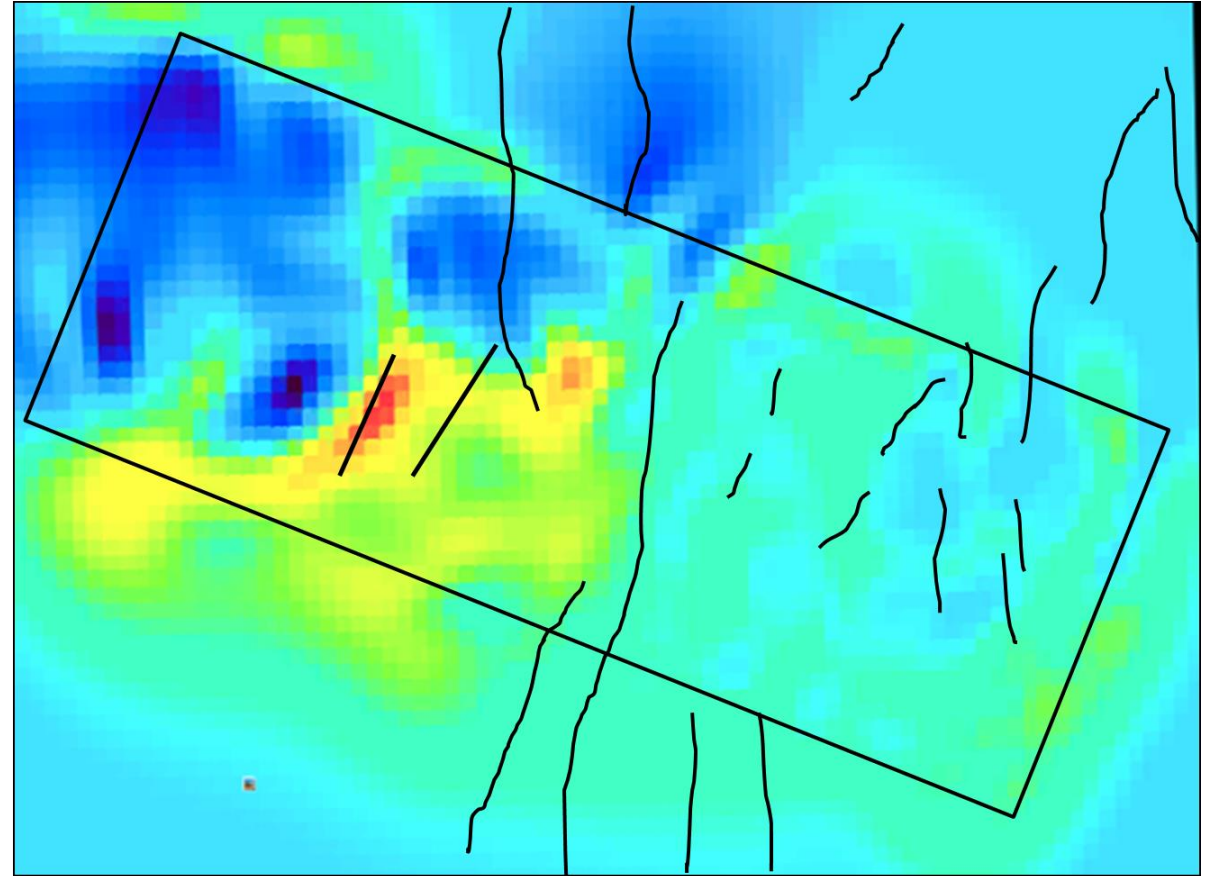
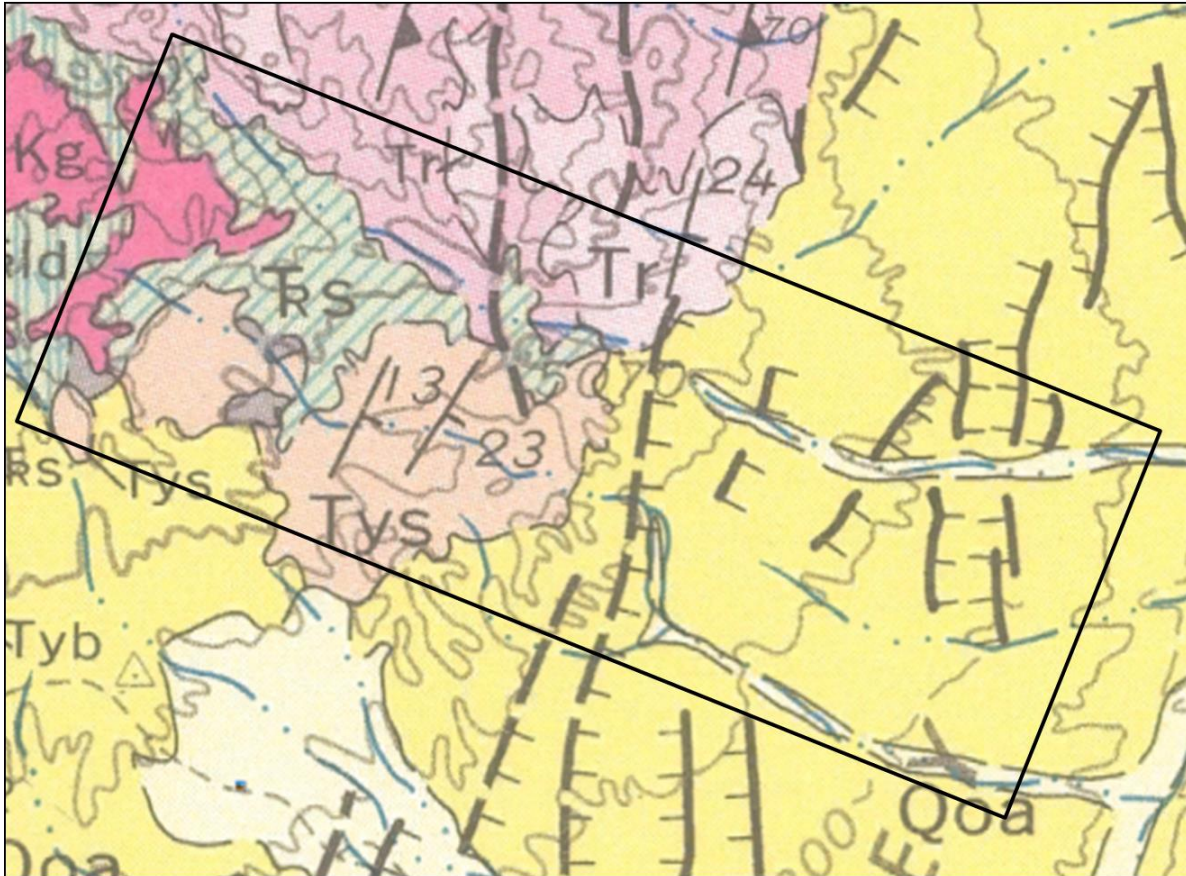
- Leap of faith – never been to Vancouver before deciding to move
- Enrolled in master's program, upgraded to PhD in 2012
- A very challenging first year

# Elevenmile Canyon



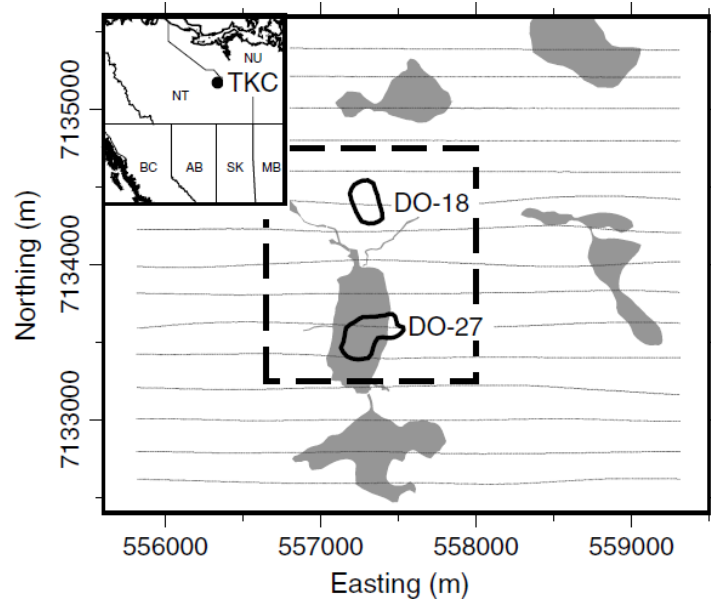
- The Elevenmile Canyon, located in the Basin and Range of Western Nevada, contains a low geothermal anomaly
- The canyon lies on the eastern flank of Stillwater Range and extends into the basin between Dixie and Fairview Valleys, both which are associated with geothermal activity

# Elevenmile Canyon





# TKC



- Joint UBC-GIF effort resulting in 3 peer-reviewed papers, multiple abstracts/conference talks, synthetic studies, and more
- A nice complement to my EM-focused thesis

**Table 2. Summary of the five different surveys used.**

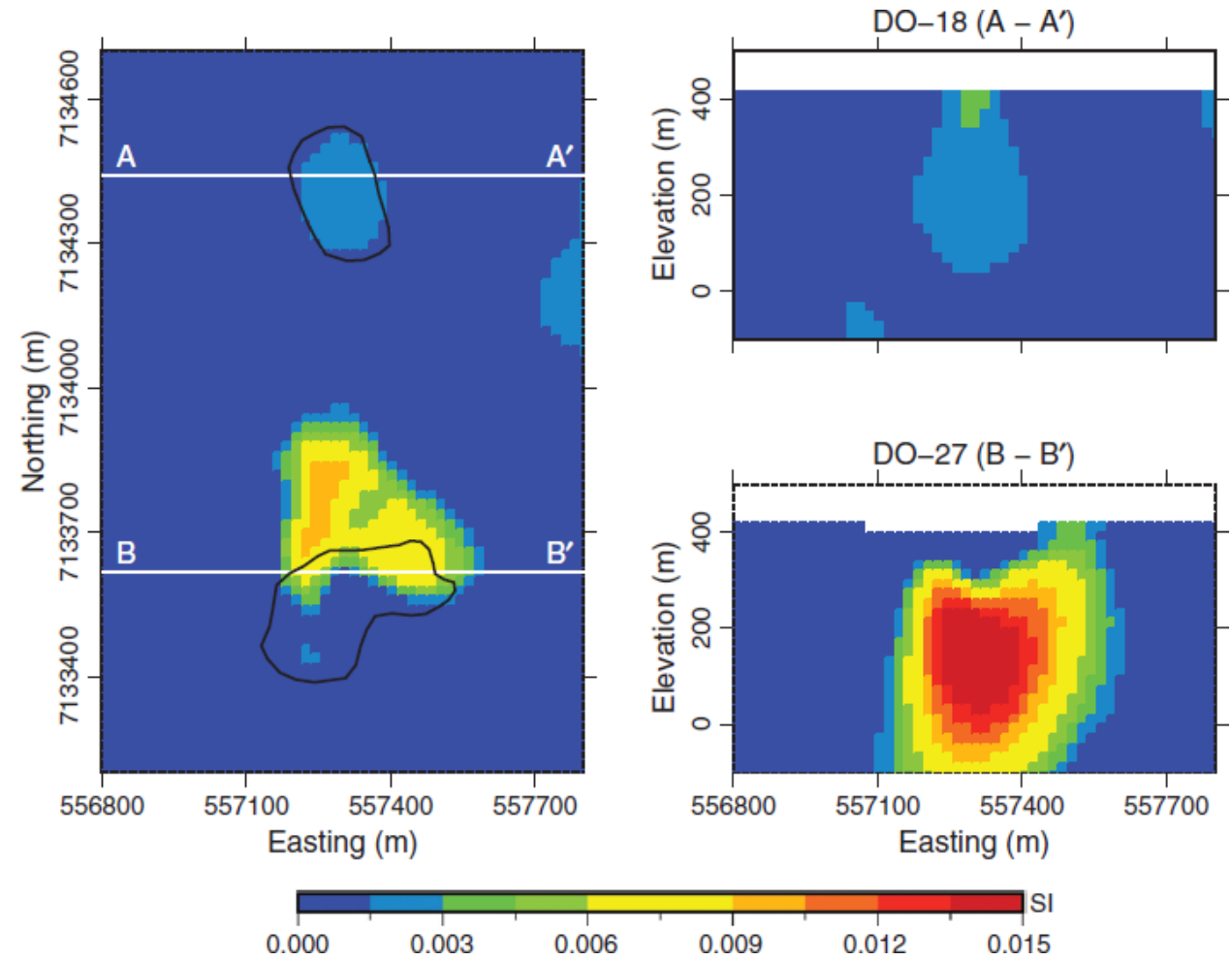
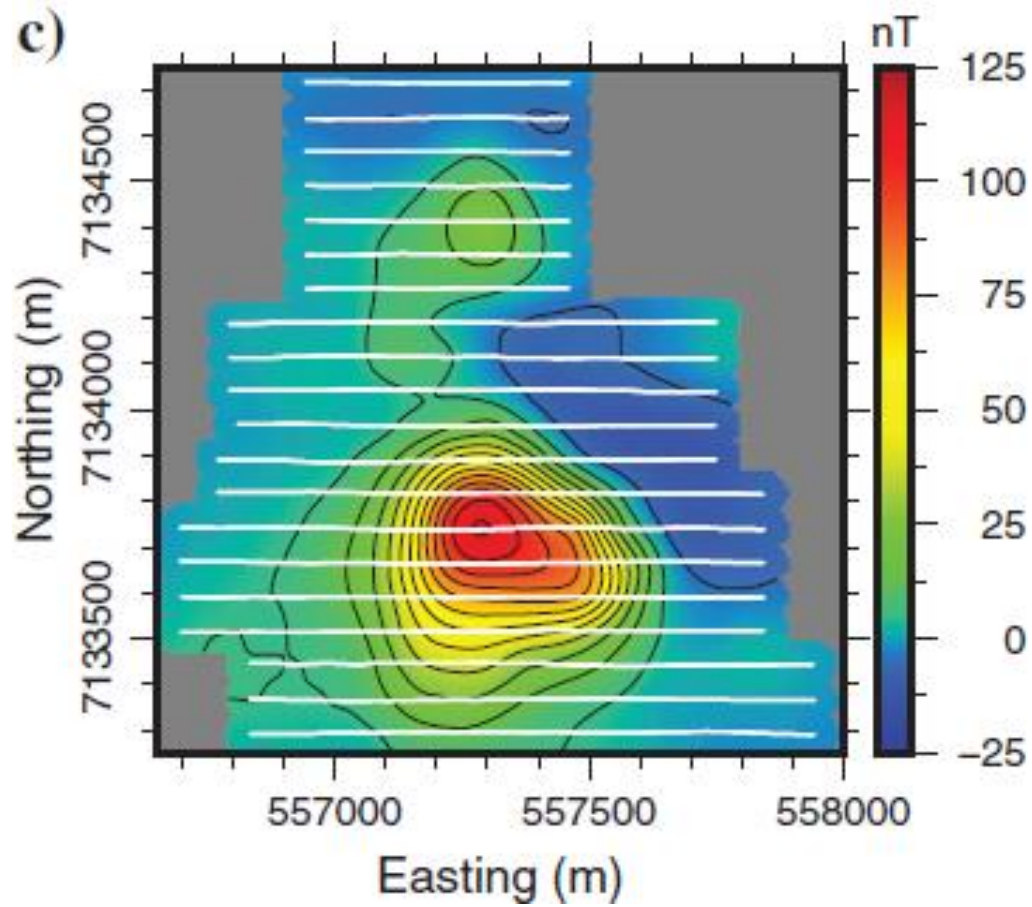
System	Year collected	Data collected
Dighem	1992	FEM, magnetics
Ground gravimeter	1994	Gravity
Falcon	2001	Gravity gradiometry
AeroTEM	2003	TEM, magnetics
VTEM	2004	TEM, magnetics

**Table 3. Parameters for the airborne magnetic surveys.**

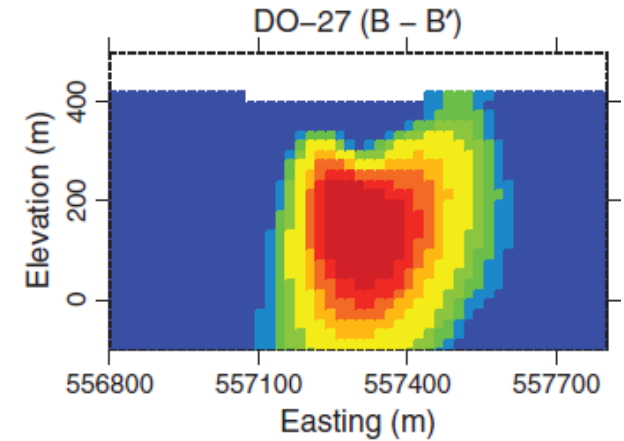
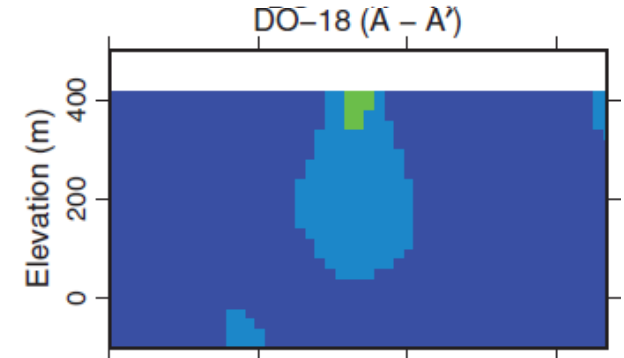
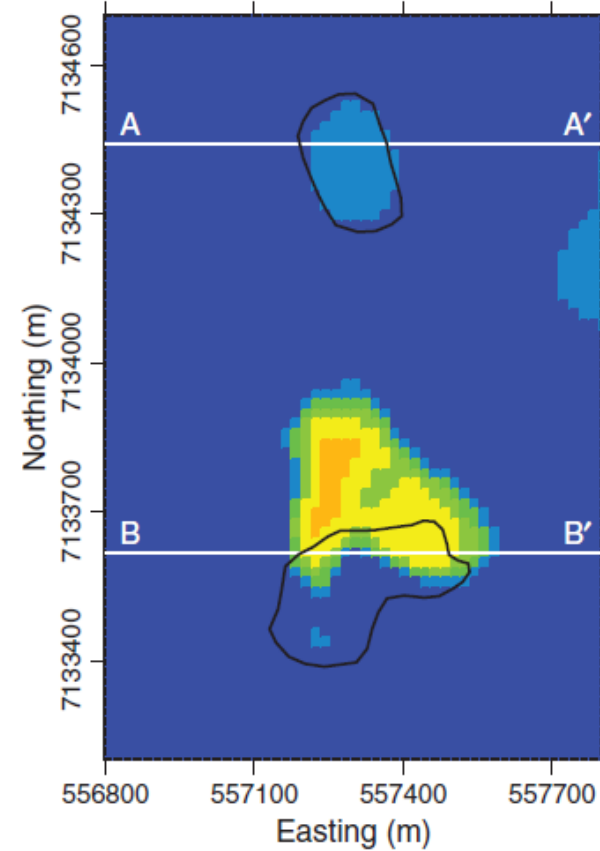
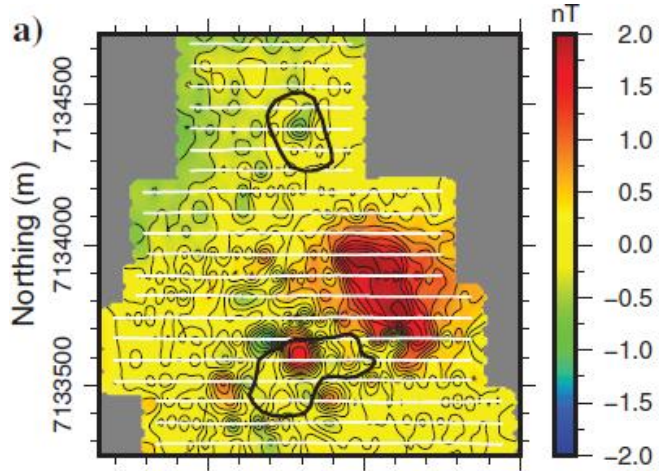
System	DIGHem	VTEM	AeroTEM
Flight line spacing (m)	200	75	75
Number of data	6274	26334	22561
Inclination (°)	83.0	83.3	83.0
Declination (°)	21.0	19.5	20.0
Field strength (nT)	59,500	59,580	59,500



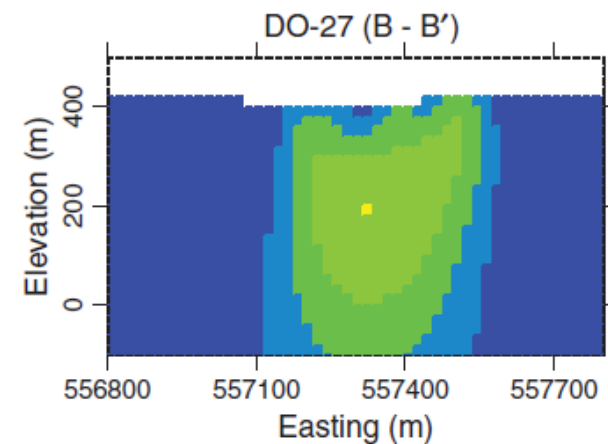
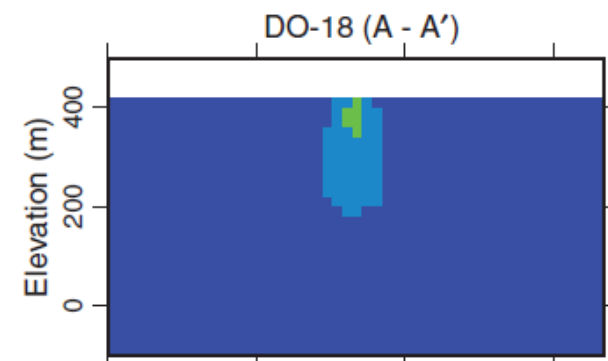
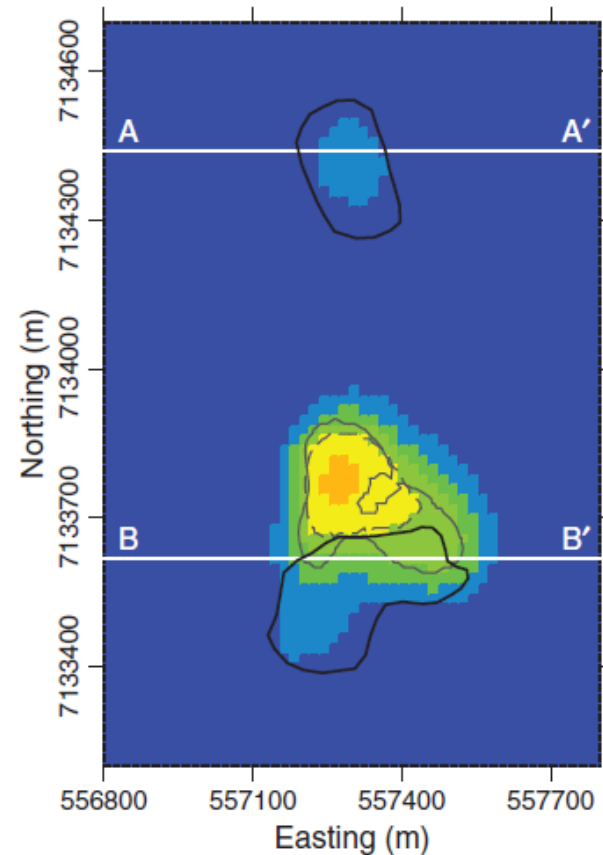
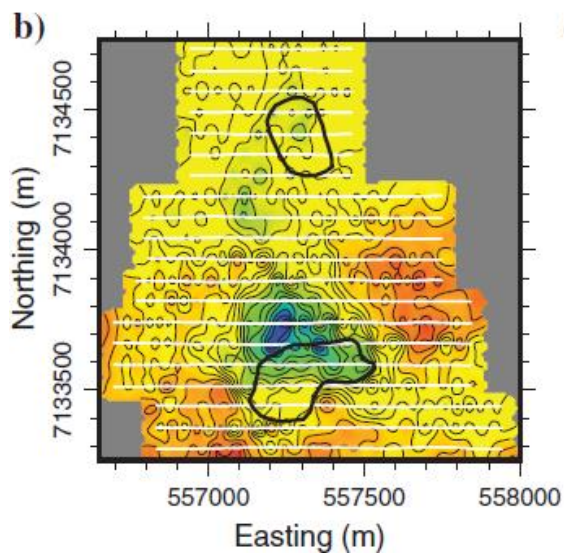
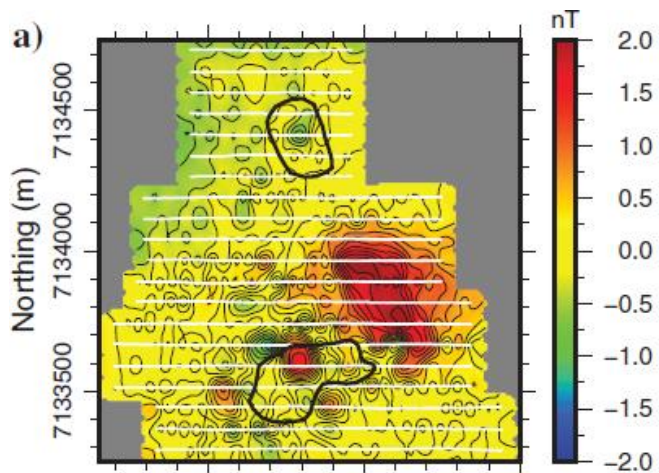
# TKC



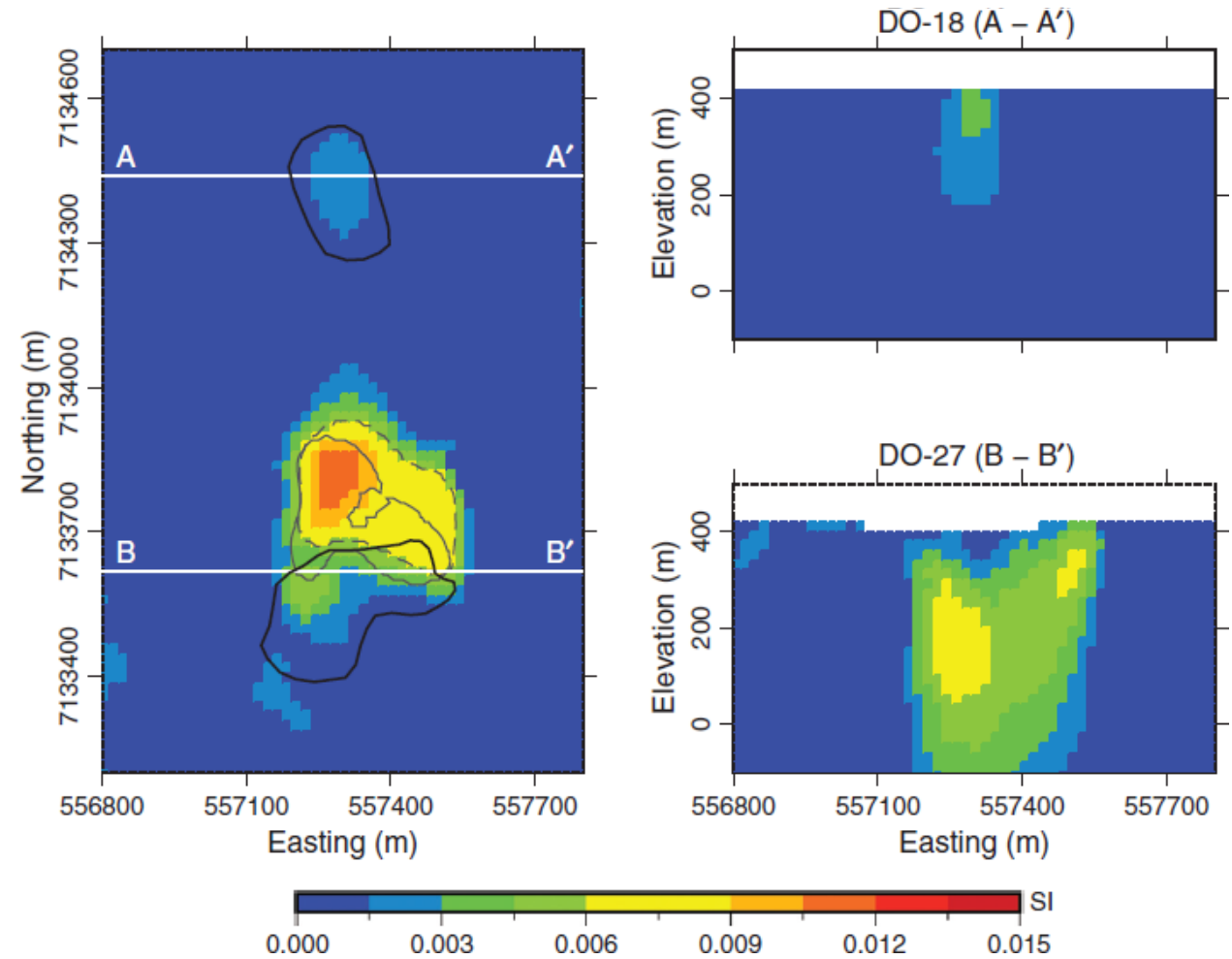
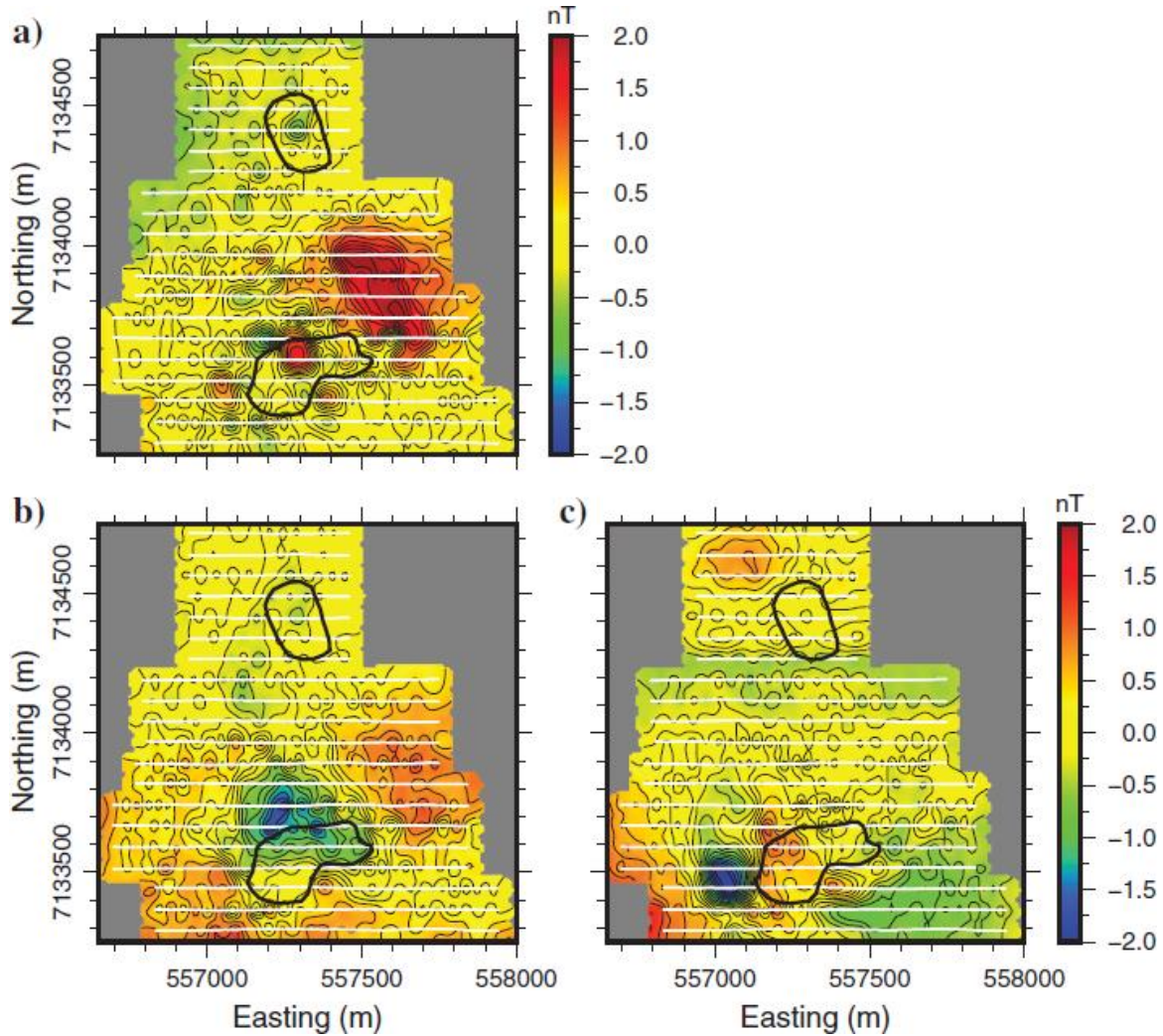
# TKC: Induced inversion



# TKC: MVI



# TKC: bulk-magnetization inversion



# Community involvement

- 20% of geoscientists identify female
- Yet half of undergraduate degrees in geoscience are awarded to women
- Found a community within another male-dominated field

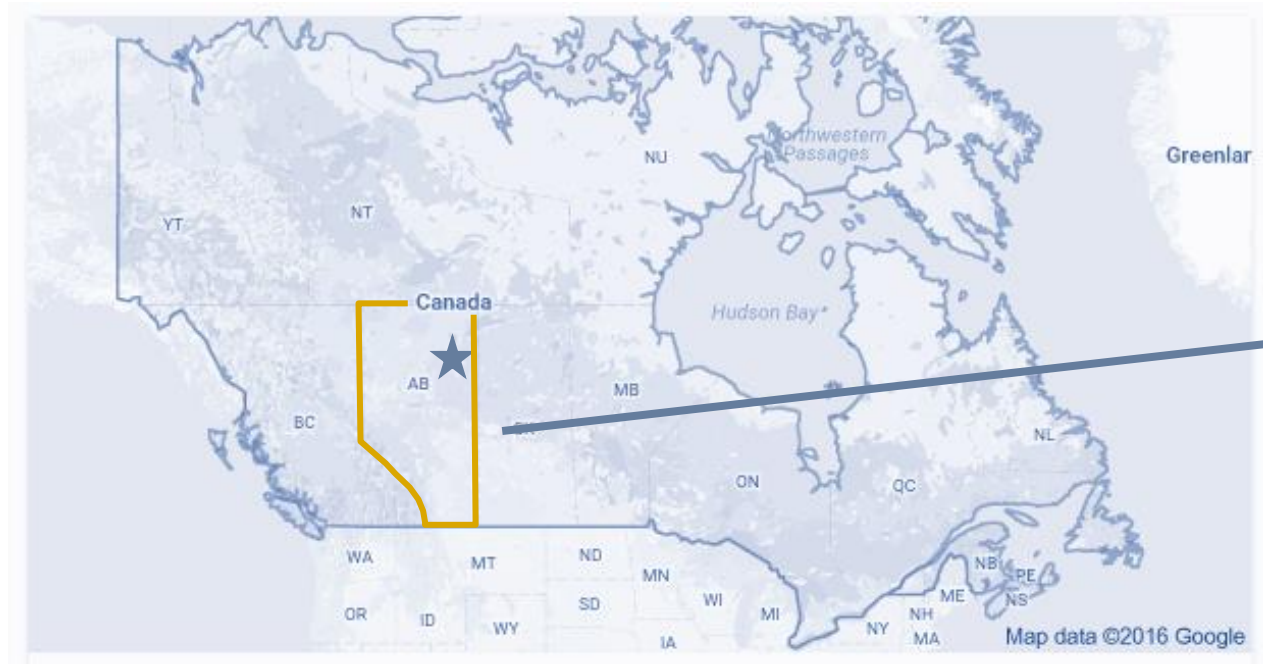


# Community involvement

- Been a director for 5 non-profits, two with president roles
- Advocated for responsible land use management
  - Erosion
  - People conflicts
  - Land ownership
  - Access for future generations
  - Grant proposals
  - Permitting

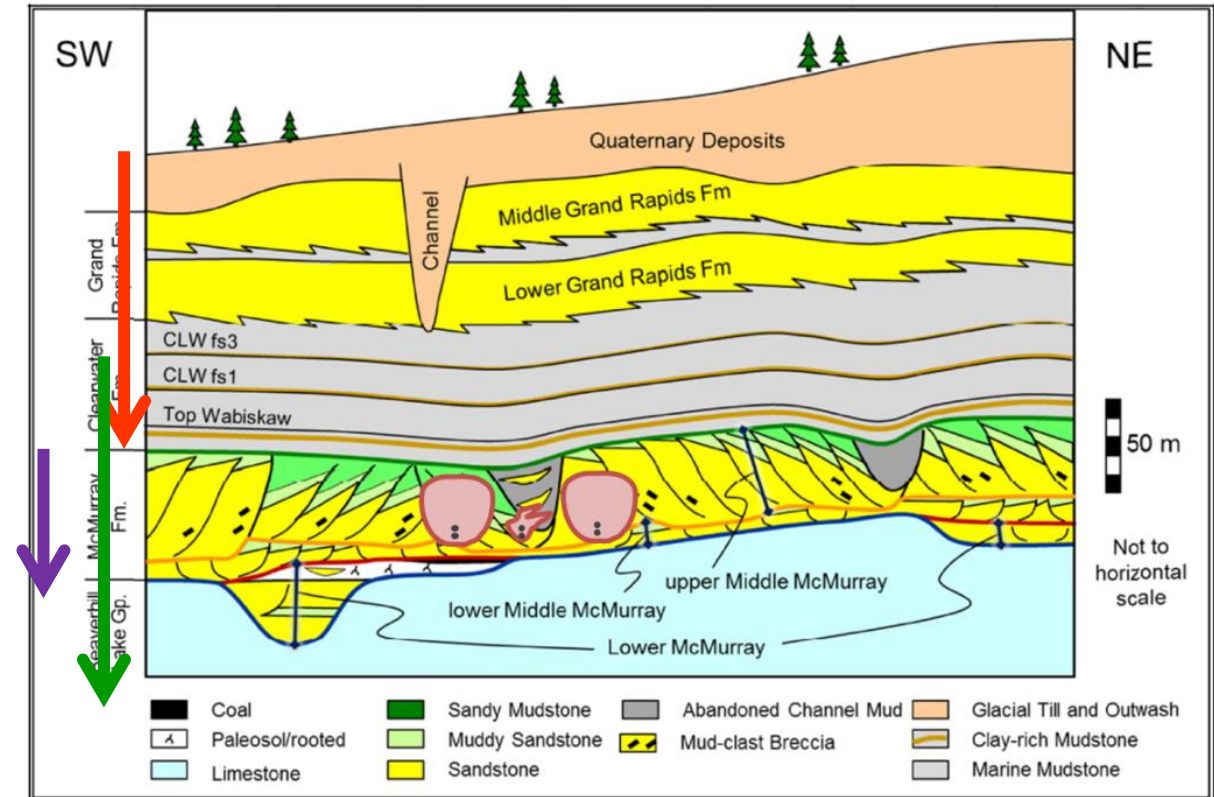


# EM for SAGD – thesis project



# Geologic questions

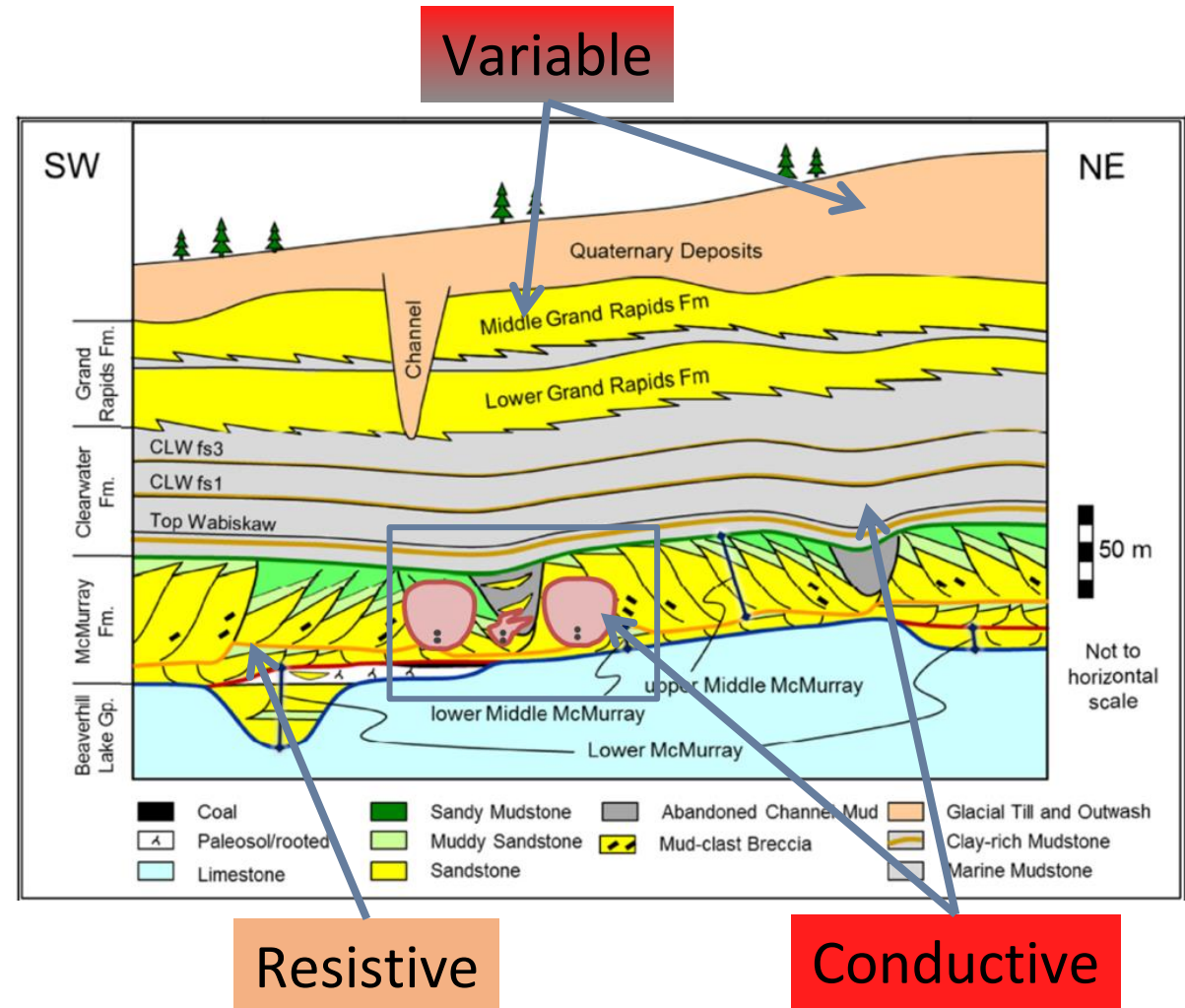
- Regional →
  - Quaternary channels
  - Clearwater Fm
- Local-scale →
  - McMurray Fm
  - Devonian basement
- Monitoring →
  - SAGD steam growth





# Resistivity contrasts

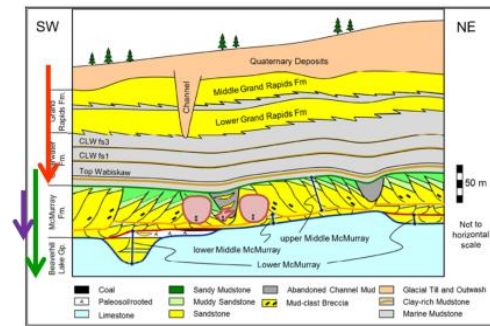
- Regional →
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# Research questions

- Regional →
  - Quaternary channels
  - Clearwater Fm
- Local-scale →
  - McMurray Fm
  - Devonian basement
- Monitoring →
  - SAGD steam growth

- Can EM be used?
  - Feasibility
- Why?
  - **Resistivity** contrasts (Butler and Knight, 1998; Mansure et al, 1993; Tøndel et al, 2014)
  - Less expensive than seismic (Engelmark, 2007)
  - Permanent installations (Tøndel et al, 2014)
- How?
  - Many survey choices

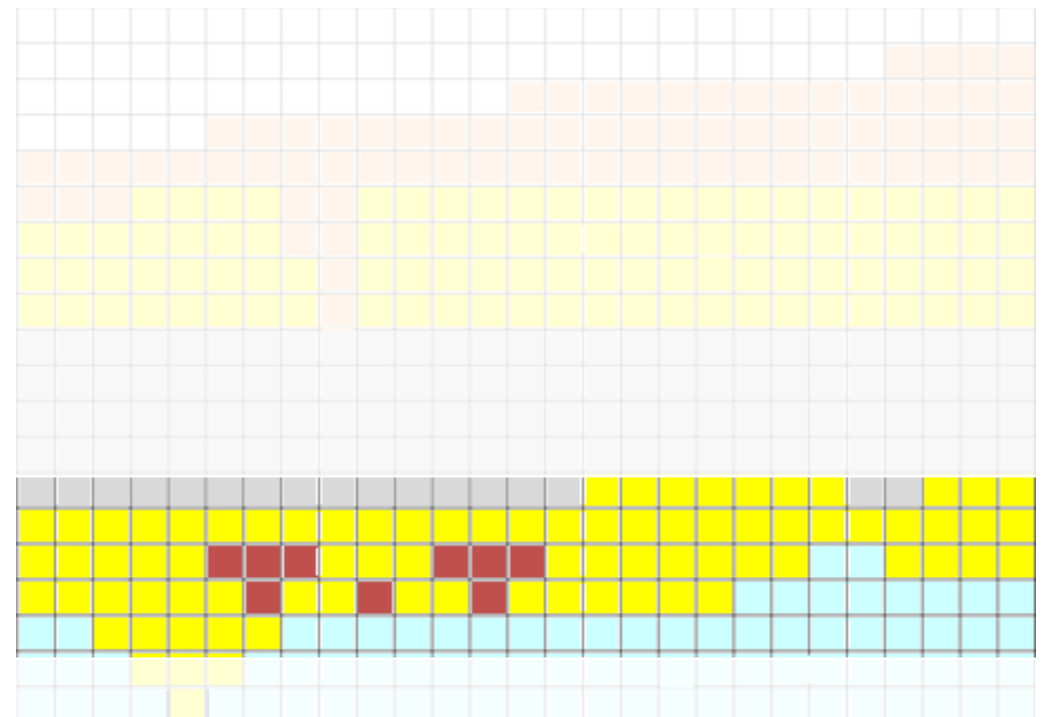
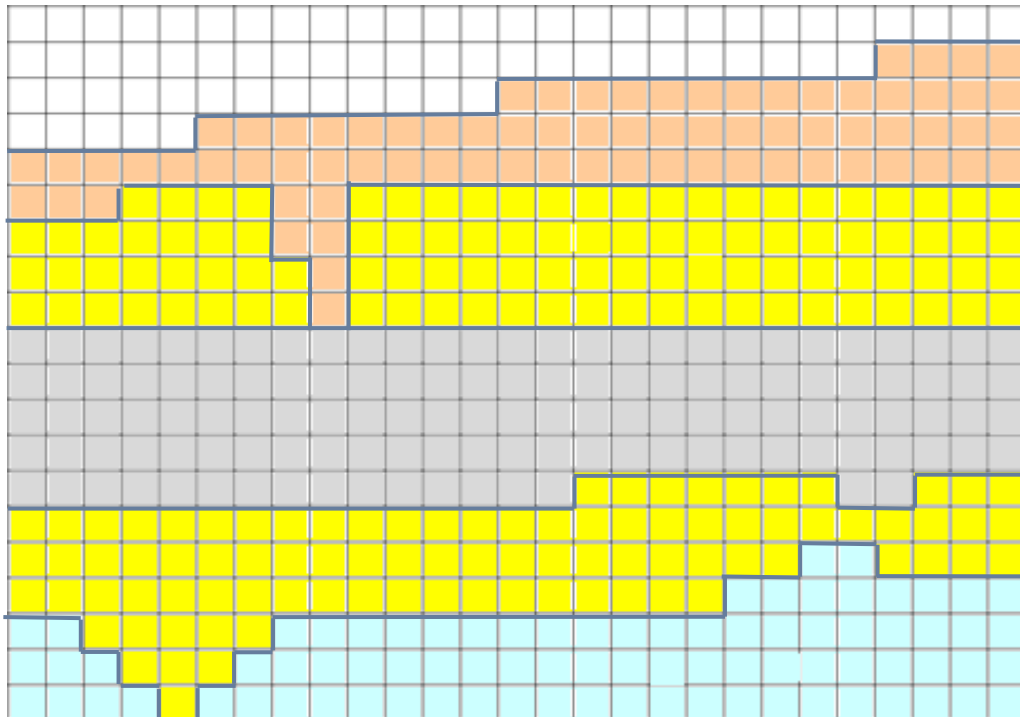




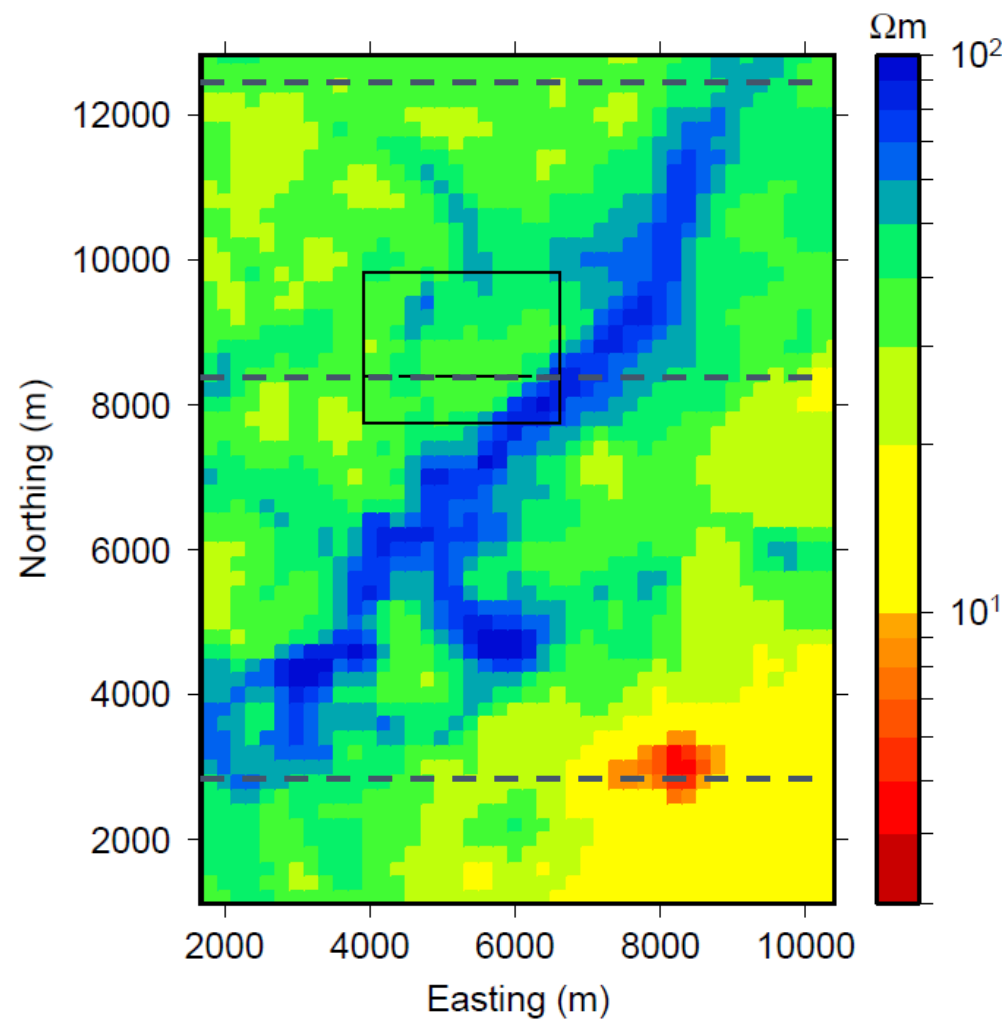
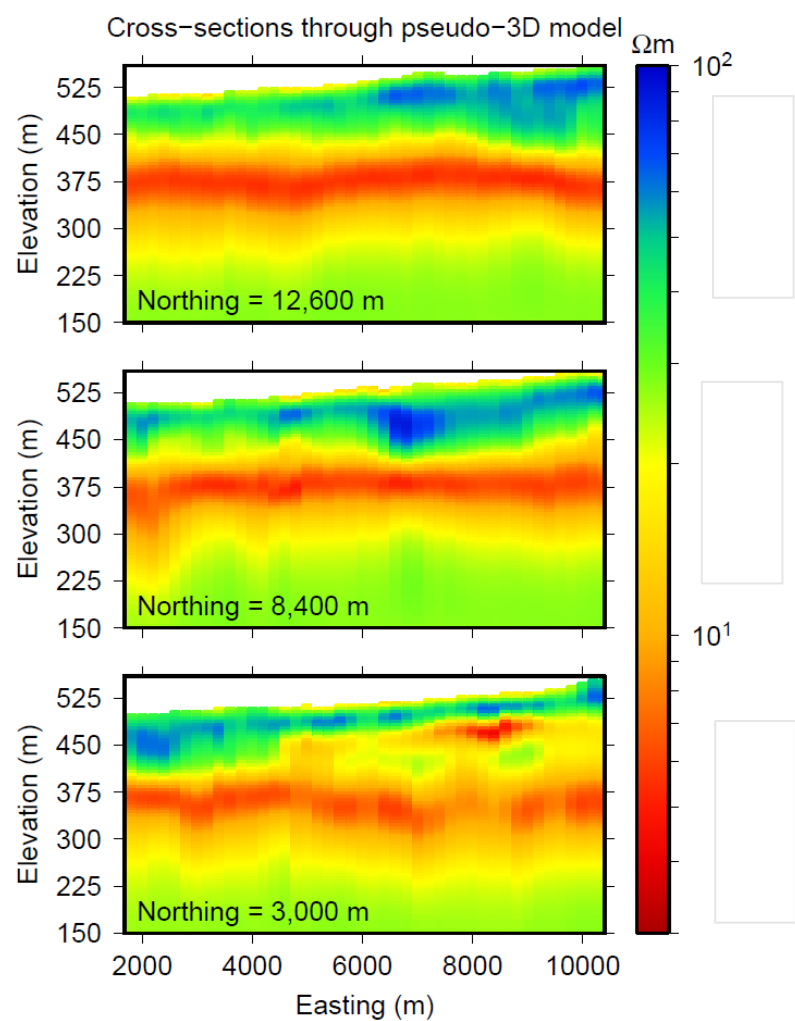
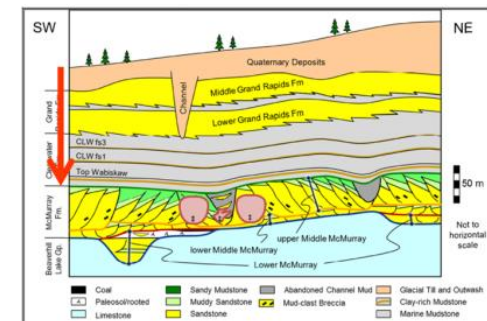
model ← data

# Inversion

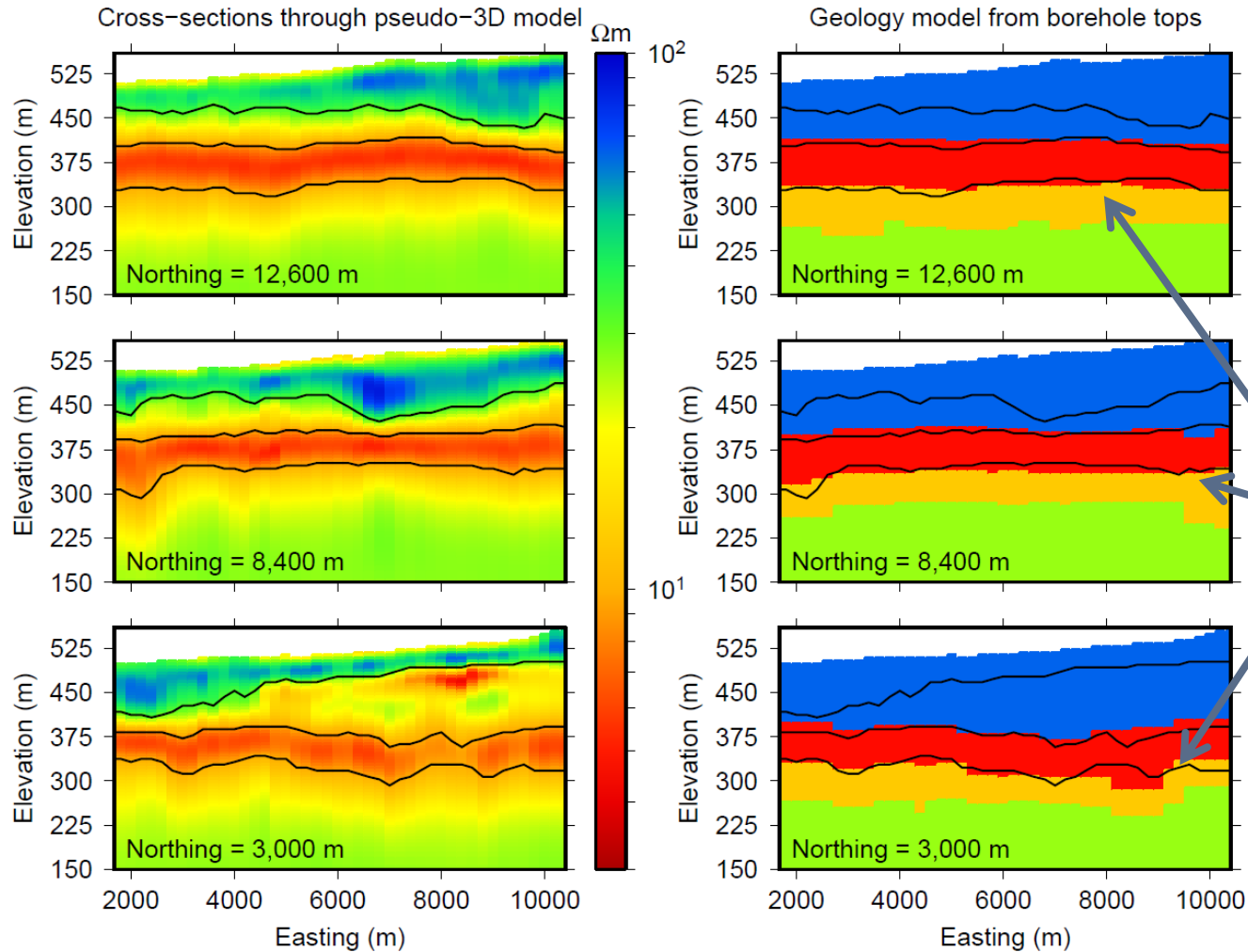
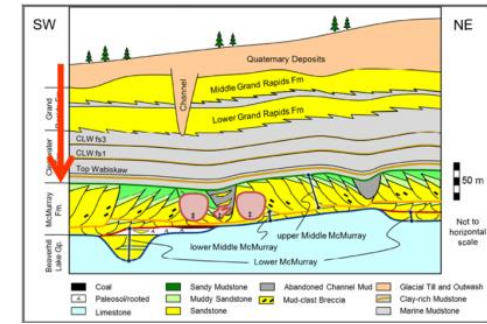
- Incorporate a priori information
  - Geologic surfaces
  - Background model
  - Active cells
  - Directional smoothing



# Recovered model

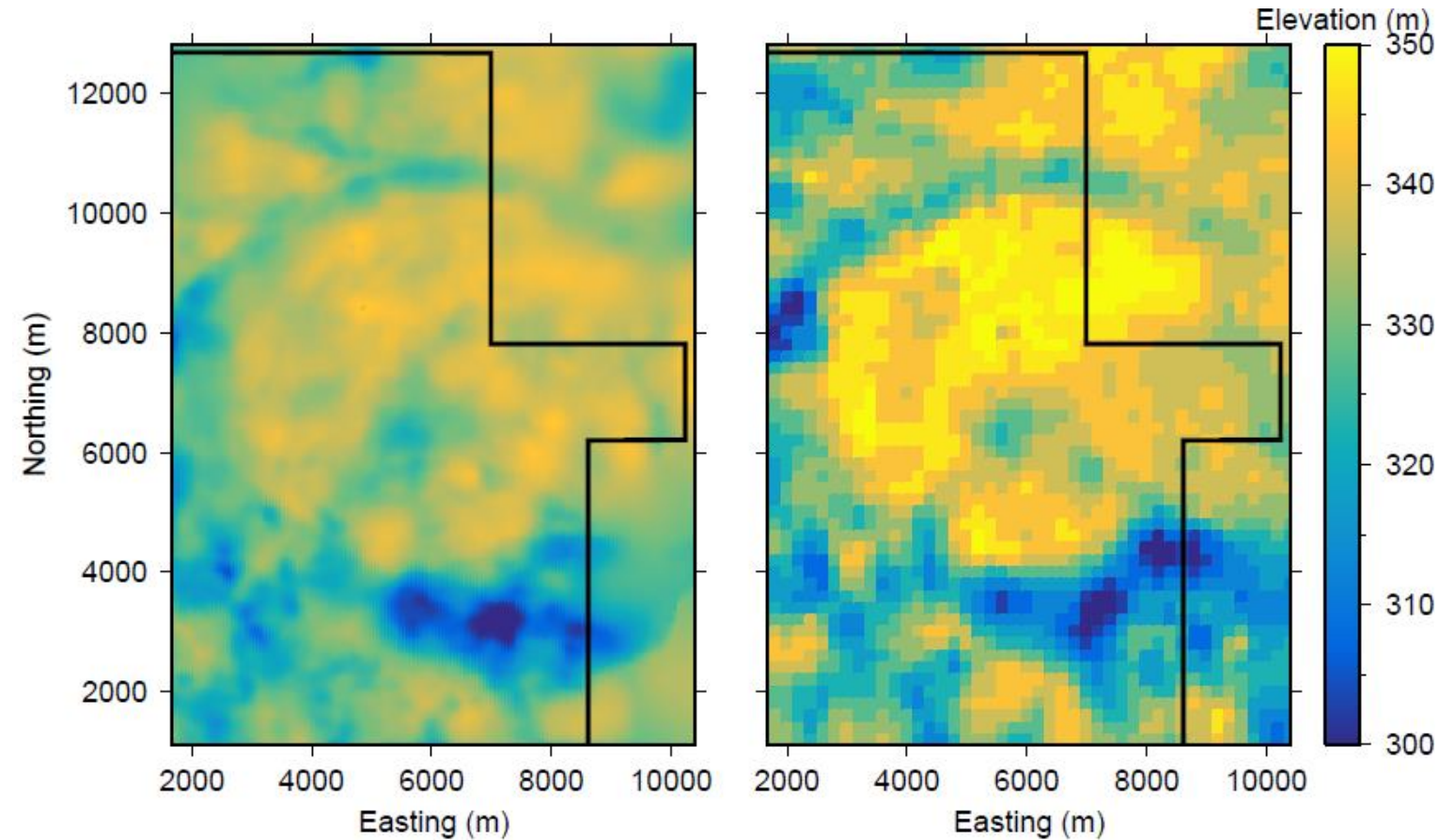


# Interpretation



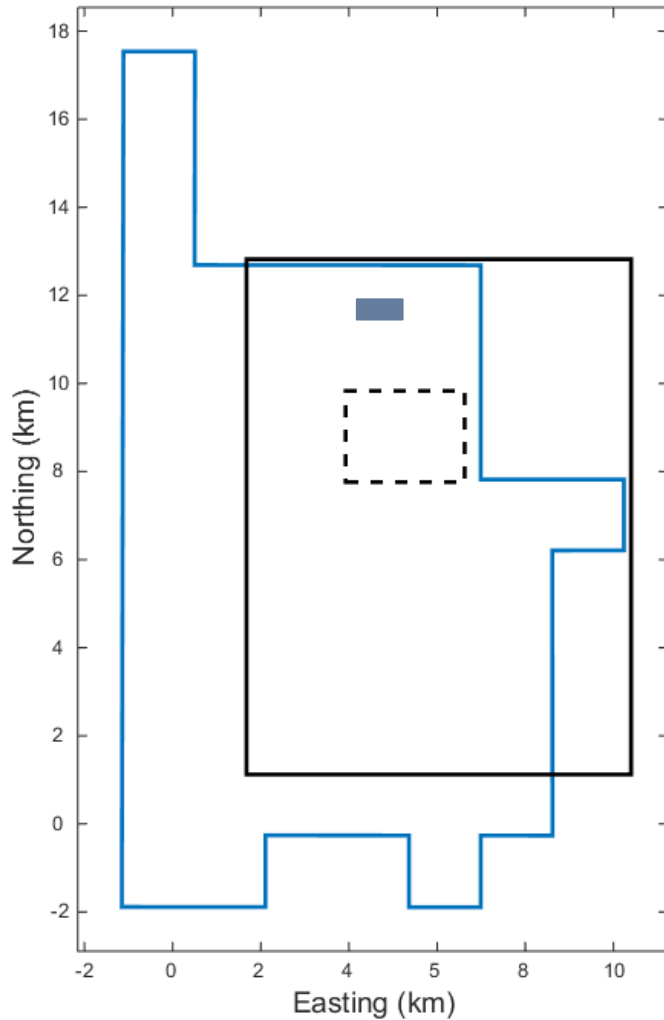
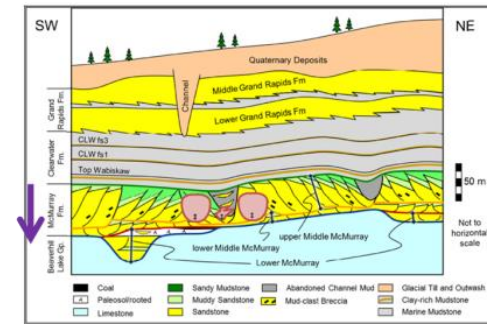
- Interpreted layers match nicely with geology model from borehole top
- Surprising! Recovered top of McMurray Formation

# Compare structure maps

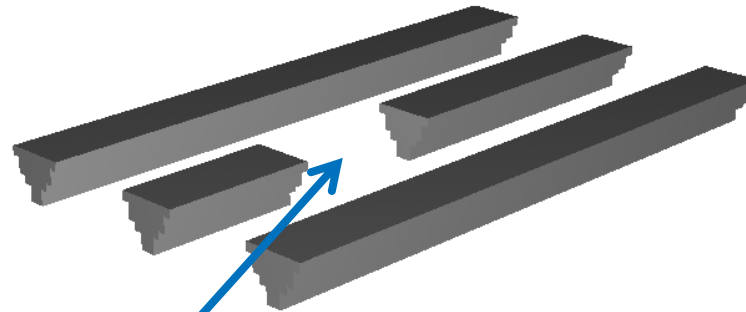


- Map top of McMurray Fm
  - From pseudo-3D model
- Comparison to structure map from borehole data
  - Imperial AER SAGD application
- Many structural similarities and similar elevations
- But... no info below McMurray

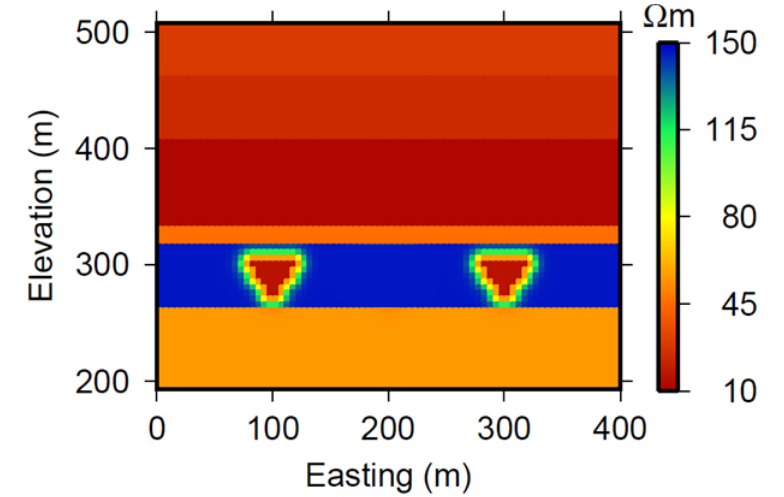
# Field-based example: Aspen



- Add steam chambers to background model

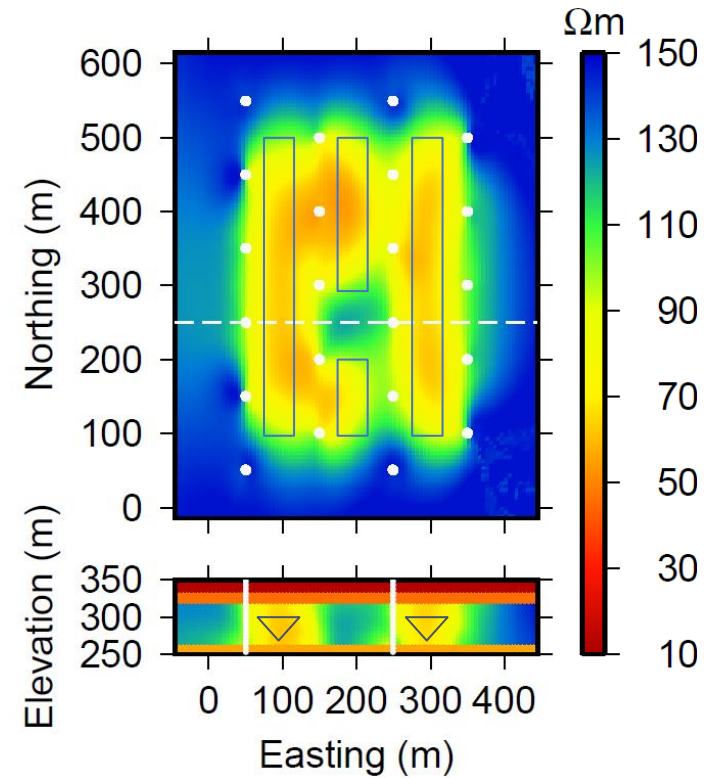
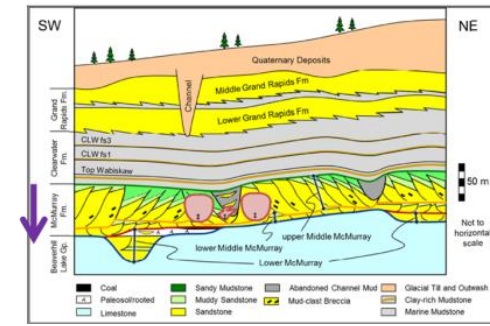
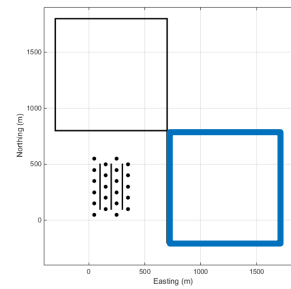


- Gap of no steam growth





# Inversion: east TX



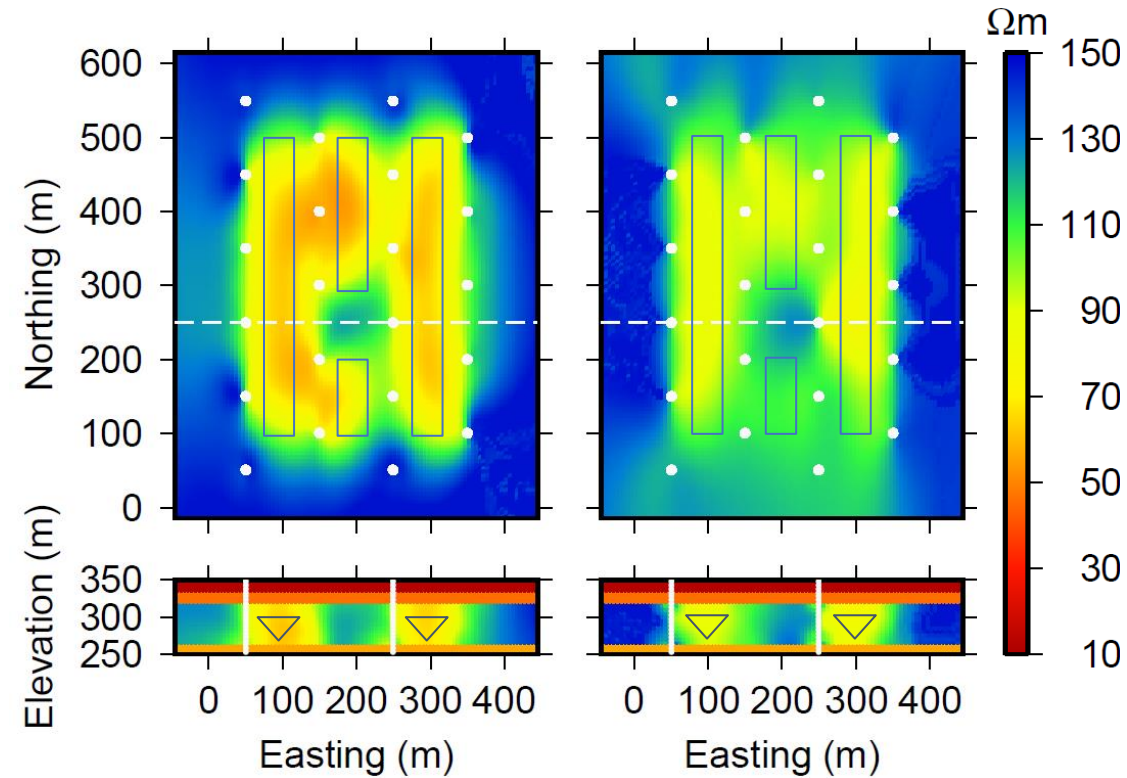
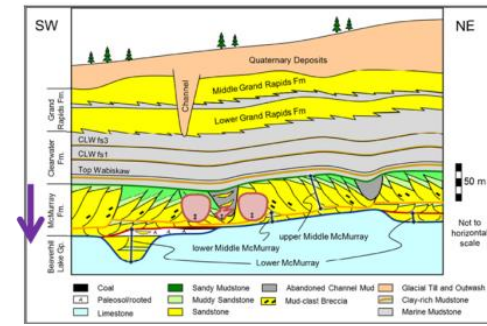
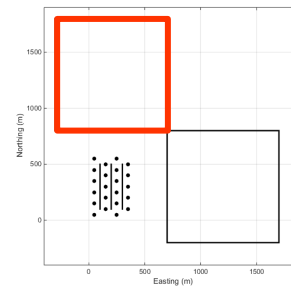
- Pros

- Amplitude
- Chamber lengths
- Easternmost chamber
- Gap clearly recovered

- Cons

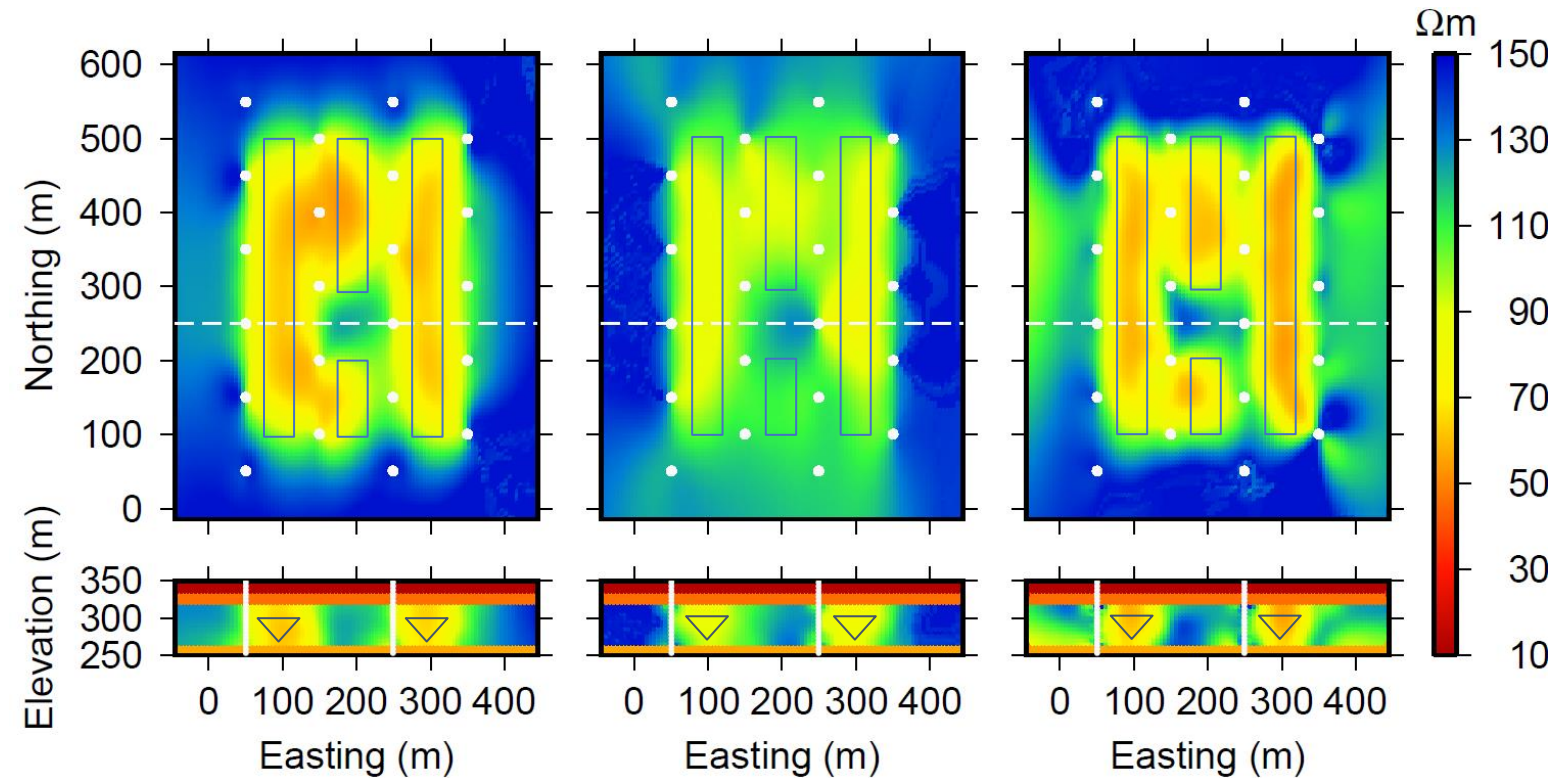
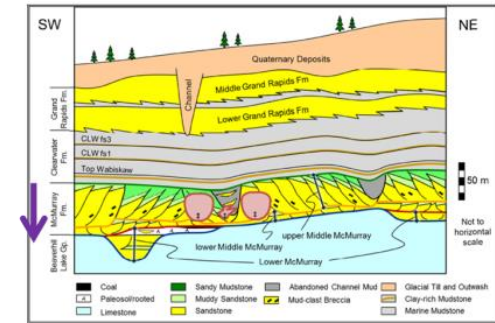
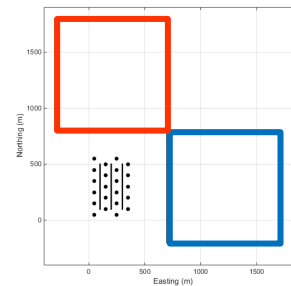
- Vertical resolution
- Western chambers

# Inversion: north TX



- Pros
  - 3 distinct chambers
  - Gap clearly recovered
- Cons
  - Vertical resolution
  - Amplitude
  - Southern edges

# Inversion: both TXs



## • Pros

- Best of both!
- 3 distinct conductive chambers
- Resistive gap clearly recovered

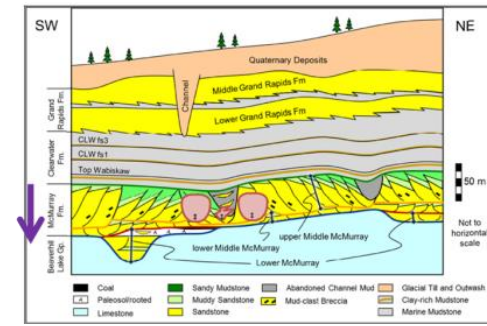
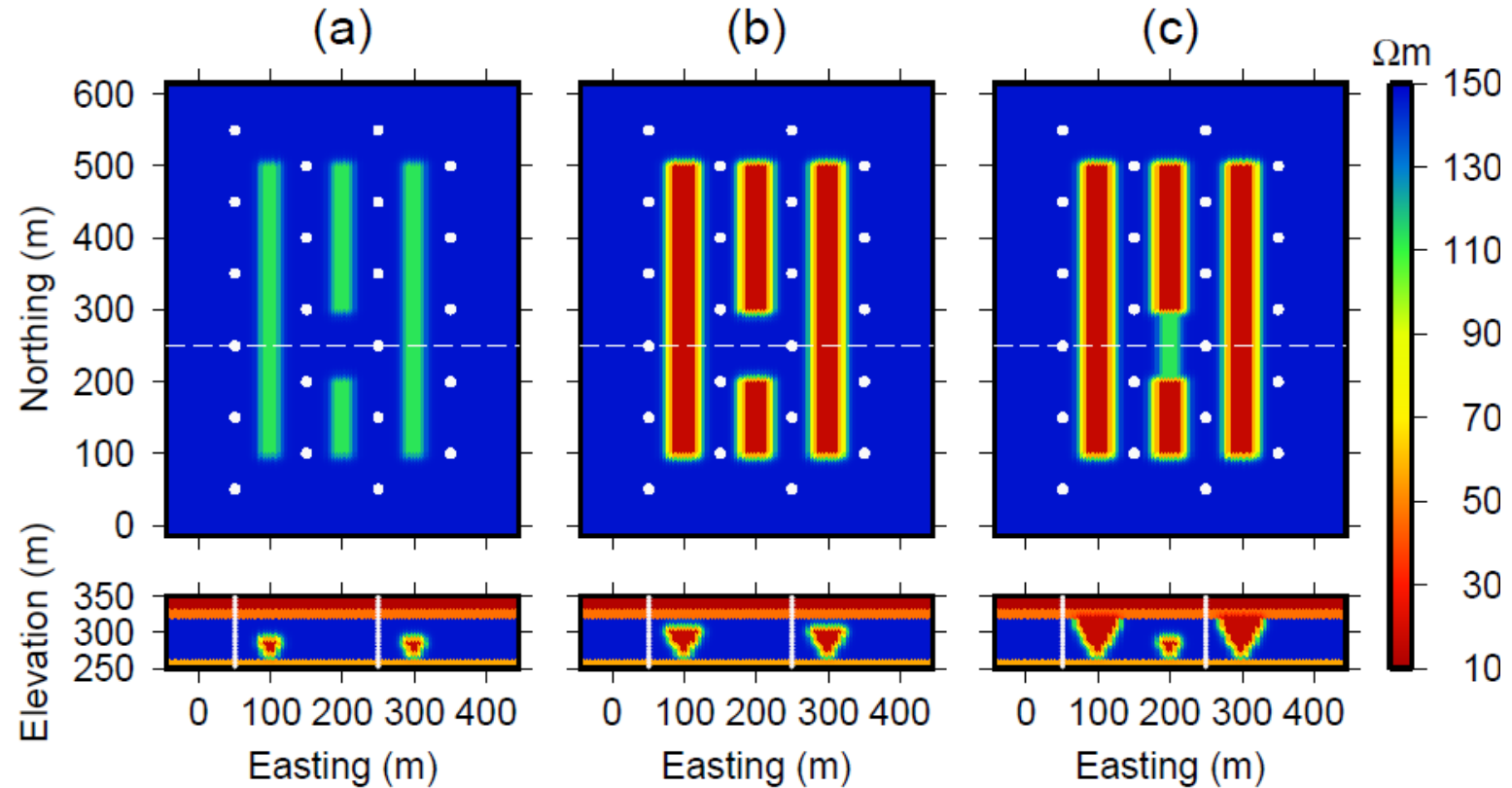
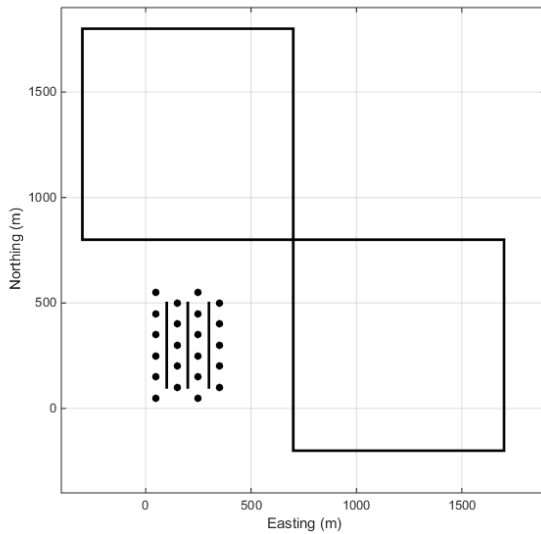
## • Bonuses

- Few txs → fast inversion
- Data includes  $E_z$  only
- Promising **monitoring tool!**  
||
**time-lapse**

# Time-lapse model

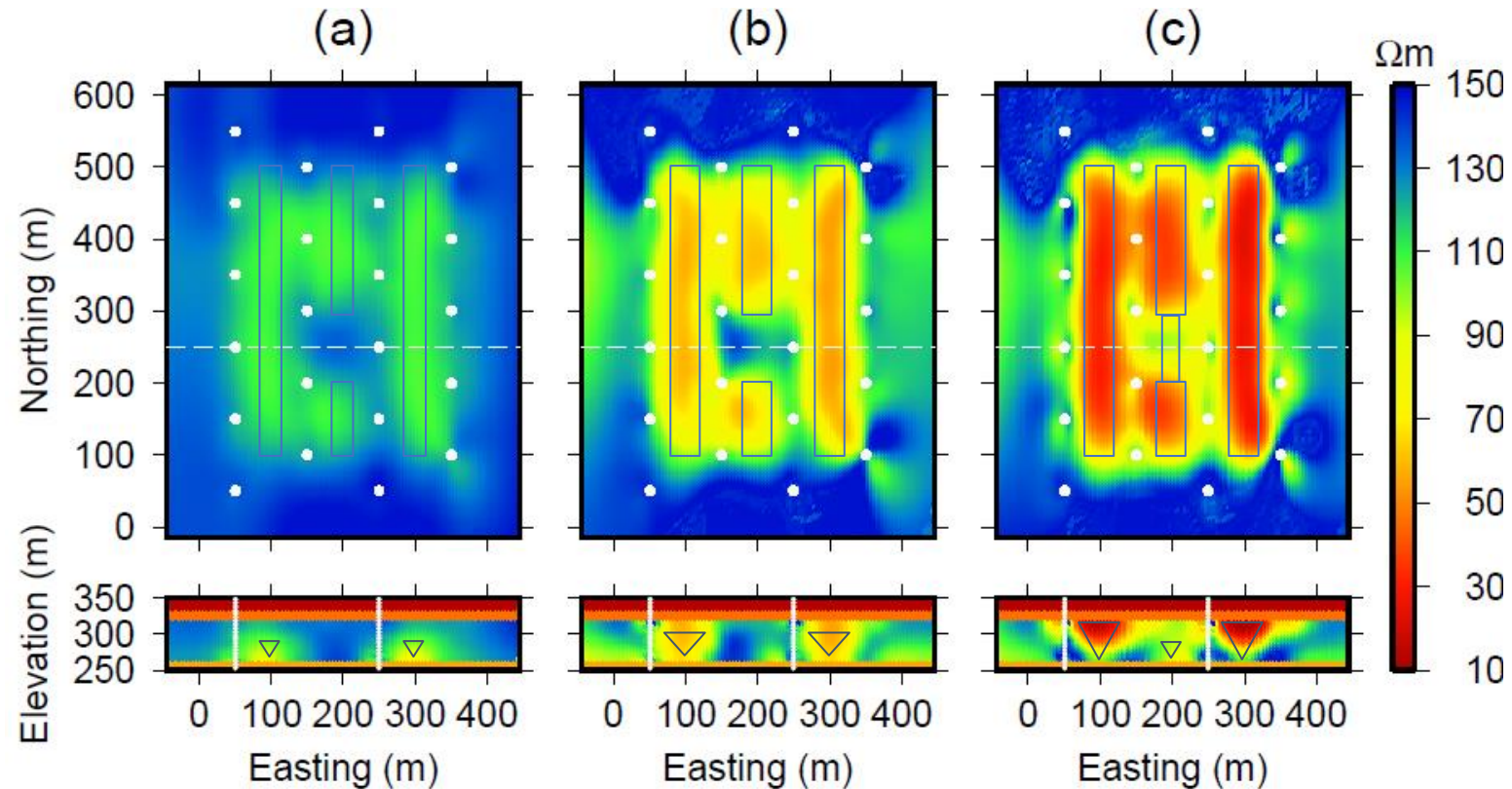
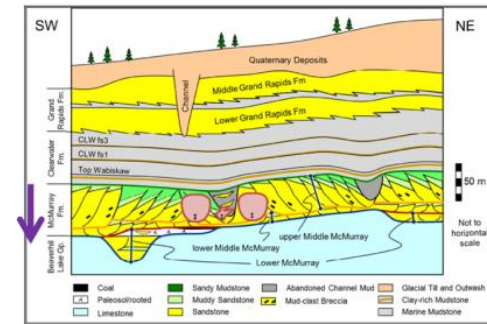
- Steam chambers grow over time → **monitoring**

- Same survey design



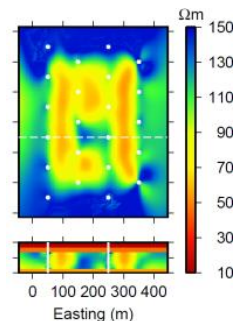
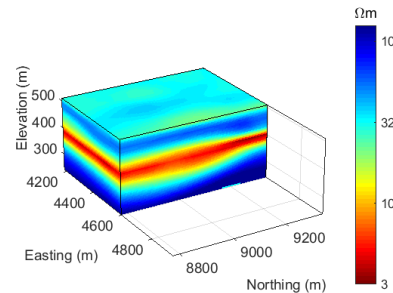
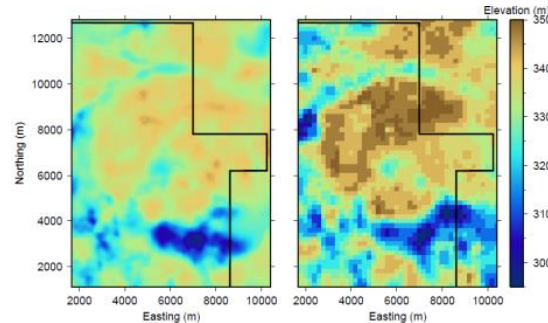
# Time-lapse results

- Cascading
  - Use (a) to start (b), use (b) to start (c)
- Recovered growth over time
- Gap imaged at each step!
  - High-resolution



# Concluding exploration strategy

- Regional →
  - Quaternary channels
  - Clearwater Fm
- Local-scale →
  - McMurray Fm
  - Devonian basement
- Monitoring →
  - SAGD steam growth



- Regional, large-scale exploration
  - Acquire seismic data **and airborne EM**
  - Drill, core, and log wells
- Identify prospect area
  - Focused studies and surveys, **including surface EM surveys**
  - Obtain AER approval
- Production
  - Produce oil and monitor
  - **Surface + borehole combination surveys**

# Postdoc

2017

- Continued developing GIFTtools to advance inversion for industry
- Directly worked with 7 of the big mining companies
- Unexpected benefits to my career from this!

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- Big changes too... adopted a highly energetic rescue dog





# Community involvement

- WGC

- [wgcanada.org](http://wgcanada.org)



Women Geoscientists in Canada

- BC Geophysical Society

- [bcgsonline.org](http://bcgsonline.org)

- Society of Exploration Geophysicists Mining Committee

# Condor Consulting

2017 - 2021

- Incredible exposure to MANY projects across the world
- Learned a tremendous amount and worked with talented geophysicists
- Didn't do an inversion for a year
- Attended conferences and presented talks

# Condor Consulting

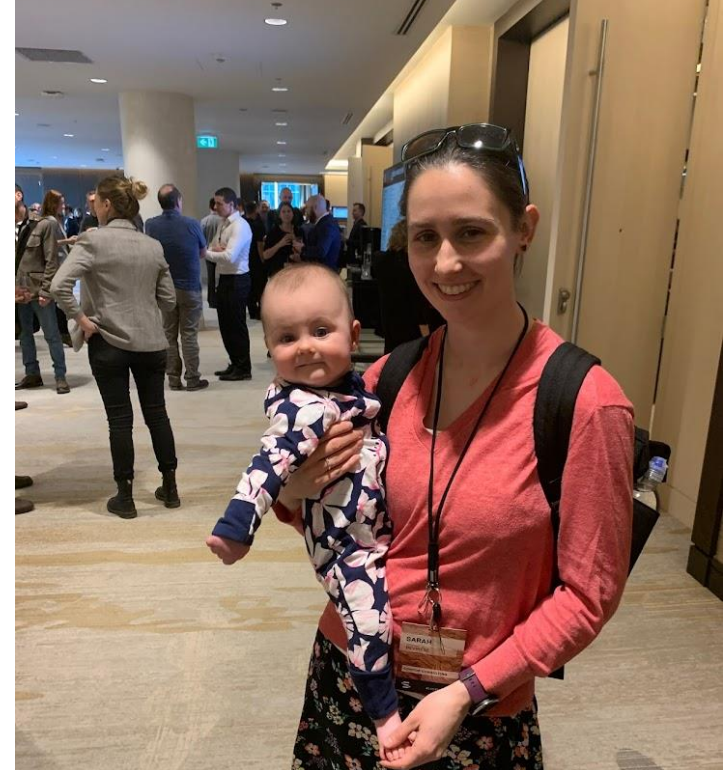
2017 - 2021

- Incredible exposure to MANY projects across the world
- Learned a tremendous amount and worked with talented geophysicists
- Didn't do an inversion for a year
- Attended conferences and presented talks
  
- Some more life changes: pregnancy, baby, conferences/travel while doing both, adapting to motherhood, slammed by a pandemic during mat leave, buying a house

# Motherhood

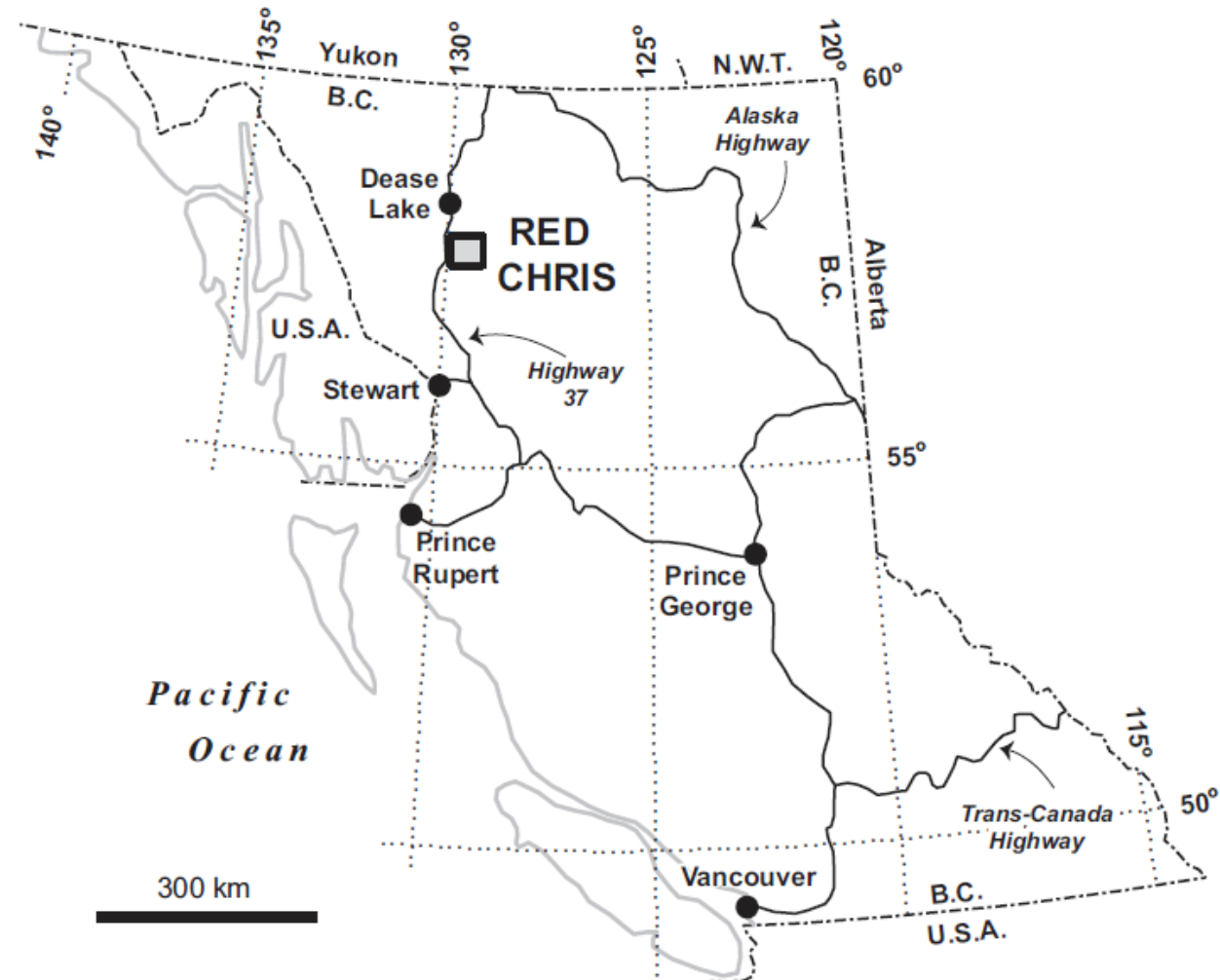
Mid-2019 onwards

- Navigating maternity leave
- Became P.Ge.



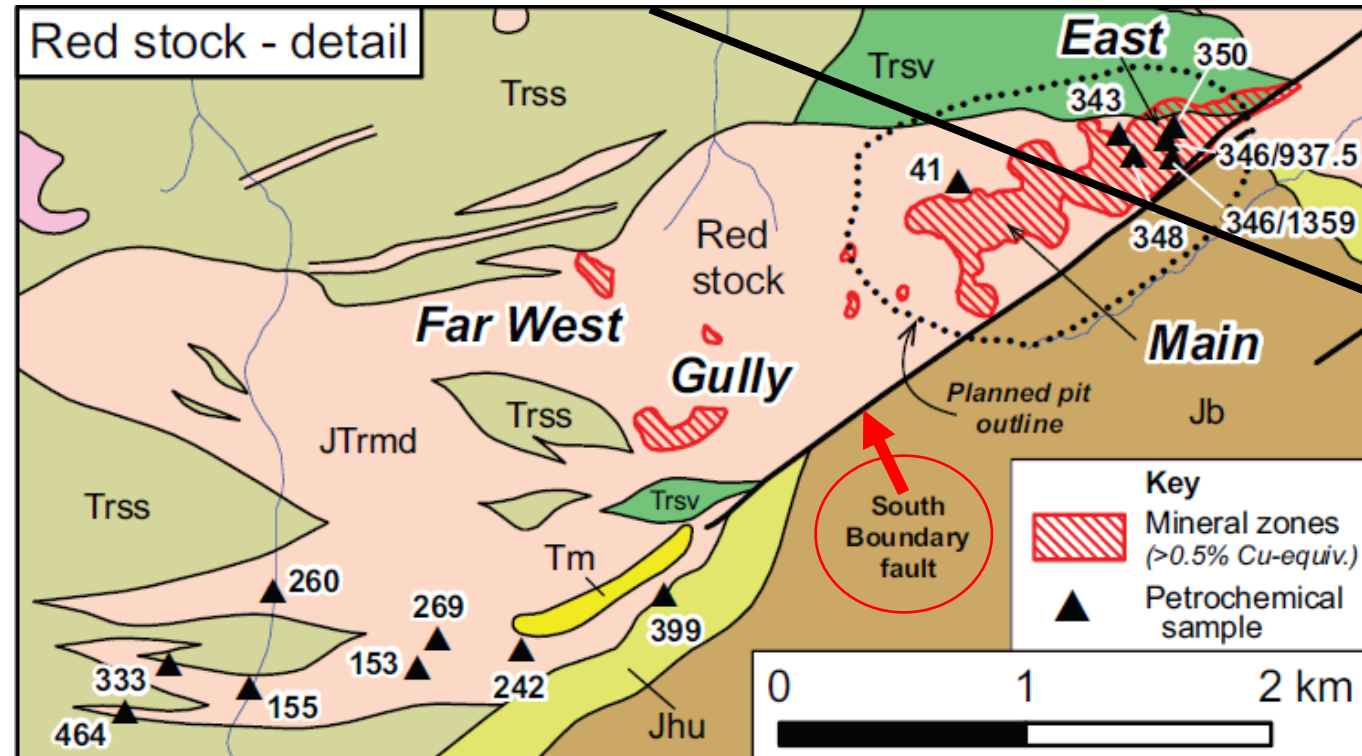
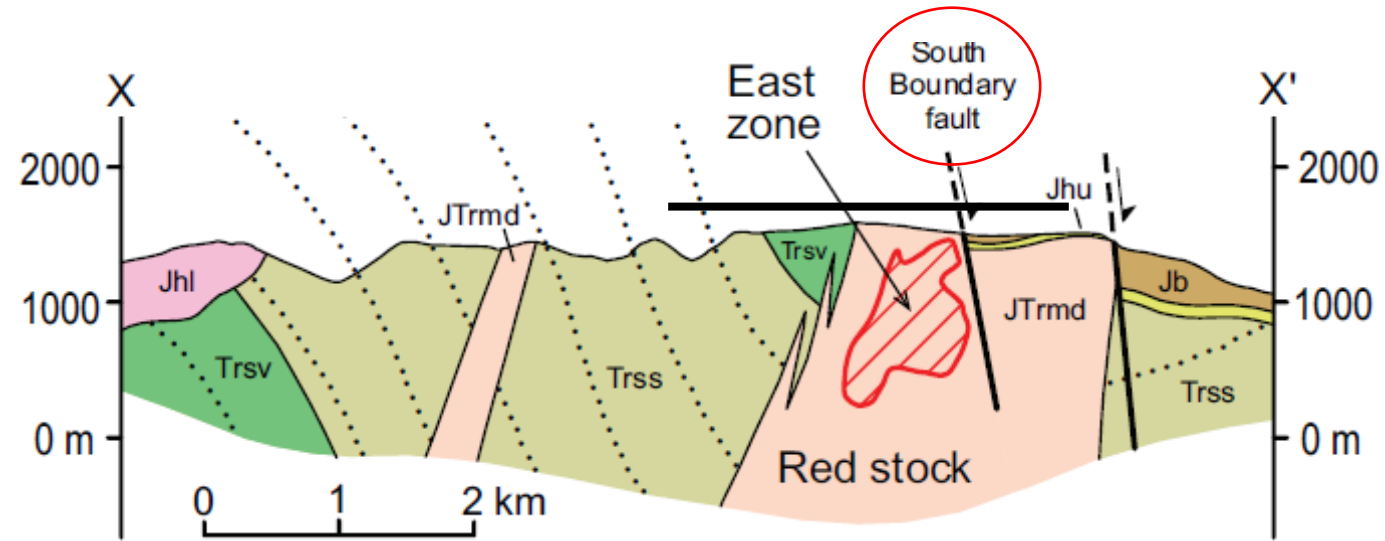
# Red Chris copper porphyry deposit

- Located in NW BC
- Mined since 2014 and life extends to 2043
- Produces Cu, Au, and Ag



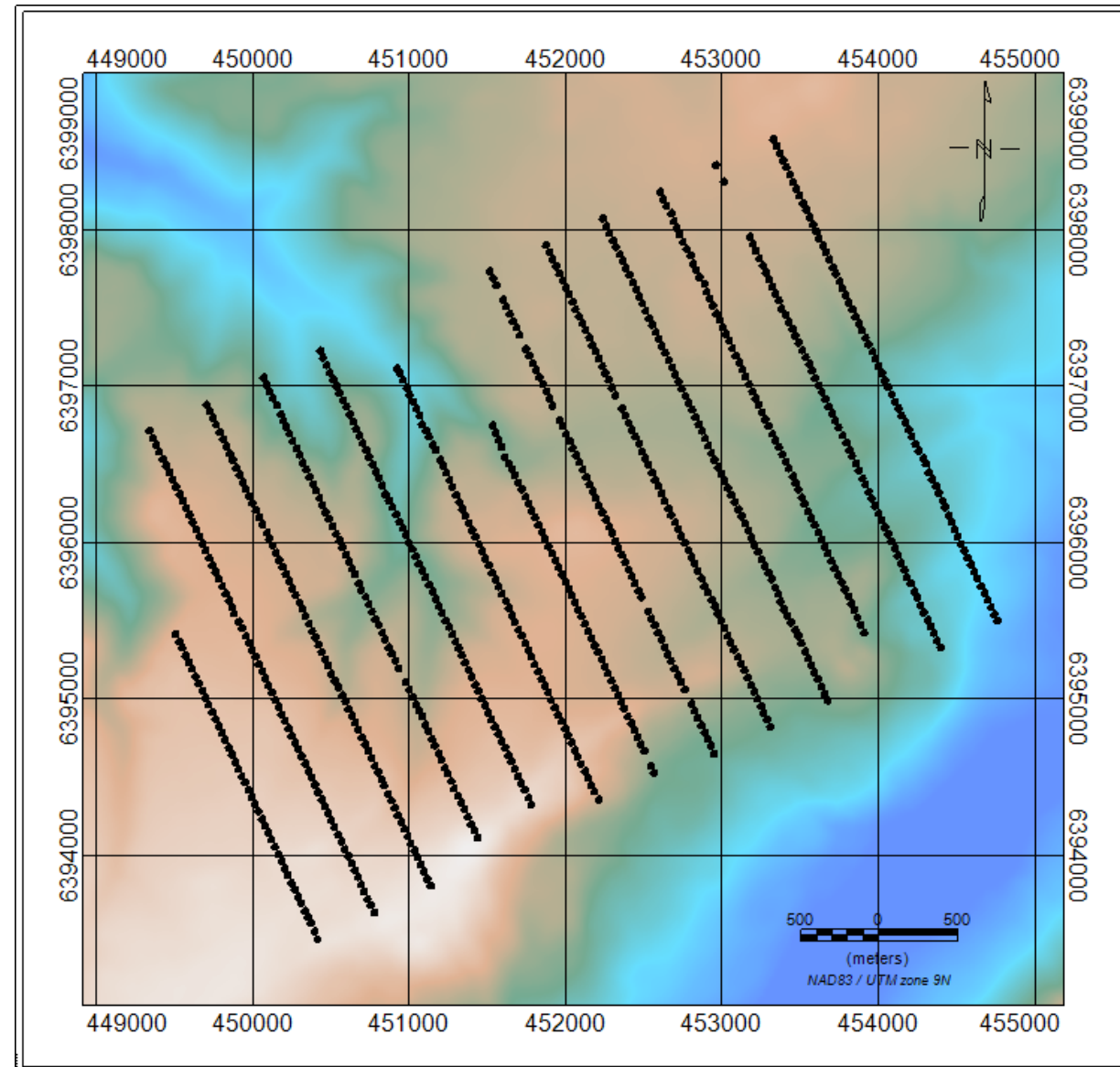
# Geology

- The deposit lies within the **Red Stock unit**
  - porphyritic diorite, monzodiorite, and monzonite
- **Mafic volcanics to the north**
  - basaltic-andesitic volcanics and volcanoclastics
- **Stuhini Group to the north, east, and west**
  - sandstone and siltstone
- **Bowser Lake Group to the south**
  - sandstone, siltstone, and conglomerate
- **Hazleton Group sits between the Red Stock and the Bowser Lake Group.**
  - Siltstone, sandstone, and minor limestone

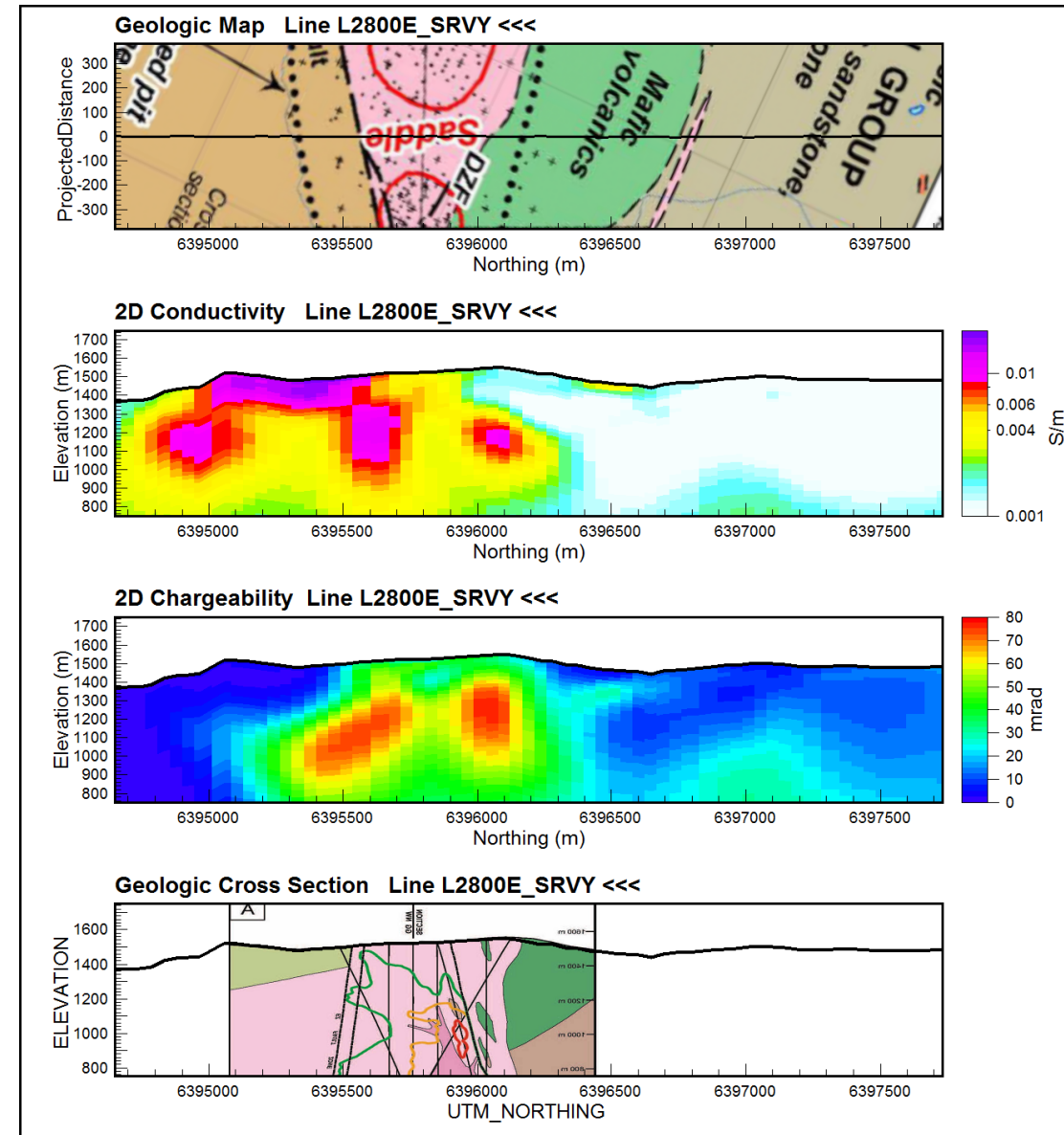
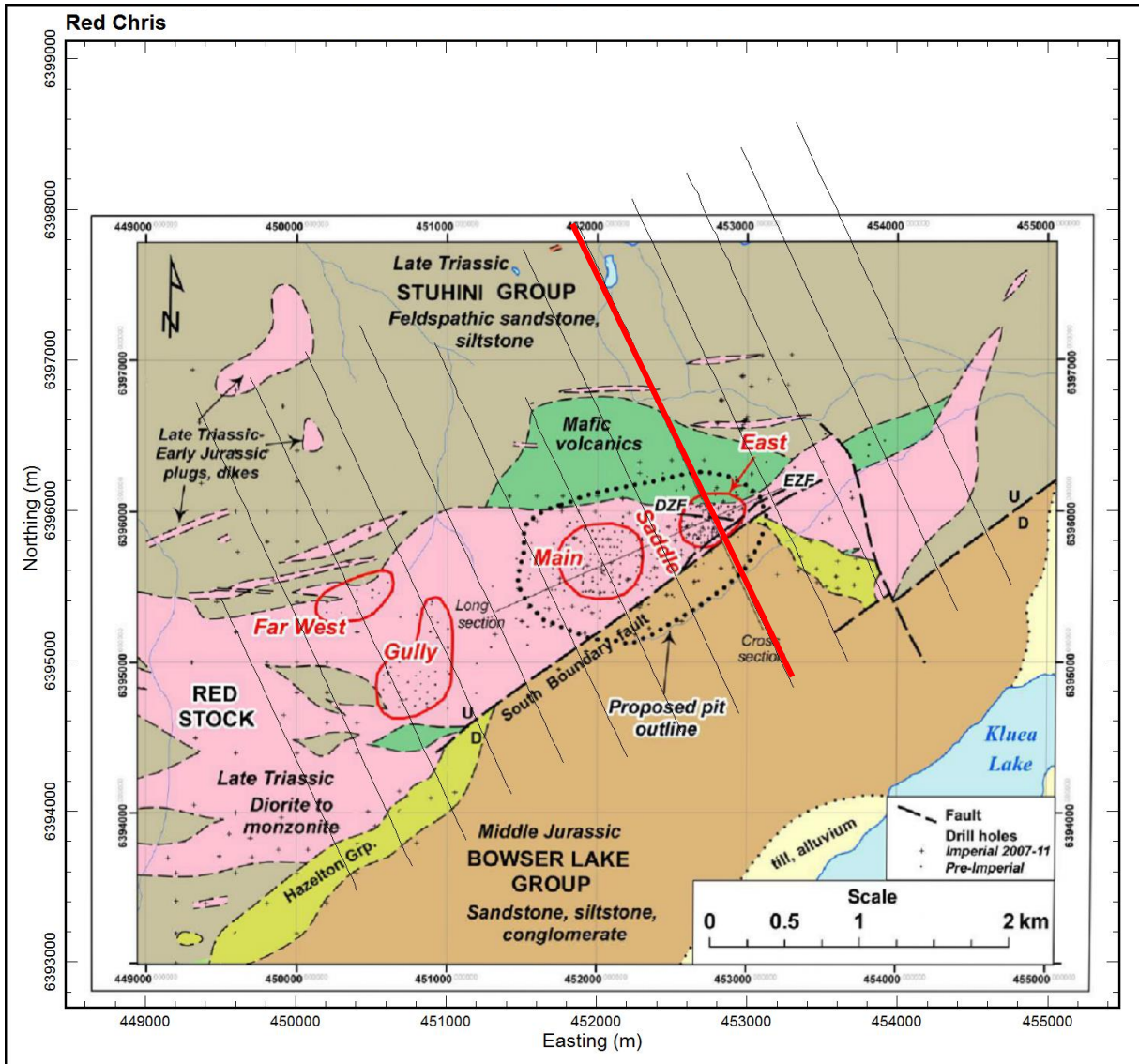


# Survey

- Collected July 4-20, 2009
- Titan 24 DCIP and MT system
  - 100 m station interval
  - 13 2.4 km lines, 400 m separation
  - Used a combined PDR and PDL array with 24 receivers measuring the in-line voltages and 13 receivers measuring cross-line voltages

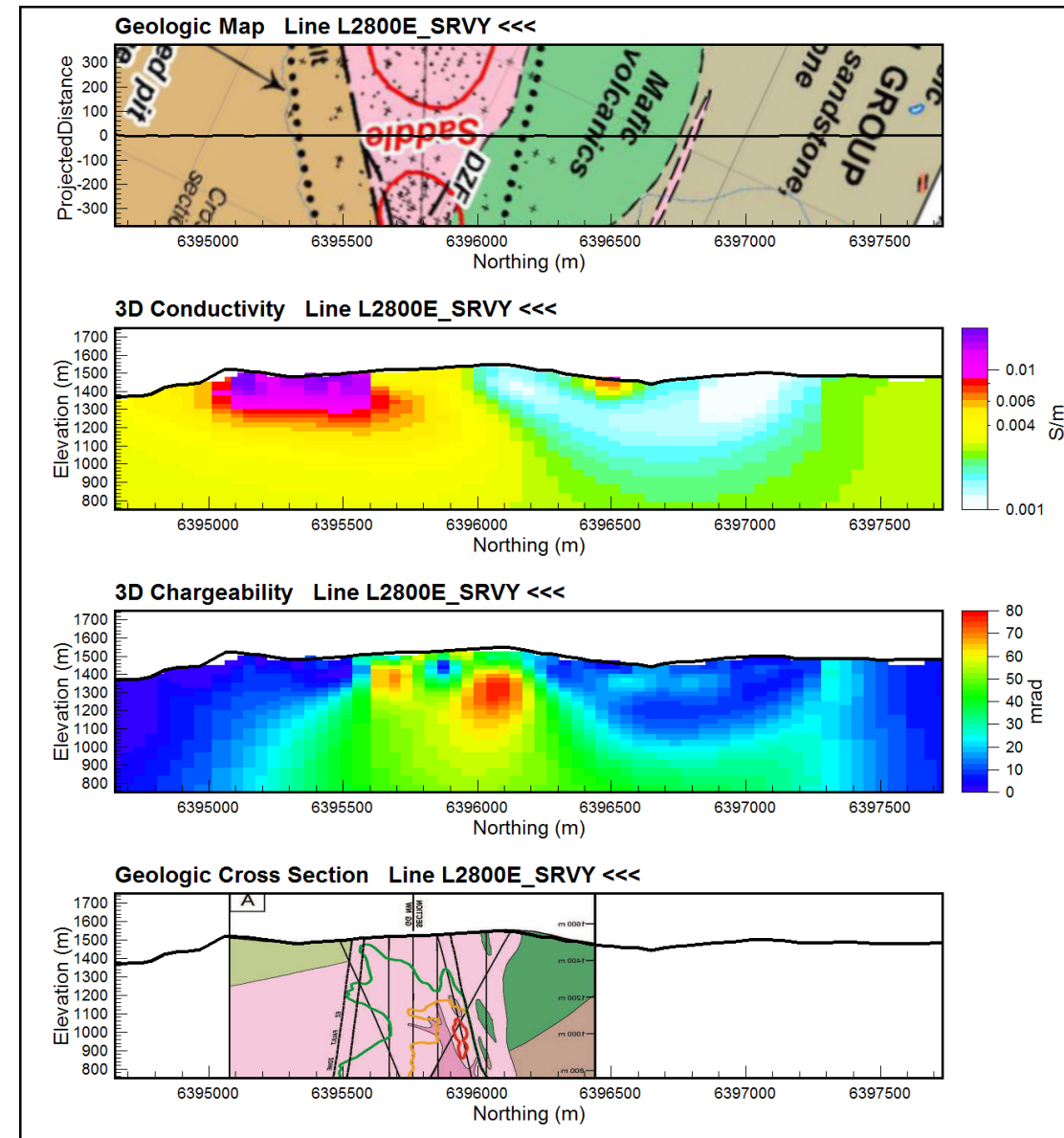
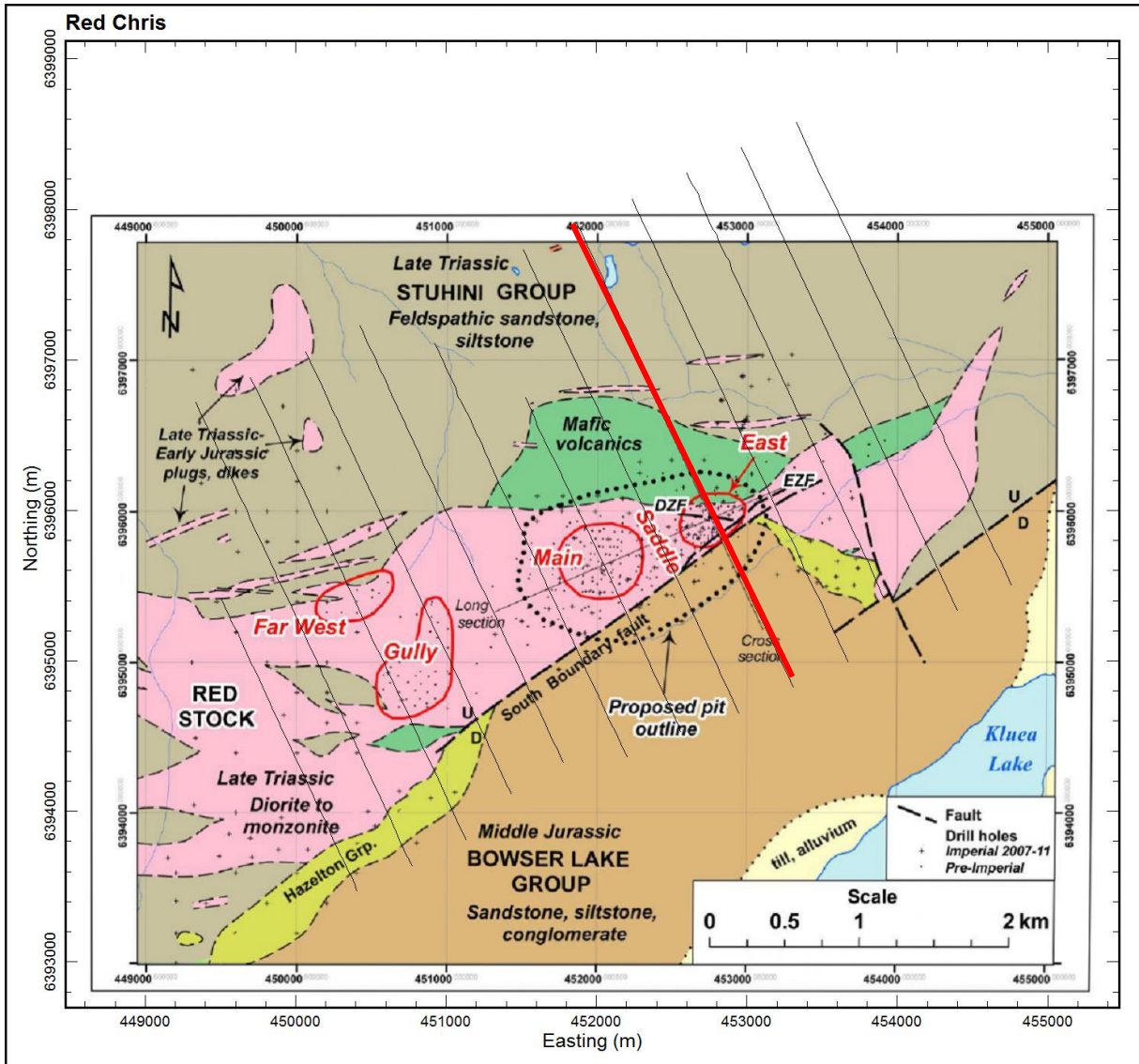


# 2D inversions: Line 2800



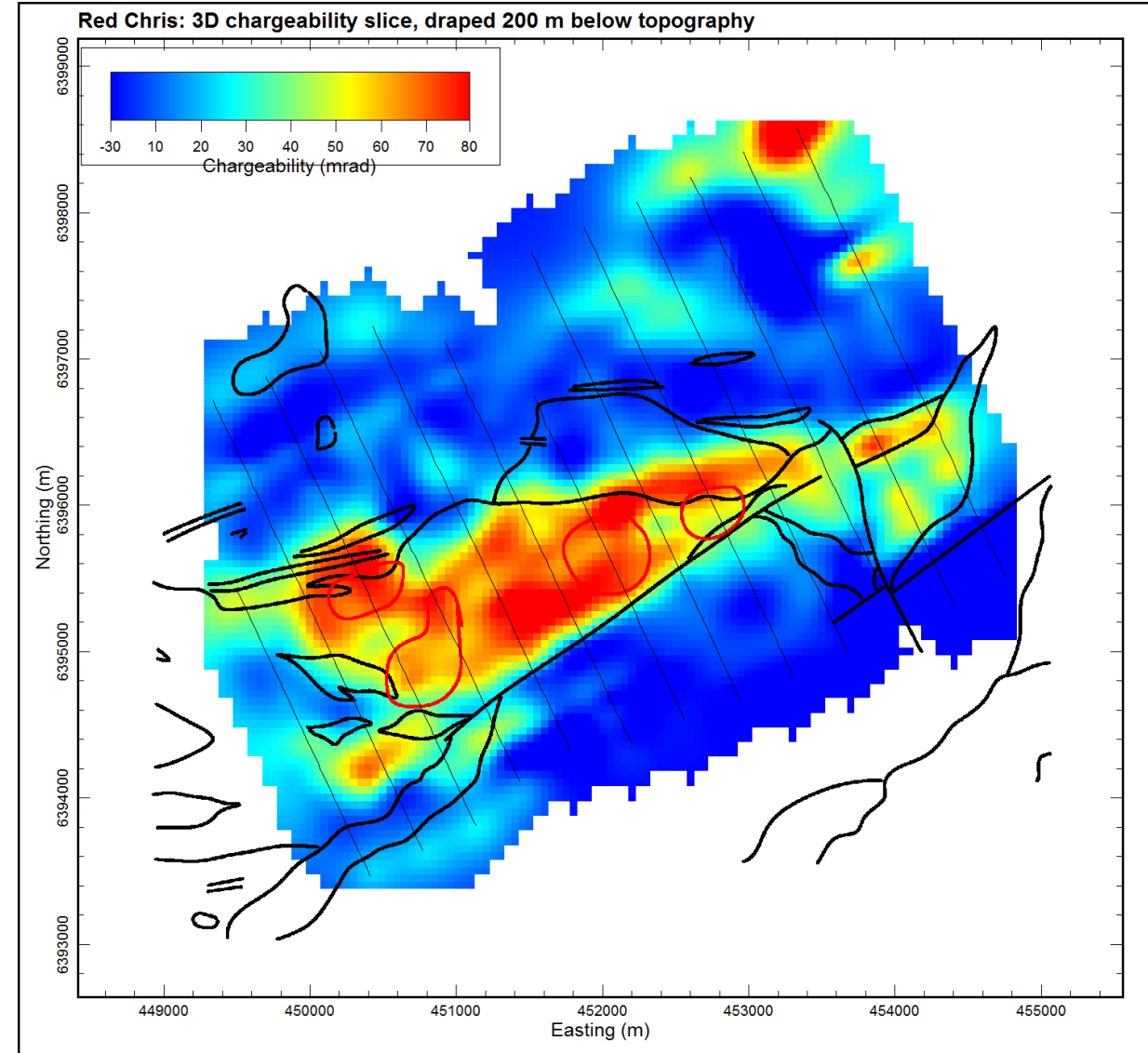
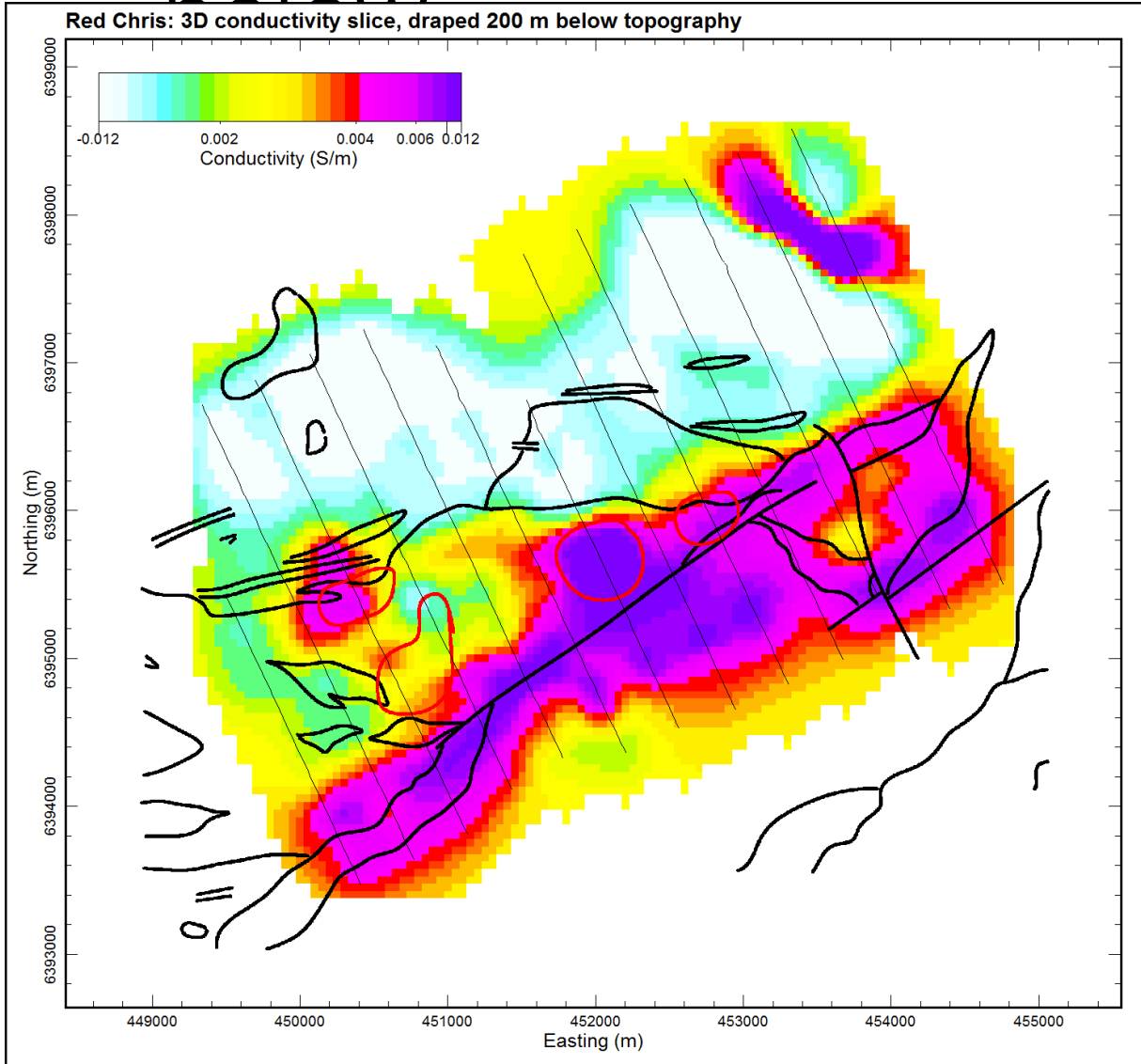


# 3D inversion: Line 2800



# Interpretation: depth slices draped 200 m

below



# Dual career couple

Mid-2019 onwards

- Navigating being a dual-career couple
  - With a toddler
  - In a pandemic



# Mental health importance

- In this industry, we must focus on the health and safety of people, a value that's highly important with a lot of field work, which is often remote.
- But also need to really consider our mental health. Grad school, pandemics, remote field work/mine sites take their toll.
- Do you know where to turn if you need to talk, get something off your chest?



# Teck Resources Limited

Mid-2021 onwards

- After academia and consulting, joined a major mining company
- A very different experience where I am learning and stretching:
  - Daily collaboration with geologists and geochemists
  - Learning more about deposits at all scales
  - Global project profile working in greenfields, evaluations, and brownfields
  - First exposure to “a big company” – hr, legal, etc
  - And field work!

# Current role

## Brownfields

- Support geophysical evaluations at Teck's operations
  - Highland Valley Copper, BC
  - Red Dog, AK
  - Quebrada Blanca, Chile



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## Brownfields

- Support geophysical evaluations at Teck's operations
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## Greenfields + Generative

- Propose and carry out surveys
- Help with filling project pipeline
- Move projects from target definition to drill testing





# Summary: thankful

- Deeply thankful for my parents who sacrificed a good life in Europe to give my sister and me lots of opportunities in the US
- Forever grateful to my husband for believing in me more than I believed in myself during grad school and for making a home that separates life from work (whereas I can often blur that boundary)
- Motivated by my daughter and dog – they have provided me with a new perspective on life
- Blessed with having worked and studied with incredible geoscientists

What's next?

