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Geological Modelling of Geophysical Data: Beyond the 3D Inversion Black Box

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Paterson, Grant & Watson Limited

Bill Morris

McMaster University

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Contents

- Motivation / Introduction
- Quick review of “old” modelling/interpretation techniques
- The approach: bring geology into the equation
- Two case studies:
  - Bathurst, NB
  - NWT Iron Ore exploration
- Conclusions/Final remarks

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Motivation

- The constant request for “give me a drilling target”…
  - Out of airborne data (i.e., sufficient resolution and physical property contrast?)
  - Or when the mineralization is non-magnetic (e.g. alteration zones➔*to the side* of the big magnetic “blob”!)
- The usual “interpretation” of geophysical data with a number of blocky polygons totally disconnected from the geology of the area

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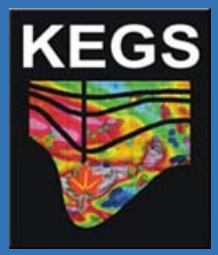

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Back to basics: 2D modelling

- A simple model can provide with good information on physical properties and some ideas on geometry
- However, we must keep in mind that models are non-unique

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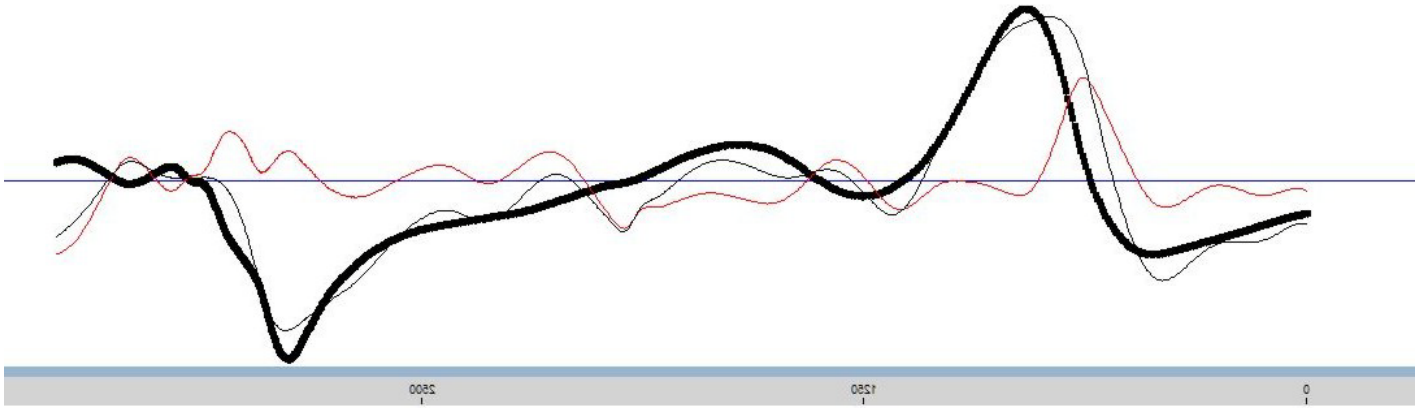

Simple case:

- Mag data
- Inclination: 80 deg; Declination: 24.1

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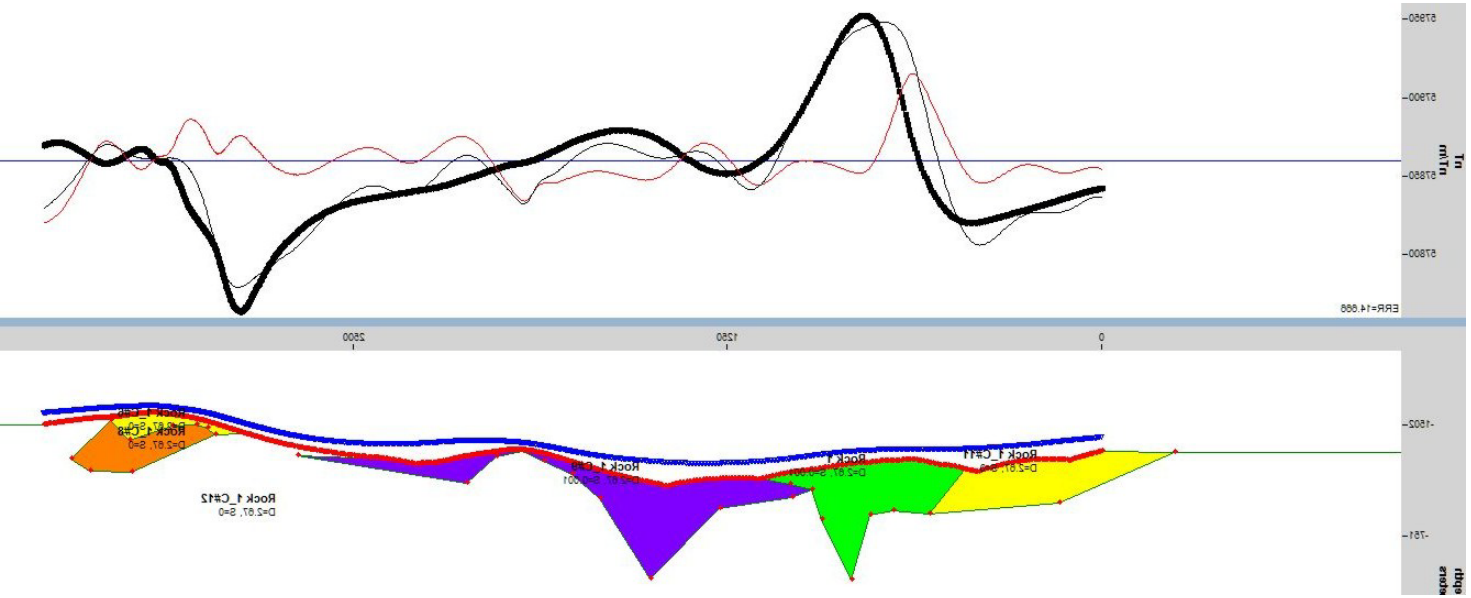

Model 1:

- 5 bodies with “awkward” geometries and susceptibilities on 0-0.0008 cgs

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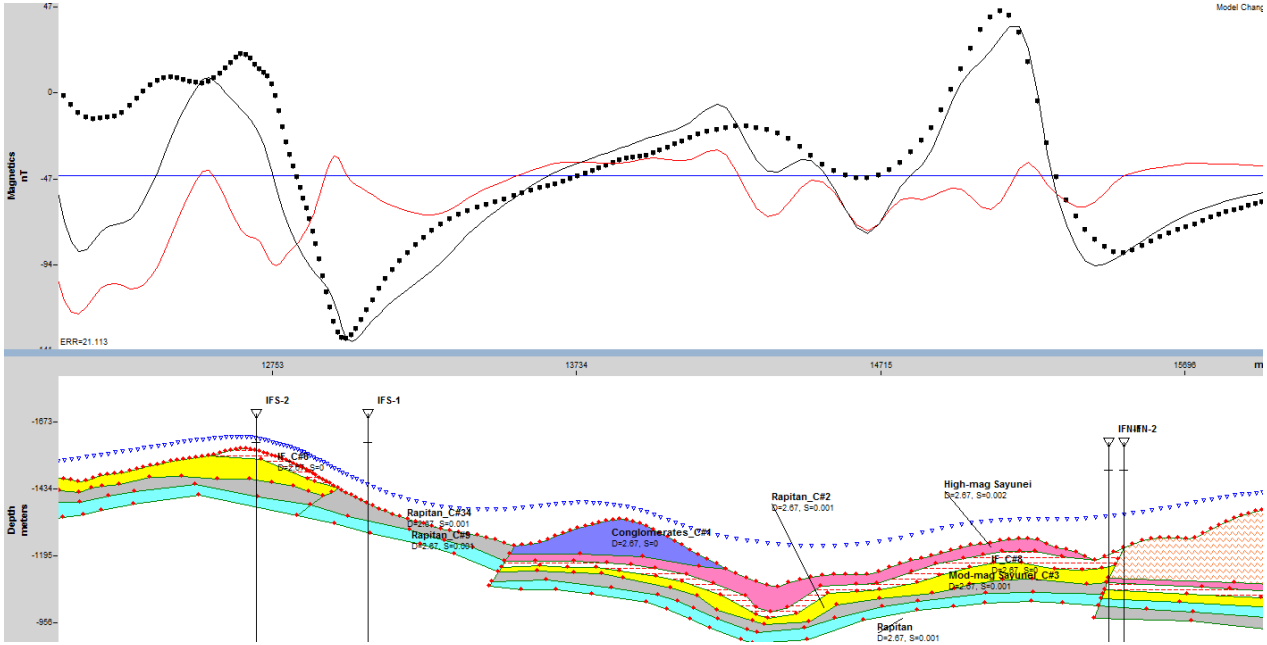

Model 2:

- A series of sub-horizontal bodies
- Folds and faults
- *However: this requires a priori knowledge of the structure/geology*

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Hold it!!
…….Geology???

- What do we need:
  - Structure (strike/dip, faults, folding)
  - Lithology (rock type, and more than that, physical properties)
- Normally we have a few scarce strike/dip points and no susceptibility at all
- We must obtain these constraints from somewhere else

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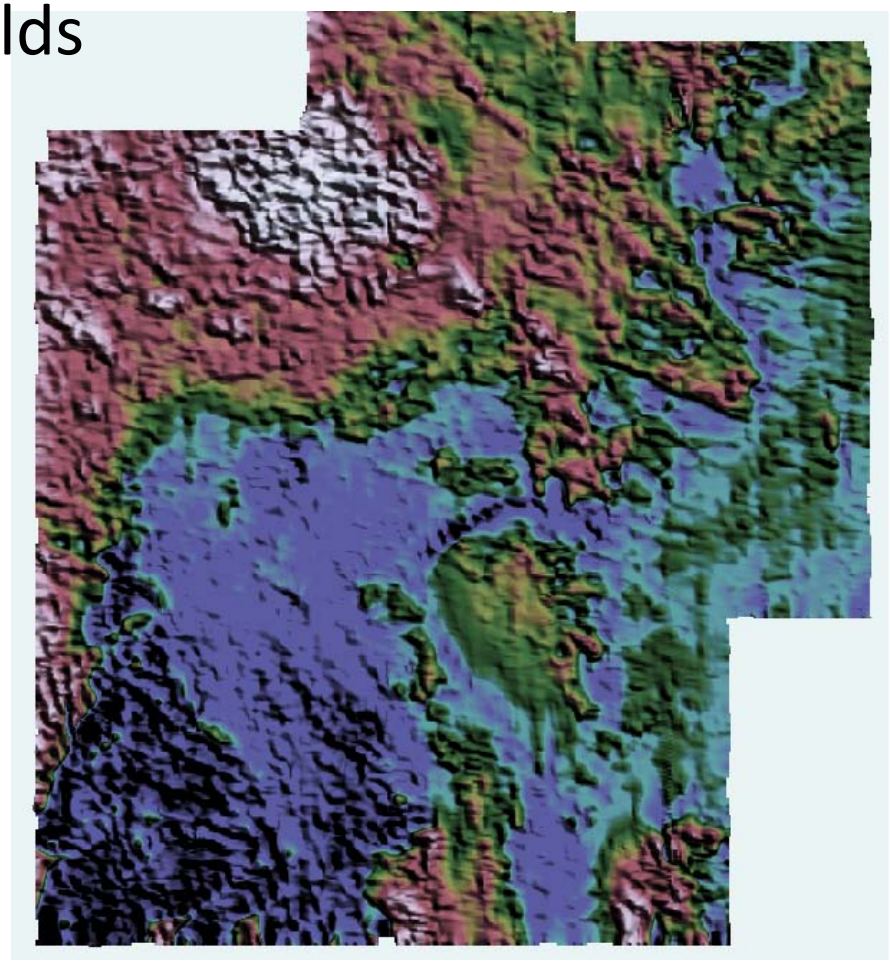
Faults

A first pass interpreting the data (qualitative) can give information on faults, contact locations, folds



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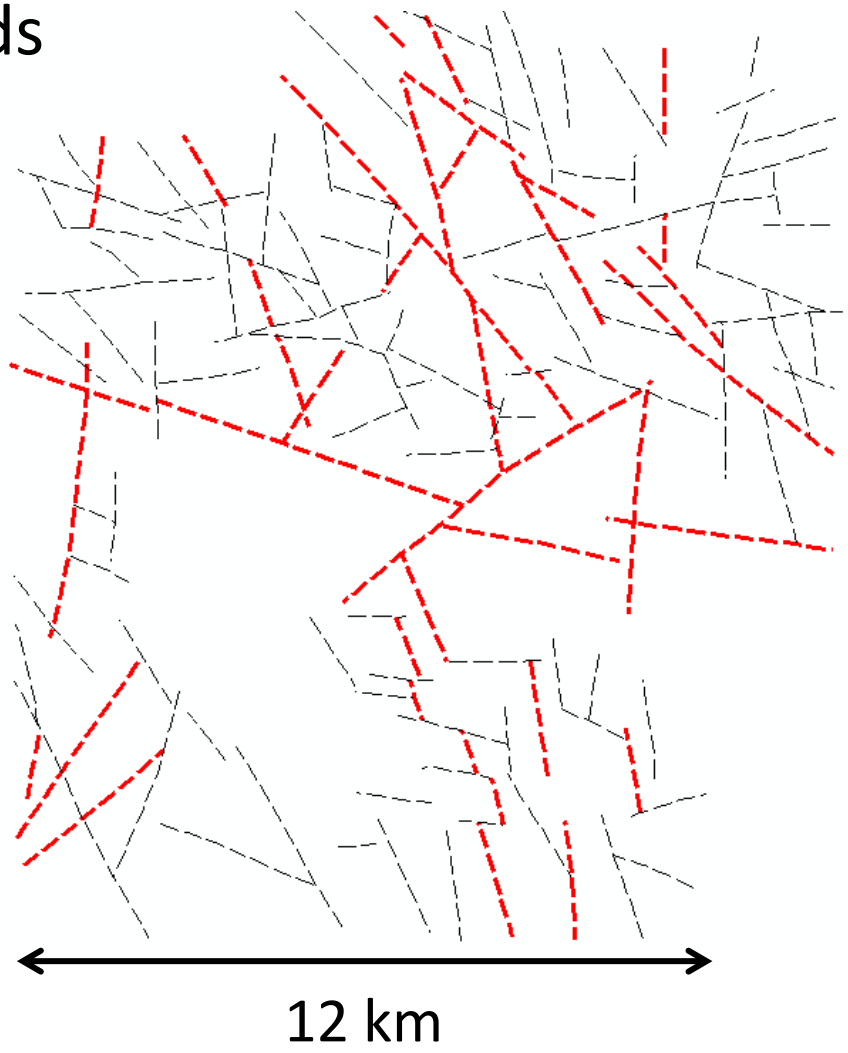

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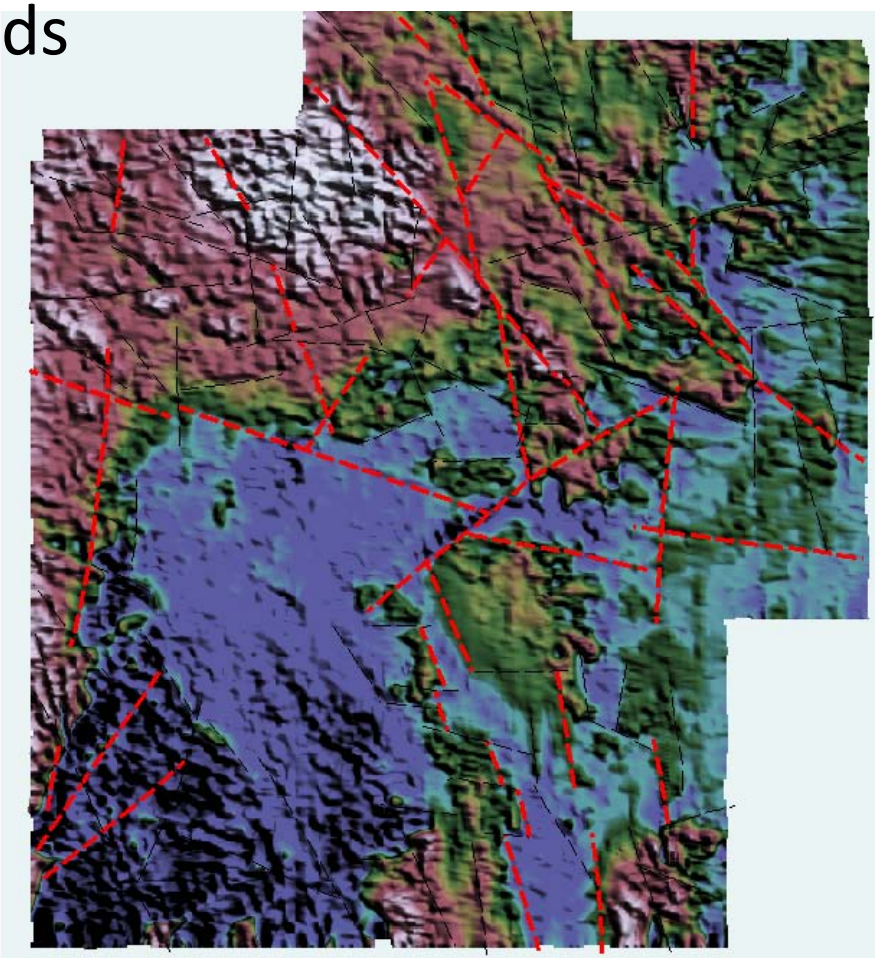

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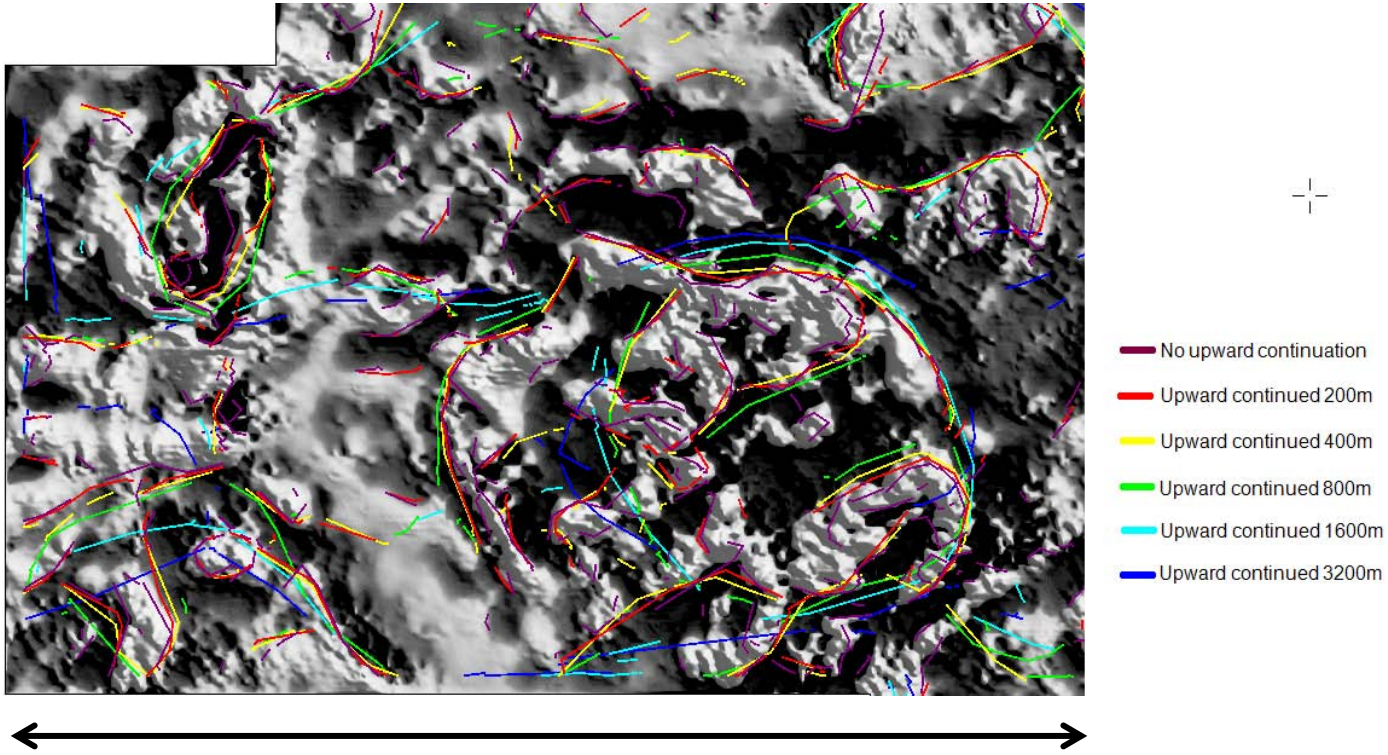
Strike and Dip

Worms: used to determine relative dip direction



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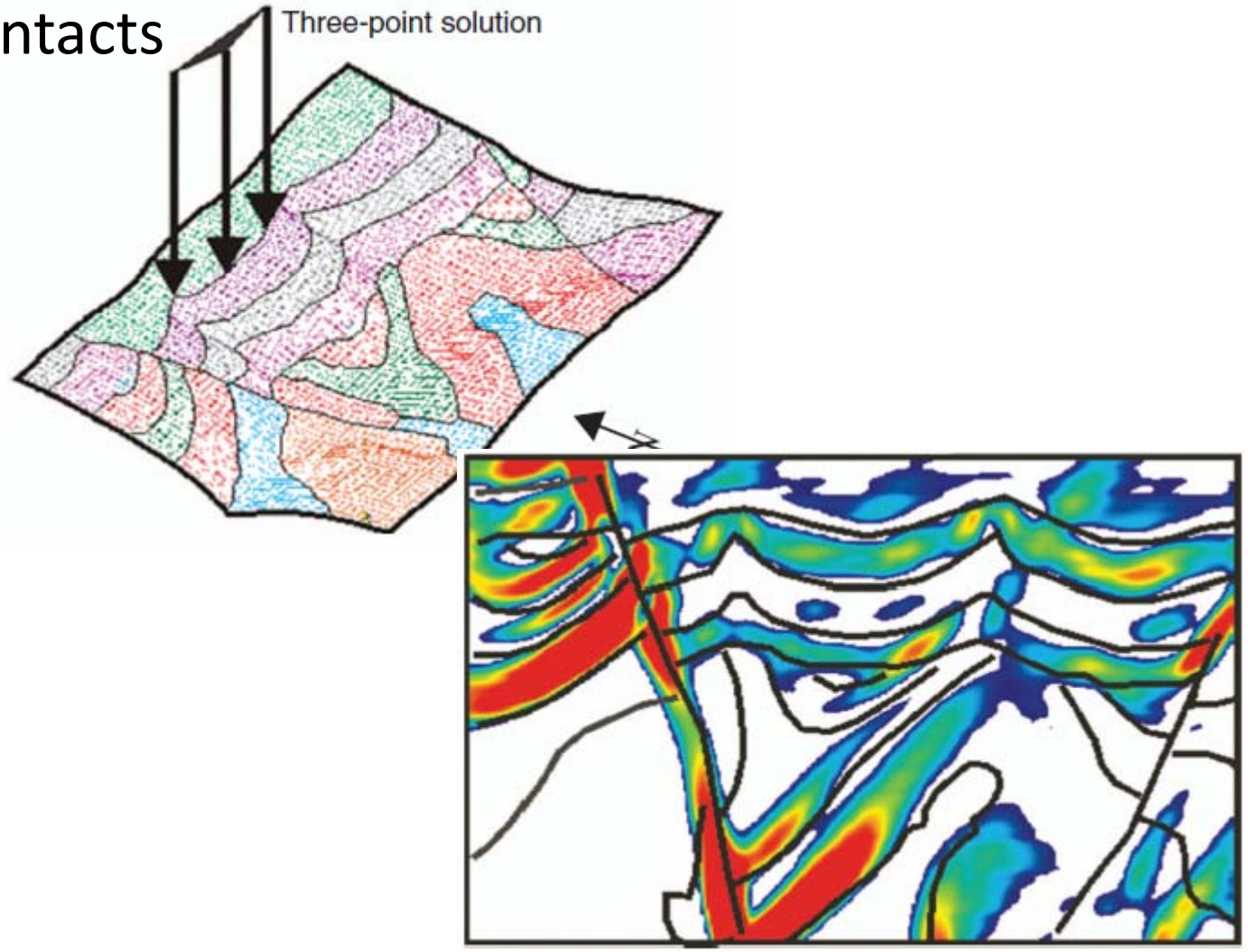
Strike and Dip

Three point solutions: require topographic relief and confidence on the location of contacts



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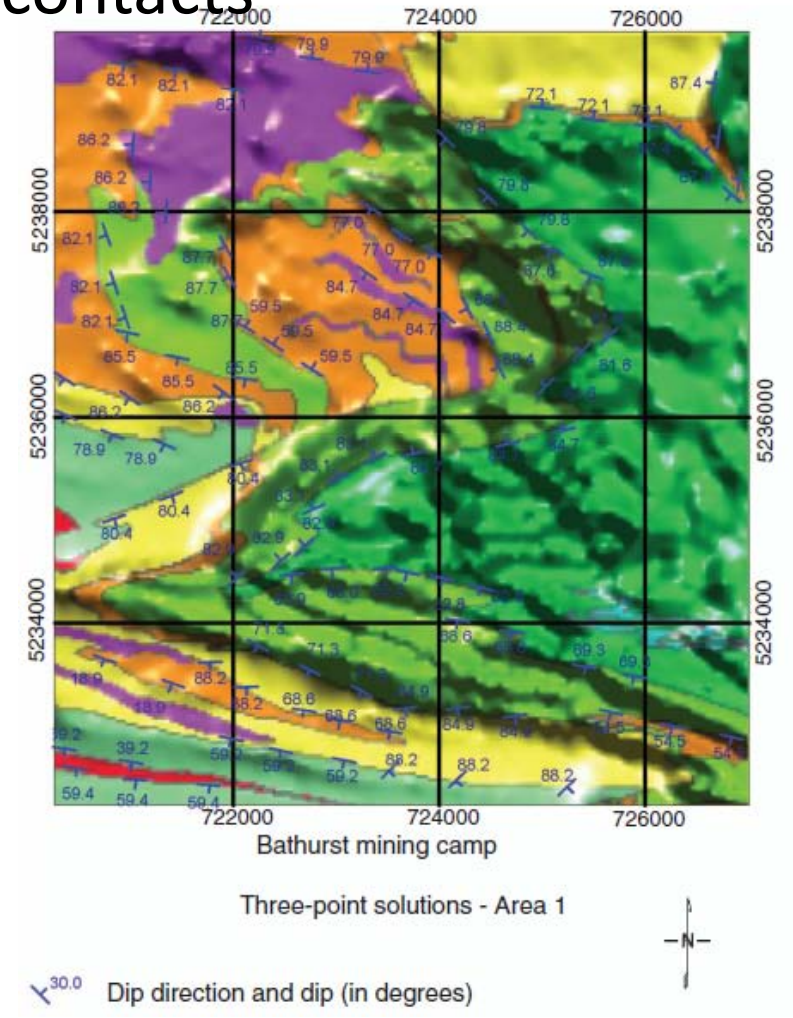

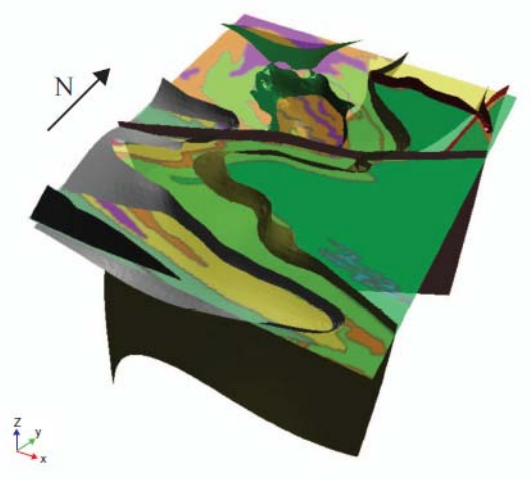

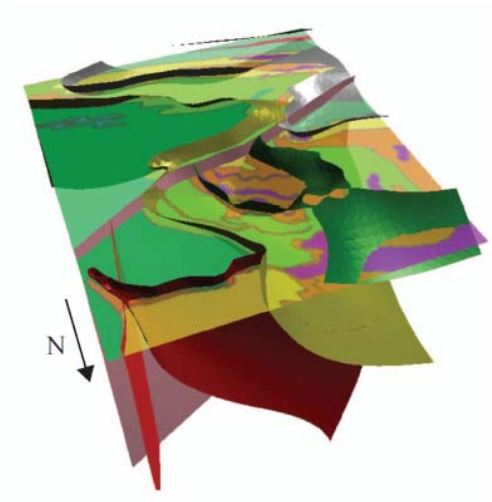

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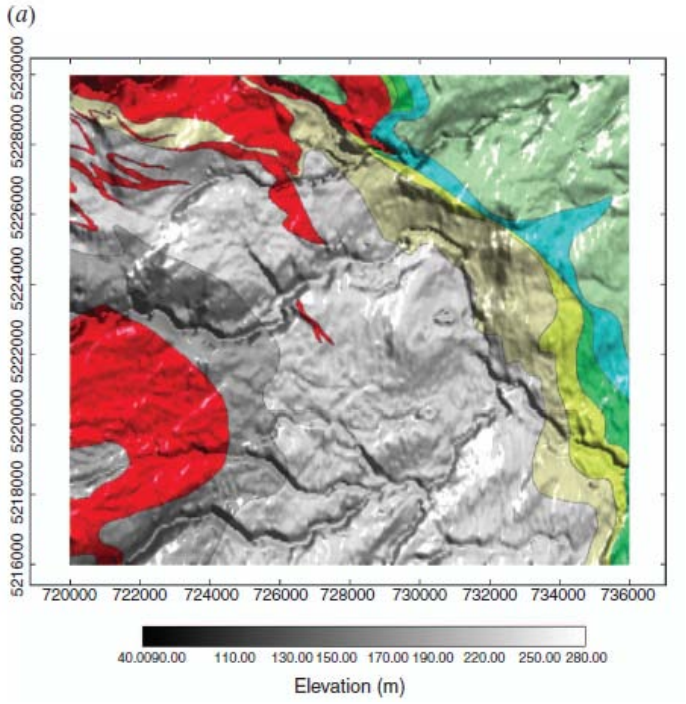
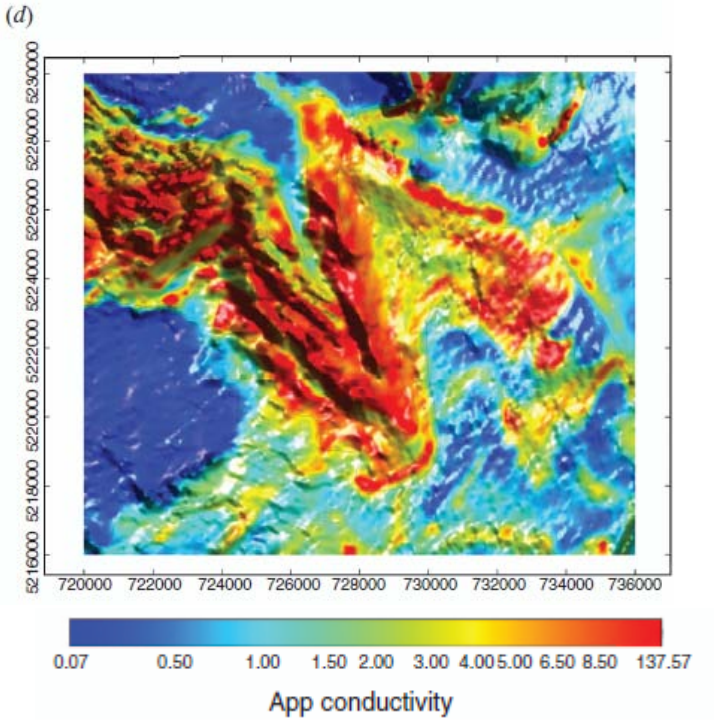
Strike and Dip

Three point solutions: a case where geophysics and topography could make a difference



Geology & Topography



EM & Topography

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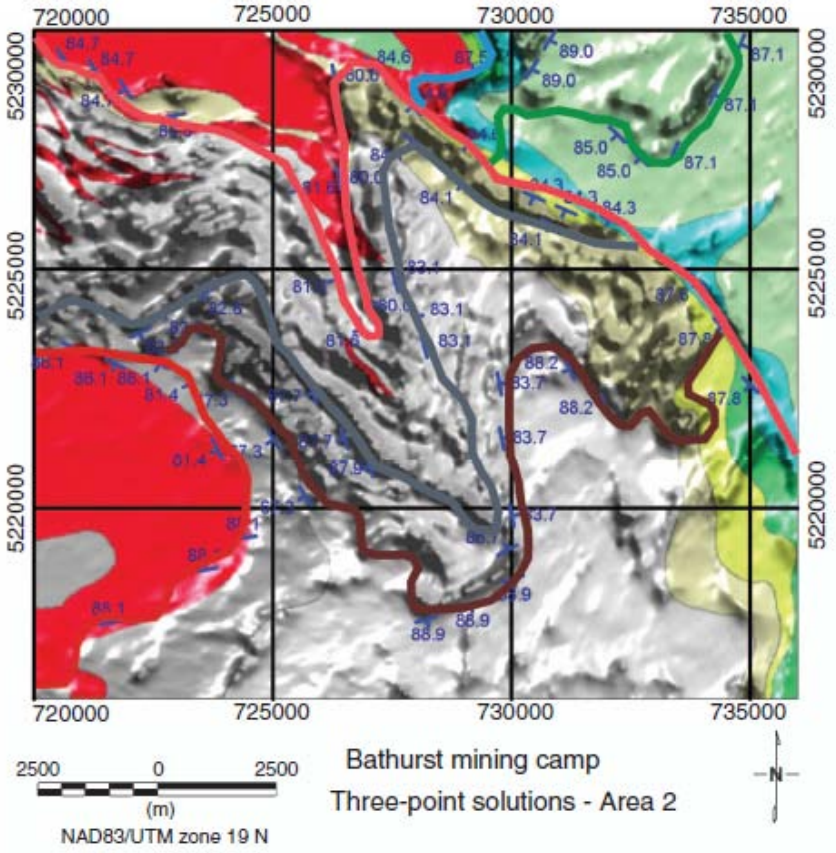

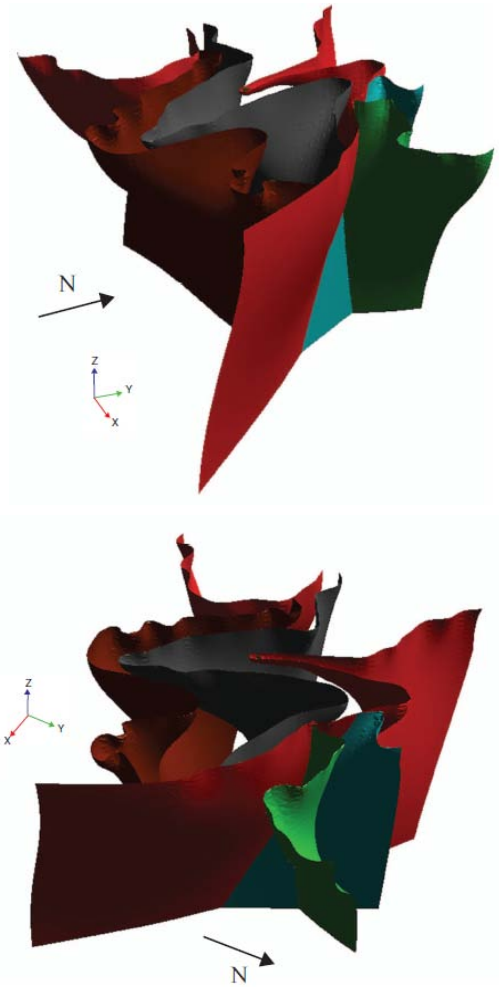

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Back to basics: 2D modelling

- Now we want to put everything on a coherent picture
- Case 1: Bathurst, NB
- Case 2: Iron ore exploration project, NWT

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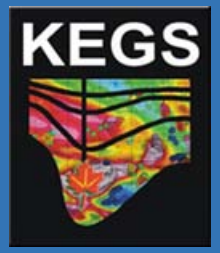

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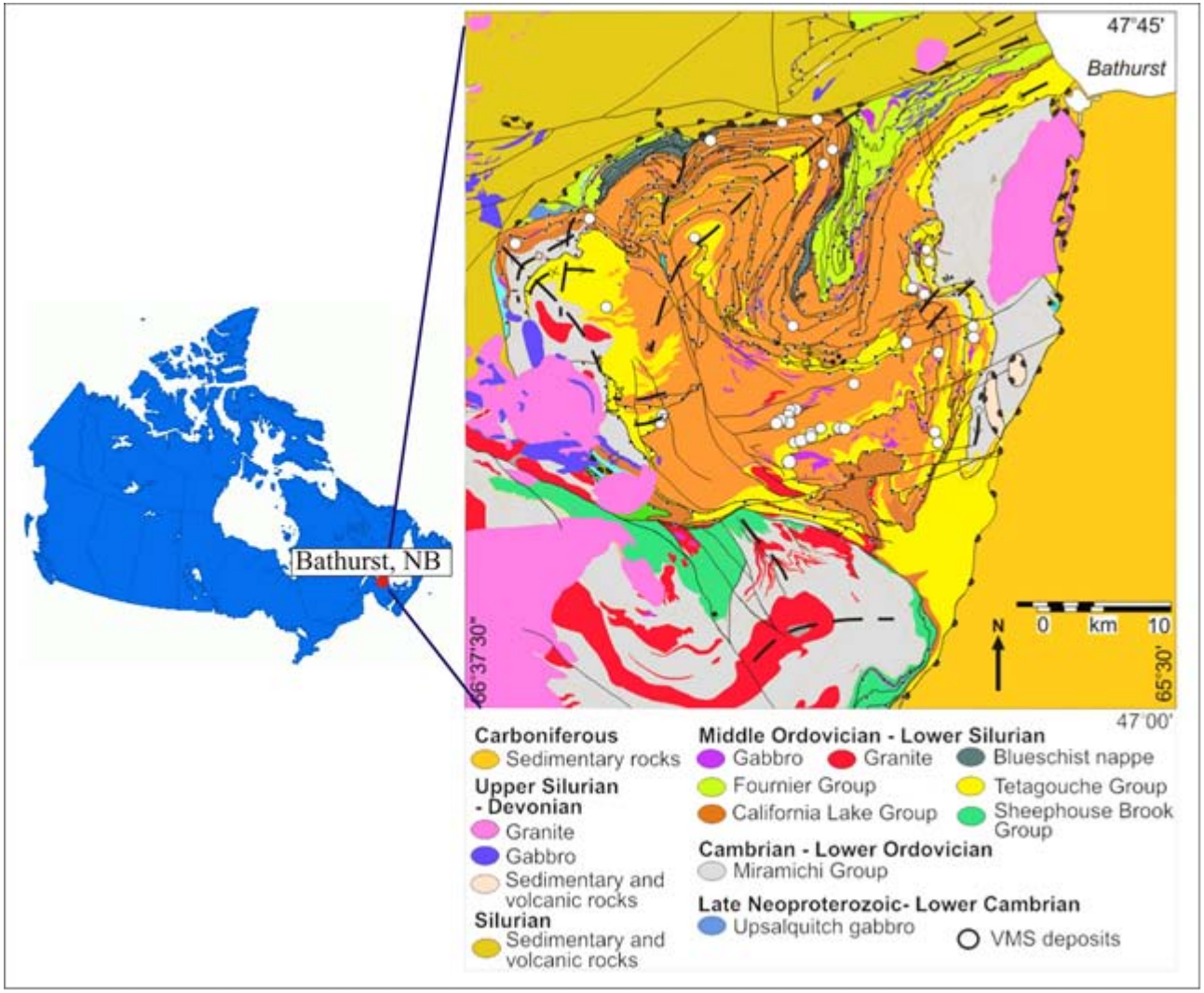
Case 1:
Bathurst Mining Camp

- One of Canada's oldest mining districts for VMS deposits
- Host to 25 massive sulfide deposits with resources > 1Mt
- Approximately 70% of those were discovered in the 1950s using a combination of geology and geophysics

Bathurst Mining Camp



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Bathurst Mining Camp

- EXTECH II a big step forward. Not the final word on the geology of the camp.
- A good understanding of the bedrock geology at the surface. Not so much at depth.
- EXTECH II identified the mineralized horizons, but only found the non-economic Camelback deposit.
- Real potential exists in the extension of known mineralized horizons at depth.
- ➔ TGI-3

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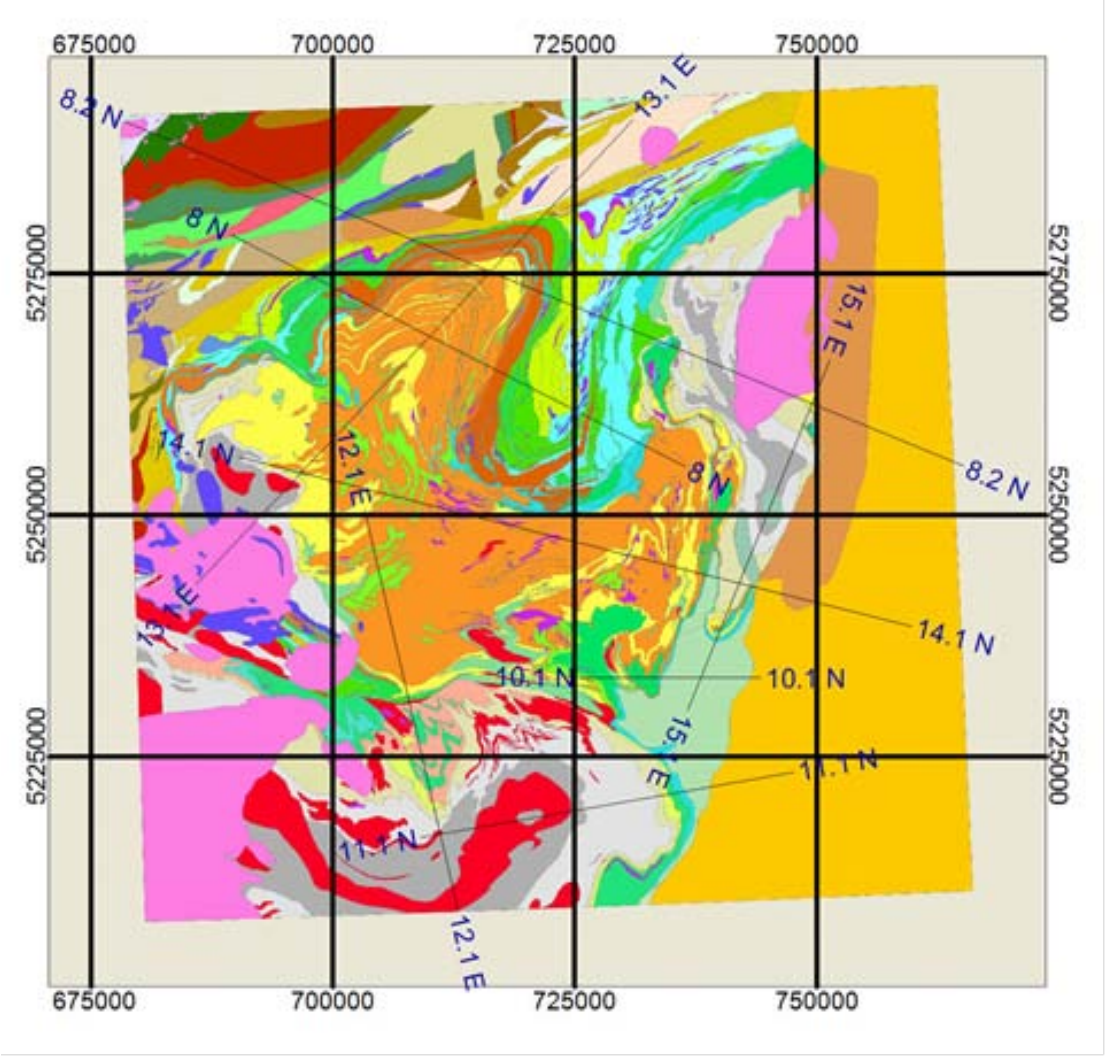

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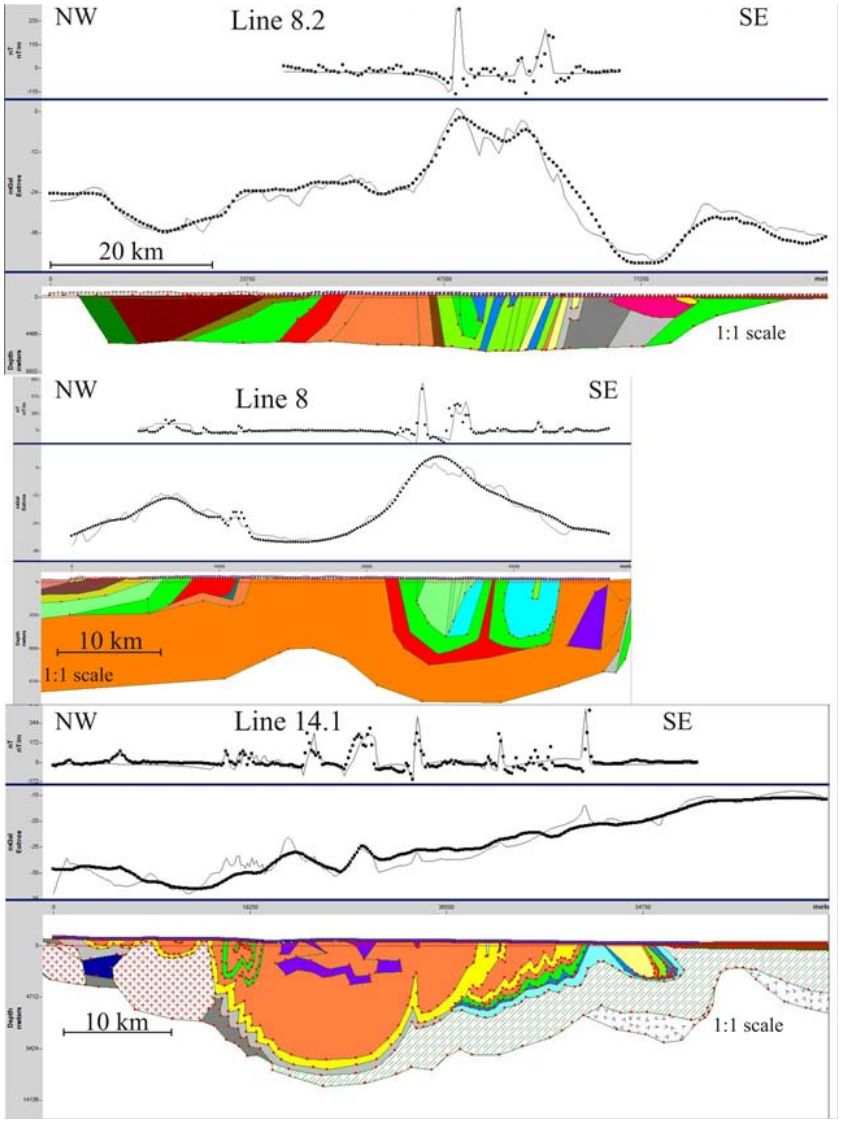

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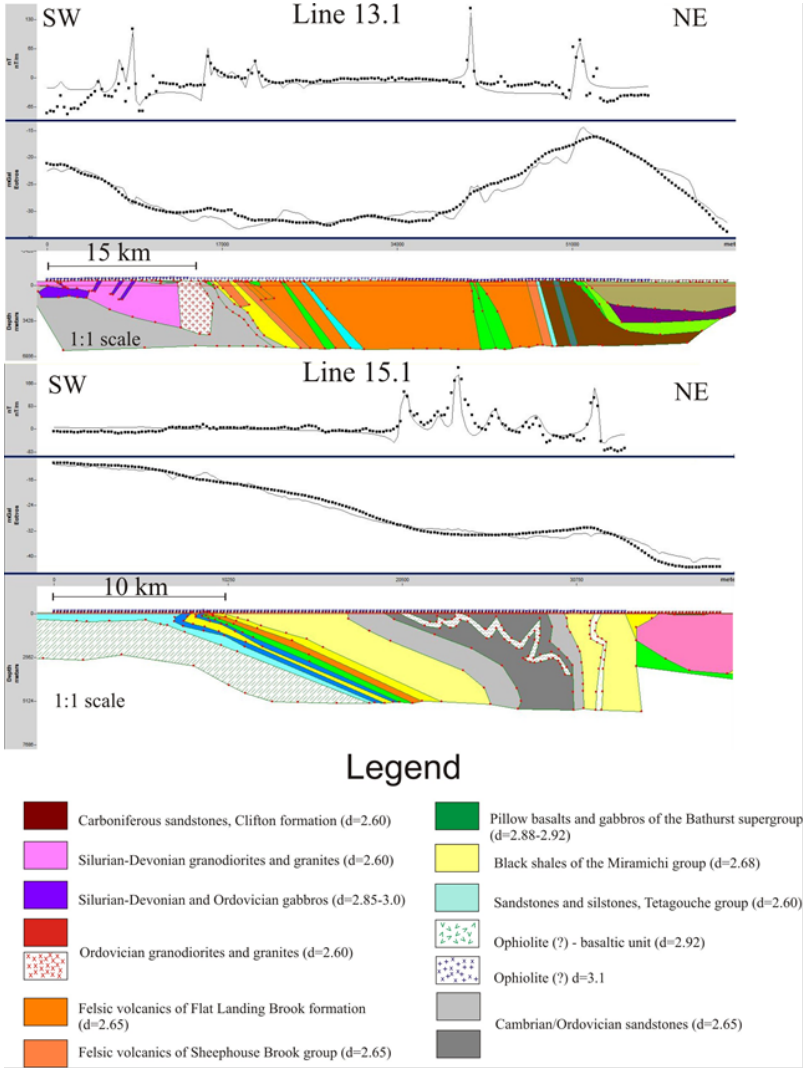

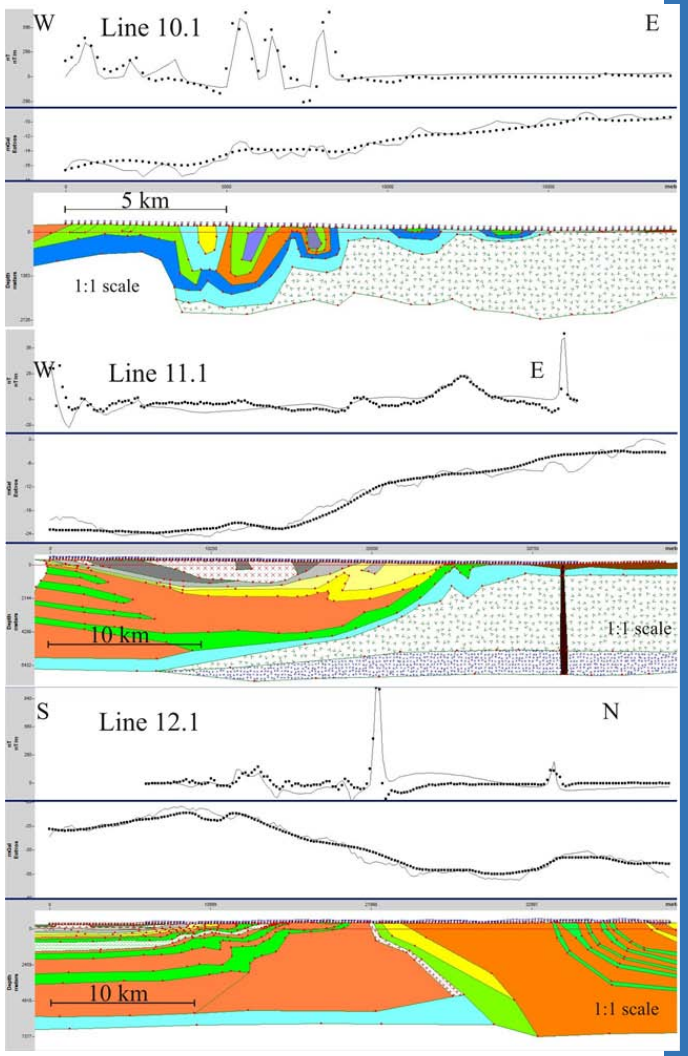

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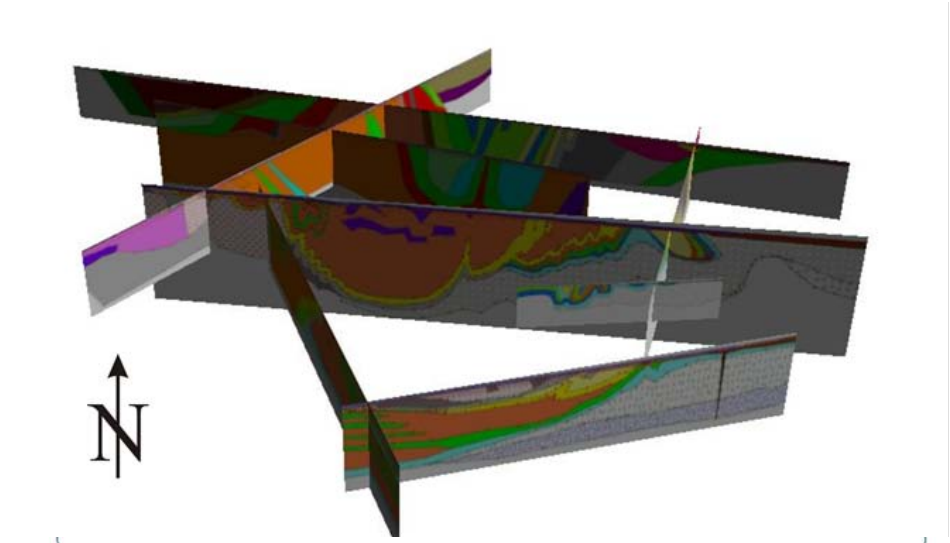

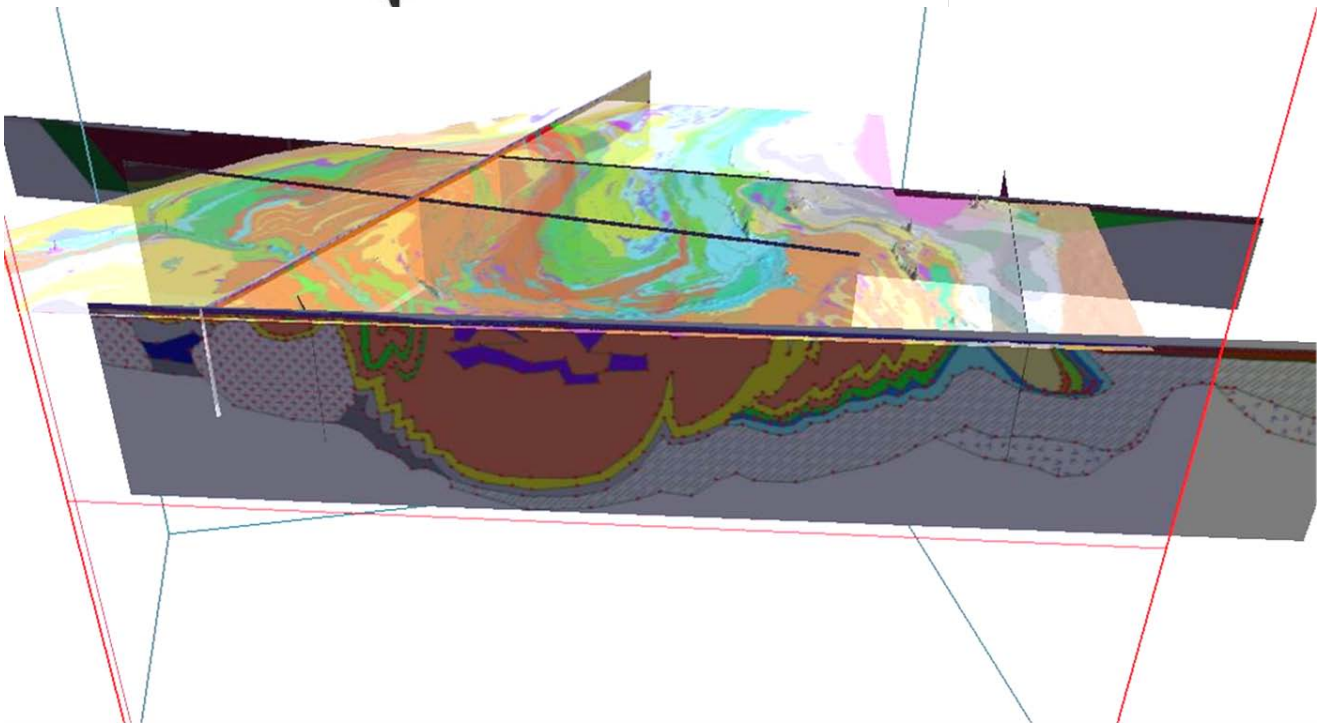

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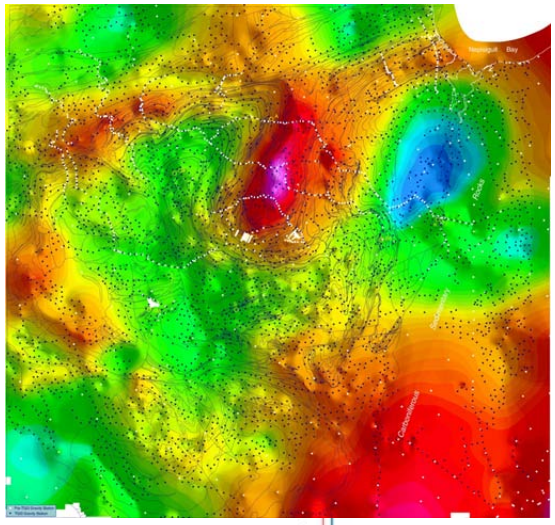

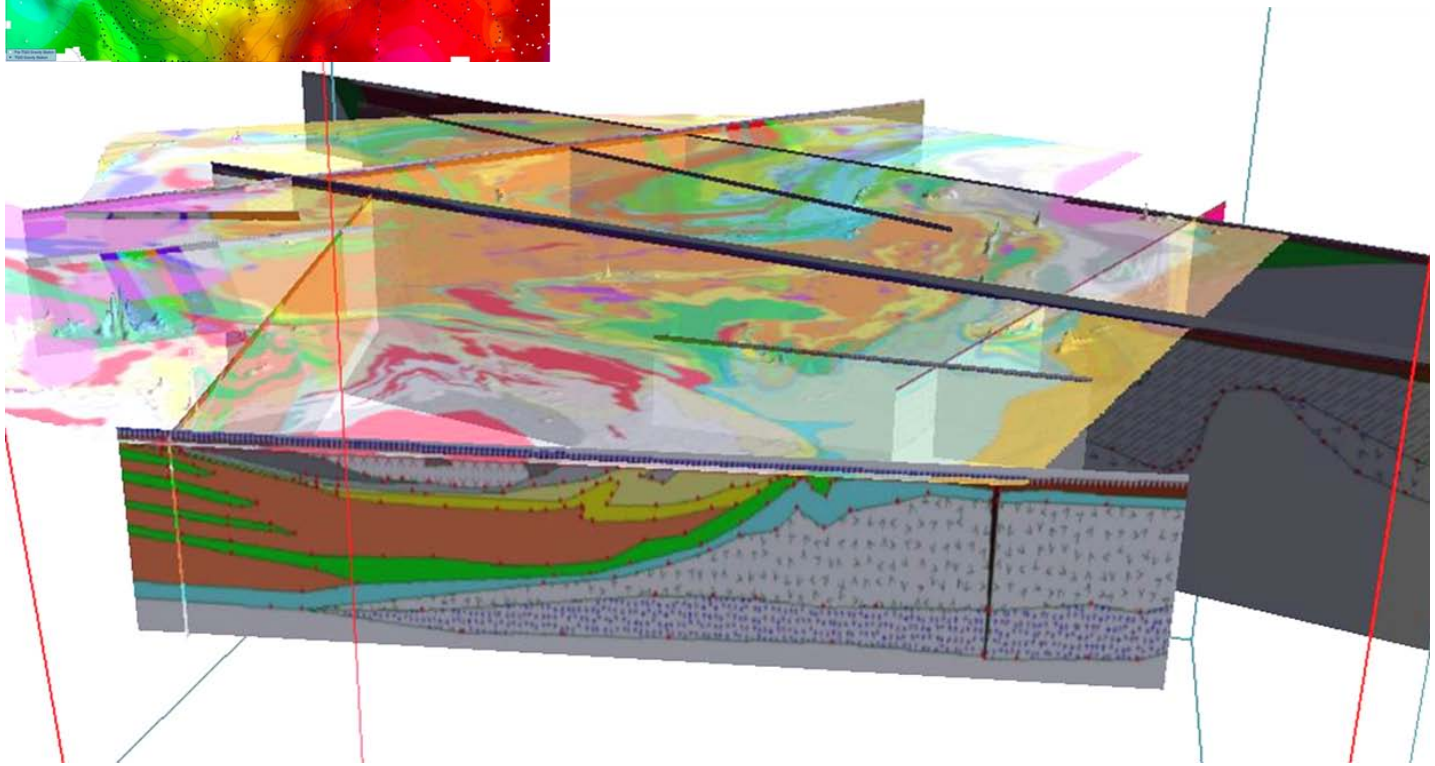

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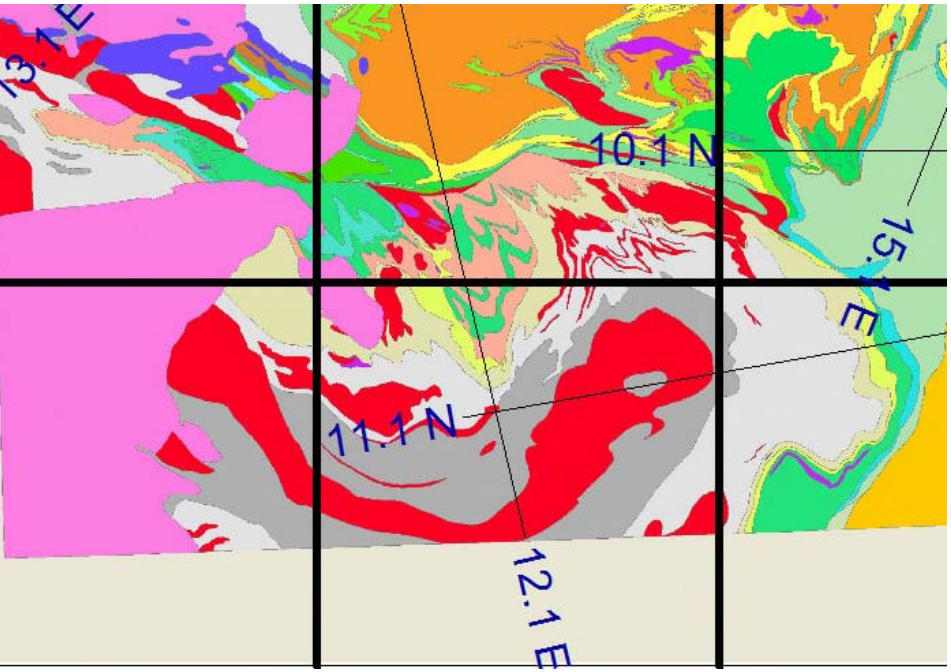

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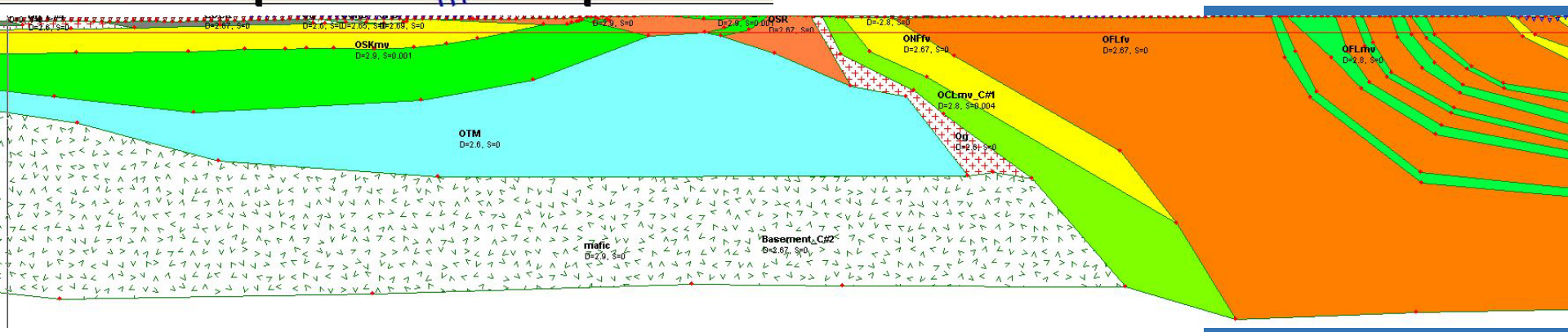
Modelling implies that the Miramichi and Mullin Stream Granite form a thin skin over the Clearwater Stream Formation that hosts the Chester deposit



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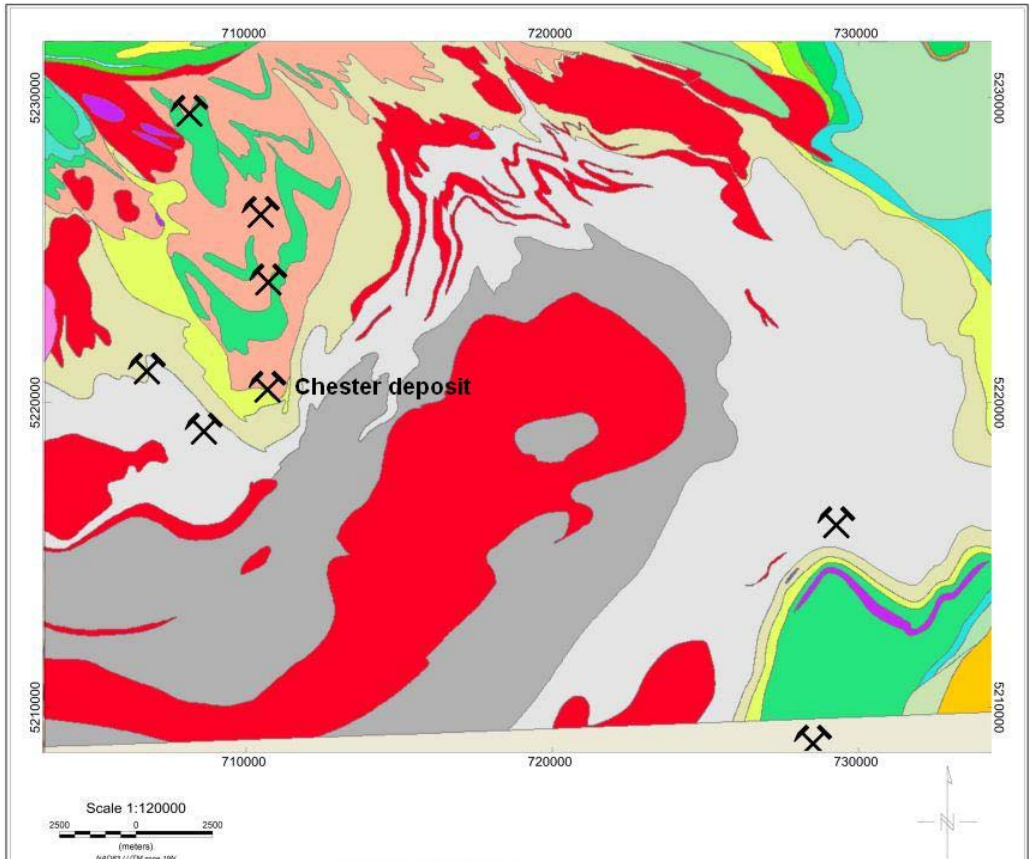

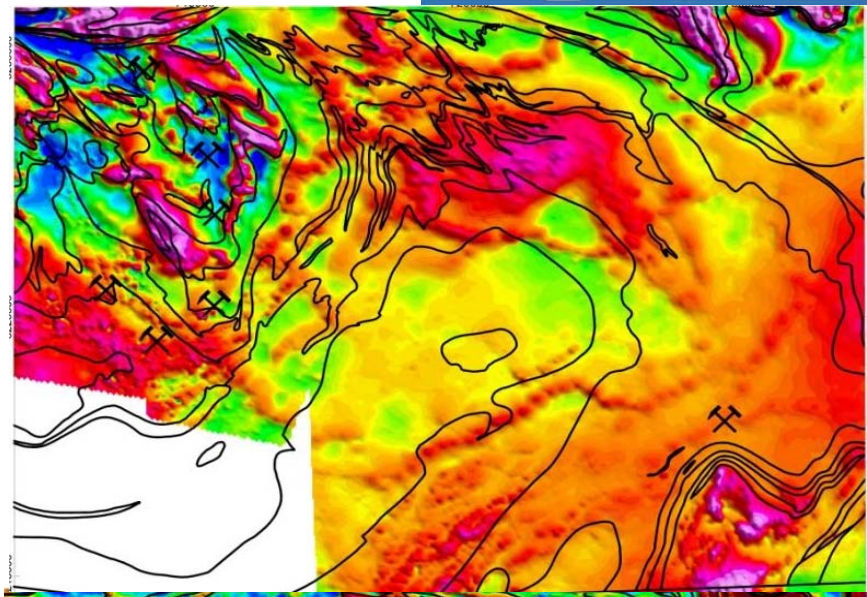

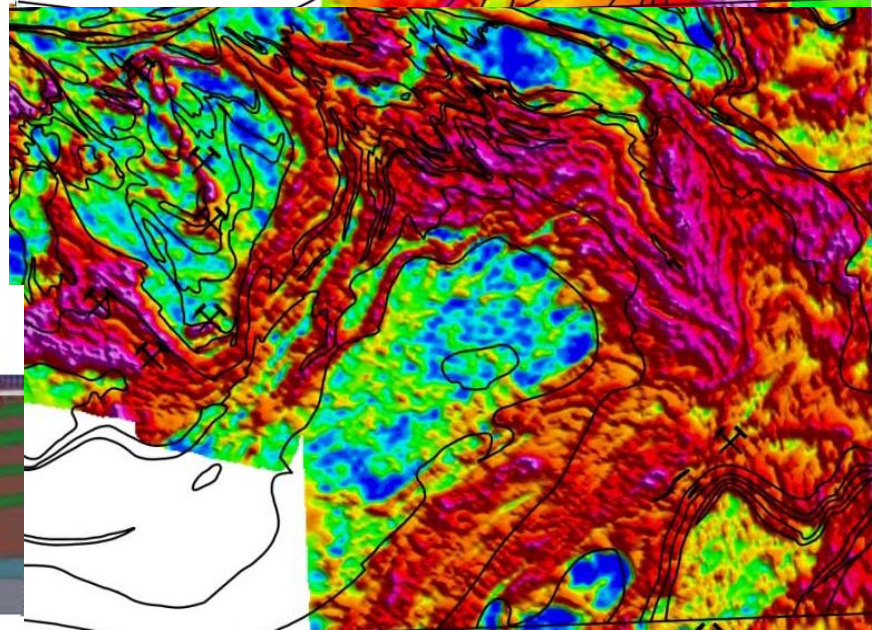

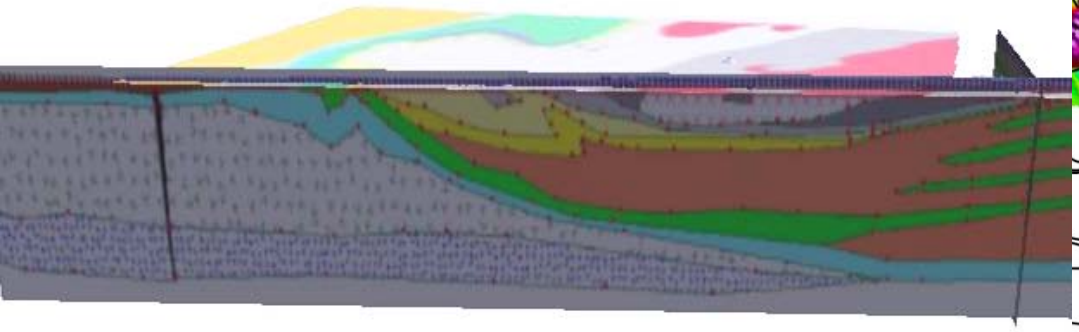

Case 2:
Iron Ore exploration project, NWT

- Target: iron formation within the Rapitan Group
- Late Precambrian age
- Rapitan Group contains abundant evidence of glaciogenic deposition. It includes massive mixtites which contain numerous faceted and striated clasts. Finely bedded and laminated sedimentary rocks of the Lower Rapitan contain many large isolated intra- and extra-basinal clasts
- The iron formation (IF) is interbedded with thin mixtite beds and contains large exotic clasts

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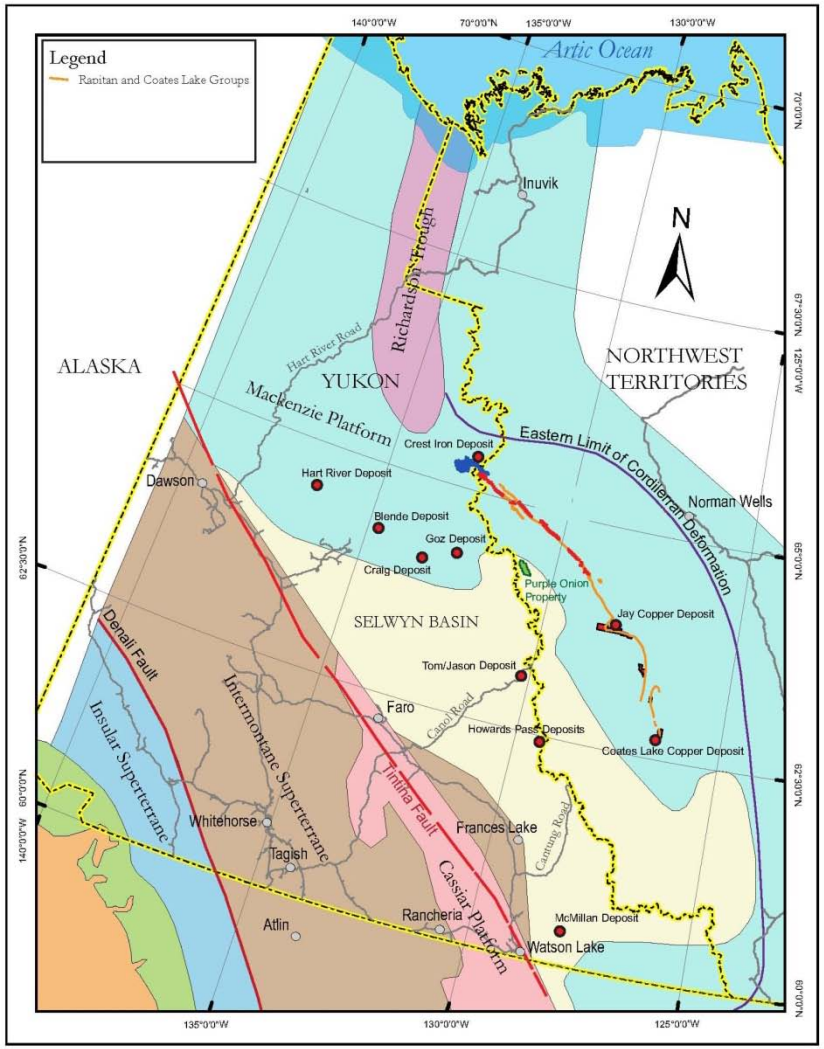

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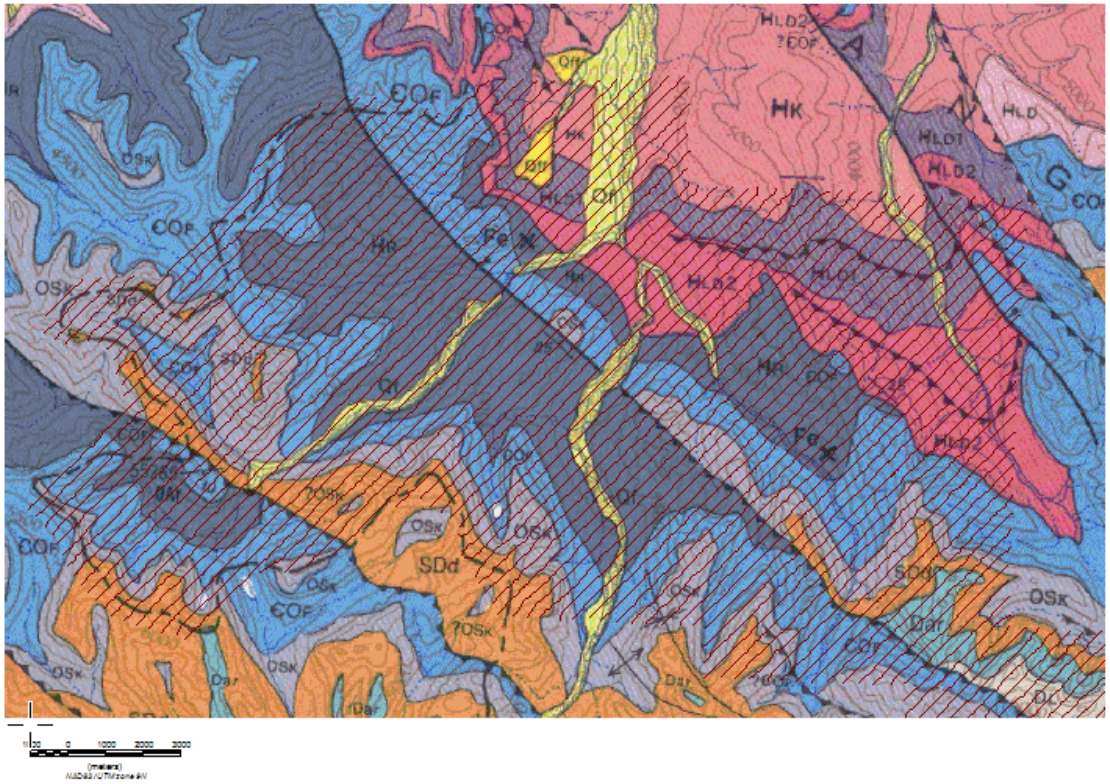


SILURIAN AND DEVONIAN
UPPER SILURIAN AND LOWER DEVONIAN

SDd — *Dolomite, silty, pale orange weathering; limestone, micritic; marine*

ORDOVICIAN AND SILURIAN
UPPER ORDOVICIAN AND LOWER SILURIAN

OSK — *MOUNT KINDLE FORMATION: dolomite, light grey weathering, siliceous; minor chert; marine*

CAMBRIAN AND ORDOVICIAN
UPPER CAMBRIAN AND LOWER ORDOVICIAN

COF — *FRANKLIN MOUNTAIN FORMATION and equivalents: dolomite and limestone; shale interbeds; marine*

CAMBRIAN
LOWER CAMBRIAN

CSK — *SEKWI FORMATION: limestone, dolomite; minor shale and quartzite. May include Backbone Ranges Formation locally*

CB — *BACKBONE RANGES FORMATION: sandstone, dolomite, varicoloured shale; marine and (?) nonmarine*

PRECAMBRIAN

HS — *SHEEPBED FORMATION: shale, dark grey to black; marine*

HK — *KEELE FORMATION: limestone, dolomite, quartzite, shale and conglomerate; marine*

HT — *TWITYA FORMATION: shale, siltstone and limestone; marine?*

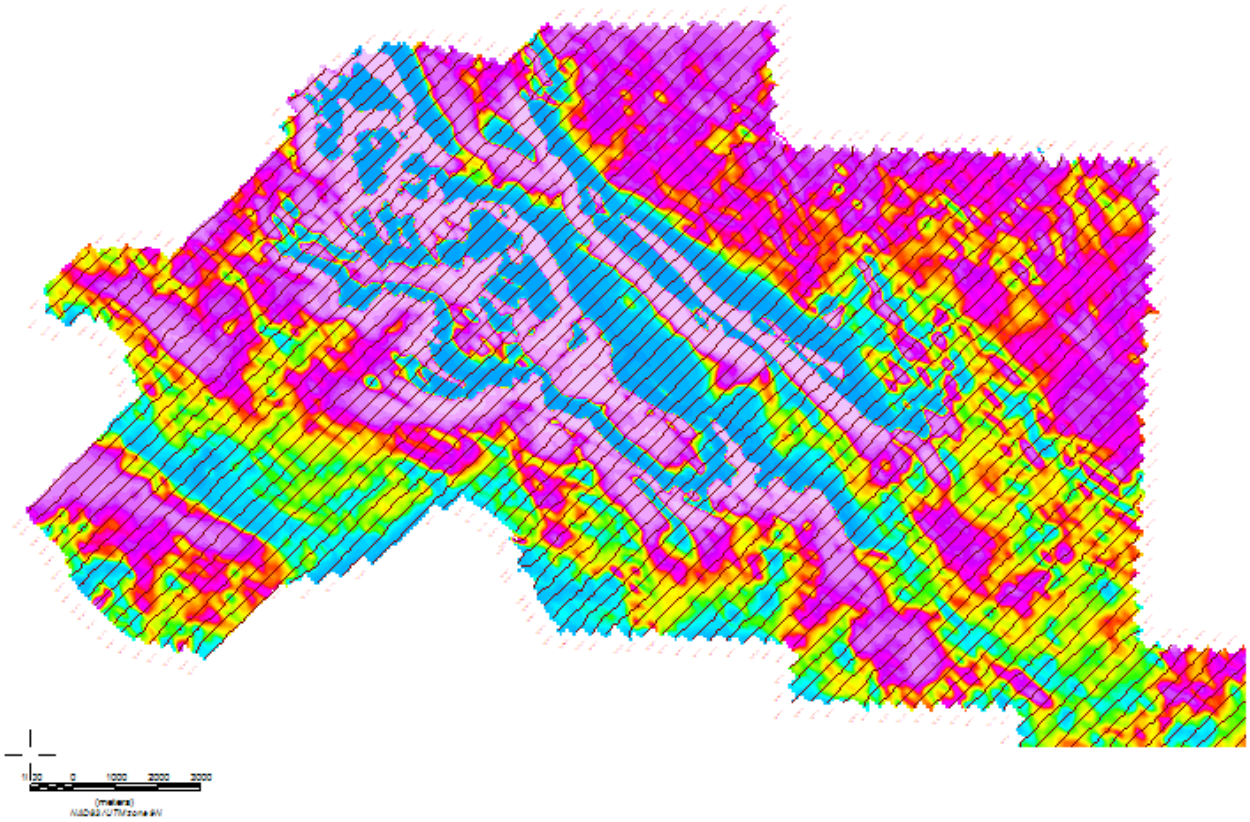
HR — *RAPITAN FORMATION: diamictite, massive; and siltstone, highly ferruginous, dark red weathering; iron formation at several horizons in the lower one-third of the unit*

HLD2 — *LITTLE DAL FORMATION (HLD1-HLD2) Dolomite, limestone, quartzite, shale and gypsum; marine*

HLD1 — *Limestone, fine grained, massive, light grey weathering; marine*

HK — *KATHERINE GROUP: quartzite, dolomite, shale; undivided; marine and (?) nonmarine*

Case 2:
Iron Ore exploration project, NWT



RTP_1VD Magnetics

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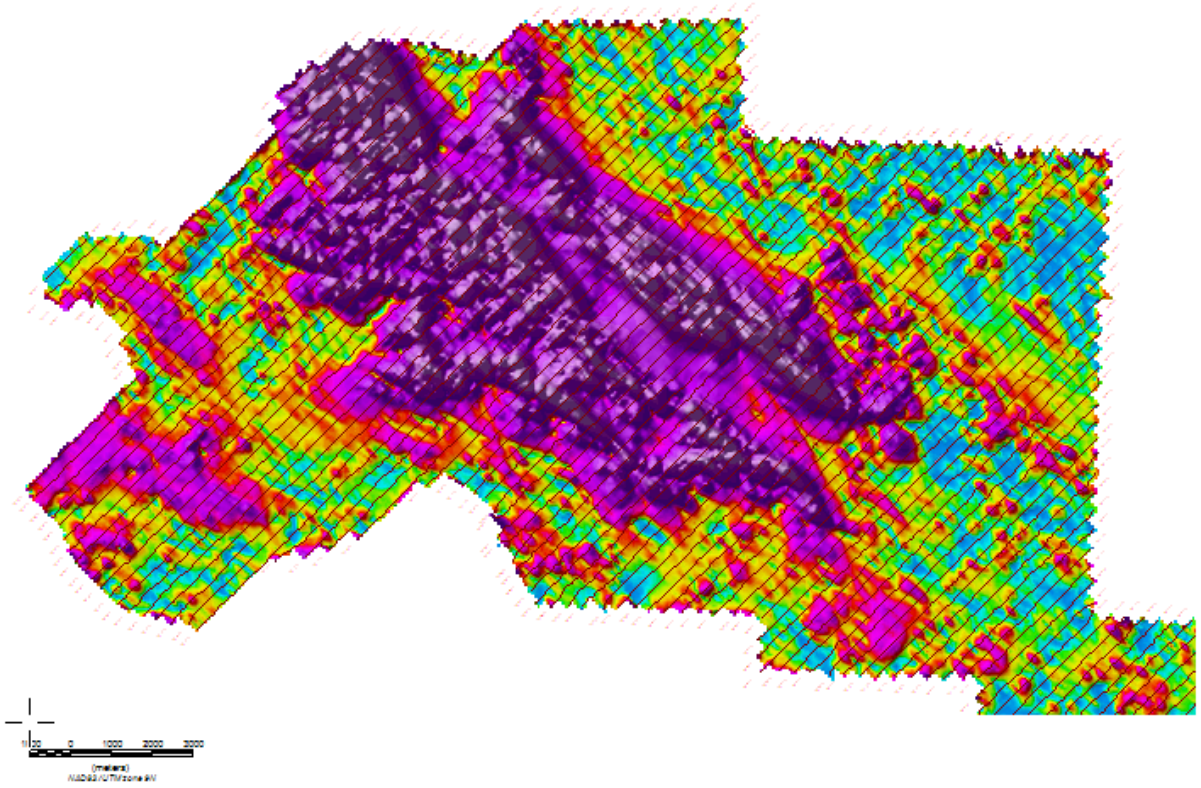

Amplitude of Analytic Signal (of TMI)

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Case 2:
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- ASIG exhibits high intensity and extended magnetic anomalies
- Fe target? All good!
- Interpretation 1:
  - Outline main magnetic horizons and recommend ground check

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Case 2:
Iron Ore exploration project, NWT

- Ground follow-up (field mapping, susceptibility measurements & ground magnetic survey) results
  - IF non magnetic (hematite)
  - There is a large magnetic conglomerate unit ABOVE the IF
  - Secondary magnetic unit below the IF
  - Decided to model 2D sections for improved geologic control (*non direct targetting*)

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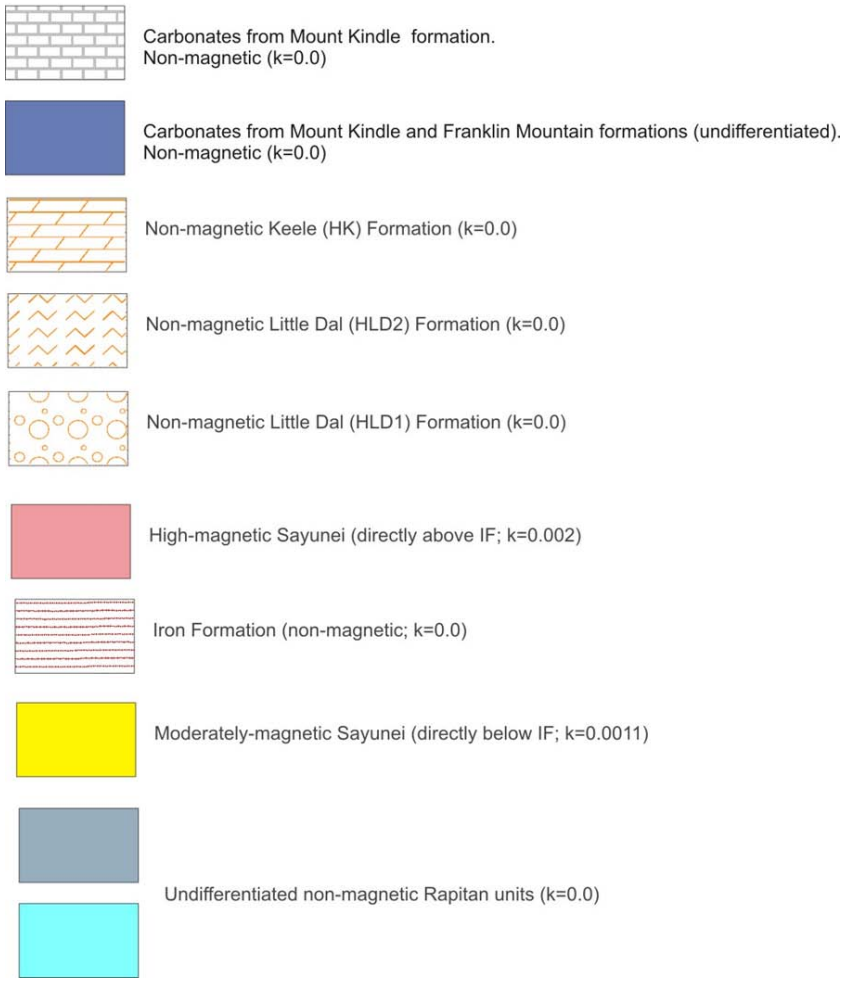
Legend for all models:



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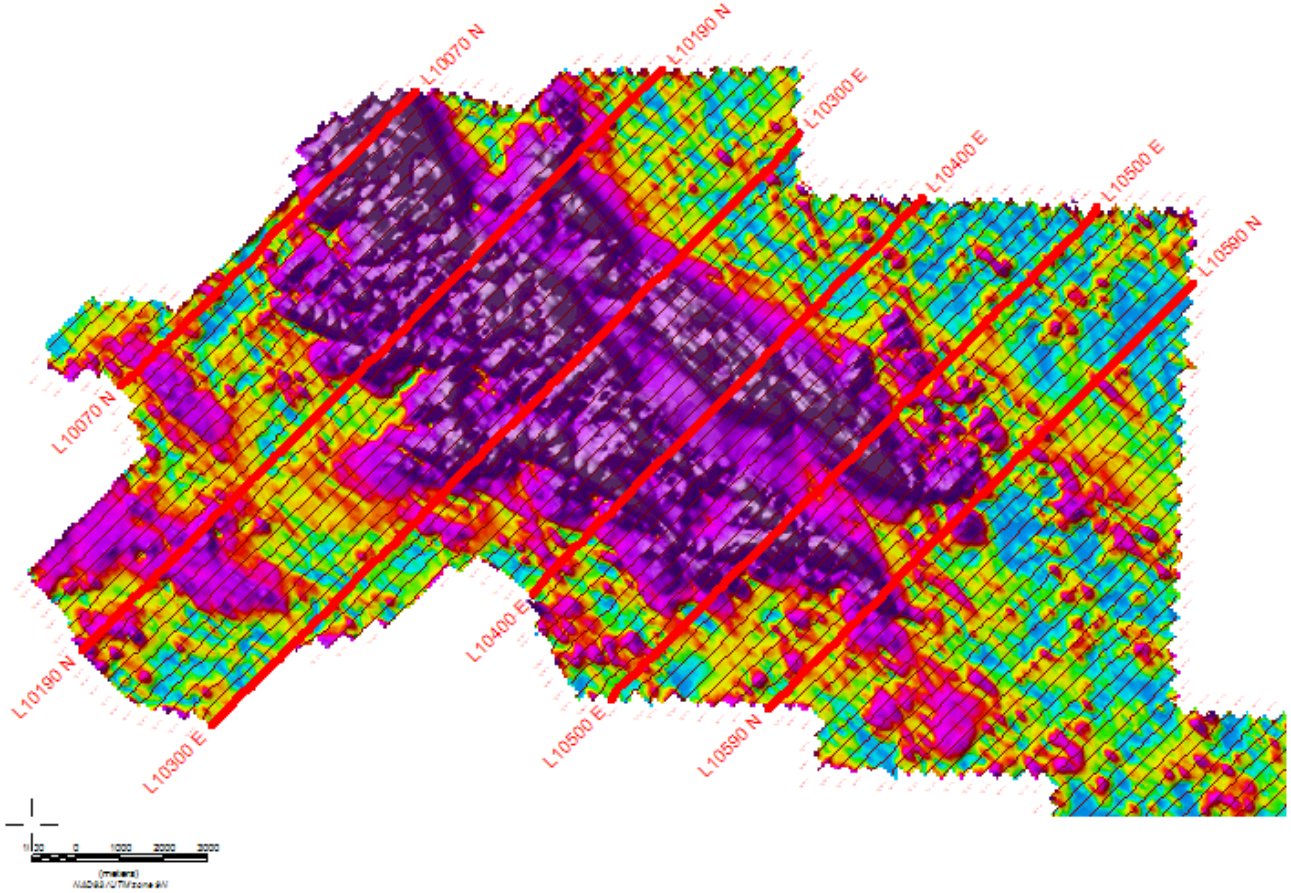

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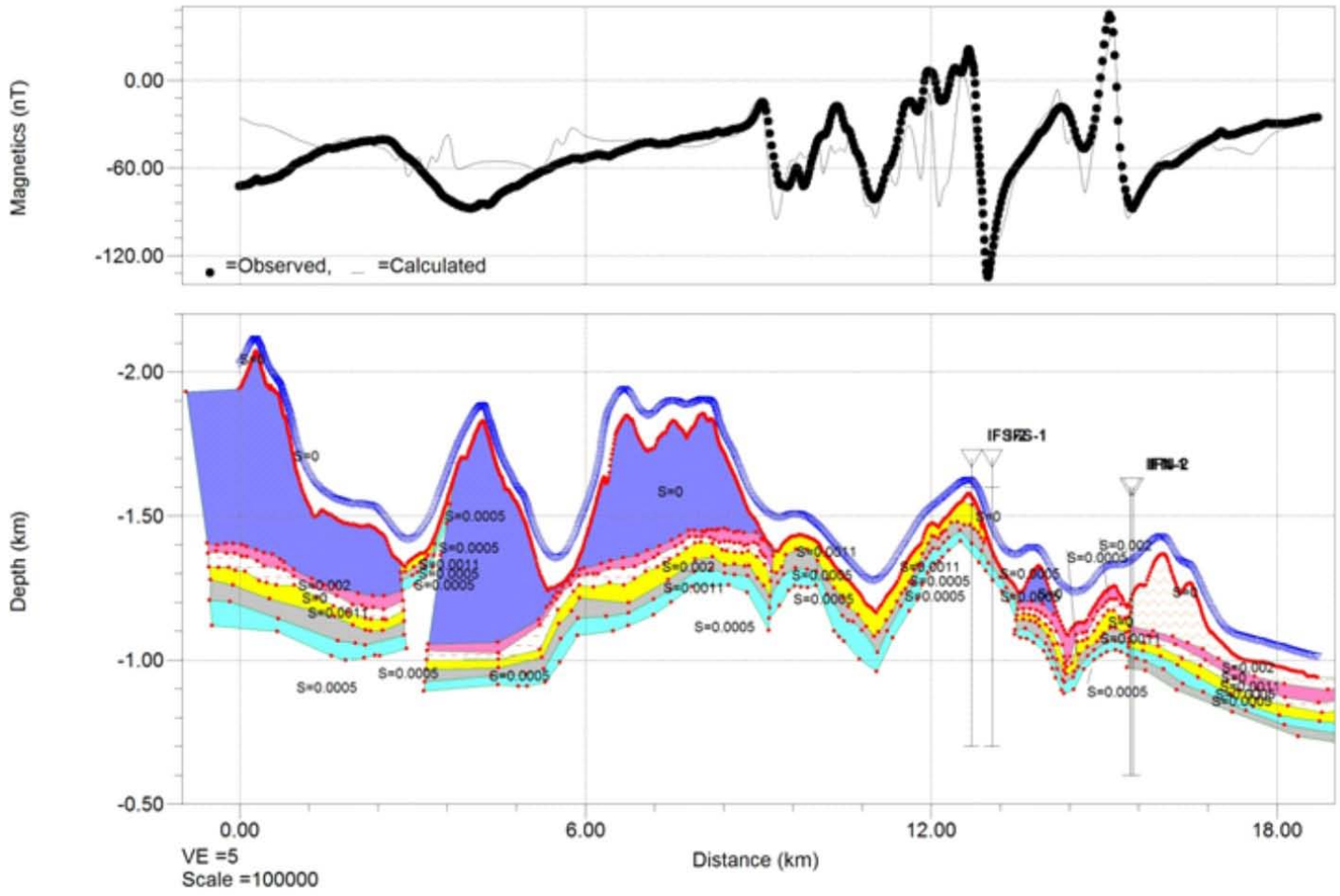

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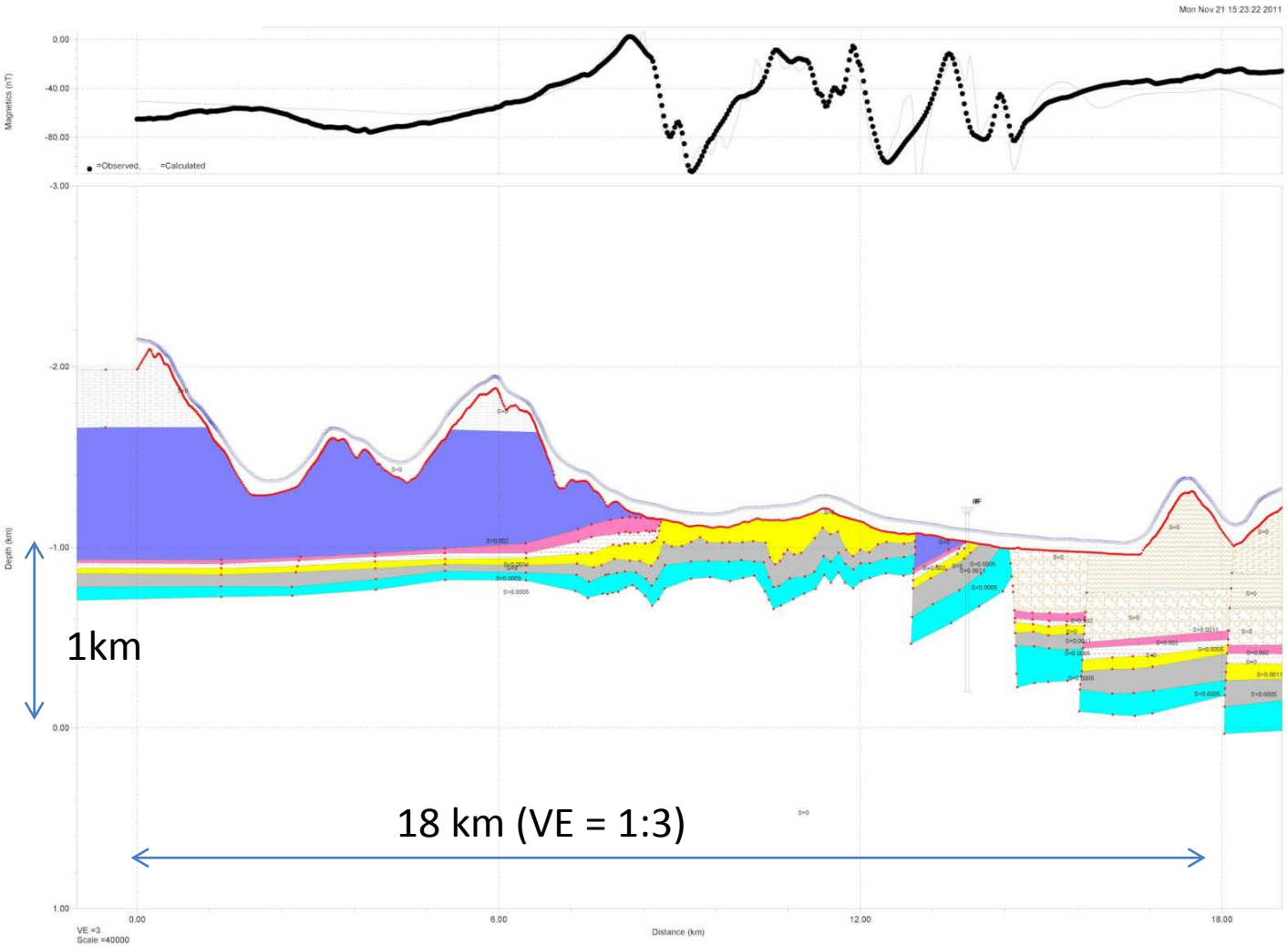
Case 2:
Iron Ore exploration project, NWT



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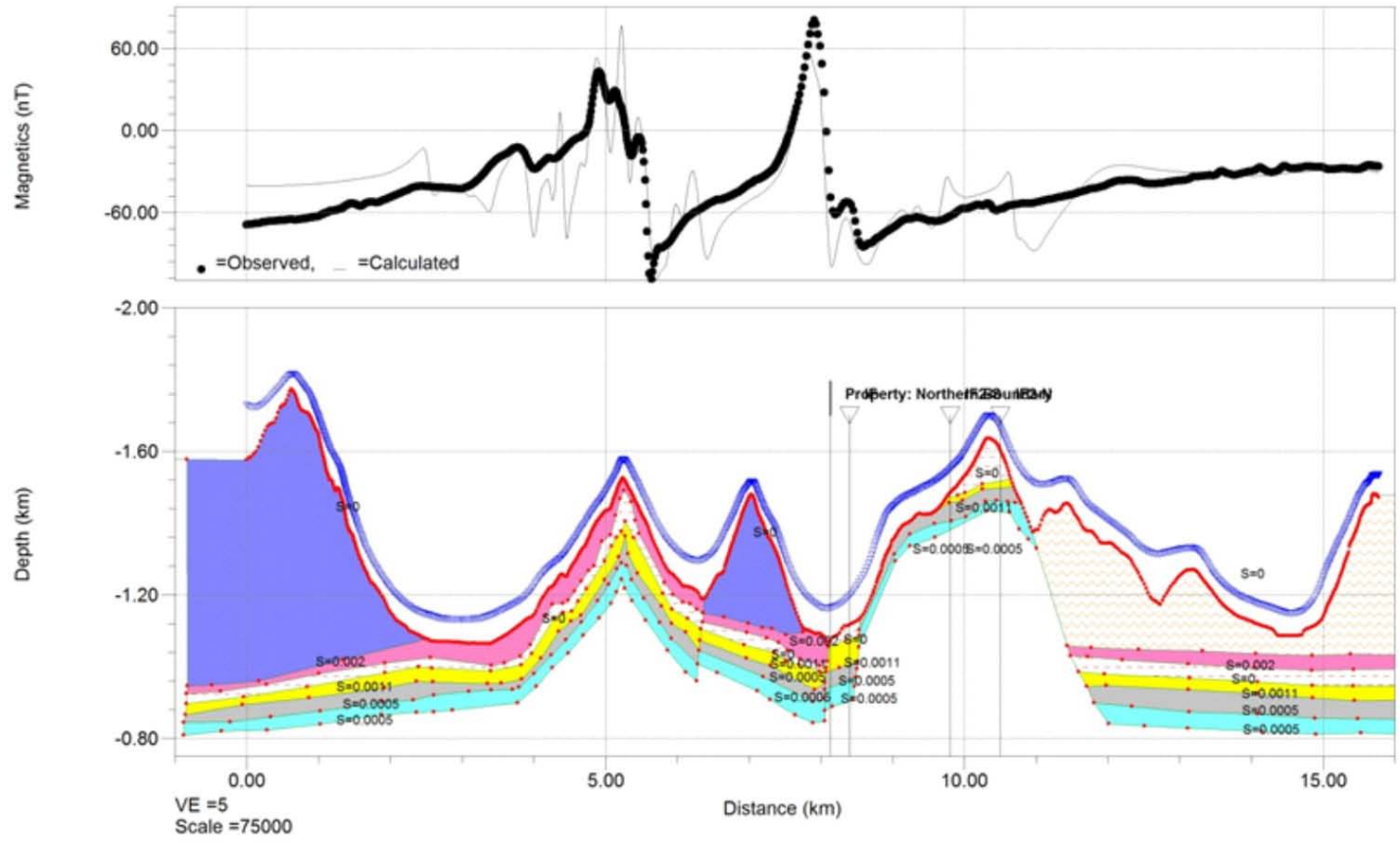

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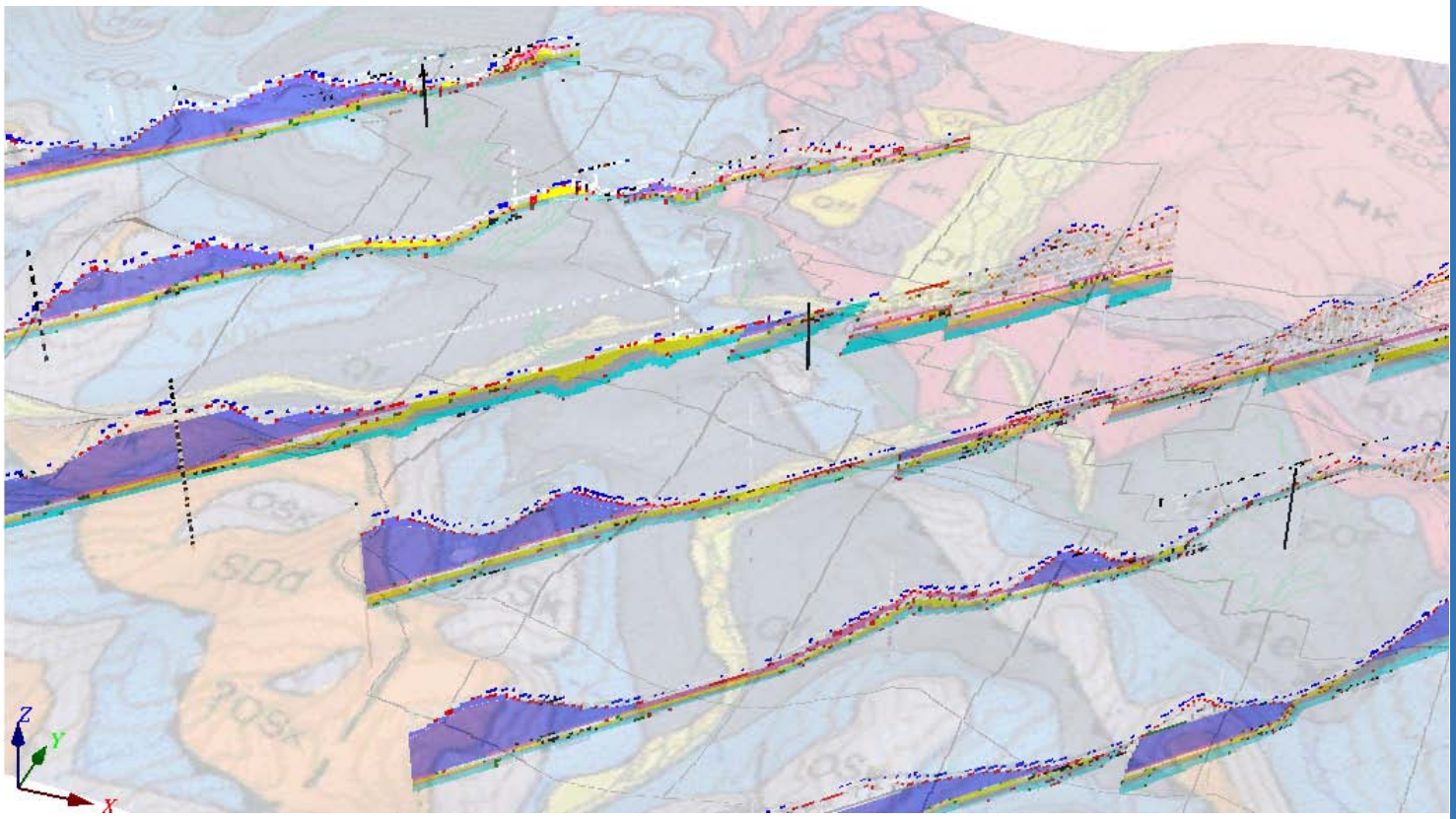

3D model integration

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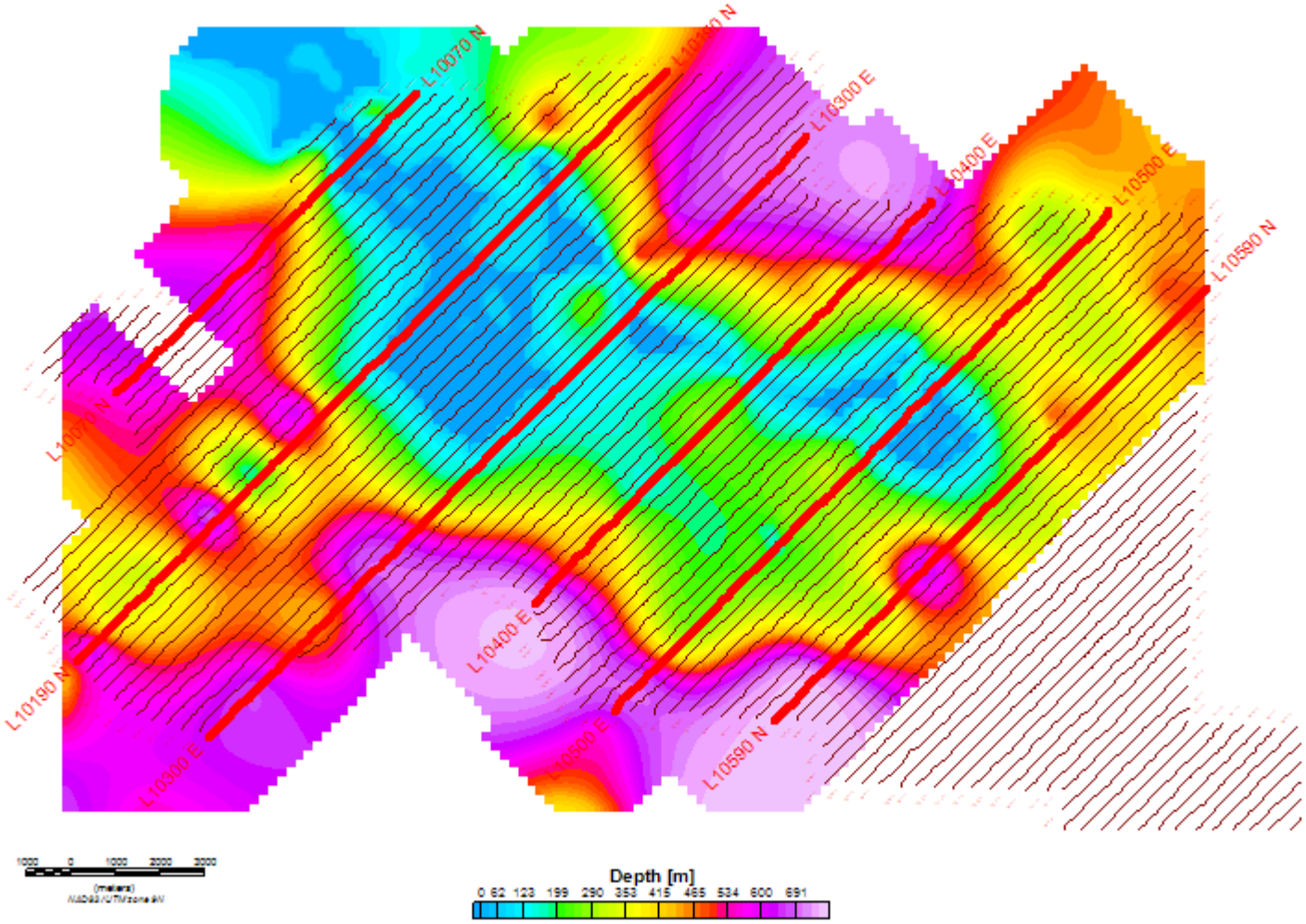
Iron Ore exploration project, NWT



Final: target definition, depth to IF

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Summary & Conclusions

- The advancement of computing power and inversion algorithms have made 3D inversions of potential field data quite popular
- However, care must be taken on when and how can we apply them. Main questions to answer before inverting:
  - Can I resolve the target? (do we have enough physical property contrast?)
  - Is the size of the project (small enough) and the resolution of the data sufficient for the 3D inversion?
  - Do we have enough geological constraints?

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Summary & Conclusions

- 2D inversion, although “less sexy” than a 3D voxel gives the user full control on the geological constraints
  - Ability to obtain geometry (strike, dips), depth extension (depending on physical property contrast) and important structural information (folds & faults)

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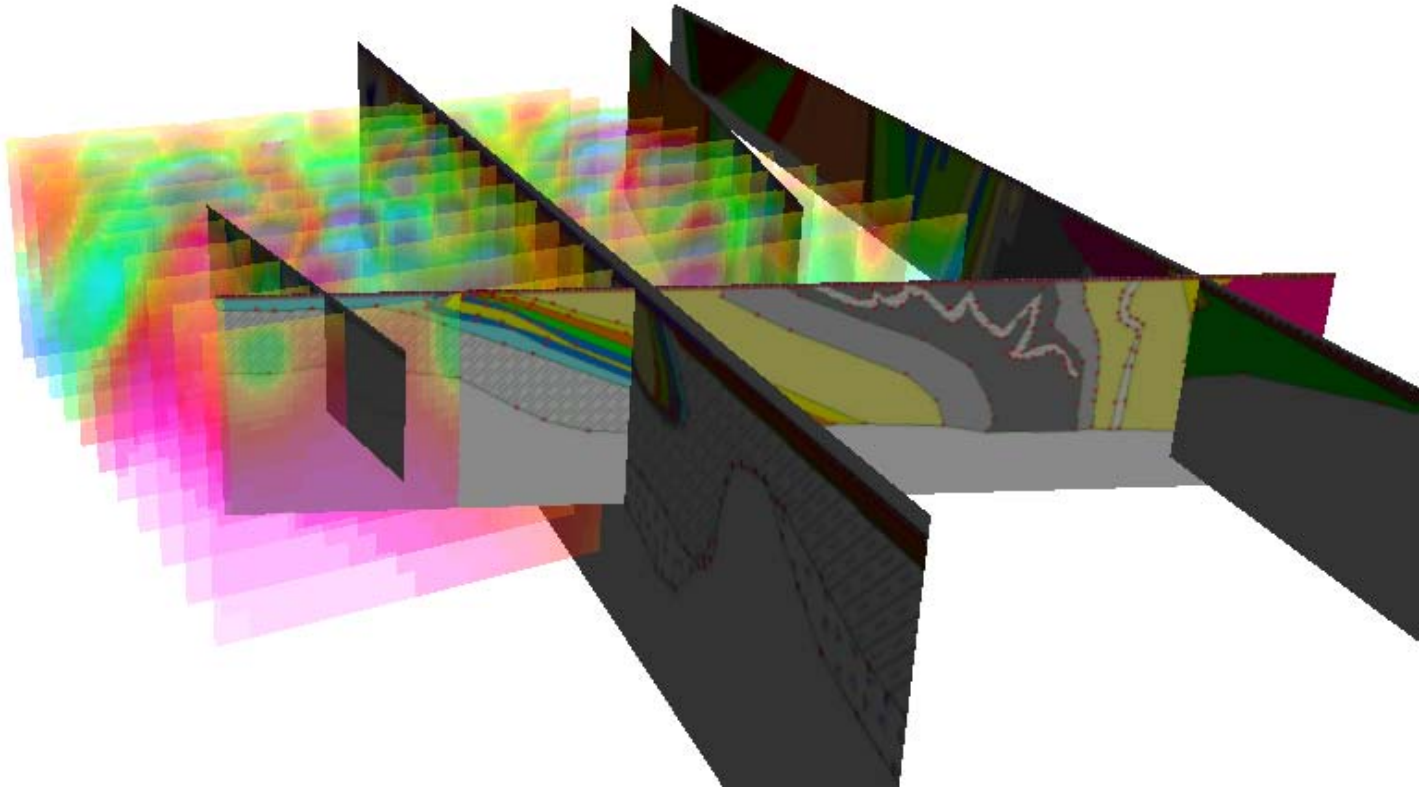
Summary & Conclusions

- Bathurst: too large for a 3D inversion, and/or too complex for proper geological constraints on a 3D inversion



(3D Gravity inversion & 2D Modelling)

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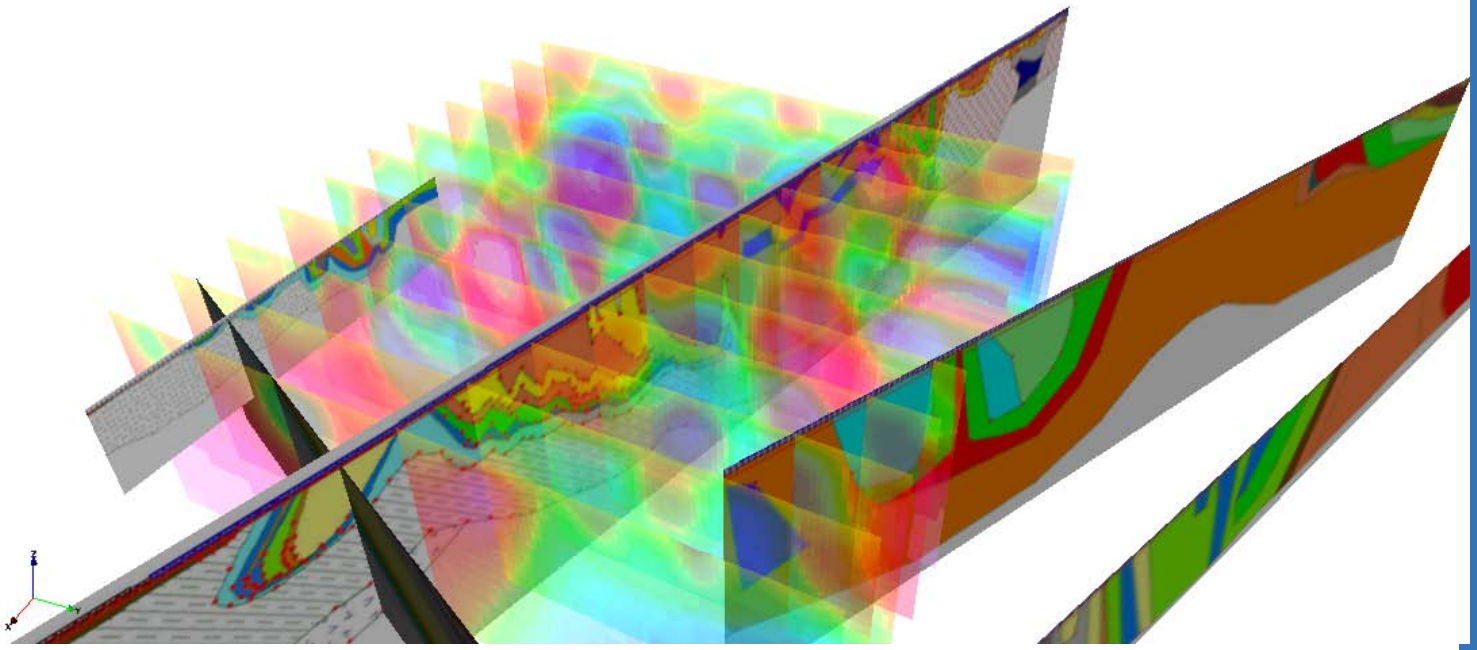

(3D Gravity inversion & 2D Modelling)

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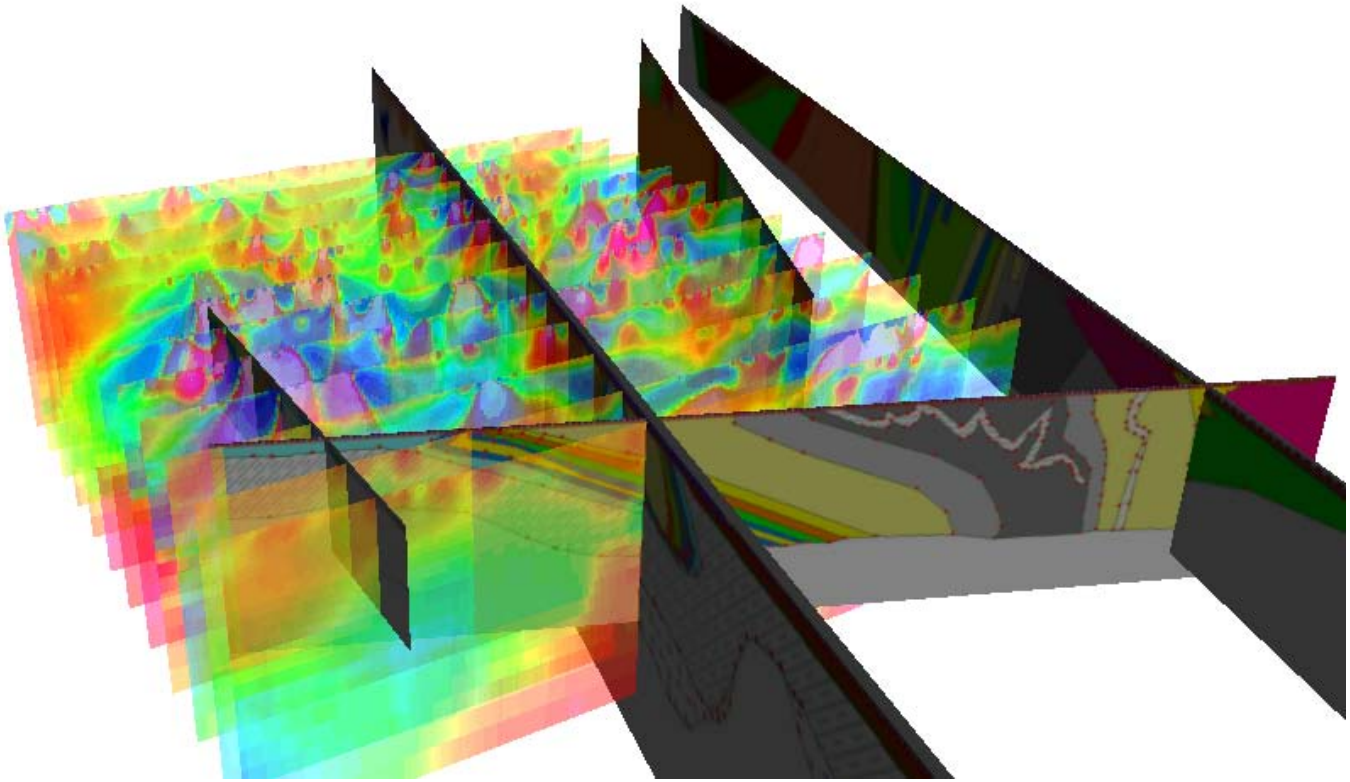

(3D Magnetic inversion & 2D Modelling)

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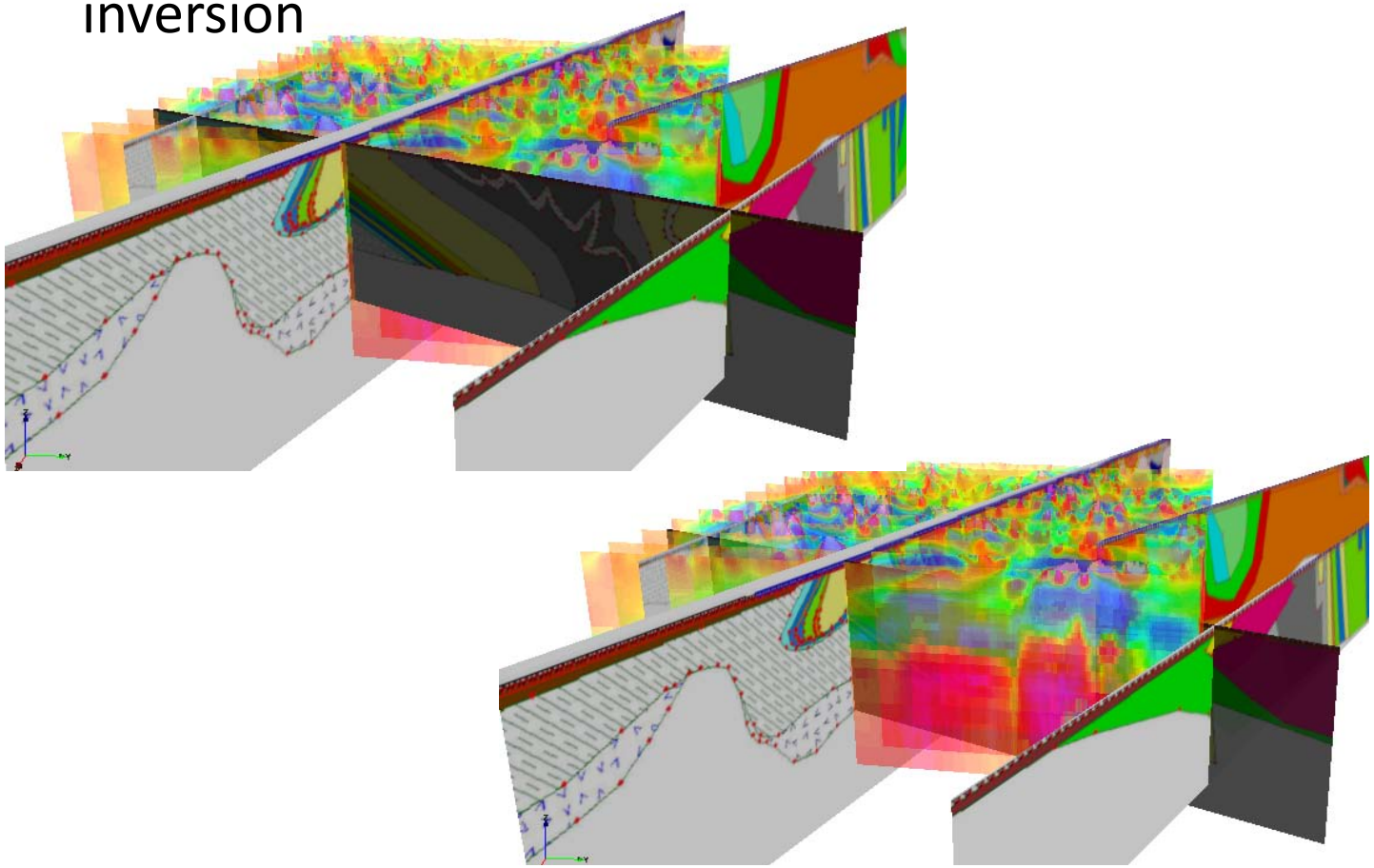

(3D Magnetic inversion & 2D Modelling)

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Summary & Conclusions

- Detailed exploration projects:
  - Resolution of the data versus size of the target and physical contrast is key.
  - NWT project shows that thinking out of the box and focusing on geological mapping rather than on direct targetting ("drill the purple"), can provide with meaningful information

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