MobileMT: Applications in exploration for basement-hosted uranium deposits

(on the Shadow project example)

from innovations to discoveries

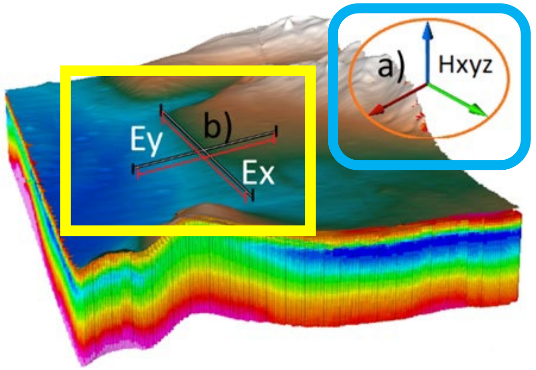
Airborne EM Surveying for Uranium Exploration

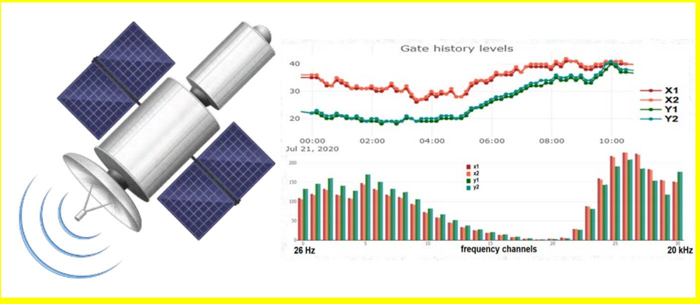
- EM surveys can aid in identifying faulting and favorable lithologies
- Can detect basement features where they coincide with graphitic zones - important marker for uranium deposits
- The **MobileMT system** has a superior depth of investigation compared with other airborne EM systems, even in conductive environments, and under conductive units
- It is also sensitive to resistivity differentiations including in the thousands and tens of thousands of ohm-m’s range

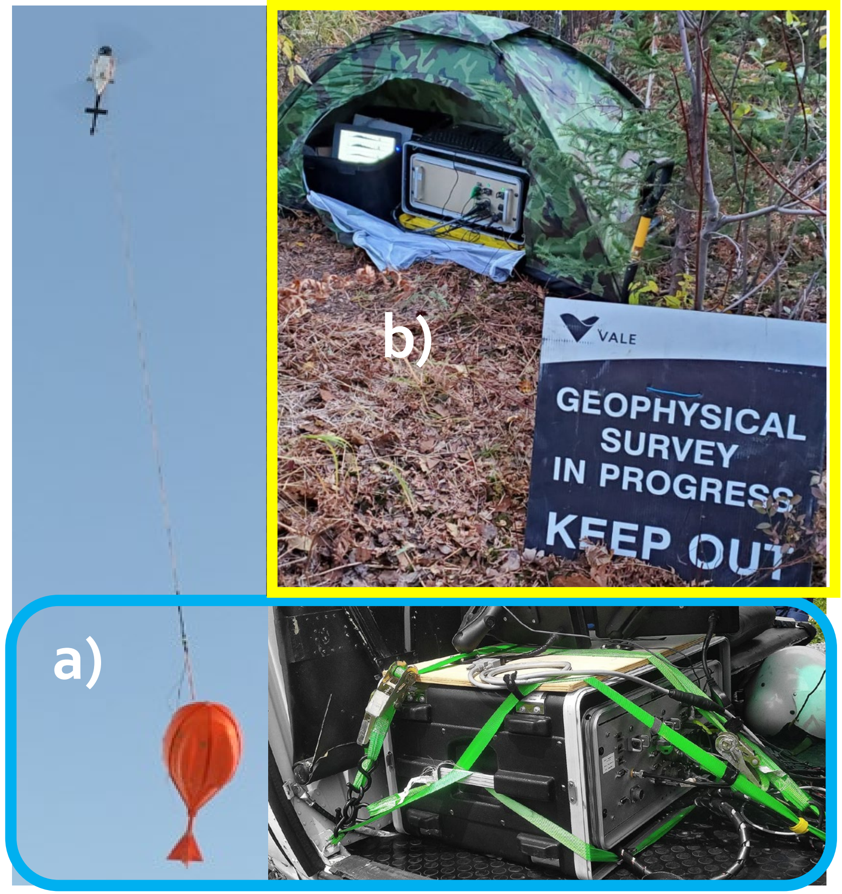
MobileMT System

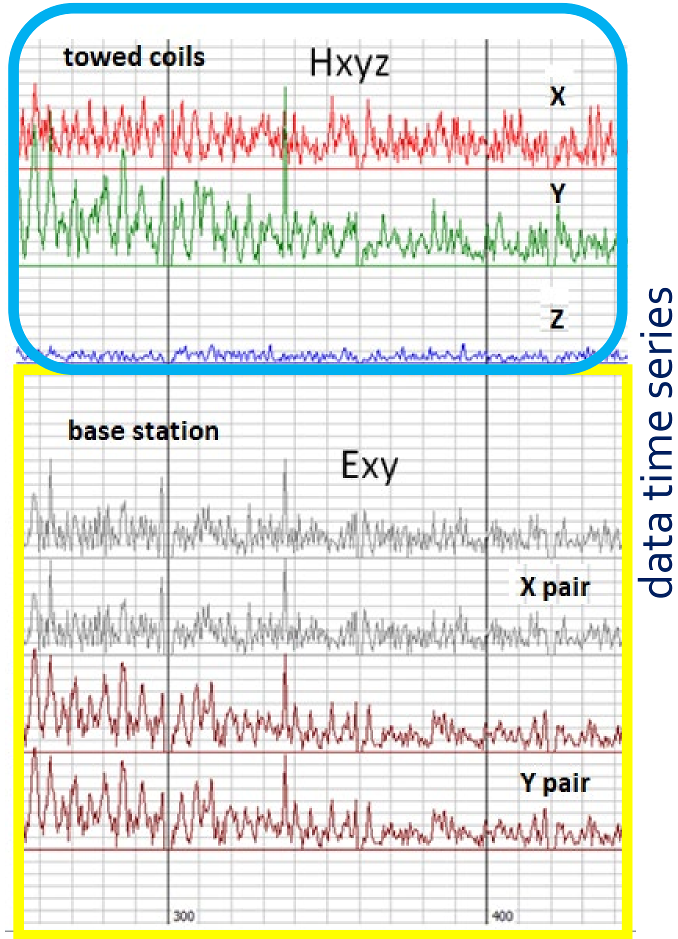
- Utilizes naturally occurring EM fields, over a broad frequency, to understand variations in subsurface electrical structure
  - Data at higher frequencies → shallow geoelectrical variations
  - Data at lower frequencies → deeper structure
- Capable of detecting resistivity contrasts in any direction (i.e., horizontal/vertical)
- Depth of investigation in conductive environments exceeds several hundreds of meters, and in resistive environments can be > 2 km

MobileMT – data acquisition and processing









H **towed coils**

$$H = \begin{bmatrix} Hx \\ Hy \\ Hz \end{bmatrix}$$

E **base station**

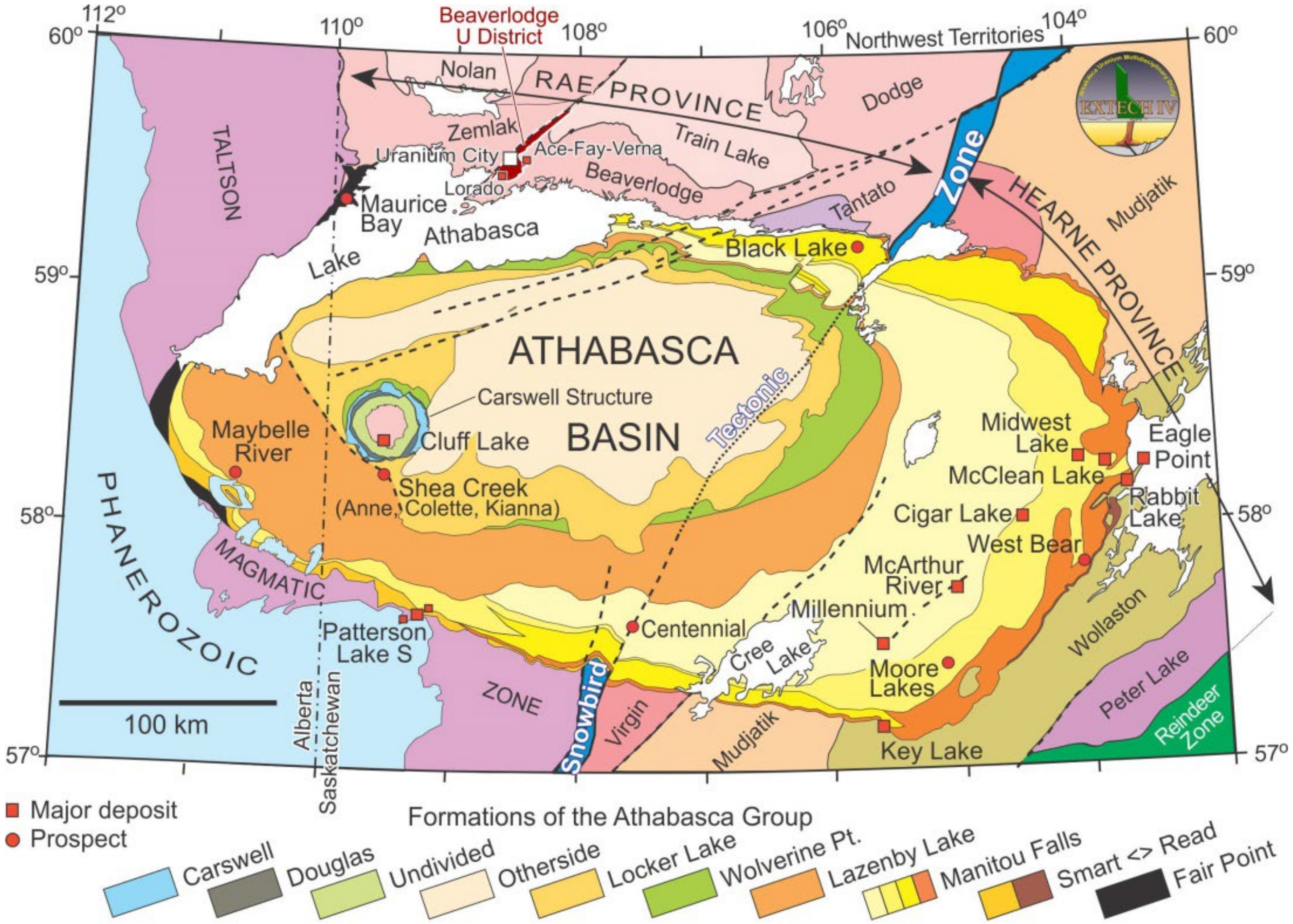
$$E = \begin{bmatrix} Ex \\ Ey \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} Hx \\ Hy \\ Hz \end{bmatrix} = \begin{bmatrix} Yxx & Yxy \\ Yyx & Yyy \\ Yzx & Yzy \end{bmatrix} \begin{bmatrix} Ex \\ Ey \end{bmatrix}$$

$$\sigma = \mu\omega|Y^2|$$

Athabasca Basin Uranium Deposits

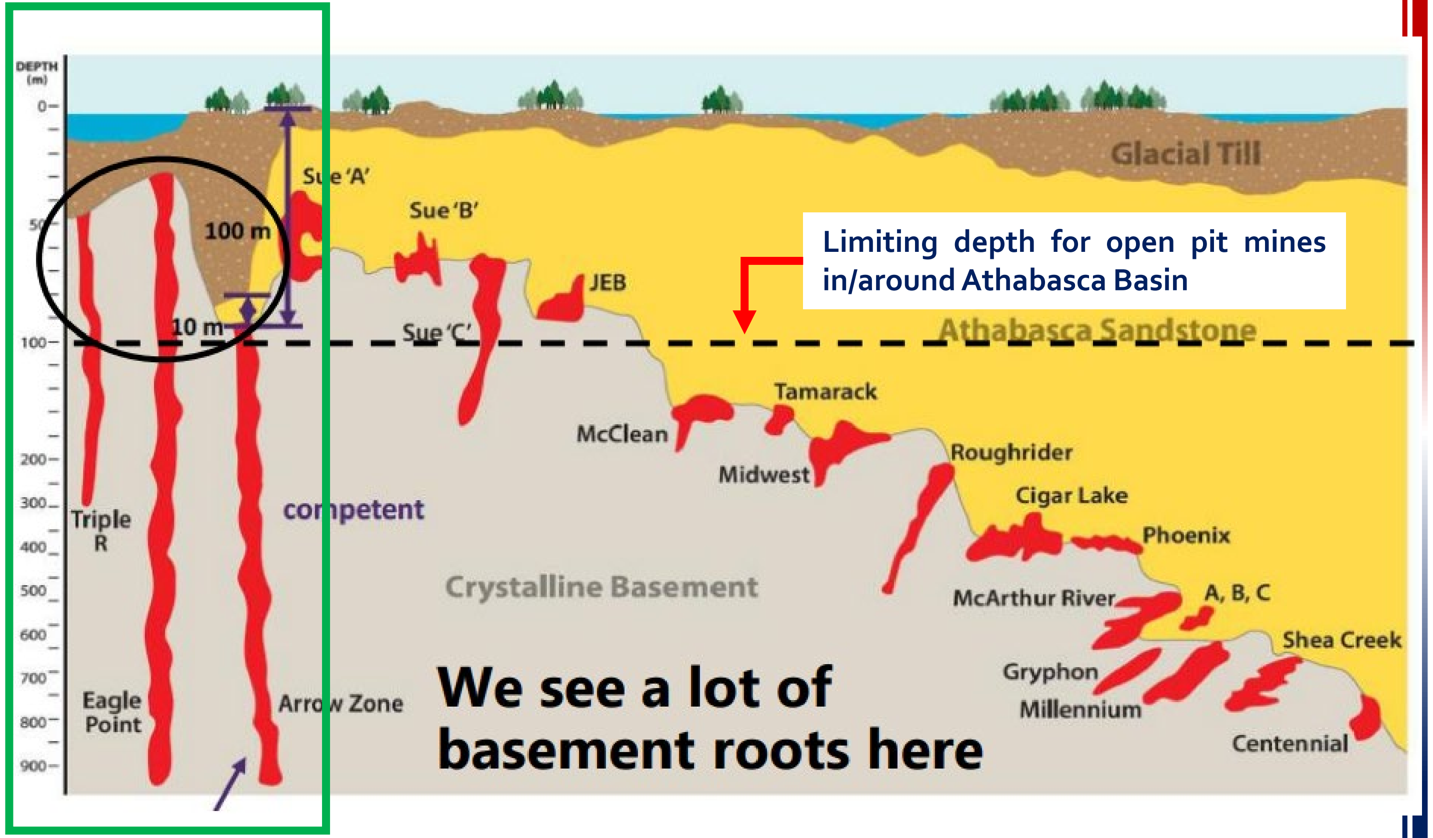
- Athabasca Basin is a Proterozoic sedimentary basin where Athabasca Group sandstones unconformably overlie graphite-rich meta-sedimentary basement rocks
- Eastern Athabasca region has been the hub of uranium exploration and mining for the past ~50 yrs
- In the Athabasca Basin, the unconformity related uranium deposits consist of massive pods, veins and disseminated uraninite



The Athabasca and Beaverlodge Districts

Unconformity Related Uranium Deposits

- Unconformity related uranium deposits represent the largest high-grade U ore-bodies
- Exceptional grade and size results from combined efficiency of a series of U-fractionation mechanisms
- Distinction between 3 types of unconformity related deposits
  1. Sandstone hosted mineralization **ABOVE** the unconformity
  2. Mineralization **AT** the unconformity
  3. Basement-hosted, fracture controlled or vein mineralization **BELOW** the unconformity or on periphery of basin



The goal is to avoid sandstone cover, and focus on near surface mineralization.

From Baselode Energy corporate presentation (2020).

Pros of Basement-Hosted Deposits

Basement-Hosted Deposits

- "Simpler" geology; no sandstone
- More competent rock
- Easy mineability
- Examples: Arrow, Rabbit Lake, Eagle Point, Uranium City

The goal is to avoid sandstone cover, and focus on near surface mineralization.

Traditional Unconformity Deposits

- Complex geology; sandstone
- Incompetent
- Mine engineering difficulties
- Deeper mines require freezing
- High CAPEX
- Examples: McArthur River, Cigar Lake, Phoenix, Midwest

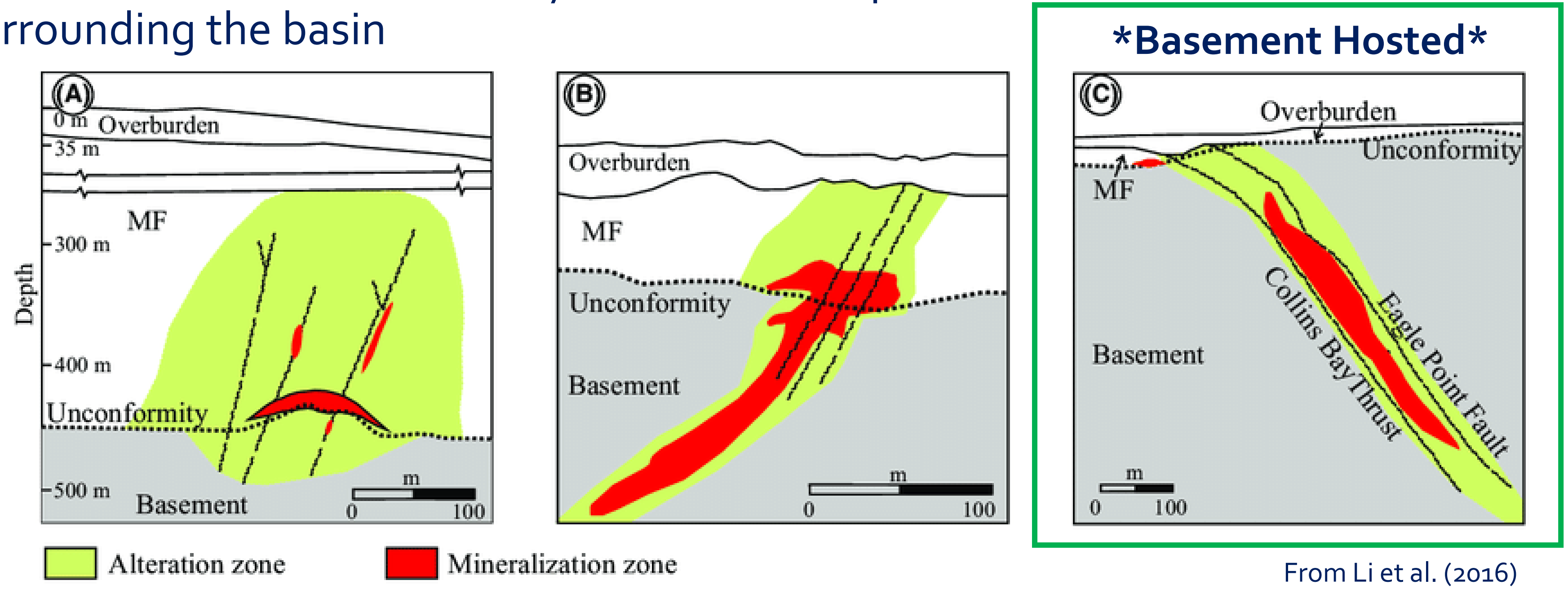
From Baselode Energy corporate presentation (2020).

Basement Hosted Uranium Deposits

- Uranium mineralization requires:

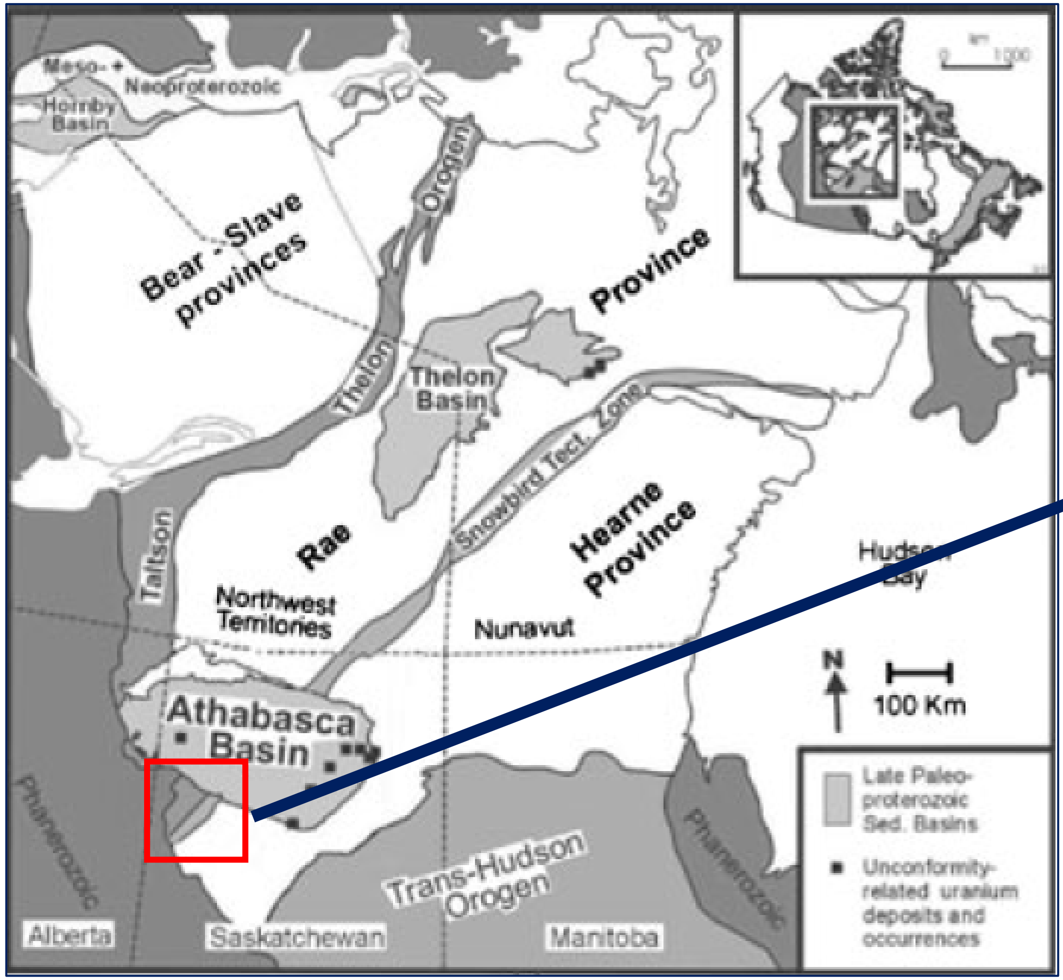
1. Fluids with right composition
2. Structural traps with the right geometry
3. Geochemical traps with right agents that produce precipitation

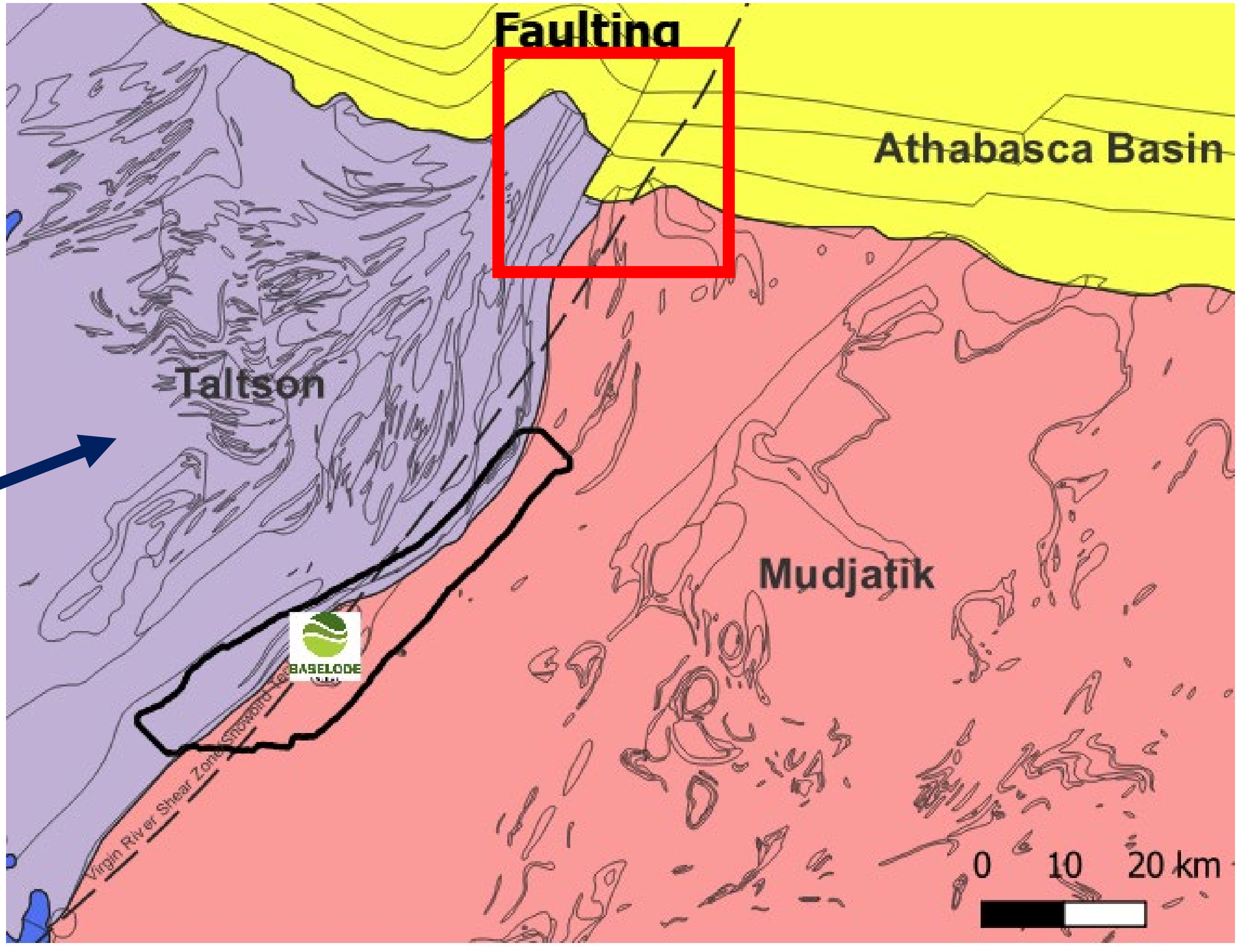
- Athabasca Basin is an optimal structural and chemical trap
- Same structures and chemistry for uranium deposition exist in basement rocks surrounding the basin



From Li et al. (2016)

Baselode Energy Shadow Project: Potential for Uranium Deposits

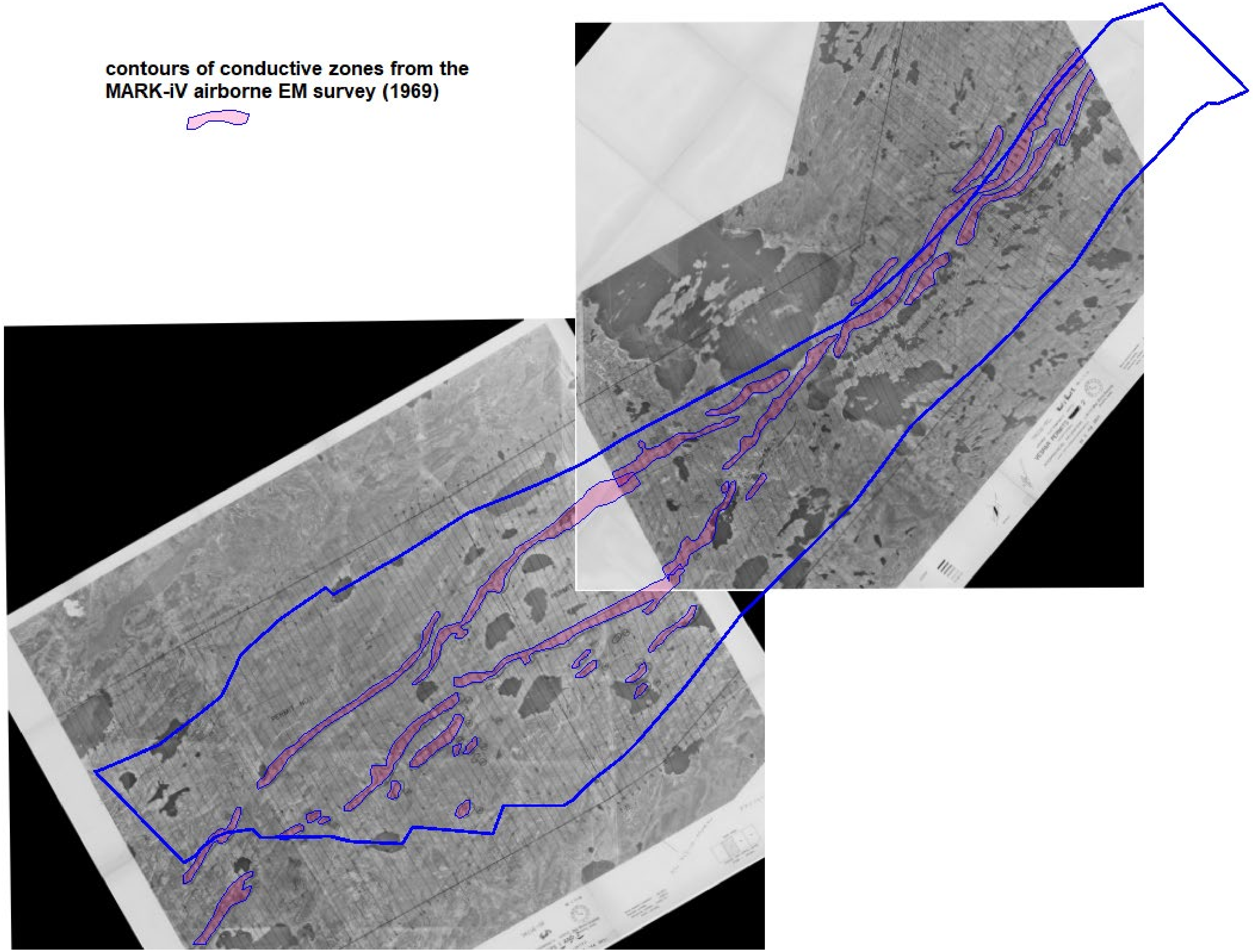




From Cloutier et al. (2011).

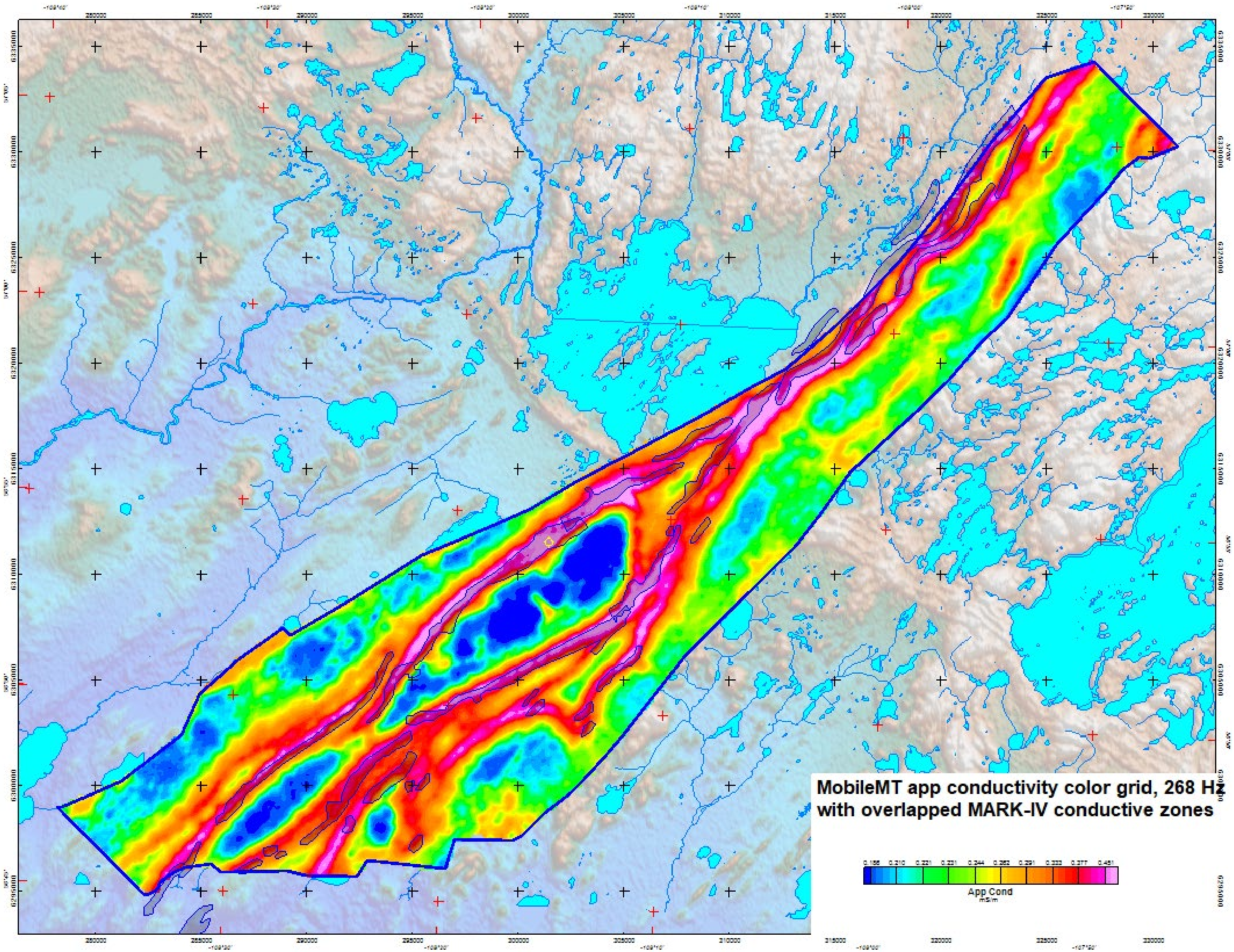
Historical (1969) Airborne EM Survey

contours of conductive zones from the MARK-iV airborne EM survey (1969)



MobileMT Airborne Survey (2020)

- During September 2020 Expert Geophysics conducted an ~1370 km geophysical survey over the Shadow Block for Baselode Energy
- Acquired magnetic, magneto-telluric, and VLF-EM data
- Final products include inverted resistivity-depth data
- Range of inverted resistivities between 800 to 20,000 ohm-m (from 1D model prospective)

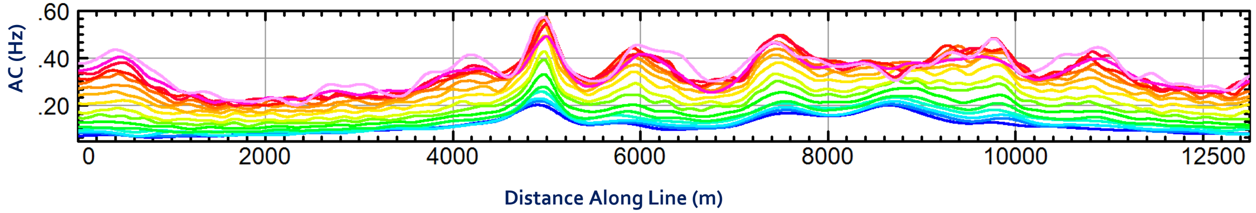


Add a footer

Shadow Project MobileMT Data

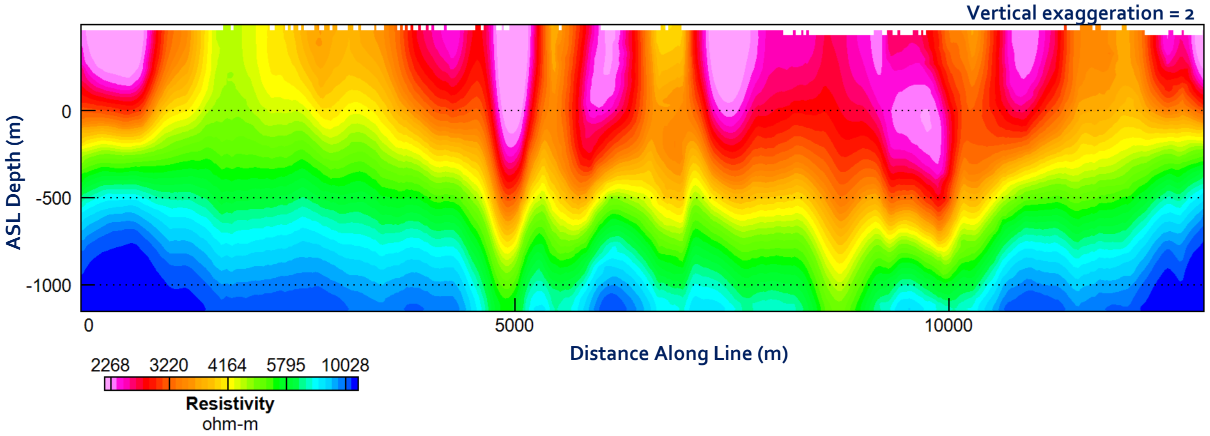
- Output from MobileMT system is apparent conductivity at a number of frequencies for each data point

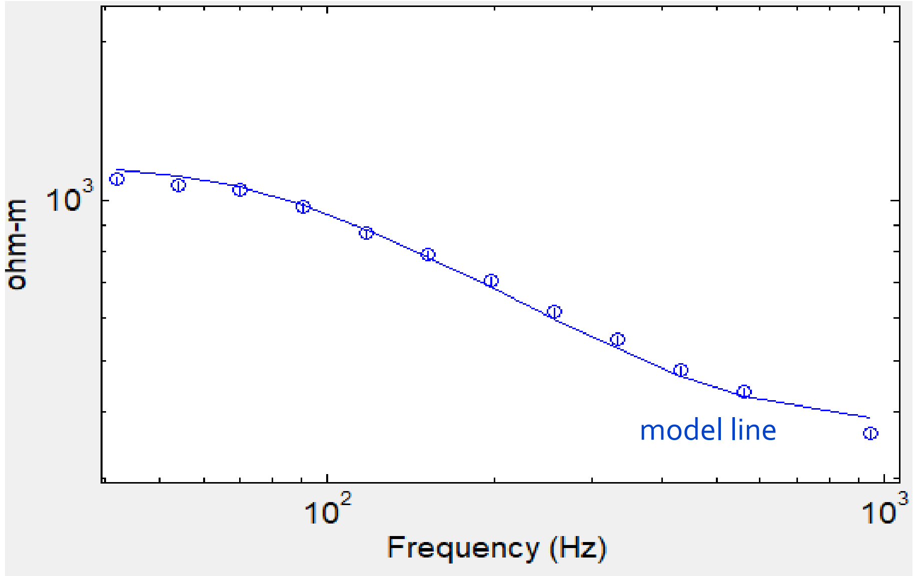
Example profile data from ~25 (cool colors) to 900 (warm colors) Hz



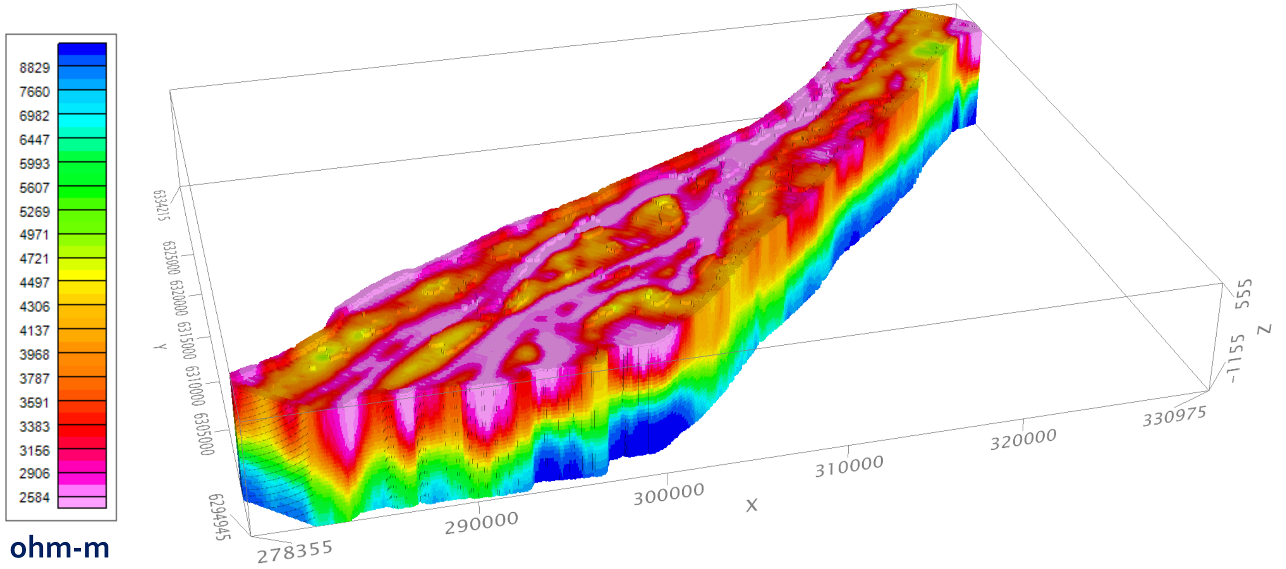
- Apparent conductivity frequency data are inverted to provide a resistivity depth information for **each measurement point** along a line

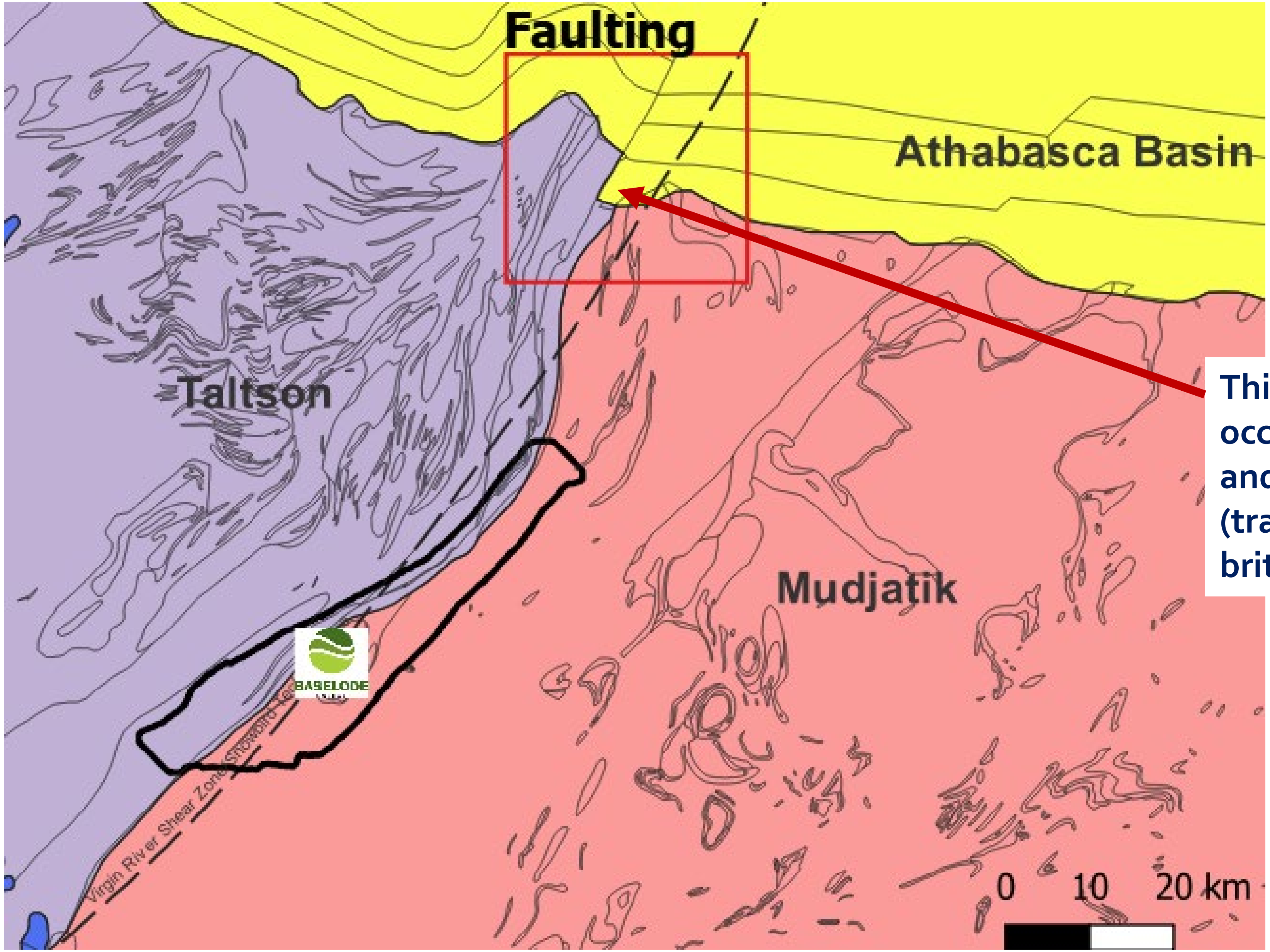
- 1-D res-depth models for each measurement can be used to construct 2-D sections along line, and 3-D voxels





Apparent resistivity (res = 1/cond) curve for each data station is input to inversion routine, which attempts to find an optimal model, based on certain constraints to fit the empirical data.



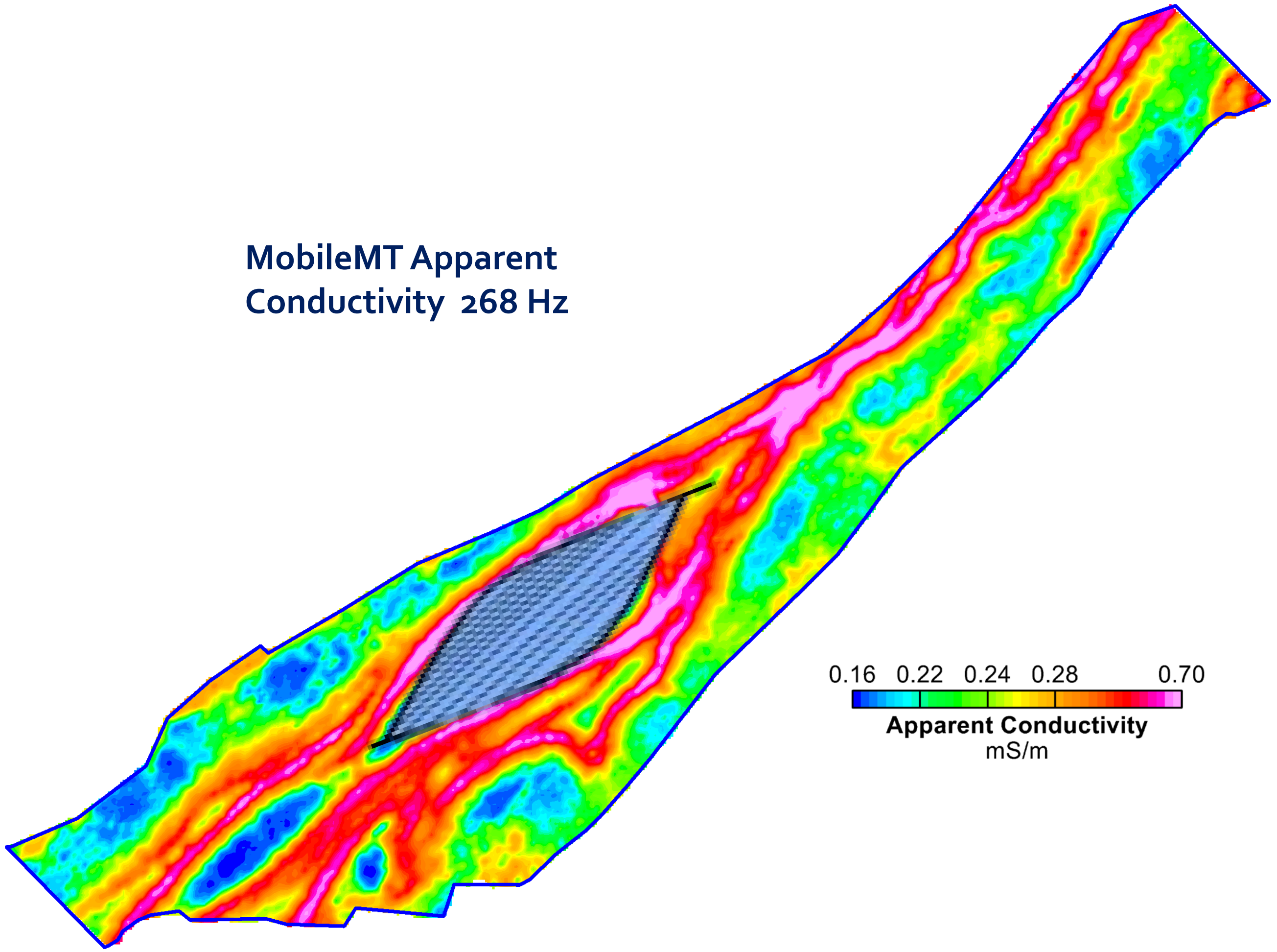


General structural position

This offset must have occurred after basin formation and due to brittle deformation (transition from ductile to brittle regime)

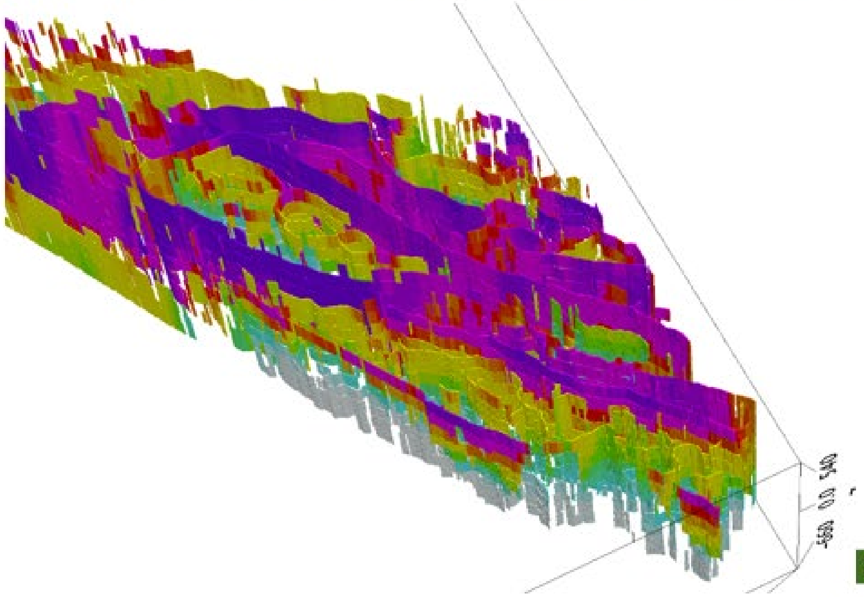
Evidence of Deformation

- Lozenge-shape is indicative of shear tectonic zone, tells us the structure in the region is intense
- This shape is observable in the apparent conductivity data from the MobileMT survey (*one large-scale example shown) and allows delineation of conductive features straddling this feature for further analysis

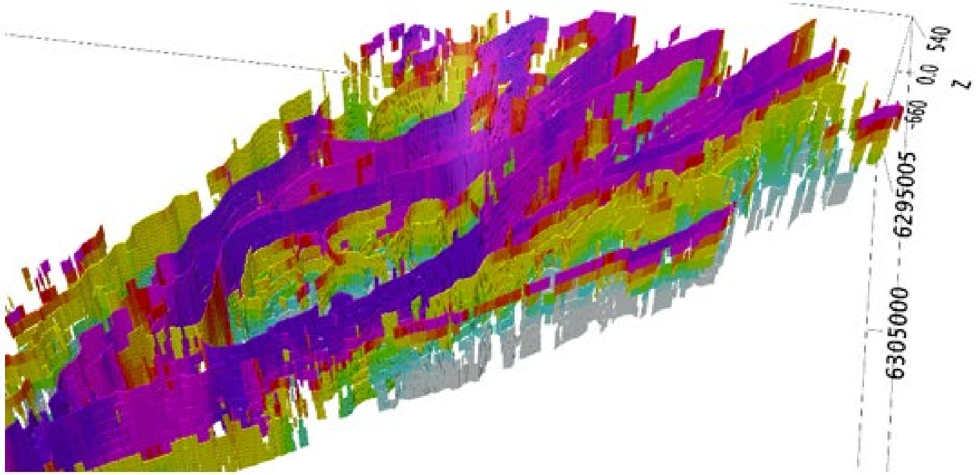


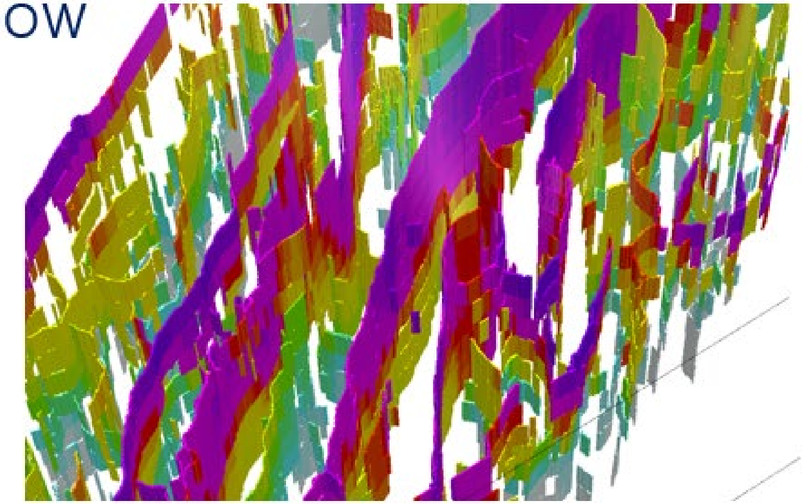
Low resistivity axes in 3D (1 km depth range)

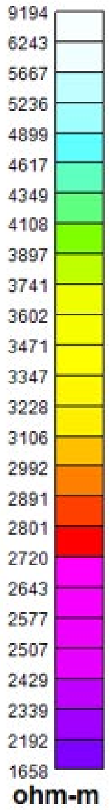
Proterozoic crystalline basement, Virgin River Shear Zone (Northern Saskatchewan)



BASELODE
ENERGY
SHADOW

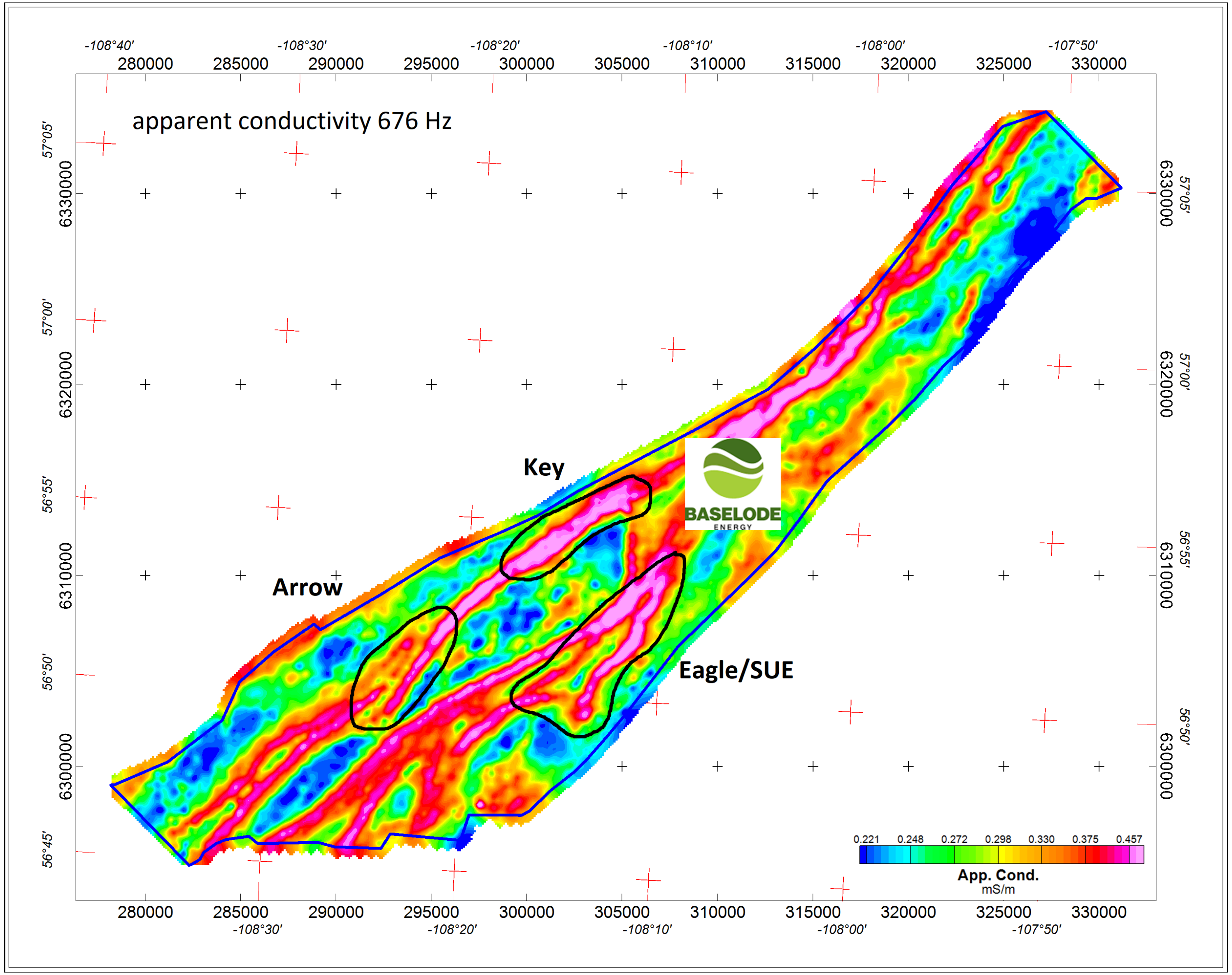


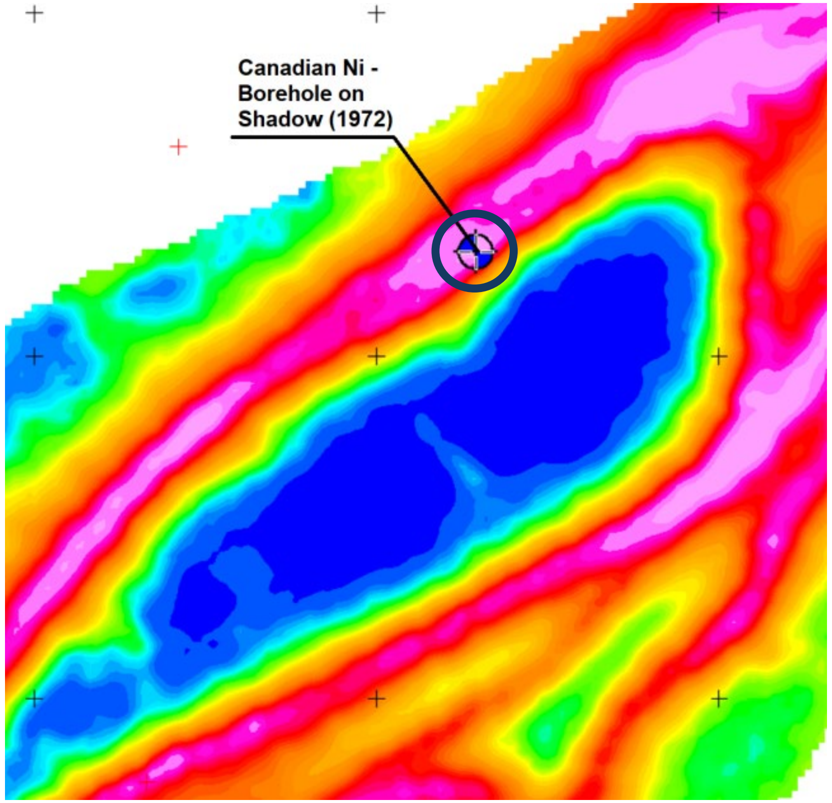




Results of Survey

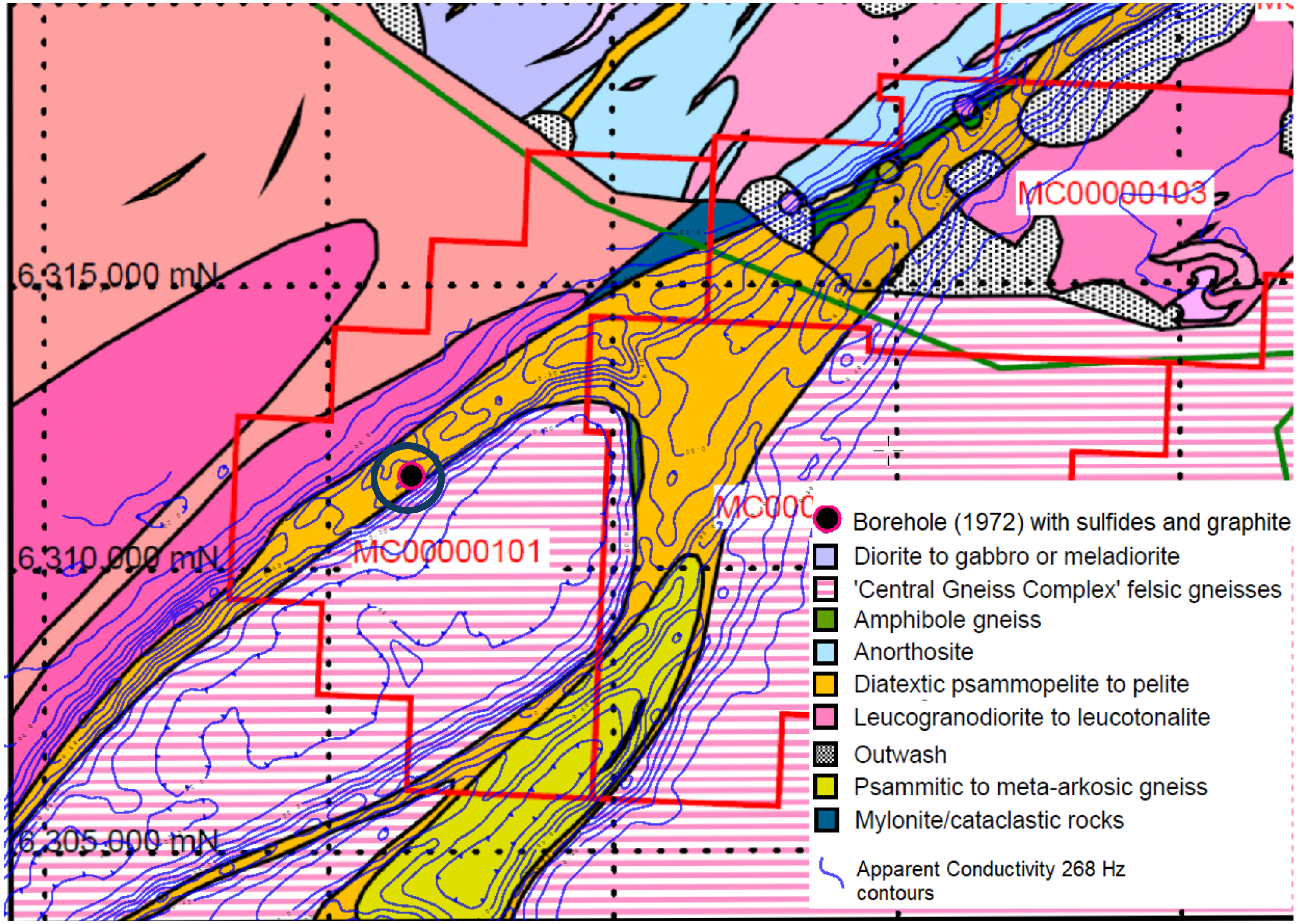
- 3 areas of interest identified by Baselode Energy based on various data products (Key, Arrow and Eagle/SUE similar targets)
- Coincide with lengths along linear, NE-SW trending conductors (along VRSZ)





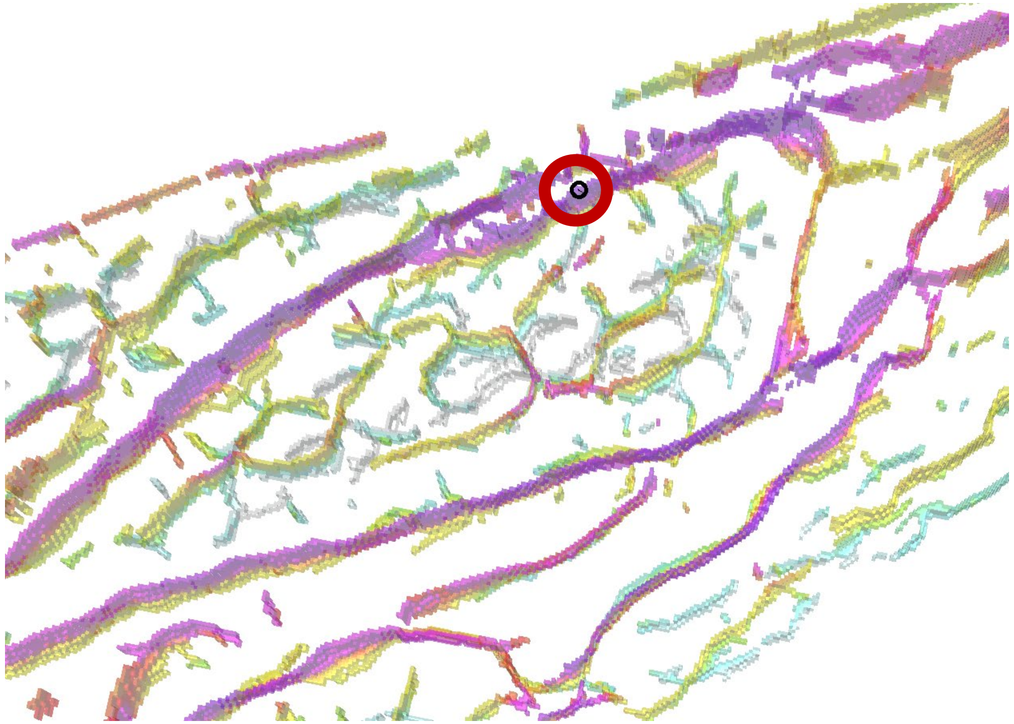
Conductive rocks

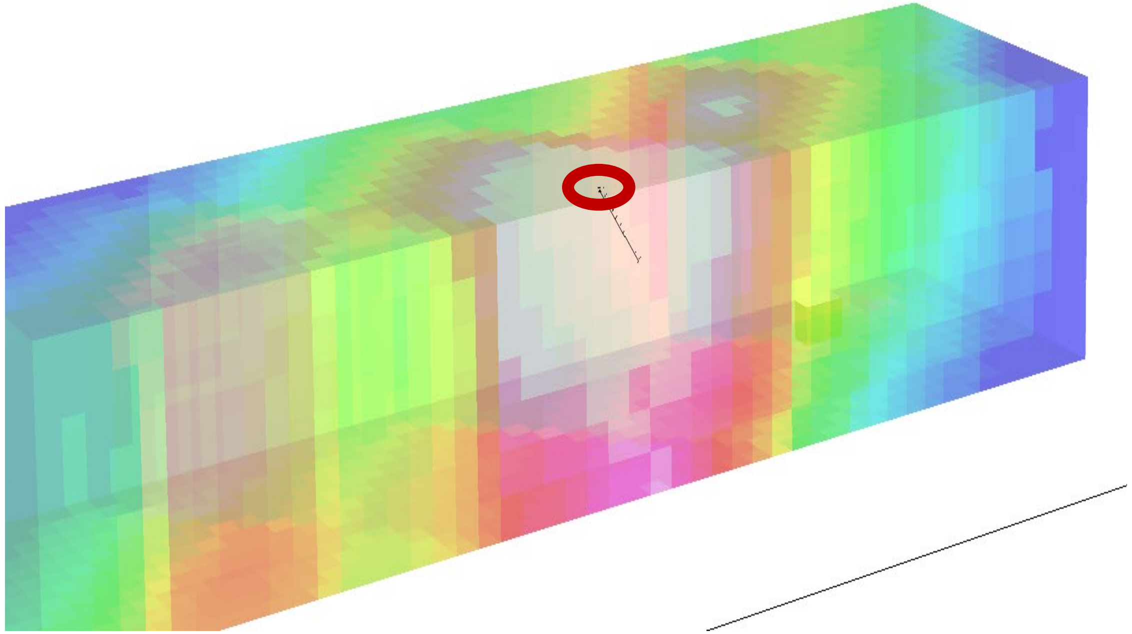
- Diatextic psammopelite to pelite
- Psammitic to meta-arkosic gneiss



Geology from "Eagle Plains Resources Ltd. Tarku Project. 2013 Exploration Program" by Dave Billard

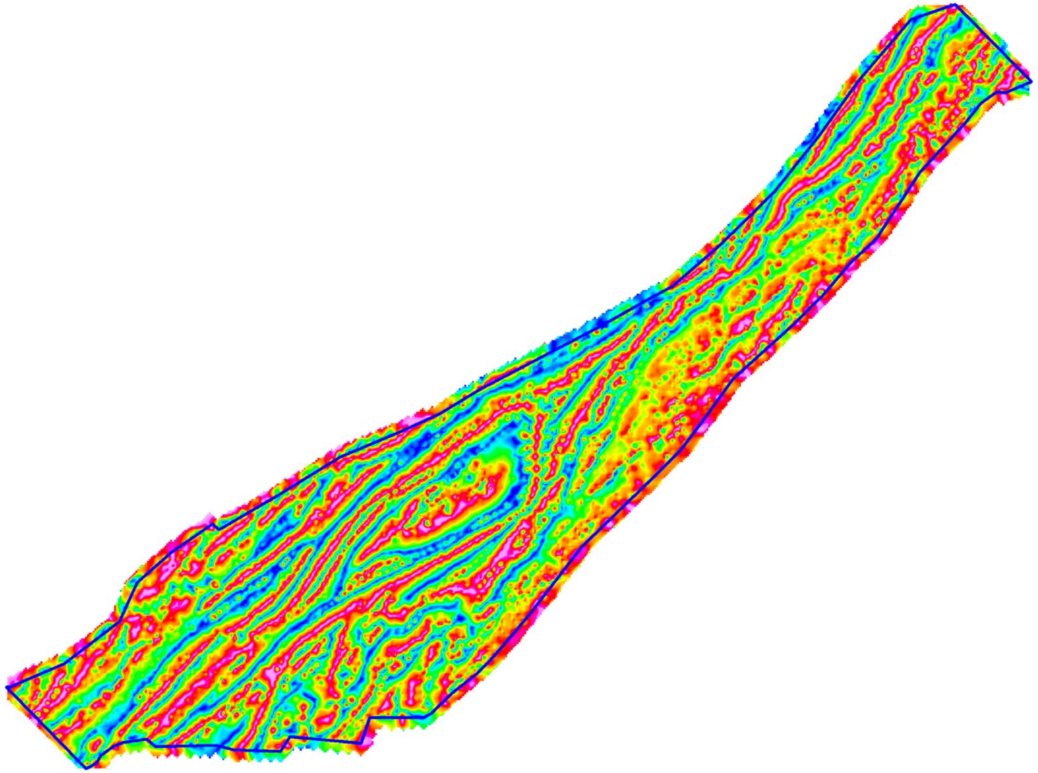
Canadian Nickel historical (1972) drillhole with sulphide and graphite mineralization over the MobileMT survey results



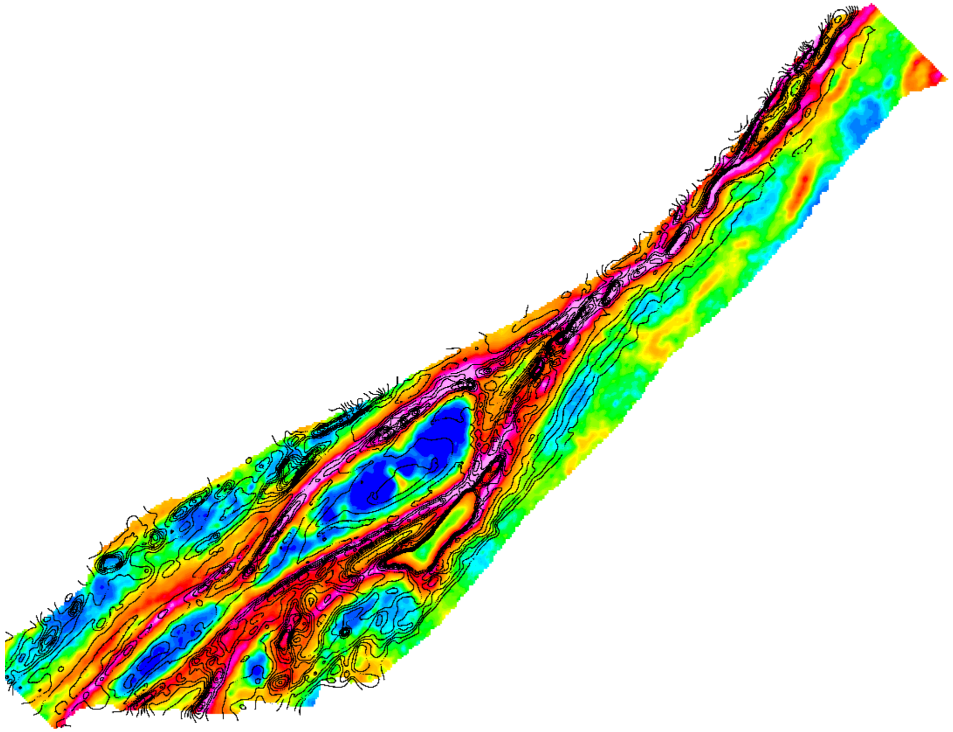


Comparing Magnetics and EM

- magnetic and conductive anomalies are correlated in general
- Magnetic trends identify fractures/faults – conduits for fluid flow
- Conductive anomalies, especially discrete, often form where fluids precipitate and mineralization occurs
- Together fluids + structure = necessary ingredients for uranium mineralization

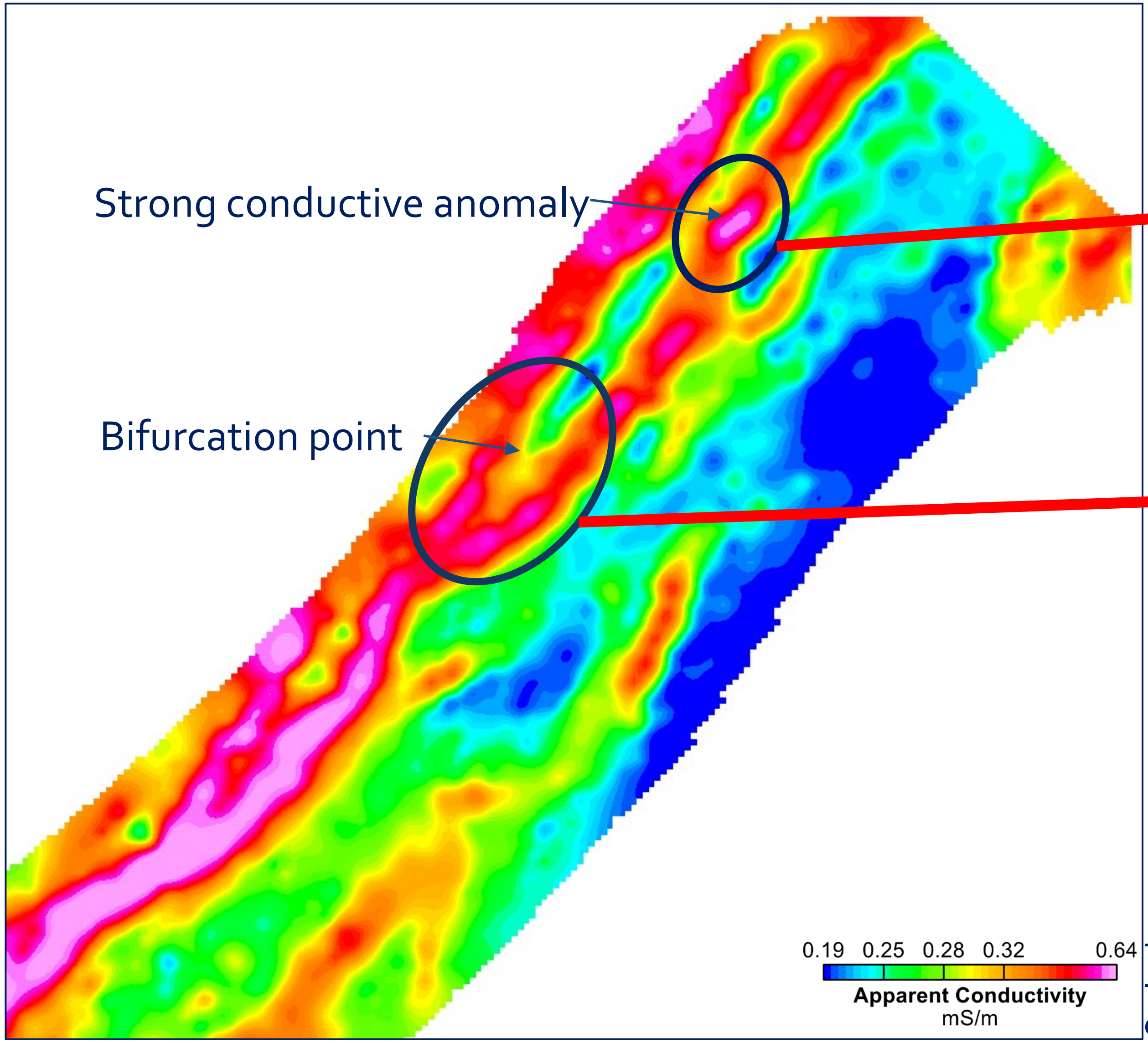


Magnetic Tilt Derivative

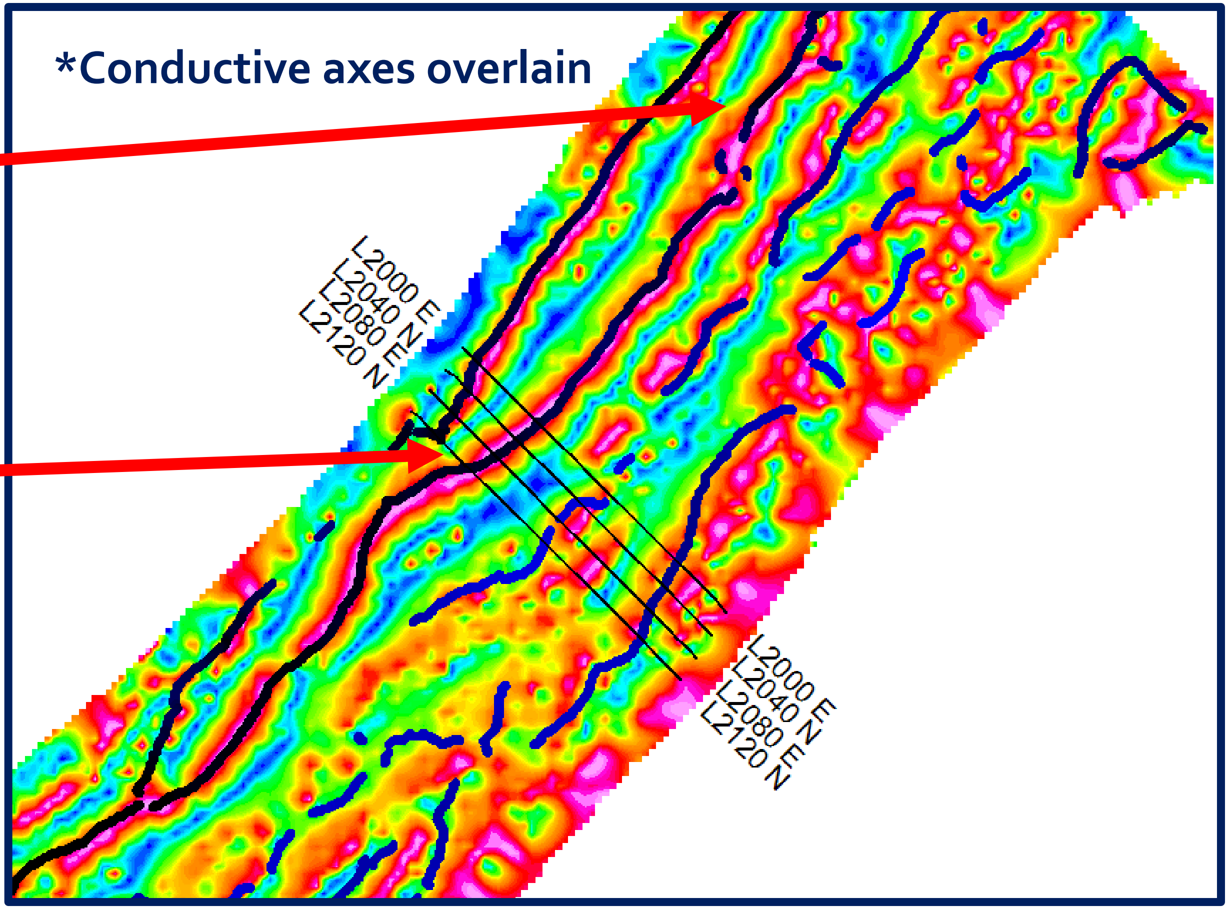


App Cond @ 268 Hz with Total Magnetic Intensity Contours Overlain

Apparent Conductivity at 676 Hz

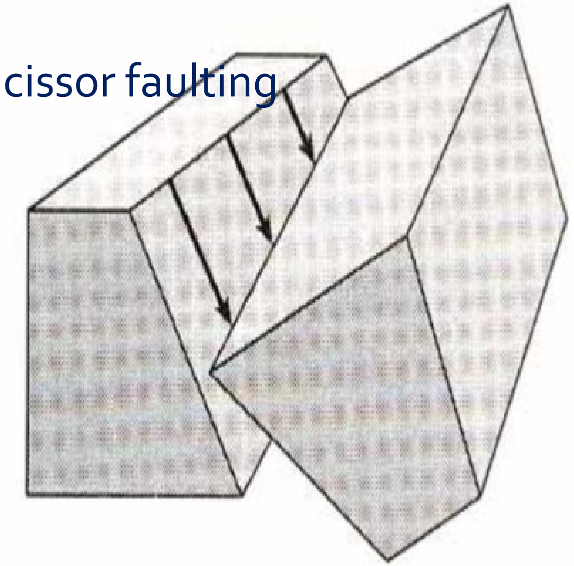


Magnetic Tilt Derivative

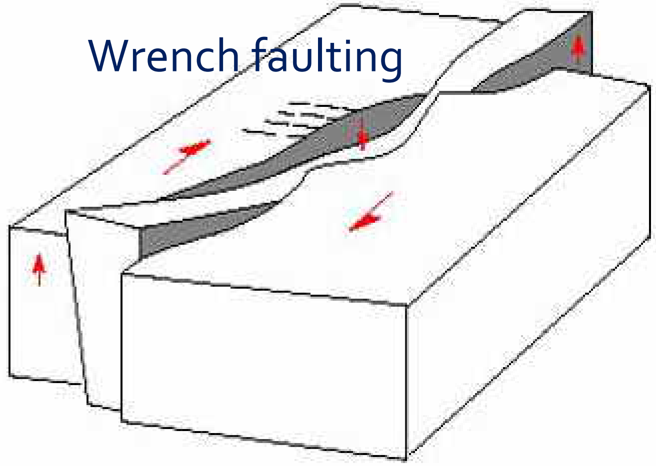


- Magnetic derivatives can be used to identify structures
- Break in smooth linear features can be indicative of fractures/breaks, which can coincide with areas that facilitate fluid migration and support mineralization

Scissor faulting

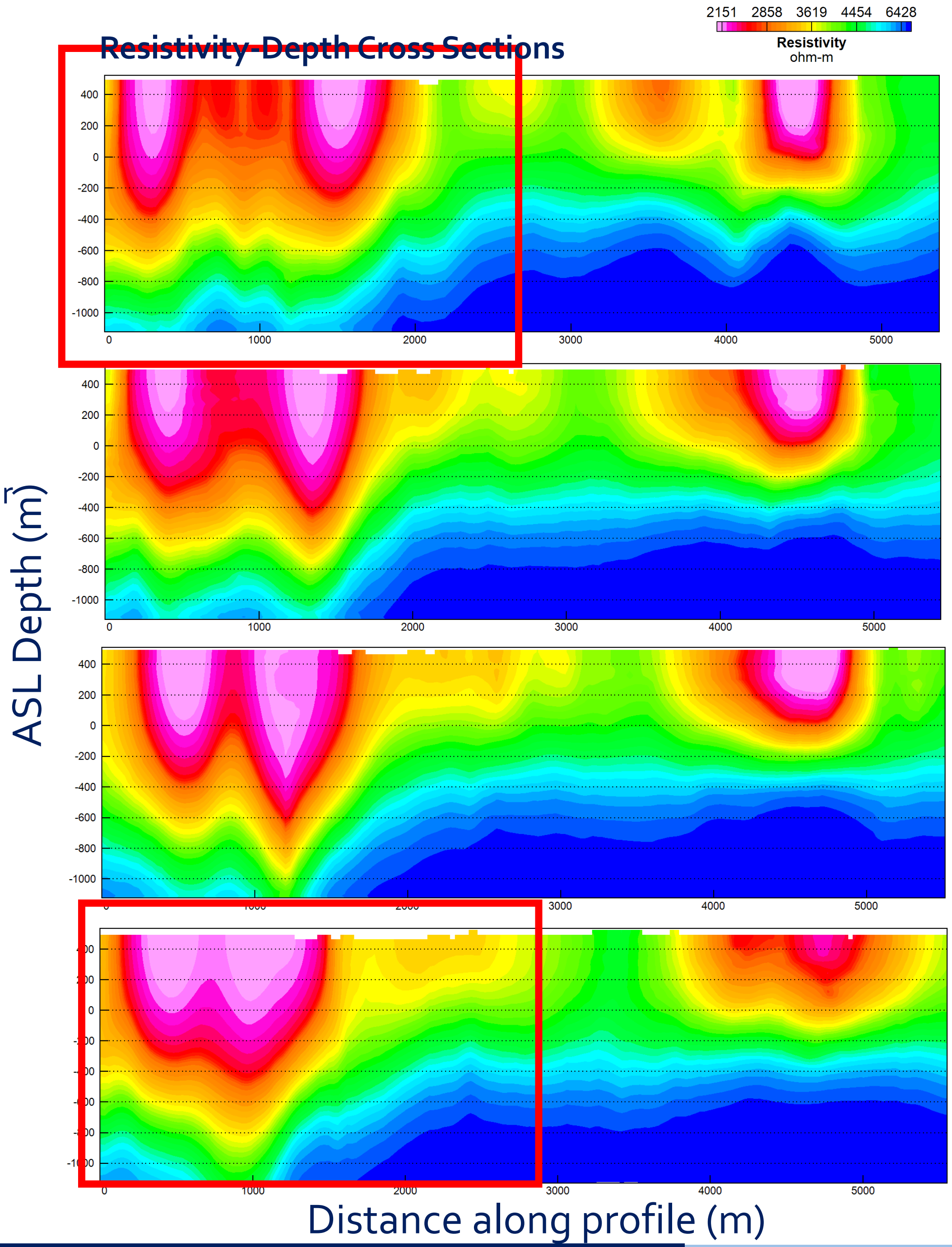


Wrench faulting

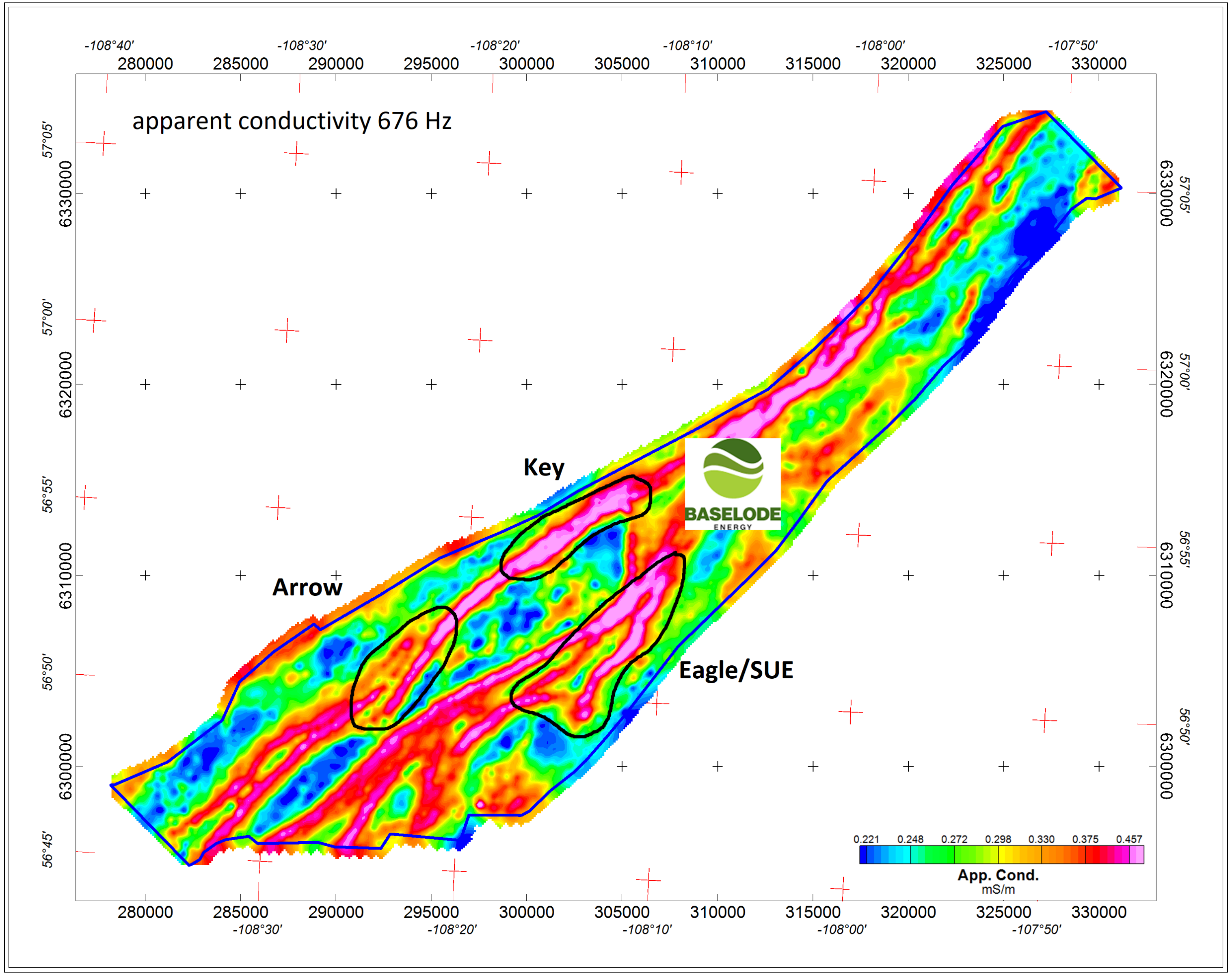


This block diagram of a wrench-fault zone shows that vertical movement is often very complex. Faults may appear to be normal or reverse along the fault zone, and fault reversals and scissoring are common; horizontal displacement is greater than these vertical complications.

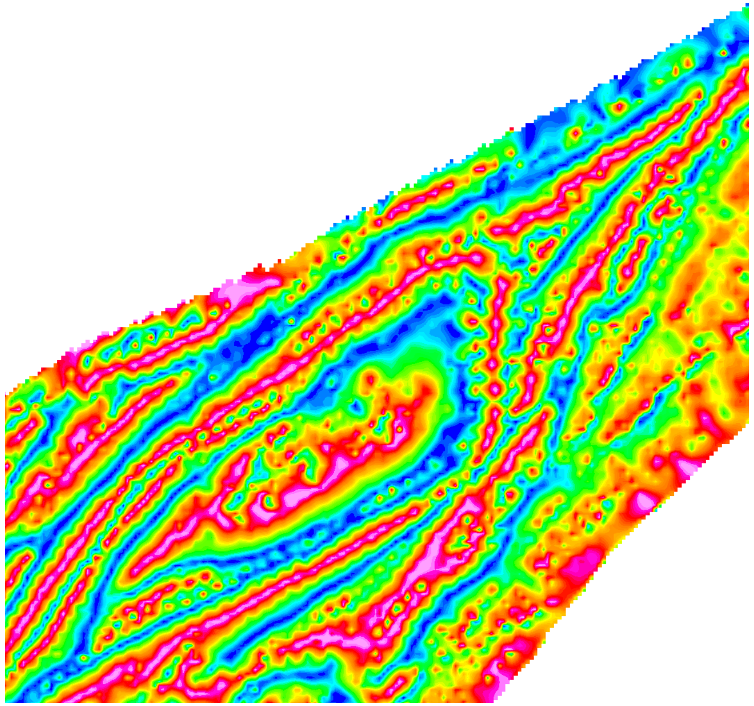
- Flower structures with pivot points (ideal places for fluids)
- Two broad conductors merge toward the south at the bifurcation point
- For northernmost line, the western conductor is deeper than the eastern conductor; this switches moving north to south, and where they merge, the right conductor penetrates deeper than the left
- This could be due to scissor faulting (flower structures with pivot points, fault ramps)



Key, Arrow, Eagle/SUE similar target areas



Deviations from “smooth”, “linear” features in the EM and magnetic data

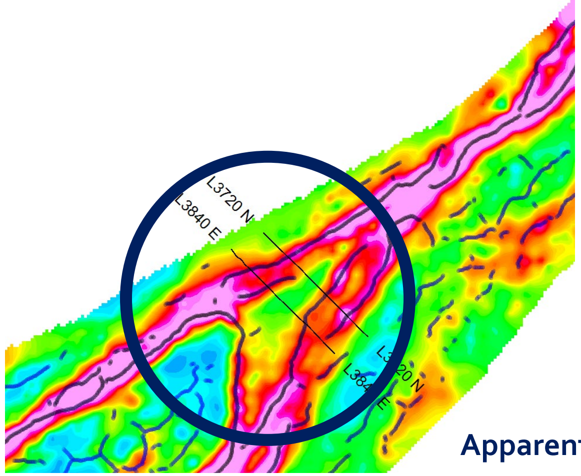


Magnetic tilt derivative

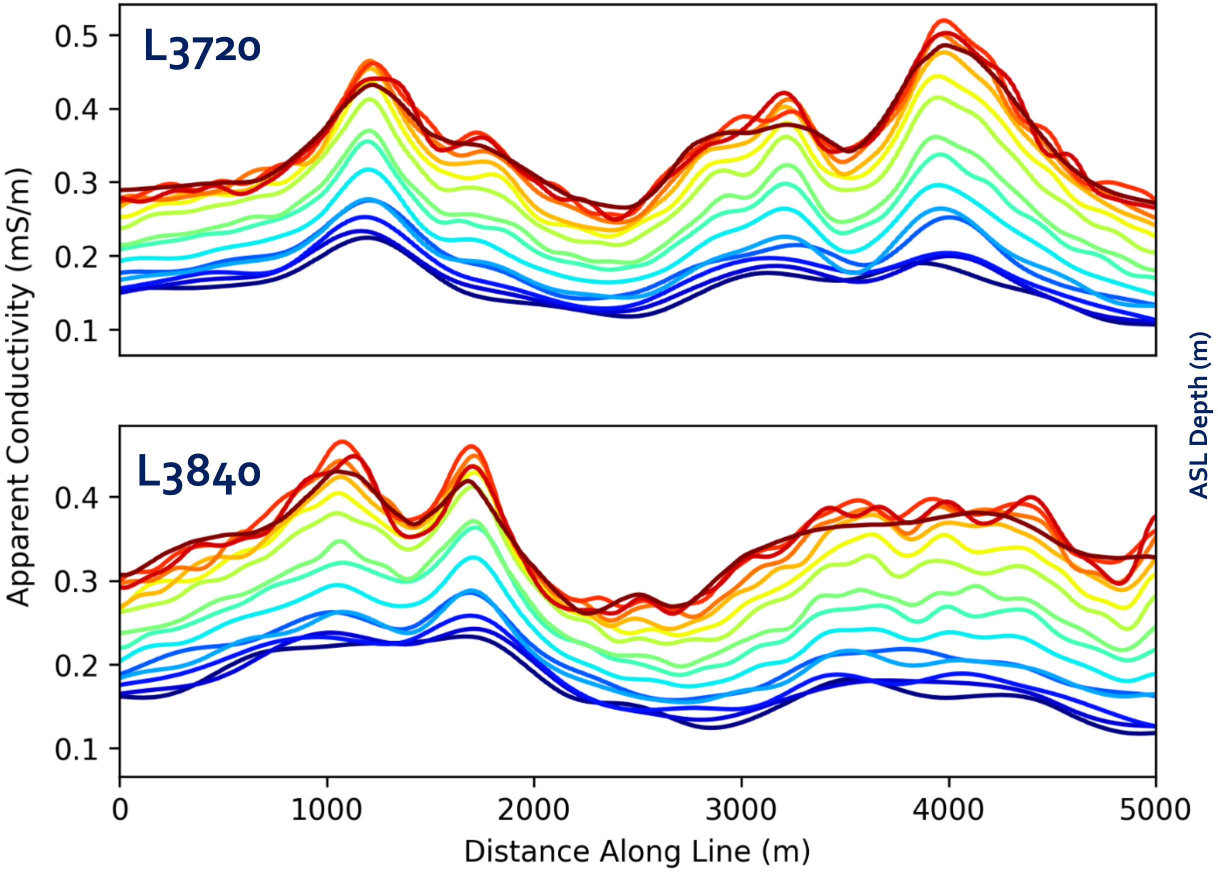
Key similar target

- Two separate conductive features
- Conductive feature on the west starts out as a single conductor in the north, and bifurcates at south (vice versa for eastern feature)

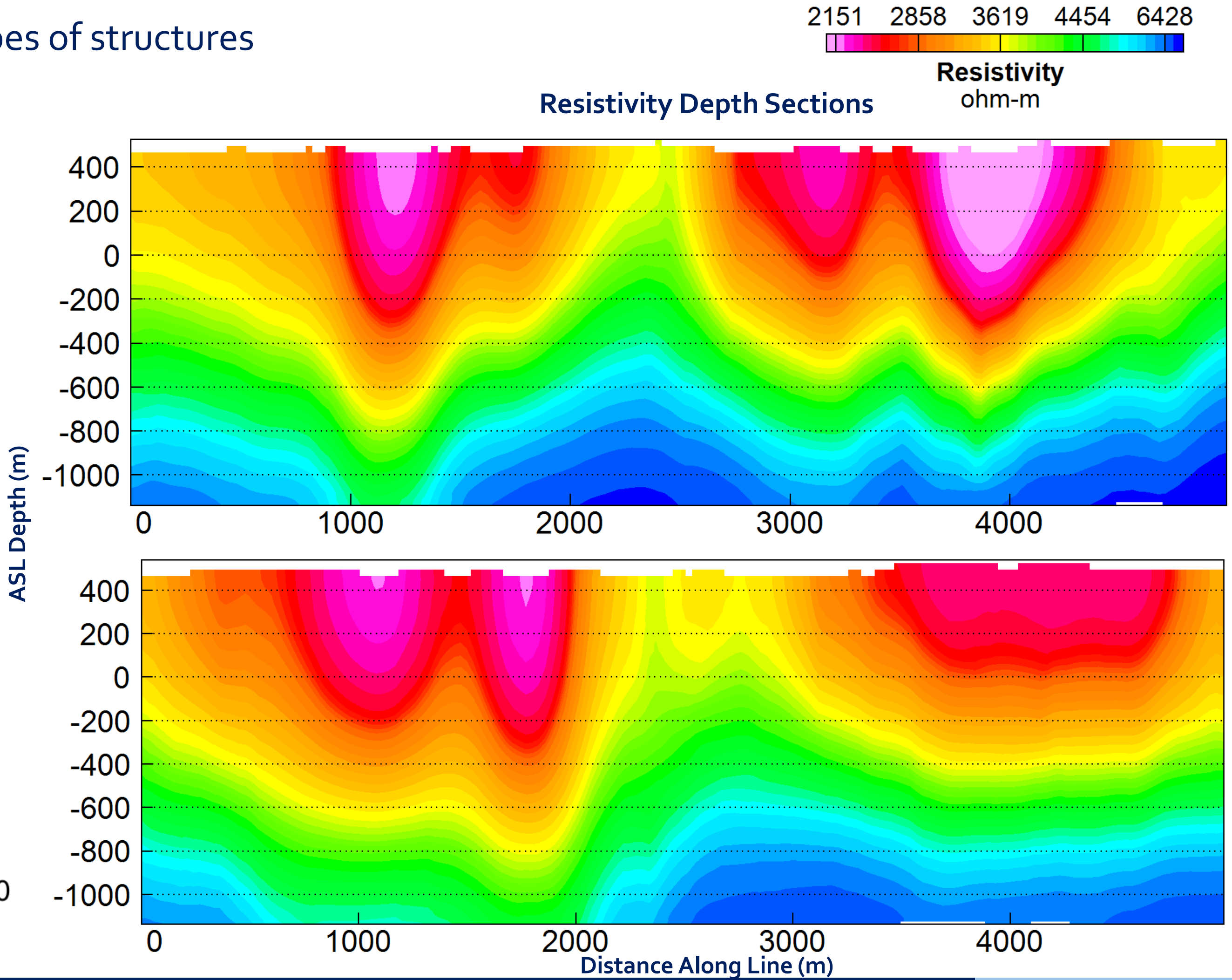
- Vertical displacement and horizontal shear
- We can see different types of structures



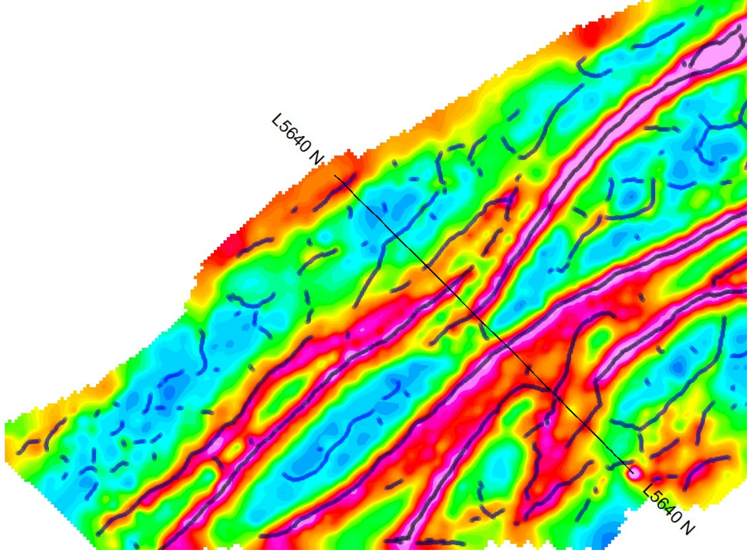
Apparent Conductivity Profiles



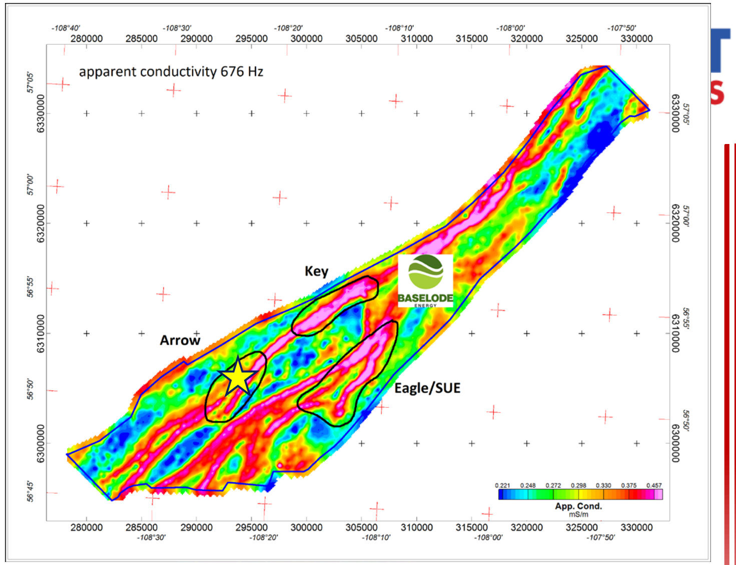
Resistivity Depth Sections

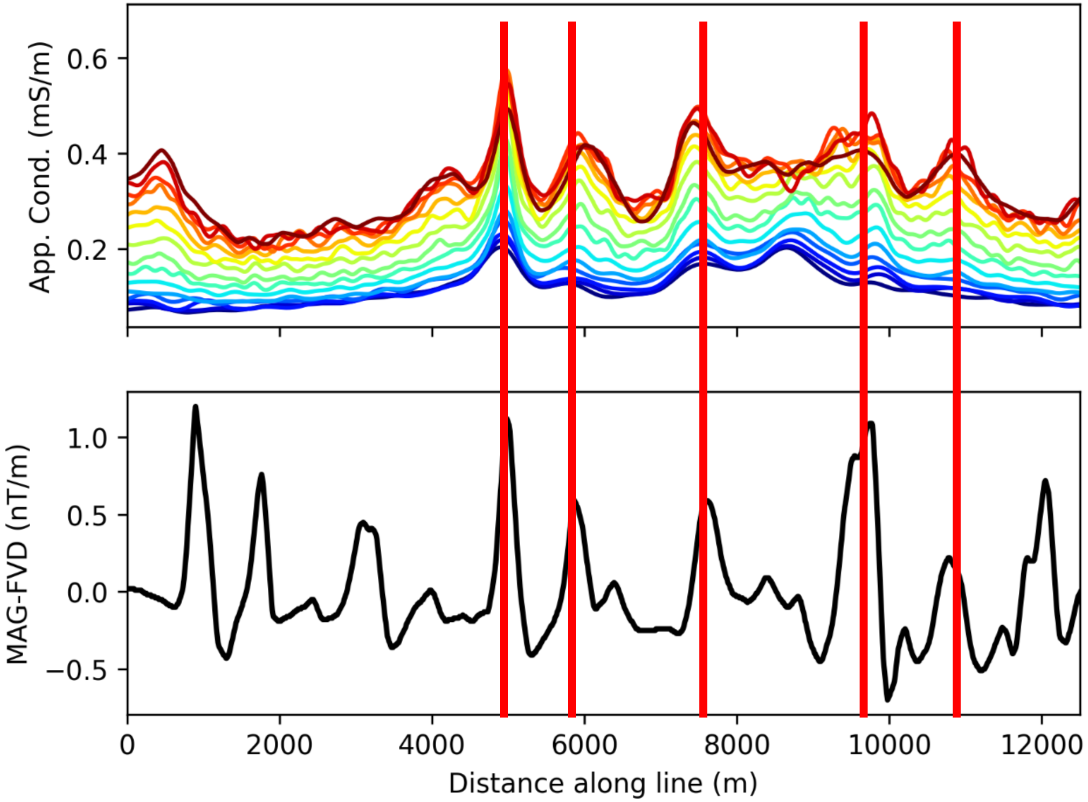


Arrow similar Target Area



Where conductive and magnetic anomalies coincide, good indicator of structure + fluids, which are both necessary for uranium mineralization





Vertical exaggeration = 3