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EXPERT GEOPHYSICS

Deep Structural Electromagnetic Imaging for Targeting Basement-Hosted and Unconformity-Related Mineralization

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Expert Geophysics Surveys Inc.

from innovations to discoveries

ABSTRACT

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Deep Structural Electromagnetic Imaging for Targeting Basement-Hosted and Unconformity-Related Mineralization

Detection and exploration of deep-rooted structural systems with specific mechanical and chemical traps are critical for targeting basement-hosted and unconformity-related uranium deposits. These deposits are often controlled by complex fault networks, shear zones, and fluid migration pathways that are challenging to delineate with conventional geophysical techniques. Geophysical EM methods, which are sensitive to electrical properties of the subsurface, can be used to produce resistivity-depth models, through inversion modelling of the acquired data. These inverted models can be used to image structures and zones of alteration as they often demonstrate resistivity contrasts when compared to their surrounding host rock. MobileMT, an airborne natural field EM system developed by Expert Geophysics Limited, is uniquely suited to map such geoelectrical complexities across a wide range of resistivities and depths.

The MobileMT system, which exploits magnetotelluric currents in the audio-frequency range (26 Hz to 21 kHz), currently offers the greatest depth of investigation among airborne electromagnetic systems. In addition, the MobileMT system is sensitive to resistivity contrasts in both the low- and high-resistivity ranges, including resistivities of thousands of ohm-m. Owing to its three-component total-field sensor, MobileMT is sensitive to geoelectrical boundaries in all directions, providing comprehensive detection of both horizontal and vertical conductivity contrasts. This capability enables not only the detection of metallic or graphitic conductors, but also the recognition of resistive features that may represent structural or lithological domains acting as fluid migration channels or chemical traps.

Post-processing of MobileMT data involves the generation of inverted resistivity-depth data that can be visualized as 2D sections along each line, or a 3D volume spanning the surveyed area. Special computational workflows support trend analysis at multiple depth levels to model the cores/axes of structures - conductive and/or resistive. Concatenation of these structural axes extracted from different depths yields a unique volumetric perspective of the subsurface, from the near-surface environment down to depths exceeding 1 km. Such detailed structural mapping allows the identification of continuous geoelectrical axes and potential targets for follow-up diamond drilling.

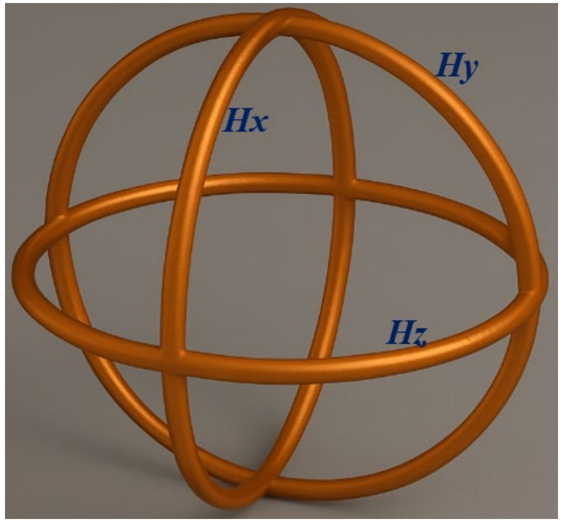
Field examples demonstrate that the 3D rendition of geoelectrical axes can be used to interpret large-scale tectonic shear zones where they are characterized by zones of lower resistivity, fault-related architectures, and tectonic lozenges inferred to host elevated porosity and permeability. These features are interpreted as possible paleofluid conduits and zones of chemical reactivity, directly relevant for uranium mineralization. The ability to recognize these 3D structural patterns, demonstrated by MobileMT surveys over the Athabasca and Angikuni basins, provides a framework for targeting exploration drilling. In this context, MobileMT extends structural mapping from shallow cover to basement depths, as well as enhances the resolution of prospective corridors, offering exceptional opportunities for discovery in complex uranium-bearing terrains.

Presentation outline

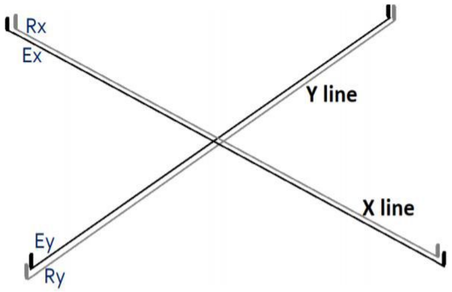
- Introduction to airborne MobileMT technology
- Technical solutions and advantages
- Structural modelling from MobileMT data
- Field examples with drilling confirmations

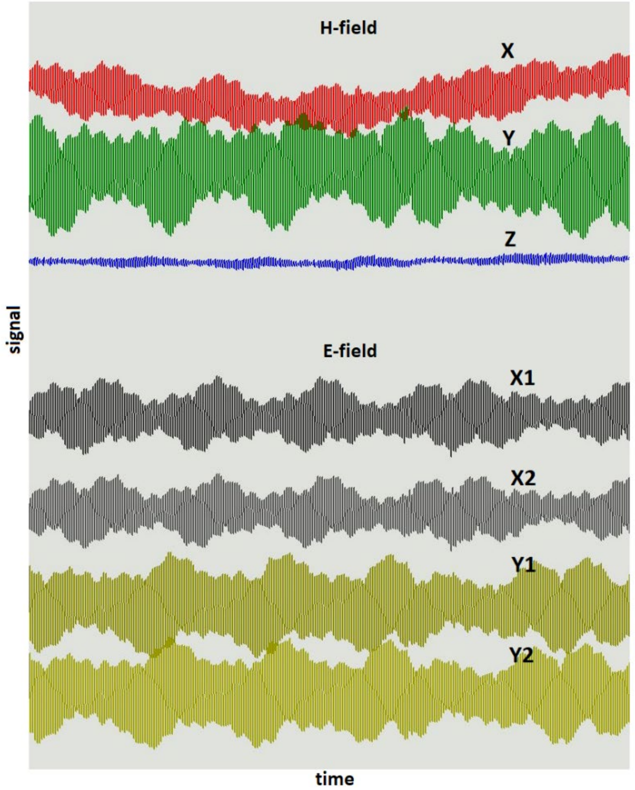
MobileMT configuration

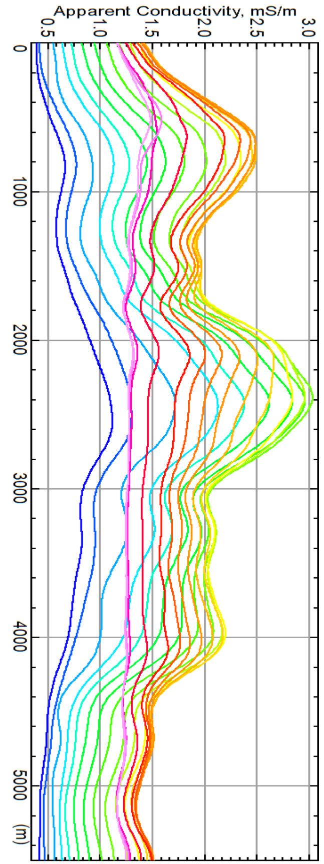
Three-component *H* receiver



E receiver – base station





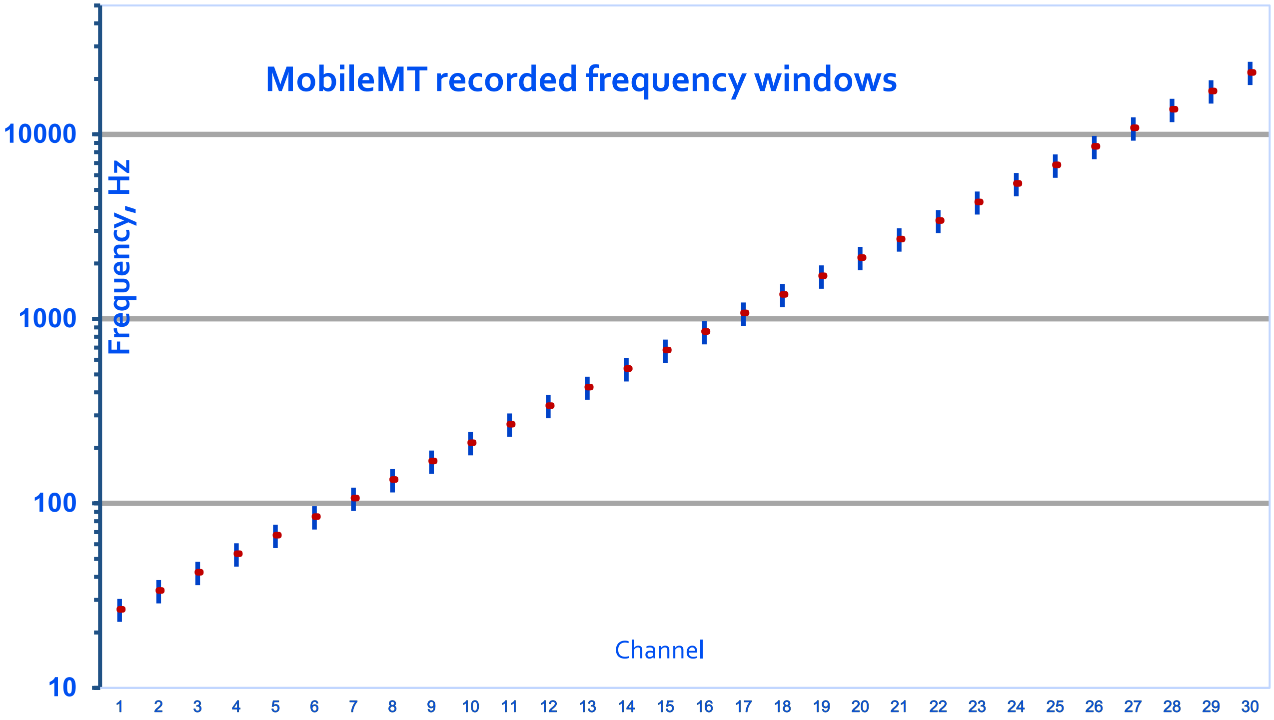


MobileMT relates the 3-component magnetic-variation vector in the air, $\mathbf{H}(f) = [Hx, Hy, Hz]^T$, to the 2-component electric-field vector at the remote base, $\mathbf{E}(f) = [Ex, Ey]^T$, via transfer tensors $\mathbf{T}(f)$:

$\mathbf{H} = \mathbf{T}\,\mathbf{E} = [\ \mathbf{T}_1\ \mathbf{T}_2\ ]\ \mathbf{E}$ (with column vectors $\mathbf{T}_1$, $\mathbf{T}_2$)

Frequency windows

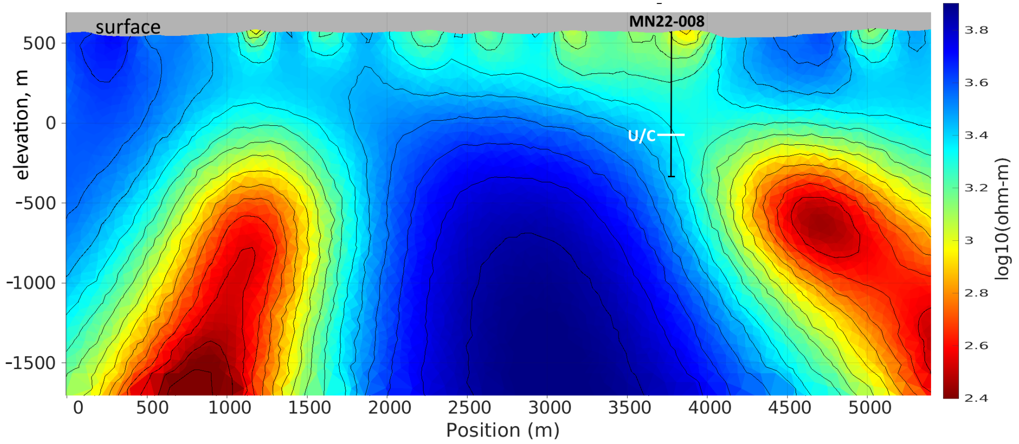
Heli MobileMT 26-21,000 Hz
Drone MobileMT 14-13,000 Hz



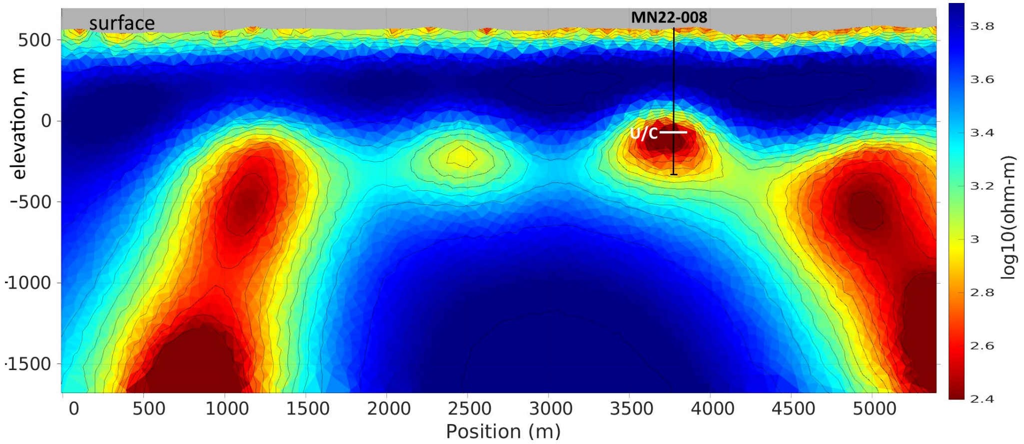
High in-depth resolution;
Recovering deep and shallow geology;
Selecting frequencies with the best natural signal;
Elimination of industrial frequency noise.

Mann Lake Project
southeastern Athabasca Basin

Inversion 12 frequencies (26-338 Hz)



Inversion 15 frequencies (26-338 Hz + 5300-8600 Hz)

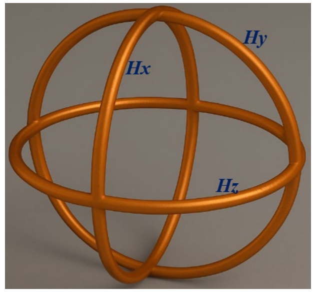


Confirmed with the post-survey DH - graphite, pyrite, and chalcopyrite mineralization near the unconformity

Total filed

MobileMT H receiver measures the component of $\partial \mathbf{B}/\partial t$ along its three axes.

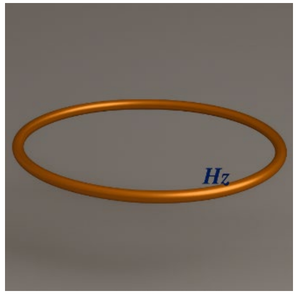
the **total field** response is rotationally invariant and sensitive to any direction of a boundary or an anomaly source.



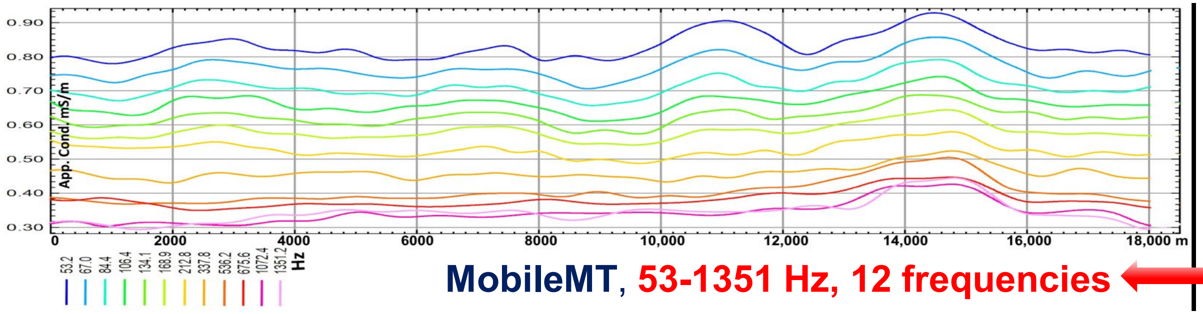
Tipper

A vertical-only channel

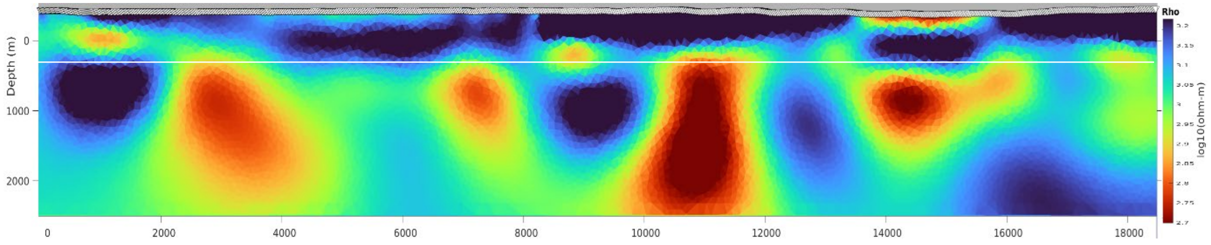
There is no signal when the receiver is positioned symmetrically above the source or boundary.

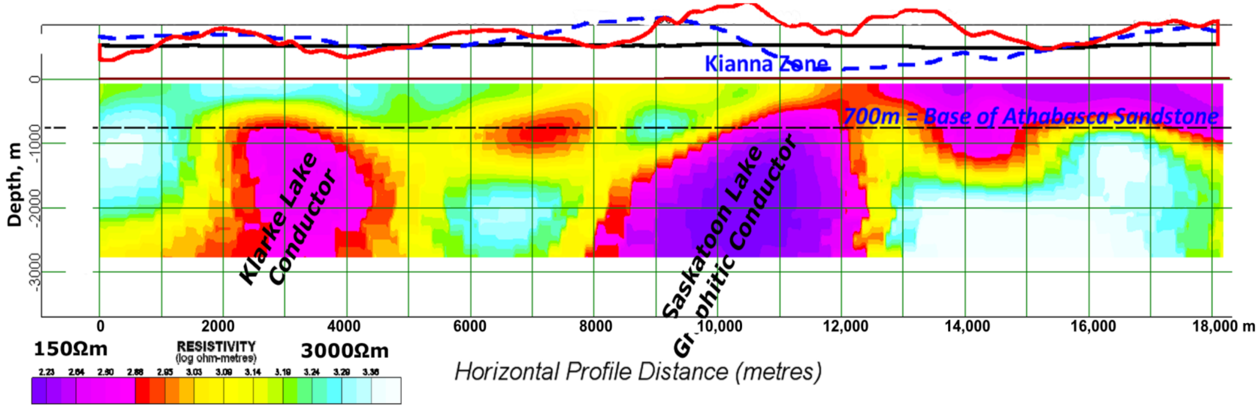


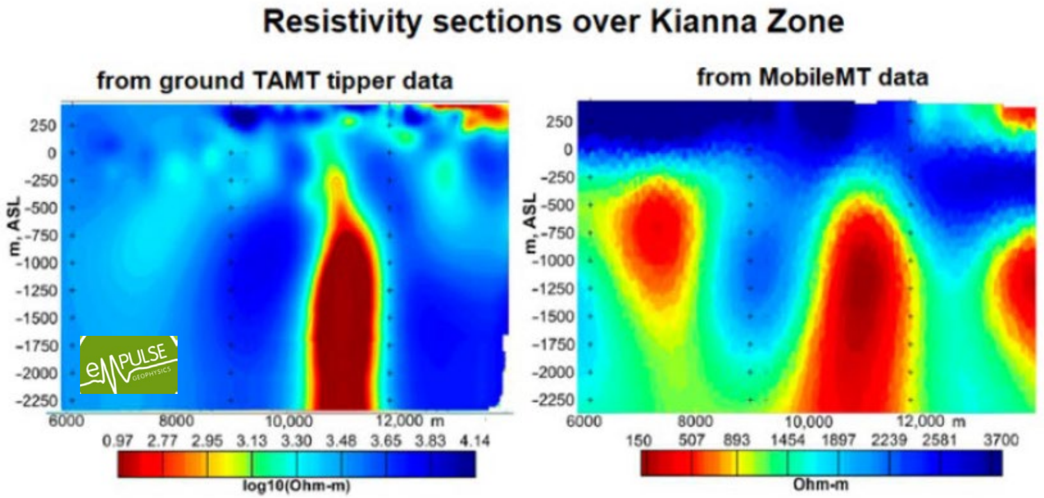
Shea Creek, Athabasca Basin

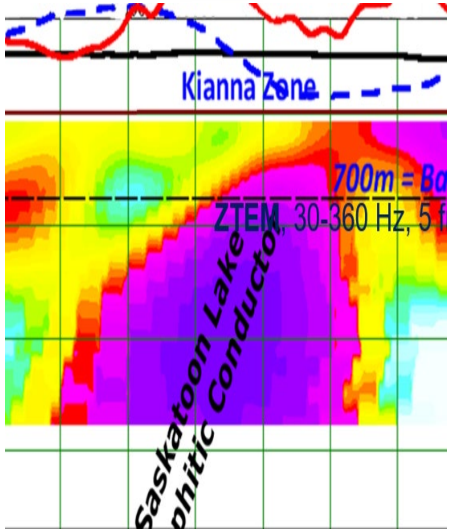


MobileMT, **53-1351 Hz, 12 frequencies** ⟷ **ZTEM**, **30-360 Hz, 5 frequencies**





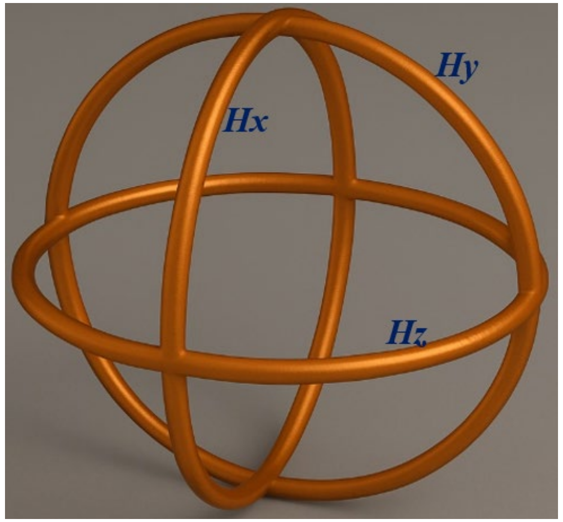




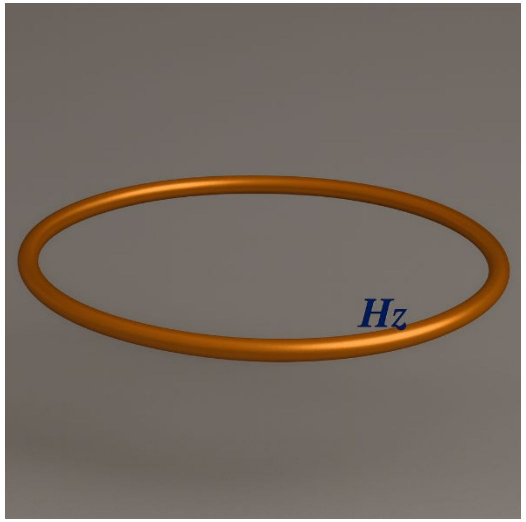
From ZTEM data

Both tipper data (ground TAMT and airborne ZTEM) do not recover the horizontal unconformity contact

Total field sensor (MobileMT)



Tipper sensor (ZTEM)



The total field sensor is sensitive to more inhomogeneities than tipper data and provides information with more details

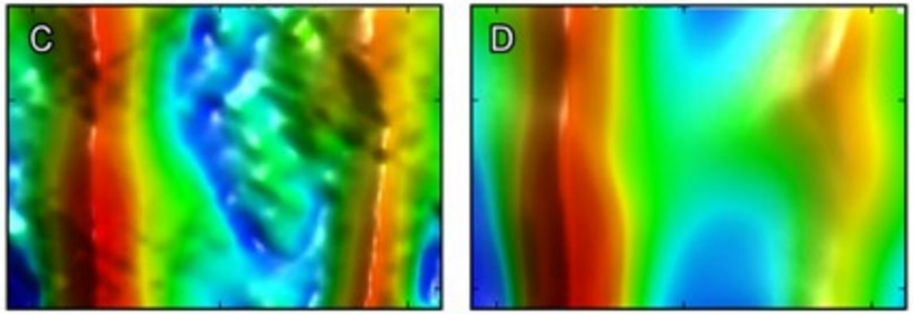
A comparison between airborne EM responses along the Virgin River Shear Zone: The Difference Depth Makes

Francis Moul, Condor North Consulting; Daniel Sattel, EM Solutions LLC*

Open House, 2023

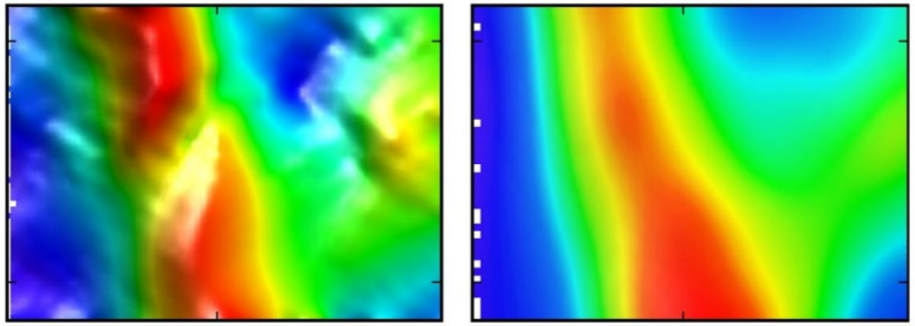
Basement Depth ~ 50 m

MobileMT 676 Hz AppCon | ZTEM 720 Hz AppCon



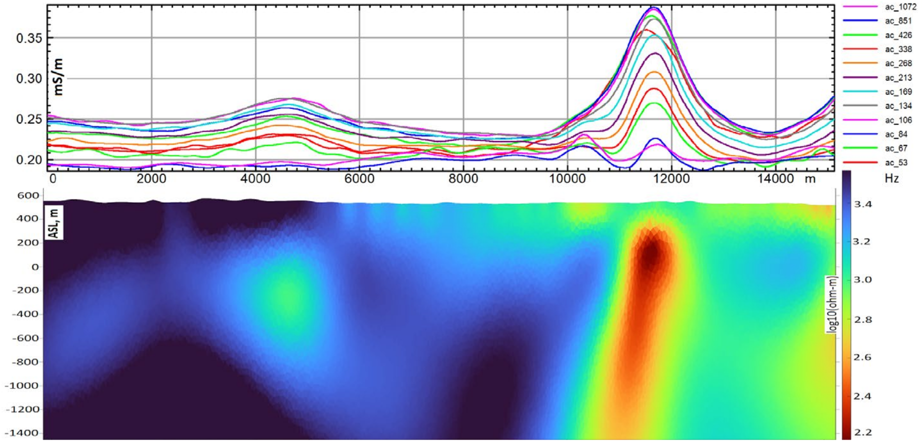
Basement Depth ~ 600 m

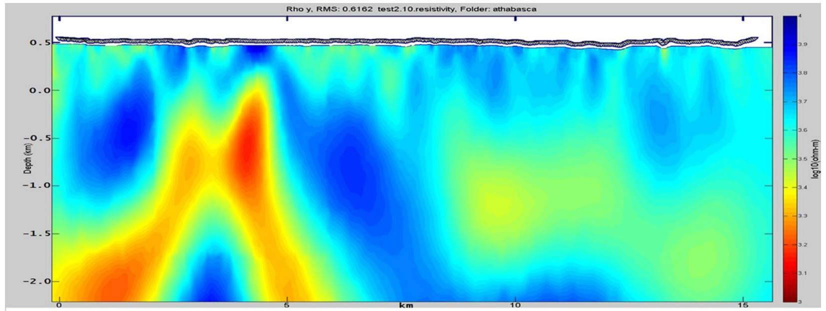
MobileMT 336 Hz AppCon | ZTEM 360 Hz AppCon



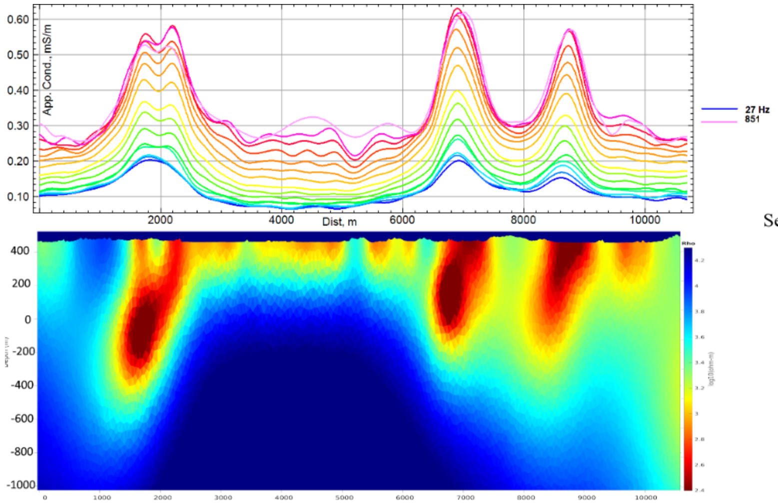
MobileMT resistivity sections examples

South of Athabasca Basin

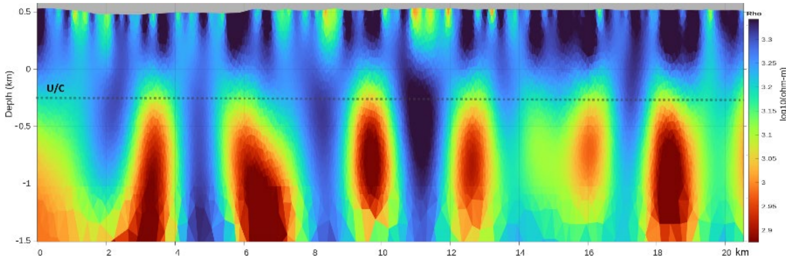


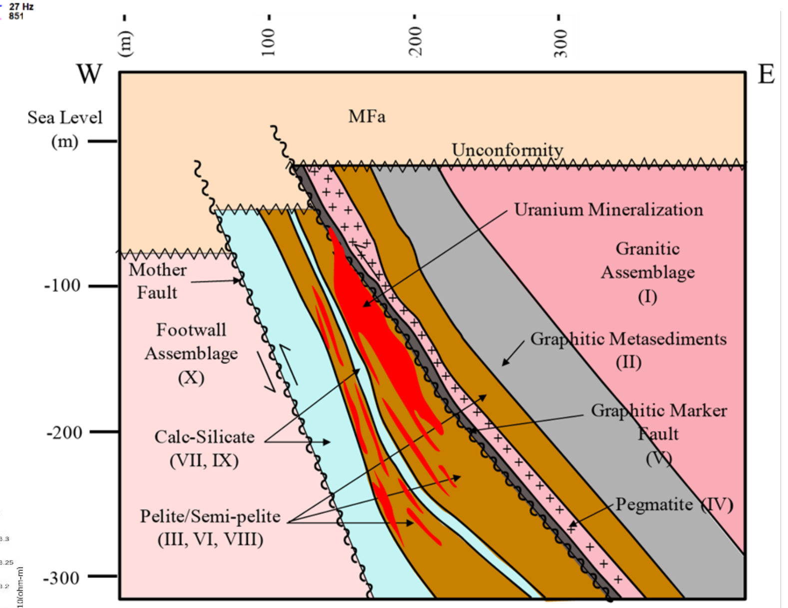


Virgin River Shear Zone



Western Athabasca Basin





Generalized west-east cross-section through the basement-hosted Millennium Deposit, Athabasca Basin, Saskatchewan, Canada. Roy et al., 2005

These are examples of MobileMT resistivity sections over different regions of the Athabasca Basin. Not only are solo and discrete conductive structures observed over the Athabasca Basin, but there are complex conductive structures, including branching, joints, dipping, and continuing into overlying sandstones as alteration zones. Recovered electromagnetic thicknesses of the structures, in the inverted images, appear much wider than the actual geological units due to:

- multiple conductive strands
- strong surrounding alteration
- structural thickening
- highly anisotropic conductivity along graphitic foliation, and
- the ambiguity of inversion approximations during unconstrained inversions.

Structural modelling concept of MobileMT data

Apparent conductivity or inverted resistivity grid

ACF along grid rows with the setting of correlation radius and adaptive window filter size; compute weighting coefficients

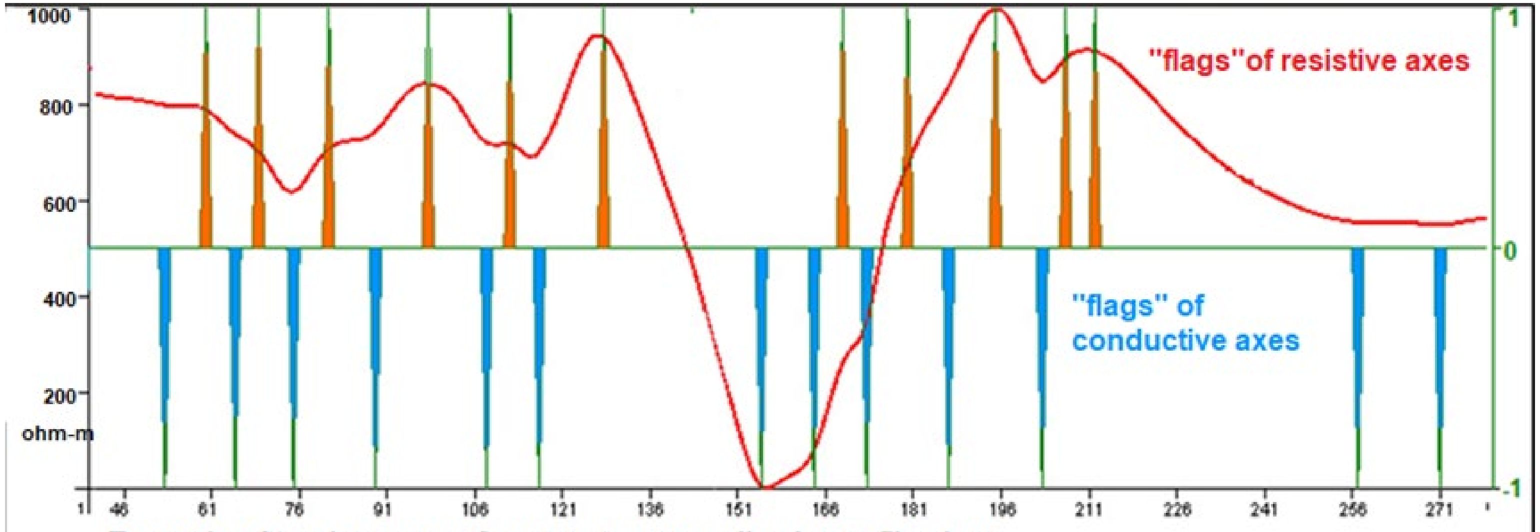
Convolution of the initial field with the filter coefficients

Shift window by 1 node along row / survey line

Repeating procedures for the next frequency/depth level

Assigning apparent conductivity or inverted resistivity to the defined “flags” of anomalies

Combining the results into a database, gridding and creation of 3D voxels

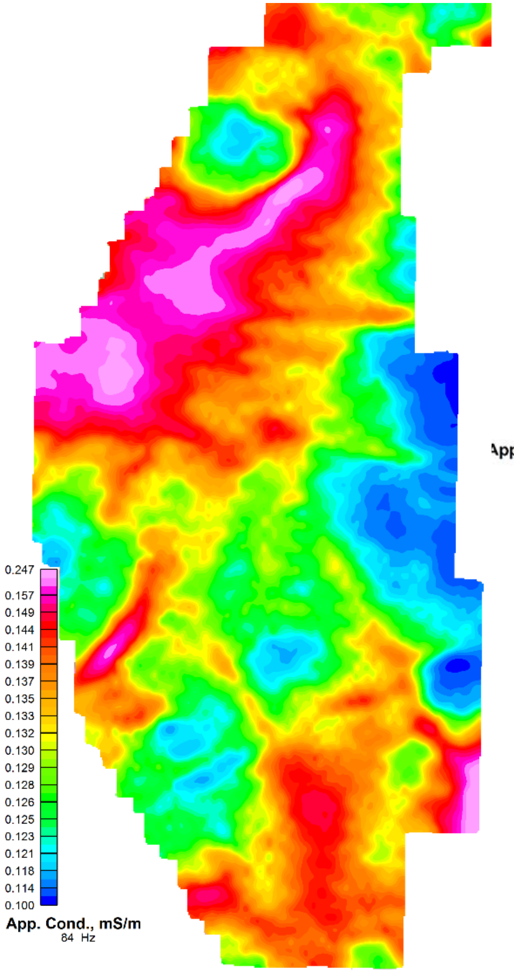


Example of tracing axes of resistivity anomalies in profile view

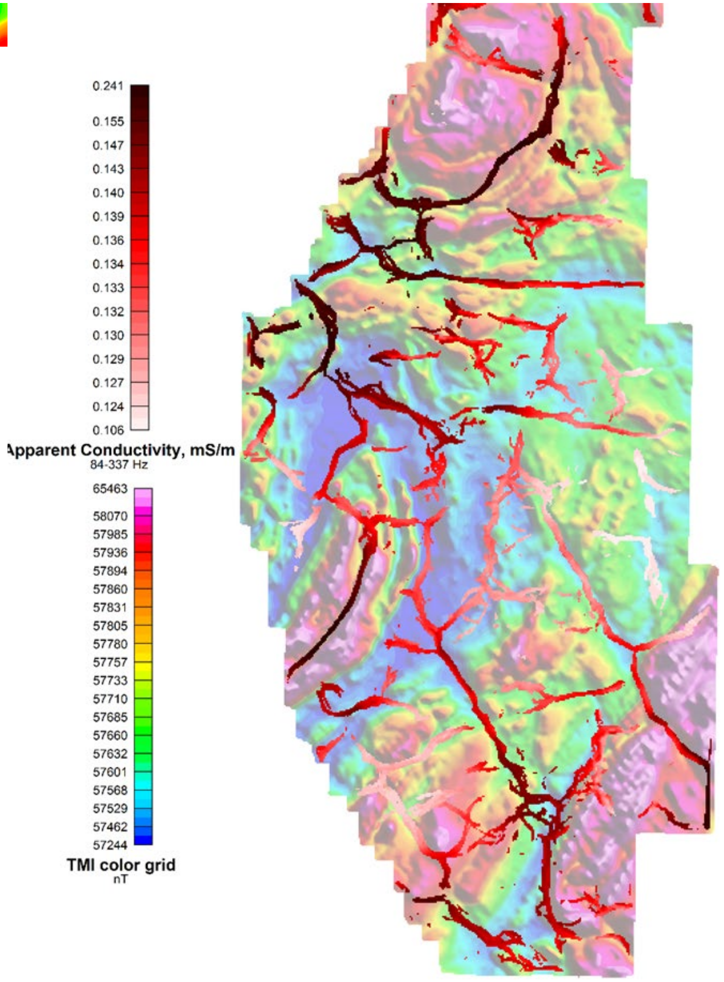
For precise mapping and modelling of cores of subvertical structures, and delineating complex structural zones, we extract correlated anomaly axes, reducing the ambiguity of inversion approximations and focusing interpretation on the most probable geological centers and structural controls, thereby enabling more focused and cost-effective exploration. The conductive (and resistive, if needed) anomaly axes are traced based on the algorithm of adaptive energy filtering, which allows for optimal estimation of the parameters of informative and correlated signals with various spectral-correlation characteristics.

Outputs of structural modelling of MobileMT data

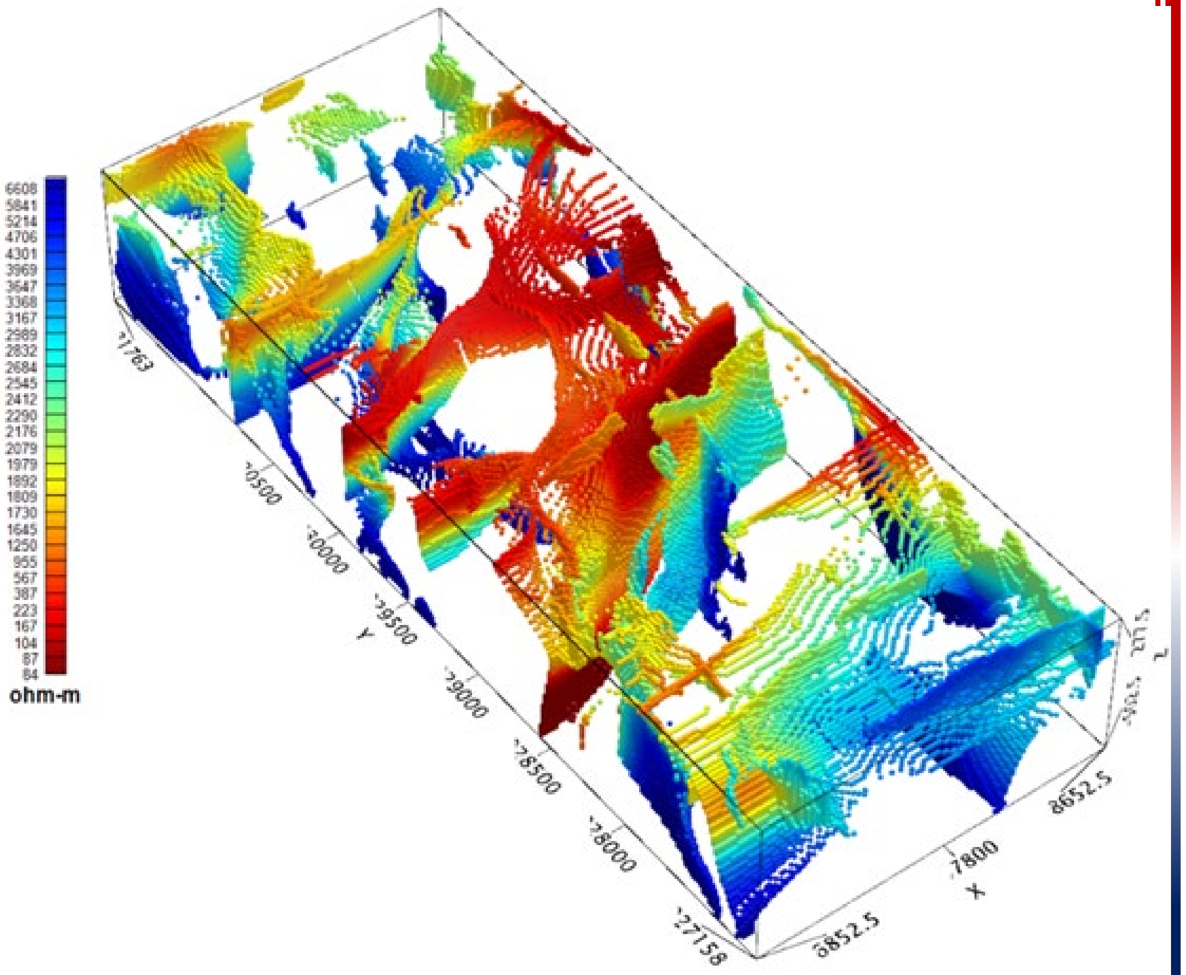
Southern border of Athabasca Basin



Original apparent conductivity map, 84 Hz



Apparent conductivity conductive trends 84-337 Hz range of frequencies over magnetic field color grid



Modelling of conductive structures from the inverted (resistivity-depth) MobileMT data in 3D view. The depth range is >1 km

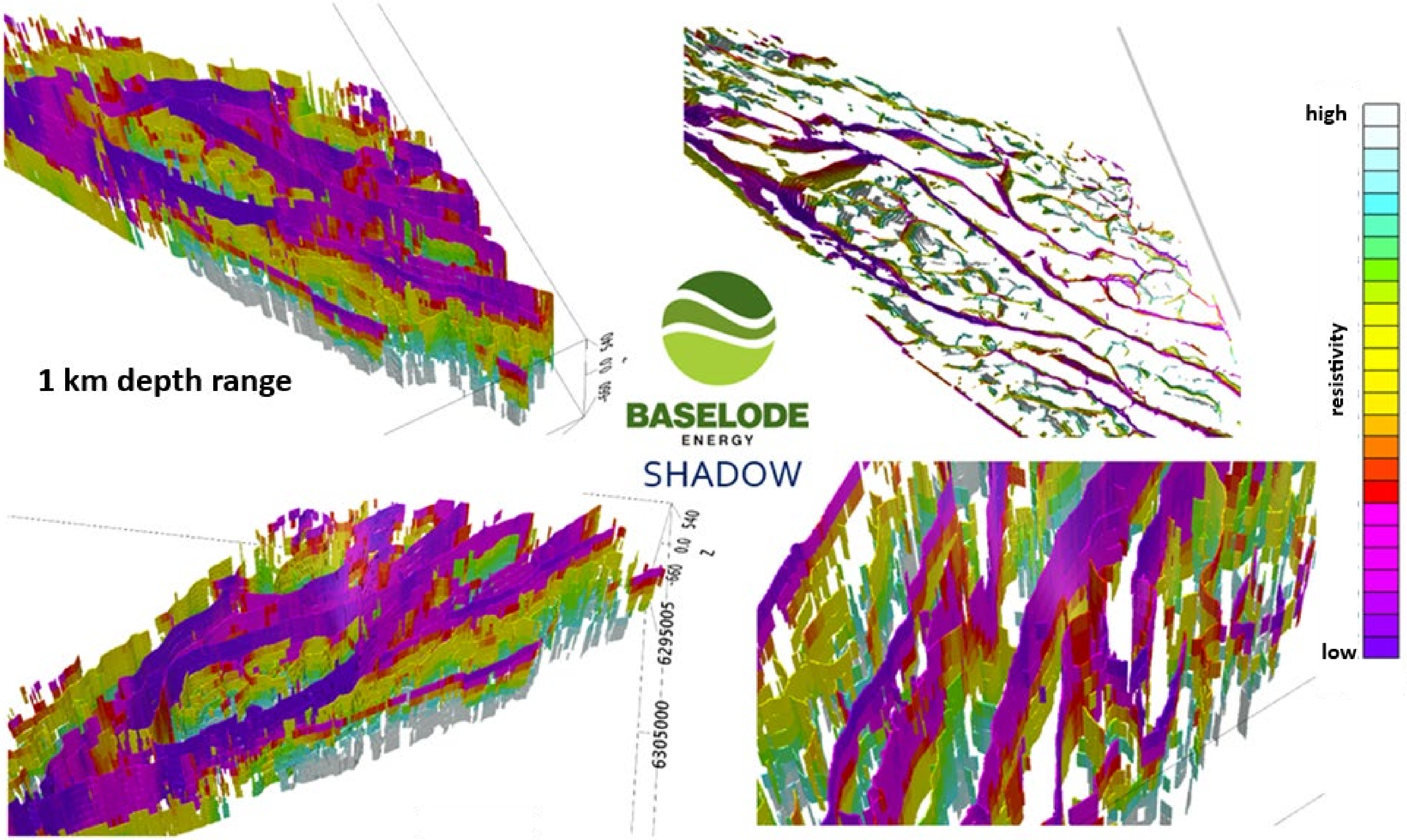
Structural modelling of MobileMT data in 3D view (a fragment from Angikuni Basin)

dark red is more conductive

Shadow Project

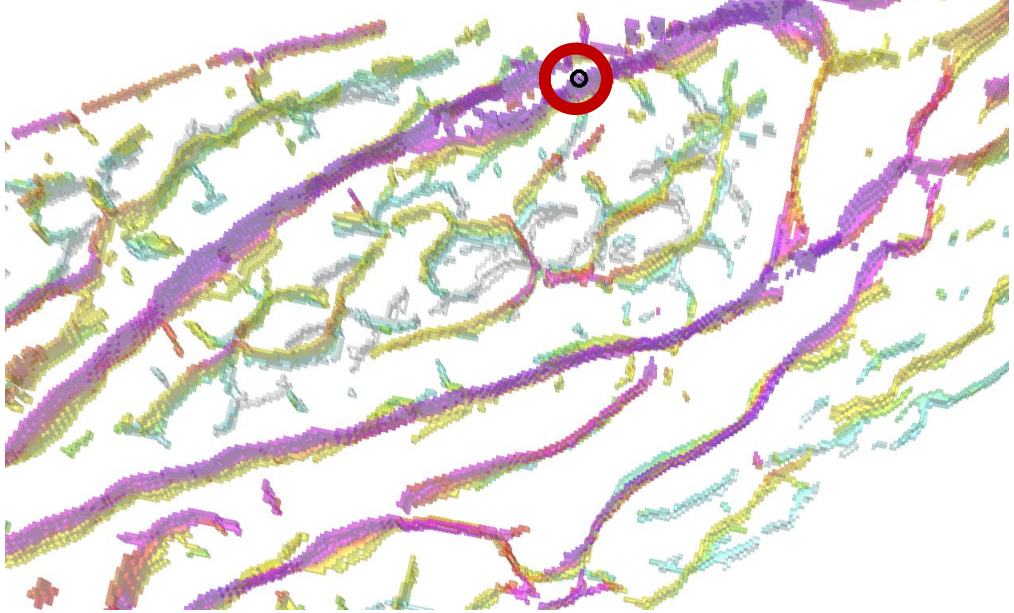
Modeled conductive structures from inverted MobileMT data, in 3D view

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



Shadow Project

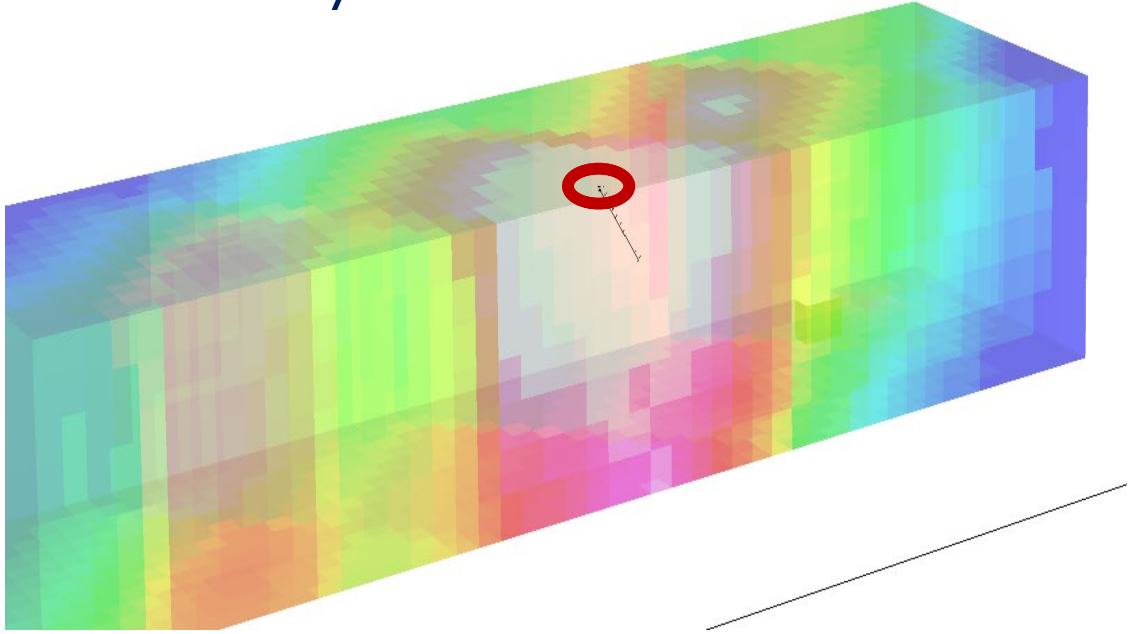
Modelled conductive structures From inverted MobileMT data



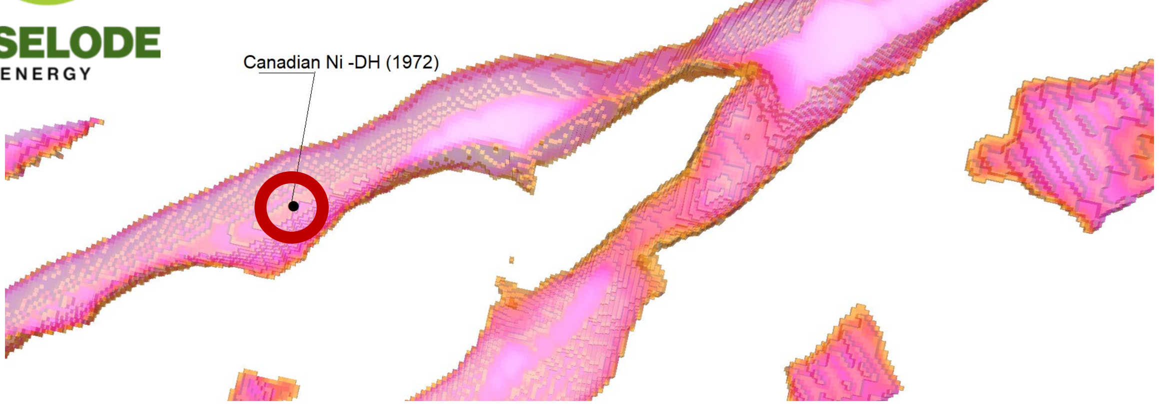
historic drilling confirms the presence of graphite and sulphides

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

Resistivity voxel of inverted MobileMT data

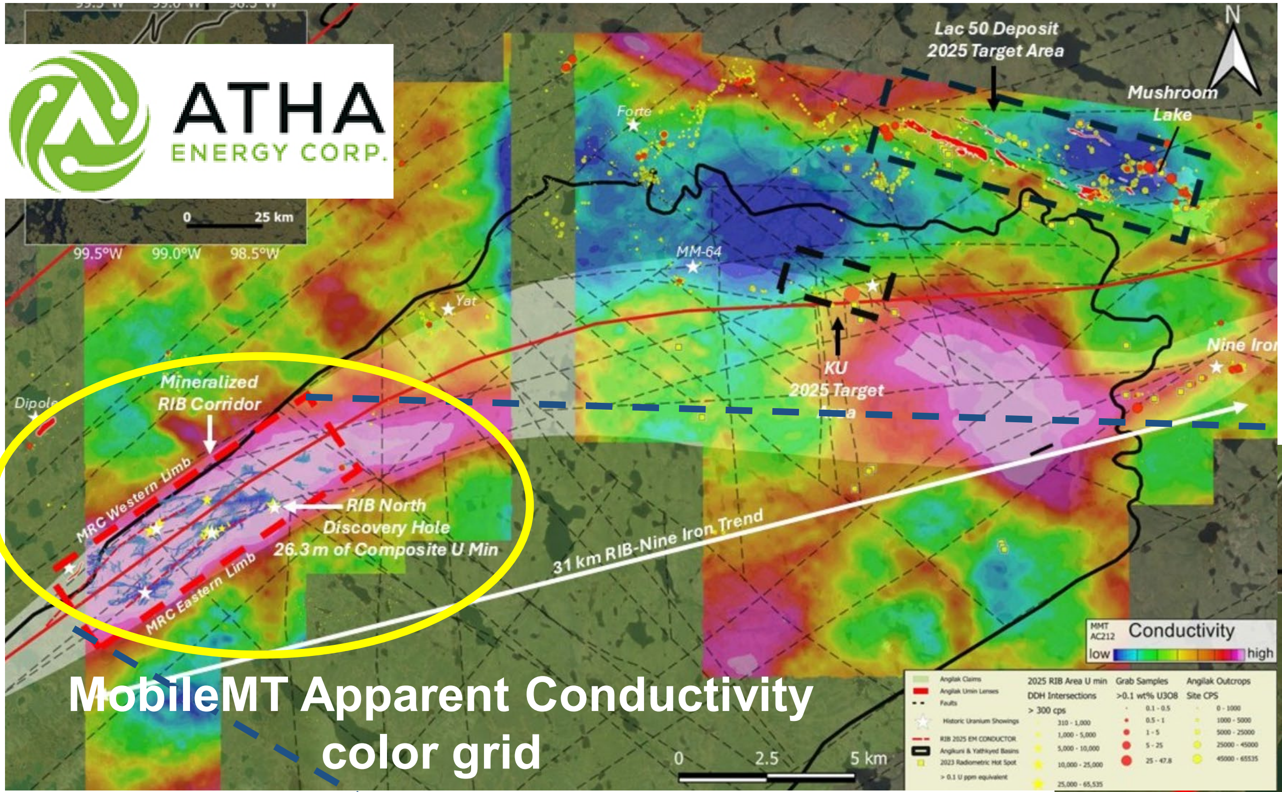


Isosurface of conductive zones

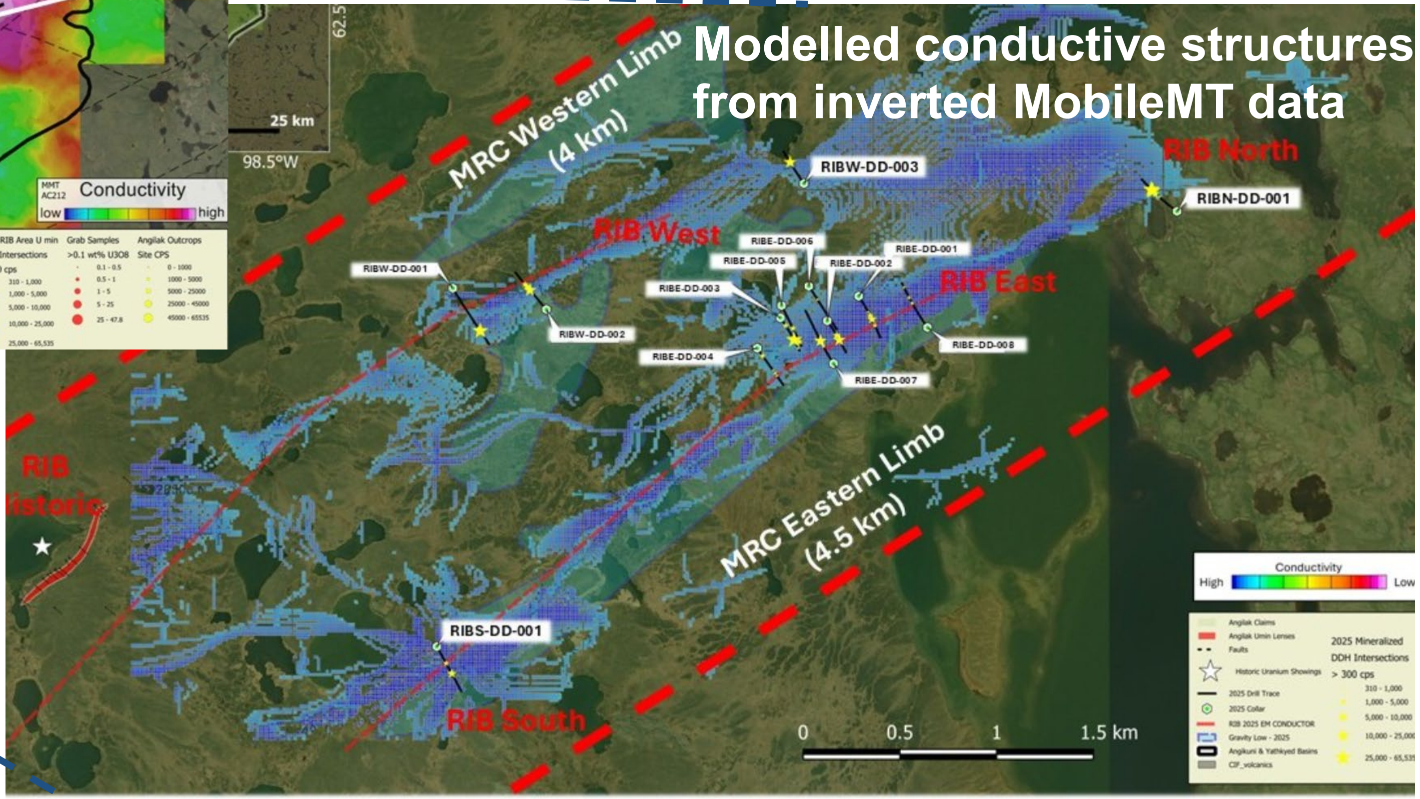


The **Angikuni Basin** hosts some of the highest-grade uranium discoveries outside of the Athabasca

Recent (2025) drilling confirms the presence of graphite and related U mineralization



MobileMT Apparent Conductivity color grid

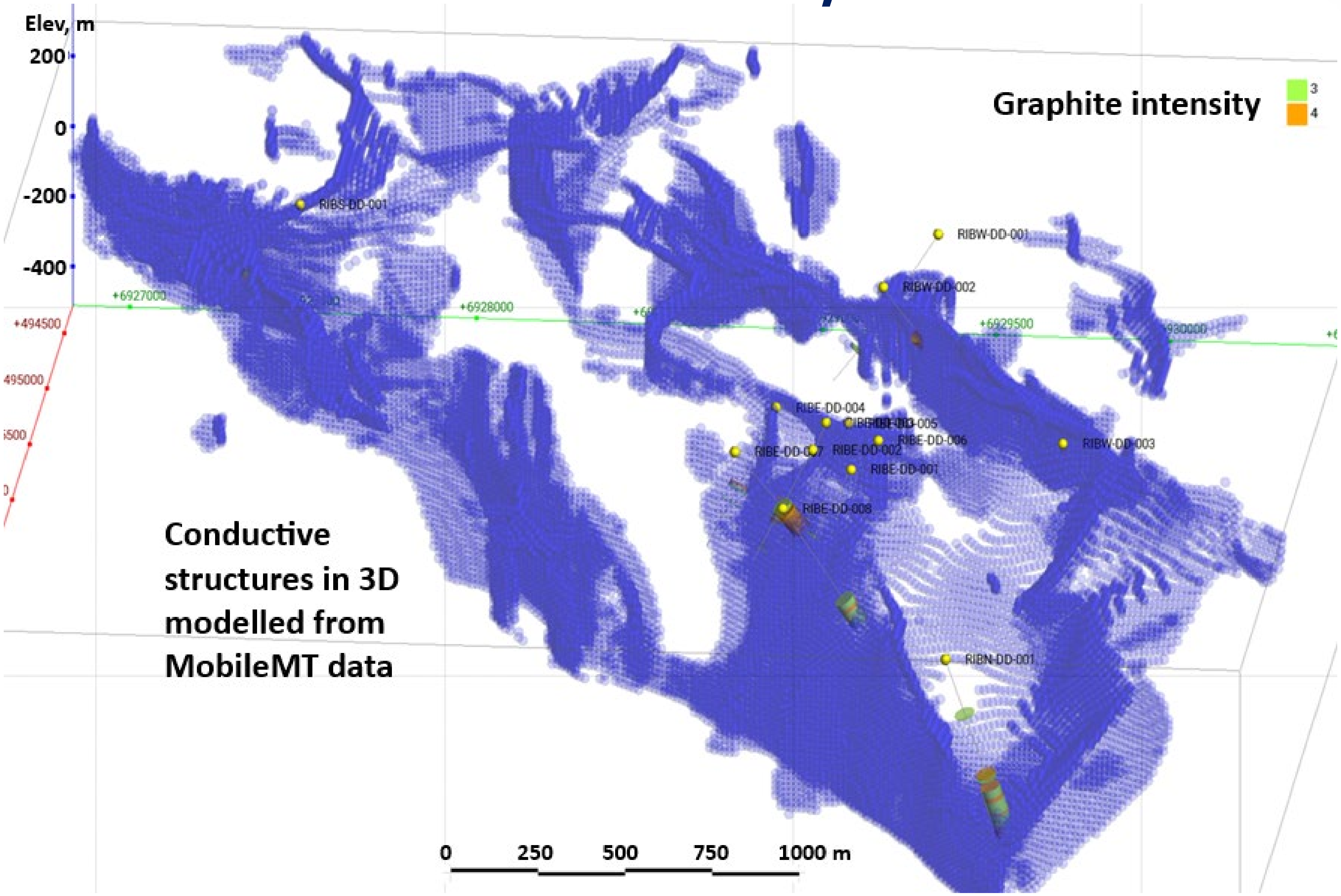


Modelled conductive structures from inverted MobileMT data

Figure 2: 2025 Angilak Exploration Program – EM Inversion Model &Drill Collar Locations from Mineralized RIB Corridor

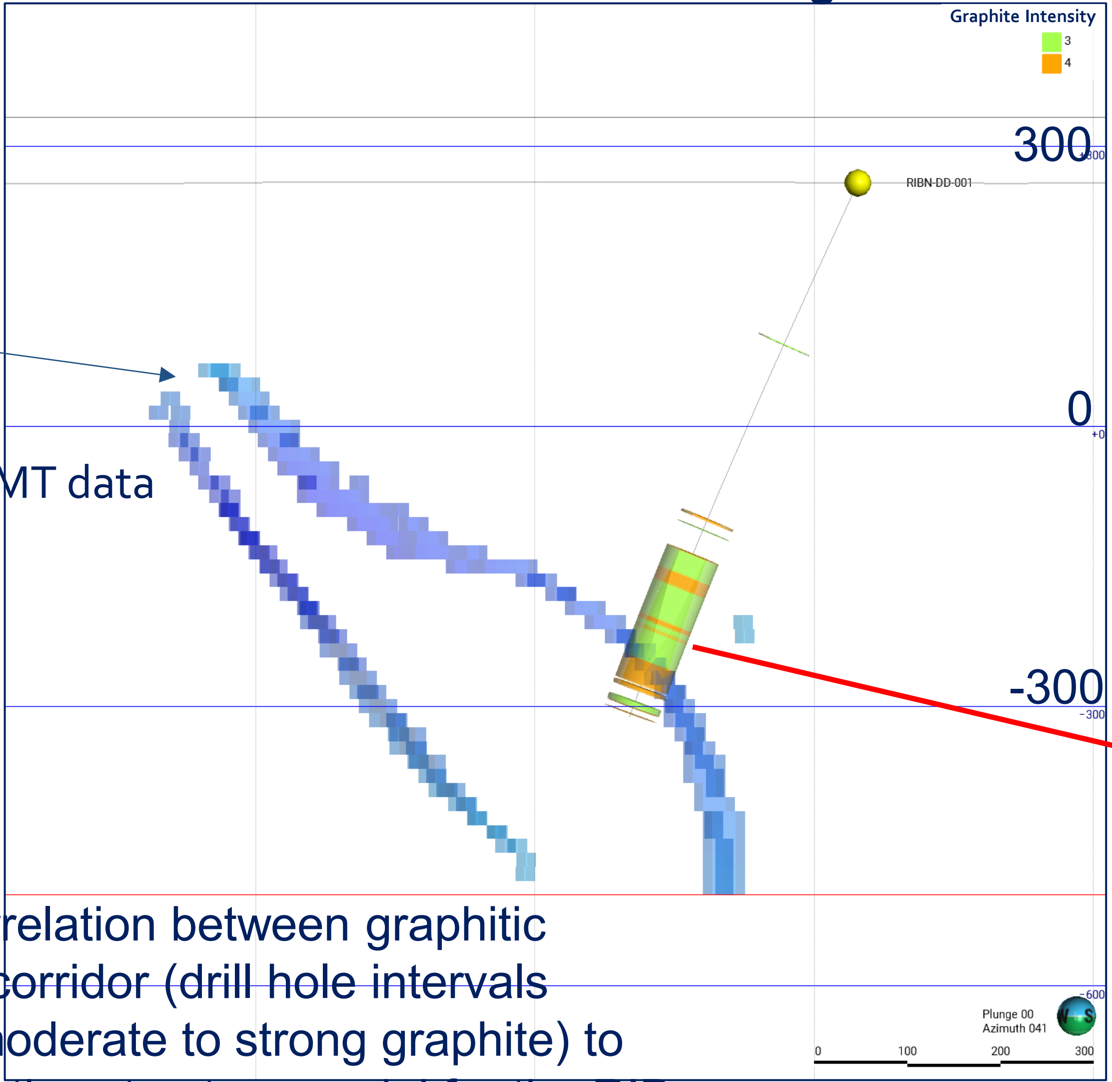
Extracted structures (in 3d view on the right) from the mineralized RIB conductive Corridor (MRC, outlined on the top)

MRC zone, with DHs

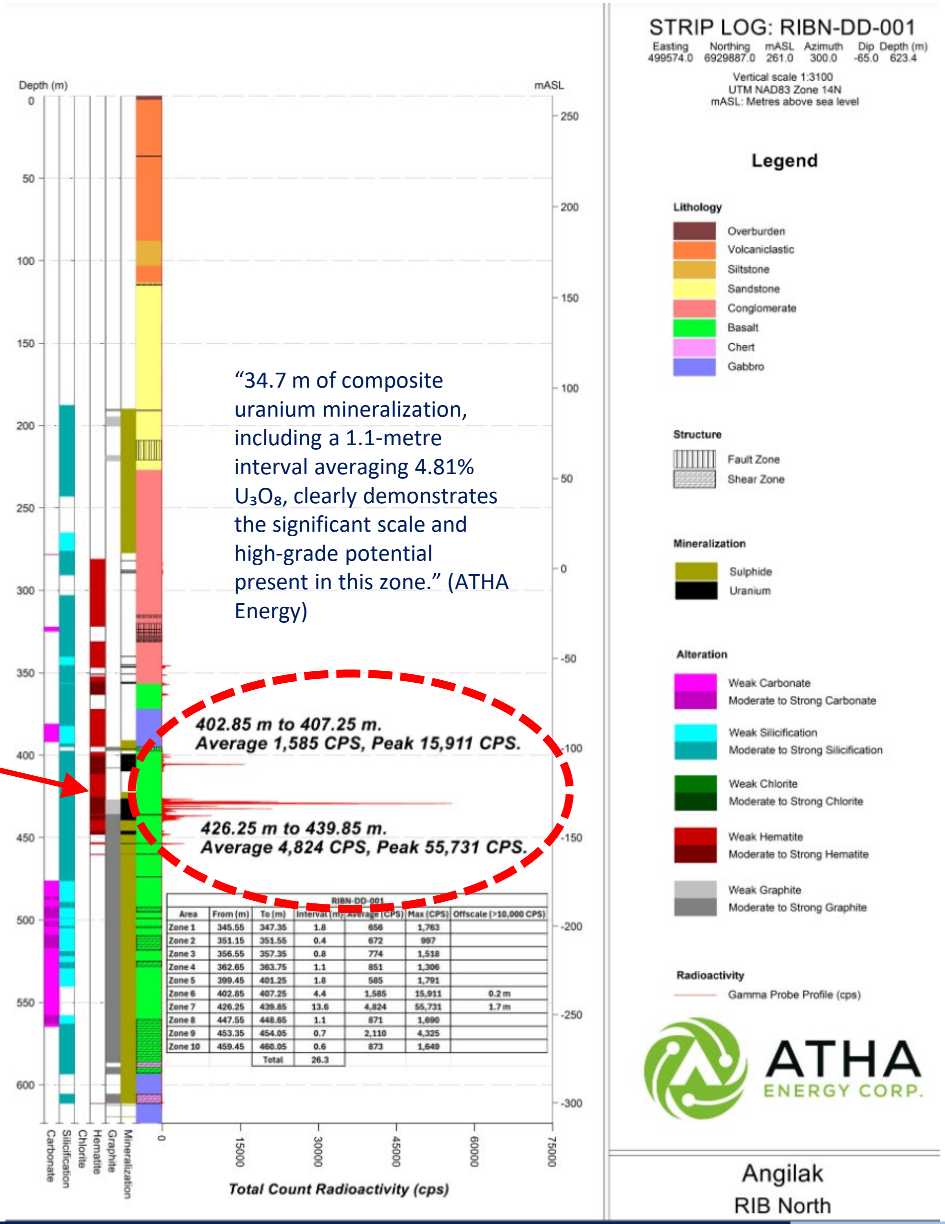


Conductive structure model with projected RIBN-DD-001 drillhole
Cross-section looking NW

Modelled conductive structures from MobileMT data



Shows correlation between graphitic structural corridor (drill hole intervals showing moderate to strong graphite) to the conductive structure model for the RIB north discovery hole (RIBN-DD-001)



RIBN-DD-001

Area	From (m)	To (m)	Interval (m)	Average (CPS)	Max (CPS)	Offscale (>10,000 CPS)
Zone 1	345.55	347.35	1.8	656	1,763	
Zone 2	351.15	351.55	0.4	672	997	
Zone 3	356.55	357.35	0.8	774	1,518	
Zone 4	362.65	363.75	1.1	851	1,306	
Zone 5	399.45	401.25	1.8	585	1,791	
Zone 6	402.85	407.25	4.4	1,585	15,911	0.2 m
Zone 7	426.25	439.85	13.6	4,824	55,731	1.7 m
Zone 8	447.55	448.65	1.1	871	1,690	
Zone 9	453.35	454.05	0.7	2,110	4,325	
Zone 10	459.45	460.05	0.6	873	1,649	
		Total	26.3			

Conclusions:

- Airborne natural total field MobileMT technology effectively detects and recovers controlling mineralization conductive structures.
- A broader set of measured frequencies enhances depth resolution and allows greater flexibility in frequency selection for data inversion.
- Additional goal-oriented modelling of conductive structures from inverted MobileMT data refines targeting and drilling planning.

Acknowledges:

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