LOOKING INTO OUR WORLD

7th & 8th OCTOBER 2020

Chile Explore Group

EXPERT GEOPHYSICS

from innovations to discoveries

MobileMT technology – new abilities of airborne EM in mineral exploration

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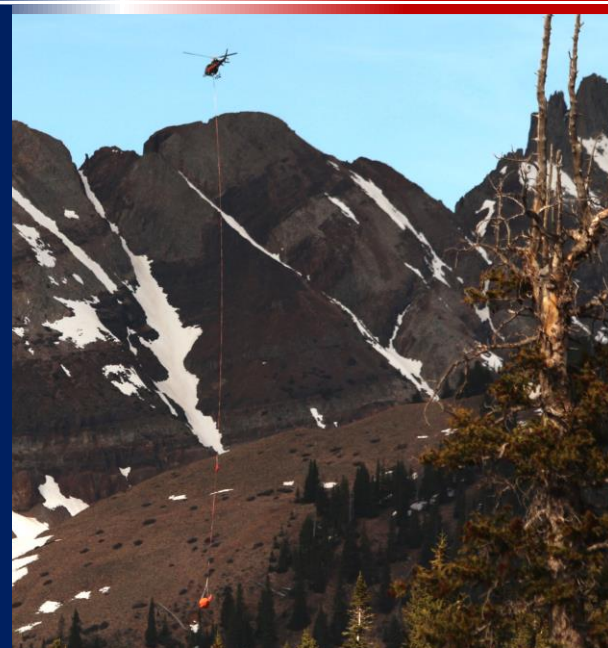

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Hello everyone. Many thanks to organizers for inviting us to participate in the symposium. Thanks to everyone for attending. Today I am going to demonstrate exploration capabilities of airborne broadband natural electromagnetic field measurements on the example of the latest development in this field – MobileMT technology.

Presentation Outline

EXPERT GEOPHYSICS

MobileMT

- Airborne EM methods and depth of investigation
- Natural energy source
- Data acquisition and data processing
- Advantages and capabilities –technical solutions and field examples
  - frequency range
  - depth of investigation
  - measured components
  - survey terrain clearance
- Current experience
- Discussion

I will start the presentation with some brief description of the main principles used in the airborne electromagnetic sector and their comparison based on the depth of investigation;

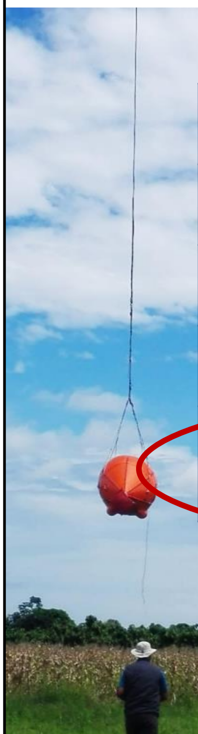
Then I will describe the MobileMT source of energy, the data acquisition method and the data processing way;

The next topic outlines technical solutions and their effect on exploration advantages and capabilities of the technology;

Afterwards I will analyze main technical parameters of the technology with demonstration some field examples in different geoelectrical conditions and terrain environments.

And at the end I will inform you about the current experience with MobileMT airborne EM technology.

Airborne EM Methods and Depth of Investigation

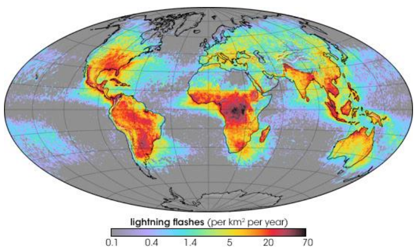


Principle	Primary field source	Depth of investigation
VLF	Remote radio communication signal	~30-50 m
Frequency-domain	Current-carrying loop or coil	~50-150 m
Time-domain	Current-carrying loop	Several hundred meters
Magnetovariational & Magnetotellurics	Natural EM field in audio-frequency range	~1-2 km

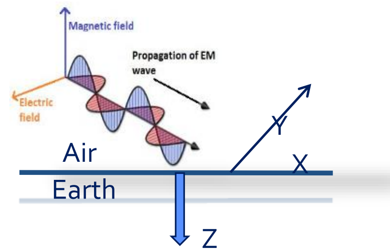
I'd like to begin with a couple words about main principles used in the airborne electromagnetic methods. As you can see in the table, the principles differ in the primary field sources and consequently in depth of investigations. The shown depth of investigations here are approximate and very conditional depending on an environment conductance but ratios between them are close to the reality.

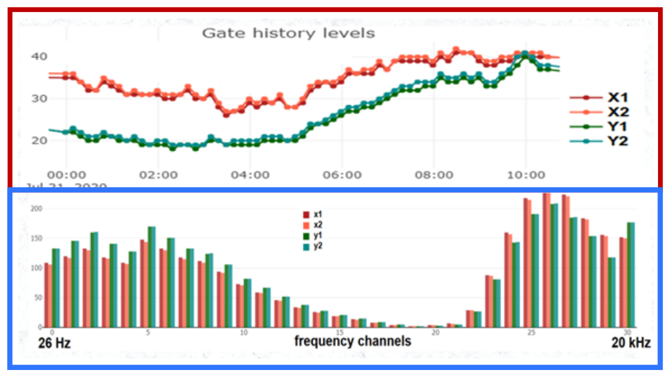
We are in this magnetotellurics principle with the MobileMT technology. The principle provides with the greatest depth of investigation what we will discuss in detail later.

MobileMT Energy Source

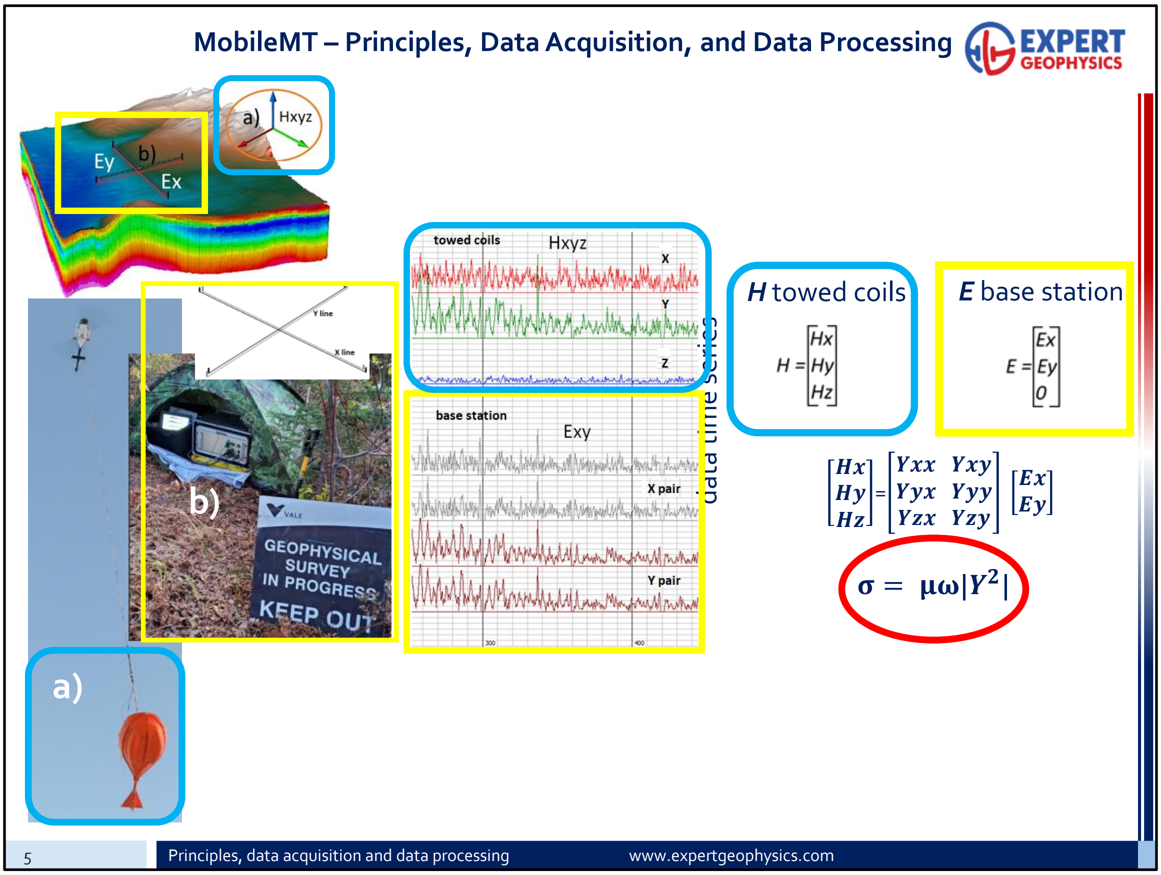


Average yearly counts of lightning flashes per square kilometer, based on data collected by NASA satellites between 1995 and 2002. (NASA, Visible Earth)





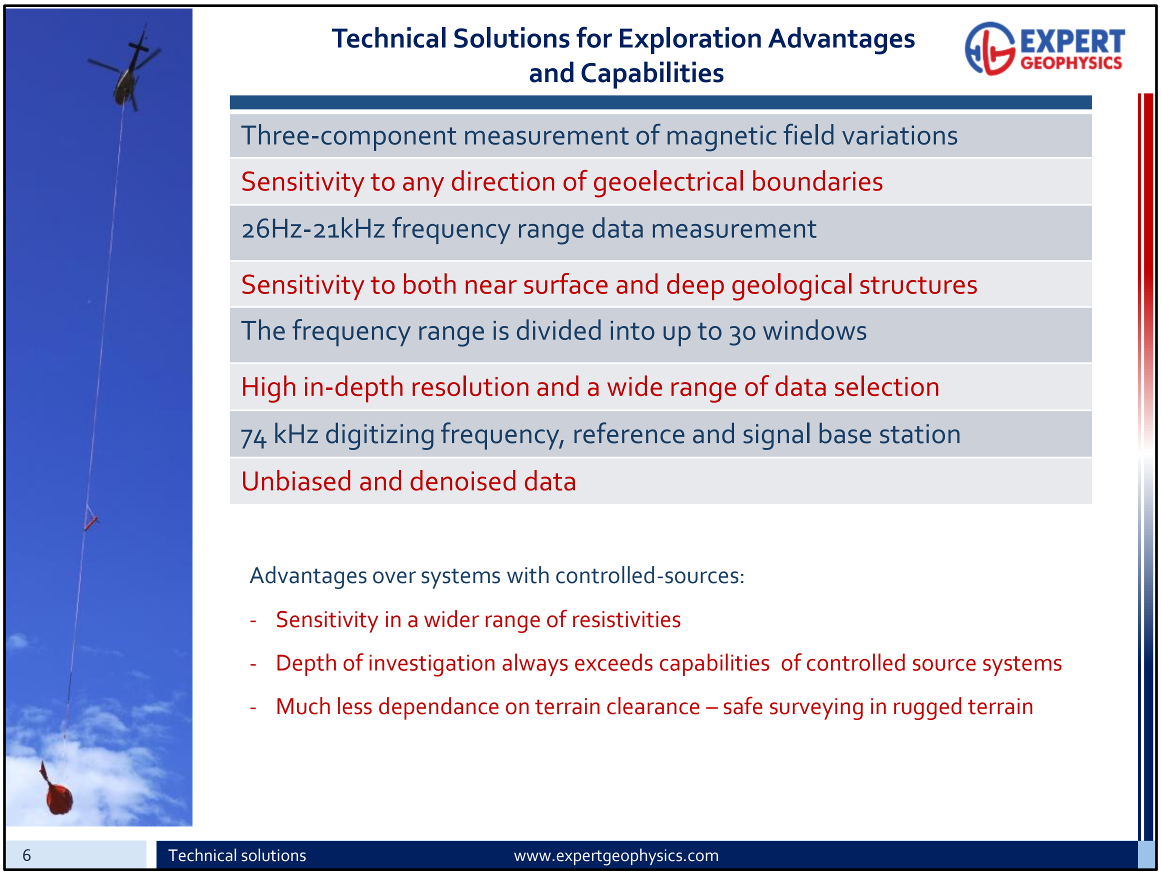
In the MobileMT technology natural electromagnetic fields are used to investigate the electrical conductivity structure in the geological subsurface.
Worldwide lightning events and thunderstorm activity cause natural variations in the Earth magnetic field, inducing electric currents (known as telluric currents) in the geological environment. The natural phenomena create strong electromagnetic source signals over the MobileMT measured frequency range (as a part of the audio-magnetotelluric range frequency). That is why MobileMT system doesn’t use any artificially driven generator or a transmitter.
Here (red outline) you can see an example of a frequency gate history levels on the base station monitored during a day. And below (blue outline) the typical signal spectrum for each frequency channel in the full range of frequencies measured by the MobileMT system.



The MobileMT technology is very close to the ground magnetotelluric method. But there are some specific features, obviously, because it's an airborne modification.

The measurement system consists of the two main parts: the first is the ground stationary electrical components base station consisting of independent signal and reference channels what provides bias free and denoised data (yellow outlines). And the second is the 3 components of the towed magnetic field variations receiver (blue outlines). This electromagnetic data digitized and recorded at 74 kHz to produce a representative data series for high quality data synchronization and processing.

Fast Fourie Transform technique is applied to the merged recordings with calculation of six admittances matrixes on the different time bases and in different frequency bands. In the result of modular computation of the matrixes determinants, as rotation invariant parameters, we calculate apparent conductivity for each frequency window as a main parameter of the MobileMT mapping (red outline).



Let's look at some technical solutions which enable specific exploration advantages and capabilities of the technology.

- Three components measurement of magnetic field variations. Actually it's a total field what provides with sensitivity to any direction of geoelectrical boundaries, from horizontal to vertical. I will show corresponded field examples.
- 4 orders of frequency measurements, in the range 26 Hz to 21 kHz, what means covering from near surface up to deep (>1 km depth) structures.
- The frequency range is divided up to 30 windows what provides high in-depth resolution and a good opportunity for data selection.
- Very high digitizing frequency of the measured data and independent signal and reference channels on the base station provide with bias free and denoised data.

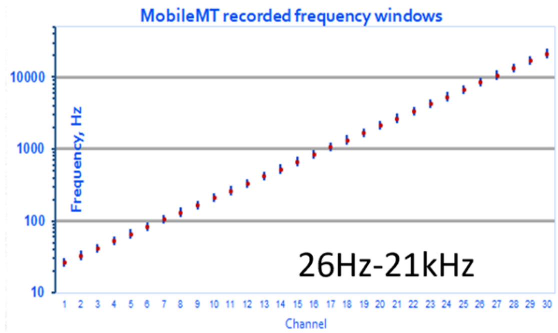
There are three main advantages of the natural field method:

- Depth of investigation exceeds capabilities of systems with controlled sources;

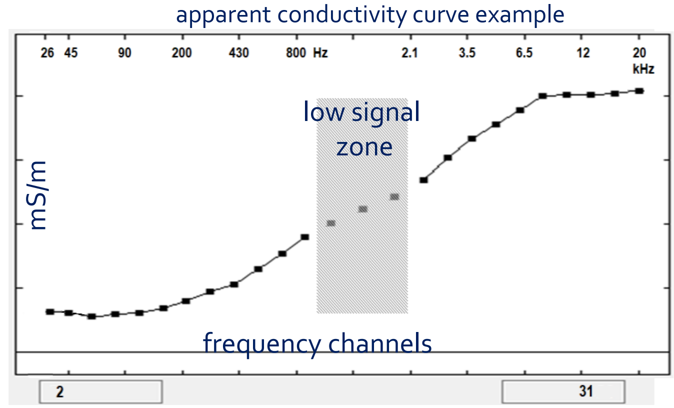
- sensitivity not only to conductors but to resistivity differences in thousands and tens of thousands Ohm-m what is challenging for the time-domain principle, for example;

- there is no critical dependence on the system terrain clearance what means safety during surveys in the ragged terrain conditions.

MobileMT Frequency Range

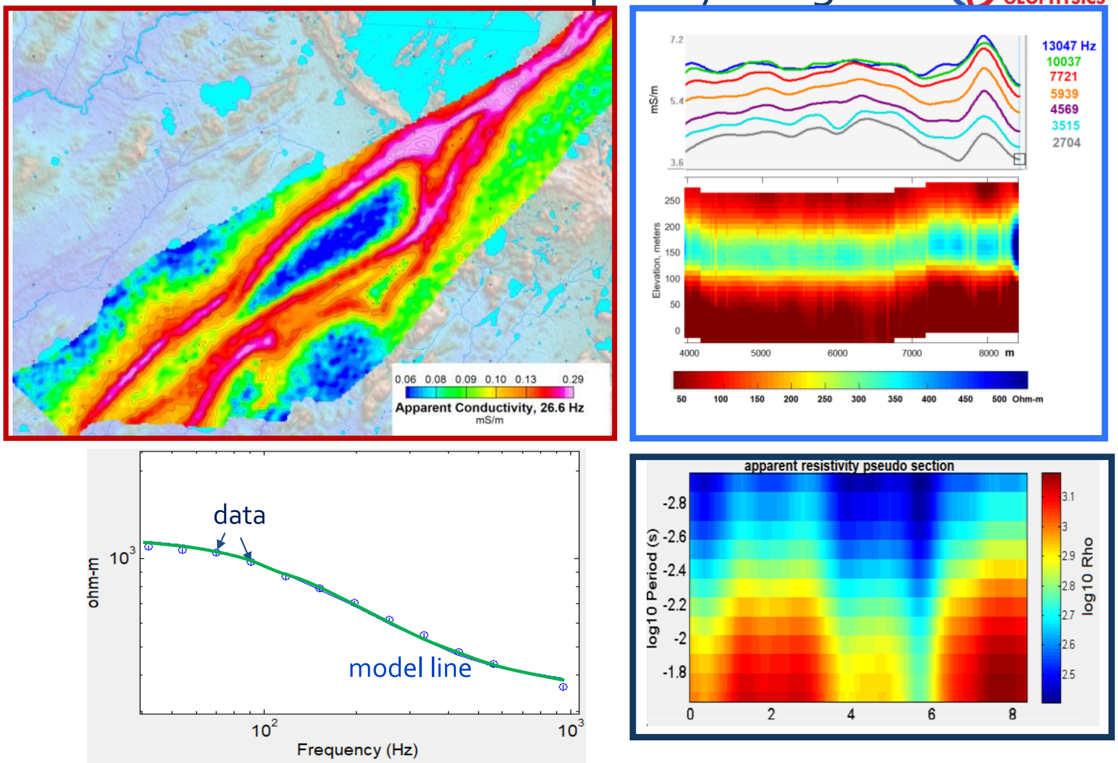


apparent conductivity curve example



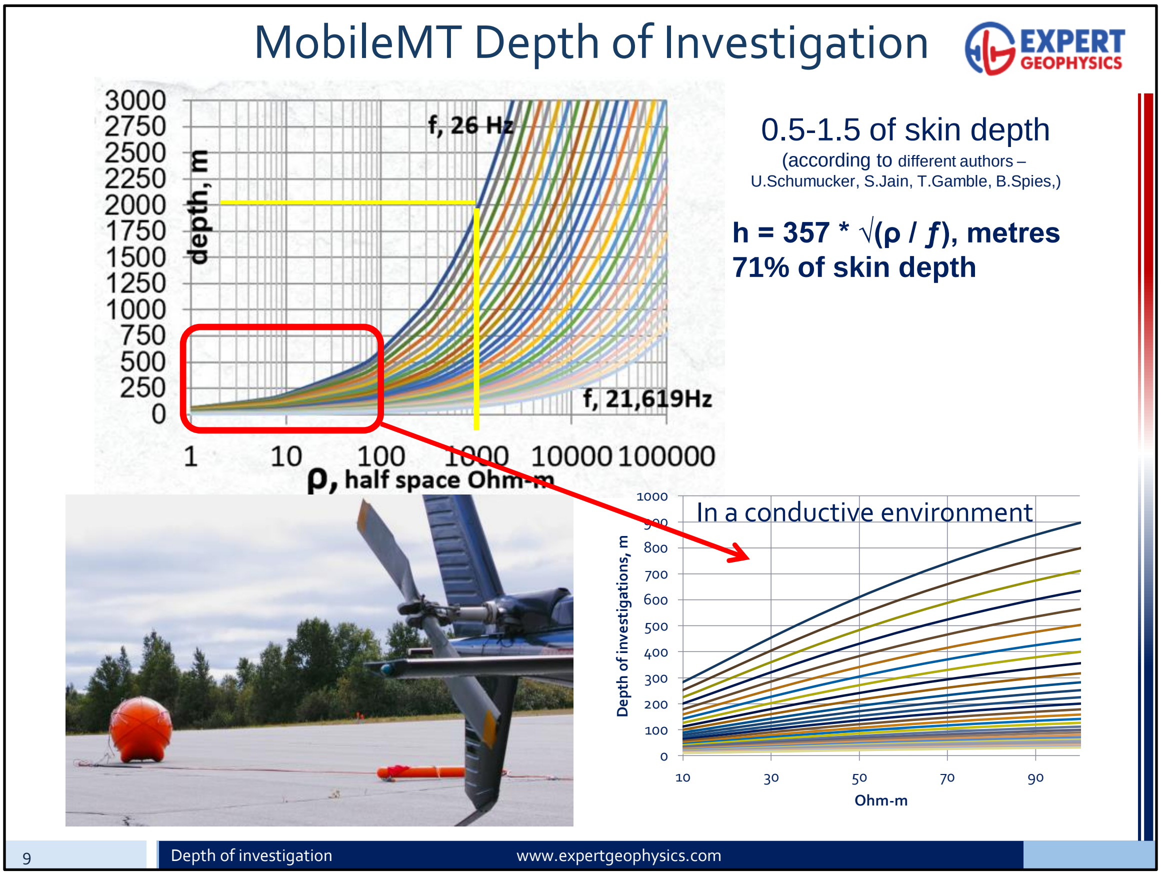
Let's look in details into the MobileMT frequency range. The system is operated in the range from 26 Hz to 21 kHz. And typically the range is divided onto 30 windows. And here is an example of the apparent conductivity curve over a station. It doesn't mean that we accept the data in all generated frequency windows, but we always have a choice of a windows number with the best quality and best signal.

MobileMT Frequency Range

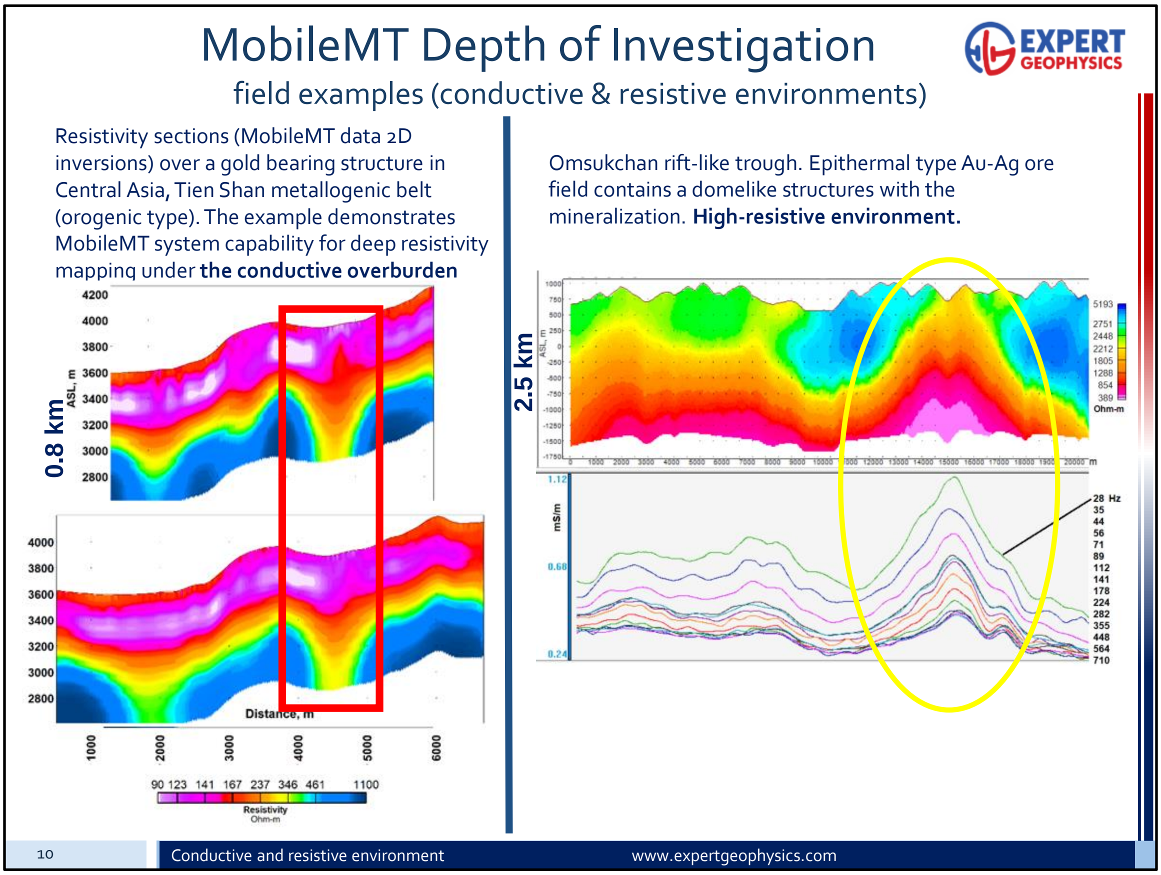


8 | Frequency range | www.expertgeophysics.com

Here you can see an example of an apparent conductivity map for the lowest frequency (red outline). These are apparent conductivity profiles for some highest frequencies with the corresponded resistivity-depth image (blue outline). This an example of a resistivity curve data in the range up to 1000 Hz with the modeled line (green), and an apparent resistivity pseudo section in the same frequency range alone a line (dark outline).



For estimation of the depth of investigation we can use the calculated diagrams for homogeneous half space with different resistivities.
Different researchers suggest to use the skin depth multiplied by 0.5 to 1.5 coefficient. We use 71% of skin depth for the calculations. For example, we can reach 2 km depth at 1000 Ohm-m average resistivity (yellow). Even in a conductive environment (red), the method based on the passive fields in the frequency range, is able to reach a decent depth always exceeding capabilities of airborne systems with controlled primary field sources.



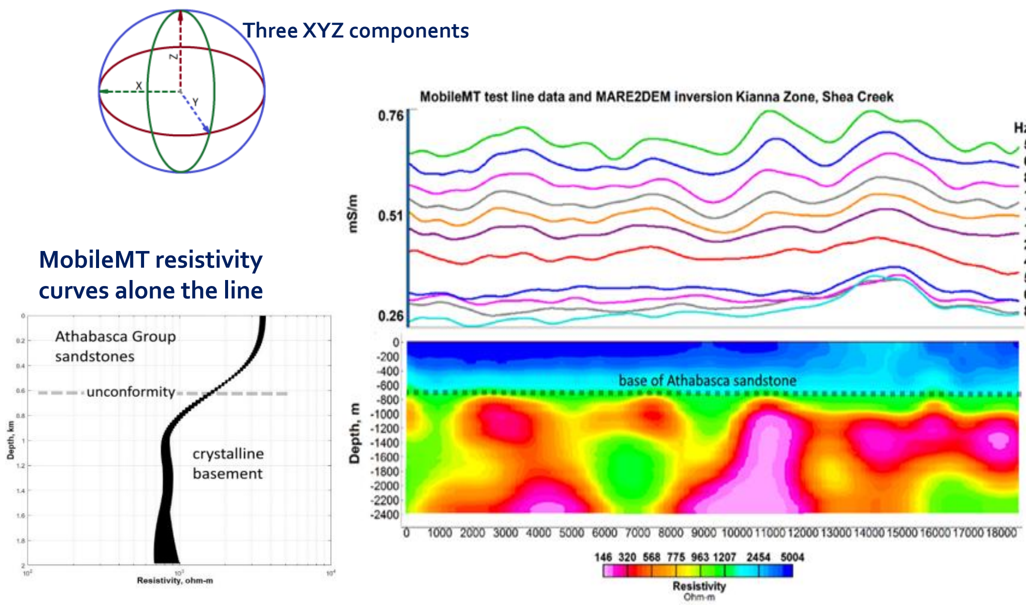
On this slide you can see two examples – in the conductive (on the left) and resistive (on the right) environments.

On the left is quite conductive conditions with a thick (~400m) conductive overburden, with resistivity around 100 Ohm-m and below. This is a gold bearing structure in the Central Asia (orogenic type of gold) which we can see under the conductive overburden. Open-pit mining is used in the region, but from exploration point of view to see deeper is very important because this structure (red rectangle) is one of the main mineralization controlling factor. And we can see the controlling factor mostly under the thick conductive overburden.

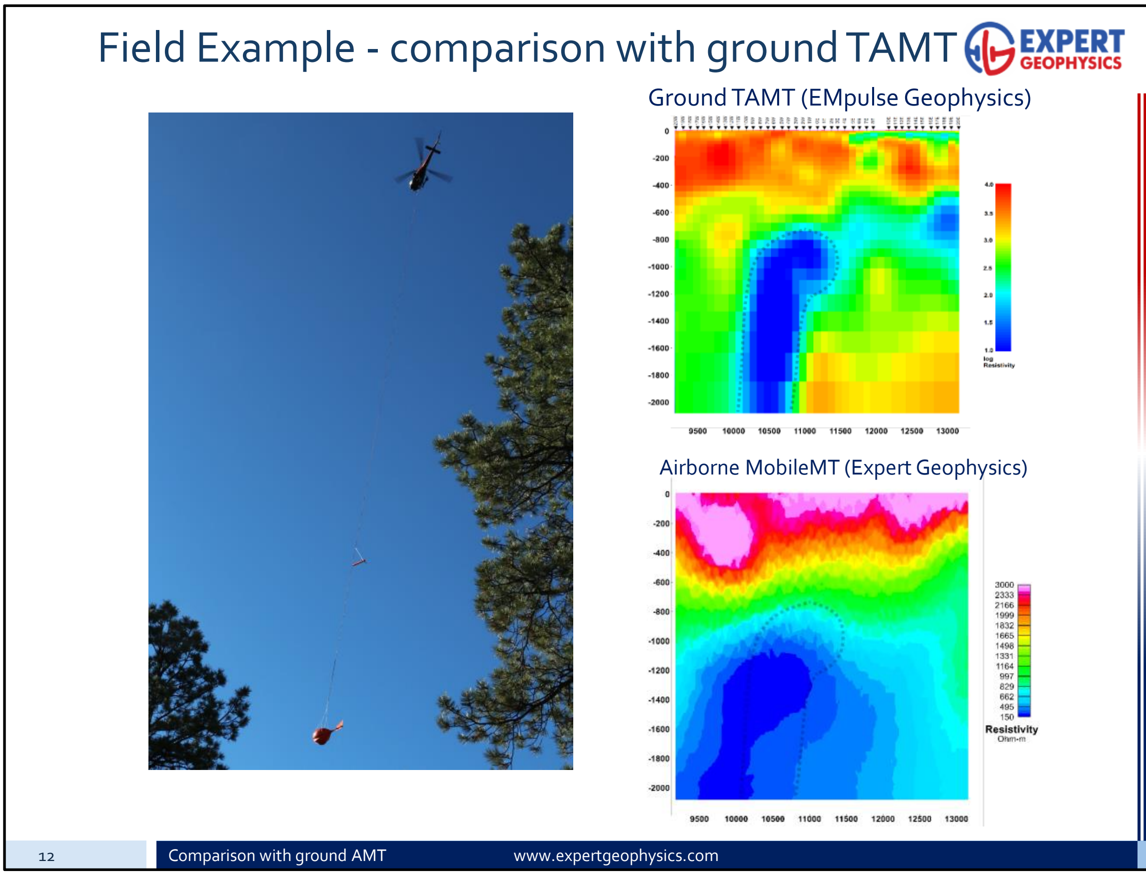
The second example, on the right, represents comparatively resistive conditions where we estimate depth of investigations as 2.5 km. Here we can see clearly the deep domal structure which controls epithermal gold-silver mineralization (yellow oval).

MobileMT Total Field Measurements

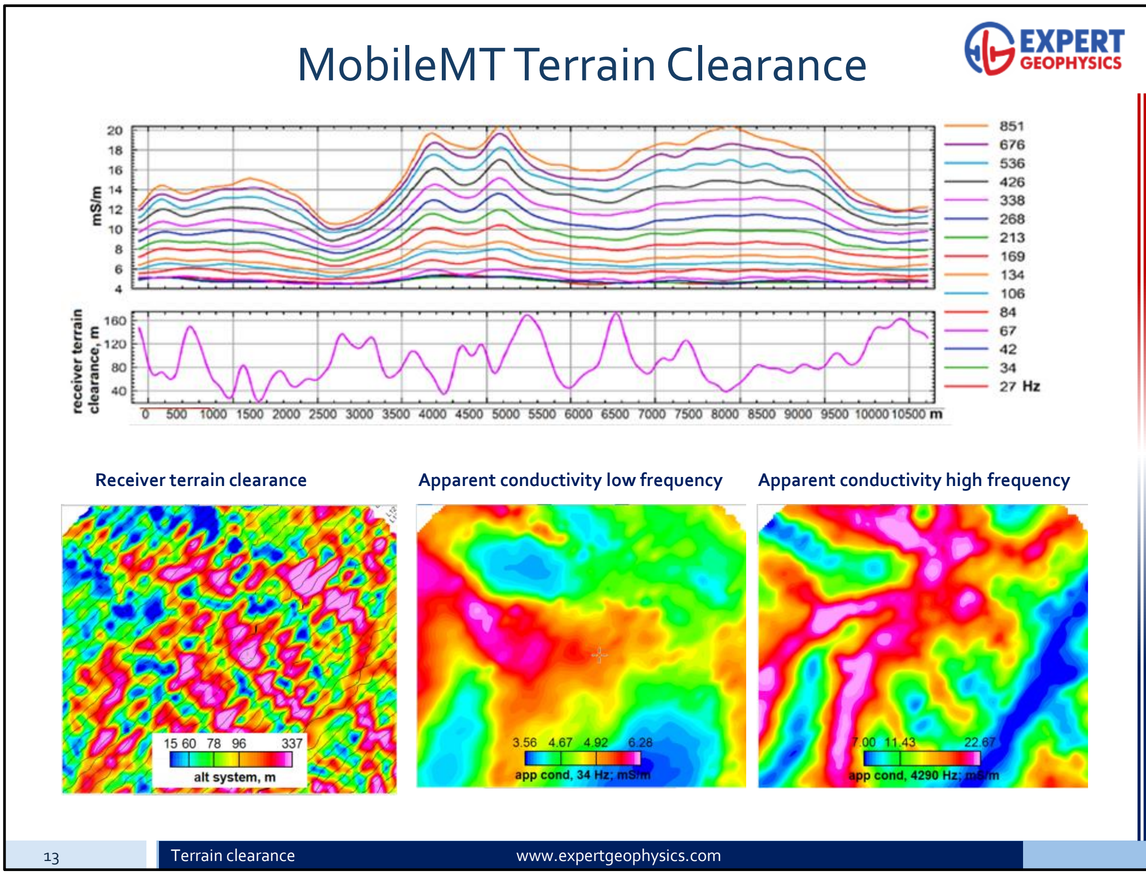
Sensitivity to any direction of geoelectrical boundaries



This example from the Athabasca basin demonstrates the sensitivity of the system to any direction of geoelectrical boundaries. We can see the horizontal contact between the sandstones and the basement on the depth around 700 meters and, at the same time, the complex morphologies of the conductors on the contact and below.



These resistivity sections, from a part of the line in the previous slide. The section on the top from the ground transient audio-magnetotelluric data. We can see the MobileMT inverted data is very comparable with the ground method results. This part of the line is over a known uranium deposit. The target's top is on the depth 700-800 m on the unconformity contact.

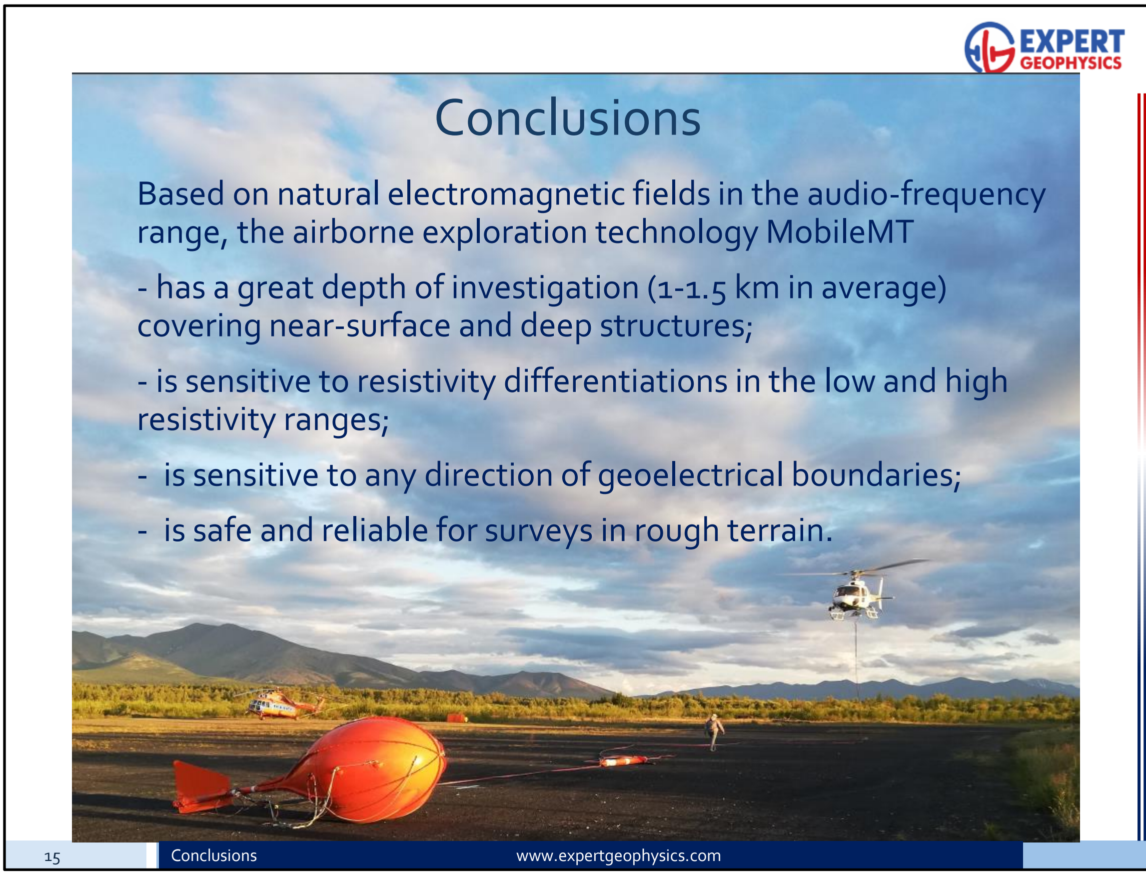


MobileMT output apparent conductivity data doesn't depend on the receiver terrain clearance in the wide range. As you know this is a very critical parameter for systems with controlled primary field source that affects data and flight safety.
The MobileMT data example on the slide is from an area with very rugged terrain and the receiver height sometimes exceeds 300 m above the surface. But we don't see the height reflection in the MobileMT data, not in the profiles or in the maps.

MobileMT Current Experience

- By October 2020 flown ~ 25,000 line-km of MobileMT commercial surveys in six countries - Australia, Canada (5 provinces), Ecuador, Kyrgyzstan, Russia (two regions) and USA (2 states);
- Successful MobileMT surveys in high-elevation ragged terrain – Ecuador (terrain elevation up to 4200 m), USA (terrain elevation up to 4000 m) and Kyrgyzstan (terrain elevation up to 5000 m)
- Historical MobileMT applications for exploration porphyries, orogenic Au, epithermal Au-Ag and subepithermal Au; VMS, uranium, Ni-Cu-Co sulphides.

By today, around 25,000 line km surveys have been flown with the MobileMT system, in Australia, in 5 provinces of Canada, in Ecuador, Kyrgyzstan, in two regions of Russia, and in two states of USA. Several surveys were performed in the high elevation ragged terrain – in Ecuador, Colorado and Kyrgyzstan.
The MobileMT surveys have been applied in exploration programs for porphyries, orogenic gold, epithermal gold-silver and subepithermal gold, VMS, uranium and Ni-Co sulphides.



We can conclude that the airborne MobileMT technology, based on natural electromagnetic fields has several advantages including the great depth of investigation covering near surface and deep structures in more than 1 km depth; sensitive to resistivity differentiations in the low and high resistivity ranges including thousands Ohm-m; sensitive to any direction of geoelectrical boundaries and safe and reliable for surveys in rugged terrain conditions.

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Thank you very much for your attention and interest and please go ahead with questions.