Drone based experimental TEM surveys over Lake Baikal and a uranium occurrence

V. Hallbauer-Zadorozhnaya[1], Yu. A. Davydenko[2,3], Parshin A.V.[2], and E. Stettler[1,4]
[1]AeroPhysX (pty) Ltd, South Africa, valeriya.hallbauer@gmail.com
[2]Irkutsk National Research Technical University, Russia, dya@geo.istu.edu
[3]Gelos Ltd, Russia, davidenkoya@gmail.com
[4]University of Witwatersrand, South Africa, stettlere@gmail,com

SUMMARY

The results of experimental TEM surveys using drones, carried out at the Bolshoe Goloustnoye site on Lake Baikal and at a uranium deposit are presented. L Baikal is a unique geoelectrical situation, where low-resistivity lacustrine sediments are located under a relatively isotropic water body. The upper part of the sedimentary sequence is represented by diatomaceous silt with high conductivity, the lower part has denser clayey sediments. The task was to investigate the possibility of using a drone based TEM survey for delineating the electrical stratigraphy of the subsurface at depths between 50-200 m separated into layers and blocks.
The geology of the uranium bearing area consists of a high-resistivity crystalline basement, overlain by low-resistivity sedimentary deposits (sands, clays) and effusive rocks and the TEM survey was undertaken to determine if the U mineralized strata have a distinctive resistivity signature.
The combined instrumentation unit consisted of an EGI-500 generator providing bipolar current pulses, a Mars 4.0 which is a multi-channel electrical prospecting potential difference recorder, a PDI-50 receiver loop and a SibGIS UAS - unmanned 6-rotor aircraft with a payload of up to 10 kg.
In both cases, a grounded electrical line AB was used as a source of the electromagnet field. Sixteen traverses of survey data were measured over the Baykal ice sheet and five traverses over the uranium deposit.
For the interpretation of the TEM data the $S\tau$ technique was used, which allows tracing the change in the apparent longitudinal conductivity with depth. On the sections, a high-resistivity layer is clearly distinguished, corresponding to the water of Lake Baikal as well as sedimentary deposits, composed by several blocks of low resistivity. The U-bearing layers are confidently identified in all profiles at depths of 120-170 m.

Keywords: Unmanned Aerial Vehicles (UAV), drone, TEM, S-plane, conductance

INTRODUCTION

In the first two decades of the 21st century airborne electromagnetic surveying has become widespread. In recent years, drones have been used in the transient EM soundings method. The UAS technology has several advantages over conventional airborne platforms to collect geophysical data such as resolution, accuracy, and cost but off-course presently have limited endurance and weight carrying capabilities. But in comparison to ground surveying a drone can collect in several days hundreds of thousands of sounding points. In the aircraft and helicopter version, as a rule, the field source (transmitter loop) is mounted directly on the wings of the aircraft or suspended on a cable under the helicopter. The weight restriction of a drone does not allow carrying a weight of more than 10 kilograms, where the transmitter source are located on the ground. As a rule, an ungrounded rectangular loop is used as a source of electrical current. In our cases, a long grounded AB line with a current of 5 A was used.

Experimental TEM surveys have been carried out on two sites: at the coastal part of Lake Baikal (delta of Bolshoe Goloustnoye river) and over a uranium occurrence in Easter Siberia. TEM surveying at both sites were made within one, two day period and one single day, with a high data density: the flight line spacing varied between 50 and 100m, the data sampling rate along flight lines is about 10 m.

INSTRUMENTATION AND OPERATIONS TECHNOLOGY

The UAV-MPP technology applied on Lake Baikal and on at the uranum deposits used a special versions of the components of the ‘Mars’ electrical survey system (*Patent No. 2574861*), and the SibGIS UAS unmanned platform (*Patent No. 2736956*).
The instrumentation assembly consist of the following units described below. On the ground we have:

a) EGI-500 generator that delivers bipolar 50% duty cycle current pulses. It consists of two separate units, one delivering the stabilized current and the second a pulse switcher. The duration of the block shaped current pulse is 5 ms on and 5ms off.
b) A long (2.2 km) grounded transmitter line AB is used as a source of the current pulses. The iron stakes (electrodes) of the transmitter cable are grounded into the water through holes drilled into the ice.
In the air we have:
a) A SibGIS UAS which is an unmanned 6-rotor hexacopter with a payload of up to 10 kg.
b) The “Mars 4.0” which is a multi-channel electrical prospecting potential difference recorder that collects the full TEM data series and functionally consists of an ADC, a GPS-enabled synchronization unit, a data storage module and a USB interface for connecting to a PC.
c) A PDI-50 receiver loop hanging below the hexacopter and has an equivalent surface area of 50 m^2 that records the secondary induced field.
d) Microcomputer with a GNSS-reference system mounted on to the drone. The onboard software stores the data.
The Figure 1 demonstrates the drone with suspended receiver box and vertical magnetic dipole (loop).

Figure 1. Unmanned Aerial Vehicles with receiver box and VMD. Diameter of VMD is 1 m, surface are 2500 m^2.

INTERPRETATON VIA MODIFICATION OF THE CALCULATION OF APPARENT LONGITUDINAL CONDUCTANCE Sτ

The so-called method of differential transformation of emf signals into the curves of apparent longitudinal conductance as function of time or depth (method Stau, Sτ) was proposed by Sidorov and Tikshaev (1970). The Sτ method has certain advantages. Its use allows determining the conductance of the section and determining the depth (or time) where Sτ increases noticeably. Usually increasing conductance is associated with the presence of a low resistive object (bodies and/or layers) in the resistivity section. We used this property when interpreting airborne data. The procedure of the modified method is described by Davydenko et al. (2022) as well as presented in another abstract presented on the 25th EM Induction Workshop (Hallbauer-Zadorozhnaya and Stettler, 2022).

RESULTS AND DSCUSSION
LAKE BAIKAL

An electrical line 2.16 km long was grounded (floated) into water of Lake Baikal along the shore at the Bolshoe Goloustnoye site (Figure 2). Six profiles were conducted parallel to the electrical line AB, nine – perpendicularly. The TEM points located directly above the current line were not interpreted due to the powerful noise generated by it.

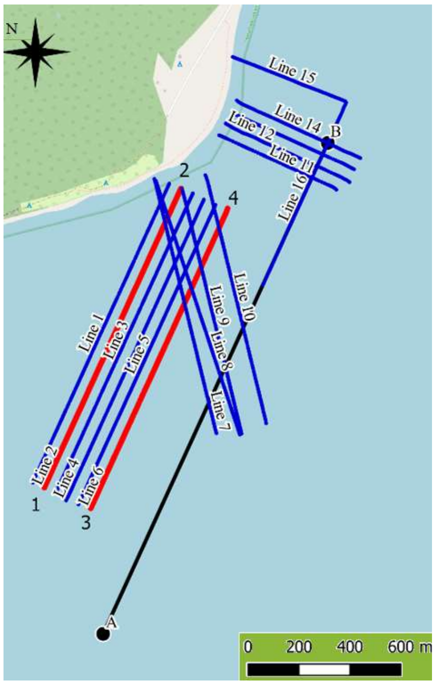


Figure 2. The layout of the profiles on the site Bolshoe Goloustnoye site on Lake Baikal. The black line indicates the location of the AB line. The profiles of electromagnetic induced polarization soundings (EMS-IP) are marked in red.

The emf curves were smoothed and after applying the procedure of the modified Stau method for each sounding, St(H) curves are calculated. An example of a cross-section of apparent longitudinal conductance for profile 6 is shown in Figure 3.

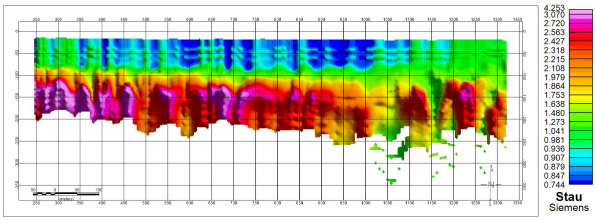
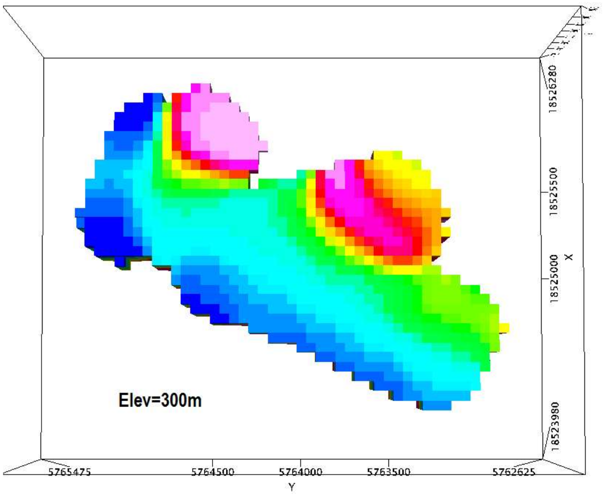
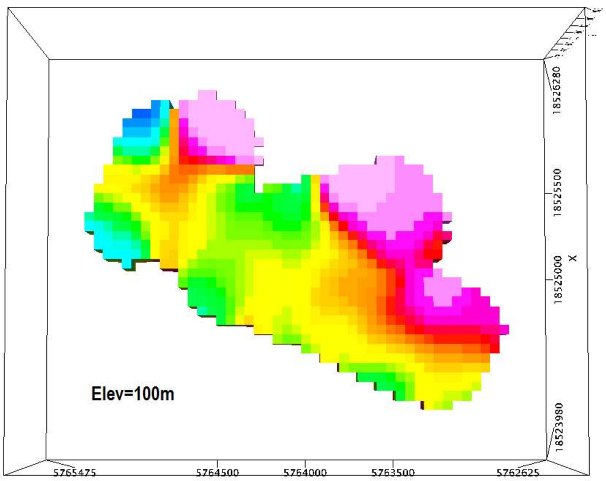


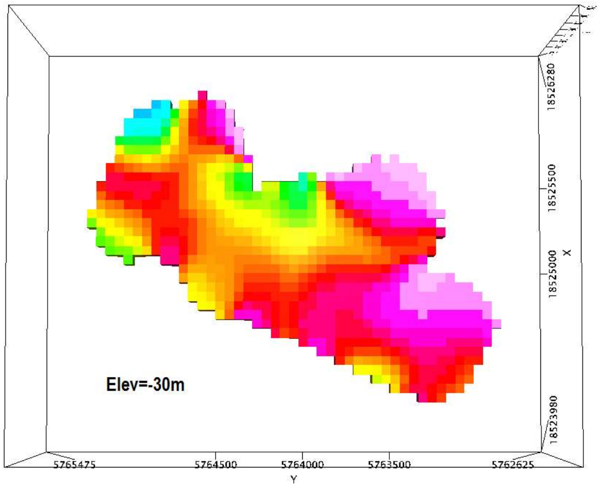
Figure 3. Apparent longitudinal conductance along profile 6 (close to current line AB). The section clearly shows a high-resistivity layer corresponding to Lake Baikal water and sedimentary deposits.

However, noise, instrumental interferences and geological distortions make it difficult to develop software for interpretation, especially when the TEM profile crosses the electrical transmitter line. The change in the shape and intensity with distance from the current source are now recorded and will aid in future surveys and interpretation.

A sufficiently dense network of profiles made it possible to present a three-dimensional visualization of the TEM data using the model of a "floating" plane. Figure 4 demonstrates the geo-electrical cuts at different elevations (200 m, 100 m, -30 m, -200 m).







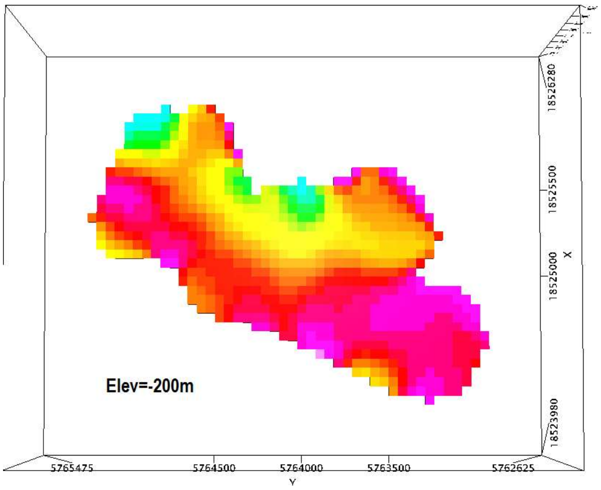


Figure 4. Geo-electrical cuts at different elevations (200 m, 100 m, -30 m, -200 m). colour bar is in Figure 3.

Conductivity of the lacustrine sediments increase with depth. A low resistive ring structure is located at some distance from the delta of the Goloustnaya River.

URANIUM OCCURRENCE

The area investigated is located on the Viktim Plateau, West Siberia. Five profiles have been carried out. Permafrost is ubiquitous in the area, its lower boundary is fixed at depths of 55-90 m from the surface. In the first approximation, the geoelectric section can be represented as follows:-

- crystalline rocks of the basement (granitoids, diorites, limestones, metamorphic shales and sandstones) have a resistivity (190 - 2000 Ohm.m) and occur at a depth of 120-160 m;
- Overlying U enriched sedimentary deposits (sands, clays with a thickness of 40-150 m) have la ow-density (2.0 g/cm^3), are weakly magnetic (0.024 SI units), low-resistivity (40 Ohm.m) and low-velocity (2150 m/s);

- the effusive stratum (several covers of basalts separated by tuff layers) is characterized by an average density (2.5 g/cm3), high magnetic susceptibility (2.0 - 230 SI units), high resistivity (1200 - 8000 Ohm.m) and acoustic velocity (3800 m/s).

The contrast of physical properties predetermines the effective use of the geoelectric methods to identify the enriched strata of rocks in the section.

Figure 5 demonstrates structures on the west side (5a) and on the east side (5b).

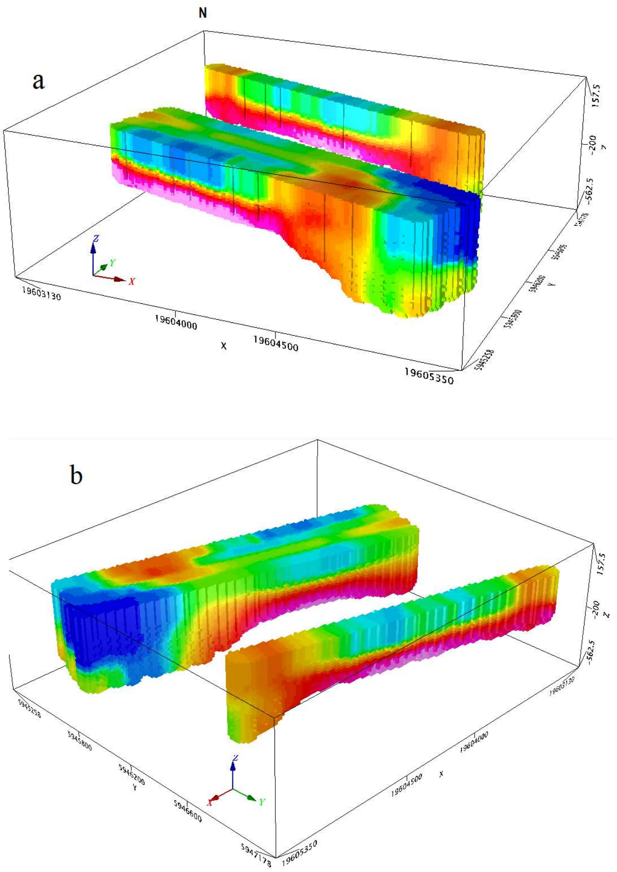


Figure 5. 3D visualization of apparent longitudinal conductance. a) View from the west, b) view from the east. Colour bar is on the Figure 3

These structural features of the section are characteristic of all five profiles. In the west part of the site at depths of 120-160 m, a remarkable conductor is observed, which we identify as a enriched complex. The east side of the site is highly restive. It is known that another thin layer of sedimentary rocks (also enriched) is located above the main deposit. In this case, it is quite possible that in the geoelectric section both layers appear as one with a slightly changed (convex) surface shape. We also note that a decrease in the longitudinal conductivity of the upper layer (basalts) is observed. This occurs because the secondary electromagnetic field rapidly propagates in the resistive rocks but concentrates in the conductor. Figures 5a and b show a three-dimensional image of the geoelectric sections. It is obvious that the correlation of the main elements of the block is correlated both horizontally and in plan, which indicates the stability of the transformation algorithm Sτ and its applicability for interpreting the TEM data.

Conclusions

Experimental airborne TEM surveying using a drone demonstrates the effectiveness of TEM operations as shown in the Lake Baikal example that senses an conductor below a thick layer (100-250 m) of fresh highly resistive water.

Interpretation of the TEM data using the “floating” plane model indicates the stability of the transformation algorithm Sτ and its applicability for interpretation the TEM namely for lateral differentiation in the upper part of the sedimentary material and the identification of large structures of various resistivity’s.

To optimize the interpretation process, it is essential to place the sounding profiles parallel too and removed from the current (transmitter) line.

The survey carried out at the site of the uranium occurrence showed the high efficiency of the airborne TEM in identifying and contouring the conductor at a depth of 150 m.

Acknowledgements

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