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Airborne TDEM by He-filled balloon

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ABSTRACT

Performing Time Domain Electromagnetic surveys in rugged terrain is a challenging task and as an alternative to mundanely laying out loops or using a helicopter system, a central loop configuration Time Domain EM system has been fitted to a 5m diameter He–filled balloon with a capacity to lift a ~48kg payload. The transmitter and receiver loops have a diameter of 10 and 5m, respectively. The balloon is handled by an operator and 3 assistants and measures while drifting above the topography. The TDEM electronics was custom built by Elta-Geo in Novosibirsk, Russia and records the soundings to a HP IPAQ handheld PC via BlueTooth communication. A maximum transmitter current input of up to 20 Amp is possible using a conventional half sine waveform.

One of the areas where the balloon was employed was the N'teisha gold occurrence in Yemen where the gold is situated in narrow shear zones, between 0.5 and 2m wide. Although the shear zones are possibly too narrow to be detected by the TDEM system an interesting conductivity anomaly was detected in the vicinity of the shear zones that still has to be further investigated.

Key words: Time domain electromagnetic, TDEM, Helium balloon, central loop configuration, N'teisha gold occurrence, Yemen

INTRODUCTION

Laying out loops to perform TDEM soundings is an often challenging task especially in rugged terrain or when lots of scrubs or trees are present. Normally airborne TDEM by winged aircraft or helicopters are then considered but these have their own challenges with noise, varying receiver position and orientation to account for. It is thus natural to start considering other ways to move the transmitter and receiver loops along and the concept of airborne floating transmitter/receiver loops was envisaged. The first experiments began in 2004 using an infinite length, plastic bag (used to store borehole samples) 6cm in diameter, filled with He, 100m long, bend into a loop 25 x 25m and using a FASTEM48 lightweight TDEM system. This was unsuccessful as the frame was not rigid enough, and did not have enough 'lift'.

Having subsequently moved to Yemen and carrying magnetometers, gamma ray spectrometers and TDEM equipment up and down 800-1000m mountain peaks on a daily basis necessitated a revisit of the He filled balloon concept of carrying equipment. Thani Dubai Mining LLC funded an experiment where the plan was to fit a magnetometer, a gamma-ray spectrometer, a NIR spectrometer, a GPS and a TDEM system onto the balloon platform, being controlled by 1 to 3 handlers that just walk, with the balloon floating 4-5 m above the surface.

This short paper deals with the experience gained with mostly the TDEM system on a He–filled balloon platform and one of the results obtained in Yemen on the N'teisha gold prospect.

BALLOON, LOOP CONSTRUCTION.

Balloon design.

Centre to the balloon concept is the question of whether to go for a blimp or a proper balloon. A blimp builder in Johannesburg convinced me that a blimp cannot be controlled and one must definitely go for a proper balloon. Next to consider, is the size of the balloon and for a) practical reasons in the manufacturing of He-filled balloons, b) handling the balloon and c) the cost involved of filling the balloon it was decided as a compromise to experiment with a 5m diameter balloon size. The golden rule is that under normal room temperature and pressure 1 cubic metre of He lifts 1 kg. A 5m diameter balloon has a capacity for 70 cubic m of He but since the balloon material weighs already 17 kg and the balloon cannot be fully filled as space needs to be allowed for the expansion of the He in the midday heat, the balloon eventually only had a pick-up lift capability of ~48kg. Two balloons were purchased with a 5m diameter and one with a 2m diameter. Special small fabric belts were fitted to the outside of the balloon to strap in the TDEM loops, to fasten the GPS receiver to the top of the balloon and to strap a small basket to the bottom.

One cylinder of commercially available liquid He holds 10 cubic m of He but since He is very mobile and can move through metal it is often found that the cylinders only hold 9 cubic m. One cylinder retails for about US$180, and it takes ~7 cylinders to fill the 5 m diameter balloon. It is necessary to top up the balloon with He on a daily basis and an additional bottle is used every 2 days. As the instrumentation exceeded the ~48kg payload weight limitation, the smaller 2m diameter balloon was often fitted to the top of the bigger one.

Loop design.

The transmitter loop has a 5 m radius and is assembled from easily obtainable non-conductive material. Plastic conduit piping as found in the building industry to house electrical cabling and available at any hardware store, even in Yemen, is used strengthened by light weight wooden rods inserted into the conduit. Hard board strips are fastened with nylon screws to the outer loop and the transmitter wire loops are strapped to the hard board with cable-ties. The transmitter wire loops are placed 6 cm apart to limit the back emf effects when pulsing the transmitter current. Important is that everything has to be non-conductive so composite materials such as carbon fibre, which would have been perfect because of its strength, cannot be used as it is electrically conductive. The transmitter wire is of aluminium, 3cm in diameter and with a total length of over 400m, has a total resistance of only 0.2 Ω. For the work in Yemen, 12 windings were used, but more can be added to increase the dipole moment. If the transmitter current is up to 20 amp then the dipole moment of the transmitter is 18 000 amp.m^2. However we mostly used a 10 amp current to be able to work longer with the lead acid battery.

The receiver loop, as part of a central loop configuration fits snugly around the waist of the balloon, has a 2.5m radius and is manufactured the same way as the transmitter loop. The loop has to be able to expand and contract with the pressure of the He inside the balloon. The receiver loop has 16 windings. An additional resistor of between 100 and 200 Ω is normally placed parallel over the receiver loop to dampen the loop response.

The transmitter and receiver electronics, GPS and battery (lead-acid) as well as other equipment is carried in a plastic basket below the balloon. Data from the TDEM system is sent to a HP Ipaq handheld PC by BlueTooth communication.

To provide extra lift a smaller ballon can be seen on top of the bigger one. Utmost care must be taken when windy conditions arise because the balloon has got the capacity to drag the operators in medium strength winds. It is best operated from 6:00 to 10:00 and again from 15:30 to 19:00. However the advantage is the possible measurement of hundreds of soundings per day against perhaps 50 or 60 soundings when laying out the loops by hand.

A docking station is also necessary to keep the balloon safe when not in use. The docking station has to be anchored properly as under strong wind the balloon can move the docking station.

Figure 1. TDEM ballon in operation in Yemen. The loops are about 5m above the surface.

TDEM Equipment.

The TDEM equipment used is a custom built Cycle 7 TDEM system, built by Elta-Geo of Novosibirsk, Russia. The number of time channels are programmable, there are 128 but only the data from the first 64 channels were used for the work in Yemen. The transmitter on- and off times are also programmable and for Yemen a 4 millisecond on and 8 milliseconds off sequence was used. The off time can be set, up to 1 minute. The transmitter waveform is the traditional half sine.

No build-up of static electricity was observed on the balloon.

THEORETICAL CONSIDERATIONS.

Spies (1989) pointed out that the time at which the electromagnetic response of a buried conductive entity can be first measured, is determined by its depth of burial and the average conductivity of the overlaying medium. The response time is therefore independent of the type of source or receiver or their separation. From Spies(1989) the maximum depth **d** of investigation for a central loop configuration can be determined from the near zone approximation

$$\mathbf{d} = 0.55*(I*\rho A/\acute{\eta})^{0.2}$$

where I = current, ρ = medium resistivity, A = surface area of the loop and ή = noise level. For 10 Amp and ή = 0.5 nV/m^2 a depth of investigation of ~100m can be achieved, depending on the noise level.

The TDEM apparent resistivity is calculated from the near zone equation for a central loop configuration (Niu, 1992):

$$P_a = \mu_0/4\pi t(2\mu_0 ab/5tV)^{2/3}$$

where a is the transmitter loop area, b is the receiver coil equivalent area, V is the measured induced electromotive force, normalised by the transmitter current and t is the measurement time. The apparent depth H is derived from the diffusion depth as given by Spies, (1989) as

$$H = K(\rho_a t/2\mu_0)^{0.5}$$

where K is an adjustment factor (commonly K<1). With the above two expressions apparent resistivity and depth profiles are generated but in future more sophisticated interpretation may follow.

In Figure 2 the raw receiver signal appears for 2 individual soundings, the left on a more resistive medium than appears on the right hand side. The first sounding shows noisy data towards the end of the recording that sometimes is consistent on adjoining soundings.

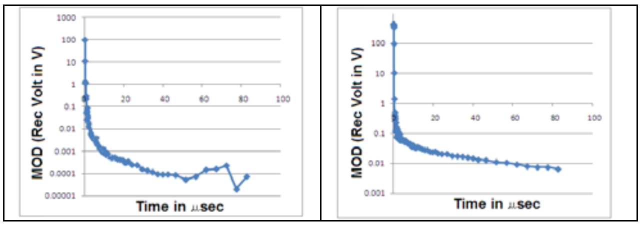

Figure 2. Two example soundings from the balloon TDEM system.

APPLICATION.

The N'teisha gold prospect is south of the Wadi Medden ore body in the southern part of Yemen about 100 km NW from the coastal town of Al Mukalla. The gold occurrences were originally discovered by Hunting Geology and Geophysics and further mapped out by Russian and former East German geologists between 1985 and 1988 in the former Peoples Democratic Republic of Yemen. The gold occurs in steeply dipping shear zones filled with a quartz-carbonate-sulphide vein material varying in width from a few centimetres to 2m. Most mineralised zones trend NNW and dip 60-80^o E. The host rock of the shear zones are lavas and pyroclastics, ranging from andesite to basalt. A set of NNW trending hornblende-porphyry dykes pre-date the gold mineralization and largely controls the distribution of the gold bearing shear zones (Parker, 1996).

The surrounding rock (andesite to basalts) is magnetic; the mineralized shear zones have a very slight consistent magnetic signature that can be mapped out by a very small station spacing. However a pervasive magnetic signature 'grain' with also a NNW trend, yet unexplained, hampers the identification of the mineralized shear zones on magnetic data alone. Therefore the presence of a nearby hornblende-porphyry dyke increases the confidence in locating new shear zones because the dykes controlled the mineralization. However a second or third geophysical method is necessary to identify shear zones positively with confidence. TDEM was applied to determine its effectiveness in identifying the shear zones and their structural behaviour. A number of traverses were completed over the N'teisha shear zones. Figure 3 below shows the location of one traverse and the measured resistivity section along the traverse. Note that highly resistive rocks are coloured red and purple hues. Although the resistivity section shows the location of 2 shear zones that approximately fit the locality of the outcropping shear zones there is a slight discrepancy between the mapped position of the shear zones and the position indicated on the TDEM section, which makes one hesitant in ascribing the TDEM results as being able to locate the mineralised shear zones with confidence, because the surrounding rock on its own is also highly fractured.

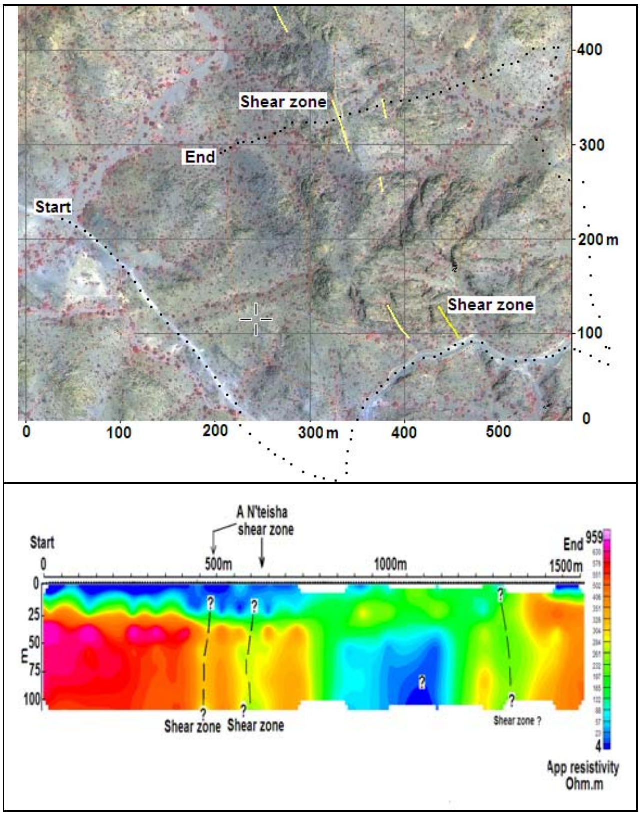

Figure 3. The top image shows the location of the traverse on a Quick Bird image. The bottom image depicts the apparent resistivity section along the traverse.

The slightly more conductive zones in the resistivity pseudo section have an almost vertical dip which may not correspond with the true dip of the N'teisha shear zones.

A very conductive region underlies a part of the pseudo section and still has to be further investigated.

CONCLUSIONS.

An alternative to doing TDEM soundings on the surface in difficult terrain has established. Although the Helium adds considerably to the cost of doing TDEM soundings this is compensated by the increase in production. The noise levels on the sounding data are comparable to those achieved with soundings recorded on the ground. No receiver base station was used to remove spherics noise.

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