High-Resolution Near Surface Airborne Electromagnetics – SkyTEM Survey for Uranium Exploration at Pells Range, WA

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SUMMARY

The SkyTEM airborne EM system has been deployed in Australia since late 2006, and has been flown for a variety of applications including salinity mapping, palaeochannel detection, geological mapping and base metals exploration. Economic geological applications of the system have included gold and uranium exploration, as well as direct detection of massive sulphides. The SkyTEM instrument was designed to produce airborne electromagnetic data of a quality comparable to that which can be obtained from existing ground TEM systems, and is unique in that it can alternately transmit in low-moment, early-time sampling, and high-moment, late-time sampling modes, thus providing a combination of high-resolution shallow information with a maximum depth of exploration comparable to that of other contemporary EM systems. The instrument directly measures parameters crucial to quantitative interpretation of the electromagnetic data, including pitch, roll and altitude of the transmitter and receiver as well as transmitted current.

We demonstrate application of the SkyTEM system to palaeochannel mapping for uranium exploration at Pells Range, Western Australia. The SkyTEM data is shown to provide results in very good agreement with geological mapping and regional-scale drilling. The SkyTEM survey successfully mapped a paleochannel system within the Moogooloo Sandstone which is host to the uranium mineralisation.

Key words: airborne electromagnetics, SkyTEM, uranium, laterally-constrained inversion, spatially-constrained inversion.

INTRODUCTION

The SkyTEM system is a configurable, broadband helicopter electromagnetic system originally designed for groundwater exploration and aquifer vulnerability mapping (Sorensen and Auken, 2004). The entire system is carried as an external sling load suspended from the helicopter as shown in Figure 1. No operator is required in the helicopter. The measurement configuration is based on a 314 m^2 or 494 m^2 transmitter (Tx) loop and vertical and horizontal in-line axis receiver (Rx) coils. Tx and Rx geometry is illustrated in Figure 2.

Transmitter

The transmitter loop is roughly hexagonal with nominal diameter which can be configured to vary from about 15m – 30m. The 4 turn transmitter loop is mounted on a light weight wooden/PVC lattice frame, and is powered by a motor generator, which is suspended on the tow cable between the helicopter and the loop (Figure 1). Total weight of the system, including electronics and generator, is 300 – 400 kg, depending on the Tx loop size.

A unique feature of SkyTEM is that the system is capable of operating in a dual transmitter mode:

- Low moment (LM) mode where low current, high base frequency and fast Tx switch off provide early time data and high spatial sampling for shallow imaging;
- High moment (HM) mode, where a higher current and lower base frequency provides high quality late time data for deep imaging.

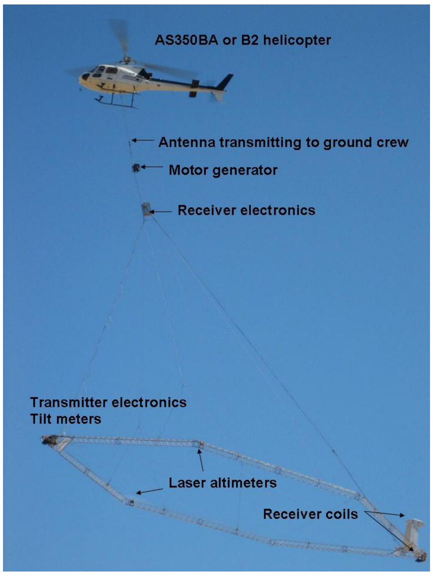

Figure 1. SkyTEM system in operation in Australia, October 2006 (314 m^2 Tx loop).

The system can operate in either the LM or HM mode, or in a combined (dual) mode. In dual mode, LM and HM data are acquired sequentially, (although the LM mode only uses one Tx turn). The exact sequencing of HM and LM measurements is completely programmable, and can be designed to trade off vertical versus horizontal resolution depending on the specific survey objective.

Transmitter waveform specifications in the LM and HM modes are as follows:

Low moment

- 1 transmitter turn
- Current approx. 35 A
- Peak moment (494 m^2 Tx loop): 16,800 nAI
- Repetition frequency typically 222.22 Hz (programmable)
- Switch off ~6 microseconds.

High moment

- 4 transmitter turns
- Current approx. 100 A
- Peak moment (494 m^2 Tx loop): 197,600 nAI
- Repetition frequency 25 Hz
- Switch off typically 40 microseconds.

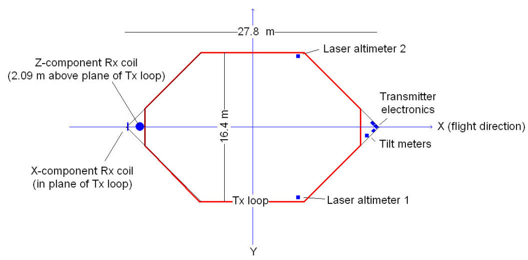

Figure 2 SkyTEM transmitter-receiver geometry for 314 m^2 loop.

The nominal LM and HM Tx current waveforms are shown in Figure 3. The Tx waveform is measured on the ground once per month to verify correct Tx operation. Unlike some other airborne electromagnetic systems, it is not possible to record the SkyTEM waveform in flight (e.g., at high altitude) as both Rx coils are null-coupled to the Tx in order to avoid saturating the Rx electronics and to suppress any primary signal in the off-time due to any leaking current in the Tx loop. The waveform shape and timing are temperature-independent, whereas the amplitude (ie peak current) depends on the ambient temperature during survey operations. The peak Tx current is recorded just before the onset of the Tx current ramp for each transient recorded during a survey. During data processing and interpretation, the measured peak current is used to scale the amplitude of the complete waveform.

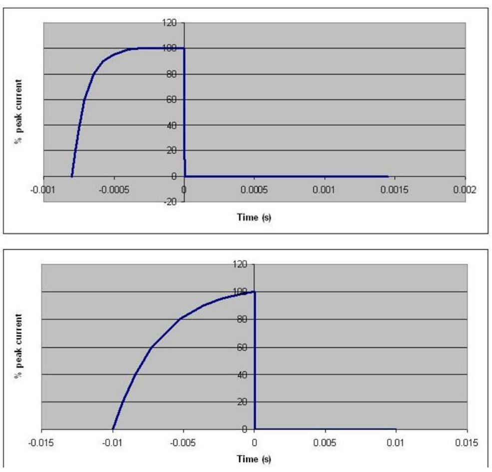

Figure 3 SkyTEM low-moment (top) and high-moment (bottom) transmitter current waveforms.

The SkyTEM instrument also has a very low drift and a self-response (bias) which can be demonstrated to be below the natural EM noise level. These qualities mean that there is no requirement for repeated high altitude flights during survey operations to check system drift, and that no levelling of the final measured responses is required.

Receiver

The receiver coils are shielded, overdamped, multi-turn loops, with a first-order cut-off frequency of 450 kHz. The effective area of the coils is 31.4 m^2.

The TEM receiver instrument is suspended on the tow cable between the helicopter and the Tx loop (Figure 1). The receiver samples the transient decay at 20 delay times in LM mode (designated channels 2 – 21), and 24 times in HM mode (designated channels 7 – 30). Receiver channel delay times are measured from the top of the current turn-off ramp (0 s in Figure 3).

In LM mode, the channel centre times range from 11.8 microseconds up to about 1.14 milliseconds, and in HM mode from 50 microseconds to 8.8 ms. The receiver electronics have a first-order cut-off frequency of 106 kHz.

FIELD EXAMPLE

A 1200 line km SkyTEM survey was flown over the Pells Range area in April 2007, on behalf of NewEra Uranium Ltd. The survey area is located approximately 35 km west of Gascoyne Junction. The survey boundary is shown in blue in Figure 4. Flight lines were oriented SW-NE and were spaced at 200 m. The survey was flown in dual transmitter mode, with a 314 m^2 transmitter loop. Peak transmitter moments at high and low-moments were 12,500 A.turn.m^2 and 100,500 A.turn.m^2 respectively.

Data from the Pells Range survey has been interpreted using both laterally-constrained inversion (LCI, see Auken et al., and Reid et al., this volume) and a newer inversion algorithm, spatially-constrained inversion (SCI, Viezzoli et al, this volume). The SCI was confined to an area of known uranium mineralisation identified during a regional exploration program by AFMECO in the 1970's (red outline on Figure 4). Uranium assays of up to 2.5 kg/t have been obtained in the area.

The known uranium mineralisation is hosted within the Permian Moogooloo Sandstone (Fairburn, 1977; Kwitko, 1978). Within the main area of interest (red outline in Figure 4), the sandstone dips to the NNW at around 9°. The sandstone unconformably overlies a fossiliferous limestone of the Permian Callytharra Formation. All uranium exploration drillholes in the area were terminated upon encountering the limestone, so its precise thickness distribution is unknown. However, Fairburn (1977) reports the limestone to be around 55 m thick in the Pells Range area. The Moogooloo Sandstone is overlain by interbedded sandstones, siltstones, shales and quartzwacke of the Permian Billidee and Coyrie Formations. Quaternary cover includes alluvium in the modern channel of the Gascoyne River, and colluvium forming scree and talus slopes.

Uranium mineralisation identified during previous exploration occurs within paleochannels in the Moogooloo Sandstone containing interbedded zones of carbonaceous siltstone. Gamma logging of regional drillholes has demonstrated an association between the carbonaceous content within the sandstone and uranium mineralisation. Borehole resistivity logs indicate that the carbonaceous intervals are more conductive than the host sandstones.

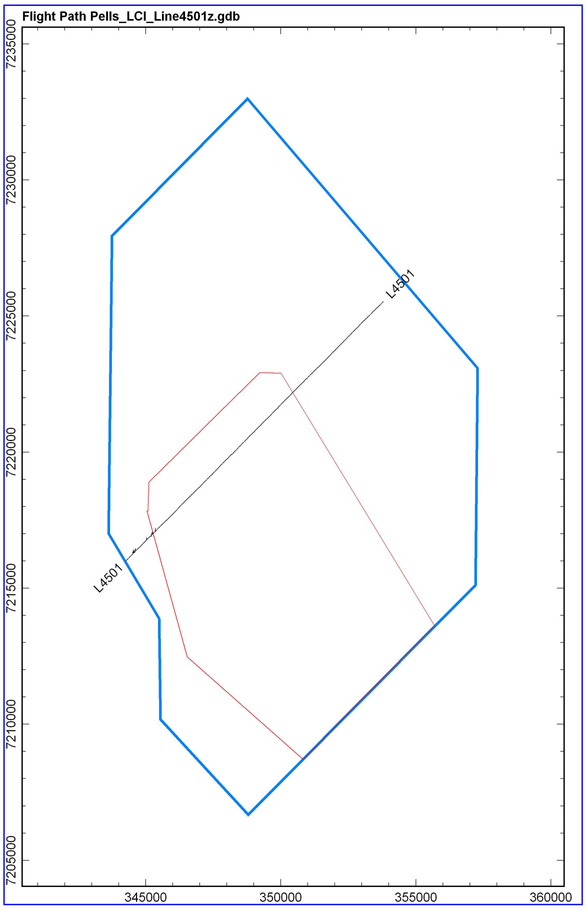

Figure 4 Pells range SkyTEM survey area (blue). The detailed area shown Figures 5 and 6 is outlined in red.

Figure 5 shows a plan image of the mean conductivity within the 0-10 m depth slice derived from the SCI. Correlation with outcrop geology maps shows that the Callytharra Formation limestones are resistive (~9 mS/m) whereas the overlying Moogooloo Sandstone has a higher conductivity of around 20~mS/m. Sequences overlying the Moogooloo Sandstone (Billidee and Coyrie Formations) are highly conductive (~100 mS/m). Quaternary alluvium in the Gascoyne River Valley has conductivity ~50 mS/m.

Figure 6 shows the 50-60 m depth slice from the SCI. An anomalous zone of elevated conductivity, ~3 km in N-S extent, can be identified within the Moogooloo Sandstone at around 349800E, 7214500N, highlighted by the yellow arrow. These anomalous conductors are interpreted as being palaeochannels which contain carbonaceous material, and host the uranium mineralisation. Several well-defined paleochannels can be identified in this and other depth slices. Analysis of deeper depth slices (not shown) indicates that the depth to the channels increases to the NW, consistent with the known geology.

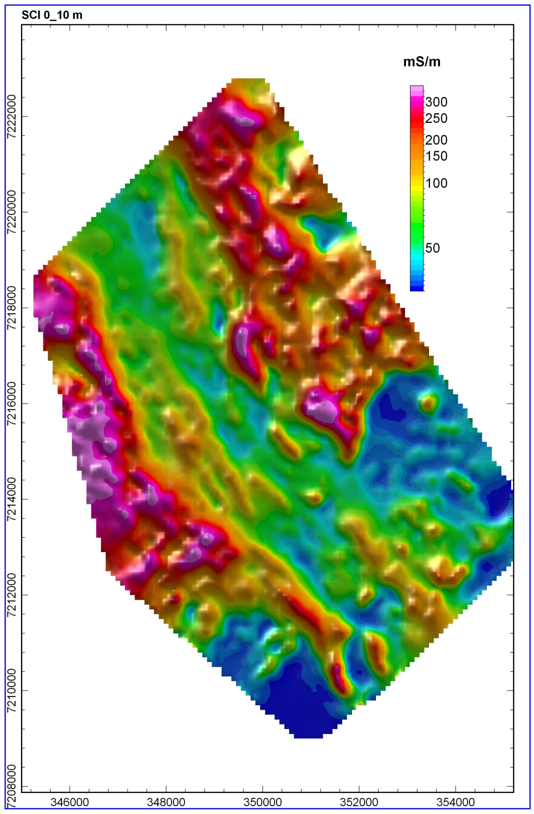

Figure 5 0-10 m SCI depth slice. The moderately-conductive zone trending NW through the centre of the area is the modern valley of the Gascoyne River. Highly conductive areas in the NE and NW correspond to outcrop/subcrop of the Coyrie and Billidee Formations. Resistive zones in the SW and SE correspond respectively to Callytharra Fm Limestones and Moogooloo Sandstone.

Figure 7 shows a conductivity cross section derived from the LCI for Line 4501 (Figure 4), annotated with a geological interpretation.

CONCLUSIONS

SkyTEM is a high-resolution helicopter TEM system highly suitable to quantitative geological mapping. When operated in the dual high- and low-moment mode the system provides both high shallow resolution and good depth of investigation. The instrument also has a self-response below the natural noise level, and there is therefore no requirement for drift-correction or levelling of the data.

A recent SkyTEM survey at Pells Range has yielded results consistent with mapped geology and extensive regional drilling. The survey clearly identified a palaeochannel system within the Moogooloo Sandstone which is associated with known uranium mineralisation, and has provided clear targets for follow-up drilling.

ACKNOWLEDGMENTS

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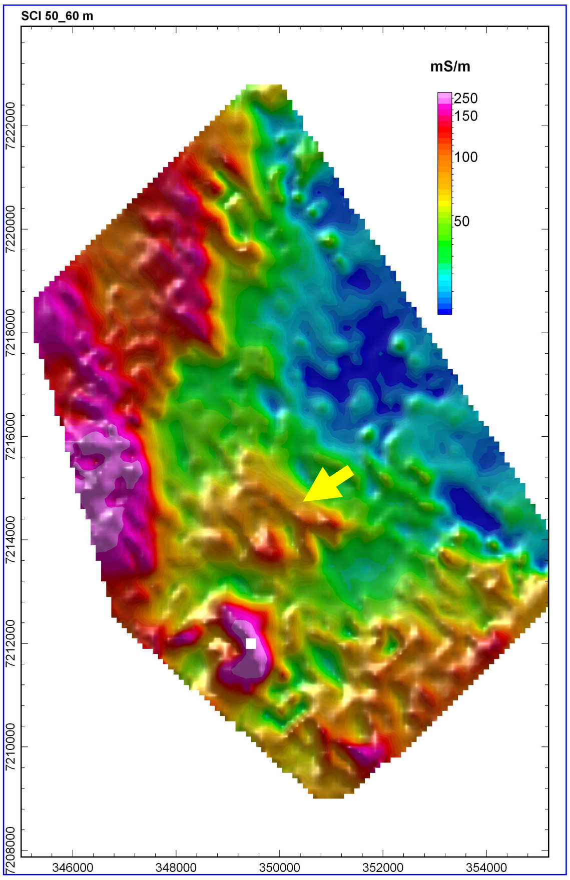

Figure 6 50-60 m SCI depth slice. The arrow indicates the anomalous conductors interpreted as carbonaceous palaeochannels within the Moogooloo Sandstone. Thick Coyrie and Billidee Fm cover is present in the NW of the area.

REFERENCES

Fairburn, W. A., 1977, Carnarvon Basin TR 6330H Annual Report 1977: AFMECO Pty. Ltd. Report WA262D.

Kwitko, G., 1978, Carnarvon Basin TR 6330H, TR6328H, 6329H, 6331H and 6623H Annual Report 1978: AFMECO Pty. Ltd Report WA288D.

Sorensen, K. I and Auken, E., 2004, SkyTEM – a new high-resolution helicopter transient electromagnetic system: Exploration Geophysics, , **35** 191-199.

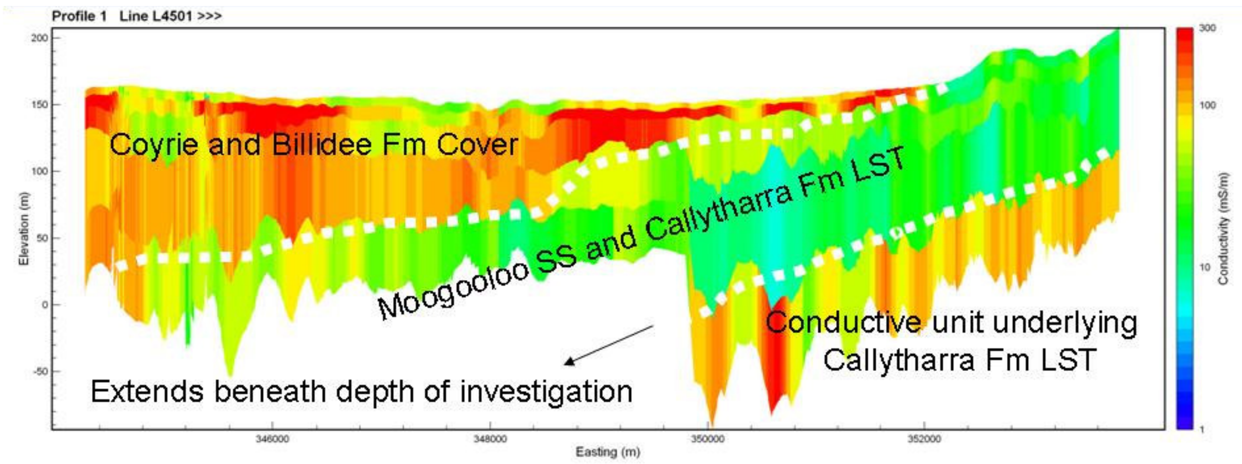

Figure 6 LCI conductivity cross-section from Line 4501 (Figure 4).