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First look at data from a three-dimensional audio-magnetotelluric survey at the McArthur River mining camp, northern Saskatchewan[1,2]

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Abstract: As part of EXTECH IV, three-dimensional audio-magnetotelluric data were collected in the McArthur River uranium mining camp, northern Saskatchewan. One hundred and thirty five audio-magnetotelluric stations were acquired along 11 profiles over the P2 and P2 North mineralized zones with an average site spacing of 300 m. The new audio-magnetotelluric data extend the coverage of an earlier two-dimensional survey and were acquired to provide a three-dimensional view into the subsurface conductivity structure of the McArthur River deposit, the overlying Athabasca Group sandstone, the basement rock types and offsets, and the alteration assemblages associated with the deposit. Digital comb filters were tuned to and removed strong harmonics; then robust audio-magnetotelluric responses were calculated. The resulting induction arrows map different domains of coherent and complex electrical strike. Data qualities and distribution are ideal for the next stage — calculation of a three-dimensional audio-magnetotelluric model.

Résumé : Dans le cadre du programme EXTECH IV, on a recueilli des données audio-magnétotelluriques tridimensionnelles dans le camp minier uranifère de McArthur River, dans le nord de la Saskatchewan. Les données ont été recueillies à 135 stations espacées en moyenne de 300 m, le long de 11 profils recoupant les zones minéralisées P2 et P2 North. Ces nouvelles données audio-magnétotelluriques, qui étendent la couverture d'un levé bidimensionnel antérieur, ont été recueillies afin de représenter en trois dimensions la structure de la conductivité du sous-sol liée au gisement de McArthur River, aux grès sus-jacents du Groupe d'Athabasca, aux lithologies du socle et à leurs rejets transversaux, ainsi qu'aux assemblages d'altération associés au gisement. Des filtres en peigne numériques ont été ajustés sur un puissant signal harmonique afin d'en éliminer les effets; on a ainsi pu calculer de solides réponses audio-magnétotelluriques. La carte des vecteurs d'induction qui a été élaborée permet de représenter différents domaines où les directions électriques sont cohérentes ou complexes. La qualité et la répartition des données sont idéales pour entreprendre l'étape suivante : le calcul d'un modèle audio-magnétotellurique tridimensionnel.

[1] Contribution to the Targeted Geoscience Initiative (TGI) 2000–2003.
[2] Contribution to the 2000-2003 EXploration Science and TECHnology [EXTECH IV], Athabasca Uranium Multidisciplinary Study [AUMS]

INTRODUCTION

The EXTECH IV Athabasca uranium multidisciplinary study project (Jefferson et al., 2003a, b, c) comprises a diverse set of geoscientific components to test methods for enhancing the development of a mature uranium exploration and mining camp. Situated near the base of the Athabasca Basin, uranium deposits are found at depths up to 1 km below the surface and are commonly associated with electrically conductive graphitic material in the basement gneiss of the buried Precambrian Shield. A magnetotelluric component was added to the EXTECH IV program during 2000 using funding provided by the Targeted Geoscience Initiative program and the EXTECH IV industrial partners. Reports have been published of the two-dimensional profiling carried out in 2000 (Craven et al., 2001) and 2001 (Craven et al., 2002, in press). Herein, we present preliminary plots of the data from a recent three-dimensional survey over the McArthur River deposit (location shown in Jefferson et al., 2003a, Fig. 2), discuss their preliminary analysis, and present plans for future work.

The first objective of the magnetotelluric subproject within EXTECH IV is to evaluate a natural-source electromagnetic technique as a tool in the search for graphitic material associated with deep uranium ore in the Athabasca

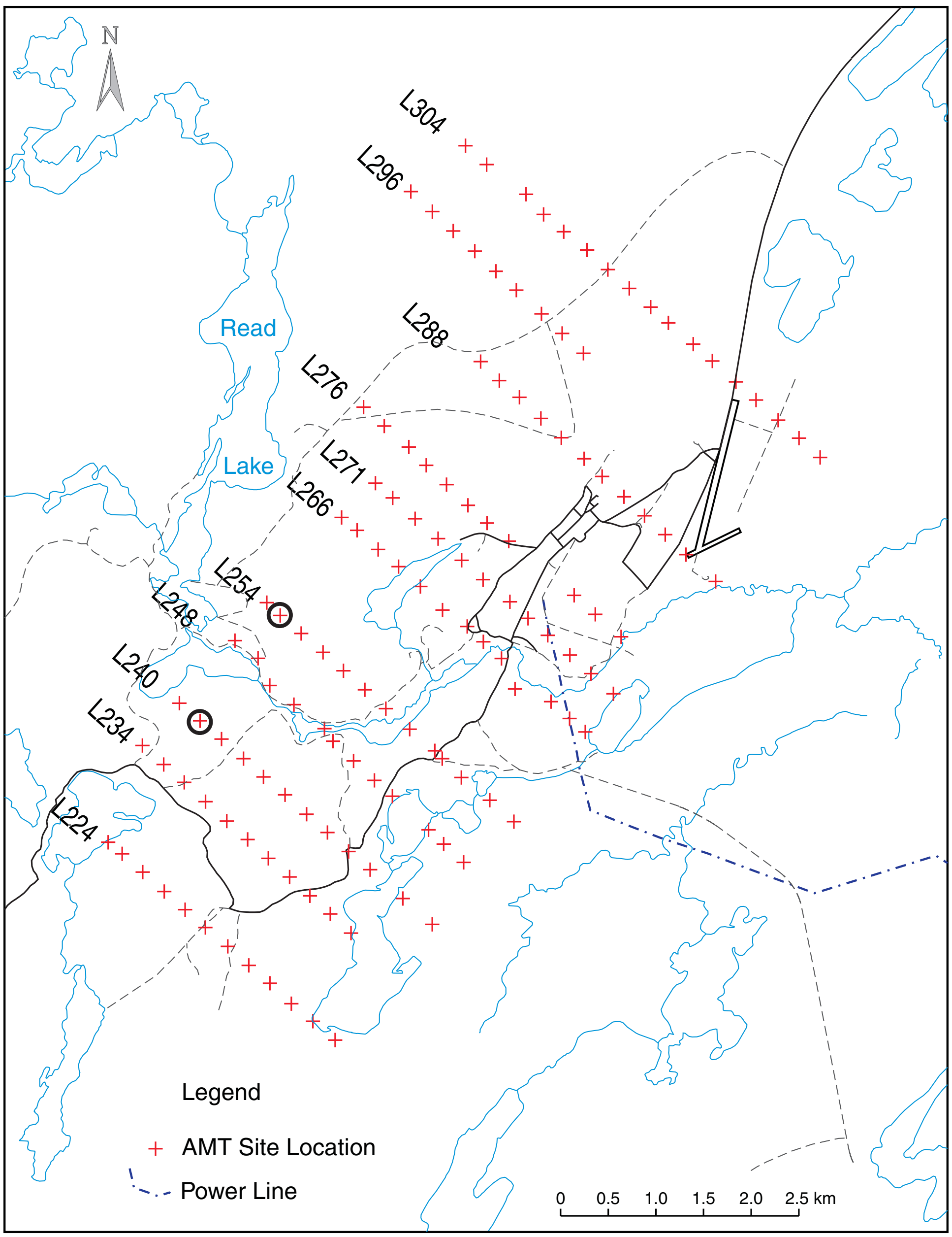


Figure 1. *Three-dimensional audio-magnetotelluric sites for 2002. Sites along the 11 lines were acquired in 2002. Data from two sites are shown in Figure 3.*

Basin. To achieve this goal will require an evaluation of recent enhancements to data-collection equipment (e.g. 24-bit analog to digital conversion) and processing techniques (e.g. robust signal processing algorithms). This objective was investigated with the two-dimensional magnetotelluric profiling and modelling at Shea Creek and McArthur River discussed in Craven et al. (2001, 2002, in press). The Shea Creek and McArthur River survey locations are shown in Jefferson et al. (2003a, Fig. 2). The primary conclusion of those studies was that magnetotellurics can detect subsurface conductivity contrasts attributable to basement and sedimentary alteration assemblages and that overall, it is an effective tool in the exploration for structures such as those observed in the McArthur River area.

The success of these activities prompted the three-dimensional survey in the McArthur River region. The primary goal of the new three-dimensional acquisition program was to determine the ability of magnetotellurics to map in three dimensions the variations in 1) regional resistivity contrasts within the basin and underlying crust associated with changes in basin sandstone porosity or brine content of an interconnected fluid phase, 2) undulation of the basement–sedimentary interface, 3) alteration zones associated with subvertical faults or the unconformity, and 4) tectonically disturbed graphitic conductors in the sub-Athabasca basement.

MAGNETOTELLURIC ACQUISITION PROGRAM

The magnetotelluric proposal was approved in March 2002 and the survey was completed in July 2002, having been delayed in part by forest fires in the area. The magnetotelluric data were acquired in the audio frequency range of 1 to 20 000 Hz (hence the reference to audio-magnetotellurics in the remainder of this paper) using three Metronix 24-bit ADU-06 systems. One system was a fixed reference station in a culturally quiet location, whereas the other two were deployed within the survey area, an active mine site. Each audio-magnetotelluric measurement (Fig. 1) location consisted of a perpendicular pair of 50 m dipoles, two orthogonal magnetic field sensors, and one vertical magnetic field sensor. Survey lines (Fig. 1) were chosen to match a recent pole-dipole survey so as to reduce the line cutting required for the survey and facilitate possible future comparison and constrained inversion of the two data sets. Two crews collected the data during the daytime over a one-week period at a rate of 16 to 26 sites a day.

PRELIMINARY DATA ANALYSIS

The time series at each site were examined and it was immediately obvious that a strong harmonic noise source, with a fundamental frequency at 850 Hz, was contaminating the time series (Fig. 2). The origin of this noise source is unknown. Digital comb filters tuned to the harmonics were used to remove their effects and robust audio-magnetotelluric responses were calculated (Larsen et al., 1996). The responses shown in Figure 3 were obtained using the multifrequency capability of the McNeice and Jones (2001) decomposition technique for the sites indicated in Figure 1. The data in Figure 3 are of extremely good quality and generally representative of the overall quality; however, data collected just west of the airstrip shown in Figure 1 are of lesser quality owing to the presence of electrical activity associated with the mine workings. The noisy responses in the audio-magnetotelluric 'dead-band' of 1 to 5 kHz may be related to lower signal levels generally associated with natural electromagnetic sources during the daytime (Garcia and Jones, 2002).

Induction arrows point toward lateral contrasts in conductivity within the subsurface; arrows should therefore be aligned orthogonal to the prevailing electrical strike directions (Parkinson, 1959; Jones 1986; Craven et al., 2001). In the region southwest of L254 (Fig. 4), the strike direction indicated by the induction arrows is generally orthogonal to the profiles (i.e. northeast-southwest). This is in agreement with earlier observations made by Craven et al. (2001) from the single two-dimensional profile wherein it was demonstrated that the arrows may be used to delineate linear basement graphitic units. In the northern portion of the survey

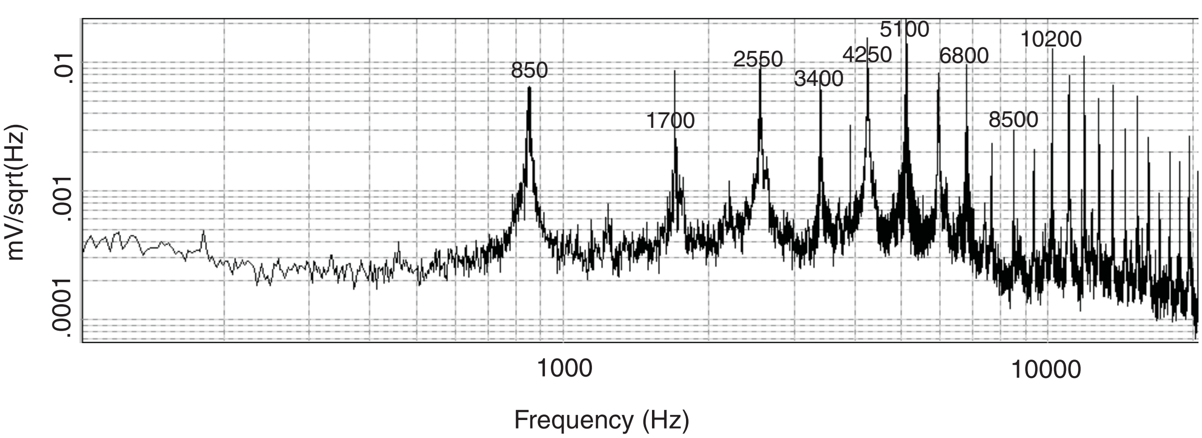
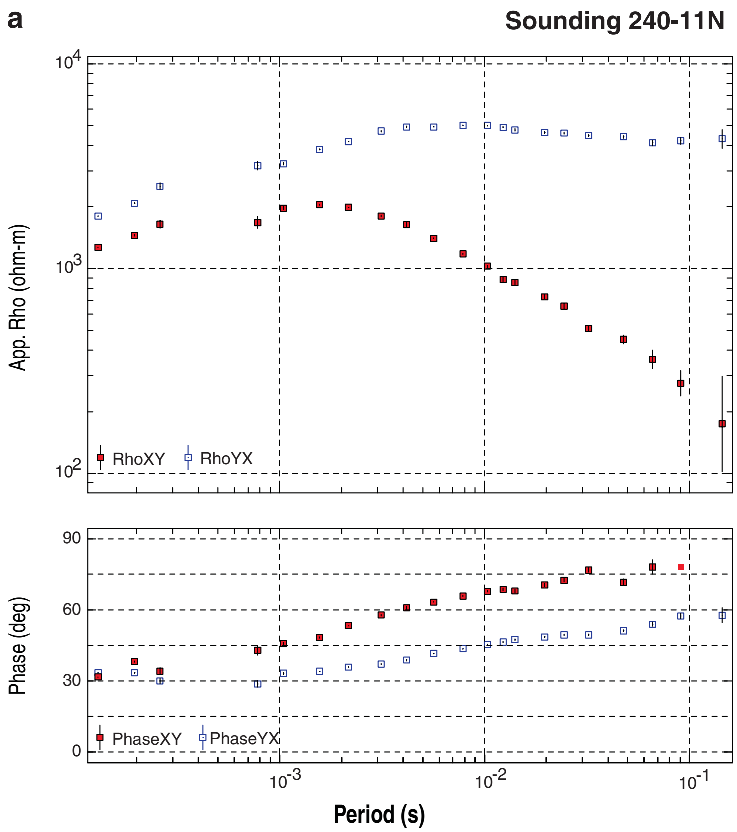


Figure 2. *Harmonics of 850 Hz within the electric-field data collected at the remote site.*



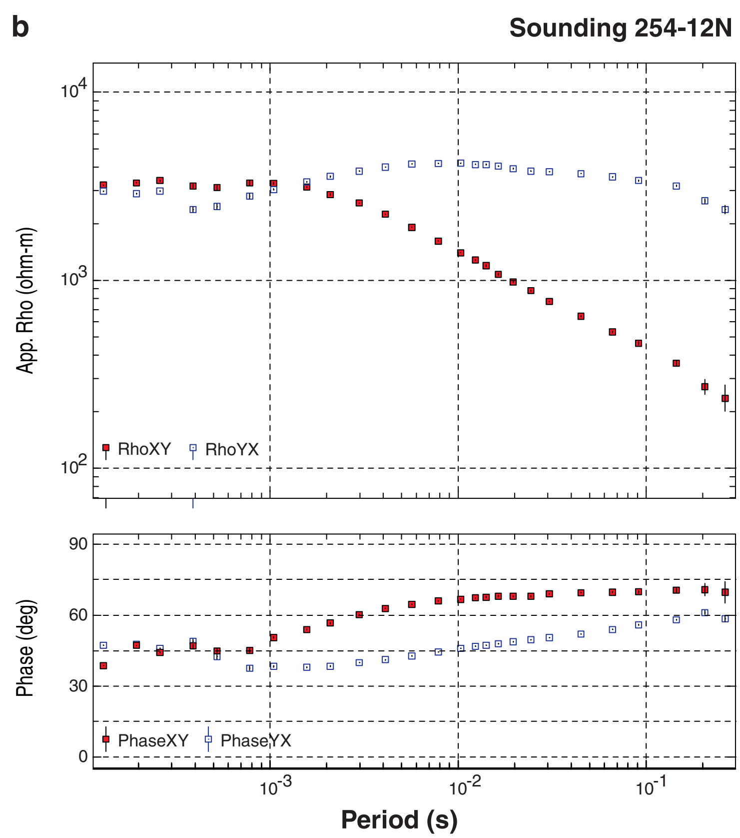


Figure 3.

*Plot of responses at **a**) site240-11N and **b**) site 254-12N (shown in Fig. 1).*

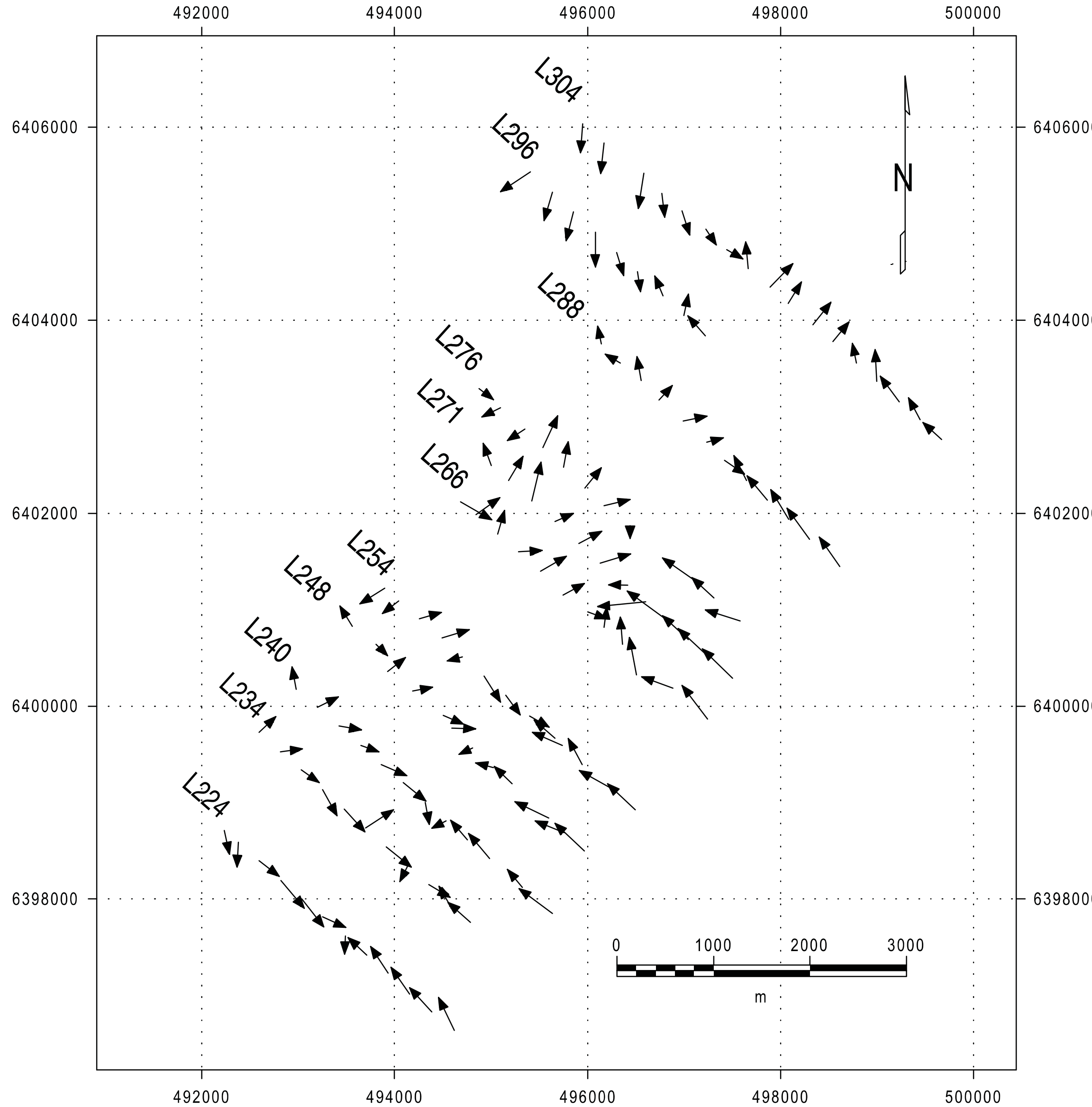


Figure 4. *Real induction arrows at 100 Hz.*

area, the strike directions inferred from the induction arrows suggest that the electrical structure is more complex and the graphitic basement units may be truncated along strike.

PLANS FOR FUTURE WORK

Full three-dimensional modelling of the audio-magnetotelluric data is an ambitious task; however, the existing data grid is perfect for such analyses. The primary hurdle to overcome is the determination of the appropriate lines to use two-dimensional algorithms. A useful by-product of this determination will be the identification of regions requiring three-dimensional analysis. Wherever possible, the data examination and modelling should take into account the vertical magnetic field as incorporation of this data into inversion has been shown to be particularly effective in discriminating between multiple conductors (Siripunvaraporn and Egbert, 2000). Rock property and borehole data (Mwenifumbo et al., 2002, in press) and other EXTECH IV data sets (e.g. White et al., 2003) must also be taken into account in order to constrain the inversion procedure.

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Charlie Jefferson provided invaluable guidance for generating an effective partnership within this subproject. The drafting staff at Cameco were extremely helpful in providing Figure 1. Cindy Hildebrand was thorough in the preparation work for this survey.

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