EXTECH IV Sub-project 1: Seismic Studies at the McArthur River Mining Camp

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Hajnal, Z., White, D.J., Reilkoff, B., Adam, E., Bellefleur, G., Koch, R., Powell, B., and Annesley, I.R. (2001): EXTECH IV sub-project 1: Seismic studies in the McArthur River mining camp; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2001-4.2.

Abstract

A multi-element seismic reflection acquisition program was conducted in northern Saskatchewan focusing on the McArthur River uranium mining camp. The program was designed to provide the subsurface geometry of the McArthur River ore deposits and the geology that hosts them. The seismic program consisted of 39 km of regional 2D seismic data acquisition along two profiles, eight kilometres of high-resolution data acquisition along two profiles, a limited 3D high-resolution survey including three-component recording, high-frequency three-component vertical seismic profiles, and a 3D three-component vertical seismic profile.

1. Introduction

As part of the EXTECH IV Athabasca Uranium Multidisciplinary Studies Project, seismic reflection and auxiliary downhole seismic surveys were conducted within the McArthur River uranium mining camp in winter 2001 (February and March). The seismic reflection program was multi-faceted and designed to address a variety of objectives of EXTECH IV uranium studies. Here, we report on the acquisition of the various seismic data sets and the objectives of each of these components. Preliminary results for the 2D high-resolution survey and the high-frequency VSP data can be found in the two papers by White *et al.* (this volume).

2. Objectives of the Seismic Project

The overall objective of the seismic sub-project is to image the subsurface geology on a regional as well as deposit scale (Hajnal *et al.*, 2000). Specifically, the objectives of the seismic study are:

1) to define the regional basement structure underlying the Athabasca Basin,
2) to define the subsurface stratigraphy of the sedimentary rocks within the basin,
3) to provide a detailed image of the basement unconformity which hosts the majority of the uranium ore deposits,
4) to characterize the basement unconformity using seismic attributes and identify attributes that define zones of mineralization,
5) to locate and image faults including those that have been instrumental in ore deposition, and
6) to determine the seismic signature of a known ore deposit.

The outcome of a successful program will result in enhanced, cost-effective tools that will facilitate exploration in the Athabasca and similar basins.

3. The Seismic Acquisition Program

Objective 1 is addressed primarily by the regional seismic reflection survey, and elements 2 to 6 are addressed by a variety of high-resolution components as described below.

The seismic acquisition program comprises the following objectives:

1) thirty-nine kilometres of regional 2D seismic profiling along lines A and B;
2) eight kilometres of high-resolution seismic profiling along lines 12 and 14;
3) limited 3D high-resolution survey;
4) high-resolution three-component recording;
5) high-frequency zero-offset and near offset-vertical seismic profiles; and
6) 3D Vertical Seismic Profile.

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Kinetex Inc. of Calgary, Alberta was contracted to acquire the seismic reflection data at McArthur River. They provided the equipment and crew to conduct elements 1 to 4 and 6 of the seismic acquisition program. In addition, downhole seismic recording equipment and crew were provided by the Geological Survey of Canada for objectives 5 and 6, and the University of Alberta provided a high-frequency Vibroseis truck for objective 5.

a) Regional 2D and High-resolution Seismic Profiles (Objectives 1 and 2)

A total of 39 km of regional 2D seismic reflection profiling was conducted along two lines (A and B in Figure 1) using the recording parameters shown in Table 1. A third regional profile planned along Line C (coincident with high-resolution line 14 shown in Figure 2) was abandoned due to limited access along the southeastern segment of the line because of thin ice/open water on one of the creeks. Instead, 1.5 km were added to the southeastern end of line B, and the source interval was reduced from 50 m to 25 m on the ends lines A and B to maximize the rate at which full fold coverage was achieved. Eight kilometres of high-resolution 2D profiling (Lines 12 and 14 in Figure 2; Figures 3 and 4) was completed using the acquisition parameters shown in Table 2. Preliminary processing results of these data are reported in White *et al.* (this volume).

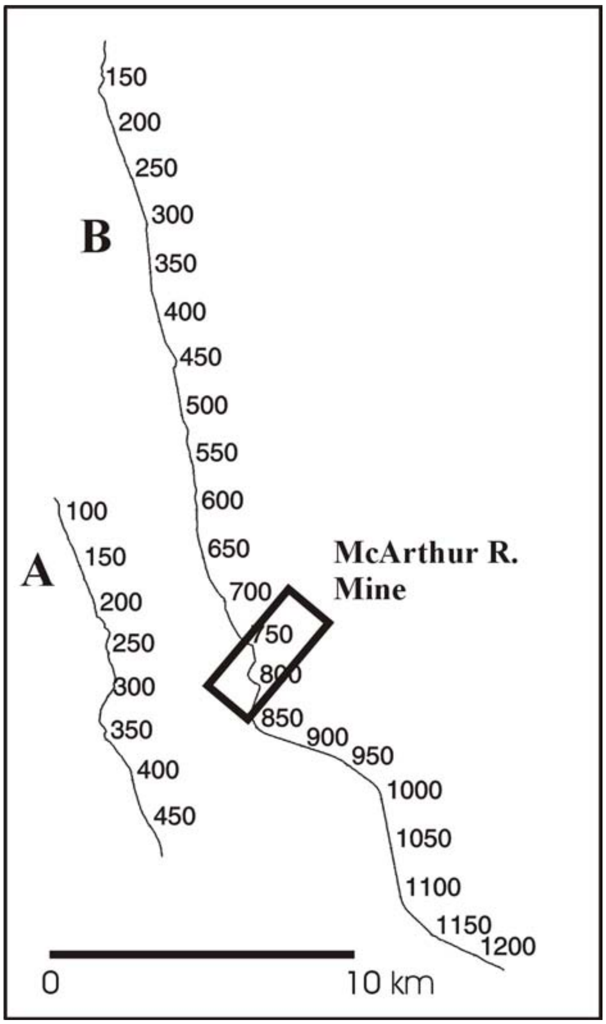

Figure 1 - Regional survey location and mining camp location. Survey parameters are given in Table 1. Survey station numbers are labelled.

Table 1 - Regional acquisition parameters.

Recording Instrument	IO-System 2000 24-bit telemetry with noise burst edit and diversity stack
Source	two to three, 22 000 kg IVI Y-2400 Vibroseis buggies
Peak Force per unit	47,700 lb
Number of recording channels	960 vertical component
Vibration point (VP) interval	50 m, 25 m for 3 km at line ends
Geophone group interval	25 m
Geophones per group	six over 25 m
Geophone type	10 Hz
Sample interval	4 ms
Sweep Frequencies	10 to 84 Hz linear upsweep
No. of sweeps per VP	six (4 Vibes) or 10 (3 Vibes)
Sweep Length	28 s
Record length (correlated)	18 s
Line ends	Roll-on, roll-off
Nominal stack fold	120

b) Limited 3D High-resolution Survey (Objective 3)

To obtain constraint on the true 3D geometry of structures imaged by the high-resolution survey in the immediate vicinity of the McArthur River mine, a limited high-resolution 3D survey was conducted. The concept of the 3D survey was minor augmentation of the 2D survey to obtain adequate 3D coverage. Initial design considerations for the limited 3D survey are described in Hajnal *et al.* (2000). The actual survey geometry is shown in Figure 5. Three-dimensional coverage was achieved by recording shots from the 2D lines on a series of cross-receiver lines (10, 4, and 6), as well as recording a series of auxiliary shot lines on these receiver lines and by receivers on the 2D lines (12 and 14). The acquisition parameters (similar to the 2D high-resolution parameters) are provided in Table 3. Combining the standard cable geophone channels and the VectorSeis geophones (deployed on lines 4 and 6), a total of almost 1600 vertical component recording channels were available for the 3D survey.

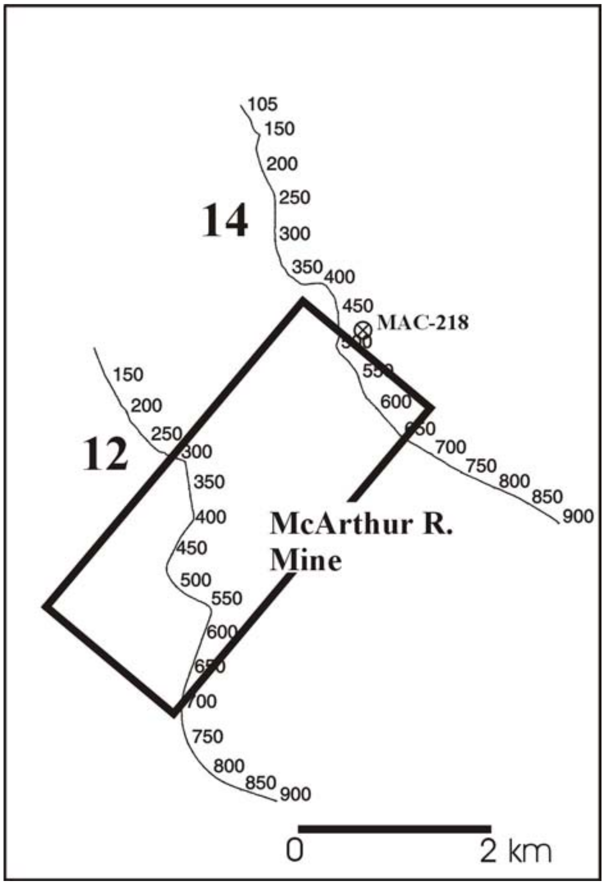

Figure 2 - Location of high-resolution survey lines and borehole MAC-218. Survey parameters are given in Table 2. Survey station numbers are labelled.

Table 2 - High-resolution acquisition parameters.

Recording Instrument	IO-System 2000 24-bit telemetry, with noise burst edit and diversity stack
Source	two 22 000 kg IVI Y-2400 Vibroseis buggies
Peak Force per unit	47,700 lb
Number of recording channels	960 vertical component
Vibration point (VP) interval	20 m
Geophone group interval	5 m
Geophones per group	six over 5 m
Geophone type	10 Hz
Sample interval	1 ms
Sweep Frequencies	30 to 170 Hz non-linear (3 dB/ octave) upsweep
No. of sweeps per VP	four
Sweep Length	12 s
Record length (correlated)	6 s
Line ends	Roll-on, roll-off
Nominal stack fold	120

Figure 3 - Kinetex Vibroseis truck used for regional and high-resolution profiling.

Figure 4 - Kinetex recording truck.

c) High-resolution Three-component Recording (Objective 4)

As a supplement to the standard 10 Hz vertical component geophone groups, the seismic contractor offered the use of 600 prototype VectorSeis three-component digital geophones for deployment on the cross recording lines (4 and 6). Addition of these units accommodated adequate coverage for the 3D survey, but also provided the opportunity to test three-component seismic reflection profiling for the first time (to our knowledge) in a mining camp. Modelling studies have suggested that the S-wave scattering response of steeply-dipping ore-bodies is stronger than the P-wave scattering response. As S-waves are best detected using horizontal-component geophones, use of the VectorSeis three-component (one vertical and two orthogonal horizontal components) geophones in the vicinity of a known orebody may allow the testing of these modelling results with applications toward the enhancement of seismic exploration techniques.

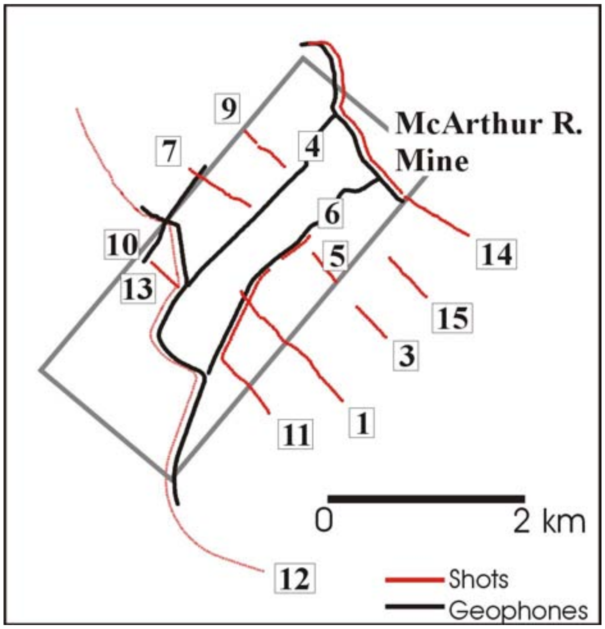

Figure 5 - 3D survey geometry. Survey parameters are given in Table 3.

Table 3 - 3D high-resolution acquisition parameters.

Recording Instrument	IO-System two 24-bit telemetry, with noise burst edit and diversity stack
Source	two 22 000 kg IVI Y-2400 Vibroseis buggies
Peak Force per unit	47,700 lb
Number of recording channels	960 vertical component 600 VectorSeis three-component digital phones
Vibration point (VP) interval	20 m
Geophone group interval	5 m vertical component groups 4.2 m VectorSeis three-component
Geophones per group	six over 5 m, vertical component groups one at station, VectorSeis three-component
Vertical Geophone type	10 Hz
Sample interval	1 ms
Sweep Frequencies	30 to 170 Hz non-linear (3 dB/octave) upsweep
No. of sweeps per VP	four
Sweep Length	12 s
Record length (correlated)	6 s

d) High-frequency Vertical Seismic Profiles (Objective 5)

Zero-offset and near-offset vertical seismic profiles (VSPs) were acquired using the GSC four-level downhole seismic acquisition system, deployed in borehole MAC-218 (see Figure 2 for location; Table 4). The seismic source was a mini-Vibroseis system from the University of Alberta (Figure 6). Full VSPs were recorded with the source located at distances of 27 m and 326 m from the borehole collar. The objectives of the VSPs and preliminary processing results for these data sets are reported in White *et al.* (this volume).

e) 3D Vertical Seismic Profile (Objective 6)

The four-level downhole seismic tool was used during the 3D survey (see above), which provides a means of constructing a low-fold 3D image of the subsurface in the vicinity of the borehole complementing the surface 3D image. Due to the location of the downhole system beneath the overburden layer, it provides the potential advantage of providing improved spatial resolution.

4. Acknowledgments

This is sub-project 1 of EXTECH IV, a partnership funded by the Geological Survey of Canada (Targeted Geoscience Initiative and Proposal Approval System), Natural Sciences and Engineering Research Council of Canada (NSERC), Saskatchewan Energy and Mines, Alberta Geological Survey, COGEMA Resources Inc., and Cameco Corporation. We thank the Cameco Corporation McArthur River minesite personnel for their cooperation and support during the seismic survey. Special thanks to Dan Brisbin for making logistical arrangements on our behalf. Geological Survey of Canada contribution 2001098.

5. References

Hajnal, Z., Reilkoff, B., Pandit, B., White, D., Adam, E., Matthews, R., and R. Koch, (2000): Seismic modeling prior to the EXTECH IV Athabasca Basin Seismic Reflection Survey; *in* Summary of Investigations 2000, Volume 2, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 2000-4.1, p104-109.

Table 4 - High-frequency VSP acquisition parameters.

Parameter	Zero-offset VSP	Offset VSP
Source	Mini-Vibroseis	Mini-Vibroseis
Sweep Frequencies	20 to 300 Hz linear upsweep	20 to 200 Hz linear upsweep
Sweeps per VP	four to eight	four to eight
Source offset from collar	27 m	326 m
Receiver spacing	2.5 m	5 m
Depth range covered	60 to 460 m	60 to 460 m
Number of recording levels	156	80
Recording Instrument	Oyo Seismograph	Oyo Seismograph
Downhole tool	four-level Vibrometrics	four-level Vibrometrics

Figure 6 - University of Alberta mini-Vibroseis truck.