Borehole Geophysical Logging of Two Deep Surface Boreholes and One Underground Borehole at McArthur River

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Abstract

Multi-sensor geophysical measurements including spectrometric natural γ-ray, spectral γ-γ density, full waveform sonic, resistivity, and temperature were made in two deep drill holes at McArthur River. The main objective was to expand our understanding of the geophysical characteristics of the basement rocks underlying the Athabasca Basin and to aid in the interpretation of surface high-resolution seismic and electrical survey data. There are significant differences in the physical rock properties between the basement rocks and the overlying sandstones that accurately define the sandstone/basement contact where there is minor alteration. Logging underground in the uranium ore zone indicates that uranium ore exhibits low velocities (<5 km/s) compared to the altered gneisses.

Keywords*: geophysics, Athabasca Basin, uranium, basement, ore, McArthur River.*

1. Introduction

This report summarizes the 2002 fieldwork for sub-project 2 of EXTECH IV – Athabasca Uranium Multidisciplinary Study, with emphasis on basement and ore parameters. Multi-sensor borehole geophysical logs were acquired in two deep boreholes at McArthur River; borehole MAC-265 and MAC-266, north and south of the P2 structure, respectively (Figure 1). Borehole MAC-265 was extended by EXTECH IV an extra 150 m into fresh basement in order to investigate the physical rock properties not yet determined in the boreholes that have been logged previously at McArthur River. Borehole logging also successfully measured *in situ* acoustic properties of high-grade uranium ore in one underground hole through the P2 North orebody.

2. Geophysical Logging

Multi-sensor borehole logs from McArthur River included natural γ-ray spectrometry (Total count, %K, eU, eTh), spectral γ-γ density, resistivity, full waveform sonic, and temperature. These data were acquired in the two boreholes, MAC-265 and MAC-266, between August 31 and September 4, 2002. Table 1 summarizes the logging results from each of the two boreholes and in one underground borehole (21-08) that intersected approximately 18 m of high-grade uranium ore. The underground borehole was logged to collect the *in situ* full waveform acoustic properties of high-grade uranium ore, for which very little is known (neither density nor compressional wave velocity (Vp)). The multiparameter probe was used for the underground logging, including temperature to help characterize the thermal characteristics of the ore body.

3. Local Lithology

Boreholes MAC-265 and MAC-266 intersected the four members of the Manitou Falls Formation (MFa, MFb, MFc, and MFd) as observed in other boreholes in the vicinity of the McArthur River P2 North deposit. The general description of the Manitou Falls Formation members is given in Mwenifumbo *et al*. (2000) and Bernier (this volume). Picks for members were made by G. Drever, Cameco Corporation, in the field. Digital data were provided to S. Bernier for further analysis that will be reported later. Basement rocks near the McArthur River P2 zone consist mainly of pelitic and semi-pelitic gneisses, calc-silicate gneiss, and pegmatites. A detailed description of the basement rocks intersected in MAC-266 that is given in Table 2. This hole also intersected a slightly mineralized fault zone in MFa near the unconformity.

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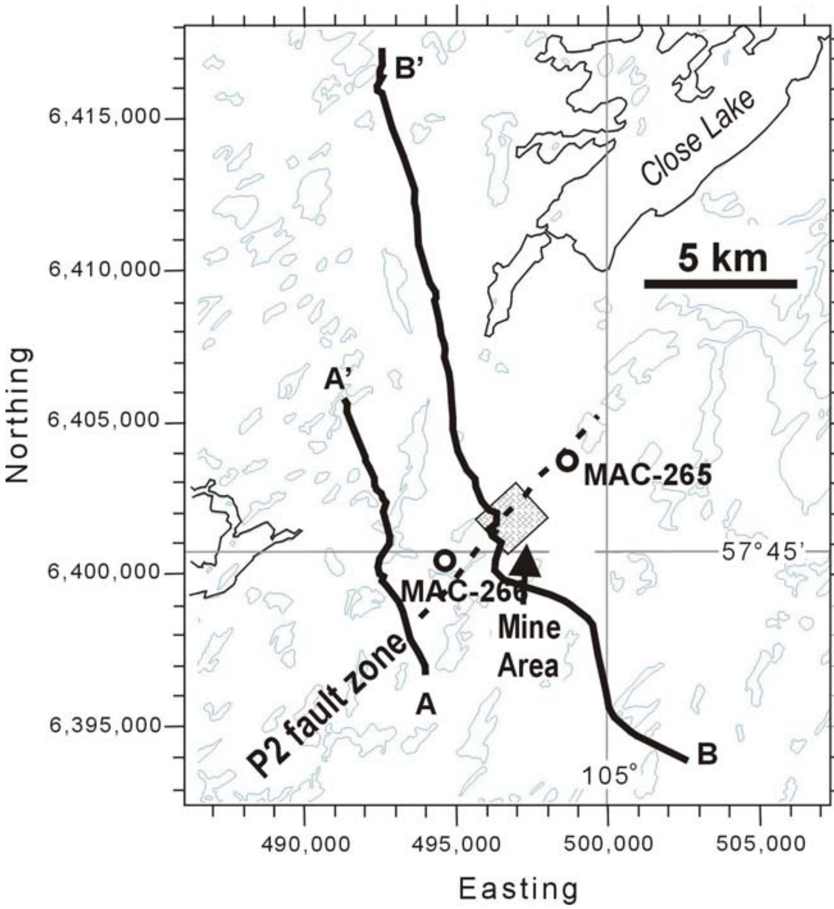

Figure 1 - Location map of the two boreholes, MAC-265 and MAC-266, in relation to the P2 fault zone, the P2 North mine area, and the two high-resolution seismic survey lines.

4. Geophysical Logging Results

Figure 2 shows the preliminary logging results from borehole MAC-265 including total count gamma-ray, galvanic resistivity, density, and compressional wave velocity (Vp) logs. The density and Vp logs indicate changes in these physical properties between 140 and 240 m. They are slightly higher compared to the sections above and below; density >2.5 g/cm^3 and the Vp >5 km/s. This section straddles the MFd and MFc members and therefore does not reflect changes in the stratigraphy. There is a very significant change in resistivity in this section, >9 KΩ-m. The current interpretation of this change in resistivity, density, and Vp, is that it reflects a decrease in porosity due to silicification. This interpretation is based on the previous observations in boreholes MAC-218, RL-088, and RL-092 in the McArthur River area (Mwenifumbo *et al*., 2000). These three parameters mainly respond to porosity changes in otherwise mineralogically uniform Athabasca sandstones. The uranium ore between 520 m and the basement/sandstone contact at 580 m exhibit lower density and Vp primarily due to an increase in the degree of fracturing and/or alteration that generally results in an increase in porosity.

Table 1 - Summary of logging conducted at McArthur River, Athabasca Basin, August to September 2002.

Borehole	Total (m)	Probe	No. of Runs	Date	Speed (m/min)	Logged (m)
MAC-265	1460	Multiparameter	2	2002-08-31	9	730
		Acoustic	2	2002-09-01	9 and 6	730
		Gamma	2	2002-09-01	9	730
		Density	2	2002-09-01	9	730
		IP/Resistivity	2	2002-09-02	9	730
MAC-266	1260	Multiparameter	2	2002-09-02	9	630
		Acoustic	2	2002-09-03	9 and 6	630
		Gamma	2	2002-09-03	9	630
		Density	2	2002-09-04	9	630
	1260	IP/Resistivity	2	2002-09-04	9	630
21-08	90	Multiparameter	2	2002-08-30	6	45
	90	Acoustic	2	2002-08-30	1	45

__Table 2 - Drill-core log description of borehole MAC-266, based on field logging by G. Drever and assistants, Cameco Corporation.__

From (m)	To (m)	Formation	Lithology
0	15.50	Overburden	
15.50	197.00	MFd	**Fine sandstone** with mudstone intraclasts and minor interbeds.
197.00	293.30	MFc	**Medium sandstone:** pebbly and cross-bedded.
293.30	406.00	MFb	**Interbedded conglomerate, sandstone and mudstone.** Sandstone is cross-bedded, mudstone planar and drab coloured.
406.00	515.30	MFa	**Interbedded** horizontally bedded **sandstone, conglomerate** and minor **red mudstone** interbeds and intraclasts.
515.30	540.75	FLZN	**Fault zone with basement wedge:** zone of sheared, brecciated, and faulted basement gneiss and conglomerate. Significant core loss, rotated bedding, and mylonitic fabrics, most intense adjacent to the 4 m wide basement wedge.
540.75	568.35	MFa	**Interbedded sandstone and conglomerate** is brecciated and mylonitized within the fault zone just below the basement wedge. Remainder of unit is strongly bleached and silicified to 557.3 m where there is a significant increase in maroon mudstone.
568.35	590.50	PELT	**Pelitic gneiss:** a well foliated medium-grained red to greenish grey pelitic gneiss. Red (hematitized) paleoweathering zone extends down to 575.3 m.
590.50	593.30	PEGM	**Pegmatite:** massive coarse-grained pegmatitic segregation.
593.30	605.00	SMPL	**Semi-pelitic gneiss** with several anatexitic zones ranging from 10 to 100 cm in width. The unit is typically well foliated.
605.00	619.20	PELT	**Pelitic gneiss:** medium-grained grey to greenish grey garnet cordierite pelitic gneiss with well-developed gneissosity. Trace graphite and weak to moderate disseminated pyrite. Graphite is present along foliation planes (605.3 m), but rarely in significant amounts. Pyrite is weakly disseminated and associated with narrow quartz pyrite veins and veinlets throughout the unit.
619.20	626.00	CALC	**Calc-silicate gneiss:** grey to greenish grey well-foliated medium-grained calc-silicate gneiss with a light and dark banding.

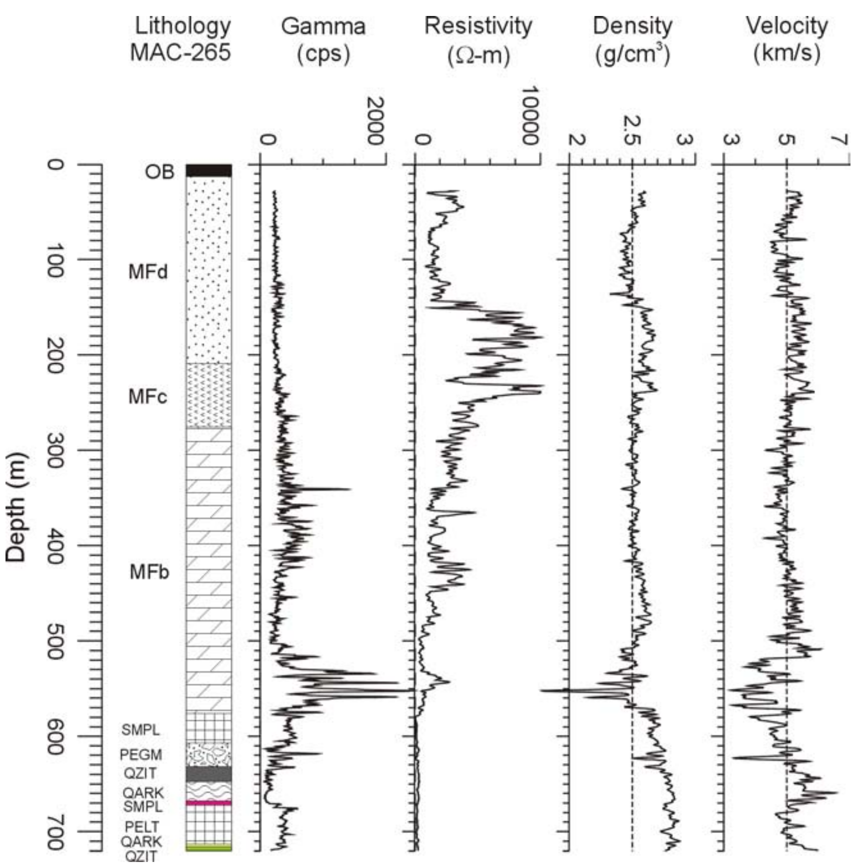

__Figure 2 - Total count gamma, resistivity, density, and velocity logs from MAC-265, north of the P2 ore zone. OB=overburden, MF=Manitou Falls Formation, SMPL=semipelitic gneiss, PEGM=pegmatite, QZIT=quartzite, QARK=quartz-rich arkose, and PELT=garnet cordierite pelite.__

Density is generally higher in the basement rocks compared to the overlying sandstone, (>2.65 g/cm^3). In the basement there is a general increase in density with depth and there is no distinct change in densities between the pelitic gneisses and the quartzites and pegmatites. The Vp log, however, shows distinguishable differences between quartzites and pelites; the quartzites having slightly higher velocities than the pelites. Detailed analyses of these data are underway. An interesting observation in the resistivity log is that fairly low resistivities are typical of basement rocks (~100 Ω-m). This observation is contrary to what has been seen in other boreholes in the McArthur area (Mwenifumbo *et al.*, 2000). Because the density and Vp logs show high densities and velocities, this low resistivity signature in the basement rocks cannot be attributed to an increase in porosity. The probable cause might be due to changes in the borehole fluid chemistry in this part of the borehole. Increased salinity in the borehole fluids usually cause the lowering of resistivity. Sampling and analysis of the borehole fluids in the basement may explain the decrease in resistivity.

The gamma-ray spectral logs (total count gamma, percent K, equivalent uranium (eU in ppm) and equivalent thorium (eTh in ppm)) from MAC-265 are shown in Figure 3. More information on the lithology is detected from these logs. The higher gamma-ray count rate in MFb is primarily due to increases in thorium that is associated with layers of conglomerate in the Athabasca sandstones and correlates fairly well with the presence of heavy elements. Petrographic, chemical, and SEM analyses by the principal author (data are not presented here) revealed that the primary source of thorium is a thorium-rich aluminophosphate (crandallite). The high gamma-ray count rate in MFb near the unconformity (525 to 570 m) is due to uranium and thorium. The semi-pelitic and pelitic gneisses are easily distinguished from pegmatites and quartzites by their higher potassium content.

Figure 4 shows the full waveform logging results from underground borehole 21-08 which intersects the P2 North ore zone. Included in this figure are the uranium ore grade estimates from gamma-ray logging data, Vp, and the variable density log (VDL). There are several low-velocity zones in the ore that may be attributed to fracturing (see the VDL). The overall acoustic signature of the uranium ore zone, however, is characterized by lower velocities (<5 km/s). We plan to confirm this observation with acoustic property measurements in the laboratory.

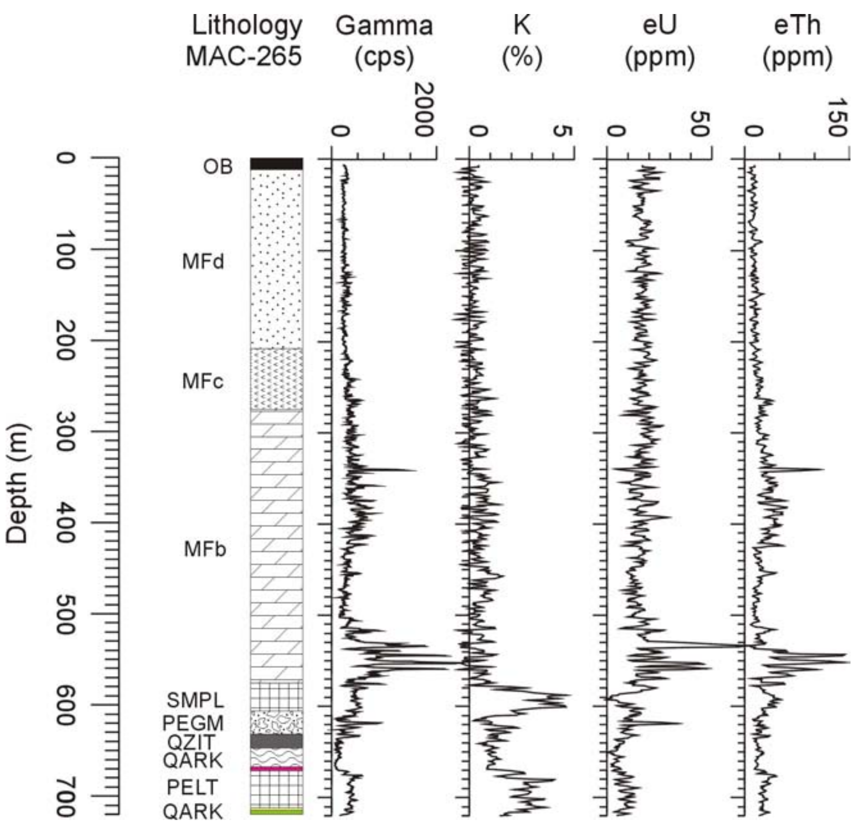

Figure 3 - Gamma-ray spectrometry data; total count gamma, %K, eU, and eTh logs from MAC-265. Abbreviations as in Figure 2.

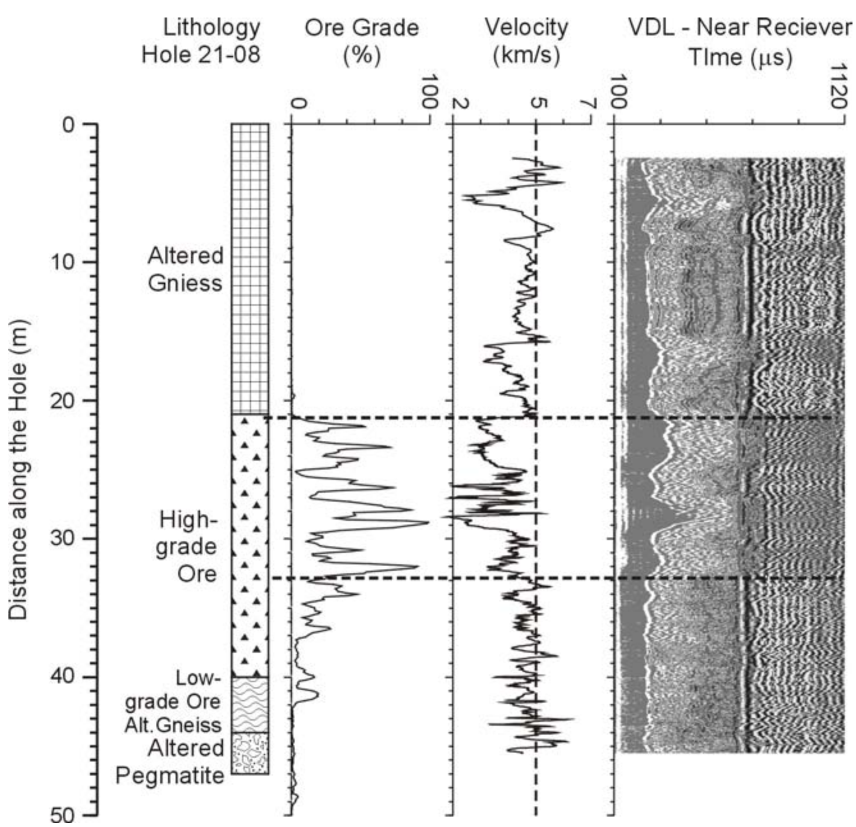

Figure 4 - Ore grade estimates, velocity, and full waveform sonic (variable density log (VDL)) from underground borehole 21-08 in the P2 North orebody, McArthur River.

5. Conclusions

Logging was successfully completed for the most common basement rocks in the McArthur

River area. These include semi-pelitic/pelitic gneisses, quartzites, and pegmatites. These data provide a more comprehensive set of information on the geophysical characteristics of the basement rocks in the McArthur River area. The *in situ* physical rock property data including resistivity, density, and velocity will be compiled and integrated with associated sub-projects, and should significantly aid in the interpretation of the basement characteristics as recognized from the seismic (Hajnal *et al*., this volume; Gyorfi *et al*., this volume; White *et al*., this volume), magnetotelluric (Craven *et al*., this volume), and gravity (Wood and Thomas; this volume) data. The collection of the acoustic logging data in a high-grade uranium ore zone has provided us with an insight into the acoustic properties of the uranium ore that should help in the design and interpretation of surveys aimed at outlining the ore.

6. Acknowledgments

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7. References

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