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Seismic Exploration within the Flin Flon VMS Mining Camp, Manitoba, Canada

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ABSTRACT

Preliminary assessment of the seismic reflectivity of rocks within the FlinFlon VMS mining camp has been conducted in advance of 2D and 3D seismic data acquisition for the purposes of deep exploration. Rock property measurements made on representative core samples and in situ downhole geophysical logging demonstrate that significant variations in acoustic impedance exist amongst rocks from the camp demonstrating the potential for the generation of significant reflections. Specifically, reflections should occur from contacts of rhyolites (which constitute the primary ore-bearing horizon) and mafic volcanic/intrusive rocks (gabbros or basalts), from sulphide occurrences ,from shear zones in the mafic rocks, and from contacts between the metasedimentary rocks (Missi Group) and metavolcanics. Vertical seismic profiles demonstrate the strong in situ reflectivity of the mine geology at frequencies that will be used in subsequent 2D and 3D seismic acquisition.

INTRODUCTION

The Flin Flon mining camp comprises more than 25 producing or past-producing Cu-Zn mines with total production and reserves exceeding 110 million metric tonnes (Syme and Bailes, 1993). Mining in the Flin Flon area dates back to the early 1900's with a mine and smelter having been established by the late 1920's. The 62.4 Mt Flin Flon mine deposit, which exceeded the size of other deposits in the area by an order of magnitude, ceased production in 1990. Production of a number of smaller deposits in the area (e.g., Trout Lake, 777, Callinan) continues to supply the smelter in Flin Flon.

In a concerted effort to support exploration for new ore deposits in the vicinity of Flin Flon and surrounding region, a program of seismic investigations has been implemented as part of the Targetted Geoscience Initiative-3 (TGI-3) Saskatchewan-Manitoba project. This project is a joint Federal-Provincial effort led by the Geological Survey of Canada with active participation by Hudson Bay Mining and Smelting Ltd. The seismic program is designed to provide a basis for constructing a 3-dimensional geological model for the mining camp, to scrutinize and refine the current conceptual exploration model for the camp, and ultimately to provide new drill targets. Preliminary data have been acquired to assess the reflectivity characteristics of the rocks that characterize the mining camp geology. Results of initial data analysis are presented here, for rock property measurements, downhole geophysical logging and vertical seismic profiles (see Figure 1 for locations). A total of 40 km of high-resolution 2D seismic profiling (line locations shown in Figure 1) will commence in April of 2007 followed by a 3D survey.

GEOLOGY

The following geological description is summarized primarily from Syme and Bailes (1993). The Flin Flon metavolcanic belt consists of polydeformed supracrustal and intrusive rocks. The volcanic rocks constitute an island arc-back arc assemblage (Amisk Group), which is unconformably overlain by continental alluvial sediments (arkoses, greywacke, conglomerate and argillite) and intercalated volcanic rocks of the Missi Group. The Flin Flon, Callinan, and 777 deposits occur in the west limb of the Hidden Lake synform residing within a 200-m-thick package of rhyolitic flows and breccias (Mine rhyolite) that is sandwiched between the South Main basalt in the stratigraphic footwall and the Hidden Lake basalt in the hanging wall. Interpreted thrust faults as the north end of the Hidden Lake synform (Figure 1) suggest that the ore-bearing horizon may be replicated at depth. Mineralization consists of sphalerite, chalcopyrite, and pyrite. Magnetite is scattered through the basaltic rocks.

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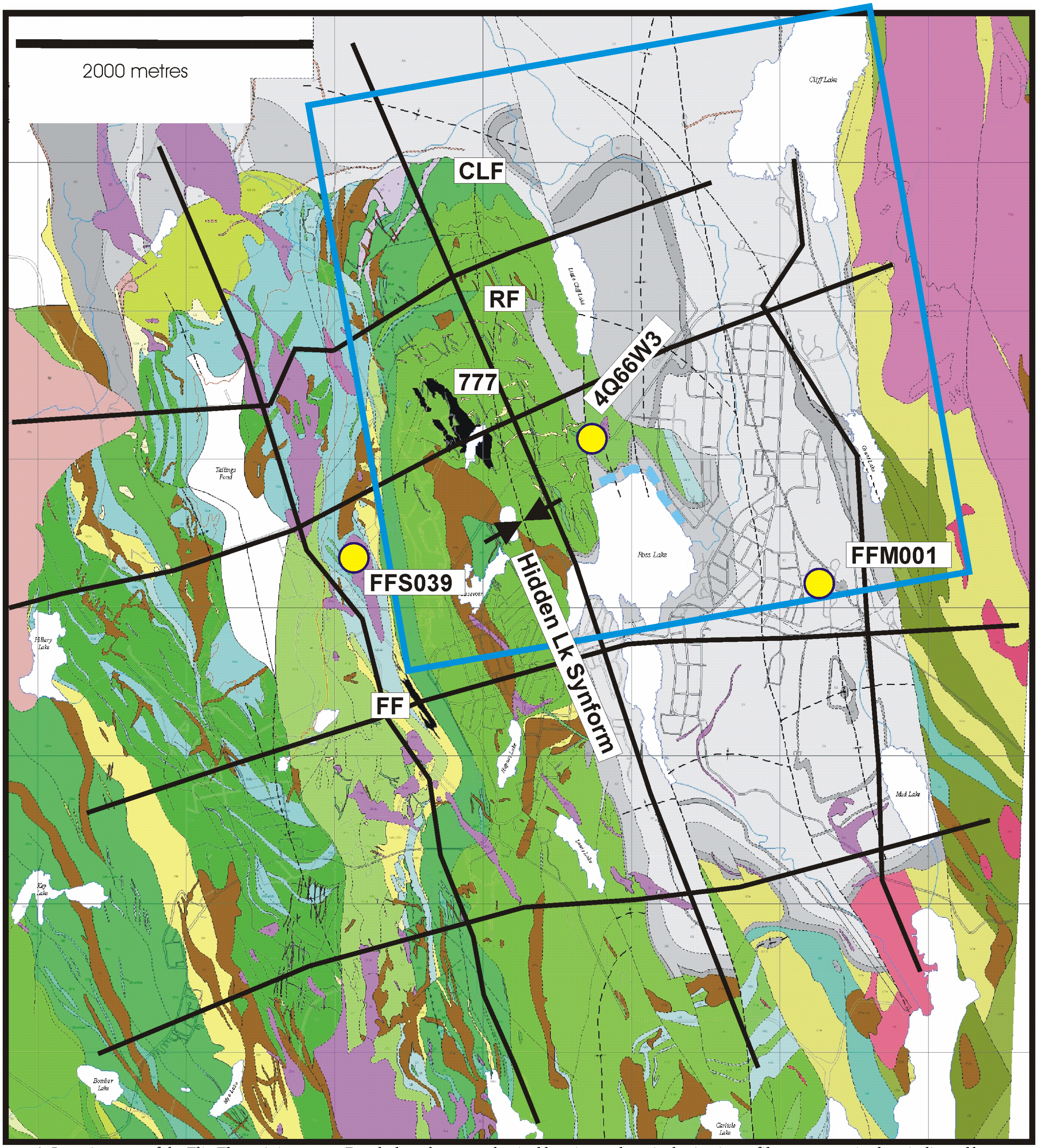

Figure 1: Location map of the Flin Flon mining camp. Boreholes where geophysical logging and vertical seismic profiles were acquired are indicated by the yellow dots. The black lines indicate 2D seismic profiles that are to be acquired in April, 2007 with the blue rectangle outlining the area of a planned 3D seismic reflection survey. The vertical projection of the orebodies onto the Earth surface are indicated in black (FF=Flin Flon; 777=Callinan-777). The primary lithologies are mafic flows (greens), rhyolites (yellow), Missi sedimentary rocks (grey), gabbros (brown), volcanoclastic rocks/breccias (blues), and younger intrusive rocks (pinks).

ROCK PROPERTIES AND GEOPHYSICAL LOGS

Rock properties provide a basis for assessing the likely seismic reflectivity of rocks within the Flin Flon mining camp. To determine the seismic impedance (strictly speaking, acoustic impedance), uni-axial acoustic velocity and density measurements were made on a representative set of rock core samples. The results are shown in Figure 2. The mean seismic impedance of the massive sulphides (Z~27) is much higher than for any of the other rock types measured. The mafic units (basalt, pyroxene and pyroxene gabbro to a lesser extent) have high mean impedance values (Z=19-20) distinguishing them from the remaining lithologies that cluster between Z=14-15. The impedance contrast between the mafic samples and the other units has a reflection coefficient (R=(Z1-Z2)/(Z1+Z2)) R=0.12-0.18, significantly higher than a value of R=0.05 which is often considered the threshold for observing significant reflections. Furthermore, impedance values for the tectonites are relatively low (Z~17) compared to the mafic units, implying that faults (e.g., Club Lake and Railway faults) will be visible where they cut the mafic units, and if the faults are thick enough. Another interesting property of the tectonites is that they are likely to be strongly anisotropic as they are characterized by a pronounced foliation. The impedance contrast, and thus the reflection coefficient, will be higher for waves hitting the faults at a normal angle.

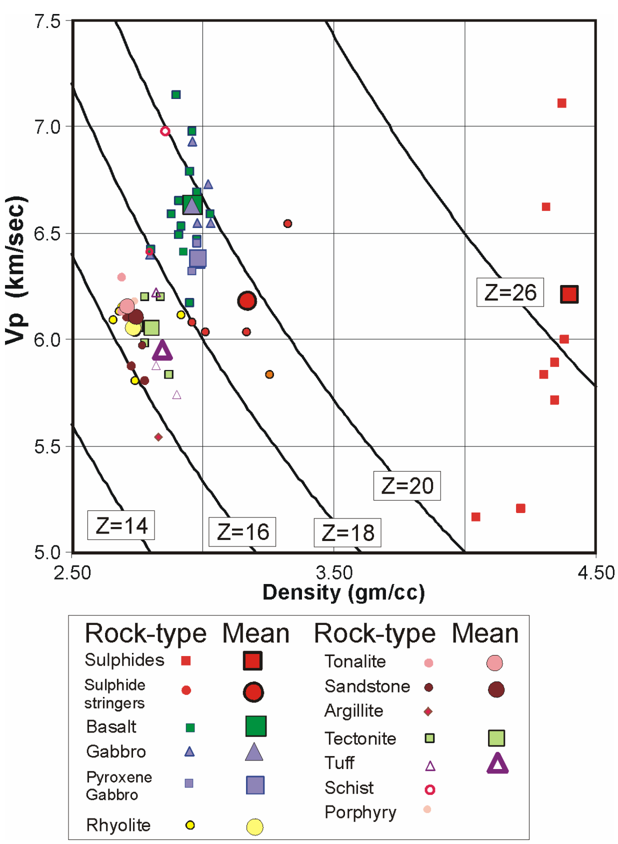

Figure 2: Density versus acoustic velocity (Vp) determined for representative rock core samples.

Multi-sensor geophysical logs were acquired in several drillholes (see Figure 3 for data and Figure 1 for drillhole locations) to determine the in situ rock properties of mineralized zones and host rocks as a further aid in the delineation and exploration of the deposits with seismic methods. The geophysical logs acquired in these drill holes included natural gamma ray spectrometry, density, full waveform sonic (compressional, Vp and shear, Vs, wave velocities), magnetic susceptibility, resistivity and temperature. The natural gamma-ray logs accurately define the lithology; the Missi sedimentary rocks and rhyolites having the highest gamma-ray activity whereas the basalts and gabbros have the lowest activity with the exception of the magnetic-rich gabbros that have unusually

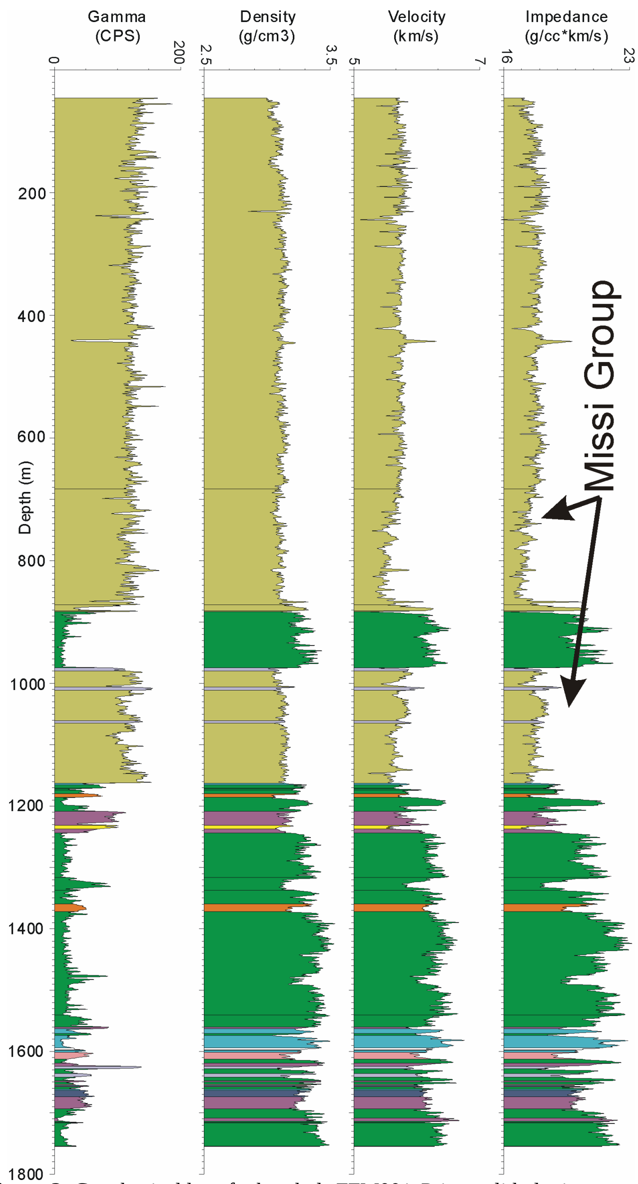

Figure 3: Geophysical logs for borehole FFM001. Primary lithologic units are Missi sedimentary rocks (tan), mafic flows (green), rhyolite (yellow), gabbros (blue/purple).

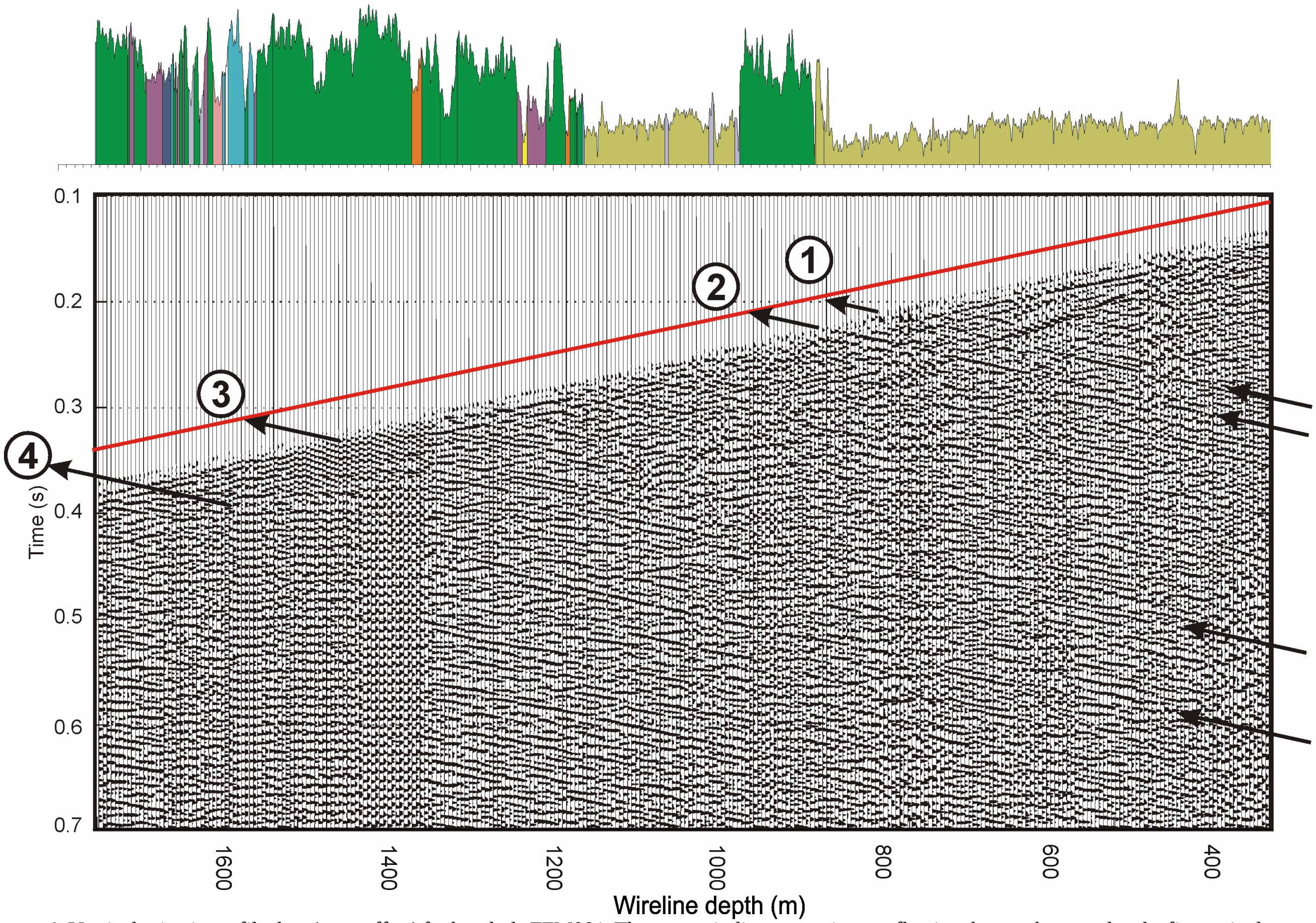

Figure 4: Vertical seismic profile data (near-offset) for borehole FFM001. The arrows indicate prominent reflection that can be traced to the first arrival (red line) corresponding to the borehole where they can be correlated directly with the geology. Labels are referred to in the text. The geophysical log along the top of the plot is the acoustic impedance from Figure 3. See Figure 3 caption for lithologic legend.

high activity from originating from the three radioelements; potassium, uranium and thorium. The rhyolites are also all enriched in potassium, uranium and thorium. The compressional wave velocity (Vp) and density data show good contrasts between Missi sedimentary rocks and the basalts and gabbros. The Missi sedimentary rocks exhibit low densities and velocities whereas these physical rock properties are high in basalts and gabbros. The altered basalts and gabbros have lower velocities and densities compared to the unaltered rocks. The acoustic impedance (a product of density and velocity) is significantly lower in the Missi sedimentary rocks compared to either the basalts or gabbros providing a good target for surface and hole-to-hole seismic exploration techniques.

VERTICAL SEISMIC PROFILES

Vertical seismic profiles (VSP's) were acquired in the same drillholes where geophysical logging was conducted. The VSP's provide a means of assessing the in situ reflectivity of the mine geology at frequencies and wavelengths similar to those used for surface seismic profiling. An 8-level 3-component downhole clamping geophone system was used to record 150-450 gm dynamite shots detonated at the surface near the borehole collar. In addition to the dynamite sources, mini-Vibroseis sources were tested as an alternate, operating in both vertical- and horizontal-mode operation. Horizontal-model Vibroseis operation was designed to test shear-waves as a viable exploration tool. The near-offset dynamite VSP acquired in borehole FFM001 is shown in Figure 4 along with the seismic impedance log from Figure 3. There is prominent reflectivity observed over the depth of the borehole, with particularly strong reflections (labeled 1 and 2 in Figure 4) generated from the top and bottom of a mafic volcanic unit within the Missi sandstone, at the base of a thick column of mafic volcanics (labeled 3) and at greater depths than the bottom of the borehole (e.g., labeled 4 in Figure 4).

CONCLUSION

Rock property acoustic velocity and density measurements, downhole geophysical logging and vertical seismic profiles demonstrate the reflectivity characteristics of the Flin Flon mine camp geology. The various lithologies can be sorted according to seismic impedance into 3 primary groups: sulphides having very high impedance (Z~21-30), mafic volcanics and mafic intrusives having high impedance values (Z~18-21), and other lithologies (rhyolite, tonalite, sandstone, tectonites) with intermediate impedances (Z~16-18). The juxtaposition of rocks from the different groups provides significant impedance contrasts capable of generating reflections. The VSP data from FFM001 demonstrate clear reflections at seismic wavelengths/frequencies from a contact of mafic volcanics with sandstone and at the base of a thick mafic volcanic flow.

REFERENCES

Syme, E.C., and Bailes, A.H., 1993. Stratigraphic and Tectonic Setting of Early Proterozoic Vocanogenic Massive Sulfide Deposits, Flin Flon, Manitoba, Economic Geology, 88, 566-589.