INTRODUCTION

Mine waste rock piles, or rockwaste dumps, containing metallic sulphides are a favourable environment for the generation of acid mine drainage (AMD). There are many physical, geochemical and biological processes that lead to the production of AMD within waste rock piles. One of the most critical of these is water flow and water distribution in the waste rock. To fully understand this process, it is critical to know the internal structure of waste rock piles. In this paper, the authors show the results of an investigation where resistivity and ground penetrating radar (GPR) geophysical methods have been used to study mine dumps.

METHODS

Resistivity measurements are sometimes used to monitor AMD plumes in mine waste sites (see Smith et al. 2001, Campbell and Fitterman 2000 and Campbell et al. 1999), but little work has previously focused on the structure of mine dumps. It is commonly known that the resistivity method is useful to image ground stratigraphy and structure. This method can also be used for monitoring fluid flow in unsaturated conditions (Buettner et al. 1999; Versteeg et al. 2000). On the other hand, GPR is an uncommon method for mine waste investigation, mostly because conductive materials such as sulphide bearing rocks tend to attenuate GPR signal. Nevertheless, the method has successfully been used to characterize solid waste dumps where leachate comparable to AMD is found (Orlando and Marchesi 2001).

FIELD WORK AND SURVEY RESULTS

The Laronde Mine is situated in the Abitibi mining region in the province of Quebec, Canada (Fig. 1). It is a Cu-Zn-Au-Ag deposit with AMD generating waste rock. Resistivity and GPR surveys were carried out on a 30m x 30m grid located on top of an inactive waste rock dump (Fig. 2) in July 2002. A second series of surveys were taken in October of 2002, at the same time as an infiltration test was carried out in order to map fluid flow within the mine dump. Numerical modeling of water flow within typical mine dumps has shown the presence of a wetting front to a depth of about 5m (Aubertin et al. 2002). Geophysical surveys were designed in order have depths of investigation comparable to the depth of the wetting front.

Resistivity measurements were carried out using an ABEM Lund multi-electrode system with 41 electrodes and a minimum spacing of 1m giving a maximum penetration depth of about 6m. Seven E-W profiles 5m apart were performed. GPR measurements were carried out using a Sensors & Software Pulse EKKO IV during the July 2002 field program and with a MALA Ramac system for the October 2002 field program.100 MHz antennas were used to perform 14 profiles (7 E-W and 7 N-S) also 5m apart. A total of 3 data series were obtained for each
method corresponding to the profiles carried out in July 2002, and in October 2002 before and after the infiltration test.

Figure 3 shows a GPR profile and the resistivity model obtained from inverting the collected resistivity data for line x=15m on the grid. A slightly dipping near surface conductive zone to the West can be correlated with a reflection on the GPR profile. The base of a resistive layer at about 3-4m of depth can equally be correlated with a decrease of the GPR signal amplitude at about 85ns. High resistivities near the surface around x=10m and x=22m can be associated with diffraction hyperbolas found on the GPR profile. In general, resistivities greater than 750 ohm.m were observed near the surface and lower resistivities at depths greater than 3-4m with the exception of the southern part of the grid where low resistivities were encountered from surface to depth.

Figures 4 and 5 compare the results of the July and October surveys. Figure 4 shows the GPR profiles for y=20m. The October profile shows greater signal attenuation, which can be attributed to a drop of resistivity in the ground. This is confirmed by the results of time-lapse inversions (Fig. 5) where the difference of ground resistivity between the July and October surveys for x=25m can be seen. This can be explained by the fact that during the July field program, very dry conditions were encountered. On the other hand, numerous rainfalls occurred before the October field program. Therefore, water content near the surface of the waste rock pile was lower in July than in October thus resulting in a resistivity drop within the pile. Note that the most significant resistivity variation occurs within the first meter of waste rock.

An infiltration test was carried out within the survey grid. A shallow rectangular pond was dug in order to retain the water to an area of about 40m² (opposite corner x-y coordinates are (15,11) and (20,19)). The estimated infiltration rate is about 30 to 40 litres/min and the test was performed within a 24-hour period. Figure 6 shows the resistivity ratio between the profiles measured before and after the infiltration test for lines x=15m, x=20m and x=25m. Significant resistivity drops are induced near the infiltration zone at depths ranging from 1m to 3m. Moreover, these resistivity drops are not uniformly distributed within the infiltration area, thus suggesting a preferential flow pathway towards the northern portion of the mine dump.

CONCLUSIONS

The resistivity and GPR methods appear to be efficient geophysical methods to characterize the internal structure of the Laronde waste rock pile. The authors have shown that these methods were able to detect seasonal water content variations. Likewise, time-lapse DC resistivity inversions showed water flow preferential pathways within the mine dump. Further work is planned on this test site and will consist of longer-term infiltration tests and lysimeter measurements coupled with the geophysical methods discussed in this paper.

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REFERENCES


FIGURES

Figure 1. Laronde Mine location. Figure 2. Survey grid position within the waste rock pile.
Figure 3: GPR profile (a) and DC resistivity inversion results (b) for line x=15m.

Figure 4: GPR profiles for line y=20m: July 2002 (a) and October 2002 (b).

Figure 5: Time lapse inversion results for line x=25m: July 2002 (a), October 2002 (b) and compared resistivity ratio (c).

Figure 6: Resistivity ratio between before and after October 2002 infiltration test for lines x=15m (a), x=20m (b) and x=25m (c).