

Electrochemical Prevention of Acid Mine Drainage

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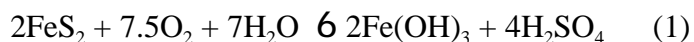
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ABSTRACT: One of the most serious problem facing the mining industry is the oxidation of sulphide rich mine tailings and sulphide rich orebodies that ultimately results in the release of metal-rich acidic waters. Enpar Technologies patented electrochemical protection provides a new cost effective engineering solution to the acid drainage problem. This new approach can complement conventional strategies or it can be used on its own to mitigate AMD/ARD. By using electrochemistry, the thermodynamic stability of sulphide rich minerals is significantly improved. This is possible because sulphide rich minerals frequently exhibit semiconductor properties. Electronegative polarization is used to prevent the oxidation of sulfide rich mineral deposits in a manner similar to that used in cathodic protection of steel structures. The resulting cathodic polarization leads to *in-situ* electrochemical reduction of oxygen at the tailings/soil interface and a shift of the redox potential of the sulphide minerals to a stability field where oxidation is not thermodynamically favoured. Results from a field installation at a mine tailings site near Sudbury is presented in this article along with a discussion on future field application systems.

1 INTRODUCTION

Acid mine drainage (AMD) resulting from the disposal of mining waste containing sulphide minerals is considered one of the largest environmental problems facing the mining industry today. AMD is formed as a result of the oxidation of sulphide minerals that ultimately results in the release of metal-rich acidic waters. The oxidation of iron sulphides is catalyzed by bacteria and proceeds according to the following reaction:



where FeS_2 represents pyrite.

The conventional method of dealing with the AMD problem involves treatment by liming. More recently geotextile liners and engineered soil covers have been developed to prevent the infiltration of oxygen to the tailings to reduce the oxidation rate of the tailings.

ENPAR Technologies Inc., based in Guelph, Ontario, Canada, has developed and patented a novel electrochemical technology for the prevention of AMD from tailings deposits. This new approach involves negatively polarizing the tailings/electrolyte

interface, thus, reducing dissolved O_2 , *in situ*, at the surface of the tailings. The end result is to stop the oxidation of the tailings. A modified design (patent pending) has been developed for low level sulphide wastes including waste rock.

2 SCIENTIFIC BASIS OF THE TECHNOLOGY

The scientific principles behind implementation of the technology were established through a series of laboratory experiments. Sulphide minerals are known to behave as semi-conductors; high-sulphide bedrock has been shown to act as an electrode in an electrochemical cell. Laboratory studies and field tests conducted by ENPAR demonstrated that high sulphide tailings can act as an electronic conductor. Therefore, large bodies of sulphide rich tailings are amenable to electrochemical manipulation. Basically, the tailings deposit can be converted into the cathode of an electrochemical cell.

Figure 1 illustrates a schematic of an electrochemical system utilizing tailings as the cathode. Electrons are transferred to the tailings through the electrical circuit, negatively polarizing

the tailings/electrolyte interface, reducing the redox potential of the tailings.

Oxygen is reduced, *in situ*, at the tailings/electrolyte interface through the electrochemical reduction of O₂ as described by the following reaction:



The rate at which the electrochemical reduction reaction proceeds is controlled predominantly by the applied current density which is related to the rate at which oxygen diffuses through the soil cover or overburden to the tailings. As well as removing dissolved oxygen, hydroxyl ions will be generated at the tailings, therefore inhibiting the oxidation of sulphide minerals and associated release of metal ions. The negative polarization of tailings also changes the thermodynamic properties of the iron sulfide minerals in the tailings to more stable conditions.

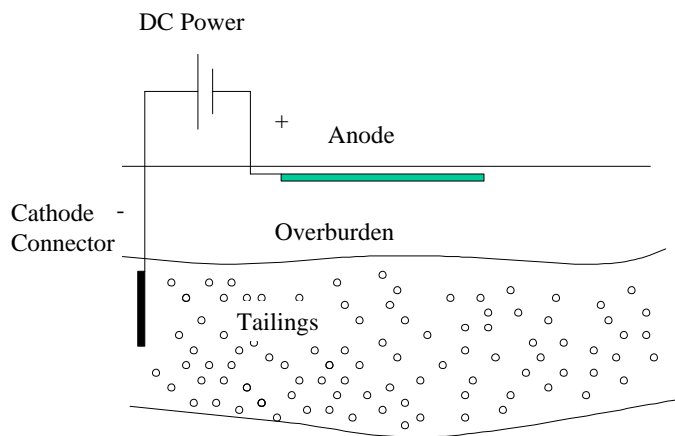


Figure 1: Schematic of Electrochemical Protection System

2.2 Monitoring Oxygen, In Situ

The aforementioned electrochemical principles can be exploited as a method of determining O₂ concentration at the tailings/overburden interface. Since the tailings is acting as a single large conductor, it is possible to survey the impact of the electrochemical treatment on the tailings by conducting half-cell potential surveys.

A half-cell potential survey consists of a series of field potential measurements between the conductive tailings body (which behaves as a metallic structure) and a reference electrode placed in contact with the earth directly above the tailings under investigation. The reference electrode commonly used for such surveys is a copper-copper sulphate reference electrode. It consists of a copper rod in a saturated solution of copper sulphate crystals. This reference

cell has a stable, constant potential against which the potential of the tailings is measured. A schematic of how the measurement is recorded is presented in Figure 2. The potential that is recorded is a measure of the redox potential of the tailings which is an indirect measure of O₂ concentration.

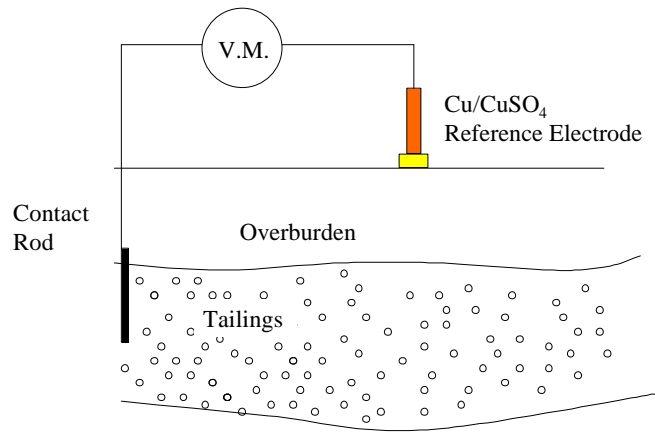


Figure 2: Half-Cell Survey of Tailings

3 FIELD TESTING OF ELECTROCHEMICAL SYSTEM

3.1 Installation

In the spring of 1998 ENPAR installed a pilot-scale electrochemical treatment system at a tailings deposit in the Sudbury basin (Ontario, Canada). The tailings deposit encompasses a 5 ha area and consists primarily of pyrrhotite at a concentration of approximately 60-70%. The tailings is overlain with a 2-2.5 m deep cover comprised of glacial fluvial sands and gravel. Oxidation of the tailings and subsequent contamination of the groundwater with acidic leachate were encountered prior to installation of the treatment system.

After initial testing and characterization of the tailings pond, a 1.2 ha plot was selected for use as a test area for the system. The remaining area of the tailings deposit acts as the control and was also monitored during the pilot test. Anodes were installed in the overburden, contact was made to the tailings body, and then DC power was supplied to the system using a rectifier.

3.2 Results

A first static half-cell potential survey of the tailings site was performed prior to installation of the electrochemical treatment system in the spring of 1999. The results presented in Figure 3 show that the redox potential (unpolarized potential) of the tailings was in a positive potential range for most of the site.

After the electrochemical treatment system was energised for approximately one month, half-cell potential measurements were recorded immediately after current interruption “instant off” (Figure 4). The potentials in the treatment area (bounded by 0 to 100 south and 60 east to 40 west) are much more electronegative than the original static potentials and the untreated tailings area. The half-cell potential measurements of the tailings indicated that oxygen has been depleted at the tailings (by greater than 99.9%) and that the tailings are thermodynamically more stable (i.e. less likely to oxidize).

Another electrochemical indication that we have successfully induced cathodic polarization on the tailings is presented in Figure 5 which shows the difference in potential between the instant off potential and the fully depolarization survey which was recorded 18 hours after current interruption. In the treated area most of the potential has depolarized by more than 50 mV which shows that we have successfully induced cathodic polarization to the tailings and promoted the beneficial reactions discussed in the introduction section.

3.2 Leachate Monitoring

Lysimeters were installed in the unsaturated zone of the tailings throughout the control and treatment area. Changes in pore water chemistry are expected to be detected gradually once the contaminated pore water is displaced within the treatment zone. Preliminary leachate results sampled 3 months after start-up indicated an increase in porewater pH in the treatment zone of 0.7 units to a pH of 4.14. Leachate at the test site will be sampled during the following year.

3.3 Power Requirements

The test site is currently operating at a power consumption of approximately 9.6 kW. However, the system is installed at a site with an overburden characterized by high electrical resistivity (gravel and sand) of greater than 500,000 ohm-m. Future installations at sites undergoing the development of decommissioning plans will include a low resistivity cover (less than 10,000 ohm-m), such as silt, clay or silt loam. The lower resistivity overburden (i.e. soil) would decrease power costs significantly. An electrochemical system can be designed to utilize solar panels to provide DC power. As an alternative, under certain conditions, a galvanic system requiring no external power source can be designed and implemented. The design of an electrochemical system is site specific and depends primarily on site characteristics.

4 FUTURE DIRECTIONS

The field site will be continued to be monitored during the following year. An electrochemical treatment system has been developed for the remediation of low sulphide tailings and waste rock and is progressing to pilot-scale testing.

5 SUMMARY

A novel electrochemical treatment system to prevent the formation of acid mine drainage is currently undergoing pilot-scale testing at a tailings deposit. The electrochemical technology has been successful in removing dissolved oxygen and lowering the redox potential at the tailings/electrolyte interface. Also, by negatively polarizing the tailings, a thermodynamically stable environment is created within the tailings. By removing oxygen *in situ*, the technology tackles the problem at the source, thereby, shutting down the formation of AMD. The technology is robust and modular and can be used in conjunction with a low cost soil cover to remediate and revegetate a tailings deposit.

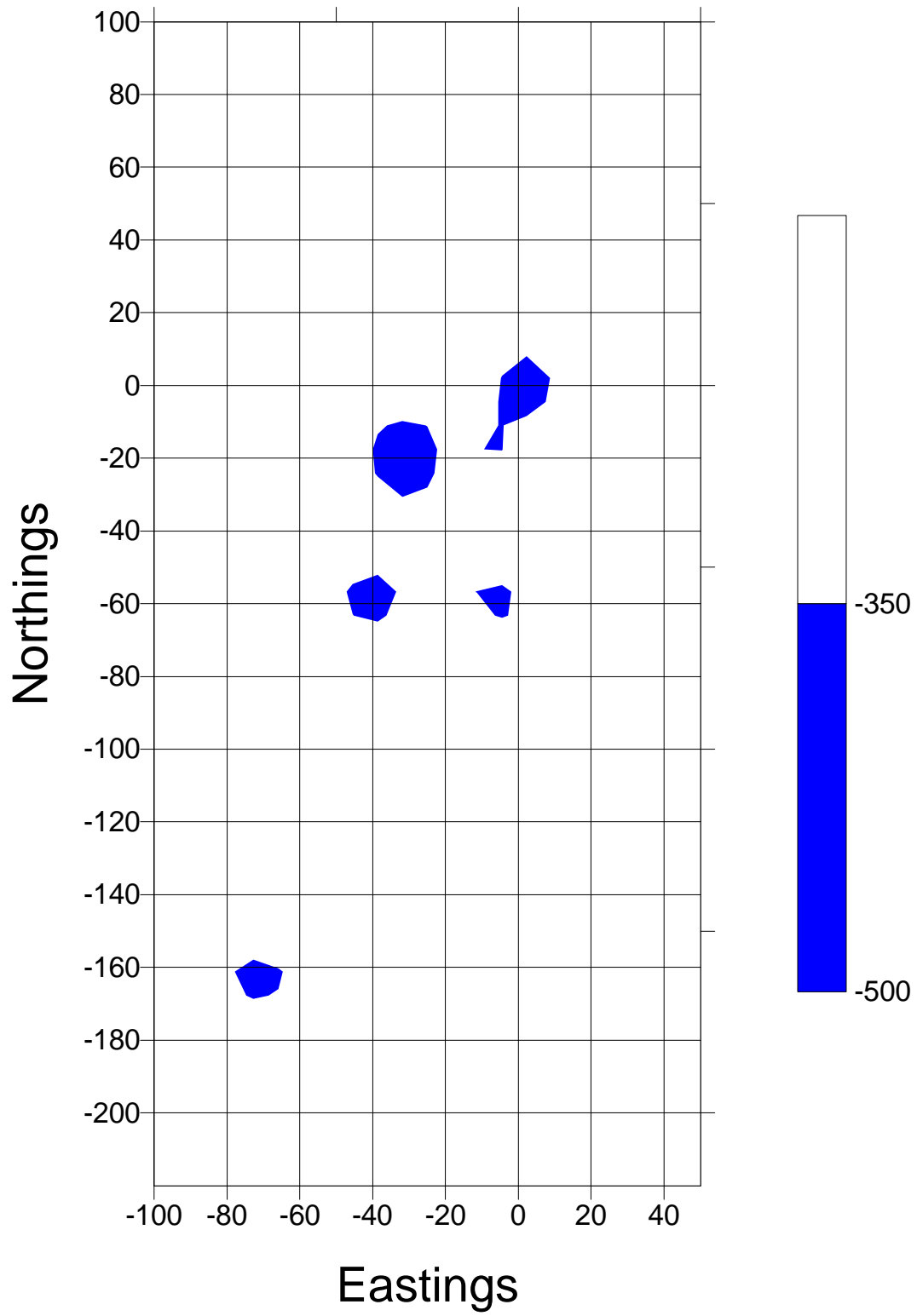


Figure 3: Static Measurement - May 22, 1999

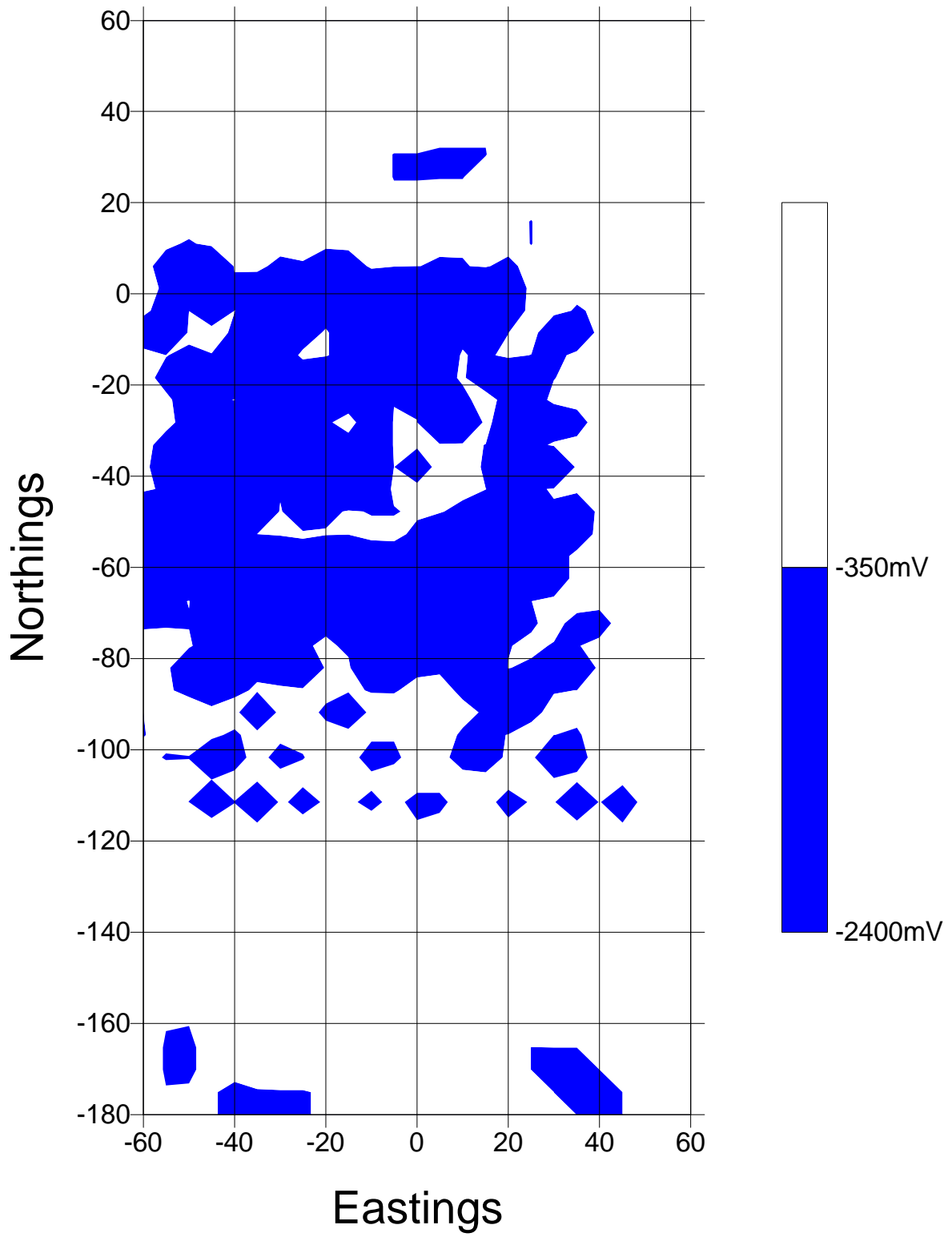


Figure 4: Instant Off Measurement - Aug. 4, 1999

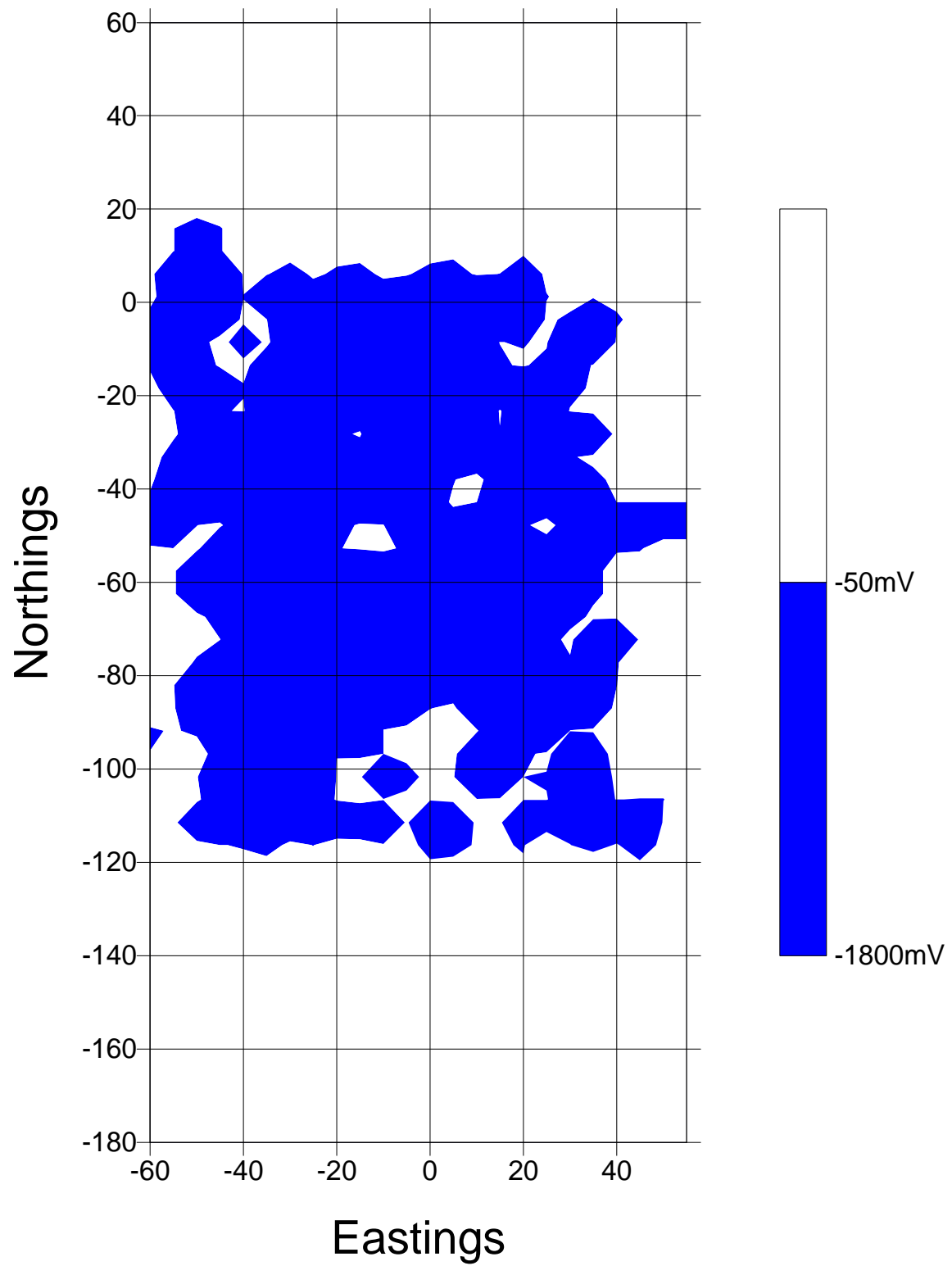


Figure 5: Polarization Based on 18 h Off