



Exploration Report EX2004-1

Detection of base-metal massive sulphide type mineralization using conductivity measurements on rock-powder slurries: an example from the Photo Lake Cu-Zn deposit, Snow Lake, Manitoba (NTS 63K16)

by M.A.F. Fedikow and G.G. Conley
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Foreword

This report represents part of an ongoing effort to complete publication of outstanding databases and studies begun while the principal author was an employee of Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey. A series of publications based on these data and entitled 'Exploration Reports' will be released via the Department's website.

This report presents data generated from a co-operative project between the Manitoba Geological Survey and Hudson Bay Mining and Smelting Co. Ltd. (HBMS). This study of the specific conductance response of the Photo Lake Cu-Zn massive sulphide type deposit (Snow Lake), using slurries of outcrop-derived rock powder and de-ionized water, is a small portion of a much larger rock-geochemical co-operative study between the Manitoba Geological Survey and HBMS. HBMS collected outcrop rock-chip samples during exploration on its properties in the Photo Lake area. These samples were powdered and, together with rock-geochemical analyses for trace- and major-element geochemistry, were made available to the senior author in 1996 while he was still an employee of the Manitoba Geological Survey. This Exploration Report represents the first product from this joint venture and continues to build the foundation of developing and testing exploration-geochemical technologies applicable to mineral exploration in Manitoba.

Abstract

Conductivity measurements on rock-powder slurries, representing water-extractable metal, have delineated a distinctive zonation of specific conductance (K) associated with the host rocks of the Photo Lake Cu-Zn massive sulphide type deposit near Snow Lake, Manitoba. The pattern is marked by a central zone of low K (12–20 microsiemens·cm⁻¹) directly over the approximate surface projection of the deposit. Irregularly distributed zones of elevated K surround this central low. This zonation is attributed to electrochemical processes modified by physical and chemical attributes of both the primary and secondary environments in the survey area. Rapid and inexpensively determined bedrock-geochemical conductivity patterns, such as those present above the Photo Lake deposit, could assist in exploration for blind base-metal massive sulphide mineralization, as well as provide insights into the morphology of partial- and selective-extraction soil-geochemical survey results over similar mineralized zones.

Contents

Foreword	3
Abstract	4
Contents.....	5
Introduction	6
Geological setting of the survey area	6
Sample collection and preparation	6
Analytical method	7
Data presentation.....	7
Results	7
Discussion	8
Conclusions	9
Acknowledgments	9
References	9

Figures

Figure 1: Regional geological setting and location of the Photo Lake Cu-Zn massive sulphide type deposit, Snow Lake area	11
Figure 2: Local geological setting of the Photo Lake Cu-Zn massive sulphide type deposit, Snow Lake area	12
Figure 3: Outcrop rock-chip sample locations, contoured specific conductance data (in $\mu\text{S} \cdot \text{cm}^{-1}$) and location of the surface projection of the Photo Lake Cu-Zn massive sulphide type deposit, Dub 21 grid, Snow Lake area.	13
Figure 4: Colourized contour map of specific conductance measurements (in $\mu\text{S} \cdot \text{cm}^{-1}$) on rock-powder slurry samples, Dub 21 grid, Photo Lake survey.	14
Figure 5: Hypothetical model for the distribution of selective- and partial-extraction soil-geochemical anomalies formed in response to oxidizing and reducing poles of a mineralization-related electrochemical cell.	15

Introduction

As part of ongoing development and testing of exploration-geochemical methodologies at the Manitoba Geological Survey, the Photo Lake Cu-Zn deposit was targeted as a base-metal 'laboratory' where bedrock- and soil-geochemical techniques could be assessed. One of these surveys has been published as an open file report (Fedikow, 1999). This report deals with the attempt to isolate a water-extractable total-metal signature from outcrop chip samples. It should be noted that the Photo Lake Cu-Zn deposit does not outcrop, nor is there diagnostic wallrock alteration exposed in outcrop in the immediate vicinity of the deposit that would readily identify the area as prospective. Diamond-drill testing of ground electromagnetic conductors undertaken subsequent to airborne geophysical surveys is credited with discovery of the deposit.

Geological setting of the survey area

The Photo Lake Cu-Zn-Au-Ag-Pb volcanogenic base-metal massive sulphide deposit (533 623 t grading 4.7 g/t Au, 4.5% Cu and 6% Zn; T. Heine, pers. comm., 1999) occurs in west-central Manitoba within the Snow Lake segment of the Proterozoic Flin Flon greenstone belt (Figure 1). It was discovered in 1994 as a result of the diamond-drill testing of an airborne electromagnetic anomaly. The deposit is hosted by Photo Lake rhyodacite-rhyolite (Figure 2) that forms part of the mature-arc section of the Snow Lake arc assemblage (Bailes, 1996). The rhyodacite unit comprises a monotonous and relatively uniform sequence of felsic volcanic and derived gneissic rocks (Bailes, 1996). A period of volcanic quiescence in the sequence is interpreted from the presence of the Photo Lake deposit and a 90 m thick heterolithic breccia that also occurs within the rhyodacite sequence (Bailes, 1996). Mineralization is present as three discrete lenses: lens #1 is Cu rich in the upper mine levels but becomes Zn rich at depth; lens #2 is Zn rich; and lens #3 is uneconomic and undeveloped. Sulphide mineralization in these lenses has an overall east-west strike, a dip of 40–60°N and a plunge of 40–45°NE.

Synvolcanic hydrothermal alteration of the hostrocks has been documented in the mine environment, as well as in outcrop 700 m northwest of the deposit (Bailes, 1996; Heine and Prouse, 1998). A strongly altered zone, containing chlorite with patchy and irregularly developed porphyroblasts of biotite, staurolite, magnetite and garnet, borders the #1 lens on the north. Less altered rhyolite is marked by patchy and moderate chloritization and sericitization. Garnet porphyroblasts (up to 3 cm) are present in the chlorite patches. The 'footwall' style of alteration on the north side of the deposit is not consistent with local north-facing strata and suggests the deposit is isoclinally folded (Bailes et al., 1996, 1997). Northwest of the deposit, felsic rocks are altered and contain 15–30% garnet, 5–40% amphibole porphyroblasts, and 2% disseminated pyrrhotite and lesser pyrite and chalcopyrite. Future rock-geochemical and -mineralogical studies at the deposit have been made possible by the collection of an archival suite of 104 underground rock-chip samples, as well as core samples collected from seven complete diamond-drill holes (Heine and Prouse, 1998).

Sample collection and preparation

Several representative chips of each outcrop in the survey area were collected for trace- and major-element geochemical analysis. An approximate weight of 1 kg of rock was collected for each sample, with the weathering rind on the sample removed in the field with a rock pick. Samples were shipped to a commercial laboratory for major- and trace-element geochemical analysis. Variations in trace-element geochemical data from this rock sampling survey will be reported at a later date. Pulp derived from sample preparation were returned and the conductivity for each sample was measured.

Analytical method

Measurement of conductivity in rock-powder slurries, derived from outcrop rock-chip samples collected by Hudson Bay Mining and Smelting Co. Ltd. in the general area of the Photo Lake Cu-Zn deposit, was carried out as follows:

- 1) 0.50 g of rock powder were weighed into a 150 ml tall-form beaker that was thoroughly washed in dilute HCl and in distilled and de-ionized water.
- 2) 100 ml of de-ionized water was added to the rock powder in the tall-form beaker, along with an acid-washed stirring bar.
- 3) The beaker containing the rock powder and de-ionized water was placed on a magnetic stirrer for 2 minutes. A timer was used to monitor the time.
- 4) After two minutes, the beaker was removed from the magnetic stirrer, the bar was removed with a magnet, and the conductivity and pH were measured using a Radiometer conductivity meter (type CDM Ze) with a Radiometer conductivity electrode (type CDC 104), and a Fisher Accumet pH meter (model 620) with a Fisher Universal glass pH electrode (#13-636-3) and a Fisher Calomel reference electrode (#13-639-62).

Specific conductivity was measured first to avoid the introduction of KCl from the pH reference electrodes into the solution. Corrected conductivity or specific conductance (K) and the hydrogen ion (H^+) or H_3O^+ (ag) were calculated using the following equations (*after* Govett and Atherden, 1987):

$$K = K_s - K_w - 0.34982(10^{(6-pH_s)} - 10^{(6-pH_w)}) - 0.1976(10^{(pH_s-8)} - 10^{(pH_w-8)})$$

$$H^+ \text{ (ppb)} = 10^{(6-pH_s)} - 10^{(6-pH_w)}$$

where

K = corrected specific conductance of the slurry in microsiemens·cm⁻¹ (μS·cm⁻¹)

K_s = conductivity reading on sample slurry

K_w = conductivity reading on water blank

pH_s = pH reading on sample slurry

pH_w = pH reading on de-ionized, distilled water blank

Data presentation

Corrected specific conductance values were plotted according to their UTM coordinates on the sampling grid (Figure 3) and contoured with arbitrarily selected 4 μS·cm⁻¹ contour intervals. The results are depicted in Figure 4.

Results

A solid bar in Figures 3 and 4 depicts the position of the surface projection of the Photo Lake Cu-Zn massive sulphide zone of mineralization. In Figure 4, the deposit is located at the southwestern end of a zone of low specific conductance (12–16 μS·cm⁻¹). This ‘ K ’ low has a long axis that is oriented east to slightly northeast, parallel to the strike of the orebody. The low has approximate dimensions of 400 m by 180 m and, for the most part, occurs to the north of the deposit. Rock-powder slurries in this zone have specific conductance responses of 12–20 μS·cm⁻¹. The bulk of the K low occurs northeast of the Photo

Lake deposit, extending for approximately 275 m east of the east end of the orebody. This central low is surrounded by a more extensive, irregularly shaped zone of specific conductance values that vary from >28 to $>40 \mu\text{S}\cdot\text{cm}^{-1}$.

The overall pattern is one of a central low that, for the most part, encircles the Photo Lake orebody and extends in a southwest-northeast direction. It should be noted that the pattern is truncated by sampling to the southwest but it is open to the northeast.

Discussion

The results obtained from the Photo Lake *K* survey and depicted in Figure 4 bear a strong resemblance to the hypothetical model for the anomaly pattern produced at surface over a reduced 'body' of mineralization (Figure 5). The reducing pole or cathode would correspond to the central low or zones of element depletion observed directly over the body, and the anodes or oxidizing poles that flank the reducing low correspond to scattered or irregularly distributed peaks or trace-element highs. The irregular distribution or asymmetric distribution of trace-element anomalies (or elevated *K*) is probably the result of deposit geometry, structural overprint of the deposit and host rocks, chemistry and zoning of the reduced body, water table depth and characteristics of groundwater flow.

The central low and peripheral *K* highs delineated in the outcrop associated with the Photo Lake Cu-Zn deposit represent a focused exploration target. In the absence of surface exposures of the deposit and associated alteration, the *K* anomaly has reduced a large area of exploration to a much smaller zone where traditional exploration approaches, such as ground geophysics and diamond-drilling, can be utilized. As such, the measurement of *K* in rock-powder slurries becomes a rapid, inexpensive and cost-effective geochemical technique of identifying areas for detailed follow-up.

The mechanisms of formation of the zones of *K* around the Photo Lake deposit are undoubtedly the result of the electrochemical mobilization of metals from the deposit and its alteration halo into the surrounding bedrock. This concept is not a new one and has been discussed in one form or another by Bolviken and Logn, 1975; Govett, 1976; Smee and Sinha, 1979; Sivenas and Beales, 1982a, b; Smee, 1983; Govett et al., 1984; and Govett and Atherden, 1987. These papers describe electrochemical models and their effects on the distribution of trace metals in soils above known mineralized zones. In the case of the Photo Lake deposit, a Mobile Metal Ion[®] process survey (Fedikow, 1999) was able to document zones of elevated base and precious metals vertically above the mineralization in glaciofluvial sand. Although empirical in nature, it would appear that element distributions in soils above the Photo Lake deposit are reflecting the mobilization of metals from source and into the surrounding bedrock. This process of metal redistribution apparently does not end within bedrock but continues to influence element distribution in soils above the bedrock, as reflected by the results at Photo Lake and in numerous other case histories where distinctive soil and vegetation geochemical patterns, developed above base-metal mineralization, mimic geophysical responses.

A practical application of measuring the hydrogen ion (H^+) and specific conductance in soils has been presented by Ferreira and Fedikow (1990) for the Rod Cu-Zn and Big Island Zn-Cu-Au massive sulphide type deposits. In this study, the authors were able to demonstrate that the traditional aqua regia-atomic absorption spectrophotometry trace-element soil-geochemical signature (humus and B-horizon) of the Big Island base-metal deposit in Flin Flon could be reproduced by the measurement of conductivity in soil slurries. Furthermore, the large area surveyed with traditional soil geochemistry was significantly reduced, based on the measurement of *K*, to a much smaller, focused area.

The Photo Lake rock-slurry conductivity survey further establishes the linkage that exists between a base-metal massive sulphide type deposit, its electromagnetic geophysical signature and the unique distribution of metals in host rocks and transported and reworked soils present above the blind deposit.

These linkages provide an indirect method for explorationists who find themselves confined to environments with postmineralization rock mantled by transported overburden of indeterminate depth and variable composition.

Conclusions

The specific conductance survey undertaken in the area of the Photo Lake Cu-Zn massive sulphide deposit has resulted in the identification of unique rock-geochemical features in rocks associated with the deposit. The following conclusions are evident from this study:

- A multisample specific conductance (K) low occurs partly over the surface projection of the Photo Lake deposit. This zone of water extractable metal extends to the northeast of the deposit and indicates that the response mimics the north dip and the northeast plunge of the mineralized zone.
- The K low is surrounded by K highs that are irregularly distributed around the periphery of the K low.
- This distribution of K highs about a central K low is strongly suggestive of an electrochemical mechanism of formation for these geochemical responses. The central K low corresponds to the cathode or reducing pole, and is characterized by low metal contents. The anodes or oxidizing poles that flank the reducing pole are characterized by K highs.
- These distinctive K patterns represent an area of focus for more traditional exploration approaches, such as ground geophysics and diamond-drilling.
- A geochemical survey based on the specific conductance of rock powder slurries can be used in new exploration areas where no exploration focus has been achieved. The survey can focus attention on electrochemical cells generated by massive sulphide type mineralization.

Specific conductance measurements are rapid, inexpensive and cost effective. As such, they represent another nontraditional geochemical technique that can be applied to base-metal massive sulphide exploration.

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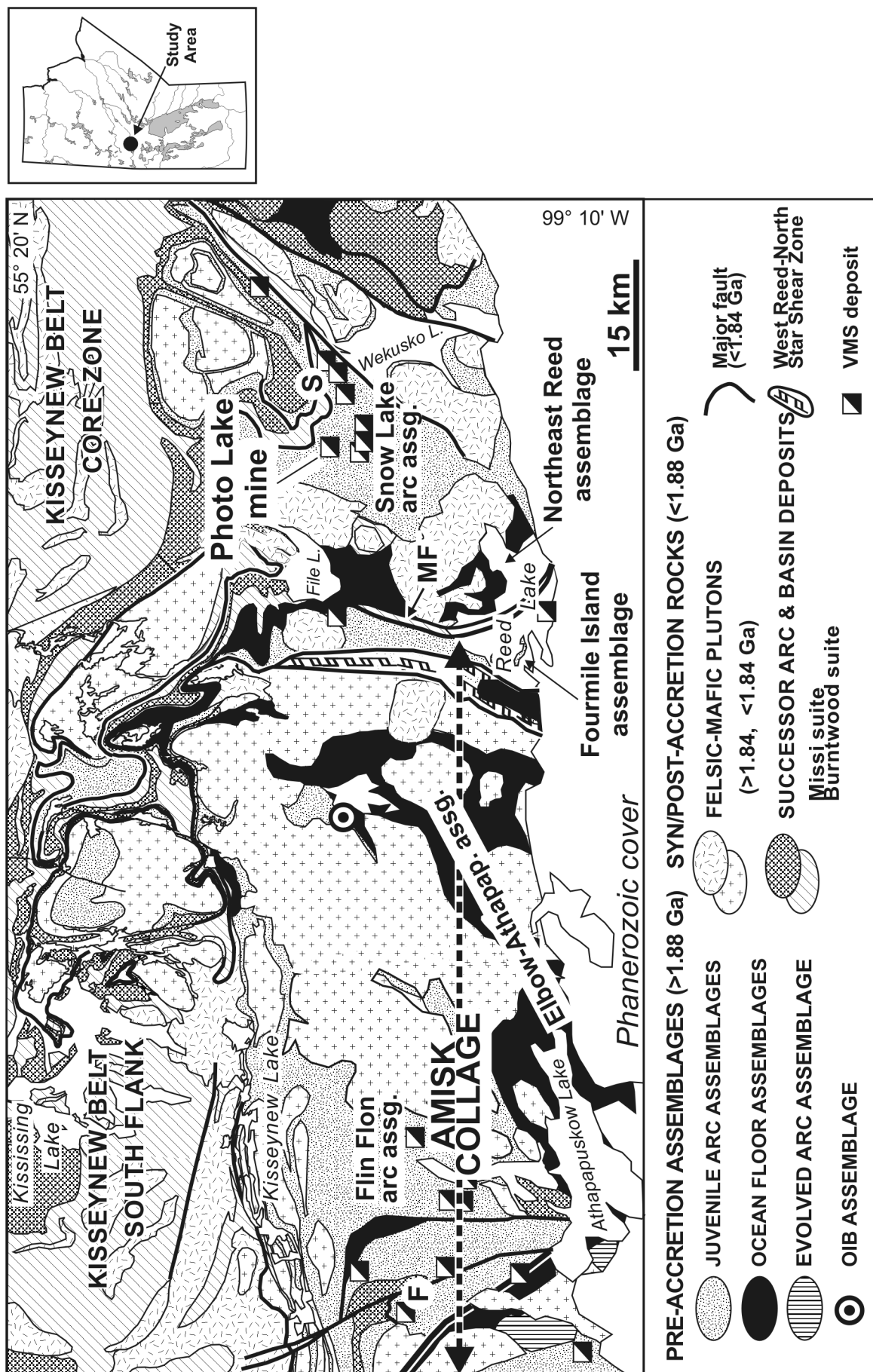


Figure 1: Regional geological setting and location of the Photo Lake Cu-Zn massive sulphide type deposit, Snow Lake area (after Bailes, 1996).

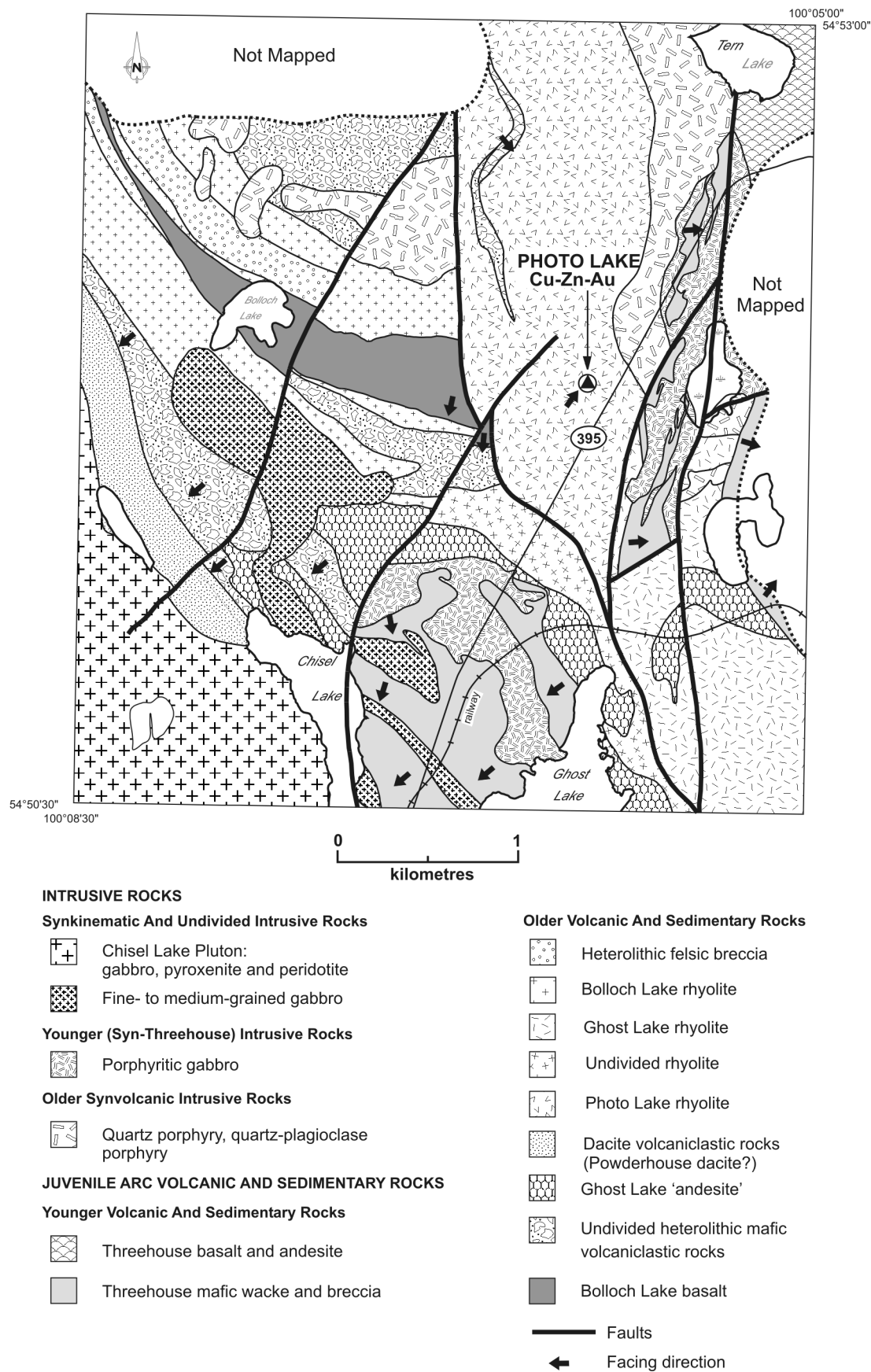


Figure 2: Local geological setting of the Photo Lake Cu-Zn massive sulphide type deposit, Snow Lake area (from Bailes, 1996).

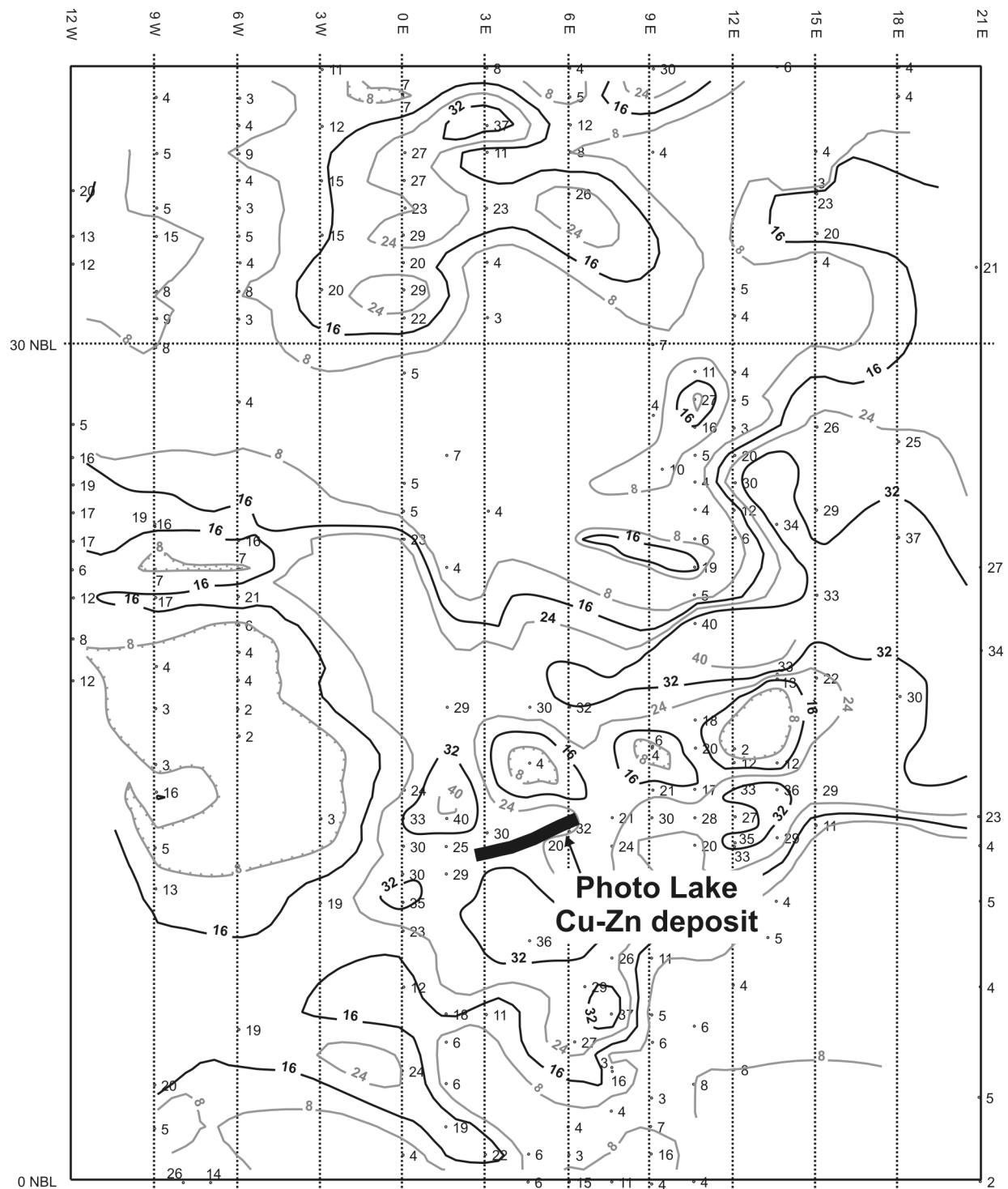


Figure 3: Outcrop rock-chip sample locations, contoured specific conductance data (in $\mu\text{S} \cdot \text{cm}^{-1}$) and location of the surface projection of the Photo Lake Cu-Zn massive sulphide type deposit, Dub 21 grid, Snow Lake area.

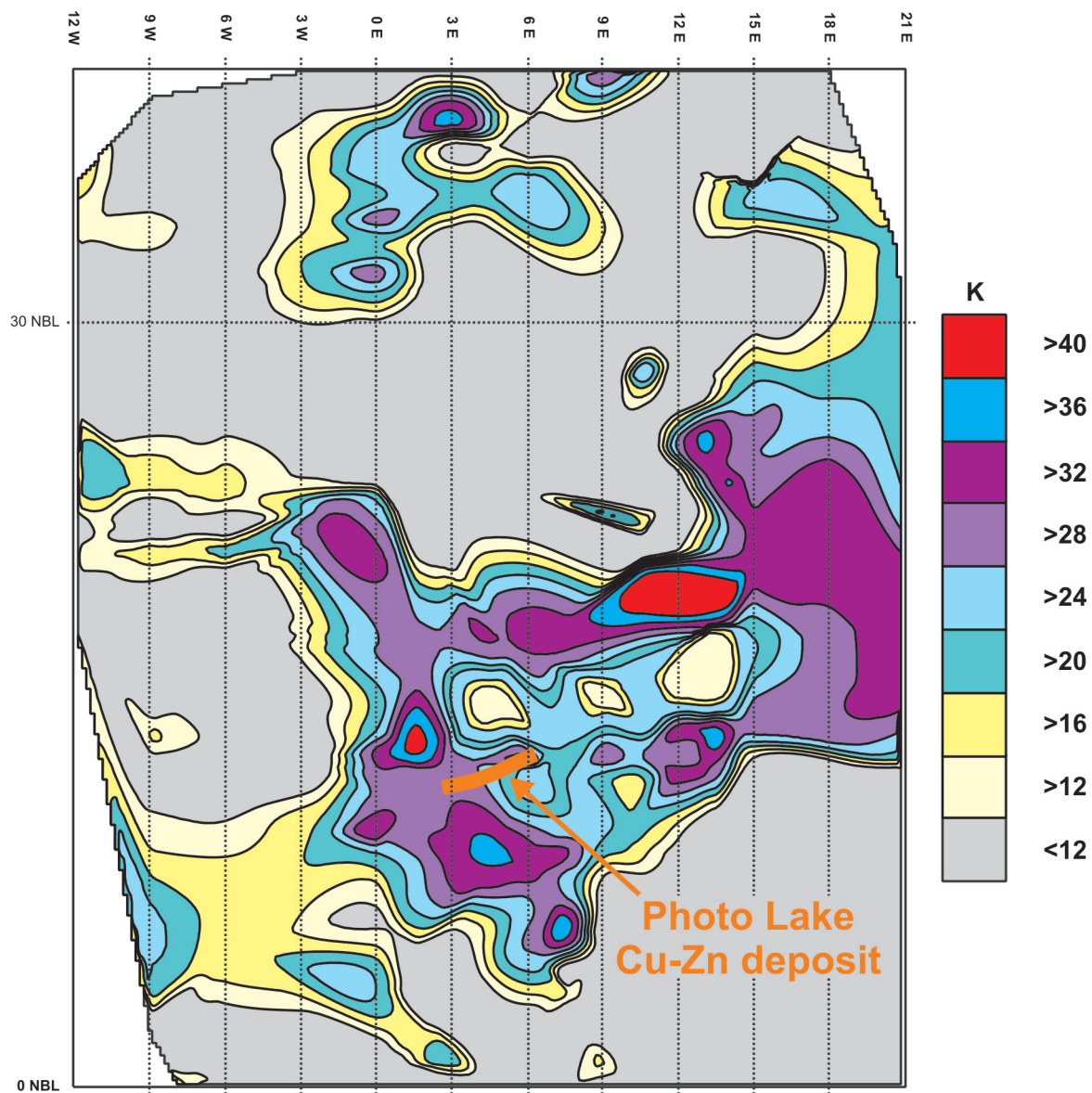


Figure 4: Colourized contour map of specific conductance measurements (in $\mu\text{S} \cdot \text{cm}^{-1}$) on rock-powder slurry samples, Dub 21 grid, Photo Lake survey.

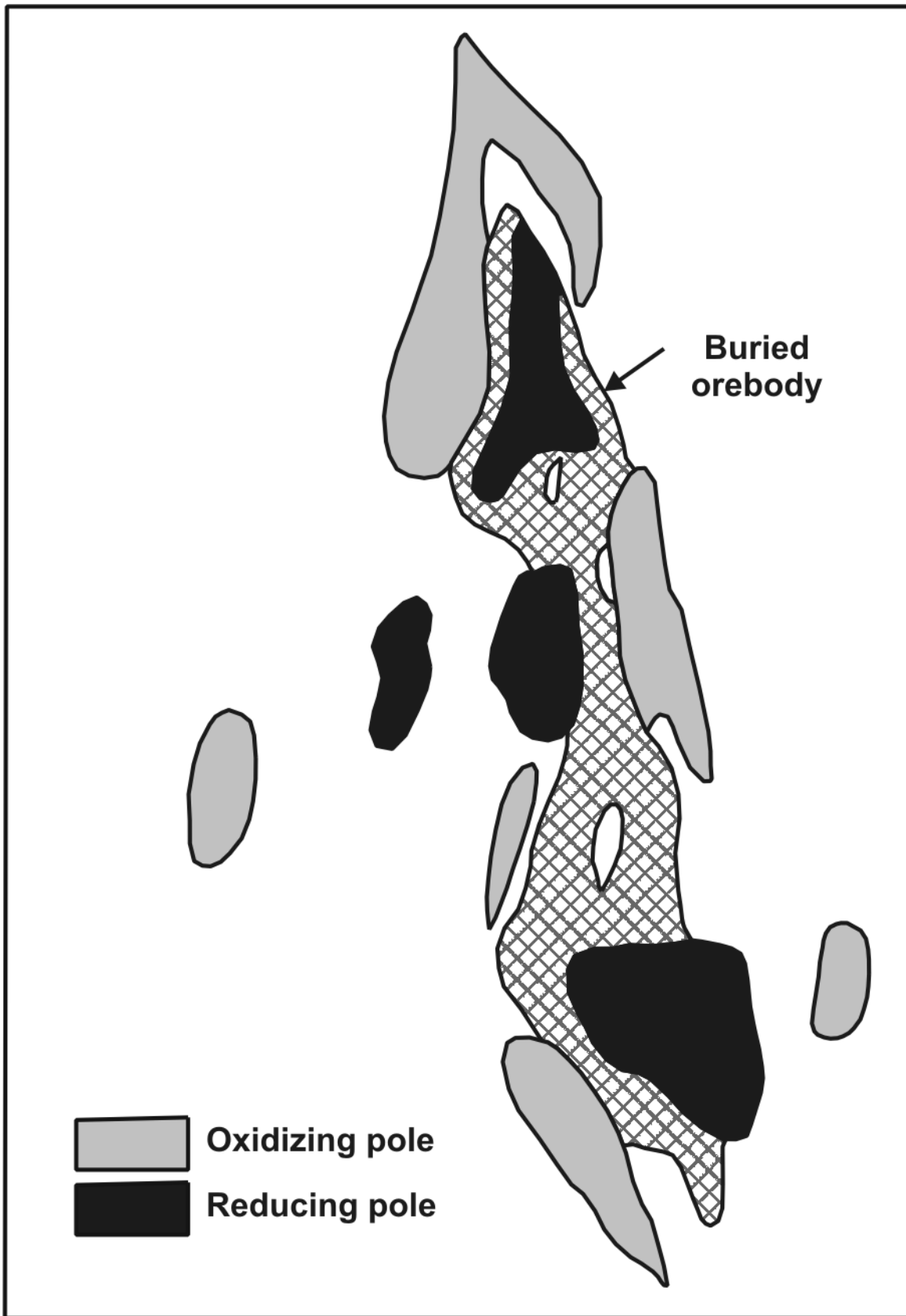


Figure 5: Hypothetical model for the distribution of selective- and partial-extraction soil-geochemical anomalies formed in response to oxidizing and reducing poles of a mineralization-related electrochemical cell.