Application of Detailed Ground Magnetic Surveys in an Acid Rock Drainage Study along Highway 101, Lower Sackville to Mount Uniacke (NTS 11D/13), Nova Scotia

R. D. Fitzgerald[1] and T. A. Goodwin

Introduction

Acid rock drainage (ARD) was first identified in Nova Scotia in 1961 when sulphide-bearing Meguma Group rocks exposed in the construction of Halifax International Airport oxidized and lowered the pH of the receiving streams, resulting in a major fish kill between 1957 and 1960 (Environmental Protection Service, 1976). Early studies identified pyrite as the main mineral responsible for ARD in the Meguma Group (Ferguson and Erickson, 1987). Recent study of Halifax Formation slate in central Nova Scotia, however, indicates pyrrhotite is also commonly found within the slate (Zentilli and Fox, 1998; Fox *et al.*, 1997; Haysom *et. al.*, 1997; Fox and Robinson, 1996; King, 1994). Pyrrhotite was found to oxidize faster than pyrite, resulting in rapid generation of ARD (Zentilli and Fox, 1998; Fox *et al.*, 1997; Haysom *et al.*, 1997; Fox and Robinson, 1996).

Previous research has confirmed the presence of pyrrhotite and magnetite (both minerals are magnetic) in metasedimentary rocks of the Meguma Group (Howells and Fox, 1998; King, 1997). Evaluating pyrrhotite concentrations with ground magnetic surveys in the Meguma Group, therefore, may provide a useful tool for planners and developers when assessing the potential for ARD. To date, ARD studies utilizing ground magnetic surveys to evaluate pyrrhotite concentrations in the Meguma Group have been limited to central Nova Scotia (Howells and Fox, 1998; Fox *et al.*, 1997; King, 1997).

Given the distribution of pyrrhotite throughout the Meguma Group, the main objective of this study is to assess the reliability of ground magnetic surveys in locating pyrrhotite-rich rock in the Meguma Group. A further outcome of the study is to better define geologic contacts between the various metasedimentary members of the Meguma Group in the study area, which is characterized by thick till cover.

Study Area

The study area is located in central Nova Scotia between Lower Sackville and Mount Uniacke (NTS 11D/13), approximately 20 km northwest of Halifax (Fig. 1).

Bedrock Geology

The study area is underlain by the Cambro-Ordovician Meguma Group, consisting of two formations (Fig. 2). The Goldenville Formation has an approximate minimum thickness of 5400 m and consists of a thick sequence of grey to greenish-grey metasandstones (Ryan *et al.*, 1996). The Goldenville Formation is conformably overlain by the younger Halifax Formation, which varies in thickness from 500 m to 13 500 m, and consists of dark grey to grey-green slate and metasiltstone (Schenk, 1995).

Goldenville Formation

The Goldenville Formation has been subdivided based on lithology by Ryan *et al.* (1996). The Steve's Road member, which occurs within the study area, is at the top of the Goldenville Formation and is approximately 700 m thick. This

[1]Master of Applied Science student, Department of Geology, St. Mary's University, Halifax, Nova Scotia B3H 3C3 (rogerf@hfx.eastlink.ca)

Fitzgerald, R. D. and Goodwin, T. A. 2005: *in* Mineral Resources Branch, Report of Activities 2004; Nova Scotia Department of Natural Resources, Report ME 2005-1, p. 7-13.

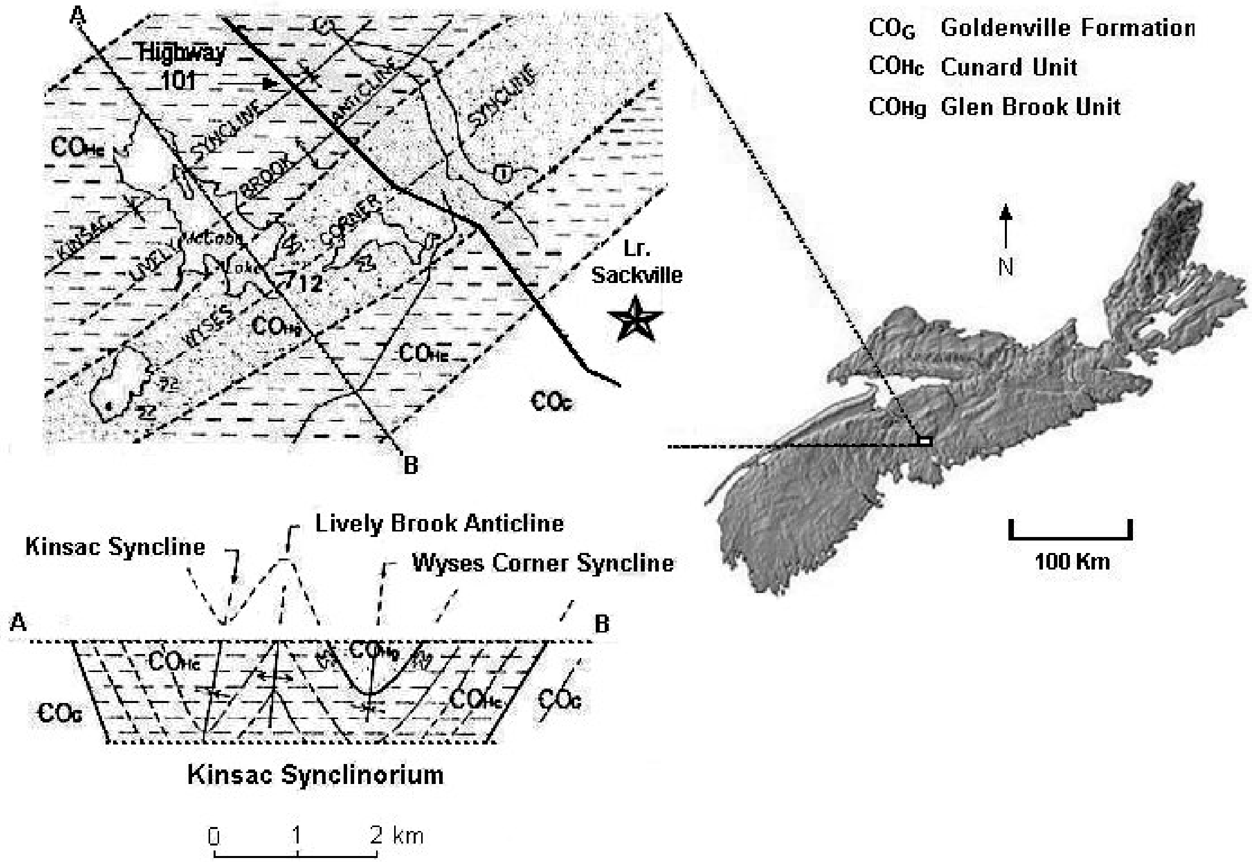

Figure 1. Map of the study area showing bedrock geology and location of the ground magnetic survey line along Highway 101. Profile A-B is a cross section through the Kinsac Synclinorium (revised from Horne *et al*., 1998).

member consists of medium-grained meta-quartz arenite (metasandstone) and is interbedded with minor metasiltstone and slate. The mineralogy includes trace amounts of sulphide minerals and magnetite (Haysom *et al.,* 1997, Fig. 3). The Goldenville Formation below this unit consists of undivided sandstone, siltstone and slate.

Halifax Formation

Beaverbank Member

The Beaverbank Member represents the basal unit of the Halifax Formation and consists of metasiltstone, silty slate, and meta-quartz arenite (metasandstone) beds (Ryan *et al.,* 1996). It generally fines upward, with decreasing metasandstone towards the top (Ryan *et al.,* 1996), and has been subdivided into the upper beds and lower beds (Fig. 4). It was suggested by Ryan *et al.* (1996) that this member is the equivalent of the Green Bay Formation, as described by O'Brien (1988), which was assessed to have a thickness of 2 km. Coticule zones containing up to 60% spessartine garnet are present in the upper part of this member and are diagnostic features, making it a useful marker horizon. The lower beds contain abundant ilmenite, while the lower section of the upper beds contains abundant pyrite. The top section of the upper beds of this member was found to contain abundant pyrrhotite and pyrite with locally abundant ilmenite (King, 1997; Haysom *et al.,* 1997, Fig. 3).

Cunard Member

Overlying the Beaverbank Member is the Cunard Member. This member consists of finely laminated

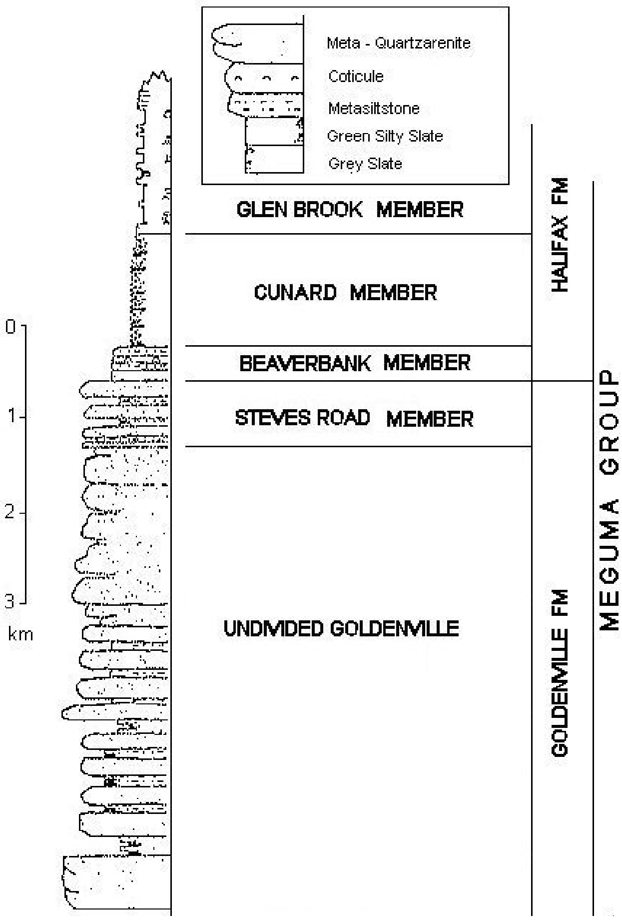

Figure 2. Stratigraphy of the Meguma Group in the study area (modified after Ryan *et al.*, 1996).

grey to black-grey slate, and is approximately 1100 m thick (Ryan *et al.*, 1996).

The Cunard Member (formerly referred to as the Rawdon unit) was further subdivided by Horne (1995) into subunits “a” and “b” (Fig. 3). King (1997) describes subunit “a” as having abundant pyrrhotite and also containing pyrite, biotite, chlorite and minor ilmenite. He further describes subunit “b” as having abundant ilminite and containing rutile and chlorite, with trace amounts of pyrite. The Cunard Member is further characterized by a distinctive high magnetic signature (King, 1997; Ryan *et al.*, 1996), with subunit “a” having the highest content of sulphides (> 5%; Haysom *et al.*, 1997).

Glen Brook Member

The Glen Brook Member conformably overlies the Cunard Member (Fig. 3). In the study area, this member contains thinly banded greenish-grey metasiltstone and rare metasandstone beds (Horne *et al.*, 1998). This member is approximately 1900 m thick in the Rawdon Syncline area (Ryan *et al.*, 1996) and contains only trace amounts of sulphide minerals (Haysom *et al.*, 1997). King (1997) describes the Glen Brook Member as containing abundant ilmenite, biotite, and chlorite, which may affect its magnetic character.

Ground Magnetic and Chip Sampling Survey

An EG & G Geometrics Model G-856A magnetometer was used to acquire the ground magnetic data for this study. Total field magnetic readings were recorded approximately every 12.5 m for a total of 538 stations.

The magnetic survey followed a 10 km line parallel to Highway 101 (Fig. 1). The entire line was surveyed over a period of several days. A new base station was established daily for each line segment and diurnal variations were observed and corrections made for on a daily basis. At each station the total field magnetic readings were recorded along with UTM coordinates. Descriptive comments, including the presence of outcrop, guardrails, logging roads, ATV trails and garbage, were recorded. The line was oriented perpendicular to the regional structure and crossed all members of the Meguma Group on both sides of the Kinsac Syclinorium (Fig. 1).

Once the ground magnetic survey was completed, the plotted results were used in combination with observed outcrop locations to determine optimum rock sampling site locations. Outcrops were revisited and 5 kg samples of composite rock chips were collected for future geochemical analysis. The sampling program was designed to ensure that the rock samples collected were representative of each member in the study area. Fourteen rock samples were collected along the entire length of the line (Figs. 4 and 5). The sampling stations were selected to: (1) give stratigraphic representation, (2) give spatial representation over the length of the survey line, and (3) systematically sample representative members of variable magnetic intensities.

In some instances, there were no outcrops along the survey line available to sample for certain members (e.g. Beaverbank Member). Samples,

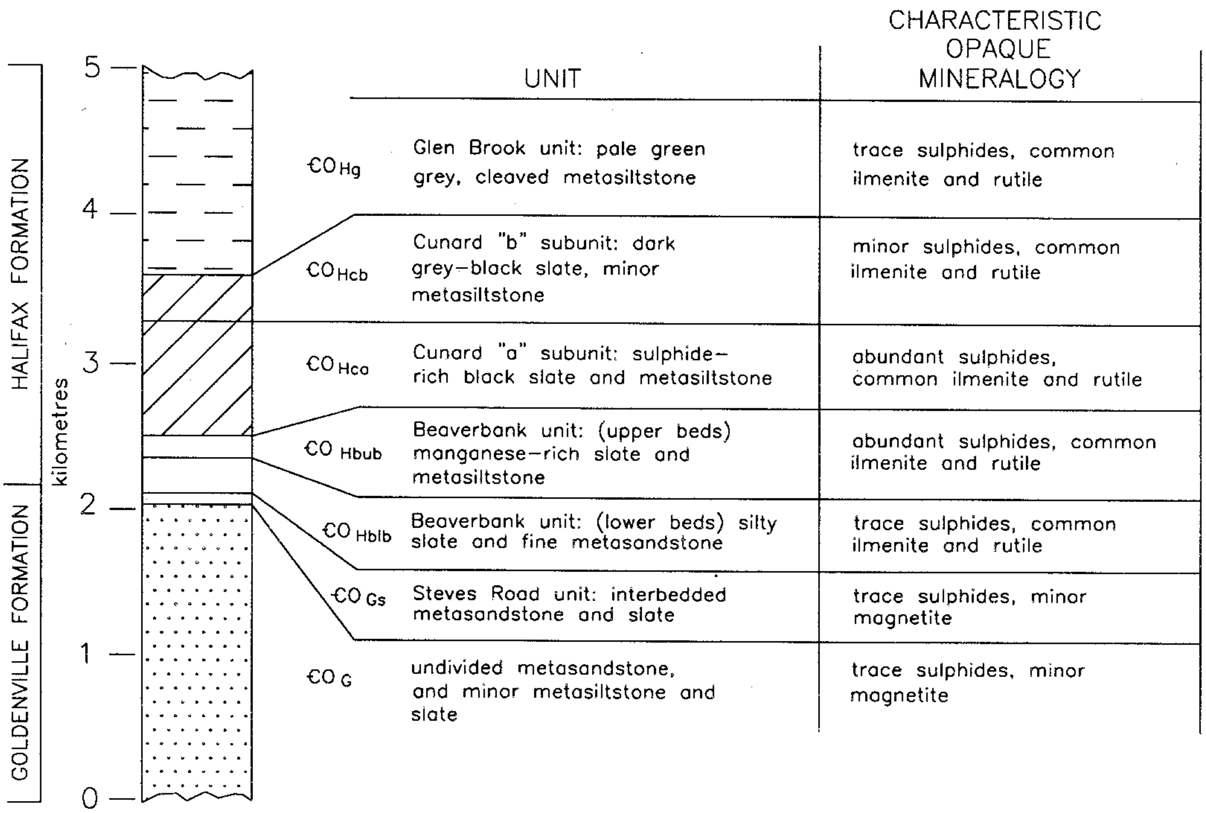

Figure 3. Revised stratigraphy of the Meguma Group in central Nova Scotia, with subdivision of the Beaverbank Member and abundance of sulphide minerals (modified after Haysom *et al.*, 1997).

therefore, were collected from nearby outcrops located off the survey line but estimated to be as close as possible to the same stratigraphic level.

Results

Total field magnetic results for the entire line are presented as a line graph in Figure 4 and as an x-y scattergram in Figure 5. The plotted data in both graphs have been corrected for diurnal variations and for cultural effects (e.g. culverts, power lines). These cultural effects produced spurious low readings and have been removed from Figures 4 and 5. Stations that were characterized by the highest magnetic readings were revisited in the field. Outcrops at these locations were tested with a hand-held magnetic susceptibility meter and numerous thin beds were identified as having extremely high magnetic susceptibilities. These outcrops were further characterized by their rusty iron-stained appearance. Fresh samples contained abundant sulphides, dominated by pyrrhotite (approximately 5%, visual estimation). A hand magnet and hand lens were used to support the observation that the chief sulphide mineral was pyrrhotite. Cultural effects were not observed at any of these sites; therefore, the high total field magnetic readings were presumed to be caused by the presence of pyrrhotite in bedrock. This demonstrates that the magnetometer can be used to locate pyrrhotite-rich beds and can be used as a predictive tool in ARD studies.

The proposed geologic contacts presented in Figure 5 take into consideration previous bedrock mapping (Horne *et al.*, 1998; Ryan *et al.*, 1996; Ryan, 1995), mineralogical investigations (Haysom *et al.*, 1997; Fox and Robinson, 1996; Fox *et al.*, 1997; King, 1994, 1997; Zentilli and Fox, 1998), evaluation of aeromagnetic data (King, 1994, 1997), and our field observations.

Discussion

The highest magnetic measurements in the study

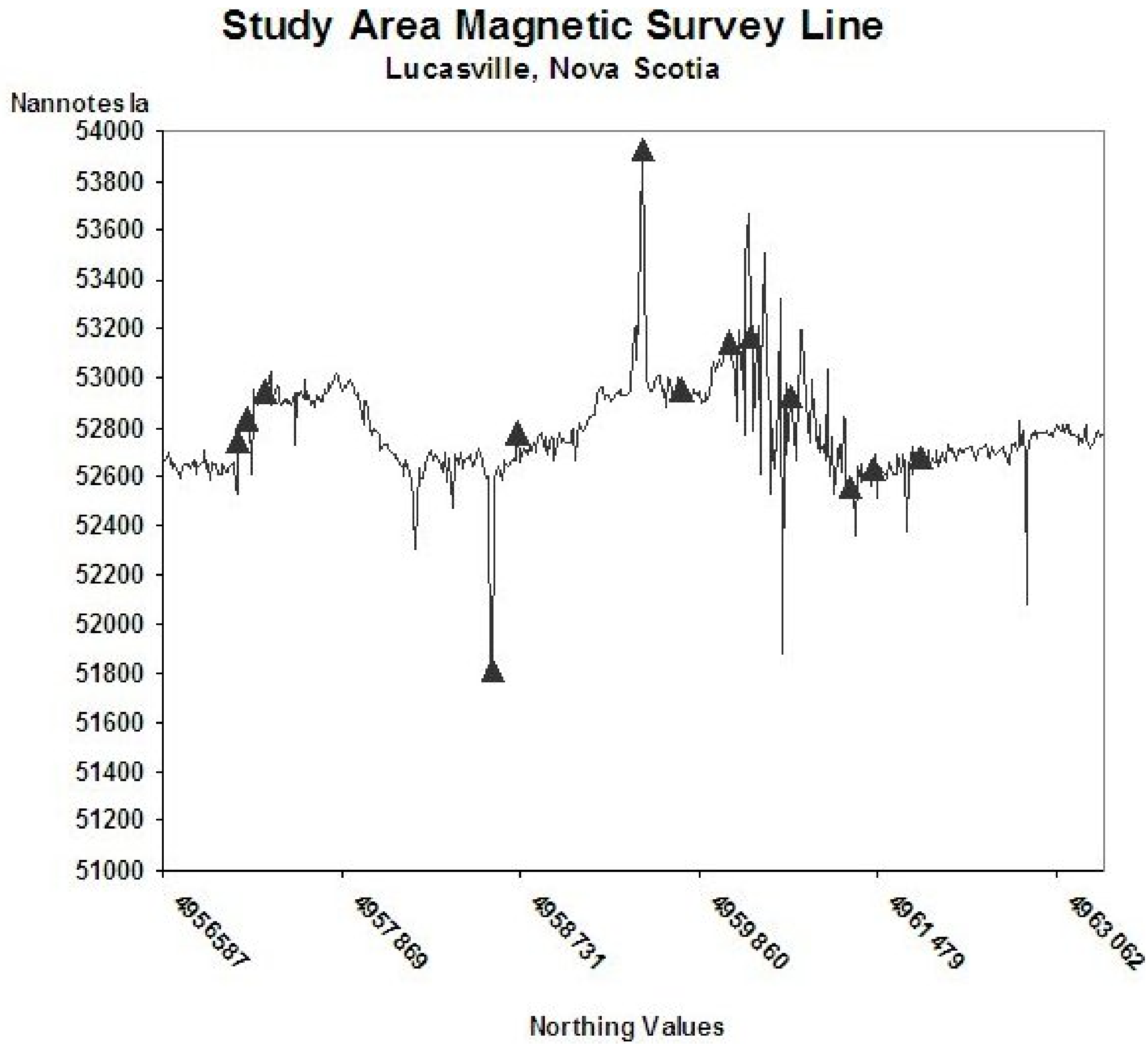

Figure 4. Line graph of corrected magnetic survey readings with corresponding selected sample locations, which are represented by triangles.

were from the pyrrhotite-rich Cunard Member. This was closely followed by the Beaverbank Member, which also contains locally abundant sulphides, dominated by pyrrhotite.

In the field, these two members were characterized by their red rusty appearance, the presence of sulphides, and their high magnetic susceptibilities. Therefore, these two members are likely to generate problems with respect to acid rock drainage when exposed to oxidizing conditions.

The Glen Brook Member, the Steve's Road Member, and the undivided Goldenville Formation are characterized by low ground magnetic readings, negligible to trace sulphide content, and low magnetic susceptibility readings. These three members, therefore, are less likely to contribute in the generation of ARD when exposed to oxidizing conditions.

Figures 4 and 5 show a rising magnetic response of the Goldenville Formation on the north end of the survey line. This may be attributed to the presence of magnetite in a thermal aureole associated with intrusion of the South Mountain Batholith (McGrath, 1970), which outcrops approximately 2 km to the north.

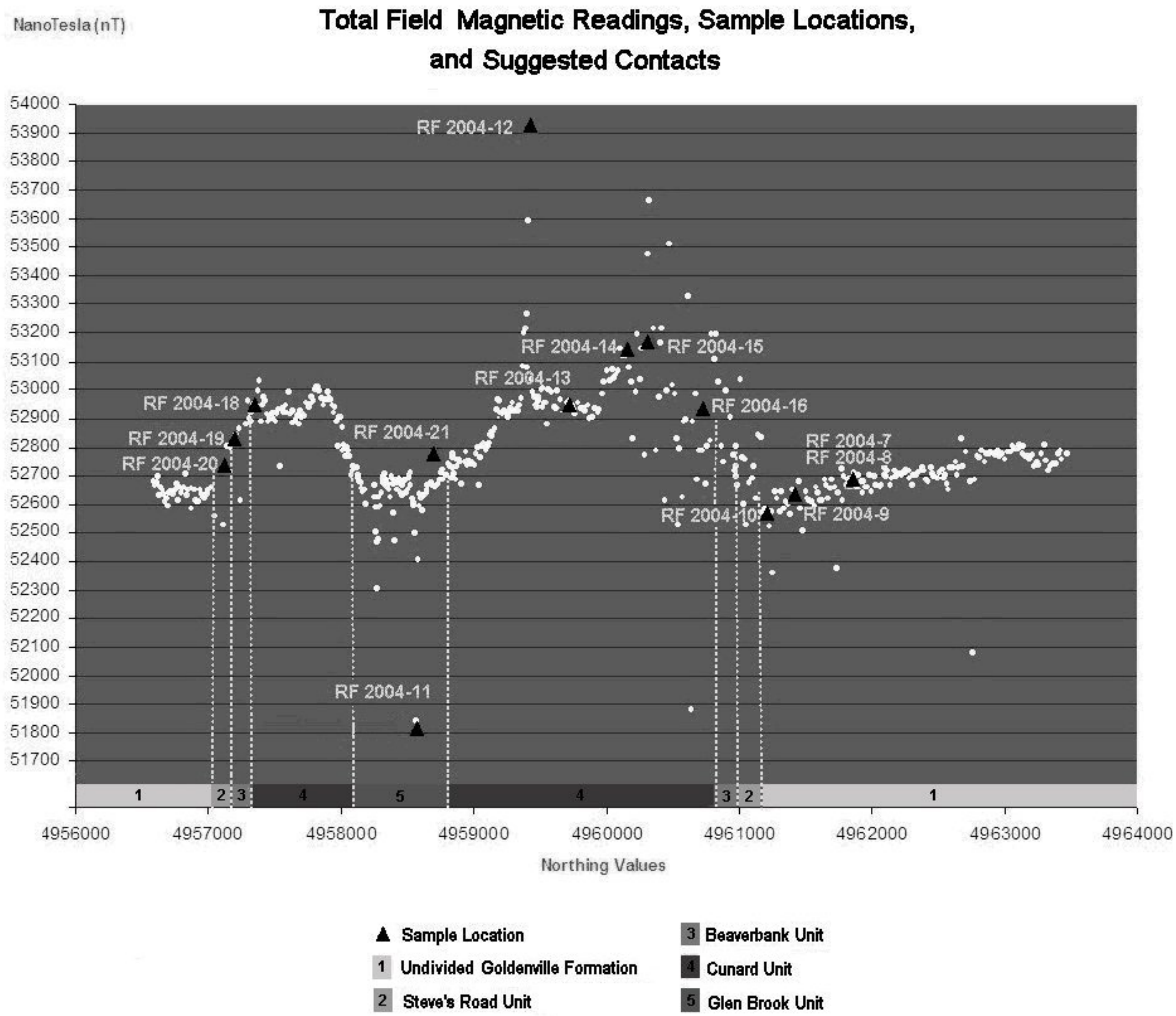

Figure 5. Corrected Total Field magnetic results for the Highway 101 line along with proposed contacts of members within the study area. Rock samples collected from outcrops are represented as triangles.

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