GS-2 Toward a new sub-Phanerozoic Precambrian basement map of the Flin Flon Belt, Manitoba (parts of NTS 63J, K, L)

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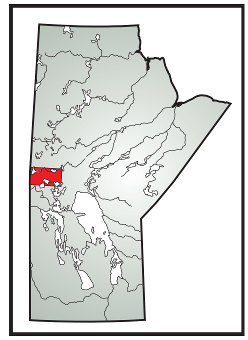

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Summary

The Flin Flon Belt is one of the largest Paleoproterozoic volcanogenic massive sulphide (VMS) districts in the world. With the intent of supporting private-sector resource exploration in the Flin Flon–Snow Lake area, the Manitoba Geological Survey, in collaboration with the Saskatchewan Geological Survey and the Geological Survey of Canada, has initiated a new mapping project in the sub-Phanerozoic portion of the Flin Flon Belt. The main objective of this project is to produce a set of revised geological maps for the sub-Phanerozoic geology of the Flin Flon Belt. This project also aims to better define the various domains of the sub-Phanerozoic portions of the Flin Flon Belt using new geophysical, isotopic, geochronological and geochemical data. The purpose of this investigation is to compare and possibly correlate rocks in the sub-Phanerozoic domains with those in the well-documented tectonostratigraphic assemblages of the exposed portion of the belt.

The renewal of the sub-Phanerozoic Flin Flon Belt map is a multiyear project that started in the last two years with the gathering and compiling of geophysical and geochemical data. More than 13 000 whole-rock geochemical analyses from both the sub-Phanerozoic and exposed portions of the Flin Flon Belt have been incorporated into a single GIS-based database. A field program was initiated in 2009 to document some of the known mineral deposits in the sub-Phanerozoic Flin Flon Belt. Selected drillcores from the Talbot, Fenton, Harmin and Moose VMS deposits were studied and sampled for whole-rock geochemical, geochronological (U-Pb) and Sm-Nd isotope analyses; analytical results are pending. Increasing our understanding of the setting of the various known deposits in the covered portion of the Flin Flon Belt will help to develop and tailor exploration models in these highly prospective but hidden rocks.

Introduction

The Flin Flon Belt is one of the largest Paleoproterozoic volcanogenic massive sulphide (VMS) districts in the world. It is composed of a series of tectonostratigraphic assemblages (juvenile arc, juvenile ocean-floor back-arc, ocean plateau, ocean-island basalt, evolved plutonic arc), is flanked to the north by gneiss of the Kisseynew Domain and extends south beneath the Phanerozoic rocks of the Western Canadian Sedimentary Basin (Figure GS-2-1). All VMS deposits found to date are located within the juvenile-arc volcanic rocks.

Extensive mineral exploration spanning almost a century in the exposed parts of the Flin Flon Belt has led to the discovery of more than 25 ore deposits (as well as 40 subeconomic deposits; Syme et al., 1999), the most recent being the Lalor Lake deposit (2007) in the Snow Lake area. Recent exploration activity has, however, been more focused on the southern extension of the belt beneath the Phanerozoic cover, rather than within the exposed parts of the belt. Advances in geophysics during the last 20 years have rendered the Phanerozoic cover virtually transparent, thus leading to the discovery of several VMS deposits (e.g., Sylvia, Talbot, Reed, Fenton), as well as other base-metal deposits (e.g., Namew Lake) in the sub-Phanerozoic Flin Flon Belt.

Although successful mineral exploration in the sub-Phanerozoic Flin Flon Belt is still viable by applying standard geophysical techniques and diamond-drilling, a better understanding of the regional distribution of the various tectonostratigraphic assemblages and geological domains, particularly the location of favourable host rocks within juvenile-arc assemblages, will provide valuable guidance for new exploration programs.

Previous work

Previous sub-Phanerozoic maps of the Flin Flon Belt are the product of two federal-provincial collaborative efforts: Project Cormorant in the 1980s (e.g., Blair et al., 1988) and the Shield Margin Project in the Hanson Lake–Flin Flon–Snow Lake area in the 1990s as part of the federally sponsored National Mapping Program (NATMAP; e.g., Leclair et al., 1997; NATMAP Shield Margin Working Group, 1998). Each project involved the integration of extensive drillcore data and the acquisition of new, federally funded, high-resolution aeromagnetic and gravity surveys.

The mapping effort under the NATMAP program, conducted by A. Leclair of the Geological Survey of Canada, led to the publication of a set of 1:100 000 scale bedrock geology maps of the sub-Phanerozoic extension of the Flin Flon Belt (Figure GS-2-2; NATMAP Shield Margin Working Group, 1998). Based mainly on aeromagnetic and gravity anomaly data, as well as a comprehensive relogging program of mainly mineral-exploration drillcore, this project resulted in the recognition of several major domains in the buried basement, each with distinctive geophysical and geological

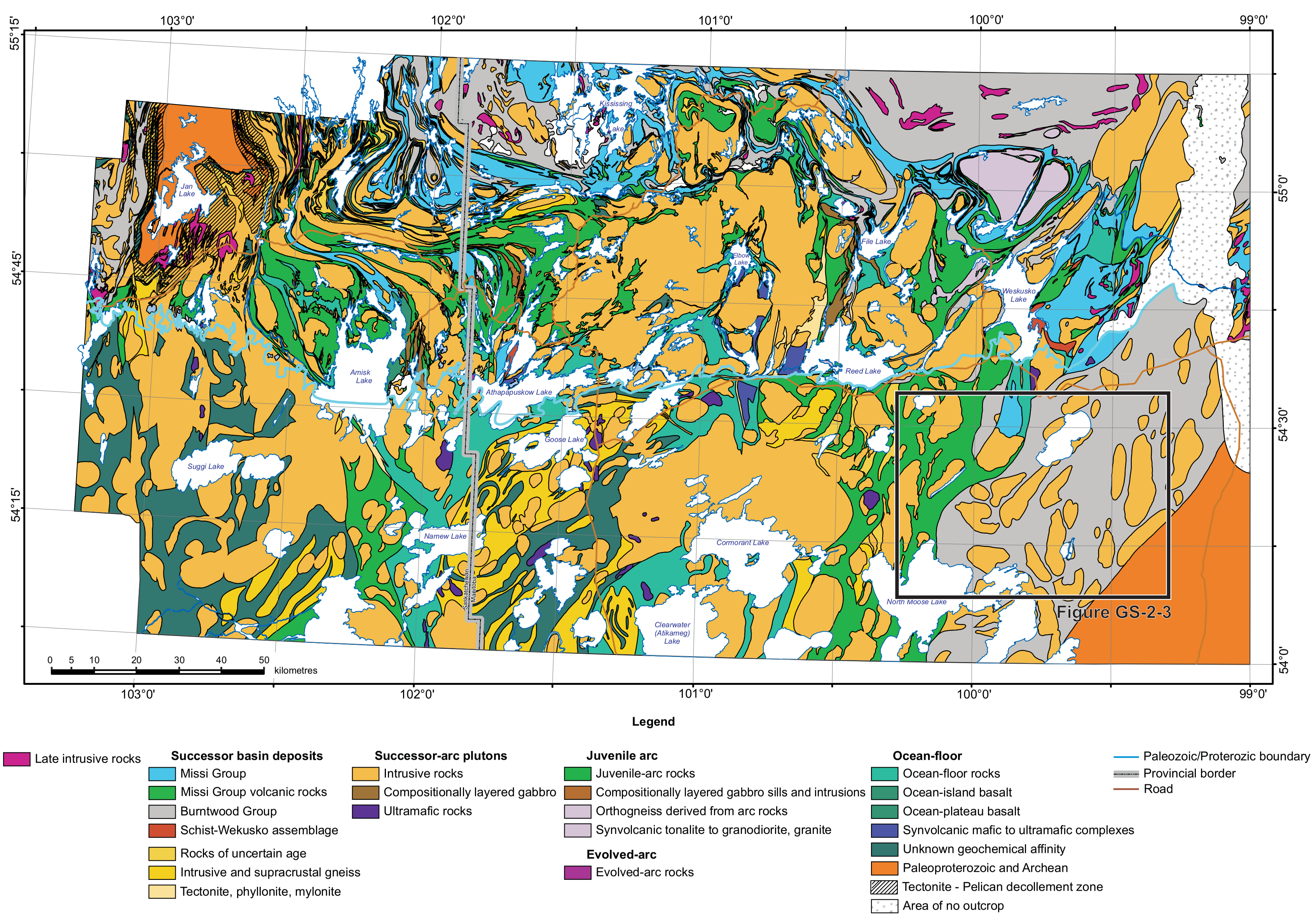

Figure GS-2-1: *Generalized geology of the Flin Flon Belt, including its sub-Phanerozoic southern extension* (modified from *NATMAP Shield Margin Working Group, 1988).*

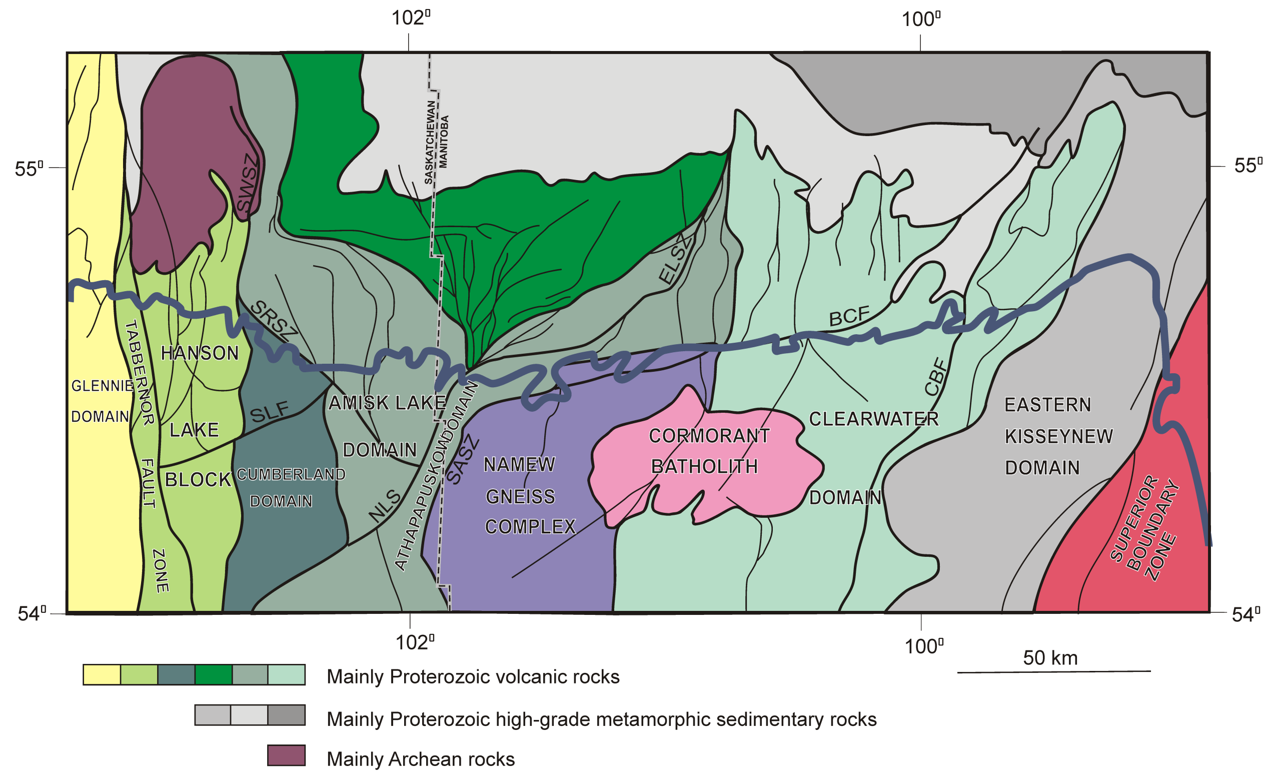

Figure GS-2-2: *Interpreted lithotectonic domains of the buried Flin Flon Belt (*after *NATMAP Shield Margin Project Working Group, 1998). Abbreviations of major fault and shear zones: BCF, Berry Creek Fault; CBF, Crowduck Bay Fault; ELSZ, Elbow Lake Shear Zone; NLS, Namew Lake Structure; SASZ, South Athapapuskow Shear Zone; SLF, Suggi Lake Fault; SRSZ, Spruce Rapids Shear Zone; SWSZ, Sturgeon Weir Shear Zone. The heavy blue line is the contact between the Precambrian (above the line) and Paleozoic-covered Precambrian.*

character (Leclair et al, 1997; NATMAP Shield Margin Working Group, 1998). Most of these domains represent sub-Phanerozoic extensions of major tectonic elements (tectonostratigraphic assemblages) in the exposed shield, but some domains appear to be restricted to the sub-Phanerozoic basement (Leclair et al., 1997). No analytical work (e.g., whole-rock or isotope geochemistry) and only limited geochronological investigations were carried out on these domains under the NATMAP program.

Objectives

The main objective of the current project is to produce a set of revised geological maps for the sub-Phanerozoic geology of the Flin Flon Belt in Manitoba. The project was initiated under the federal Targeted Geoscience Initiative 3 (TGI-3) program, with the intent of stimulating private-sector resource exploration in areas of high base-metal potential in established mining communities. Concurrent investigations in the Saskatchewan extension of the Flin Flon Belt (Flin Flon and Glennie domains) are being conducted by the Saskatchewan Geological Survey (*see* Morelli and MacLachlan, 2008). After mapping in both Saskatchewan and Manitoba is completed, the results will be integrated into a single, seamless, trans-border geological map.

This current project also aims to better characterize the various domains of the sub-Phanerozoic portions of the Flin Flon Belt using new geophysical, geochronological and geochemical data, including radiogenic-tracer isotope analyses. The results will facilitate comparison and correlation between the sub-Phanerozoic domains and the well-documented tectonostratigraphic assemblages of the exposed portion of the belt.

Methodology

Geophysics

This newest attempt at revising the sub-Phanerozoic bedrock map of the Flin Flon Belt involves detailed analysis of company-owned high-resolution aeromagnetic data that have either been released in the public domain or been made available to the Manitoba Geological Survey (MGS) for this project. Both traditional and more recent techniques for analyzing and displaying geophysical data, such as vertical and horizontal gradients, and ‘Slope’ and ‘maxima’ analyses (*see* details below), are being applied to building the new maps.

Figure GS-2-3 demonstrates four different ways to display the aeromagnetic data used in this project. Figure GS-2-3a is the ‘histogram-equalized residual total

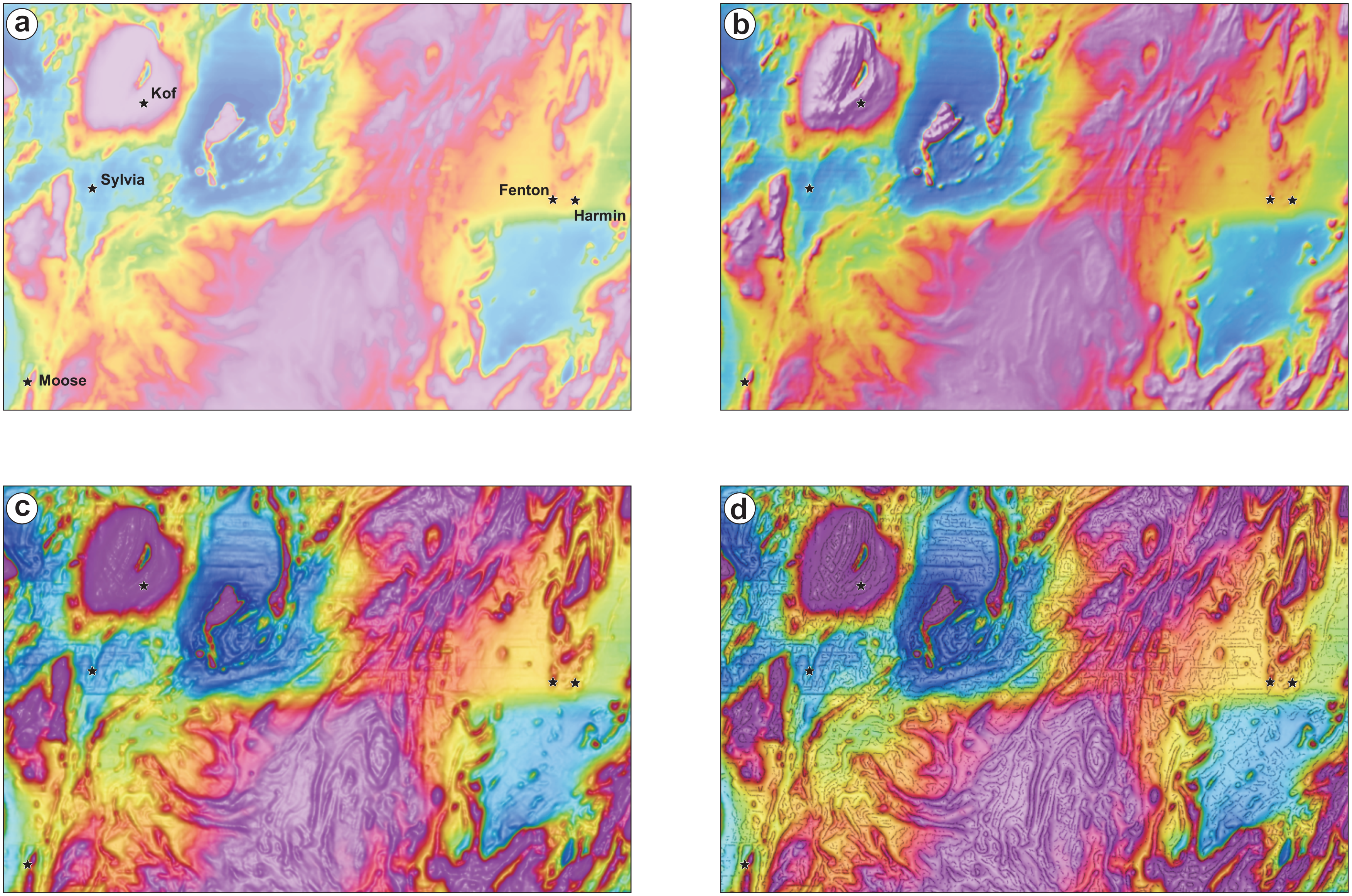

Figure GS-2-3: *High-resolution aeromagnetic survey images of the sub-Phanerozoic Flin Flon Belt just south of Reed Lake, Manitoba:* ***a)*** *residual total field, no shading;* ***b)*** *residual total field, hill-side shading;* ***c)*** *residual total field, shaded relief from 'Slope' analysis;* ***d)*** *residual total field with 'Slope' analysis and 'max slope' markings (dots). See text for details.*

field' for an area just south of Reed Lake. This simple way of presenting the data shows the distribution of the more magnetic versus the less magnetic rock packages. Figure GS-2-3b is the same 'histogram-equalized residual total field' dataset superimposed on a 'hillshade surface' (illumination from the northwest at 45º). This technique enhances the aeromagnetic response in areas where the vertical gradient is steep and positive, and at a high angle to the illumination. It highlights the internal trends in magnetic zones of very high amplitude (purples) but is less effective or ineffective in the more homogeneous areas, where there is not enough 'positive relief' to generate shading at this angle of illumination. Figure GS-2-3c displays the same 'histogram-equalized residual total field' dataset on a 'Slope' analysis surface, calculated by ArcGIS® Spatial Analyst. The 'Slope' function calculates the maximum rate of change in value from each cell to its neighbours, and assigns a slope value. The lower the slope value, the flatter the surface and the lighter the colour shade; the steeper the slope value, the steeper the surface and the darker the colour shade. As this technique uses 'maximum slope angle' with no regard for the amplitude or orientation of the breaks in the dataset, it equally enhances breaks of any amplitude and of all orientations. This technique highlights internal trends in the homogeneous areas of the survey, including artificial anomalies generated by flight lines (e.g., east-west trends in Figure GS-2-3c). Finally, Figure GS-2-3d shows the 'histogram-equalized residual total field' dataset on a 'Slope' analysis surface with 'max slope' markings (dots). The dots are located at the maxima of the horizontal gradient of the total magnetic field. Anomalies are sharply delineated and the internal trends of the various domains highlighted, thus facilitating the task of tracing the finest details of the aeromagnetic pattern.

Core logging, geochemistry and geochronology

A major component of the current project involves the examination and sampling, and in some cases relogging, of the extensive collection of drillcores from the sub-Phanerozoic portion of the Flin Flon Belt. More than 2600 holes, contained in both nonconfidential and confidential files, have been drilled in the study area during the past century. Of the 2600 holes, more than 600 were drilled after completion of the NATMAP program. The current drillcore survey aims at verifying the geophysical and geological domains delineated using geophysical surveys in the sub-Phanerozoic portion of belt.

The geophysical and geological data are being integrated with a GIS-based geochemistry and geochronology database that includes more than 13 000 samples from the entire Flin Flon Belt (exposed and sub-Phanerozoic portions; Figure GS-2-4; *see* details below). This GIS-based database is a key part of the project and will enable the rapid and efficient analysis of subsets of different data from specific portions of the belt. It will be possible to efficiently compare the various sub-Phanerozoic domains and the exposed tectonostratigraphic assemblages.

Another major component of this project is to identify available drillcores from portions of the sub-Phanerozoic Flin Flon Belt that are under-represented and/or missing in the exposed belt, and selectively sample core from these portions for whole-rock geochemistry, isotope (Sm-Nd) and geochronological (U-Pb) analyses. The results of these analyses will provide a better framework for correlation of the various units 1) within the sub-Phanerozoic domains, and 2) between the sub-Phanerozoic domains and the tectonostratigraphic assemblages of the exposed portion of the belt. First priority will be given to rock assemblages with known associated mineralization, starting in the areas south and southeast of Reed and Wekusko lakes and proceeding to additional 'underexplored' areas of the sub-Phanerozoic Flin Flon Belt.

Recent activities

Data compilation

The Manitoba Geological Survey has been gathering and compiling data for the last two years in preparation for this project. In collaboration with several exploration companies currently active in the Flin Flon Belt, (i.e., Hudson Bay Exploration and Development Company Limited, Rockcliff Resources Inc., VMS Ventures Inc. and International Samuel Exploration Corp.), the MGS has obtained access to their most recent geophysical surveys covering the sub-Phanerozoic portion of the belt. The geophysical data are being analyzed and, in combination with older geophysical surveys, used to refine the sub-Phanerozoic geological domains.

The MGS also compiled more than 10 000 whole-rock geochemical analyses from drillcores from the sub-Phanerozoic part of the Flin Flon Belt that were provided by some of the exploration companies. Approximately 3000 additional whole-rock (and a few isotope) geochemical analyses from various exposed portions of the belt, compiled from the past 30 years of mapping by various (mainly MGS) geologists, were added to this database. All of these analyses were integrated into a single, GIS-based database to enable querying and analysis of the distribution of the various rock assemblages in the Flin Flon Belt.

Fieldwork

A small field program of approximately 10 days was conducted in early August 2009 to document some of the known mineral deposits in the sub-Phanerozoic Flin Flon Belt. Selected holes from the Talbot, Fenton, Harmin and Moose VMS deposits were studied and sampled for whole-rock geochemical analysis, Sm-Nd isotope geochemical analysis and U-Pb dating. Analytical results are pending.

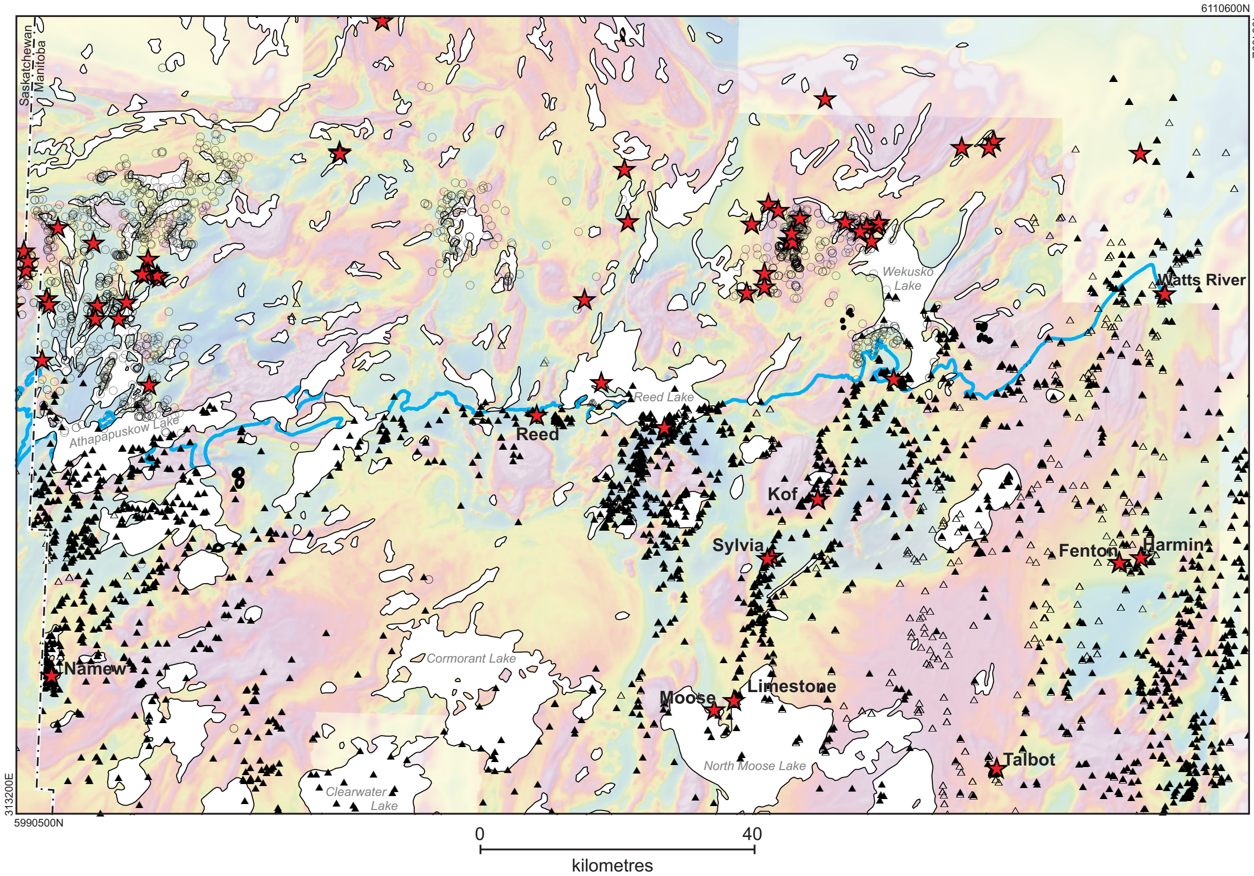

***Figure GS-2-4:** Locations of selected drillholes (black triangles), sub-Phanerozoic geochemical samples from drill-cores (open triangles) and surface geochemical samples (open circles) for the Flin Flon Belt. Blue line is the limit of the Phanerozoic cover. Red stars show the locations of various ore/mineral deposits in the Flin Flon Belt (only the sub-Phanerozoic deposits are labelled for clarity).*

The Talbot, Fenton and Harmin deposits are located in the easternmost portion of the Flin Flon Belt, in high-grade metamorphic rocks of the 'Eastern Kisseynew Domain' (Leclair et al., 1997; Figures GS-2-2, -4). Although the hostrocks for these deposits were previously interpreted to be of sedimentary origin, recent work by Hudson Bay Exploration and Development Company Limited has suggested that some of these high-grade rocks (upper amphibolite to lower granulite facies quartzofeldspathic gneiss and biotite-garnet gneiss) may be partly volcanic in origin.

The Moose deposit is located south of Wekusko Lake in the 'Clearwater Domain' (Figures GS-2-2, -4), a possible extension of the Snow Lake assemblage south of the Berry Creek Fault (Leclair et al., 1997; Figure GS-2-2). The hostrocks for the Moose deposit are bimodal felsic-mafic volcanic sequences of lower greenschist metamorphic grade.

Economic considerations and future work

Just like the exposed portion of the Flin Flon Belt, the sub-Phanerozoic portion of the belt is very prospective for VMS base-metal sulphides and gold deposits. Increasing our understanding of the setting of the various known deposits in the covered part of the belt will help in developing and tailoring exploration models in these highly prospective but difficult-to-access rocks.

The renewal of the sub-Phanerozoic Flin Flon Belt map is a multiyear project that began with data compilation in 2007 and is now gaining momentum with the beginning of a field program in 2009. Data collection, such as core (re-)logging and sampling for geochemistry and geochronology in the various Precambrian domains of the sub-Phanerozoic will continue over the next few years, leading to the production of a modern and integrated map product of the sub-Phanerozoic part of the Flin Flon Belt.

Acknowledgments

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