Highlights of the new 1:10 000 scale geology map of the Flin Flon area, Manitoba and Saskatchewan (part of NTS 63K12, 13)1
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Summary
A five year collaboration between the Manitoba Geological Survey, the Saskatchewan Geological Survey, the Geological Survey of Canada, researchers from Laurentian University, and Hudson Bay Exploration and Development Company Limited has led to the production of a new 1:10 000 scale bedrock geological map for the Flin Flon mining camp. A coherent lithostratigraphic and structural framework now spans the provincial border and has resulted in recognition of the volcanogenic massive sulphide–hosting stratigraphy in areas well outside the immediate mine surroundings. An improved understanding of the importance of subsidence structures and associated high-temperature hydrothermal alteration in the generation of the volcanogenic massive sulphide (VMS) deposits has led to recognition of exploration potential in the hangingwall in both Saskatchewan and Manitoba. Both early thrust faulting that predates deposition of the Missi Group and late thrust faulting that imbricates the Missi Group with the older volcanic rocks have been recognized. The critical role of thrust faulting at various scales in the overall architecture of the camp has been revealed by the integration of surface map data into a 3-D (three-dimensional) model constrained by drillholes and 3-D seismic surveys. Based on new U-Pb geochronology, the VMS-hosting volcanic rocks of the Flin Flon Block are ca. 1.89 Ga, as are rocks in the western Hook Lake Block. Volcanic rocks in the eastern Hook Lake Block, however, are about 10 Ma younger.

Introduction
The Flin Flon area of the Paleoproterozoic Flin Flon Belt is world-renowned for its volcanogenic massive sulphide (VMS) deposits (Figure GS-1-1). Three active (Callinan, 777 and Trout Lake) and three past-producing (Flin Flon, Mandy and Schist Lake) VMS mines occur in the immediate vicinity of the town of Flin Flon, which makes this area one of the most productive base-metal regions in Canada.

The Flin Flon area has been mapped at various scales by geologists of several organizations during the last 70 years. Despite the fact that each of these mapping efforts was successful in increasing our understanding of this prolific base-metal area, the need for a new, comprehensive, crossborder, state-of-the-art, detailed lithostratigraphic bedrock map of the area to support exploration for VMS deposits still existed in the early 2000s.

In November 2009, the Manitoba Geological Survey and the Saskatchewan Geological Survey announced the release of a new 1:10 000 scale crossborder geological map of the Flin Flon area (Figure GS-1-2). This major collaboration between the Manitoba Geological Survey, the Saskatchewan Geological Survey, the Geological Survey of Canada, researchers from Laurentian University, and Hudson Bay Exploration and Development Company Limited was initiated in 2005 under the Government of Canada Targeted Geoscience Initiative (TGI-3) with the intent of stimulating private-sector resource exploration in areas of high base-metal potential in established mining communities.

This report is intended to highlight the breakthroughs accomplished during the last five years, leading to the production of this new map. Detailed accompanying notes for this map are planned for release in 2010 (R-L. Simard et al., work in progress, 2009), along with a DVD that will include a digital version of the map, a geochemistry and geochronology database for the area, extensive references and a photo atlas of rocks of the Flin Flon area.

Summary of previous work
Conditions for bedrock mapping in the Flin Flon area are exceptional in many respects. Exposure is commonly 40–80%, the outcrops are lichen-free and the regional metamorphic grade is lower-greenschist facies ( epidote-chlorite; Bailes and Syme, 1989), allowing for good preservation of primary textures and structures. These exquisite conditions have attracted repeated mapping efforts in the area over time.

The following section summarizes the most recent contributions to the volcanology and structure of the Flin Flon area by participants in the TGI-3 project. For more details on previous work, please refer to Bailes and Syme (1989) and Thomas (1989). An extensive list of previous work will be included in an upcoming geological report on the geology of the Flin Flon area (R-L. Simard et al., work in progress, 2009).

Three major mapping efforts from the 1950s to the 1990s have left ‘legacy’ maps of the Flin Flon area. To date, the detailed 1:12 000 scale map by Stockwell (1960) was the only map of the area that showed coherent stratigraphy and structure across the provincial border. More recent maps of the area were produced on each side of the border in the 1980s and 1990s, namely the 1:20 000 scale bedrock map of the Flin Flon–White Lake area by Bailes and Syme (1989) of the Manitoba Geological Survey and the 1:10 000 scale bedrock map of the Douglas–Phantom

**Figure GS-1-1:** Geology of the Flin Flon Belt, showing locations of known volcanogenic massive sulphide (VMS) deposits (modified from Syme et al., 1999); inset map shows the location of the Flin Flon Belt within the Trans-Hudson Orogen (THO).
Figure GS-1-2: The new 1:10 000 scale bedrock geology map of the Flin Flon area, Manitoba and Saskatchewan (Simard et al., 2009). Small insets show various features found on the map, such as (from top to bottom) one lithostratigraphic legend showing split-colour boxes with the lighter shade indicating an area of no outcrop; two close-ups of the geology showing outcrops, various structures, and mineral occurrences/past producers and their commodities; an extensive reference list of previous work in the area used to build the map; and a geochronology table for the area.
Lake area by Thomas (1990, 1992) of the Saskatchewan Geological Survey. Although these mapping efforts significantly increased our understanding of the geology of the area and the setting of the VMS deposits it hosts, these maps did not provide a coherent geological framework that allowed correlation of map units and structures across the provincial border.


Structural studies by Lewis et al. (2006, 2007), MacLachlan (2006c), Lafrance (unpublished work, 2006–2009), Pehrsson (unpublished work, 2006–2008), Kremer and Simard (2007), Cole et al. (2007), Lafrance et al. (2007) and MacLachlan and Devine (2007), in conjunction with 3-D modelling of the area based on 2-D (two-dimensional) and 3-D seismic data recently acquired by HudBay Minerals Inc. and the Geological Survey of Canada (Schetselaar, 2009) have greatly helped advance and refine our understanding of the structural history of the area and unify it across the border (Figures GS-1-3 and -4).

**Highlights from the new Flin Flon map**

- One comprehensive, coherent lithostratigraphic legend has been developed across the provincial border.
- One VMS-hosting stratigraphy for the Flin Flon–Callinan–777 deposits (Figures GS-1-3 and -4) has been recognized:
  - The stratigraphy and geochemistry of the volcanic rocks associated with the Flin Flon–Callinan–777 VMS deposits record the infilling of a subsidence basin with abundant volcanioclastic material, localized felsic magmatism and the development of an intense hydrothermal alteration system (Flin Flon formation; Bailes and Syme, 1989; Syme et al., 1999; Devine, 2003), which terminated with a hiatus in volcanism and formation of the VMS deposits. Following VMS deposition there was resurgence in volcanism and subsidence marked by the development of one or more mafic shield volcanoes atop this subsidence structure (Hidden and Louis formations; Syme et al., 1999; DeWolfe and Gibson, 2005, 2006; DeWolfe, 2008).
  - The VMS-hosting stratigraphy has been mapped across major structures in the Flin Flon Block, including the Flin Flon Lake Fault, which has considerably enlarged the prospective area away from the immediate mine surroundings. New areas such as the Phantom Lake and Green Lake peninsulas just south of Phantom Beach are now considered as part of the southern extension of the main VMS host horizon for the Flin Flon–Callinan–777 deposits.
- New prospective areas in the hangingwall sequence have been recognized, including the following:
  - A semiconformable alteration zone exists in the hangingwall stratigraphy on the west side of the Flin Flon Lake Fault just east of Douglas Lake, Saskatchewan. This alteration horizon sits a few hundreds of metres below the former Newcor mine, which was known for its gold-bearing arsenopyrite, pyrite and sphalerite. The nature of this alteration system is similar to footwall alteration in a number of other VMS deposits in the world, which might suggest potential for VMS mineralization in the Douglas Lake area (MacLachlan, 2006c).
  - A synvolcanic subsidence structure complete with associated synvolcanic faults and mafic and felsic magmatism occurs within the hangingwall stratigraphy just southeast of Carlisle Lake, Manitoba. This kind of synvolcanic structure hosts VMS deposits in the Flin Flon area, and in this case is also spatially associated with a well-developed gossan (Simard, 2006a). In addition, smaller subsidence structures were also recognized in the hangingwall rocks just north of Louis Lake (DeWolfe, 2008).
- A new structural model has been developed and is fully integrated with the new lithostratigraphy. This structural model includes the recognition of the following:
  - Multiple episodes of thrusting exist in the area, both early and late in the structural history (pre- and postdeposition of the Missi Group). Some of the early thrust faults (mainly north-striking, west-vergent structures) repeat the VMS host stratigraphy including the VMS mineralization and are reworked by a series of late thrust faults (mainly east-striking, north-vergent structures), which imbricated the Missi Group sedimentary rocks with the volcanic rocks.
  - Early thrust movement occurred on major north-striking structures, namely the Cliff Lake Fault and most likely the Hook Lake Fault.
- Improved geochronological controls have been obtained on the age of volcanic rocks that host the
Figure GS-1-3: Simplified geology of the Flin Flon area, outlining the major stratigraphic units and structures (from Simard et al., 2009).
Several VMS-hosting felsic volcanic rocks of the Flin Flon formation are now dated at ca. 1890 Ma (Rayner, in press), which indicates that this is the predominant age of volcanism in the Flin Flon Block. This age is 10 Ma younger than previously recognized (see geochronology table for the Flin Flon area on the map face [e.g., Figure GS-1-2] for a detailed list of available age data).

A quartz-porphyritic rhyolitic sill (previously referred to as the Myo intrusions), dated at 1888.9 ±1.7 Ma (Bailey, pers. comm., 2006), cuts the top of the ca. 1890 Ma Flin Flon formation (Rayner, in press) and the base of the overlying Hidden formation on the west side of the Flin Flon Fault at a very low angle. These relationships suggest a very short hiatus in volcanism between the formation of the VMS deposits and the resurgence of volcanism and subsidence recorded in the hangingwall stratigraphy.

The base of the Western Hook sequence of the Hook Lake Block is intruded by an early dioritic phase of the Cliff Lake pluton dated at 1888 ±1 Ma (Rayner, in press), which suggests that the Western Hook sequence is age correlative with the VMS-hosting rocks of the Flin Flon Block to the west.

The Eastern Hook sequence of the Hook Lake Block has an age of 1882 ±1 Ma (Rayner, in press), which makes it younger than the VMS-hosting rocks of the Flin Flon Block and the western sequence of the Hook Lake Block.

The 1:10 000 scale bedrock map provides the surface, 2-D base layer for the development of a 3-D model for the Flin Flon area:

- The 3-D modelling integrates surface mapping and the newly defined stratigraphy with subsurface drillhole and seismic data (Schetselaar, 2009). The emerging 3-D model emphasized the importance of thrust faulting observed at the surface in the 3-D architecture of the mine area.

**Economic considerations**

Detailed remapping of the Flin Flon area has greatly enhanced our understanding of the setting of the numerous VMS deposits in the area, which will be valuable in improving exploration models for the area.

By refining the VMS-bearing stratigraphy and improving the understanding of the structural history of the Flin Flon area, this project has resulted in the recognition of the mine horizon well beyond the immediate mine...
surroundings, opening potentially prospective ground for exploration. The expert understanding of volcanology required to map and interpret the Flin Flon rocks in greater detail than previous studies has resulted in the recognition of new alteration systems and subsidence structures in the hangingwall stratigraphy of the Flin Flon–Callinan–777 deposits on both sides of the border. Ability to recognize these subsidence structures has proven essential for exploring for this type of VMS deposit in and around the Flin Flon area, and may be applicable to greenstone belts elsewhere in Manitoba and Saskatchewan.

The geochronology that has accompanied the mapping yielded a revised age of ca. 1890 Ma for the volcanism that hosts the VMS deposits in the main Flin Flon mining camp, and demonstrates that the Western Hook sequence of the Hook Lake Block is correlative in age. The new ages provide an additional tool for evaluating the prospectivity of contemporaneous but previously unexplored successions.

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References


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