Highlights of the New 1:10 000-scale Geology Map of the Flin Flon Area, Manitoba and Saskatchewan (parts of NTS 63K/12 and /13) [1]

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Abstract

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 (VMS)-hosting strata 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 VMS deposits has led to an increase of exploration potential in the hanging wall in both Saskatchewan and Manitoba. Both early thrust faulting that pre-dates deposition of the Missi Group and late thrust faulting that resulted in imbrication of 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 model constrained by drill holes 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 old, as are rocks in the western Hook Lake block. Volcanic rocks in the eastern Hook Lake block, however, are about 10 Ma younger.*

Keywords: *Flin Flon, stratigraphy, volcanology, bedrock mapping, VMS deposits, subsidence structures, thrust faulting, U-Pb geochronology.*

1. Introduction

The Flin Flon area of the Paleoproterozoic Flin Flon Belt is world renowned for its volcanogenic massive sulphide (VMS) deposits (Figure 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 over 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, cross-border, state-of-the-art, detailed litho-stratigraphic 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 "cross-border" geological map of the Flin Flon area (Figure 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 made during the last five years, leading to the production of this new map. Detailed accompanying notes for the map are planned for release in 2010, along with a DVD which will include a digital version of the map, a geochemical and geochronological database for the area, extensive references, and a photo atlas of rocks of the Flin Flon area.

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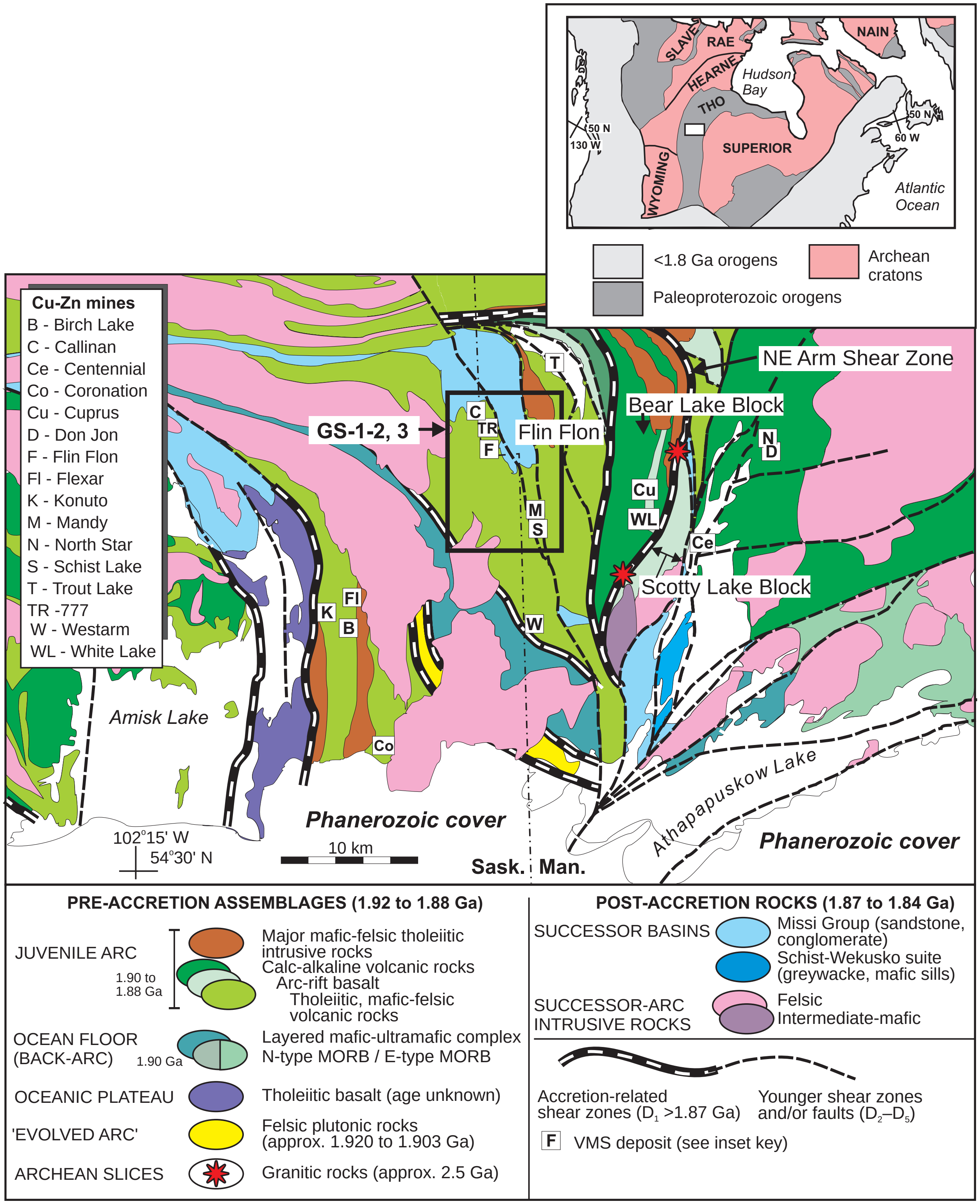

***Figure 1** - Geology of the Flin Flon Belt, showing locations of known VMS deposits (modified from Syme* et al., *1999); inset map shows the location of the Flin Flon Belt within the Trans-Hudson Orogen (THO).*

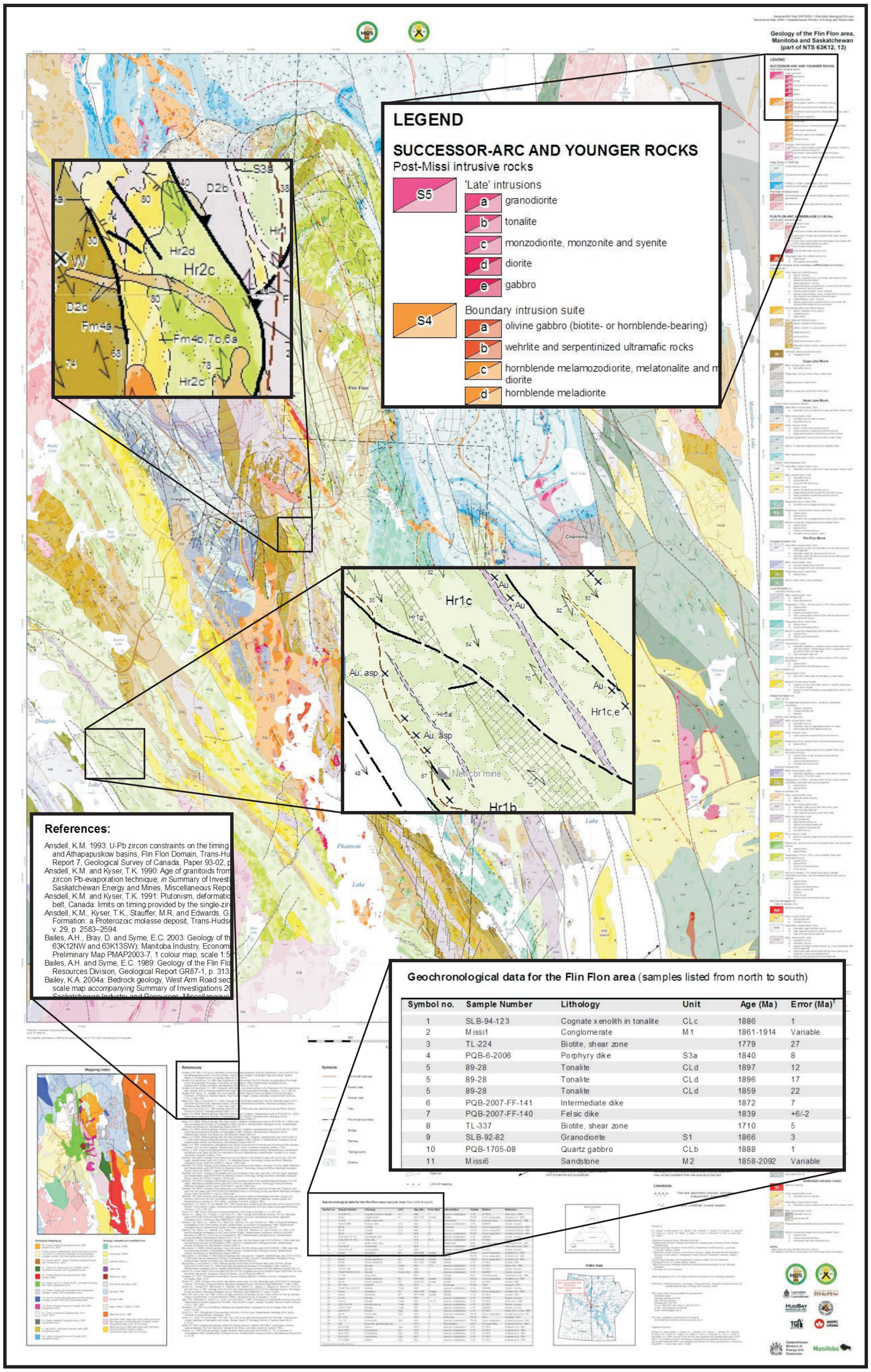

Figure 2 - The new 1:10 000-scale bedrock geology map of the Flin Flon area, Manitoba and Saskatchewan (Simard* et al., *2009). Small insets show various features found on the map such as (from top to bottom): 1) lithostratigraphic legend showing split colour boxes with the lighter shade of colour indicating areas of no outcrop; 2) close-ups of the geology showing outcrops, various structures, and mineral occurrences/past producers and their commodities; 3) an extensive reference list of previous work in the area used to compile the map; and 4) a synthesis of geochronological data for the area.

2. Summary of Previous Work

Conditions for bedrock mapping in the Flin Flon area are exceptional in many respects. Exposure is commonly 40 to 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 the upcoming accompanying notes.

Three major mapping efforts from the 1950s to the 1990s have left "legacy" maps of the Flin Flon area. To date, Stockwell's detailed 1:12 000-scale map was the only map that showed coherent stratigraphic units and structure across the provincial border (Stockwell, 1960). 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 Lake area by Thomas (1990, 1992) of the Saskatchewan Geological Survey. Although these mapping efforts significantly increased our understanding of the geology and the setting of the VMS deposits it hosts, these maps did not provide a coherent geologic framework that allowed correlation of map units and structures across the provincial border.

Starting in the early 2000s under the TGI-1 and later TGI-3 programs, detailed work on the volcanic rocks by Ames *et al.* (2002), MacLachlan *et al.* (2002), Devine (2003), Gibson *et al.* (2003, 2006, 2007, 2009, unpubl. work), Tardif (2003), Bailey (2004a, 2004b, 2005a, 2005b, 2006), DeWolfe and Gibson (2005, 2006), MacLachlan (2006a, 2006b, 2006c), Simard (2006a, 2006 b), Cole *et al.* (2007, 2008), Kremer and Simard (2007), MacLachlan and Devine (2007), Simard and Creaser (2007), Simard *et al.* (2007), and DeWolfe (2008), has shaped the newly proposed "trans-border" stratigraphic framework for the area (Figures 3 and 4).

Structural studies by Lewis *et al.* (2006, 2007), MacLachlan (2006c), Pehrsson (unpubl. work, 2006-08), Cole *et al.* (2007), Kremer and Simard (2007), Lafrance *et al.* (2007; unpubl. work, 2006-09), and MacLachlan and Devine (2007), in conjunction with 3-D modelling of the area based on 2-D and 3-D seismic data recently acquired by HudBay Minerals Inc. and the Geological Survey of Canada (Schetselaar, 2009), have much advanced and refined our understanding of the structural history of the area, and unified it across the border (Figures 3 and 4).

3. Highlights from the New Flin Flon Map

First and foremost, a single comprehensive, coherent lithostratigraphic legend has been developed across the provincial border, which has lead to the recognition of one VMS-hosting stratigraphic succession for the Flin Flon–Callinan–777 deposits (Figure 3 and 4). The stratigraphic succession and geochemical signature of the volcanic rocks that host the Flin Flon–Callinan–777 VMS deposits records the infilling of a subsidence basin with abundant volcaniclastic material, localized felsic magmatism and the development of an intense hydrothermal alteration system (Flin Flon formation; Bailes and Syme, 1989; Devine, 2003; Syme *et al.*, 1999). Basin subsidence 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 stratigraphic succession has been mapped across major structures in the Flin Flon Block, including the Flin Flon Lake Fault, which has considerably enlarged the prospective area beyond the immediate mine surroundings. In addition, areas such as the Phantom Lake and Green Lake peninsulas just south of Phantom Beach are now considered to be part of the southern extension of the Millrock member of the Flin Flon formation (Figure 3), which hosts the Flin Flon–Callinan–777 deposits.

Mapping undertaken as part of this project has also lead to the recognition of areas in the hanging wall succession with greater prospectivity than previously appreciated. On the west side of the Flin Flon Lake Fault just east of Douglas Lake, Saskatchewan a semi-conformable zone of silicification was mapped (Figure 3). This alteration zone occurs a few hundred meters below the former Newcor mine that 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). Southeast of Carlisle Lake, Manitoba, a syn-volcanic subsidence structure complete with associated synvolcanic faults and mafic and felsic magmatism occurs within the hanging wall succession. This kind of syn-volcanic subsidence structure hosts VMS deposits in the Flin Flon area, and in this case is also spatially associated with a well-developed gossan (Simard, 2006a). Smaller subsidence structures were also recognized in the hanging wall rocks just north of Louis Lake (DeWolfe, 2008).

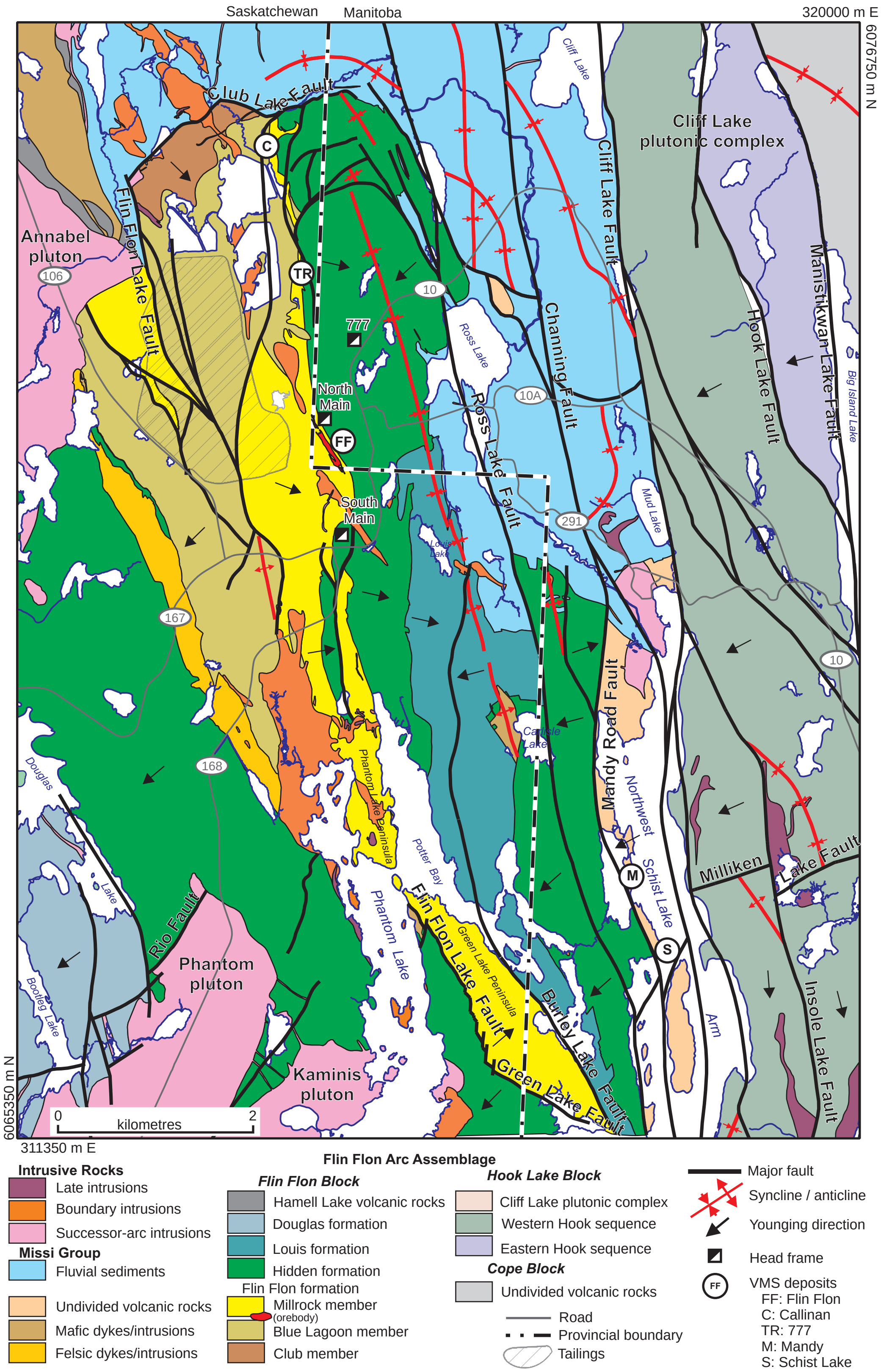

Figure 3 - Simplified geology of the Flin Flon area, outlining the major stratigraphic units and structures (from Simard* et al., *2009).

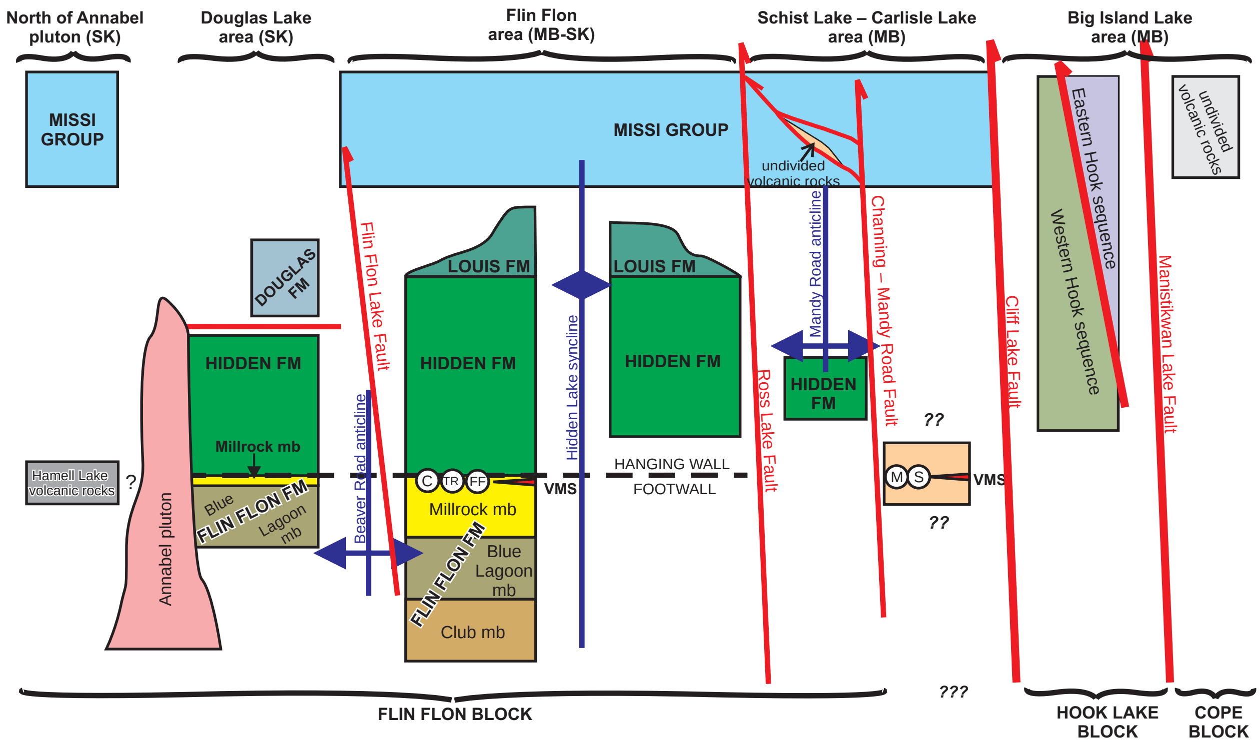

Figure 4 - Schematic stratigraphic sections of the Flin Flon area (modified from Devine, 2003; DeWolfe and Gibson, 2006; Simard, 2006a; Kremer and Simard, 2007; MacLachlan and Devine, 2007; Simard and Creaser, 2007; DeWolfe, 2008; Gibson* et al.*, 2009). Please refer to listed references or the upcoming accompanying notes for more details on the stratigraphy of the area. Abbreviations for VMS deposits are as defined on Figure 3.

A new structural model has been developed and is fully integrated with the new litho-stratigraphy. This structural model includes the recognition of multiple episodes of thrusting in the area, both early and late in the structural history (pre- and post-deposition of the Missi Group). Early, mainly north-south–striking, west-vergent thrust faults repeat the VMS-bearing stratigraphic succession, including the mineralization, and are reworked by a series of late, mainly east-west, north-vergent thrust faults, which imbricated the Missi Group sedimentary rocks with the volcanic rocks. Early thrust movement has also been recognized on major north-south structures, such as the Cliff Lake and Hook Lake faults that were originally thought to be late strike slip faults only.

Improved geochronological controls have been obtained on the age of volcanic rocks that host the mineralization and other units in the Flin Flon area. Several VMS-hosting felsic volcanic rocks of the Flin Flon formation are now dated at ~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 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 very low angle. These relationships suggest a very short hiatus in mafic volcanism and subsidence between the footwall and hanging wall stratigraphy. The hiatus in mafic volcanism is characterized by minor rhyolite volcanism and formation of the VMS deposits. An early dioritic phase of the Cliff Lake pluton dated at 1888 ±1 Ma (Rayner, in press) intrudes the base of the Western Hook sequence of the Hook Lake Block, which suggests that the Western Hook sequence is age correlative with the VMS-hosting rocks of the Flin Flon Block to the west. In contrast, the Eastern Hook sequence of the Hook Lake Block has an age of 1882 ±1 Ma (Rayner, in press), and is thus 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 development of a 3-D model for the Flin Flon area. The 3-D modelling integrates surface mapping and the newly defined stratigraphic framework with subsurface drill hole and seismic data (Schetselaar, 2009). The emerging 3-D model emphasized the importance of thrust faulting observed at surface in the 3-D architecture of the mine area.

4. Economic Significance

Detailed remapping of the Flin Flon area has greatly enhanced our understanding of the setting for the numerous VMS deposits in the area, which will be valuable in improving exploration models. By refining the VMS-bearing stratigraphic framework and improving the understanding of the structural history of the Flin Flon area, this project has resulted in the recognition of the VMS-bearing member of the Flin Flon formation well beyond the immediate mine surroundings, thus 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 hanging wall 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 new geochronological data 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 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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6. References

Ames, D.E., Tardif, N., MacLachlan, K., and Gibson, H.L. (2002): Geology and hydrothermal alteration of the hanging wall stratigraphy to the Flin Flon–777–Callinan volcanogenic massive sulphide horizon (NTS 63K12NW and 13SW), Flin Flon area, Manitoba; *in* Report of Activities 2002, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p20-34.

Bailes, A.H. and Syme, E.C. (1989): Geology of the Flin Flon–White Lake area; Manitoba Energy and Mines, Mineral Resources Division, Geol. Rep. GR 87-1, 313p.

Bailey, K.A. (2004a): Bedrock geology, West Arm Road section, Creighton, Saskatchewan (part of NTS 63K/12); 1:2000-scale map *with* Summary of Investigations 2004, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2004-4.2.

__________ (2004b): Bedrock geology, Myo Lake section, Creighton, Saskatchewan (part of NTS 63K/12); 1:2000-scale map *with* Summary of Investigations 2004, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2004-4.2.

__________ (2005a): Bedrock geology, Phantom Lake section, Creighton, Saskatchewan (part of NTS 63K/12); 1:2000-scale preliminary map *with* Summary of Investigations 2005, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2005-4.2.

__________ (2005b): Bedrock geology, Myo Rhyolite Distribution Map, Creighton, Saskatchewan (part of NTS 63K/12); 1:10 000-scale preliminary map *with* Summary of Investigations 2005, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2005-4.2.

__________ (2006): Emplacement, petrogenesis and volcanic reconstruction of the intrusive and extrusive Myo rhyolite complex, Flin Flon and Creighton, Saskatchewan; unpubl. M.Sc. thesis, Laurentian University, Sudbury, 123p.

Cole, E.M., Gibson, H.L., and Lafrance, B. (2007): Preliminary description of the lithofacies and structure of the Schist Lake mine area, Flin Flon, Manitoba (part of NTS 63K12); *in* Report of Activities 2007, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p33-42.

Cole, E.M., Piercey, S.J., and Gibson, H.L. (2008): Geology and geochemistry of the Schist Lake mine area, Flin Flon, Manitoba (part of NTS 63K12); *in* Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p18-28.

Devine, C. (2003): Origin and emplacement of volcanogenic massive sulphide-hosting, Paleoproterozoic volcaniclastic and effusive rocks within the Flin Flon subsidence structure, Manitoba and Saskatchewan, Canada; unpubl. M.Sc. thesis, Laurentian University, Sudbury, 279p.

DeWolfe, Y.M. (2008): Physical volcanology, petrology and tectonic setting of intermediate and mafic volcanic and intrusive rocks in the Flin Flon volcanogenic massive sulphide (VMS) district, Manitoba, Canada: growth of a Paleoproterozoic juvenile arc; unpubl. Ph.D. thesis, Laurentian University, Sudbury, 269p.

DeWolfe, Y.M. and Gibson, H.L. (2005): Physical description of the Bomber, 1920 and Newcor Members of the Hidden Formation, Flin Flon, Manitoba (NTS 63K16SW); *in* Report of Activities 2005, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p7-19.

__________ (2006): Stratigraphic subdivision of the Hidden and Louis Formations, Flin Flon, Manitoba (NTS 63K16SW); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p22-34.

Gibson, H.L., Bailes, A.H., Tourigny, G., and Syme, E.C. (2003): Geology of the Millrock Hill area, Flin Flon, Manitoba (parts of NTS 63K13SW and 63K12NW); Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, Prelim. Map PMAP2003-6, 1:500 scale.

Gibson, H.L., Bailey, K., DeWolfe, M., Gilmore, K., Devine, C., Sims, D., Bailes, A., and MacLachlan, K. (2006): Evidence for cauldron subsidence at the Flin Flon Mining Camp: implications for the location of volcanogenic massive sulphide deposits; *in* Open House 2006, Abstract Volume, Saskatchewan Geological Survey, Sask. Industry and Resources, Nov. 27 to 29, Saskatoon, p24.

Gibson, H.L., DeWolfe, M., Lafrance, B., Bailey, K., Devine, C., Sims, D., Gilmore, K., Bailes, A., Simard, R-L., and MacLachlan, K. (2007): The relationship between rifting, subsidence, volcanism, and VMS deposits at Flin Flon, Manitoba; *in* Manitoba Industry and Mines Convention, Winnipeg, Prog. Abstr., p55.

Gibson, H.L., Lafrance, B., DeWolfe, M., Devine, C., Gilmore, K., and Pehrsson, S. (2009): Volcanic reconstruction and post depositional modification of a cauldron subsidence structure within the Flin Flon VMS District; Prospectors and Developers Association of Canada, March 1 to 4, Toronto, abstr.

Kremer, P.D. and Simard, R-L. (2007): Geology of the Hook Lake Block, Flin Flon area, Manitoba (part of NTS 63K12); *in* Report of Activities 2007, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p21-32.

Lafrance, B., Gibson, H.L., Pehrsson, S., DeWolfe, Y.M., and Lewis, D. (2007): Structural investigations in the Flin Flon mining camp; Manitoba Mining and Minerals Convention 2008, Winnipeg, Prog. Abstr., p54-55.

Lewis, D., Lafrance, B., and MacLachlan, K. (2007): Kinematic evidence for thrust faulting and reactivation within the Flin Flon Mining Camp, Creighton, Saskatchewan; *in* Summary of Investigations 2007, Saskatchewan Geological Survey, Sask. Ministry of Energy and Resources, Misc. Rep. 2007-4.2, Paper A-2, 10p.

Lewis, D., Lafrance, B., MacLachlan, K., and Gibson, H. (2006): Structural investigations of Millrock Hill and the Hinge Zone of the Beaver road Anticline, Creighton, Saskatchewan; *in* Summary of Investigations 2006, Volume 2, Saskatchewan Geological Survey, Sask. Industry Resources, Misc. Rep. 2006-4.2, Paper A-10, 11p.

MacLachlan, K. (2006a): Bedrock geology Douglas Lake area, Flin Flon Domain (part of NTS 63K12); 1:3000 scale prelim. map *with* Summary of Investigations 2006, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Mines, Misc. Rep. 2006-4.2.

__________ (2006b): Bedrock geology Green Lake area, Flin Flon Domain (part of NTS 63K12); 1:3000 scale prelim. map *with* Summary of Investigations 2006, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Mines, Misc. Rep. 2006-4.2.

__________ (2006c): Stratigraphy, structure, and silicification: new results from mapping in the Flin Flon Mining Camp, Creighton, Saskatchewan; *in* Summary of Investigations 2006, Volume 2, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2006-4.2, CD-ROM, Paper A-9, 25p.

MacLachlan, K. and Devine, C. (2007): Stratigraphic evidence for volcanic architecture in the Flin Flon Mining Camp: implications for mineral exploration; *in* Summary of Investigations 2007, Volume 2, Saskatchewan Geological Survey, Sask. Ministry of Energy and Resources, Misc. Rep. 2007-4.2, CD-ROM, Paper A-1, p29.

MacLachlan, K., Gibson, H.L., and Bailey, K.A. (2002): Stratigraphic and intrusive relationships in the Myo Lake Section, Flin Flon mine sequence, Creighton, Saskatchewan; *in* Summary of Investigations 2002, Saskatchewan Geological Survey, Sask. Industry and Resources, Misc. Rep. 2002-4.2, CD-ROM, Paper B-2, 10p.

Rayner, N. (in press): New U-Pb zircon ages from the Flin Flon Targeted Geoscience Initiative Project 2006-2009: Flin Flon and Hook Lake blocks; Geol. Surv. Can., Current Research 2009-13.

Schetselaar, E. (2009): 3D modelling in the Flin Flon exploration camp: interpretative and numerical methods for enhancing 3D geological insight & targeting; Prospectors and Developers Association of Canada, March 1 to 4, Toronto, abstr.

Simard, R-L. (2006a): Geology of the Schist Lake–Mandy mines area, Flin Flon, Manitoba (part of NTS 63K12); *in* Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p9-21.

__________ (2006b): Geology of the Schist Lake–Mandy mines area, Flin Flon, Manitoba (parts of NTS 63K12); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map, PMAP 2006-1, scale 1:5000.

Simard, R-L. and Creaser, R.A. (2007): Implications of new geological mapping, geochemistry and Sm-Nd isotope data, Flin Flon area, Manitoba (part of NTS 63K12); *in* Report of Activities 2007, Manitoba Sciences, Technology, Energy and Mines, Manitoba Geological Survey, p7-20.

Simard, R-L., Kremer, P.D., MacLachlan, K., DeWolfe, Y.M., Gibson, H.L., Devine, C., Lafrance, B., Ames, D., Price, D.P., and Pehrsson, S. (2007): Geology of the Flin Flon area, Manitoba (part of NTS 63K12); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map, PMAP 2007-1, scale 1:10 000.

Simard, R-L., MacLachlan, K., Gibson, H.L., DeWolfe, Y.M., Devine, C., Kremer, P.D., Lafrance, B., Ames, D.E., Syme, E.C., Bailes, A.H., Bailey, K., Price, D., Pehrsson, S., Cole, E., Lewis, D., and Galley, A.G. (2009): Geology of the Flin Flon area, Manitoba and Saskatchewan (part of NTS 63K12, 13); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Geoscientific Map MAP2009-1/Sask. Ministry of Energy and Resources, Geoscience Map 2009-1, scale 1:10 000.

Stockwell, C.H. (1960): Flin Flon–Mandy, Manitoba and Saskatchewan; Geol. Surv. Can., Map 1078A, scale 1:12 000.

Syme, E.C., Lucas, S.B., Bailes, A.H., and Stern, R.A. (1999): Contrasting arc and MORB-like assemblages in the Paleoproterozoic Flin Flon Belt, Manitoba, and the role of intra-arc extension in localizing volcanic-hosted massive sulphide deposits; Can. J. Earth Sci., v36, p1788-1767.

Tardif, N.P. (2003): Hanging wall alteration above the Paleoproterozoic, Callinan and Triple 7 volcanogenic massive sulphide deposits, Flin Flon, Manitoba, Canada; unpubl. M.Sc. thesis, Laurentian Univ., Sudbury, 100p.

Thomas, D.J. (1989): Geology of Douglas Lake–Phantom Lake area (part of NTS 63K12-13); *in* Summary of Investigations 1989, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 89-4, p44-54.

__________ (1990): Bedrock geology, Douglas-Phantom lakes area (parts of NTS 63K12-13); *in* Summary of Investigations 1989, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 90-4, p13-20.

__________ (1992): Highlights of investigations around the Flin Flon mine: reassessment of structural history; *in* Summary of Investigations 1992, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 92-4, p3-13.