**GS-1   STRATIGRAPHY OF VOLCANOGENIC MASSIVE SULPHIDE-HOSTING
VOLCANIC AND VOLCANICLASTIC ROCKS OF THE FLIN FLON FORMATION,
FLIN FLON (NTS 63K12 AND 13), MANITOBA AND SASKATCHEWAN
by C.A. Devine[1], H.L. Gibson[1], A.H. Bailes, K. MacLachlan[2], K. Gilmore[3] and
A.G. Galley[4]**

SUMMARY

Detailed stratigraphic sections, 1:500-scale mapping, clast counts and descriptions of the footwall stratigraphy to the Flin Flon, 777 and Callinan volcanogenic massive sulphide (VMS) deposits have established several distinctive eruptive and volcaniclastic members belonging to a newly defined unit, the Flin Flon formation. Detailed stratigraphic correlation of the newly defined members has assisted identification of stratigraphic repetitions due to early thrust faulting and associated drag folding. This better understanding of the stratigraphy, depositional environment and subsequent deformation will allow a more comprehensive analysis of the present position of the VMS horizon in three dimensions.

INTRODUCTION

A complex succession of felsic and basalt-dominated heterolithic volcaniclastic rocks host the Flin Flon Main, Callinan and 777 volcanogenic massive sulphide (VMS) deposits within the Paleoproterozoic Flin Flon Belt of Manitoba and Saskatchewan (Fig. GS-1-1, GS-1-2). The north-trending, VMS-hosting, 30 to 700 m thick volcanic-volcaniclastic succession is recognized for at least 5 km along strike and has an average dip of 60ºE (Fig. GS-1-2). The volcaniclastic rocks have been interpreted to occupy a volcano-tectonic depression within a basaltic footwall succession (Syme and Bailes, 1993).

This study is part of the Flin Flon Targeted Geoscience Initiative, involving the Geological Survey of Canada, the Manitoba Geological Survey, the Saskatchewan Geological Survey and Laurentian University. Its goals are to refine our knowledge of the volcanic stratigraphy hosting the Flin Flon VMS deposits, establish the provenance of the clasts in volcaniclastic units, determine mechanisms by which the volcaniclastic breccias were emplaced, and ascertain their environment of deposition. This will assist in further exploration along the known VMS horizon through deep drilling, and establish the continuation and potential of this VMS-rich stratigraphic interval further to the south and west.

METHODOLOGY

To acquire the most quantitative data possible on the components, thickness and characteristics of the VMS host and footwall strata, fifteen detailed stratigraphic sections from surface and drillhole exposures, and eight 1:500-scale surface and underground maps were completed over a 5000 m long segment of the Flin Flon stratigraphy. This segment defines the footwall and host stratigraphy for over 80 million tonnes of massive sulphide mineralization in three known VMS deposits (Fig. GS-1-2).

More than 100 clast count locations were established using a 1 m by 1 m grid (121 points) to count clast populations and determine the amount of matrix. The long and short axes of the three largest clasts of each different clast type were measured within the grid boundaries, and detailed clast descriptions (colour, shape, phenocryst and amygdule size and percentage, and alteration mineralogy) were made. In addition, detailed depositional unit descriptions were collected, including amount and composition of matrix, sorting, thickness, bed forms and internal size grading. Observations with respect to the paragenetic sequence of syn- to postvolcanic dike emplacement were completed in order to determine focal points for dike activity during the evolution of the Flin Flon stratigraphy and generation of the VMS deposits. In conjunction with the trace- and major-element geochemistry, these data will be used to describe and reconstruct the volcano-tectonic depression that hosts the Flin Flon VMS deposits.

[1] Mineral Exploration Research Centre, Department of Earth Sciences, Laurentian University, Sudbury, Ontario P3E 2C6

[2] Saskatchewan Geological Survey, Saskatchewan Industry and Resources, 2101 Scarth Street, Regina, Saskatchewan S4P 3V7

[3] Hudson Bay Exploration and Development Ltd., P.O. Box 1500, Flin Flon, Manitoba R8A 0A2

[4] Geological Survey of Canada, 537-601 Booth Street, Ottawa, Ontario K1A 0E8
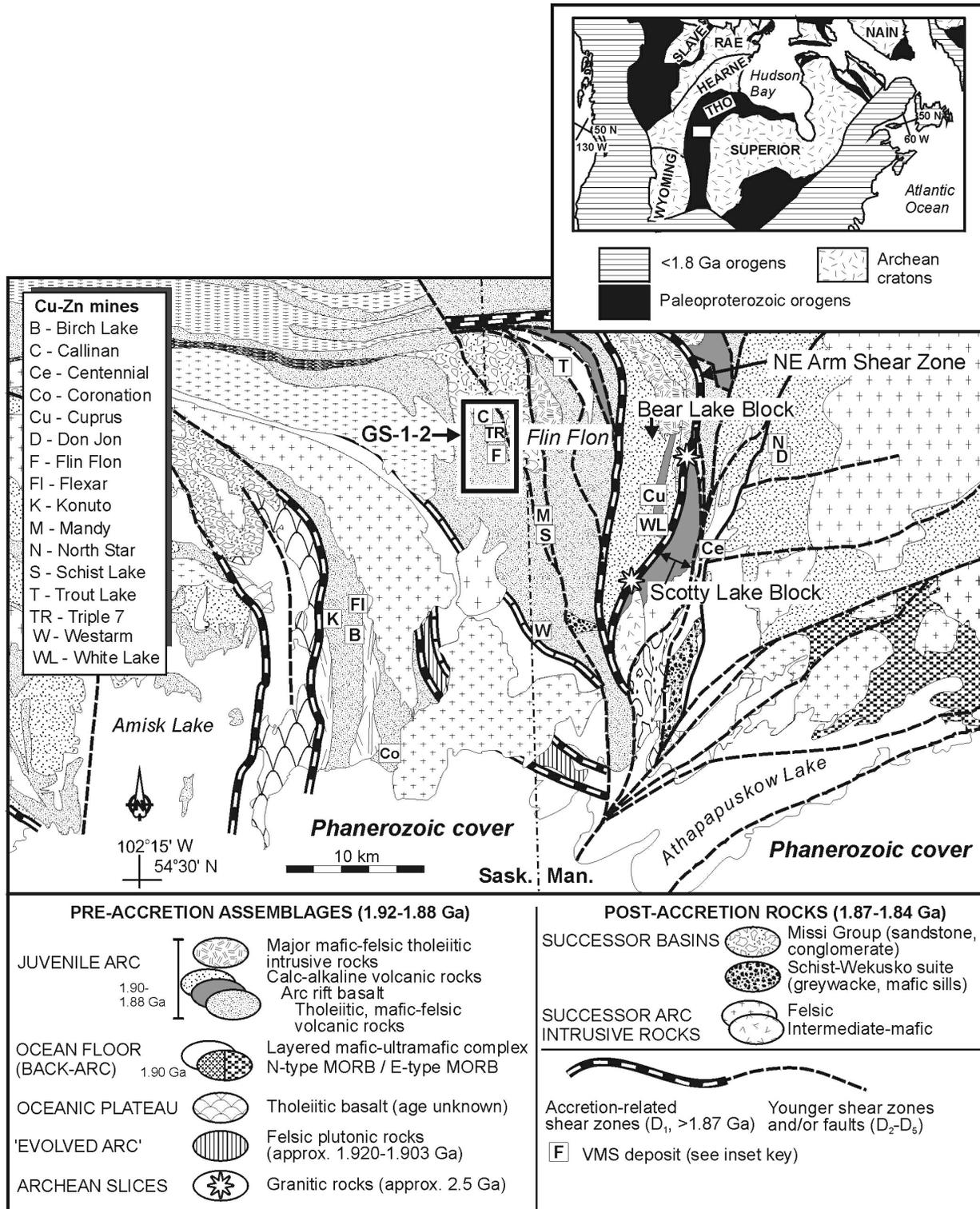
Figure GS-1-1: Tectonic assemblages of the Flin Flon Belt, with locations of contained VMS deposits (modified from Syme et al., 1996).
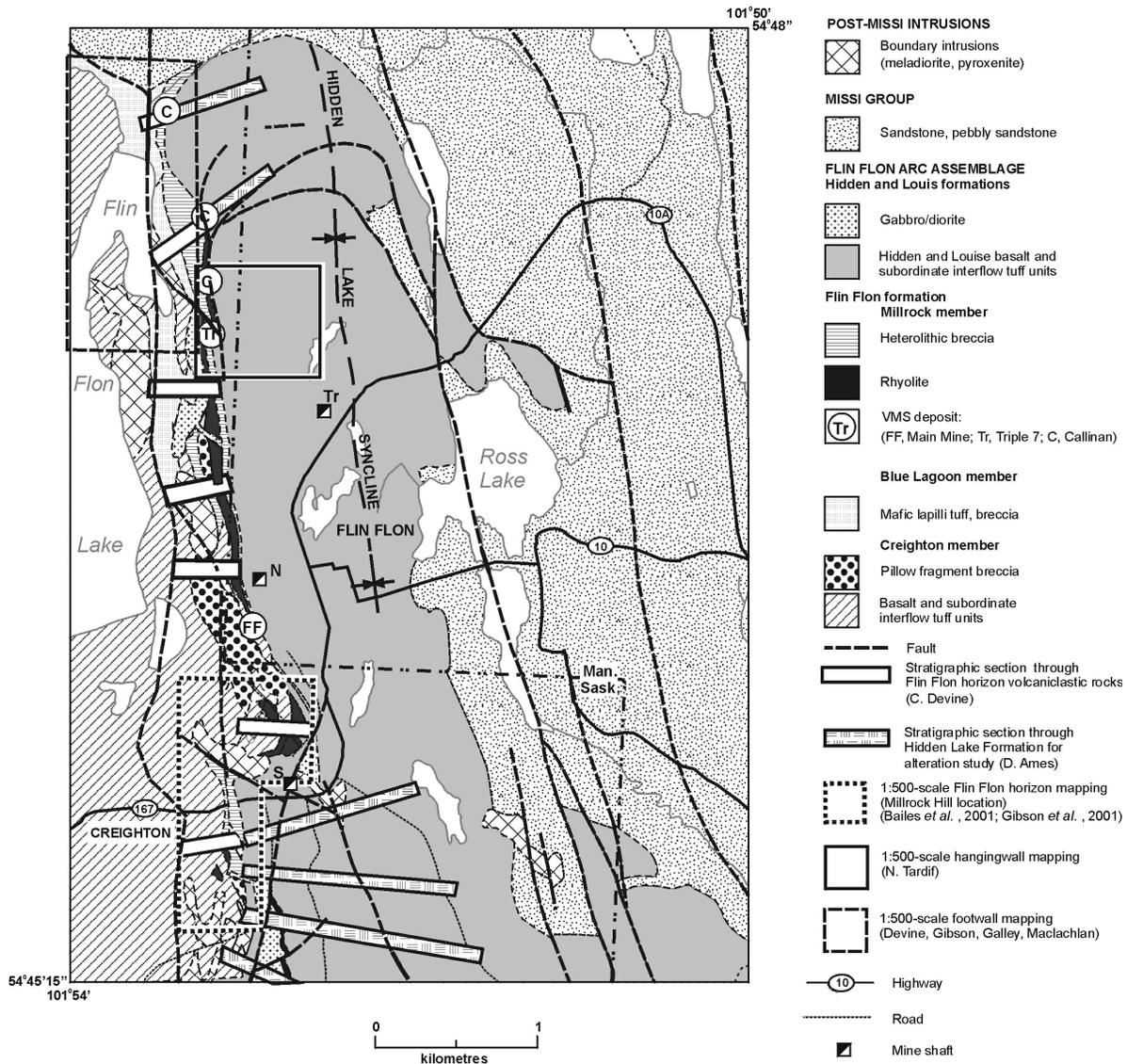
Figure GS-1-2: Simplified geology of the Flin Flon area, illustrating the location of the various study areas examined for this study (after Bailes and Syme, 1989).

REGIONAL GEOLOGY

There are 27 known VMS deposits within the Paleoproterozoic Flin Flon greenstone belt of the southeastern Reindeer Zone, Trans-Hudson Orogen (Fig. GS-1-1). The VMS-rich greenstone belt consists of a series of accreted oceanic terranes that include arc, back-arc, ocean-floor and successor-arc successions ranging in age from 1.9 to 1.84 Ga (Stern et al., 1995). The VMS deposits are concentrated within the Flin Flon and Snow Lake oceanic-arc assemblages. The present study is located within the Flin Flon arc assemblage, which consists of 1.91 to 1.88 Ga juvenile metavolcanic rocks unconformably overlain by fluvial sedimentary rocks of the ca.1.84 Ga Missi Group. The volcanic rocks consist of basalt, basaltic andesite flows and breccia, and lesser rhyolite flows, all of which were erupted and emplaced in an island-arc–back-arc setting (Syme and Bailes, 1993).

STRATIGRAPHIC DIVISIONS

Informal stratigraphic subdivisions of the volcanic rocks hosting the Flin Flon VMS deposits have been previously proposed by Stockwell (1960), Bailes and Syme (1989), Thomas (1994) and Price (1997). Stratigraphic subdivision has been difficult due to the interlayering of various stratigraphic units, accompanied by rapid and complex facies changes and subsequent overprinting by polyphase fold-fault events. This has resulted in several attempts to define formations (Table GS-1-1).

Table GS-1-1: Stratigraphic nomenclature used for the present study, compared to that used by previous researchers in the area.

		Current Study 2002	Stockwell (1960)	Syme and Bailes (1993)	Thomas (1994)	Price (1997; pers. comm., 2002)
Hangingwall stratigraphy		*Louis fm.*	porphyritic andesite, basalt and flow breccia	Burley Lake basaltic andesite and andesite	Hapnot, Louis Lake basaltic andesite	
		Hidden fm.		Hidden Lake basalt and basaltic andesite	Hangingwall sequence (Hidden Lake basalt)	Hidden Lake fm.; Hanging wall fm; 1920 fm
VMS host stratigraphy	*Flin Flon formation*	*Millrock member*	andesite breccia; quartz porphyry; quartz porphyry breccia	Railway volcaniclastic rocks, "Mine rhyolite", South Main rhyolite domes, South Main pillow fragment breccia	Callinan porphyry, Footwall volcaniclastic rocks	Mine Package fm.
Footwall stratigraphy		*Blue Lagoon member*	porphyritic andesite breccia	plagioclase-phyric mafic volcaniclastic rocks	Footwall volcaniclastic rocks	Hydro Line fm.; Tailings fm.
		Creighton member	andesite, basalt, dacite, and flow breccia			Footwall fm.
		Club member			Club Lake felsic eruptive unit	Club Lake fm.
		Undifferentiated volcanic rocks		South Main basalt	Creighton fm.	

In this study, detailed mapping and stratigraphic analysis have resulted in refinement of the VMS host and footwall stratigraphy (Table GS-1-1). The succession hosting the Flin Flon Main, Callinan and 777 massive sulphide deposits is herein termed the Flin Flon formation (Fig. GS-1-2, GS-1-3). The Flin Flon formation is truncated at the north end of the study area along a disconformable fault contact with the younger Missi Group siliciclastic strata, and is terminated at the south end of the map area by a complex interrelationship between an F_2 anticlinal fold closure and several generations of faulting. The rocks of the Flin Flon formation have been affected mainly by greenschist facies regional metamorphism, with the biotite isograd transecting the formation within a few hundred metres of its northern fault contact.

The Flin Flon formation is subdivided into four mappable, informal members containing units of heterolithic and monolithic breccias, rhyolite flows and domes, and massive and pillowed basalt flows and flow-top breccias. The rock types comprising these members have been described using Fisher's (1966) nongenetic, granulometric classification for volcaniclastic rocks.

Club Lake member

The Club Lake member, the oldest member of the Flin Flon formation (Fig. GS-1-3), consists of four main units: heterolithic basalt±rhyolite breccia; dominantly rhyolite breccia; massive, aphyric rhyolite; and sparsely feldspar-phyric to aphanitic pillowed basalt flows (Fig. GS-1-4, GS-1-5).

The heterolithic basalt breccia (Fig. GS-1-4a) contains subrounded to angular clasts of fine-grained, dark-coloured, feldspar-phyric basalt, sparsely amygdaloidal feldspar-phyric basalt and scoriaceous basalt, and lesser amounts of massive to flow-banded, aphyric, aphanitic rhyolite. Clasts are generally lapilli size but can range up to 85 cm long. Individual depositional units are moderately to poorly sorted, thick- to thin-bedded, matrix-supported tuff and tuff-breccia.

The dominantly monolithic rhyolite breccia contains abundant subangular to angular, aphyric, aphanitic rhyolite clasts and less common, small, aphyric, fine-grained basalt lapilli in a fine-grained mafic matrix. Clasts range up to 52 cm in length. Individual units are clast supported, range from 0.5 to 2.7 m in thickness, and are moderately to well sorted and normally size graded.
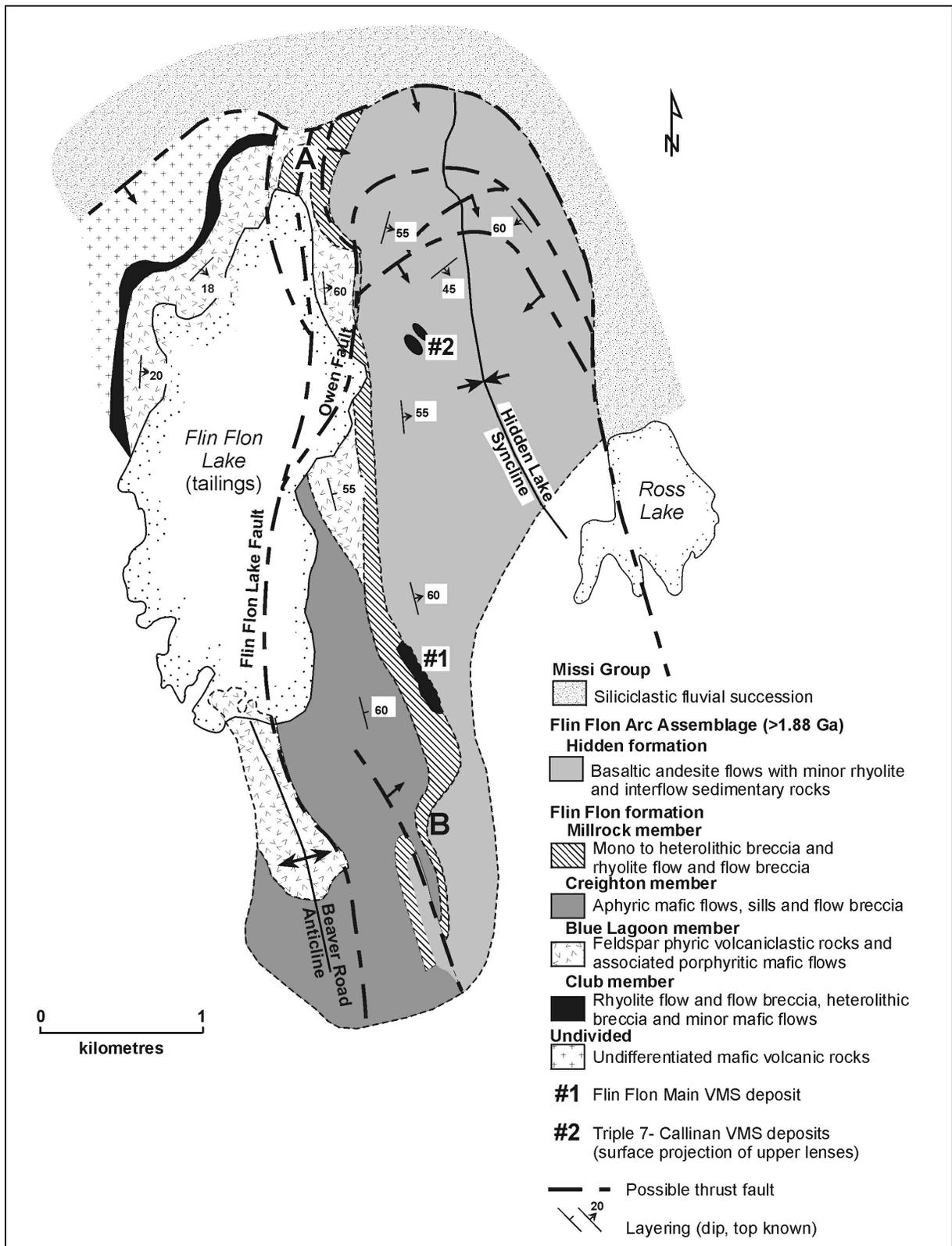
Figure GS-1-3: Preliminary map illustrating the position of proposed early thrust faults and associated repetition of the Flin Flon formation. Structural data for the Hidden Lake formation are from Bailes and Syme (1989). A-B indicates tectonostratigraphic section illustrated in Figure GS-1-6.
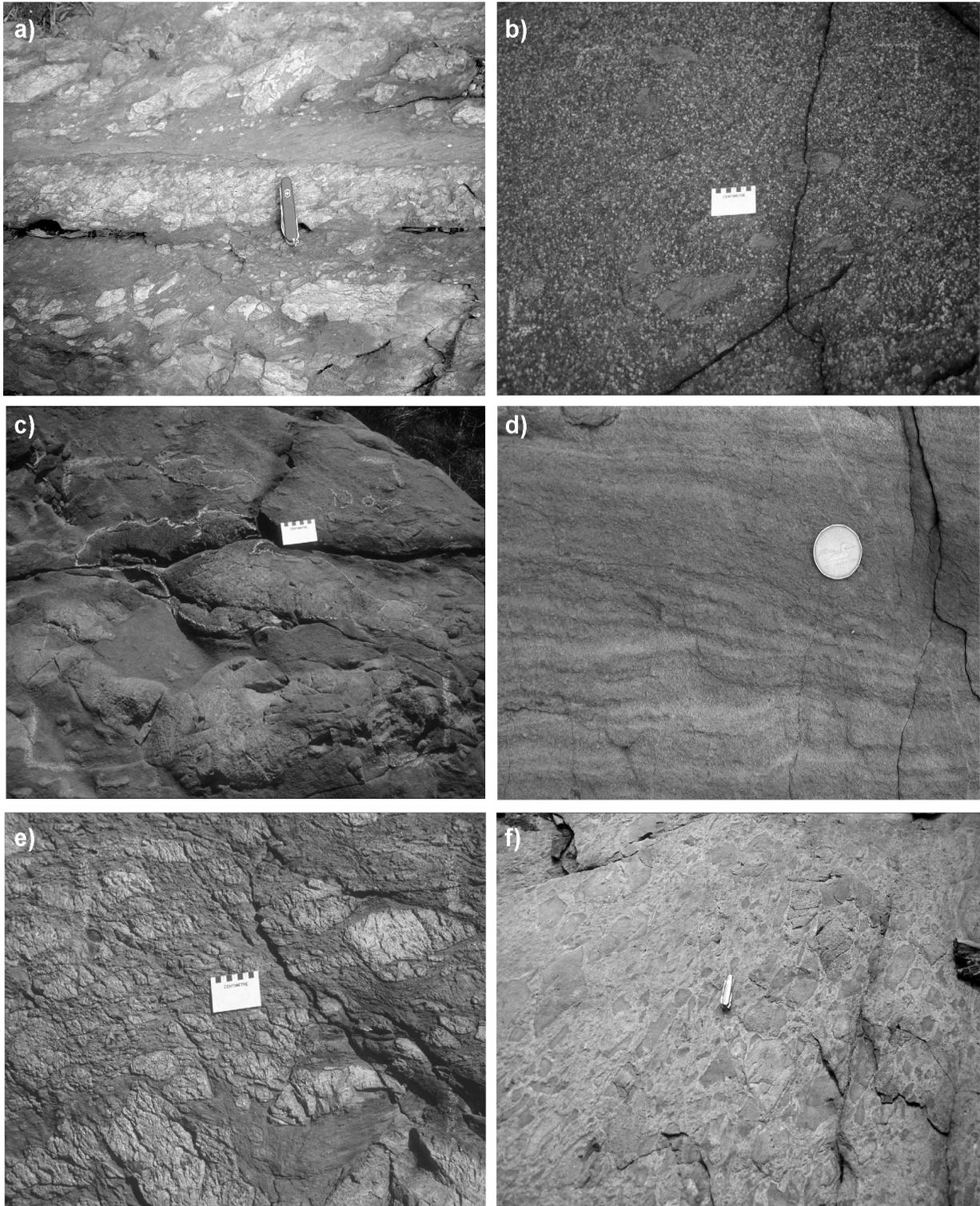
Figure GS-1-4: a) Beds of monolithic rhyolite tuff-breccia interbedded with layers of mafic tuff and lapilli tuff; knife is 9 cm in length. b) Heterolithic crystal lapilli-tuff with basalt clasts and abundant feldspar phenoclasts in the matrix. c) Amoeboid basalt breccia with an individual amoeboid-shaped clast at centre. d) Mafic bedded tuff with crosslaminations. e) Rhyolite-dominated heterolithic breccia. f) Heterolithic basalt tuff-breccia.
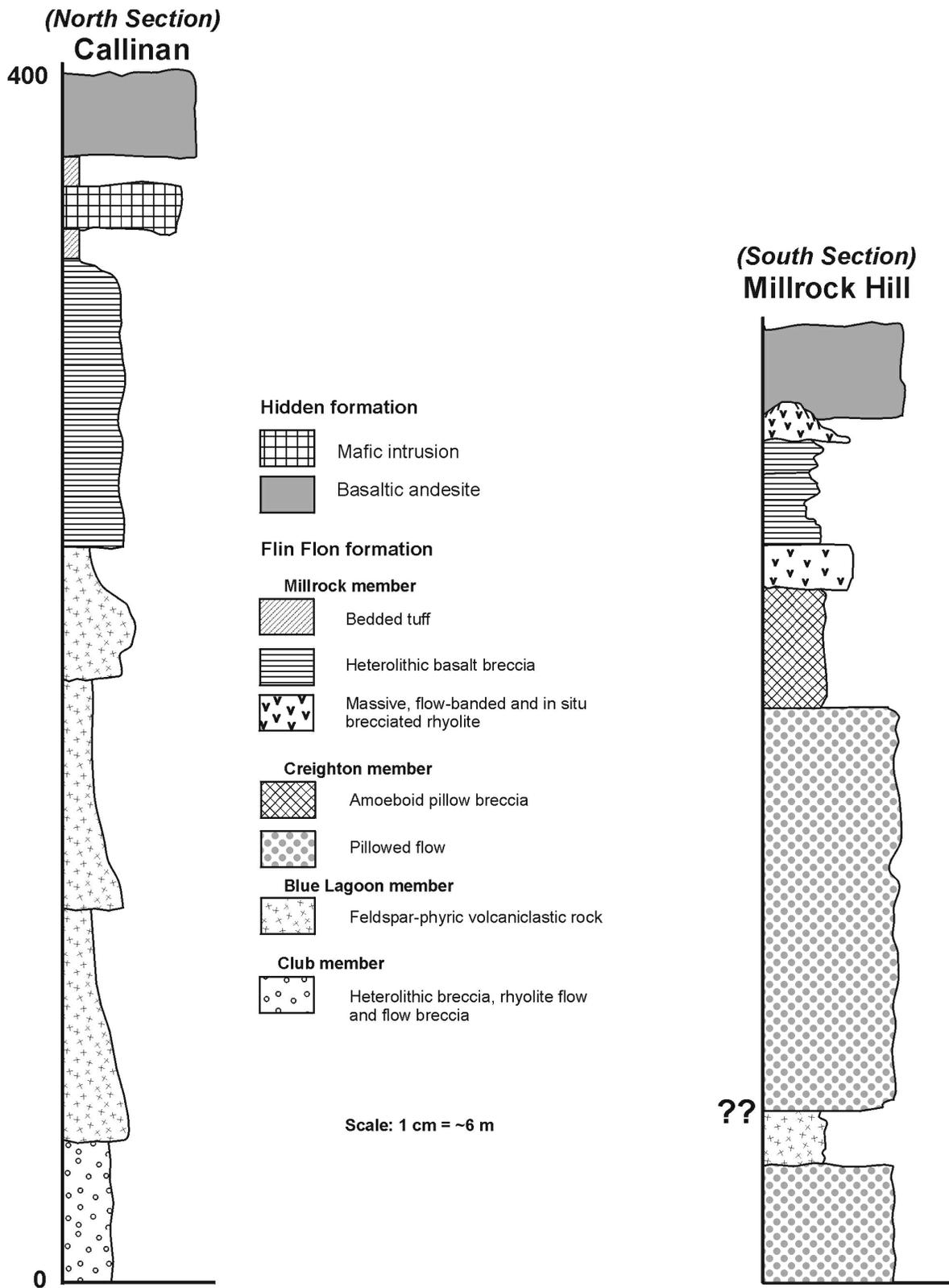
Figure GS-1-5: Schematic stratigraphic sections from the volcaniclastic-rich northern and eruptive-dominated southern parts of the Flin Flon formation.

The rhyolite is massive, aphyric, aphanitic and locally flow banded. This unit has a minimum thickness of 5 m and is in sharp, flow-banded contact with volcaniclastic rocks. Conformable but sharp contacts between massive rhyolite and overlying volcaniclastic rocks suggest emplacement of the former as either a flow or a sill.

Blue Lagoon member

The Blue Lagoon member conformably overlies the Club Lake member and is a distinctive unit characterized by varying amounts and sizes of feldspar crystals that may constitute 5 to 25% of the matrix and that range in size from 0.2 to 1 cm (Fig. GS-1-3, GS-1-5). It contains several subsidiary rock types, including rhyolitic tuff, heterolithic crystal lithic basaltic breccia, and feldspar-phyric massive and pillowed basalt flow and flow breccia.

The rhyolitic tuff is a thin to medium planar-bedded unit containing less than 5% quartz crystals up to 3 mm in size.

The heterolithic basaltic volcaniclastic breccia units (Fig. GS-1-4b) consist of crystal tuff, crystal lapilli-tuff, crystal lapillistone, crystal tuff-breccia and crystal-rich block breccia. Individual units have normal to reverse size-grading, are dominantly matrix supported (approx. 70 % matrix), are poorly to well sorted and have thicknesses ranging from 0.1 to 8.2 m. Although most beds have a feldspar-rich matrix, some intercalated beds have little to no feldspar in the matrix.

Many different clast textures are observed in the heterolithic basaltic breccia units. Amygdaloidal clasts are aphyric or feldspar phyric, contain 5 to 50% quartz- and feldspar-filled amygdules, and range in size from 2.1 to 41.6 cm. Amygdaloidal clasts range in colour from white to grey to pink-brown, and are generally subrounded and oriented parallel to the strike of the volcaniclastic beds. Wispy clasts differ from amygdaloidal clasts in their irregular, wispy shape and fine-grained texture. Wispy clasts contain 5 to 15% amygdules, are generally subangular (irregular) to angular, range up to 13 cm in size and contain 5 to 15% feldspar phenocrysts.

Creighton member

The contact between the Blue Lagoon member and the Creighton member is observed on an island in the tailings pond, with the former clearly underlying the latter. To the southeast, it appears that the contact relationship is reversed, suggesting contemporaneous deposition of the two members (Fig. GS-1-3). The Creighton member rapidly thickens to the south to become the dominant footwall lithology below the Flin Flon deposit (Fig. GS-1-3), where it includes a unit previously identified as the South Main basalt (Syme and Bailes, 1993). The member consists of aphyric flows and sills of basalt and amoeboid basalt breccias (Fig. GS-1-3c). The latter are clast-supported, moderately to poorly sorted tuff-breccia units, and consist of scoriaceous, aphyric basalt clasts with 40% amygdules and sparsely amygdaloidal basalt clasts with 10 to 20% amygdules. Clasts range from 25 to 95 cm in size and have distinct chilled margins and well-preserved, irregular, amoeboid shapes.

Millrock member

The uppermost member of the Flin Flon formation unconformably and locally conformably overlies the previously deposited footwall strata. This is believed to be a function of both rapid tilting of the underlying strata during emplacement of the Millrock member (Syme and Bailes, 1993) and localized erosion due to channellized mass flow. The Millrock member hosts the Flin Flon, Callinan and 777 VMS deposits, and includes heterolithic and monolithic footwall breccias, aphyric to quartz-feldspar–phyric rhyolite and contemporaneous volcaniclastic rocks (Fig. GS-1-3). The Railway heterolithic volcaniclastic rocks of Bailes and Syme (1989) are also included in this member.

The bedded tuff unit (Fig. GS-1-4d), located at the top of the member, contains thin beds of ash-sized material that are locally sulphide stained. The tuff, although mainly planar bedded, is locally crosslaminated and shows soft-sediment slump structures. It locally contains scoriaceous basalt, feldspar-phyric basalt and aphyric rhyolite clasts; the matrix may contain minor amounts of feldspar and quartz crystals 1 to 2 mm in size.

Monolithic, coherent rhyolite ranges from massive to flow banded to in situ brecciated, with quartz crystals that range in size from 3 to 5 mm. Jigsaw-fit clasts in the breccia are angular to subangular and do not appear to be transported.

Monolithic rhyolite breccias range in size from lapillistone to blocky breccia. This clast-supported unit has a rhyolitic matrix and contains subangular to angular rhyolite clasts with 2 to 5 mm quartz crystals and less than 5% amygdaloidal basaltic clasts. This unit generally fines upwards and has bed thicknesses ranging from 1.2 to 4.5 m.

Rhyolite-dominated, heterolithic breccia units (Fig. GS-1-3e) consist of clast-supported lapillistone and

tuff-breccia, with an ash-sized mafic matrix. Clasts are elongate, rounded to angular in shape and range from centimetres to metres in size. Clast types include quartz-phyric rhyolite, sparsely amygdaloidal basalt and scoriaceous, aphyric basalt. Beds range from 0.4 to 9.9 m in thickness.

Basalt-dominated heterolithic breccia units, including lapilli-tuff, lapillistone and tuff-breccia, are clast supported with rounded to angular, sparsely amygdaloidal and scoriaceous, aphyric basalt clasts, and quartz-phyric rhyolite clasts in a fine, ash-sized matrix. Bed thicknesses range from 0.2 to 4.6 m.

Monolithic basaltic lapilli-tuff to lapillistone units contain subrounded to angular clasts of scoriaceous to sparsely amygdaloidal basalt up to 30 cm in size. This matrix-supported unit fines upwards and has beds ranging from 0.25 to 5 m in thickness.

The heterolithic basaltic breccia units (Fig. GS-1-3f) comprise lapilli-tuff to tuff-breccia with subrounded to angular clasts. These clasts include sparsely amygdaloidal, amygdaloidal, scoriaceous, aphyric basalt; wispy-shaped, aphanitic, aphyric basalt; feldspar-phyric basalt; fine-grained gabbro; and rare sulphide (sphalerite) clasts (the latter only observed underground), all in a fine-grained, mafic matrix. Depositional units range from 0.4 to 6 m in thickness, and are dominantly clast supported (70–80% clasts) and well to poorly sorted. Clasts range from 0.2 to 80 cm in size, and the unit fines upward to the ash-sized bedded tuff at the top of the VMS host member.

In heterolithic basalt breccia units, aphyric amygdaloidal basalt clasts are fine grained, subrounded to angular and variably coloured, from grey to pinkish grey to white. Amygdule content ranges from 2 to 30%, and averages 15%. Amygdaloidal feldspar-phyric clasts are generally highly amygdaloidal, more so than the aphyric clast type. Amygdule content ranges from 5 to 45% (30% average). Feldspar crystals range from 1 to 10% and are 1 mm in size. These fragments are subrounded, with some angular and rounded clasts as well. The common colour is white or pinkish grey, and most clasts are lapilli sized. Wispy clasts are fine grained, dark grey in colour, have irregular, angular shapes with a platy appearance, contain 2 to 10% amygdules, and are feldspar phyric (1–2%). Gabbroic clasts constitute less than 1% of the entire clast population. They are pink-brown in colour, are rounded to subrounded, have mafic (?pyroxene) crystals, are sparsely amygdaloidal and range from 3.5 to 4.6 cm in size. Sphalerite and pyrite clasts observed underground at 777 are a brassy brown colour and highly attenuated, with lengths of 20 to 60 cm and widths of only 1 cm.

SUBVOLCANIC INTRUSIVE ROCKS

The Flin Flon formation volcaniclastic strata and subordinate flows are transected by dense swarms of subvolcanic mafic dikes. These dike swarms appear to have been active during emplacement of the Flin Flon formation, but also include feeder dikes for the overlying Hidden Lake formation. Many of the early-stage dikes have peperitic margins, and are affected by zones of intense, fracture-controlled alteration. The immediate host volcaniclastic strata are also commonly silicified, chloritized and/or altered to amphibole and clinozoisite with accompanying sulphide staining. In some cases, the dike swarms are so intense that they can only be differentiated from one another by the presence of chilled margins and small screens of highly altered host strata. These are very similar situations to those described for sheeted dike swarms in ophiolite complexes (Lydon and Jamieson, 1984 and references therein).

IMPLICATIONS FOR EMPLACEMENT

It is evident from the above descriptions of volcaniclastic rocks that the Flin Flon formation and its members form a complex succession of heterolithic and monolithic, felsic and mafic volcaniclastic rocks and flows. The schematic reconstructed cross-section in Figure GS-1-6 illustrates the range in thickness of the different members of the Flin Flon formation and how they have been emplaced within a structurally controlled basin, as originally interpreted by Syme and Bailes (1993). The bedded tuff deposits are interpreted to have been emplaced by low-concentration mass flows (turbidity flows or currents) or suspension deposits where ash-sized material is deposited from the tail end of a flow. The coarser breccias are interpreted to have been emplaced as channellized, high-concentration mass flows carrying large amounts of material downslope en masse. The chaotic nature of the VMS footwall succession is indicative of a high-energy, unstable regime typical of rapid basin development with associated faulting. The occurrence of intense dike swarms is supportive of the presence of synvolcanic faults developing in a localized rift environment. The recognition of these dike swarms will assist in delineating the focal points for hydrothermal activity for both known and unknown VMS deposits.

DISTRIBUTION OF MEMBERS AND TENTATIVE STRUCTURAL INTERPRETATION

Previous work by Stockwell (1960), Bailes and Syme (1989), Price (1997) and Thomas (1994) indicates that the Flin Flon formation has been deformed by polyphase folding and extensive faulting, including thrust faults. The

Flin Flon formation

Boundary intrusion
Hidden formation
- Mafic intrusion
- Basalt, basaltic andesite

Millrock member
- Bedded tuff
- Heterolithic basalt breccia
- Monolithic basalt breccia
- Massive, flow-banded and in situ brecciated rhyolite

Blue Lagoon member
- Feldspar-phyric volcaniclastic rock

Club member
- Heterolithic breccia, rhyolite flow and flow breccia
- Massive sulphide deposit

Figure GS-1-6: Schematic tectonostratigraphic section through the Flin Flon formation, extending south from the northern termination of the formation against the Club Lake Fault. Location of section indicated by A-B on Figure GS-1-3.

earliest foliation (S_1), only observed in the closures of F_2 folds, may be axial planar to an earlier set of F_1 isoclinal folds. The most prominent penetrative fabric (S_2) is axial planar to northerly-trending, southeast-plunging F_2 folds, such as the Beaver Road anticline and Hidden Lake syncline (Stockwell, 1960; Price, 1997; Fig. GS-1-4). These, along with northerly-trending shear and fault zones, such as the Flin Flon Lake and Owen faults, dominate the structure of the Flin Flon area. The Flin Flon, Callinan and 777 VMS deposits, which have been interpreted to occur on the east limb of the Flin Flon anticline, are elongate parallel to a shallow (37°) southeast-plunging extensional fabric that is collinear with the F_2 fold axes and manifested by the elongation of amygdules, pillows and clasts.

Although previous work has clearly defined the Hidden Lake syncline (Bailes and Syme, 1989), the location of the north extension of the Beaver Road anticline beneath Flin Flon Lake and the west limb of this F_2 structure remained poorly constrained and uncertain. However, the distribution of the Flin Flon formation, particularly the four members that constitute this formation as illustrated in Figure GS-1-4, indicates that the Flin Flon anticline is structurally repeated by faulting and that the lower two members of the formation, the Club and Blue Lagoon members, occur on the west side of Flin Flon Lake where they dip shallowly to the east. The northerly-trending and east-dipping faults responsible for this structural repetition are interpreted to be thrust faults, based on 1) their attitude, which is typically parallel to the strike of the enclosing units but more steeply dipping; and 2) repetition of units and members, in both surface outcrops and drill core, which clearly places older members on top of younger members and, in places, the Flin Flon formation upon younger Missi Group sedimentary rocks west and north of Flin Flon Lake. Clearly, the nature, orientation and kinematics of these northerly-trending faults, which were first recognized by Stockwell (1960) to repeat basalt flows of the Hidden Lake formation, must be carefully documented and evaluated. However, a tentative structural interpretation based on the new stratigraphy and mapping places the Blue Lagoon member and, more importantly, the VMS-hosting Millrock member within structurally stacked panels below, and on the east side of, Flin Flon

Lake. This stratigraphic and structural interpretation has significant ramifications for exploration and is in the process of being refined and evaluated.

CONCLUSIONS AND FUTURE WORK

Volcaniclastic rocks of the VMS-hosting Flin Flon formation are very complex heterolithic units that are divisible into four distinctive and mappable members. This new stratigraphic subdivision, which clearly defines the characteristics of the volcaniclastic rocks hosting the VMS deposits at Flin Flon, allows their recognition elsewhere and may prove to be a powerful tool for tracing volcanic stratigraphy with the potential to host more VMS mineralization. The stratigraphy has also facilitated recognition of thrust faults, which have repeated the formation and also, perhaps, the contained VMS mineralization. Future work will use the detailed clast count data to determine possible emplacement mechanisms for the volcaniclastic rocks, by examining the stratigraphic distribution of the size and percentage of clasts. In addition, geochemistry and petrography of the clasts will provide evidence for the provenance of the various units that constitute this formation.

REFERENCES

Bailes, A.H. and Syme, E.C. 1989: Geology of the Flin Flon–White Lake area; Manitoba Energy and Mines, Minerals Division, Geological Report GR87-1, 313 p.

Bailes, A.H., Bray, D. and Syme, E.C. 2001: Geology of the South Main shaft area, Flin Flon (part of NTS 63K/13SW); Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Preliminary Map 2001F-2, scale 1:500.

Fisher, R.V. 1966: Rocks composed of volcanic fragments; Earth Science Reviews, v.1, p. 287–298.

Gibson, H.L., Bailes, A.H., Tourigny, G. and Syme, E.C. 2001: Geology of the Millrock Hill area, Flin Flon (parts of NTS 63K/13SW, /12NW); Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Preliminary Map 2001F-1, scale 1:500.

Lydon, J.W. and Jamieson, H.E. 1984: The generation of ore-forming hydrothermal solutions in the Troodos ophiolite complex: some hydrodynamic and mineralogical considerations; *in* Current Research, Part A, Geological Survey of Canada, Paper 84-1A, p. 617–625.

Price, D. 1997: Flin Flon–Creighton generalized geological map (1:10 000); Hudson Bay Exploration and Development Co. Ltd., internal map.

Stern, R.A., Syme, E.C., Bailes, A.H. and Lucas, S.B. 1995, Paleoproterozoic (1.90–1.86 Ga) arc volcanism in the Flin Flon Belt, Trans-Hudson Orogen, Canada; Contributions to Mineralogy and Petrology, v. 119, p. 117–141.

Stockwell, C.H. 1960: Flin Flon–Mandy area, Manitoba and Saskatchewan; Geological Survey of Canada, Map 1078A, scale 1:12 000, with descriptive notes.

Syme, E.C. and Bailes, A.H. 1993: Stratigraphic and tectonic setting of volcanogenic massive sulfide deposits, Flin Flon, Manitoba; Economic Geology, v. 88, p. 566–589.

Syme, E.C., Bailes, A.H. and Lucas, S.B. 1996: Tectonic assembly of the Paleoproterozoic Flin Flon belt and setting of VMS deposits; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Winnipeg, Manitoba, May 27–19, 1996, Field Trip guidebook B1, 131 p.

Thomas, D.J. 1994: Stratigraphic and structural complexities of the Flin Flon mine sequence; *in* Summary of Investigations 1994, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 94-4, p 3–10.