GS-2 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

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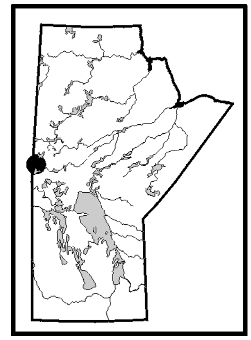

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SUMMARY

The objective of this subproject of the Flin Flon Targeted Geoscience Initiative is to gain a better understanding of the nature and distribution of hydrothermal alteration within the hanging wall strata, herein called the Hidden formation, to the Flin Flon–777–Callinan volcanogenic massive sulphide (VMS) deposits of the Paleoproterozoic Flin Flon Belt.

Important findings to date from this study include

- recognition of extensive zones of hydrothermal alteration, within the hanging wall strata, that include both distal and proximal alteration facies;
- definition of two distinct, synvolcanic dike swarms within the Hidden and Louis formations, one of which includes felsic dikes; dike swarms are important for localizing hydrothermal fluid upflow zones; and
- identification of a rhyolite flow unit with associated sulphidic sedimentary rocks, called the ‘Tower member’, at the top of the Hidden formation; this increases the exploration potential for another VMS-bearing horizon in the Flin Flon area, at the upper contact of the Hidden formation with the Louis formation.

INTRODUCTION

The Flin Flon Targeted Geoscience Initiative (FFTGI) is a three-year (2000–2003) federal initiative designed to develop new criteria to assist exploration and mining companies in increasing ore reserves, thereby stabilizing the economy of this northern mining community. The project objectives are to 1) increase the understanding of the volcanic and hydrothermal history of the western Paleoproterozoic Flin Flon volcanic belt with respect to formation of volcanogenic massive sulphide (VMS) deposits; and 2) assist the development of exploration strategies that support the discovery of new VMS deposits (Galley and Bailes, 2001).

The premise of this study is that most VMS hydrothermal systems result in alteration of not only the strata underlying the massive sulphide deposit, but may also affect overlying strata. This hanging wall alteration may be a function of one of two processes. The first is continuation of the hydrothermal fluid flow responsible for the formation of the VMS deposit during the progressive burial of the deposit by volcanic flows and sediments. There are many examples of this process in the Noranda camp, resulting in either zones of alteration, extending for up to 500 m above a known VMS deposit (e.g., the Ansil deposit; Riverin et al., 1990), or stacked orebodies formed at successive seawater-rock interfaces (e.g., the Amulet deposits; Gibson and Watkinson, 1990). The second process involved in the generation of hanging wall alteration is the formation of an entirely new subseafloor hydrothermal system, triggered by the cooling of a thick pile of volcanic flows. Whereas the continuation of an existing hydrothermal system into the hanging wall would result in the formation of discrete alteration pipes, the generation of a new hydrothermal system should result in broader, semiconformable alteration with associated, discrete, disconformable alteration pipes. Both cases can result in the periodic formation of sulphidic sedimentary, or ‘exhalite’, units (Franklin et al., 1981).

The Flin Flon–777–Callinan VMS horizon provides an ideal setting for a hanging wall alteration study, due to the relative compositional homogeneity and 600–700 m thickness of the hanging wall basalt succession. The study involves detailed stratigraphic examination and sampling of the Hidden formation along its 5000 m known strike length, as well as traverses within a correlative mafic-flow succession farther west in Saskatchewan, where the VMS-bearing succession is believed to be duplicated due to folding (Fig. GS-2-1). Flow-facies variations were defined along evenly spaced sections. In addition, the presence and type of interflow sedimentary rocks and the nature and extent of alteration were documented along these sections.

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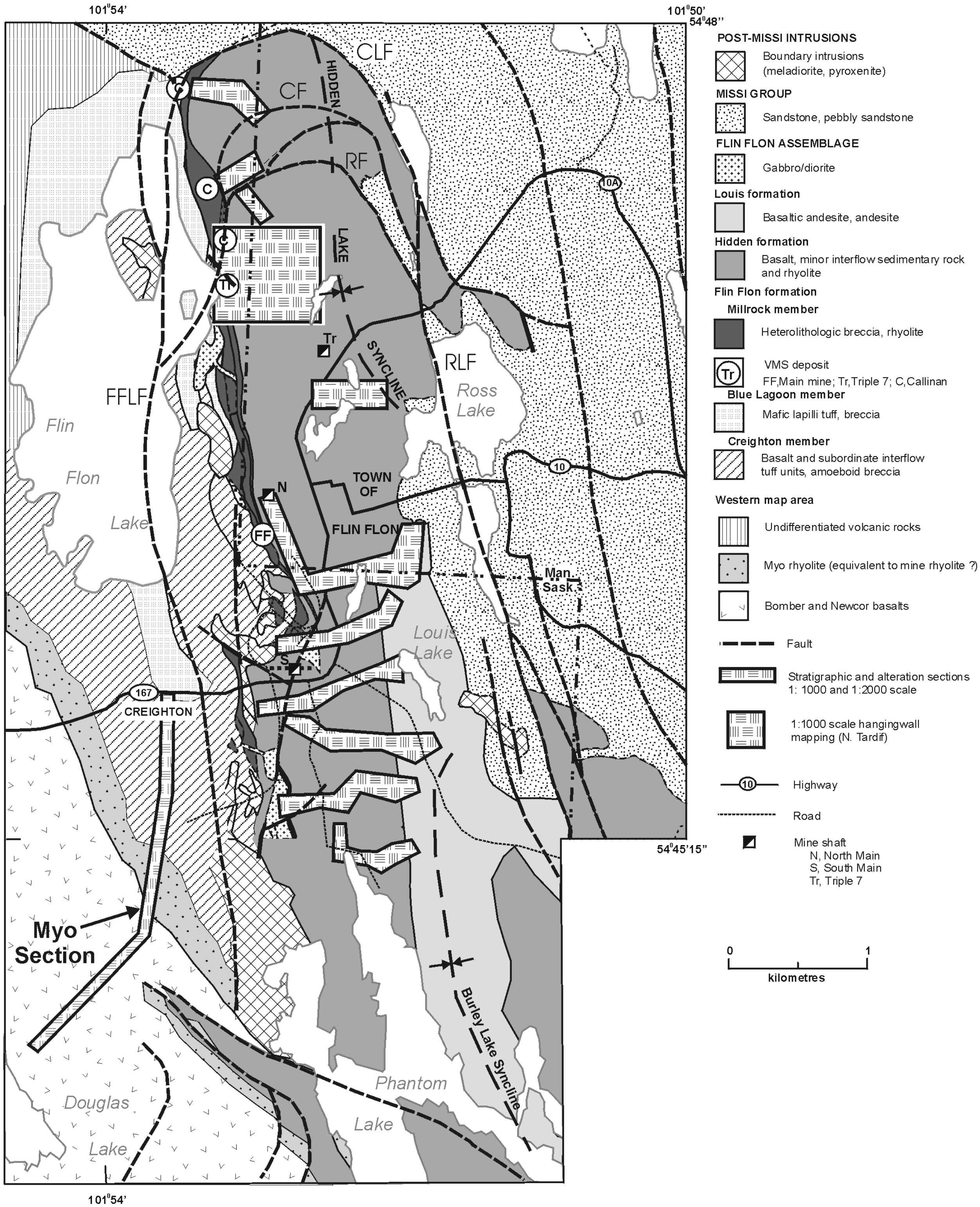

Figure GS-2-1: Simplified geology of the Flin Flon block, showing the location of detailed traverses in the hanging wall of the Flin Flon-777-Callinan VMS horizon. Abbreviations: CLF, Club Lake Fault; CF, Catharine Fault; FFLF, Flin Flon Lake Fault; RF, Railway Fault; RLF, Ross Lake Fault.

During the 2001 and 2002 field seasons, mapping of the hanging wall stratigraphy to the Flin Flon mine horizon consisted of 1) ten traverses, mapped at 1:1000 and 1:2000 scale, extending from the Club Lake Fault in the north to Phantom Lake in the south; 2) a 1:2000-scale section through the western, southwest-younging limb of the Beaver Road anticline, from Myo Lake towards Douglas Lake (K. Maclachlan); and 3) a detailed 1:1000-scale study above the 777 orebody (M.Sc. thesis, N. Tardif, Laurentian University; Fig. GS-2-1).

The Myo Lake section (Fig. GS-2-1) is thought to be broadly correlative with the east-younging limb that hosts the Flin Flon VMS deposits. In particular, the Myo rhyolite (Thomas, 1990) is thought to be correlative with the Flin Flon VMS-bearing horizon (K. Gilmore, pers. comm., 2002).

GEOLOGY OF THE HANGING WALL STRATIGRAPHY TO THE FLIN FLON–777–CALLINAN VMS HORIZON

One of the objectives of the FFTGI is to develop a 1:10 000-scale geological compilation of the Flin Flon structural block, in order to standardize unit correlations as defined by various workers, including Stockwell (1960), Bailes and Syme (1989), Thomas (1990) and Hudson's Bay Exploration and Development Co. Ltd. (HBED). An early result of this synthesis is to define the immediate hanging wall basalt succession to the Flin Flon–777–Callinan VMS deposits as the Hidden formation, and the VMS hostrock package and underlying volcaniclastic and eruptive units as the Flin Flon formation (Fig. GS-2-1). The Hidden formation contains an unnamed lower member, the '1920 member', the Reservoir member and, at its top, the Tower member. For the purposes of this study, it is assumed that the basalt stratigraphically above the Myo rhyolite is equivalent to the Hidden formation.

Hidden formation

The Hidden formation is dominated by basaltic andesite flows, with subordinate interflow sediment and rhyolite. Stratigraphic tops are to the east and southeast in the main mine package, the tops indicators including distribution of amygdules, gas cavities and pipe vesicles, re-entrant selvages, pillow morphology and stacking, and graded beds, channels and load casts of the sedimentary rocks. The apparent thickness is variable due to structural complications caused by D_2 folding at both the lower contact, particularly in the Millrock Hill–Phantom Lake area to the south, and the upper contact in the Railway Fault–Ross Lake area in the central part (Fig. GS-2-1). The lower contact in the southern area is duplicated by D_1 thrust faults focused along interflow sediment horizons. The exposed thickness of the Hidden formation varies from approximately 650 m in the area between the 777 and Flin Flon deposits, to 880 m south of the Flin Flon deposit, to 400 m just north of Phantom Lake. Along the west shore of Phantom Lake, Stockwell (1960) showed the mafic flows of the Hidden formation thinning out and interlayering with mafic volcaniclastic units, similar to those observed as interflow sedimentary rocks farther north in the study area.

The lower mafic flows of the Hidden formation are in contact with heterolithic breccia and rhyolite of the Flin Flon formation. The upper contact of the Hidden formation is defined by the first appearance of pyroxene-plagioclase–phyric basalt of the Louis formation. The upper contact is further defined by the presence of rhyolite flows, and related talus debris and sulphidic mafic and felsic interflow sedimentary rocks, which form the Tower member of the Hidden formation (Fig. GS-2-2, GS-2-3).

Descriptions of the Hidden formation are given for the North Callinan, 777, Flin Flon, Phantom Lake and Myo Lake sections.

North Callinan section

The northernmost contact of the Hidden formation is bordered by younger Missi Group formation along the D_1 Club Lake Fault. In this northern third of the study area, the Hidden formation is affected by numerous, refolded, D_1 thrust faults (Fig. GS-2-1). A 200 m thick gabbro intrudes the base of the sequence and contains numerous rafts of basalt, sedimentary rocks and mafic dikes. Removing this intrusion, the lower 110–160 m section of the Hidden Lake succession consists of a pale grey weathering icelandite, informally known as the '1920 member' (D. Price, pers. comm., 2002) This distinctive unit is approximately 60 m thick and has acicular amphibole needles and 20% feldspar microphenocrysts, along with large gas cavities that are the focus for intense epidote-amphibole-sulphide alteration. The upper contact of the '1920 member' is peperitic into fine-grained mafic tuff, forming extensive, altered breccia zones up to 30 m wide. The peperite suggests that the unit flowed and/or intruded into a sequence of fine-grained, mafic volcaniclastic rocks and siltstone at shallow levels. The mafic volcaniclastic rocks contain abundant sedimentary structures, such as normal grading, channels, dropstones and load casts. The mafic volcaniclastic rock–siltstone occurs in varying amounts in the basal section of the Hidden formation, along its entire 5000 m strike length, as remnants

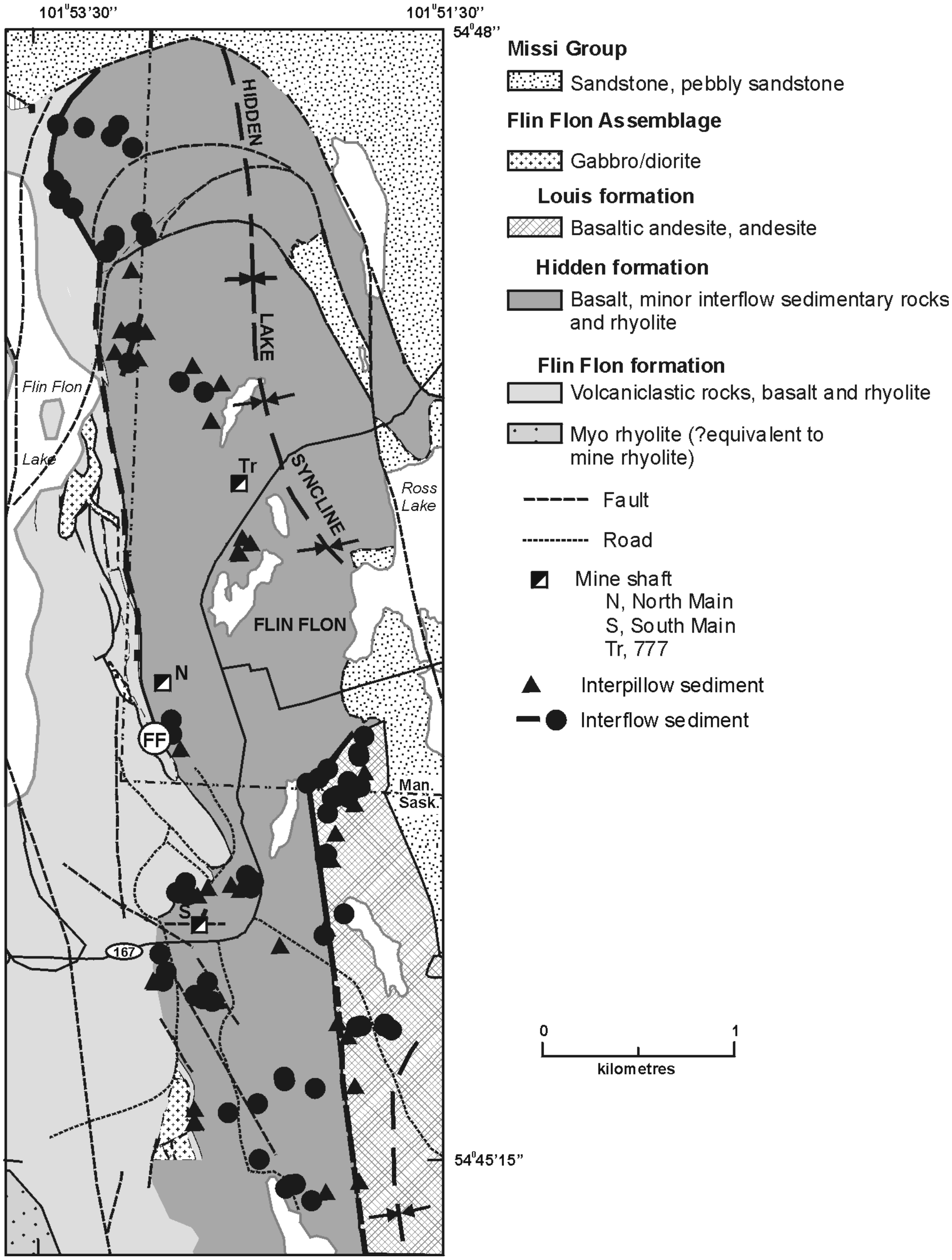

Figure GS-2-2: Distribution of interflow sedimentary rocks in the Hidden and Louis formations; note the concentration of sedimentary rocks as interflow, interpillow and peperite near the base of the two formations. See Figure GS-2-1 for traverse locations.

between pillows and as more intact interflow intervals. In most cases, these mafic sedimentary rocks are the focus for much of the alteration observed within the Hidden formation.

Above this basal section are 10 to 65 m thick flows of plagioclase-phyric, sparsely plagioclase-phyric and aphyric basalt flows that are dominantly pillowed, with pillow size being moderate (at 45 to 70 cm). Massive flows display laminar cooling cracks, 5 to 20 cm gas cavities at the top, and elutriation pipes at the lower contact due to extrusion into wet, unconsolidated sediment. The dominant trend of comagmatic mafic dikes is 145° which is subparallel to the plunge of the D_2 folds. The north Callinan section contains subequal proportions of intrusive and extrusive mafic rocks (45%) and 10% sediment (>60 m cumulative thickness).

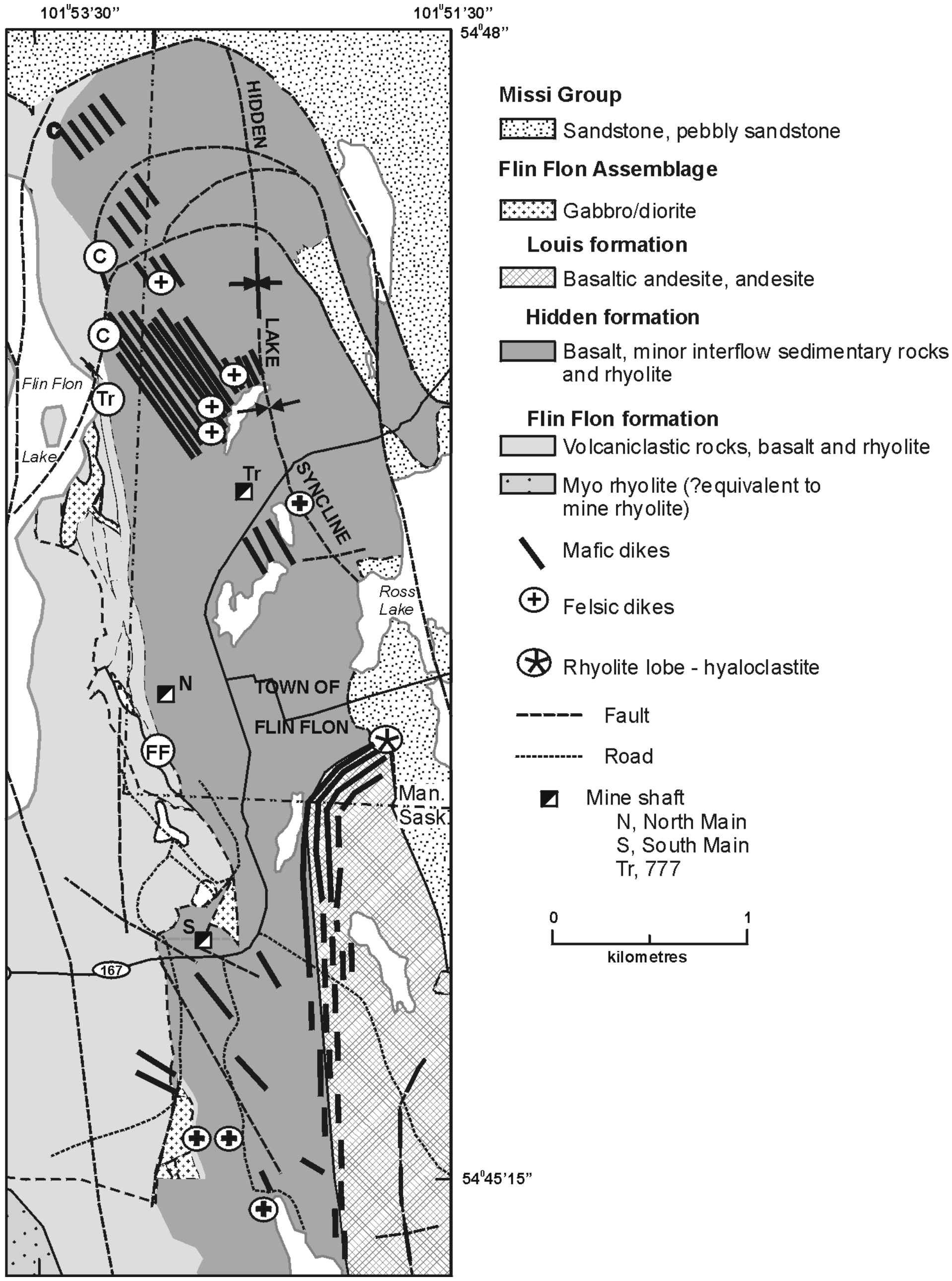

Figure GS-2-3: Distribution of mafic dike swarms, felsic dikes and the Tower member felsic lobe-hyaloclastite flow at the top of the Hidden formation. See Figure GS-2-1 for location of traverse areas.

777 section

The central 777 area extends from the northern limit of the town of Flin Flon to the Railway Fault (Fig. GS-2-1). The stratigraphic sequence exposed in this area is bounded by the Flin Flon formation at its base and terminated 650 m above this by the Hidden Lake syncline (Fig. GS-2-1). Detailed mapping of an area up-plunge from the 777 VMS deposit (Tardif, work in progress; Galley and Bailes, 2001) defined approximately seven basaltic andesite flows crosscut by a series of mafic dikes and subordinate felsic dikes that strike 145° (Fig. GS-2-4, Table GS-2-1). This section is dominated by amygdaloidal, plagioclase- and/or pyroxene-phyric flows and minor aphyric flows with associated flow-top breccia. The flows vary from 15 to 430 m thick and are dominantly pillowed, with pillows ranging in size from 0.1 to 10 m (Table GS-2-1). Contacts between flows are sharp and irregular, with some flows showing an irregular transition from pillowed to amoeboid-shaped pillow breccia.

Within interpillow areas, three different textures are observed: 1) thinly bedded to laminated clastic sedimentary

Table GS-2-1: Description of flow units in the Hidden formation, 777 section (N. Tardif, M.Sc. in progress).

Flows		Field description	Mineralogy , volcanic textures/structures	Alteration mineralogy, textures	Contacts
Flow 6 (~10-20 m)	Epidotized, aphyric, mega-pillowed andesite	Medium, densely packed pillows (1% mafic mineral (pyroxene replacing albite?), 1-10% quartz amygdules increasing at pillow margins); minor epidote-altered interpillow sedimentary rocks; 1-2% epidote patches at pillow margins; trace pyrite in interpillow selvages	Fine-grained matrix (high albite microlites (25-30%), hyalopelitic, minor quartz, actiniolite); trace-1% sulphides associated with amygdules; 5% quartz amygdules	Fine-grained actinolite (30%) - epidote (25%), trace pyrite; finely disseminated to coarse grained epidote; epidote greater at margins of amygdules	Irregular and sharp with flow 5
Flow 5E (~60 m)	Epidotized, aphyric, pillowed andesite	Medium to large, densely packed pillows/ tubes (up to 4 m); minor epidote-altered interpillow sedimentary rocks; minor epidote patches (1-2%) at pillow margins, ±pyrite at interpillow selvages	Fine-grained matrix (high albite microlites (25-30%), pilotaxitic, minor quartz, actinolite); 5% quartz amygdules	Very fine grained, pervasive actinolite (25%) - epidote (25-50%); epidote greater at margins of amygdales	Irregular and sharp with flow 5
Flow 5A-D (~430 m)	Feldspar-phyric, amygdular, pillowed andesite	Medium to very large, densely packed pillows/tubes (up to 6 m), concentrically flow banded; plagioclase (10%), pyroxene (2%), chlorite (1-3%); pillows decrease in size near top of flow into a matrix-controlled, amoeboid-shaped breccia; strong epidote-actinolite in smaller pillows and at pillow selvages ±sulphides; 30% quartz-feldspar amygdules; moderately epidote-altered and minor cherty interpillow sedimentary rocks, thinly laminated to finely bedded and interpillow breccia; epidote patches abundant in lower part of flow, in interstitial selvages of breccia and replacing breccia fragments	Fine-grained matrix (±albite microlites (20-30%), hyalopelitic to pilotaxitic, quartz, biotite, ±carbonate); 10-30% quartz-epidote-feldspar-chlorite amygdules; 10% medium to large albite porphyroclasts; albite content decreases with increasing epidote-actinolite-pyrite alteration (patches/gossan)	Fine-grained matrix, medium to high epidote (25-60%) strongly associated with quartz amygdules; trace pyrite, ± minor actinolite (0-30%) and chorite (0-10%)	Irregular and gradational into amoeboid-shaped breccia; sharp with sill; sharp and irregular with flows 6 and 7
Flow 4 (~30 m)	Patchy epidote-aphyric pillowed andesite	Medium to very large, densely packed aphyric pillows/tubes (up to 10 m) concentrically flow-banded and amoeboid-shaped breccia; pillows decrease in size near top of flow into a matrix-controlled amoeboid breccia to the northwest (~10 m); quartz/feldspar amygdules (5%); moderately epidote-altered interpillow sedimentary rocks, ±pyrite-chlorite-chert, thinly laminated to finely bedded, injecting into tubes/pillows; minor interpillow breccia; alteration increases at pillow margins, ±pyrite-chlorite; moderate epidote patches in tube cores	Fine-grained matrix (high albite microlites (30-35%), hyalopelitic, minor quartz, actinolite, biotite); 1-2% quartz amygdules ± carbonate; quartz/albite porphyroclasts (4%); albite decreases with increasing epidote-actinolite-pyrite alteration (patches)	Moderately clotty and pervasive epidote (25-35%) - actinolite(15-25%) - chlorite (20-25%) alteration, fine grained in matrix	Irregular and gradational into amoeboid-shaped breccia, sharp with flow 5

Table GS-2-1: *Description of flow units in the Hidden formation, 777 section (N. Tardif, M.Sc. in progress).* (continued)

Flows		Field description	Mineralogy , volcanic textures/structures	Alteration mineralogy, textures	Contacts
Flow 3 (~80 m)	Aphyric pillowed andesite	Medium, densely packed, concentrically flow-banded pillows; minor to moderately epidote-altered, thinly laminated to finely bedded interpillow sedimentary rocks (± moderate chert) and minor interpillow breccia (15-40%); plagioclase (7%), pyroxene (3%), quartz-feldspar amygdules (10-15%); 2-10 cm epidote-altered, amoeboid-shaped fragments ±pyrite in matrix; moderate to strong epidote patches in pillow cores and amoeboid-shaped breccia ±chlorite at margins; fracture-controlled epidote; 3-20 m interflow sediment near top of flow, between flows 3A and 3B	Fine-grained matrix (microlites, hyalopelitic and minor pilotaxitic albite (10-20%) ± actinolite, pyroxene, biotite, low quartz); 1% quartz amygdules ± carbonate; albite content decreases with increasing epidote-actinolite-pyrite alteration (patches)	Moderate to strong pervasive epidote (35-60%); moderate actinolite (30%) - chlorite(10-15%); trace pyrite	Gradational into amoeboid-shaped pillow breccia, sharp with flow 4; pillows flattened near sharp contact with dikes
Flow 2 (~25 m)	Pyroxene-phyric pillowed andesite	Medium, densely packed pillows (10% pyroxene and 10% quartz + minor feldspar amygdules) with minor, thinly laminated, epidote-altered interpilllow sedimentary rocks (minor chert) and minor interpillow breccia	Strongly altered, fine- to medium-grained matrix; very low albite (1%), moderate pyroxene (5-10%), actinolite porphyroclasts (5%); 15% quartz amygdules surrounded by actinolite-chlorite-epidote halos	Strong, finely disseminated epidotization; moderate development of acicular, fine-grained actinolite; minor fine-grained chlorite in matrix	Sharp, irregular with flow 3
Flow 1 (~15 m)	Feldspar-phyric pillowed andesite	Medium, densely packed pillows (1% pyroxene, 1% feldspar, 1% quartz-feldspar amygdules); minor, thinly laminated, epidote-altered interpilllow sedimentary rocks; minor fracture-controlled epidote veins; generally, alteration is pervasive and fracture-controlled, ghostly at pillow cores and near margins of dikes	Fine-grained matrix (quartz±actinolite±pyroxene, no albite microlites) 10% quartz amygdules and albite porphyroclasts (8%)	Strong actinolite (30-35%), moderate chlorite (15%), epidote (15%) in matrix	Sharp, sheared with flow 2

rocks with bedding planes parallel to pillow selvages; 2) interpillow chert; and 3) interpillow hyaloclastite. Peperitic textures within interpillow and interflow mafic sedimentary strata are locally observed. Discontinuous units of mafic sedimentary rocks occur in the basal 120 m of the Hidden Lake sequence, between the massive gabbro flow and flow 1, and between flows 3 and 4 (Fig. GS-2-4).

The central 777 deposit area is transected by a mafic dike swarm trending 145°, perpendicular to the stratigraphy (Fig. GS-2-3). Mafic dikes are of andesitic composition and vary from aphyric to feldspar- and pyroxene-phyric. Felsic dikes of rhyolitic composition are also concentrated in this zone and are generally crosscut by the mafic dikes.

Flin Flon section

The lower approximately 100 m of the Hidden formation in the Flin Flon to South Main section contains 10 to 15 m thick units of aphyric and minor feldspar-phyric basalt containing gas cavities, along with beds of scoriaceous, amoeboid breccia and peperite. The overall 500 m thick sequence changes upsection from basaltic flows and pyroclastic rocks to alternating lobe-hyaloclastite and closely packed pillows, characterized by pipe vesicles and concentric cooling cracks. This mafic flow facies is overlain by rhyolite of the Tower member at the top of the Hidden formation. The Tower member consists of aphyric to sparsely quartz-phyric, lobe-hyaloclastite rhyolite flows with

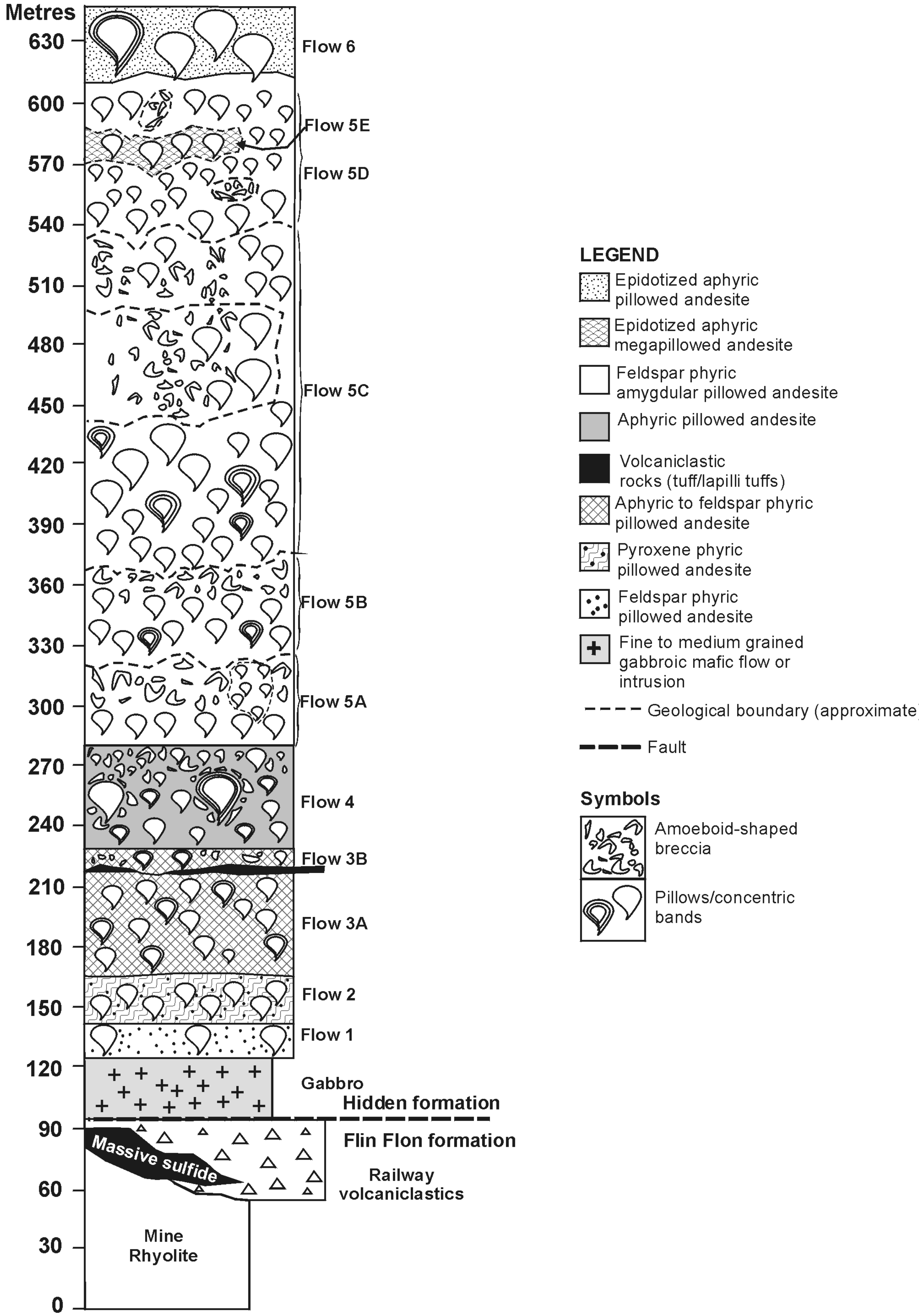

Figure GS-2-4: Stratigraphic section through the Hidden formation above the 777 VMS deposit, based on 1:1000-scale mapping by Tardif (see Figure GS-2-1 for location).

felsic volcaniclastic talus and distal sulphidic mafic siltstone. The hydrothermal alteration overprint on the volcanic sequence also differs from other sections (Fig. GS-2-5, GS-2-6, GS-2-7).

Phantom Lake section

The Millrock Hill to Phantom Lake section in the south is strongly sheared at its base due to the presence of a subsequently deformed early thrust-fault system (Galley et al., 2001). The lowermost 115 m contain mafic tuffaceous rock as interpillow material, accompanied by up to 60 m thick zones of globular peperite. The principal tuffaceous interflow units occur at 70, 200, 230 and 255 m above the base of the formation. The mafic tuff layers are strongly sheared, and may contain accretionary lapilli, graded bedding, quartz-phyric rhyolite fragments and minor scoria. Basaltic andesite flows vary between 5 and 60 m in thickness, and are generally aphyric to sparsely feldspar- and/or pyroxene-phyric. Pillow morphology varies from megapillows (>12 m) to rounded equant pillows (approx. 50–70 cm) and very minor amoeboid breccia. The upper 120 m of pillowed basalt contain concentric cooling cracks, radial pipe vesicles and scoriaceous, amoeboid breccia. Flow indicators suggest a southward flow direction for the flows in this section. The top of the section is characterized by a thin (<1 m) bed of mafic sediment of the Tower member, overlain by the feldspar-pyroxene–phyric basalt of the Louis formation.

Myo Lake section

A section through the western, southwest-younging limb of the Beaver Road anticline (Stockwell, 1960) was mapped at a scale of 1:2000 (Fig. GS-2-1). The base of the ‘hanging wall’ section, described herein, is marked by a slightly sheared contact with the top of the Myo rhyolite. At this locality, on the east side of Myo Lake, the rhyolite (unit 1, Fig. GS-2-8) is sparsely quartz and plagioclase phyric and massive. Within this section, there is a relatively high degree of strain and some transposition of units into the main, southeast-striking, steeply (60–80º) southwest-dipping foliation. Considering the overall degree of flattening, thicknesses have not been corrected for dip and are therefore apparent thickness only (Fig. GS-2-8). The section is just less than 1500 m thick, including covered sections between outcrops and the 50% intrusive material.

Five different types of volcanic rocks are distinguished, based on their field characteristics (unit numbers correspond to those on Fig. GS-2-8):

1) unit 2: dark brown weathering, aphyric, sparsely to nonamygdular (quartz+plagioclase–filled, <5%, 5–25 mm diameter), pillowed flows, the pillows typically of relatively large size (75–200 cm) with irregular shapes, concentric cooling fractures, pipe vesicles near the margins, thin rims and patchy epidotization

2) unit 3: light greenish brown to yellowish brown weathering, aphyric, strongly amygdular (quartz+plagioclase–filled, 10–30%, 1–50 mm diameter), pillowed flows, the pillows commonly of small to medium size (30–150 cm) with pervasive epidotization and silicification

3) unit 4: light to medium greenish brown weathering, aphanitic to fine-grained, sparsely to moderately amygdular (quartz+plagioclase±mafic–filled, 2–10%, 5–15 mm diameter), massive flows, typically with large (3–10 cm) quartz- and epidote-filled gas cavities and epidosite patches

4) unit 5: light greenish grey weathering, sparsely (<2%, <5 mm) to moderately (5–10%, 3–8 mm) plagioclase±pyroxene-phyric, non- to sparsely amygdular (<2%), massive to pillowed flows, with patchy epidotization

5) unit 6: aphyric to sparsely quartz- and plagioclase-phyric (<2%, <4 mm), massive to fragmental rhyolite (may be partly intrusive and/or resedimented volcaniclastic rocks).

Close to 50% of this section consists of intrusive material, most of which has a sill-like orientation. Because of deformation, however, it is difficult to determine if this is primary or partially a result of transposition. Based on field characteristics, seven different groups of intrusive rocks have been distinguished (unit numbers correspond to those on Fig. GS-2-8):

1) unit 8: fine-grained to aphanitic, aphyric, light greenish brown weathering, sparsely to moderately amygdular (quartz+plagioclase±mafic, < 5%) dikes and sills, commonly with large (3–10 cm) epidote- and quartz-filled gas cavities and epidosite patches

2) unit 9: light greenish grey–weathering, plagioclase- and pyroxene-phyric (5–15%, 5–12 mm), nonamygdular dikes and sills

3) unit 10: fine- to medium-grained, aphyric to sparsely plagioclase-phyric (<2%, <8 mm), equigranular gabbro

4) unit 11: aphyric, fine-grained to aphanitic, nonamygdular, reddish brown weathering, mafic dikes, commonly with flow banding

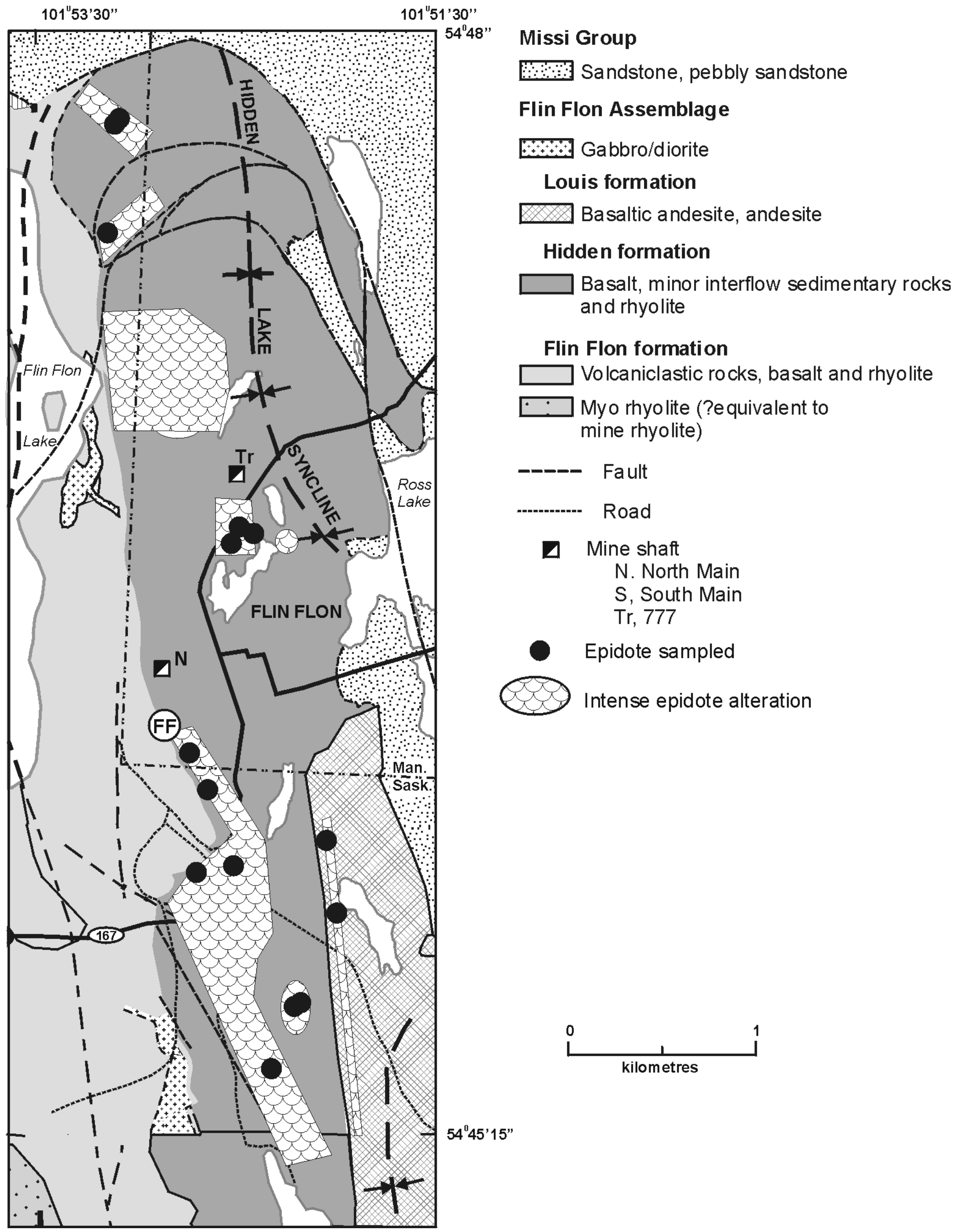

Figure GS-2-5: Distribution of epidote alteration in the hanging wall Hidden and Louis formations, as defined through mapping in this study. See Figure GS-2-1 for location of traverse areas.

5) unit 12: medium- to coarse-grained leucogabbro, locally with pegmatitic patches

6) unit 13: aphyric, aphanitic, nonamygdular, blue-grey–weathering, mafic to intermediate dikes

7) unit 14: light greenish brown, fine-grained, sparsely plagioclase-phyric (<2%, <5 mm) intermediate dikes

Where contact relationships are not observed or are significantly strained, it is difficult to distinguish between intrusive rocks of unit 8 and volcanic rocks of unit 4; a volcanic origin has been assumed in such cases.

This section also contains a variety of sedimentary rocks, including thinly bedded to laminated chert and cherty argillite (unit 7) that may be interbedded with thinly bedded mafic tuff and lapilli tuff, locally with felsic fragments (unit 7a), or with thinly to moderately bedded, normally graded, mafic greywacke (unit 7b).

Both the strongly amygdular (unit 3) and the nonamygdular (unit 2) flows occur throughout the section, although the proportion of sparsely to nonamygdular flows decreases toward the top of the section. Massive flows are also more common near the base of the section, whereas the top is dominated by pillowed flows and amoeboid pillow breccia.

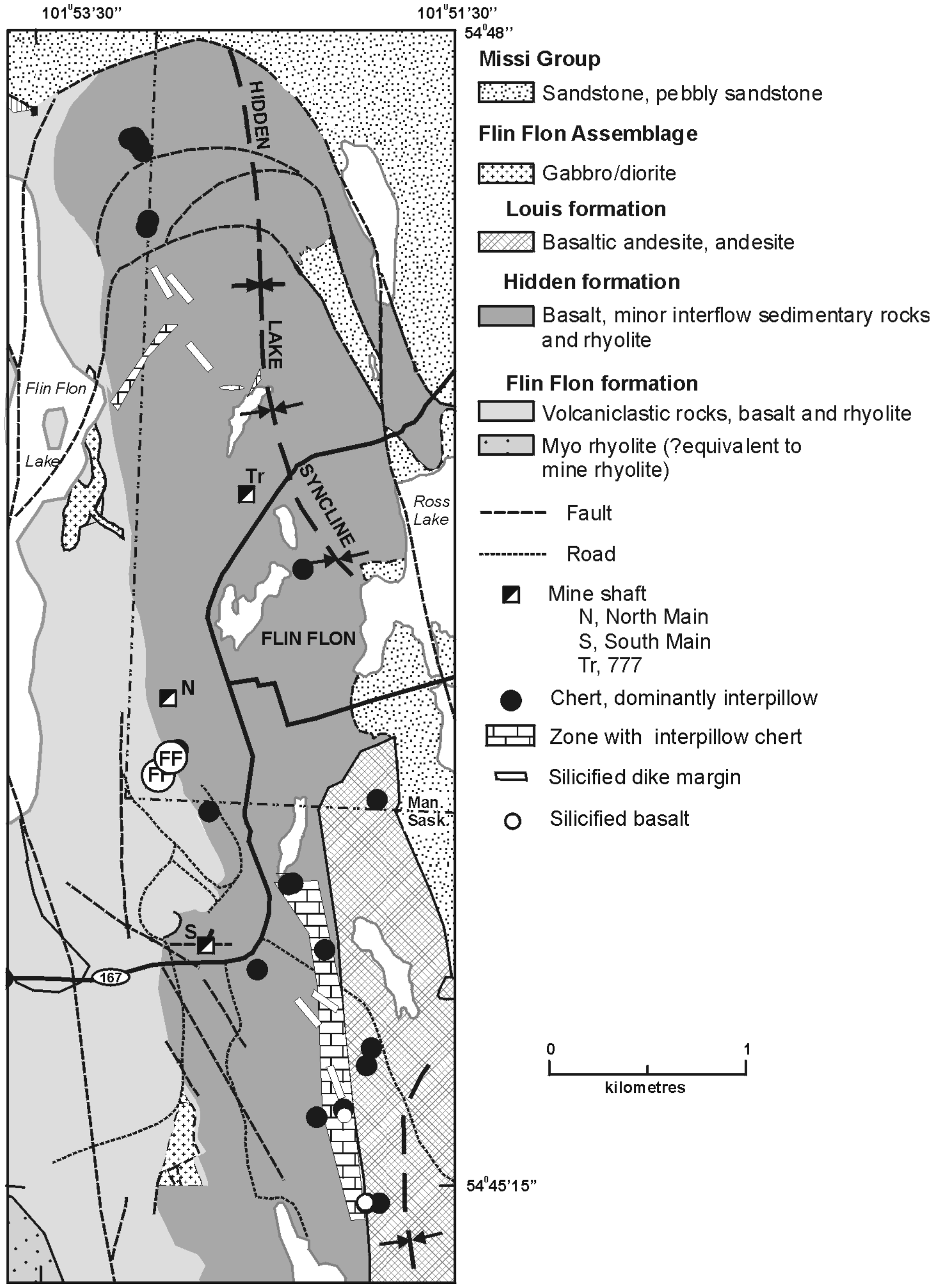

Figure GS-2-6: Distribution of interpillow chert and silicification in the hanging wall Hidden and Louis formations, as defined through mapping in this study. See Figure GS-2-1 for location of traverse areas.

Plagioclase- and pyroxene-phyric flows are rare and were only observed in one outcrop near the base of the section. However, the occurrence of similar dikes throughout the section suggests that the magma source for these flows was still active and may have been feeding flows higher in the sequence. Cherty horizons occur throughout the sequence, although they are most prevalent at the base and rare at the top. Accretionary lapilli within mafic tuff horizons indicate a subaerial eruption column and relatively shallow water deposition for at least part of the succession. Mafic dikes and sills are common throughout the section, are texturally and compositionally similar to the volcanic rocks, and are inferred to be synvolcanic. In some cases, textural relationships such as peperitic margins and irregularly fractured tops with chert infill suggest that sills have intruded into unlithified sediments. A horizon of amoeboid, mixed mafic volcanic rocks and chert at the top of the lowermost pillowed flow suggests that the pillows flowed into unlithified cherty sediments that were deposited prior to the initiation of this sequence of mafic volcanism.

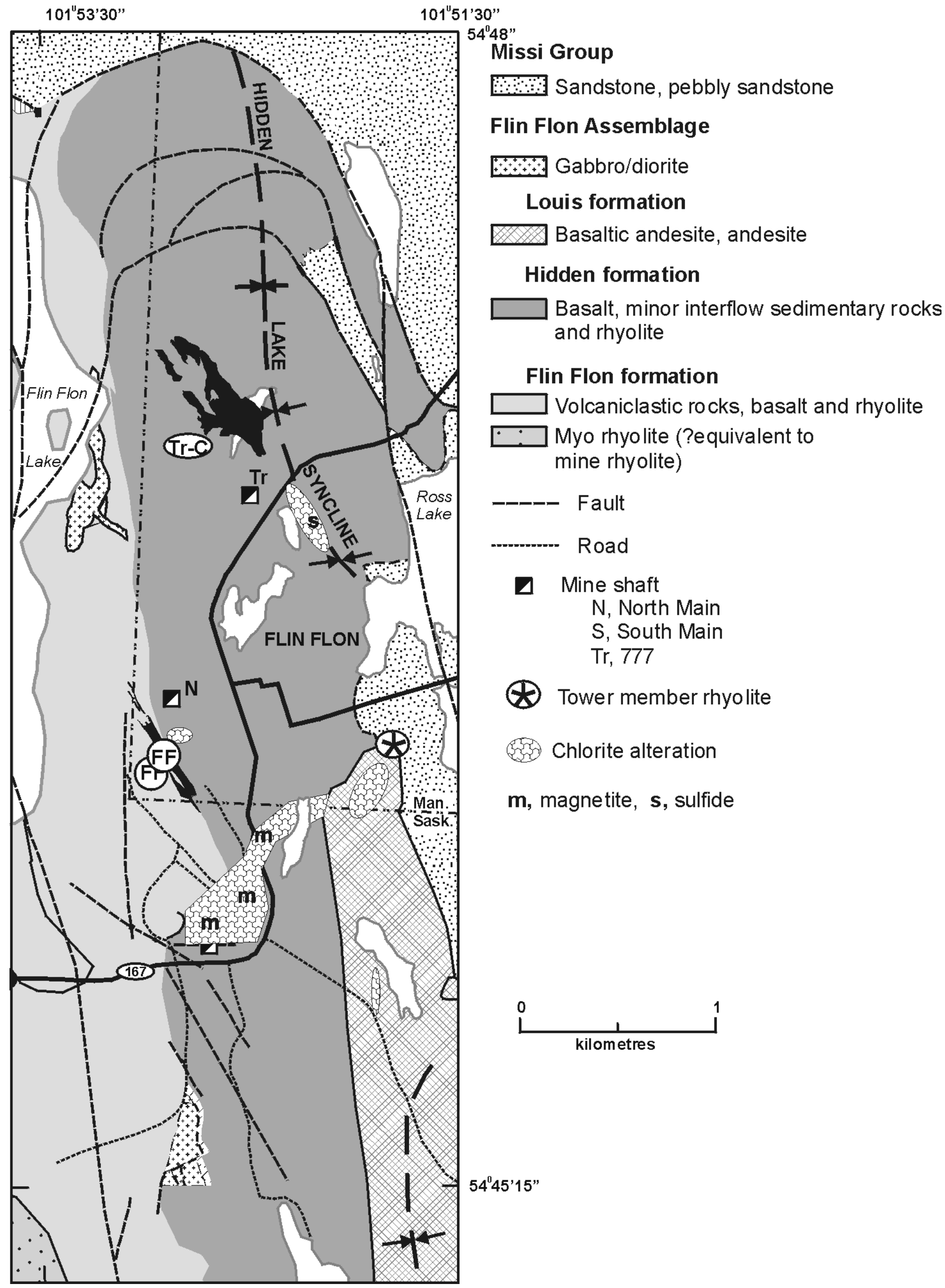

Figure GS-2-7: Distribution of chlorite in the hanging wall Hidden and Louis formations, as defined through mapping in this study. See Figure GS-2-1 for location of traverse areas.

Louis formation

The lower part of the Louis formation was mapped in this study where it overlies the mafic sedimentary rocks and rhyolite of the Tower member (Hidden formation). The Louis formation contains feldspar-pyroxene–phyric basaltic flows and sills, and minor aphyric pillowed basalt, scoriaceous amoeboid breccia and scoriaceous lapilli tuff. Globular peperite is common in the lower Louis basalt, with sediment as interpillow material extending up to 80 to 120 m above the Hidden-Louis contact. Plagioclase-phyric (15%) and pyroxene-phyric (amphibole pseudomorphs after clinopyroxene, 15%) pillowed flows vary from 10 to 30 m in thickness, with rounded pillows 1 to 1.5 m in size that contain 5 to 10% vesicles.

The Louis formation contains a gabbroic dike swarm (Fig. GS-2-3) with three to six dikes displacing the sedimentary rocks and rhyolite of the Tower member. The gabbroic dikes are massive to columnar jointed, 15 to 40 m wide and contain vesicles that may be concentrated in linear zones along the top of each dike.

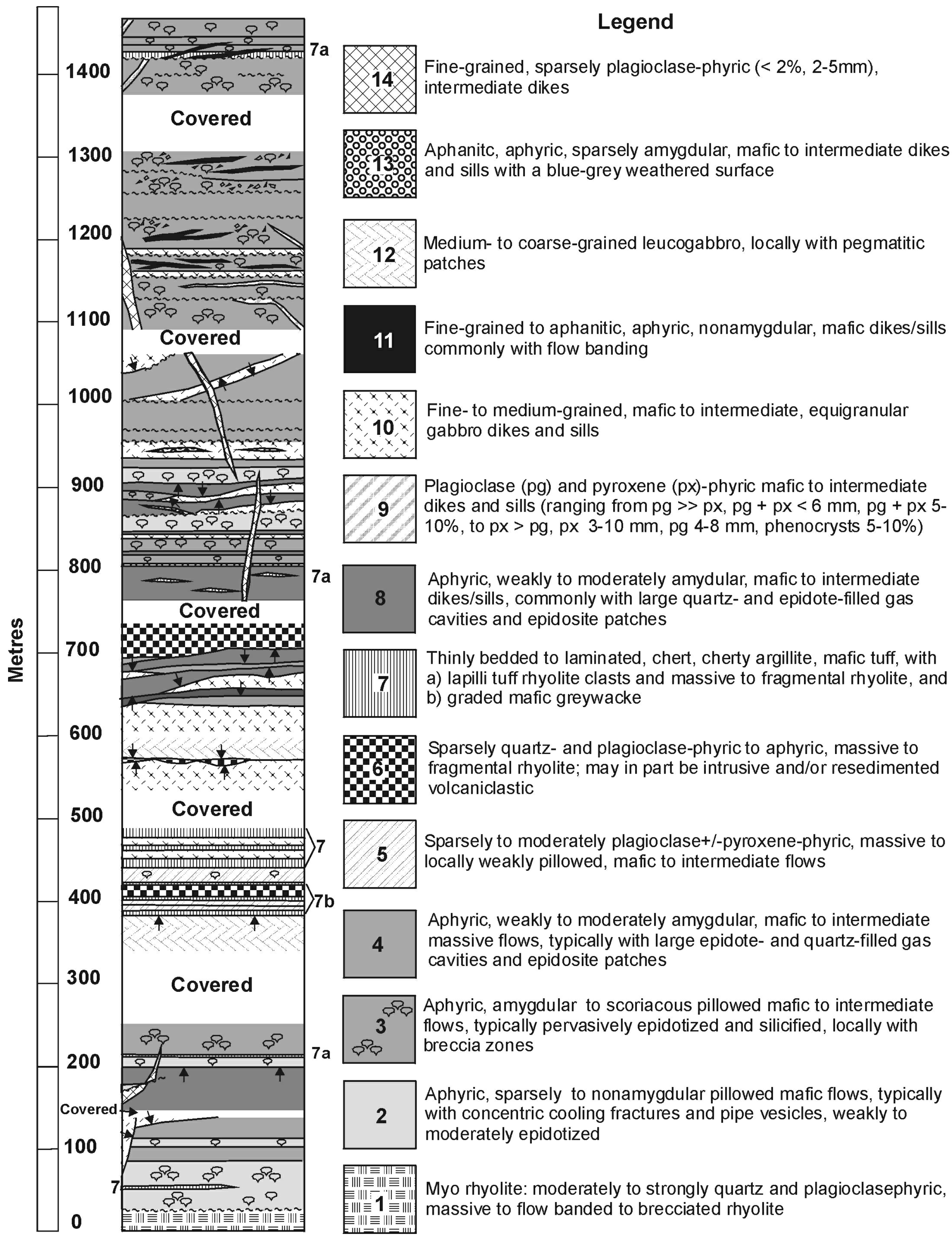

Figure GS-2-8: Stratigraphic section through the Hidden formation–equivalent above the Myo rhyolite (see Fig. GS-2-1). Chilled margins are indicated by arrows within the various intrusions. The thickness of the thinnest units depicted may be exaggerated for clarity.

HANGING WALL ALTERATION IN THE FLIN FLON–777–CALLINAN VMS HORIZON

Hydrothermal alteration in the Hidden and Louis formations comprises the following types: epidote-quartz alteration, silicification, chloritization, feldspar-quartz alteration and sulphide mineralization. A pervasive middle greenschist facies metamorphic assemblage, consisting of actinolite-epidote-albite-quartz ±biotite, characterizes regional metamorphism in the Flin Flon area (Bailes and Syme, 1989).

Epidote-quartz alteration was mapped as textural types (i.e., coarse grained, fine granular with diffuse boundaries, replacement interpillow material, cores of pillows, along columnar joints, concentrated around amygdules, pervasive, patchy, ribbons, fractures) to define the paragenesis, distribution and controls on alteration. Epidote-quartz alteration is most intense in the lower two-thirds of the Hidden formation (Fig. GS-2-5).

Silicification is not an abundant alteration type in the Flin Flon camp. In the southern segment of the Louis dike swarm, there is minor silicification of pillows (Fig. GS-2-6). Silicification (quartz>>epidote) is locally concentrated along dike margins in both of the dike swarms. 'Chert' commonly replaces interpillow sediment and occurs 1) at the base of the Hidden and Louis formations, and 2) in the upper 120 m of the Hidden formation (Fig. GS-2-6). Quartz is common as a vesicle filling.

Chlorite alteration is concentrated 1) in a chlorite-magnetite discordant zone above the Flin Flon main deposit towards rhyolite of the Tower member (Hidden formation) and extending into the Louis formation; and 2) associated with gossans near the top of the Hidden formation in the trend of the felsic dikes (Fig. GS-2-7). The chlorite alteration zone above the Flin Flon main deposit also contains anomalous sulphide mineralization. Chlorite occurs in the matrix and pillow selvages, and fills amygdules.

Sulphidic zones in the hanging wall basalt were found to be associated with the chlorite alteration described above, in sedimentary rocks near the base of the Hidden formation, and in the rhyolite and associated sediment at the top of the Hidden formation.

FUTURE STUDIES

Geochemical classification of the volcanic rocks of the Hidden formation, the Louis formation and the Myo section is in progress on approximately 120 basalt, rhyolite and dike samples. Interflow and interpillow sediment was sampled for geochemistry, petrography and x-ray diffraction, to identify the nature and composition of the detrital and hydrothermal components. Definition of the compositions of the orebodies (Jonasson et al., GS-4, this volume) and the sediment alteration will test the validity of a hydrothermal plume above the Flin Flon–777–Callinan mine horizon. Core logging and sampling of interpillow material from four drillholes through the Hidden formation in 2002 provides a depth component to the hanging wall plume study. In total, close to 400 samples of the hanging wall strata and alteration were submitted for analysis, including 230 sediment samples, 20 chert samples, 78 volcanic samples, 12 dike samples and 20 epidote-altered basalt samples.

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