

Geology and Hydrothermal Alteration of the Flin Flon–Triple 7–Callinan VMS Horizon Hanging-wall Stratigraphy: Flin Flon Targeted Geoscience Initiative

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Abstract

The objective of this sub-project of the Flin Flon Targeted Geoscience Initiative (FFTGI) is to gain a better understanding of the nature and distribution of hydrothermal alteration within the hanging-wall strata, herein informally called the “Hidden Formation”³, to the Flin Flon–Triple Seven–Callinan volcanogenic massive sulphide (VMS) deposits of the Paleoproterozoic Flin Flon belt.

Important findings to date from this study include:

- 1) The recognition of extensive zones of hydrothermal alteration within the hanging-wall strata, including both distal and proximal alteration facies.*
- 2) The definition of two distinct, synvolcanic dyke swarms within the “Hidden” and “Louis” formations, one of which includes felsic dykes. Dyke swarms are important for localizing hydrothermal fluid upflow zones.*
- 3) The recognition of a rhyolite flow unit with associated sulphidic sedimentary rocks called the “Tower Member” 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”.*

Keywords: *Flin Flon, Proterozoic, volcanogenic massive sulphide deposits, volcanic rocks, stratigraphy, hydrothermal alteration, interpillow sediment, peperite, synvolcanic intrusions.*

1. Introduction

The FFTGI is a three-year (2000-03) federal initiative, undertaken in partnership with the Manitoba Geological Survey, Saskatchewan Industry and Resources, Hudson Bay Exploration and Development Co. Ltd., and Laurentian University, 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 understanding of the volcanic and hydrothermal history of the western Paleoproterozoic Flin Flon volcanic belt in relation to VMS deposit formation, and 2) assist the development of exploration strategies which support the discovery of new VMS deposits (Galley *et al.*, 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. Hanging-wall alteration may be a function of one of two processes. The first is the continuation of 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 that resulted in either zones of alteration extending for up to 500 m above a known VMS deposit, such as at Ansil (Riverin *et al.*, 1990), or stacked orebodies formed at successive seawater-rock interfaces. The Amulet deposits are an example of the latter (Gibson and Watkinson, 1990). The second process involved in the generation of hanging-wall alteration is the formation of an entirely new sub-seafloor 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, semi-conformable alteration with associated, discrete disconformable alteration pipes. Both cases can result in the periodic formation of sulphidic sedimentary units, or “exhalites” (Franklin *et al.*, 1981).

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³ Informal stratigraphic names are in italics surrounded by quotation marks.

The Flin Flon–Triple Seven–Callinan VMS horizon provides an ideal setting for a hanging-wall alteration study due to the relative compositional homogeneity and 600 to 700 m thickness of the hanging-wall basalt succession. The study involved detailed stratigraphic examination and sampling of the “*Hidden Formation*” along its 5000 m strike length. Variations in flow morphology, the presence and type of interflow sediments, and the nature and extent of alteration were defined for each of the sections. A traverses across a correlative mafic flow succession further west in Saskatchewan, where the VMS-bearing succession is believed to be duplicated by folding (Figure 1), was also studied.

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 between the Club Lake Fault in the north, and 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) detailed 1:1000 outcrop mapping above the Triple 7 orebody (M.Sc. thesis, N. Tardif, Laurentian University) (Figure 1).

The Myo Lake section (Figure 1) is considered to be broadly correlative with the east-younging limb that hosts the Flin Flon VMS deposits. In particular, the Myo rhyolite (Thomas, 1992) is thought to be correlative with the Flin Flon VMS bearing horizon (K. Gilmore, pers. comm., 2002).

2. Geology of the Hanging-wall Stratigraphy to the Flin Flon–Triple Seven–Callinan VMS Horizon

One of the objectives of the FFTGI is to develop a 1:10 000 scale geologic compilation of the Flin Flon structural block in order to standardize unit correlations as defined by previous 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 has been to informally define the immediate hanging-wall basalt succession to the Flin Flon–Triple Seven–Callinan VMS deposits as the “*Hidden Formation*”, and the VMS-host rock package and underlying volcanoclastic and eruptive units as the “*Flin Flon Formation*” (Figure 1). The “*Hidden Formation*” contains the “*1920 Member*” and the “*Tower Member*”. The basalt flow dominated succession above the “*Myo rhyolite*” is tentatively correlated with, and included in the “*Hidden Formation*”, although it has not been subdivided into members.

a) “*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, with numerous top indicators such as distribution of amygdaloids, gas cavities and pipe vesicles, re-entrant selvages, pillow morphology, and stacking; in the sediments, graded beds, channels and load casts are indicators. The apparent thickness is variable due to structural complications, particularly in the Millrock Hill to Phantom Lake area, where the lower contact is duplicated by D₁ thrust faults focused along interflow sediment horizons and at the upper contact, in the area between the Railway Fault to Ross Lake, D₂ folding has occurred (Figure 1). The exposed thickness of the “*Hidden Formation*” varies from ~650 m between the Triple Seven and Flin Flon deposits to 880 m south of the Flin Flon deposit and down to 400 m just north of Phantom Lake. Along the west shore of Phantom Lake, Stockwell’s 1960 map shows the mafic flows of the “*Hidden Formation*” thinning out and inter-layering with mafic volcanoclastic units similar to those observed as interflow sediments further north in.

The lower mafic flows of the “*Hidden Formation*” are in contact with heterolithic breccias and rhyolite of the “*Flin Flon Formation*”. The upper contact of the “*Hidden Formation*” is defined by the first appearance of pyroxene-plagioclase phyric basalts of the “*Louis Formation*”. The upper contact is also characterized by the presence of rhyolite flows and related talus debris, and sulphidic mafic and felsic interflow sediment which form the “*Tower Member*” of the “*Hidden Formation*” (Figure 2).

Descriptions of the “*Hidden Formation*” are divided into the North Callinan, Triple Seven, Flin Flon, Phantom Lake, and Myo Lake sections.

b) North Callinan Section

The Club Lake Fault forms the northern boundary of the “*Hidden Formation*” with the younger Missi Group. In this northern third of the study area, the “*Hidden Formation*” is affected by numerous, refolded, D₁ thrust faults (Figure 1). A 200 m thick gabbro intrudes the base of the sequence and contains numerous rafts of basalt, sediment, and mafic dykes. Excluding this intrusion, the lower 110 to 160 m of the section consists of a pale grey-weathering icelandite informally known as the “*1920 Member*” (D. Price, pers. comm., 2001). This distinctive unit is ~60 m thick, has acicular amphibole needles and 20% feldspar microphenocrysts, along with large gas cavities which are the focus for intense epidote-amphibole-sulphide alteration. The upper contact of the “*1920 Member*” with fine-

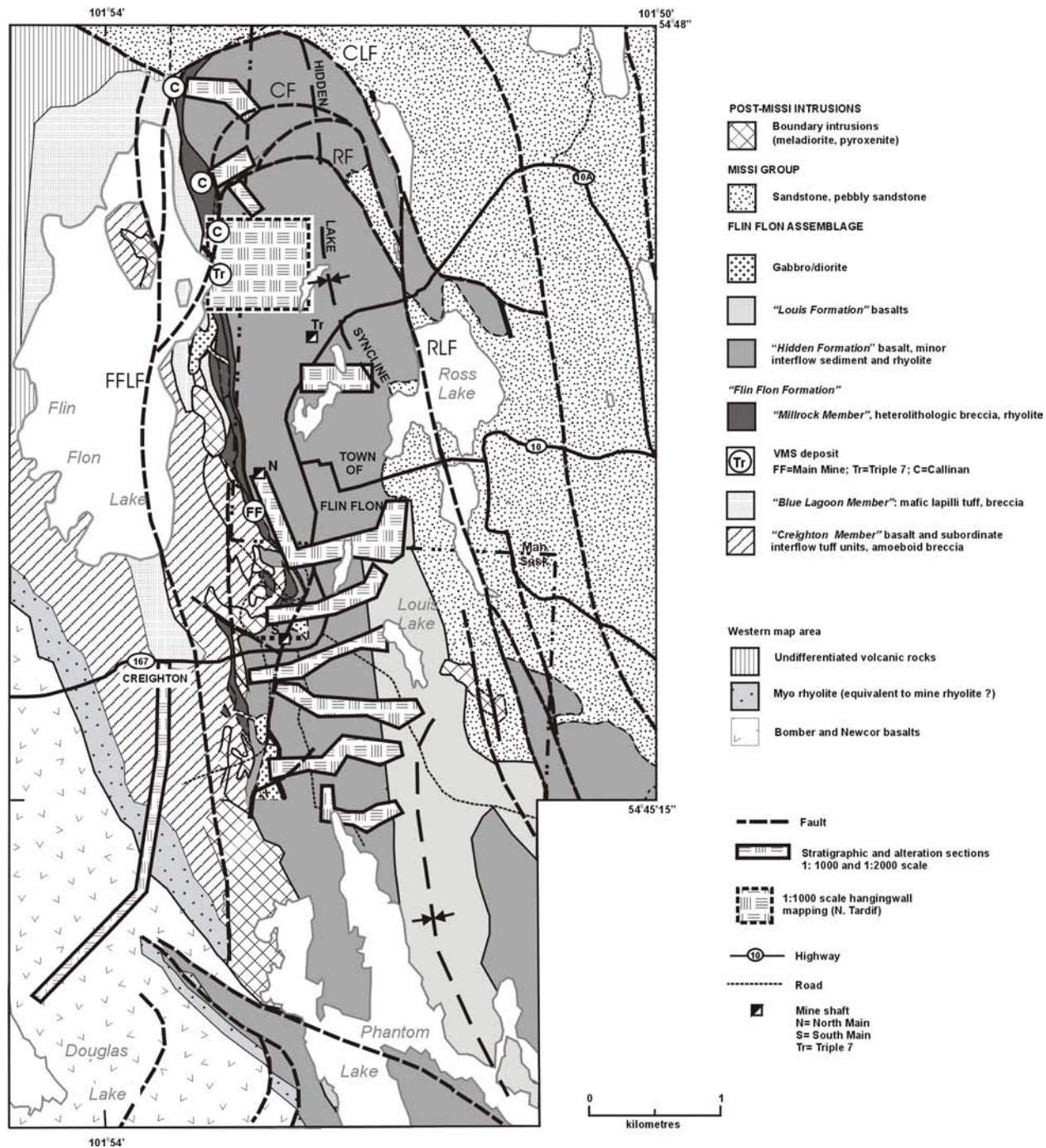


Figure 1 - Simplified geology of the Flin Flon block showing the location of detailed traverses in the hanging wall of the Flin Flon–Triple 7–Callinan VMS horizon. CLF=Club Lake Fault, CF=Catharine Fault, RF=Railway Fault, and RLF=Ross Lake Fault.

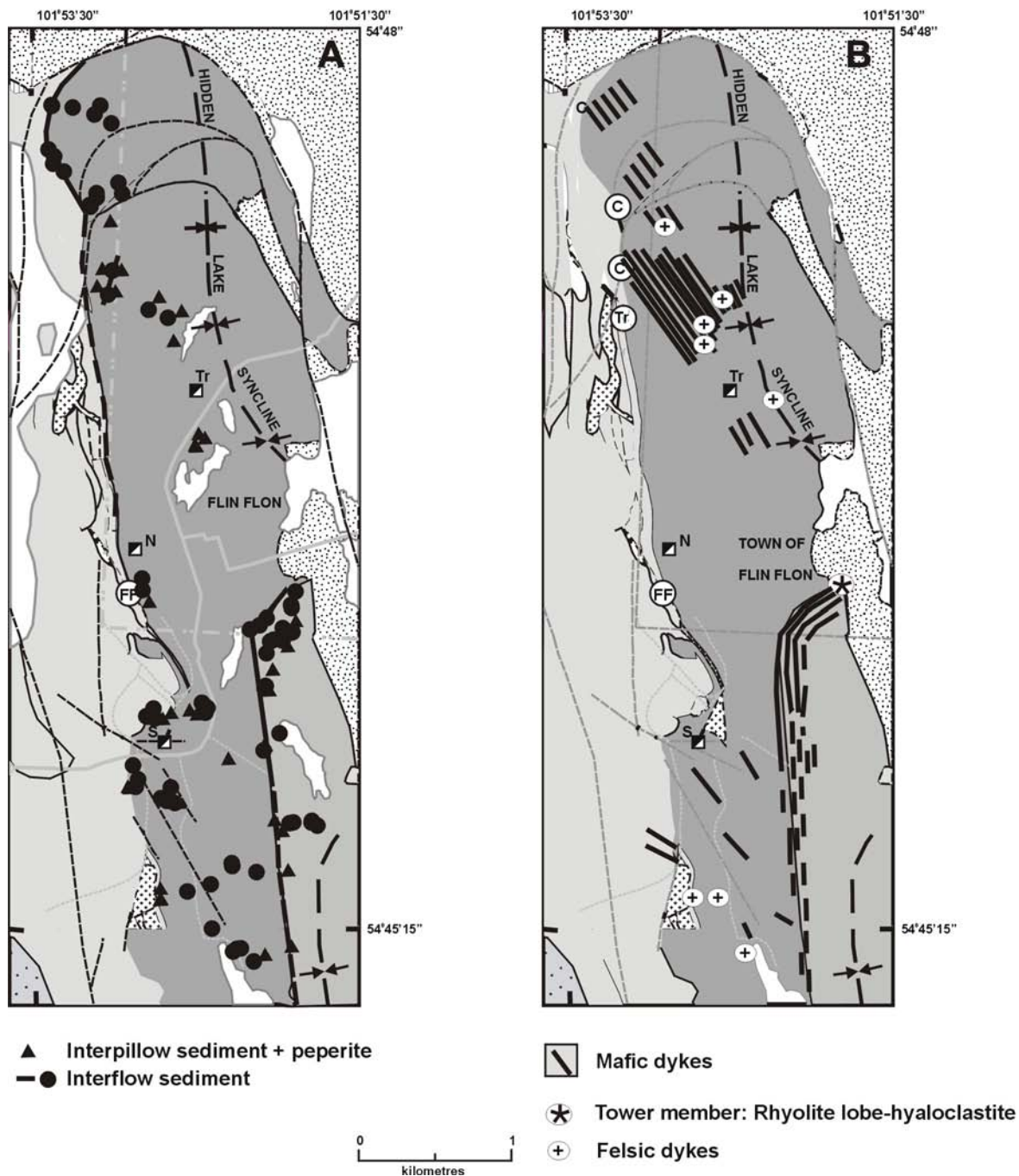


Figure 2 - A) Distribution of interflow sedimentary rocks in the "Hidden" and "Louis" formations. Note the concentration of sedimentary rocks as interflow, interpillow, and peperite near the base of the two formations. B) Distribution of mafic dyke swarms, felsic dykes, and the "Tower Member" felsic lobe-hyaloclastite flow at the top of the "Hidden Formation". See Figure 1 for legend.

grained mafic tuff is peperitic, and forms altered breccia zones up to 30 m wide. The occurrence of peperite indicates that the unit flowed and/or intruded into a sequence of un lithified, mafic volcanoclastic rocks and siltstone at shallow levels. The mafic volcanoclastic rocks contain abundant sedimentary structures such as normal grading, channels, dropstones, and loadcasts. The mafic volcanoclastic/siltstone occurs in varying amounts in the basal section of the “*Hidden Formation*” along the entire 5000 m strike length as remnants between pillows and as more intact interflow units. In most cases, these mafic sedimentary rocks are the focus for much of the alteration observed in 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; pillows are typically 45 to 70 cm wide. Massive flows display laminar cooling cracks, 5 to 20 cm diameter gas cavities at the top, and elutriation pipes at the lower contact. The latter are due to extrusion into wet unconsolidated sediment. The dominant trend of comagmatic mafic dykes is 145° which is subparallel to the plunge of the D₂ folds. The north Callinan section contains sub-equal amounts of intrusive and extrusive mafic rocks (45%) and 10% sediment (>60 m cumulative).

c) Triple Seven Section

The central Triple Seven area extends from the northern limit of the town of Flin Flon to the Railway Fault (Figure 1). In this area the “*Hidden Formation*” is bound by the “*Flin Flon Formation*” at its base and terminated 650 m above this in the core of the Hidden Lake syncline (Figure 1). Detailed mapping of an area up-plunge from the Triple Seven VMS deposit (Tardif, pers. comm., 2002; Galley *et al.*, 2001) defined about seven basaltic andesite flows crosscut by a series of mafic dykes and subordinate felsic dykes that strike 145° (Figure 3; Table 1). This section is dominated by amygdaloidal, plagioclase and/or pyroxene-phyric flows and minor aphyric flows with associated flow top breccia. Flow thickness varies from 15 to 430 m, are predominantly pillowed, with pillows from 10 cm to 10 m wide (Table 1). Contacts between flows are sharp and irregular with some flows showing an irregular transition from pillowed to amoeboid-shaped pillow breccia. Interpillow areas include: 1) thinly bedded to laminated clastic sedimentary rocks with bedding planes parallel to pillow selvages; 2) chert; and 3) hyaloclastite. Locally there are peperitic textures within interpillow and interflow mafic sedimentary rocks. Discontinuous units of mafic sedimentary rocks occur in the basal 120 m of the “*Hidden Formation*” between: 1) the massive gabbro flow and Flow 1 and 2) Flows 3 and 4 (Figure 3). The central Triple Seven deposit area is transected by a mafic dyke swarm trending 145°, perpendicular to the strike of flows (Figure 2B). Mafic dykes are of andesitic composition varying from feldspar phyric, aphyric, to pyroxene phyric. Felsic dykes of rhyolitic composition are also concentrated in this zone and generally are crosscut by the mafic dykes.

d) Flin Flon Section

The lower ~100 m of the “*Hidden Formation*” in the Flin Flon to South Main section contains 10 to 15 m thick units of gas cavity-bearing aphyric and minor feldspar-phyric basalts, along with beds of scoriaceous, amoeboid breccia, and peperite. The 500 m thick sequence changes up-section from basaltic flows and volcanoclastic 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 flows with felsic volcanoclastic talus and distal sulphidic mafic siltstone. The hydrothermal alteration overprint on the volcanic sequence also differs from other sections (Figure 4).

Phantom Lake Section

The Millrock Hill to Phantom Lake section is strongly sheared at its base by an early thrust fault (Galley *et al.*, 2001) that was subsequently reactivated. The lowermost 115 m contain mafic tuffaceous interpillow material, accompanied by up to 60 m thick zones of globular peperite. The principal tuffaceous, interflow units are at the 70, 200, 230, and 255 m levels above the base of the formation. The mafic tuff layers are strongly sheared, and some contain accretionary lapilli, graded bedding, quartz-phyric rhyolite fragments, and minor scoria. Basaltic andesite flows vary between 5 to 60 m thick, and are generally aphyric to sparsely feldspar and/or pyroxene phyric. Pillow morphology varies from megapillows (>12 m) to rounded equant pillows (~50 to 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 such as re-entrant selvages, pillow morphology, and stacking 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 basalts 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 (Figure 1). The base of the “hanging-wall” section is marked by a slightly sheared

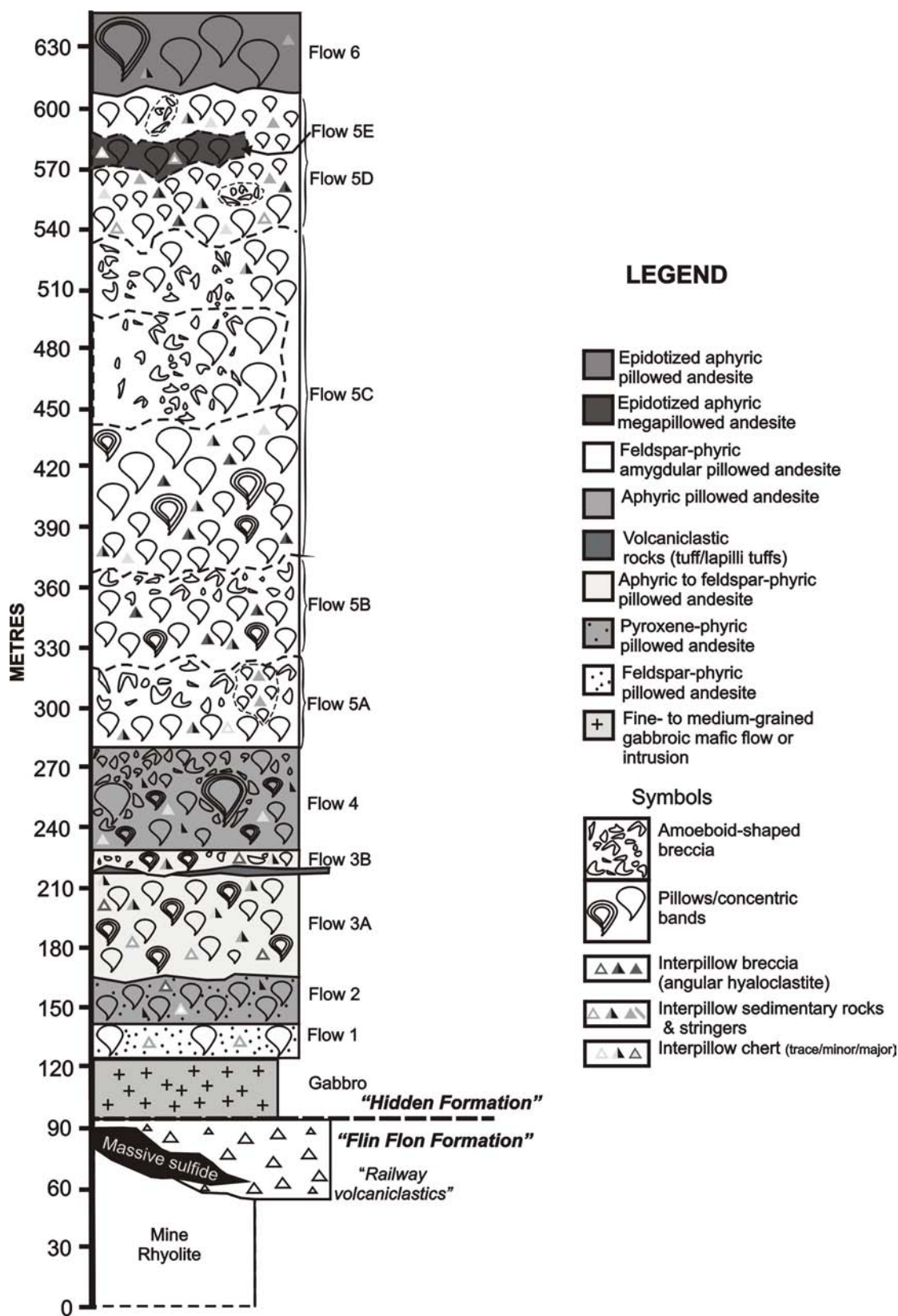


Figure 3 - Stratigraphic section through the "Hidden Formation" above the Triple Seven VMS deposit. See Figure 1 for location.

Table 1 - Description of flow units in the "Hidden Formation", Triple Seven section.

Flows		Field Description	Mineralogy - Volcanic Textures/Structures	Alteration Mineralogy, Textures	Contacts
Flow 6 approx. 10 to 20 m	Epidotized aphyric mega- pillowed andesite	Medium densely packed pillows (1% mafic mineral pyroxene replacing albite?), 1 to 10% quartz amygdalites increasing at pillow margins). Minor epidote-altered interpillow sedimentary rocks. 1 to 2% epidote patches at pillow margins. Trace pyrite in interpillow selvages.	Fine grained matrix (high albite (25 to 30%) microlites, hyalopelitic, minor quartz, actinolite). Trace to 1% sulphides associated with amygdalites. Quartz amygdalites (5%).	Fine-grained actinolite (30%)/epidote (25%). Trace pyrite. Fine disseminated epidote to coarse grained. Epidote greater at margins of amygdalites.	Irregular and sharp with Flow 5
Flow 5E approx. 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 to 2%) at pillow margins +/- pyrite at interpillow selvages.	Fine-grained matrix (high albite (25 to 30%) microlites, pillotaxitic, minor quartz, actinolite). Quartz amygdalites (5%).	Very fine-grained, pervasive actinolite (25%)/epidote (25 to 50%). Epidote greater at margins of amygdalites.	Irregular and sharp with Flow 5
Flow 5A to 5D approx. 430 m	Feldspar- phyric amygdalar pillowed andesite	Medium to very large, densely packed pillows/tubes (up to 6 m), concentrically flow banded. Plagioclase (10%), pyroxene (2%), chlorite (1 to 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. Quartz/feldspar amygdalites 30%. Moderate 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 replace breccia fragments.	Fine-grained matrix (+/-) albite (20 to 30%) microlites, hyalopelitic to pillotaxitic, quartz, biotite, +/- carbonate. Quartz/epidote/feldspar/chlorite amygdalites (10 to 30%). Medium to large albite porphyroclasts (10%). Albite content decreases with increasing epidote/actinolite/pyrite alteration (patches/gossan).	Fine-grained matrix, medium to high epidote (25 to 60%) strongly associated with quartz amygdalites. Trace pyrite +/- minor actinolite (0 to 30%) and chlorite (0 to 10%).	Irregular and gradational into amoeboid-shaped breccia. Sharp with sill. Sharp and irregular with Flows 6 and 7.
Flow 4 approx. 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 northwest (approx 10 m). Quartz/feldspar amygdalites 5%. Moderate 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 to 35%) hyalopelitic, minor quartz, actinolite, biotite), 1 to 2% quartz amygdalites +/- carbonate. Quartz/albite porphyroclasts (4%). Albite decreases with increasing epidote/actinolite/pyrite alteration (patches).	Moderate clotty and pervasive epidote (25 to 35%)/actinolite (15 to 25%)/chlorite (20 to 25%) alteration, fine grained in matrix.	Irregular and gradational into amoeboid-shaped breccia, sharp with Flow 5.
Flow 3 approx. 80 m	Aphyric pillowed andesite	Medium, densely packed concentrically flow banded pillows. Minor to moderate epidote-altered, thinly laminated to fine bedded interpillow sedimentary rocks (+/- moderate chert) and minor interpillow breccia 15 to 40%. Plagioclase (7%), pyroxene 3%, quartz/feldspar amygdalites (10 to 15%). 2 to 10 cm epidote-altered amoeboid-shaped fragments +/- pyrite in matrix. Moderate/strong epidote patches in pillow cores and amoeboid-shaped breccia +/- chlorite at margins. Fracture controlled epidote. 3 to 20 m interflow sediment near top of flow, in between flows 3A and 3B.	Fine-grained matrix (microlites, hyalopelitic and minor pillotaxitic albite (10 to 20%) +/- actinolite, pyroxene, biotite, low quartz). Quartz amygdalites (1%) +/- carbonate. Albite content decreases with increasing epidote/actinolite/pyrite alteration (patches).	Moderate to strong pervasive epidote (35 to 60%). Moderate actinolite (30%)/chlorite (10 to 15%). Trace pyrite.	Gradational into amoeboid-shaped pillow breccia, sharp with Flow 4. Pillows flattened near sharp contact with dikes.
Flow 2 approx. 25 m	Pyroxene- phyric pillowed andesite	Medium, densely packed pillows (10% pyroxene and 10% quartz/minor feldspar amygdalites) with minor thinly laminated, epidote-altered interpillow sedimentary rocks (minor chert) and minor interpillow breccia.	Strongly altered, fine- to medium-grained matrix. Very low albite (1%), moderate pyroxene (5 to 10%), actinolite porphyroclasts (5%). 15% quartz amygdalites surrounded by actinolite/chlorite/epidote halos.	Strong epidote, fine dissemination. Moderate acicular fine grained actinolite, minor fine grained chlorite in matrix.	Sharp irregular with Flow 3.
Flow 1 approx. 15 m	Feldspar- phyric pillowed andesite	Medium, densely packed pillows (1% pyroxene, 1% feldspar, 1% quartz/feldspar amygdalites). Minor thinly laminated, epidote-altered interpillow sedimentary rocks. Minor fracture controlled epidote veins. Generally, alteration is pervasive, fracture controlled, ghostly at pillow cores and near margins of dikes.	Fine-grained matrix (quartz, +/- actinolite, pyroxene, no albite microlites), 10% quartz amygdalites, and albite porphyroclast (8%).	Strong actinolite (30 to 35%), moderate chlorite (15%), epidote (15%) in matrix.	Sharp sheared with Flow 2.

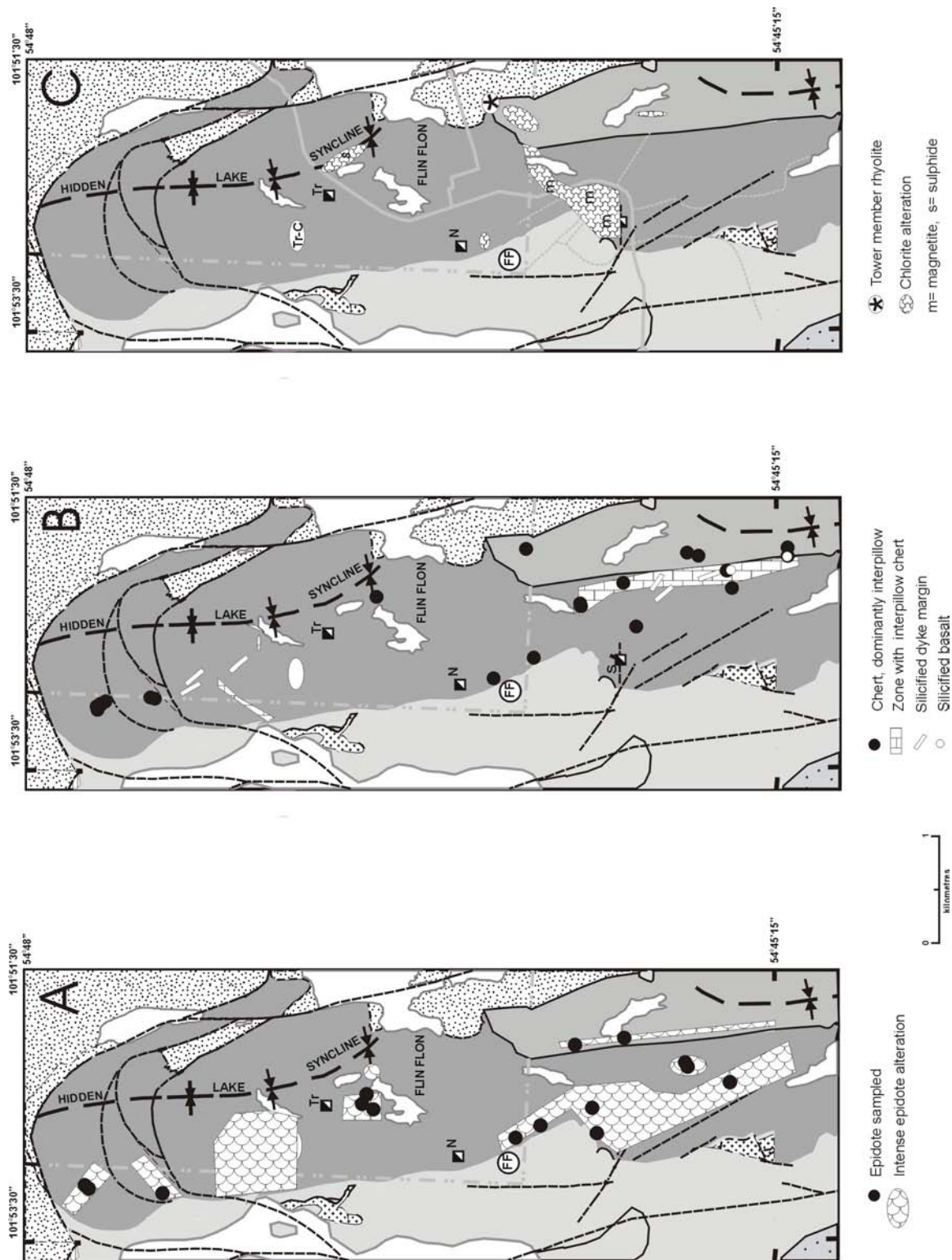


Figure 4 - Distribution of A) epidote alteration, B) interpillow chert and silicification, and C) chlorite in the hanging wall of the "Hidden" and "Louis" formations. See Figure 1 for legend.

contact with the top of the Myo rhyolite, which is sparsely quartz and plagioclase phyric and massive. There is a relatively high degree of strain and some transposition of units into the main southeast striking, steeply (60 to 80°) southwest-dipping foliation has undoubtedly occurred. Considering the overall degree of flattening, thicknesses have not been corrected for dip and are thus, apparent thickness only (Figure 5). The section is about 1500 m thick, including covered sections between outcrops and the ~50% intrusive material.

Five different types of volcanic rocks are distinguished:

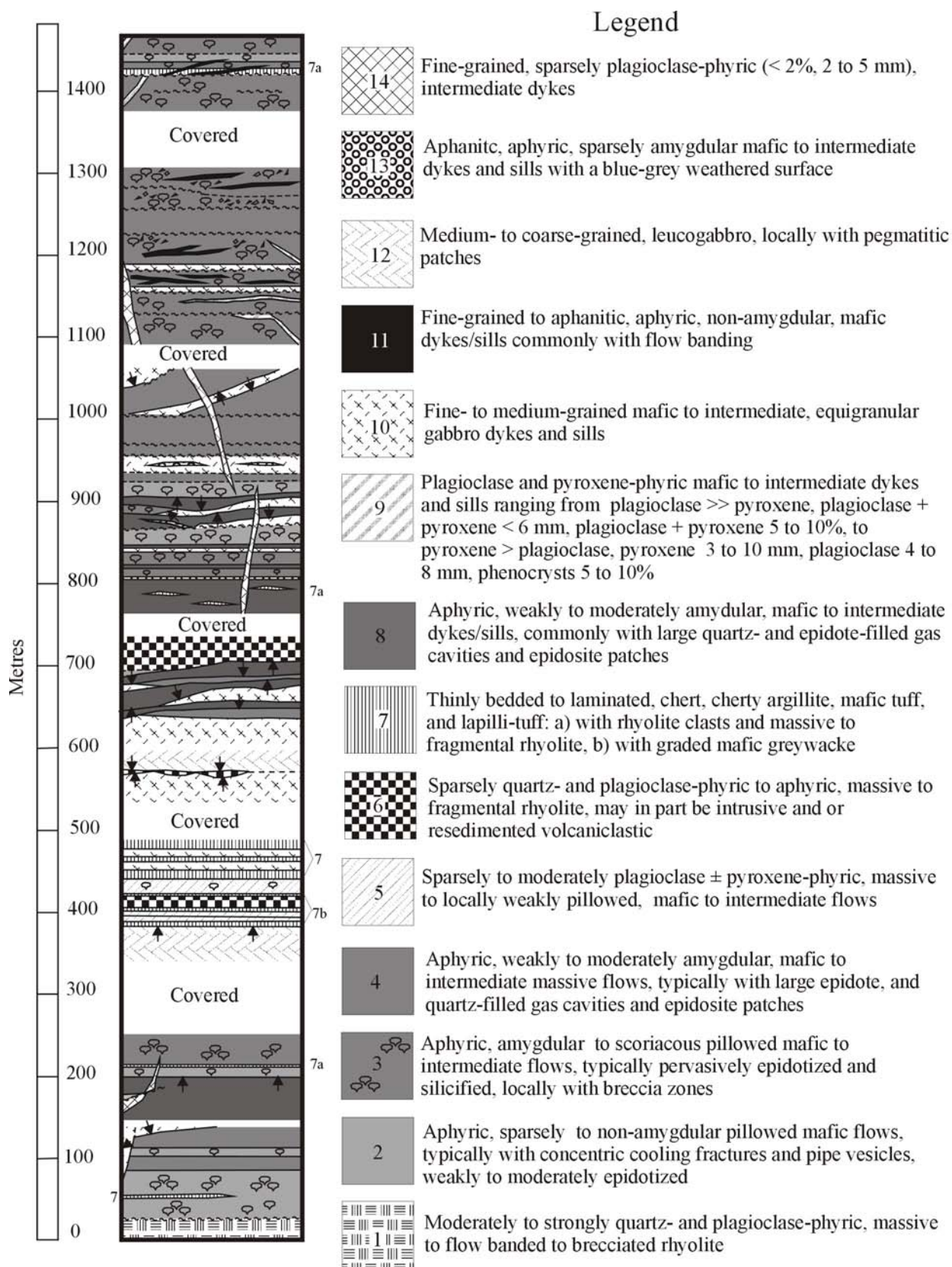
- 1) dark brown-weathering, aphyric, sparsely to non-amygdaloidal (quartz and plagioclase filled, <5%, 5 to 25 mm diameter) pillowed flows, typically with concentric cooling fractures, pipe vesicles near the margins, thin rims, patchy epidotization, irregular shapes, and relatively large size (75 to 200 cm) (unit 2, Figure 5);
- 2) light greenish to yellowish brown-weathering, aphyric, strongly amygdaloidal (quartz+plagioclase, 10 to 30%, 1 to 50 mm diameter), pillowed flows, commonly with pervasive epidotization and silicification, and small to medium size (30 to 150 cm) (unit 3, Figure 5);
- 3) light to medium greenish brown-weathering, aphanitic to fine-grained, sparsely to moderately amygdaloidal (quartz, plagioclase±mafic, 2 to 10%, 5 to 15 mm diameter) massive flows, typically with large (3 to 10 cm) quartz- and epidote-filled gas cavities and epidote patches (unit 4, Figure 5);
- 4) light greenish grey-weathering, sparsely (<2%, <5 mm) to moderately (5 to 10%, 3 to 8 mm) plagioclase±pyroxene porphyritic, non- to sparsely amygdaloidal (<2%) massive to pillowed flows, with patchy epidotization (unit 5, Figure 5); and
- 5) aphyric to sparsely quartz and plagioclase-phyric (<2%, <4 mm) massive to fragmental rhyolite (may in part be intrusive and/or resedimented volcanoclastic) (unit 6, Figure 5).

Close to 50% of this section consists of intrusive material, most of which has a sill-like orientation. However, because of deformation, it is difficult to determine if this is primary or partially a result of transposition. Seven different groups of intrusive rocks have been distinguished:

- 1) fine-grained to aphanitic, aphyric, light greenish brown-weathering, sparsely to moderately amygdaloidal (quartz, plagioclase±mafic, <5%) dykes and sills, commonly with large (3 to 10 cm) epidote and quartz-filled gas cavities and epidote patches (unit 8, Figure 5);
- 2) light greenish grey-weathering, plagioclase and pyroxene porphyritic (5 to 15%, 5 to 12 mm), non-amygdaloidal dykes and sills (unit 9, Figure 5);
- 3) fine- to medium-grained, aphyric to sparsely plagioclase-phyric (<2%, <8 mm), equigranular gabbro (unit 10, Figure 5);
- 4) aphyric, fine-grained to aphanitic, non-amygdaloidal, reddish brown-weathering, mafic dykes, commonly with flow banding (unit 11, Figure 5);
- 5) medium- to coarse-grained leucogabbro, locally with pegmatitic patches (unit 12, Figure 5);
- 6) aphyric, aphanitic, non-amygdaloidal, blue-grey weathering mafic to intermediate dykes (unit 13, Figure 5); and
- 7) light greenish brown, fine-grained, sparsely plagioclase porphyritic (<2%, <5 mm) intermediate dykes (unit 14, Figure 5). Where contact relationships are not observed or are significantly strained, it is difficult to distinguish between unit 8 intrusive rocks and unit 4 volcanic rocks, and a volcanic origin has been assumed in such cases.

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

Both the strongly amygdaloidal (unit 3) and the non-amygdaloidal (unit 2) flows occur throughout the section, although the proportion of sparsely to non-amygdaloidal flows decreases toward the top. Massive flows are also more common near the base of the section, whereas the top is dominated by pillowed flows and amoeboid pillow breccia. Plagioclase and pyroxene-phyric flows are rare and were only observed in one outcrop near the base of the section. Similar dykes throughout the section, however, suggest 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 dykes 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 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.

e) “Louis Formation”

The lower part of the “*Louis Formation*” was mapped in this study where it overlies the mafic sediments and rhyolite of the “*Tower Member*” of the “*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 Formation*” with sediment as interpillow material extending up to 80 to 120 m above the “*Hidden-Louis*” contact. Plagioclase (15%) and pyroxene- (amphibole pseudomorphs after clinopyroxene, 15%) phyric pillowed flows vary from 10 to 30 m thick, contain rounded pillows 1 to 1.5 m, and contain 5 to 10% vesicles.

The “*Louis Formation*” contains a gabbroic dyke swarm (Figure 2B) with three to six dykes displacing the sediments and rhyolite of the “*Tower Member*”. The gabbroic dykes are massive to columnar jointed, 15 to 40 m wide and contain vesicles commonly concentrated in linear zones along the top of the dyke.

3. Hanging-wall Alteration to the Flin Flon–Triple 7–Callinan VMS Horizon

Hydrothermal alteration of the “*Louis Formation*” resulted in epidote-quartz alteration, silicification, chlorite alteration, feldspar-quartz alteration, and sulphide staining. A pervasive middle greenschist facies metamorphic assemblage consisting of actinolite, epidote, albite, and 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 amygdalae, pervasive, patchy, ribbons, fractures) to define the paragenesis, distribution, and controls on epidote-quartz alteration. Epidote-quartz alteration is most intense in the lower two-thirds of the “*Hidden Formation*” (Figure 4A).

Silicification is not an abundant alteration type in the Flin Flon camp. In the southern segment of the Louis dyke swarm there is minor silicification of pillows (Figure 4B). Silicification (quartz>> epidote) is locally concentrated along dyke margins in both of the dyke swarms. “Chert” commonly replaces interpillow sediment and is distributed: 1) at the base of the “*Hidden*” and “*Louis*” formations; and 2) in the upper 120 m of the “*Hidden Formation*” (Figure 4B). Quartz is common as a vesicle filling.

Chlorite alteration is concentrated in two areas: 1) a chlorite-magnetite discordant zone above the Flin Flon main deposit towards the rhyolite of the “*Tower Member*” of the “*Hidden Formation*” and extending into the “*Louis Formation*”, and 2) near the top of the “*Hidden Formation*” in the zone of the felsic dykes, and is associated with gossans (Figure 4C). The chlorite alteration zone above the Flin Flon main deposit also contains anomalous sulphides. Chlorite occurs in the matrix, selvages and fills amygdalae.

Sulphidic zones in the hanging-wall basalts are associated with chlorite alteration in sediments near the base of the “*Hidden Formation*” and in the rhyolite and associated sediment at the top of the “*Hidden Formation*”.

4. Future Studies

Geochemical characterization of basalt, rhyolite, and dyke samples from the “*Hidden Formation*”, “*Louis Formation*”, and the Myo Lake section is in progress. Interflow and interpillow sedimentary rocks were sampled for geochemistry, petrography, and x-ray diffraction to identify the nature and composition of the detrital and hydrothermal components. Comparison of trace element signatures of sulphides in the ore bodies (Jonasson, pers. comm., 2002), and trace element signatures of hydrothermal alteration and mineralization in the interpillow material of the “*Hidden Formation*” will test the hypothesis that a hydrothermal plume exists above the Flin Flon–Triple Seven–Callinan mine horizon. Core logging and sampling of interpillow material, from four drill holes through the “*Hidden Formation*”, completed in 2002, provide a depth component to the hanging-wall plume study. In total, close to 400 samples of the hanging-wall strata and alteration were selected for analysis, including 230 sediment samples, 20 chert samples, 78 volcanic samples, 12 dyke, and 20 epidote-altered basalt samples.

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