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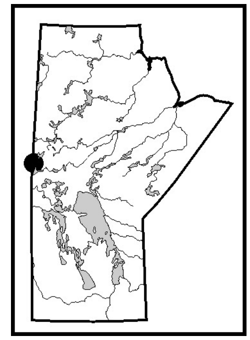
Geology of the Schist Lake–Mandy mines area, Flin Flon, Manitoba (part of NTS 63K12)

by R-L. Simard



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Summary

The Flin Flon area of the Paleoproterozoic Flin Flon Belt is well known for its volcanogenic massive sulphide (VMS) deposits. With the intent of assisting industry in the search for new reserves/mines in established mining communities, the Government of Canada launched in 2005 a new five-year Targeted Geoscience Initiative (TGI-3) in the Flin Flon area. As part of this initiative, the Manitoba Geological Survey, in collaboration with other surveys and researchers, is participating in the production of a new 1:10 000 scale 'cross-border' geological map of the Flin Flon area. This report summarizes the findings of the first field season for this project.

The Schist Lake–Mandy mines area, 4 km south of Flin Flon, was the focus of 1:5000 scale geological mapping during the 2006 field season. This new mapping allowed recognition of rocks comparable to those in the hangingwall to the Flin Flon–Callinan–Triple 7 ore deposits (i.e., the Hidden and Louis formations) as far south as Green Lake. The area is dominated by these rocks, which form the core of the mapped area and are bounded by the Burley Lake Fault to the west and the Mandy Road Fault to the east. The new mapping identified a potential VMS-hosting environment in the Hidden formation just southeast of Carlisle Lake. This area is considered to be of potential economic interest as it contains a subsidence structure with synvolcanic faults, a previously unrecognized felsic extrusive dome, and areas with pronounced gossan development on the rocks.

Introduction

The Flin Flon area of the Paleoproterozoic Flin Flon Belt is well known for its volcanogenic massive sulphide (VMS) deposits. Three active (Callinan, Triple 7 and Trout Lake) and three past-producing (Flin Flon, Mandy and Schist Lake) VMS mines occur in the immediate vicinity of the town of Flin Flon, which makes this area one of the most productive base-metal regions in Canada. Despite its productive past, however, Flin Flon area's reserves are rapidly being depleted and new reserves/deposits are needed to maintain the economic viability of the Hudson Bay Mining and Smelting Co. Ltd. smelter at Flin Flon.

With the intent of stimulating private-sector resource exploration in areas of high base-metal potential in established mining communities, the Government of Canada launched a new five-year Targeted Geoscience Initiative (TGI-3) in 2005. As part of this initiative, the Manitoba Geological Survey, in collaboration with the Saskatchewan Geological Survey, the Geological Survey of Canada, and researchers from Laurentian University, is participating in production of a new 1:10 000 scale 'cross-border' geological map of the Flin Flon area.

This report summarizes the first year of observations and data collected during a nine-week field program of 1:5000 scale bedrock geological mapping in the Schist Lake–Mandy mines area, located 4 km south of Flin Flon. The field and analytical studies in this area are intended to characterize and differentiate the various volcanic sequences, provide constraints on their distribution and assess their stratigraphic position relative to those hosting the VMS deposits at Flin Flon.

Regional setting

The Paleoproterozoic Flin Flon Belt is part of the Reindeer Zone of the Trans-Hudson Orogen (Figure GS-1-1). The Flin Flon Belt consists of a series of tectonostratigraphic assemblages (juvenile arc, juvenile ocean-floor back arc, ocean plateau, ocean-island basalt and evolved plutonic arc) that range in age from 1.92 to 1.87 Ga. All of the VMS deposits mined to date in the Flin Flon area are associated with the juvenile Flin Flon arc assemblage (Syme et al., 1999).

The volcanic rocks of the Flin Flon area are part of the 1.9 Ga juvenile Flin Flon arc assemblage, which consists mainly of tholeiitic subaqueous pillowed basalt and basaltic andesite, with lesser amounts of heterolithic mafic breccia and mafic and felsic volcaniclastic rocks, and minor dacite to rhyolite flows (Bailes and Syme, 1989). The VMS deposits in the area occur in association with the felsic volcanic units in synvolcanic collapse structures and calderas, within the main mafic volcanic complex (Bailes and Syme, 1989; Syme and Bailes, 1993; Figure GS-1-2).

Bedrock geology of the Schist Lake–Mandy mines area

The simplified bedrock geology of the Schist Lake–Mandy mines area, based on the 2006 field season mapping at 1:5000 scale (Simard, 2006), is summarized in Figure GS-1-3. Exposure in the Schist Lake–Mandy mines area, similar to that in most of the Flin Flon area, is exceptional, with commonly 30 to 70% lichen-free outcrop. Regional

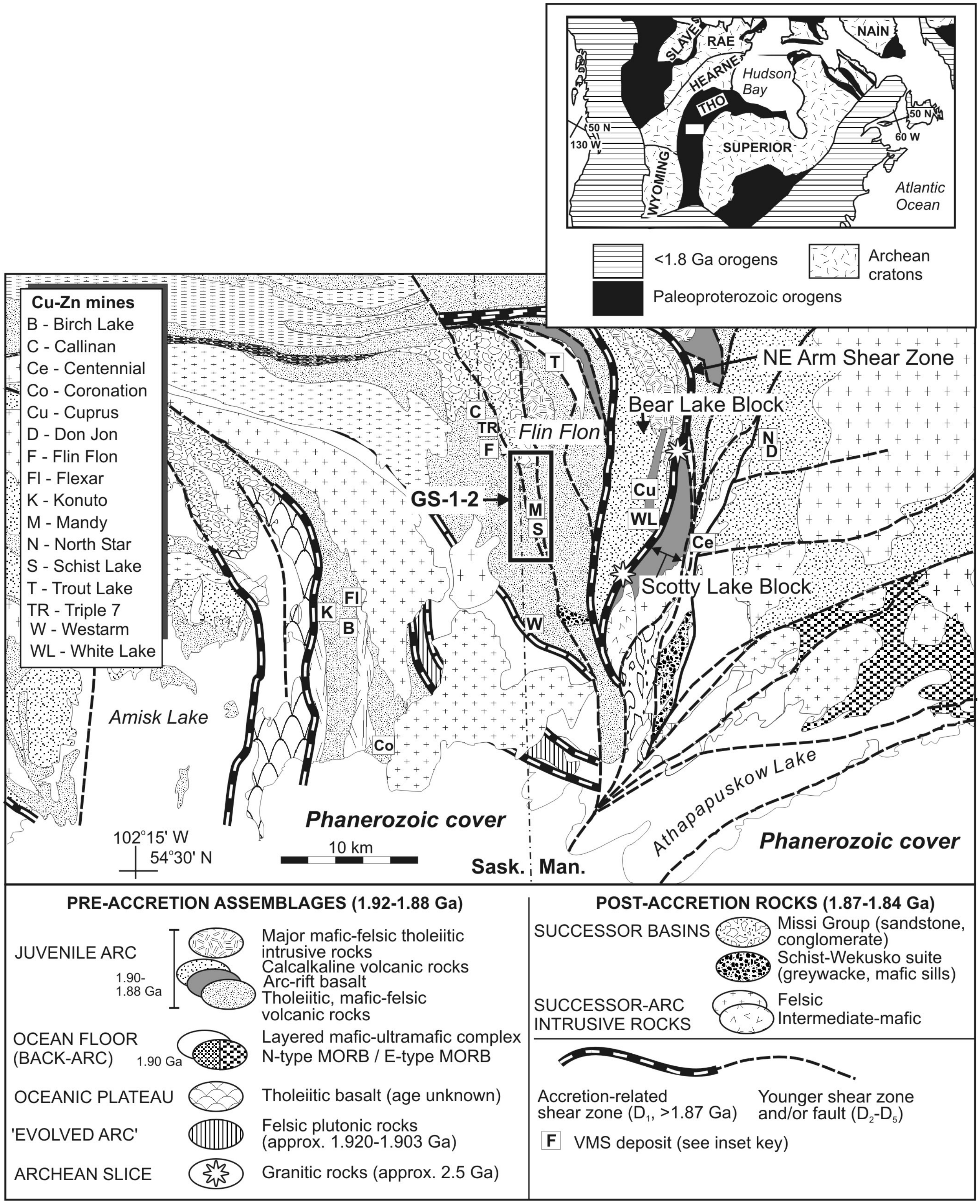

Figure GS-1-1: *Geology of the Flin Flon Belt, showing locations of known volcanogenic massive sulphide (VMS) deposits (*modified from *Syme et al., 1999); box indicates the area covered by Figure GS-1-2; inset map shows the location of the Flin Flon Belt within the Trans-Hudson Orogen (THO).*

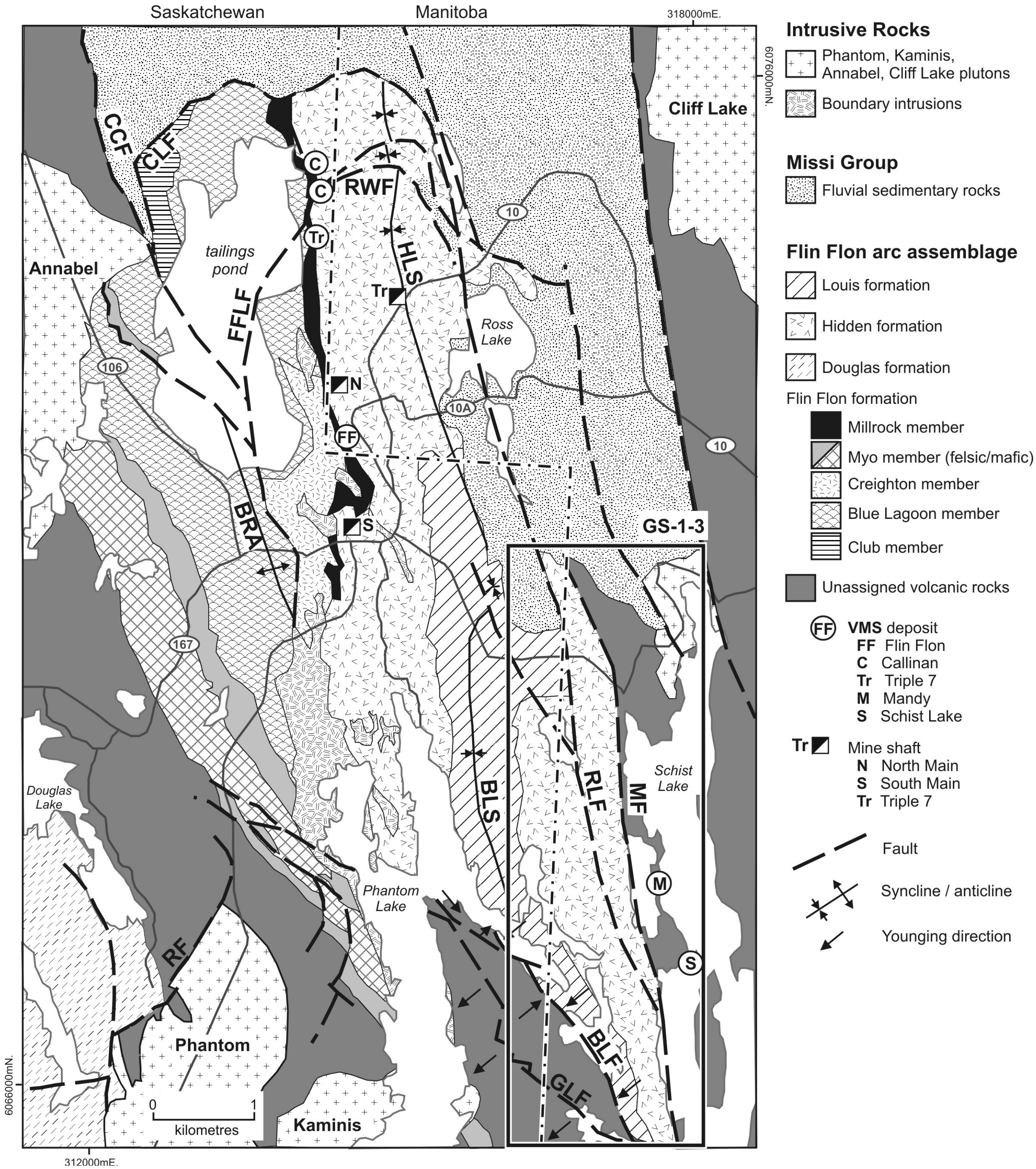

Figure GS-1-2: *Simplified geology of the Flin Flon area, showing the major structures in the area; box indicates the area covered by Figure GS-1-3. Abbreviations: BLF, Burley Lake Fault; BLS, Burley Lake syncline; BRA, Beaver Road anticline; CCF, Creighton Creek Fault; CLF, Cliff Lake Fault; FFLF, Flin Flon Lake Fault; GLF, Green Lake Fault; HLS, Hidden Lake syncline; MF, Mandy Road Fault; RF, Rio Fault; RLF, Ross Lake Fault; RWF, Railway Fault.*

metamorphism is lower greenschist facies (epidote-chlorite; Bailes and Syme, 1989), with good preservation of primary textures. The rocks in the area are weakly deformed, with one to two faint foliations best observed at unit contacts or in finer grained clastic rocks. Regional and local, narrow, brittle to ductile faults commonly offset the stratigraphy. Although several shear zones, each 1 to 3 cm wide, can be observed on outcrops, the significant faults offsetting the stratigraphy are rarely exposed, commonly being located in small gullies between outcrops that form weak to strong lineaments visible on airphotos. The amount and quality of exposures in the

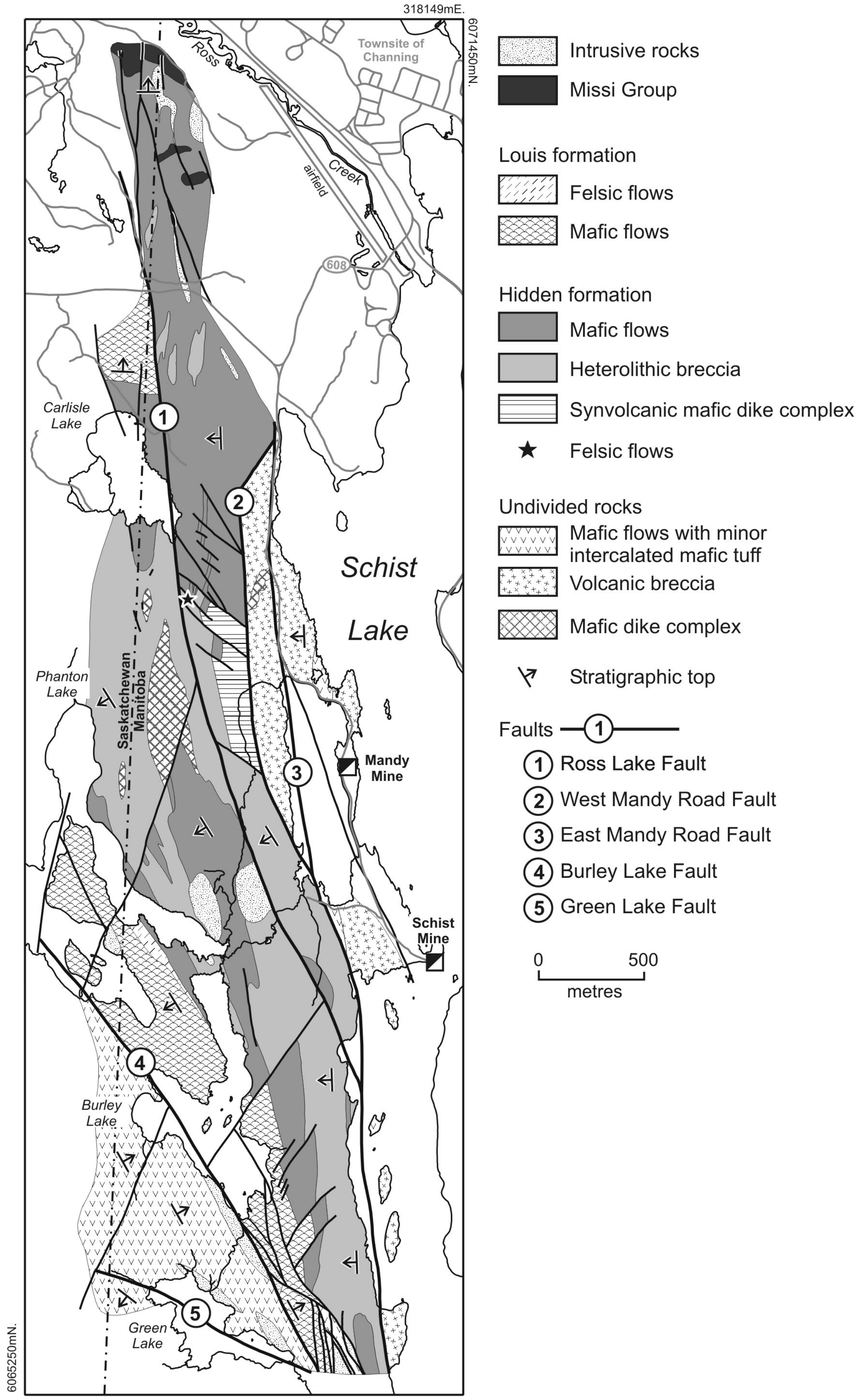

Figure GS-1-3: *Simplified bedrock geology of the Schist Lake–Mandy mines area, Flin Flon, Manitoba.*

Schist Lake–Mandy mines area allow for detailed volcanic lithofacies mapping and stratigraphic analysis of these rocks.

Recent detailed geological mapping and stratigraphic analysis of volcanic rocks of the Flin Flon mines area (Devine, 2003; Tardif, 2003; DeWolfe and Gibson, GS-2, this volume; Gibson, unpublished data, 2000–2006), have allowed the establishment of an informal stratigraphic subdivision of rocks hosting and occurring within the footwall and hangingwall to the Flin Flon, Callinan, and Triple 7 massive sulphide deposits (Figure GS-1-4a; Devine, 2003; DeWolfe and Gibson, GS-2, this volume). Figure GS-1-4 summarizes this informal stratigraphy for the Flin Flon mines area.

Rocks equivalent to the Flin Flon–Callinan–Triple 7 hangingwall strata have been recognized in the Schist Lake–Mandy mines area (Figures GS-1-2, -3, -4b). They occur west of the Mandy Road Fault, around Carlisle Lake, and east of the Burley Lake Fault (*see* Hidden Lake formation and Louis formation descriptions below). More work is required before rocks east of the Mandy Road Fault and west of the Burley Lake Fault can be associated with any of the known stratigraphic units in the Flin Flon area (*see* descriptions below).

Hidden formation

In the Schist Lake–Mandy mines area, rocks of the Hidden formation occur west of the Mandy Road Fault around Carlisle Lake (Figure GS-1-3). To the west, they are conformably overlain by rocks of the Louis formation; to the north, east of Ross Lake Fault, they are unconformably overlain by siliciclastic rocks of the Missi Group. This suite of rocks was previously mapped as andesite, basalt and flow breccia (unit 1), andesite breccia (unit 3) and porphyritic andesite breccia (unit 4) by Stockwell (1960), and as pillow fragment breccia (unit 11) and aphyric and sparsely porphyritic flows (unit 3b) and pillow fragment breccia (unit 3c) of the Burley Lake basaltic andesite (unit 3) by Bailes and Syme (1989).

The Hidden formation rocks in the Schist Lake–Mandy mines area consist of aphyric to sparsely plagioclase-phyric basalt flows with minor mafic volcaniclastic rocks to the north, and abundant heterolithic mafic breccia intercalated with aphyric to sparsely plagioclase-phyric basaltic flows to the south. They form a thick, semicontinuous, subvertical to steeply dipping volcanic sequence that trends north and faces west. The middle of this package of rocks is cut by the north-trending, sinistral, strike-slip Ross Lake Fault. The base of the Hidden

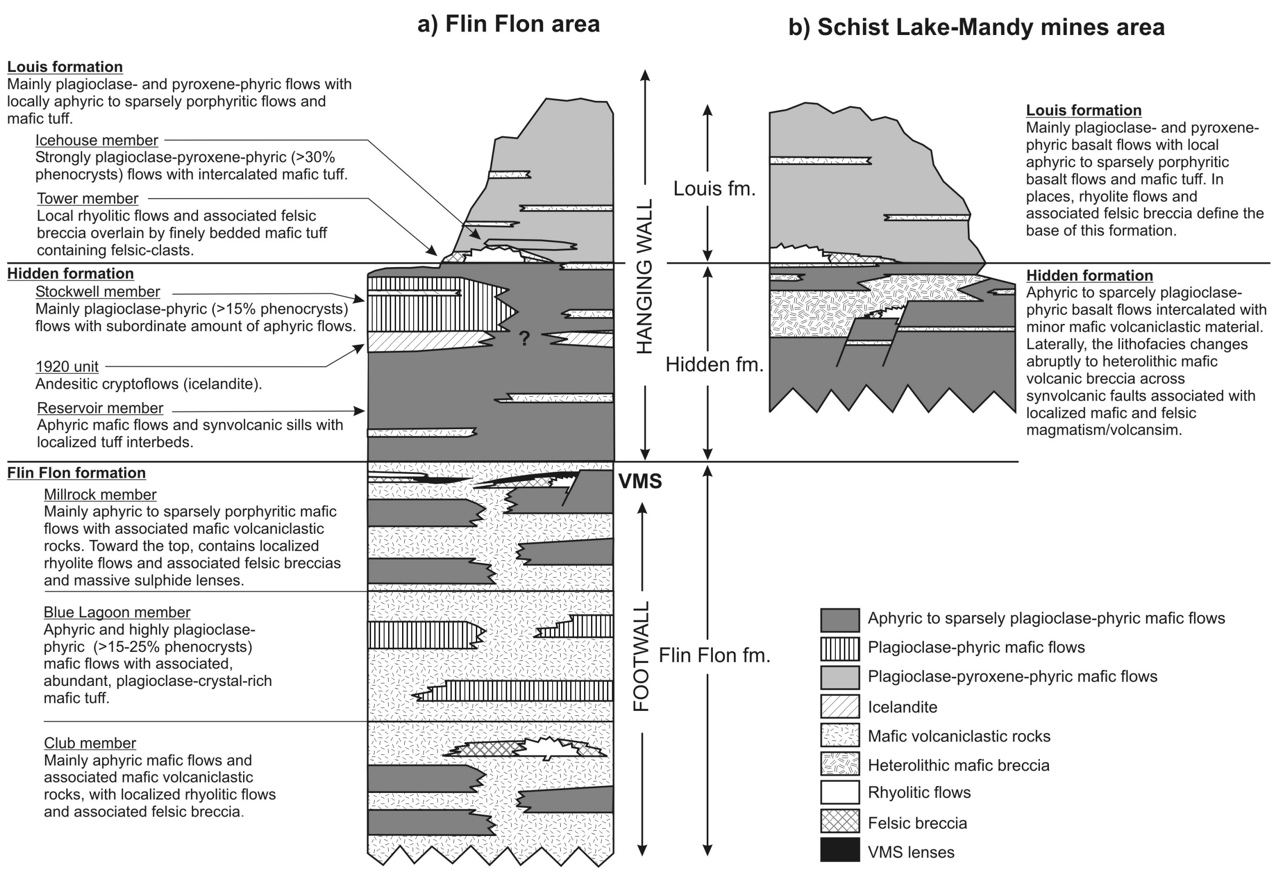

***Figure GS-1-4:** Schematic stratigraphic section of the Flin Flon area: **a)** Flin Flon area schematic stratigraphy (modified from Devine, 2003; DeWolfe and Gibson, GS-2, this volume), **b)** Schist Lake–Mandy mines area schematic stratigraphy.*

formation is truncated to the east by the Mandy Road Fault. The maximum thickness of the Hidden formation in the Schist Lake–Mandy mines area is <450 m on the east side of the Ross Lake Fault and up to 800 m on the west side (Figure GS-1-3).

Aphyric to sparsely plagioclase-phyric basaltic flows

Hidden formation basalt flows in the Schist Lake–Mandy mines area usually weather buff brown to brown, but are dark green where more deformed. They are dark green on fresh surfaces. The flows are generally aphyric to sparsely plagioclase phyric, with <7% plagioclase phenocrysts (<2 mm). Flow thicknesses, which generally decrease up-section, vary significantly from >50 m for pillowed flows with minor amoeboid pillow breccia lenses near the base of the section, to 3 to 10 m for 'organized' flows (massive to pillowed to amoeboid pillowed top; massive to amoeboid pillowed top; pillowed to amoeboid pillowed top; Bailes and Syme, 1989) toward the top. The organized flows are locally intercalated with massive to well-bedded pillow breccia, heterolithic mafic breccia and mafic tuff or both (*see* description below). The basaltic flows of the Hidden formation total ~400 m east of the Ross Lake Fault by Carlisle Lake, and <250 m intercalated with important amounts of heterolithic breccia west of the Ross Lake Fault.

Pillowed flows

The thick pillowed flows generally show closely packed, well-shaped pillows, 30 to 90 cm in size, with dark reddish brown to dark green, chloritized, 1 to 2 cm thick chilled margins (Figure GS-1-5a); locally, megapillows up to 3 m in size were observed. Pillows are usually amygdaloidal (5–15% of 1–2 mm quartz-filled amygdules) and commonly show concentric thermal contraction cracks (Figure GS-1-5a). Large pillows locally show radial pipe amygdules at their margins. Interpillow material usually forms <10% of the outcrops and consists of brownish fine-grained material with angular reddish brown fragments of chilled pillow margin (hyaloclastite), or massive to well-bedded greenish mafic tuff. Where megapillows were observed, amoeboid pillow breccia formed some of the interpillow material.

Organized flows

The thinner 'organized' flows form sequences that are dominated by 5 to 10 m thick zoned flows composed of massive to megapillowed to pillowed to amoeboid pillow-breccia morphologies, and include flows both with and without the pillowed section or massive base. Where present, the massive base is usually slightly more plagioclase phyric than other parts of the flow (up to 10% plagioclase phenocrysts 1–2 mm in size), and it shows an increase in the amount and size of the quartz-filled amygdules from <2% (2 mm in size) near the base to >5% (up to 3 cm in size) close to the top. Gas cavities up to 7 cm long and 1 cm thick, partly filled with quartz, are locally observed toward the top of massive divisions. Elongated to rounded, epidote-quartz alteration patches are also commonly observed in massive flows, and increase in size and abundance toward the top of the flows (Figure GS-1-5b). The massive part of the organized flows is usually 1 to 5 m thick and grades either into megapillows and pillows with abundant smaller amoeboid pillows and amoeboid pillow breccia, or directly into amoeboid pillows and amoeboid pillow breccia (Figure GS-1-5c).

The pillowed part of the organized flows can be 0.3 to 5 m thick. Pillows are usually irregularly shaped (amoeboid) and loosely packed with abundant interpillow material, including amoeboid pillow breccia. The pillows are 0.2 to 3 m in size. They are commonly highly amygdaloidal (up to 30% of 1–5 mm quartz-filled amygdules) and show thin (<1 cm), dark reddish brown to dark green chilled margins and local epidote-quartz alteration patches. Pillowed parts of the flows typically grade both vertically and laterally into amoeboid pillow breccia.

Amoeboid pillow breccia is composed of poorly sorted, subangular, highly vesicular to scoriaceous fragments of amoeboid pillows (Figure GS-1-5d). Thin (<1 cm), dark brown to dark green chilled margins are observed on the sides of some fragments. The matrix is composed of smaller broken pieces of the same material, as well as abundant angular fragments of the chilled pillow margins, plagioclase crystals and fine mafic material.

Mafic volcaniclastic rocks

Mafic volcaniclastic rocks of the Hidden formation in the Schist Lake–Mandy mines area consist mainly of massive to crudely bedded, heterolithic, mafic volcanic breccia with lesser amounts of well-bedded, fine-grained mafic tuff. Heterolithic breccia is the dominant rock type west of the Ross Lake Fault, where it constitutes >60% of the rocks of the Hidden formation and is interbedded to the south with organized flows. It totals more than 500 m in thickness. East of the Ross Lake Fault, the heterolithic breccia is virtually absent in the north, but is the prominent unit to the south. This transition from mainly flows in the north to mainly breccia in the south is abrupt and corresponds to an important mafic and felsic dike complex along a northwest-trending fault just southeast of Carlisle Lake (*see* details below). The total thickness of breccia south of this fault structure is up to 250 m.

Heterolithic mafic volcanic breccia

Heterolithic mafic volcanic breccia of the Hidden formation usually weathers buff brown to brown and is

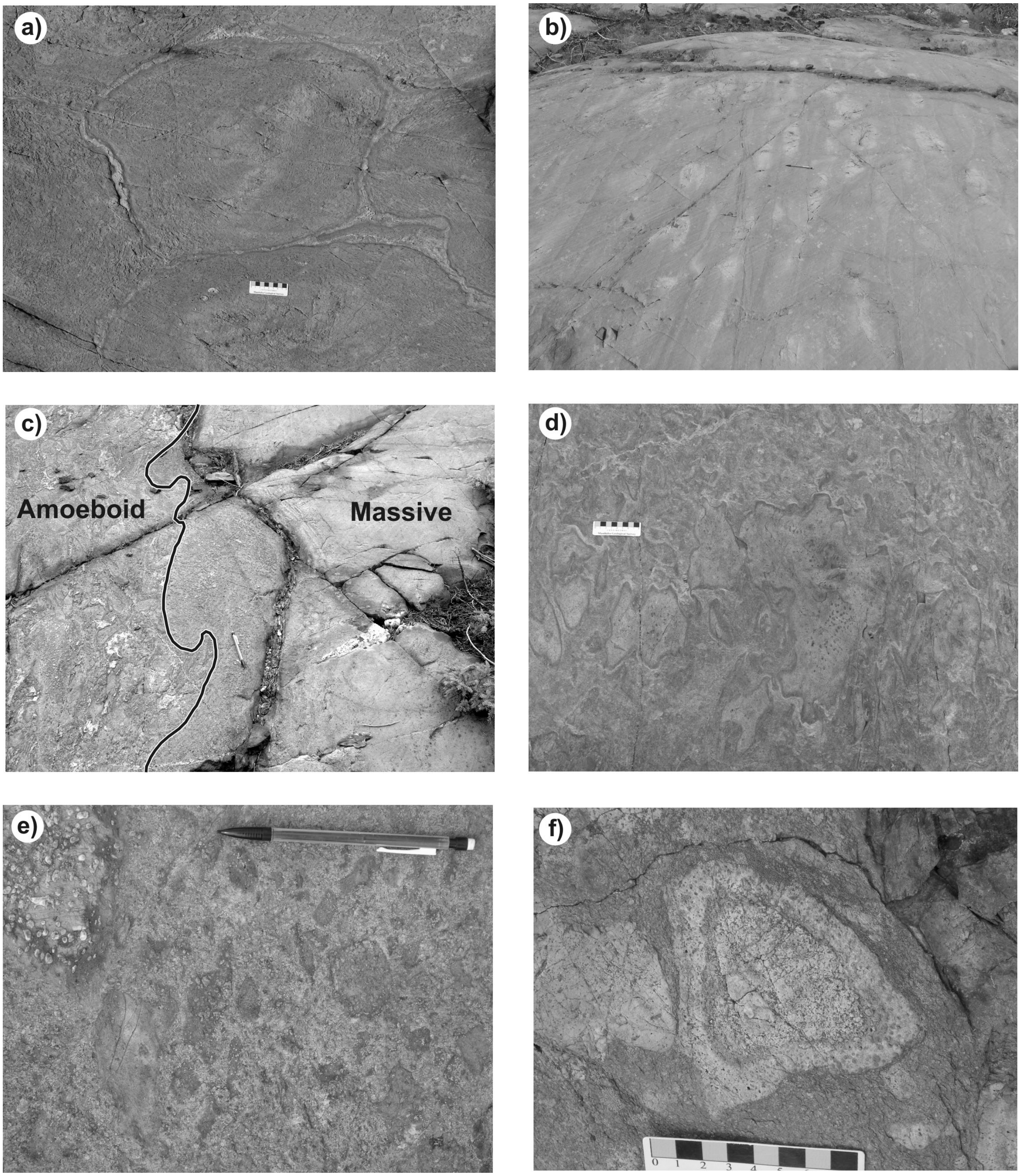

Figure GS-1-5: *Outcrop photographs of the Hidden formation rocks in the Schist Lake–Mandy mines area:* ***a)*** *closely packed aphyric pillows showing concentric thermal contraction cracks;* ***b)*** *massive aphyric basalt flow showing elongated epidote-quartz alteration patches (tops to the left);* ***c)*** *massive to pillowed basalt flow with a well-developed amoeboid top breccia (tops to the left);* ***d)*** *amoeboid pillow breccia composed of poorly sorted, subangular, highly vesicular to scoriaceous fragments of amoeboid pillows; note the darker chilled margin around the fragments;* ***e)*** *heterolithic mafic volcanic breccia composed of subangular, amygdaloidal aphyric basalt (upper left corner), aphyric nonamygdaloidal basalt (middle left) and sparsely plagioclase-phyric basalt (lower centre) in plagioclase-crystal-rich matrix;* ***f)*** *angular felsic-cored clast with mafic scoriaceous envelopes in heterolithic mafic volcanic breccia. Pencil for scale (14 cm long).*

medium green on fresh surfaces. It is mainly massive, clast supported and very poorly sorted in the north and the east. To the west and south, however, it is crudely bedded to bedded, matrix supported and shows a greater proportion of lapilli breccia and lapilli tuff (Figure GS-1-5e). These breccia beds commonly show normal grading but also display rare reverse grading.

Fragments are poorly sorted, subangular to angular, and range in size from <0.5 to 60 cm. All fragments are mafic in composition but vary in texture: buff brown to beige-green aphyric basalt; buff brown to green amygdaloidal (5–35% of 0.5–4 mm quartz-filled amygdules) aphyric basalt; pillowed basalt fragments still showing part of their chilled margin; dark reddish brown, chilled, pillow margin fragments; scoriaceous basaltic fragments; rare plagioclase-phyric amygdaloidal to nonamygdaloidal basalt; and a few felsic-cored clasts with mafic scoriaceous envelopes (Figure GS-1-5f). The matrix of the heterolithic breccia is poorly sorted and characteristically plagioclase-crystal rich (10–30% plagioclase, 1–5 mm in size).

The unit displays an overall fining to the south and west. The high angularity of the contained fragments and local preservation of fragments with fragile structures, such as scoriaceous and cored clasts, suggest they underwent a minimum amount of transport and likely were derived from a local source. The abrupt transition from mainly flows in the north to mainly breccia in the south along a series of northwest-trending faults just southeast of Carlisle Lake suggests that these faults may be synvolcanic in origin. For this reason, the heterolithic breccia is interpreted to be the product of debris flows deposited in a fault-bounded subsidence structure from local sources to the north. The cored clasts, with scoriaceous envelopes, are typical of spatter deposit. Because they were only observed in proximity to the transition area, the fault structures may have localized some 'fountaining' volcanism.

Mafic tuff

Thin (<3 m), well-bedded, fine-grained mafic tuff intervals are found here and there intercalated with the mafic flows of the Hidden formation. They are usually thinly bedded mafic mudstone and siltstone, and commonly show normal grading. One fairly continuous 2 m thick interval of this mafic mudstone and siltstone forms the uppermost unit of the Hidden formation on the peninsula in Potter Bay, just east of the Manitoba-Saskatchewan border.

Thin-bedded, tuffaceous 'sand-silt couplets' and graded beds are taken to suggest a resedimented origin for these rocks. They may represent turbidite deposits in an unstable volcanic environment. They also mark periods where a hiatus or quiescence in volcanism occurred.

Synvolcanic and younger mafic and felsic magmatism

The rocks of the Hidden formation are cut by several generations of mafic and felsic dikes. Numerous plagioclase-pyroxene-phyric and aphyric mafic dikes, trending 315 to 340º, cut across the flows. These dikes are in turn cut by plagioclase-quartz-phyric rhyolite dikes trending 000 to 015º. The latter cut across all units of the Hidden formation and, locally, faults that offset the stratigraphy on the east side of Carlisle Lake. These felsic dikes are, in turn, cut by multiple, mainly aphyric mafic dikes trending 340 to 000º. Distinguishing between the first and second generations of mafic dikes is not generally possible in the field.

Northwest-trending felsic dikes in the area are interesting, as some of them locally run parallel to and along 'synvolcanic' faults southeast of Carlisle Lake. These thin felsic dikes are usually also associated with multiple mafic dikes that trend in the same direction. Mafic dikes locally form very closely packed intrusive complexes to the east, with <10% of screens (1–5 m^2) of the host rocks visible. Mafic dikes similar to those in this intrusive complex cut across pillowed flows on the north side of the complex. These dikes locally inject interpillow spaces, suggesting that their emplacement occurred prior to induration of the interpillow material. Up-section, the dike complex ceases to be present and its termination is marked by a small quartz-plagioclase-phyric rhyolite lobe. The rhyolitic lobe, which has felsic breccia just below it, is interpreted to be part of a small extrusive dome (Figure GS-1-6a). A gossan zone is associated with the rhyolite dome to the south. This mafic-felsic dike complex is interpreted to be a synvolcanic dike swarm emplaced along synvolcanic subsidence faults.

Comparison of Hidden formation at Flin Flon to the Schist Lake–Mandy mines area

The Hidden formation stratigraphy directly overlying the Flin Flon–Callinan–Triple 7 ore deposits is a 400 to 880 m succession of thick, aphyric and plagioclase-phyric, mainly pillowed and massive basaltic flows that average 30 m in thickness. They are intruded by abundant mafic sills and dikes, and interlayered with minor mafic volcaniclastic rocks (Figure GS-1-4a; DeWolfe and Gibson, GS-2, this volume, Tardif, 2003; DeWolfe and Gibson, 2005; Gibson, unpublished data 2000–2006, DeWolfe, unpublished data, 2004–2006). The abundance of thick flows and high volume of sills and dikes above the Flin Flon–Callinan–Triple 7 ore deposits suggest a vent-proximal setting for these volcanic rocks. They are interpreted as products of voluminous volcanism forming a shield volcano erupted during a period of resurgent basalt volcanism and subsidence (DeWolfe and Gibson, 2005). This shield volcanism immediately followed a hiatus in volcanism during which the Flin Flon–

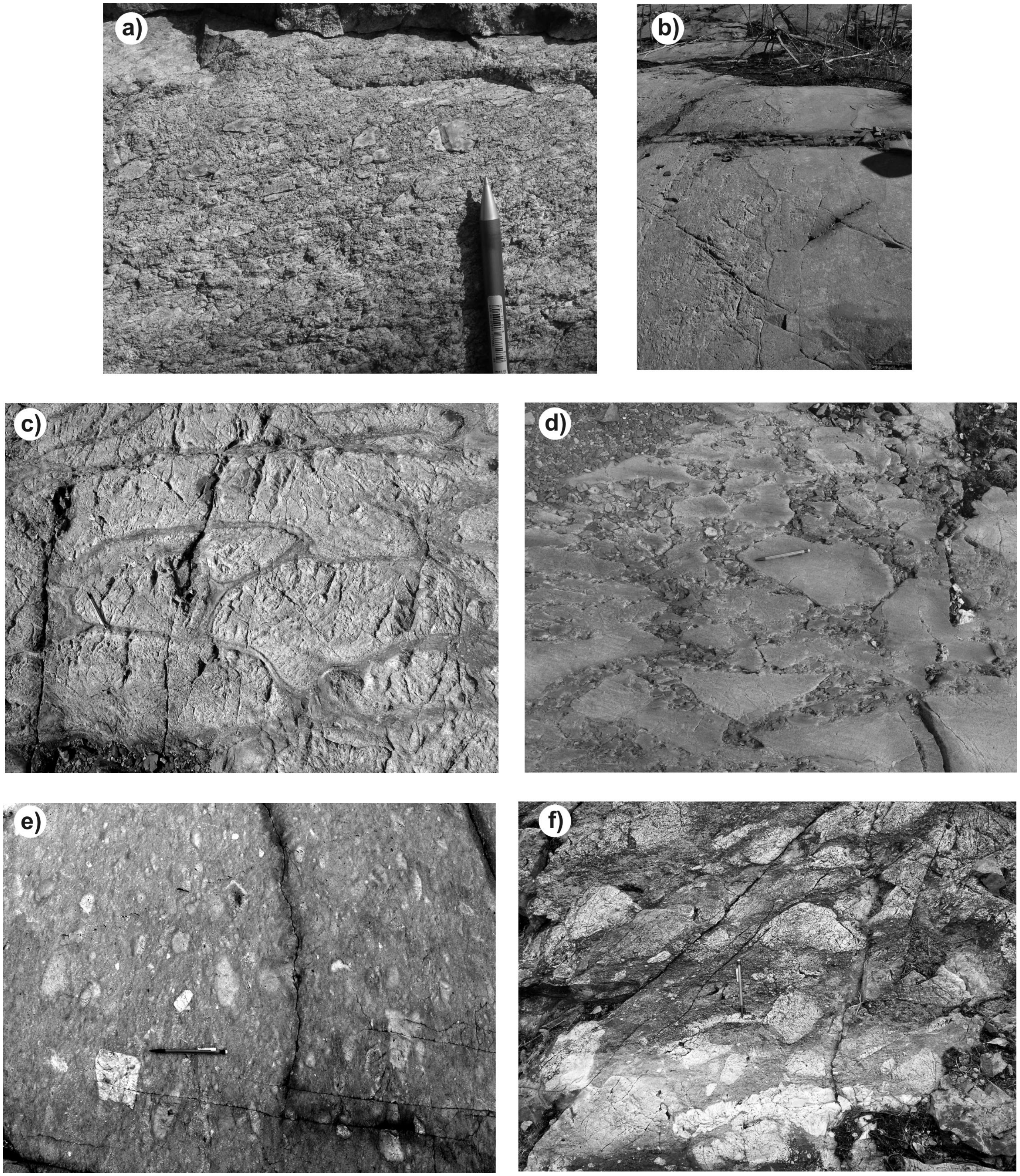

Figure GS-1-6: *Outcrop photographs of the rocks in the Schist Lake–Mandy mines area:* ***a)*** *poorly sorted, massive felsic breccia associated with a rhyolite lobe, Hidden formation;* ***b)*** *undulating basal contact of massive coarse-grained flows of the Louis formation (to the right) sinking into monolithic flow-top breccia of the underlying flow (tops to the right);* ***c)*** *nicely shaped pillowed flows of the Louis formation (tops to the right);* ***d)*** *clast-supported, massive, poorly sorted, heterolithic, mafic volcanic breccia east of the Mandy Road Fault;* ***e)*** *matrix-supported, massive, poorly sorted, heterolithic mafic and felsic breccia east of the Mandy Road Fault, showing very angular, light-coloured felsic clasts mixed with subrounded mafic clasts;* ***f)*** *clast-supported, monolithic felsic breccia east of the Mandy Road Fault. Pencil for scale (14 cm long).*

Callinan–Triple 7 VMS deposits were formed (DeWolfe and Gibson, 2005).

In the Schist Lake–Mandy mines area, the Hidden formation flows are generally thinner and accompanied by volumetrically minor synvolcanic dikes and sills. This suggests a less proximal volcanic environment, farther away from the main vent of the Hidden formation shield volcano, than that directly above the Flin Flon–Callinan–Triple 7 VMS deposits. The presence of Hidden formation synvolcanic subsidence structure(s) in the Schist Lake–Mandy mines area, marked by abundant breccia and associated mafic and felsic magmatism-volcanism, is unique in the Flin Flon area. It most likely represents a small subsidence structure on the side of the main volcanic edifice that is centred on the Flin Flon area.

Louis formation

In the Schist Lake–Mandy mines area, rocks of the Louis formation are exposed on the peninsula between Phantom and Burley lakes, and extend south to the east tip of Green Lake and west to the Burley Lake Fault (Figure GS-1-3). These rocks were previously mapped as porphyritic andesite (unit 2) by Stockwell (1960) and as the plagioclase-phyric and glomerophyric flows of the Burley Lake basaltic andesite (unit 3a) by Bailes and Syme (1989).

The Louis formation rocks in the Schist Lake–Mandy mines area consist mainly of plagioclase-pyroxene-phyric basalt flows intercalated with a lesser amount of aphyric and plagioclase-phyric basalt flows and mafic volcaniclastic rocks, as well as quartz-plagioclase-phyric rhyolite flows and associated felsic breccia at the base of the formation (Figure GS-1-4). The rocks form a subvertical to steeply dipping, thick, continuous volcanic stratigraphic sequence that trends north-northwest and faces west. An exception to this is the southernmost exposures of the Louis formation east of Green Lake, where a faulted wedge faces east (Figure GS-1-3). The western, upper part of the Louis formation is faulted by the Burley Lake Fault. The maximum observed thickness of the Louis formation in the Schist Lake–Mandy mines area is <400 m, near Phantom Lake in the north, decreasing to <100 m at Green Lake in the south (Figure GS-1-3).

Rhyolite flows

Massive to locally brecciated, plagioclase-quartz-phyric rhyolite flows conformably overlie well-bedded mafic tuff of the Hidden formation to the east, and define the base of the Louis formation on the peninsula between Phantom and Burley lakes (Figure GS-1-3). This rhyolite dome is composed of at least two flows (each 20–30 m thick) that show internal autobrecciation and flow banding. The flows weather light beige to white and are medium grey on fresh surfaces. This felsic dome is faulted off to the north and thins to the south. It is conformably overlain by basaltic flows to the west. No other felsic rocks were observed in the Louis formation in the map area.

Basaltic flows

Louis formation basaltic flows in the Schist Lake–Mandy mines area usually weather buff brown to brown, and are dark green on fresh surfaces. They constitute more than 90% of the Louis formation rocks in the area.

Plagioclase-pyroxene-phyric flows

The majority of the Louis formation basalt flows (>70%) are plagioclase-pyroxene phyric, with 10 to 12% plagioclase phenocrysts (1–3 mm) and 3 to 7% pyroxene phenocrysts (0.5–3 mm). Flows are generally very thick (up to 80 m) and show thick (20–50 m), massive, coarse-grained (2–4 mm pyroxene and plagioclase crystals) bases with thin (1–10 m) pillowed and/or amoeboid pillowed and breccia tops. Where exposed, the basal contact of these massive coarse-grained flows is undulating and, in places, shows a 1 to 2 m thick chilled margin (fine- to medium-grained equigranular texture) with 10 to 20 cm long pipe vesicles perpendicular to the basal contact (Figure GS-1-6b). Up-section, the massive part of the flow becomes finer grained and increasingly porphyritic. Where the flows become fine grained to porphyritic, epidote-quartz patches appear along with quartz-filled amygdules; they increase in abundance and size toward the top of the flows. The overlying pillows are 40 to 80 cm in size and usually amygdaloidal, and some display concentric thermal contraction cracks (Figure GS-1-6c).

To the south, near the contact with the Hidden formation aphyric flows, the plagioclase-pyroxene-phyric flows of the Louis formation are thinner (5–10 m) and lack a thick, coarse-grained massive base. The pillows are generally larger (40–150 cm), in places showing megapillows up to 3 m in size.

Aphyric and plagioclase-phyric flows

Aphyric and plagioclase-phyric flows are intercalated in places with the plagioclase-pyroxene-phyric flows, especially to the north. These flows average 10 to 30 m in thickness and are massive to pillowed, with various amounts of quartz-filled amygdules. Pillows are usually closely packed, with <5% interpillow material (hyaloclastite). They average 40 to 80 cm in size, with 1 to 2 cm thick, dark green chilled margin. Some show concentration of amygdules in their upper portion, or concentric thermal contraction cracks, or both.

Mafic volcaniclastic rocks

Minor, thin, well-bedded, fine-grained mafic tuff intervals (<3 m) are intercalated with the mafic flows of the Louis formation. They are usually thinly bedded mafic mudstone and siltstone.

Synvolcanic gabbroic intrusions

On the northernmost part of the peninsula between Phantom and Burley lakes, massive, aphyric to sparsely porphyritic flows of the Louis formation appear to grade into massive, medium- to coarse-grained, equigranular to slightly plagioclase- and pyroxene-phyric gabbro intrusions.

Comparison of the Louis formation at Flin Flon to the Schist Lake–Mandy mines area

The Louis formation stratigraphy in the Flin Flon camp is localized in the core of the north-northwest-trending Burley Lake syncline. Its total observed thickness varies from <200 m on the west limb to greater than 800 m in the nose of the fold at Louis Lake, just south of the town of Flin Flon (DeWolfe, pers. comm., 2006).

The Louis formation rocks and stratigraphy are very similar at Flin Flon and in the Schist Lake–Mandy mines area. In both places, the formation is composed mainly of plagioclase-pyroxene-phyric basaltic flows, with minor aphyric and plagioclase-phyric basaltic flows, mafic volcaniclastic rocks, and local rhyolite flows and associated felsic volcaniclastic rocks near the base (Figure GS-1-4). One small difference is that the basaltic flows in the Flin Flon camp are generally thinner (averaging 15 m and ranging up to 60 m; DeWolfe, pers. comm., 2006) than those in the Schist Lake–Mandy mines area (averaging 50 m and ranging up to 80 m).

The main difference between Louis formation rocks at Flin Flon and those in the Schist Lake–Mandy mines area is that the former are exposed in the core of the Burley Lake syncline, whereas the latter form a single, homoclinal, west-facing sequence. Further work is required to define the location of the Burley Lake syncline as it extends south into the Schist Lake–Mandy mines area.

Undivided volcanic rocks

The rocks east of the Mandy Road Fault and west of the Burley Lake Fault are not yet assigned to any existing stratigraphic unit in the Flin Flon camp; more field and analytical work is required before doing so.

West of the Burley Lake Fault

Rocks west of the Burley Lake Fault are poorly exposed (<10% exposure). In the southwestern portion of the map area around the Green Lake Fault, the rocks become more hornfelsed, and foliations and delicate primary textures are less commonly observed. Just north and west of Green Lake, several pink feldspar-quartz-phyric porphyry dikes (1–3 m wide) were observed trending northwest to north-northwest.

North of the Green Lake Fault, the rocks consist of subvertical to vertical, northwest-trending, east-facing, thin, aphyric, plagioclase-phyric and plagioclase-pyroxene-phyric basalt flows that are typically intercalated with thin units of well-bedded mafic tuff and local heterolithic breccia. A north-northeast-trending fault west of Green Lake breaks these volcanic rocks into two slightly different packages.

Along Burley Lake, north of the north-northeast-trending fault, the basaltic flows are slightly plagioclase phyric (<2%, <1 mm in size), weather buff brown to dark brown and are dark green on fresh surfaces. Basalt flows in the area are thin (1–5 m thick) and are locally interbedded with thin (<1 m thick), well-bedded mafic tuff. Flows are usually massive at their base, and amygdule abundance increases toward the top. Some massive flows show a 3 to 10 cm thick frothy top overlain by 0.3 to 3 m thick monolithic flow-top breccia. Other massive flows display a >5 m thick pillowed top, with pillows slightly flattened and up to 1.5 m long and 60 cm high. Pillows in these flows have a 1.5–2 cm, dark green chilled margin and are amygdule rich toward their tops (~10%, up to 0.7 cm in size). Most flows in the area show disseminated pyrite in both massive and pillowed facies.

To the southwest, toward the Green Lake Fault, the basalt flows are plagioclase-pyroxene phyric (7–10% plagioclase, 0.2–1.5 mm; 5% pyroxene, 0.2–2.5 mm), weather dark brown to very dark green, and are dark green to black on fresh surfaces. These rocks are hornfelsed, highly fractured and shattered by numerous epidote-quartz veins <0.5 mm thick. The flows are massive and contain 5 to 10% round quartz-amygdules 0.5 to 3 cm in diameter.

South of the north-northeast-trending fault, rocks along Burley Lake form a 100 m thick package of aphyric, medium- to fine-grained, 5 to 10 m thick massive flows with local mafic sills and intercalations of thin, well-bedded mafic tuff (1–3 m thick). Massive flows show epidote-quartz patches, which increase in abundance toward the flow top, and an upward decrease in grain size. The well-bedded mafic tuffaceous rocks consist of locally graded, finely bedded mafic siltstone (medium green) and mudstone (light green to beige), and constitute <10% of the rocks.

South of this package, the rocks north of Green Lake consist of massive to pillowed plagioclase-phyric basalt flows and local pyroxene-plagioclase-phyric or aphyric varieties. They are locally interbedded with thin, well-bedded mafic tuff and mafic breccia. In places, well-exposed sequences of massive to pillowed to amoeboid brecciated flows are exposed, but lack of exposure limits observation of complete flows and prevents thorough description of the volcanic sequence in this area. Similar to other areas, massive flows display epidote-quartz patches that increase in abundance and size toward the flow top. Pillows are 50 to 80 cm in size with <1.5 cm thick, dark green, chloritic chilled margins and local epidote-quartz alteration patches. Rare exposures of pillows with no chilled margin and well-developed concentric thermal contraction cracks were observed.

East of Mandy Road Fault

The rocks east of the Mandy Road Fault on the west shore of the Schist Lake are of considerable interest as they host the past-producing Schist and Mandy VMS mines. Only part of this area was remapped during the 2006 field season, as they are the focus of a new M.Sc. thesis by E. Cole at Laurentian University under the supervision of H. Gibson and S. Piercey.

Overall, the rocks east of the Mandy Road Fault consist of three or more faulted packages of vertical to subvertical, north-trending and west-facing volcanic rocks. The faults bounding these rock packages are not well exposed (beneath roads or lakes). The rocks are overall moderately to highly deformed, with one to three well-developed foliations.

Volcanic breccia units

Two heterolithic mafic breccia units, one heterolithic mafic and felsic breccia unit, and one felsic breccia unit have been observed east of the Mandy Road Fault. The two heterolithic mafic breccia units are restricted to the northern part of the map area, whereas the felsic breccia units are restricted to the south.

The northernmost heterolithic mafic breccia, east of the west and east arms of the Mandy Road Fault and west of the minesite road, consists of massive, poorly sorted, usually clast-supported lapilli breccia to breccia. Clasts are angular to subangular and range in size from 1 to 50 cm. They are all mafic in composition but vary in texture and colour: light to medium green and brown, amygdaloidal to nonamygdaloidal aphyric basalt; brownish, plagioclase-phyric amygdaloidal basalt; and dark reddish brown, aphyric, amygdaloidal to nonamygdaloidal basalt (pillow fragments, chilled margin pieces?). The matrix, which is usually plagioclase-crystal rich, is poorly sorted and composed of lapilli-size fragments of similar composition to that of the contained clasts.

The other heterolithic mafic breccia unit, on the east side of the east arm of the Mandy Road Fault, consists of massive to well-bedded, poorly sorted, clast- to matrix-supported lapilli breccia to breccia with lapilli to tuffaceous bed intervals (Figure GS-1-6d). It is locally intercalated with aphyric basaltic flows (*see* description below). Clasts in this breccia unit are angular to subrounded and range in size from 0.5 to 60 cm in clast-supported beds and 3 to 15 cm in matrix-supported beds. Contained clasts are all mafic in composition, but vary in texture and colour: dark brown to green to light green to beige, aphyric, amygdaloidal to nonamygdaloidal basalt; sparsely plagioclase-phyric to plagioclase-phyric basalt; scoriaceous mafic clasts; and pillow fragments. The matrix is poorly sorted and composed of lapilli and finer grained fragments of composition similar to that of the larger clasts. In places along the shore of Schist Lake, this unit is altered and hematized (dark purple clasts in light green chloritic matrix).

The heterolithic mafic and felsic volcanic breccia unit is poorly exposed in the map area, and restricted to a small peninsula on the shore of Schist Lake, as well as small islands in the southernmost part of the area. It consists of massive, poorly sorted, clast-supported breccia with angular to subrounded clasts of dark green to beige, plagioclase-phyric, amygdaloidal to nonamygdaloidal basalt; dark green to beige, aphyric, amygdaloidal to nonamygdaloidal basalt; beige scoriaceous mafic clasts; beige aphyric rhyolite; and pinkish plagioclase-phyric rhyolite (Figure GS-1-6e). The felsic clasts usually represent <15% of the clast content and are very angular. The matrix to the breccia is usually chloritic and rich in plagioclase crystals (up to 30%, 1–4 mm in size). On the southernmost peninsula, this breccia unit is interbedded with well-bedded mafic siltstone and mudstone.

Felsic volcanic breccia is exposed on the northern tip of one island on Schist Lake. It consists of very angular, aphyric, massive rhyolitic clasts and blocks of well-bedded felsic tuff (up to 50 cm long) in a beige-grey, fine-grained felsic matrix (Figure GS-1-6f).

Mafic volcaniclastic rocks

A 200 m thick package of well-bedded, fine- to coarse-grained mafic sandstone, siltstone and mudstone occurs between the east and west arms of the Mandy Road Fault. These mafic volcaniclastic rocks are usually thinly bedded and commonly show normal grading. They also show small- and large-scale S-folds that plunge gently to the southeast. These folds could be related to the faults in the area (drag folds?).

Basaltic flows

A package of ~150 m of aphyric to sparsely plagioclase-phyric, massive, pillowed and amoeboid basalt flows is intercalated with the heterolithic breccia north of the Schist and Mandy minesites. The pillows are amygdaloidal and show very irregular shapes (amoeboid), with up to 30% disrupted and shattered, very fine grained, interpillow mafic sedimentary rocks (peperite?). Plagioclase-phyric massive basaltic flows were observed in two locations south of the aphyric flows. The southernmost occurrence on a small island south of the Schist and

Mandy minesites is crosscut by small shear zones and shows disseminated 1 to 3 cm pockets of pyrrhotite.

Economic considerations

Volcanogenic massive sulphide (VMS) deposits in the Flin Flon area occur in association with the felsic volcanic units in synvolcanic collapse structures and calderas, within the main mafic volcanic complex (Bailes and Syme, 1989; Syme and Bailes, 1993). The ability to recognize these structures is key to exploring for VMS deposits in and around the Flin Flon area, as well as in other greenstone belts in Manitoba.

This summer's 1:5000 scale bedrock mapping of the Schist Lake–Mandy mines area has identified a potential subsidence structure complete with associated synvolcanic faults and local fault-associated mafic and felsic magmatism. This structure, within the Hidden formation rocks just southeast of Carlisle Lake, also has a spatially associated and well-developed gossan. Other smaller gossans were observed in the area, often associated with mafic and felsic dikes.

Until recently, rocks of the Hidden formation occurring in the hangingwall to the Flin Flon–Callinan–Triple 7 VMS deposits were never considered as a serious exploration target. The recent mapping at both Flin Flon (DeWolfe and Gibson, GS-2, this volume) and in the Schist Lake–Mandy mines area, however, clearly shows that the hangingwall stratigraphy possesses the very same volcanic structures that focused mineralization and ore formation in the underlying Flin Flon formation. Thus, these rocks should be and are being re-evaluated in terms of their exploration potential.

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