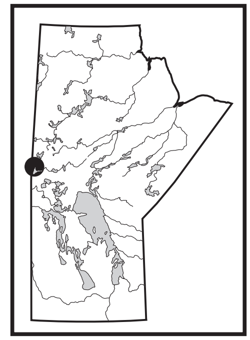
GS-2 Geology of the Hook Lake Block, Flin Flon area, Manitoba (part of NTS 63K12)

by P.D. Kremer and R-L. Simard



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Summary

The Hook Lake Block is one of several fault-bounded domains in the Flin Flon assemblage of the Paleoproterozoic Flin Flon Belt. It is bounded to the east and west by the Manistikwan Lake and Cliff Lake faults, respectively, and represents a comparatively unique volcanic and volcaniclastic stratigraphy with respect to the Flin Flon Block to the west. Based on field mapping of the northern segment of the Hook Lake Block in the summer of 2007, the area has been subdivided into two distinct sequences: 1) a western sequence consisting of aphyric to feldspar-phyric basaltic flows, associated volcaniclastic rocks with lesser felsic (quartz- and feldspar-phyric rhyolite) volcanic rocks, accompanied by a stratigraphically overlying sequence of reworked mafic and felsic proximal volcanic rocks interleaved with plagioclase- and pyroxene-phyric basaltic flows; and 2) an eastern sequence of massive to fragmental, quartz- and feldspar-phyric rhyolitic flows in a thick package of heterolithic mafic to mafic–felsic breccia. The western sequence is interpreted to be the product of proximal reworking of older mafic and felsic volcanic rocks accompanied by lesser mafic volcanism in a subsidence structure and/or basin. The eastern sequence is largely fragmental and also likely the product of infilling of a basinal domain by locally derived volcaniclastic detritus. The boundary between the two sequences is marked, in places, by the Cliff Lake pluton and elsewhere by the Hook Lake Fault. The latter is subparallel to, and has a similar kinematic history as, the block-bounding Manistikwan and Cliff Lake faults.

Sulphide mineralization (disseminated to semimassive/massive pyrite±pyrrhotite±chalcopyrite±sphalerite) was observed associated with massive to fragmental quartz- and feldspar-phyric rhyolite flows and domes throughout both sequences. This mineralization suggests that potential exists within the Hook Lake Block for volcanogenic massive sulphide (VMS) deposits. Small amounts of remobilized sulphide mineralization accompanied a minor sinistral reactivation event along the Cliff Lake Fault.

Introduction

The Flin Flon area of the Paleoproterozoic Flin Flon Belt is well known for its 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.

With the intent of stimulating private-sector mineral 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 observations and data collected during the summer of 2007 on the rocks of the Hook Lake Block, located 1 km east of Flin Flon. The data were collected during the final three weeks of a twelve-week field program of 1:5000 scale bedrock geological mapping. The field and pending analytical studies in this area are intended to characterize and differentiate the various volcanic sequences, provide constraints on their distribution and assess whether these rocks are part of the same volcanic sequence that hosts the Flin Flon–Callinan–Triple 7 mines at Flin Flon.

Regional setting

The Paleoproterozoic Flin Flon Belt is part of the Reindeer Zone of the Trans-Hudson Orogen (Figure GS-2-1). The 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 (Syme et al., 1999). All VMS deposits mined to date in the Flin Flon area are associated with the juvenile Flin Flon arc assemblage (Syme et al., 1999).

Volcanic rocks of the Flin Flon area are part of a 1.9 Ga juvenile 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 at Flin Flon are spatially associated with felsic volcanic units in synvolcanic subsidence structures and calderas, within the main mafic volcanic complex (Bailes and Syme, 1989; Syme and Bailes, 1993; Figure GS-2-2).

Baildes and Syme (1989) subdivided the rocks of the Flin Flon area into structural blocks. Each block is fault bounded and displays unique units and stratigraphic sequences. Near Flin Flon, rocks west of the Cliff Lake

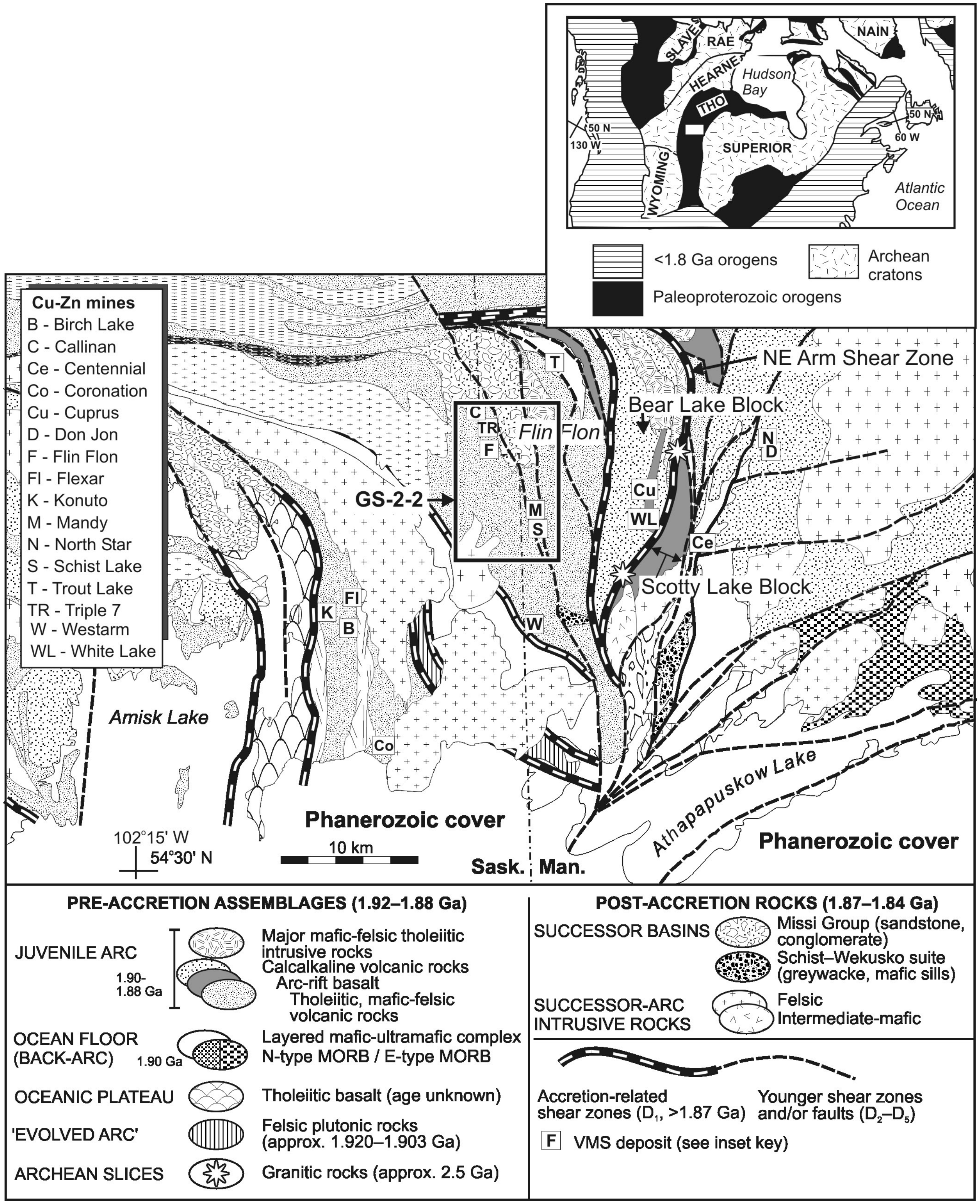

Figure GS-2-1: *Geology of the Flin Flon Belt, showing locations of known volcanogenic massive sulphide (VMS) deposits (*modified from *Syme et al., 1999); box indicates the area covered by Figure GS-2-2; inset map shows the location of the Flin Flon Belt within the Trans-Hudson Orogen (THO).*

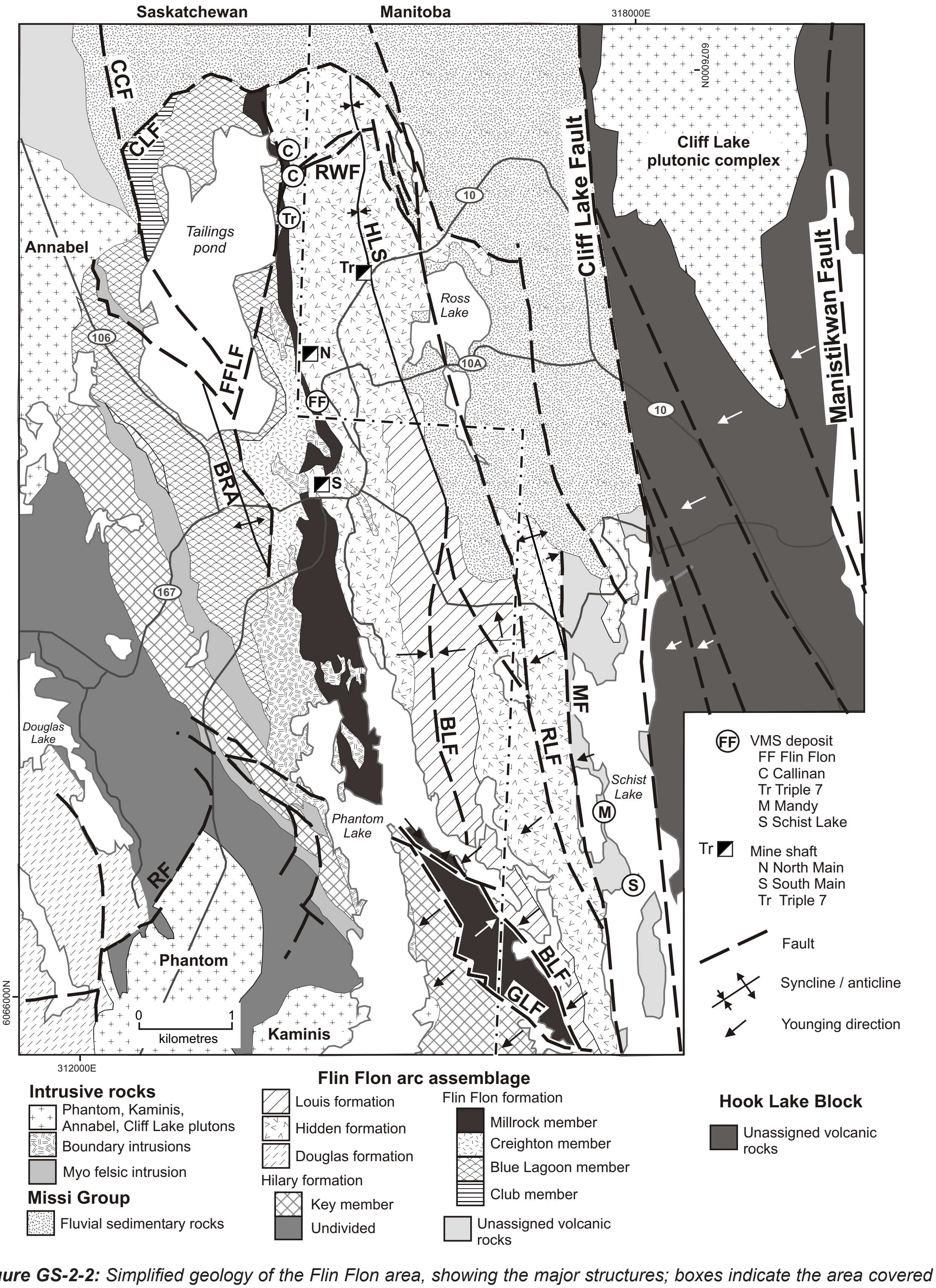

Figure GS-2-2: *Simplified geology of the Flin Flon area, showing the major structures; boxes indicate the area covered by recent 1:5000 scale bedrock mapping. Abbreviations: BLF, Burley Lake Fault; BRA, Beaver Road anticline; FFLF, Flin Flon Lake Fault; GLF, Green Lake Fault; HLS, Hidden Lake syncline; MF, Mandy Road Fault; RF, Rio Fault; RLF, Ross Lake Fault; RWF, Railway Fault.*

Fault belong to the Flin Flon Block, which includes the Flin Flon, Callinan and Triple 7 massive sulphide deposits. Rocks east of the Cliff Lake Fault, which are the subject of this report, belong to the Hook Lake Block (Figure GS-2-2).

Bedrock geology of the Hook Lake Block

The Hook Lake Block is bounded by the Manistikwan Lake Fault on the east, and the Cliff Lake Fault on the west (Bailes and Syme, 1989; Figure GS-2-2). Mapping in the Hook Lake Block during 2007 focused on the northern portion (Figure GS-2-2). The simplified geology of the area is shown in Figure GS-2-3.

Bedrock exposure in the Hook Lake Block is generally very good and consists of approximately 30–50% lichen-free outcrop that decreases in amount, size and quality east of the Cliff Lake plutonic complex (Figure GS-2-3). The exposed sequence faces west to southwest (Bailes and Syme, 1989) and, according mapping in 2007 and unpublished geochemical data (K. Gilmore, pers. comm., 2007), consists of two distinct volcanic sequences separated by the Hook Lake Fault and the Cliff Lake plutonic complex (Figure GS-2-3, -4). Variably textured mafic and felsic dikes and plugs intrude both sequences.

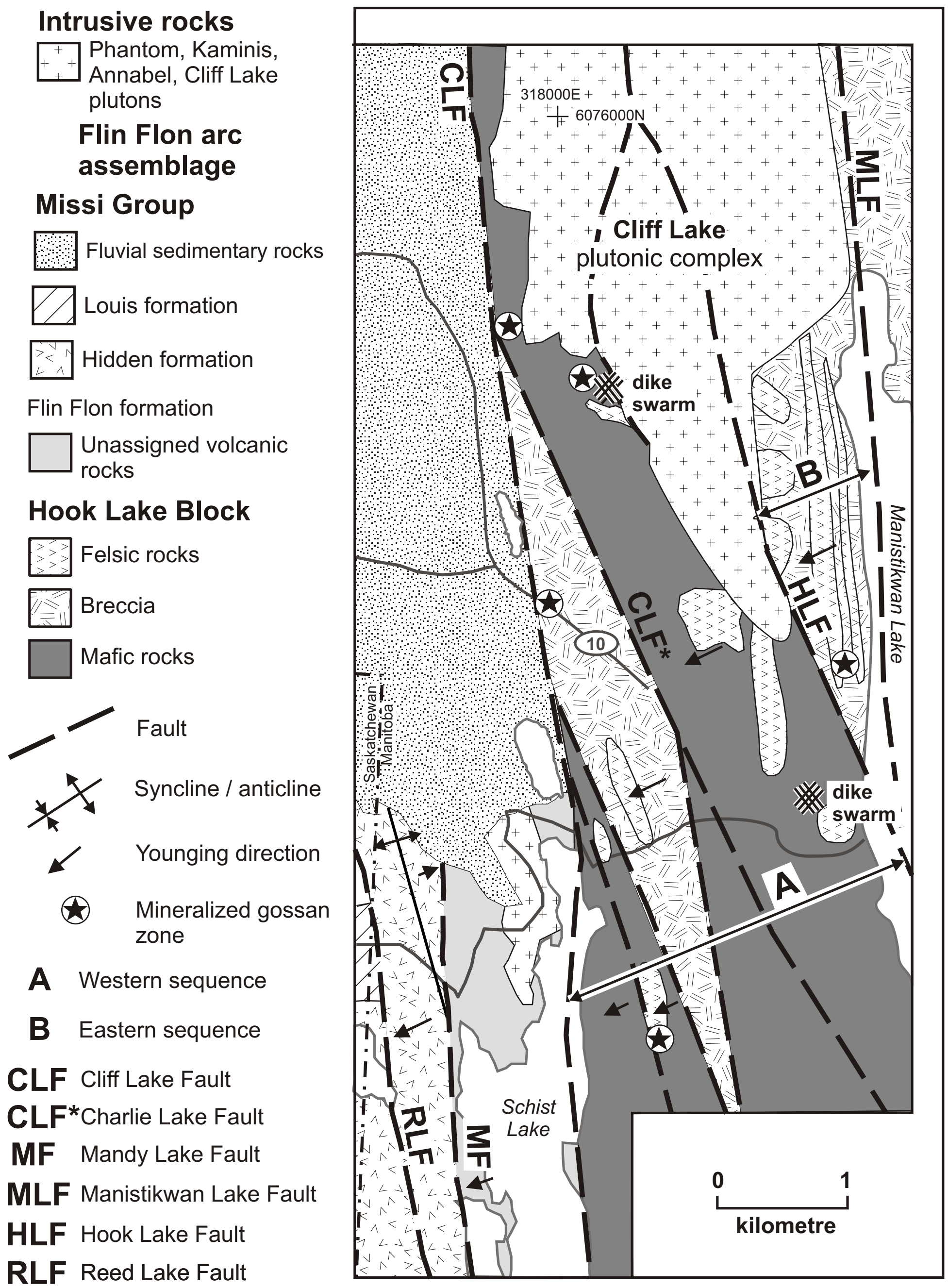

Figure GS-2-3: *Simplified bedrock geology of the Hook Lake Block, Flin Flon, Manitoba.*

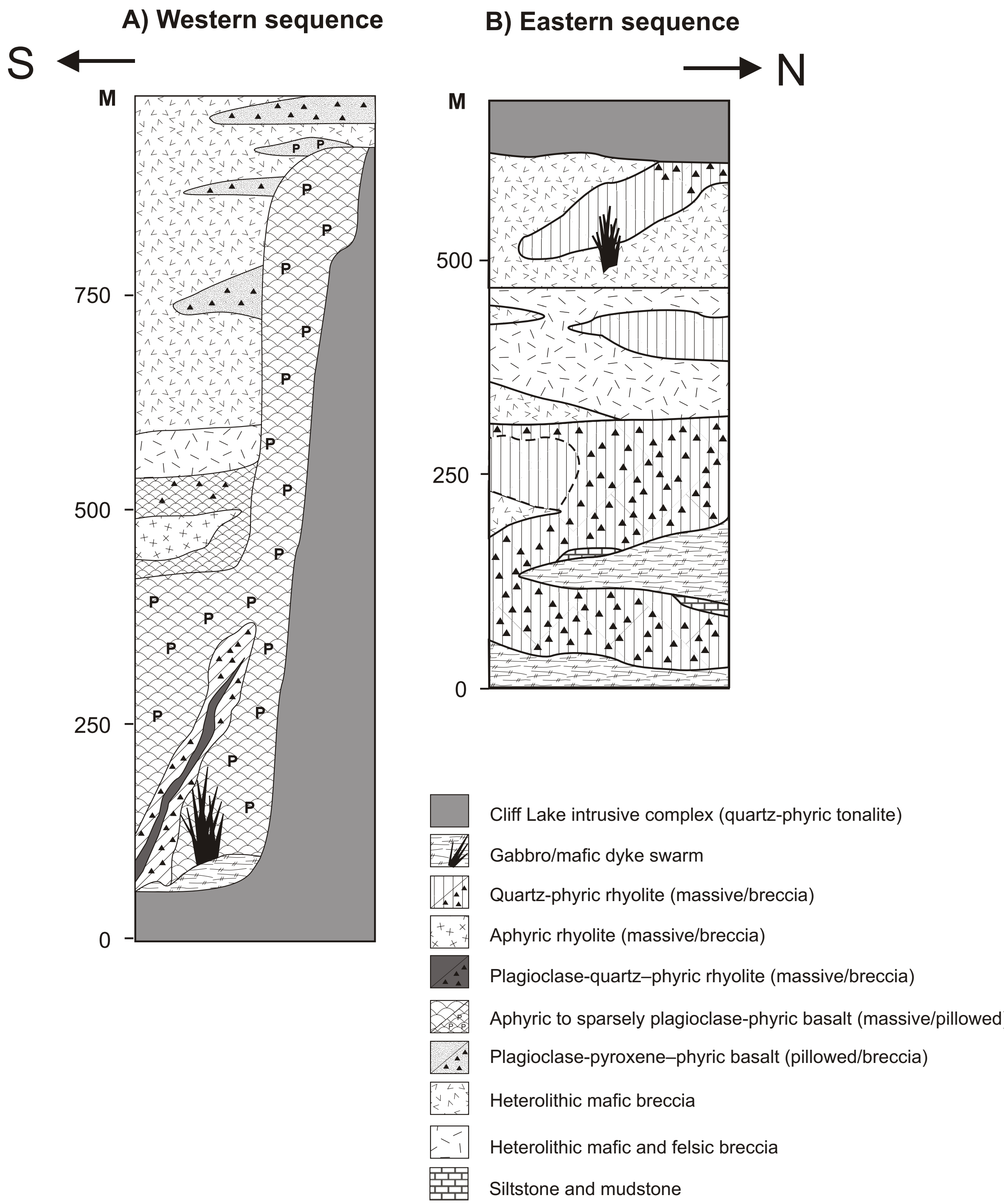

***Figure GS-2-4:** Schematic stratigraphic section of the Hook Lake Block, Flin Flon: **a)** western sequence, **b)** eastern sequence.*

All rocks in the area are moderately to highly fractured and show varying amounts of alteration. Rocks up to 0.5 km west of the Cliff Lake intrusive complex are hornfelsed. Samples of all rock types were collected for thin section and whole rock geochemical analysis. Results are pending.

The western sequence, located between the Cliff Lake plutonic complex and the northwest-trending Hook Lake Fault, consists largely of aphyric to sparsely feldspar-phyric basaltic flows and strongly feldspar-phyric basaltic flows and associated volcaniclastic rocks. It also includes lesser amounts of variably quartz-feldspar–phyric rhyolitic flows and domes, and overlying heterolithic mafic to mafic–felsic breccia interlayered with plagioclase- and pyroxene-phyric pillowed and amoeboid pillowed basaltic flows and breccia (Figure GS-2-4). This sequence is equivalent to the Grant Lake sub-block of the Hook Lake Block, as defined by Bailes and Syme (1989).

The eastern sequence, located east of the Cliff Lake plutonic complex and the northwest-trending Hook Lake Fault, consists of poorly exposed massive to fragmental quartz- and feldspar-phyric rhyolite flows in a thick package of heterolithic mafic to mafic–felsic breccia (Figure GS-2-4).

Western sequence

Volcanic rocks

Aphyric to sparsely feldspar-phyric basalt flows

A thick sequence of southwest-facing, aphyric to sparsely feldspar-phyric basaltic flows occurs at the base of the western sequence. They are best exposed between Highway 10 and the northwest arm of Schist Lake and, to the north, immediately west of the Cliff Lake plutonic complex. The basalt weathers brown to black and is dark grey to green on fresh surfaces. Individual flows include pillowed and/or massive, and amoeboid basalt capped by amoeboid flow-top breccia. In the north, thick 30–60 m successions of pillowed flows are intercalated with minor massive basaltic flows. In the south, massive basalt forms approximately 30% of observed flows. They are generally <10 m thick and characterized by lack of internal structure; oblate to irregular, elongate zones of epidosite alteration; and an increase in quartz-feldspar–filled amygdules (10%) and quartz-filled gas cavities (up to 5 cm) towards their top. Thick upper selvages and thermal contraction cracks were observed at the tops of a few massive flows. Pillowed basalt is abundant and forms the basal unit of individual flows where massive basalt is absent. Throughout this western sequence, pillow selvages are well developed and nonrecessive, and range between 0.5 and 1.5 cm in thickness. Pillow size decreases upsection, from 0.5–2.5 m at the base to 0.2–0.8 m at the top. Pillows are close packed and flows contain <15% epidotized hyaloclastic interpillow material. Syngenetic hydrothermal quartz-epidote alteration occurs throughout pillowed flows and is most pronounced in pillow cores (Figure GS-2-5a). Centimetre-scale concentric zoning from the selvage to the core of individual pillows is locally present (Figure GS-2-5b). Up to 30% quartz–, quartz-feldspar– or chlorite–filled amygdules (1–10 mm) are common throughout pillowed flows, with larger amygdules concentrated at the rims and smaller ones concentrated in the cores of individual pillows. Pillow forms are generally well preserved and locally indicate southwest younging. Amoeboid breccia contains 10–40 cm irregular clasts within highly epidotized matrix, and occurs at the top of most aphyric flows.

Complete aphyric flow assemblages are readily mapped where relatively clean and continuous exposure exists. Measured flow thickness is variable, and ranges from as little as 10 m up to 75 m. Although centimetre- to metre-scale parasitic folds exist throughout aphyric mafic flows, stratigraphic relationships and pillow morphology consistently indicate southwest tops and the sequence to be homoclinal.

Aphyric basalt grades westward into weakly feldspar-phyric varieties with <5%, fine-grained (1–2 mm), euhedral feldspar phenocrysts. No sharp contacts were observed between the two units, and the transition seems to be at a consistent distance from the Cliff Lake plutonic complex to the east. The latter may reflect destruction of the small feldspar phenocrysts in the contact metamorphic aureole of the intrusion rather than an 'appearance' at a specific distance from the pluton.

Feldspar-phyric basalt

A thin veneer of feldspar-phyric mafic breccia occurs within aphyric basaltic flows at the south margin of the map area, west of Highway 10. The unit is clast supported, with <10% fine-grained, strongly foliated chloritic matrix containing abundant plagioclase crystal fragments up to 3 mm in size. Clasts are composed exclusively of moderately to strongly feldspar-phyric basalt with 15–20%, 2–5 mm, euhedral to subhedral plagioclase phenocrysts. Approximately 10% quartz- and feldspar-filled amygdules (1–2 mm) are present in all clasts. Clasts are rounded to subangular and 5–25 cm in size, and locally show moderate degrees of stretching with weak subparallel alignment. One narrow body of pillowed feldspar-phyric basaltic flow was observed but could not be traced. Feldspar-phyric basaltic flows are not present in the stratigraphy in the northern part of the map area.

Quartz- and feldspar-phyric rhyolite

Rhyolite weathers buff white and is pale blue-grey on fresh surfaces. It contains 5–10%, 2–5 mm quartz±feldspar phenocrysts. Massive rhyolite, which is homogeneous throughout its extent, usually has associated lenses of weakly to well-developed autoclastic breccia occurring at the top or on the lateral margins of massive rhyolitic flows/domes. At one locality, west of the Cliff Lake pluton, a mafic dike swarm with associated felsic dikes and gossanous mineralized zone can be traced eastward in the stratigraphically underlying mafic volcanic rocks beneath a large quartz-feldspar–phyric rhyolitic flow and breccia. Numerous gossan zones and sulphide occurrences were observed in close association with rhyolitic flows and breccia units throughout the Hook Lake Block (Figure GS-2-3; *see* 'Discussion and economic considerations' section).

Foliation in the rhyolitic rocks is generally manifested as sets of spaced to closely spaced fracture cleavage. It subparallels the dominant schistosity in spatially associated mafic volcanic and volcano-sedimentary rocks.

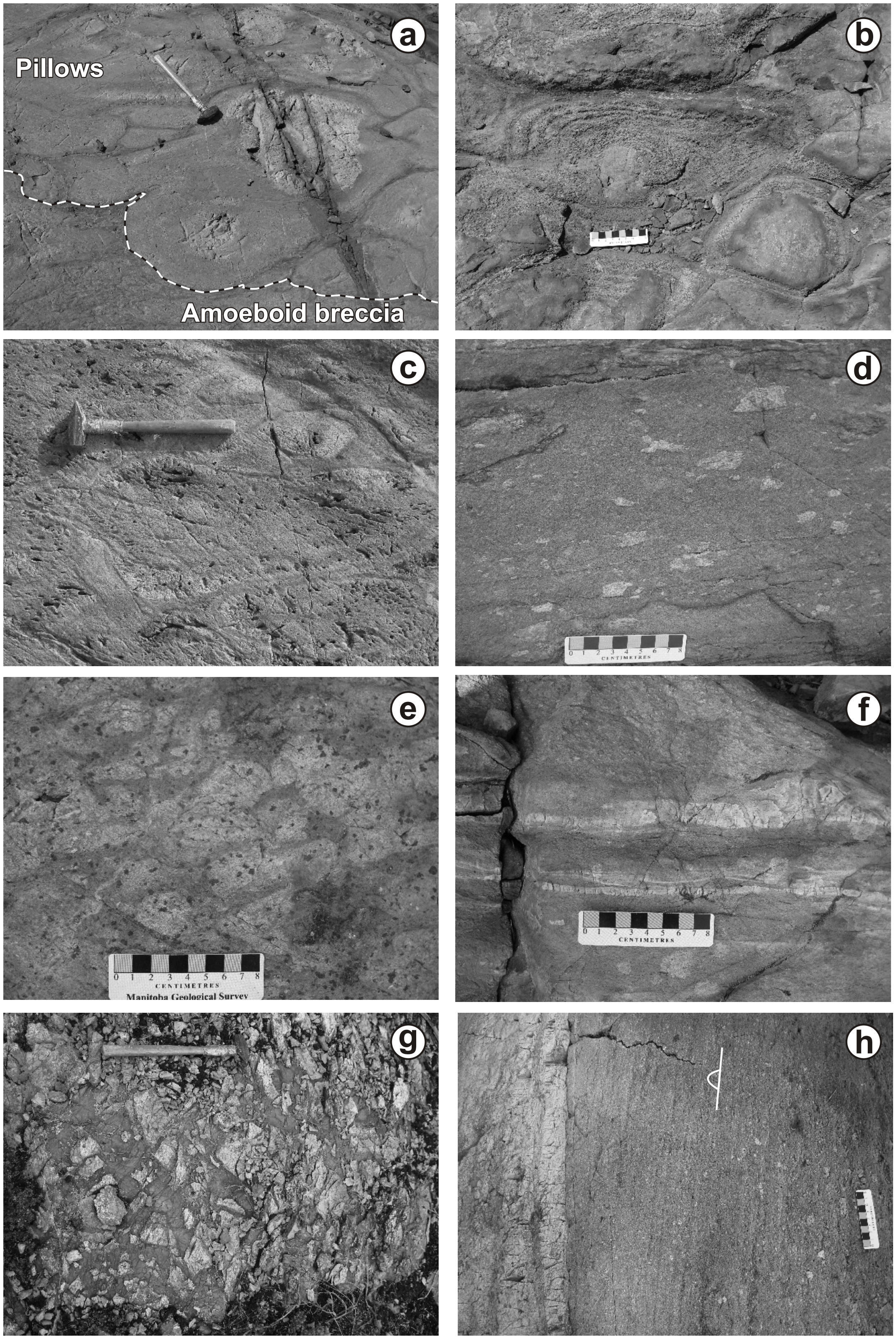

Figure GS-2-5: *Photographs of various units of the Hook Lake Block:* ***a)*** *syngenetic hydrothermal quartz-epidote alteration in aphyric pillowed flows, with hammer for scale;* ***b)*** *centimetre-scale concentric zoning in aphyric pillows;* ***c)*** *plagioclase- and pyroxene-phyric pillow basalt;* ***d)*** *heterolithic, clast-supported, mafic–felsic volcanic breccia;* ***e)*** *mono-lithic plagioclase- and pyroxene-phyric volcanic breccia;* ***f)*** *bedded fine-grained tuff (bottom) and scoriaceous lapilli tuff (top);* ***g)*** in situ *brecciation of massive rhyolite by iron-carbonate alteration; and* ***h)*** *graded bedding in reworked volcanic rocks, with tops to the west.*

Plagioclase- and pyroxene-phyric basalt

Plagioclase- and pyroxene-phyric pillowed basalt flows weather buff-beige to brown and has dark green to grey fresh surfaces. Pillows range in size from 0.1 to 2 m, and average size varies across stratigraphy, generally decreasing towards the top of flows. Stubby to equant pyroxene phenocrysts (10–15%), 2–6 mm in diameter, are the most distinctive feature of this rock. Fine-grained plagioclase phenocrysts, 0.5–3 mm in diameter, constitute 10–15% of the basalt. Pillow selvages are typically thin (0.5 cm) but locally increase in thickness up to 2 cm. Pillows are closely packed and contain very minor interpillow material. Where observed, interpillow material consists of epidotized and weakly to moderately silicified hyaloclastic material. Quartz-filled amygdules and gas cavities (5–20%), locally reaching 6 cm in size, occur in the majority of pillows and are concentrated around the rims of individual pillows *(*Figure GS-2-5c*)*. Amygdules show a general increase in size and abundance towards the top of flows. Southwest-younging topping directions, based on pillow forms and flow architecture, can be determined with confidence where clean exposures exist. Eyebrow structures with recessive filling were observed at one outcrop and displayed tops consistent with those derived from pillow forms. Because they are parallel to, and may be related to, a prominent fracture set, care must be taken in their interpretation.

Amoeboid pillow breccia, which locally contains up to 20% epidotized matrix, is gradational with pillowed basaltic flows. At some locations west of Highway 10, where amoeboid pillow breccia forms traceable units that stratigraphically overlie pillowed basalt, it is interpreted to represent the tops of flows. In an excellent exposure east of Mud Lake, however, amoeboid pillow breccia occurs as irregular, discontinuous zones within a coherent pillowed flow, and its relationship to the pillowed portion is not clear.

Volcaniclastic rocks

Monolithic to heterolithic mafic to mafic–felsic breccia

Reworked volcanic rocks (Figure GS-2-5d) intercalated with plagioclase- and pyroxene-phyric basalt occur predominantly, but not exclusively, in a basin towards the top of the western sequence. Their weathered and fresh surfaces are similar to those of the underlying volcanic flows. The basal unit consists of clast- to locally matrix-supported, poorly sorted, heterolithic mafic–felsic breccia. Clasts range from 2–100 cm in size and include quartz-feldspar–amygdaloidal aphyric, plagioclase-phyric, and plagioclase-pyroxene–phyric basalt; mafic scoriaceous lapilli; and feldspar±quartz–phyric rhyolite. Felsic clasts are generally slightly larger than mafic types and show greater angularity.

In the south, this unit is intercalated with plagioclase-pyroxene–phyric basalt flows. Where the breccia immediately overlies these flows, it contains clasts that are almost exclusively (95%) subangular to rounded plagioclase-pyroxene–phyric basalt. They range in size from 2 to 30 cm and contain varying amounts of quartz- and feldspar-filled amygdules *(*Figure GS-2-5e*)*. The remaining quartz- and feldspar-phyric rhyolite clasts (5%) are angular to subangular and 5–50 cm in diameter, and contain quartz 'eyes' up to 0.5 cm in size. Gradational changes in the breccia occur upsection. Fragments of aphyric basalt, moderately to strongly feldspar-phyric basalt with 15–20%, 2–5 mm plagioclase phenocrysts, and highly vesicular mafic scoriaceous lapilli <5 cm in size begin to appear in abundance. The average size of the clast population decreases upsection to less than 10 cm, the proportion of felsic clasts increases to approximately 20%, and the amount of matrix increases to a maximum of 15–20%. Bedded tuff and scoriaceous lapilli tuff are locally present throughout the section (Figure GS-2-5f).

In the north, similar breccia units are observed with a slightly different 'stratigraphy'. Heterolithic mafic–felsic breccia dominates the base of the basin, with 5–20% angular to subangular, 2–40 cm clasts of aphyric to slightly porphyritic rhyolite mixed with a variety of subrounded, 0.5–25 cm mafic clasts (highly amygdaloidal aphyric basalt, plagioclase-phyric basalt and plagioclase-pyroxene–phyric basalt). These heterolithic mafic–felsic breccia units are locally intercalated with heterolithic mafic breccia, with sharp bedding contacts locally developed.

The matrix of volcaniclastic breccia in the western sequence is composed of chlorite±actinolite, with varying amounts of plagioclase (±pyroxene) crystals and crystal fragments. The matrix typically displays a pronounced anastomosing foliation. Primary sedimentary features are rare in volcaniclastic units of the western sequence and, as a result, reliable top determinations are scarce.

Eastern sequence

The eastern sequence is characterized by the absence of mafic volcanic flows in the stratigraphy. It is dominated by a sequence of reworked volcanic rocks interlayered with aphyric to quartz- and feldspar-phyric rhyolite flows.

West of Manistikwan Lake, rhyolite similar in appearance to rhyolite observed within the western sequence occurs in abundance. It outcrops as both laterally continuous layers and irregular discontinuous lobes. Basal massive rhyolitic flows, which weather white and have blue-grey fresh surfaces, are typically aphyric or contain 5–10%, 2–5 mm quartz and feldspar phenocrysts. Massive rhyolite is typically capped by monolithic felsic breccia and locally overlain by well-bedded, fine- to very fine grained felsic tuff. Felsic breccia is clast supported, with a general increase in the amount of matrix and decrease in the size of clasts upsection. Matrix material is primarily chlorite±sericite and is sometimes highly silicified. At one location southeast of the Cliff Lake pluton in an otherwise massive quartz-phyric rhyolite, a narrow zone of intense iron-carbonate alteration has formed an *in situ* pseudobreccia (Figure GS-2-5g).

Reworked volcanic rocks in the eastern sequence consist of monolithic aphyric basalt breccia, heterolithic mafic lapilli tuff to breccia, heterolithic mafic–felsic breccia and minor laminated mafic and felsic tuff. Volcanic breccia is clast to matrix supported and shows variations in clast size and clast population across section. Bedding is readily observed throughout the eastern sequence and can occasionally be used for reliable top determinations (Figure GS-2-5h). Two small outcrops of interbedded pebble conglomerate, greywacke and laminated siltstone were observed on the western shore of Manistikwan Lake, but they could not be traced due to large gabbroic intrusions in the vicinity.

Intrusive rocks

Several generations of mafic and felsic intrusions crosscut all rock types within the stratigraphy of the Hook Lake Block. The most abundant intrusive phase consists of numerous mafic dikes trending northwest to north-northwest. Mafic dikes are ubiquitous throughout the stratigraphy, in some cases forming more than 80% of outcrop. There is abundant variation in the texture and mineralogy of mafic dikes, including 1) plagioclase- and pyroxene-phyric dikes containing up to 60% plagioclase and pyroxene phenocrysts, which are 2–4 mm near dike margins and increase to >1 cm in the centre; 2) aphanitic to very fine grained basaltic dikes, with locally compound margins; and 3) feldspar-phyric dikes of intermediate composition, with 25%, 3–6 mm euhedral feldspar phenocrysts concentrated towards their centres. Larger equivalents of these dikes east of the northwest arm of Schist Lake and west of Manistikwan Lake include fine-grained, equigranular, oikocrystic and plagioclase-glomeroporphyritic gabbroic phases (Figure GS-2-6a, b). Minor shearing is localized along the contacts of some dikes.

Numerous aphyric to feldspar-phyric rhyolite dikes and domes occur throughout the Hook Lake Block. Narrow dikes generally trend north and typically crosscut mafic dikes and dike swarms. Larger lenticular to irregular rhyolite intrusions with numerous offshoots (<3 m in width) occur west of Manistikwan Lake, east of Mud Lake, west of the Cliff Lake pluton and surrounding the southern segment of the Cliff Lake pluton.

The northeastern portion of the map area is dominated by the Cliff Lake plutonic complex. The Cliff Lake pluton is very well exposed and forms a prominent topographic high in the area. The majority of the Cliff Lake pluton is composed of medium- to coarse-grained, quartz-phyric tonalite with 30%, 0.5–1 cm quartz phenocrysts. Quartz diorite phases are abundant along the western and southern edges. The margins of the Cliff Lake pluton are characterized by abundant xenoliths of mafic volcanic rocks (locally up to 75%). Xenoliths range from less than 0.1 m to many tens of metres in size, display baked margins and are locally partially resorbed. Primary volcanic features are well preserved in larger xenoliths (Figure GS-2-6c, d). Features in volcanic rocks adjacent to the Cliff Lake pluton to the west and south have been overprinted and homogenized by recrystallization due to the thermal effects of the intruding body (contact metamorphism?).

A small intrusion of melagabbro norite southwest of the Cliff Lake pluton is coarse- to very coarse grained. It displays a 'knobby' texture and contains 60% clinopyroxene (0.5–2 cm), 20% orthopyroxene and 20% interstitial anhedral plagioclase (Figure GS-2-6e).

Structural geology and kinematics

The dominant structural features in the map area are the north- to northwest-trending, block-bounding Cliff Lake and Manistikwan Lake faults. The Manistikwan Lake Fault is located just off the western shore of Manistikwan Lake and not exposed in the map area. The Cliff Lake Fault is similarly hidden, although an excellent exposure occurs in a quarry just east of Highway 10 prior to the Flin Flon turn-off. The Cliff Lake Fault, which trends north-northwest, is approximately 15 m wide at its maximum and juxtaposes volcanic and volcaniclastic rocks of the Hook Lake Block to the east with fluvial sedimentary rocks of the Missi Group to the west. Close examination of the Cliff Lake Fault indicates two generations of movement. The dominant, early movement forms a pervasive mylonitic ductile foliation with well-developed dextral S-C fabrics (Figure GS-2-6f). This early fabric is overprinted by multiple sets of small-scale conjugate kink bands with steep axes, consistent with shortening subparallel to the trend of the fault. The early mylonitic fabric is further crosscut by coincident quartz-chlorite–filled tension-gash structures with associated pyrite plus minor chalcopyrite mineralization. The tension gashes are at an angle of 10–15º counterclockwise and locally offset by sinistral shear bands subparallel to the tension gashes. The strain gradient into the Cliff Lake Fault is very sharp. Immediately west, approximately 3 m beyond the fault margin, polymictic conglomerate of the Missi Group shows only weak deformation and no evidence of shearing.

Numerous ductile-brittle splays, 0.5–5 m wide, emanating from the Cliff Lake Fault truncate and disrupt the stratigraphy of the Hook Lake Block in the map area. Kinematic indicators are sparse along these subsidiary structures but, where noted, show both dextral and sinistral shear sense (Figure GS-2-6g, h). It is currently unclear whether the deformation history of these structures is akin to that noted in the Cliff Lake Fault (i.e., early dextral followed by minor sinistral reactivation).

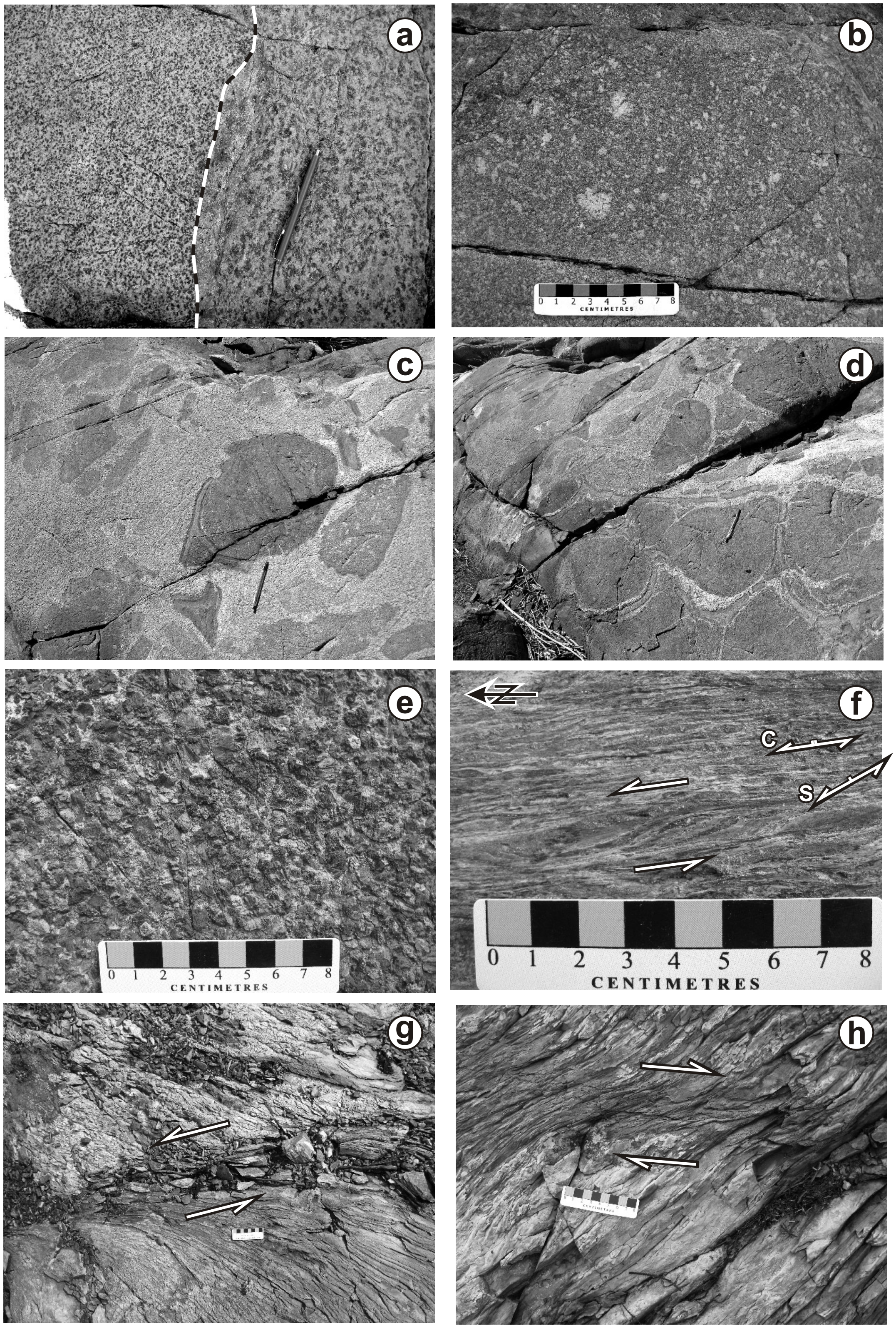

Figure GS-2-6: *Photographs of various intrusive and structural relationships in the Hook Lake Block:* ***a)*** *intrusive contact between pyroxene-phyric (left) and oikocrystic gabbro (right), with pen magnet for scale;* ***b)*** *plagioclase-glomeroporphyritic gabbro;* ***c)*** *xenoliths of aphyric pillow basalt in the Cliff Lake pluton, with pencil for scale;* ***d)*** *large screen of pillow basalt intruded by tonalite–quartz diorite of the Cliff Lake pluton, with pencil for scale;* ***e)*** *knobby-textured melagabbro norite west of the Cliff Lake pluton;* ***f)*** *prominent dextral S-C fabric in the Cliff Lake Fault;* ***g)*** *narrow shear zone showing sinistral shear sense; and* ***h)*** *narrow shear zone showing dextral shear sense.*

The Hook Lake Fault trends northwest and separates the western and eastern sequences. It is consistent in appearance, orientation and kinematics with splays from the Cliff Lake Fault; however, it has not itself been traced directly into the Cliff Lake Fault.

Two foliations (local S_1 and S_2) occur throughout the Hook Lake Block rocks. The S_1 foliation is present in all volcanic and volcaniclastic rocks, trends between 320 and 355º, and is subparallel to the Cliff Lake Fault and its associated splays. The overprinting S_2 foliation, which is in the majority of outcrop, is generally oriented 10–20º clockwise to S_1. The orientation of the S_2 foliation is consistent with, and may be related to, a sinistral reactivation event on the Cliff Lake Fault. Further thin section analysis is pending to test this interpretation.

Despite the abundance of outcrop, good exposures of x-y foliation planes are rare, thus rendering the systematic collection of lineation data rather difficult. This is further hindered by the small angle separating the two dominant foliations. Where observed, stretching, mineral and intersection lineations show a consistent shallow to moderate southeast plunge. It is likely that multiple generations of subparallel lineations exist in the map area, but they currently cannot be assigned to a particular deformation event.

Discussion and economic considerations

The stratigraphy of the western sequence is very well documented and, up to Charlie Lake Fault, seems little affected by major structures west of the Cliff Lake plutonic complex. The thick sequence of mixed heterolithic breccia, both felsic and mafic, overlying the aphyric to sparsely feldspar-phyric basaltic flows is interpreted to represent proximal resedimentation of pre-existing mafic and felsic volcanic rocks into a subsidence structure and/or basin within the Hook Lake Block. The northern margin of this preserved basin seems to be marked by the mafic dike swarm with associated felsic dikes east of Grant Lake. This dike swarm, which traces eastward into the underlying mafic volcanic rocks stratigraphically beneath a large quartz-feldspar–phyric rhyolitic flow and breccia, is associated with gossanous mineralized zones (Figure GS-2-3). Grab samples from an old trench in the mineralized zone contain massive, thinly layered pyrrhotite and pyrite with minor chalcopyrite. Assay results are pending. Mafic flows immediately surrounding the trench show noteworthy quartz-epidote alteration patches, which are interpreted to have resulted from paleohydrothermal activity in this area.

The southern segment of the western sequence has been more substantially affected by deformation. The thick sequence of heterolithic breccia filling the subsidence basin has been dismembered by several north-northwest–trending splays off the Cliff Lake Fault, resulting in discontinuous screens of partial stratigraphic sections juxtaposed against one another. This is particularly prominent east of Mud Lake.

Narrow sulphide zones associated with the contact of gabbroic to fine-grained mafic dikes have been observed in a few locations throughout the western sequence. They mostly occur where mafic dikes crosscut massive felsic rocks. The observed mineralization consists of disseminated pyrrhotite (<5%) with some pyrite (<2%).

Very old trenches, along with recent drill pads, are located just north of the Channing Road turn-off in the swamp. Scattered outcrops of mafic breccia in this area contain well-developed gossan with disseminated pyrrhotite and minor pyrite (2–20%; Gale and Eccles, 1988).

Rocks of the eastern sequence are composed mainly of laterally continuous breccia layers with subordinate mafic flows. A significant proportion of the breccia is felsic in composition, or contains felsic as well as mafic clasts. The abundance of breccia, combined with a lack of flows, suggest that these rocks, similar to those of the western sequence, could represent proximal resedimentation of pre-existing felsic and mafic volcanic rocks into a subsidence structure and/or basin.

Rocks in the eastern sequence have been heavily explored for copper-zinc since the 1930s. Primary sulphide associated with rhyolite flows occurs as discontinuous lenses and lobes of disseminated (<10%), stringer to locally semimassive (20–30%) pyrite±pyrrhotite, sphalerite and chalcopyrite. Mineralization occurs either at the contact between massive and fragmental rhyolite flows, within fragmental rhyolite or between fragmental rhyolite and overlying volcanic-volcaniclastic rocks. An example of the latter occurs approximately 300 m west of Manistikwan Lake, just south of the Cliff Lake plutonic complex. This sulphide occurrence has been previously documented (Gale and Eccles, 1988, occurrence 61) and been the focus of drilling by Hudson Bay Exploration and Development Co. Ltd. in the early 1980s. Parts of the zone have prominent sphalerite mineralization, with assays up to 12% Zn reported by Gale and Eccles (1988). The association of mineralization with the fragmental rhyolite flows suggests potential for volcanogenic massive sulphide–type mineralization in the area (Gale and Eccles, 1988).

Remobilized sulphide has been observed in and close to the Cliff Lake Fault and associated faults. The mineralizing event in the Cliff Lake Fault exposure at the quarry off Highway 10 can be correlated with the second (sinistral) movement along the fault, as evidenced by the presence of sulphide (pyrite±minor chalcopyrite) in association with crosscutting quartz-chlorite tension gashes. If larger or more strongly developed structures related to this deformation event are present elsewhere in the region or even the belt, they could represent future exploration targets.

Overall, recent mapping in the Hook Lake Block has highlighted many similarities between these rocks and those of the neighbouring Flin Flon Block. Both blocks contain volcanic stratigraphy displaying significant subsidence and/or basin structures with associated felsic volcanism plus or minus VMS-type mineralization. However, a direct assessment of the potential link between the western or eastern stratigraphy of the Hook Lake Block and that of the Flin Flon Block is still premature. Heterolithic breccia sequences and felsic volcanic rocks, which are similar to those found in the Flin Flon Block spatially associated with the Flin Flon–Callinan–Triple 7 mines (Figure GS-2-2; Bailes and Syme, 1989; Devine, 2003; DeWolfe and Gibson, 2006) and the Schist and Mandy VMS deposits (Figure GS-2-2; Bailes and Syme, 1989; Simard, 2006; Simard, GS-1, this volume; Cole et al., GS-3, this volume), are found in the map area. However, further analytical work (geochemistry, isotopes and geochronology) is required before a more complete comparison with the ore-hosting sequences at Flin Flon and Schist Lake can be made.

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