GS-3 Preliminary description of the lithofacies and structure of the Schist Lake mine area, Flin Flon, Manitoba (part of NTS 63K12)

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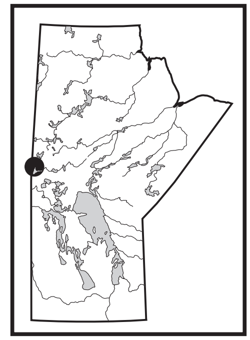

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Summary

The goal of this two-year research project is to characterize and describe the Schist Lake and Mandy volcanogenic massive sulphide (VMS) deposits and their hostrocks. A further objective is to determine if these VMS deposits are time stratigraphic equivalent to those occurring in the main Flin Flon camp. The first year of this two-year project focused on the Schist Lake mine area, where detailed lithofacies and alteration-facies maps were completed, along with detailed field descriptions of each lithofacies. The mine is hosted by a succession of mafic and felsic volcaniclastic rocks that were deposited in a submarine basin. The rocks are strongly deformed throughout the map area, although there is a marked increase in deformation close to a north-northwest–trending sinistral shear zone that divides the peninsula on which the mines occur into eastern and western blocks. Within this shear zone, the Schist Lake orebody occurs as a series of ore lenses that plunge steeply to the east, parallel to a strong lineation. The distribution of the chlorite alteration facies suggests that the eastern block is part of the footwall to the Schist Lake deposit, whereas the small localized patches of iron staining and sericite alteration in the western block are consistent with the latter alteration being part of the hangingwall to the deposit. However, given the unknown amount of displacement within the shear zone, alteration facies in the western block may be unrelated to the Schist Lake deposit.

Introduction

The Flin Flon district, which lies within the Paleoproterozoic Flin Flon Belt, is well known for its volcanogenic massive sulphide deposits. Six current (Callinan, Triple 7 and Trout Lake) and past-producing (Flin Flon, Mandy and Schist Lake) VMS deposits occur in the immediate vicinity of the town of Flin Flon, which makes this area one of the most productive base-metal districts in Canada. Recent detailed regional mapping in the Flin Flon area, carried out under the Targeted Geoscience Initiative (MacLachlan, 2006; Simard, 2006) and as research funded by the Natural Sciences and Engineering Research Council of Canada (NSERC; Devine et al., 2002; DeWolfe and Gibson, 2006), is designed to better characterize the camp stratigraphy and structure. The relationship between the Callinan–Triple 7–Flin Flon and the Schist Lake–Mandy deposits remains unresolved and is an important question. The object of this research is to document the volcanic and structural setting of the Schist Lake and Mandy deposits, record the alteration types associated with these deposits and, ultimately, assess the viability of correlating the Schist Lake–Mandy deposits with the Callinan–Triple 7–Flin Flon deposits.

Regional geology

The Paleoproterozoic Trans-Hudson Orogen (THO) is a collisional belt that extends from South Dakota through Saskatchewan, Manitoba and northern Quebec into Greenland (Figure GS-3-1). It formed during the collision of two Archean cratons, the Superior craton to the east and the Rae-Hearne craton to the west, at 1830–1800 Ma (Hoffman, 1988; Lewry and Collerson, 1990; Lewry et al., 1994; Corrigan et al., 2005).

The Flin Flon Belt has been subdivided into four main tectonostratigraphic assemblages that formed at ca. 1.90 Ga: isotopically juvenile oceanic arc, ocean floor, oceanic plateau–ocean island and isotopically evolved oceanic arc (Syme, 1990; Syme and Bailes, 1993; Stern et al., 1995). Volcanic rocks in the Flin Flon area are part of a ca. 1903 Ma juvenile arc assemblage (Syme et al., 1999), consisting mostly of subaqueous mafic rocks with associated volcaniclastic deposits and minor felsic flow and volcaniclastic rocks (Bailes and Syme, 1989). Juvenile arc assemblages host all 27 known volcanogenic massive sulphide deposits in the Flin Flon greenstone belt, including the Mandy and Schist Lake deposits.

Geology of the Schist Lake–Mandy area

The Schist Lake and Mandy mines are located 5 km southeast of the town of Flin Flon (Figure GS-3-2). The first comprehensive map of the area, completed by C.H. Stockwell in the 1940s (Stockwell, 1960), subdivided the volcanic rocks hosting the Schist Lake and Mandy deposits into andesite, basalt, dacite, dacite flow breccia, andesite breccia, quartz porphyry and quartz porphyry breccia. The rocks generally strike northwest and dip steeply to the east. Cairns et al. (1957) studied the Schist Lake and Mandy deposits, and suggested that they are hosted along strike from one another within a sericite carbonate schist, derived from a fine-grained, grey, quartz

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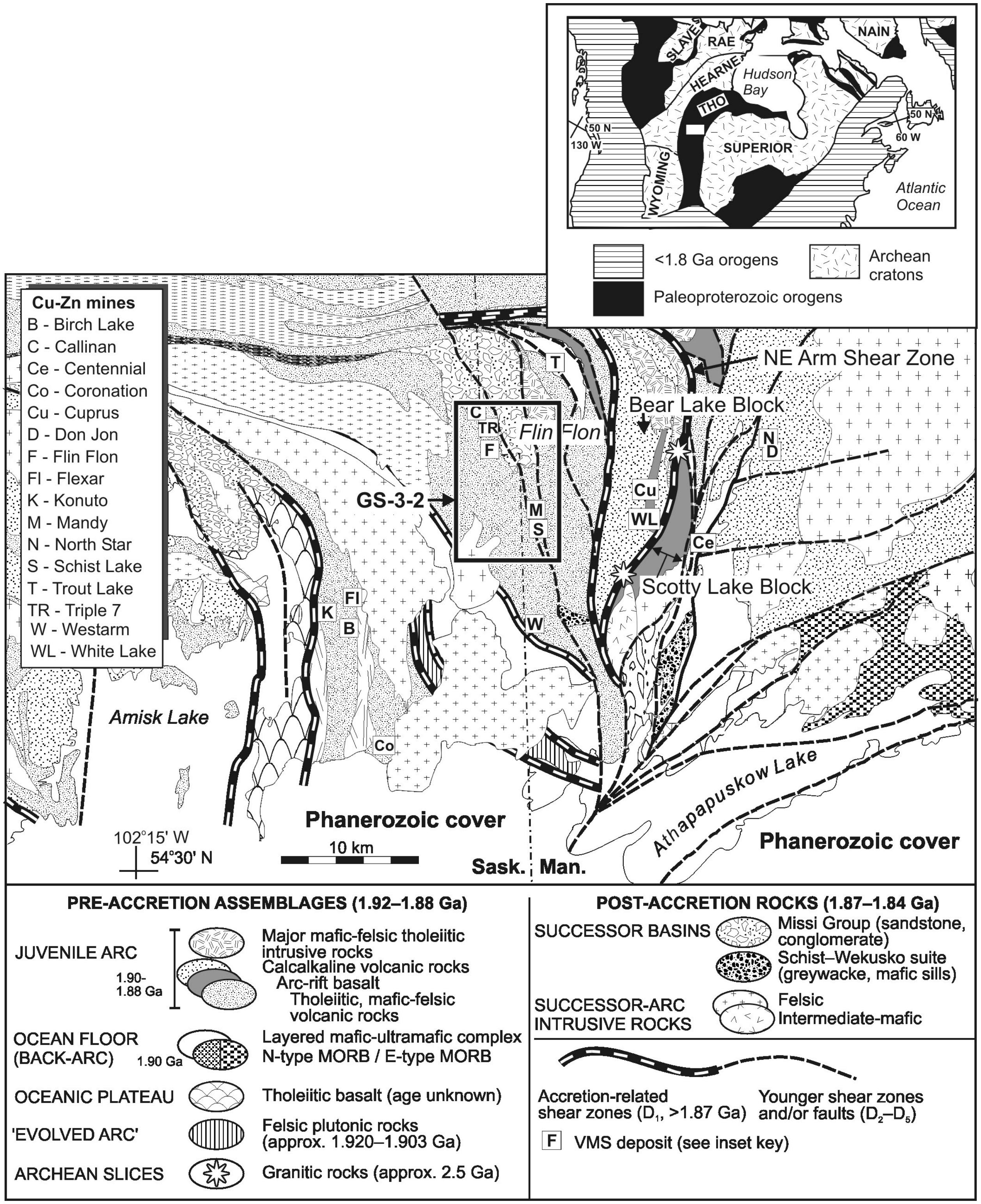

Figure GS-3-1: *Geology of the Flin Flon Belt, showing locations of known volcanogenic massive sulphide (VMS) deposits (*modified from *Syme et al., 1999); box indicates the area covered by Figure GS-3-2; inset map shows the location of the Flin Flon Belt within the Trans-Hudson Orogen (THO).*

porphyry. Level plans and sections of the Schist Lake mine, compiled and interpreted when the mine was in production from 1954 to 1976, show the orebodies occurring within a quartz porphyry unit and localized sericite schist (Cotter, 1969). Bailes and Syme (1989) further refined the mine stratigraphy and linked the deposits to a heterolithic felsic volcanic breccia that is strongly chloritized, silicified, pyritized and foliated near the orebodies.

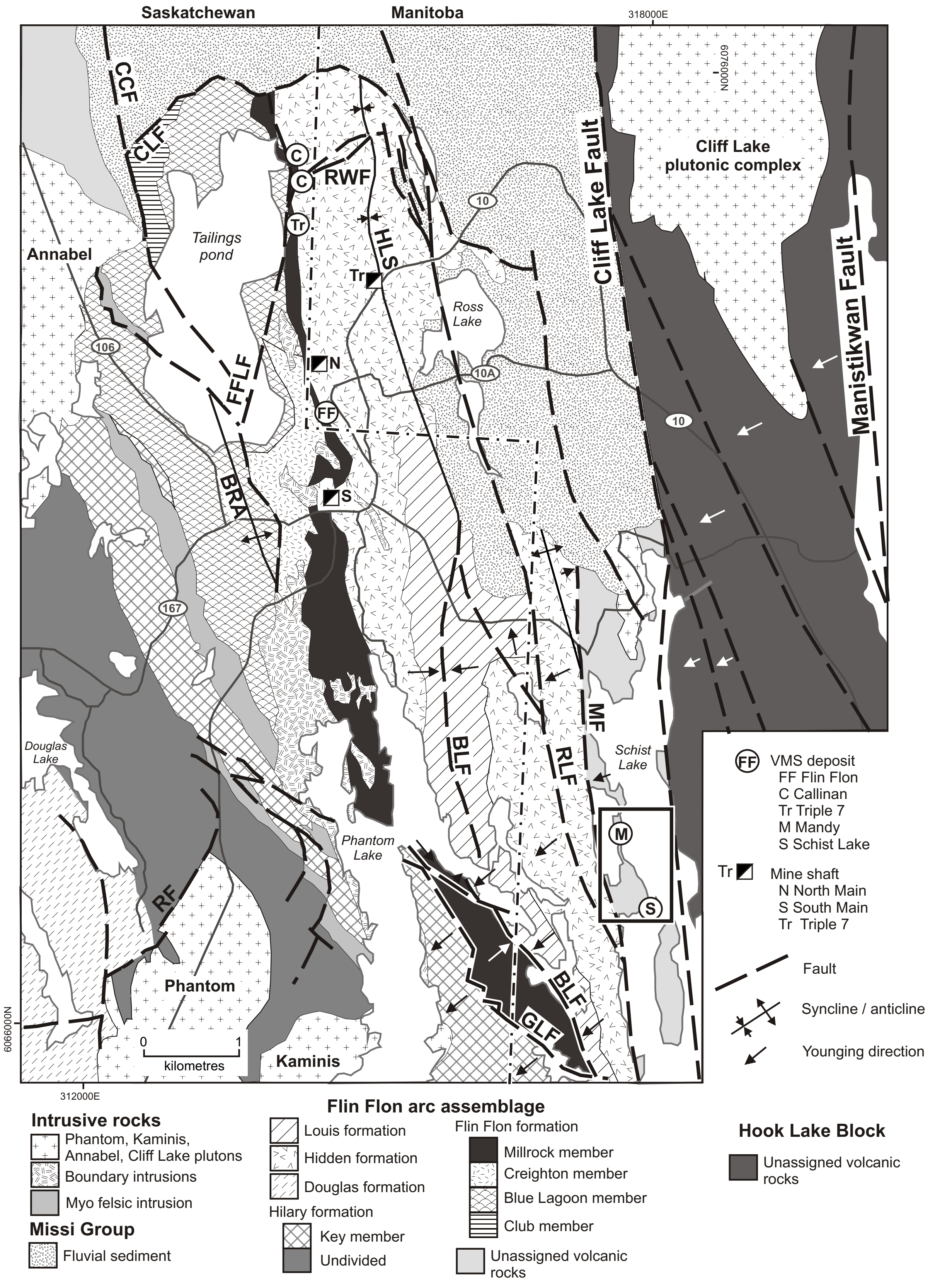

Figure GS-3-2: *Simplified geology of the Flin Flon area, showing the major structures; box indicates the location of the Schist Lake–Mandy mines area (*modified from *Simard. 2006). Abbreviations: BLF, Burley Lake Fault; BRA, Beaver Road anticline; CCF, Creighton Creek Fault; CLF, Cliff Lake Fault; 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.*

Price (Hudson Bay Exploration and Development Co. Ltd. [HBED], internal report, 1971) determined that the rocks in the Schist Lake area display two prominent foliations and a strong lineation; the foliations strike 330° and 360°, and dip steeply to the east. The pronounced stretching lineation, observed in elongated fragments and amygdules, plunges 40–50° to the south, parallel to the plunge of the Schist Lake orebody (Cotter, 1969). Price (HBED, internal report, 1971) noted that the foliation is the strongest structural element in the Schist Lake–Mandy area and that it could be an axial-planar cleavage related to the Mandy Road anticline; the intensity of the foliation is variable. Bailes and Syme (1989) considered the Schist Lake–Mandy area to occur within a fault-bounded block.

Historical review of the Schist Lake and Mandy mines

The Mandy mine was the first mine in the Flin Flon area. It was discovered in 1915 by two prospectors, S.S. Reynolds and F.C. Jackson, and was brought into production in 1916 by Hudson Bay Mining and Smelting Co. Ltd. The open pit operation closed in 1919, to be reopened temporarily in 1943, until finally being closed in 1944. During these periods of operation, 125 000 tonnes of ore grading 8.22% copper and 11.38% zinc were extracted (Gilmore, 2000). The Mandy orebody consisted of several zones: an inner core rich in chalcopyrite, surrounded by a sphalerite-rich zone of mixed sulphide, and an outer zone dominated by pyrite (Bailes and Syme, 1989). Only the chalcopyrite-rich zone was mined. The orebody was 30 m long and 4 m wide, and extended to a depth of 10 m (Bailes and Syme, 1989). The ore lenses were elongate parallel to the strike of the foliation and dipped steeply to the east (HBED, internal report, 1971). The orebody was reported to contain gold and silver (Bruce, 1918).

The Schist Lake mine was an underground mine that produced 1.88 million tonnes grading 4.21% copper and 7% zinc from 1954 until 1976 (Gilmore, 2002). The orebody consisted of two main zones, each composed of several lenses (Figure GS-3-3; HBED archive data). The north zone contained three ore lenses with a maximum size of 60 m by 300 m, whereas the south zone contained four lenses that ranged from 60–120 m in length and 300–600 m in depth (Figure GS-3-3; HBED archive data). Howkins and Martin (1970) suggested that the four lenses of the south zone may have been part of one sulphide lens that was segmented by faults. The orebody contained a

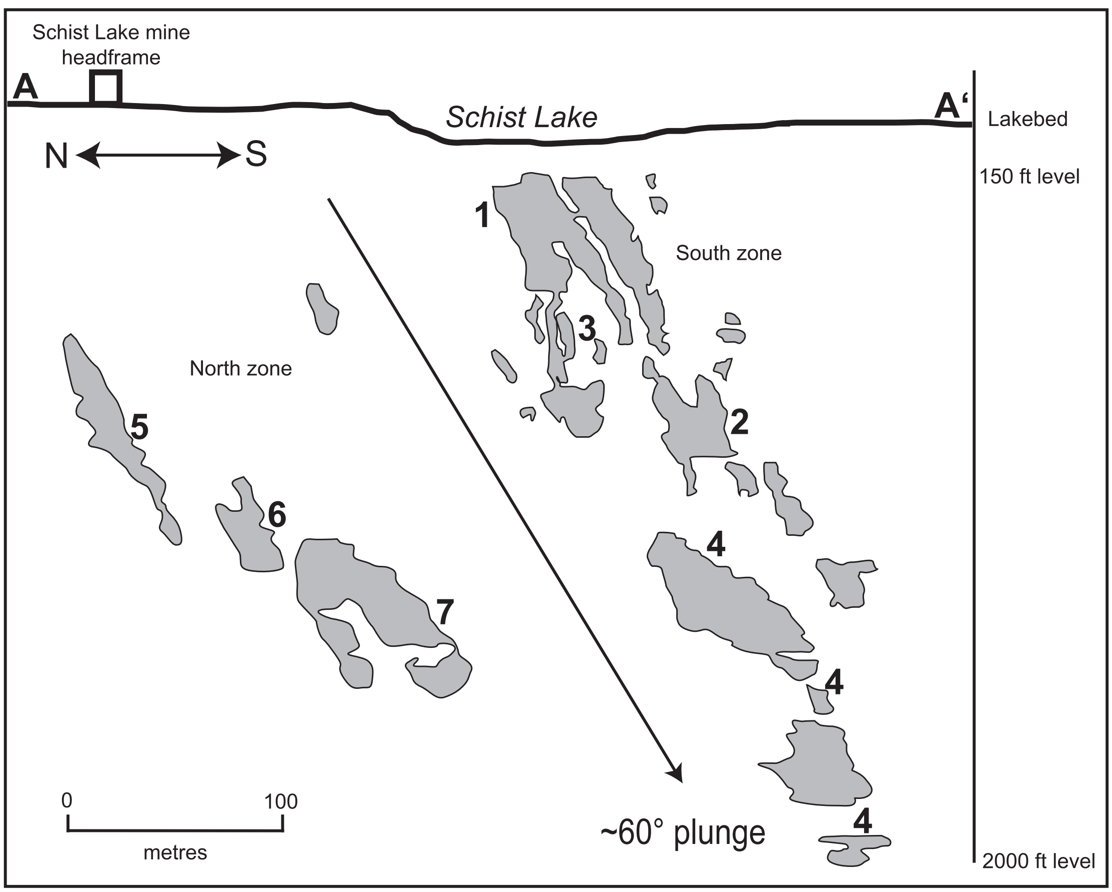

*Figure GS-3-3: Schematic section of the Schist Lake orebody (*from *Hudson Bay Exploration and Development Co. Ltd. archive data). Numbers 1–4 represent the ore lenses in the south zone and numbers 5–7 represent the ore lenses in the north zone. See Figure GS-3-4 for location of section.*

pyrite-sphalerite-chalcopyrite assemblage with minor galena, but did not contain pyrrhotite (Bristol, 1974).

Geology of the Schist Lake mine area

The rocks of the Schist Lake mine area are generally well exposed along the east and west shores of the Schist Lake peninsula, with fewer outcrops in the forested areas in the middle of the peninsula (Figure GS-3-4). The volcanic strata have undergone significant deformation and are strongly foliated (*see* details below). The volcanic strata are strongly foliated and metamorphosed to the lower greenschist facies, containing a mineral assemblage dominated by chlorite, actinolite and albite, with localized epidote patches.

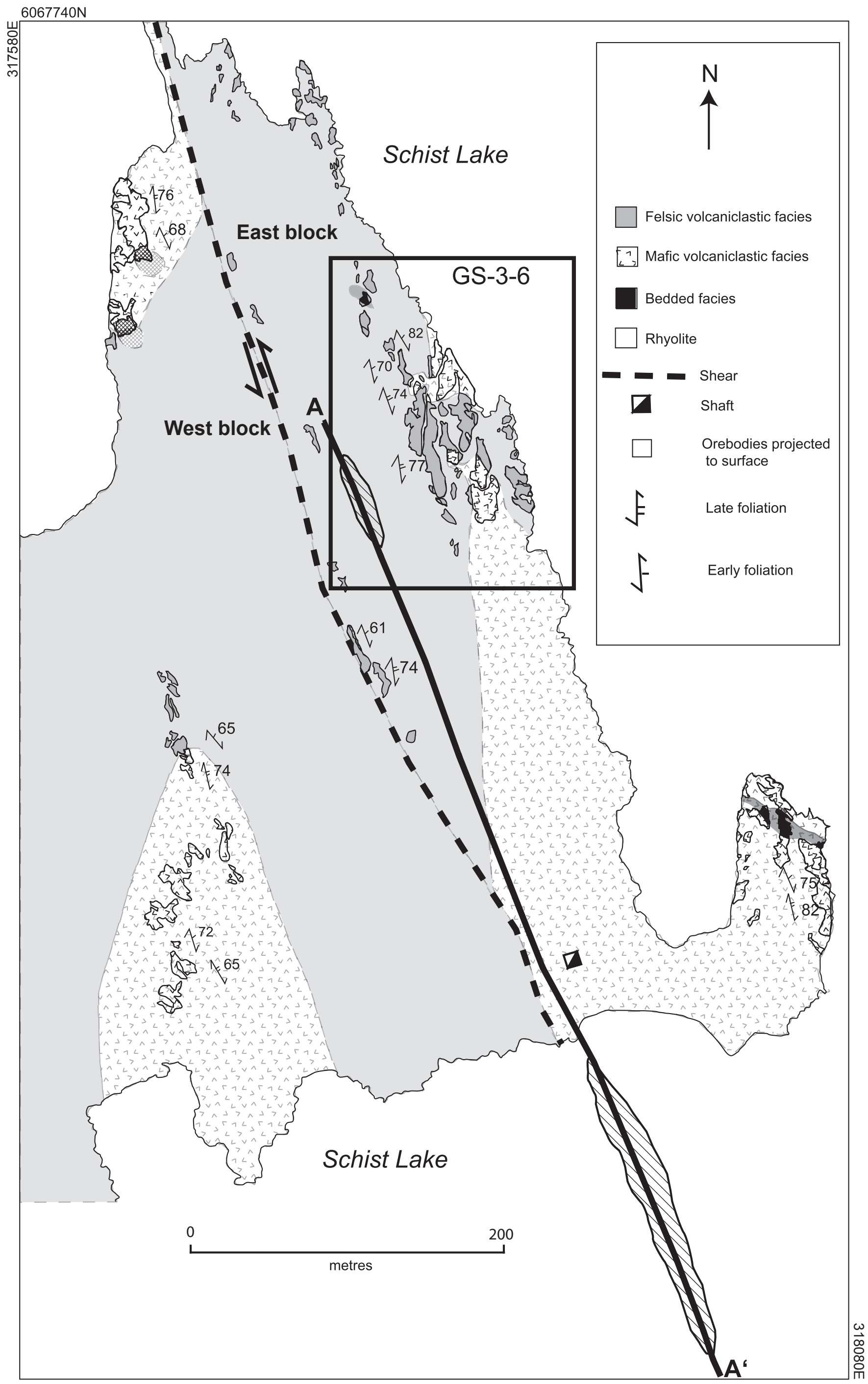

Figure GS-3-4: *Geology of the Schist Lake mine peninsula, including the surface projection of the orebody and the location of the shaft; box indicates the location of the alteration map (Figure GS-3-6). A–A' represents the line of section in Figure GS-3-3.*

During this research, volcanic strata of the Schist Lake mine area were subdivided into 18 units that are grouped into three lithofacies types, based on their concentration of felsic and mafic clasts:

1) **mafic volcaniclastic facies:** a) clast-supported monolithic mafic volcaniclastic unit; b) matrix-supported monolithic mafic volcaniclastic unit; c) homogeneous mafic unit; d) heterolithic mafic volcaniclastic unit; e) clast-supported monolithic mafic volcaniclastic unit; f) heterolithic mafic volcaniclastic unit; g) massive crystal-rich mafic unit
2) **felsic volcaniclastic facies:** a) heterolithic felsic volcaniclastic unit; b) homogeneous sericitic felsic unit; c) felsic volcaniclastic unit with minor tuff beds; d) heterolithic felsic volcaniclastic unit; e) massive felsic unit; f) matrix-supported heterolithic felsic volcaniclastic unit
3) **bedded facies:** a) plagioclase-rich volcaniclastic unit with tuff beds; b) finely laminated tuff unit; c) massive mafic volcanic unit with tuff beds

Lithofacies descriptions

Mafic volcaniclastic facies

The mafic volcaniclastic facies consists of both heterolithic and monolithic mafic volcaniclastic rocks and a thin homogeneous mafic unit. It is characterized by breccia, composed mainly of mafic clasts in a mafic matrix. The breccia tends to be moderately to well sorted and can be both clast and matrix supported. The clasts range in size from 1 to 45 cm and include aphanitic mafic, plagioclase-porphyritic mafic and, locally, aphanitic felsic clasts. The aphanitic mafic clasts are grey on weathered surfaces and dark grey on fresh surfaces. They are homogeneous, subrounded to rounded, and contain up to 10% quartz-filled amygdules that range from 0.5 to 3 mm in diameter (Figure GS-3-5a). The plagioclase porphyritic clasts are homogeneous and subrounded, and contain 5–10% plagioclase phenocrysts ranging from 0.5 to 3 mm in size. They are pale grey on weathered surfaces and dark grey on fresh surfaces. The aphanitic felsic clasts are homogeneous and subrounded; they have a white weathered surface and a pale grey fresh surface. The matrix is very fine grained, mafic and, when not altered, dark brown-grey. Localized portions of the matrix display a mottled white and red-brown pattern; the white colour is possibly due to sericite alteration (*see* details below).

The thin, homogeneous mafic unit is brown-green when weathered and dark grey when fresh. It is very fine grained, aphanitic and aphyric. Where it is cut by a network of quartz veins, the mafic unit has pseudoclastic appearance. Although the presence of clasts is possible, they have not been observed. The mafic volcaniclastic facies has a maximum observed thickness of 60 m.

Felsic volcaniclastic facies

The felsic volcaniclastic facies consists of heterolithic volcaniclastic and massive felsic units. It is characterized by breccia composed mainly of felsic clasts in either a mafic or felsic matrix (Figure GS-3-5b). The breccia is moderately sorted and can be both clast and matrix supported. Clasts range in size from 1 to 35 cm and average 4 cm, and include aphanitic felsic, quartz-porphyritic felsic, amygdaloidal mafic and aphanitic mafic types. The aphanitic felsic clasts are homogeneous and subrounded; they have a whitish appearance when weathered and are pale grey when fresh. The quartz-porphyritic felsic clasts are homogeneous, subangular to subrounded and contain 10% quartz phenocrysts that range from 0.5 to 3 mm in size; they are white-grey on weathered surfaces and pale grey on fresh surfaces. The amygdaloidal mafic clasts are aphanitic and composed of 20% amygdules that are 4–6 mm in size. The aphanitic mafic clasts are homogeneous and subrounded, and contain 3% amygdules up to 2 mm in size. The matrix is very fine grained and can be either mafic or felsic in composition; further petrographic work is pending to assess the nature of the matrix.

The massive felsic unit is homogeneous and very fine grained. It is red-brown on weathered and grey on fresh surfaces. Locally, this unit is white and has a chalky texture, possibly due to sericite alteration (*see* details below). The felsic volcaniclastic facies has a maximum observed thickness of 120 m.

Bedded facies

The bedded tuff facies constitutes a very small portion of the Schist Lake mine area, where the tuff beds are intercalated with thicker volcaniclastic units.

The bedded tuff facies consists of fine laminations of coarse and fine material. The very fine grained beds tend to be only a few millimetres thick and are pale grey (Figure GS-3-5c). The coarse beds contain 25% plagioclase phenocrysts, 0.5–6 mm in size, and tend to be darker grey-pink. The bedded facies has a maximum observed thickness of 50 m.

Structural observations

Two foliations, defined by the alignment of chlorite and sericite and by the flattening of clasts, are present throughout the area. The main foliation strikes 340–360° and dips 70–85° east. It is overprinted by a second foliation that strikes 310–330° and dips 60–70° east. A stretching lineation, defined by the elongation of clasts (1:3 ratio) in the volcaniclastic rocks, trends 110–140° and plunges 55–65°. Both lineation and foliations are more intensely developed in a north-northwest–striking shear zone that transects the centre of the peninsula. The elongation of the clasts increases to a ratio of 1:6 within the shear zone. The second foliation shows an anticlockwise

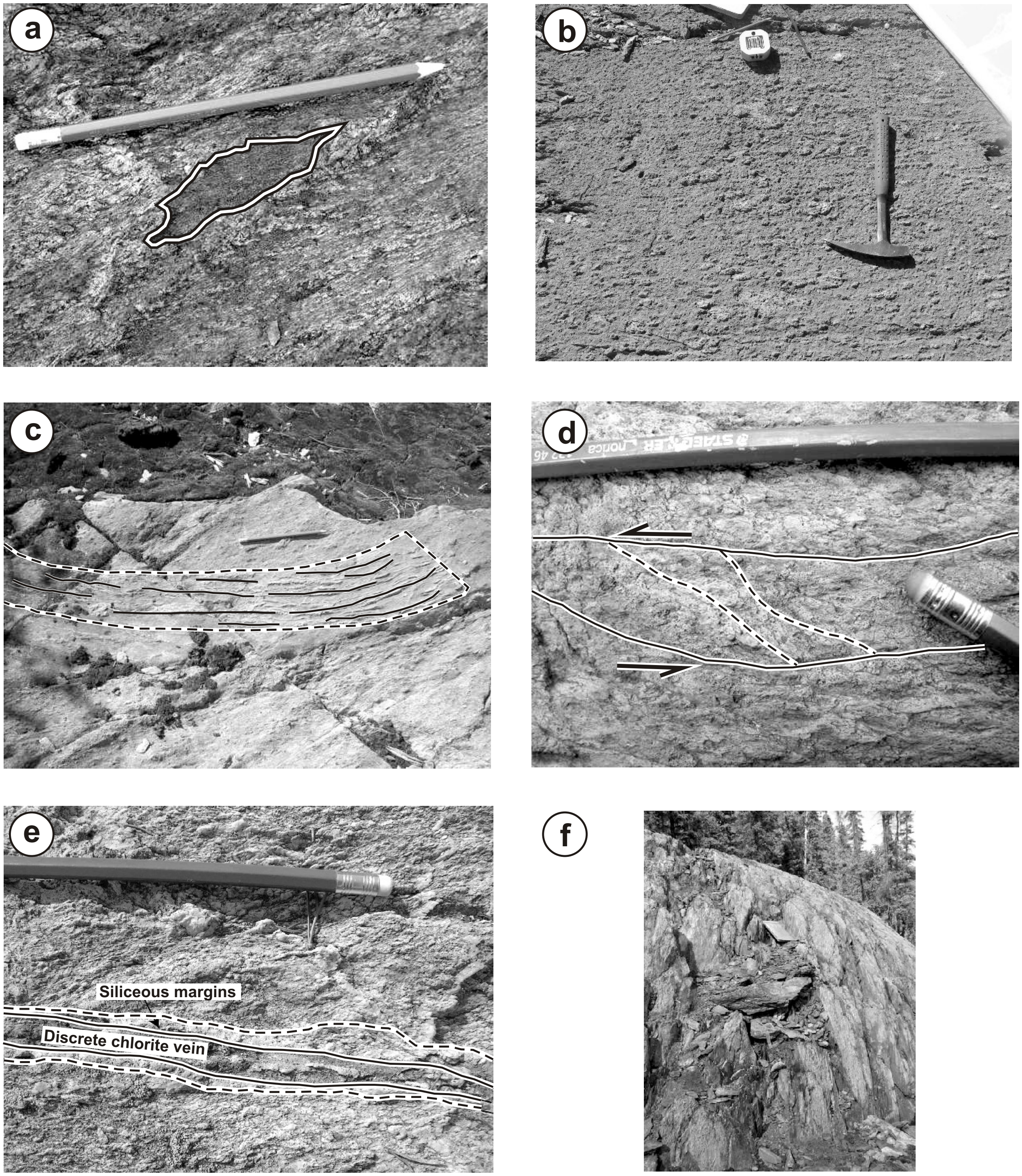

***Figure GS-3-5:** Outcrop photographs of Schist Lake mine volcaniclastic lithofacies: **a)** typical mafic volcaniclastic facies, showing aphanitic, aphyric mafic clast (outlined) in a mottled, brown-white sericitic matrix; **b)** typical felsic volcaniclastic facies, containing white, angular felsic clasts in a mafic (?) matrix; unit is moderately sorted with respect to clast size; **c)** clast of plane-bedded tuff (outlined by dashed line, beds are solid lines) in a brown mafic matrix; **d)** C/S fabric in a sericite-altered felsic unit; the early foliation (dashed line) curves into the late foliation (solid line), indicating a sinistral sense of movement; **e)** chlorite vein (outlined by solid black lines) with more resistant, siliceous margins (outlined by dashed lines) in a sericite-altered felsic unit; **f)** irregular network of massive, green to black chlorite veins up to 20 cm wide in a more massive mafic unit (possible stringer zone); veins generally have an ~315° orientation.*

change in orientation as it passes into the plane of the main foliation. This geometry, together with an increase in fabric development in the shear zone, suggest that the second foliation is a mylonitic S-fabric that was displaced along the main foliation, which acted as a C-fabric during sinistral, east-side-up shear parallel to lineation (Figure GS-3-5d).

Alteration facies descriptions and mineralization

The Schist Lake mine peninsula exhibits four different types of alteration: 1) iron staining, 2) chlorite, 3) sericite, and 4) quartz veining (Figure GS-3-6).

Iron staining

Iron staining is a common occurrence in the rocks of the Schist Lake mine area, particularly in the eastern block, where it imparts a bright orange red to deep purple colour, when it is more intense, to the otherwise light-coloured rocks. The stained zones are parallel to the main foliation and are linear in appearance, with a tendency to follow shear zones or fractures. Along fractures, the hostrock is more intensely altered to a deep purple colour that diffuses outwards to red and then orange. These iron-stained zones are found throughout the area (Figure

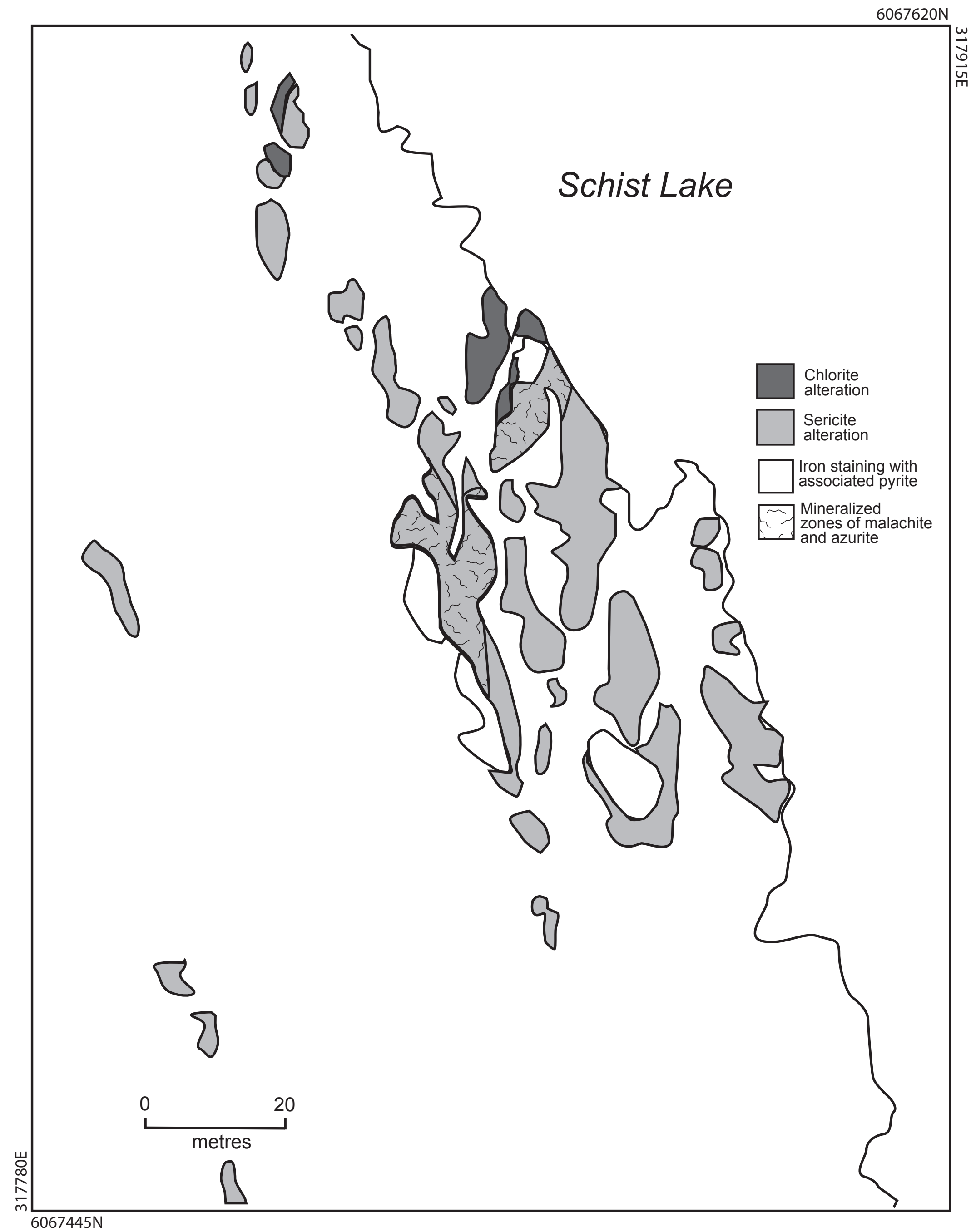

Figure GS-3-6: *Outcrop alteration of part of the eastern shore of the Schist Lake mine peninsula.*

GS-3-6) and also as spots scattered within the rock. The stained zones have diffuse boundaries with the hostrock.

Chlorite

Chlorite alteration is found in two morphologies: as a vein stockwork and as small discrete veins. Where the chlorite is found as veins, it is a dark green black colour. This alteration feature is particularly prominent on the western shore of Schist Lake (Figure GS-3-6), where it forms 5–25 cm wide stockwork veins that are orientated ~315° and almost vertical (Figure GS-3-5f). These veins cover an area of 20 m^2 and gradually decrease in size farther inland, where they almost disappear except for isolated patches. Isolated patches of chlorite veins occur throughout the strata of the mine peninsula.

The second type of chlorite alteration is found as discrete chlorite veins with resistant silicified envelopes (Figure GS-3-5e). This type of alteration is found proximal to the main chlorite alteration zone and the veins are randomly orientated.

Both types of chlorite alteration are surrounded by areas of iron-stained rock.

Sericite

Sericite alteration occurs throughout most of the lithofacies of the eastern block (Figure GS-3-6), where it imparts a whitish appearance and, when scraped, has a chalky nature (Figure GS-3-5a). It occurs along foliation planes and is most prominent in the more massive felsic units, producing rocks that are very white in colour. The contact between sericitized and nonsericitized areas is indistinct and gradational.

Quartz veining

Quartz veins are observed in most parts of the peninsula, particularly in the eastern block, where they have various thicknesses. The most common quartz veins are <1 cm thick and randomly oriented, and crosscut their hostrocks in a network pattern. Localized quartz veins, 1–3 m in thickness, are associated with areas of intense iron staining, whereas other quartz veins that range from 10–20 cm in thickness trend northeast but have a limited strike length.

Mineralization

Other than the Schist Lake mine, only small surface occurrences of mineralization have been found in the Schist Lake mine area, mostly within strata of the eastern block. Malachite has been observed within the plane of the main 340° foliation, along with chalcopyrite and azurite. Small patches of disseminated pyrite are also common, most notably within the iron-stained zones.

Interpretation

The Schist Lake mine peninsula consists mostly of coarse volcaniclastic rocks. The different clast types observed in the various volcaniclastic facies suggest multiple sources and mixing. The absence of proximal volcanic facies, such as flows, and the abundance of volcaniclastic rocks suggest a more distal depositional environment (Fisher and Schmincke, 1984). The angularity of clasts, well-sorted character and wide range of sizes (1–45 cm) all suggest that there has been a moderate amount of transportation of volcanic debris (Fisher and Schmincke, 1984), although this varies from unit to unit, given the variable sorting and clast shape. Most of the volcaniclastic units are clast supported, with fine-grained material making up the matrix. This suggests that the volcaniclastic facies were transported and deposited by high-concentration mass flows. The observed thickness of the volcaniclastic units is at least 200 m, which may include some structural thickening. The abundance and thickness of the volcaniclastic deposits suggests that they were deposited in a basin.

Alteration is more prominent east of the main shear, where chlorite and sericite alteration are more pervasive. Iron staining is preferentially developed along fractures and small shear zones. The chlorite vein alteration present in the eastern block is typical of that found in footwall VMS deposits (Grifkins et al., 2005), which suggests that the east block of the Schist Lake mine area may contain footwall strata of the Schist Lake deposit. The rocks in the west block show very little alteration, except for small localized patches of iron staining and sericite alteration. This would be consistent with alteration observed in the hangingwall to VMS deposits (Grifkins et al., 2005), although it has not yet been determined if the western block represents the hangingwall.

Economic considerations

Although the Schist Lake and Mandy deposits were the first to be mined in the Flin Flon area, their stratigraphy and relationship to the other Flin Flon VMS deposits is still not known. The stockwork chlorite veins and sericite alteration within the east block suggest that this block contains the footwall strata to the Schist Lake deposit. The main shear zone may have dismembered the Schist Lake orebody along the main foliation and lineation plunge, and the sinistral and vertical offset on this shear suggests that hangingwall strata to the Schist Lake deposit may occur farther to the south and deeper.

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