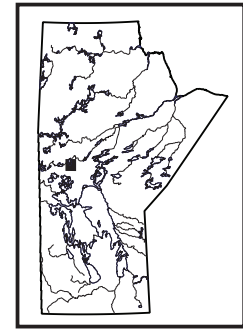**GS-7** **Examination of exploration drillcore from the south Wekusko Lake area, eastern Flin Flon belt, north-central Manitoba (parts of NTS 63J5, 12, 63K8, 9)**
by K.D. Reid and S. Gagné

Summary

Drillcore from 15 historical and recent exploration drillholes that penetrated the Phanerozoic cover south of Wekusko Lake were examined during a two-week period in the summer of 2016. These drillholes intersected a variety of metamorphosed sedimentary, volcanic and plutonic rocks, which were documented, photographed and sampled in an effort to further understand the highly prospective sub-Phanerozoic extension of the Flin Flon belt. In addition, three drillholes that penetrated the volcanic hostrocks of the Copper-Man volcanogenic massive-sulphide (VMS) deposit were examined. This work complements and builds on work started in 2009 and 2010 to investigate the sub-Phanerozoic Flin Flon belt and provide critical new data to constrain exploration models for VMS deposits in this geologically complex and challenging area. The objectives of this season's fieldwork were to 1) document the volcanic facies and alteration associated with the Copper-Man deposit and rocks south of Wekusko Lake; 2) obtain additional whole-rock geochemical data for an area not covered by previous regional compilations; and 3) identify the extent, depositional facies and metamorphic grade of sedimentary rocks, interpreted as Burntwood group turbidites and Missi group sandstone and conglomerate, that extend south from Wekusko Lake, in order to understand the complex tectonostratigraphy of the area.

Introduction

The Paleoproterozoic Flin Flon belt is one of the world's most prolific VMS districts, originally hosting 154 million tonnes (Mt) of ore and still containing more than 64 Mt in preproduction and subeconomic deposits (e.g., Syme et al., 1999; Galley et al., 2007). Current production is from the Triple 7 mine in Flin Flon, the Reed mine south of Reed Lake and the Lalor mine near Snow Lake. The year 2016 marks 100 years of mining in the Flin Flon belt. During that time, exploration methods for deposits have evolved from surface prospecting in the exposed portions of the belt to deep-penetrating geophysical surveying, coupled with diamond-drill testing, in areas of deep overburden and/or Phanerozoic cover. During the past century, most mine development and exploration have occurred in the exposed portion of the belt or in areas of relatively thin cover. However, the recent discovery of the world-class Lalor VMS deposit by drilling to a depth of more than 800 m highlights the importance and potential of deep exploration. The sub-Phanerozoic part of the belt has received comparatively minor exploration attention during the past 25 years despite being much larger than the exposed portion of the belt, thus leaving vast areas of prospective rocks yet to be explored. Examination of recent and historical exploration drillcore by the Manitoba Geological Survey is a cost-effective way to better understand the sub-Phanerozoic geology and inform models for future deep exploration.

Previous work

Examination of exploration drillcore and interpretation of magnetic and gravity data (e.g., Blair et al., 1988; Leclair et al., 1997) have resulted in the recognition of a number of geologically distinct domains beneath the Phanerozoic cover (Figure GS-7-1). The most recent maps were compiled by the NATMAP Shield Margin Project Working Group (Leclair et al., 1997; Leclair and Viljeon, 1997) and released as a series at 1:100 000 scale. The eastern portion of the sub-Phanerozoic Flin Flon belt is subdivided into three geophysically recognizable domains: the Cormorant batholith, the Clearwater domain and the East Kisseynew domain (Figure GS-7-1). The discovery of VMS deposits in the East Kisseynew domain, typically considered to be dominated by metasedimentary gneiss and granitic plutons, and thus less prospective, has raised questions about the tectonic setting and magmatic affinity of the volcanic rocks associated with these deposits. Simard and McGregor (2009) and Simard et al. (2010) began relogging and sampling drillcore from several sub-Phanerozoic VMS deposits, as well as assembling an extensive compilation of company geophysical and geochemical data. Deposits located in the Clearwater domain (e.g., Copper-Man, Kofman, McClarty, Sylvia, Limestone and Moose) and East Kisseynew domain (e.g., Watts River, Harmin, Fenton and Talbot) of Leclair et al. (1997) are hosted by lower metamorphic-grade and higher metamorphic-grade volcanic and sedimentary rocks, respectively (Figure GS-7-1; see also Simard et al., 2010, Figure GS-6-3). Preliminary geochemical results show that deposits found in higher metamorphic-grade rocks of the East Kisseynew domain likely formed in a rifting arc and/or at the onset of back-arc magmatism (Simard et al., 2010). Quartzofeldspathic gneiss associated with the
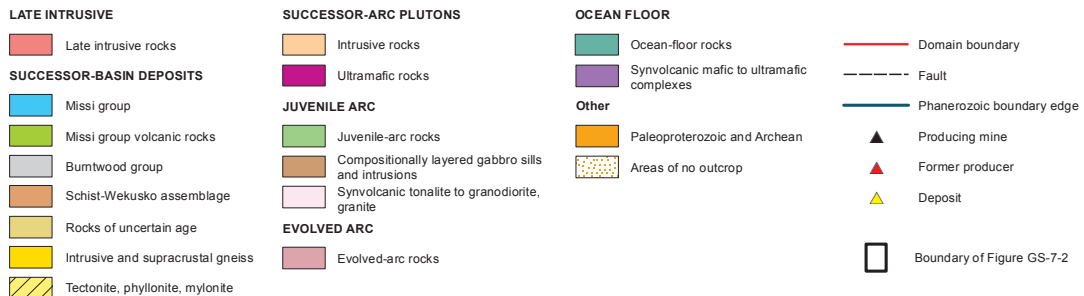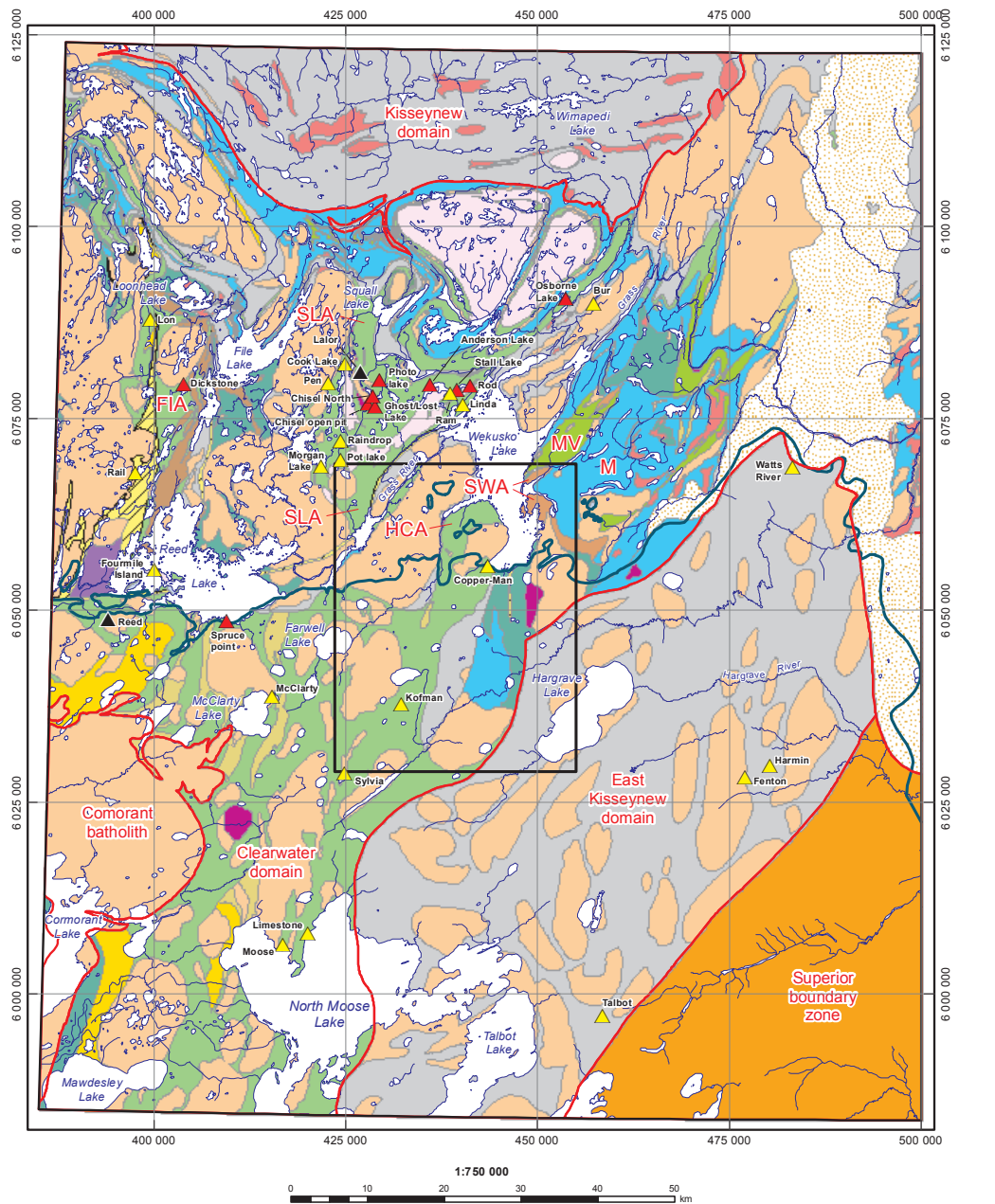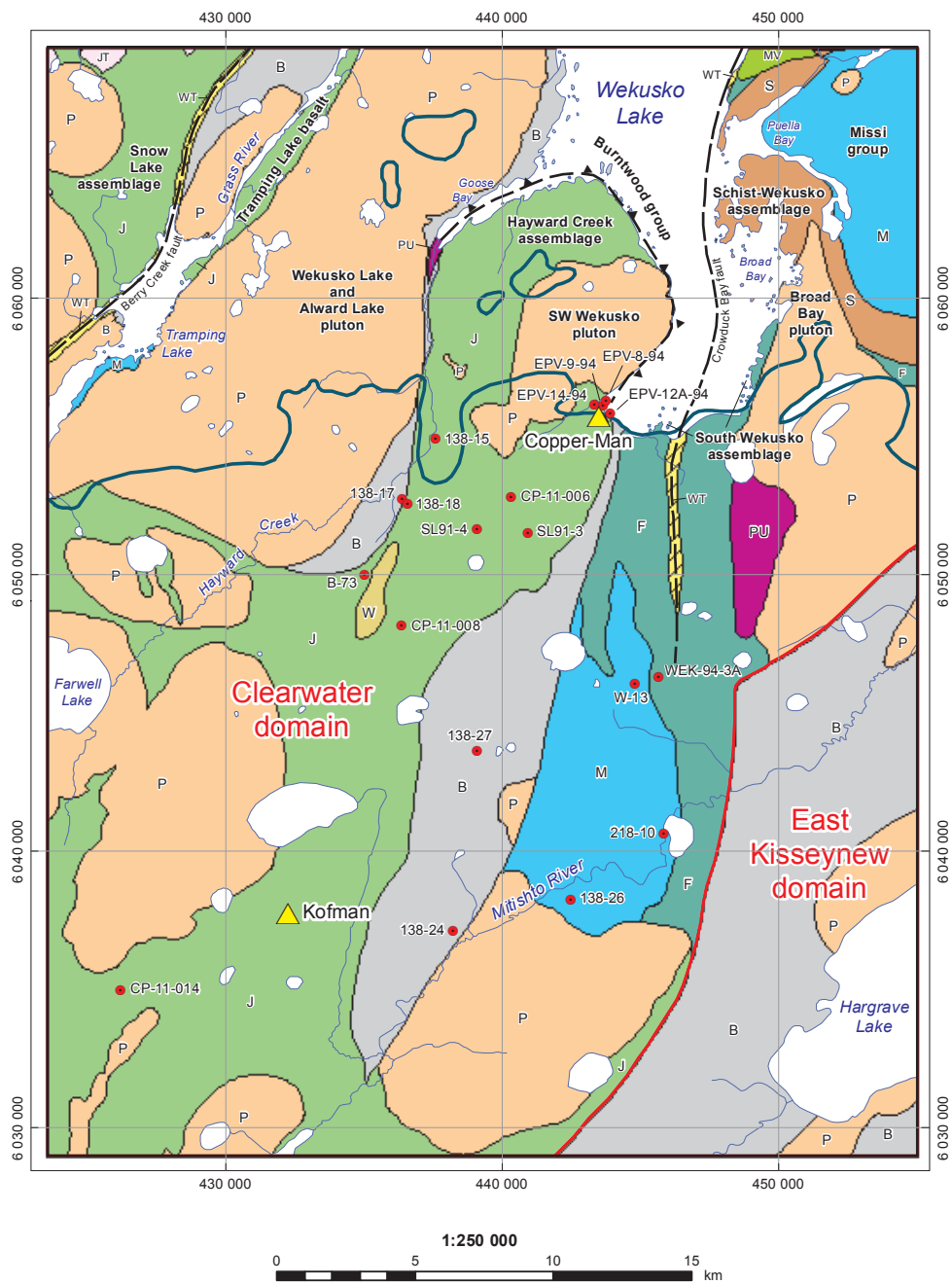
Figure GS-7-1: *Generalized geology of the exposed and sub-Phanerozoic eastern Flin Flon belt, showing major tectonostratigraphic assemblages/domains and volcanogenic massive-sulphide deposits (modified from Leclair and Viljoen, 1997; NATMAP Shield Margin Project Working Group, 1998). Box outlines the study area shown in Figure GS-7-2. Exposed tectonostratigraphic assemblages: FIA, Fourmile Island assemblage; HCA, Hayward Creek assemblage; M, Missi group; MV, Missi group volcanic rocks; SLA, Snow Lake assemblage; SWA, Schist-Wekusko assemblage. Thick red lines define sub-Phanerozoic domains.*

Figure GS-7-2: *Geology of the south Wekusko Lake area (modified from NATMAP Shield Margin Project Working Group, 1998), showing the collar locations of drillholes discussed in this report.*

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Fenton deposit, believed to represent a recrystallized volcanic mudstone/felsic tuff, yielded a unimodal U-Pb zircon age population centred at 1.865 Ga; this is interpreted as the approximate age of a single igneous/volcanic source and possibly represents the age of VMS mineralization in the area (Simard et al., 2010). This is in contrast to most deposits in the Flin Flon and Snow Lake areas, which are associated with 1.92–1.88 Ga oceanic-arc assemblages (e.g., Stern et al., 1995a; Galley et al., 2007). Simard et al. (2010) suggested that these data might provide evidence for a younger prospective back-arc basin of 'successor-arc' age (i.e., 1.88–1.83 Ga) in the East Kisseynew domain of the sub-Phanerozoic, as well as prospective tholeiitic to transitional oceanic-arc environments farther west in lower metamorphic-grade rocks of the Clearwater domain.

Discovery of the Reed deposit in the fall of 2007 renewed interest in the exposed and sub-Phanerozoic geology of the Reed Lake area. Gagné (2015) investigated the sub-Phanerozoic geology in the Reed Lake area, directly west of the current study area (Figure GS-7-1). Geological mapping and geochemical analyses revealed that mafic and felsic volcanic rocks hosting the Reed deposit share many features with rocks exposed on the western shore of Reed Lake and extending north to the Dickstone deposit. That study also showed that the volcanic rocks associated with the Fourmile Island deposit are distinct, suggesting they represent a different stratigraphic level within the same sequence or that they form an entirely separate stratigraphic package (Gagné, 2015).

Geological Framework of the South Wekusko area

The southern half of Wekusko Lake was mapped at 1:20 000 scale between 1992 and 1998, and the resulting marginal notes and map were published in 2005 (Gilbert and Bailes, 2005). This work outlined five tectonostratigraphic components: 1) Hayward Creek assemblage of juvenile-arc affinity, 2) south Wekusko assemblage of ocean-floor affinity, 3) Schist-Wekusko assemblage of successor-arc affinity, 4) Burntwood group turbidites, and 5) Missi group sandstone and conglomerate (see Figure GS-7-2). Multiple large granitoid intrusions of 'successor-arc' age also occur in the area.

The map of Bailes and Galley (2007) shows that the Snow Lake assemblage is bounded on the west side of Tramping Lake by the Berry Creek fault (Figure GS-7-2). A narrow package of Burntwood group and granitoid rocks lies between the Berry Creek fault and the Grass River, whereas a narrow unit of volcanic rocks, termed the 'Tramping Lake basalt', forms the eastern shoreline of Tramping Lake (Bailes and Galley, 2007). East of Tramping Lake and west of Hayward Creek is the Wekusko Lake pluton (granodiorite and granite; 1.84 Ga), which transitions to the Alward Lake pluton (tonalite, quartz diorite and subordinate diorite) moving southward (Gilbert and Bailes, 2005).

The map of the NATMAP Shield Margin Project Working Group (1998) indicates that Burntwood group rocks extend south from Goose Bay along Hayward Creek beneath Phanerozoic cover (Figure GS-7-2). However, this is not supported by the mapping of Gilbert and Bailes (2005), which indicates that the Burntwood group terminates near the end of Goose Bay.

The Hayward Creek assemblage (1.88 Ga) to the east is a package of arc-volcanic, intrusive and sedimentary rocks that forms a lozenge south of Goose Bay and is bounded to the west by Hayward Creek before extending south beneath Phanerozoic cover (Figure GS-7-2). At the core of the Hayward Creek assemblage is the Southwest Wekusko Lake pluton, which varies from granodiorite to diorite (see map of Gilbert and Bailes, 2005).

Burntwood group greywacke and mudstone, interpreted to be in thrust contact with the Hayward Creek assemblage, are observed along the western shoreline (and some islands) of Wekusko Lake and extend south from Goose Bay, narrowing to a <1 km wide package at the southern end of the lake (Figure GS-7-2).

East of the Burntwood group at the south end of Wekusko Lake is a package of pillowed basalt flows and related gabbro sills that is geochemically similar to the 1.90 Ga mid-ocean–ridge basalt of the Elbow-Athapapuskow ocean-floor assemblage (Stern et al., 1995b) and is termed the south Wekusko assemblage (Gilbert and Bailes, 2005). The north-trending Crowduck Bay fault at the south end of the lake (Figure GS-7-2) is defined by amphibole-chlorite-carbonate phyllonite.

The Crowduck Bay fault trends north, west of Broad Bay, before trending northeast into Crowduck Bay (not shown on Figure GS-7-2), resulting in Burntwood group rocks (1.85–1.84 Ga) being juxtaposed against the Schist-Wekusko assemblage (1.88–1.83 Ga 'successor-arc' volcanic, volcaniclastic and hypabyssal intrusive rocks; Figure GS-7-2), as well as stratigraphically younger Missi group volcanic rocks, conglomerate and crossbedded sandstone (Connors and Ansdell, 1994; Ansdell et al., 1999; Gilbert and Bailes, 2005). East of Broad Bay, the Schist-Wekusko assemblage is separated from the south Wekusko assemblage by the wedge-shaped granitic to granodioritic Broad Bay pluton (Figure GS-7-2).

Drillcore examination

The drillcores examined from south of Wekusko Lake fall into three general groupings on the basis of geographic area and rock type: 1) volcanic rocks at the Copper-Man deposit, 2) Hayward Creek–south Wekusko Lake volcanic rocks, and 3) south Wekusko Lake sedimentary rocks. Although all rocks discussed in this report have been subject to regional metamorphism (greenschist

to amphibolite facies), the prefix 'meta-' has been dropped for the sake of brevity.

Volcanic rocks at the Copper-Man deposit

Drillholes EPV-8-94, EPV-9-94 and EVP-14-94 intersected heterolithic tuff breccia, dacite and basalt associated with the Copper-Man VMS deposit. The structural hangingwall of the deposit is dominated by matrix-supported heterolithic tuff breccia with narrow (<4 m) intervals of quartz-phyric dacite that may indicate episodic felsic volcanism or may be structurally repeated by folding or thrust faulting (EVP-9-94; Figure GS-7-3). Clasts in the tuff breccia include (in relatively equal proportions) quartz-phyric dacite, aphyric and plagioclase-phyric basalt (locally amygdaloidal) and pyroxene-phyric andesite in a matrix of mafic, green pyroxene crystal–bearing tuff. Shard-like and cuspate fragments suggest that these rocks are the product of pyroclastic volcanism (Figure GS-7-4a, b). Common alteration observed in the structural hangingwall includes local pervasive silicification that results in haloes around fragments (Figure GS-7-4b) and weak sericite alteration of some quartz-phyric dacite clasts.

A few boxes that contained the best intercepts of mineralization are missing from the core library; however, some split and whole drillcore containing stringer and disseminated sphalerite-chalcopyrite mineralization is present from drillcores EVP-9-94 and EVP-14-94. The mineralization is hosted by light grey, weakly sericitized dacite/rhyodacite and green chloritized basalt. This chloritized basalt forms the structural footwall to the deposit and contains stringer sulphides (Figure GS-7-4c) and local amygdules (Figure GS-7-4d). Approximately 450 m to the northeast, drillhole EVP-8-94 intersected heterolithic tuff breccia and minor intervals of dacite, similar to that observed in the hangingwall of drillcores EVP-9-94 and -14-94 (Figure GS-7-4e), but did not intersect mineralization or basalt. This drillhole was intended to test a shallow conductor at the most northerly extent of drilling on the deposit; however, the modelled conductor was not explained and, although another deep-seated conductor (200+ m depth) was noted in the area, it was never tested (Assessment File 73676, Manitoba Growth, Enterprise and Trade, Winnipeg). It is possible that, with a revised geological model, deep geophysical surveying and drill testing, more VMS mineralization may be found at depth and/or along strike from this prospect.

Hayward Creek–south Wekusko Lake volcanic rocks

Drillcores from the area beneath Phanerozoic cover and along strike from the exposed Hayward Creek assemblage (Gilbert and Bailes, 2005) consist primarily of volcaniclastic rocks that range in composition from mafic
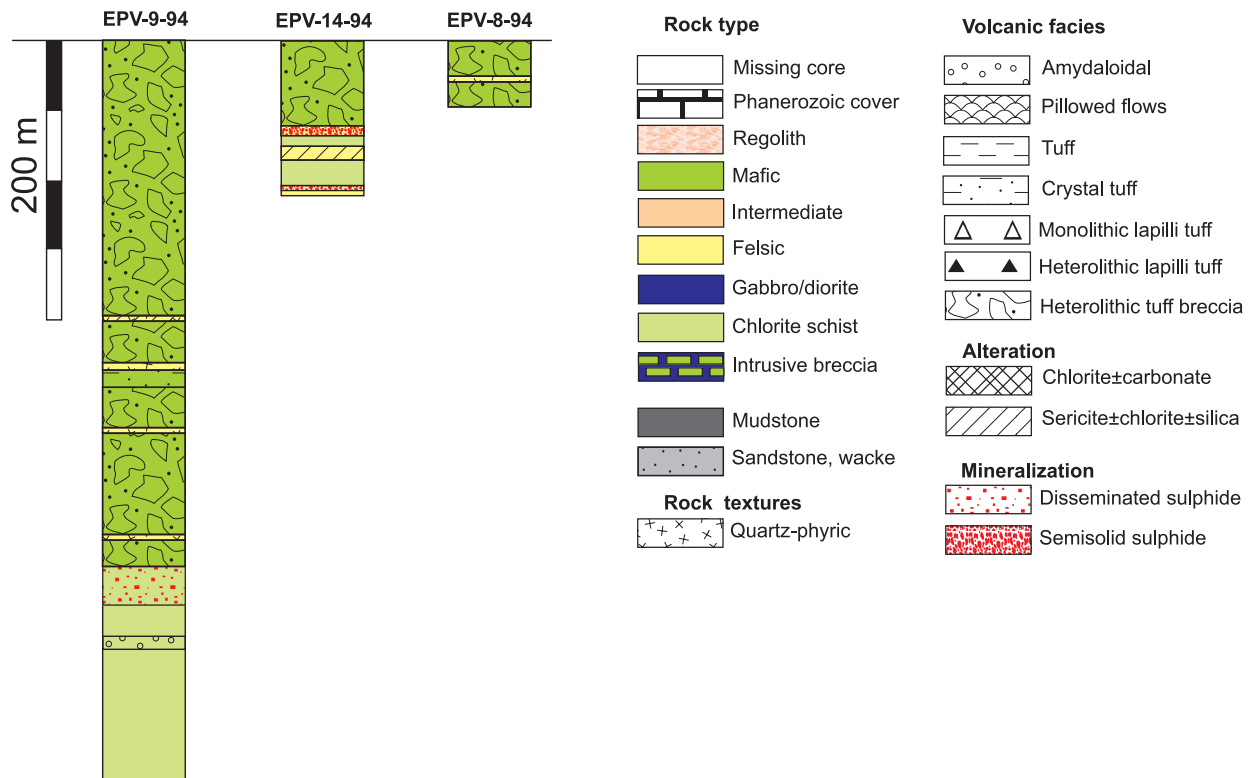

Figure GS-7-3: *Schematic sections of examined drillcore from volcanic rocks hosting the Copper-Man deposit; see Figure GS-7-2 for drillhole-collar locations.*
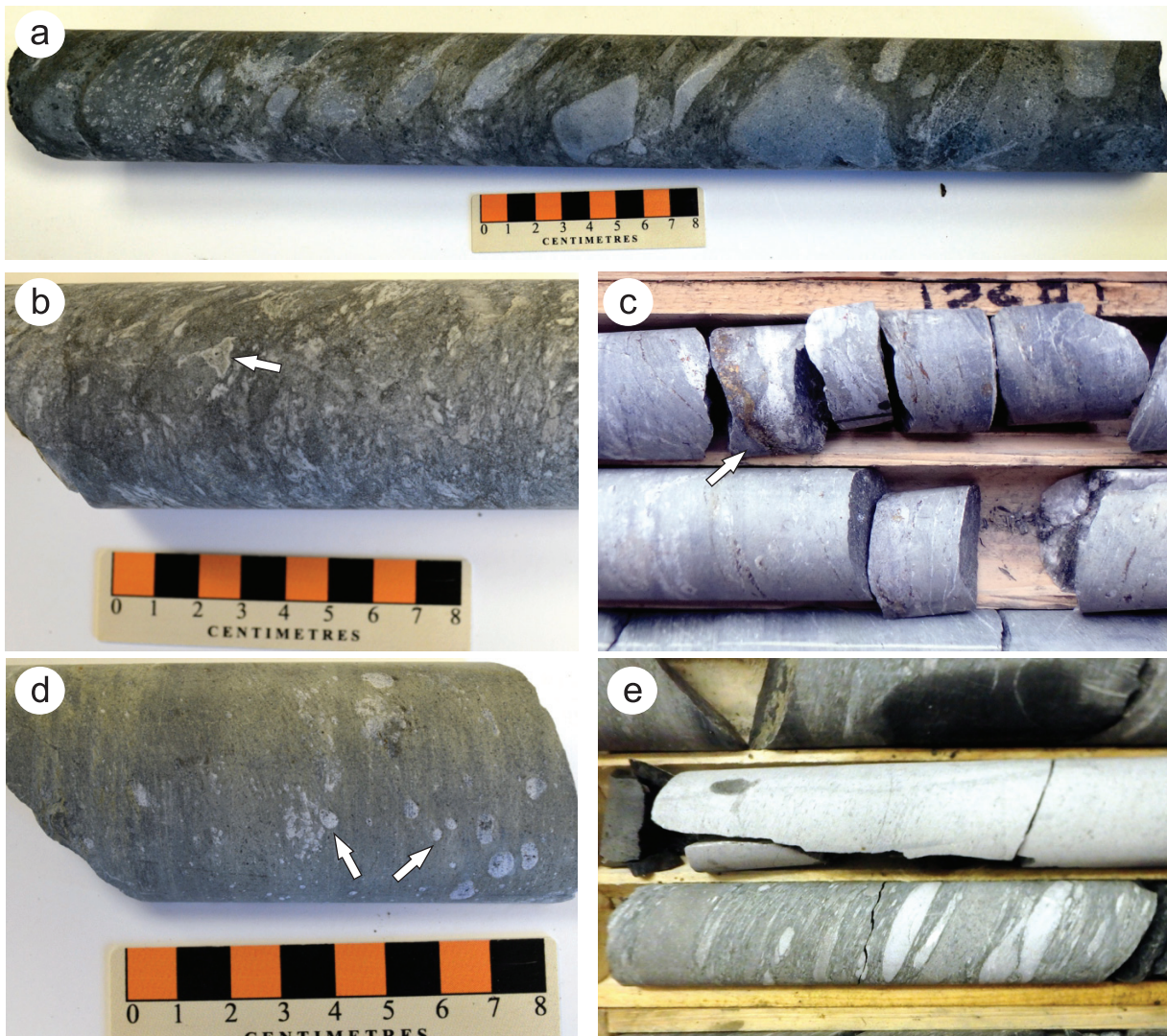
Figure GS-7-4: Volcanic rocks associated with the Copper-Man deposit: *a)* heterolithic tuff breccia showing quartz-phyric dacitic fragments (light grey) and mafic fragments of various compositions in a fine-grained, green pyroxene–phyric tuff matrix, drillcore EVP-9-94, 349 m; *b)* silicified, shard-like, felsic lapilli fragments (arrow) in a green-grey tuff matrix, drillcore EVP-9-94, 247 m; *c)* stringer of sphalerite and chalcopyrite (arrow) in chloritized footwall basalt (core diameter 4.76 cm), drillcore EVP-9-94, 412 m; *d)* chloritized basalt with quartz amygdules (arrows), drillcore EVP-9-94, 379 m; *e)* coherent dacite and heterolithic tuff breccia (core diameter 4.76 cm), drillcore EVP-8-94, 24 m.

to felsic (Figure GS-7-5). The upper portion of drillcore SL91-3 consists of weathered mafic feldspar-crystal tuff (Figure GS-7-6a), whereas the lower section of the core is dominated by moderately to strongly flattened mafic lapilli tuff (Figure GS-7-6b). Moderate to strong pervasive chlorite alteration of the matrix and selected fragments is overprinted by metamorphic 'pinhead' garnets and minor biotite. High strain obliterates primary features in the upper portion of drillcore SL91-4; however, the rock is intermediate to felsic in composition with locally observable feldspar phenocrysts (1–4 mm) and a few scattered, 20–50 cm thick, dark green-black, aphyric mafic sections that have sharp foliated contacts and are interpreted to be mafic dikes. In a lower strain domain near the end of the drillcore, felsic fragments have a jigsaw-fit

texture with little to no tuff matrix; these could represent autobrecciation or quenching of a coherent felsic flow (Figure GS-7-6c).

The main constituents of drillcores 138-15, 138-17, 138-18 and B-73 are brown-black mafic tuff that contains variable amounts (5–20%) of 0.5–2 mm feldspar crystals (e.g., Figure GS-7-6d). Drillcore 138-15 contains laminated, brown-beige tuff that grades into pyroxene-feldspar–crystal tuff with patchy to stratabound epidote alteration affecting portions of the tuff. Sections of drillcore from this drillhole are reported to contain trace to minor Zn mineralization (Assessment File 92428); however, several boxes, including those with the mineralized intervals, were missing from the drillcore library, so alteration and rocks directly hosting the mineralization were
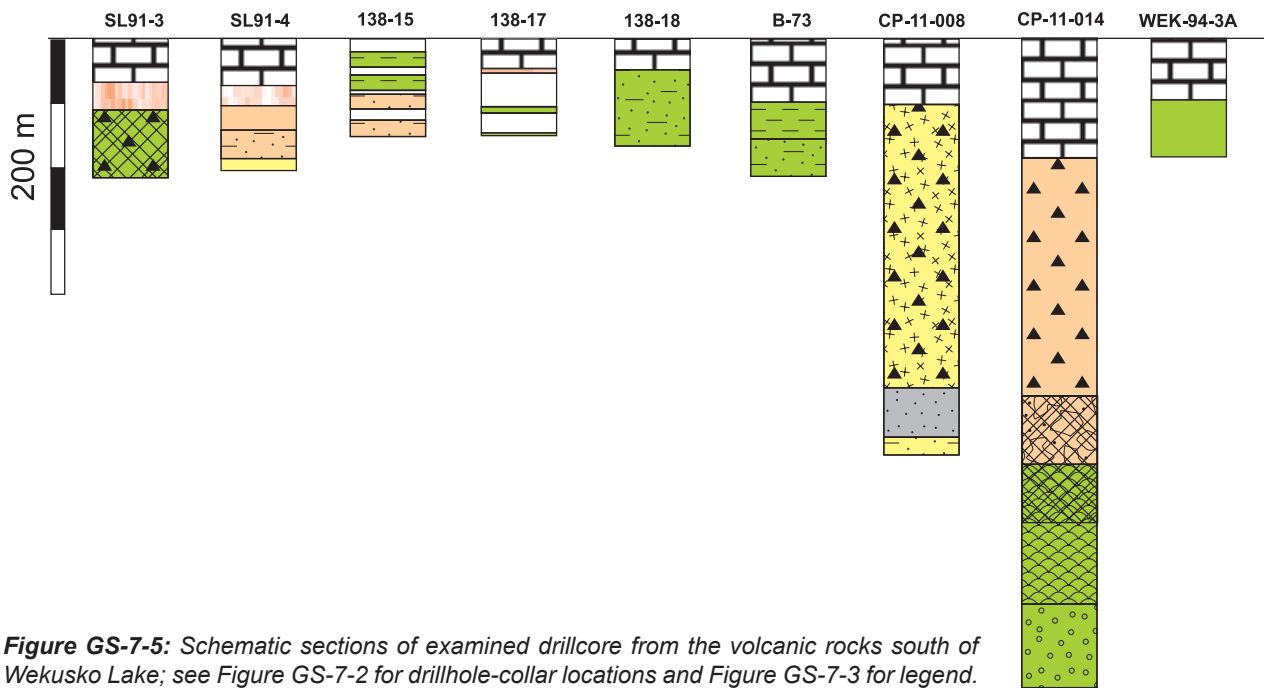
Figure GS-7-5: *Schematic sections of examined drillcore from the volcanic rocks south of Wekusko Lake; see Figure GS-7-2 for drillhole-collar locations and Figure GS-7-3 for legend.*

not observed. Most of the boxes containing drillcore 138-17 were missing from the library and the core that is present is poorly preserved, largely broken into discs along the foliation (Figure GS-7-5). The core that is present, however, contains dark brown feldspar-bearing mafic tuff with no apparent quartz (Figure GS-7-6d). Drillcore 138-18 consists of feldspar-crystal tuff that is bedded at the centimetre scale; however, toward the end of the drillhole, it becomes relatively massive, with 1–3 mm feldspars and dark green, flattened, mafic lithic fragments (Figure GS-7-6e). The upper half of drillcore B-73 contains weakly laminated, brown-beige tuff (Figure GS-7-6f) that is separated from feldspar-crystal tuff in the lower portion of the core by a narrow interval (<8 m) of graphite-bearing mafic tuff.

Drillcore CP-11-008 contains a moderately strained sequence (225 m) of felsic heterolithic lapilli tuff that consists mainly of quartz-phyric dacite with ~5–10% dark green, flattened mafic fragments, possibly basaltic scoria or pumice (Figure GS-7-7a). It is separated from a ~50 m thick package of bedded feldspathic wacke by a narrow package (<3 m; not shown on Figure GS-7-5) of felsic tuff breccia (Figure GS-7-7b). The feldspathic wacke displays graded bedding on a centimetre scale; several graded beds suggest younging downhole (Figure GS-7-7c). The feldspathic wacke interval grades into quartz-feldspar–crystal lapilli tuff that continues to the end of the drillhole. Strain shadows around quartz phenocrysts in the dacite are filled with beige carbonate (Figure GS-7-7a), whereas weak chloritization overprints the matrix of the tuff breccia (Figure GS-7-7b).

Southwest of the Kofman deposit, drillhole CP-11-014 intersected relatively low strain volcanic rocks. The upper section of the drillcore is dominated by intermediate feldspar- and pyroxene-crystal lapilli tuff that contains scattered lapilli- to block-size fragments (Figure GS-7-7d). At the base of this package is a heterolithic tuff breccia that contains fragments of basalt and feldspar-pyroxene–phyric andesite (composition similar to the feldspar-pyroxene–crystal lapilli tuff). The tuff breccia grades into calcite-annealed basalt breccia that, in turn, grades into relatively massive, dark green basalt containing minor epidotized hyaloclastite and calcite amygdules, indicating that it is likely a flow. Toward the bottom of the drillcore, the basalt becomes massive and is moderately silicified, with quartz amygdules (up to 1 cm) present (Figure GS-7-7e).

The easternmost drillhole examined that contains volcanic rocks, WEK-94-3A (Figure GS-7-2), intersects monotonous, dark green, aphyric to fine-grained feldspar-phyric basalt. These rocks are interpreted to represent the extension of ocean-floor basalt, which extends south from Wekusko Lake (e.g., Leclair et al., 1997; Leclair and Viljoen 1997).

Primary textures observed in drillcores to the southsouthwest of Wekusko Lake indicate that intermediate to mafic tuff and feldspar-crystal tuff are the most common volcanic facies in the area, but heterolithic lapilli tuff, basalt and dacite also occur. All of the rocks display varying degrees of alteration; however, the strong pervasive chlorite alteration of mafic volcaniclastic rocks noted in drillhole SL91-3 is typical of discordant-style VMS-related alteration and is only a short distance from the
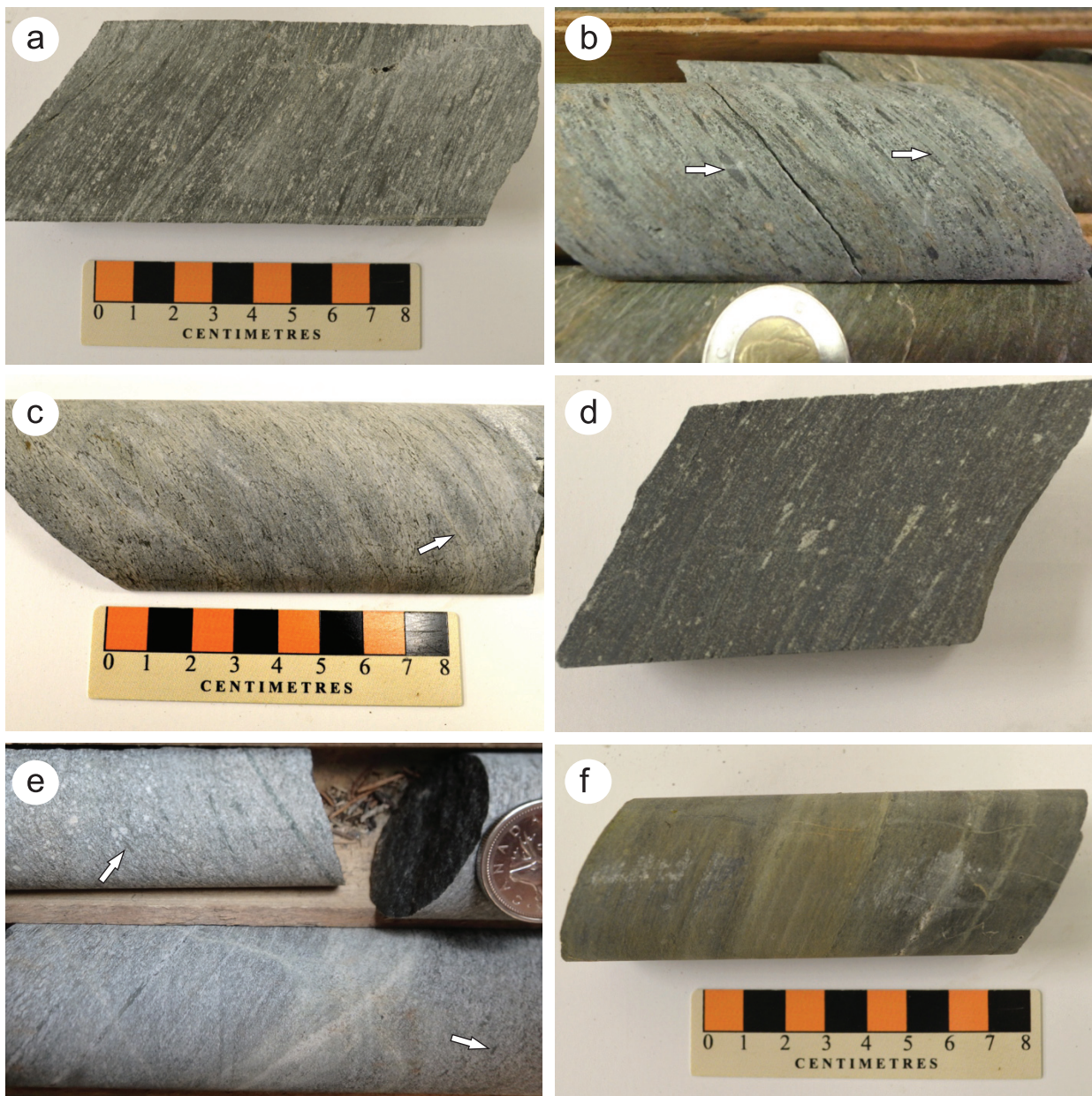
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Figure GS-7-6: *Volcanic rocks from the Hayward Creek–south Wekusko Lake area:* ***a)*** *mafic feldspar-crystal tuff, drillcore SL91-3, 60.4 m (198 ft.);* ***b)*** *mafic lapilli tuff that is pervasively chlorite altered and contains 'pinhead' garnets in the matrix (arrows show flattened lapilli), drillcore SL91-3, 98.8 m (324 ft.);* ***c)*** *clast-supported breccia with jigsaw fit (arrow shows clast outline), drillcore SL91-4, 113.7 m (373 ft.);* ***d)*** *mafic feldspar-crystal tuff (core diameter 3.65 cm), drillcore 138-17, 46.6 m (153 ft.);* ***e)*** *feldspar-crystal tuff with a few flattened mafic lapilli (arrows; core diameter 3.65 cm), drillcore 138-18, 63.4 m (208 ft.);* ***f)*** *weakly laminated mafic tuff, drillcore B-73, 70.1 m (230 ft.).*

weakly mineralized drillhole CP-11-006 (Figure GS-7-2). These two features indicate that hydrothermal activity conducive to the formation of VMS deposits occurred in the area and that further testing of this favourable stratigraphy should be conducted. In contrast to the volcaniclastic rocks that occur to the west, drillhole WEK-94-3A intercepts relatively unaltered, monotonous, dark green basalt of possible ocean-floor affinity (e.g., Syme et al., 1999).

South Wekusko Lake sedimentary rocks

Drillcores from EPV-12A, W-13 and 218-10 contain well-bedded, 0.5–3 m thick intervals of pebbly sandstone, wacke and mudstone (Figure GS-7-8). The pebbly sandstone contains abundant quartz and feldspar grains, as well as dark grey lithic fragments (Figure GS-7-9a, b). The beds often have sharp, sometimes scoured contacts with underlying mudstone and contain dark grey, subangular tabular fragments interpreted as mudstone rip-up
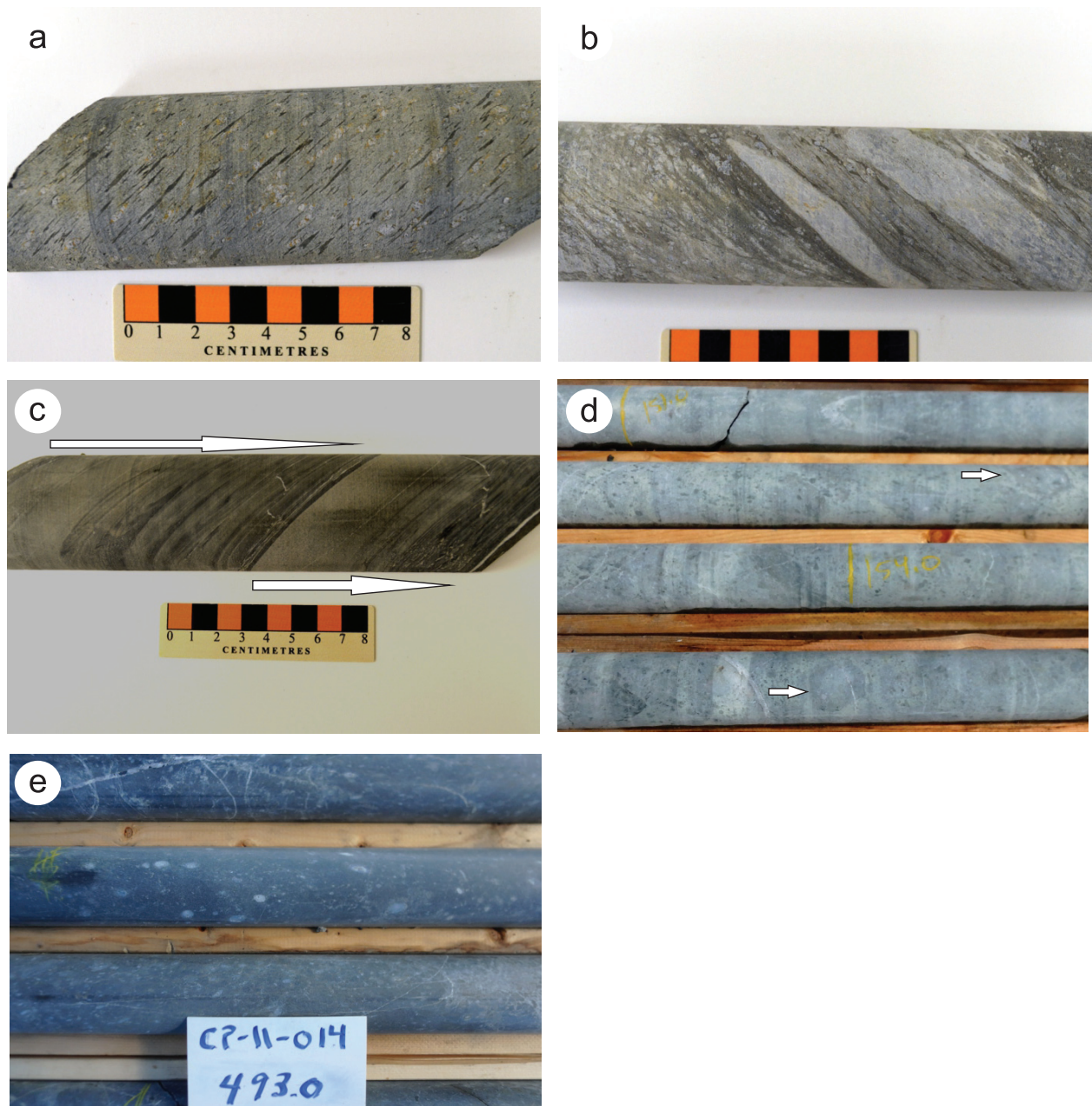
Figure GS-7-7: *Volcanic rocks from the Hayward Creek–south Wekusko Lake area: **a)** quartz-phyric dacite with mafic la-pilli, drillcore CP-11-008, 192 m; **b)** heterolithic tuff breccia with chloritized matrix, drillcore CP-11-008, 262.5 m; **c)** bedded feldspathic wacke (arrows show two fining sequences), drillcore CP-11-008, 290.7 m; **d)** intermediate feldspar-pyroxene–crystal tuff with block-size clasts (arrows show clasts; core diameter 4.76 cm), drillcore CP-11-014, 155.5 m; **e)** silicified basalt with 1 cm quartz amygdules (core diameter 4.76 cm), drillcore CP-11-014, 493 m.*

clasts (Figure GS-7-9b). Mudstone from drillcore EVP-12A differs from that of drillcore W-13 in that it contains pinhead (~1 mm) staurolite/garnet porphyroblasts (Figure GS-7-9a) instead of radiating andalusite (Figure GS-7-9c). Sandstone and wacke in drillcore 218-10 contain 1–2 mm, orange-brown porphyroblasts believed to be staurolite (not shown). Drillcore from the upper portion of drillcore 138-26 intersects pyroxene-feldspar–phyric andesite and minor tuff before intersecting wacke and dark grey, andalusite-bearing mudstone. The contact

relation between the volcanic and sedimentary units is masked by brittle faults annealed with calcite.

Drillcore 138-27 intersects predominantly dark grey, massive (structureless) to laminated mudstone. Dark grey, aluminous, mud-rich intervals contain andalusite porphyroblasts that display well-developed chiastolite crosses (Figure GS-7-9d). In the last few metres of the drillcore, wacke is intercalated with medium-grained quartz diorite (Figure GS-7-9e).
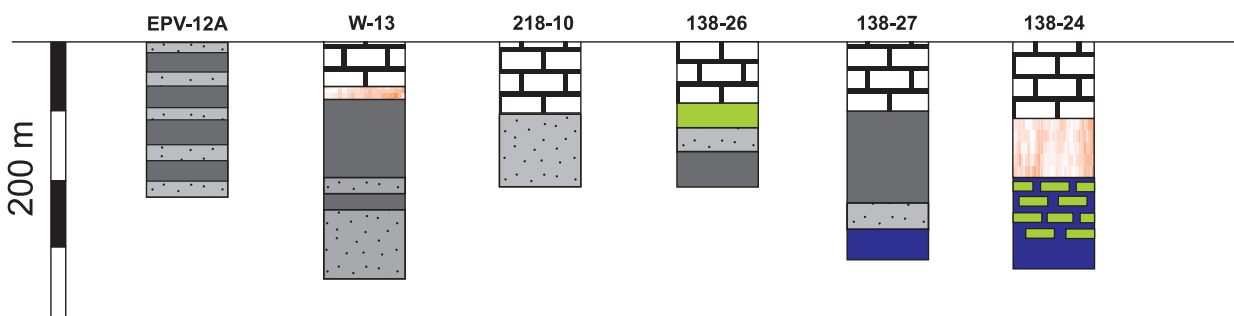
Figure GS-7-8: *Schematic sections of examined drillcore from the sedimentary rocks south of Wekusko Lake; see Figure GS-7-2 for drillhole-collar locations and Figure GS-7-3 for legend.*

Plutonic rocks

Drillcore 138-24 displays a well-developed regolith between 57 and 99 m. Less weathered rocks downhole reveal graphite- and sulphide-rich intermediate tuff and porphyritic dacite that are brecciated and intruded by a medium-grained gabbro to quartz diorite. The intrusive breccia varies from wallrock that has an angular jigsaw fit, with minor quartz diorite in the interstices, to partially consumed subrounded xenoliths that have well-developed reaction haloes and are supported by a quartz diorite/gabbro matrix. In places, sulphides appear to have been mobilized into fractures and interstices between some of the fragments (Figure GS-7-9f). As mentioned in the 'South Wekusko sedimentary rocks' section, drillcore 138-27 has 30–40 cm quartz diorite intervals intercalated with mudstone over the last few metres of the drillhole.

Metamorphic grade

At the south end of Wekusko Lake, mudstone in drillcore EVP-12A-94 and chlorite-altered mafic volcaniclastic rocks in drillcore SL91-3 contain disseminated pinhead staurolite/garnet porphyroblasts. To the south, however, similar mudstone in drillcores W-13, 138-26, and 138-27 does not contain garnet/staurolite, but rather andalusite. The fine-grained character of pelitic mudstone, the lack of biotite overgrowths on chlorite and sericite, and the lack of staurolite and/or garnet porphyroblasts tentatively suggest that metamorphic grade decreases to the south-southwest of drillhole EVP-12A-94. The presence of randomly oriented crystals of euhedral andalusite is interpreted to be related to contact metamorphism, possibly resulting from emplacement of quartz diorite/gabbro intrusions like those observed in drillcores 138-26 and 138-24. In hand specimen, sandstone and wacke in drillcore 218-10 appear to contain staurolite porphyroblasts, but this has yet to be confirmed by petrography.

Discussion

Zinc-copper mineralization at the Copper-Man deposit is hosted by bimodal volcanic rocks (basalt flows and dacite) that contain pervasive chlorite and sericite alteration. A thick succession of heterolithic tuff breccia that shows local silicification and weak sericite alteration of felsic clasts defines the hangingwall. Gilbert and Bailes (2005) drew analogies between the Hayward Creek assemblage and the upper portion of the Chisel sequence in the Snow Lake assemblage (e.g., Bailes and Galley, 2007), based on the prevalence of fragmental rocks and similar, evolved, tholeiitic to calcalkaline geochemical affinities. However, their geochemical data for the Hayward Creek assemblage were obtained only for mafic rocks and do not include niobium (Nb). Geochemical analyses of felsic and mafic rocks from the Copper-Man deposit (pending) will provide further information on the geochemical affinity and tectonic setting of the volcanic rocks hosting the deposit.

A wide variety of mainly volcaniclastic rocks is present beneath the Phanerozoic cover south of Wekusko Lake. Intermediate to mafic tuff is common in drillcores from the western half of the study area (e.g., 135-15, 138-18, B-73; Figure GS-7-2), whereas intermediate to felsic flows or volcaniclastic rocks are associated with drillcores farther to the east (e.g., SL91-4 and CP-11-008; Figure GS-7-2). Drillcore SL91-3 contains mafic feldspar-crystal tuff and lapilli tuff that have been pervasively chloritized (now an assemblage of chlorite±garnet±biotite); this style of alteration is associated with subconcordant to discordant VMS-related alteration zones in the Snow Lake assemblage (e.g., Bailes et al., 2016). South of the Kofman VMS deposit, drillcore CP-11-014 contains a bimodal sequence of basalt and intermediate volcaniclastic rocks that is overprinted by epidotization and silicification, and contains sections of volcanic breccia cemented by calcite. This alteration is considered typical of regional semiconformable alteration zones (e.g., Bailes et al., 2016). The recognition of subconcordant- to discordant-style hydrothermal alteration, as well as more regional semiconformable-style alteration, provides valuable new information for companies exploring for sub-Phanerozoic VMS deposits south of Wekusko Lake. Specifically, this new information indicates that both broad (diffuse) and
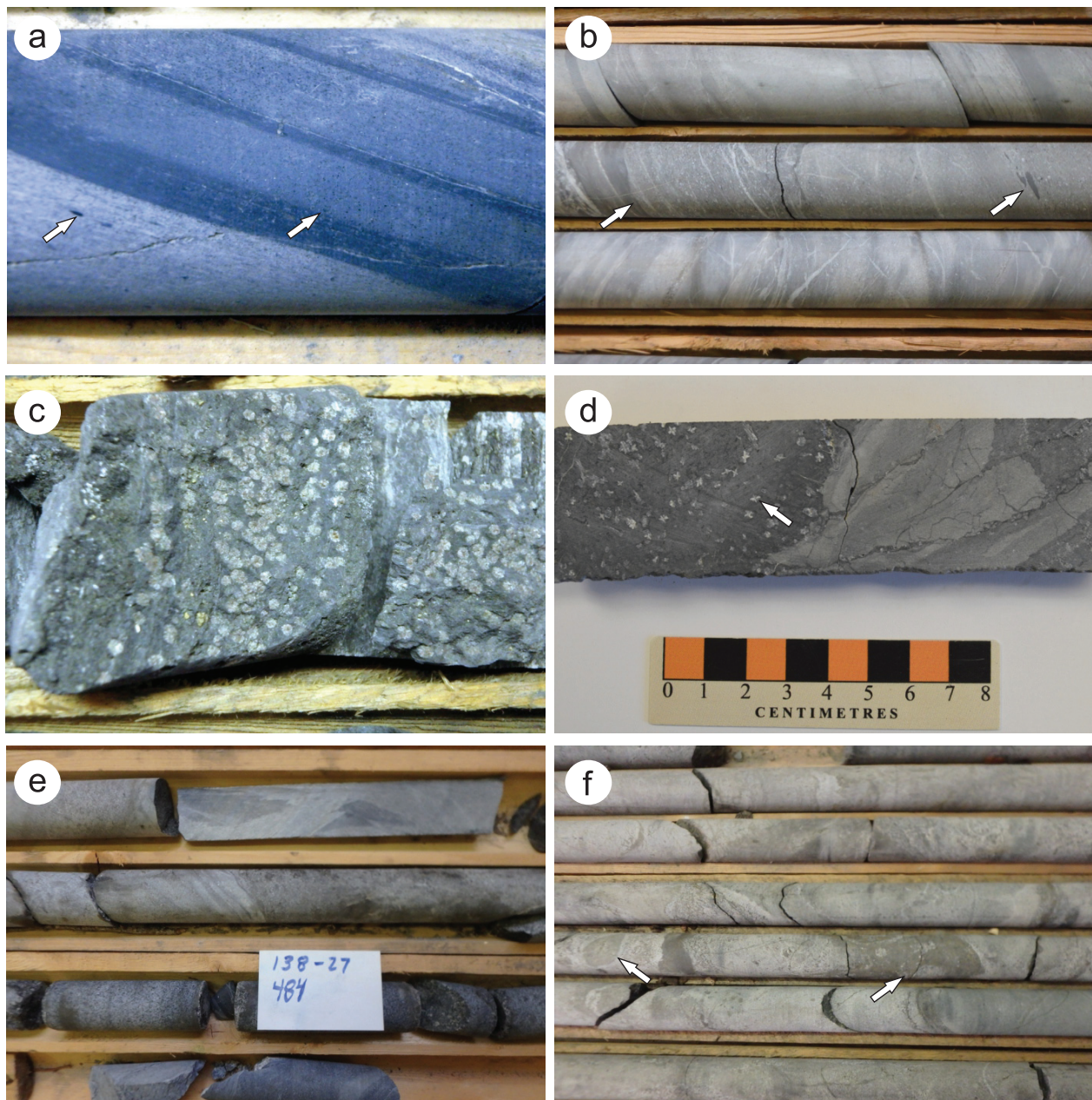
Figure GS-7-9: *Sedimentary and plutonic rocks from south Wekusko Lake area: **a)** sharp contact between pebbly sandstone with quartz and lithic grains (left arrow) and garnet/staurolite–bearing mudstone beds (right arrow; core diameter 4.76 cm), drillcore EPV-12A, 112.5 m; **b)** pebbly sandstone bed with well-developed basal scour into underlying mudstone (left arrow) and mudstone rip-up clasts (right arrow; core diameter 3.65 cm), drillcore W-13, 167.6 m (550 ft.); **c)** andalusite porphyroblasts in dark grey mudstone (core diameter 3.65 cm), drillcore W-13, 86.9 m (285 ft.); **d)** chiastolite (andalusite) crosses in dark grey mudstone (core diameter 3.65 cm), drillcore 138-27, 59.1 m (194 ft.); **e)** quartz diorite intercalated with wacke (core diameter 3.65 cm), drillcore 138-27, 147.2 m (483 ft.); **f)** xenoliths of andesite/dacite (left arrow) and graphitic sulphide (right arrow) in quartz diorite/gabbro (core diameter 3.65 cm), drillcore 138-24, 158.5 m (520 ft.).*

focused sub-seafloor hydrothermal alteration, which is linked to the formation of VMS deposits, affected much of the sub-Phanerozoic volcanic rocks southwest of Wekusko Lake and that the potential for discovering new VMS deposits in this area is above average. Geochemistry should yield constraints on the magmatic affinity and tectonic setting of the associated volcanic rocks.

The map produced by the NATMAP Shield Margin Project Working Group (1998) shows a package of Burntwood group turbidites that extends to the south and widens, and is juxtaposed against Missi group conglomerate and sandstone to the east (Figure GS-7-2). Although minor quartz and lithic pebbly sandstone and mudstone are associated with the lower portions of turbidite

sequences, no significant intercepts of conglomerate were observed in drillcore during this study; rather, a general east-to-west fining was observed, with sandstone and mudstone in drillcore 218-10 to nearly all mudstone in drillcore 138-27 (Figures GS-7-2, 8). Based on these observations, there appears to be much less Missi group than is currently interpreted, and most of the observed rocks from drillholes W-13, 218-10 and 138-26 could be considered part of the Burntwood group, or possibly similar to the transitional facies described by Syme et al. (1995) for Missi group rocks along the southern shoreline of Tramping Lake (Figure GS-7-2). Gilbert and Bailes (2005) indicated that Burntwood group rocks extend into Goose Bay a short distance before terminating, contrary the map of the NATMAP Shield Margin Project Working Group (1998), which indicates that Burntwood group rocks extend southward beneath Phanerozoic cover (Figure GS-7-2). The only drillhole in the area that apparently intersects this unit is 138-17. Despite poorly preserved and partial drillcore, observations suggest that it is mainly feldspathic tuff and not the dark grey turbiditic mudstone characteristic of the Burntwood group. This reinterpretation may indicate that favourable volcanic stratigraphy extends to the west; unfortunately, no other drillholes are available that might provide additional constraints on how far west it might extend.

Economic considerations

Bimodal (felsic and mafic) volcanic rocks of possible arc affinity, widespread hydrothermal alteration (i.e., epidote, chlorite) and known VMS mineralization all indicate that the area south of Wekusko Lake is highly prospective for VMS exploration. The volcanic rocks intersected in drillhole 138-15 are reported to contain 1.02% Zn between 58.8 and 60.1 m (192.8 and 197.3 ft.; Assessment File 92428). A more recent drillhole (CP-11-006) intersected a disseminated sulphide lens between 222 and 234 m that contains sphalerite mineralization, including a short interval (0.35 m) containing 3.93% Zn (Assessment File 63J1159).

The Reed Lake–Wekusko Lake area includes Ni-Cu±Co sulphide deposits (Jackfish and Rice Island) and occurrences of Ni-PGE±Co mineralization (Reed Lake layered mafic–ultramafic intrusion and leucogabbro of the Wine deposit; see Gagné 2015, Figure GS-3-2), indicating significant regional potential for these types of deposit, which have historically received little exploration attention in the region south of Wekusko Lake. As such, sulphide-graphite–rich intermediate tuff and dacite intruded by gabbro in drillcore 138-24 represent a sub-Phanerozoic example of a magmatic system that could produce Ni-Cu±Co sulphide deposits. Historically, the core was partially split and sampled for Cu-Zn but not assayed for Ni, Co or platinum-group elements (Assessment File 92428). Assay results for a grab sample from this drillcore are pending.

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