Report of Activities 2003

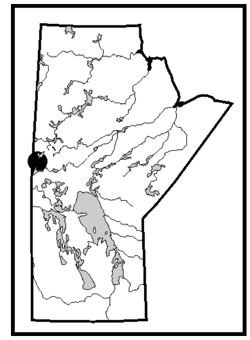
Published by:
Manitoba Industry, Economic Development and Mines
Manitoba Geological Survey, 2003.

ERRATA:

The publisher/department name in the bibliographic reference cited immediately below the title of each GS report should read **Manitoba Industry, Economic Development and Mines** instead of **Manitoba Industry, Trade and Mines**.

GS-1 Geological investigations in the northern Flin Flon Belt, Manitoba (parts of NTS 63K13NE and 14NW)

by H.P. Gilbert



Gilbert, H.P. 2003: Geological investigations in the northern Flin Flon Belt, Manitoba (parts of NTS 63K13NE and 14NW); *in* Report of Activities 2003, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 9–21.

Summary

The aim of the project is to determine the nature and distribution of the distinctive tectonostratigraphic components in the northern Flin Flon Belt through detailed (1:20 000-scale) geological mapping and geochemical investigations. Recent (2001) data indicate that both arc and transitional arc-MORB[1]–like volcanic rock suites occur within the project area, which extends north from Wabishkok Lake to the volcanic rock–metasedimentary gneiss contact at the north margin of the Flin Flon Belt. The northernmost part of the volcanic terrane is inferred to be of juvenile arc affinity, whereas the section immediately to the south that extends through Dismal Lake is geochemically transitional and of possible arc-rift origin, according to the limited data available. Both the inferred arc-type and arc-rift volcanic rock suites appear to consist almost entirely of basalt, related gabbro and metamorphic derivatives, in contrast to the more varied rock assemblages in analogous volcanic suites elsewhere in the Flin Flon Belt. A section of transitional basalt, geochemically and lithologically similar to Dismal Lake basalt, also occurs south of the west end of Wabishkok Lake.

Localities of economic interest occur within both the arc-type and transitional arc-MORB–like volcanic sequences within the project area. Two occurrences of prominent Cu-Zn-Au mineralization within the Blueberry Lake map area, which have been the focus of several exploration programs since ca. 1960, were investigated in 2003. In the east part of Blueberry Lake, base-metal mineralization in felsic volcanic rocks is now known to be located at or close to the contact between arc basalt and transitional basalt of possible arc-rift origin. Both the Blueberry Lake occurrence and the Ham Lake deposit to the north, close to the north margin of the greenstone belt, are interpreted as being hosted by arc-type volcanic rocks. Between these two occurrences, transitional basalt in the Dismal Lake Block contains a conformable zone, close to the south margin of the section, characterized by electromagnetic anomalies and localized base-metal sulphide mineralization. This stratigraphic zone warrants renewed investigation, in view of the recently identified geochemical setting of the locality. An additional target is represented by a 30 m wide zone of silicic and epidotic alteration that contains sporadic sulphide mineralization, within the transitional basalt section southwest of Wabishkok Lake.

Introduction

A two-week field program in the north part of the Flin Flon Belt focused on the Bluenose Lake and Blueberry Lake areas, located west and east of Wabishkok Lake, respectively (Fig. GS-1-1, -2; Gilbert, 2003a). Fieldwork in the Blueberry Lake area was facilitated by the gravel road leading to Sherridon and by winter logging roads, whereas access to Bluenose Lake was by boat and canoe via Wabishkok Lake. The most recent mapping in this part of the northern Flin Flon Belt was carried out by the author (Gilbert, 1996–2003) and Zwanzig et al. (1995).

The main purpose of the project is to determine the nature and distribution of the distinctive tectonostratigraphic components in the northern Flin Flon Belt, and to evaluate the economic potential of both these components and specific localities of mineralization within the volcanic terrane. The project includes both detailed (1:20 000-scale) geological mapping and concurrent geochemical investigations. At Bluenose Lake, geochemical sampling was undertaken to establish the distribution of arc and back-arc basin basaltic terranes indicated by recent mapping in that area (Gilbert, 2001a, b; Gilbert, unpublished data, 2002). The main fieldwork was carried out farther east, in the area north of the Blueberry Lake, where previous mapping indicated the presence of both MORB-like and juvenile arc volcanic rocks (Gilbert, 2001a, 2003b). Features of special interest in the latter area are

1) felsic volcanic rocks associated with electromagnetic (EM) anomalies, northeast of Blueberry Lake (Fig. GS-1-2; Gilbert, 2001b, 2003a);
2) a mineralized alteration zone within basalt-derived amphibolite, associated with a base-metal sulphide deposit immediately north of Ham Lake; and
3) base-metal mineralization within basalt and derived gneiss, 1.5 km west-northwest of Ham Lake, approximately

[1] mid-ocean ridge basalt

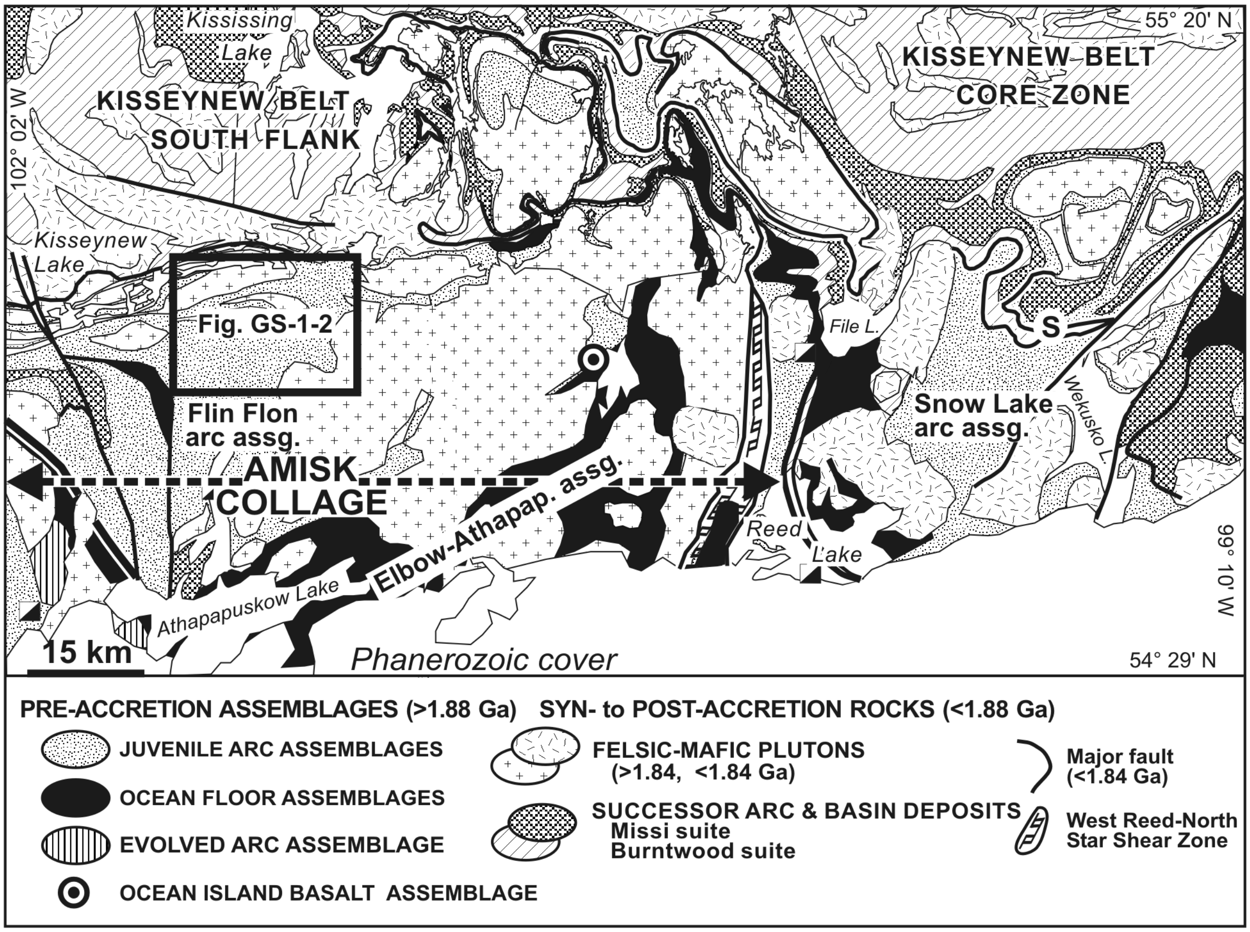


Figure GS-1-1: Simplified geology of the Flin Flon greenstone belt, showing the major tectonostratigraphic assemblages and location of the project area.

on-strike with the Ham Lake deposit.

Supracrustal rocks in the Bluenose Lake–Wabishkok Lake–Blueberry Lake area consist mainly of basaltic flows, amphibolite and derived gneiss that include both arc and MORB-like volcanic types (Table GS-1-1). Minor rhyolite and volcanic fragmental rocks (at Blueberry Lake) and an enclave of massive to fragmental rhyolite within gabbro (southwest of Kotyk Lake) are attributed to juvenile arc volcanism. Localized base-metal sulphide mineralization and hydrothermal alteration of volcanic rocks in the vicinity of Ham Lake suggest these rocks are also of oceanic arc affinity, because virtually all of the VMS ore deposits in the Flin Flon Belt are hosted by juvenile arc type volcanic rocks (Syme and Bailes, 1993). Confirmation of the geochemical affinities of the various tectonic components in the northern Flin Flon Belt will be established after completion of geochemical analysis of the volcanic rocks that were collected in the current (2003) field season.

Mapping in 2003 extended to the north boundary of the Flin Flon Belt. At that locality, close to the contact between basalt and paragneiss of the Kisseynew sedimentary gneiss domain, the volcanic rocks are variously attenuated and altered to garnet-bearing mafic gneiss. A granitoid terrane (approximately 1 km wide in the section north of Blueberry Lake) occurs between the volcanic rocks to the south and paragneiss to the north.

Tectonostratigraphic setting

The north part of the Flin Flon Belt is a tectonic collage of arc- and MORB-like components that are separated by major faults related to 1.88 to 1.87 Ga tectonic accretion (Lucas et al., 1996; Gilbert, 1998, 1999). Arc volcanic rocks are predominant; subordinate MORB-like rocks and transitional arc to MORB-type components are tectonically intercalated with the arc volcanic rocks. The MORB-like rocks include at least three geochemically distinct types, which are invariably in fault contact with arc volcanic rocks, consistent with the contact relationships of analogous rocks elsewhere in the Flin Flon Belt (Syme, 1995; Lucas et al., 1996). The Animus Lake Block (Fig. GS-1-2) is a

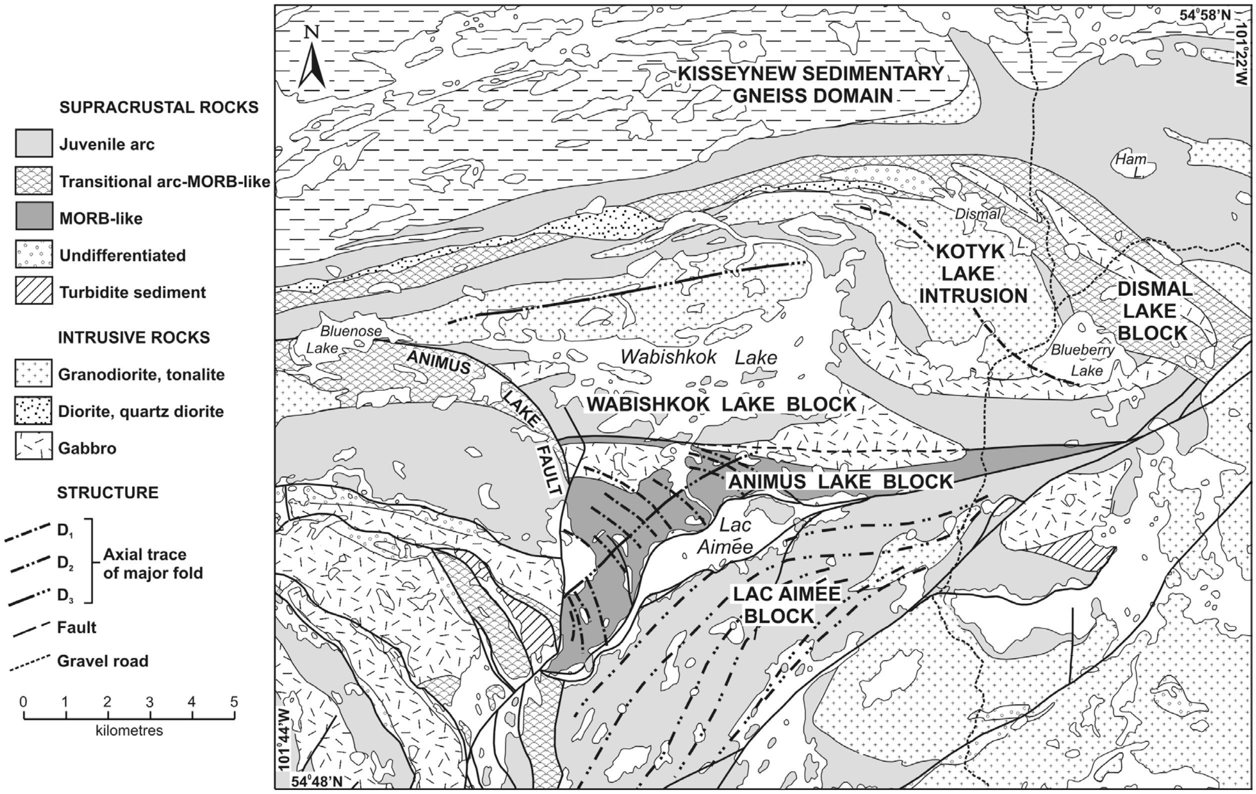


Figure GS-1-2: Generalized geology of the Lac Aimée–Wabishkok Lake–Dismal Lake area.

Table GS-1-1: Table of formations in the Bluenose Lake–Wabishkok Lake–Blueberry Lake area.

Precambrian (Proterozoic)	
Post–1.88 Ga intrusive rocks	
	Granodiorite, granite, quartz diorite, tonalite; minor diorite, granodiorite, felsic porphyry, pegmatite and aplite (5)
1.92-1.87 Ga volcanic, intrusive and sedimentary rocks (Amisk Collage)	
Intrusive rocks	
	Gabbro, pyroxenite, minor hornblendite (4)
Volcanic and sedimentary rocks of juvenile arc affinity	
	Sedimentary rocks of probable exhalative origin (J3)
	Rhyolite, dacite and felsic porphyry (J2)
	Basalt, related fragmental and intrusive rocks, derived amphibolite and gneiss (J1)
Volcanic rocks of transitional arc-MORB–like affinity	
	Basalt, mafic tuff and related intrusive rocks; derived amphibolite and gneiss (T1)

Unit numbers in parentheses refer to map units on Preliminary Map PMAP2003-2

highly deformed tectonic wedge that is geochemically similar to the Elbow-Athapapuskow assemblage — an ocean-floor volcanic terrane that extends through the south-central part of the Flin Flon Belt, 20 km south of Lac Aimée (NATMAP Shield Margin Project Working Group, 1998). The MORB-like Animus Lake Block has been interpreted as a dismembered part of the Elbow-Athapapuskow assemblage that was tectonically transported and intercalated with arc components in the northern part of the Flin Flon Belt during tectonic accretion at 1.88 to 1.87 Ga (Gilbert, 1998, 1999). Geochemically distinct, transitional arc to MORB-like rocks in the area north and east of Wabishkok Lake (Dismal Lake Block) are separated from arc volcanic rocks to the south (Wabishkok Lake Block) by granitoid rocks (Kotyk Lake intrusion; Fig. GS-1-2). Geochemically transitional rocks also occur near the west end of Wabishkok Lake, where they are interpreted to extend west through the south part of Bluenose Lake. The northernmost component of the Flin Flon Belt, which extends north and west from the vicinity of Ham Lake (Fig. GS-1-2), consists of mafic volcanic and related intrusive rocks that are locally altered and mineralized, and are of inferred arc volcanic origin.

Structure

The Bluenose Lake–Wabishkok Lake–Blueberry Lake area encompasses at least two major structural domains in the north part of the Flin Flon Belt, separated by the north- to northwest-trending Animus Lake Fault (Fig. GS-1-2). West of this fault, major structural features such as primary stratigraphic layering, major folds, regional foliation and block-bounding faults trend northwest to west, whereas, east of the fault, the trends of several block-bounding faults and major folds are northeast to east. The Animus Lake Fault is thus considered to be a major crustal feature that was initiated during 1.88 to 1.87 Ga tectonic accretion of the Amisk Collage, and may represent the north part of an early thrust plane that extended across the width of the greenstone belt, along which a part of the Elbow-Athapapuskow ocean-floor assemblage (now the Animus Lake Block) was tectonically transported to the north flank of the belt.

D_1 and D_2

The Animus Lake Block is a highly deformed tectonic wedge that is dominated by a series of tight to isoclinal, northwest-trending F_1 folds (Fig. GS-1-2; Table GS-1-2). The block was apparently subjected to D_1 deformation prior to final juxtaposition against the adjacent Lac Aimée fault block to the southeast, because the axial traces of the F_1 folds are discordant to the northeast-trending, block-bounding fault (Gilbert, 1997, 1998, 1999). Minor F_2 folds in both the Animus Lake and Lac Aimée blocks plunge west to southwest. Although no major F_2 folds were recognized in the Animus Lake Block, F_2 folds are the dominant structural element in the Lac Aimée Block ('Lac Aimée anticlinorium' of Gilbert, 2002). In the Wabishkok Lake Block immediately to the north, D_2 resulted in northeast-plunging minor folds that range from open flexures to tight similar folds, locally associated with axial-planar, strain-slip cleavage (Gilbert, 2001a). The limited evidence for stratigraphic facing direction in the Wabishkok Lake Block suggests that the north-facing panel of pillowed basalt in the south part of the block may represent the south limb of a major F_1 synform, the axial plane of which extends northwest from Blueberry Lake through the area occupied by the Kotyk Lake granitoid intrusion (Fig. GS-1-2).

D_3 and D_4

The Wabishkok Lake Block is dominated by the east-northeast-trending 'Wabishkok Lake antiform' of inferred D_3 age (Gilbert, 2001a), which is delineated by the pattern of regional (S_1) foliation and resulted in a regional Z-shaped flexure in both the supracrustal rocks and the Kotyk Lake intrusion (Fig. GS-1-2). The Wabishkok Lake antiform is characterized by an open style and shallow, east-northeast plunge, in contrast to F_2 folds in the northern Flin Flon Belt, which have moderate to steep plunge and are generally tighter in style.

Mafic volcanic rocks and related gneiss in the area north of Blueberry Lake (Gilbert, 2003a) constitute the south-east limb of the F_3 Wabishkok Lake antiform (Fig. GS-1-2); these rocks extend northwest to west around the margin of the Kotyk Lake granitoid intrusion. The east-northeast axial trend of the Wabishkok Lake antiform is roughly parallel to the volcanic rock–metasedimentary gneiss contact at the north margin of the greenstone belt, which appears

Table GS-1-2: Post-accretionary history of deformation of supracrustal rocks in the northern Flin Flon Belt.

	Animus Lake Block	Lac Aimée Block	Wabishkok Lake Block
D_1	Tight to isoclinal F_1 folds with northwest-trending axial planes dominate the fault block.	Inferred early folds (coeval with regional S_1 foliation) may have been eradicated by subsequent deformation.	Inferred synform with northwest-trending axial plane (extends from Blueberry Lake through the Kotyk Lake granitoid intrusion).
D_2	Minor F_2 folds with moderate to steep, west to southwest plunge, generally tight.	Southwest-trending Lac Aimée synclinorium is the dominant regional structure. Associated minor folds with moderate to steep, west to southwest plunge, generally tight.	Northeast-plunging minor folds range from open flexures to tight similar folds, locally associated with axial-planar, strain-slip cleavage.
D_3	Northeast-trending, F_3 open fold delineated by the curvilinear pattern of F_1 axial traces. Interpreted as part of a regional flexure in the north-central part of the Flin Flon Belt ('Embury Lake fold').	Possible reinforcement of southwest-trending F_2 folds during D_3.	'Wabishkok Lake antiform', with east-northeast-trending axial plane, is an open fold with shallow, east-northeast plunge. The axial trace is roughly parallel to the volcanic rock–metasedimentary gneiss contact at the north margin of the Flin Flon Belt.
D_4	Localized brecciation and faulting, commonly accompanied by retrogressive, greenschist-facies metamorphism.		

to have had a significant influence on the attitude of the F_3 major fold (Fig. GS-1-1).

A major open fold of inferred F_3 age in the Animus Lake Block, similar to the Wabishkok Lake antiform, is delineated by the curvilinear pattern of F_1 axial traces (Fig. GS-1-2). This northeast-trending open fold is part of a regional flexure in the north-central part of the Flin Flon Belt ('Embury Lake fold' of Stauffer, 1990). This flexure may have been caused by late sinistral movement along the Kisseynew–Flin Flon boundary, accompanied by crustal-scale deformation of the Amisk Collage (Ashton, 1993). Late (D_4) deformation in the northern Flin Flon Belt consisted of localized brecciation and faulting that was commonly associated with retrogressive, greenschist-facies metamorphism. Further details on the deformation history of this area are provided in Gilbert (1996, 1997, 2001a, 2002).

Stratigraphy

Comprehensive lithostratigraphic details of the diverse tectonic components in the northern Flin Flon Belt have been previously published (Gilbert, 1996, 1997, 1998, 1999, 2001a). This report provides additional information, based on the brief, two-week field program in 2003.

Arc volcanic rocks (Wabishkok Lake Block)

Supracrustal rocks in the west part of the Wabishkok Lake Block consist almost exclusively of aphyric basalt and related mafic intrusive sills (Gilbert, 2001b). Whereas basalt is also predominant in the east part of the fault block, a variety of other volcanic rock types also occurs in the area east of Wabishkok Lake. Subordinate stratigraphic units in the Blueberry Lake area that have been previously described (Gilbert, 2001a) include pyroxene-phyric and plagioclase-phyric basalts (unit J1c, J1f)[2], and monolithic to heterolithic volcanic breccia (unit J1d, J1e). In addition, a prominent, massive to fragmental rhyolite lens (unit J2a) occurs as a skialithic enclave within gabbro southwest of Kotyk Lake (Gilbert, 2001b). A dacitic unit (unit J2c) east of Blueberry Lake and a chert unit (unit J3a) near the southeast end of Dismal Lake are located at or close to the inferred contact between the Wabishkok Lake and Dismal Lake blocks (Fig. GS-1-2; Gilbert, 2003a).

Dacite (unit J2c)

A wedge-shaped dacitic unit, approximately 350 m thick and extending for 700 m along strike, occurs close to the southeast corner of Blueberry Lake, where several base-metal exploration programs have been conducted since the locality was first staked in 1954 (Gale and Norquay, 1996; Assessment Files 90485, 93337, Manitoba Industry, Trade and Mines, Winnipeg). The dacite is a fine-grained, medium grey weathering rock that is remarkably homogeneous and characterized by a fine 'sugary' texture consistent with a tuffaceous origin; feldspar grains of apparent detrital origin (0.5–1 mm, up to 20% of the rock) are locally preserved, and traces of pale grey, felsic lapilli occur close to the southwest margin of the map unit. Fine parallel fractures that resemble the cooling fractures of volcanic flows were, however, observed elsewhere in the map unit; the sericite-quartz–filled fractures are 2 to 3 mm wide and spaced 8 to 15 cm apart. Plagioclase phenocrysts (?phenoclasts) occur sporadically in the dacitic unit, whereas garnet porphyroblasts are relatively more common; both minerals occur as 0.5 to 1.5 mm crystals that constitute up to 10% of the rock. The dacitic rock is massive to moderately foliated, with a brittle, conchoidal fracture. The origin of this enigmatic unit is assumed to be tuffaceous, but an extrusive (flow) origin cannot be ruled out. Petrographic data may provide a more definitive interpretation of the origin of the rock.

Several quartz-plagioclase porphyry dikes of inferred synvolcanic age (unit J2b) occur within the dacite (unit J2c). The porphyry intrusions are 1 to 4 m wide and highly siliceous, with cream to rusty pink weathered surfaces. Minor chalcopyrite±malachite–bearing quartz veins occur close to the southwest margin of the dacitic unit.

Chert (unit J3a)

A cream-weathering, highly siliceous rock interpreted as chert is exposed at a roadside outcrop at the inferred northeast margin of the Wabishkok Lake Block, 0.6 km southeast of the southeast end of Dismal Lake (Fig. GS-1-2; Gilbert, 2003a). This unit occurs between gabbro (to the northeast) and aphyric basalt of the Wabishkok Lake arc volcanic sequence to the southwest. The 3 to 5 m thick, aphanitic chert unit contains sporadic iron-stained domains and diffuse, branching, epidote-sericite stringers; the latter are interpreted as being derived from early tectonic fractures. The unit is associated with garnetiferous amphibolite (0.4 m thick) and is provisionally interpreted as an exhalative

[2] Numbers in parentheses throughout this report refer to map units on Preliminary Map PMAP2003-2 (Gilbert 2003a).

deposit at or close to the base of the Wabishkok Lake stratigraphic sequence.

Arc volcanic rocks (Ham Lake area)

Volcanic rocks in the vicinity of Ham Lake are the northernmost component of the Flin Flon Belt, and are characterized by relatively increased metamorphic grade and deformation, compared with rocks to the south. Original volcanic features are rarely preserved in the basaltic flows north of Ham Lake, so their tectonic affinity cannot be inferred from their appearance in the field. These rocks are provisionally interpreted to be of juvenile arc origin, because of the presence of a base-metal sulphide deposit and a conspicuous zone of hydrothermal alteration immediately north of Ham Lake (A.F. 90398, 90483). This interpretation is based on the fact that almost all massive sulphide mineral deposits in the Flin Flon Belt are located in arc-type or arc-rift–type volcanic terranes, as opposed to MORB-like volcanic sequences (Syme et al., 1996, 1999; Bailes and Galley, 1999). The stratigraphic facing direction of the panel of rocks that extends from Ham Lake to the north margin of the Flin Flon Belt is unknown; however, the spatial relationship between the Cu-Zn sulphide deposit and an inferred footwall alteration zone immediately north of Ham Lake indicates a north-facing sequence at that locality (D. Dudek, pers. comm., 2003).

Aphyric basalt and derived gneissic rocks; related gabbro (unit J1a)

Mafic volcanic flows north and northwest of Ham Lake locally display remnants of pillow selvages and amygdaloidal texture, but these rocks are largely recrystallized to amphibolite and mafic gneiss that are devoid of primary features. Diffuse to sharply defined gneissic lamination is characteristic of the gneiss, which locally contains garnet porphyroblasts; the garnets (typically 0.5–2 mm in size and approximately 10% of the rock) are commonly associated with fine anthophyllite prisms, indicating an amphibolite-facies grade of metamorphism. The garnets are disseminated or locally concentrated in concordant, 10 to 30 cm wide zones parallel to the foliation. Green hornblende porphyroblasts are also common and are assumed to be coeval with the widespread recrystallization of the basalt to medium-grained amphibolite. The meta-amphibolite is very similar to metagabbro that occurs as subordinate interlayers within the mafic volcanic sequence. Gabbroic units of both synvolcanic and younger ages are recognized; these mesocratic to melanocratic gabbros are lithologically similar, but the younger type is distinguished by the presence of basalt inclusions that were foliated prior to their incorporation. Other minor intrusive units include felsitic dikes (locally with up to 25% hornblende porphyroblasts) and, close to the north margin of the greenstone belt, granodiorite to pink pegmatite.

A major alteration zone occurs within basaltic rocks 100 m north of the north shore of Ham Lake. The zone is contiguous with the 'Ham Lake deposit', a subeconomic massive sulphide occurrence that has been the target of geophysical exploration and diamond drilling (A.F. 90398). The hostrock is a massive to strongly foliated, aphyric basalt that locally contains quartz-amygdaloidal and rare fragmental zones. These rocks are commonly folded and faulted, and apparently represented a relatively incompetent zone during D_2 and D_3 deformation. The zone of alteration is approximately 75 m wide, and is characterized by silicic, feldspathic and subordinate epidotic metasomatism, widely distributed amphibole and garnet porphyroblasts, and localized sulphide-type mineralization (Fig. GS-1-3, -4). Remnant zones of medium green basalt occur within pale grey to white, strongly silicified zones with scattered hornblende porphyroblasts (Fig. GS-1-5). Garnet blasts (0.2 to 1.5 cm across) are locally concentrated in stringers or diffuse zones that are interpreted as domains of

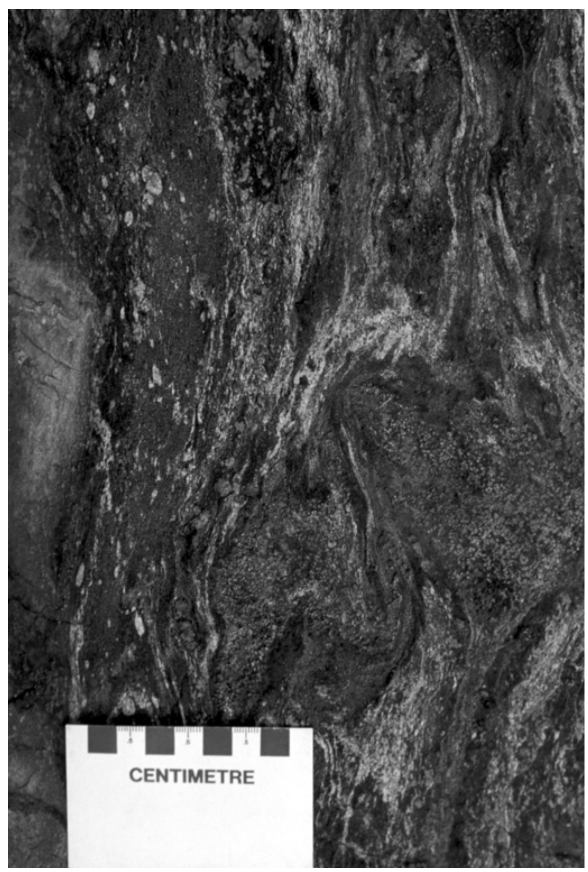


Figure GS-1-3: Contorted, disrupted garnetiferous amphibolite (unit J1h) derived from pillowed basalt, alteration zone north of Ham Lake; note dark chloritic stringers of probable pillow selvage origin and quartz-amygdaloidal domain at left side.

Figure GS-1-4: Basalt-derived garnetiferous amphibolite (unit J1h) with quartzofeldspathic net-veining, alteration zone north of Ham Lake.

Figure GS-1-5: Silicified aphyric basalt (unit J1a) with hornblende blastic overprint, alteration zone north of Ham Lake; Y-shaped remnants of nonsilicified basalt occur in the lower part of the photograph.

early metasomatism, possibly coeval with sulphide mineralization and hydrothermal alteration. Rusty-weathering domains of disseminated pyrite and pyrrhotite (±chalcopyrite) up to 70 cm wide occur sporadically within the alteration zone. Minor intrusive units of both pre- and post-D_1 ages occur within this zone; the units include leucocratic to mesocratic gabbro, pegmatitic gabbro and fine-grained leucotonalite. The earlier, probably synvolcanic gabbroic intrusions have metasomatically altered and assimilated the basaltic hostrocks (Fig. GS-1-6).

Transitional rocks (Dismal Lake Block)

Transitional arc-MORB–like basalt and related mafic gneiss in the Dismal Lake Block are geochemically distinctive from arc volcanic rocks in the north part of the Fin Flon Belt (*see* 'Geochemistry of distinctive tectonostratigraphic components in the northern Flin Flon Belt' section). The transitional rocks are also distinguished lithostratigraphically from juvenile arc sequences; they consist only of basalt, related gabbro and metamorphic derivatives, whereas the predominantly basaltic arc volcanic sequences also contain subordinate felsic volcanic rocks and volcanic fragmental and sedimentary deposits. The Dismal Lake volcanic sequence is devoid of stratigraphic top indicators, except for a single locality where graded, redeposited mafic tuff appears to be north facing.

Aphyric basalt and derived gneissic rocks; related gabbro (unit T1a)

Transitional basalt and pillowed basalt are moderately to strongly deformed and metamorphically recrystallized to amphibolite-grade mineral assemblages. Original pillow structure is rarely preserved but pillows were formerly more common, based on the widespread occurrence of derived, laminated amphibolite that is lithologically gradational with highly attenuated pillowed basalt. The strongly foliated amphibolite contains thin (0.2–2 cm) epidotic laminae with chloritic margins that are interpreted as pillow selvage remnants. Quartz (±feldspar) amygdules occur sporadically in the mafic volcanic rocks. The basaltic rocks are almost entirely aphyric, but one flow unit north of Blueberry Lake contains minor plagioclase phenocrysts (1–4 mm, 5% of the rock).

Fine-grained amphibolite and attenuated basalt are lithologically gradational with mafic gneiss, which is coarser grained and characterized by variable metamorphic mineral segregation. Garnet occurs both in fine-grained, massive to laminated amphibolite and in mafic gneiss. The porphyroblasts (up to 4 mm) are disseminated or concentrated in diffuse concordant zones (10–20 cm wide); garnet is common in amphibolite associated with localized pyritic mineralization and surficial iron staining. Garnet porphyroblasts are widespread in the area north of Dismal Lake, but are relatively rare in the west part of the fault block, in the area north of Wabishkok Lake (Fig. GS-1-2). Homogeneous, medium-grained amphibolite units (5–30 m wide) that constitute approximately 10% of the Dismal Lake sequence are interpreted as synvolcanic gabbro sills.

Mafic tuff (unit T1i)

Well-bedded mafic tuff was observed at a single locality within the transitional volcanic sequence, 1 km north of the northwest part of Dismal Lake (Gilbert, 2003a). Bedding, at a scale of 4 to 25 mm, is defined by grey-green to pale beige-green weathered tones and variable amounts of fine, detrital plagioclase grains that are locally graded. These beds indicate a provisional stratigraphic facing direction to the north. The tuff is associated with an apparently coarser, 0.5 m thick unit interpreted as redeposited volcanic breccia; this unit displays traces of pebble- to cobble-sized fragments that are defined by subtle tonal differences and quartz-amygdaloidal domains. The minimum thickness of the tuffaceous unit is 40 m.

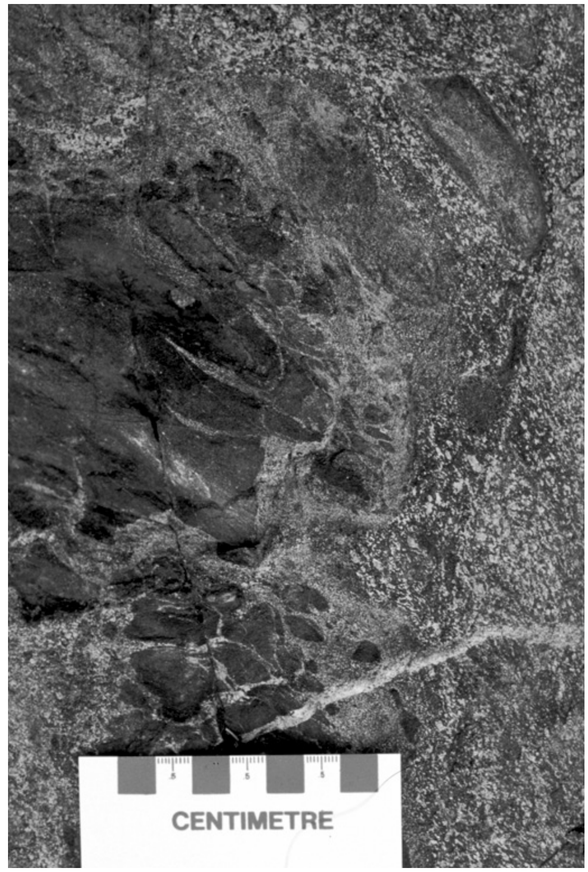


Figure GS-1-6: Basaltic enclave within gabbro (units J1a, b) showing progressive metasomatic assimilation by the intrusive rock, alteration zone north of Ham Lake.

Transitional rocks (southwest Wabishkok Lake–Bluenose Lake area)

Limited geochemical data (four analyses) indicate that the volcanic terrane south of the west end of Wabishkok Lake is geochemically akin to transitional arc-MORB–like basalt in the Dismal Lake Block (*see* ‘Geochemistry of distinctive tectonostratigraphic components in the northern Flin Flon Belt’ section). The terrane southwest of Wabishkok Lake is relatively less deformed than the Dismal Lake sequence, and is distinguished from the latter by the preservation of moderate to very large, amygdaloidal, north-facing pillows and sporadic pyritic mineralization that is locally associated with pervasive alteration. Along strike from the section southwest of Wabishkok Lake, a sequence of amphibolite and mafic gneiss at Bluenose Lake is relatively more deformed and of higher metamorphic grade. The transitional basalt terrane is bounded to the northeast by the Animus Lake Fault, which is inferred to extend northwest to west, through the north-central part of Bluenose Lake (Fig. GS-1-2).

Aphyric basalt and derived gneissic rocks; related gabbro (unit T1a)

Pillowed basalt south of the west end of Wabishkok Lake is characterized by large, north-facing pillows that range in size up to 3.5 by 0.8 m. Ovoid quartz amygdules and pipe-amygdules up to 2.5 cm long are common, locally concentrated in the marginal zones of pillows. Carbonate-filled vesicles occur sporadically and large vugs occur close to the centre of some pillows. The medium green to dark green weathering basalt locally displays interpillow epidotic alteration and epidotization in the marginal parts of pillows. At least two conformable zones of pyrite-pyrrhotite mineralization occur within the basaltic section south of the west end of Wabishkok Lake. The more northerly zone occurs at the north margin of a conspicuous gabbro sill within the mafic volcanic section, whereas the occurrence to the south is located in a 30 m wide, silicified and epidotized zone within basaltic flows (Gilbert, 2001b). Mesocratic to melanocratic mafic sills (1–50 m) within the volcanic sequence are assumed to be synvolcanic; a related mafic dike at one locality is interpreted as a discordant feeder dike. Garnetiferous amphibolite and basalt-derived gneiss occur toward the margin of the transitional basalt terrane southwest of Wabishkok Lake.

At Bluenose Lake, amphibolite and mafic gneiss along strike from the basaltic section southwest of Wabishkok Lake are devoid of primary volcanic features. These rocks, of inferred transitional arc-MORB–like geochemical affinity, consist of both homogeneous, medium green to dark green weathering amphibolite and laminated amphibolitic gneiss that is lithologically similar to the previously described laminated gneiss north of Dismal Lake. Garnet and hornblende porphyroblasts are confined to the north margin of the Bluenose Lake volcanic section, where the mafic gneiss is characterized by disseminated to stratabound garnet, epidotic and quartzofeldspathic laminae, and localized boudinage (Fig. GS-1-7). Hornblende porphyroblasts (up to 1 cm) locally overprint the gneissic lamination. The lack of original volcanic features in the section at Bluenose Lake, which is assumed to be laterally equivalent to the pillowed sequence southwest of Wabishkok Lake, may be explained either as a lateral stratigraphic variation or as a result of deformation and metamorphism that were relatively more intense in the vicinity of Bluenose Lake and therefore eradicated primary features such as pillows and amygdaloidal textures.

Geochemistry of distinctive tectonostratigraphic components in the northern Flin Flon Belt

The geochemistry of the Lac Aimée and Animus Lake blocks has been previously described (Gilbert, 1999); other fault blocks in the north part of the Flin Flon Belt have also been investigated with a view to their tectonic origin (Gilbert, 2003b). The following brief discussion is based on both previously published and new analytical data, and describes the rare earth element (REE) signatures and variations in selected trace elements that distinguish the volcanic rock suites in the northern Flin Flon Belt.

Geochemical data for several tectonic components in the northern Flin Flon Belt are shown in Figure GS-1-8. The REE signatures of Lac Aimée and Wabishkok Lake arc basalts are similar, and are also akin to other juvenile arc basaltic suites within the Flin Flon arc assemblage (Stern et al. 1995a). These rocks are characterized by moderately sloping REE profiles, enriched Th and pronounced Nb depletion, typical of subduction-related arc magmas.

The Animus Lake Block contains two distinct geochemical types that closely resemble enriched mid-ocean ridge basalt (E-MORB)–type and depleted normal mid-ocean ridge basalt (N-MORB)–type basaltic rock suites in the Elbow-Athapapuskow ocean-floor assemblage (Stern et al., 1995b). Both the E- and N-MORB Animus Lake types, which have an apparent conformable stratigraphic relationship (Gilbert, 1999), are characterized by very low Th/Nb ratios (averaging 0.09 and 0.07, respectively) compared to arc basalt and transitional basalt types in the northern Flin Flon Belt (e.g., Th/Nb ratios in Wabishkok Lake arc and Dismal Lake transitional basalts are 0.50 and 0.54, respectively). Animus Lake E-MORB–type basalt displays moderate Th and light REE enrichment (including Nb), but other REE contents are similar to N-MORB (Fig. GS-1-8d). Animus Lake N-MORB–type basalt, however, is REE-depleted (Fig. GS-1-8c); the low Th content is significant because, elsewhere within the Flin Flon Belt, Th depletion relative to N-MORB occurs only in one of the basalt suites of the Elbow-Athapapuskow ocean-floor assemblage; all other MORB-like and arc mafic volcanic rocks in the Flin Flon Belt show moderate to strong Th enrichment. (Stern et al.,

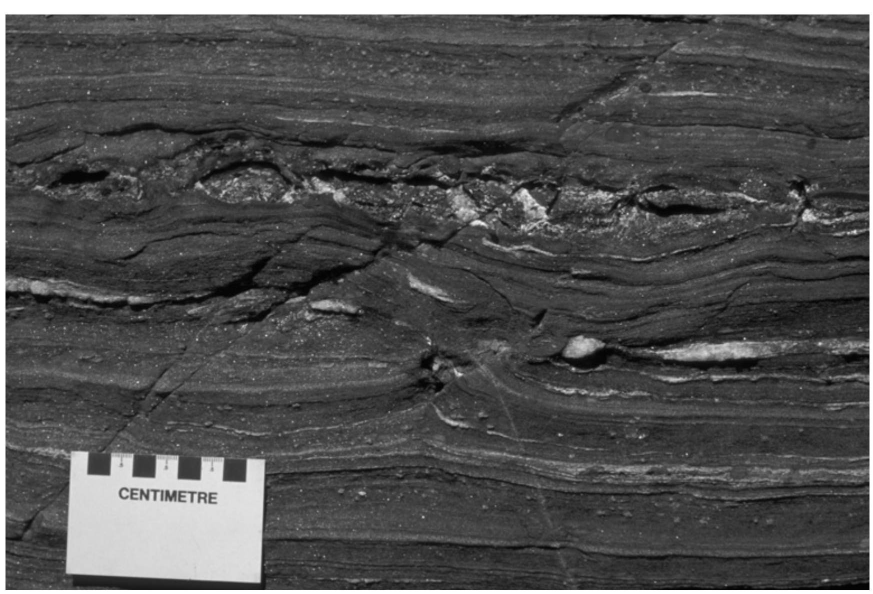


Figure GS-1-7: Finely laminated, garnetiferous amphibolite (unit T1h) derived from transitional basalt, north margin of the Bluenose Lake section.

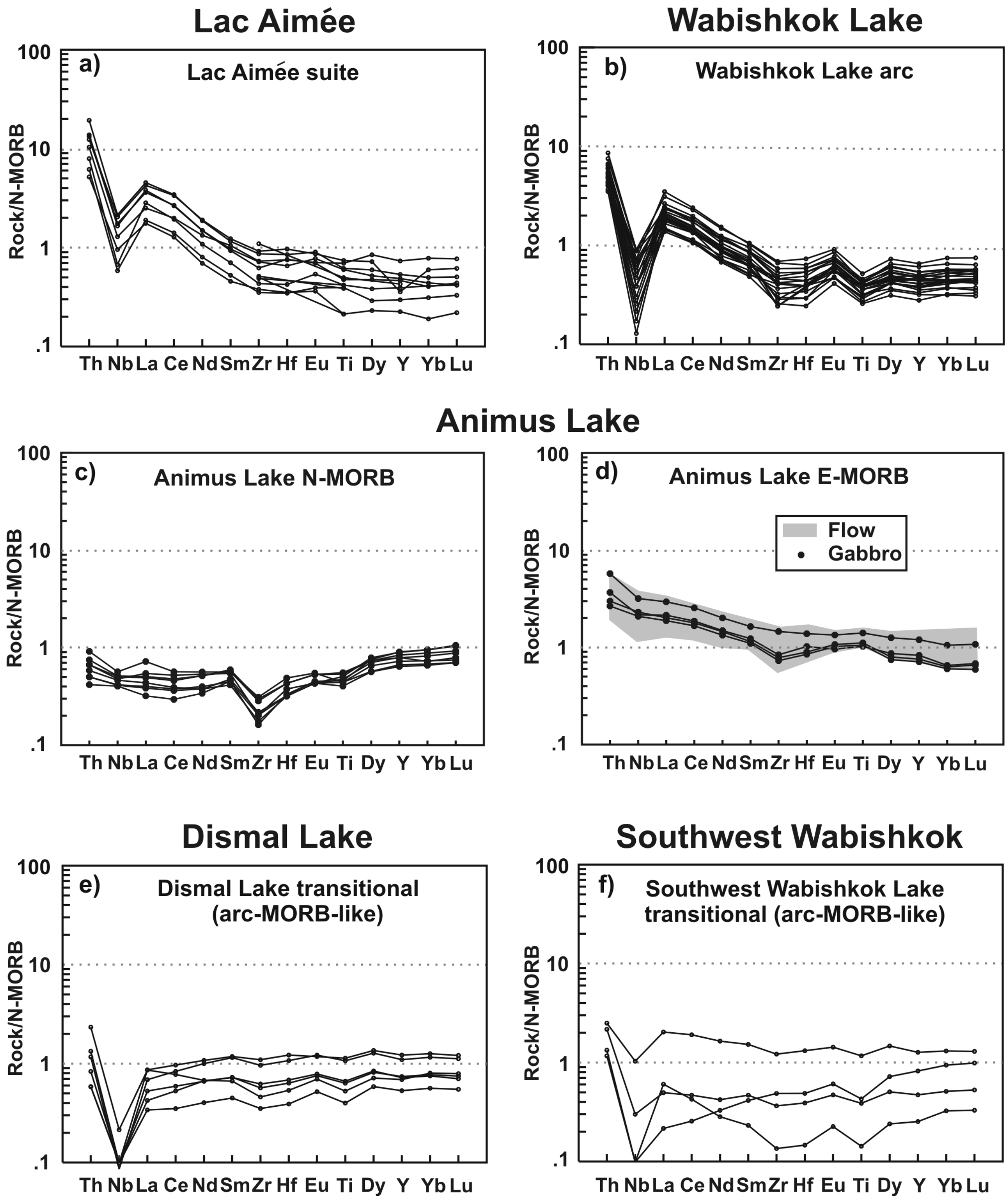


Figure GS-1-8: N-MORB–normalized extended element plots of arc, MORB-like and transitional volcanic rocks in the Lac Aimée–Wabishkok Lake–Dismal Lake area; normalizing values from Sun and McDonough (1989).

1995b; Gilbert, 1999). Low Th and Th/Nb in Animus Lake N-MORB are consistent with a back-arc basin or ocean-floor environment, but the occurrence of E-MORB–type basalt within the Animus Lake Block indicates that the source magma was modified as a result of magma mixing, metasomatism or assimilation of a crustal component.

Transitional arc-MORB–like Dismal Lake basalt is partly akin to N-MORB. Specifically, the rocks are depleted to slightly REE enriched, with flat (or slightly positively sloping) REE profiles (Fig. GS-1-8e); however, there is a negative Nb spike and Th/Nb ratios exceed primitive values. This signature, like the REE profiles of Animus Lake basalt, is also consistent with modification of an original MORB-like source magma that may previously have been depleted (relative to primitive mantle) in light REE. Mixing of such a depleted, MORB-like source with arc-type magma could result in the observed pattern of incompatible elements. The distinctive REE profile of Dismal Lake transitional basalt is possibly a result of magma mixing during the emplacement of a depleted, MORB-like source magma into an extensional back-arc basin at an early stage of arc rifting, whereby subduction-related magma (associated with rifting) was mixed with the primitive source and resulted in the hybrid arc-MORB–like Dismal Lake basalt. Alternatively, this geochemical signature may be due to magmatic processes unconnected with a subduction zone; this topic will be discussed more fully in a report on the geochemistry of the north part of the Flin Flon Belt, which will be published after analytical data from the current (2003) suite of geochemical samples have been obtained.

The volcanic section south of the west end of Wabishkok Lake is geochemically very similar to Dismal Lake basalt (Fig. GS-1-8f, e). The data are somewhat erratic and sparse, however, and more information is required in order to clearly establish the geochemical identity of this volcanic sequence.

Economic geology

Two localities of significant base-metal mineralization occur within the Blueberry Lake area (Gilbert, 2003a). Immediately north of Ham Lake, in the north part of the map area, Cu-Zn sulphide mineralization (with locally significant Au and Ag) occurs within mafic volcanic rocks of inferred juvenile arc affinity; the mineralization is associated with a conspicuous hydrothermal alteration zone. The other main locality of economic interest in the map area is close to the east end of Blueberry Lake, where base-metal and minor Au mineralization occur within an arc-type sequence of mafic to felsic volcanic rocks and gabbro, at or close to the contact with inferred arc-rift basalt. A third potential exploration target consists of a stratigraphic zone at or close to the south margin of the Dismal Lake transitional basalt section (Fig. GS-1-2). This zone contains minor pyrite-pyrrhotite showings and conformable EM anomalies (A.F. 90397; S. Masson, pers. comm., 2003), and therefore has potential for economically significant base-metal mineralization (Gilbert, 2003a).

At Ham Lake, in the area north of Blueberry Lake, a west- to west-northwest-striking zone of Cu-Zn sulphide mineralization, just north of the lakeshore, was discovered by Hudson Bay Exploration and Development Co. Limited (HBED) ca. 1958; subsequent diamond drilling of this zone yielded several sections (up to 0.5 m wide) of massive pyrite-pyrrhotite, with minor chalcopyrite (A.F. 90398; Gale and Norquay, 1996). The host rocks, reported in drill logs as 'andesite and hornblende-plagioclase gneiss', apparently correspond to rock types observed in the previously described hydrothermal alteration zone immediately north of Ham Lake (see 'Arc volcanic rocks [Ham Lake area]' section). More recent investigations of the 'Ham Zone' defined at least two east-plunging, lensoid zones of stringer to massive sulphide mineralization that extend laterally for up to 0.36 km (D. Dudek, pers. comm., 2003). A total of 51 diamond drill holes that delineate the sulphide zones yielded up to 2.6% Cu and 3.7% Zn (in 3.6 to 3.1 m wide intersections, respectively); additional intersections yielded 10.5 g/t Ag (over 7.7 m) and 14.1 g/t Au (over 0.5 m). Drillcore intercepts of the inferred footwall alteration zone associated with the ore lenses suggest a north-facing stratigraphic sequence (D. Dudek, pers. comm., 2003). Conspicuous sulphide mineralization and extensive surficial iron staining occur within basalt, related diabase and garnetiferous, layered gneiss 1.5 km to the west-northwest and approximately along strike from the alteration zone at Ham Lake. The fine- to medium-grained mafic gneiss is strongly deformed and partly silicified and epidotized. The 1.5 m wide mineralized zone at this locality contains alternating massive pyrite-pyrrhotite layers and subordinate nonmineralized amphibolitic units. The massive and stringer sulphide mineralization contains minor chalcopyrite, and is exposed over a short 8 m strike length (location 25 in Gale and Norquay, 1996).

In the east part of Blueberry Lake, northwest- to west-trending EM anomalies occur within a section of mafic to felsic volcanic rocks and gabbro (A.F. 93337; Gilbert, 2003a). Diamond drilling at that locality intersected mineralization (0.16% Cu, 0.98% Zn and 34 g/t Au) within massive sulphide layers up to 1.5 m thick (A.F. 90485). The mineralization is hosted by felsic volcanic units, up to 50 m thick, that are probably correlative with the dacitic rock unit (J2c) immediately northeast of the lakeshore (Gilbert, 2003a).

Two west-northwest-trending EM anomalies were delineated at Dismal Lake in an airborne geophysical survey conducted by HBED in 1960 (A.F. 90397; S. Masson, pers. comm., 2003). These anomalies occur along strike, at or close to the south margin of the Dismal Lake transitional basalt section, and may be part of a stratigraphic zone that extends through Dismal Lake for more than 3.5 km; a diamond-drill hole at the west end of the zone yielded massive pyrrhotite and pyrite, with a trace of chalcopyrite. A possibly correlative mineralized locality in the area north of Wabishkok Lake (Gilbert, 2001b), approximately 8 km farther west and close to the south margin of the Dismal Lake section, consists of a 0.7 m wide section of disseminated pyrite and pyrrhotite within silicified basalt and associated garnetiferous amphibolite. The stratigraphic zone that contains the EM anomalies at Dismal Lake and the mineralized locality farther west are approximately coincident with the contact between the Wabishkok Lake (arc) and Dismal Lake (arc-rift) volcanic terranes; the exact location of this contact is obscured by the Kotyk Lake granitoid intrusion (Fig. GS-1-2). The recently identified geochemical affinities of these two volcanic terranes (Gilbert, 2003b), together with the widely documented association of VMS mineralization with both juvenile arc volcanic rocks and arc rifting (Syme et al., 1999, and references therein) indicate that further exploration of this potentially fertile stratigraphic horizon is warranted.

Acknowledgments

The author is indebted to Joseph Cormier, a professional outfitter based at Pistol Lake, who generously made boats available to facilitate access to Bluenose Lake. Grade 8 students Luke Deptuch and Yari Kozel acted as geological assistants for a part of the field program, and their voluntary contribution is gratefully acknowledged.

References

Ashton, K.E. 1993: Structure of the southern flank of the Kisseynew Gneiss Belt in Saskatchewan; Trans-Hudson Orogen Transect, Trans-Hudson Orogen Transect, Report of Third Transect Meeting, Regina, Saskatchewan, April 1–2, 1993, University of British Columbia, LITHOPROBE Secretariat, LITHOPROBE Report 34, p. 84–87.

Bailes, A.H. and Galley, A.G. 1999: Evolution of the Paleoproterozoic Snow Lake arc assemblage and geodynamic setting for associated volcanic-hosted massive sulphide deposits, Flin Flon Belt, Manitoba, Canada; Canadian Journal of Earth Sciences, v. 36, p. 1789–1805.

Gale, G.H. and Norquay, L.I. 1996: Mineral deposits and occurrences in the Naosap Lake area, NTS 63K/14; Manitoba Energy and Mines, Geological Services, Mineral Deposit Series, Report 20, 91 p. and 1 map at 1:50 000 scale.

Gilbert, H.P. 1996: Geology of the Lac Aimée–Naosap Lake area; *in* Report of Activities 1996, Manitoba Energy and Mines, Geological Services, p. 32–39.

Gilbert, H.P. 1997: Geology of the Lac Aimée–Naosap Lake area (NTS 63K/13SE and 63K/14SW); *in* Report of Activities 1997, Manitoba Energy and Mines, Geological Services, p. 84–98.

Gilbert, H.P. 1998: Geochemistry of Paleoproterozoic volcanic rocks in the Lac Aimée area, Flin Flon Belt (parts of NTS 63K/13SE and 63K/14SW); *in* Report of Activities 1998, Manitoba Energy and Mines, Geological Services, p.19–22.

Gilbert, H.P. 1999: Geochemistry of Paleoproterozoic rocks in the Lac Aimée–Naosap Lake area, Flin Flon Belt (parts of NTS 63K/13SE and 63K14/SW); Manitoba Energy and Mines, Geological Services, Open File Report OF99-1, 21 p.

Gilbert, H.P. 2001a: Geology of the Wabishkok Lake area (parts of NTS 63K/13NE and /14NW); *in* Report of Activities 2001, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p.18–27.

Gilbert, H.P. 2001b: Geology of the Wabishkok Lake area (parts of NTS 63K/13NE, /14NW); Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Preliminary Map PMAP 2001F-3, scale 1:20 000.

Gilbert, H.P. 2002: Geology of the Alberts Lake area (NTS 63K/13 and 63K/14), Manitoba; *in* Report of Activities 2002, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 45–58.

Gilbert, H.P. 2003a: Geology of the Blueberry Lake area, Manitoba (part of NTS 63K14/NW); Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Preliminary Map PMAP2003-2, scale 1:20 000.

Gilbert, H.P. 2003b: Geochemistry and economic potential of tectonically distinct volcanic terranes at the north flank of the Flin Flon Belt (abstract); Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting 2003, Vancouver, British Columbia, Program with Abstracts, v. 28 (CD-ROM).

Lucas, S.B., Stern, R.A., Syme, E.C., Reilly, B.A. and Thomas, D.J. 1996: Intraoceanic tectonics and the development of continental crust: 1.92–1.84 Ga evolution of the Flin Flon Belt, Canada; Geological Society of America Bulletin, v. 108, p. 602–629.

NATMAP Shield Margin Project Working Group 1998: Geology, NATMAP Shield Margin Project area (Flin Flon Belt), Manitoba-Saskatchewan; Geological Survey of Canada, Map 1968A; Manitoba Energy and Mines, Map A-98-2, Sheets 1 to 7; Saskatchewan Energy and Mines Map 258A-1; scale 1:100 000.

Stauffer, M.R. 1990: The Missi Formation: an Aphebian molasse deposit in the Reindeer Lake zone of the Trans-Hudson Orogen, Canada; *in* The Early Proterozoic Trans-Hudson Orogen of North America, J.F. Lewry and M.R. Stauffer (ed.), Geological Association of Canada, Special Paper 37, p. 121–142.

Stern, R.A., Syme, E.C., Bailes, A.H. and Lucas, S.B. 1995a. Paleoproterozoic (1.90–1.86 Ga) arc volcanism in the Flin Flon Belt, Trans-Hudson Orogen, Canada; Contributions to Mineralogy and Petrology, v. 119, p. 117–141.

Stern, R.A., Syme, E.C. and Lucas, S.B. 1995b: Geochemistry of 1.9 Ga MORB- and OIB-like basalts from the Amisk collage, Flin Flon belt, Canada: evidence for an intra-oceanic origin; Geochimica et Cosmochimica Acta, v. 59, p. 3131–3154.

Sun, S.S and McDonough, W.F. 1989: Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes; Geological Society, Special Publication 42, p. 313–345.

Syme, E.C. 1995: 1.9 Ga arc and ocean floor assemblages and their bounding structures in the central Flin Flon Belt; Trans-Hudson Orogen Transect, Report of Fifth Transect Meeting, Regina, Saskatchewan, April 3-4, 1995, University of British Columbia, LITHOPROBE Secretariat, LITHOPROBE Report 48, p. 261–272.

Syme, E.C. and Bailes, A.H. 1993: Stratigraphic and tectonic setting of early Proterozoic volcanogenic massive sulphide deposits, Flin Flon, Manitoba; Economic Geology, v. 88, p. 566–589.

Syme, E.C., Bailes, A.H., Stern, R.A. and Lucas, S.B. 1996: Geochemical characteristics of 1.9 Ga tectonostratigraphic assemblages and tectonic setting of massive sulphide deposits in the Paleoproterozoic Flin Flon Belt, Canada; *in* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, D.A. Wyman (ed.), Geological Association of Canada, Short Course Notes, v. 12, p. 279–327.

Syme, E.C., Lucas, S.B. and Stern, R.A. 1999: Contrasting arc and MORB-like assemblages in the Paleoproterozoic Flin Flon Belt, Manitoba, and the role of intra-arc extension in localizing volcanic-hosted massive sulphide deposits; Canadian Journal of Earth Sciences, v. 36, no. 11, p. 1767–1788.

Zwanzig, H.V., Schledewitz, D.C.P. and Ashton, K.E. 1995: Geology, Flin Flon Belt–Kisseynew Belt transition zone, Manitoba-Saskatchewan; Manitoba Energy and Mines, Geological Services, Open File OF94-5; Geological Survey of Canada, Open File 3054; Saskatchewan Energy and Mines, Saskatchewan Geological Survey, Open File Report 95-1; map at 1:100 000 scale.