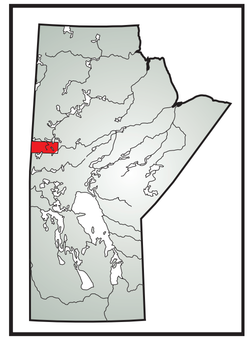
GS-5 Northern Flin Flon Belt, Manitoba: geological compilation progress report (part of NTS 63K13, 14)

by H.P. Gilbert



Gilbert, H.P. 2009: Northern Flin Flon Belt, Manitoba: geological compilation progress report (part of NTS 63K13, 14); *in* Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 47–57.

Summary

In 1986, the author initiated 1:20 000 scale geological mapping in the northern part of the Flin Flon Belt. The map area extended from latitude 54º48′N northward to the contact with the Kisseynew Domain, and from the Manitoba-Saskatchewan border in the west to Naosap Lake in the east. A compilation of the results of this mapping is underway, based on a series of preliminary maps and reports by the author, as well as unpublished geochemical data. A geological report, planned for release in 2010, will include a 1:50 000 scale geological map of the north-central part of the Flin Flon Belt, together with descriptions of the geology and geochemistry of the various tectonostratigraphic components and a geochemical database. This progress report provides 1) an outline of the main tectonostratigraphic components in the northern part of the Flin Flon Belt, 2) interpretations of the tectonic setting and magmatic source of various volcanic rock suites, and 3) some economic implications that arise from the new geological compilation.

Introduction

The Flin Flon Belt is the most prolific mining district in Manitoba, with combined reserves and production to 2007 of 183 million tonnes of Cu-Zn-Au-Ag ore from 26 different deposits (C. Beaumont Smith, pers. comm., 2009). The belt has been the subject of geological mapping by provincial and federal surveys for more than 60 years. In 1979, a detailed geological mapping program (Bailes and Syme, 1989) was initiated by the Manitoba Geological Survey (MGS); diverse geological investigations and targeted research projects have subsequently been carried out, as well as new projects that continue to the present time (Lucas et al., 1996; NATMAP Shield Margin Project Working Group, 1998; Gilbert, 2004; Simard and Creaser, 2007, and references therein). Although reconnaissance mapping has been undertaken across the entire width of the belt and beyond, detailed mapping has focused largely on the central and southern parts of the belt. In 1986, the author initiated 1:20 000 scale geological mapping in the northern part of the Flin Flon Belt (Embury-Alberts-Naosap-Wabishkok lakes area). This detailed mapping was subsequently extended to the northern margin of the volcanic terrane, where it is bounded by predominantly metasedimentary gneisses of the Kisseynew Domain, and eastward to the contact with an extensive granitoid terrane at Naosap Lake (Figure GS-5-1).

The geology of the northern Flin Flon Belt (NFFB) has been documented in various MGS reports and preliminary maps by the author between 1986 and 2004 (Gilbert, 2004, and references therein). The aim of the current compilation work is to integrate previous mapping with associated geochemical data to produce a final 1:50 000 scale geological map of the north-central Flin Flon Belt, together with descriptions of the geology and geochemistry of the various tectonostratigraphic components. Previous reports and maps by the author, as well as a geochemical database with more than 340 volcanic and related rock samples, are the basis for the new geoscientific map, which will be released in 2010. For this purpose, the various map legends of the original 1:20 000 scale preliminary maps in the Embury-Alberts-Naosap-Wabishkok lakes area will be updated and integrated into a single unified legend, based on lithostratigraphic as well as geochemical criteria. The final map and report will provide a synthesis of NFFB mapping by the author, as well as complement previous mapping in the Flin Flon–White Lake area to the south (Bailes and Syme, 1989) by highlighting lateral stratigraphic and geochemical differences within various tectonic components that extend from the south-central to the northern part of the Flin Flon Belt. The new map will also provide links to geological data in the area north of the Flin Flon Belt (Zwanzig and Bailes, work in progress, 2009), continuous with the latter via a regional basaltic formation that extends north from the NFFB and laterally for more than 100 km along the southern margin of the Kisseynew Domain. In addition, orthogneiss in the southern Kisseynew Domain, derived from 1.92–1.85 Ga volcanic and plutonic rocks (Zwanzig, 1999), is probably akin to Flin Flon Belt rocks and provides a link between the Kisseynew Domain and the NFFB to the south.

This report provides an outline of the main tectonostratigraphic components in the NFFB and highlights lateral changes within several structural corridors extending from the south-central to the northern part of the Flin Flon Belt. Interpretations of the tectonic setting and magmatic source of various volcanic rock suites are briefly discussed, as well as some economic implications that arise from the new geological compilation of the NFFB.

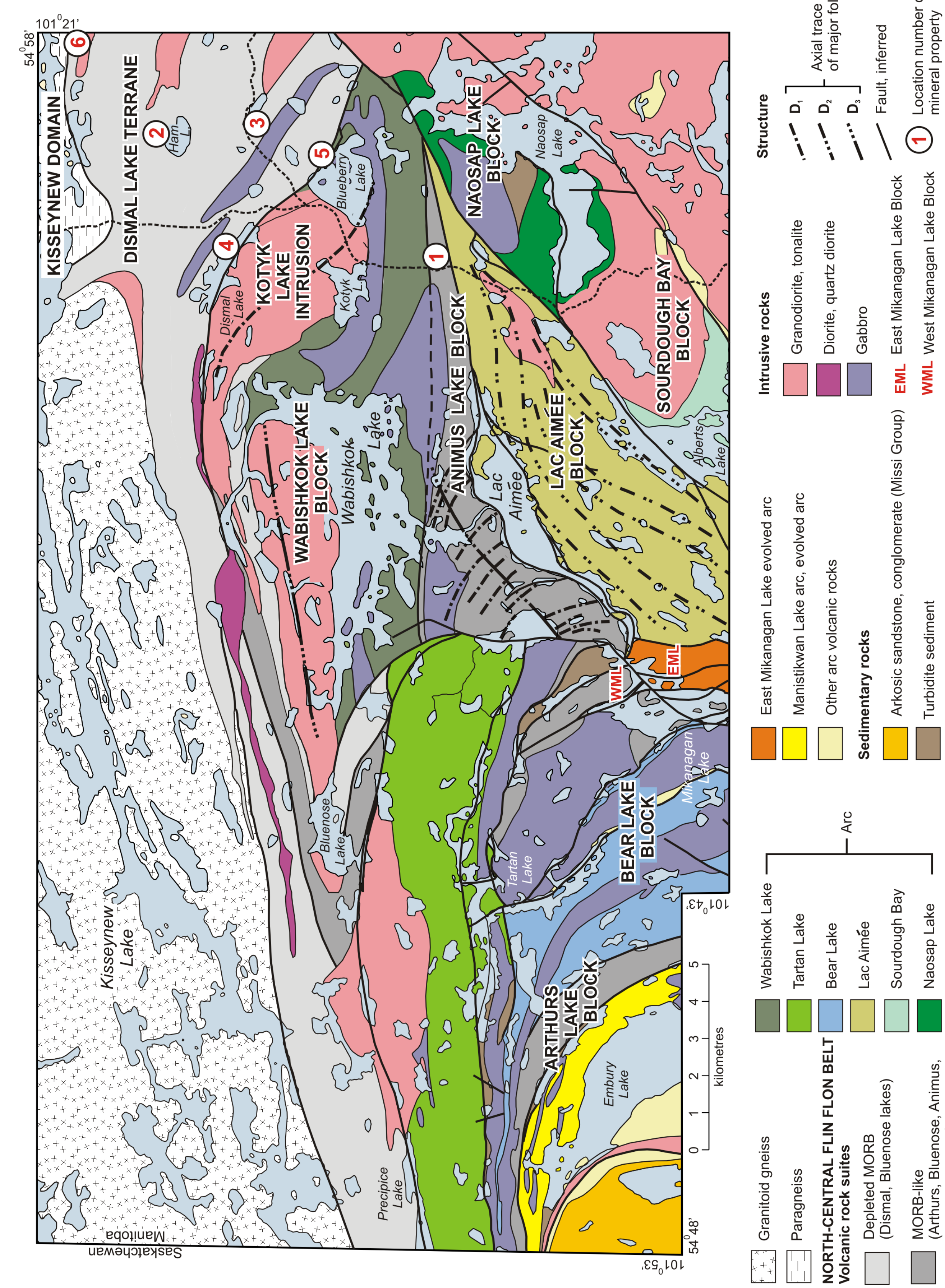


***Figure GS-5-1:** Geology of the north-central part of the Flin Flon Belt, showing the main tectonostratigraphic components.*

Tectonostratigraphic components in the northern Flin Flon Belt

The map area in the NFFB covers approximately 15 km by 35 km and contains more than 20 tectonically distinct blocks or fault slices of diverse volcanic, related intrusive and subordinate sedimentary rocks. Most of these components are akin to modern oceanic-arc rocks and are part of the Flin Flon arc assemblage (Stern et al., 1995a). Mid-ocean-ridge (MORB)–like volcanic rocks are structurally intercalated with juvenile-arc rocks, and an extensive area of depleted MORB (Dismal Lake Terrane) extends along and across the northern boundary of the Flin Flon Belt, where it is locally in fault contact with the Kisseynew Domain to the north (Gilbert, 2004). Arc-type rocks in the NFFB are assumed to be associated with subduction at a former oceanic arc, whereas MORB and depleted-MORB types are interpreted to have been associated with rifting and emplacement in a back-arc basin environment. Analogous MORB-type rocks and 1.90 Ga synvolcanic intrusions in the southern part of the Flin Flon Belt (Elbow-Athapapuskow ocean-floor assemblage) are coeval with some rocks in the tectonically juxtaposed 1.90–1.88 Ga Flin Flon arc assemblage (Stern et al., 1995b).

Arc and evolved-arc volcanic suites

Arc volcanic suites

Subaqueous mafic volcanic and related intrusive rocks of juvenile-arc affinity are the main components of the Amisk collage (Lucas et al., 1996) in the north-central part of the Flin Flon Belt, where 10 tectonically distinct arc-type suites have been interpreted as structurally juxtaposed with MORB-like volcanic rocks and sedimentary fault slices (Figures GS-5-1, -2a). The arc volcanic rocks consist of a wide range of massive to fragmental types and associated intrusions (Figure GS-5-2b, -2c). These volcanic suites are typically bimodal, consisting mainly of basalt–andesite and dacite–rhyolite[1], and include tholeiitic, transitional (calcalkaline to tholeiitic) and calcalkaline types (Figure GS-5-3a). Basalt, basaltic andesite and related fragmental rocks are predominant and form approximately one-third of the arc rocks; felsic volcanic rocks are generally minor components, except in the southeastern part of the study area where rhyolitic types form approximately 15% of the Lac Aimée Block and >50% of the northern part of the Sourdough Bay Block (Figure GS-5-1).

Geochemically, the juvenile-arc volcanic rocks are akin to modern oceanic-arc lavas and characterized by enrichment in Th and light rare earth elements (REE) but depletion of high-field-strength elements (HFSE) relative to MORB (Figure GS-5-4a). Low Nb (<2 ppm), TiO_2 (<0.8%) and, in some cases, depleted Zr are characteristic of the arc-type magmas. Such HFSE depletion is widely attributed to the refractory nature of the source magmas, which have undergone partial melting and basalt extraction prior to extrusion (Woodhead et al., 1993; Kerrich and Wyman, 1996). Compared to typical MORB-type volcanic rocks in the NFFB, the arc volcanic rocks are distinguished by elevated Th/Nb and La/Yb, and exhibit a relatively wider range of incompatible-element contents, attributed mainly to fractionation in the source magma. The range of Sm-Nd isotopic ratios in NFFB arc-type rocks, with ε_{Nd} values between –1.5 and +3.4 at 1.9 Ga, indicates that small amounts of recycled older crust (0%–10%) were incorporated in the mantle source of these volcanic suites[2] (Pearce, 1983).

Evolved-arc suites

Geochemically 'evolved' arc-type volcanic rocks occupy the East Mikanagan Lake Block (Figure GS-5-1), and analogous rocks are intercalated with 'normal' arc rocks in the Manistikwan Lake and Lac Aimée blocks. The evolved-arc rocks are geochemically distinct from normal-arc types, but stratigraphic and lithological differences are less conspicuous. The evolved-arc sequences consist largely of massive to pillowed basalt and related gabbro (± subordinate ferrobasalt, volcaniclastic and/or sedimentary rocks), and are typically less lithologically diverse than normal-arc sequences. Rhyolitic units that are locally associated with the basalts are of uncertain affinity because they are not geochemically distinctive as either 'normal' or 'evolved'.

Compared to normal-arc basalts with similar SiO_2 content, the evolved types are distinguished by higher incompatible-element contents, especially Nb and Ti (Figure GS-5-4b). This pattern reflects one or more of the following conditions during evolution of the source magma: 1) more pronounced fractionation, 2) relatively more pronounced influence (metasomatism and/or assimilation) of continental crust, and 3) lower degree of partial melting. Evolved-arc basalt and ferrobasalt are variably enriched in FeO_T (7.6–17.8%), TiO_2 (1.0–2.2%) and Th (0.7–3.6 ppm). The Sm-Nd isotopic data for evolved-arc basalt and (possibly related) felsic volcanic rocks, with ε_{Nd} values between –1.7 and +1.6 at 1.9 Ga, indicate that incorporation of older crustal material during magmatic evolution varied from 2 to >10% (Pearce, 1983; Stern at al., 1995a). There appears to be a continuum of increasing overall incompatible-element contents from Lac Aimée normal-arc through Lac Aimée evolved-arc to

[1] Terminology of volcanic rock types according to SiO_2 content is as follows: basalt, 46–53%; basaltic andesite, 53–57%; andesite, 57–62%; dacite, 62–70%; and rhyolite, >70%.
[2] Modelled on rare Archean slivers in the Flin Flon Domain (Stern at al., 1995a).

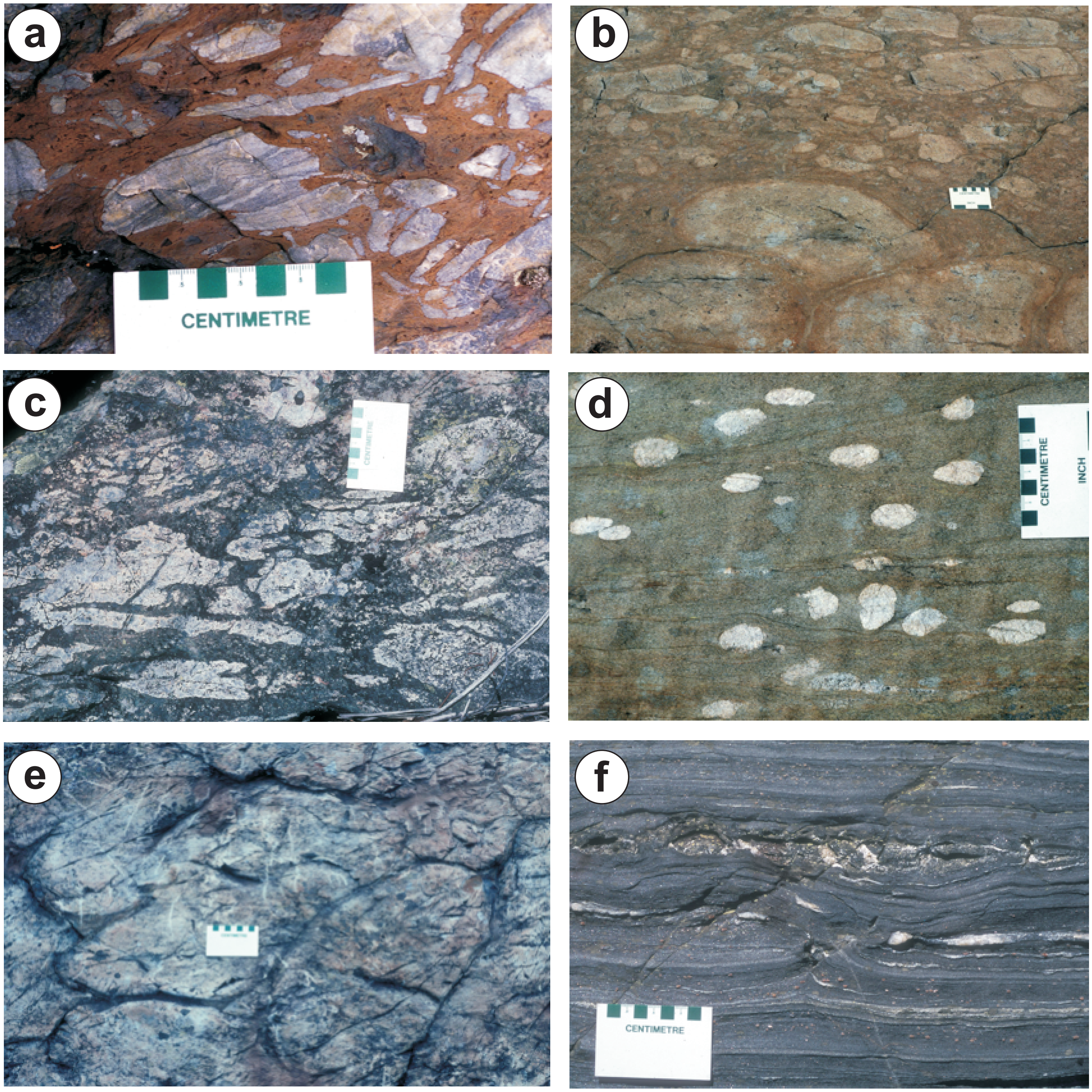


***Figure GS-5-2:** Outcrop photographs of massive and fragmental volcanic rocks in the northern Flin Flon Belt: **a)** fault breccia from a 20 m wide tectonic zone between normal mid-ocean-ridge basalt (N-MORB) and arc volcanic rocks at Bluenose Lake (Zone 14U, UTM 325479E, 6086046N, NAD 83); **b)** aphyric pillowed basalt and flow-top breccia within the Bear Lake arc volcanic suite (UTM 324143E, 6078649N); **c)** rhyolite breccia with angular to amoeboid fragments within the arc-type Sourdough Bay Block (UTM 336281E, 6077630N); **d)** plagioclase megacrysts in pillowed basalt within the Arthurs Lake N-MORB suite (UTM 319393E, 6081474N); **e)** aphyric pillowed basalt within the Animus Lake enriched mid-ocean-ridge basalt (E-MORB) suite (UTM 334423E, 6082674N); **f)** garnetiferous amphibolite derived from depleted MORB at Bluenose Lake, with fine, locally boudinaged tectonic lamination (UTM 327913E, 6086751N).*

East Mikanagan Lake evolved-arc volcanic suites (Figure GS-5-4a, -4b); the three volcanic suites have distinctive TiO_2/MgO ratios (Figure GS-5-5a), however, suggesting differences in their tectonic settings. In the TiO_2 vs. MgO diagram, Lac Aimée normal-arc basalt samples plot in the field of modern-arc magmas and East Mikanagan Lake evolved-arc rocks fall in the MORB and back-arc basin basalt (BABB) field; Lac Aimée evolved-arc rocks plot between these two fields.

Evolved-arc volcanic rocks in the Lac Aimée and East Mikanagan Lake blocks occur within a corridor that extends from Lac Aimée southwards into the central part of the Flin Flon Belt (Figure GS-5-1). Farther south in this corridor, Fe-rich tholeiite in the Scotty Lake

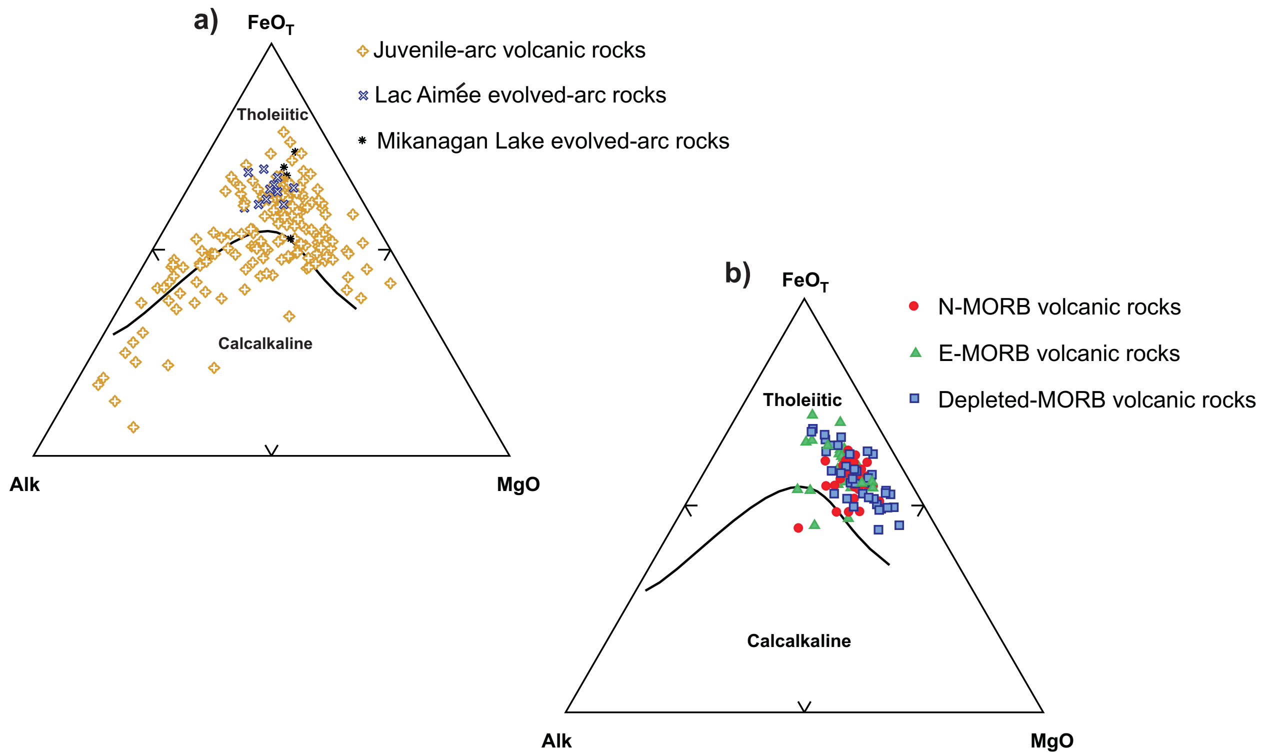


Figure GS-5-3: *Na_2O+K_2O vs. FeO_T vs. MgO ternary diagram (Irvine and Baragar, 1971) showing mafic to felsic volcanic rocks in the north-central Flin Flon Belt:* ***a)*** *arc and evolved-arc types;* ***b)*** *MORB types and depleted MORB.*

Block is lithologically and compositionally similar to the East Mikanagan Lake evolved-arc basalt. The two types have similar REE profiles (Figure GS-5-4b) and occur in monoclinal, massive to pillowed sequences with relatively low vesicularity and localized quench texture, as well as abundant mafic intrusions. Scotty Lake basalt and evolved-arc volcanic rocks in both the Lac Aimée and East Mikanagan Lake blocks could be fractionated components of a common magmatic source that evolved concomitant with the onset of arc rifting and progressive back-arc basin development. Subsequent tectonic reworking during 1.88–1.87 Ga assembly of the Amisk Collage (Lucas et al., 1996), associated with movement along a system of major faults (including the Sourdough Bay and Northeast Arm faults; Bailes and Syme, 1989) could have aligned the evolved-arc volcanic suites along a structural corridor that extends from north to south across the Flin Flon Belt (Figure GS-5-1). Furthermore, the progressive increase southward in the level of geochemically evolved composition from the Lac Aimée Block to the East Mikanagan Lake Block to the Scotty Lake Block (Figures GS-5-4b, 5a) may reflect a concurrent trend of increasingly more advanced rifting within this structural corridor.

MORB-type volcanic suites

Four tectonic enclaves of various MORB-type volcanic rocks (West Mikanagan Lake, Animus Lake, Arthurs Lake and Bluenose Lake blocks) are intercalated with the numerous arc-type fault blocks within the NFFB. The MORB volcanic suites consist almost entirely of basalt and abundant related gabbro sills, which constitute up to 30% of these sequences; they are thus lithologically and compositionally much less diverse than arc volcanic suites. The MORB volcanic suites are interpreted as back-arc rocks derived from source magmas that were largely unaffected by subduction-zone influences; ε_{Nd} values range from +3.3 to + 5.1 (at 1.9 Ga), consistent with a mantle source with little or no crustal recycling of older Proterozoic or Archean lithosphere. Several MORB suites contain abundant, aphyric to plagioclase±hornblende (pyroxene)–phyric diabase dikes; geochemical data obtained from four of these minor intrusions indicate that some, at least, are associated with arc-type rather than MORB-type magmatism.

Two MORB volcanic types—normal (N-MORB) and enriched (E-MORB)—are recognized in the NFFB (Figures GS-5-3b, -4c, -4d). These MORB types are analogous to geochemically similar varieties of MORB in the Elbow-Athapapuskow ocean-floor assemblage in the southern part of the Flin Flon Belt (Stern et al., 1995b). The N-MORB in the ocean-floor assemblage is assumed to be derived from depleted mantle in an ocean-ridge environment, whereas the source of the E-MORB rocks is interpreted as enriched mantle, similar to that of plume-related, ocean-island basalt (Stern et al., 1995b).

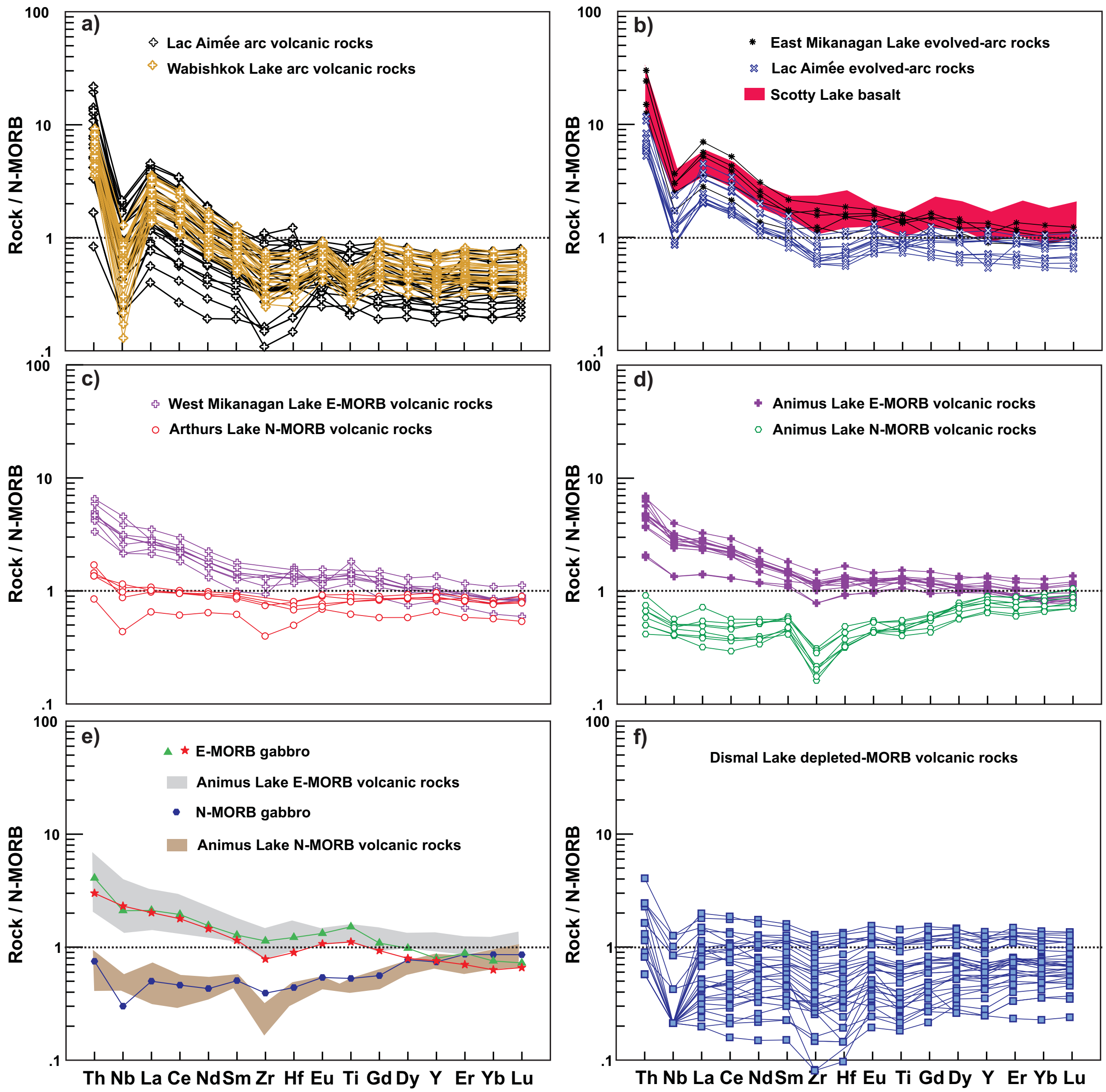


Figure GS-5-4: *Incompatible-element plots of mafic to intermediate volcanic rocks in the north-central Flin Flon Belt:* ***a)*** *juvenile-arc rocks;* ***b)*** *evolved-arc types and Scotty Lake basalt (Bailes and Syme, 1989);* ***c)*** *E-MORB and N-MORB types;* ***d)*** *Animus Lake MORB-type rocks;* ***e)*** *gabbro intrusions within/at the margin of the arc-type Wabishkok Lake Block, compared with Animus Lake MORB;* ***f)*** *Dismal Lake depleted MORB. Normalizing values* after *Sun and McDonough (1989).*

The distinctive REE patterns for the various MORB suites in the NFFB are comparable to the compositional differences between formations in the Elbow-Athapapuskow ocean-floor assemblage. Geochemical variation there has been attributed to mixing of depleted MORB and enriched mantle together with, in some cases, a subduction-modified mantle source, but without any crustal assimilation (Stern et al., 1995b).

West Mikanagan Lake E-MORB suite

The West Mikanagan Lake E-MORB sequence (Figure GS-5-1) is a uniform, monoclinal section of massive to pillowed basaltic flows and related gabbro. South of Mikanagan Lake, in the area structurally along strike from the E-MORB volcanic suite, the stratigraphic sequence in the arc-type Whitefish Lake–Mikanagan Lake Block (Bailes and Syme, 1989) is demonstrably different from the E-MORB West Mikanagan Lake section; these two contrasting sequences are assumed to be separated by a major fault.

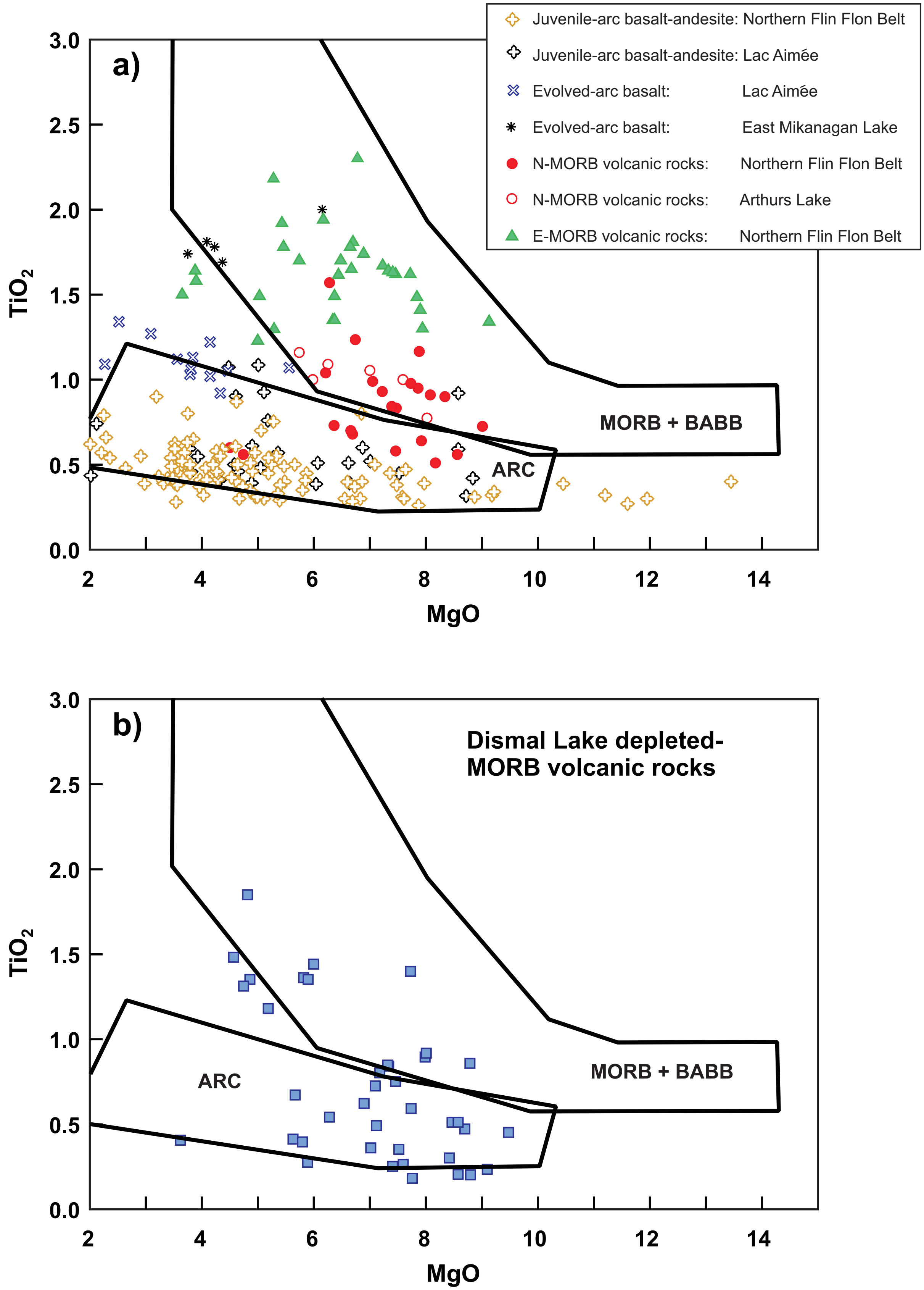


Figure GS-5-5: *TiO_2 vs. MgO plot of mafic to intermediate volcanic rocks in the north-central Flin Flon Belt:* ***a)*** *juvenile-arc, evolved-arc and MORB-type rocks;* ***b)*** *Dismal Lake depleted-MORB types. Compositional fields of modern intra-oceanic rocks are from Stern et al. (1995b). Abbreviations: MORB, mid-ocean-ridge basalt; BABB, back-arc basin basalt.*

The West Mikanagan Lake E-MORB rocks are high-TiO_2 tholeiite that displays smooth, negative-sloping profiles in plots of incompatible elements, characterized by moderately elevated Th and light REE but lacking HFSE depletion relative to N-MORB (Figure GS-5-4c). The E-MORB plots show no negative Nb anomalies, unlike those of arc volcanic rocks in the NFFB (Figure GS-5-4a). The +3.5 ε_{Nd} value (at 1.9 Ga) for West Mikanagan Lake E-MORB is indistinguishable from the projected value for depleted mantle of that age (DePaolo, 1981), indicating that the source magma is juvenile in origin.

Arthurs Lake N-MORB suite

Arthurs Lake N-MORB basalt and abundant related gabbro intrusions occupy a crescent-shaped tectonic slice ('Arthurs Lake Block') between the Manistikwan and Bear Lake fault blocks (Figure GS-5-1). South of the Arthurs Lake Block, a heterogeneous assemblage of structurally intercalated volcanic and subordinate epiclastic rocks occurs within the 'Grassy Narrows Zone' between the Manistikwan and Bear Lake blocks (Bailes and Syme, 1989). The Arthurs Lake N-MORB suite consists mainly of aphyric and plagioclase-megaphyric basaltic flows; interlayered synvolcanic gabbro sills form approximately one-third of the fault block. The N-MORB rocks are characterized by pseudohexagonal plagioclase megacrysts that occur in approximately half of the flows and related gabbro sills but have not been observed within the compositionally and probably stratigraphically equivalent Grassy Narrows basalt to the south. The megacrysts are typically 1–6 cm in size and constitute 5%–15% of their hostrock (Figure GS-5-2d).

Arthurs Lake basalt is compositionally very similar to modern N-MORB, with similar or slightly lower incompatible-element contents except for slightly enriched Th compared to N-MORB (Figure GS-5-4c). Arthurs Lake N-MORB rocks plot within the 'MORB + BABB' field in the TiO_2 vs. MgO diagram (Figure GS-5-5a). A +3.3 ε_{Nd} value (at 1.9 Ga) for Arthurs Lake N-MORB is similar to that of West Mikanagan Lake E-MORB, consistent with a juvenile magmatic origin.

Animus Lake E-MORB and N-MORB suites

The MORB-type basaltic rocks and related gabbro within the Animus Lake Block (Figure GS-5-1) are located at a major structural divide in the NFFB, between northeast-trending rocks to the east (at Lac Aimée) and northwest-trending formations to the west (in the Tartan-Mikanagan lakes area). These MORB-type rocks are juxtaposed against several geochemically contrasting fault blocks that include arc, evolved-arc and E-MORB types. Animus Lake basaltic flows are aphyric and mostly pillowed (Figure GS-5-2e); top determinations indicate a complex structural pattern. The volcanic sequence is characterized by repeated folding, with at least 11 anticline-syncline early fold pairs (Gilbert, 1997). The structural pattern suggests that the sequence may originally have consisted of a lower E-MORB section overlain by N-MORB basalt (Gilbert, 1998, 1999).

The two MORB types within Animus Lake Block are compositionally distinct, with no apparent gradation (Figure GS-5-4d), and thus are likely to be in fault contact. Although there is little field evidence for tectonic contacts between N-MORB and E-MORB sections, several thin enclaves of arc-type rocks within the MORB terrane (e.g., greywacke-siltstone, volcanic breccia and rhyolite; Gilbert, 1997, 2002; Gale and Norquay, 1996) are interpreted as fault slivers. Both N-MORB and E-MORB volcanic suites have potential counterparts represented by geochemically similar gabbroic intrusions within the contiguous Wabishkok Lake Block, which are possibly derived from the same magmatic sources as the respective Animus Lake volcanic rock suites (Figure GS-5-4e). The Nd isotope ratios of Animus Lake volcanic rocks are primitive (ε_{Nd} values of +5.1 at 1.9 Ga in N-MORB and +3.9 in E-MORB) and coincide with the variation within the Elbow-Athapapuskow ocean-floor assemblage (ε_{Nd} values of +3.3 to +5.4 at 1.9 Ga in N-MORB and +3.1 to +4.5 in E-MORB; Stern et al., 1995b).

The similar tectonostratigraphic character of the Animus Lake Block and the Elbow-Athapapuskow ocean-floor assemblage (i.e., structural intercalation of contrasting N-MORB and E-MORB types) suggests that they may be related. The Animus Lake Block may be a dismembered part of the ocean-floor assemblage that was tectonically transported from the southern to the northern part of the Flin Flon Belt during tectonic accretion ca. 1.88–1.87 Ga (Lucas et al., 1996). On the other hand, the presence of gabbroic intrusions in the contiguous Wabishkok Lake Block that may represent local source magmas for the Animus Lake MORB rocks suggests that the Animus Lake Block may not have undergone major tectonic transport.

Depleted-MORB volcanic suites

Mafic volcanic rocks geochemically transitional between arc-type basalt and MORB extend along the margin of the NFFB in the area north of Wabishkok and Dismal lakes (Dismal Lake Terrane, Figure GS-5-1). Compositionally equivalent rocks (Bluenose Lake depleted-MORB suite) occupy a fault slice that extends from the central part of Bluenose Lake southeast toward Wabishkok Lake (Figure GS-5-1). Moreover, the Dismal Lake suite is geochemically equivalent to the Moody Lake basalt that extends along the southern margin of the Kisseynew Domain, north of the Flin Flon Belt (Zwanzig and Bailes, work in progress, 2009). The Dismal Lake depleted MORB is laterally continuous with the Moody Lake basalt, and together these rocks extend for more than

100 km from File Lake and Moody Lake in the east to the Bluenose Lake–Precipice Lake area in the west.

The Dismal Lake depleted-MORB terrane is up to 6 km wide and consists largely of pillowed, aphyric basalt flows, derived finely laminated amphibolite and subordinate related gabbro (Figure GS-5-2f). These rocks are generally more attenuated and deformed than the supracrustal rocks within the Flin Flon arc assemblage to the south. Plagioclase-phyric flows are confined to a 200 m wide zone close to the southern margin of the depleted-MORB terrane, where pillows indicate that the sequence is north facing; there is little evidence elsewhere for top directions within this terrane. Laminated amphibolite and mafic gneiss are commonly porphyroblastic with garnet±hornblende, and domains of silicic alteration (±garnet±pyrite) occur sporadically within both massive and laminated parts of the sequence. Heterolithic arc-type rocks in the vicinity of Ham and Dismal lakes (Figure GS-5-1) are interpreted as fault-bounded, allochthonous enclaves within the depleted-MORB terrane.

Geochemically, the Dismal Lake volcanic suite displays a flat to slightly positive-sloping incompatible-element profile, typical for N-MORB rocks (Figure GS-5-4f). The low average Th content of 0.12 ppm is the same as that of modern N-MORB (Sun and McDonough, 1989), in contrast to NFFB arc basalt in which Th is significantly enriched (average Th content of 0.75 ppm). On the other hand, the conspicuous negative Nb anomaly in Figure GS-5-4f is typical for arc-type rocks, and the average Th/Nb ratio (0.13) in Dismal Lake basalt exceeds the 'primitive' value (0.1) for MORB-type rocks (Stern at al., 1995b). In the TiO_2 vs. MgO diagram (Figure GS-5-5b), the depleted-MORB rocks overlap the MORB + BABB and arc fields due to their wide range of TiO_2 content (0.23–1.85%). The substantial range of overall REE contents (Figure GS-5-4f) is attributed primarily to fractionation, in association with mixing of different mantle types in the source magma. The generally flat REE profile and a primitive Nd isotopic composition (ε_{Nd} value of +5.2 at 1.9 Ga) for the Dismal Lake depleted-MORB rocks are consistent with juvenile magmatism in a back-arc basin setting.

The combination of MORB- and arc-type features displayed by the Dismal Lake depleted-MORB rocks is interpreted as the result of mixing of depleted and enriched MORB-like mantle and subduction-modified magmatic sources, as described for several formations in the Elbow-Athapapuskow ocean-floor assemblage ('MORB types with arc signature'; Stern et al., 1995b). Variations in the ratio of these different mantle components could account for the compositional range between the several NFFB volcanic suites that are interpreted to have been erupted in back-arc settings (N-MORB, E-MORB and depleted-MORB types). Similar compositional variation within modern BABB has been attributed to differences in the depth and amount of partial melting in the mantle source; the amount of partial melting would be least in E-MORB and greatest in subduction-modified mantle components (Fryer et al., 1990). In addition, such compositional variation in modern BABB may reflect the extent of rifting, such that the magmatic source at the initiation of back-arc extension may contain more subduction-modified mantle than basalts that are erupted later in the development of the back-arc basin (Stern et al., 1990). In this model, the Dismal Lake depleted-MORB sequence may represent an earlier stage of extensional back-arc basin development, compared to N-MORB and E-MORB suites elsewhere in the NFFB.

Economic considerations

The potential for mineralization throughout the northern Flin Flon Belt (NFFB) has been discussed previously in numerous reports by the author (Gilbert, 2004, and references therein). Discussion here is confined to several properties in the northeastern part of the study area that exemplify how tectonic setting may influence the potential for economically significant mineralization. The main targets of past mineral exploration programs in the NFFB have been located in juvenile-arc terranes, in many cases situated at or close to the margins of arc or arc-rift sequences where these are juxtaposed against back-arc, MORB-type volcanic suites. Various recent exploration projects (post-1996) have been carried out in arc-type rocks interpreted here as allochthonous fault-bounded enclaves within the Dismal Lake depleted-MORB terrane. Several mineral properties in the NFFB (locations 1 to 6 in Figure GS-5-1) that exemplify such tectonostratigraphic relationships are described briefly:

1) **Aimée property (1988; Assessment File 71655, Manitoba Innovation, Energy and Mines, Winnipeg):** This property, first explored by diamond-drilling in 1949, contains base-metal and gold mineralization 1) in juvenile-arc rocks within the Lac Aimée Block; 2) at the faulted contact between the Lac Aimée arc rocks and back-arc basalts in the Animus Lake Block; and 3) in a 20 m thick sulphide-facies iron formation at the faulted contact between the Wabishkok Lake arc rocks and back-arc basalts in the Animus Lake Block, within an 8 km long zone that includes, along strike, skialithic enclaves of iron formation within a gabbroic intrusion emplaced between the two fault blocks (Gilbert, 1997).
2) **Ham Lake property (2002; Assessment File 73994):** This occurrence of base-metal and gold mineralization, discovered in 1959, occurs within a heterolithic sequence of mafic to felsic volcanic rocks and related breccia (Gilbert, 2003a). The section contains pervasive crosscutting alteration, as well as granitoid to ultramafic intrusive rocks, some or all of which are postvolcanic. The mineralization is classified as vein type, possibly representing remobilized volcanogenic

massive sulphide (VMS)–type mineralization (Gale and Norquay, 1996). The arc-type hostrocks are interpreted as a fault-bounded tectonic enclave within the Dismal Lake depleted-MORB terrane.

3) **Bacon Lake grid (1998; Assessment File 73546):** Felsic and mafic, arc-type volcanic rocks contain disseminated to massive sulphidic mineralization, associated with garnet-anthophyllite alteration and pervasive gabbroic intrusions. This zone, located within the Dismal Lake depleted-MORB terrane 2 km south of Ham Lake, may represent a structurally repeated part of the Ham Lake section.

4) **Dismal Lake South property (1997; Assessment File 73348):** Electromagnetic (EM) anomalies at Dismal Lake, discovered in 1995, indicate a potential for economic mineralization within mafic and felsic, arc-type volcanic rocks at the southern margin of the Dismal Lake Terrane, along the contact with the Kotyk Lake granitoid pluton (Figure GS-5-1; Gilbert, 2003b). A single diamond-drill hole through this zone yielded massive pyrite-pyrrhotite (±chalcopyrite). As at Ham Lake and the Bacon Lake grid, the arc-type rocks at Dismal Lake are interpreted as a structurally emplaced enclave within the depleted-MORB terrane; these three inferred fault slices are 0.6–0.8 km wide and extend along strike for 1.5–2.5 km, possibly up to 5 km.

5) **Blueberry property (1989; Assessment Files 93337 and 90485):** Base-metal and minor gold mineralization occurs in the northeastern part of Blueberry Lake, at the east end of the arc-type Wabishkok Lake Block, immediately south of the Dismal Lake depleted-MORB terrane (Gilbert, 2003b, 2004). The mineralization is hosted by rhyolitic rocks within a mainly basaltic sequence with related gabbro sills. Associated EM anomalies are subparallel to the west-northwest-trending (inferred) faulted contact with depleted-MORB rocks to the north, which is locally less than 100 m away (Gilbert, 2003b).

6) **Kisseynew property (1997; Assessment File 73343):** A series of base-metal sulphide occurrences at the northern margin of the Dismal Lake depleted-MORB terrane defines a mineralized horizon that extends laterally for at least 8 km, parallel to the contact with paragneiss of the Kisseynew Domain to the north (Gale and Norquay, 1996, locations 1 to 5). The mineralization and associated alteration occur mainly in sulphide-facies iron formation within an arc-type sequence that includes andesite, felsic volcanic rocks, tuff and related porphyroblastic gneiss. This diverse section is located immediately south of the contact with paragneiss to the north. As on the Dismal Lake South property (4), the arc-type rocks at the northern margin of the Dismal Lake Terrane are interpreted to be in fault contact with the contiguous depleted-MORB rocks.

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