Introduction

The Paleoproterozoic Flin Flon Belt has been the subject of geological mapping by provincial and federal surveys for more than 60 years. Although reconnaissance and regional 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 where the main volcanic-hosted massive sulphide deposits have been found (*Figure 1*). In 1986, the author initiated 1:20 000 scale geological mapping in the northern part of the Flin Flon Belt. The map area extended northward from latitude 54° 48'N to the contact with the Kisseynew Domain, and from the Manitoba-Saskatchewan boundary in the west to Naosap Lake in the east. The results of this mapping have been compiled in a 1:30 000 scale geoscientific map, a draft of which is shown in this poster.

The geoscientific map, to be released in winter 2010-2011, is based on field and associated geochemical data gathered over the course of eleven field seasons and shows the distribution of compositionally distinctive fault blocks, the main intrusions and the principal geological structures found in the map area. The map will be accompanied by notes containing descriptions of the various tectonostratigraphic components, discussion of their geochemistry, crustal setting and inferred magmatic origin, as well as sections on the structural and economic geology of the area. A data repository item containing analytical data from 345 rock samples, together with lithological and textural information, will be associated with this publication.

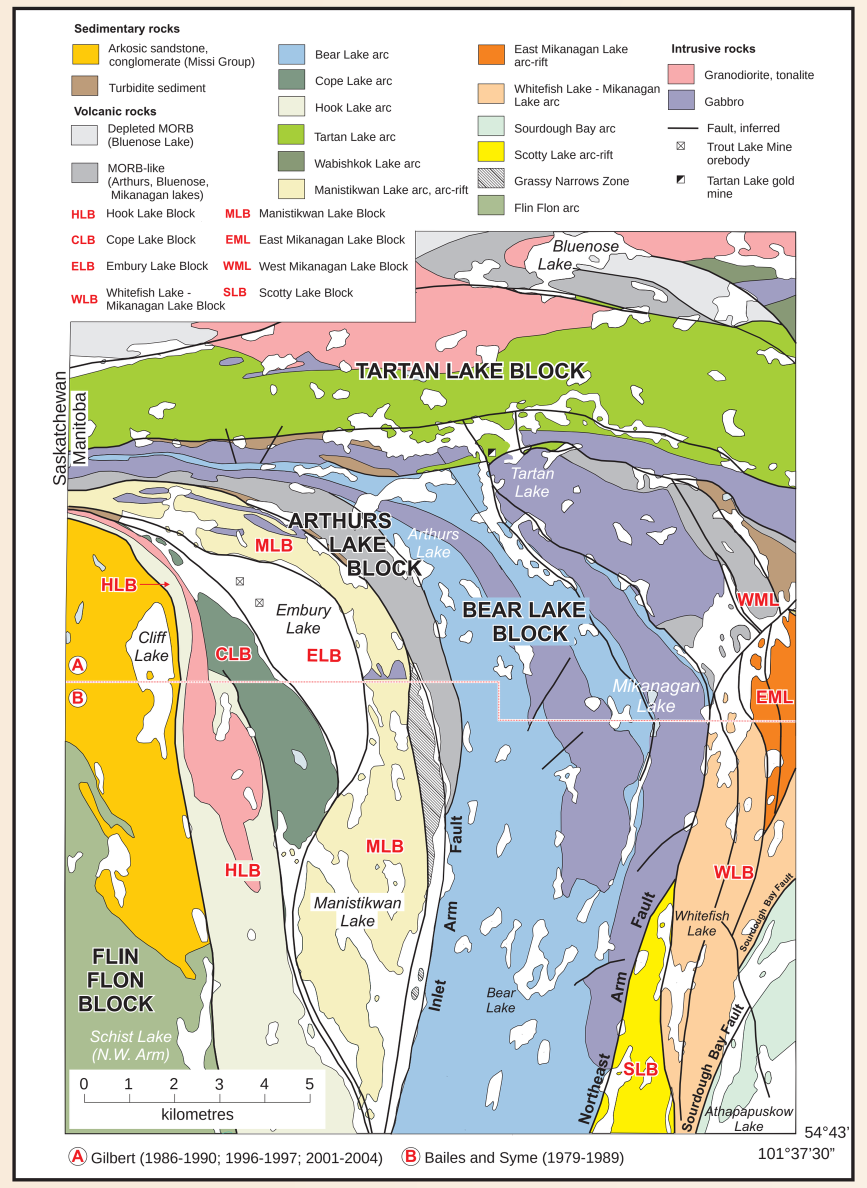


Figure 1: Geology of the western part of the Flin Flon Belt, showing the lateral extent of tectonically defined components between the northern and south-central parts of the Flin Flon Belt (Bailes and Syme, 1989).

Geology of the northern Flin Flon Belt

The map area in the northern Flin Flon Belt (NFFB) is approximately 20 by 33 km in size, and contains over 20 tectonically distinct blocks or fault slices of diverse volcanic, related intrusive and subordinate sedimentary rocks; most of these 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 type rocks, and an extensive area of depleted-MORB (Dismal Lake assemblage) 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; Zwanzig and Bailes, 2010).

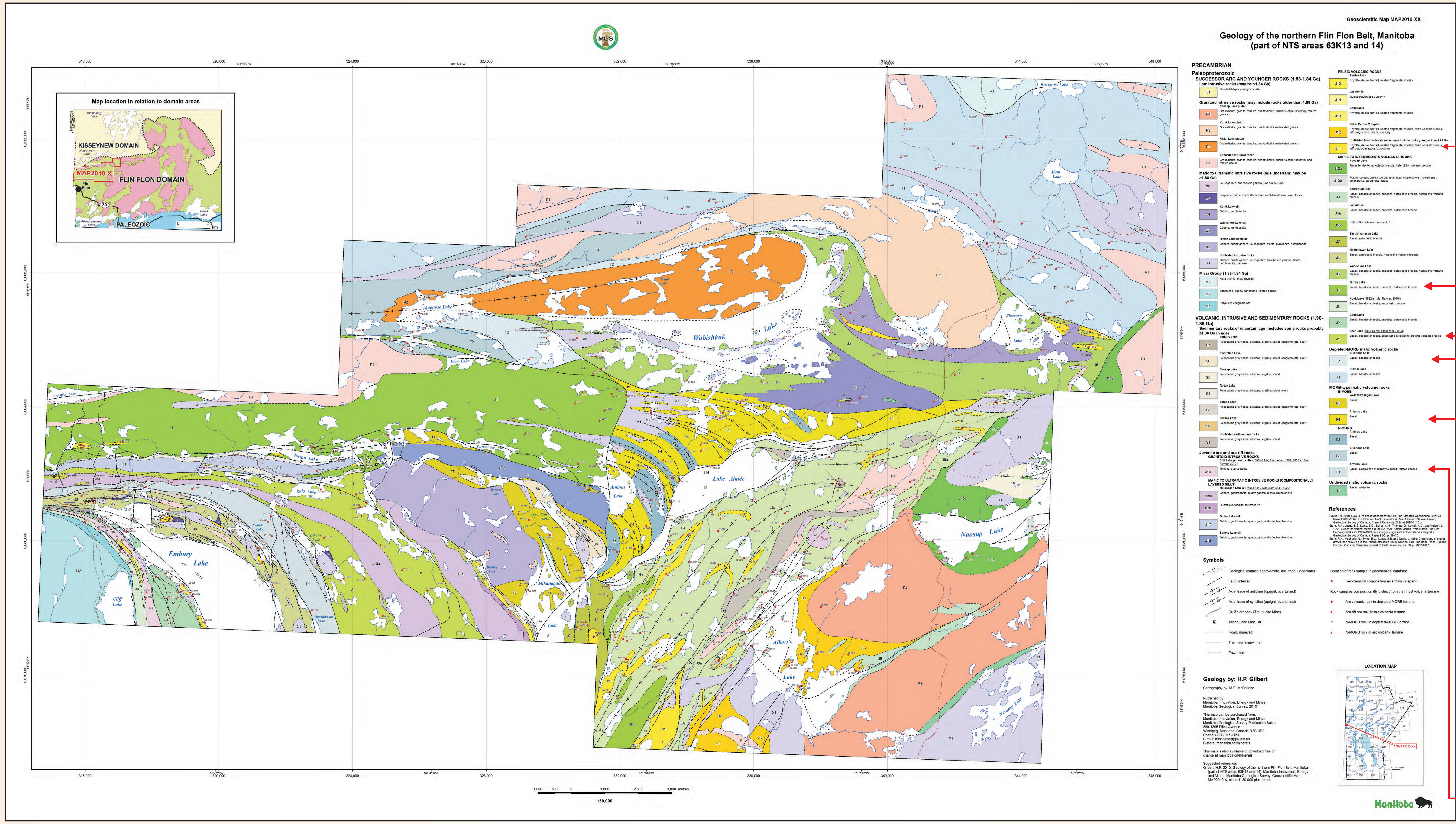
Arc-type rocks in the NFFB are assumed to be associated with subduction at a former oceanic arc, whereas MORB and depleted-MORB types are interpreted to have been associated with rifting and emplacement in a back-arc basin environment. The age of the MORB rocks is not known, but analogous MORB-type formations in the southern part of the Flin Flon Belt (Elbow-Athapapuskow ocean-floor assemblage) are associated with 1.90 Ga synvolcanic intrusions that are coeval with some rocks in the tectonically juxtaposed 1.90-1.88 Ga Flin Flon arc assemblage (Stern et al., 1995b).

Arc and arc-rift volcanic suites

Arc volcanic rocks consist of a wide range of massive to fragmental types and associated intrusions (*Figures 2 - 7*). Basalt and basaltic andesite are predominant and felsic types generally minor, except in the northern part of the Sourdough Bay Block where rhyolitic types constitute over half of the volcanic rock suite (unit J12 in the geoscientific map). Geochemically, the juvenile arc volcanic rocks are characterized by enrichment in Th and light REE but depletion of high-field-strength elements (HFSE) relative to MORB (*Figure 8a*).

Arc-rift volcanic rocks occupy the East Mikanagan Lake Block, and compositionally similar rocks are intercalated with arc-type rocks in the Manistikwan Lake and Lac Aimée blocks. The arc-rift sequences (map units J6 - J8) consist largely of massive to pillowed basalt and related gabbro (± subordinate ferrobasalt, volcaniclastic and/or sedimentary rocks); they are thus less diverse lithologically compared to normal arc sequences. The arc-rift types are distinguished by higher overall incompatible-element contents relative to arc basalts with similar SiO_2 content (*Figure 8b*). They are variably enriched in FeO^T (7.6%-17.8%), TiO_2 (1.0%-2.2%) and Th (0.7-3.6 ppm).

There appears to be a continuum of increasing overall incompatible-element contents from Lac Aimée normal arc through Lac Aimée arc-rift to East Mikanagan Lake arc-rift volcanic suites (*Figure 8a, 8b*). The arc-rift rocks occur within a corridor that extends from Lac Aimée southwards into the central part of the Flin Flon Belt, where Fe-rich tholeiite in the Scotty Lake Block is lithologically and compositionally similar to East Mikanagan Lake arc-rift basalt (*Figure 1*). Scotty Lake basalt and the arc-rift volcanic rocks farther to the north could be fractionated components of a common magmatic source that evolved concomitant with the onset of arc rifting and progressive back-arc basin development. The recognition of this rift-related corridor has implications for future mineral exploration programs because VMS-related mineralization in the Flin Flon Belt is commonly associated with rifting of arc-type sequences (Syme et al,1999).



MORB-type volcanic suites

Four tectonic enclaves of MORB-type volcanic rocks are intercalated with the numerous arc-type fault blocks within the NFFB. The MORB volcanic suites (map units F1 - F5) consist almost entirely of basalt and abundant related gabbro sills, which constitute up to 30% of these sequences (*Figures 9 - 12*); 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. The relative ages of the MORB and arc-type magmatism in the NFFB are uncertain. Diabase dikes geochemically akin to arc-type rocks in several MORB suites suggest the latter predate arc magmatism, but cross-cutting relationships of a MORB-affiliated gabbro sill suggests it postdates arc magmatism.

Two MORB volcanic types - normal (N-MORB) and enriched (E-MORB) - are recognized in the NFFB. Whereas E-MORB volcanic suites are relatively enriched in REE (especially light REE) compared to modern ocean-ridge basalt, N-MORB types display flat incompatible element profiles, relatively depleted or roughly coincident with those of modern N-MORB (*Figures 8c, 8d*).

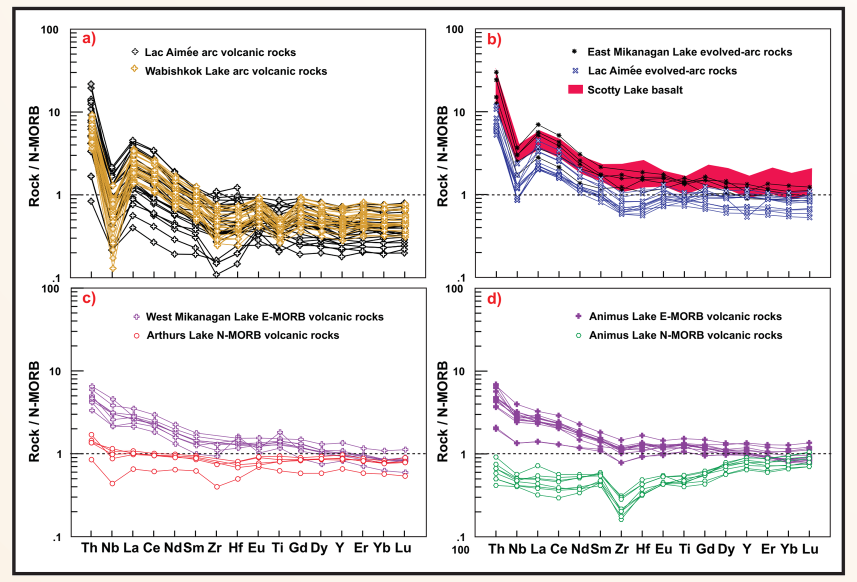


Figure 8: N-MORB-normalized, incompatible-element plots of mafic to intermediate volcanic rocks in the northern Flin Flon Belt: a) juvenile arc rocks; b) arc-rift types and Scotty Lake basalt; c) E-MORB and N-MORB types; d) Animus Lake MORB-type rocks. Normalizing values after Sun and McDonough (1989).

Depleted-MORB volcanic suites

Mafic volcanic rocks depleted in REE that are geochemically transitional between arc-type basalt and N-MORB extend along the north margin of the NFFB in the area north of Wabishkok and Dismal lakes. Dismal Lake 'depleted-MORB' (map unit T1) is laterally continuous with geochemically similar rocks (Moody Lake basalt; Zwanzig and Bailes, 2010) that extend along the southern margin of the Kisseynew Domain, north of the Flin Flon Belt. The Dismal Lake and Moody Lake basalts 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 assemblage is up to 6 km wide and consists largely of pillowed, aphyric basalt flows, derived finely laminated amphibolite and subordinate related gabbro (*Figure 13*). Pillows at Dismal Lake indicate that the sequence is north facing at that locality, but elsewhere there is little evidence to indicate stratigraphic tops.

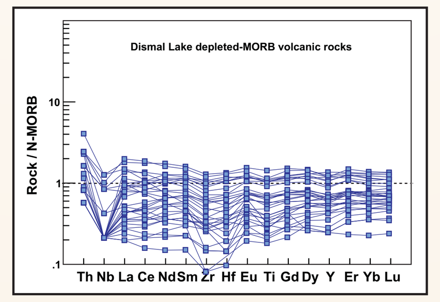


Figure 14: N-MORB-normalized, incompatible-element plot of mafic volcanic rocks in the Dismal Lake depleted-MORB volcanic suite (map unit T1). Normalizing values after Sun and McDonough (1989).

Geochemically, the Dismal Lake volcanic suite displays a flat to slightly positive-sloping incompatible-element profile, typical for N-MORB rocks (*Figure 14*). On the other hand, the conspicuous negative Nb anomaly shown in *Figure 14* 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). The substantial range of overall REE contents is attributed primarily to fractionation, in association with mixing of different mantle types in the source magma.

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).

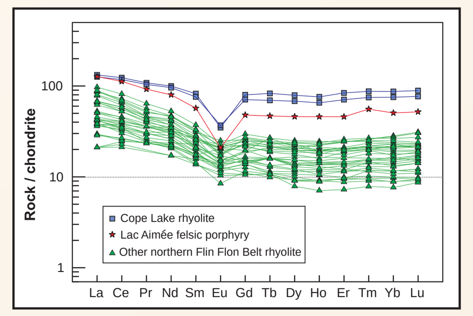


Figure 15: Chondrite-normalized, incompatible-element plot of felsic volcanic rocks in the NFFB, showing REE enrichment in the Cope Lake rhyolite. Normalizing values after Sun and McDonough (1989).

Felsic volcanic rocks

Felsic volcanic rocks form less than 15% of the arc assemblage in the Flin Flon Belt except in the northeastern part (Alberts Lake area), where the rhyolitic Baker Patton Complex (map unit J12) constitutes over half of the northern Sourdough Bay Block. Although rhyolitic rocks are volumetrically only a minor part of the arc assemblage, they are economically the most important component because most of the volcanogenic massive sulphide (VMS) ore deposits in the Flin Flon Belt are hosted by felsic volcanic rocks.

Two high-silica rhyolite samples from a locality at the east margin of the Cope Lake Block (map unit J 13) are distinguished by relatively higher overall REE contents - especially HFSE - and a more pronounced Eu anomaly, compared to the majority of felsic volcanic rocks elsewhere in the NFFB (*Figure 15*). The Cope Lake rhyolite is classified as FIII type according to the scheme for Archean volcanic rocks of Lesher et al. (1986), in common with rhyolite in the Flin Flon mine sequence (Syme, 1998). The FIII types are interpreted as derived from high-level, subvolcanic magma chambers, representing a heat source for hydrothermal convection systems that are directly associated with VMS-type mineralization. The Cope Lake rhyolite is also identified as economically significant due to its proximity to the Trout Lake (Cu-Zn) ore deposit, located approximately 0.5 km northeast of the rhyolite (map unit J 13). The Trout Lake deposit (>10 million tonnes ore reserves and production to 2007) occurs in a sequence that contains sedimentary rocks as well as felsic porphyry types that are possibly co-magmatic with the Cope Lake rhyolite.

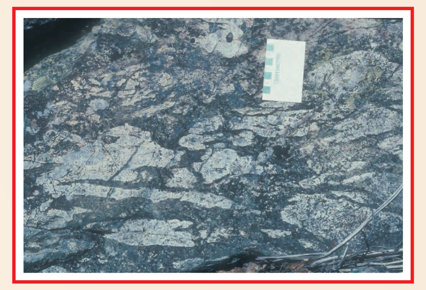


Figure 2: Rhyolite breccia (map unit J11) with angular to amoeboid fragments within the arc-type Lac Aimée Block (Zone 14U, UTM 336281E, 6077630N, NAD 83).

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Figure 3: Marginal zone of >2 m long pillow in Tartan Lake arc basalt flow, with quartz amygdales and thermal contraction fractures; Tartan Lake arc volcanic suite (map unit J4); UTM 330045E, 6083022N.

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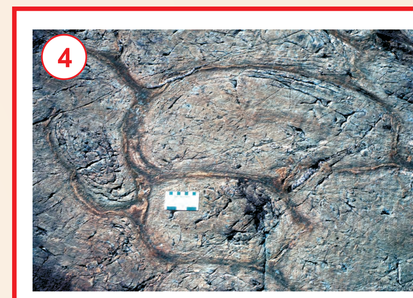

Figure 4: Plagioclase-phyric pillowed basalt (SiO_2 = 53.0%) with quartz amygdales and hornblende pseudomporphs after pyroxene, showing concentric thermal contraction fractures; associated with pillow-breccia; Bear Lake arc volcanic suite (map unit J1); UTM 324272E, 6080749N.

Figure 5: Aphyric, quartz-amygdaloidal pillowed basalt, with concentric thermal contraction fractures; intruded by synvolcanic diabase dike with laminated margin; Bear Lake arc volcanic suite (map unit J1); UTM 323759E, 6078992N.

Figure 6: Contact between aphyric, quartz-amygdaloidal pillowed basalt and underlying mafic lapilli tuff; Bear Lake arc volcanic suite (map unit J1); UTM 324737E, 6080481N.

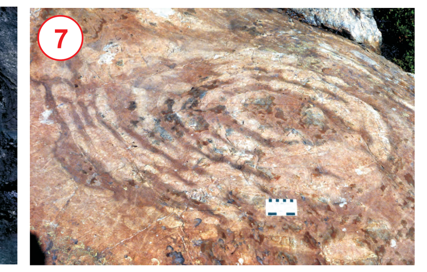

Figure 7: Concentric rhythmic lamination within a basaltic andesite sequence, attributed to separate intrusive pulses within a basaltic lava tube; Bear Lake arc volcanic suite (map unit J1); UTM 323865E, 6079068N.

Figure 13: Laminated, garnetiferous mafic gneiss (map unit T2) derived from Bluenose Lake depleted-MORB volcanic flows (map unit T2); UTM 327913E; 6086751N.

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Figure 9: Aphyric pillowed basalt with flow-top breccia; Animus Lake E-MORB volcanic suite (map unit F4); UTM 334677E, 6082556N.

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Figure 10: Plagioclase-megaphyric pillowed basalt, Arthurs Lake N-MORB volcanic suite (map unit F1); UTM 321188E, 6080421N.

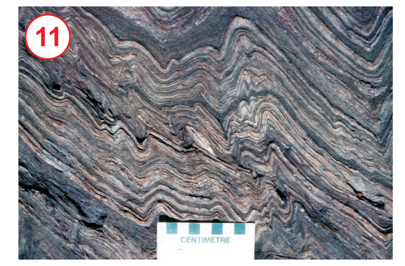

Figure 11: Strongly deformed, laminated amphibolite derived from pillowed basalt, Arthurs Lake N-MORB volcanic suite (map unit F1); UTM 317293E, 6081789N.

Figure 12: Anorthositic gabbro within basaltic sequence; Arthurs Lake N-MORB volcanic suite (map unit F1); UTM 320526E, 6081293N.

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