Mapping and Geological Report GR2011-1 publication

The Flin Flon Belt is one of the largest Paleoproterozoic volcanogenic massive sulphide (VMS) districts in the world, with over 162 million tonnes of Cu-Zn-(Au) ore (combined reserves and production to 2007) in 27 past and currently active mines (Manitoba Innovation, Energy and Mines, 2010). This belt has been the subject of geological mapping by provincial and federal surveys for more than 60 years; in addition to localized detailed mapping, reconnaissance and regional mapping have been undertaken across the entire width of the belt and beyond. A detailed mapping program was initiated in 1979 by the Manitoba Geological Survey in the south-central part of the Flin Flon Belt, where most of the VMS deposits have been found. In 1986, detailed, 1:20 000 scale mapping was initiated by the author in the Embury-Wabishkok-Naosap lakes area of the northern Flin Flon Belt (NFFB). The map area extends from latitude 54° 48' N northward to the contact with the Kisseynew Domain, and from the Manitoba-Saskatchewan border in the west to Naosap Lake in the east (*Figure 1, 2*). Geological mapping in the NFFB was undertaken by the author between 1986 and 2004, except for the years 1991–1995 and 1999–2000 when mapping projects were carried out elsewhere (Wekusko Lake and Max Lake areas).

A series of preliminary maps and annual summary reports were published coincident with the years of NFFB mapping, and an open file report on the geochemistry of rocks in the Lac Aimée-Naosap Lake area is also available (Gilbert, 1999). Geochemical investigations concurrent with detailed field mapping have revealed a structurally complex pattern of tectonically distinct allochthons in the north part of the Flin Flon Belt. Compilation of the NFFB mapping and analysis of stratigraphic, structural and geochemical data are the basis for a comprehensive report (GR2011-1) that is scheduled

for release within the next few weeks. Geological Report GR2011-1, which is accompanied by a 1:30 000 scale compilation map of the NFFB (Map GR2011-1-1), contains descriptions of the various tectonostratigraphic components, as well as discussions of their crustal setting, inferred magmatic sources, structural history and economic geology. Various map legends for the original 1:20 000 scale preliminary maps in the Embury–Wabishkok–Naosap lakes area have been integrated into a single unified legend in Map GR2011-1-1, based on lithostratigraphic as well as geochemical criteria. This map complements previous mapping in the Flin Flon-White Lake area to the south (Bailes and Syme, 1989) by highlighting lateral stratigraphic and geochemical differences, as well as similarities within various tectonic components that extend from the south-central to the northern part of the Flin Flon Belt (Figure 3). Map GR2011-1-1 also provides a link to geological data in the area north of the Flin Flon Belt, continuous with the latter via a regional basaltic formation that extends northwards from the NFFB and laterally for over 100 km along the southern margin of the Kisseynew Domain (Zwanzig, 2010). Geological Report GR2011-1 and Map GR2011-1-1 are accompanied by two appendices and a GIS map that are available only in digital form. Analytical data on the geochemistry of 344 rock samples collected between 1986 and 2004 are provided in Appendix 1, which also includes mineralogical, petrographical and lithologic notes for each sample. Appendix 2 contains a comprehensive collection of field photographs as well as a less broad based collection of photomicrographs. The interactive GIS map (Map GR2011-1-2) is a digital version of Map GR 2011-1-1 in which the analytical data for geochemical samples (listed in Appendix 1), as well as field photographs and photomicrographs (listed in Appendix 2) can be gueried with the click of a mouse at over 400 localities shown on the map. The same information is available directly from the Excel spreadsheets of Appendix 1 and (interactively) from Appendix 2, in which images of field photographs and photomicrographs are linked with their associated captions and UTM locations. Geological Report GR2011-1 will be available both in hard copy and digital form, to be downloaded free of charge at manitoba.ca/minerals. A DVD that contains all components

| | Print components | Digital components on accompanying/stand-alone DVD |
|----------------------------|-------------------------|----------------------------------------------------|
| Geological Report GR2011-1 | * | * |
| | | PDF |
| Appendix 1 | | * |
| | | PDF |
| Appendix 2 | | * |
| | | PDF |
| Accompanying Map 2011-1-1 | * | * |
| | (folded in back pocket) | PDF |
| GIS Map GR2011-1-2 | | * |
| | | ArcReader project |

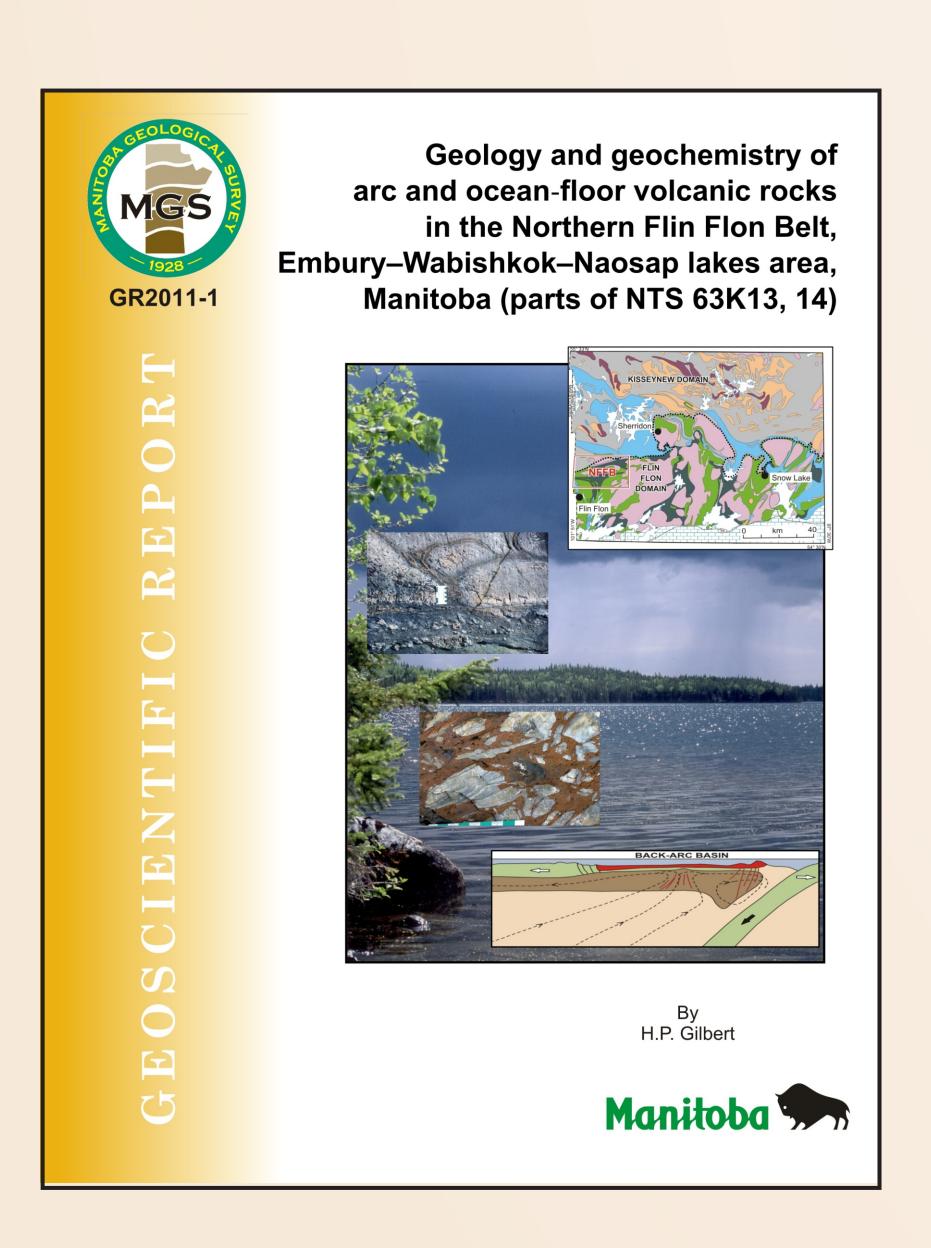
of the report will be included inside the cover-bound report; the DVD will also be available

The various components of Geological Report GR2011-1 are summarized as follows ~

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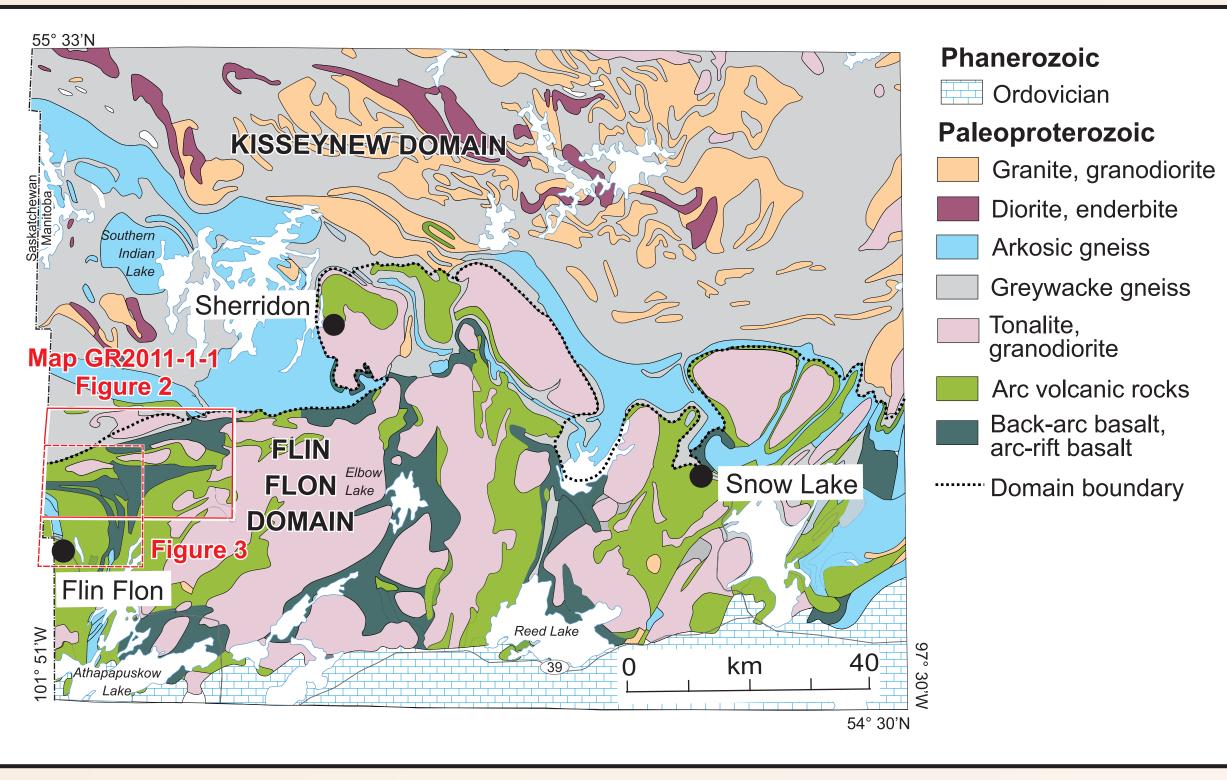


Figure 1: Regional geology map of part of the Reindeer Zone in the southern Trans-Hudson Orogen. The Flin Flon Domain (Flin Flon Belt) consists of volcanic, sedimentary and intrusive rocks in the Flin Flon-Snow Lake area, south of the Kisseynew Domain and north of the flat-lying Ordovician rocks that extend southwards from Athapapuskow and Reed lakes. The northern Flin Flon Belt (NFFB) subarea is shown in Figure 2 (inset). Figure 3 (inset) shows the lateral extent of tectonically defined components between the NFFB and the south-central part of the western Flin Flon Belt (Bailes and Syme, 1989).

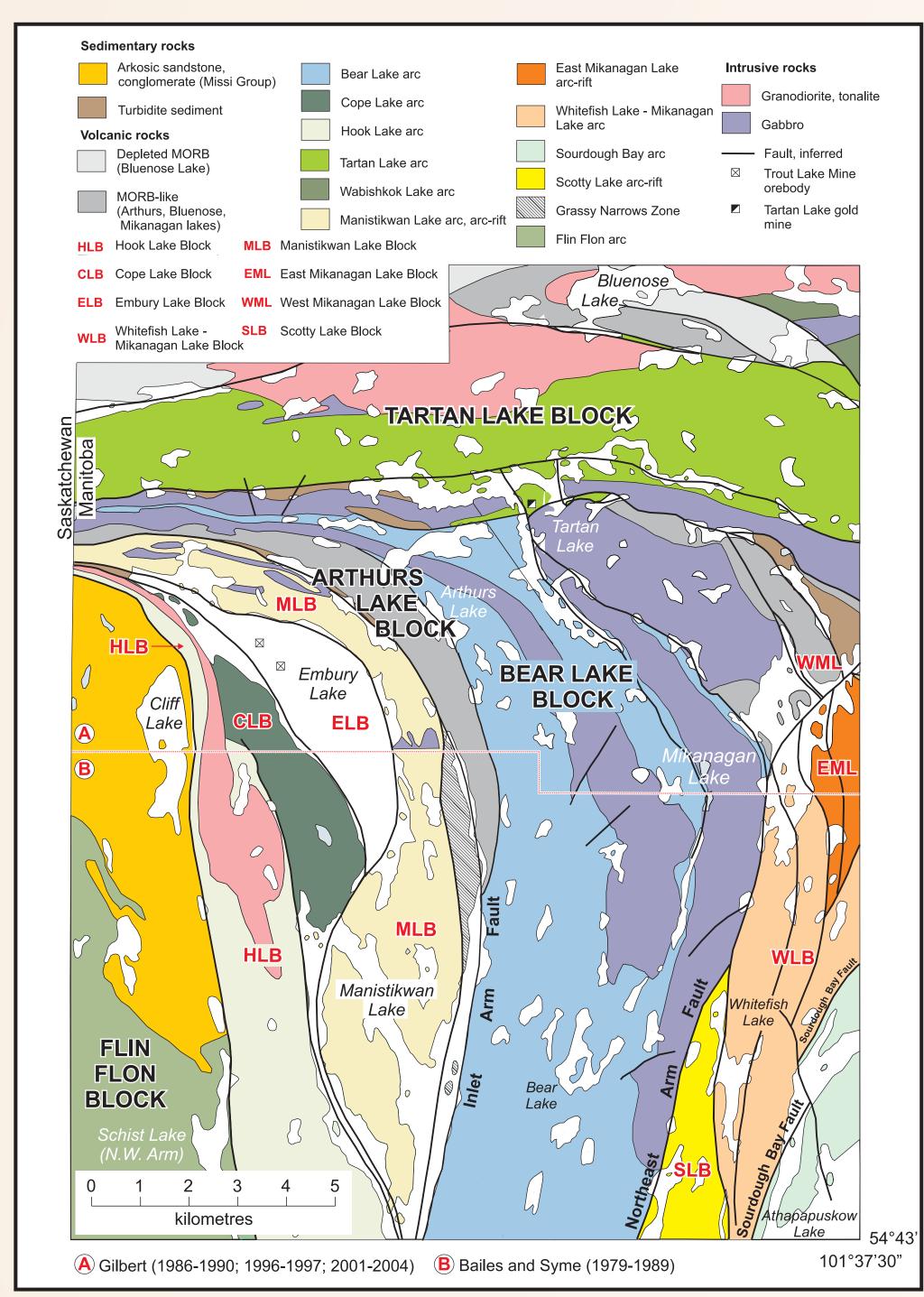


Figure 3: Geology of the western Flin Flon Belt, showing the lateral extent of tectonically defined components between the northern Flin Flon Belt (NFFB) and south-central part of the Flin Flon Belt (Bailes and Syme, 1989). Manistikwan Lake is an unofficial name for Big Island Lake lake.

N-MORB: Map units F1, F3 (Arthurs, Animus lakes)

、Plagioclase-megaphyric, synvolcanic gabbro; in

Aphyric pillowed basalt with flow-top breccia and

characteristic pale beige-grey weathered surface.

megacrysts, hornblende pseudomorphs after pyroxene

are also characteristic of this gabbro and related mafic

MORB-like mafic volcanic rocks

E-MORB: Map units F4, F5 (Animus Lake, West Mikanagan Lake)

Photomicrograph (plane-polarized light)

and a pseudomorphic (epidote-chlorite)

Photomicrograph (plane-polarized light)

epidote matrix.

Plagioclase-phyric, N-MORB-type pillowed basalt

with phenocryst aggregates (synneusis texture)

aggregate, in a plagioclase-tremolite-chlorite-

Distinctive fabric in pillowed basalt defined by

uralitic trails in pinnate patterns, interpreted as a

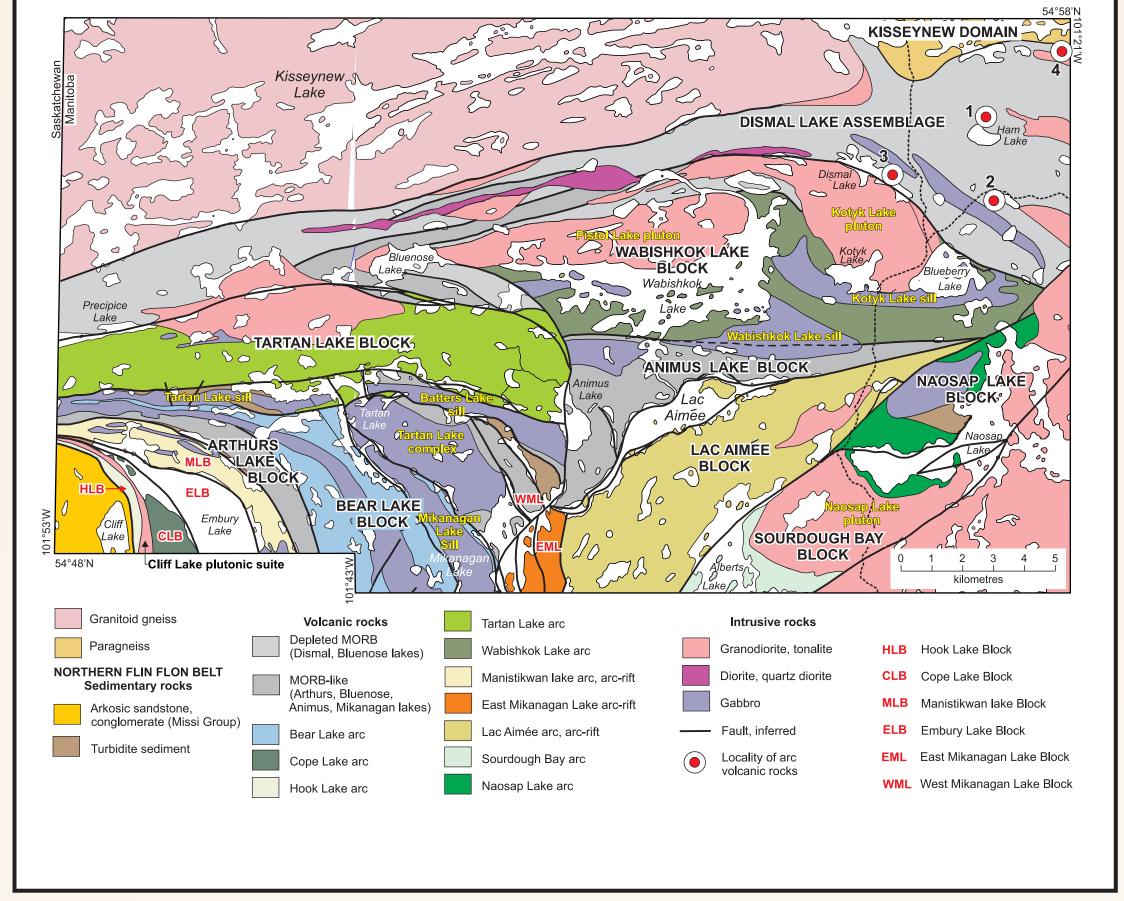
crystals. The feldspar-epidote groundmass with

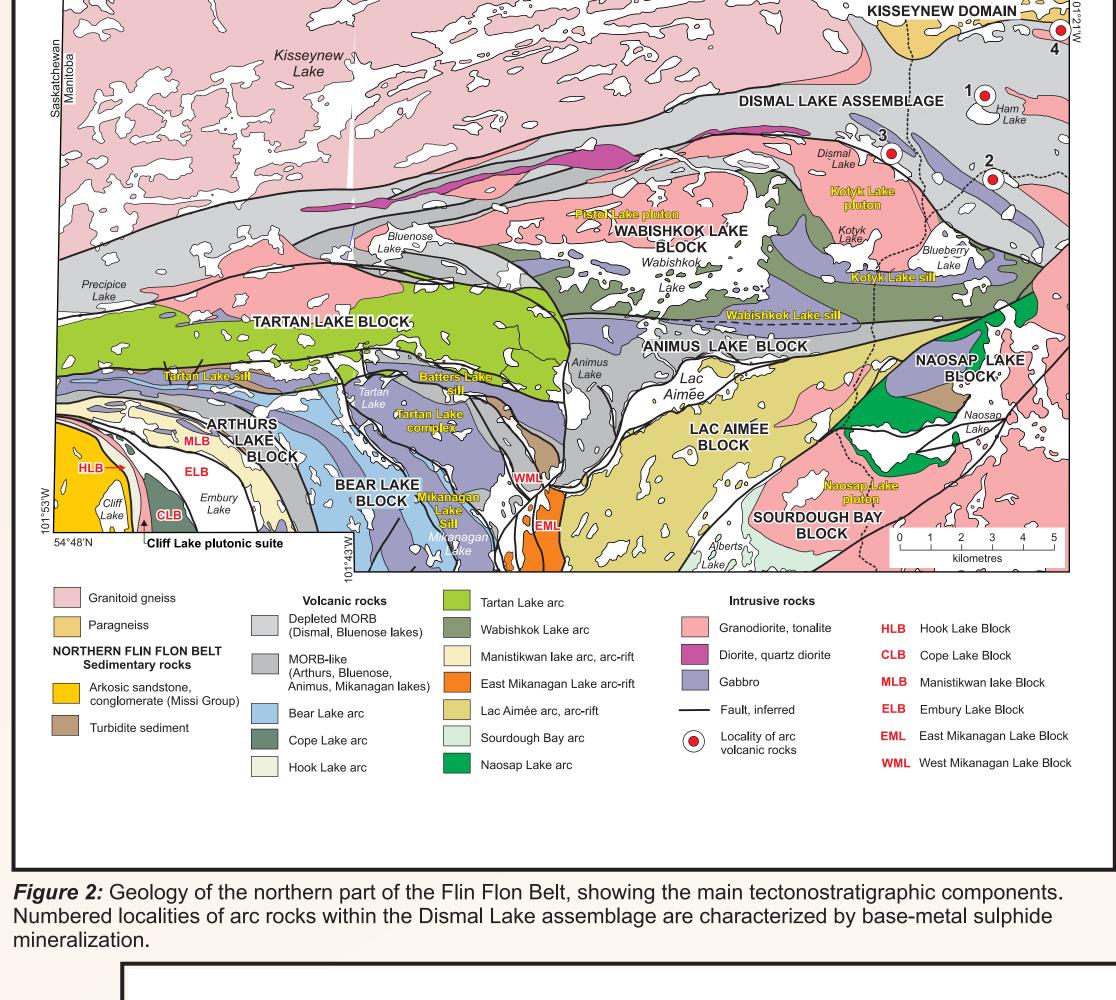
disseminated ilmenite is interpreted as derived

quench texture derived from skeletal clinopyroxene

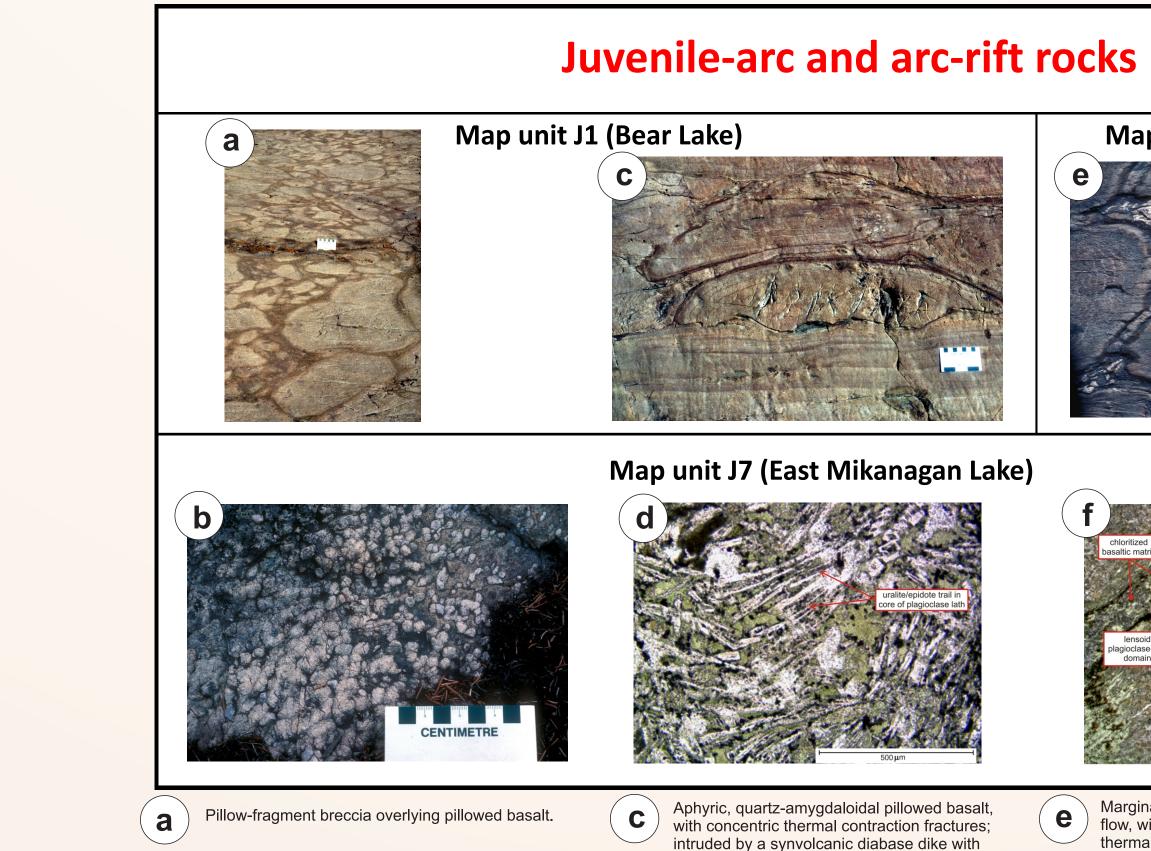
from a former glassy matrix that resulted from rapid

Granitoid gneiss Intrusive rocks Volcanic rocks Paragneiss Granodiorite, tonalite NORTHERN FLIN FLON BEL Manistikwan lake arc, arc-rift MLB Manistikwan lake Block Animus, Mikanagan lakes) East Mikanagan Lake arc-rift Arkosic sandstone, conglomerate (Missi Group) ELB Embury Lake Block Locality of arc volcanic rocks EML East Mikanagan Lake Block Sourdough Bay arc WML West Mikanagan Lake Block Hook Lake arc





signature. The location of the Trout Lake mine at the inferred in tight to isoclinal folds and locally repeated fold patterns in some fault blocks; D₁ fold axial traces were locally truncated by reactivation of contact between the Cope Lake and Embury Lake blocks block-bounding faults during D₂. suggests tectonostratigraphic contacts may, in some cases, also represent promising targets for mineral exploration. Map GR2011-1-1 ISSEYNEW DOMAIN TO INTERMEDIATE VOLCANIC ROCKS FLIN FLON DOMAIN lafic to ultramafic intrusive rocks (age uncertain, may be OLCANIC, INTRUSIVE AND SEDIMENTARY RO (1.90–1.88 Ga) Sedimentary rocks of uncertain age (includes some rocks probably ≤1.86 Ga in age) Depleted-MORB mafic volcanic rocks MORB-type mafic volcanic rocks E-MORB Juvenile-arc and arc-rift rocks GRANITOID INTRUSIVE ROCKS Cliff Lake plutonic suite (1886 ±1 Ma²; 1888 ±1 Ma²) Tonalite, quartz diorite J18b Quartz-eye tonalite, ferrotonalite N-MORB rock in depleted-MORB terrane



Universal Transverse Mercator Zone 14 NAD 83

Depleted MORB: Map unit T2

Laminated, garnetiferous mafic gneiss derived from

Bluenose Lake basalt (T2) as well as the Dismal Lake

depleted-MORB assemblage (T1), where pillows are

basaltic flows. Such rocks are widespread in the

not well preserved due to deformation.

Photomicrograph (plane-polarized light)

Quench texture in pillowed basalt defined by

clinopyroxene crystals. The feldspar-epidote

that resulted from rapid cooling.

filamentous uralitic trails and chains in fern-like or

pinnate patterns, assumed to be derived from skeletal

groundmass is interpreted as a former glassy matrix

Variolitic texture in arc-rift basalt, with minor quartz Photomicrograph (plane-polarized light) Plagioclase laths with uralite/epidote cores amygdules. The pale-weathering varioles, which (interpreted as original clinopyroxene), evident increase in size and are coalescent from pillow rim in both long section and (at upper right) in toward pillow core, consist of feldspathic domains with cross-section, assumed to be due to quenching quench textures (see adjacent photomicrographs from same location). The varioles are interpreted as derived of basaltic magma. The matrix is chloritic. by spheroidal crystallization directly from a melt (as described by Fowler et al., 1987), rather than by devitrification of a basaltic glass or liquid immiscibility

laminated margins.

flow, with quartz amygdules, interpillow chert and thermal contraction fractures filled with saussuritized plagioclase. Diffuse concentric zoning (pale to dark weathering) is attributed to alteration. Photomicrograph (plane-polarized light) Lensoid plagioclase-rich domain within a chloritized,

Geology of the Embury–Wabishkok–Naosap lakes area, Manitoba

(parts of NTS 63K13, 14)

Geology by H.P. Gilbert (1986–1990, 1996, 1997, 2001–2004)

1000 500 0 1000 2000 3000 metr

Marginal part of a large (>2 m long) pillow in a basalti

Map unit J4 (Tartan Lake)

basaltic matrix (variolitic texture); both domains display evidence of rapid cooling (skeletal uralite/epidote filaments). Note the quartz-filled microfracture confined

to the plagioclase-rich lens, suggesting it solidified prior

to the surrounding basaltic groundmass.

³ Manistikwan lake is an unofficial name for Big Island Lake

This map is also available to download free of charge at manitoba.ca/minerals

Gilbert, H.P. 2011: Geology and geochemistry of arc and ocean-floor volcanic r in the northern Flin Flon Belt, Embury–Wabishkok–Naosap lakes area, Man (parts of NTS 63K13, 14); Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Geoscientific Report GR2011-1, p xxxxx.

Juvenile-arc and arc-rift rocks

Map unit J8a (Lac Aimée)

Suggested reference for Map GR2011-1-1:

⁴ Stern et al. (1993)

Garnet-hornblende-cummingtonite-feldspar-quarta gneiss derived from pillowed basalt. Irregular garnetiferous domains are assumed to represent zones of metasomatic alteration. Note ovoid quartz amygdules and dark grey stringers derived from pillow selvages. This gneiss, located in a zone of hydrothermal alteration associated with base-metal mineralization at Ham Lake, Lake (unit 7), and 2) quenched, tholeiitic basalt

Map unit U (Ham Lake)

Northern Flin Flon Belt: geological history

structural trends.

The D₃ event resulted in regional open folds, such as the

the regional structure in the western part of the NFFB. The

Northeast Arm Fault is a crustal-scale structure that divides

the NFFB into western and eastern parts, distinguished by

northwest- to west-trending and northeast- to east-trending

regional faults, respectively. The latest deformation event (D

resulted in brittle faulting, typically at high angles to earlier

mineralization, based on the association of volcanogenic

across the width of the Flin Flon Belt (Inlet Arm Fault.

massive sulphide mineralization with arc-rifting elsewhere in

the Flin Flon Belt (Syme et al., 1999). These two panels are

spatially associated with major, crustal-scale faults that extend

Northeast Arm Fault). Several localities of felsic volcanic rocks

in the NFFB may also be prospective for base metal and/or

precious metal mineralization, based on their geochemical

Two north-trending panels of rift-related rock types that have

been identified in the NFFB may have a potential for economic

east-northeast-trending Embury Lake antiform that dominates

The Flin Flon Belt is characterized by numerous allochthons that are

Amisk Collage. This collage resulted from a 1.88-1.87 Ga collisional

tectonic event that juxtaposed crustal segments of various types

floor (back-arc) fault blocks or slices, together with the products of

as well as turbidite sedimentation. Granitoid plutons of probable late

ocean-floor assemblages, and lensoid turbidite fault slices are locally

emplaced at contacts between arc or between arc and ocean-floor

volcanic rocks. Mafic intrusive sills occur within or at the margins of

After 1880–1870 Ma tectonic amalgamation of the oceanic-arc system

predated 1870–1840 Ma successor-arc magmatism and sedimentation.

The early (D₁) and later (post-1840 Ma) D₂ deformation events resulted

the first (D₄) fold event affected juvenile-arc and back-arc rocks but

some fault blocks; most or all of these intrusions are interpreted as

coeval with the arc/back-arc volcanism or subsequent arc-rifting.

distinguished geochemically and/or stratigraphically and are part of the

including juvenile arc, back-arc ocean-floor, ocean plateau, ocean-island

subsequent 1.87-1.84 Ga successor-arc magmatism, and fluvial-alluvial

successor-arc age locally 'stitch' the contacts between juvenile-arc and

and evolved plutonic arc. The NFFB consists of arc, arc-rift and ocean

is interpreted as derived from arc or arc-rift type volcanic flows within Scotty Lake basalt, south of Photomicrograph (crossed polars) Cordierite-anthophyllite-biotite gneiss probably derived Orthopyroxene mantled by derived anthophyllite. from altered intermediate volcanic rocks. Chloritic Pleochroism is unusually strong in the orthopyroxene aggregates (not shown) and anthophyllite needles that (pink or red to pale or medium gray-green). The overprint a large cordierite porphyroblast are attributed assemblage includes quartz, plagioclase, K-feldspar

to contact metamorphism.

Extrusive or shallow intrusive ferrobasalt with

Photomicrograph (plane-polarized light)

and cordierite porphyroblasts (up to 2 by 3 cm).

Aphyric andesite within the metamorphic aureole of the Naosap Lake pluton. The dark grey linear feature is possibly part of a pillow selvage. Randomly distributed hypidiomorphic plagioclase and sporadic, zoned epidote-chlorite-quartz? cavity filling. Plagioclase amphibole porphyroblasts with feldspathic haloes laths with secondary amphibole cores resemble reflect metasomatic alteration by contiguous granitoid feldspars in 1) arc-rift basalt at East Mikanagan Photomicrograph (crossed polars) The original orthopyroxene-biotite-cordierite Mikanagan Lake (Bailes and Syme, 1989). assemblage is overprinted by anthophyllite (ragged

porphyroblasts and small elongate prisms). The

assemblage includes quartz, plagioclase and K-

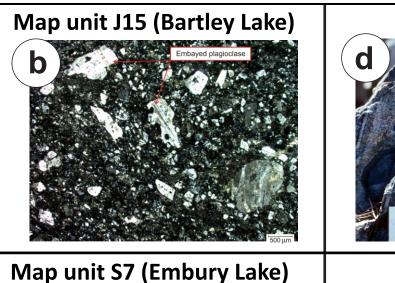
Map unit J10a (Naosap Lake)

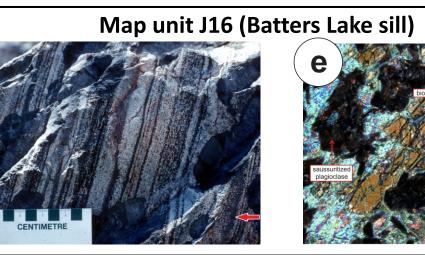
Juvenile-arc and arc-rift rocks

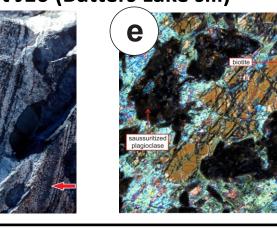


Sedimentary rocks (age

breccia and basalt.







Map unit X1 (intrusion breccia Mafic-ultramafic intrusive rocks (age

Photomicrograph (plane-polarized light)
Lensoid to highly contorted lithic fragments,

with subaerial deposition for this deposit.

Photomicrograph (crossed polars)

1 m) felsic tuff unit between heterolithic volcanic

- Thinly layered sedimentary rocks with cyclic plastically deformed during deposition of this narrow located at the margin of the Embury Lake Block. The greywacke-siltstone-argillite deposits are undeformed at this locality, but elsewhere are isoclinally folded and disrupted.
- Igneous layering defined by variations in Felsic lapilli crystal-tuff. Plagioclase phenoclasts feldspar:hornblende ratio in the compositionally layered Batters Lake sill. Gradation within single roughout the rock. Plagioclase crystals are layers from mafic-rich (basal) to more feldspathic ubhedral to embayed, due to partial resorption upper parts (e.g., layer at red arrow) suggests rior to incorporation. The lack of sorting and the stratigraphy is south facing (to the left). vell preserved feldspar shapes are consisten
- Photomicrograph (crossed polars) relict clinopyroxene enclosed by pseudomorphic
- Intrusion breccia emplaced within a splay of the ortheast Arm Fault at Bluenose Lake; angular uartzitic fragments occur within an altered, ramafic rock matrix. Lamination in the clasts ossibly represents primary layering suggesting sedimentary precursor. Warping of the lamination predated subsequent more brittle deformation that resulted in formation of the angular quartzitic

Northern Flin Flon Belt: tectonostratigraphic assemblages

The area mapped (shown in Map GR2011-1-1) is underlain by more than 20 stratigraphically and tectonically distinct blocks or fault slices that contain volcanic and/or sedimentary successions. Most of these fault blocks are dominated by volcanic rocks, which are grouped into three main compositional types: 1) juvenile arc and arc-rift (unit J);

2) normal mid-ocean-ridge basalt (N-MORB) and enriched mid-ocean-ridge basalt (E-MORB) (unit F); and

3) depleted MORB (unit T). The rocks with various MORB-like compositions are interpreted as products of back-arc magmatism as opposed volcanism in a mid-ocean-ridge setting. Arc rocks are predominant in the NFFB and are part of the 1881–1889 Ma Flin Flon arc assemblage (Rayner, 2010). MORB-like volcanic rocks (unit F) are structurally intercalated with juvenile-arc rocks, and an extensive area of depleted MORB (unit T) 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; Figure 1). The age of these volcanic rocks (units F, T) is not known, but similar MORB-type rocks in the southern part of the Flin Flon Belt that may possibly be coeval with those in the NFFB are 1901–1904 Ma in age (Stern et al., 1995).

A series of lensoid turbidite deposits (units S1-S7) are intercalated with the various arcand MORB-type fault blocks between Embury Lake and Naosap Lake (Figure 2; Map GR2011-1-1). Most of these sedimentary rocks are fault bounded and apparently devoid of volcanic interlayers; their age is uncertain, except for those occupying the Embury Lake Block that are of successor-arc age (1843 ±9 Ma, age of youngest detrital zircon, Ordóñez-Calderón et al., 2011).

Fluvial-alluvial sedimentary rocks of successor-arc age (Missi Group, units M1–M3) occupy a 6 km wide sedimentary basin in the Cliff Lake area, western Flin Flon Belt (Figure 2, 3). Missi Group polymictic conglomerate and sandstone were deposited in the 1846-1842 Ma time interval (Stern et al., 1999), concurrent with uplift of older volcanic terranes (units J. T. F) and late successor-arc plutonism (unit P). Granitoid plutons (units P1–P4) are emplaced in both arc and MORB-type volcanic rocks

along the northern and eastern margins of the NFFB (Figure 2). Although none of these intrusions has been dated, their setting suggests they are stitching plutons of late successor-arc age (ca. 1.84 Ga). In contrast, smaller granitoid intrusions (P1) that occur sporadically within the Flin Flon arc assemblage are probably synvolcanic, penecontemporaneous with the 1886–1888 Ma Cliff Lake plutonic suite (unit J19; Stern et al., 1999; Rayner, 2010).

Mafic and subordinate ultramafic intrusions occupy over 15% of the area of the NFFB; they are classified as 1) compositionally layered sills (units J16, J17 and J18), and 2) mafic to ultramafic intrusions of uncertain age (unit X). The 1881 +3/-2 Ma Mikanagan Lake Sill (Stern et al., 1999) is emplaced in the upper part of an arc-rift sequence and has been interpreted as rift-related (Zwanzig et al., 2001). Other more homogeneous gabbroic intrusions (units X1–X6), emplaced both within arc and MORB-type sequences, may also be synvolcanic in age (e.g., Wabishkok Lake and Kotyk Lake sills, *Figure 2*).

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