# Tectonic Controls on Mafic Magmatism in the Superior Province

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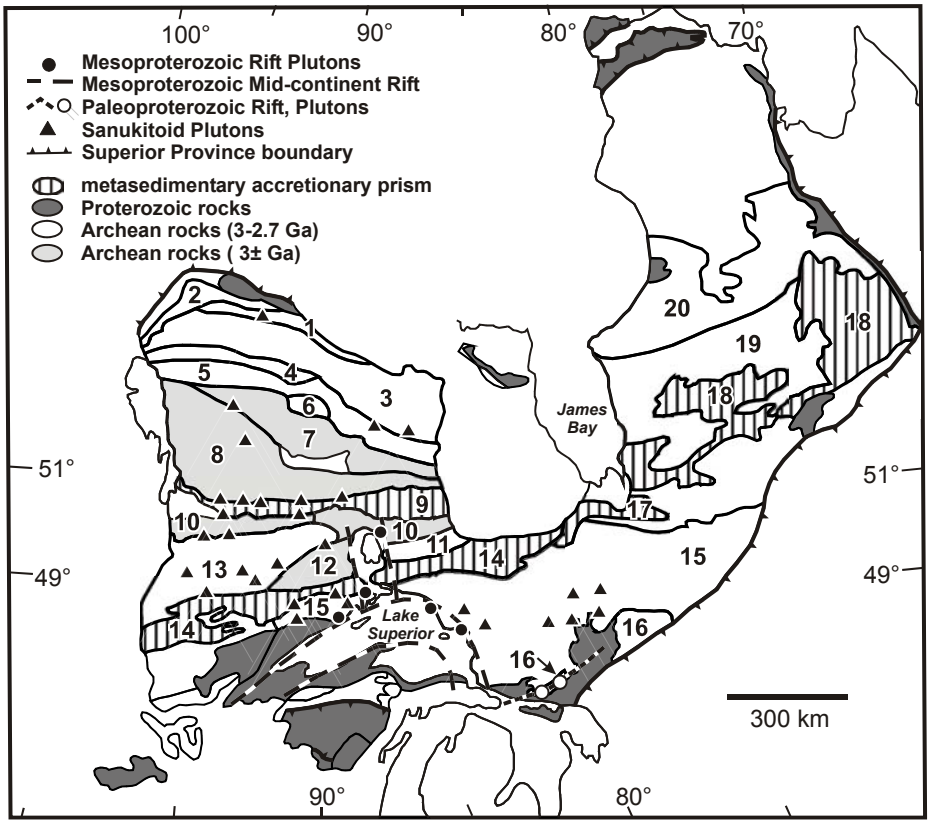
The Superior Province (Fig. 1) consists of a central ~ 3 Ga nucleus, the North Caribou terrane, with an Andean arc on its south flank containing autochthonous 2.8 and 2.7 Ga arcs (Fig.1). Southward are two inter-arc basins, several 3-2.7 Ga plume-arc fragments and two juvenile, ~ 2.7 Ga, arc-related super-terranes. To the north are a 2.76 Ga oceanic terrane, a 2.83 Ga arc and the North Superior super-terrane, with fragments from >3.5 to ~2.7 Ga. Cu-Ni-PGE mineralization is associated with mafic to ultramafic magmatism at all stages of terrane development from komatiitic volcanism and synvolcanic plutons through syntectonic to late tectonic (terrane amalgamation and cratonization) to post-cratonization rifting events (Table 1).




**Tectonic Zones**

1) Assean Lake Crustal Complex
2) Pikwitonei
3) Oxford-Stull Lake
4) Munro Lake
5) Island Lake
6) Muskrat Dam
7) North Caribou terrane I
8) North Caribou terrane II
9) English River
10) Winnipeg River
11) Onaman-Tashota
12) Marmion
13) West Wabigoon
14) Quetico
15) Wawa-Abitibi
16) Pontiac
17) Opatica
18) Opinaca/Nemiscau
19) La Grande River
20) Bienville

***Figure 1.***

***Table 1.*** *Tectonic Affinity of PGE-related mafic and ultramafic magmatism in the Superior Province*

| Stage | Unit/Pluton | Terrane | Form | Rock types | Age (Ga) | Deposits | Ref. |
|---|---|---|---|---|---|---|---|
| Synvolcanic-Oceanic | Pipestone L. sill | Munro Lake | Stratiform layered megacrystic anorthosite intrusion | Leucogabbro-anorthosite, melagabbro-gabbro | 2.83 ? | Cu-Ni, oxides | 7,2 |
| Synvolcanic-Oceanic | Trout Bay intrusion | N. Caribou terrane | Layered intrusion cutting 2853 Ma basaltic volcanics | Peridotite-pyroxenite-gabbro | 2.85 | 0.5% Ni, 0.25% Cu | 9 |
| Synvolcanic-Plume | Kidd-Munro Komatiites | Abitibi subprovince | Komatiite flows, coeval intrusions | Olivine adcumulates | 2.71 | Alexo, Dundonald | 13 |
| Synvolcanic-plume | Balmer assemblage | N. Caribou | Komatiitic flows | Spinifex textured and olivine adcumulates | 2.99-2.96 | Flat Lake Occurrence | 12,9 |
| Synvolcanic-syntectonic /Arc | Big Trout Lake | Oxford L.-Stull L. | Synvolcanic layered intrusion in greenstone stratigraphy | Dunite, peridotite, anorthosite, gabbro | 2.83 ? | Cr, PGE | 15, 16 |
| Synvolcanic-syntectonic/ Arc | Atikwa-Lawrence | West Wabigoon | Mafic-ultramafic complexes forming early phase of lobate, multi-phase batholiths internal to greenstone belts. | Pyroxenite, anorthosite, troctolite, gabbro, in complexes ranging from diorite/tonalite to tonalite/granodiorite to trondhjemite/ granodiorite | 2.73-2.70 | | 5 |
| Synvolcanic – syntectonic/ Arc | Bad Vermilion anorthosite | West Wabigoon | Synvolcanic sill in greenstone stratigraphy | Anorthosite, leucogabbro, gabbro | 2.73 | Oxides, Cu-Ni | 2 |
| Synvolcanic-syntectonic/ Arc | Montcalm gabbro | Abitibi subprovince | Layered intrusion | | 2.7? | Cu-Ni, PGE | 6 |
| Synvolcanic-syntectonic/ Arc | Doré Lake Complex | Abitibi subprovince | Layered intrusion | Anorthosite, layered zone, ferrodiorite, soda granophyre, upper border zone | 2.7 | Cu-Ni, PGE | 1 |
| Late Tectonic | Lac des Iles complex | West Wabigoon | Concentrically zoned elliptical intrusions | Dunite through gabbro to gabbro/norite | 2.69 | PGE, Cu-Ni | 14 |
| Late Tectonic to terrane amalgamation | Quetico Intrusions | Quetico subprovince | Dikes and small concentrically zoned bodies | Wehrlite to hornblendite to clinopyroxenite | 2.69 | PGE | 10 |
| Paleo-proterozoic Rifting | E. Bull L. Suite | Pontiac subprovince | Layered intrusions emplaced into Superior Province during Paleoproterozoic rifting | Gabbronorite, olivine gabbronorite, gabbronorite, leuco-gabbronorite | 2.475 | PGE, Cu-Ni | 4,18 |
| Meso-proterozoic Rifting | Duluth Gabbro, Crystal Lake Gabbro | Mid-Continent Rift | Folded sill cutting Animikie Group sediments | Gabbro, anorthositic gabbro, troctolite to olivine gabbro | 1.1 | Cu-Ni, PGE | 15 |

The ~ 3 Ga North Caribou terrane and similar units (e.g. Winnipeg River and Marmion terranes) contain greenstone assemblages with basal platformal quartz and carbonate rich metasediments overlain by komatiite-tholeiite volcanic rocks and related intrusions. The komatiites and related intrusions are plume-related, alumina undepleted komatiite (AUK) and alumina depleted komatiite (ADK) similar to those in arc subprovinces (e.g. Abitibi), but unmineralized. Synvolcanic plutonism and volcanism varies in style based on geodynamic affinity. Oceanic terranes (2.85 Ga Trout Bay assemblage and the 2.76 Ga Munro Lake terrane) are characterized by synvolcanic, thin, layered sills of megacrystic anorthosite and layered peridotite-pyroxenite-gabbro bodies. The anorthosites include

($An_{80}$-$An_{90}$) plagioclase megacrysts and minor matrix. It is hypothesized that a parental tholeiitic magma underwent early subtraction of calcic megacrysts (Phinney et al., 1988) followed by high pressure fractionation of olivine and/or orthopyroxene, then low pressure plagioclase fractionation. Similar megacrystic anorthosites form synvolcanic bodies in arcs such as the 2.7 Ga arc on the North Caribou terrane, and the west Wabigoon terrane. The anorthosites host Cr, V, and PGE mineralization (Table 1). The Wawa-Abitibi subprovince is characterized by plume-arc interaction. (Dostal and Mueller 1997) represented by interstratified arc volcanics and plume-related komatiites. The komatiites range from ADK-dominated older assemblages to AUK dominated younger assemblages (Sproule et al., 2002). The arc signature of Abitibi volcanism is more prominent in younger assemblages and is manifested by greater abundance of arc and back arc units (e.g. Ludden and Peloquin 1996). Synvolcanic Ni and PGE mineralization of the Kambalda, Mt. Keith and Boston Creek styles are a major feature of Abitibi komatiites (Table 1).

Arc-dominated units, e.g., the West Wabigoon terrane, generally lack komatiitic volcanism. They host PGE mineralization in large synvolcanic intra-belt batholiths such as the Atikwa-Lawrence batholith showing a progression from early, peripheral layered ultramafic to mafic complexes synchronous with mafic volcanism in the adjacent greenstones to later, central tonalite and granodiorite coeval and linked with felsic volcanism. The arc-related granite-greenstone subprovinces also contain synvolcanic, layered intrusions [Big Trout Lake - 2.83 Ga Oxford-Stull L. terrane (Thurston et al 1991)], [Bad Vermilion anorthosite- 2.7 Ga West Wabigoon terrane (Ashwal et al., 1983)] and [Lac Doré complex-2.7 Ga Wawa-Abitibi subprovince (Allard et al., 1985)]. These intrusions are low in greenstone belt stratigraphy, usually on the flanks of structural culminations, thus representing sill like bodies emplaced low in greenstone assemblage stratigraphy.

Archean "sanukitoid" suite intrusions ranging from dunite to granitoid compositions are posttectonic, show a spatial association with terrane-bounding structures in all types of subprovinces (Fig.1). Examples include the Lac des Iles complex (Sutcliffe et al., 1989), and the Quetico intrusions (Pettigrew et al., 2000). This magmatism is synchronous with terrane-bounding shear zones ~2700-2680 Ma, younging outward from the North Caribou terrane. Large sanukitoid intrusions are spatially associated with all major terrane boundaries throughout the Superior Province. Many sanukitoid intrusions form dikes and small concentrically zoned plugs throughout the craton.

Following the Kenoran orogeny (~2.7 Ga), the Superior craton, as part of the Kenorland supercontinent (Williams et al., 1991), was stable until lithospheric stretching at ~2.48 Ga related to the breakup of Kenorland. This Paleoproterozoic rifting produced the tholeiitic East Bull Lake Intrusive suite (Vogel et al., 1999) emplaced at mid-crustal depths (Easton, 2000) along east-trending faults on the southern margin of the Superior Province during Huronian Supergroup deposition (Fig.1).

In the Mesoproterozoic, Archean fragments were re-united into the Laurentia supercontinent at 2.0-1.7 Ga. During this re-assembly, fragments of oceanic crust and the severely tectonized mafic to ultramafic rocks of the Thompson Nickel Belt were emplaced between the Archean Superior and Hearne cratons in the 1.8 Ga rocks of the Trans-Hudson orogen. Laurentia rifted at ~ 1100 Ma forming the Mid-continent Rift. Associated with the Mid-continent Rift are layered picritic intrusions (Wolf Mountain, Leckie Lake), layered gabbro-anorthosite intrusions (Crystal Lake gabbro), tholeiitic to alkaline complexes (Coldwell Complex), all hosting PGE mineralization.

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