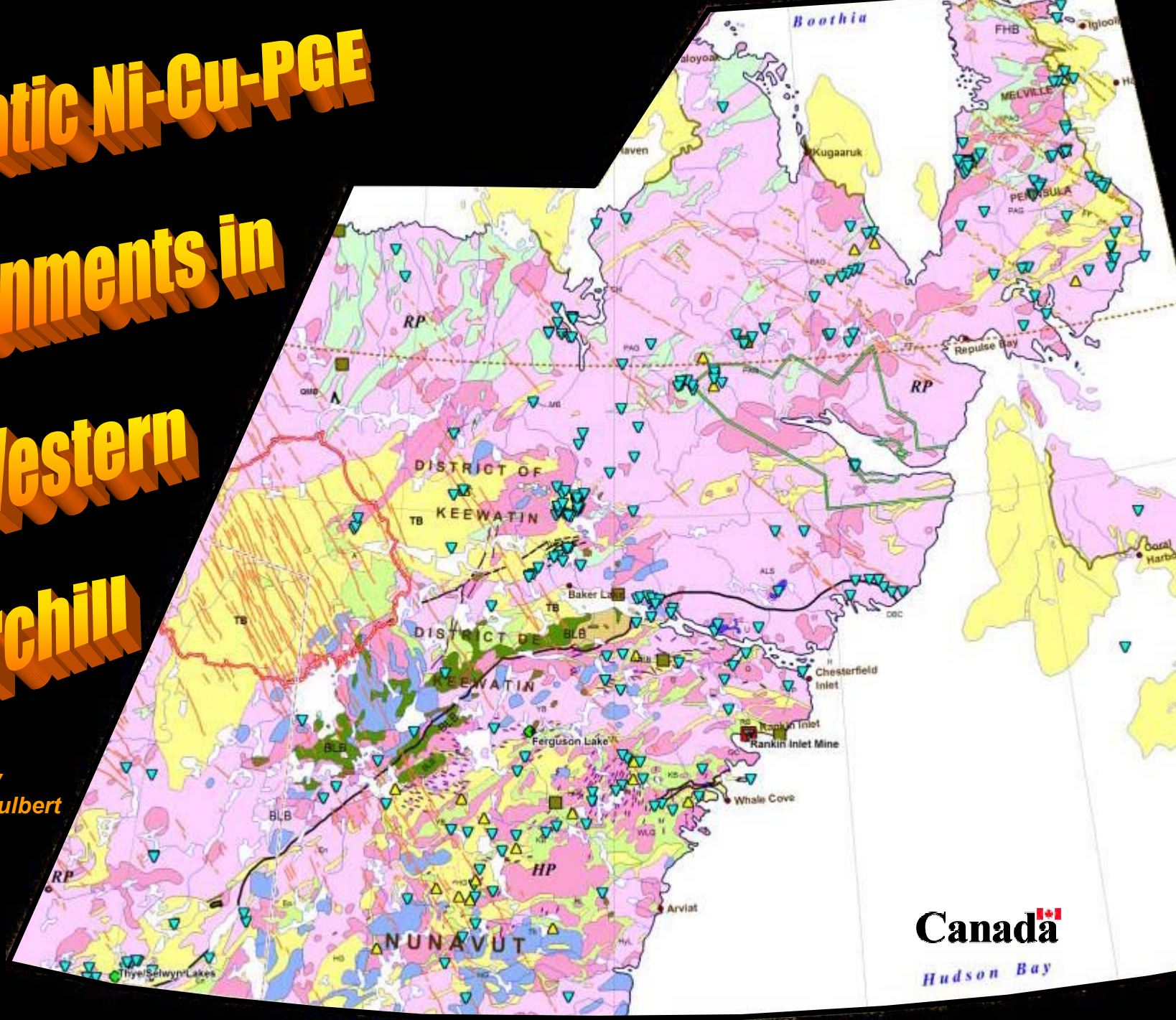
Magmatic Ni-Cu-PGE Environments in the Western Churchill

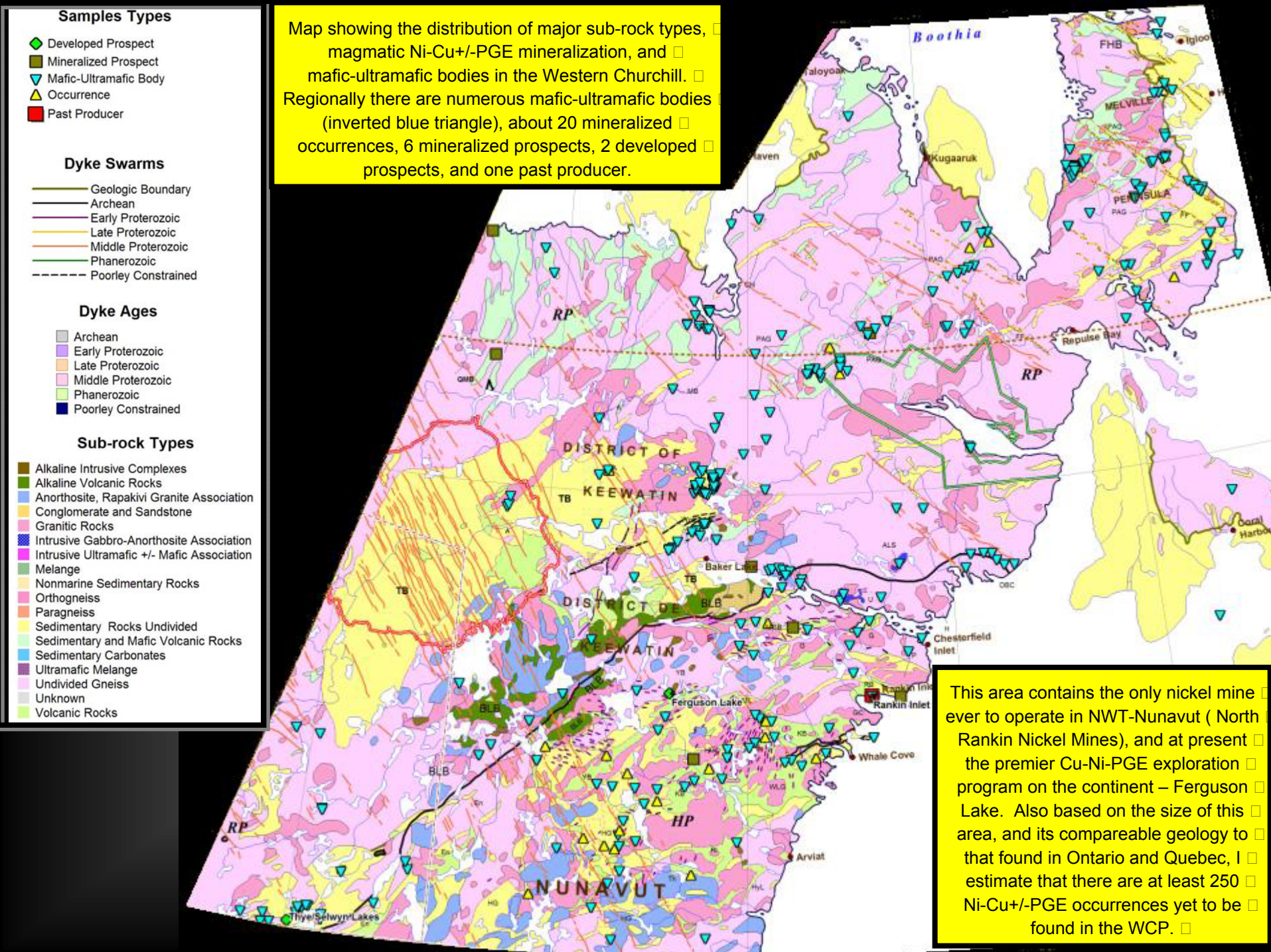
by
Larry Hulbert

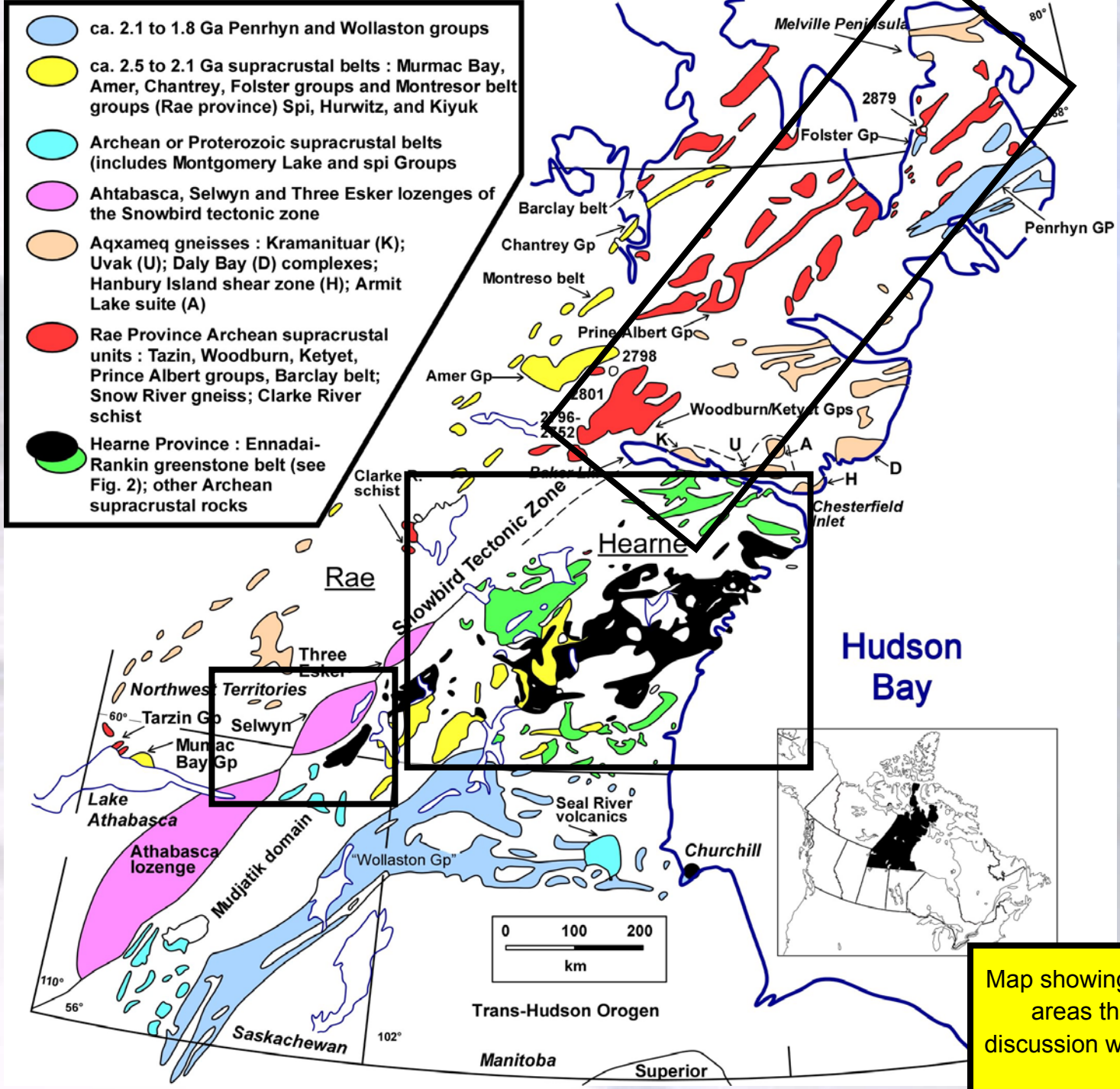


Magmatic Environments

- Komatiitic Magmatism
- Mafic-Ultramafic Intrusions
- High Pressure Noritic Magmatism

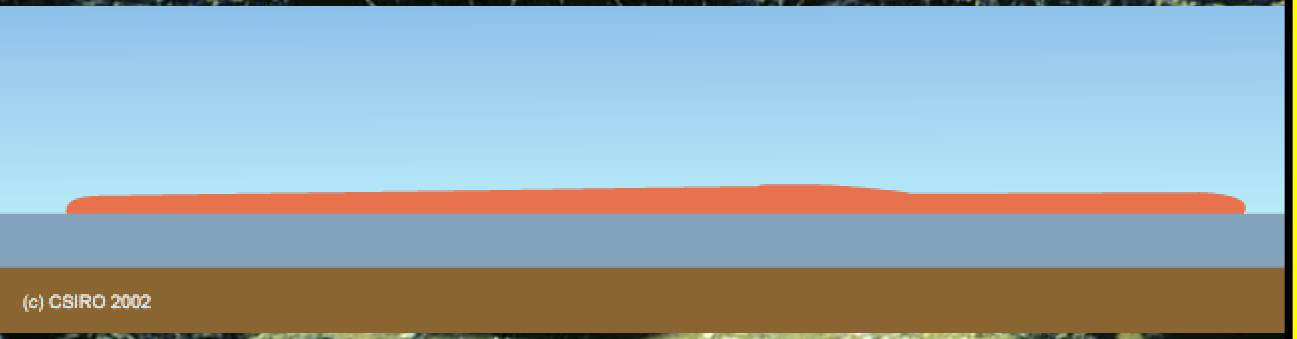
I will discuss the Ni-Cu+/-PGE metallogenic potential of this vast area with respect to three different types of magmatic environments.


Samples Types
Developed Prospect
Mineralized Prospect
Mafic-Ultramafic Body
Occurrence
Past Producer
Dyke Swarms
Geologic Boundary
Archean
Early Proterozoic
Late Proterozoic
Middle Proterozoic
Phanerozoic
Poorley Constrained
Dyke Ages
Archean
Early Proterozoic
Late Proterozoic
Middle Proterozoic
Phanerozoic
Poorley Constrained
Sub-rock Types
Alkaline Intrusive Complexes
Alkaline Volcanic Rocks
Anorthosite, Rapakivi Granite Association
Conglomerate and Sandstone
Granitic Rocks
Intrusive Gabbro-Anorthosite Association
Intrusive Ultramafic +/- Mafic Association
Melange
Nonmarine Sedimentary Rocks
Orthogneiss
Paragneiss
Sedimentary Rocks Undivided
Sedimentary and Mafic Volcanic Rocks
Sedimentary Carbonates
Ultramafic Melange
Undivided Gneiss
Unknown
Volcanic Rocks
Map showing the distribution of major sub-rock types, magmatic Ni-Cu+/-PGE mineralization, and mafic-ultramafic bodies in the Western Churchill. Regionally there are numerous mafic-ultramafic bodies (inverted blue triangle), about 20 mineralized occurrences, 6 mineralized prospects, 2 developed prospects, and one past producer.
Boothia
Igloolik
FHB
MELVILLE
Kugaaruk
PENINSULA
RP
Repulse Bay
DISTRICT OF KEEWATIN
TB
Baker Lake
DISTRICT DE KEEWATIN
BLB
Chesterfield Inlet
Ferguson Lake
Rankin Inlet
Whale Cove
HP
Arviat
NUNAVUT
Thlye/Selwyn Lakes
This area contains the only nickel mine ever to operate in NWT-Nunavut (North Rankin Nickel Mines), and at present the premier Cu-Ni-PGE exploration program on the continent – Ferguson Lake. Also based on the size of this area, and its compareable geology to that found in Ontario and Quebec, I estimate that there are at least 250 Ni-Cu+/-PGE occurrences yet to be found in the WCP.

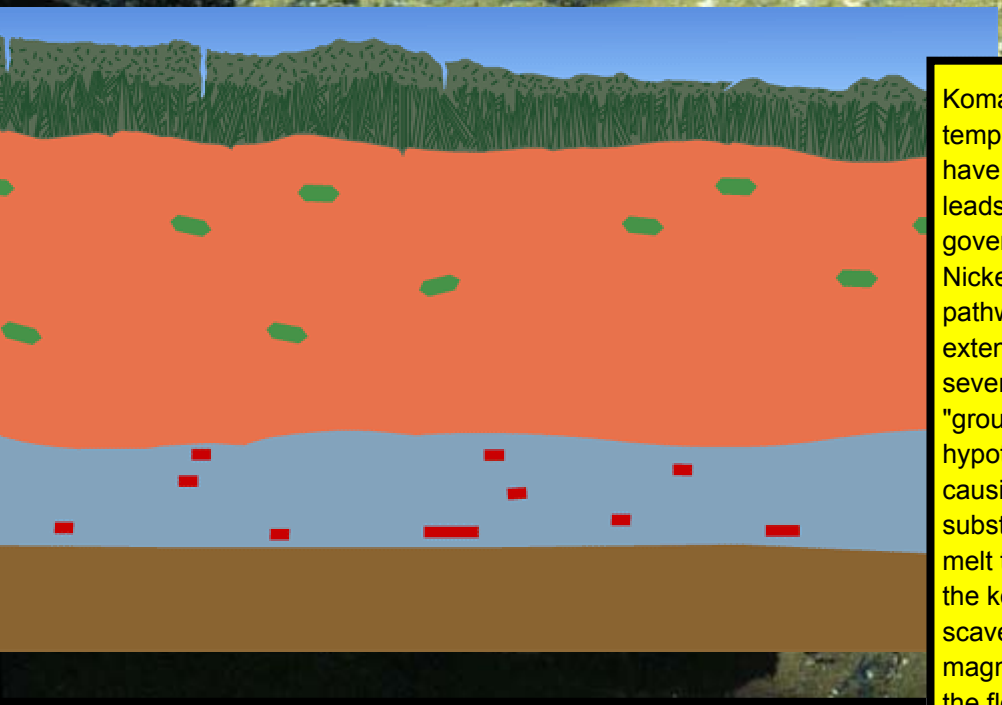


Map showing the three main areas the 30 minute □ discussion will focus around.

Komatiitic Magmatism

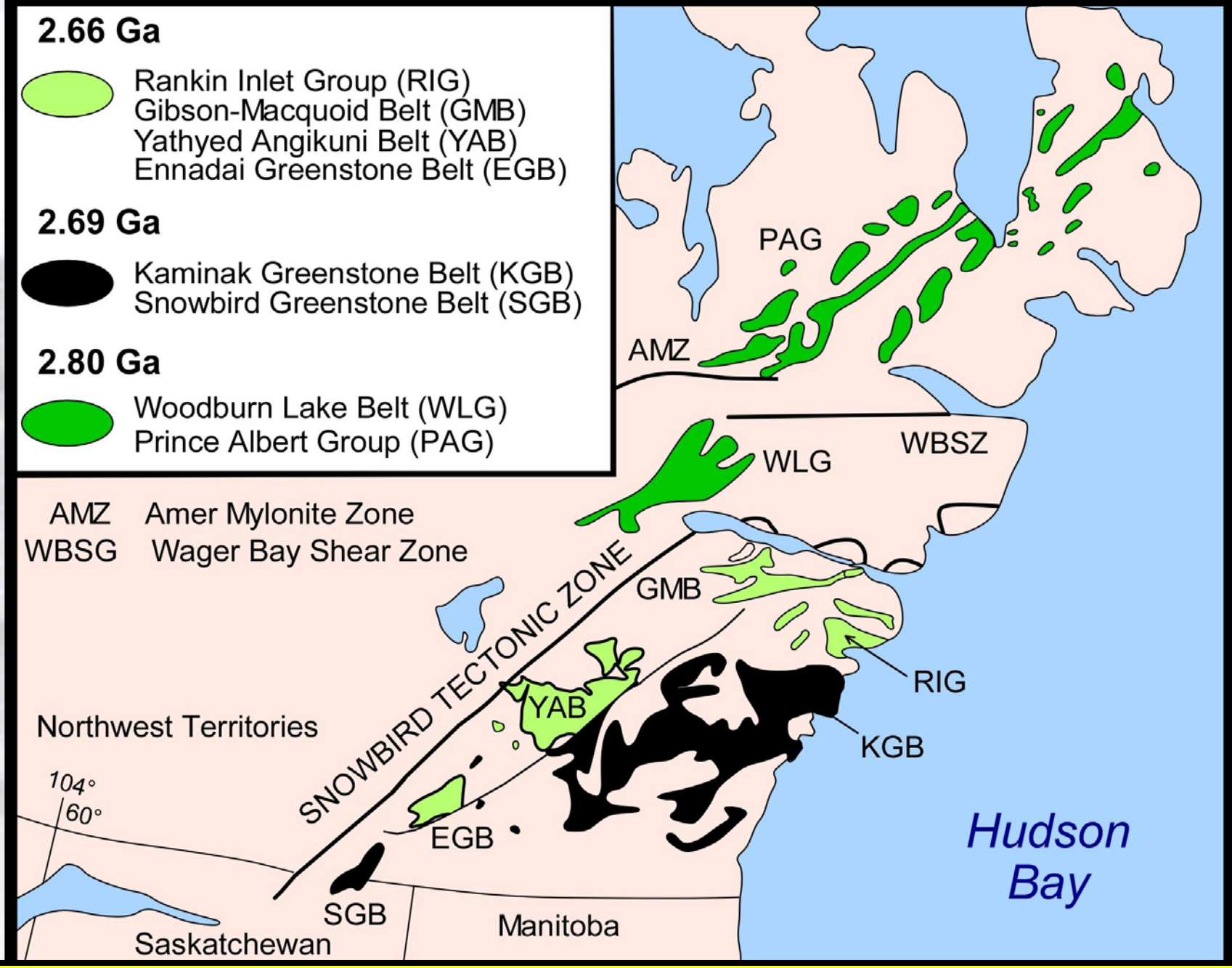


25 % of worlds total identified nickel resources in deposits with > 0.8% Ni are in komatiites.
Nickel deposits do not occur in the older komatiites terranes 3.5-3.3 Ga but do occur in the younger Archean greenstone belts (3.0-2.7 Ga). Yilgarn block in Australia is about 1000 km in length ~ WG-PAG. Karilia is about 300 km in lentgh.
Komatiites are a remarkable class of ultramafic (very magnesium-rich) lavas which are, with very few exceptions, restricted to the first half of the earth's history. A remarkable global outpouring of komatiites occurred around 2700 million years ago, and komatiites of this age host a significant proportion of the world's sulfide nickel resources.

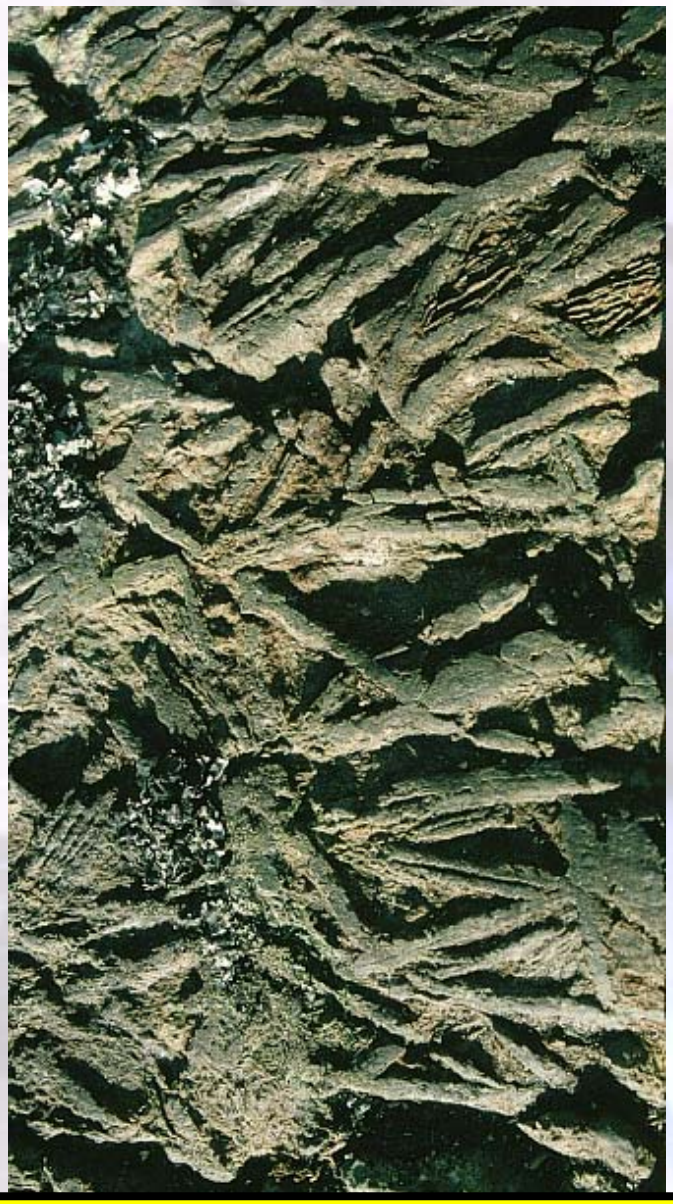


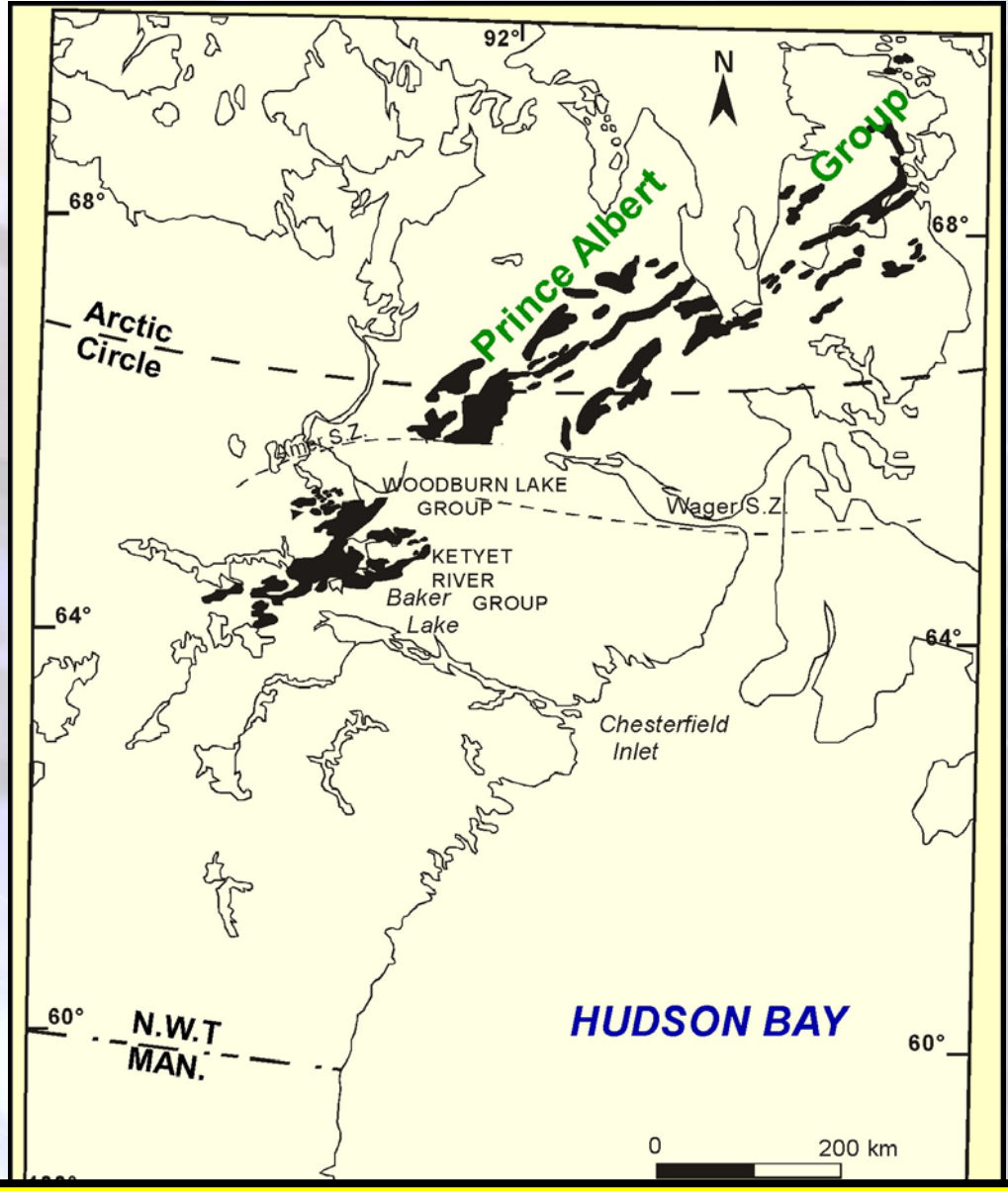
Komatiites were exeptionally hot. The most extreme examples probably erupted at temperatures in excess of 1600 degrees C. At this temperature, the lavas would have been extremely fluid, with viscosities approaching that of water. Research leads us to believe that they were erupted by much the same mechanisms that govern modern basalt lava flows.
Nickel sulfide deposits in komatiites occur largely within linear, olivine-choked lava pathways which may originally have formed as lava tubes, within regionally extensive flow fields The origin of these deposits remains controversial, but several lines of evidence strongly favour a hypothesis referred to variously as "ground melting", "thermal erosion" or "substrate erosion". According to this hypothesis, komatiite lavas melted and eroded the ground they flowed over, causing the lavas to become contaminated by this molten substrate. Where the substrate contained high proportions of sulfur, this caused an immiscible suflide melt to form, in the same way a molten sulfide matte forms in a blast furnace, with the komatiite lava being analogous to the slag. The immiscible sulfide melt scavenged Ni, Cu and platinum group metals from the silicate melt, forming an "ore magma". Orebodies formed where this ore magma pooled and froze at the floor of the flowing lava. The erosion process, and the accumulation of sulfide ores, are restricted to the major flow pathways within the lava flow lobe,

Please see accompanying animated powerpoint slide

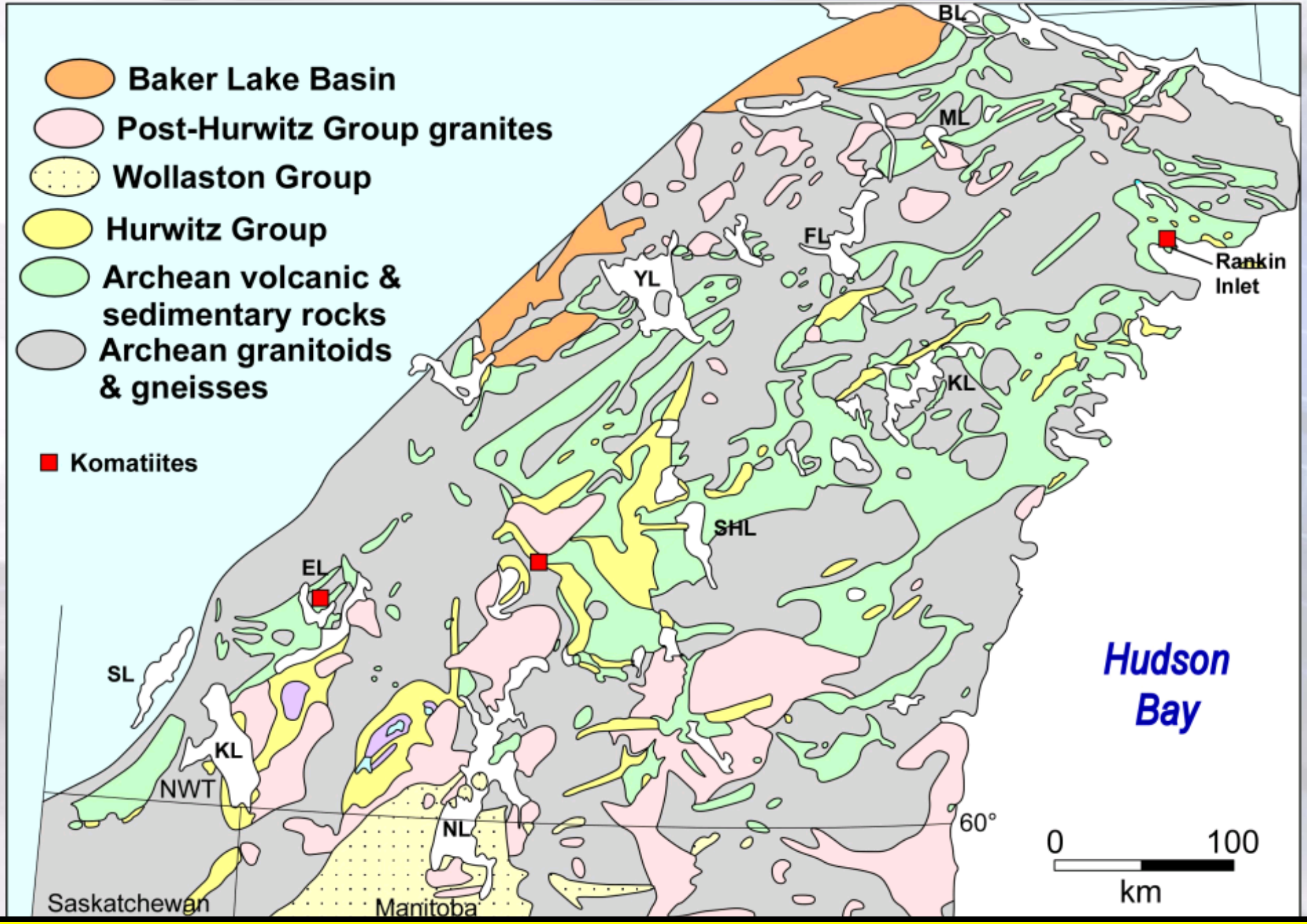


Map showing location of major Archean komatiite and greenstone belts in the in the Western Churchill. Globally these Archean komatiites fall into the “younger” group, and it is this younger group that hosts Ni deposits in W. Australia and the Abitibi.

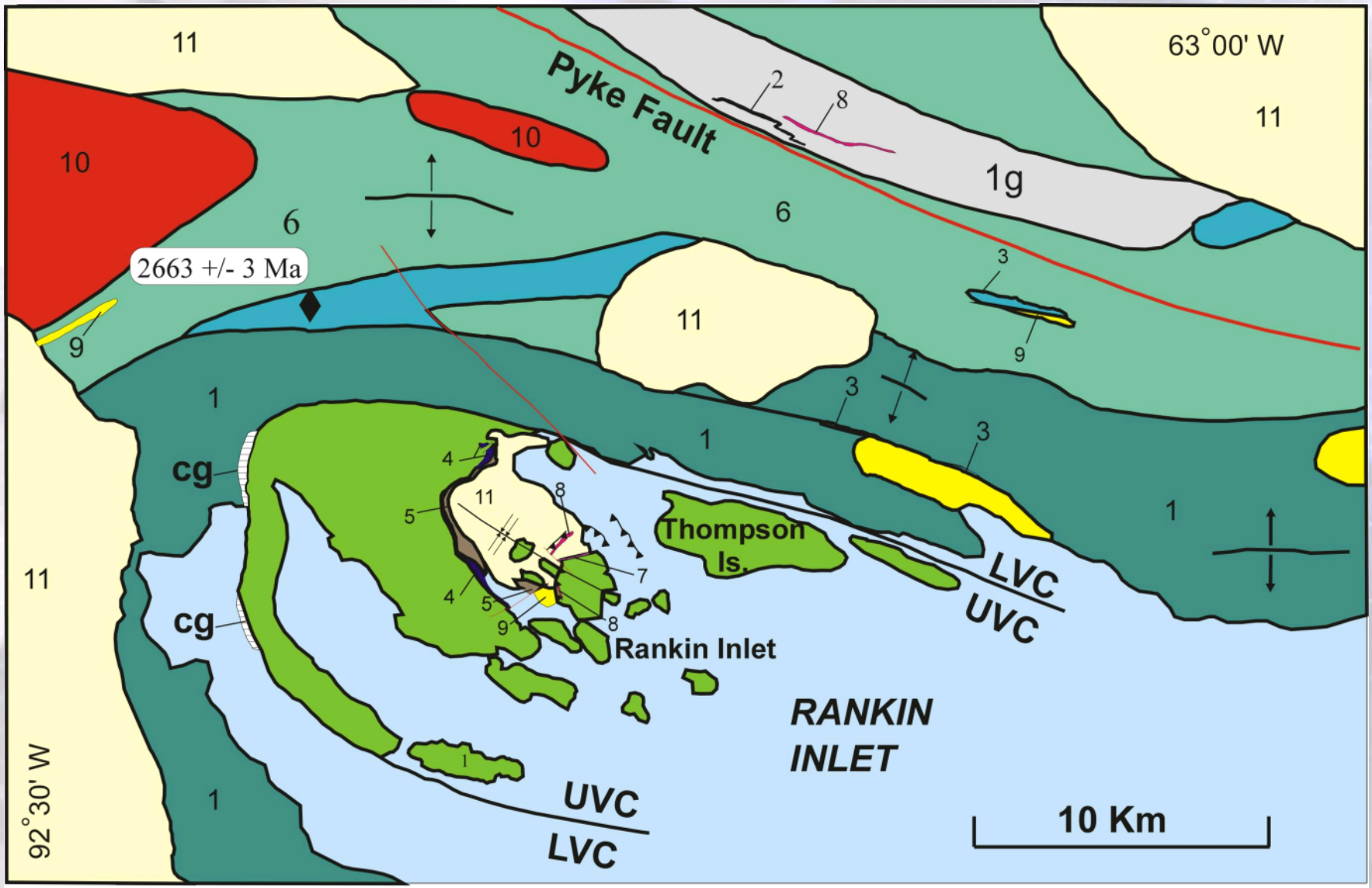




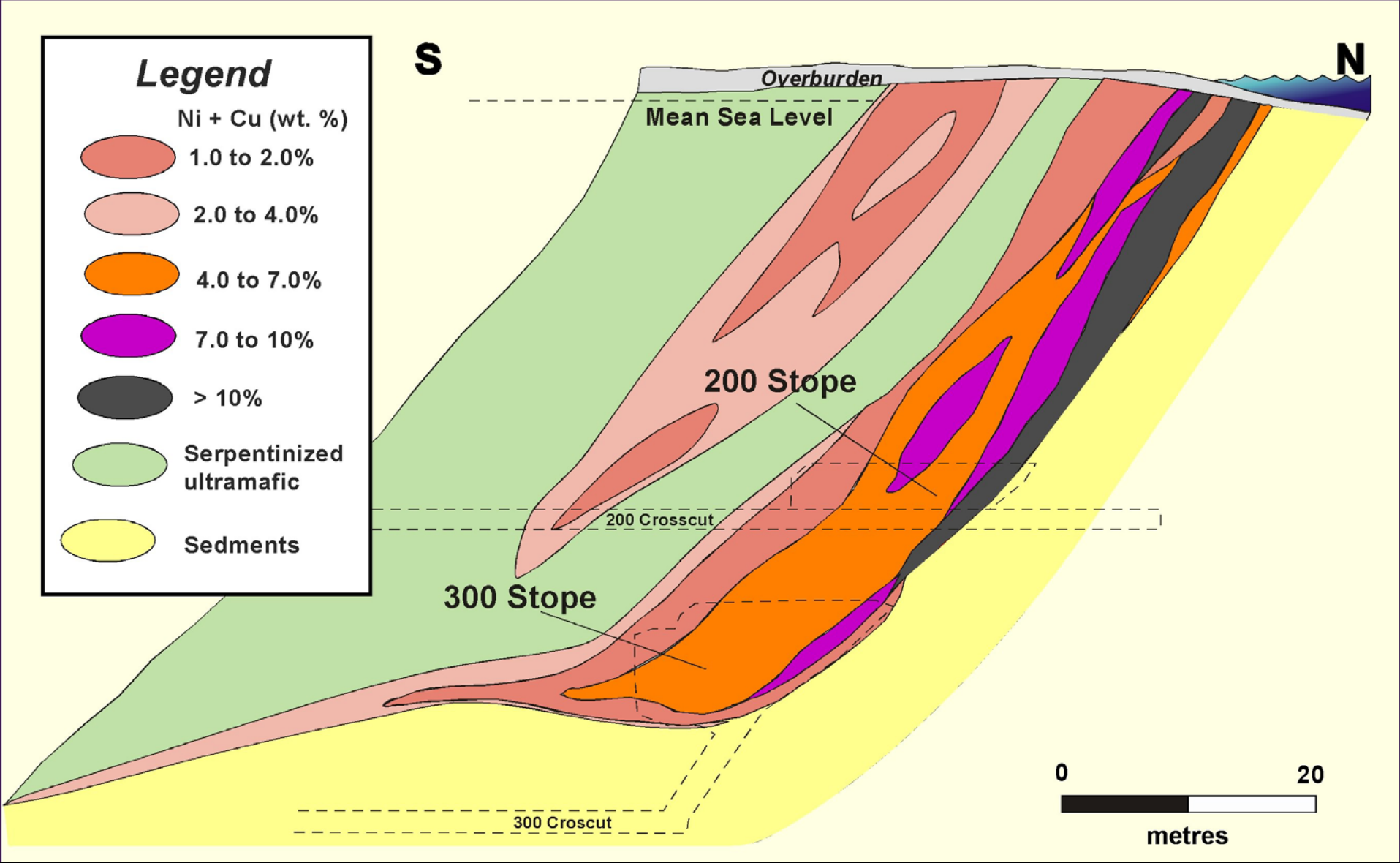
Map showing the regional distribution of the komatiitic Woodburn Lake Group, Prince Albert Group, and Ketyet Group Rae Province, Nunavut. Archean komatiites make up at least one-third of the stratigraphic sequence in these groups. This belt of Archean komatiitic rocks extends further northeast and joins up with the Mary River Group on Baffin Island. Komatiites in this belt tend to have high MgO contents and commonly display coarse olivine spinifex textures as shown in the photo to the left of the map. Since these komatiites are very similar to those found in the nickel camps of western Australian, and komatiitic bodies of the Abitibi in Ontario and Quebec the opportunity for similar discoveries in this world-class komatiitite terrane cannot be overlooked. Modified from Kjarsgaard et al., 1997 .



Simplified geological map of the Hearne province showing location of known komatiites, Ennadi Lake, Griffin Lake and Rankin Inlet.

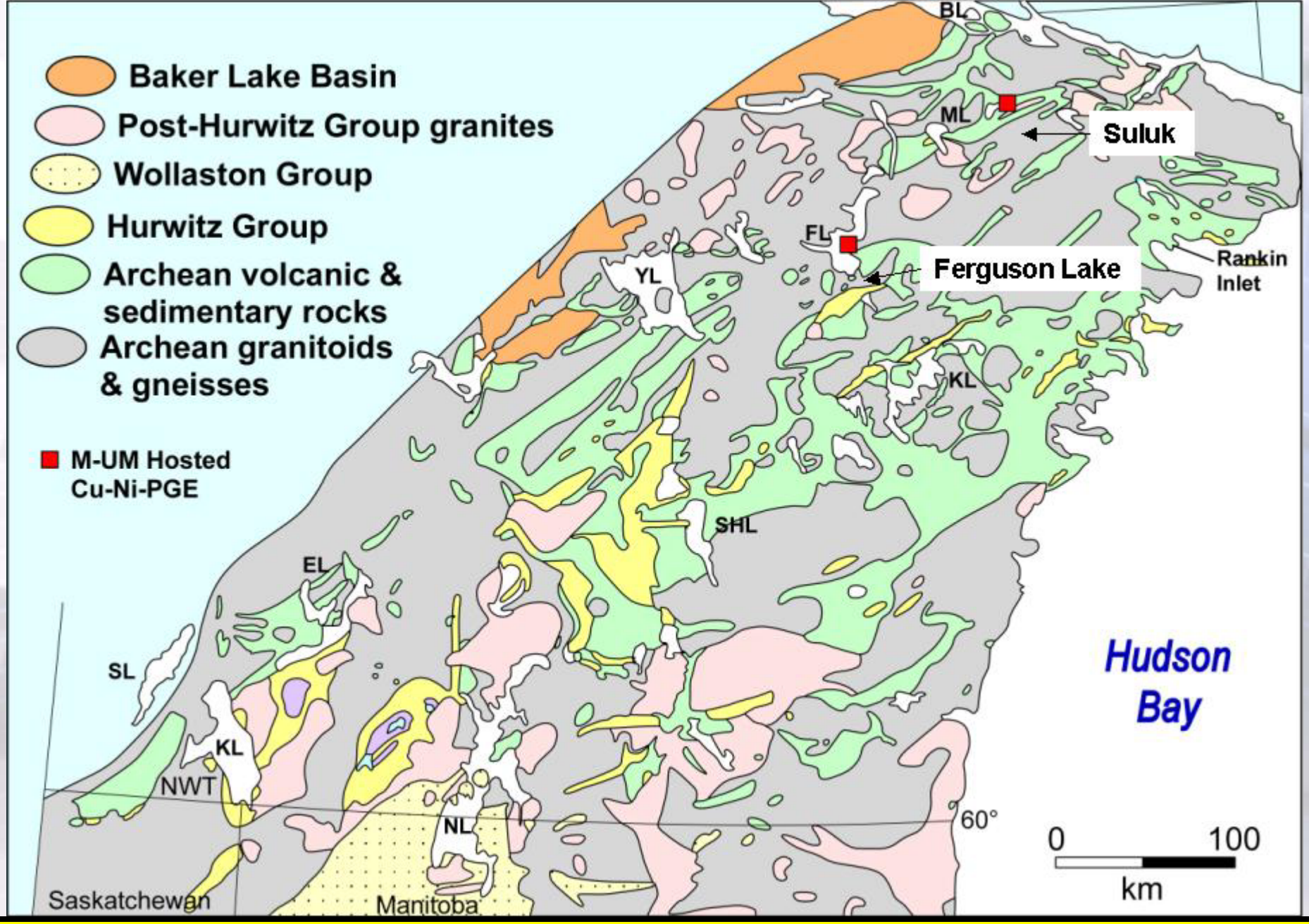


Simplified geology of the Rankin Inlet area.

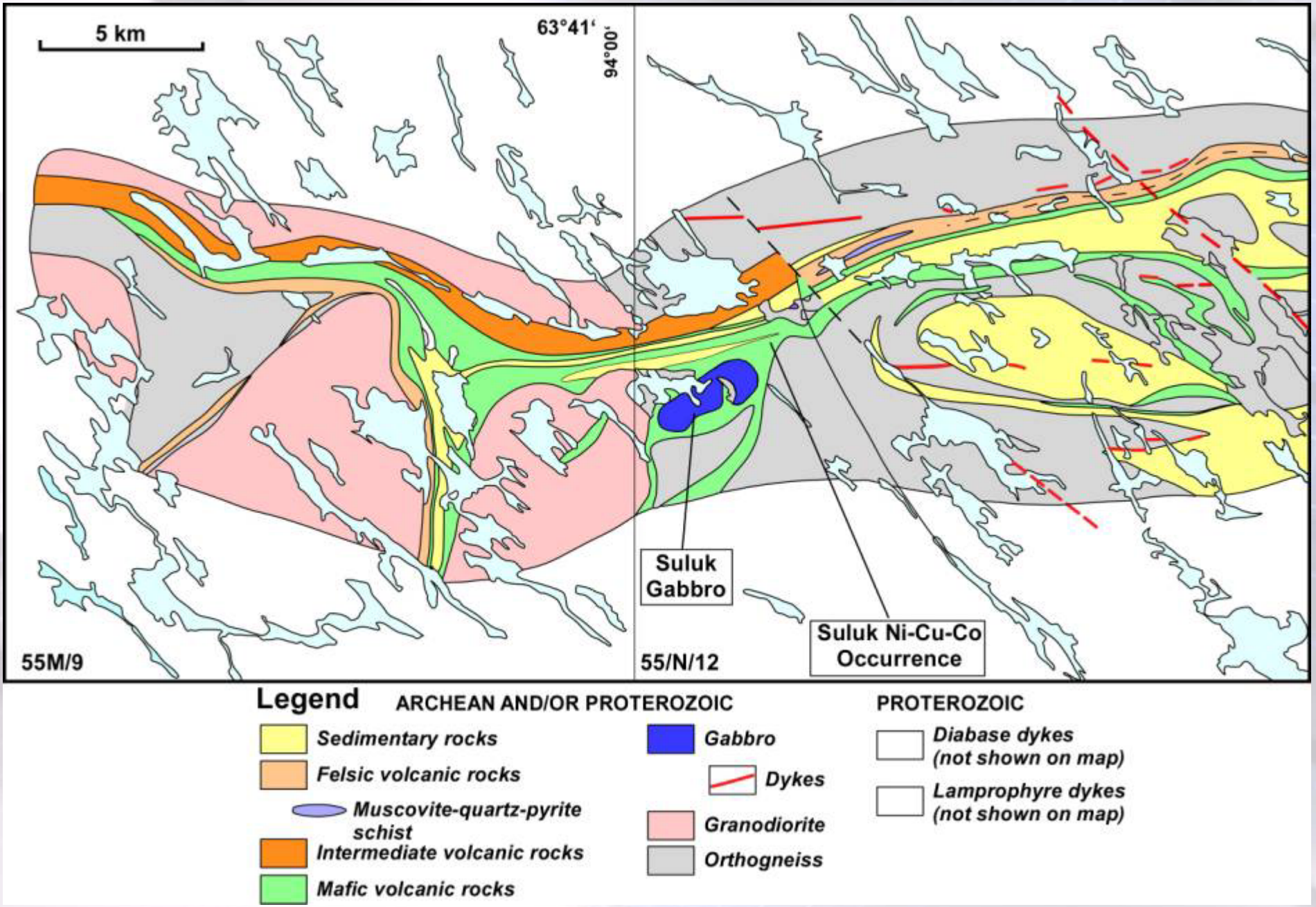


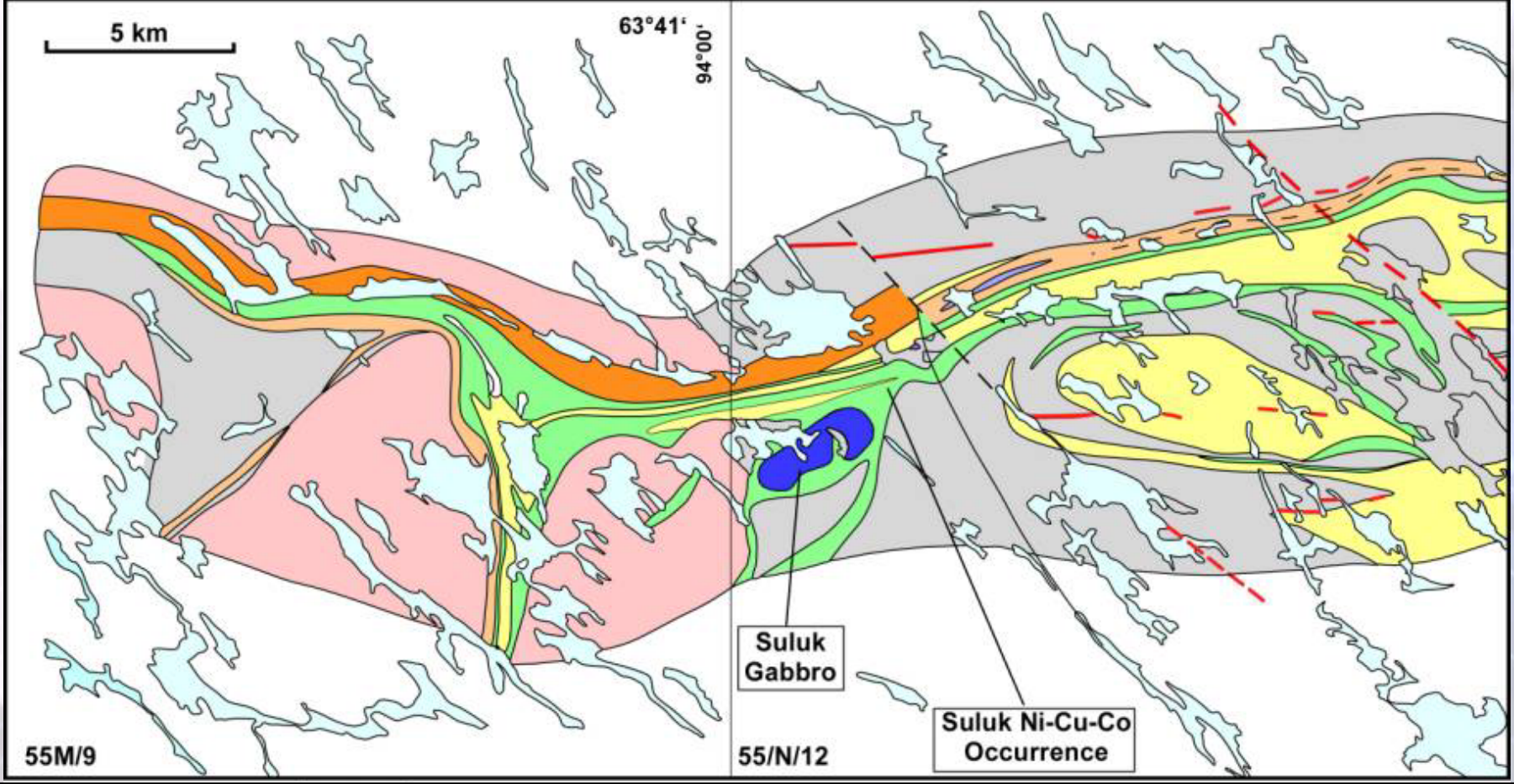
Cross-section through the North Rankin nickel deposit and associated ultramafic. Note the high grade Ni+Cu zonation and the basal embayment in the sediments where the greatest and best concentrations of sulphides occur. The deposit is hosted by a small ultramafic body approximately 100 m thick and at least 1800 m in length emplaced along the contact between sedimentary and volcanic rocks. The deposit was mined from 1957 to 1962 and had an average grade of 3.3% Ni, 0.8% Cu, 1.02 g/tonne Pt and 2.05 g/tonne Pd. Regional deformation has rotated the body from its original flat-lying attitude. Modified from Hulbert & Gregoire 1997.

Ni-Cu-PGE Mineralization Associated with Mafic-Ultramafic Intrusions

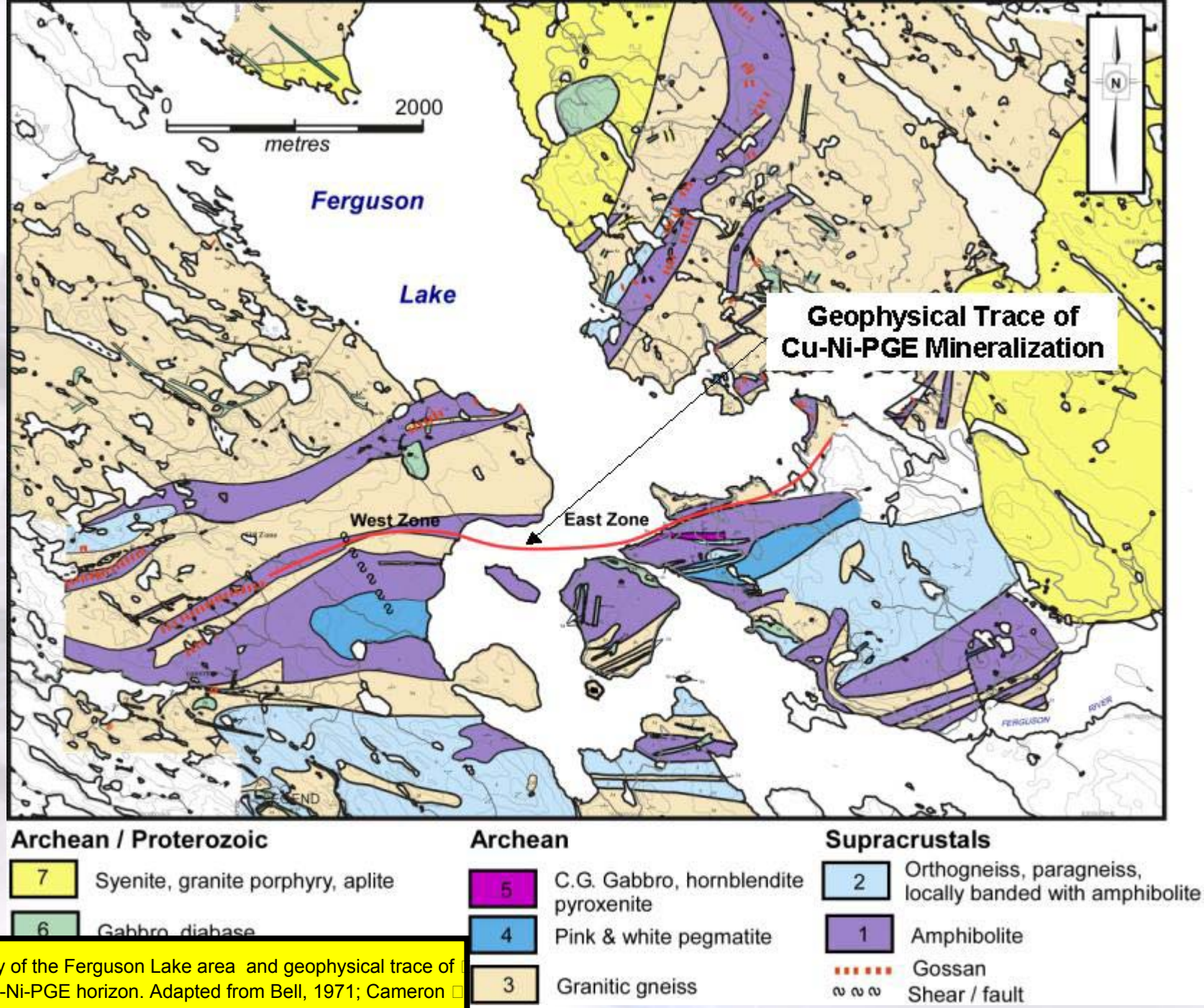


Location of significant mafic-ultramafic hosted or associated Cu-Ni-PGE mineralization. Suluk is 120 km NW of Rankin Inlet and about 110 km SE of the community of Baker Lake. The Suluk showing occurs in the Archean Gibson-MacQuoid Lake belt. Rocks in this belt have similar lithological and structural characteristics to the Archean Rankin-Ennadai greenstone belt to the south.

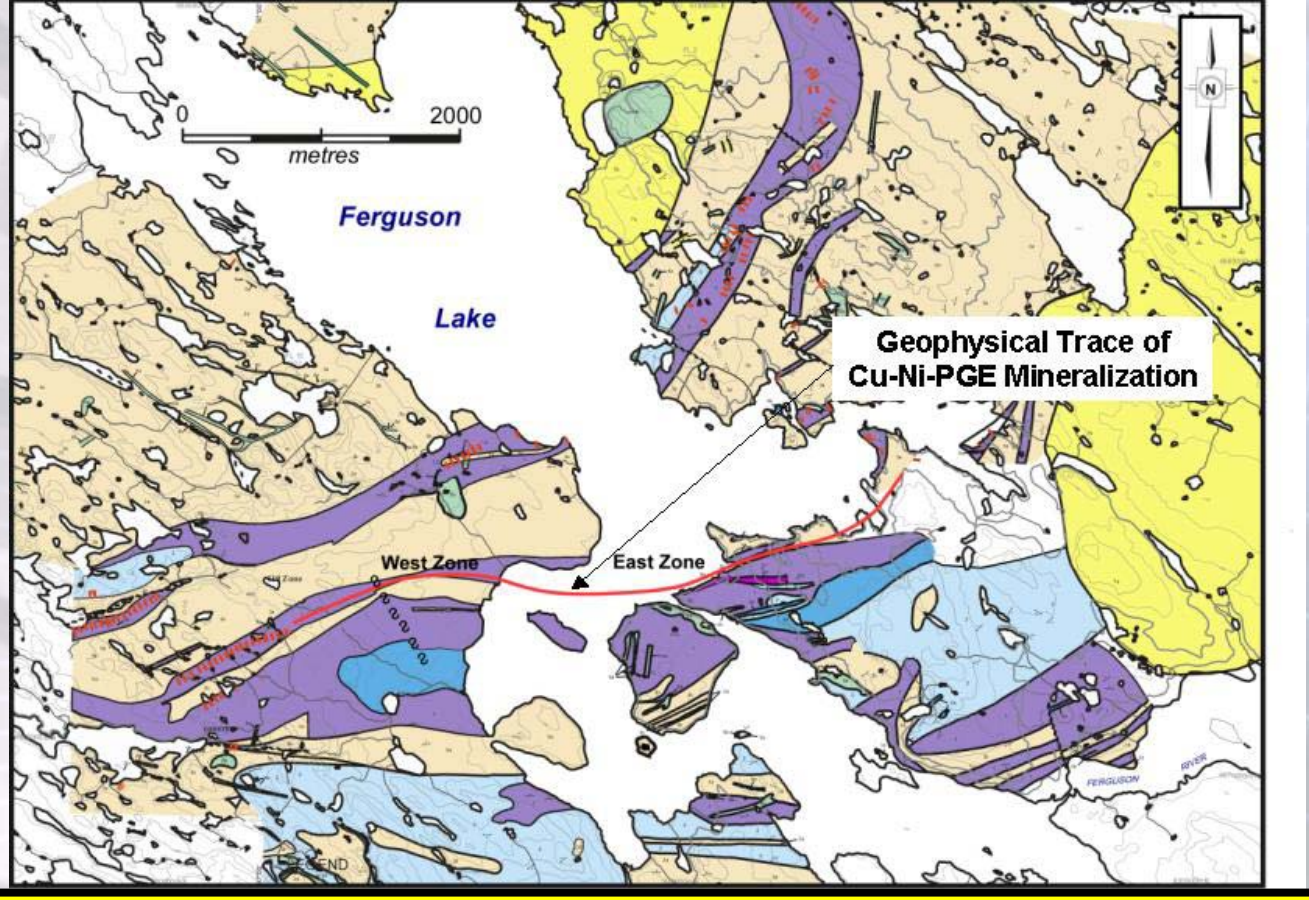

5 km
63°41'
94°00'
Suluk Gabbro
Suluk Ni-Cu-Co Occurrence
55M/9
55/N/12
Legend
ARCHEAN AND/OR PROTEROZOIC
Sedimentary rocks
Felsic volcanic rocks
Muscovite-quartz-pyrite schist
Intermediate volcanic rocks
Mafic volcanic rocks
Gabbro
Dykes
Granodiorite
Orthogneiss
PROTEROZOIC
Diabase dykes (not shown on map)
Lamprophyre dykes (not shown on map)



The Suluk showing is hosted in highly sheared and foliated mafic volcanics and consists of massive Po-Pn-Cp and magnetite and has a discontinuous surface exposed strike length of 550m. A HLEM survey delineated a 800 m long, north dipping, highly conductive body with an inferred thickness that varied from 1-10m. The close proximity of the prospect to a nearby gabbro body was thought to be the source of the Ni-Cu-Co mineralization at depth or along strike to the west. Numerous cross-cutting zones or blow-outs occur in the footwall to the main mineralized trend and form linear pods of massive sulphide averaging 1 m in width and have cross-cutting lengths of up to 10 m. In 1995 eleven evenly spaced samples collected over a strike length of 550 m averages 2.8% Cu, 3.9% Ni and 0.16% Co. In 1996 thirteen holes were drilled of which 8 tested the Suluk zone to a max depth of 225m, along a strike length of 500m. The thickest and highest grade intersection was 1.56% Cu, 4.31% Ni and 0.12% Co over 0.47m.



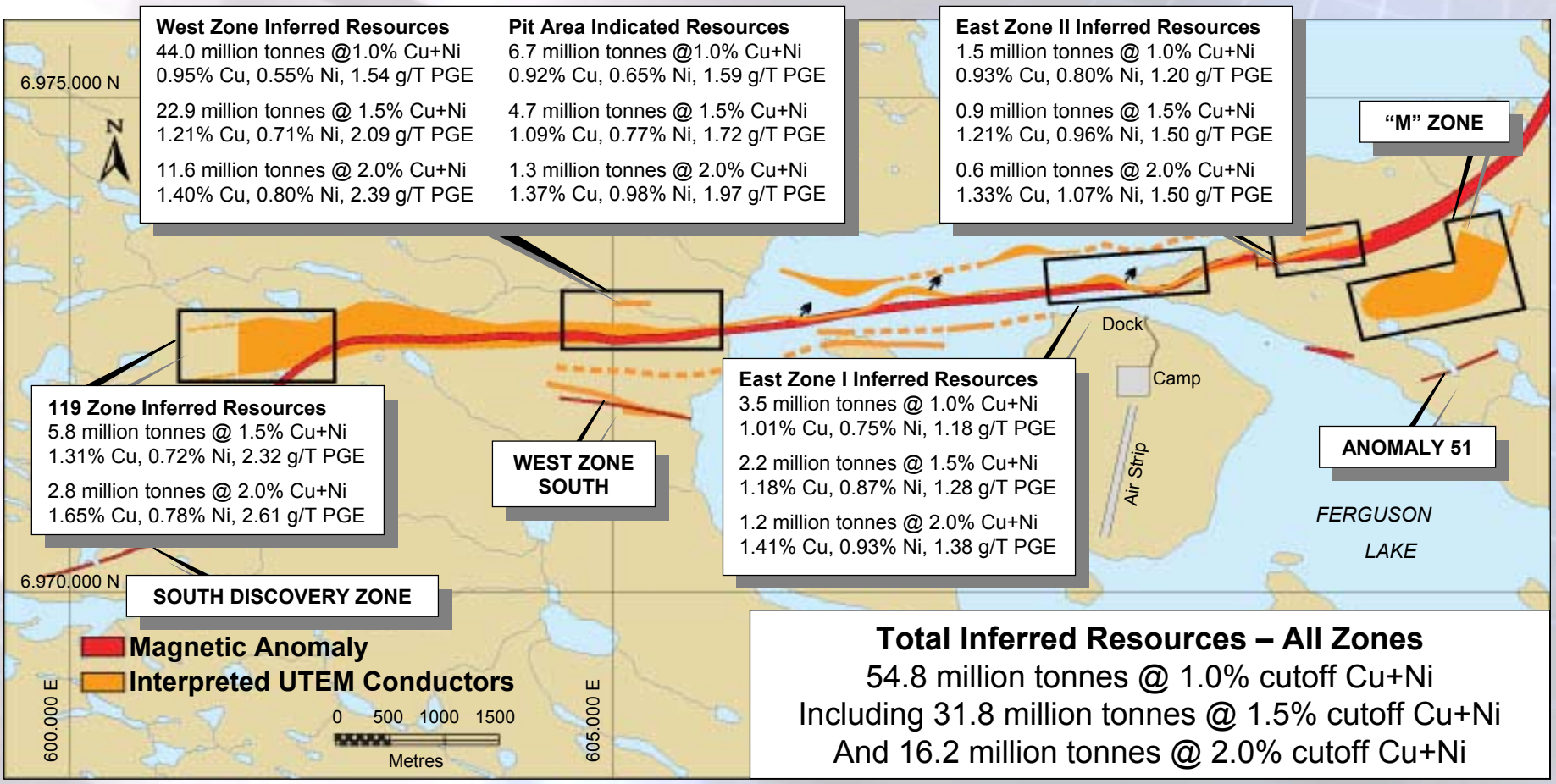
Geology of the Ferguson Lake area and geophysical trace of the Cu-Ni-PGE horizon. Adapted from Bell, 1971; Cameron 1987, INCO (CANICO) 1953, Eade 1986, Leggett et al. 1976.



Mineralization is present as a > 20 km long sulphidic zone situated in an east-west trending package of mafic volcanics sandwiched between various high grade ortho and paragneissic terranes. The volcanic rocks have been metamorphosed to upper amphibolite to granulite facies. Several syn to post-tectonic gabbros and late syenite intrusives cut the stratified rocks. The most abundant rock type in the immediate vicinity of mineralization is a medium grained mafic amphibolite containing 30 - 60% hornblende. Sulphide mineralization occurs in a 50 - 200 m wide, medium to coarse grained hornblendite subunit that has been interpreted as a metamorphosed ultramafic sill within the amphibolites. It contains more than 60% hornblende, plagioclase and minor garnet and locally displays modal banding probably related to metamorphism.

The main sulphide zone generally occurs as a single discrete horizon up to 10 metres thick but may locally comprise a series of narrow parallel horizons. A strong gossan marks the zone in outcrop. Mineralization consists of both breccia and stringer sulphides. The former type is found in discontinuous pods up to 50 cm thick consisting of 60 to 90% pyrrhotite. Inclusions of well-formed quartz and hornblende crystals as well as aggregates of both are common in the main part of the zone, which may have led to the brecciated description. In the western part of the sulphide horizon, abundant magnetite is present in the form of semi-rounded clots rimmed by sulphide. Stringer type mineralization is more continous, consisting of stratabound veinlets of chalcopyrite, pyrite and pyrrhotite comprising up to 10% by volume of the hornblendite. Amphibolite immediately adjacent to sulphides is garnetiferous.

Identified Resources -- Ferguson Lake Project

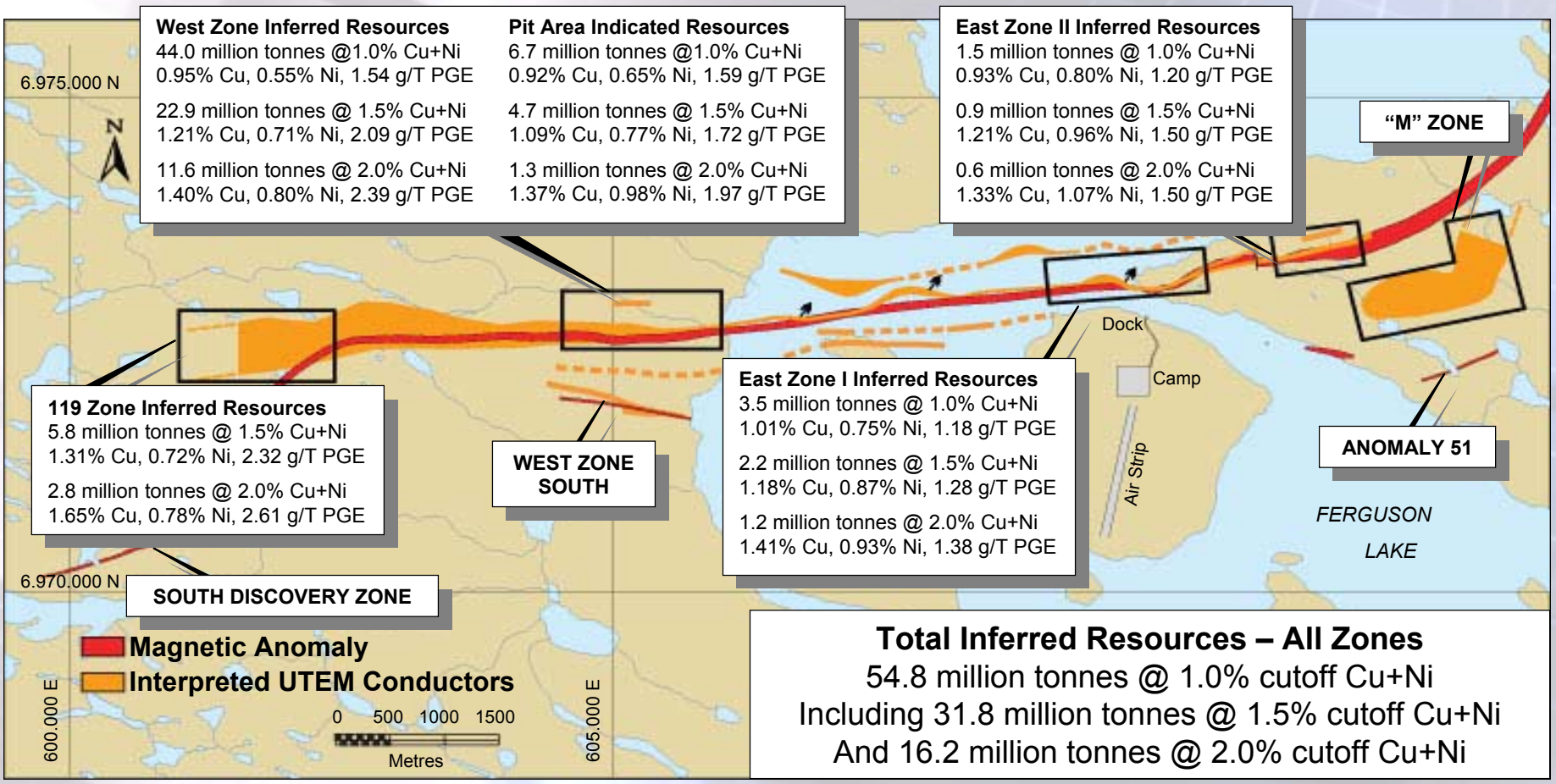


1.8 km surface expression West Zone Main massive sulphides

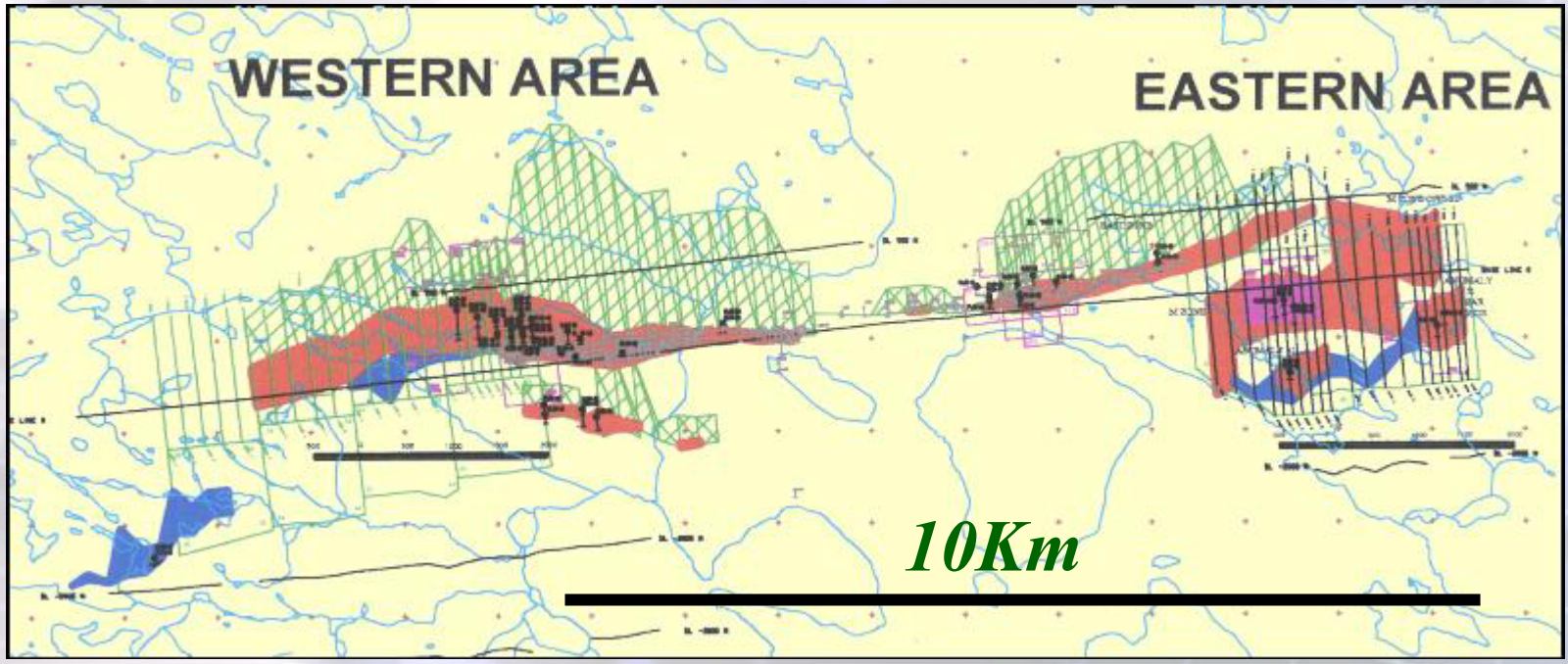
Open along strike

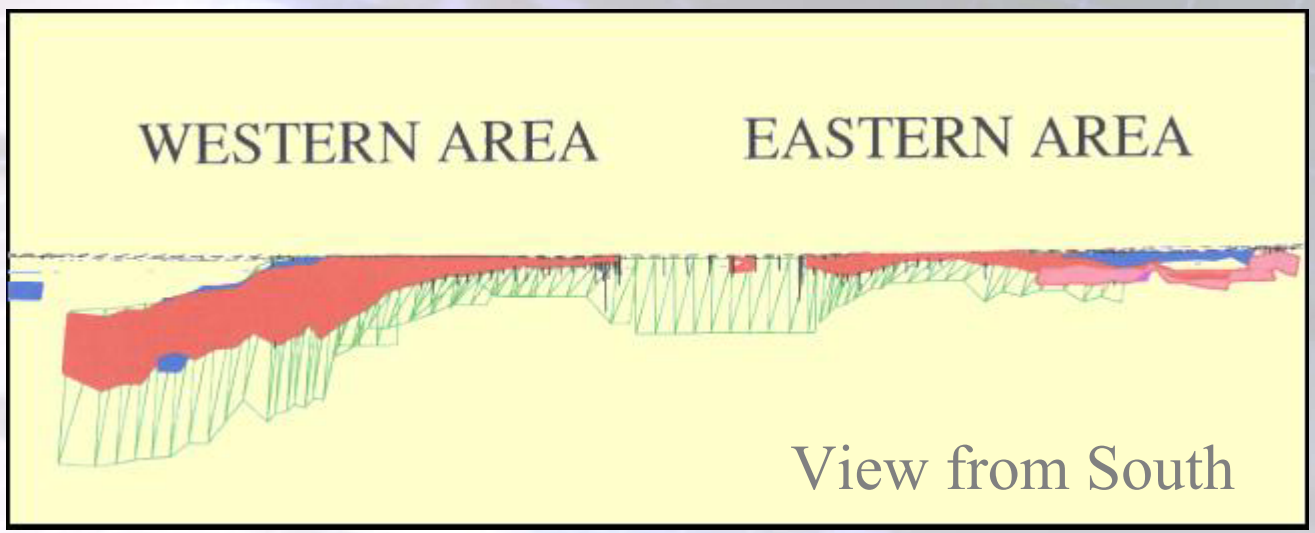
Total indicated and inferred resources of 61.5 Mt as of April 2003

Identified Resources -- Ferguson Lake Project



Canadian Nickel (Inco) carried out a large program of geophysics, mapping, diamond drilling and bulk sampling in the early 1950's, eventually outlining approximately 7.3 million tons grading 0.87% Cu and 0.75% Ni in the main mineralized zone. The deposit was traced over a strike length of 7700 metres and to a depth of about 250 metres. In 1987, Homestake Mineral Development Company optioned the property and sampled it for PGE. Samples of breccia style mineralization contained from 50-700 ppb Pt and up to 5000 ppb Pd. Samples of stringer style sulphides contained from 80-800 ppb Pt and 90-1200 ppb Pd. Sulphides also contain erratically anomalous levels of Co (up to several hundred ppm) and Au (up to a few tens or hundreds of ppb)

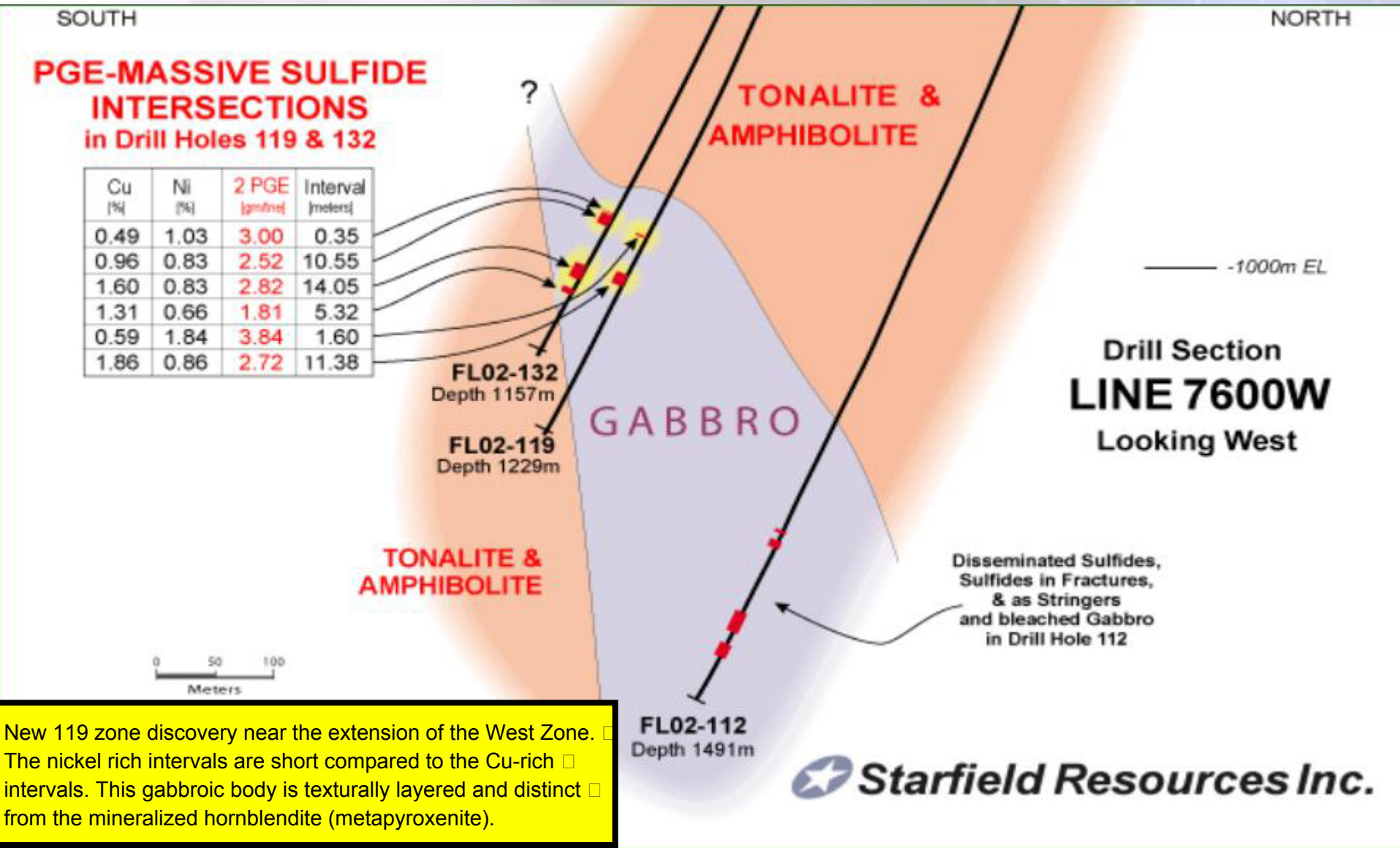




This is the final plan map and section to date of our UTEM conductors over 15 KM

2002 NEW "119 ZONE" DISCOVERY: PGE MASSIVE-SULPHIDE HORIZONS

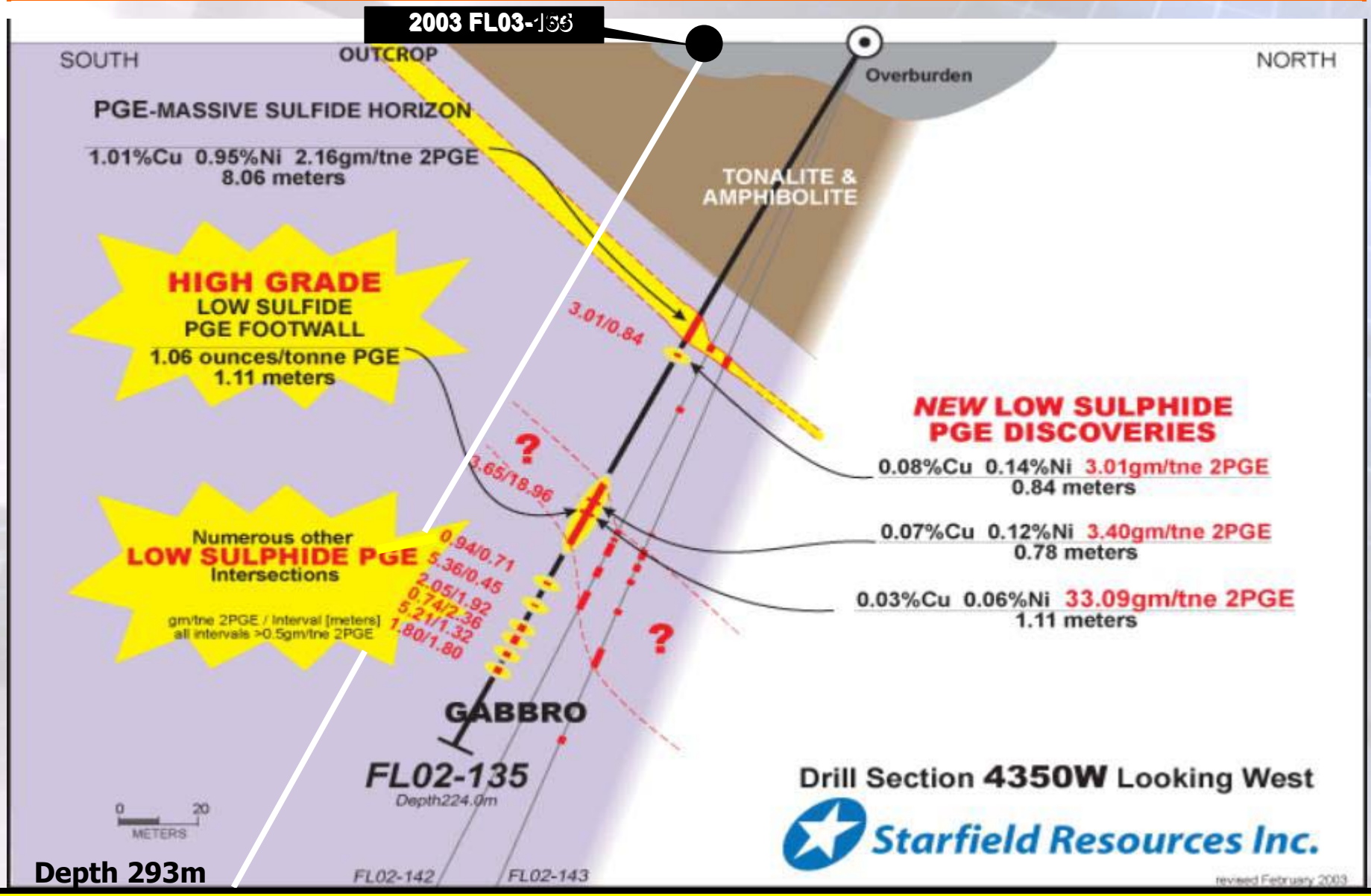
Drill Holes FL02-119 & -132 on 7600W Section



New 119 zone discovery near the extension of the West Zone. The nickel rich intervals are short compared to the Cu-rich intervals. This gabbroic body is texturally layered and distinct from the mineralized hornblendite (metapyroxenite).

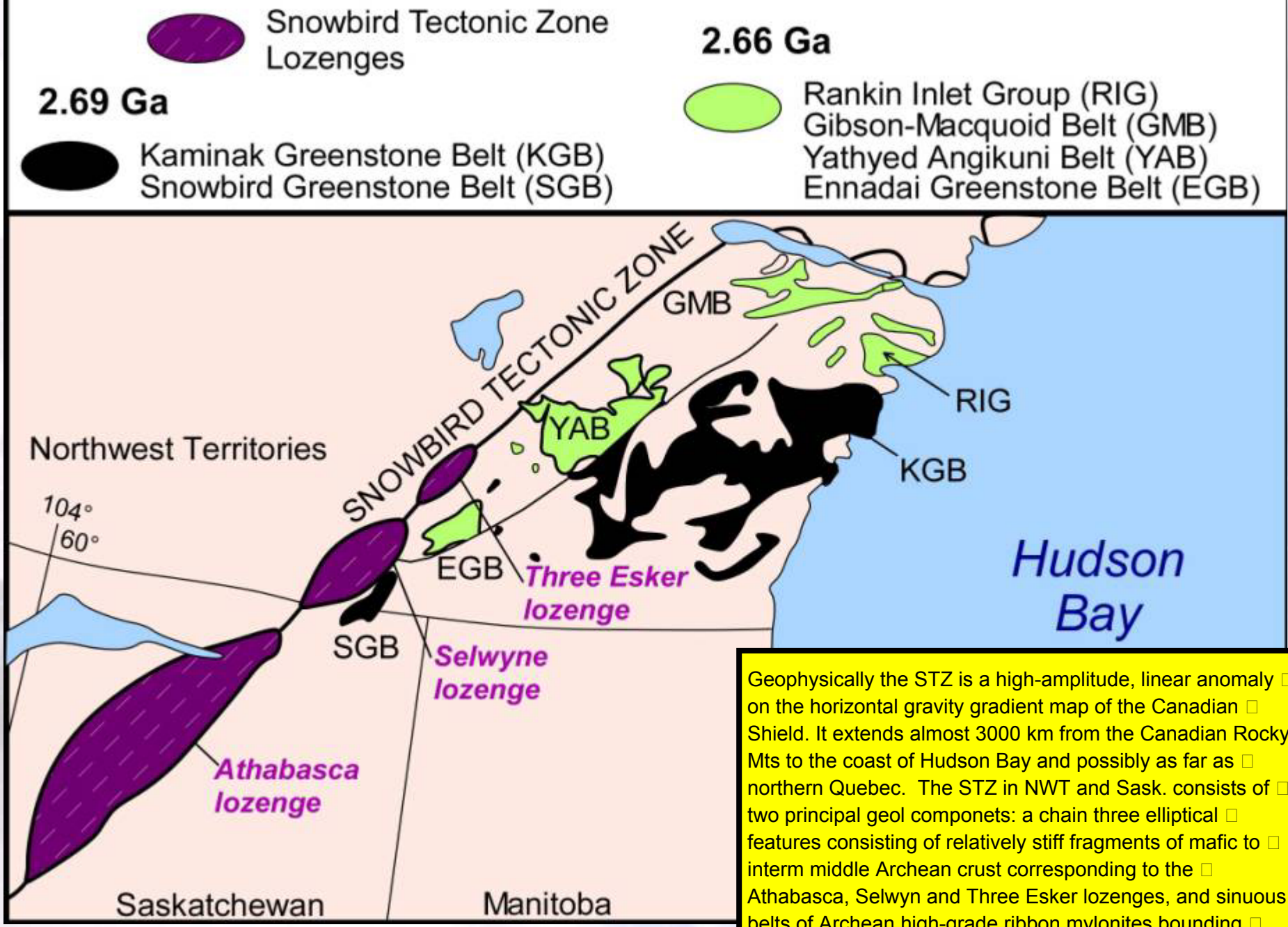
Starfield Resources Inc.

HIGH GRADE PGE – LOW SULPHIDE FOOTWALL SETTING
Drill Hole FL02-135 on 4350W Section

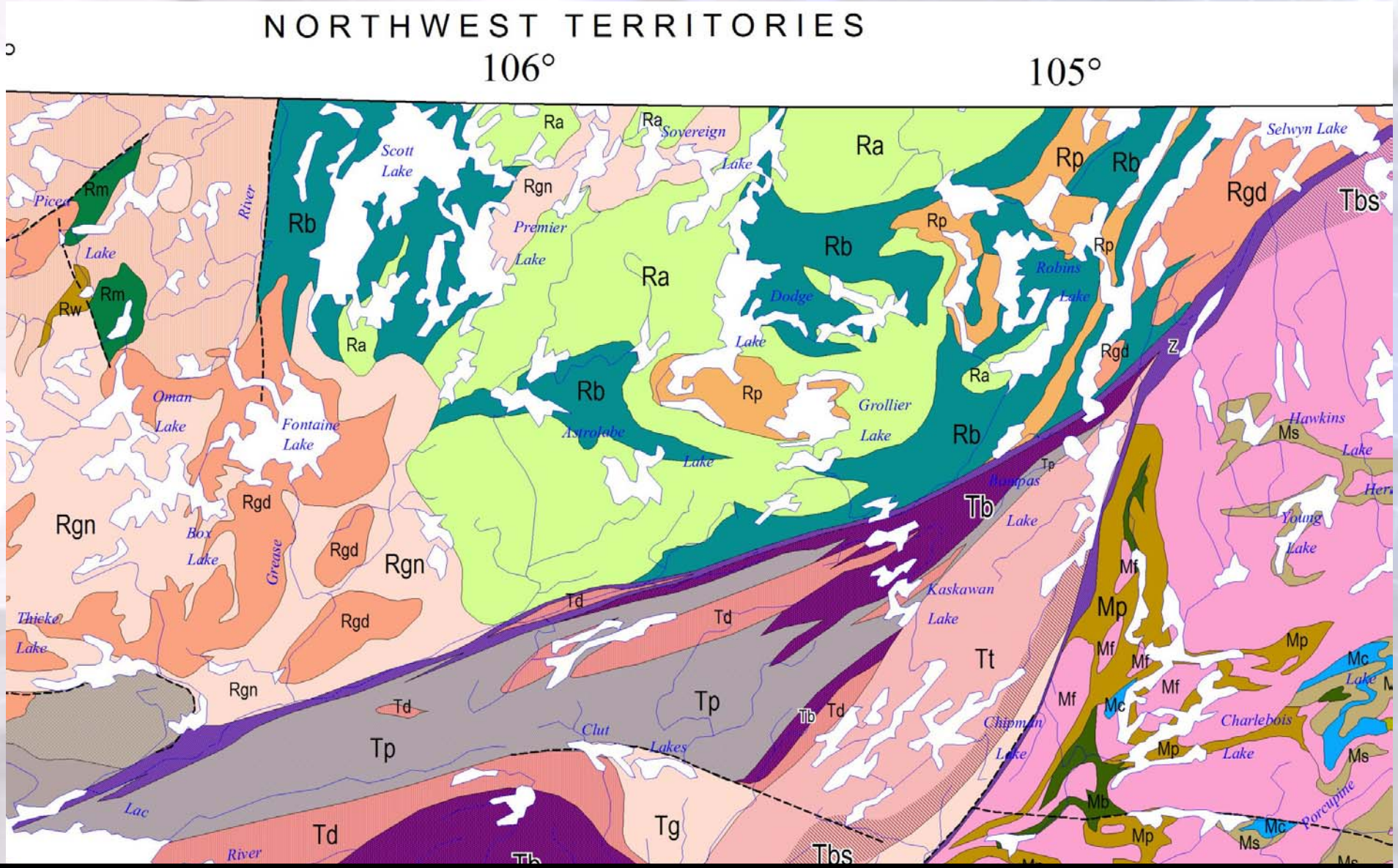


New low sulphide – high PGE zones in the structural footwall to the Cu-Ni-PGE massive sulphide horizon. Occurs in the eastern part of the West Zone

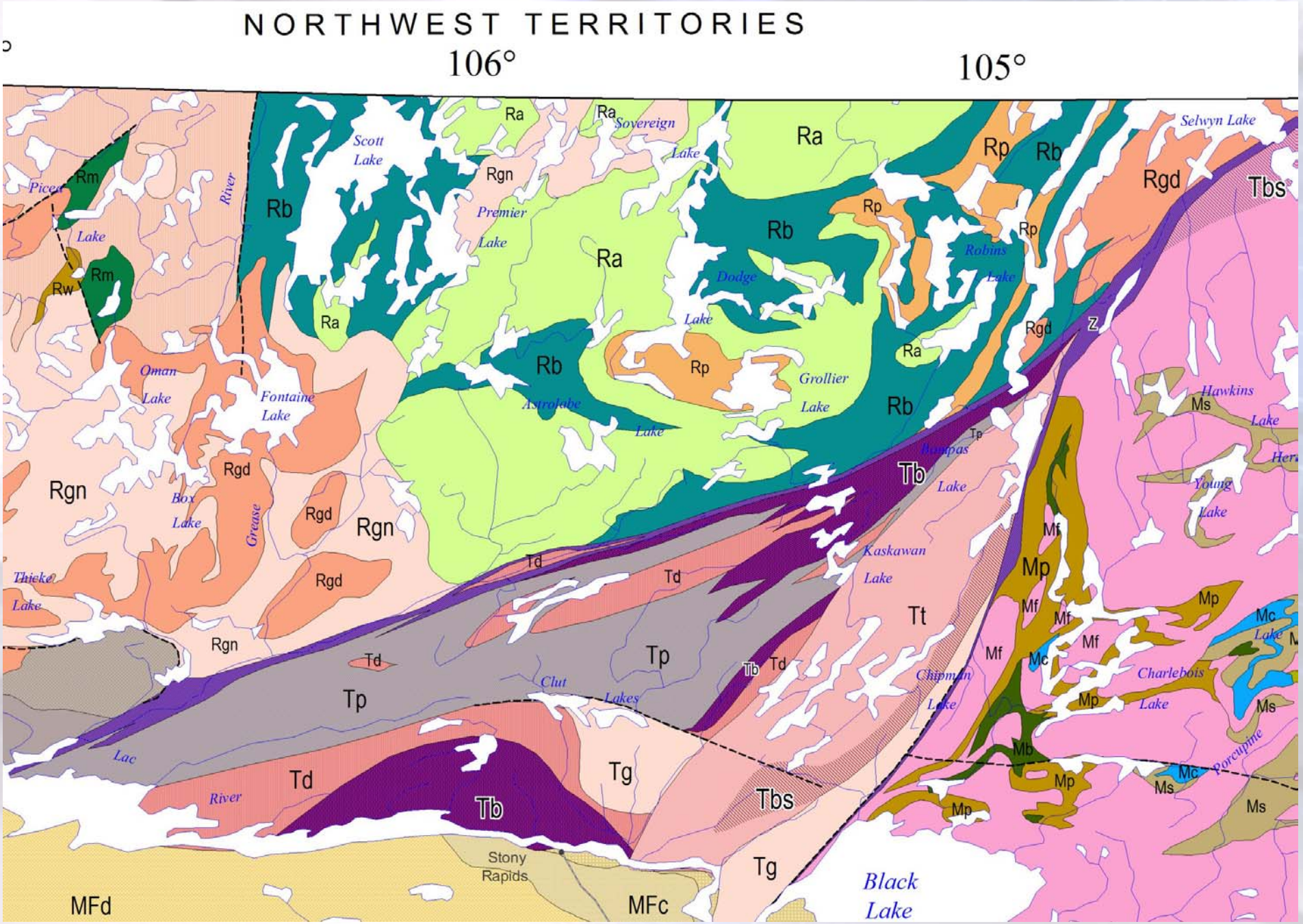
Noritic Magmatism and Ni-Cu-PGE Mineralization Associated with a Deep-Crustal Intracontinental Shear Zone



Geophysically the STZ is a high-amplitude, linear anomaly on the horizontal gravity gradient map of the Canadian Shield. It extends almost 3000 km from the Canadian Rocky Mts to the coast of Hudson Bay and possibly as far as northern Quebec. The STZ in NWT and Sask. consists of two principal geol componets: a chain three elliptical features consisting of relatively stiff fragments of mafic to interm middle Archean crust corresponding to the Athabasca, Selwyn and Three Esker lozenges, and sinuous belts of Archean high-grade ribbon mylonites bounding them. This zone is the boundary between major crustal blocks ; i.e. Rae and Hearne provinces.



At the north end of the 300x100 km Athabasca lozenge is a triangular area known as the East Athabasca mylonite triangle, also referred to as the Tantato domain. This 75 x 80 x 125 km triangle of high grade mylonites separated from the Rae and Hearne wall rocks by narrow greenschist facies mylonite belts. By late Archean this mylonite triangle was part of a deep-crustal, intracontinental shear zone . The mafic granulites in the Axis Lake – Stony Rapids area coincide spatially with an important gravity anomaly that extends under the northern margin of the Athabasca Basin. Tb = mafic granulites of Fond-du-Lac and Bohica mafic complexes ca. 2.6 ga, Tt= Chipman tonalite ca 3.2-3.4 Ga, Tg= late syn-tectonic mylonitized granite, Td= garnet-pyroxene diatexite, Tp= hb-garnet-pyroxene orthogneiss ca 2.62 Ga


NORTHWEST TERRITORIES
106°
105°
Scott Lake
Sovereign Lake
Premier Lake
Dodge Lake
Astrolabe Lake
Grollier Lake
Robins Lake
Selwyn Lake
Hawkins Lake
Young Lake
Bompas Lake
Kaskawan Lake
Chipman Lake
Charlebois Lake
Oman Lake
Fontaine Lake
Box Lake
Thicke Lake
Clut Lakes
Stony Rapids
Black Lake
Lac River
Grease River
Porcupine
Ra
Rb
Rm
Rw
Rp
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Mc
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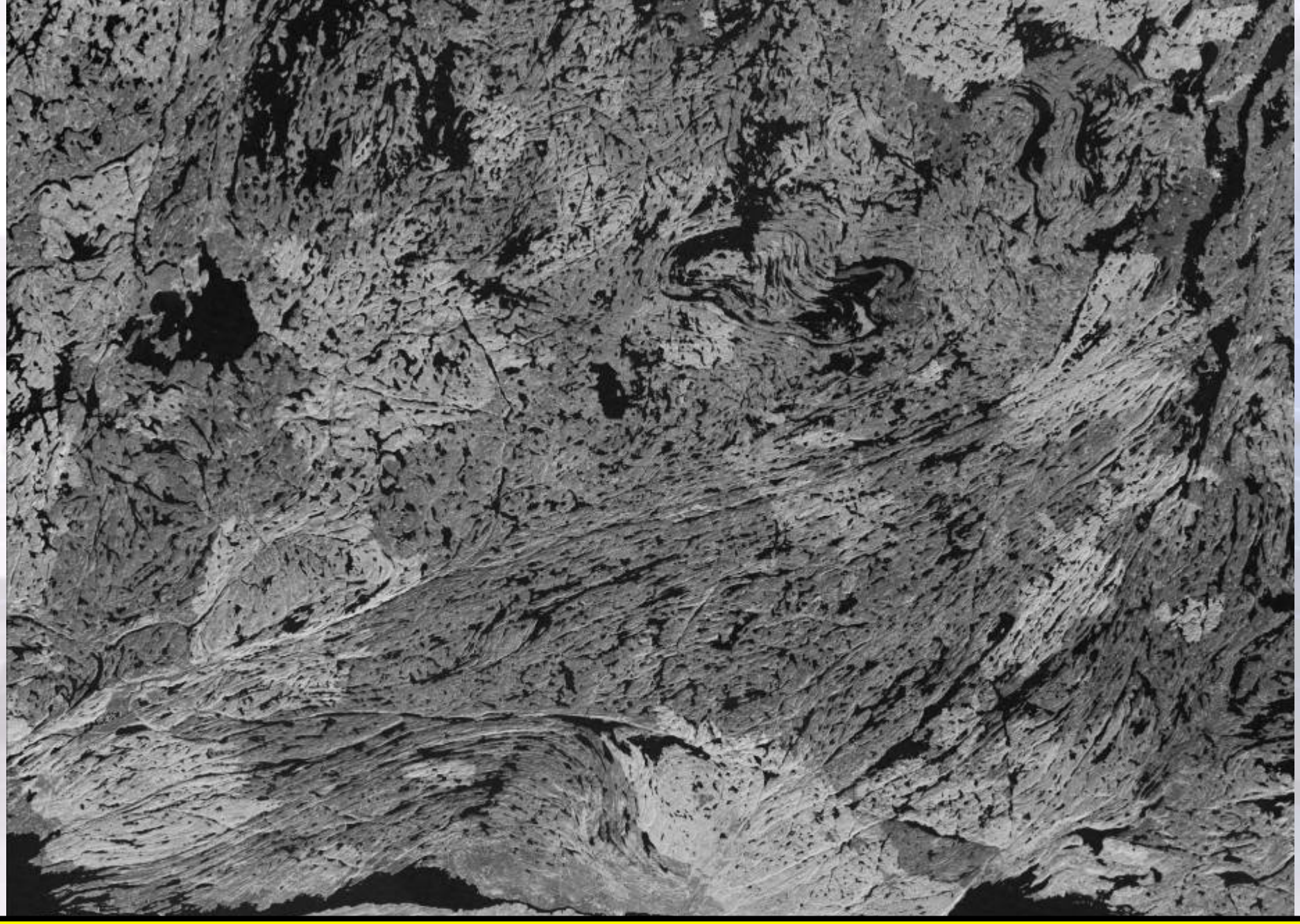
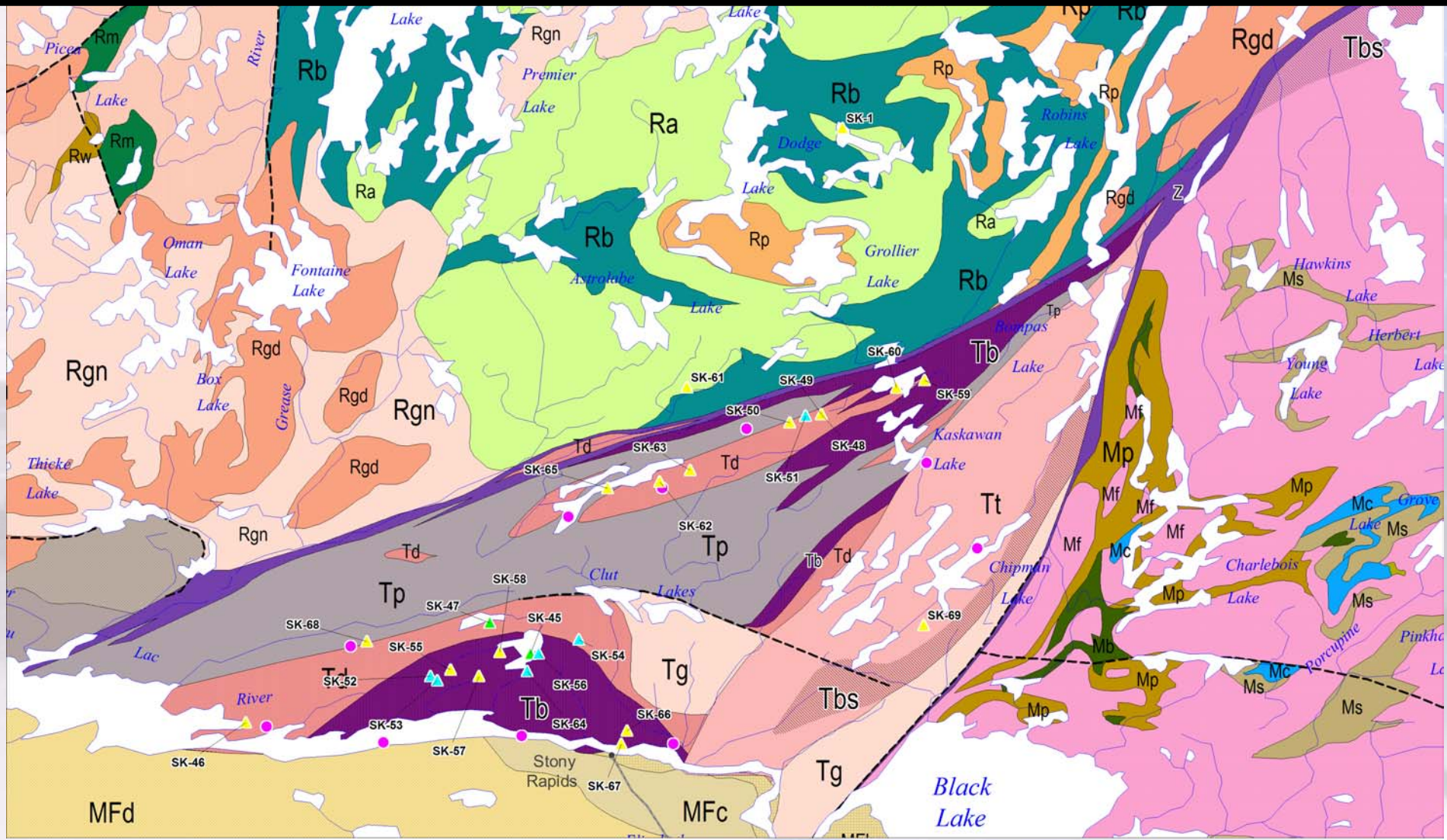
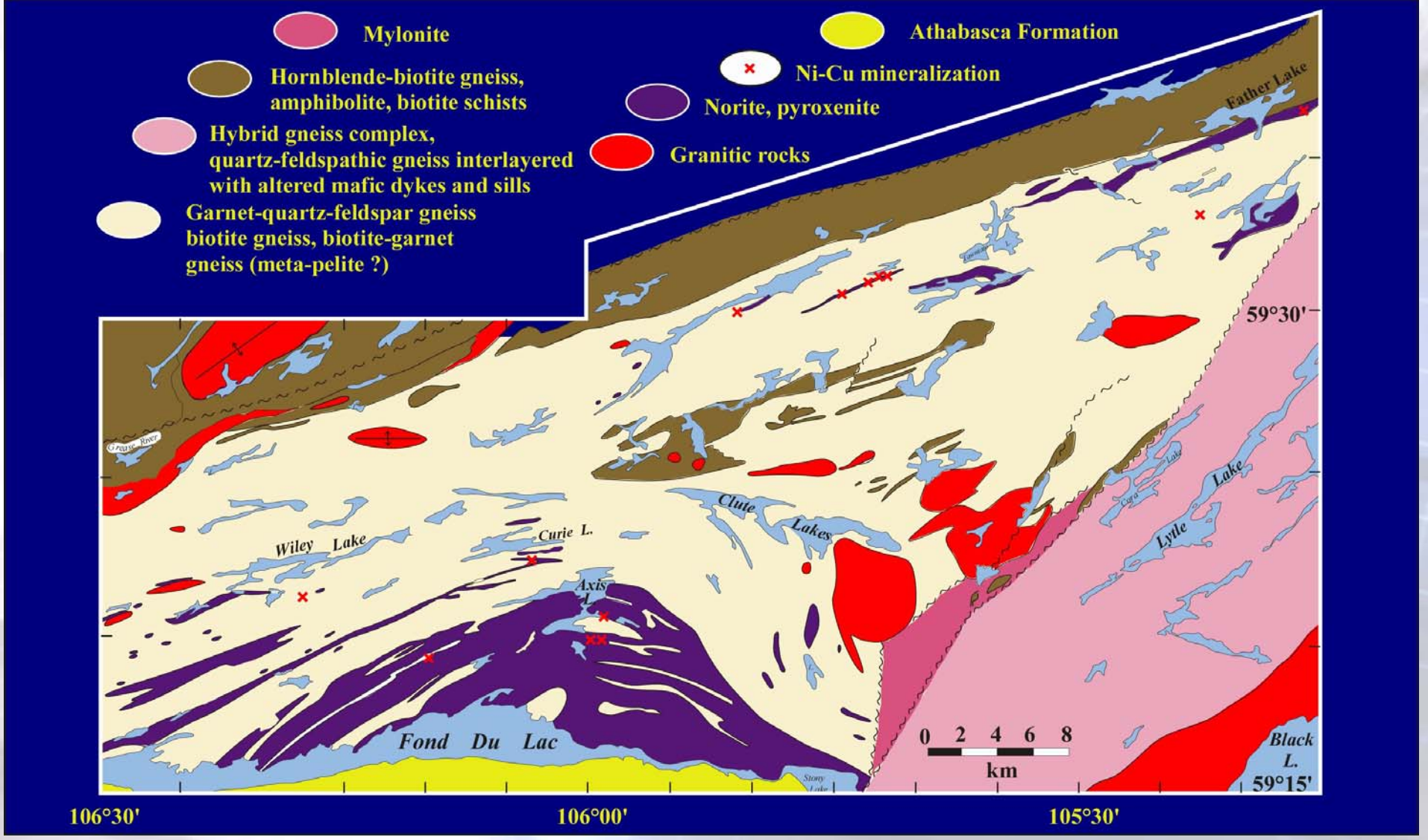


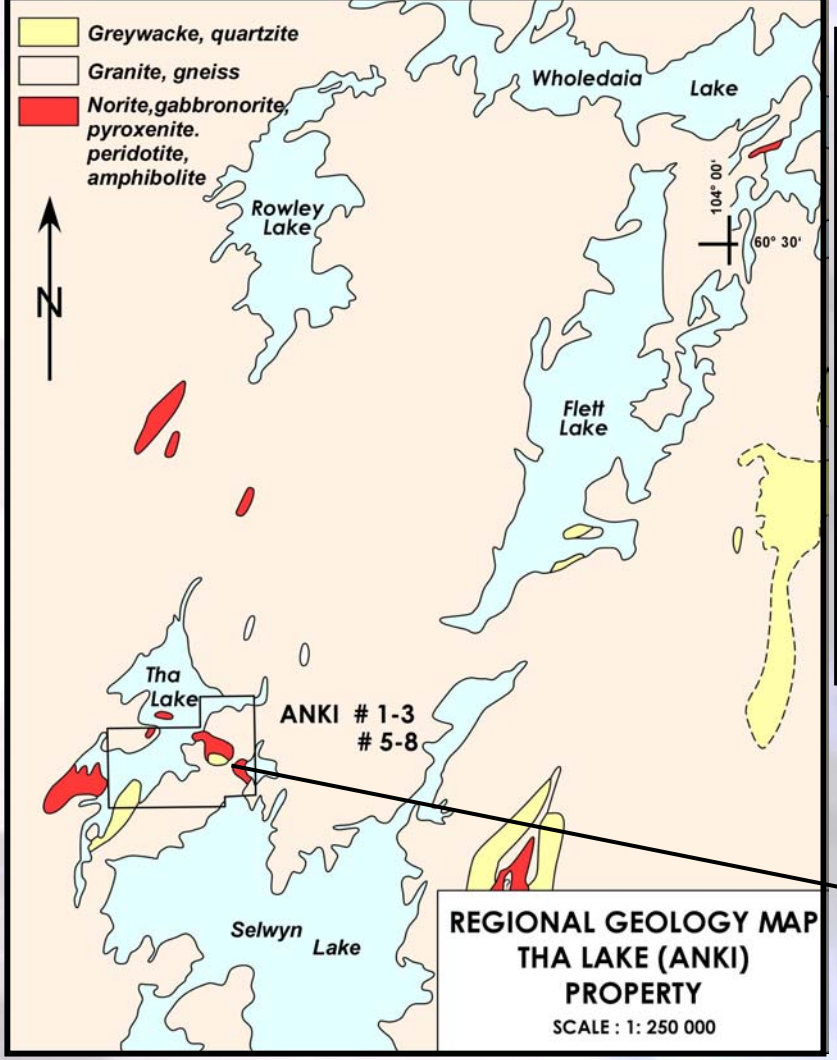
LandSat 5 bands 7-4-2 greyscale image of the East Athabasca Mylonite Triangle north of Fond du Lac and Stony Rapids. Not the well defined structural character and fabric of this domain.

East Athabasca mylonite triangle and mineral occurrences – triangle: green = deposit with reserves, blue = developed prospect, yellow = mineralized occurrence, purple circle = mafic-ultramafic intrusion. This triangle has one of the largest conc of M-UM rocks in the province, the largest and most extensive bouguer gravity anomaly in the province, the most anomalous Ni, Co, Cr lake sediment geochemistry in the province, ocurrs in a boundary zone between two major structural provinces. Metallurgically the sulphides have a high metal content and the area barge and rail access to one of the worlds largest and most sophisticated nickel refining fascilities at Fort Sask. Seen the same style of mineralization 135 km to the NE at the Tha (Selwyne Lake) occurrence and 270 km SSW of Stony Rapids in the Virgin River Shear Zone. Discontinuous mineralization over a distance of at least 405 km is not a trivial mineralizing event. Who knows how much farther it spreads from here along the STZ ? Where there is this much smoke theres gotta be fire.

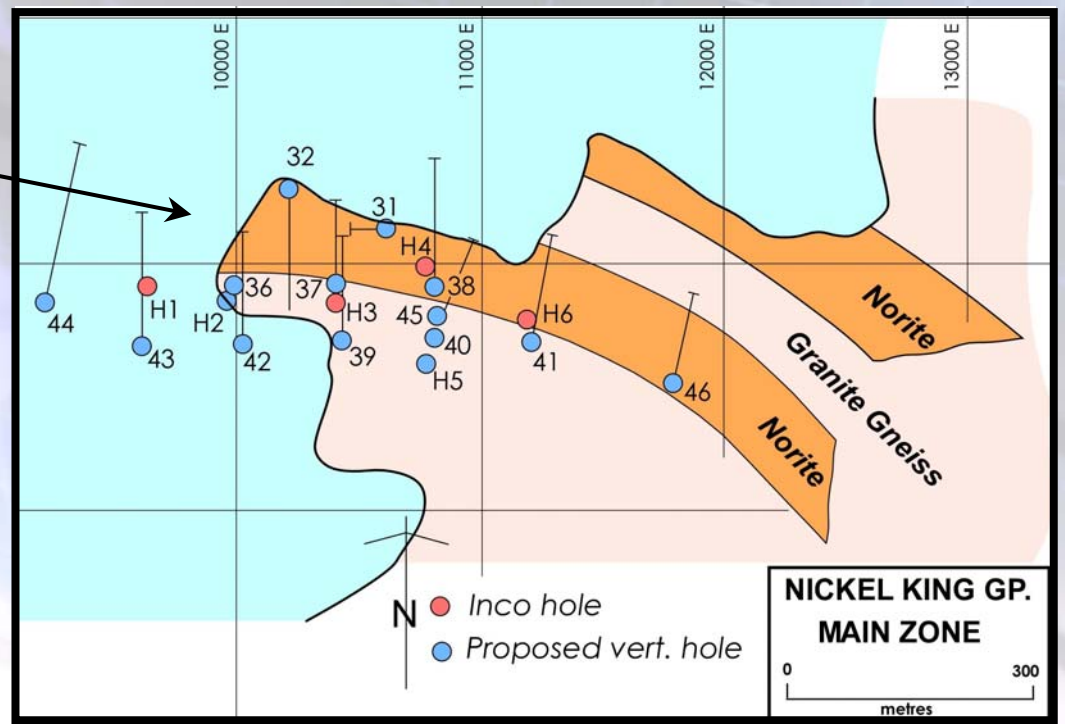




Norite-hosted Ni-Cu occurrences in East Athabasca Mylonite Triangle (“Tantato Domain”). Discovery of exploitable concentrations of Ni-Cu mineralization could easily be barged to a railhead at Fort McMurray and and then to Sherritt-Gordons nickel refinery at Fort Saskatchewan. Discoveries at Tha Lake could utilize a winter road from Stony Rapids and 65 km of ice road along Selwyne Lake where it extends south into Sask. Because it occurs in a granulite facies terrane does not rule out its economic potential – the Selebi Pikwe Ni-Cu depositin Botswana has been in continuous production since 1971 and along with diamond mining is the backbone of the economy. This mining camp occurs in Archean high grade granulites facies rocks and catalastic tectonites of the Limpopo Belt



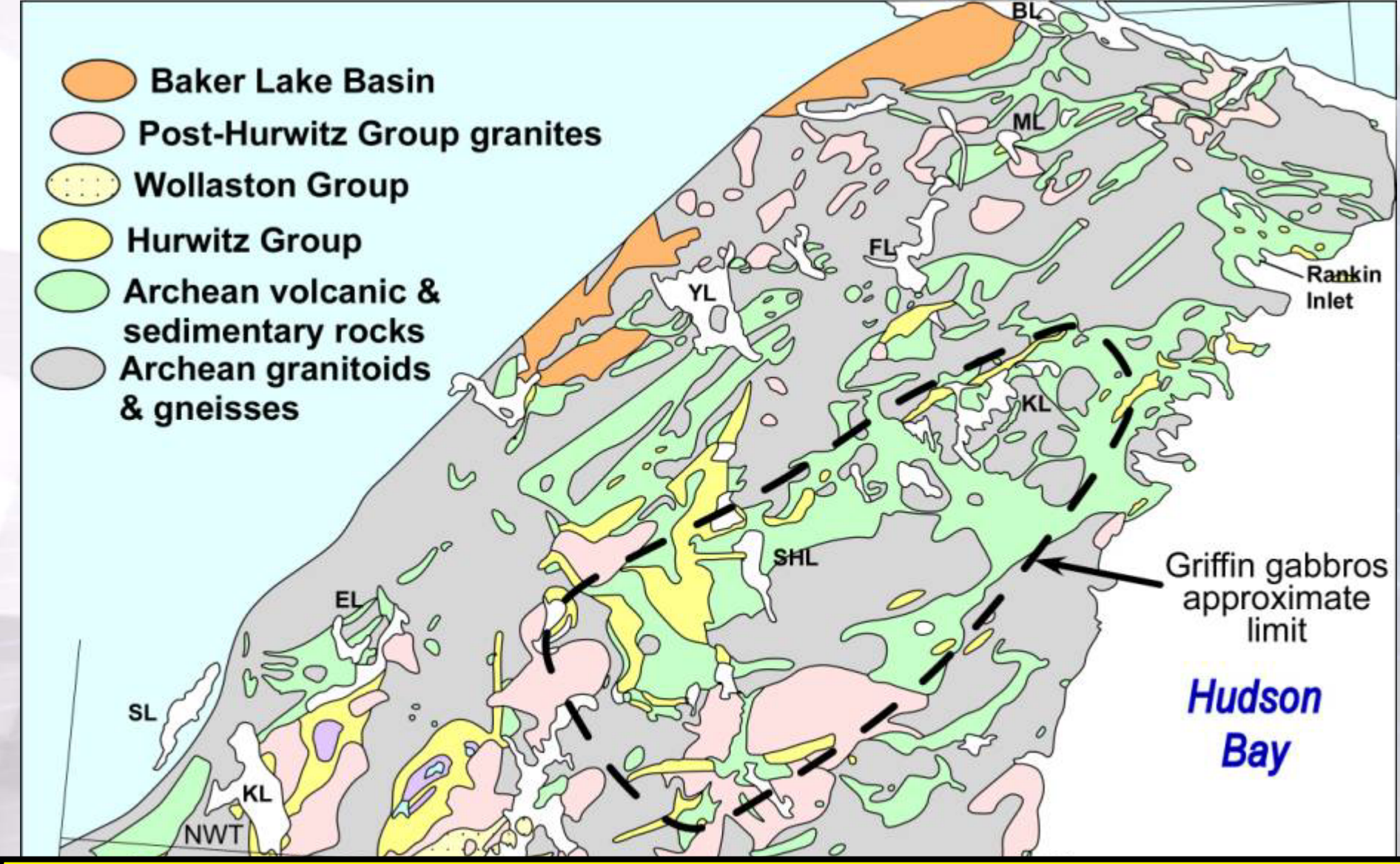
Located 550 km SE of YK and 135 km NE of Stoney Rapids. Property being explored by Navigator Exploration and Falconbridge. Ni-Cu mineralization is restricted to norite intrusions. The best min occurs in the Main Zone where drilling has discovered two overlying norite sills both of which are mineralized. The drilled sill is known as the "Deep Sill" and consists of a upper and lower mineralized zone. The sills vary in thickness from 35 to 75 m, have variable dips ranging from 10 to 50 to the south. Outcrops of the sill are marked by prominent gossans near the edge of the lake. The drilled "Deep Sill" has a weighted average of 0.92% Ni, 0.27% Cu over 8.2 m with a 13 m intersection of 1.20 Ni 0.36 Cu in the 'Upper Mineralized Zone". Sulphide concentrate in the upper zone tend to be at the top of the sill beneath the contact with the overlying gneiss. Sulphide content suggests that the sulphides are very metal rich, i.e. 10% sulphide represents between 0.5 and 1% Ni+Cu. Ni/Cu is 4:1. Massive sulphides are rare but where seen 80% sulphide contains 3-4% Ni+ Cu. Weaker min occurs in the "lower Zone" which has a strike length of 730 m.



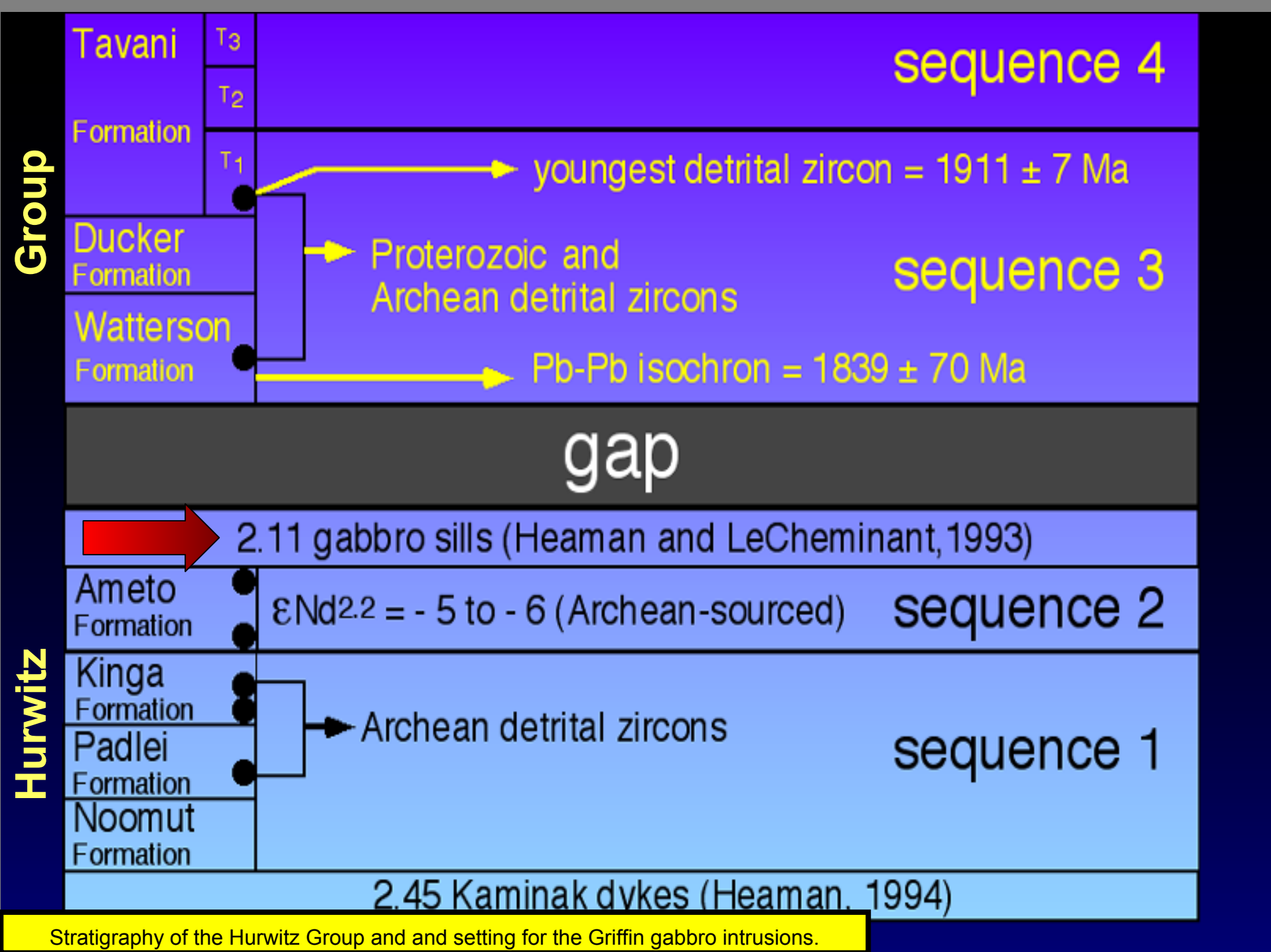
Previous work on the property established a drill indicated geological resource of 15 million tonnes grading 0.45% nickel and 0.19% copper to a depth of 250 m. Surface grab samples have also yielded significant concentrations of platinum group elements (up to 3,700 ppb combined platinum palladium) but no consistent values have been intersected by drilling.

Griffin Gabbros

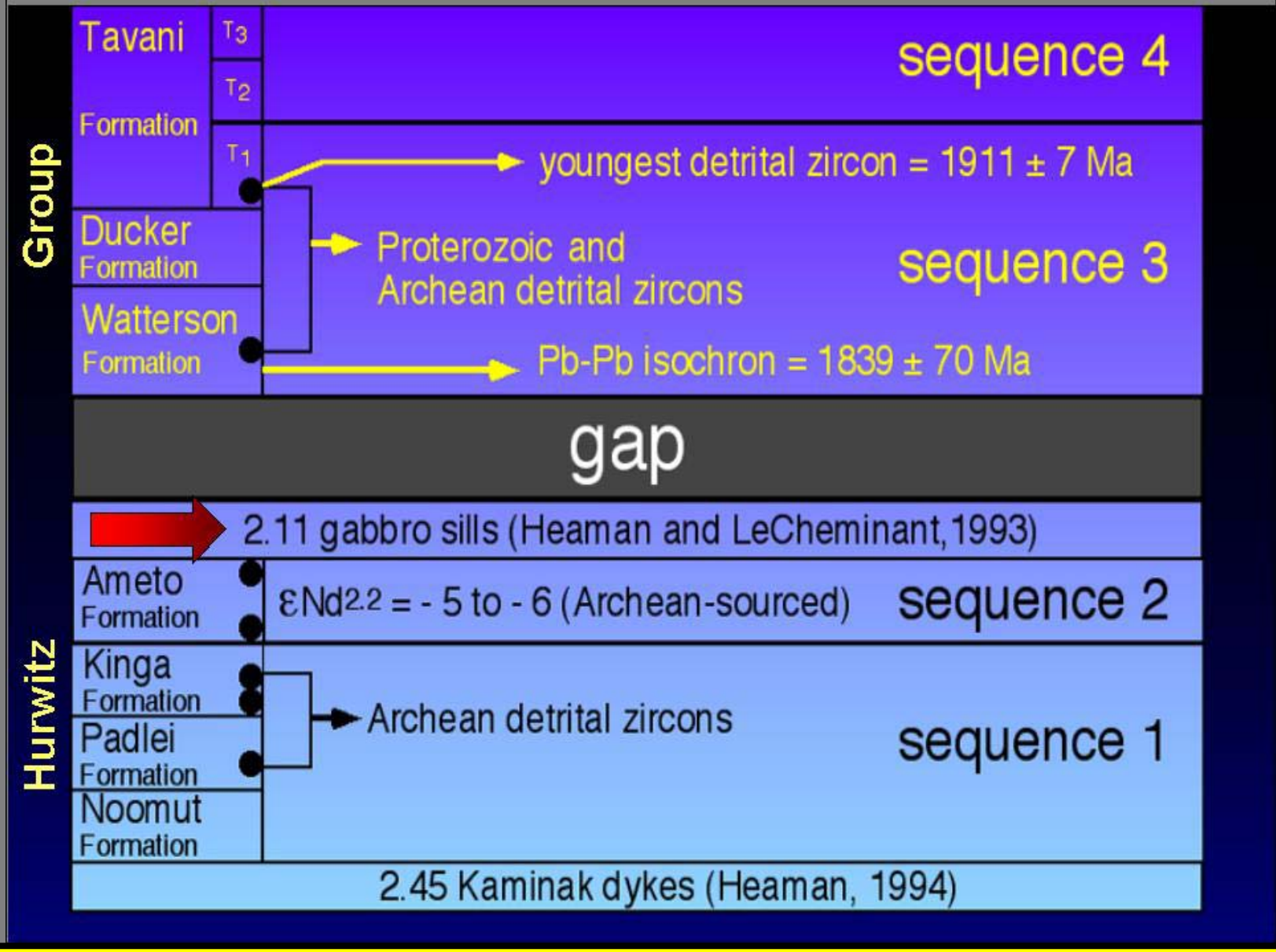
A New Magmatic Environment to Explore for Ni-Cu-PGE Mineralization ? ?



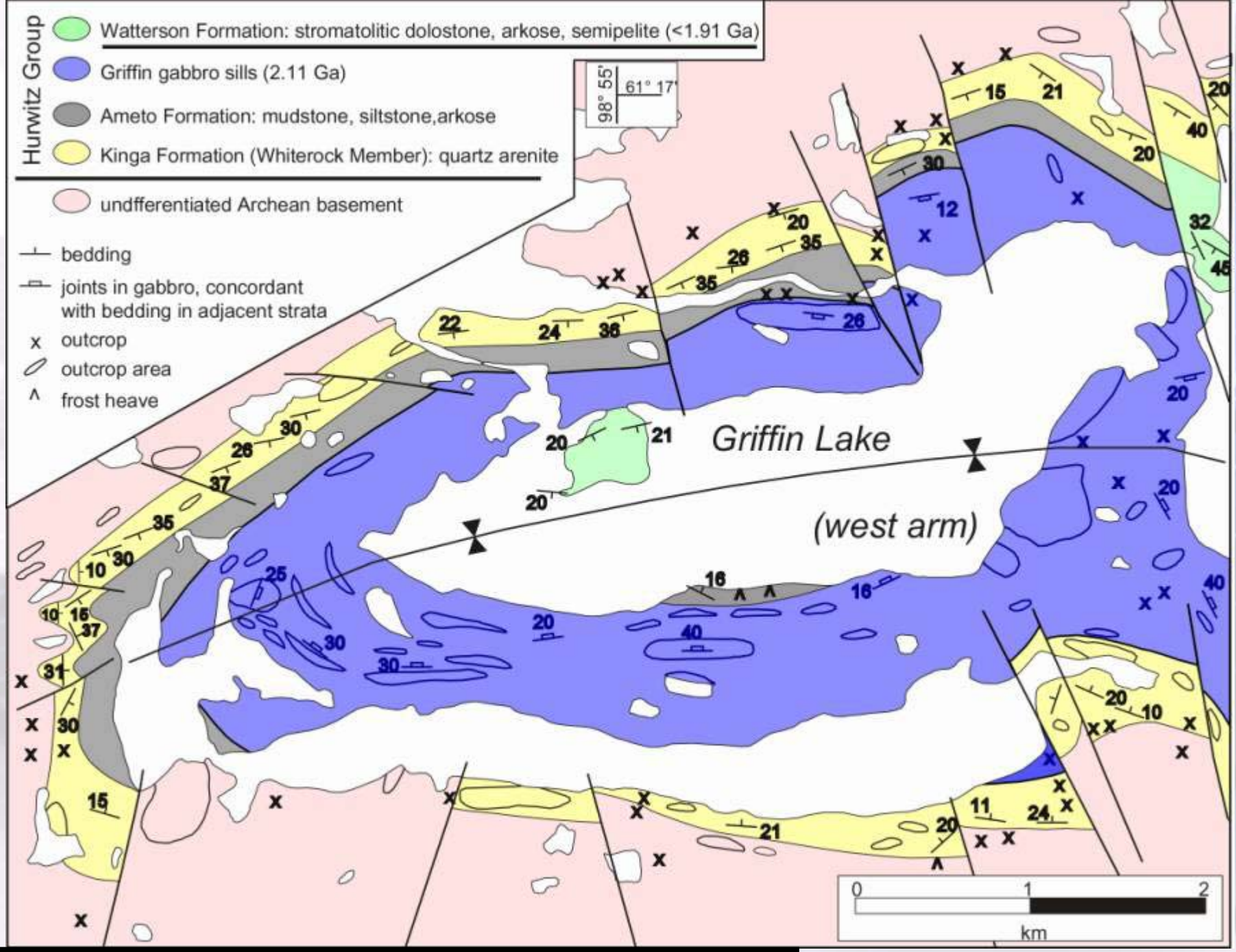
The 2.11 Ga Griffin gabbro sills and rare dykes extend discontinuously across an area 400 by 125 km (50,000 sq. km) in the central Hearne province. The sills form poorly connected, tongue-like tabular bodies primarily within the Paleoproterozoic intracratonic basin deposits of the lower Hurwitz Group The interval 2.2 – 2.0 Ga was a time of widespread global mafic magmatism. Dyke and sill swarms of this age are possibly related to the breakup of a speculative neoarchean supercontinent “Kenorland” and are found in Fennoscandia, Greenland, Siberia and North America. The Griffin gabbros have conventionally been referred to as “Hurwitz gabbros”.Those from the northern Hearne are alkaline-basalts on a silica-alkali plot whereas those in the south are subalkaline basalts.



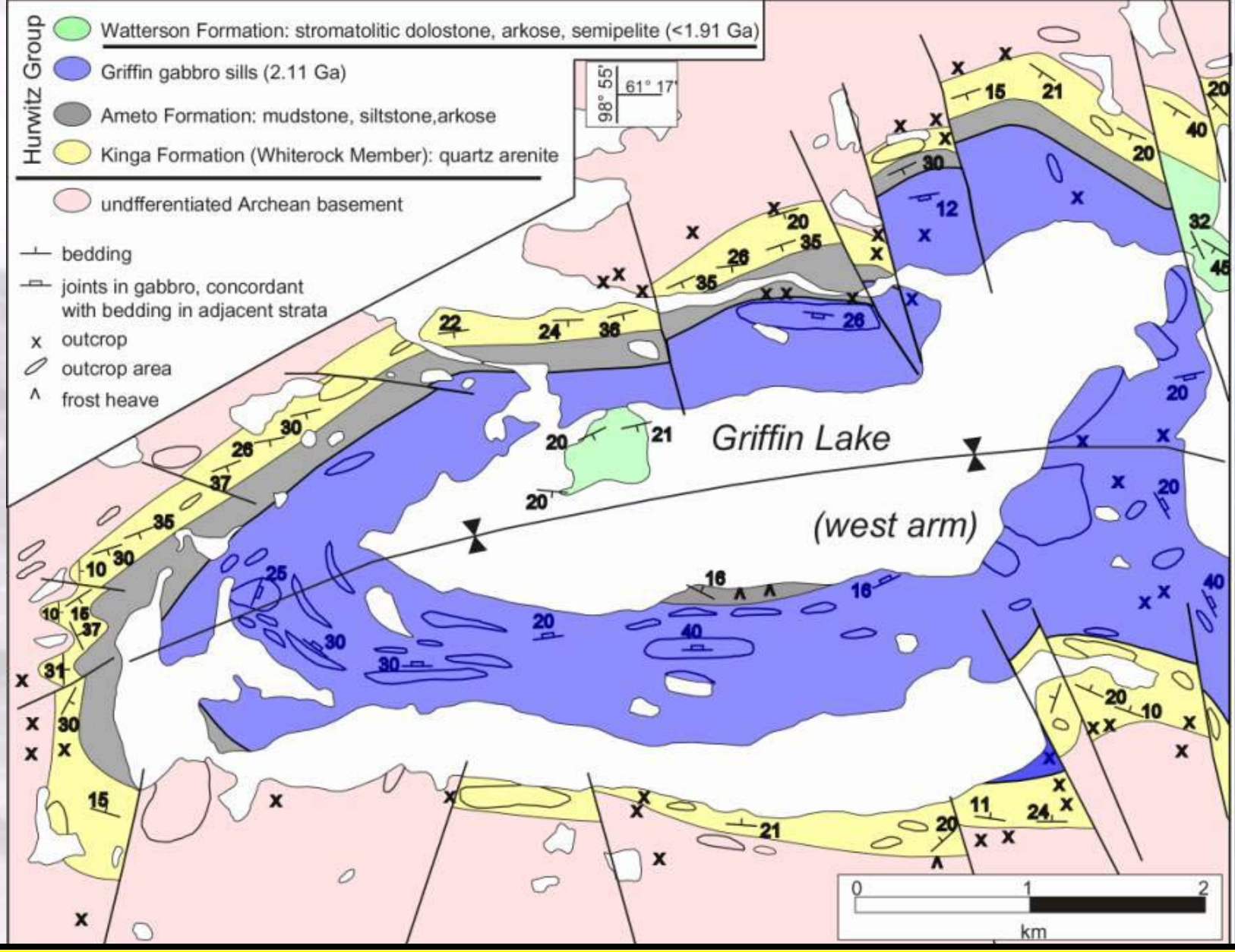
Stratigraphy of the Hurwitz Group and and setting for the Griffin gabbro intrusions.



The Griffin gabbros were emplaced at 2111 +/- 1 Ma after deposition of the lower part of the Hurwitz Group. The Hurwitz is a succession of continental to marine siliciclastics and carbonate deposits that are distributed in a series of outliers across an area 200 by 700 km. The max age of Hurwitz group is ~2.45 Ga based on baddeleyite from Kaminak dykes that cut the basement but not Hurwitz. The best estimate for start of sedimentation is ~2.3 Ga.



Simplified geological map of the Griffin gabbro type area, west arm Griffin Lake

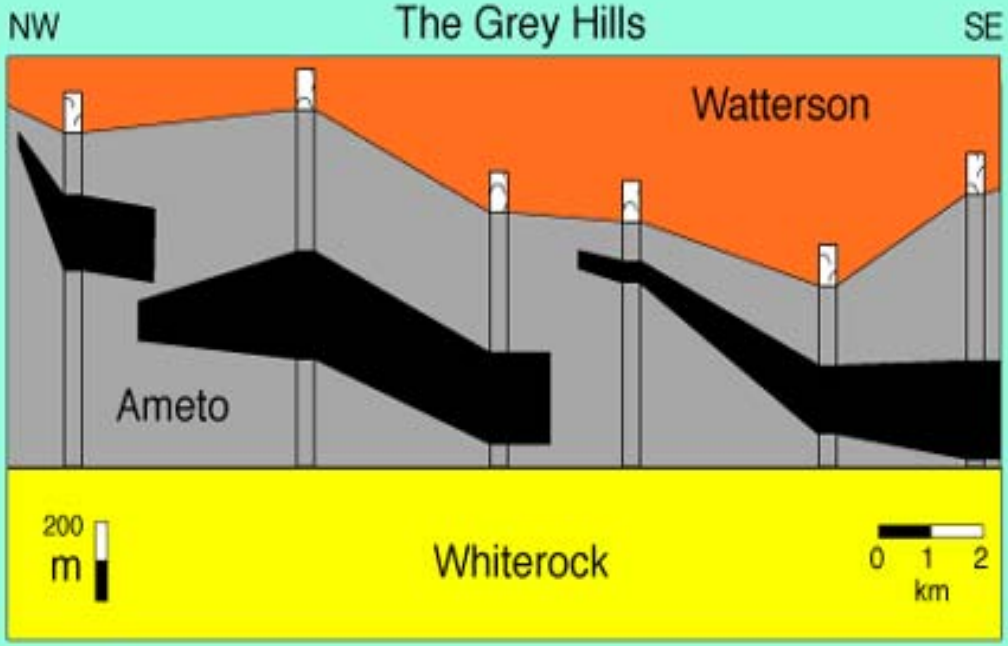


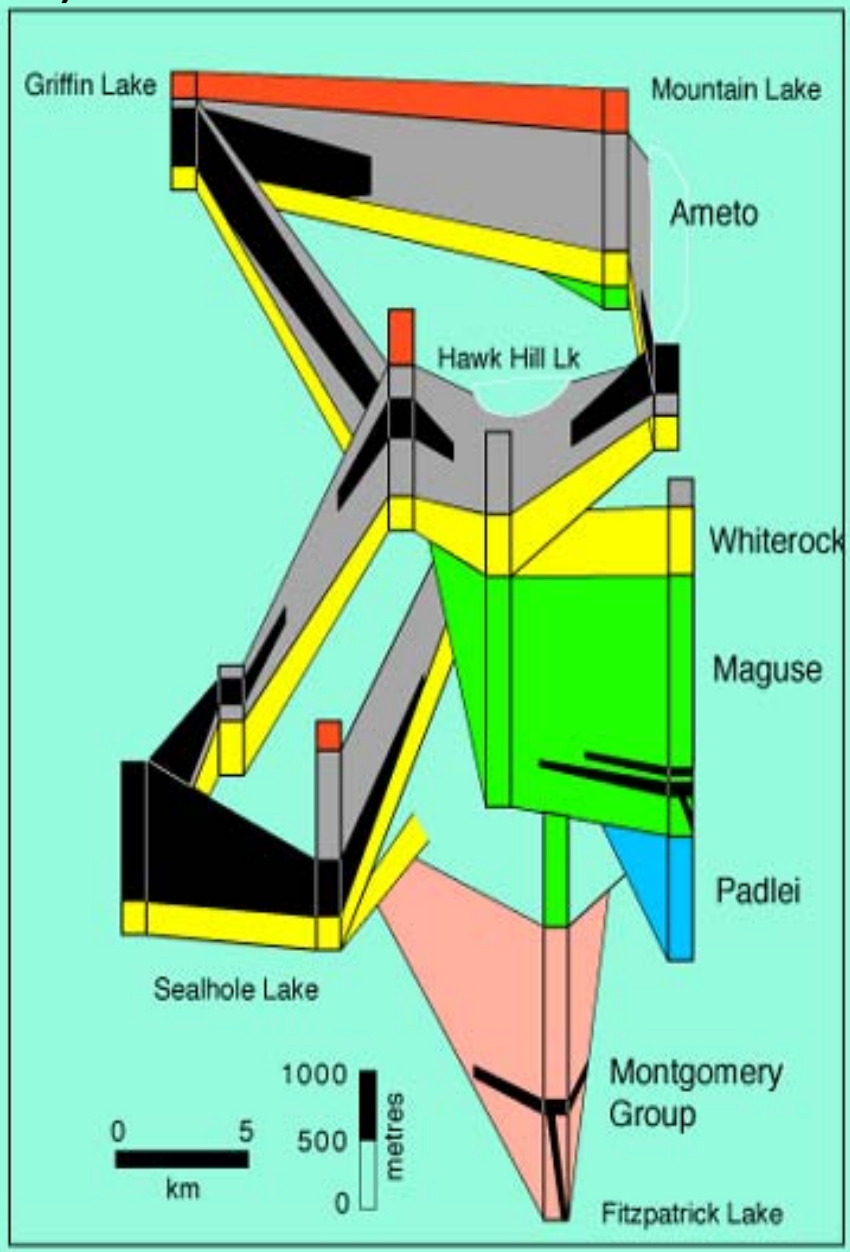
Extensive exposures are in the type area at Griffin Lake where sills define prominent ridges qlong the southern limb of an east-plunging syncline. The sills and Hurwitz group are folded under lower greenschist facies conditions. The Griffin sills are scattered independent of the basin fill geometry unlike other basins where sill sediment isopachs coincide. At Griffin lake the sill follows the White Rock Mb-Ameto Fm contact. The sills are typically massive, consisting of uniformly MG to CG plagioclase and hornblende.

Griffin gabbros: poorly connected tabular sills; rare dykes only in southeast (no regional swarm)

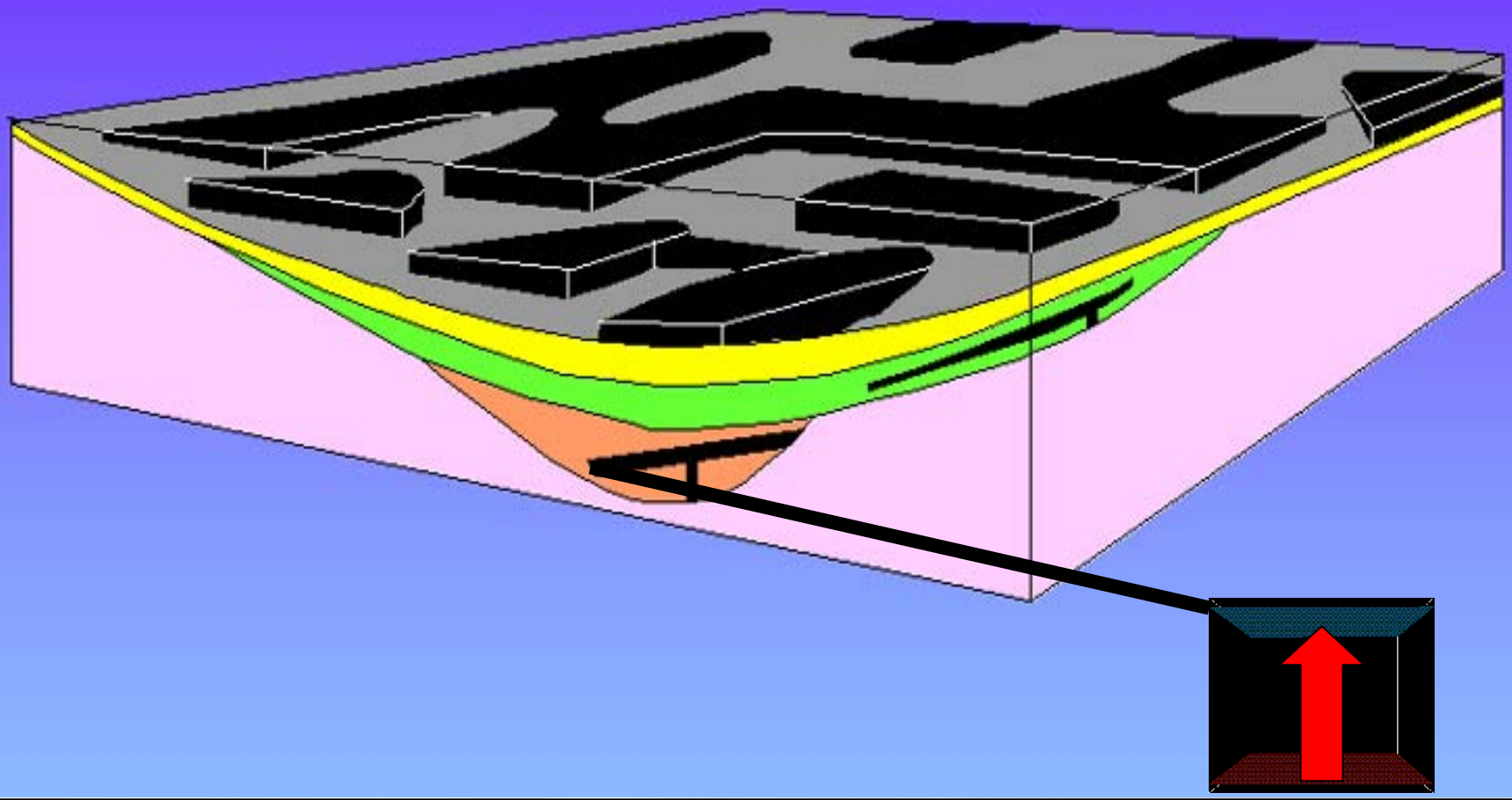
mainly in Ameto Formation

Figure Left: Stratigraphic section along The Grey Hills illustrating three en-echelon sills, each climbing upsection in the Ameto Formation, Figure Right: Fence diagram, Griffin lake to Fitzpatrick lake. Note the discontinuous nature of the sills, and feeder dykes cutting Montgomery Group at Fitzpatrick Lake. The Griffin gabbros are tongue-like, tabular bodies concordant with or gently inclined to bedding in the enclosed strat. They generally occur in the thinly stratified pelites of the Ameto Fm. Sill thickness varies from 50-300 m the thickest sill is up to 1000m at Sealhole Lake. This sill contains abundant plagioclse megacrysts and displays well developed igneous layering, mineral grading with basal zone accumulations of cm-sized Hb crystals. . Although some continue laterally up to 40 km, most sills are difficult to trace > 10 km.

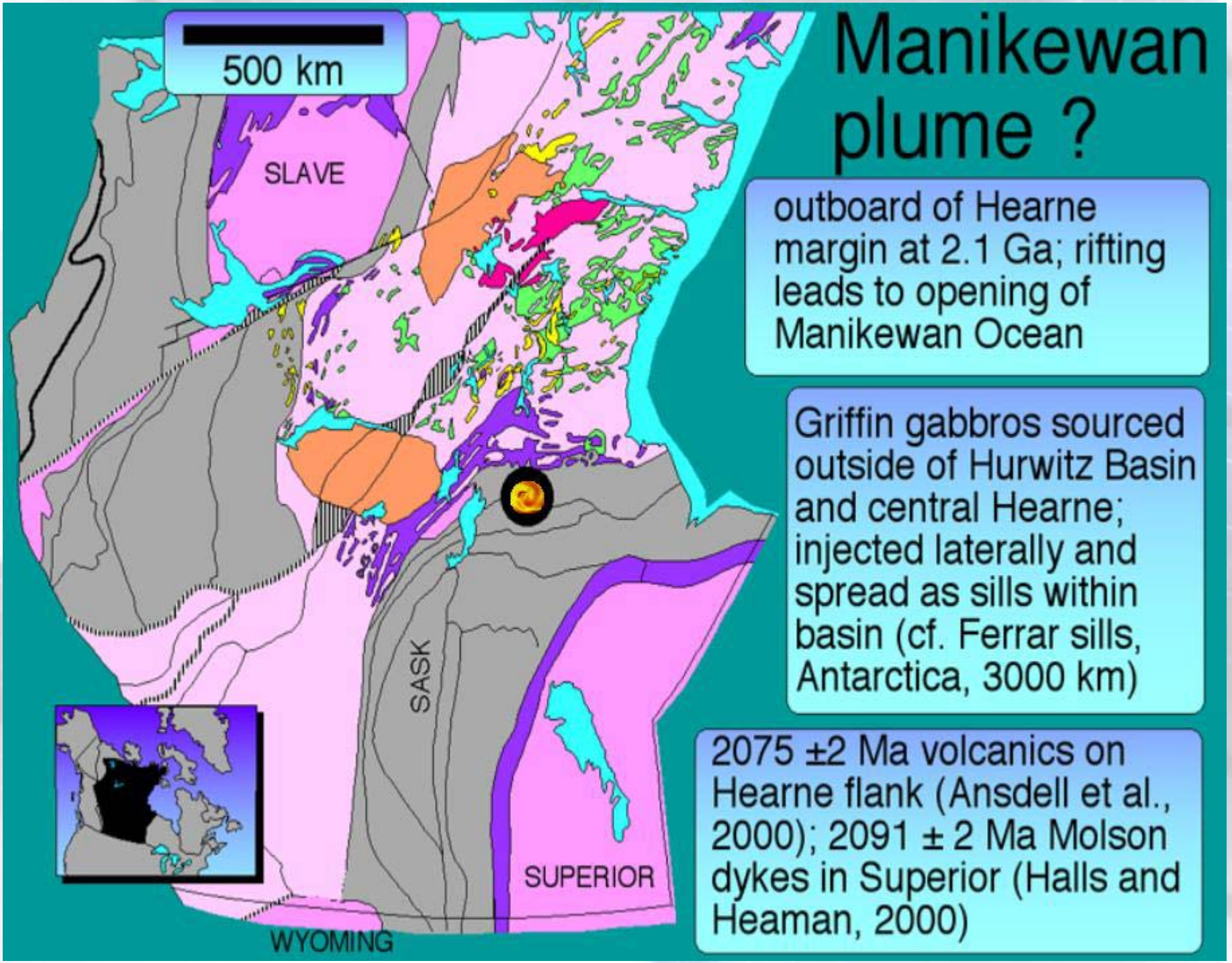




Griffin gabbro sills and dykes



Cartoon illustrating inferred sill geometry. Rather than forming sheets that are continuous in three dimensions, the sills are tongue-like tabular bodies exhibiting limited continuity in two dimensional sections perppendicular to the paleohorizontal.

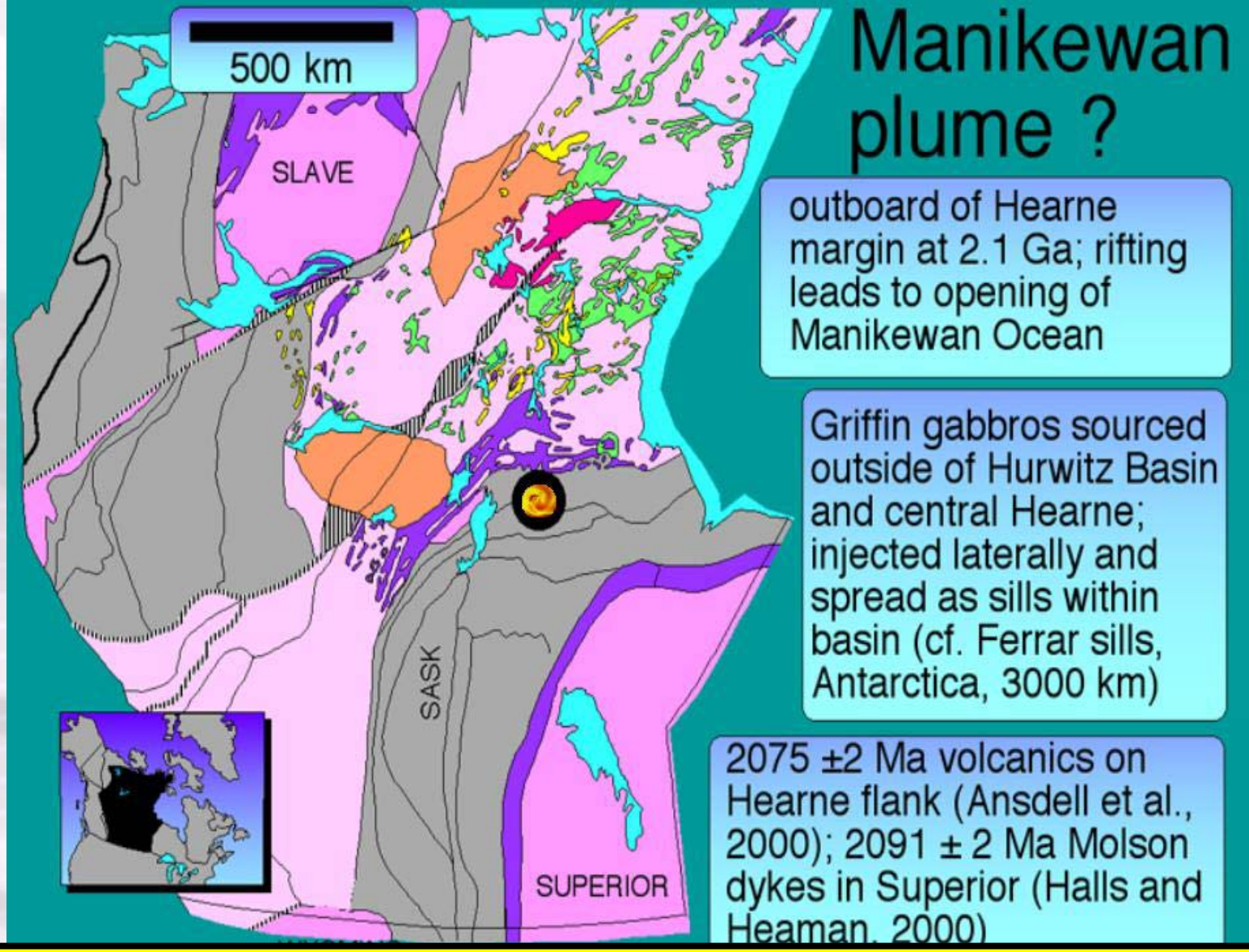


Manikewan plume ?

outboard of Hearne margin at 2.1 Ga; rifting leads to opening of Manikewan Ocean

Griffin gabbros sourced outside of Hurwitz Basin and central Hearne; injected laterally and spread as sills within basin (cf. Ferrar sills, Antarctica, 3000 km)

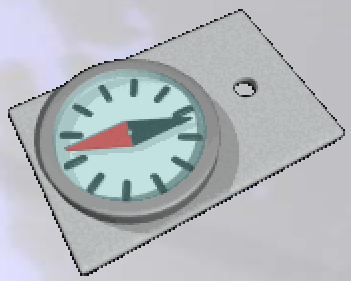
2075 ±2 Ma volcanics on Hearne flank (Ansdell et al., 2000); 2091 ± 2 Ma Molson dykes in Superior (Halls and Heaman, 2000)



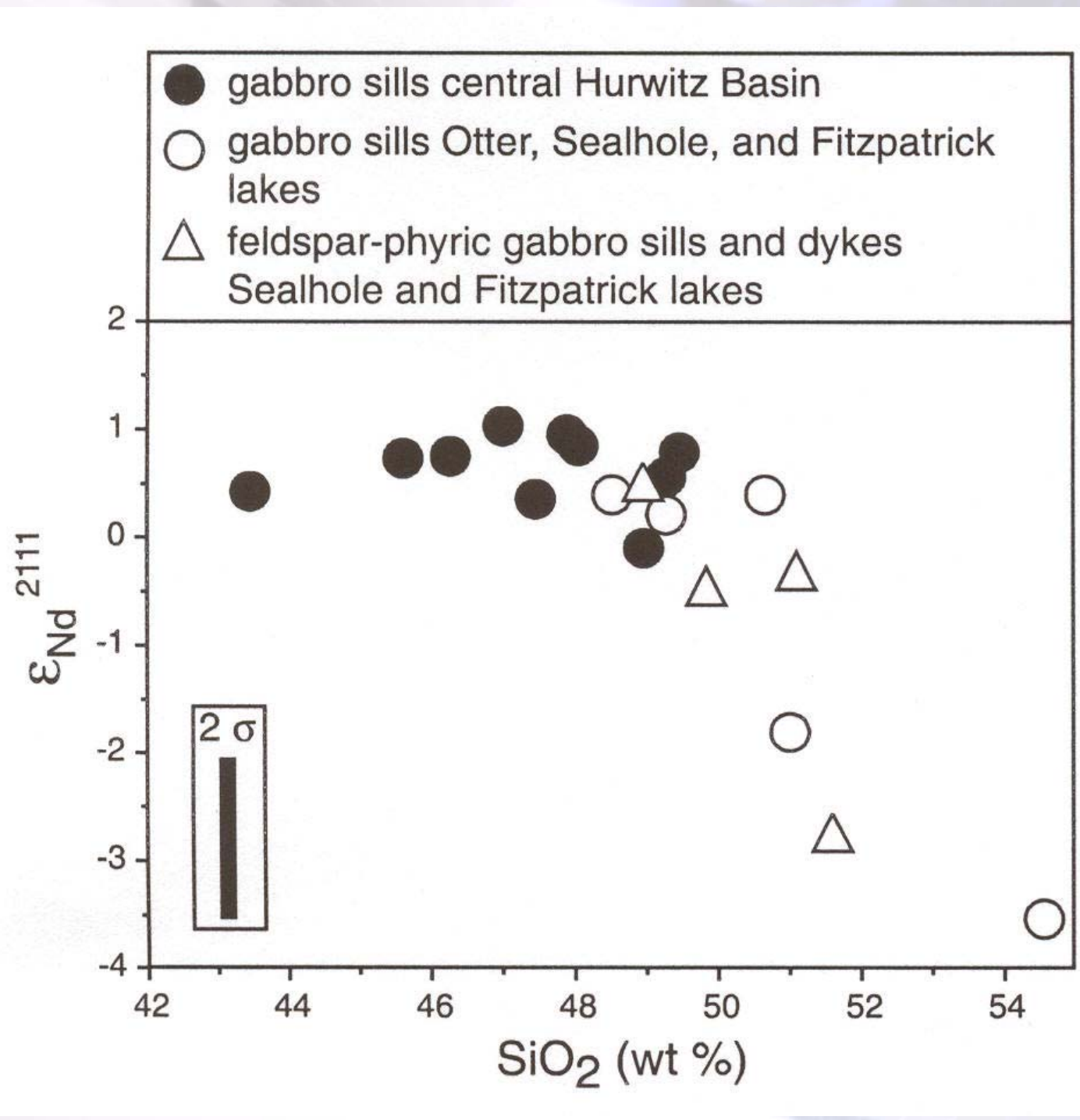
Because the Griffin gabbro sills cannot be related to a radiating dyke swarm one can only speculate on where the mantle plume source was. But regional relationships suggest that the most likely source was outboard of the Hearne margin in what was the Manikewan Ocean. Conceivably this ocean was as wide as 5000 km and separated the Hearne, Sask and Superior cratons before closing during the Trans-Hudson orogen. Aspler et al suggest that the Griffin gabbros, volcanic rocks in the lower Wollaston group and northwestern Superior dykes (Birthday Rapids dykes) and constitutes the relics of a ~2.1 Ga mantle plume related to the opening of Manikewan ocean and Circum-Superior rifting. Dynamic uplift above a mantle plume in what became the Manikewan ocean provided hydrolic head for magmas to move laterally downhill within the crust.

Griffin Gabbros

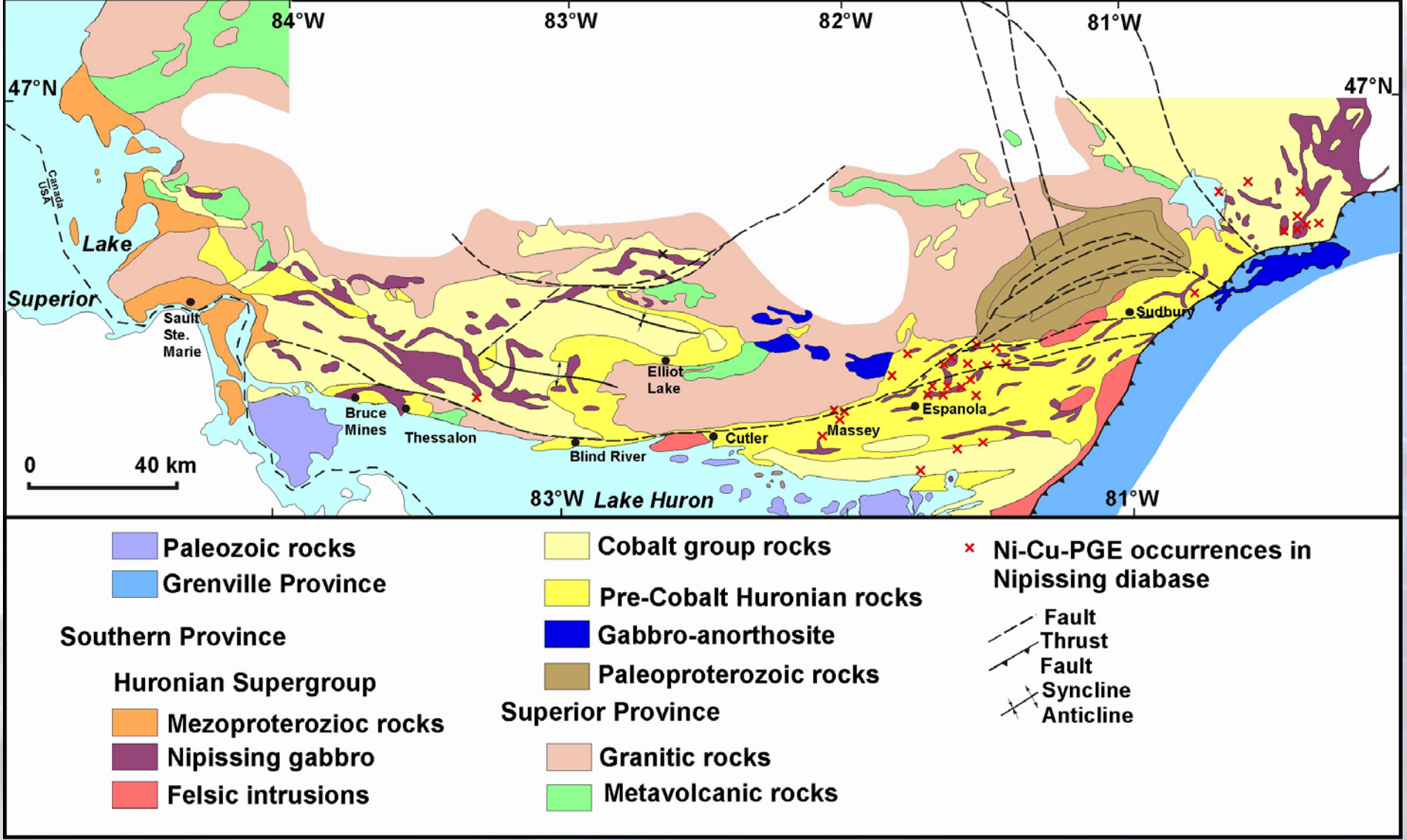
Existing Geochemical Vectors



To Focus Exploration



On spider plots normalized to primative mantle Sills in the central Hurwitz Basin have patterns similar to modern hotspot-related ocean island basalts with enrichments in Nb and La, in contrast sills in the southeast Hurwitz basin yield variably negative Nb anomalies characteristic of crustal contamination. Average MgO content is 5.20 % (n=19), but at Ducker Lake the sill has 11.76% MgO and 5.33% S. Average S contents are generally < 0.04 %. Sills and dykes in the SE display a negative epsilon Nd values, wider variation in epsilon Nd @ 2111 (0.5 to -3.6) and an inverse correlation between epsilon Nd and SiO2 – a clear indication of crustal contamination. . The lack of systematic variation of epsilon Nd with SiO2 in the central part of the basin implies that crustal contamination was not a major process affecting the magmas in this geographic locality unlike in the SE. The decrease in contamination from SE to NW may reflect temporal or downstream insulation of the magmas from the countryrocks.



Superior province analog to Griffin gabbros in Hurwitz Group - Regional extent of the 2220 Ma Nipissing diabases contained within the Huronian Supergroup and lassociated Ni-Cu-PGE mineralization showings associated with the 2.22 billion-year old Nipissing diabase (red cross symbol) and the 2.48 billion-year old gabbro-anorthosite of the East Bull Lake suite (dark blue). Also note the size and regional extent of the Nipissing bodies (purple). The greatest occurrence of mineralized Nipissing intrusions occurs to the southwest and northeast of Sudbury.

The End

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