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Regional context of the Cape Smith Belt

The Cape Smith Belt (CSB) in northern Quebec (fig.1) represents a critical segment of the Paleoproterozoic Trans-Hudson Orogen, marking the collision between the Superior Craton to the south and the Rae Province to the north at ca. 1.83 Ga (e.g., Bleeker & Kamo, 2020). This belt records a complex tectono-magnetic evolution encompassing initial continental rifting, ocean basin formation, and subsequent arc-continent collision, and is host to significant Ni-Cu-PGE mineralization linked to extensive mafic-ultramafic magmatism (e.g., Lesser, 2007; Mungall, 2007). Geologically, the CSB consists of two distinct tectono-stratigraphic domains: a southern, parautochthonous domain characterized by the Povungnituk and Chukotak Groups, consisting of volcanic sequences transitioning from early rift-related basalts to later plume-driven ultramafic flows, and a northern, allochthonous domain composed of structurally accreted oceanic and arc-related terranes (e.g., Mungall, 2007; Bleeker & Kamo, 2020).

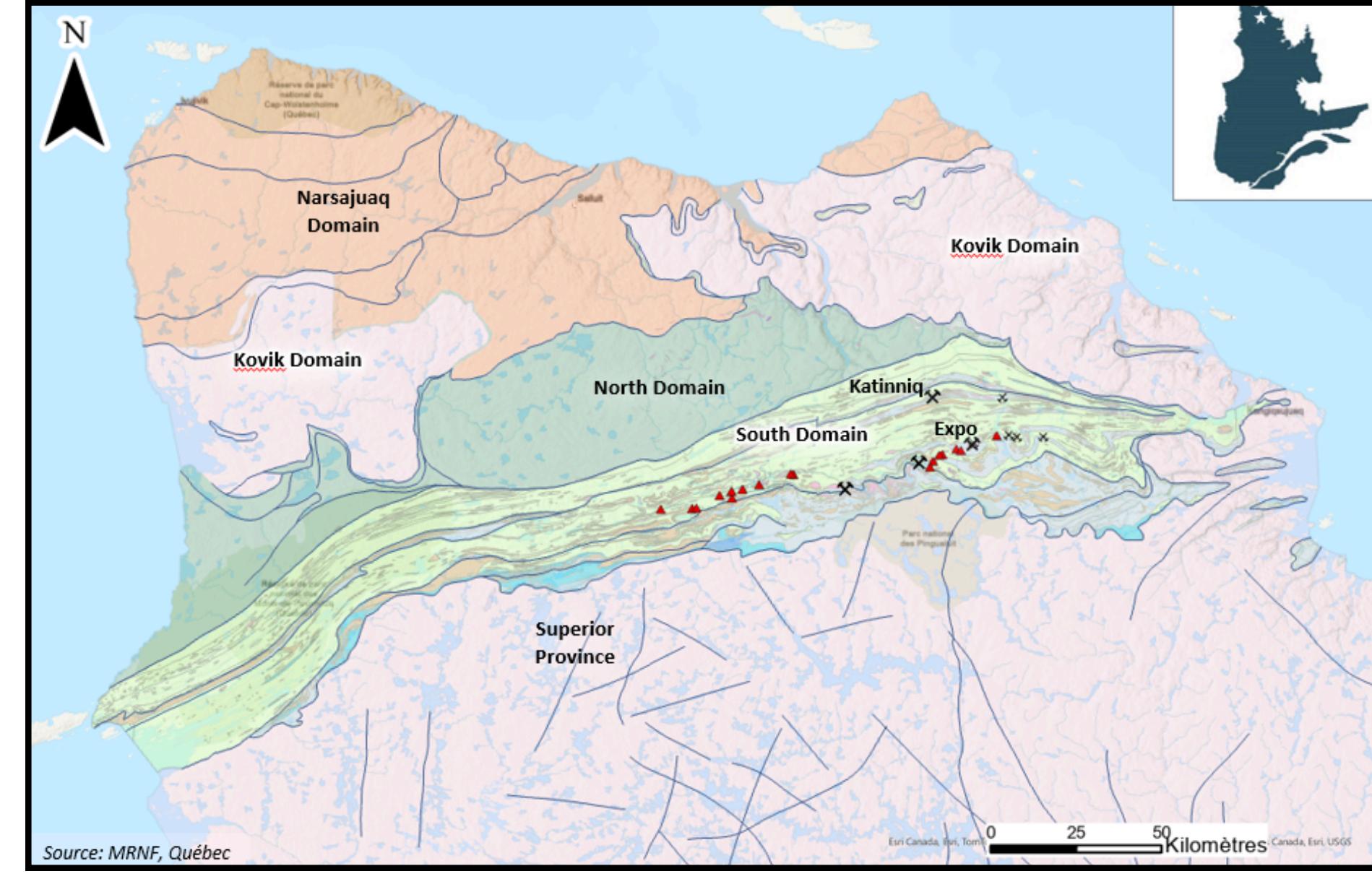


Figure 1: Major geological domains of Ungava orogen in Cap Smith Belt in northern Quebec (Source: MNRNF, Quebec)

Local geology of the Expo intrusive subsuite

Within the southern, parautochthonous domain of the CSB (fig.2), the Expo Intrusive Suite comprises an aligned series of high-Mg mafic-ultramafic intrusions including Ivakkak, Meguilon, Inukshuk, and Expo, oriented along a ENE structural trend. These intrusions form blade-shaped dykes and layered sills that progressively cut upward from Povungnituk Group basalts into the sulphidic mudstone of Nuvilic Formation. The latter played a key role towards sulfide saturation with the magmatic system (Mungall, 2007). Subsequent regional deformation produced south verging thrust faults, then folded these bodies into broad, gently NW-plunging antiforms and synforms. Each intrusion exhibits systematic lithological zonation, grading inward from marginal gabbroic rocks to layered pyroxenite and peridotite cumulates, with basal zones commonly enriched in magmatic Ni-Cu-(PGE) sulfides (Barnes & Mungall, 2018). Within this subsuite, the Inukshuk intrusion, discovered by Canadian Royalties in 2021, occupies a central position, providing a unique opportunity to investigate the detailed controls on intrusion geometry, internal stratigraphy, and mineralization processes.

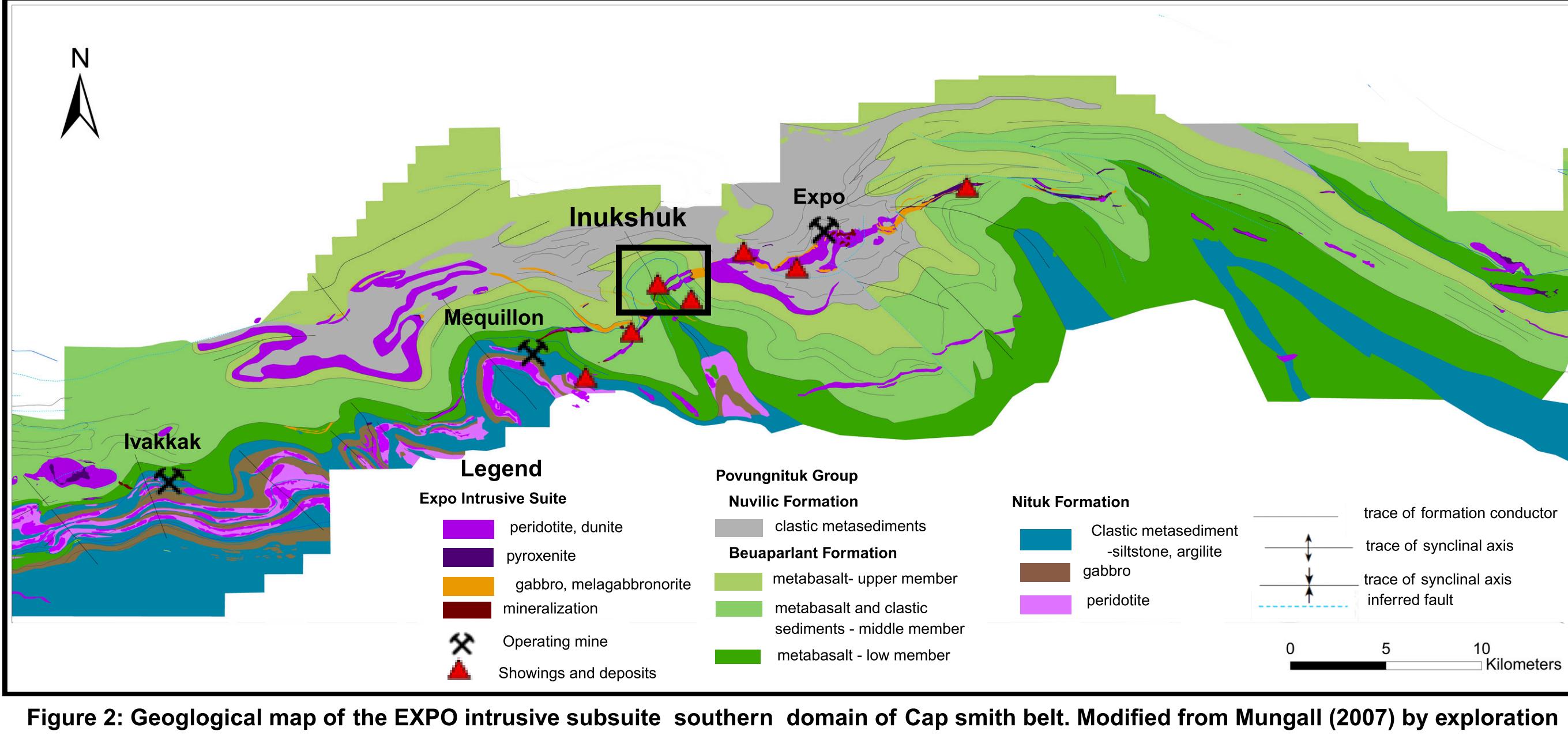


Figure 2: Geological map of the EXPO intrusive subsuite southern domain of Cap Smith belt. Modified from Mungall (2007) by exploration department of Canadian Royalties Inc.

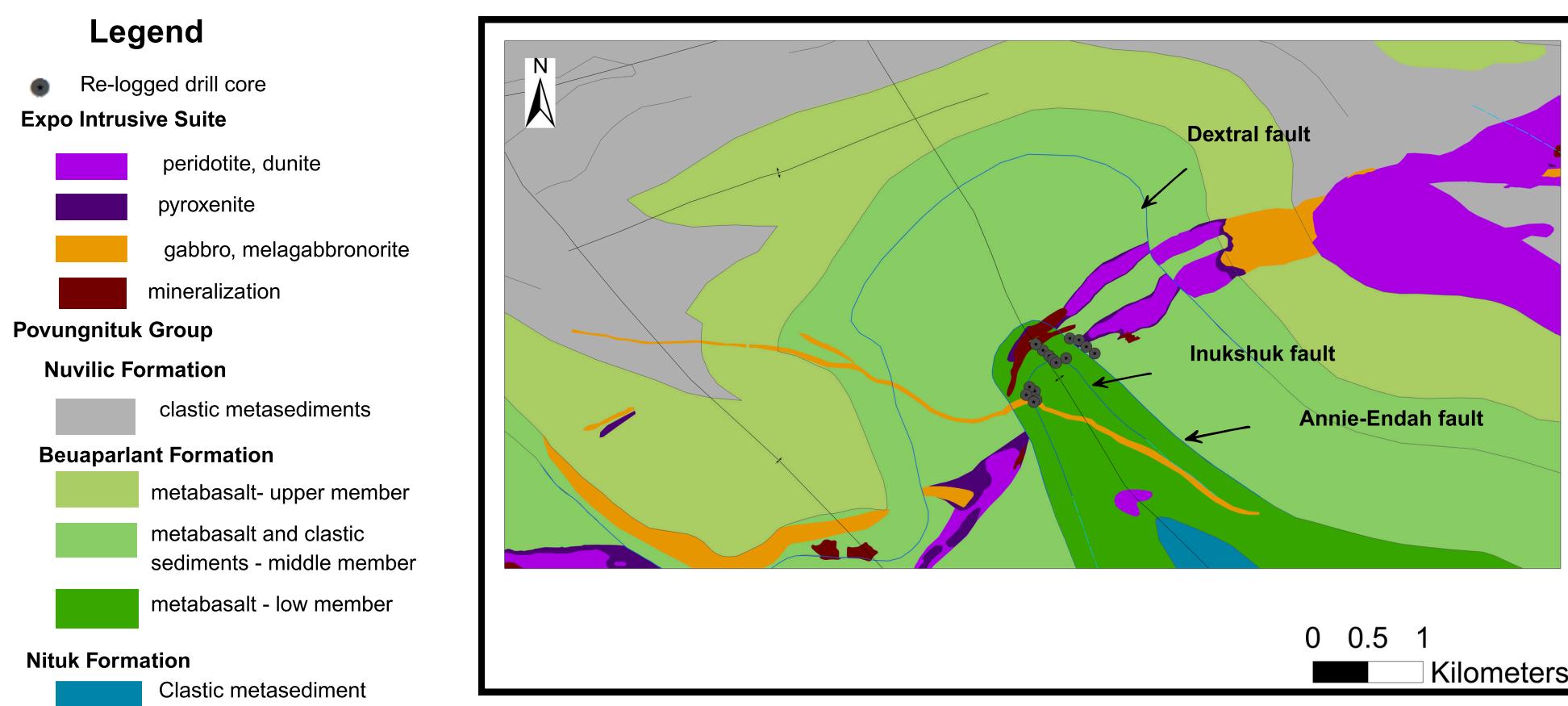


Figure 3: Antiformal structure in the immediate vicinity of the Inukshuk deposit

Litho-structural context of Inukshuk deposit

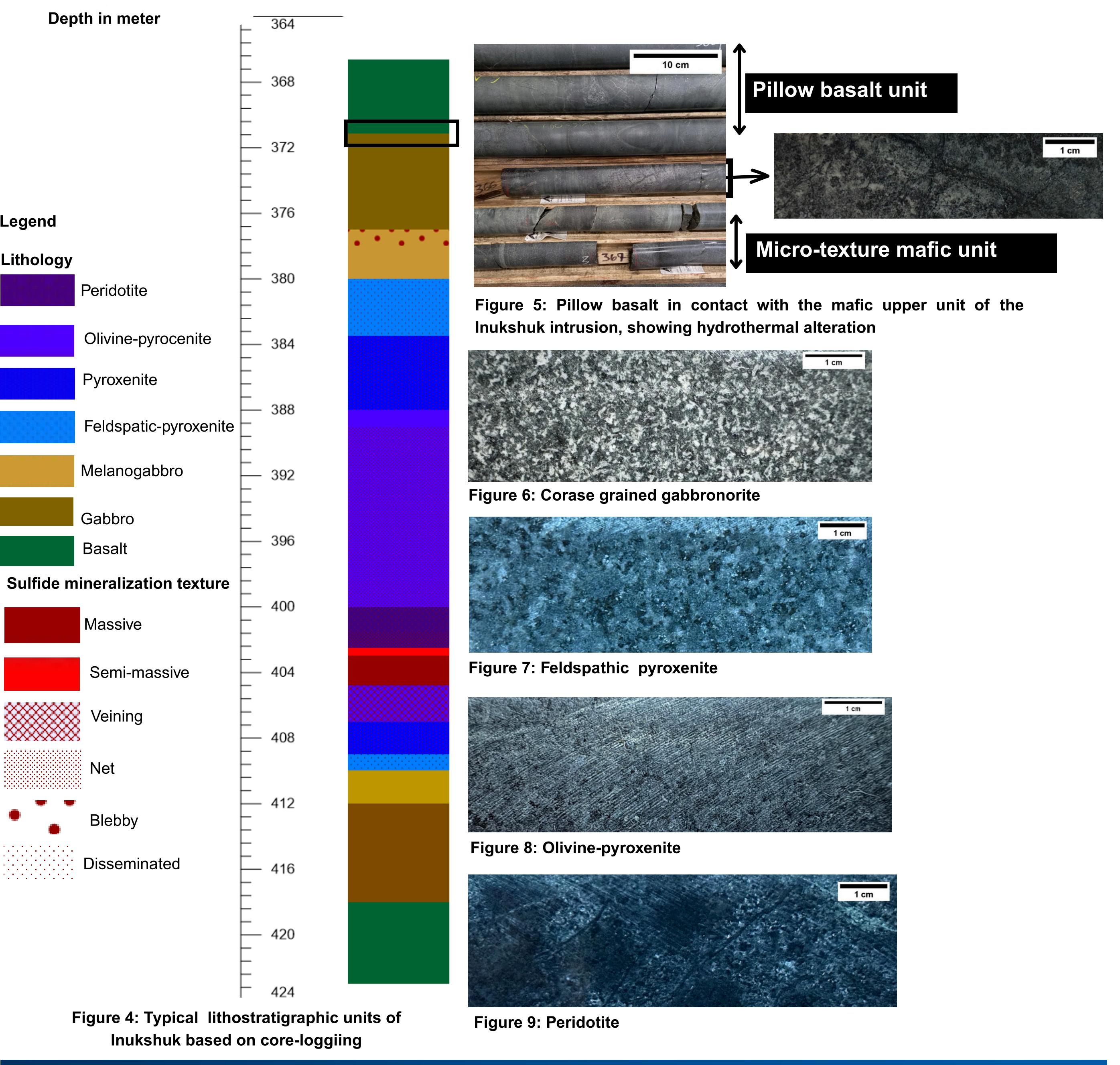
Inukshuk was affected by two phases of deformation: D1, which is responsible for offsets associated with south-verging F1 thrust faults (such as the Inukshuk fault); and D2, which folds these thrusts and produces a NW-plunging, open, upright fold system expressed as an antiform at the deposit (fig.3). The intrusion was emplaced as a suite of east-west oriented, steeply dipping, bladed mafic-ultramafic dykes into the sedimentary and basaltic strata of the Beaufortian Formation. The contact between the intrusion and the basalt is sharp, marked by a ~50 cm-wide zone of thermally metamorphosed basalt (fig.5). Internally, Inukshuk exhibits a clear vertical lithostratigraphic zoning (fig.4), characterized by marginal zones that consist of gabbronorite to gabbro (fig.6) displaying orthocumulate textures and ophiitic to subophitic crystal framework. These marginal units transition into an intermediate zone of olivine gabbronorite to feldspathic pyroxenite lithology (fig.7). The core consists of ultramafic cumulates, essentially olivine-pyroxenite (fig.8) to peridotite (fig.9) displaying mesocumulate texture.

Along the margins and within the intermediate gabbroic lithologies, scattered brown to greenish-brown acicular or granular grains of hornblende are observed. Based on petrographic observations, the hornblende is interpreted as a secondary phase formed after alteration of pyroxene.

Sulfide mineralization at Inukshuk is primarily disseminated, locally associated with varying proportions of blebby and stringer textures in the marginal gabbroic units. Toward the ultramafic core, it becomes interconnected to net-textured sulfides, with semi-massive to massive sulfides at the core.

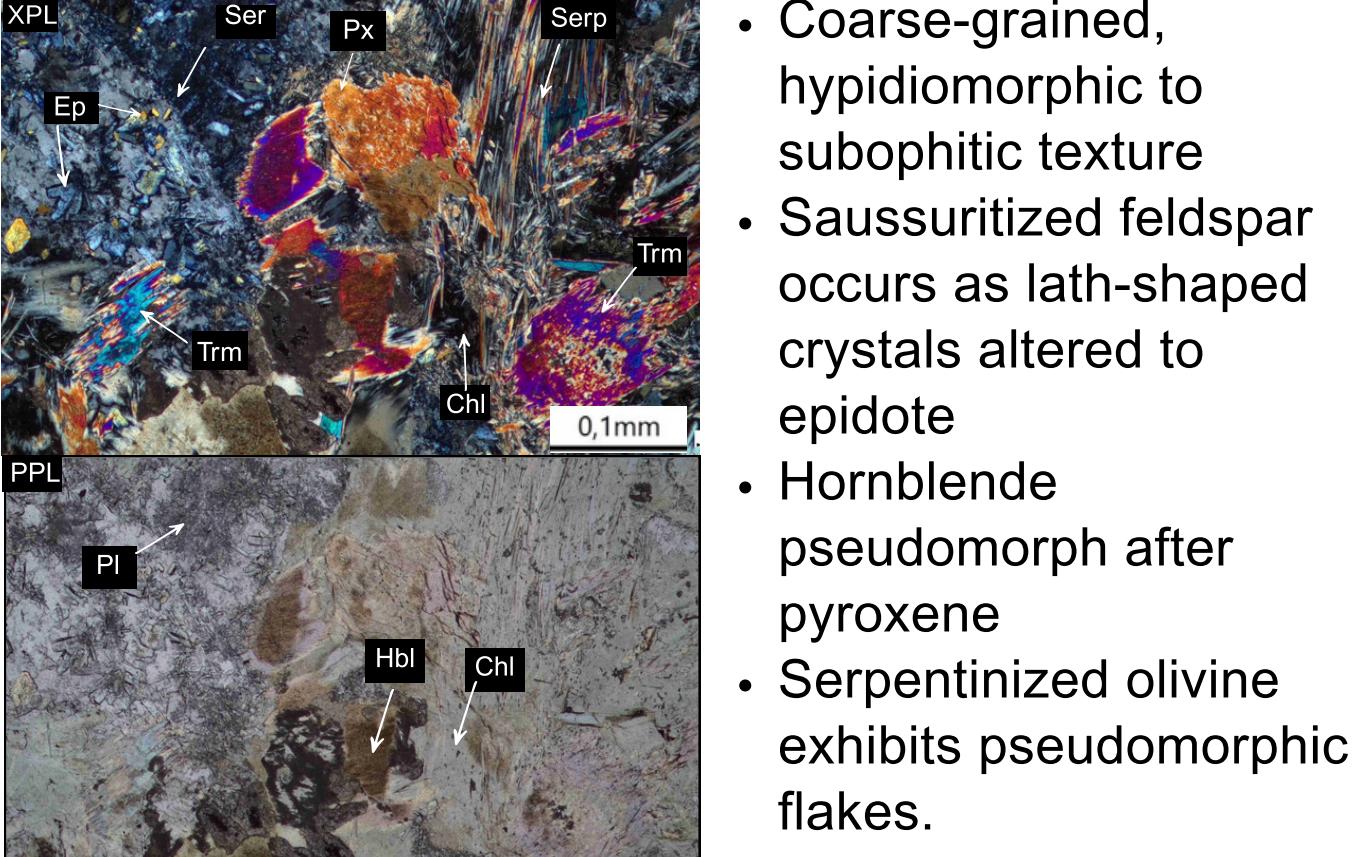
Analytical methods

- Core logging and sampling.
- Petrography examination of thin sections under transmitted and reflected light microscopy.
- Whole Rock geochemistry.
- Normative mineralogy based on major and minor oxydes calculated by MATNORM from Pruseth (2009)

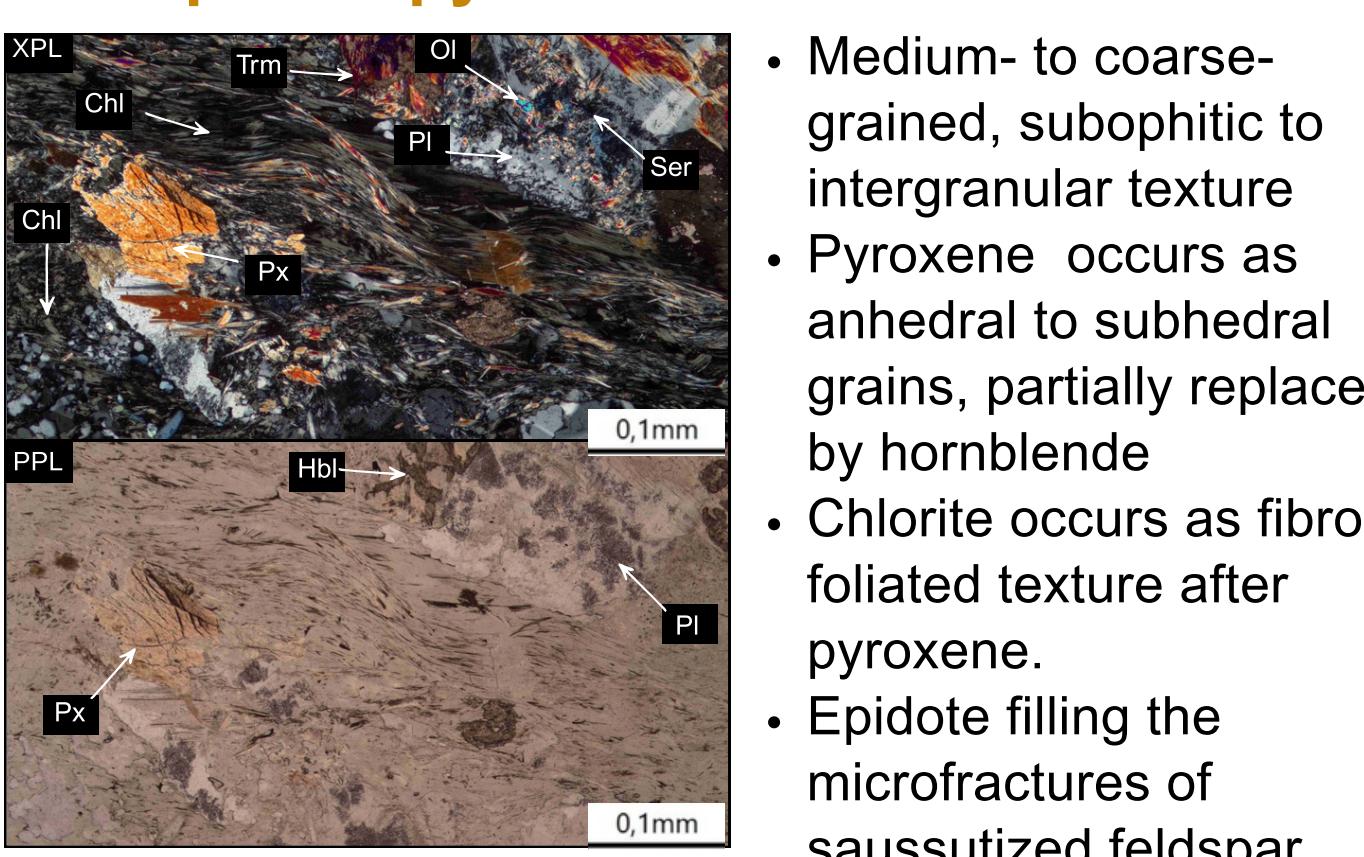


Petrography

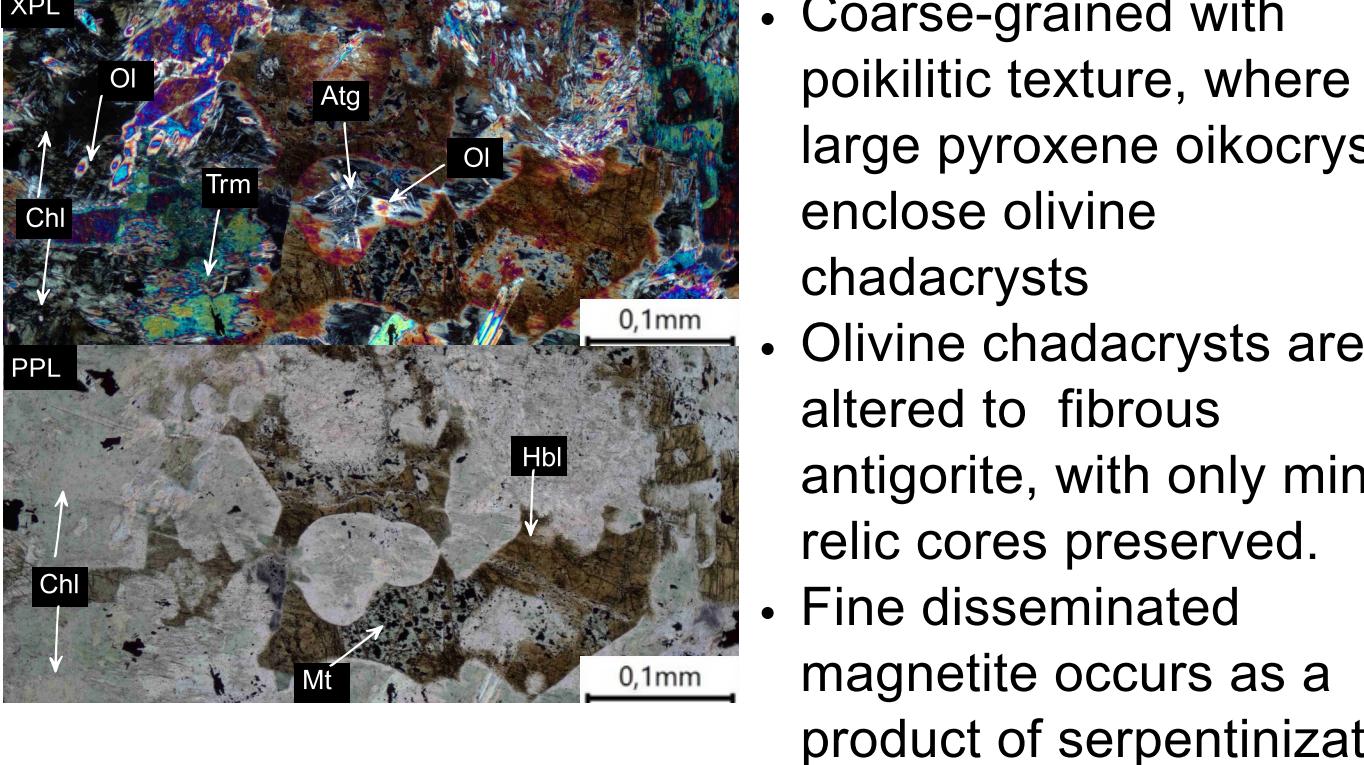
Gabbronorite/ Olivine gabbronorite



Feldspathic pyroxenite



Olivine pyroxenite



Peridotite

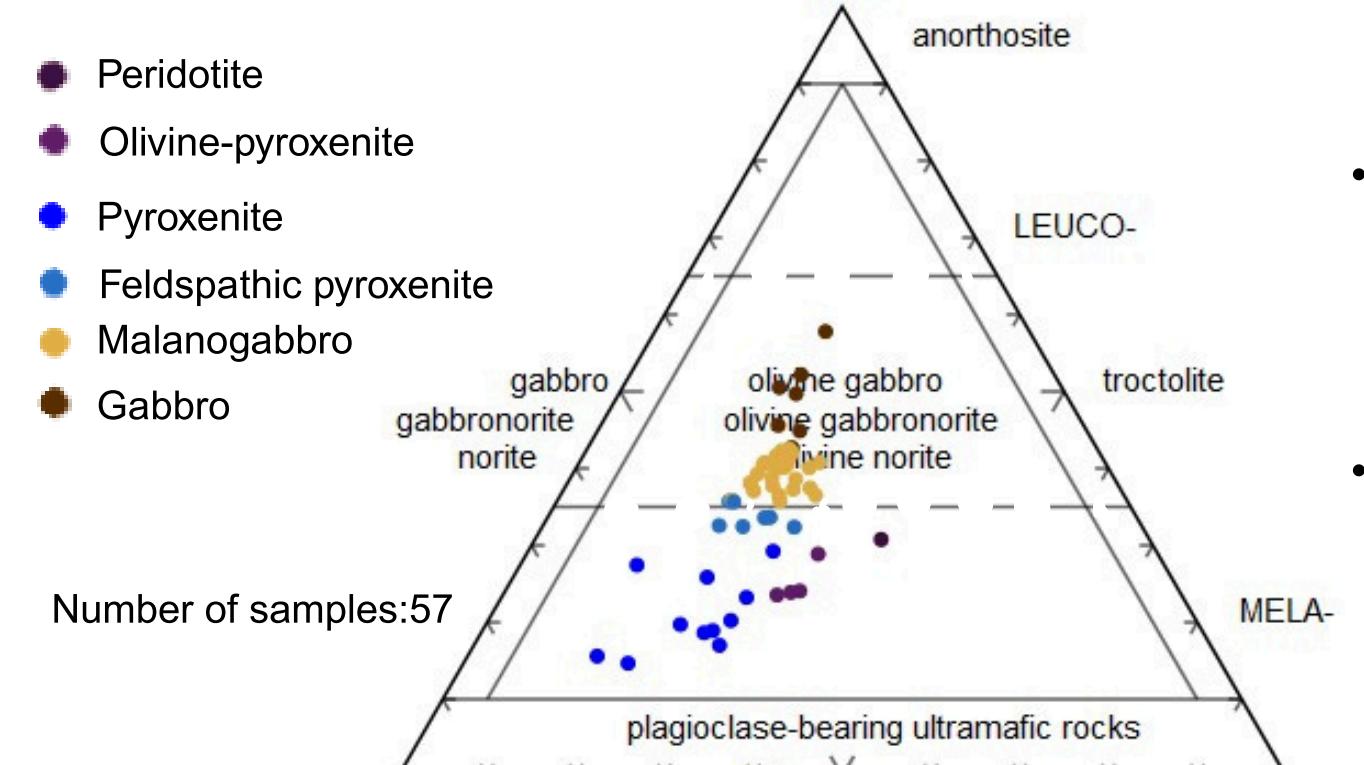


Figure 10: Modal classification of Inukshuk mafic-ultramafic rocks plotted on the IUGS Plagioclase (Plag)–Pyroxene (Px)–Olivine (Ol) ternary diagram

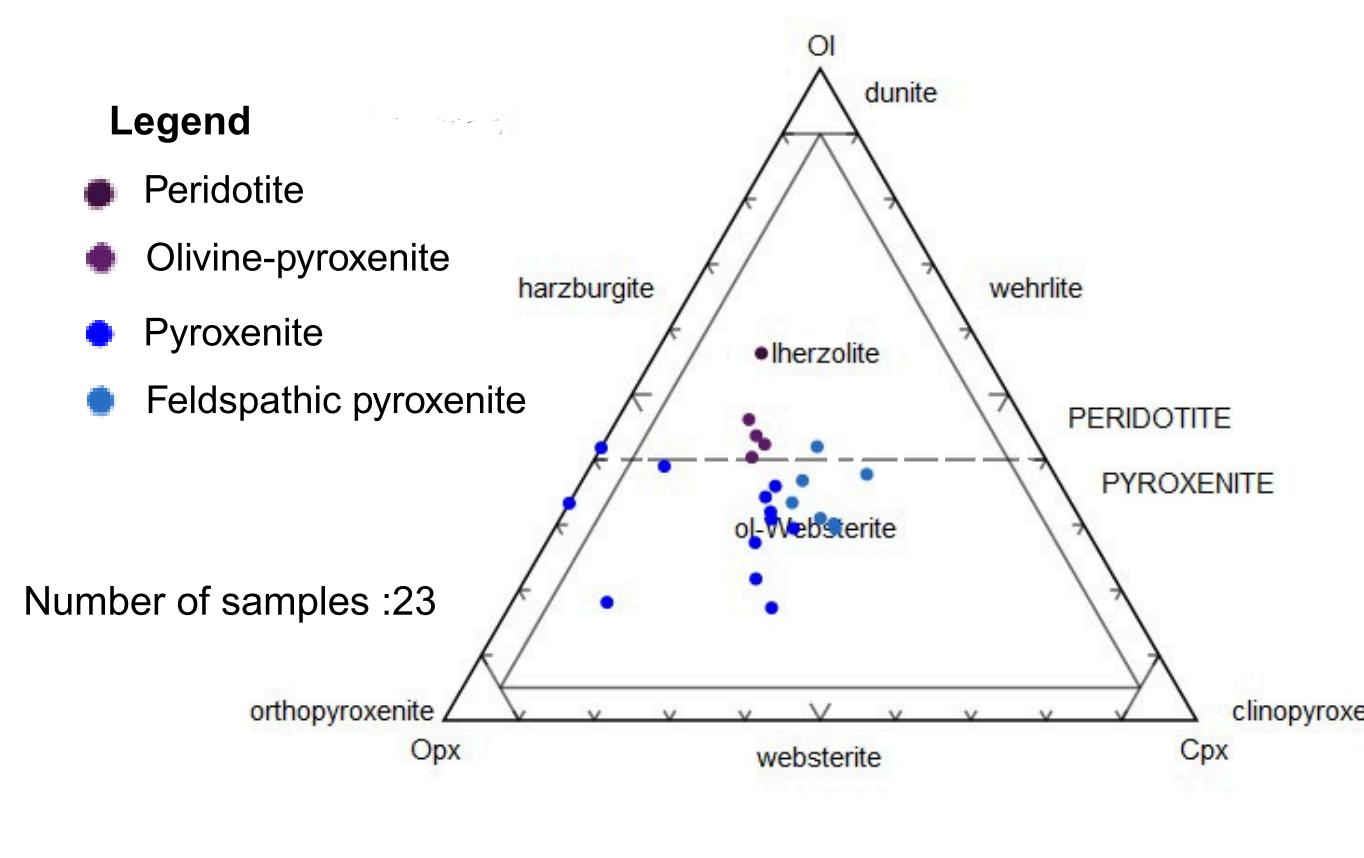
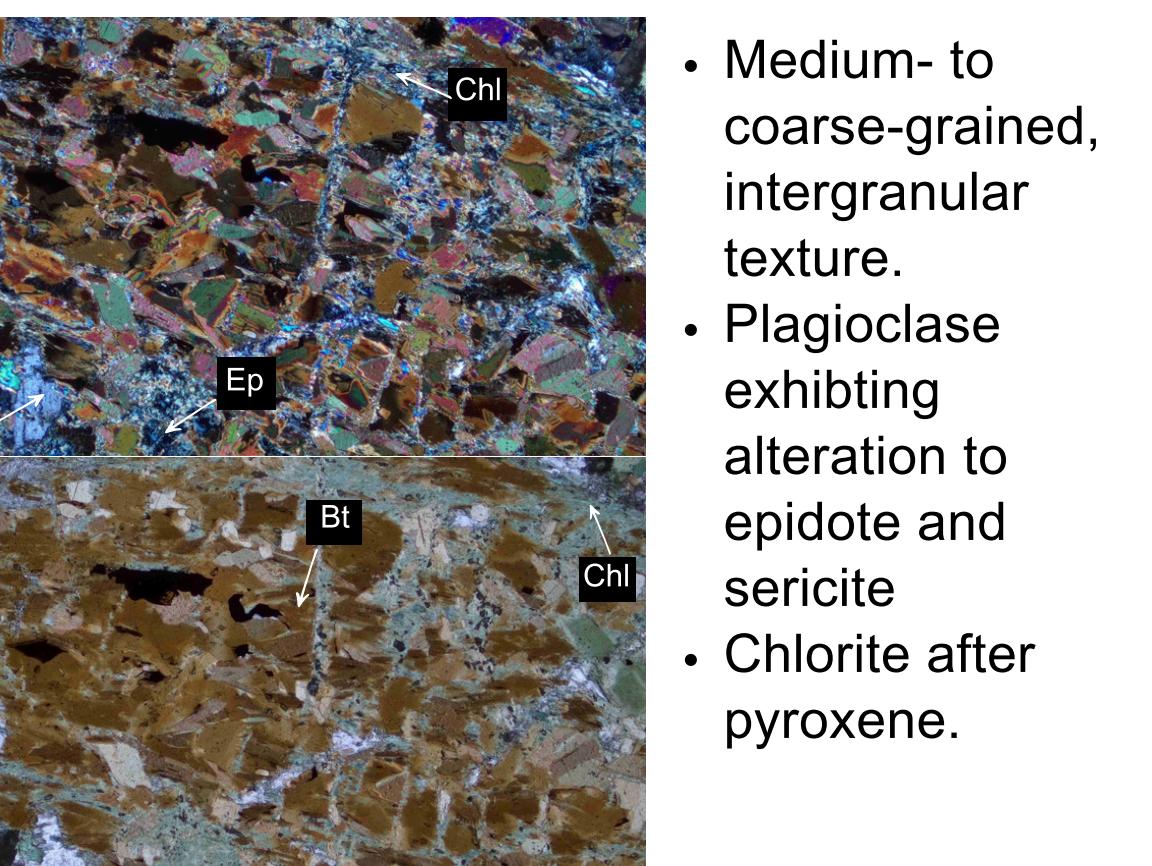
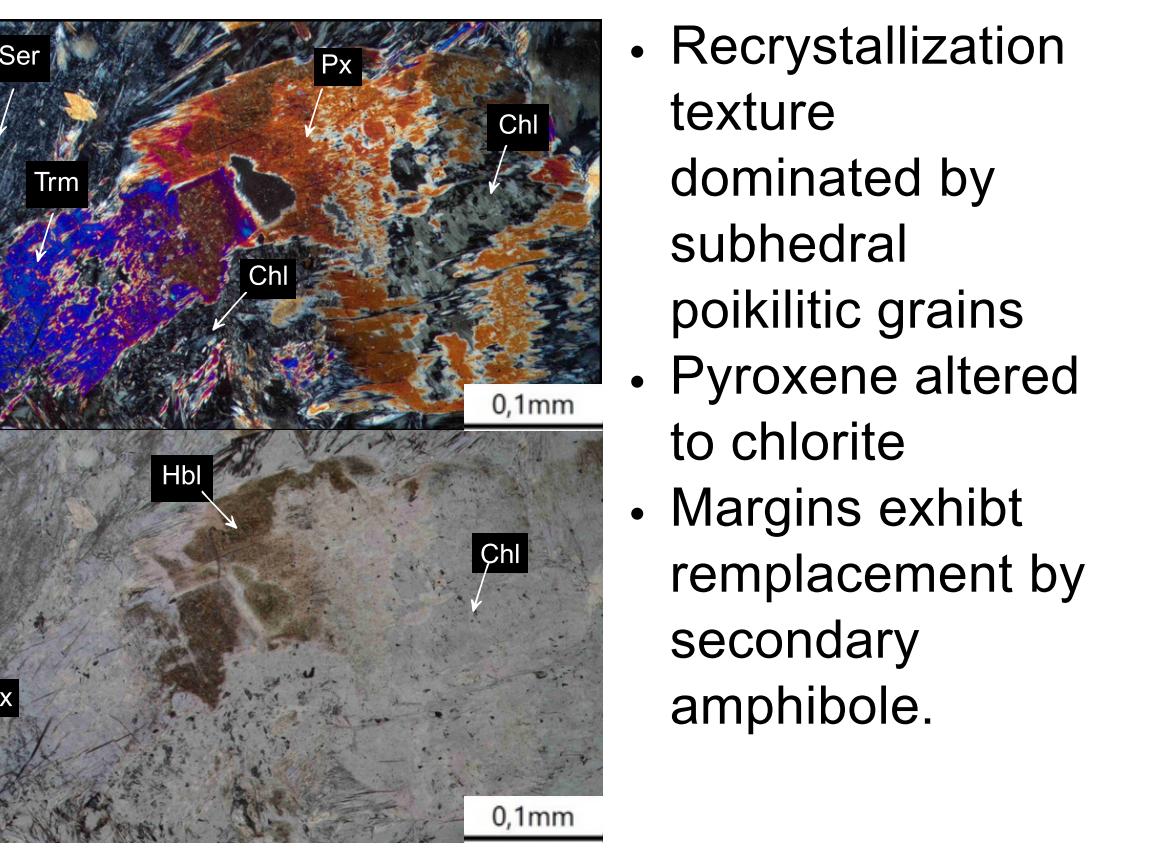


Figure 11: Modal classification of Inukshuk ultramafic rocks on the IUGS Olivine (Ol)–Orthopyroxene (Opx)–Clinopyroxene (Cpx) ternary diagram

Biotite gabbro: late-stage dyke



Pyroxenite



Peridotite

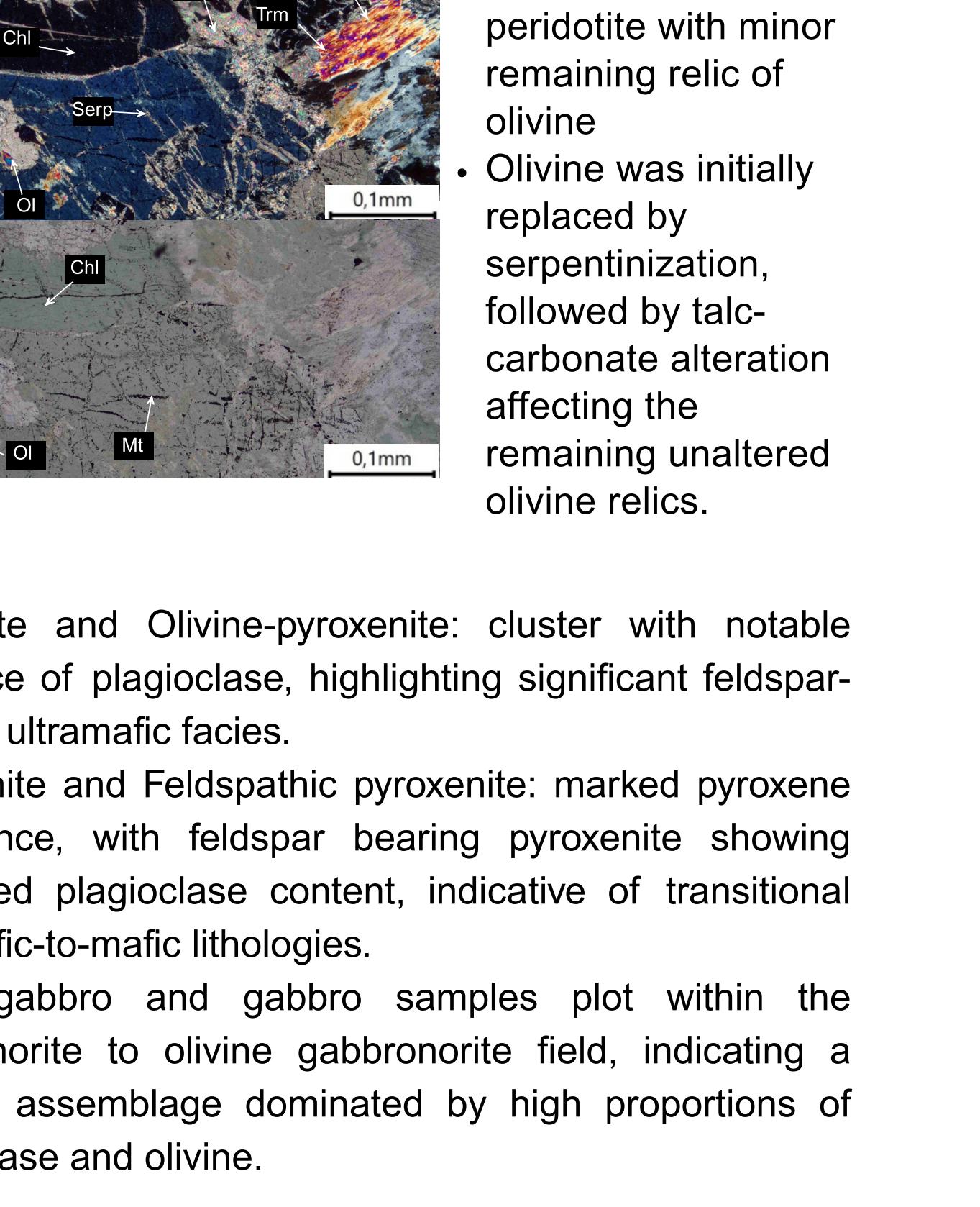


Figure 10: Petrographic observations indicate that the mafic gabbroic units of the Inukshuk intrusion are characterized by advanced saussuritization and/or sericitization of plagioclase. Pyroxenes are either completely altered or pseudomorphed to chlorite, frequently accompanied by secondary amphibole phases such as tremolite and hornblende. In high-Mg ultramafic lithologies, particularly peridotites, intense serpentinization is observed with antigorite as the dominant serpentine mineral, and localized alteration to talc and carbonate-rich assemblages. These mineralogical overprints support a metamorphic evolution from upper greenschist to lower amphibolite facies.

Normative mineralogy data reveal atypical compositions: ultramafic rocks contain considerable amounts of plagioclase, while mafic units such as gabbros and gabbronorites retain elevated modal olivine.

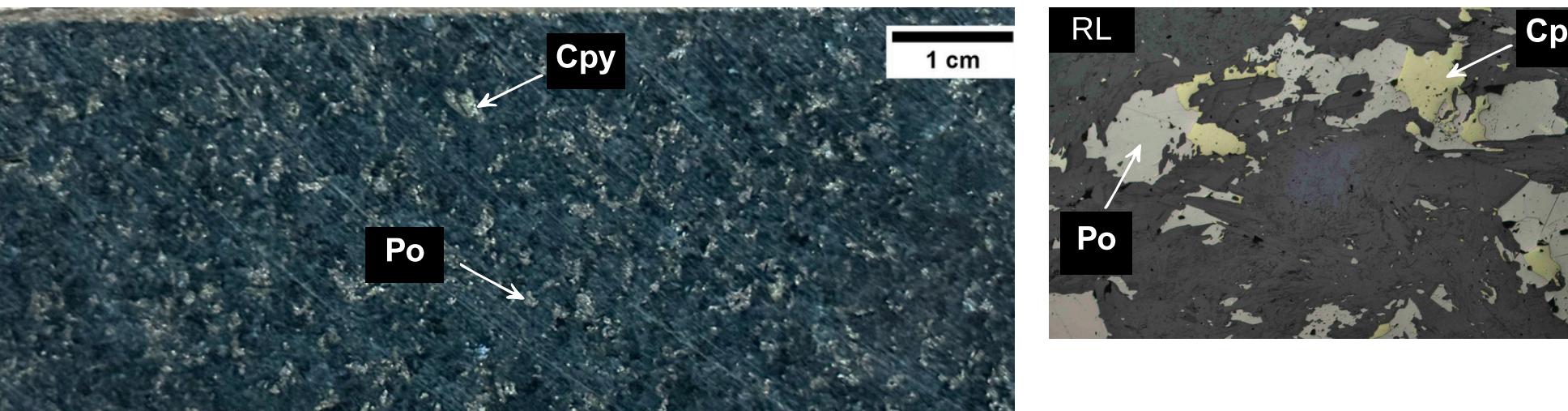
Sulfide mineralization within the Inukshuk intrusion exhibits distinct textural and zonal variations that are closely controlled by host lithology. Ultramafic units represent the most sulfide-enriched domains, ranging from finely disseminated textures to well-developed net-textured sulfides.

Massive sulfide zones exhibit predominantly magmatic mineral assemblages and textures, though locally overprinted by post-magmatic deformation. This is evidenced by the ellipsoidal to oblate geometries of pentlandite grains, indicative of strain accommodation within the Expo structural domain. Additionally, a possible magmatic foliation marked by aligned chalcopyrite lenses suggests flow-related fabric during sulfide emplacement.

Magmatic sulfide deposits generally require an external sulfur source in their genesis (Lesser, 2017). At Inukshuk, the sulfur is likely derived from **assimilation** of the Nuvilic metasediments, and graphitic mudstones and iron formations of the Beaufortian Formation. Further petrographic observations and sulfur isotope analyses are required to better constrain the relative contribution of each.

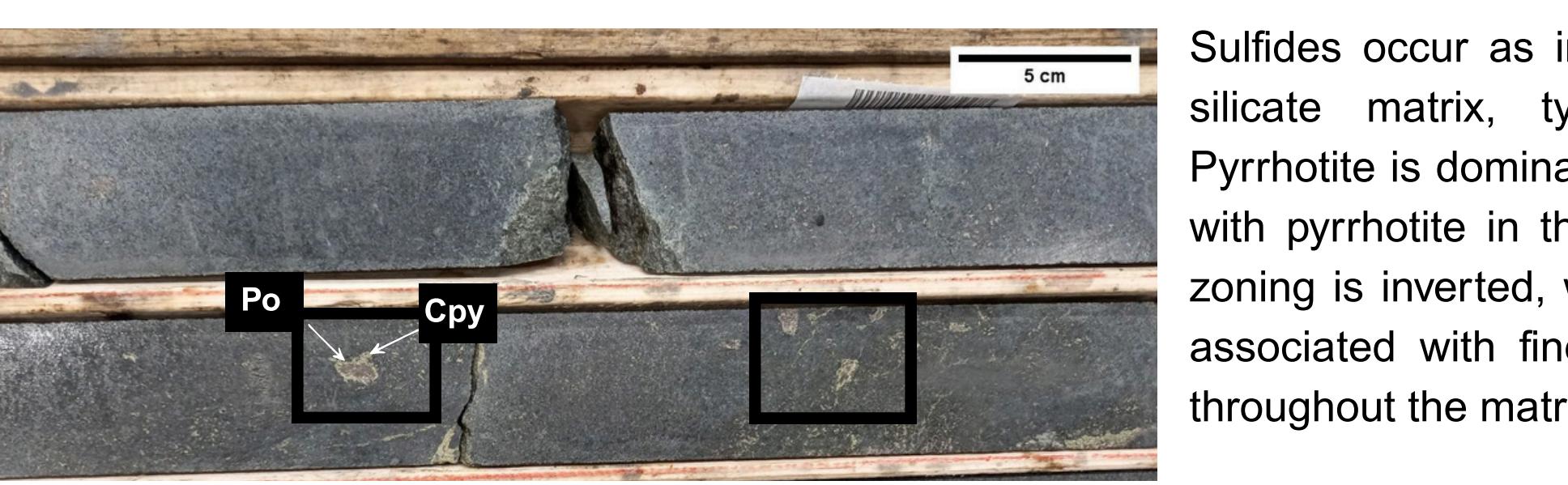
Sulfide mineralization: textures and assemblages

Disseminated sulfides



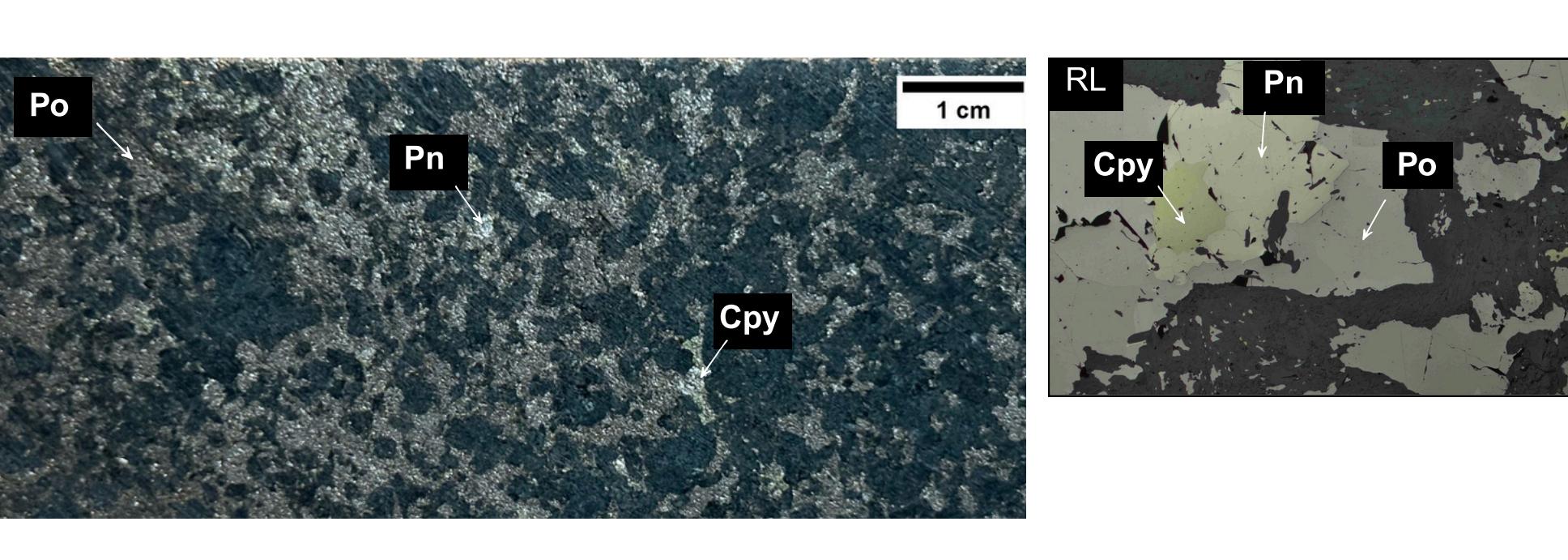
Fine to medium-grained disseminated sulfides are dispersed within the silicate matrix, dominantly pyrrhotite (Po) with minor chalcocite (Cpy) occurring as rims. Sulfides are subhedral and interstitial to cumulus silicates, locally forming blebs. This texture essentially characterizes the marginal zones.

Disseminated-Blebby sulfide



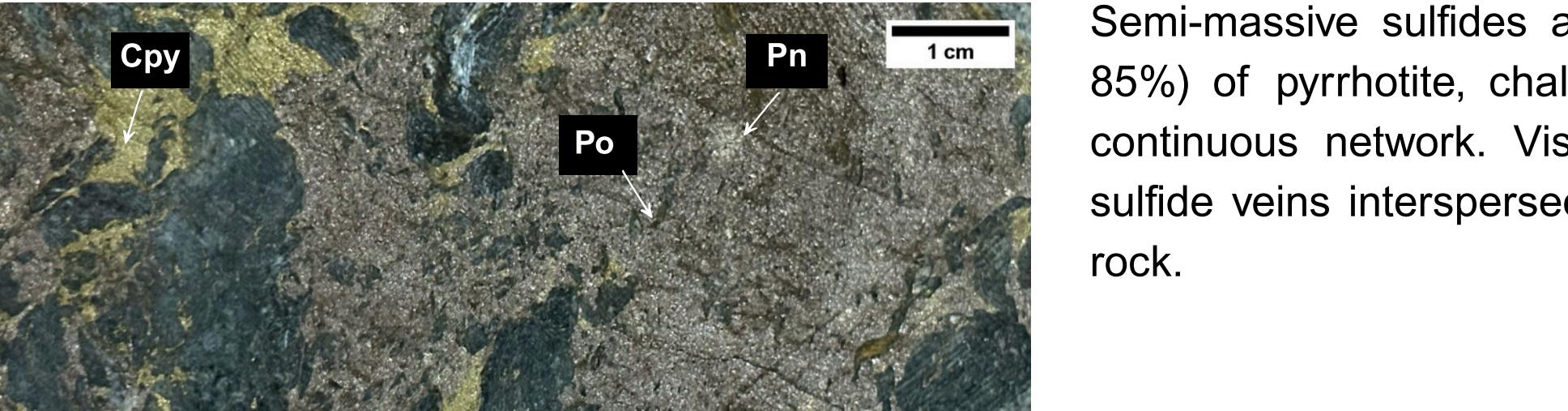
Sulfides occur as irregular, rounded blebs dispersed within the silicate matrix, typical of a blebby-disseminated texture. Pyrrhotite is dominant, and blebs often show concentric zonation with pyrrhotite in the core and chalcocite at the margins. This zoning is inverted, with Cpy occurring in cores. Sulfide blebs are associated with fine- to medium-grained disseminated sulfides throughout the matrix.

Net-Textured sulfide



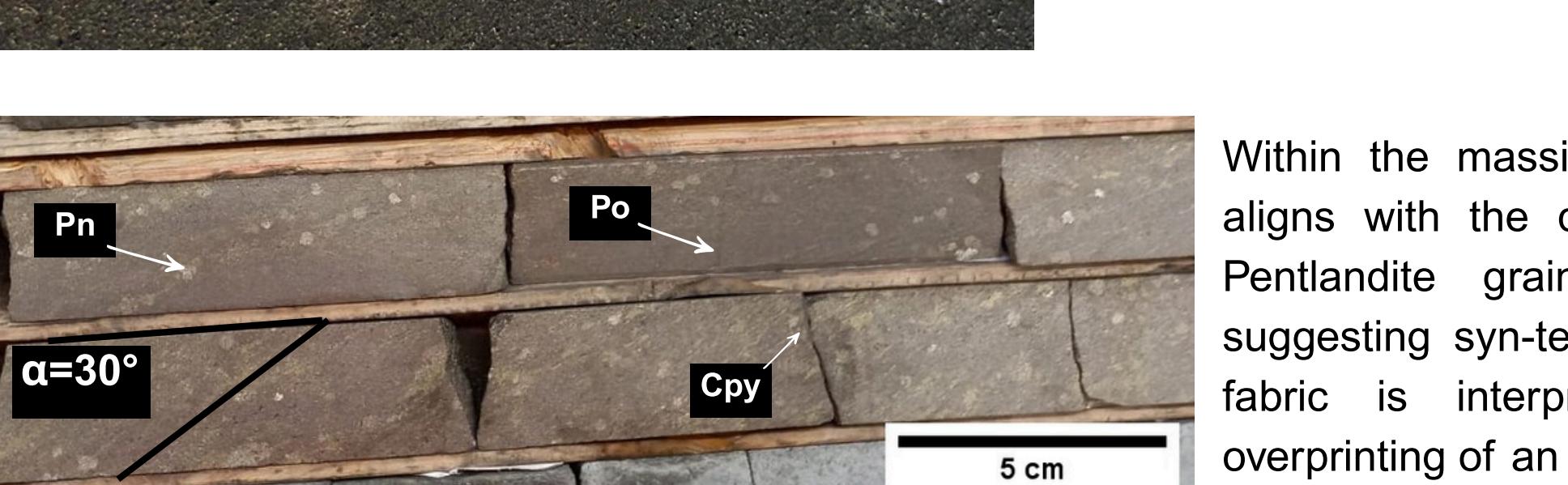
Net-textured sulfides form a semi-continuous interlocking framework of pyrrhotite (Po), chalcocite (Cpy), and pentlandite (Pn) enclosing silicate minerals. Sulfides are coarse-grained and interconnected, typical of cumulate zones in the ultramafic core. Po is dominant, with Cpy forming rims and Pn as discrete grains.

Semi-Massive sulfide



Semi-massive sulfides are characterized by a high proportion (65–85%) of pyrrhotite, chalcocite, and pentlandite forming a partially continuous network. Visually, they appear as thick, interconnected sulfide veins interspersed with patches of unmineralized silicate rock.

Massive sulfide



Massive sulfides are dominated by pyrrhotite (Po), with interstitial chalcocite (Cpy) and pentlandite (Pn), the latter displaying a bird's-eye texture within the Po matrix. Accessory magnetite (Mt), identified in thin section, occurs as globular grains within the sulfide assemblage.

Discussion

- Petrographic observations indicate that the mafic gabbroic units of the Inukshuk intrusion are characterized by advanced saussuritization and/or sericitization of plagioclase. Pyroxenes are either completely altered or pseudomorphed to chlorite, frequently accompanied by secondary amphibole phases such as tremolite and hornblende. In high-Mg ultramafic lithologies, particularly peridotites, intense serpentinization is observed with antigorite as the dominant serpentine mineral, and localized alteration to talc and carbonate-rich assemblages. These mineralogical overprints support a metamorphic evolution from upper greenschist to lower amphibolite facies.
- Normative mineralogy data reveal atypical compositions: ultramafic rocks contain considerable amounts of plagioclase, while mafic units such as gabbros and gabbronorites retain elevated modal olivine.
- Sulfide mineralization within the Inukshuk intrusion exhibits distinct textural and zonal variations that are closely controlled by host lithology. Ultramafic units represent the most sulfide-enriched domains, ranging from finely disseminated textures to well-developed net-textured sulfides.
- Massive sulfide zones exhibit predominantly magmatic mineral assemblages and textures, though locally overprinted by post-magmatic deformation. This is evidenced by the ellipsoidal to oblate geometries of pentlandite grains, indicative of strain accommodation within the Expo structural domain. Additionally, a possible magmatic foliation marked by aligned chalcopyrite lenses suggests flow-related fabric during sulfide emplacement.
- Magmatic sulfide deposits generally require an external sulfur source in their genesis (Lesser, 2017). At Inukshuk, the sulfur is likely derived from assimilation of the Nuvilic metasediments, and graphitic mudstones and iron formations of the Beaufortian Formation. Further petrographic observations and sulfur isotope analyses are required to better constrain the relative contribution of each.

Future work

- Compile the full whole-rock geochemistry dataset, including mineralized samples, to better define lithological variations across the Inukshuk intrusion.
- Determine the detailed variability of sulfide textures within the Inukshuk mafic-ultramafic sequence, including distinctions between disseminated (blebby, stringer), net-textured (net, patchy net), and massive sulfide textures.
- Develop a 3D Leapfrog model integrating lithological, geochemical, and structural data.
- Investigate the sulfur source using sulfur isotope analyses ($\delta^{34}\text{S}$).
- Determine the mineral chemistry of olivine and pyroxene as well as sulfides using EMPA.
- Estimate the parental magma composition of the Inukshuk intrusion.
- Ultimately, propose a comprehensive genetic model for the Inukshuk intrusion within the Expo intrusive subsuite.

Acknowledgment

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