Alteration of the Newtown Square and Lima Ultramafic Bodies in Delaware County, Pennsylvania

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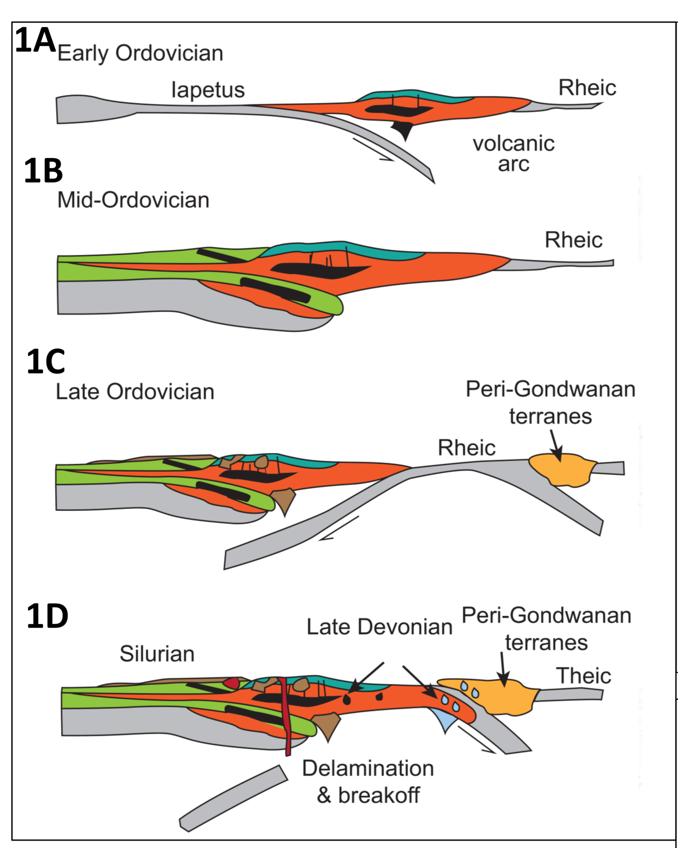
Abstract

Utilizing field work, geochemistry, and petrography, two ultramafic bodies (UMB's) in the Pennsylvania Piedmont were examined revealing varying degrees and types of alteration. The two bodies examined, Newtown Square UMB and Lima UMB, are located in Delaware County, PA, and are separated by 1 km. The bodies are oblong (~6 km x 3 km, trending NNE and SSW) and surrounded by the Wissahickon schist apart from the western edge where they border the Rosemont shear zone. The Newtown Square and Lima bodies are the two largest UMB's in a series of early Paleozoic UMB's in the Pennsylvania Piedmont which were emplaced during the Taconic Orogeny (470 Ma) and subsequently deformed. Trace elements plotted on discrimination diagrams indicate an island arc setting suggesting they were part of the collided arc system.

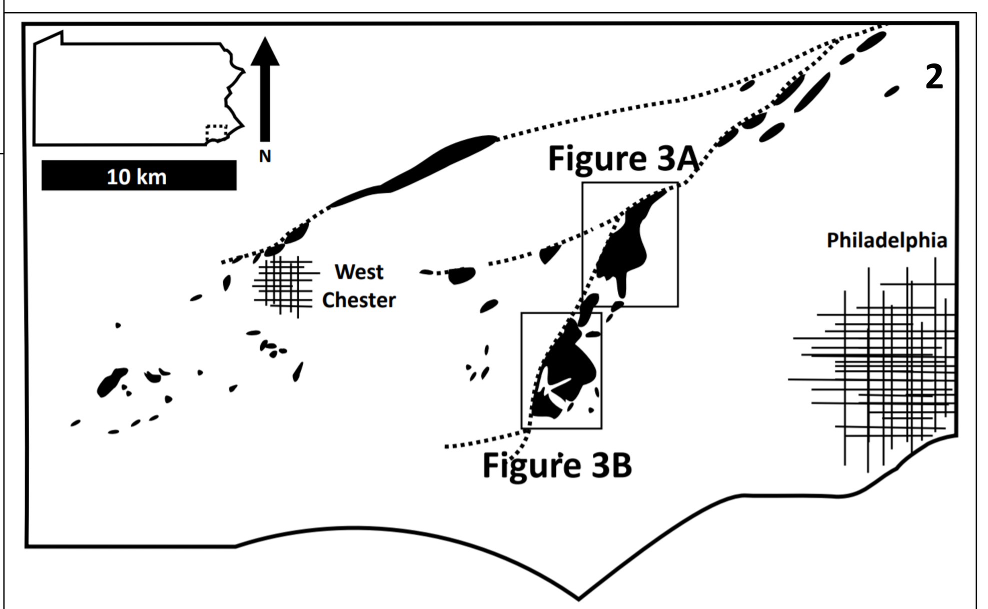
The Newtown Square UMB exhibits limited alteration (orthopyroxenite and norite lithologies) on the western side and blackwall alteration (zones of increasing hydration towards the country rock) on the eastern side of the body. The lack of alteration on the western side may be due to the presumed source of metamorphic fluids (the anhydrous, granulite-facies, mafic Baltimore gneiss) or this area's juxtaposition to the Rosemont shear zone. In contrast, the blackwall alteration of the eastern side provides a gradient from a nearly unaltered core to zones of increasing hydration (anthophyllite, talc, serpentine, respectively) to the silica-rich country rock, the Wissahickon schist. The Lima UMB contains similar rocks to the Newtown Square UMB (pyroxenite and serpentinite), however, the most abundant rock in the Lima UMB is a severely-altered ultramafic rock characterized by extensive honey-comb veining and up to 90% silica content. The occurrence of this "reaction rock" is likely due to contact metamorphism with multiple mapped granitic intrusions adjacent to the Lima body. The widespread presence of the reaction rock suggests that the granitic bodies may be continuous at depth representing one large granitic body. Geochemical and petrographic examination of these UMB's reveal an island arc affinity for their origin and subsequent deformation was significantly influenced by adjacent Baltimore Gneiss, Wissahickon schist, and granitic intrusions each imprinting a distinct style of alteration on the adjacent UMB's.

Introduction



1) **Early Paleozoic evolution of eastern Laurentia**
- **1A)** the Taconic Arc created from eastward dipping subduction
- **1B)** collision and orogenesis of the Taconic Orogeny
- **1C)** change in subduction polarity
- **1D)** slab delamination/breakoff leading to regional extension combined Acadian influences to the north

The origin of the ultramafic rocks in the Pennsylvania Piedmont is still uncertain, however, three contending hypothesis for their origin:
- ophiolite or oceanic crust obduction;
- diapiric rise of mantle in transtension; or
- lower crustal magmatic arc differentiates.

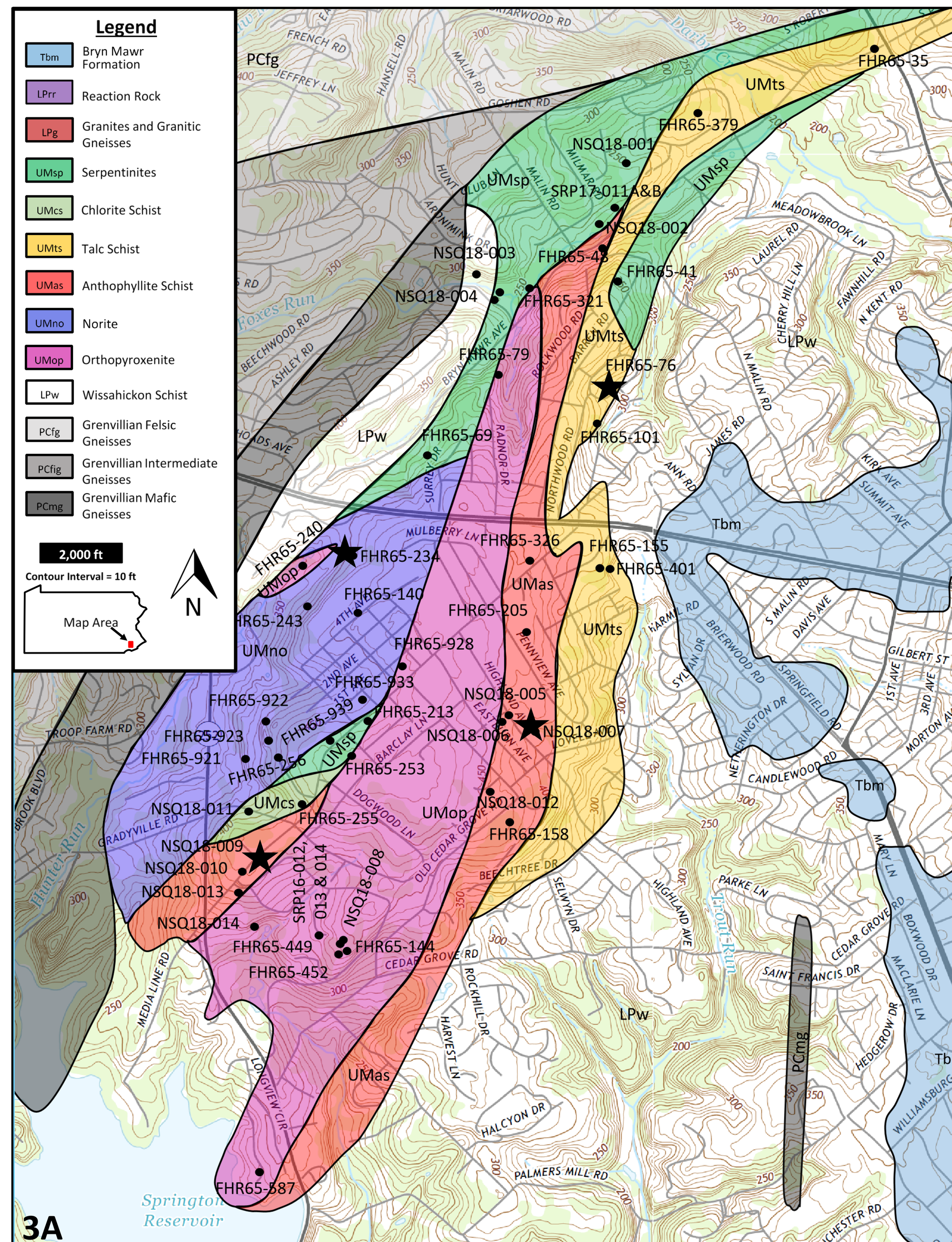


2) The map depicts the general research area located in the Pennsylvania Piedmont relative to Philadelphia and West Chester, highlighting the shear zones (dashed lines), as well as showing the UMB's present in the area. The figure also outlines the two areas of interest for the study (3A and 3B).

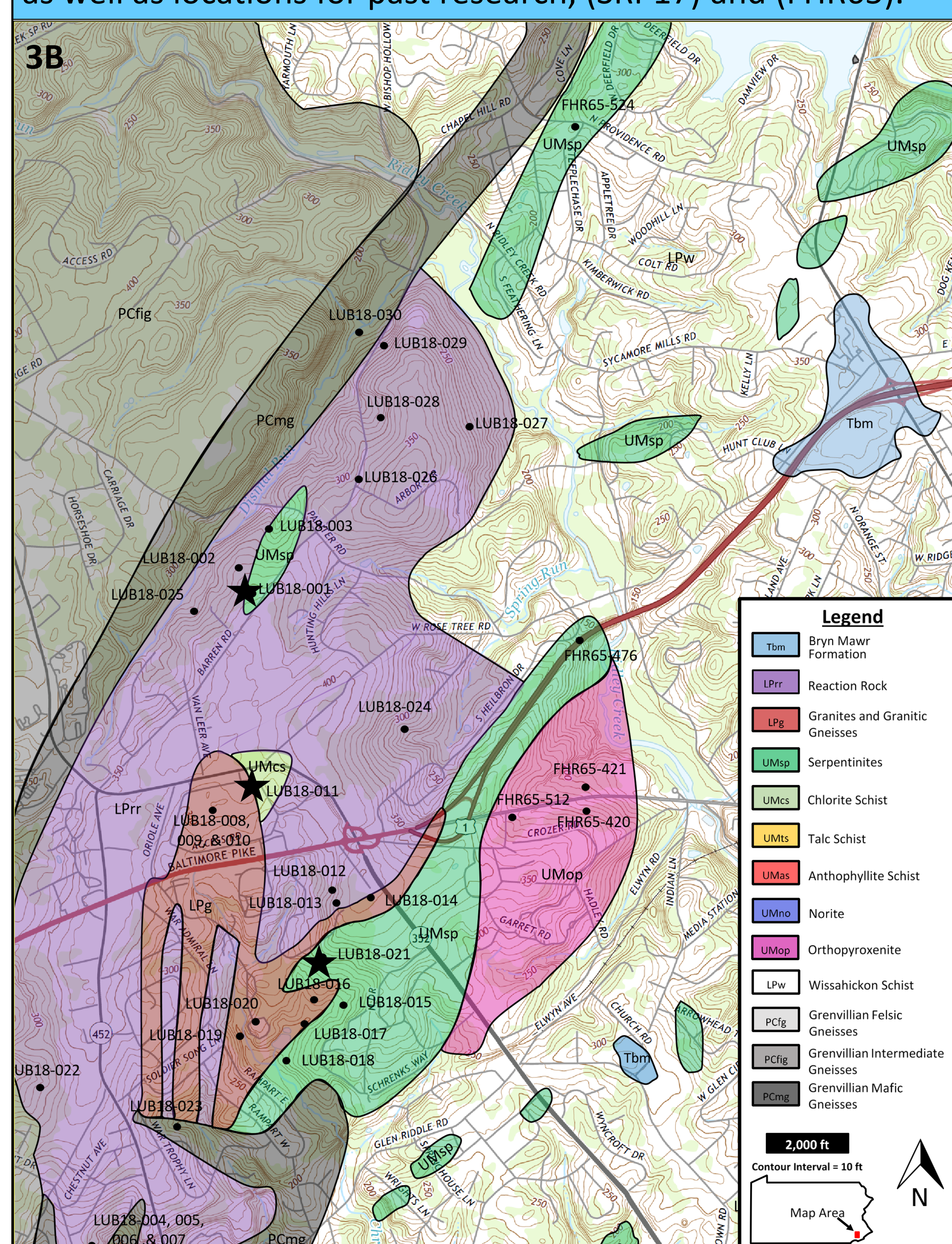
Methods

- Detailed field mapping
- Sample collection throughout both UMB's
- Hand sample examination
- Petrographic examination of thin sections with polarized light microscopy
- Whole rock geochemical analysis
- Trace element data was plotted onto discrimination diagrams

Geologic Maps



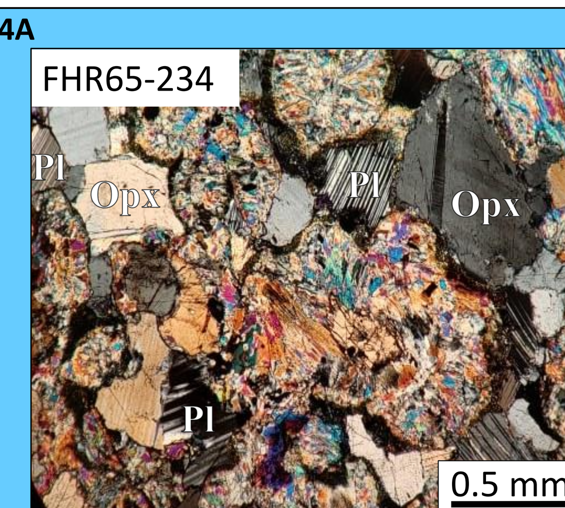
3A) The map depicts the Newtown Square UMB, lithologies present, and sample locations for current research (NSQ18) as well as locations for past research, (SRP17) and (FHR65).



3B) The map depicts the Lima UMB, lithologies present, and locations where samples were collected.

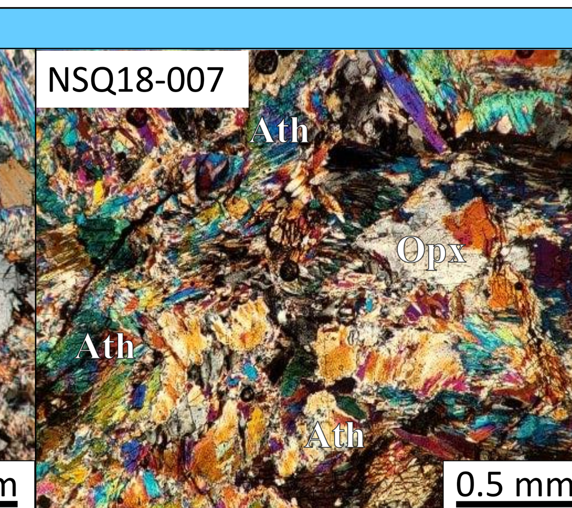
Petrographical Analysis and Thin Section Description

4A



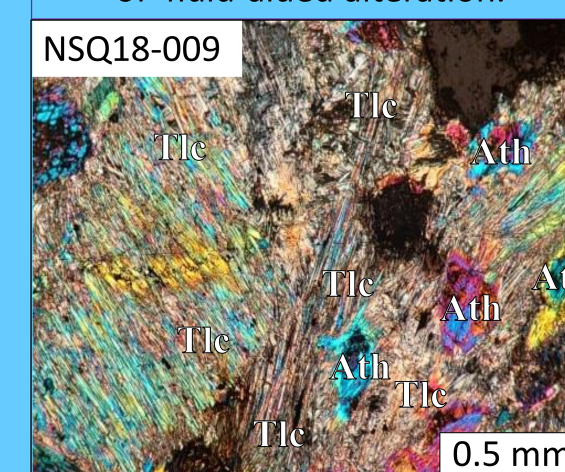
Altered Norite

Complex textures surround the porphyroclastic Opx and Pl. Ep, Ath, Tr, & Tlc as the main products of fluid-aided alteration.



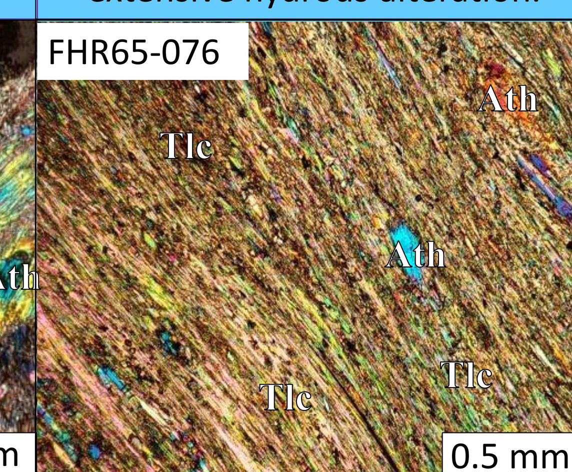
Anthophyllite Schist

Relict Opx present and Pl absent, showing the transition to a more mafic protolith and more extensive hydrous alteration.



Anthophyllite-Talc Schist

The rock is overwhelmingly anthophyllite with pods of talc throughout representing the blackwall form.

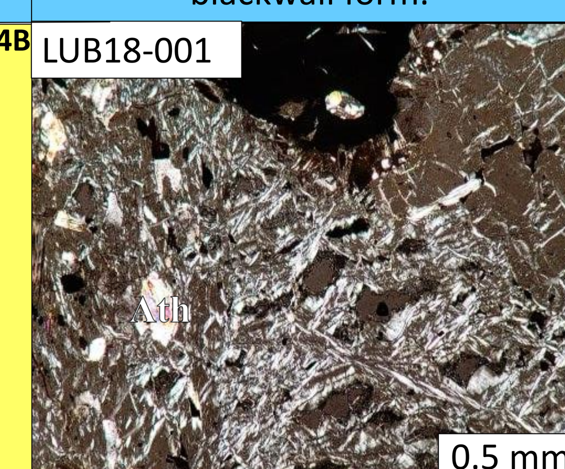


Talc-Anthophyllite Schist

The talc schist contains minor amounts of anthophyllite representing greater hydration adjacent to the country rock.

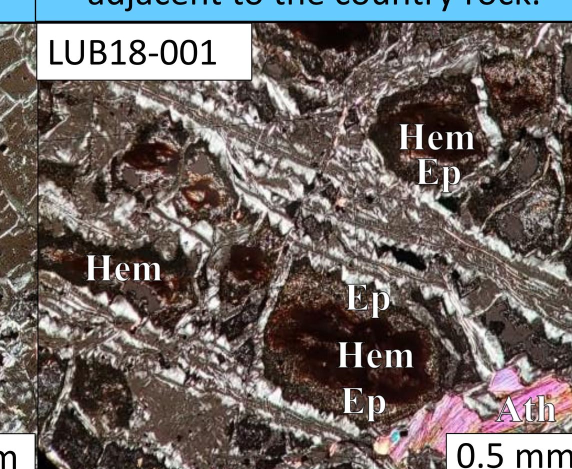
Within the Newtown Square UMB zones of increasing hydration are observed **(3A & 4A)**, and can be divided into 4 lithologic zones. The first of these zones (on the west side of the body) is norite, which is comparatively much less altered than the proceeding zones of orthopyroxene, anthophyllite schist, and finally talc schist, respectively on the east side of the body. This "onion-skin" pattern is characteristic of blackwall alteration. This is a type of hydrothermal alteration wherein alteration of varying degrees is observed creating zones which have a uniformity in their lithologic transitions. The alteration itself is likely caused by the hydrous silica-rich country rock (Wissahickon Schist) surrounding the UMB on the east side. The alteration observed on the west-side of the UMB is much less severe. This is likely attributed to the anhydrous silica-poor country rock (Baltimore Gneiss) which is adjacent to the west-side of the body.

4B



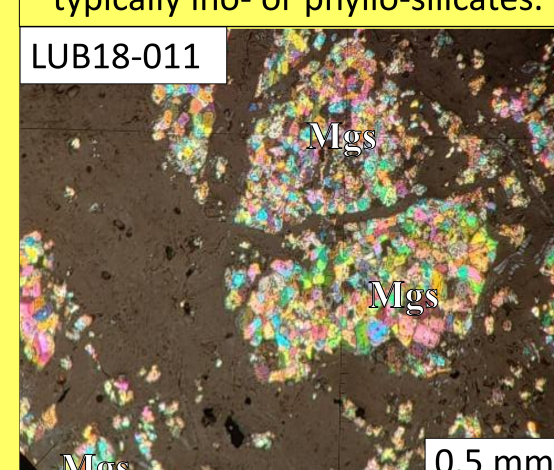
Serpentinite

Predominantly bastite texture with minor interlocking texture. Bastite texture indicate a non-olivine precursor which is typically ino- or phyllo-silicates.



Serpentinite

Hematite with coronas of epidote can be observed suggesting alteration environment rich in oxygen, calcium, and aluminum.



Serpentinite

Some serpentinite samples contain abundant magnesite demonstrating the complexity of the alteration fluid composition.

Serpentinite

The rock shows a bastite texture indicating a non-olivine precursor not typical of higher levels of a layered mafic intrusions.

The Lima UMB exhibits siliceous alteration which alters and replaces the serpentinite rock **(4B)**. This metasomatic alteration is likely linked to the intrusive granitic body (figure 3B); the result of the alteration is rock which exhibits "honeycomb" veining **(5)**

References

Deschamps, F., Godard, M., Guillot, S., and Hattori, K., 2013, Geochemistry of subduction zone serpentinites: A review: Lithos, v. 178, p. 96–127.

Shervais, J.W., 1982, Ti-V plots and the petrogenesis of modern and ophiolitic lavas: Earth and Planetary Science Letters, v. 59, p. 101–118.

Sinha, A.K., Thomas, W.A., Hatcher, R.D., and Harrison, T.M., 2012, Geodynamic evolution of the central Appalachian orogen: Geochronology and compositional diversity of magmatism from Ordovician through Devonian: American Journal of Science, v. 312, p. 907–966.

Vermeesch, P., 2006, Tectonic discrimination of basalts with classification trees: Geochimica et Cosmochimica Acta, v. 70, p. 1839–1848.

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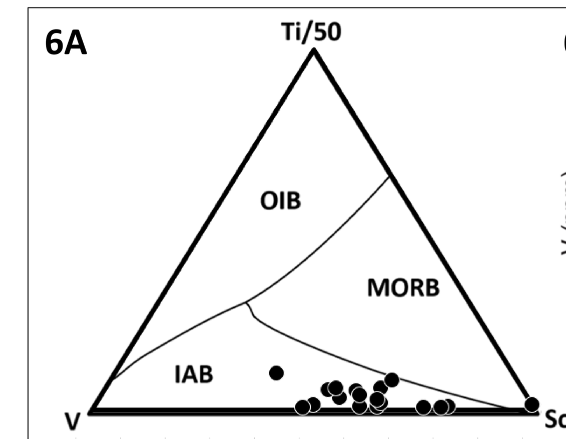
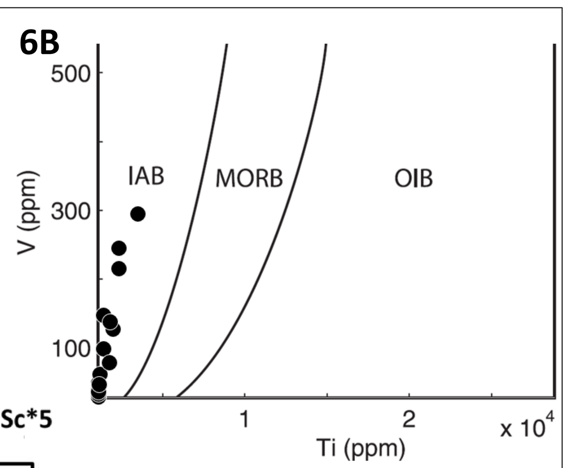
Major and Trace Element Abundances

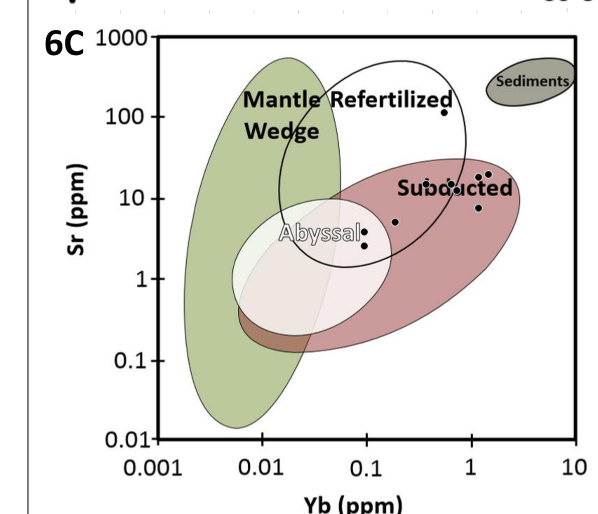
	FHR65- 234	NSQ18- 007	NSQ18- 009	FHR65- 076	LUB18- 001	LUB18- 011	LUB18- 021
Major Element (wt %)	*Norite*	*Ath Schist*	*Ath Schist*	*Tlc Schist*	*Serpentinite*	*Serpentinite*	*Serpentinite*
SiO_2	48.81	52.87	53.21	53.7	38.93	29.58	43.06
Al_2O3	12.32	1.73	2.82	3.91	0.31	0.08	0.1
$Fe_2O_3^{(T)}$	12.49	12.5	10.82	10.22	9.28	5.26	5.79
MgO	15.02	25.42	24.61	25.76	34	33.18	35.9
CaO	9.77	4.85	2.83	1.35	0.15	8.45	0.05
L.O.I.	1.34	2.3	3.99	4.62	16.87	23.69	14.22
Trace Elements (ppm)							
Sc	49	48	35	24	5	2	4
V	197	126	116	53	6	< 5	20
Ba	45	13	10	8	14	13	23
Sr	98	4	12	6	3	268	3
Cr	920	2180	2270	2690	3120	2290	2250
Ni	290	530	700	700	4840	1740	2230

Whole rock abundances for selected major and trace elements for samples depicted in the Figures 3 and 4. These samples are considered a representative subset of the twenty total analyses.

Geochemical Analysis and Diagrams







6) Trace elements plotted on petrogenetic discrimination diagrams for basaltic systems (**6A –** Shervais, 1979; **6B –** Vermeesch, 2006) and serpentinitic systems (**6C -** Deschamps et al., 2013) to determine potential environments of formation.

Abyssal serpentinites are related to the hydration of oceanic peridotites due to hydrothermal activity and alteration from seawater. These correlate with mid-ocean ridge basalts (MORB)

Mantle wedge serpentinites are developed in the mantle wedge through the hydration of peridotites, by fluids released from subducted slabs. These correlate with ocean island basalts (OIB)

Subducted serpentinites are found in suture zones near the oceanic continental transitions and can range in protolith origin (from abyssal peridotites to arc complexes) and undergo extensive alteration in the subduction channel. These correlate with island arc basalts (IAB) and are representative of the results from geochemical analysis.

Conclusions

- The Newtown Square UMB displays asymmetric alteration with blackwall alteration to the east, grading to less altered lithologies to the west.
  Possible Causes:
  - the presence of the silica-poor, anhydrous Baltimore Gneiss to the west providing less fluid
  - proximity to the Rosemont shear zone may limit alteration on the western side
- The extent of the siliceous alteration in the Lima UMB suggests that perhaps the various granitic bodies may be continuous at depth.
- Trace element analysis suggests an island arc setting for the protolith of the UMB's.