Serpentinization of the Unionville Serpentine Barrens: A Geochemical and Petrographic Study

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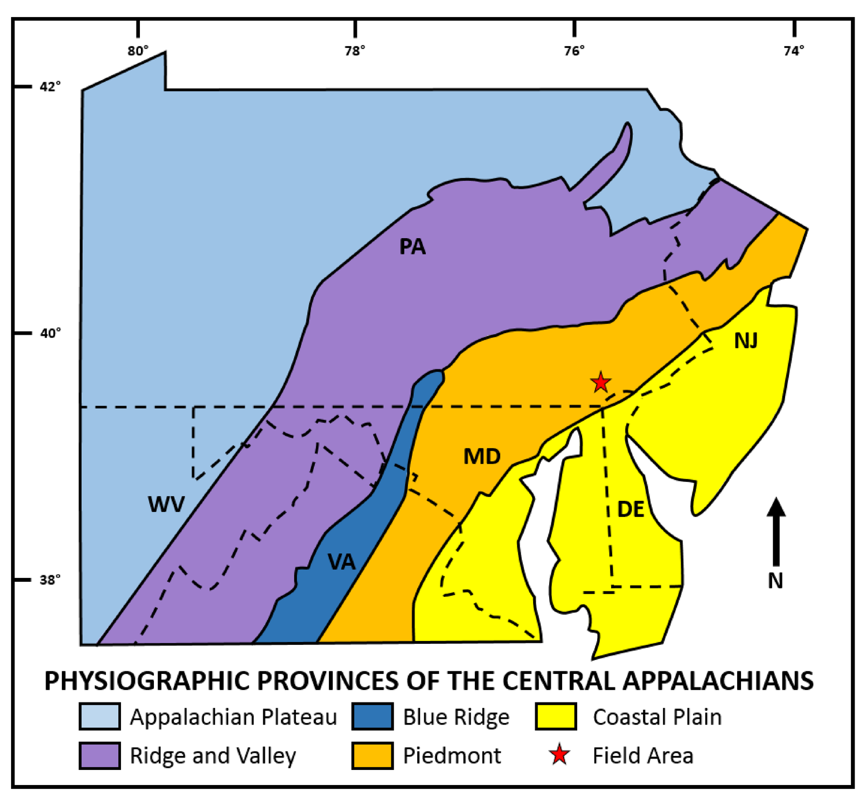
Abstract

The Unionville Serpentine Barrens, located in Newlin Township, Chester County, Pennsylvania hosts a serpentinite body that has not been fully characterized. Located in the Pennsylvania Piedmont, the Unionville serpentinite body is approximately 2 km by 1 km, surrounded by the Doe Run Schist, and is cut by several pegmatite dikes. The Unionville serpentinite body is the southernmost ultramafic body in a series of early Paleozoic ultramafic bodies in the Pennsylvania Piedmont which were deformed during the Taconic Orogeny. Several hypotheses are proposed to explain the occurrence of Piedmont ultramafics in this region, including: ophiolitic fragments, diapiric mantle, or arc-magmatic differentiation. Field relationships, thin sections, and geochemical data were analyzed to attempt to determine the nature of the protolith and its origin.

Over twenty-five samples were collected during field work and based on the rock textures (foliation, color, etc.) and field relationships, five unique groups of serpentinite samples were identified. Eleven samples representative of the groups, were chosen for thin section production. Petrographic analysis revealed the presence of various pseudomorphic textures, including mesh (lizardite after olivine), hourglass (mainly lizardite after olivine) and bastite (lizardite after pyroxene, amphibole, phyllosilicates). Based on thin section microstructures and textures, three distinct groups were identified: large mesh nets (1.0 – 0.5 mm), small mesh nets (<0.5 mm), and hourglass mixed with mesh. The field groups and thin section groups did not correlate and internally did not exhibit systematic trends. While bastite textures were observed in some thin sections they were the minority component. Relict olivine can be seen in mesh centers in five of the samples, however, this texture is not restricted to an individual group.

Ten samples were selected for geochemical analyses of major and trace elements. Bulk rock loss on ignition data (used as a proxy for water content) indicates that the outer edge of the serpentinite body is more hydrous than the interior, however, this trend does not correlate with the presence of relict grains. Plotting on petrogenetic discrimination diagrams yields an island arc basalt signature suggesting that the Unionville serpentinite body was part of an arc system prior to serpentinization.

Regional Map



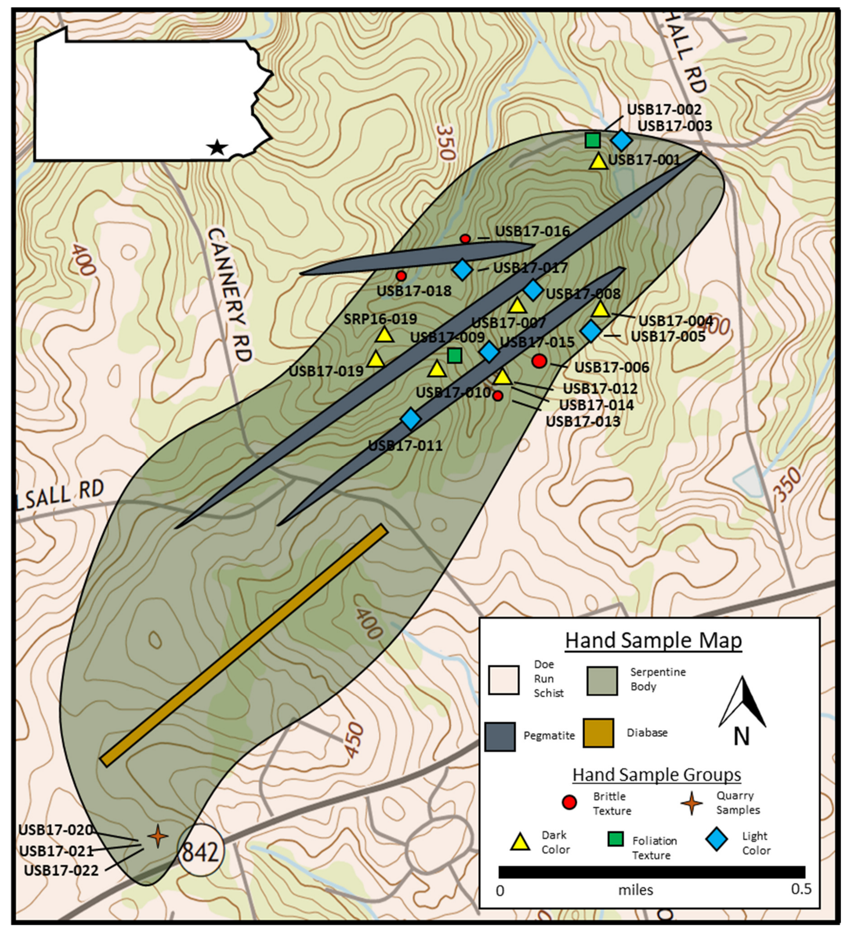
The Unionville Serpentine Body is located on the ChesLen Nature Preserve in Chester County. The body can be found in the Pennsylvania Piedmont surrounded by the Doe Run Schist. There are numerous other ultramafic bodies in the region. The Unionville Serpentine Barrens are cut by several pegmatite dykes.

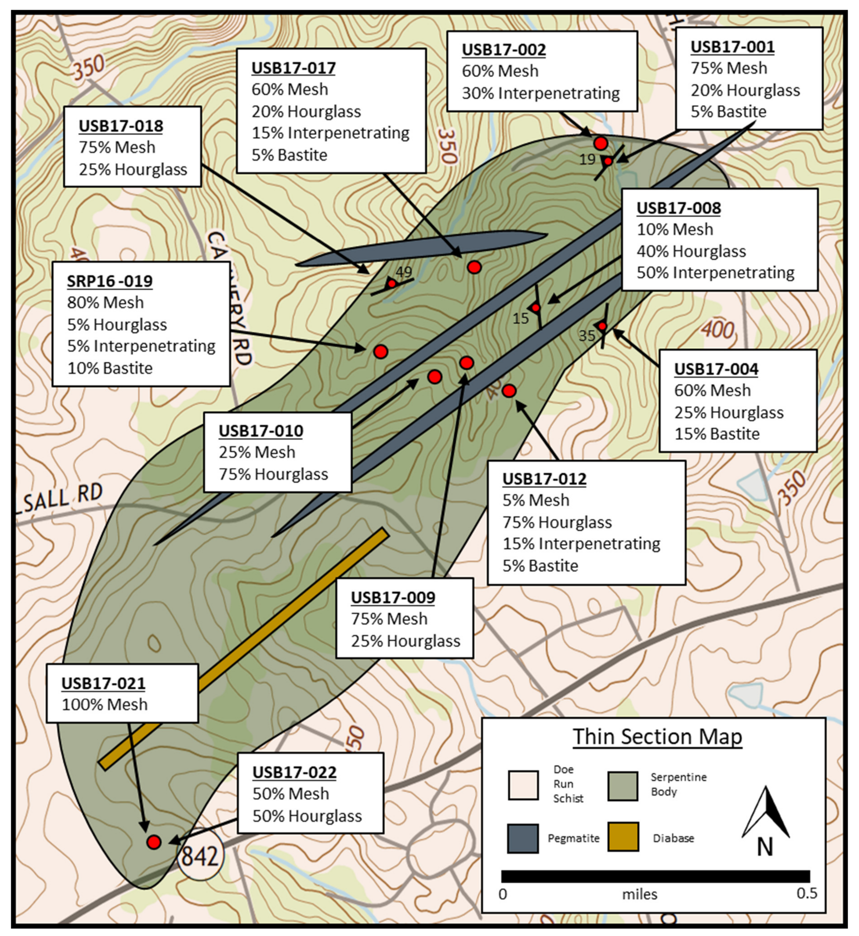
Methods

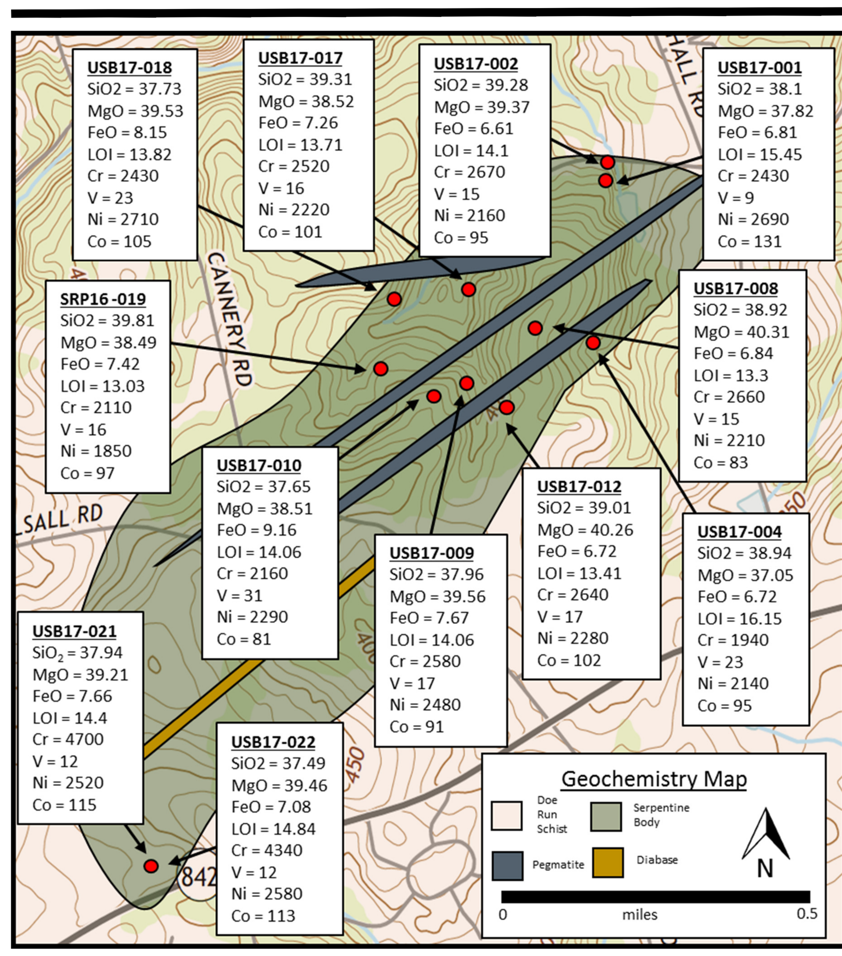
The following methods are employed in this study:

- Detailed Geologic Field Mapping
- Collection of samples throughout the serpentine body
- Petrographic Assessment of Rock Thin Sections using polarized light microscopy
- X-ray Diffraction (XRD) – to confirm the presence of lizardite as the main serpentine phase
- Major and Trace Elements determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS)
- X-Ray Fluorescence (XRF)

Geologic Maps and Analyses







Major and trace elements were examined in ten samples from the field site. Some elements particularly diagnostic for serpentinite deposits are reported on the left. Few systematic trends were observed, however, samples in close proximity to pegmatite dikes had lower levels of cobalt. The outer edges of the body also had high loss on ignition (LOI) values. If LOI is used as a proxy for H_2O content the outer edges of the body appear to be more hydrated.

Textures in Hand Sample and Thin Section

Brittle Texture

Samples were considered brittle if they were easily broken during transportation or during thin section prep. 18% of samples were brittle-type.

USB17-016

This sample was not used for thin sections because it was too brittle to be cut by the rock saw. The main mineral present is talc, giving it a soapy texture.

Quarry Samples

Quarry samples were distinctively different from other samples. Samples were lighter in color and contained large magnetite grains.

USB17-022

Quarry samples were collected in a minor pit mine with good exposure. Outcrop patterns were non-systematic with indications of shear (e.g., slickened crack-seal)

Dark Colored Texture

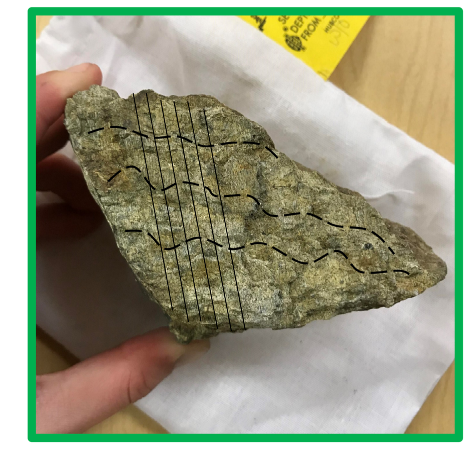
Samples were significantly darker than other samples. Most dark samples had portions of lighter rock but over 50% of the rock was dark color.

USB17-002

There is vertical veining seen in the middle of the sample. Analyses did not determine mineralogical, textural, or geochemical differences between the colors.

Foliation Texture

There were only three samples with a clear foliation fabric. Foliation varied within a single sample and made strike and dip measurements unreliable.



USB17-014

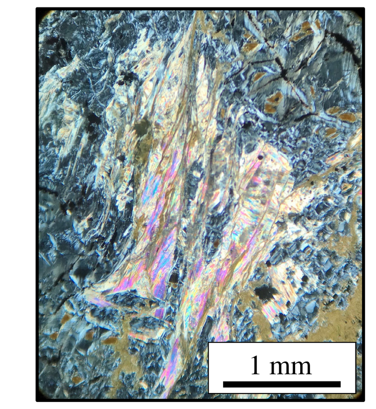
An S_1 foliation can be observed in the sample above from left to right with a secondary S_2 foliation observed top to bottom. This is one example of the complex foliation patterns exhibited.

Light Colored Texture

Samples were placed in this category if they had greater then 50% light color. 27% of the samples were placed in this category.

USB17-008

Light-colored samples did contain occasional dark pods but no mineralogical, textural, or geochemical differences were detected.



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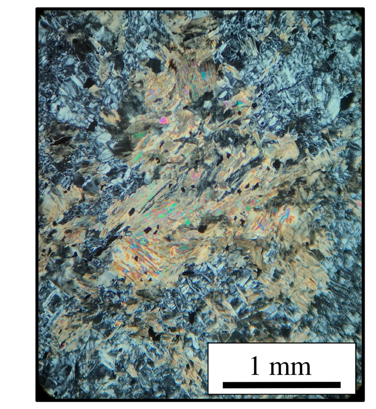

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Additional Phases

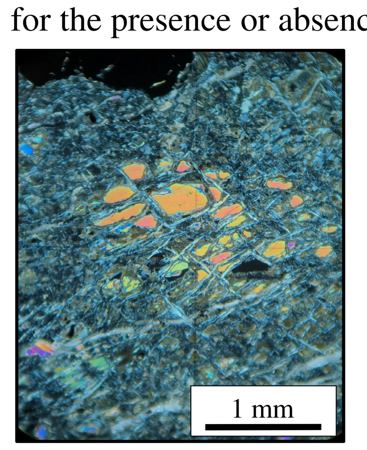
Talc was present in low modal percentages in six samples. The talc grains cross cut through the serpentine surrounding the grains. The texture suggests that talc was a secondary mineral after serpentinization because it cross-cuts the serpentine. There was no systematic trends for the presence or absence of talc.

It is quite likely that sub-microscopic brucite is present throughout all samples.

Accessory opaques (likely magnetite/chromite) are present in all samples

Relict Grains

The protolith of this sample was an ultramafic olivine-rich rock. As serpentinization occurred, the olivine metamorphosed to serpentine. Remaining olivine grains represent incomplete serpentinization (seen in four samples). There was no trend observed for the presence or absence of relict olivine.



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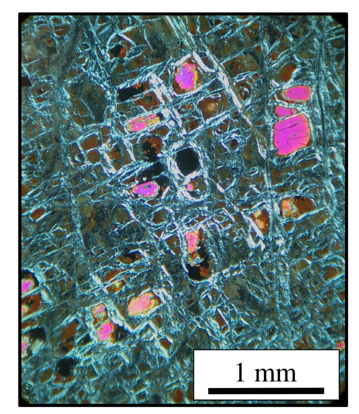
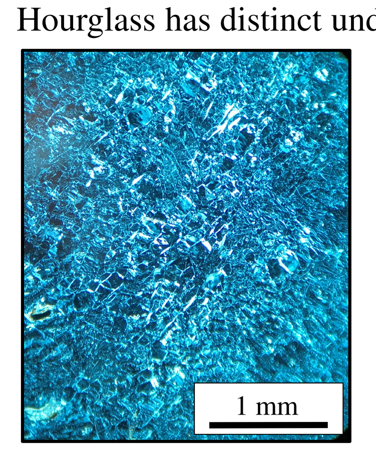


USB17-021

Relict olivine grains surrounded by serpentine under XPL. The development of mesh texture, created by pseudomorphism of serpentine after olivine (Wicks & Whitaker, 1977), can be observed.

Mesh & Hourglass

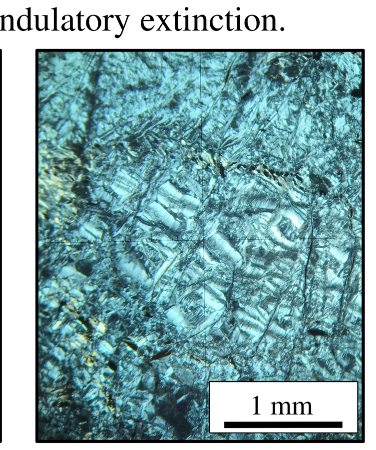
Mesh and hourglass textures are found in 100% of the samples collected and never constituting <50% of the serpentine texture present. These are interpreted to be pseudomorphic textures of serpentine after olivine (Wicks & Whitaker, 1977). Hourglass has distinct undulatory extinction.



USB17-004

Mesh texture

Mesh is recognized by the interconnected grid lines and block pattern.



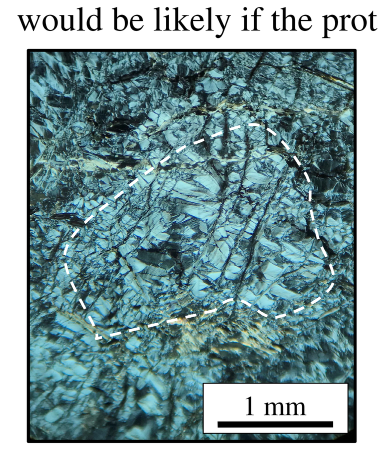
USB17-010

Hourglass texture

Hourglass is recognized by its distinct undulatory hourglass shape.

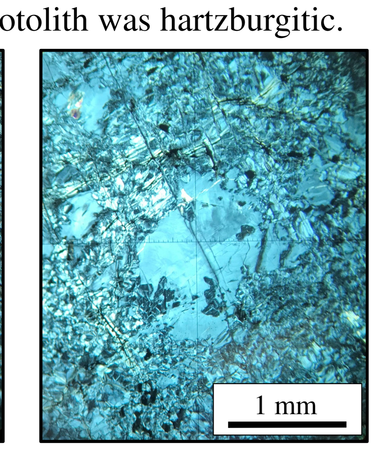
Bastite

Bastite texture is interpreted to be a pseudomorphic texture of serpentine after amphiboles, pyroxenes, or phyllosilicates (Wicks & Whitaker, 1977). This texture is found in 23% of samples and does not exceed 15% of the texture in a given sample. OPX would be likely if the protolith was hartzburgitic.



USB17-012

Bastite texture is outlined in dashed lines and only represents 5% of this sample.

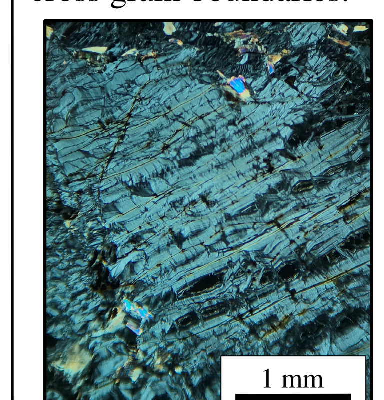


SRP16-019

This bastite example is one large bastite grain surrounded by mesh texture.

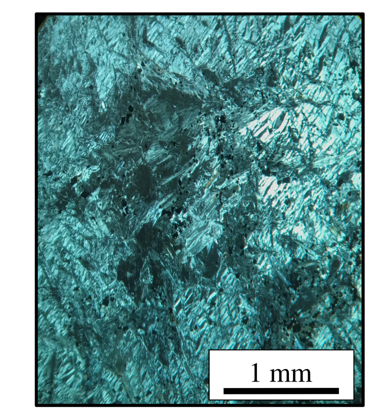
Interlocking and Interpenetrating

Interlocking and interpenetrating textures are non-pseudomorphic textures, meaning they do not retain shape or follow a preferred orientation of he replaced mineral. Interlocking textures will not cross over other grains while interpenetrating textures cross grain boundaries.



USB17-002

Interlocking texture is recognized by rectangular grains with sweeping extinction.

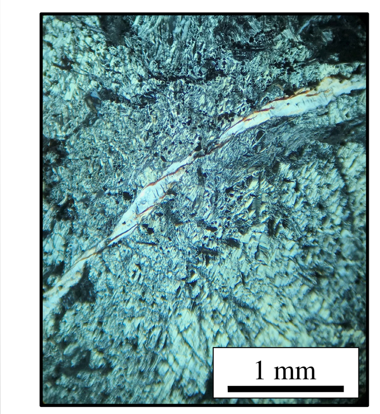


USB17-010

Interpenetrating texture is recognized by cross-cutting grains.

Chrysotile Veining

The presence of chrysotile veining suggests late stage brittle fracture and crack-seal after the main episode of serpentinization.



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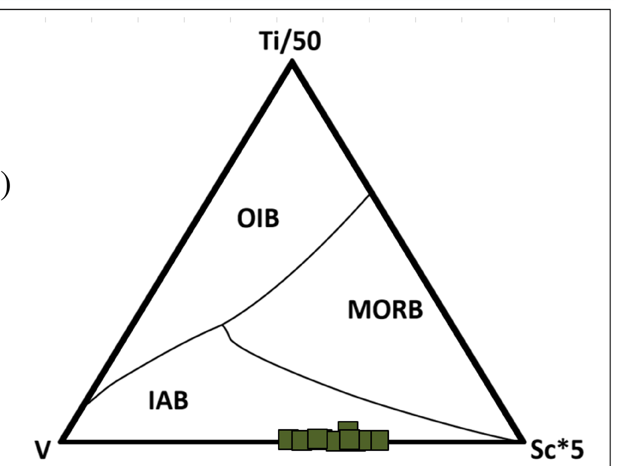
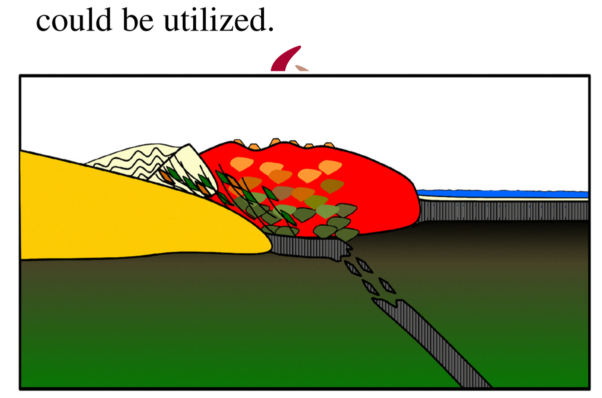
Chrysotile vein cutting through mesh serpentinite from bottom left to top right.

Geochemistry

Trace elements plotted on discrimination diagrams can indicate the petrogenesis of the protolith. The titanium- vanadium-scandium diagram has been developed for basaltic systems (Pearce & Cann, 1971) and applied to ophiolitic systems. Samples from the Unionville Serpentine Barrens plot within the Island Arc Basalt field to the left. Samples have been significantly depleted in common petrogenetic indicators, therefore, few discrimination diagrams could be utilized.





If this is an island arc basalt, the figure to the right is a depiction of the emplacement. It is proposed that this serpentine body is a magmatic differentiate where olivine accumulated through basement fractional crystallization. The Taconic Orogeny (470 Ma) and collision with the Taconic volcanic arc would be the likely source.

Conclusions

- An uncharacterized serpentine body has been characterized in this study using petrogenetic and geochemical methods
- Using these methods there were few detectable correlation demonstrating the chaotic nature of serpentinization
- Most foliations of the serpentine are conformable to the regional trends
- The predominate texture found in thin section was mesh texture - this texture is interpreted to be a pseudomorphism texture after olivine - the abundance of this texture suggests that the protolith was an olivine-rich rock (dunite-to-hartzburgite)
- The presence of chrysotile crack seal veining and talc crystallization suggests an alteration after serpentinization
- Geochemical data plotted on a basaltic discrimination diagram suggests an island arc affinity for the protolith.

Acknowledgements

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