Investigating the Origin of Pegmatite Dikes in Unionville, PA and the Geochemical Interactions With Surrounding Serpentinites

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ABSTRACT

The Unionville Serpentine Barrens in Chester County, Pennsylvania host a group of pegmatite dikes intruding into a serpentinite body, giving way to complex geochemical reactions. Limited data exists on these pegmatites pertaining to their origin and composition except for a few publications regarding adjacent corundum mining that occurred from 1839 to 1892. Field mapping and sample collection of pegmatites, serpentinites, and intermediary reaction zone rocks was conducted. Thin sections of samples were examined to investigate textural and mineralogical changes across the pegmatite-serpentinite reaction gradient. Geochemical analyses of major and trace elements were used to classify the pegmatites by composition, to identify the origin of the melt that produced the pegmatites, and to observe the extent of elemental component exchange between the pegmatites and serpentinites.

Due to historical mining in the area, outcrop is rare; therefore, general field relationships were determined by presence of localized pits and tailings piles. Existing maps largely disagree with location of pegmatite mine pits, suggesting existing maps may require revision. Pegmatite samples varied in texture by location but maintained a consistent mineralogy (Ab>Qtz>Ms>Tur). Most pegmatite thin sections exhibit some foliation, representing strain imposed on the rocks. Intermediary 'reaction rocks' are generally microcrystalline with extensive veining and brecciation, although they exhibit a gradient of textures depending on proximity to the pegmatite or serpentinite.

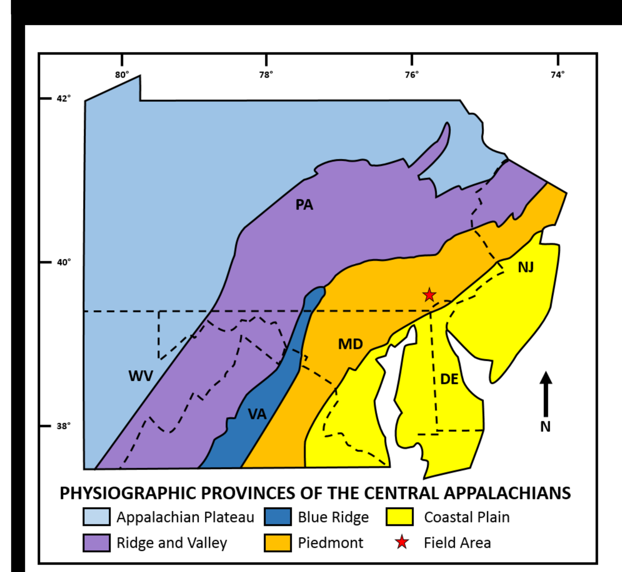
Mineralogical and geochemical data indicates that the Unionville Pegmatites are within the Muscovite-Rare Element pegmatite class. Concentrations of Si, Ce, Sr, Ni, and Cr reveal a consistent compositional gradient from pegmatite to serpentinite in strong agreement with textures observed in thin section. Examination of this geochemical gradient allows for an understanding of component exchange between pegmatites and serpentinites. Plotting trace element concentrations on petrographic discrimination diagrams suggests that the Unionville Pegmatites originated in a volcanic arc setting rather than an anatectic/metamorphic setting.

METHODS

Sample collection and field mapping were conducted; due to scarce pegmatite outcrop, field relationships were largely based on locations of observed mine tailings piles and mine pits.

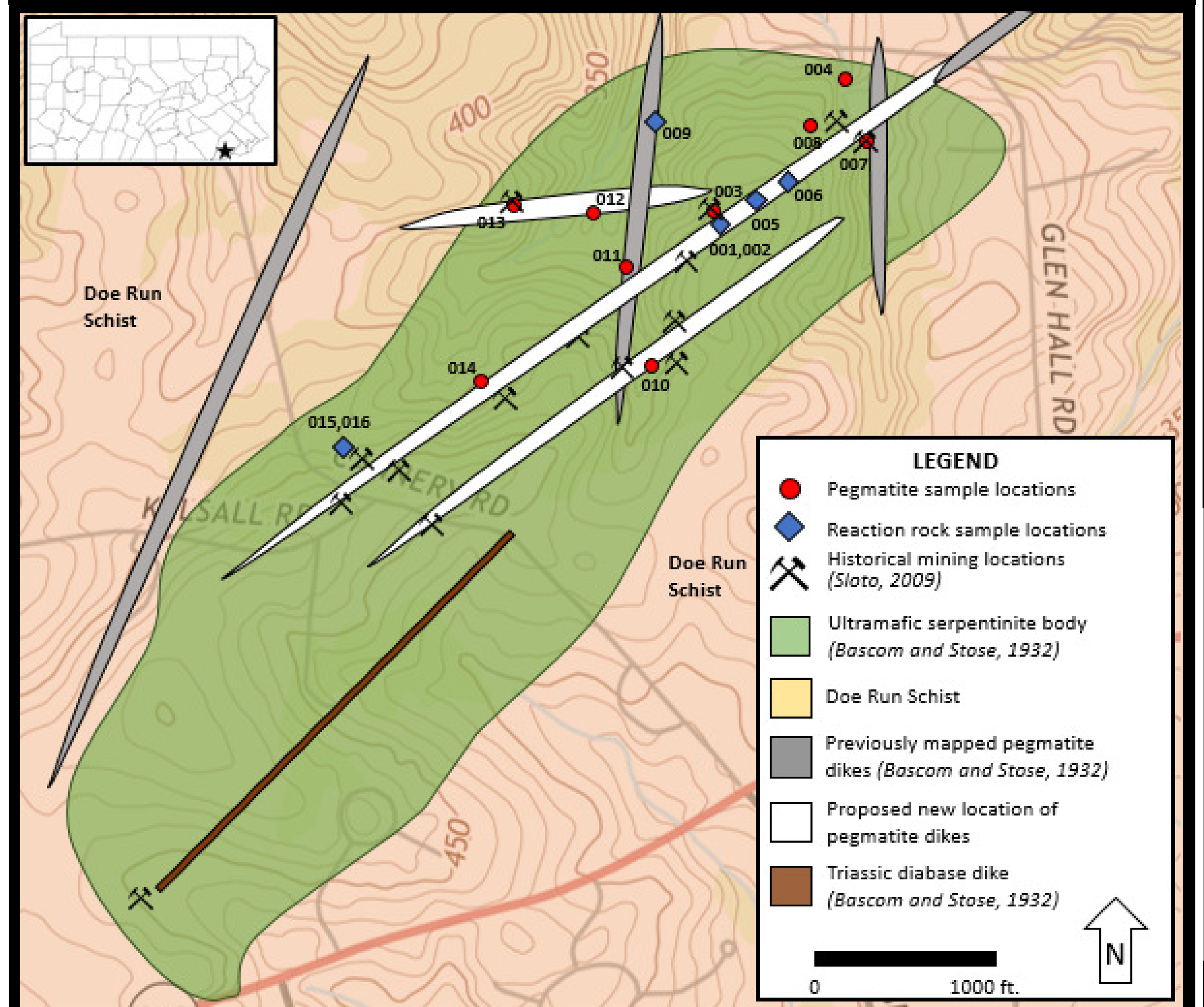
- Petrographic analysis of rock thin sections were used to assess mineralogy and textures of samples using plane polarized light (PPL) and cross polarized light (XPL)
- Major and trace elements were measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and X-Ray Fluorescence (XRF)
- Pegmatites were classified according to the scheme developed by Černý et al. 2005 based on mineralogy and geochemistry.

REGIONAL MAP



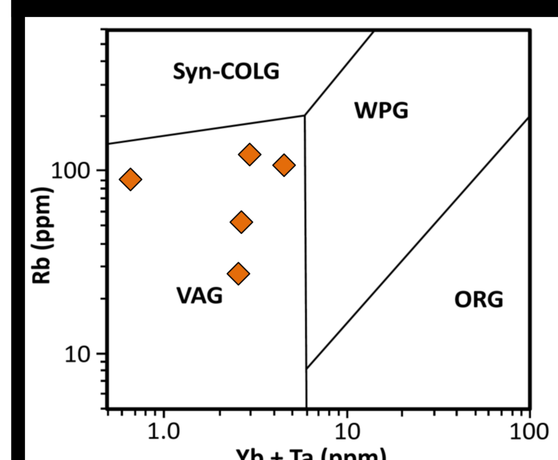
The field area is within the Piedmont Province of the Appalachian Mountain belt. Foliations, shear zones, and other elongate structures all generally conform to the regional NE to SW trends. The majority of pegmatite dikes mapped throughout this regional conform to this trends as well. It is reasonable to assume the Unionville dikes conform.

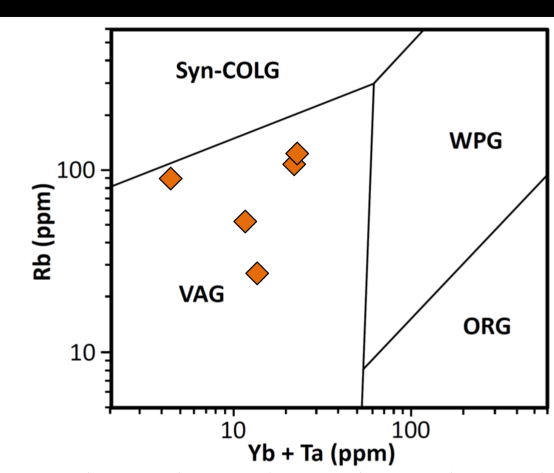
FIELD GEOLOGY



Geologic and historical map of the study area. Pegmatite locations mapped by Bascom and Stose (1932) are shown in gray. Proposed revision of pegmatites based on field relationships, historical mining locations, and regional trends are shown in white. Locations of sample collection and historical mining activity are shown as well.

GEOCHEMISTRY AND MINERALOGY



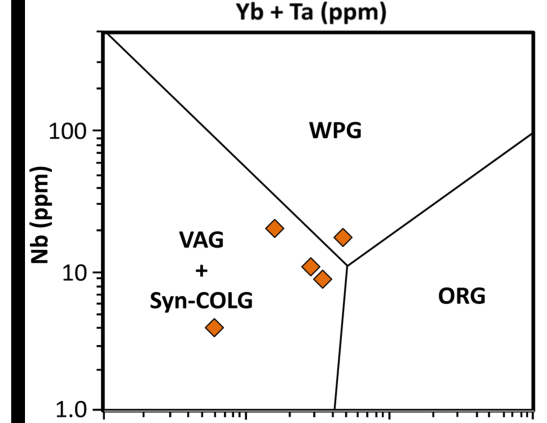


ORG – Ocean Ridge Granite

Syn-COLG – Syn-Collisional Granite

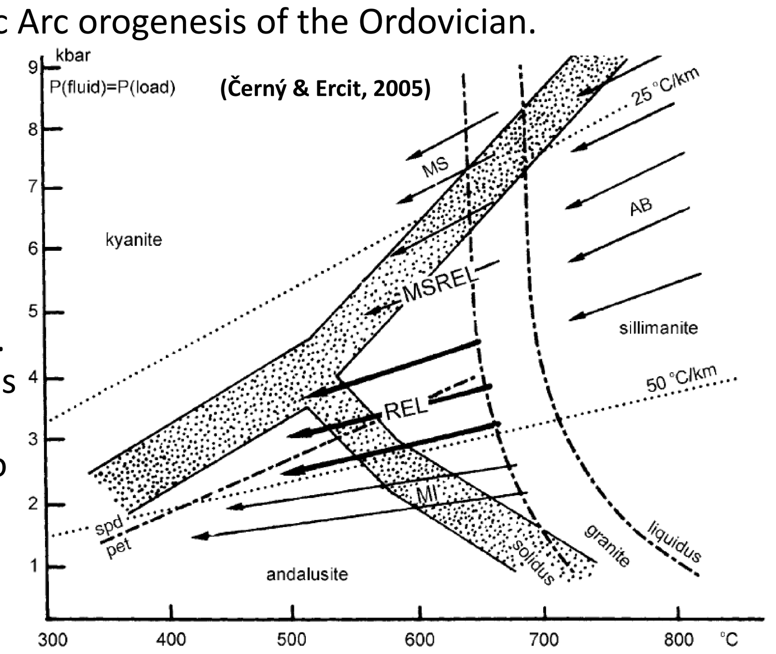
VAG – Volcanic Arc Granite

WPG – Within Plate Granite)

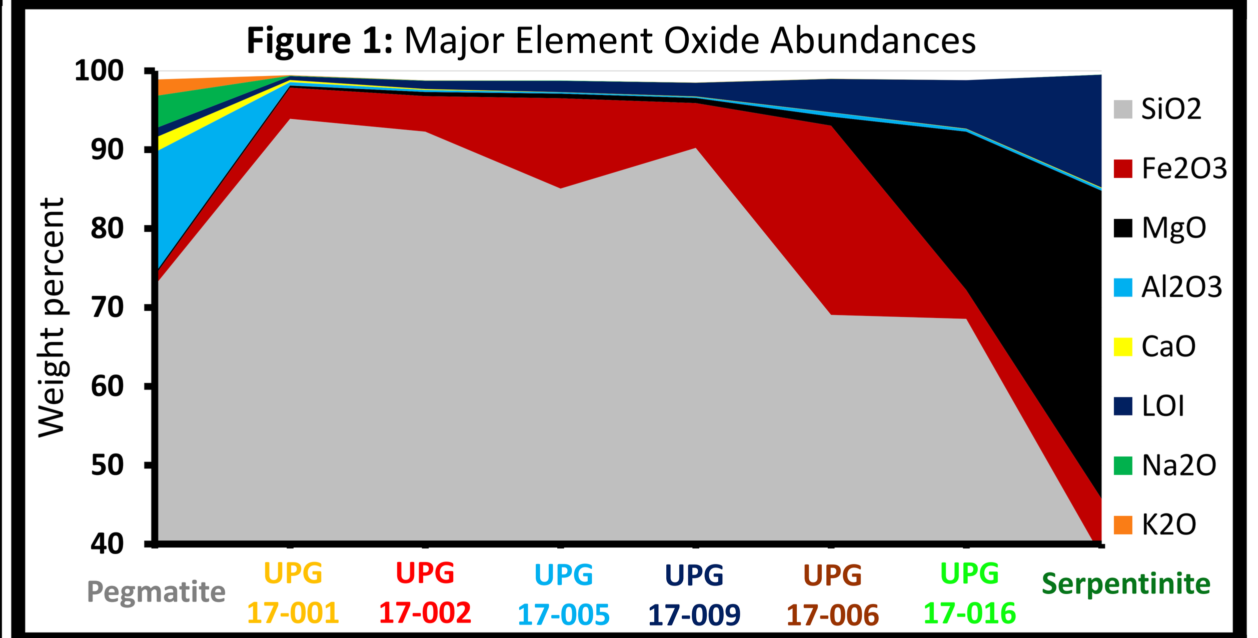


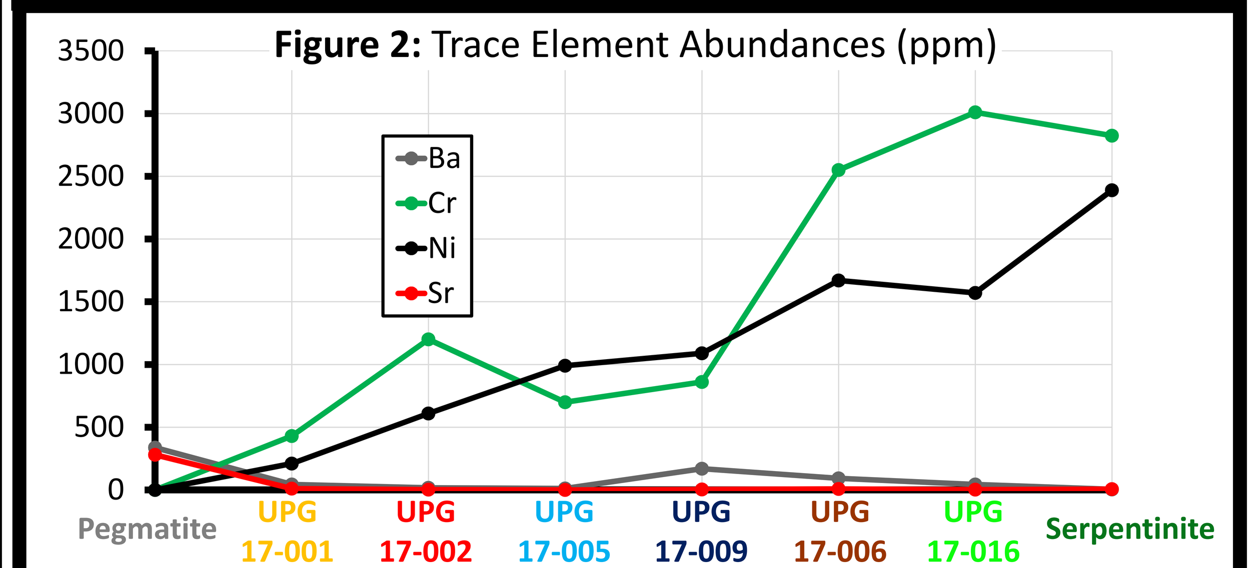
Petrogenesis: Discrimination diagrams for granitic systems after Pearce et al. (1984) plot geochemical signatures indicating that the parental magma of the pegmatites was a Volcanic Arc Granite (VAG). To the best of our knowledge, the pegmatites have not been dated, but given their arc affinity and geologic context they are likely associated with the Taconic Arc orogenesis of the Ordovician.

Pegmatite Classification: Based on mineralogy and geochemistry, the pegmatites are classified as Muscovite-Rare Element (MSREL) Class (Černý & Ercit, 2005). The MSREL class can be derived both igneous and metamorphic settings, however, the P-T conditions for crystallization are restricted to upper Greenschist to Amphibolite facies (see right) , which corresponds well to regional metamorphic conditions of ~600°C and 4-5 kbar (Alcock, 1994).



GEOCHEMICAL ANALYSES





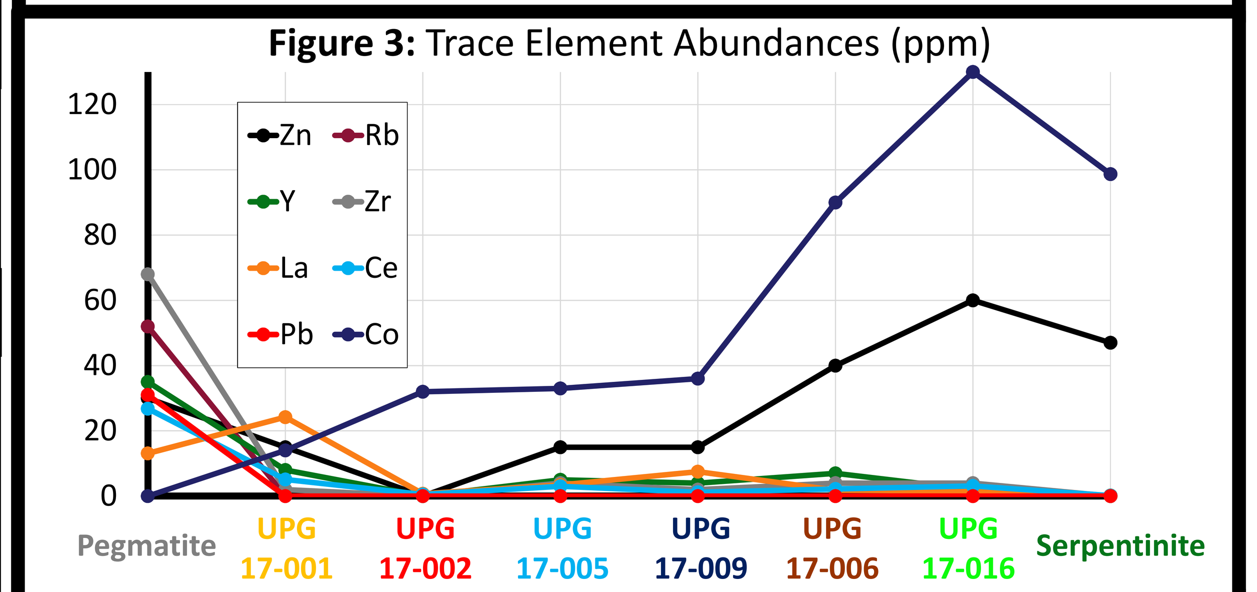
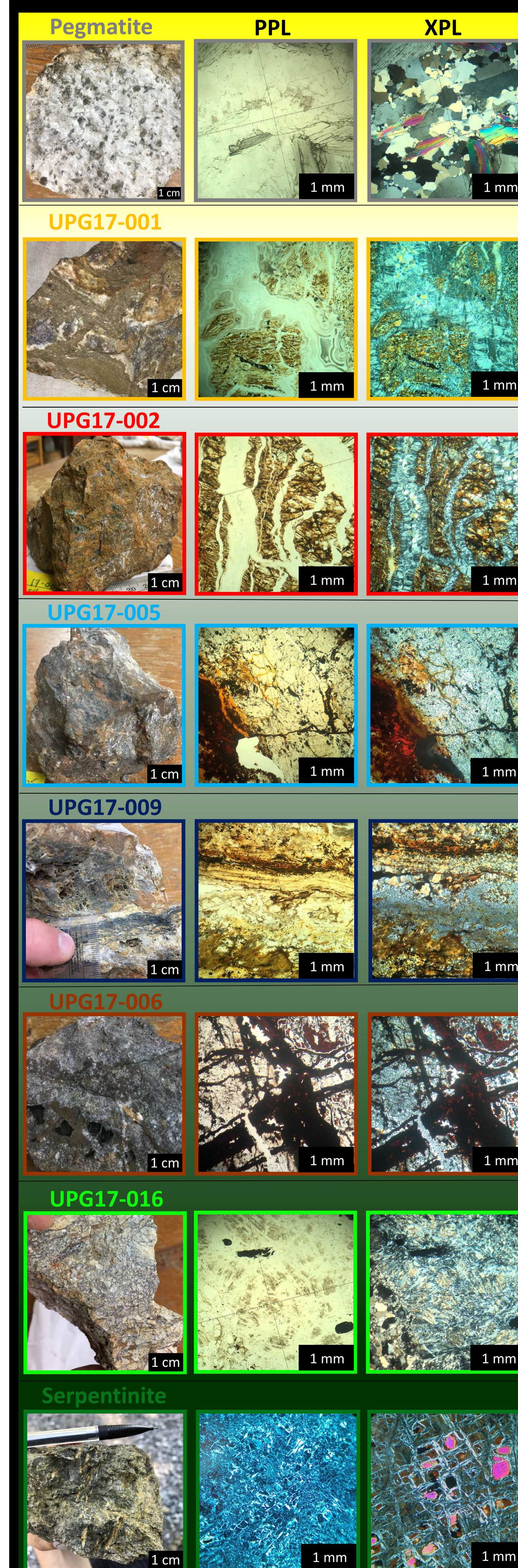


Figure 1: Major elemental oxide abundances by weight percent for each sample. Clear trends in major element oxide ratios are seen in 'reaction rock' samples between pegmatite and serpentine samples; higher SiO_2, K_2O, Na_2O, CaO, and Al_2O_3 correlate to lower abundances of Fe_2O_3, MgO, and LOI (loss on ignition/water).

Figure 2: Trace element abundances of Ba, Cr, Ni, and Sr in ppm. Serpentinites are the most Cr- and Ni-rich while pegmatites are Cr- and Ni-poor. Reaction rocks show consistent trends regarding these components.

Figure 3: Trace element abundances of Zn, Rb, Y, Zr, La, Ce, Pb, and Co showing trends in element distribution across the pegmatite-serpentinite reaction zone.

HAND SAMPLE & THIN SECTION DESCRIPTIONS



Pegmatite

Hand Sample: mainly feldspar with some graphic quartz; abundant micas ranging in size from 1 to 4 mm in diameter

Thin Section:
- 55% albitic feldspars: occur as phenocrysts up to 1 cm, often in contact with other phenocrysts
- 35% quartz: interstitial between feldspar phenocrysts; grains as large as 1 mm in diameter; some undulatory extinction
- 10% muscovite and biotite micas, minor tourmaline

UPG17-001

Hand Sample: brown with orange patches and gray-blue crystalline brecciated clasts

Thin Section:
- 50% extensively fractured microcrystalline clasts of orange material (quartz?) infilled with clear quartz veining and encased in concentric agate coatings
- 50% patches of clear microcrystalline material, likely quartz
- Accessory oxides, probably removed from serpentinite body during pegmatite emplacement

UPG17-002

Hand Sample: mottled brown/orange microcrystalline groundmass with extensive clear veining and scattered pockets of small green crystals

Thin Section:
- 50% orange microcrystalline lenses separated by extensive quartz veining and encased in concentric agate coatings indicating multiple pulses of fluid flow
- Orange material more fractured/veined than UPG17-001
- 1% chlorite inclusions in fractured microcrystalline clasts

UPG17-005

Hand Sample: mottled brown, orange, and black microcrystalline rock with colorless aphanitic mineral coatings on surface

Thin Section:
- 85% microcrystalline, colorless to gray with some orange iron staining
- 10% randomly oriented hematite veins
- 3% mica occurring in thin books oriented parallel to veins
- 2% chlorite

UPG17-009

Hand sample: a chunk of deformed, vein-banded serpentinite with regions of highly variable hardness

Thin Section:
- 50% microcrystalline quartz, 50% grains visible under microscope
- 10% iron/opaque veining; hexagonal opaque grains up to 0.2 mm, concentrated in stained quartz veining
- veins are oriented in parallel repetitive bands; cleaner quartz veins are oriented perpendicular, probably latest veining

UPG17-006

Hand sample: brown, microcrystalline, contains dark veins of very fine iron oxide crystals

Thin Section:
- 60% quartz (mostly microcrystalline)
- 25% hematite veins and opaque lenses in sets at 90° to each other; indicative of multiple events of hydrothermal fluid pulses: first, iron-rich fluid, then quartz-rich fluids
- micas occur in localized books that have been ripped apart

UPG17-016

Hand sample: mainly serpentinite with iron oxide veining and pockets of coarse brecciated clasts

Thin Section:
- 60% quartz, mostly microcrystalline
- 10% iron staining
- 30% serpentinite texture
- veins run every direction with no preferred orientation

Serpentinite

Hand sample: nearly 100% serpentine, various textures and serpentinization styles present within the rocks

Thin-Section:
- Serpentine (generally >90%) – overwhelming lizardite with late stage chrysotile veining, relict olivine grains (<5%, if present), oxides
- Mesh texture with occasional bastite/interpenetrating /interlocking

RESULTS & CONCLUSIONS

- Mapped pegmatite dike locations were revised according to field relationships, historical mining works and regional trends
- Geochemical signatures of the pegmatite samples indicate a parental volcanic arc magma, likely associated with the Ordovician-age Taconic Orogeny
- Geochemistry and mineralogy classify the pegmatites within the Muscovite-Rare Element Class
- Geochemical analyses of major and trace element abundances demonstrate a chemical reaction gradient between the pegmatite and serpentinite, illustrating the extent of component exchange and elemental mobility during the emplacement of the pegmatite
- Thin-section evaluation of textures and mineral mode are in agreement with geochemical trends
- The sharpest geochemical trends are observed from the pegmatite to the first reaction rock; this is followed by gradational increases/decreases toward the serpentinite country rock

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