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PETROGENESIS AND INTERACTIONS OF SERPENTINITES INTRUDED BY PEGMATITE DIKES, UNIONVILLE SERPENTINE BARRENS, CHESTER COUNTY, PENNSYLVANIA

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FIGURES

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PETROGENESIS AND INTERACTIONS OF SERPENTINITES INTRUDED BY PEGMATITE DIKES, UNIONVILLE SERPENTINE BARRENS, CHESTER COUNTY, PENNSYLVANIA

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ABSTRACT

The Unionville Serpentine Barrens in Chester County of southeastern Pennsylvania is a geologically unique location with drastically different geologic units in close association. The area is defined by a serpentinite body (approximately 2 km by 0.75 km) within the Doe Run Schist, and both are intruded by at least four felsic pegmatite dikes. Using a combination of field mapping and sampling, petrographic analyses, and geochemistry, the serpentinite, pegmatites, and contact aureoles have been examined. The serpentinite was determined to be a chaotic unit with few systematic trends. Geochemical analyses support the hypothesis that this unit was originally the basement component of an island arc that collided with the eastern margin of North America about 450 million years ago. Field mapping revealed that previously mapped locations of the pegmatite intrusions are not accurate; instead of the north-south orientation depicted on most geologic maps, it is more likely that the intrusions follow a northeast-southwest trend parallel to the regional geologic trends of foliation and shear zones. Based on geochemical and mineralogical data, the Unionville pegmatites are within the muscovite-rare-element class. Trace elements plotted on granitic discrimination diagrams suggest that the source melt for the pegmatite intrusions is likely volcanic-arc granites or postcollisional granites. Examination of samples collected in the contact aureoles allows for the reconstruction of the geochemical gradient across those boundaries. Petrographic textures and element concentrations across the contact aureoles depict areas largely affected by magmatic fluids where significant component exchange occurred.

INTRODUCTION

The Unionville Serpentine Barrens, located in the ChesLen Preserve, Chester County, Pa. (Figure 1), is home to a number of interesting geologic phenomena that have received little petrologic examination. The defining feature of the Unionville Serpentine Barrens is a serpentinite body (approximately 2 km by 0.75 km, trending northeast-southwest) that had been emplaced into the surrounding Doe Run Schist and then later intruded by pegmatite dikes. The locality was mined for mineral resources, including corundum, feldspar, and serpentine, in the late 1800s to early 1900s. Generations of mines have operated within the Unionville Serpentine Barrens, but the few published studies on the area have focused on

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descriptive mineralogy or regional geology with little attention to the petrogenesis of the serpentinite or pegmatites (Academy of Natural Sciences, 1872; Leidy, 1872; Willcox, 1883; Rand and others, 1892; Pennypacker, 1895a–f; Gordon, 1921; McKinstry, 1921; Bascom and Stose, 1932; Pearre, 1958; Pearre and Heyl, 1960; Wiswall, 2005; Sloto, 2009; Latham and McGeehin, 2012; Schagrin and Bosbyshell, 2013). Key questions remain unanswered, such as what is the geologic history of these rocks? and how do rocks with extreme compositional differences interact under elevated pressures and temperatures? This study presents field, petrologic, and geochemical evidence pertaining to the geologic origin of the rocks and examines the interactions of these drastically contrasting geochemical units.

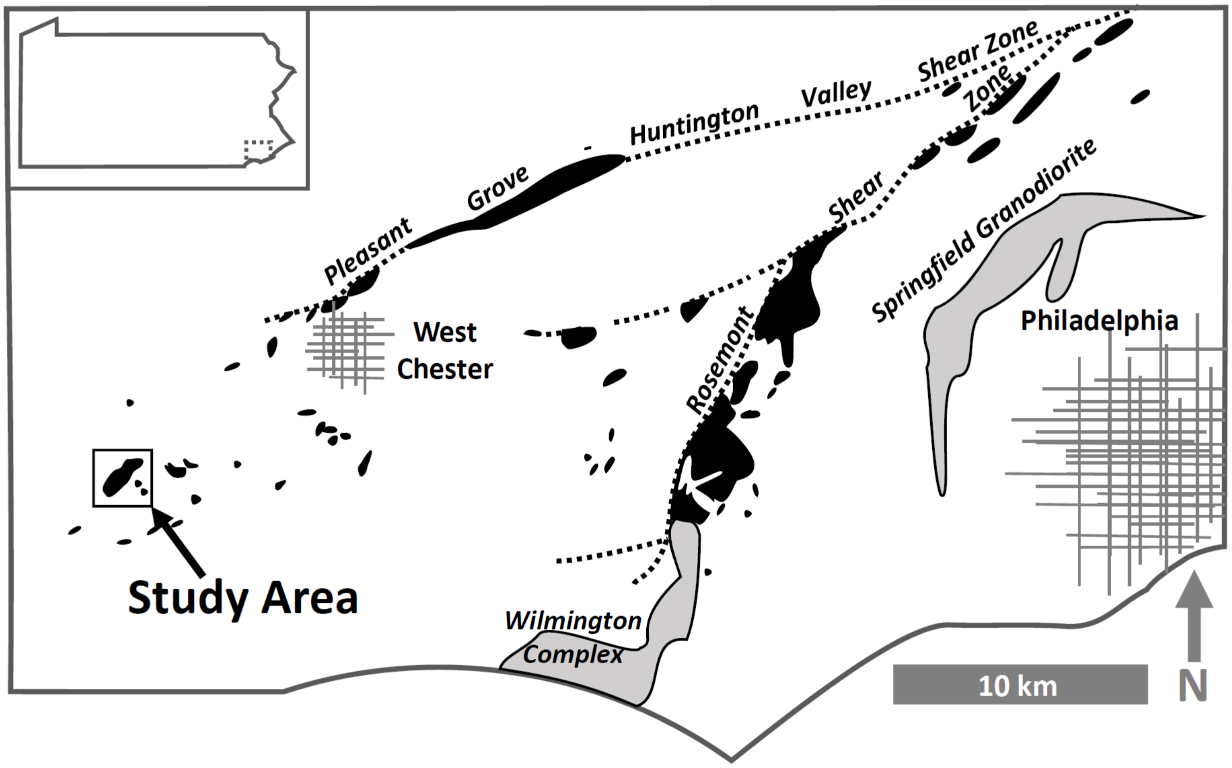

Figure 1. Generalized geologic map of southeastern Pennsylvania showing the locations of ultramafic bodies (black) and major faults (dotted lines) in the Pennsylvania Piedmont. Data modified from Bosbyshell and others (2016) and Pennsylvania Geological Survey (2019).

GEOLOGIC BACKGROUND

The Unionville Serpentine Barrens are located in the Piedmont province of the Central Appalachian mountain belt, which is composed of several suites of metamorphic and igneous rocks that owe their origin to Grenvillian (about 1100 Ma) and Taconic (about 450 Ma) orogenic events. Significant geologic investigations have been completed in the Piedmont; however a series of ultramafic rock bodies have eluded proper characterization. Most of the Piedmont ultramafic bodies, including the Unionville Serpentine Barrens, are small, elongate pods (0.5 to 2 km long and 0.1 to 0.5 km thick) of altered ultramafic rock (Figure 1). Ultramafic rocks can be included in mountain belts in a number of ways. Proposed hypotheses for the origins of the Piedmont bodies are as follows: pieces of oceanic crust caught within a tectonic collision (DeSantis, 1978; Wagner and Srogi, 1987; Carnes, 1990; Faill, 1997); igneous rock that diapirically rose from the mantle below (Bascom and others, 1909; Weiss, 1949; Amenta, 1974; Crawford and Crawford, 1974); and part of a magma chamber associated with the arc terranes that collided with North America about 470 Ma (Busé and Watson, 1960; Kerrigan and others, 2017).

Additionally, research conducted on the State Line serpentinites, a large ultramafic body about 25 km southwest of Unionville, Pa., shows it has a close association with the Baltimore Mafic Complex and has been interpreted to be part of a large layered mafic intrusion in a subarc plutonic complex (McKague, 1964; Hanan and Sinha, 1989; Sinha and others, 1997; Smith and Barnes, 2008). The possibility of the Unionville serpentinite being related to a large layered mafic intrusion has not been ruled out.

Pegmatite dikes in the Doe Run Schist and the serpentinite body at Unionville, Pa., are believed to be tabular, vertically oriented intrusions (Figure 2). Pegmatites are igneous rocks that are considered to be one of the last phases of crystallization of a cooling magma chamber; however some pegmatites can have metamorphic origins through the accumulation of partial melt. The age and exact origin of the pegmatites in the Unionville Serpentine Barrens are unknown, but they must be younger than the serpentinite and schist based on cross-cutting relationships. The composition of pegmatites is unlike that of serpentinites, while they can have a wide range of composition, most are considered to be extremely felsic. When pegmatites intrude, blackwall can develop in various zones of alteration that result as the pegmatite exchanges components with the host rock (Sanford, 1982). Pegmatites and serpentinites are rarely juxtaposed; however at Nottingham County Park in southwestern Chester County (32 km southwest from Unionville, Pa.) this rare association occurs and has been examined (Smith and Barnes, 1998). The Unionville Serpentine Barrens offers a rare opportunity to examine this interaction further.

Geologic maps of the report area show a diabase dike cutting the serpentinite and schist (Figure 2); however this could not be substantiated with field data. Samples of diabase float were occasionally encountered in the field near the east-central portion of the serpentinite body, but outcrop of the diabase was not found during this study. The location where the diabase was purported to be located is on private property, and access was not available. For these reasons, no assessment of the diabase was attempted during this study.

MINING HISTORY

In the mining literature, the Unionville Serpentine Barrens are commonly referred to as Corundum Hill, but historically, it has also been referred to as Beryl Hill, Unionville, and Point Prospect (Sloto, 2009). Corundum was first discovered at this locality in 1822 by John and Joe Bailey, farmers who were bothered by the presence of the hard deposits cutting (McKinstry, 1921). By 1844, the first corundum mine was functioning at Unionville, Pa., and operated until 1895 (Sloto, 2009). During the 60-plus years of operation, reportedly 350 to 400 tons of corundum was extracted to be used for polishing wheels and grinding or plate glass (Sloto, 2009). The corundum (having some crystals up to 60 cm in length) showed a

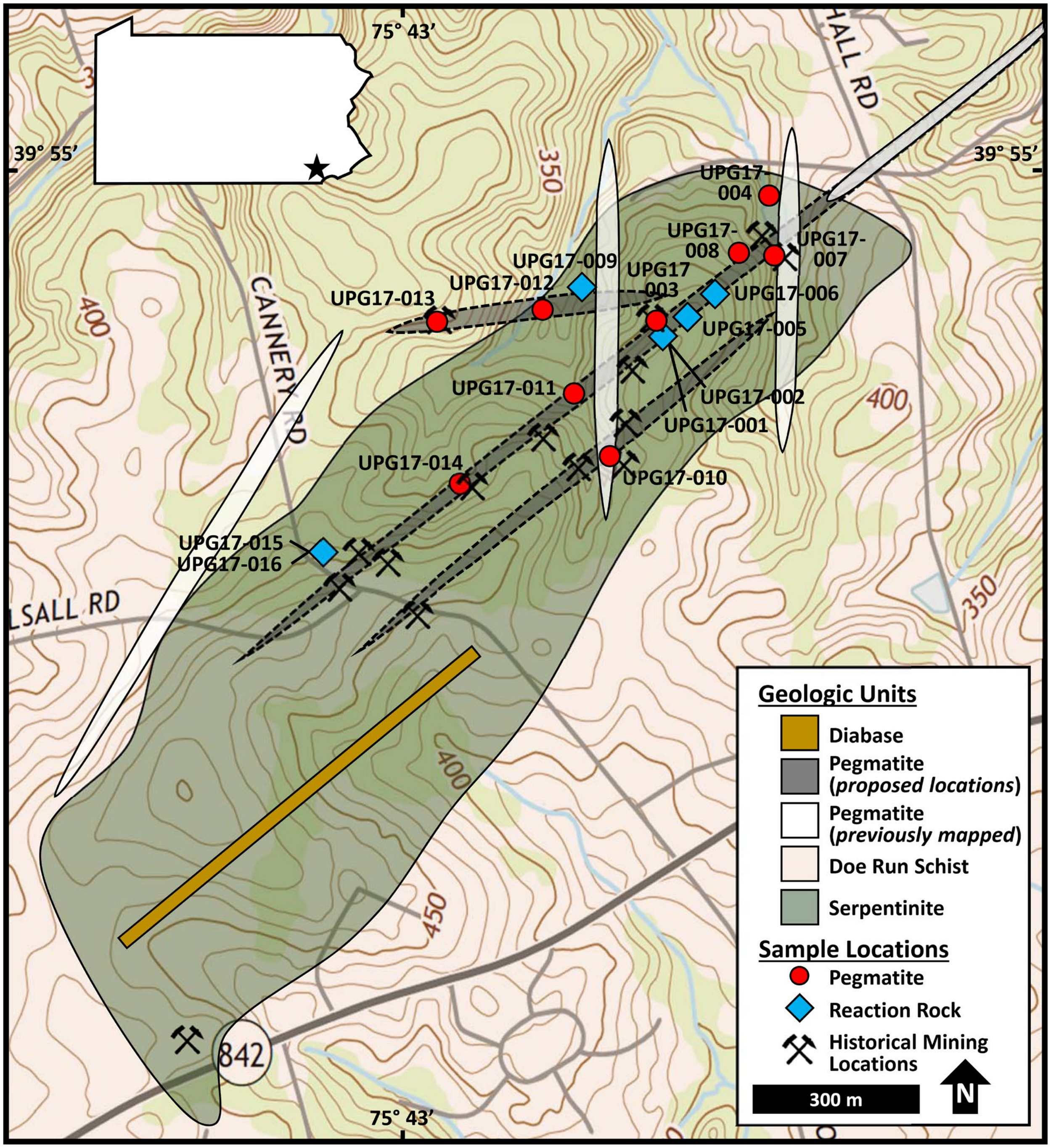

Figure 2. Map of the Unionville Serpentine Barrens showing historically mapped pegmatite locations (Bascom and Stose, 1932), proposed new locations of pegmatite intrusions, historical mining locations (Sloto, 2009), and sample locations of pegmatites and related reaction rocks.

close association with the pegmatite, which was commonly referred to as a "granular albite," but most reports placed the corundum deposits at the pegmatite-serpentinite contact and extending into the serpentinite (McKinstry, 1921). It should be noted that no corundum was found during this study.

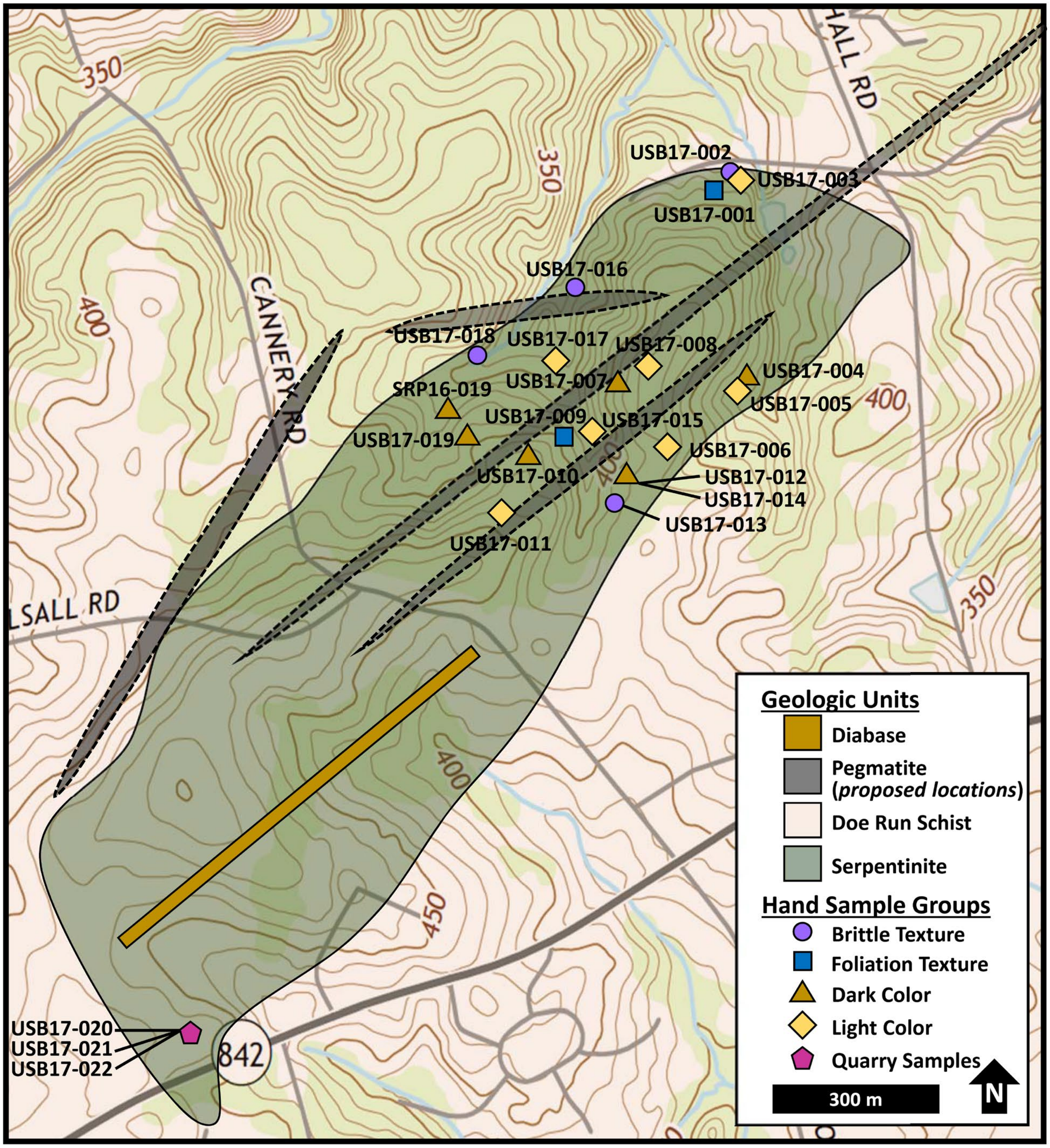

Figure 3. Map of the Unionville Serpentine Barrens showing the location of serpentinite hand samples subdivided into color and textural groups (explained in the text).

From the 1850s to the 1900s the pegmatite intrusions were mined for feldspar, some of which was used in the production of porcelain teeth (Sloto, 2009). Large tourmaline and beryl crystals were reported in the pegmatites, with one beryl crystal weighing up to 51 lbs (Sloto, 2009). Previous reports of mining activity described black tourmalines in direct contact with long crystals of grayish-white corundum (McKinstry, 1921). In the southern and eastern sides of the serpentinite body, there is a large accumulation of lode and placer

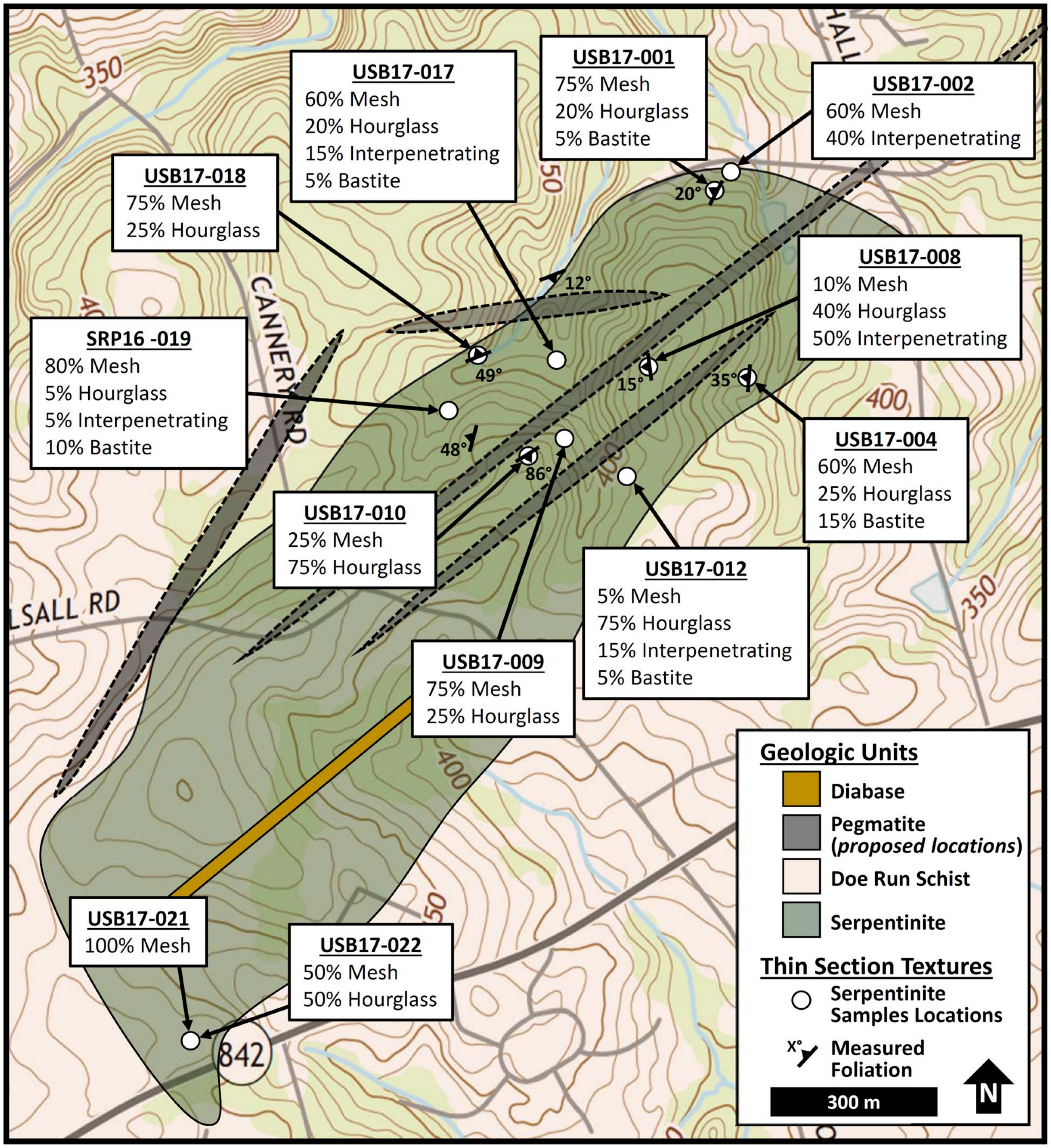

Figure 4. Map of the Unionville Serpentine Barrens showing the locations of serpentinite samples examined by thin section, percentages of serpentinite textures observed, and foliation measurements.

chromite and reportedly "thousands of tons have been taken from the soil" (Rand and others, 1892). In addition to its economic importance, the Unionville deposits are still a draw for mineral collectors in the region; however mineral collecting must be approved by the ChesLen Preserve.

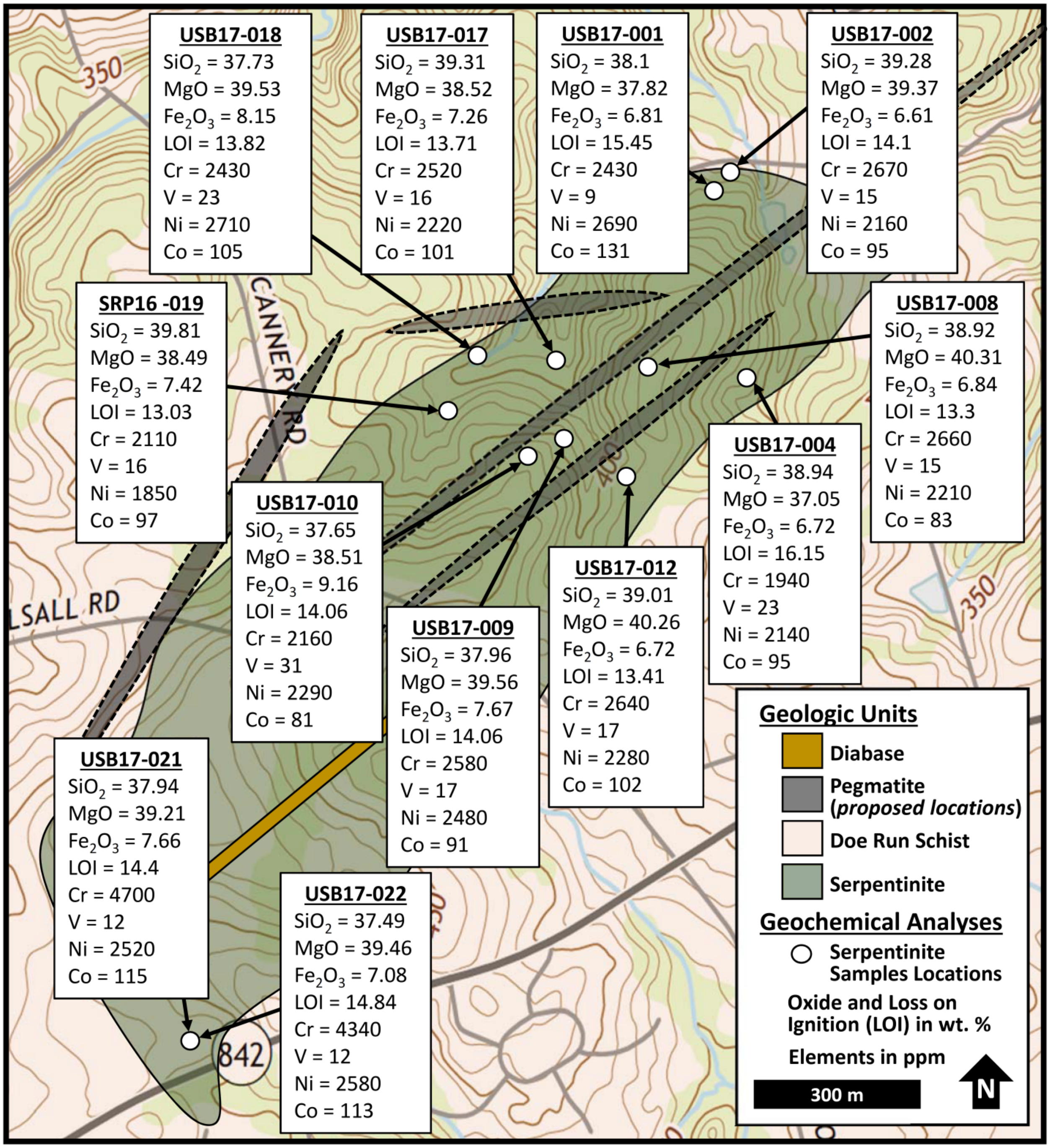

Figure 5. Map of the Unionville Serpentine Barrens showing the locations of serpentinite samples submitted for major- and trace-element analyses, with some representative analyses listed.

METHODS

A combination of field mapping, rock sampling, geochemical analyses, and petrographic analyses of rock thin sections was undertaken. Previous geologic field mapping conducted on the area (Bascom and others, 1909; Bascom and Stose, 1932; Wiswall, 2005), mineral exploration records (Sloto, 2009), and mineralogical descriptions (McKinstry, 1921; Pearre, 1958) often contradict each other or do not match observed field relations. Geologic field mapping was conducted to determine the structural and lithologic field relations. A total of 40 samples were collected throughout accessed areas for examination of macroscopic textures and mineralogy of pegmatite and aureole (reaction) rocks (Figure 2) and serpentinites (Figure 3). A subset of 24 samples was analyzed for whole-rock major- and trace-element compositions (a total of 57 elements) by X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) at Activation Laboratories of Ancaster, Ontario, Canada (Appendix 1). Samples submitted for geochemical analyses were also petrographically examined in thin section to identify microscopic textures and mineralogy. Three serpentinite samples were examined by X-ray diffraction (XRD), which positively identified the serpentinites as dominated by the mineral lizardite.

RESULTS

PEGMATITE AND CONTACT AUREOLE FIELD RELATIONSHIPS AND PETROGRAPHY

Due to historic mining at the Unionville Serpentine Barrens, few pegmatite samples or associated reaction rocks (found in contact aureoles) were collected in place. The absence of precise geographic data for collected samples made quantitative spatial reconstructions impossible; however relative relationships were investigated by examining the spatial relationships of mining remnants. Excavated mine pits and adjacent tailings piles provided the majority of samples for this study. The pits and piles containing pegmatites and reaction rocks largely did not correspond with the locations of the intrusions mapped by Bascom and Stose (1932) (Figure 2), suggesting that the pegmatite intrusions may have different strikes. The intrusion shapes and sizes depicted on previous maps correspond to field data collected for this report; however these data suggest the pegmatite bodies trend northeast-southwest rather than north-south. Historical mining locations and observed mine pits and tailings piles were used to propose revised locations of the pegmatite intrusions (Figure 2). These suggested revisions of pegmatite intrusion locations correspond to the regional geologic trends in foliations and shear zones, as well as to orientations of other nearby pegmatite intrusions (Bascom and Stose, 1932).

A representative group of six pegmatite samples and six reaction-rock samples were cut into thin sections and analyzed for bulk major and trace elements (Appendix 1). Five of the six pegmatite samples observed in thin section exhibited minor foliation; one sample (UPG17-004) lacked foliation textures and therefore was used as a representative undeformed pegmatite for this locality. Based on mineralogy and geochemistry, the Unionville pegmatites are in the muscovite-rare-element (MSREL) class of Černý and Ercit (2005). The Unionville pegmatites are characterized by an abundance of albitic feldspars (typically >50 percent) up to 3 cm across with interstitial quartz grains (approximately 30 percent). Muscovite and biotite mica compose approximately 10 percent of the mineral volume on average, with occurrences of accessory tourmaline and beryl and other minor components. In addition to corundum, various other mineral species (alkali feldspar, clinochlore, brucite, gibbsite, hematite, magnetite, margarite, muscovite, pyrite, spinel, talc, and tourmaline), mineral groups (asbestos ["mountain cork"] and limonite), and now discredited mineral species (corundellite, deweylite, euphellite, jefferisite, lesleyite, and unionite) have been reported at Unionville (Bascom and Stose, 1932; Sloto, 2009).

Adjacent to the pegmatites, within contact aureoles, are severely altered reaction rocks. Contact aureoles appear to consist of approximately 10-m-wide areas adjacent to the pegmatite intrusions. These highly altered rocks exhibit extensive veining, varying colorations, and textures consistent with metasomatic alteration (Figure 6). The pegmatite-serpentinite contact was not observed in situ; however the collected reaction rocks exhibited a gradation in composition and texture that allowed for their relative placement with respect to the pegmatites and serpentinite. Hence, although assumptions were necessary, the relative geochemical gradients were discernible. Samples directly adjacent to the pegmatite intrusions contain significant quartz veining, whereas virtually all serpentinite components have reacted out. In hand sample, reaction rocks are generally mottled or banded and microcrystalline to very fine grained, and they display slightly coarser grained, randomly oriented veins throughout. Veins in reaction rocks occur in several habits: (1) as concentric layers of microcrystalline agate coatings on highly fractured, orange clay clasts (Figures 6B and 6F); (2) as very fine grained, red hematite veins (Figures 6C and 6G); (3) as slightly colorless to white, coarser grained quartz, typically containing scattered opaque grains (Figures 6D and 6H); and (4) as completely opaque veins (some seen in Figures 6C and 6G). The photographs of hand samples and photomicrographs of thin sections seen in this study demonstrate the severely altered nature of these rocks.

PEGMATITE AND CONTACT AUREOLE GEOCHEMISTRY

Representative geochemical trends across a contact aureole from a pegmatite into the serpentinite country rocks can be seen in Figure 7, and element concentrations for the same samples are included in Appendix 1. The analyzed reaction-rock samples displayed a gradational relationship of major and trace elements. Using elemental concentrations and observed textures, it was possible to reconstruct the relative position of these samples with respect to the pegmatite and serpentinite end members. The most-pristine pegmatite (UPG17-004) was used for the end-member pegmatite composition, and the average of 12 serpentinite samples were used for the end-member serpentinite composition. The most-abrupt changes in geochemistry occur between the pegmatite and the inferred most-proximal reaction rock. A sharp contrast in SiO_2 and Al_2O_3 can be seen at this transition (Figure 7A), and thus there is interpreted to be near-complete replacement of serpentinite by silica-saturated fluids adjacent to the intruded pegmatite body. The remaining reaction-rock samples exhibit a gradational change toward serpentinite-like compositions, progressively increasing in magnesium and water (loss on ignition [LOI] is used as a proxy for water content of samples) and decreasing in silicon, calcium, sodium, and potassium. Iron trends were difficult to interpret given the variable presence of hematite veining in many of the reaction rocks.

A set of trace-element concentrations showed similar geochemical trends as observed in the major-element oxide concentrations (Figure 7). Unionville pegmatites contained significantly higher abundances of barium (Ba), strontium (Sr), cerium (Ce), rubidium (Rb),

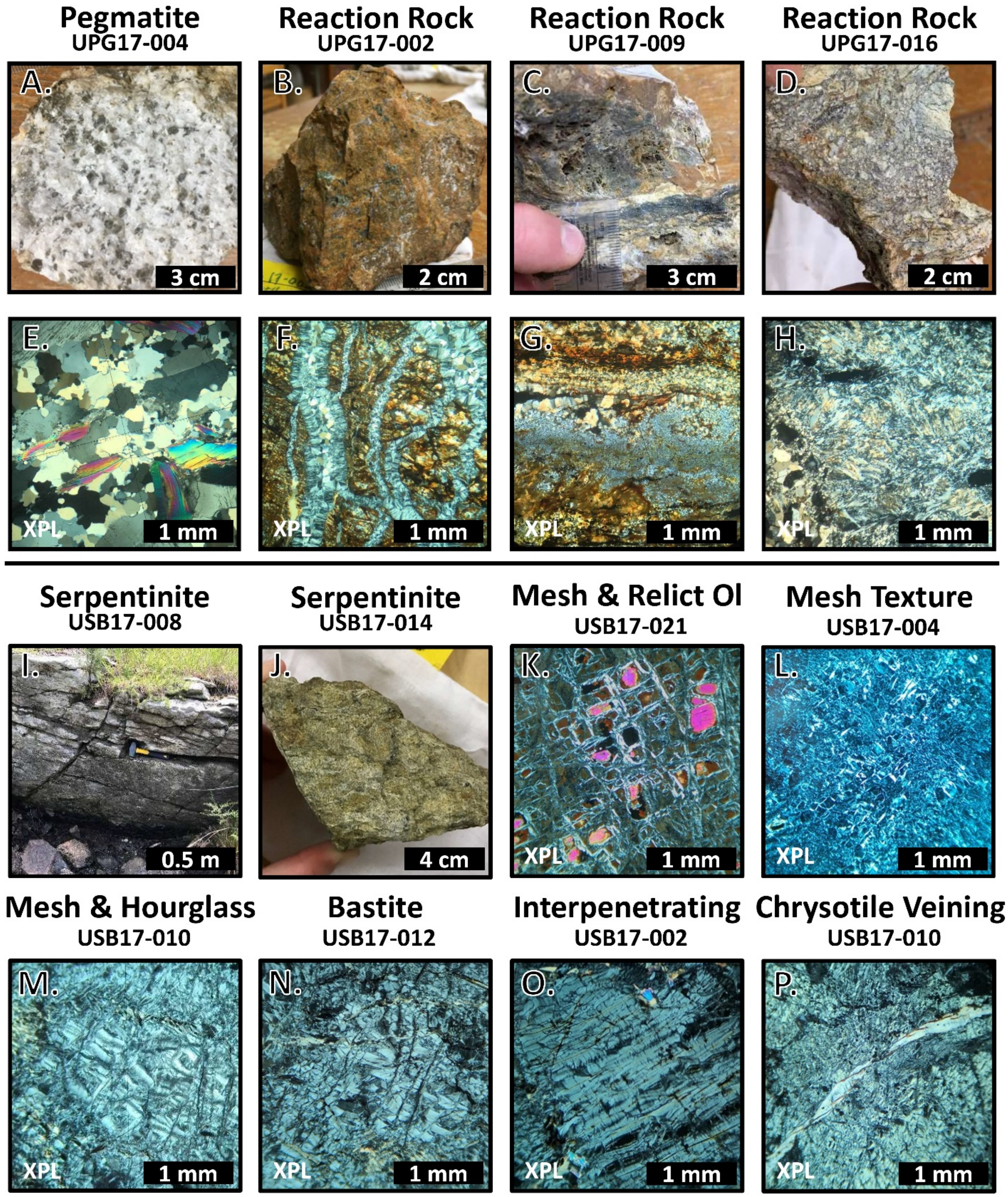

Figure 6. Images and photomicrographs of pegmatite, reaction-rock, and serpentinite hand samples from the Unionville Serpentine Barrens. (See Figures 2 for sample locations.) **A–D.** Hand samples of pegmatite and reaction rocks adjacent to pegmatite intrusions; **E–H.** Photomicrographs in cross-polarized light of samples shown in A through D; **I.** Serpentinite outcrop; **J.** Serpentinite hand sample; and **K–P.** Photomicrographs of serpentinite textures.

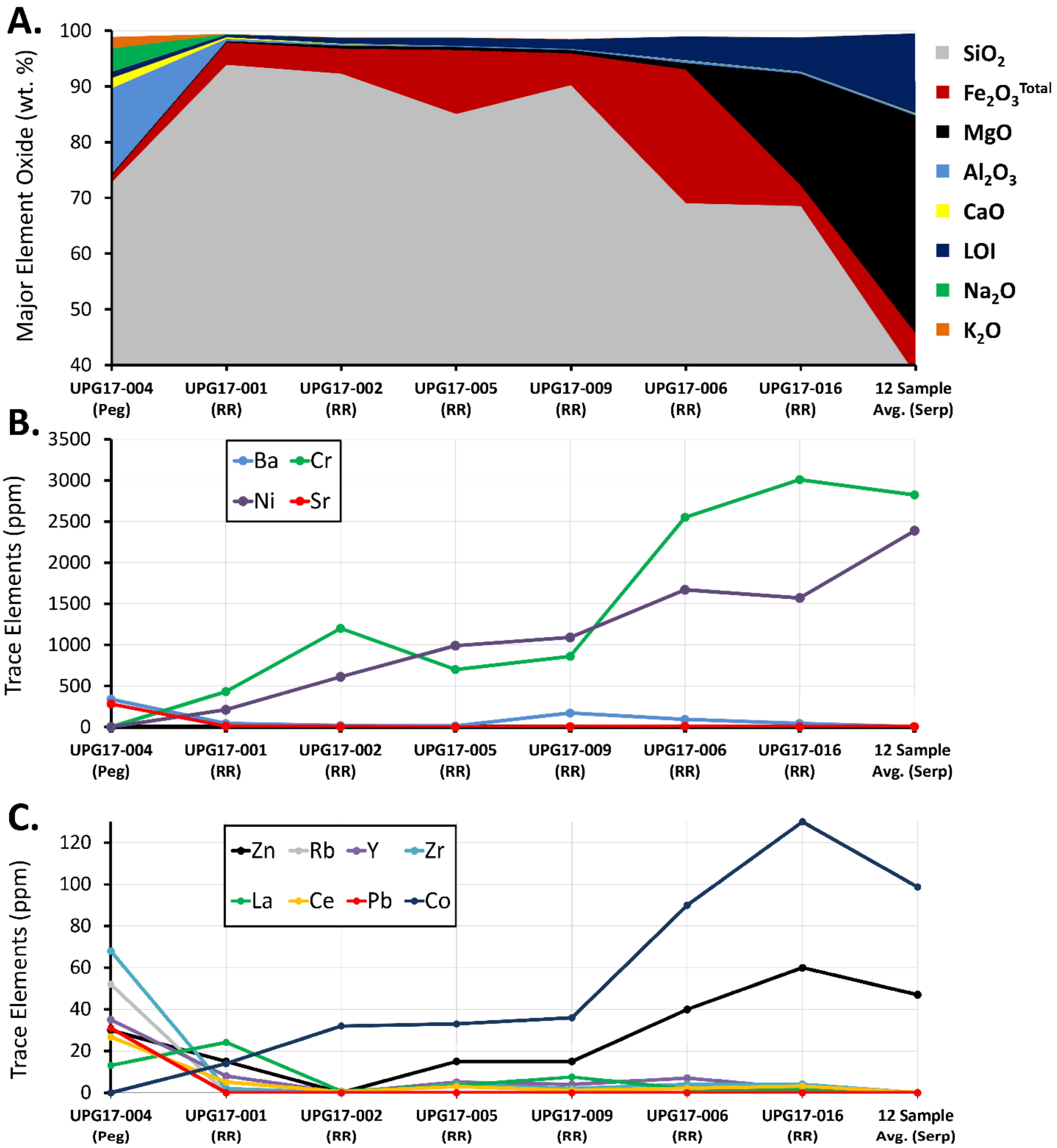

Figure 7. Representative geochemical transect across a contact aureole from pegmatite (“Peg” on left) through reaction rocks (“RR”) to serpentinite (“Serp” on right). Samples are arranged by textural and mineralogical supported evidence of alteration and not relative spatial distance in the field. (See Figure 2 for sample locations.) **A.** Major elemental oxide abundances by weight percent (total iron reported as Fe_2O_3; LOI = loss on ignition) Serpentinite values represent the average concentrations of samples shown in Figure 5). **B.** High-concentration trace-element abundances. **C.** Low-concentration trace-element abundances.

zirconium (Zr), lanthanum (La), and yttrium (Y) in comparison to the serpentinite body, while the serpentinite contained substantially more chromium, nickel, cobalt, and zinc. Based on the trends observed in these elements across the reaction-rock samples, there appears to be a relatively consistent chemical gradient between the granitic pegmatite dikes and surrounding ultramafic serpentinite.

Trace-element concentrations of the pegmatite and serpentinite samples were plotted on petrogenetic discrimination diagrams after Pearce and others (1984), Pearce (1996), and Vermeesch (2006) to identify their origin (Figure 8). The diagrams of Pearce and others (1984) and Pearce (1996) are intended for granitic compositions, which generally includes the Unionville pegmatites and can approximate the environment of formation in the absence of a pegmatite-specific discrimination diagram. Most of the pegmatite study samples plotted within the volcanic-arc-granite and the postcollisional-granite fields (Figure 8A–C), indicating that the parental magma was part of an accreted volcanic-arc system that collided with the eastern margin of Laurentia, or potentially the magma was an anatectic melt generated by high-grade metamorphism. Although the pegmatites have not been dated, they are likely associated with the Taconic orogeny given their arc or anatectic affinity and the geologic context in which they are found. Additionally, rare-earth elements were plotted on various spider diagrams and showed a negative slope with a small negative europium anomaly, suggesting the presence of plagioclase depleting the melt of europium.

SERPENTINITE FIELD RELATIONSHIPS AND PETROGRAPHY

Numerous outcrops of serpentinite were encountered at the Unionville Serpentine Barrens. Most serpentinite outcrops exhibited a massive habit, but the few that displayed a coherent foliation showed orientations ranging from 180° to 240° in strike and 15° to 50°NW in dip. The measured serpentinite foliations are consistent with regional trends of approximately 225°, 45°NW described by Wiswall (2005). Twenty-four serpentinite hand samples exhibiting a range of textures and appearances were collected. Hand samples were placed in five end-member groupings based on their color and macroscopic textures (Figure 3). The end-member groupings are as follows: dark samples (near black with durable lithology); light samples (light green to beige with durable lithology); brittle samples (medium green with delicate, easily crumbled lithology); foliated samples (medium green with durable lithology and foliated textures); and quarry (lime-green with durable lithology and abundant, large [2–4 mm] oxide minerals). The quarry samples were outliers both texturally and geographically, as they were collected in an extreme southern area of the ultramafic body from a small quarry operated by local residents, mainly for aggregate. All collected samples were plotted on a field map (Figure 3) by their end-member group to determine if any trends were present. Overall, hand-sample patterns were chaotic and did not reveal an interpretable trend.

Of the 24 serpentinite samples collected, a representative subset of 12 samples was chosen for thin-section production and geochemical analyses. Examination of these thin sections revealed a wide range of textures. The process of serpentinization via the hydrothermal alteration of mafic and ultramafic rocks can result in microtextures that are pseudomorphic, revealing details about the nature of the protolith (Wicks and Whittaker, 1977; Wicks and

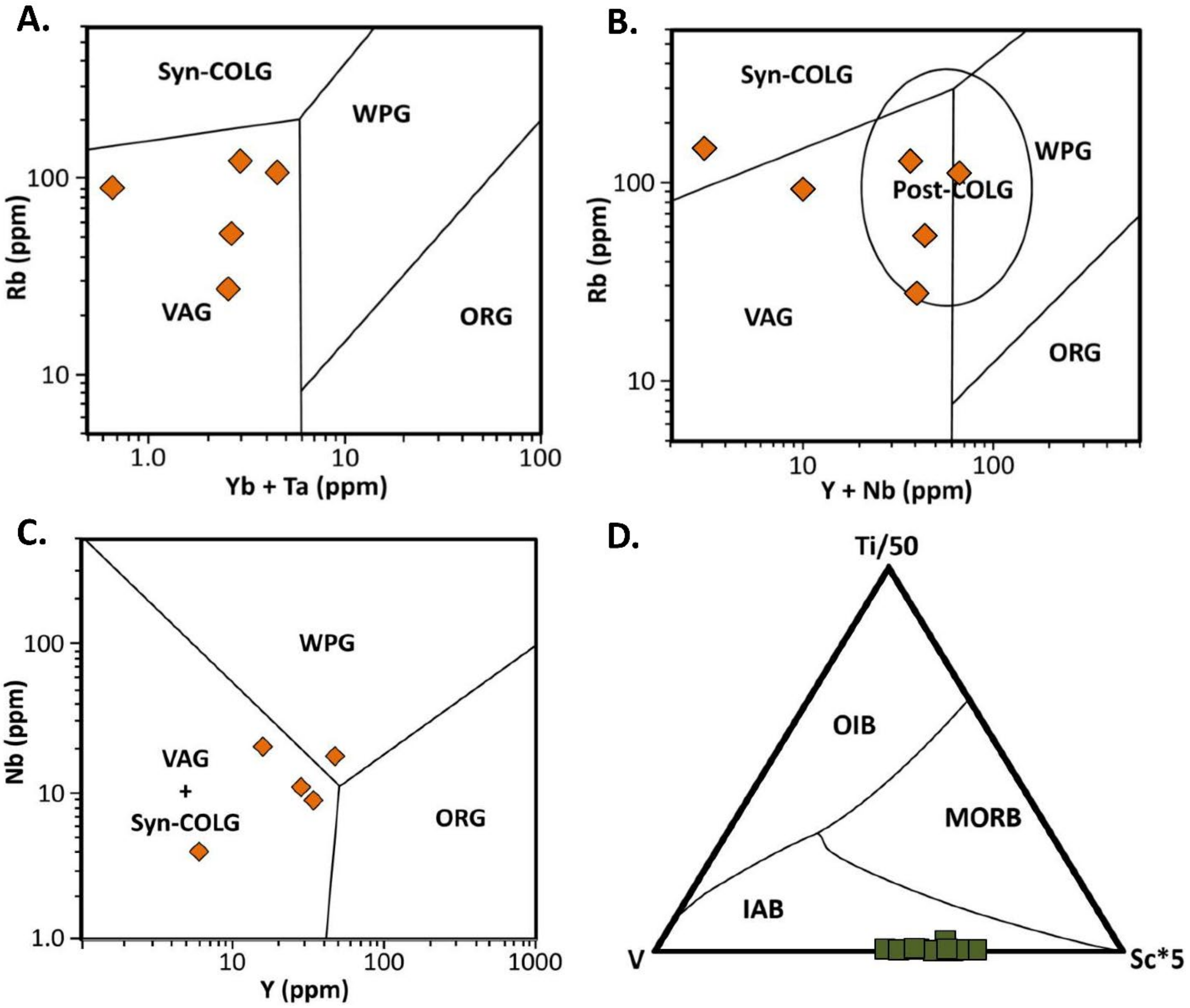

Figure 8. Discrimination diagrams showing tectonic interpretations. **A–C.** Pegmatite samples plotted on diagrams developed for granitic systems (Pearce and others, 1984; Pearce, 1996). The pegmatites mainly fall within the volcanic-arc-granite (VAG) and postcollisional-granite (Post-COLG) fields. (Other fields are ORG—ocean-ridge granite, Syn-COLG—syncollisional granite, and WPG—within-plate granite.) **D.** Serpentinite samples plotted on diagrams developed for basaltic systems (Vermeesch, 2006). The serpentinites fall within the island-arc-basalt (IAB) field. (Other fields are MORB—mid-oceanic-ridge basalts and OIB—ocean-island basalts.) To the best of the authors' knowledge, the pegmatites and serpentinites have not been dated, but given their arc or collisional affinity and geologic context, they are likely associated with the orogenic activity of the Late Ordovician into the Silurian Period.

others, 1977). Several serpentinite textures were identified through petrographic analysis, including various pseudomorphic textures: mesh (lizardite after olivine [Figures 6K and 6L]), mesh and hourglass (mainly lizardite after olivine [Figure 6M]), bastite (lizardite after pyroxene, amphibole, and phyllosilicates [Figure 6N]), interpenetrating (nonpseudomorphic texture [Figure 6O]), and chrysotile veining (late-stage crystallization aided by brittle deformation [Figure 6P]). Mesh texture in serpentinites were the overwhelming majority of microtextures present and therefore were further subdivided based on size: large mesh nets (1.0–0.5 mm) and small mesh nets (<0.5 mm). Where hourglass textures were present, they were always in close association with mesh textures. Four of the 12 thin sections showed the development of mesh textures surrounding partially consumed relict olivines (Figure 6K). Textures present in thin section did not show signs of shear or deformation.

Figure 4 shows the location of the hand samples selected for thin-section analyses and the percentages of serpentinite textures observed. Textures did not show systematic trends across the field area. Mesh and associated hourglass textures were overwhelmingly dominant in the samples examined. The presence of mesh and hourglass textures suggests an olivine-rich protolith. Bastite textures would suggest the pseudomorphism of a chained or sheeted silicate (likely orthopyroxene). While bastite, interpenetrating, and chrysotile textures were observed in some thin sections, they were the minority component. Overall, the microtextures did not exhibit discernible trends other than being dominantly mesh and hourglass.

SERPENTINITE GEOCHEMISTRY

The authors selected 12 serpentinite samples for geochemical analyses of major and trace elements. Concentrations of some elements particularly diagnostic for serpentinite deposits are listed in Figure 5 (concentrations of all analyzed elements are given in Appendix 1). Few systematic trends were observed; however some samples in close proximity to pegmatite dikes had lower concentrations of cobalt. In addition, the outer edges of the body had moderately higher LOI reported. When LOI is used as a proxy for water content, the outer edges of the body appear to be more hydrated. The presence of relict olivines in some samples, indicating incomplete hydration, does not correlate with these areas of lower LOI. Magnesium number (molar Mg/[Mg+Fe]) of serpentinite samples ranged from 0.78–0.84; however the small amount of variability did not correspond to other features.

Serpentinites are created when large fluxes of fluid significantly alter the parent ultramafic rocks; however many trace-element concentrations can remain unaltered, retaining geochemical signatures inherited from their initial crystallization (Deschamps and others, 2013). Plotting trace elements on petrogenetic discrimination diagrams of Vermeesch (2006) yielded an IAB signature, suggesting that the Unionville serpentinite body was part of an arc system prior to serpentinization (Figure 8D). The diagram shows concentrations of Ti/50 -V, and Sc*5. While titanium is considered incompatible in some metamorphic environments, Deschamps and others (2013) demonstrated that during serpentinization, titanium is essentially immobile, making it useful as a petrogenetic indicator in this system. Plotting serpentinite bulk compositions on petrogenetic discrimination diagrams intended for basaltic compositions is not ideal; however these results are consistent with other trends seen in Piedmont ultramafics (Kerrigan and others, 2017).

DISCUSSION

The units at the Unionville Serpentine Barrens are surrounded by the Doe Run Schist, a coarse-grained schist characterized by an assemblage of quartz, plagioclase, muscovite, biotite, and garnet (Bosbyshell and others, 2016). The protolith of the Doe Run Schist is thought to be a rift basin fill of clastic and volcaniclastic sediments prior to the collision of the Taconic arc (Blackmer, 2004). Bosbyshell and others (2016) dated monazite grains in the Doe Run Schist, which showed two episodes of metamorphism: (1) a Taconic metamorphic signature in the core of monazites dated at 455 Ma, and (2) a second peak metamorphic date at 409 Ma that is interpreted to be the stacking of thrust sheets from the collision of peri-Gondwana terranes. Based on foliations and metamorphic textures present in the Unionville serpentinite, it is likely that the serpentinite body was emplaced prior to peak metamorphism. To the best of the authors' knowledge, none of the Piedmont pegmatites or ultramafics have been dated; however the Baltimore Mafic Complex has been dated by U-Pb zircon geochronology, which gave a 489 Ma crystallization age and a 453 Ma metamorphic age (Sinha and others, 1997). The cross-cutting and textural relationships of the pegmatites suggest they postdate the metamorphism of the Doe Run Schist and Unionville serpentinites. Many of the collected pegmatite samples show a weak foliation, which may be due to differential stress during the emplacement process. Based on the varying degrees of preservation of serpentinite textures throughout the contact aureoles, it is reasonable to conclude that serpentinization of the ultramafic body must have been near completion during the intrusion of the pegmatites.

The pegmatites fall into the MSREL class. This group of pegmatites is generally attributed to a granitic parental melt; however there is evidence that some MSREL pegmatites may be derived from anatectic melt in metamorphic settings (Černý and Ercit, 2005). The pressure and temperature conditions for crystallization are restricted to upper greenschist to amphibolite facies (600–700°C, 500–600 MPa), which correspond to the regional metamorphic conditions of approximately 575°C and 600 MPa as reported for the surrounding Doe Run Schist (Alcock, 1989, 1994). These conditions suggest depths greater than 20 km for pegmatite crystallization. Pegmatite trace-element concentrations plotted on petrogenetic discrimination diagrams are inconclusive, but they suggest either a volcanic-arc or postcollisional source for the pegmatite melt. Two possible sources for the melt would be (1) regional, arc-related igneous bodies (i.e., the Springfield Granodiorite or the Wilmington Complex) or (2) postcollisional anatectic melting during tectonic thickening. The Springfield Granodiorite or the Wilmington Complex appear to be a less likely source due to their geographic distances from Unionville, Pa., which include the traverse of a significant shear zone (the Rosemont shear zone). Therefore, the pegmatite may have been generated at greater depths where conditions were more favorable for the generation of anatectic melt. This would have been followed by ascension and emplacement of the pegmatitic melt in the Unionville serpentinite and surrounding Doe Run Schist.

Examination of the contact aureoles of the pegmatites interacting with the serpentinite at Unionville revealed the complex migration of major and trace elements through intense metasomatism. Diffusion models for the contact aureoles were not practical given the lack of precise geographic information for the reaction rocks of the contact aureole. However, analysis of collected samples from the Unionville Serpentine Barrens provides a better understanding of the dynamics of component exchange between felsic pegmatite intrusions and ultramafic serpentinites, as well as which elements were particularly susceptible to diffusive flow in this unique system.

CONCLUSIONS

Scientific investigations were carried out to (1) characterize the nature of the serpentinite body and intruding pegmatites of the Unionville Serpentine Barrens; (2) examine the geochemical interactions of serpentinites and pegmatites, a relatively rare occurrence; (3) determine the origin and emplacement histories for the serpentinites at the Unionville Serpentine Barrens; and (4) determine how all components fit into the larger history of the Appalachian Piedmont. Examination of the serpentinite textures has determined that the protolith of the serpentinite body was an ultramafic, olivine-rich rock with an arc affinity. Trace-element concentrations plotted on petrogenetic discrimination diagrams support the hypothesis that the Unionville ultramafic body likely derived from the basement of an accreted terrane during the Taconic orogeny. The emplacement of the ultramafic body likely predates metamorphism of the Doe Run Schist, as serpentinite textures and foliations are consistent with the regional trends.

According to field observations and regional trends, the pegmatite intrusions appear to be oriented northeast-southwest, as opposed to the previously mapped north-south orientations. The locations of pegmatite outcrops, tailings piles, and historical mining operations reveal northeast-southwest trends that can be attributed to the presence of the intrusions. The pegmatites are of the MREL type and likely intruded at great depth (>20 km) after serpentinization of the ultramafic body—a supposition supported by the preserved textures in the contact aureoles. During emplacement of the pegmatites, there was significant fluid flow through the contact aureoles, with near-complete replacement of the country rock serpentinite by silica-rich fluids adjacent to the intrusions grading into "unaltered" serpentinite away from the intrusions. These geologic systems produced unique rocks with highly variable chemical compositions and appearances that illustrate the changes that occur at the contact between a granitic body and an ultramafic body.

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