

Editorial

Editorial for Special Issue “Minerals of the Southern Grenville Province”

George W. Robinson ¹, Jeffrey R. Chiarenzelli ^{1,*} and Marian V. Lupulescu ²

¹ Department of Geology, St. Lawrence University, Canton, NY 13617, USA; robinson@mtu.edu

² New York State Museum, 3140 CEC, Madison Avenue, Albany, NY 12230, USA; marian.lupulescu@nysed.gov

* Correspondence: jchiarenzelli@stlawu.edu

Received: 8 March 2020; Accepted: 9 March 2020; Published: 9 March 2020



The southern Grenville Province is famous for both the large number of mineral localities and the diversity of the mineral species found. Many of these localities have produced museum-quality specimens of both rare and common species [1]. This is undoubtedly due to the broad range of geological conditions that shaped the region, resulting in an equally wide range of mineral-forming environments, some of which appear unique. New discoveries and rediscovery of historic localities lost to time ensure that the southern Grenville Province will continue to produce mineral specimens of high quality and considerable scientific interest.

Notable geological associations include mineral occurrences hosted in a compositionally wide variety of igneous rocks including granitic and syenitic pegmatites, anorthosite and related anorogenic plutonic rocks, carbonatites, and iron-oxide–apatite (IOA) deposits. Numerous localities are also hosted in, or influenced by, metasedimentary rocks. Of particular significance are the extensive marble and calc-silicate gneisses of the Grenville Supergroup, including associated skarns and enigmatic calcite vein-dikes. In addition, minerals related to granulite-facies metamorphism, hydrothermal alteration, supergene mineralization, and weathering occur in many diverse Grenville lithologies and/or crosscut them.

This issue presents a number of recent discoveries and advances in our understanding of mineral locations in the >1.0 billion rocks of the Grenville Province in southern Ontario, Quebec, New York, and New Jersey, utilizing a variety of data ranging from classic field observations to geochronology to isotopic and geochemical tracers. Eight research papers and one review paper, representing the work of many authors, are included in the Special Issue (Table 1). We hope the Special Issue will attract interest and spur additional scientific investigation into the many mineral localities preserved in rocks of the Grenville Province. Much more will be elucidated, as new localities are discovered and new techniques are employed to study historic occurrences.

Dannenberg et al. [2] report on the crystal chemistry of aluminum-rich, chromium-dravite in the northwest Adirondacks. The tourmaline was discovered within the amphibolite-facies Upper Marble stratigraphic sequence in the Sylvia Lake Synform [3], host to more than century of zinc and talc mining. Specifically, the tourmaline occurs within talc–tremolite–cummingtonite schist in the American #1 talc mine in Balmat, St. Lawrence County, New York. The tourmalines investigated contain up to 21 wt% Cr₂O₃, some of the highest chromium concentrations reported in the literature. By studying this Cr-tourmaline sample and nine samples from the literature, the authors were able to explain why Cr³⁺, typically accommodated by the Y octahedral site, is found in both the Y and Z cation sites. A remaining question is the source of the chromium in the shallow marine to evaporitic carbonate sequence.

Table 1. List of papers—Minerals of the Southern Grenville Province.

<i>The Atomic Arrangement of Cr-rich Tourmaline from the #1 Mine, Balmat, St. Lawrence County, New York, USA</i> by Steven G. Dannenberg, Devany Di Paolo, Alix M. Ehlers, Kyle P. McCarthy, Mark T. Mancini, Matthew B. Reuter, Dennis M. Seth, Jr., Zihui Song, John M. Hughes, and Marian V. Lupulescu
<i>Constraints from Geochemistry and Field Relationships for the Origin of Kornerupine-Bearing Gneiss from the Grenvillian New Jersey Highlands and Implications for the Source of Boron</i> by Richard A. Volkert
<i>Age and Origin of Silicocarbonate Pegmatites of the Adirondack Region</i> by Jeffrey Chiarenzelli, Marian Lupulescu, George Robinson, David Bailey, and Jared Singer
<i>The Kilmar Magnesite Deposits: Evaporitic Metasediments in the Grenville Supergroup, Morin Terrane, Quebec</i> by William H. Peck and Gary R. Eppich
<i>Mineralogy of Chub Lake-Type Hematite Deposits in St. Lawrence County, NY</i> by Steven C. Chamberlain, Marian V. Lupulescu, and David G. Bailey
<i>A Silicocarbonatitic Melt and Spinel-Bearing Dunite of Crustal Origin at the Parker Phlogopite Mine, Notre-Dame-du-Laus, Quebec, Canada</i> by Robert F. Martin and Dirk Schumann
<i>Microscopic Blue Sapphire in Nelsonite from the Western Adirondack Mountains of New York State, USA</i> by Robert S. Darling, Jessica L. Gordon, and Ellis R. Loew
<i>A Review of Boron-Bearing Minerals (Excluding Tourmaline) in the Adirondack Region of New York State</i> by David G. Bailey, Marian V. Lupulescu, Robert S. Darling, Jared W. Singer, and Steven C. Chamberlain
<i>The Crystallinity of Apatite in Contact with Metamict Pyrochlore from the Silver Crater Mine, Ontario, Canada</i> by Chris Emproto, Austin Alvarez, Christian Anderkin and John Rakovan

Chiarenzelli et al. [4] address the origin of calcite vein dikes in the Adirondack Region of New York from a geochronological perspective using laser ablation multicollector inductively coupled mass spectrometry analysis of zircons (LA-MC-ICP-MS). They employ the term silicocarbonate pegmatites to represent their variable calc-silicate mineralogy, carbonate content, and exceptional size of some of the minerals they contain. Zircons from silicocarbonate pegmatites yield both Shawinigan (ca. 1165 Ma) and Ottawan (ca. 1050 Ma) U-Pb crystallization ages. Those of Shawinigan age are found in the northwest Adirondack Lowlands, while those of Ottawan age are found in the Highlands and along the complex structural boundary between them (i.e., Carthage-Colton shear zone). This finding indicates at least two distinct episodes capable of marble anatexis and melt mobilization. Carbon and oxygen isotopes from calcite samples from these localities plot in a restricted field between igneous carbonatites and carbonate sedimentary rocks and their metamorphic equivalents and skarns. Ottawan silicocarbonate pegmatites were emplaced during orogenic collapse and are spatially related to late structures and associated hydrothermal fluid flow.

In another paper addressing a classic vein dike locality, Martin and Schumann [5] document a silicocarbonatitic melt and associated spinel-bearing dunite of crustal origin from the Parker mine, Notre-Dame-du-Laus, Quebec, Canada. The Parker mine was one of several dozen mines active in the early 1900s in the Central Metasedimentary Belt of the Grenville Province extending from Bancroft, Ontario to Mont-Laurier, Quebec [6]. The mine is unusual because of the association of phlogopite with large (centimeter-scale), euhedral black spinel and forsterite crystals that are enclosed in a carbonate matrix. While diopside and clinopyroxene [1] are commonly associated with calcite vein dikes throughout the region, olivine is not. At the Parker mine, olivine and spinel are considered cumulate minerals analogous to those in layered ultramafic complexes. Supported by oxygen isotope data, the authors attribute the carbonate melt to the hydrous melting of marble at ca. 1140 Ma following the cessation of Shawinigan contractional orogenesis during crustal relaxation.

Peck and Eppich [7] address the origin of the Kilmar magnesite deposits in the granulite-facies Morin Terrane of Quebec. Traditionally interpreted to have originated by hydrothermal replacement of host lithologies [8,9], they are found associated with dolomitic marbles and intercalated metasedimentary rocks of the Grenville Supergroup. However, heterogeneous carbon and oxygen isotopic signatures indicate that the magnesite ore preserves considerable variability between layers,

as well as a signature indicating evaporitic enrichment of both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$. Boron isotope ratios are also consistent with a marine evaporite origin.

Darling et al. [10] report on the discovery of microscopic grains (0.1–2.0 mm) of blue sapphire in a small (1–2 cm width) nelsonite dike hosted by an aluminous, feldspathic, supracrustal gneiss near Port Leyden, New York in the western Adirondacks. This is the first reported occurrence of sapphire in a nelsonite, an igneous rock composed primarily of ilmenite and apatite and found associated with magmatic rocks of the anorthosite suite [11]. The authors suggest that while textural evidence (i.e., fine, hexagonal compositional zoning) and trace element abundance are consistent with a magmatic origin, elevated Cr concentrations may indicate a metamorphic origin. Further work may resolve this apparent discrepancy.

Across the region, specular hematite deposits are found developed near the contact between Grenville basement rocks and overlying Paleozoic sedimentary rocks (i.e., Potsdam sandstone). Quartz, calcite, barite, and secondary goethite are typically associated with the specular hematite. In their study, Chamberlain et al. [12] provide data relevant to the origin of six specular hematite localities in St. Lawrence County, including oxygen isotopes, x-ray diffraction, scanning electron microscope investigation, and energy dispersive analysis. Data collected suggest the occurrences formed from waters with a temperature of ca. 170 °C, which will help guide further work into how and when the specular hematite formed. Two hypotheses are outlined: pre-Potsdam weathering or post-Potsdam diagenetic fluids. However, these processes need not be mutually exclusive and their origin may lie in some combination of processes interacting along the unconformity. Additional work into the earthy red hematite deposits of the nearby Keene-Antwerp belt, host of the famous millerite occurrence [1], may help further constrain processes and timing.

Volkert [13] reports and discusses an occurrence of kornerupine at two locations in an inlier of the Grenville Province in the New Jersey Highlands surrounded by younger rocks. The author suggests that the host rock formed from metamorphosed sediments derived from a felsic-arc source. The metamorphic conditions that generated the kornerupine mineral assemblage were ≥ 600 MPa and 700 °C. The boron is interpreted to have been derived from the B-rich sediments that decomposed due to the dehydration reactions during the Ottawan prograde metamorphism. This was followed by migration of B-rich fluids to structural sites favorable for the kornerupine deposition. This discovery adds an additional locality for kornerupine in the southern Grenville including that reported in southeastern Ontario [14] and the solid solution Fe-Mg analogue, prismatine, from the Moose River in the western Adirondack Highlands [15].

In the review paper on the boron-bearing minerals (excluding tourmaline) in the Adirondack region of New York, Bailey et al. [16] provide new chemical and Raman spectral data on twelve boron minerals from the Adirondack Mountains. Chemically, the B-minerals reported in this paper range from metal borates (vonsenite) to complex borosilicates (prismatine) or borosilicate-carbonate (harkerite) mineral species that have a wide range of origins from igneous (dumortierite, prismatine), regional metamorphism (kornerupine, warwickite, serendibite, danburite), skarns (danburite, datolite, harkerite, serendibite, sinhalite, vonsenite) to retrograde/metasomatic origin (datolite, grandidierite). Most of the mineral occurrences from the Adirondack Highlands formed in lithologies proximal to the Marcy anorthosite. In the Adirondack Lowlands, the boron minerals are associated with calcareous metasedimentary rocks hosting evaporitic units/minerals. The authors suggest that the metasedimentary rocks are the source of boron. Additional isotope work is planned to confirm and constrain the geological processes that formed the boron-bearing minerals.

Emproto et al. [17] investigated the crystallinity of apatite adjacent to metamict U-bearing pyrochlore (var. betafite) from carbonatite from the Silver Crater Mine in Ontario. Using broad and focused X-ray beam analyses as well as electron backscatter diffraction (EBSD), apatite was shown to be highly crystalline. Given the long period of contact between the two minerals (>1.0 billion years) this result confirms past studies of apatite 'self-annealing' and suggests it may be a possible repository for radioactive actinide minerals over geologic time-spans.

Most of the localities discussed in these eight contributions have been known for more than one hundred years and some for more than two hundred [1]. Moreover, while of great interest to mineral collectors and museums, very few historically discovered Grenville mineral localities have been investigated using modern analytical techniques, despite their potential to add significantly to the geological history of the region. More studies bridging the gap between classic mineralogy and holistic attempts to understand their significance to the geology of the Grenville Province are needed.

Acknowledgments: The authors would like to acknowledge the peer reviewers and editorial staff at *Minerals*, without whom the Special Issue could not have been published.

Conflicts of Interest: The authors declare no conflict of interest. The funders of each study, acknowledged separately, had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Robinson, G.W.; Chiarenzelli, J.R.; Bainbridge, M. *Minerals of the Grenville Province—New York, Ontario, and Quebec*; Schiffer Publishing Ltd.: Atglen, PA, USA, 2019; p. 207.
2. Dannenberg, S.G.; Di Paolo, D.; Ehlers, A.M.; McCarthy, K.P.; Mancini, M.T.; Reuter, M.B.; Seth, D.M., Jr.; Song, Z.; Valladares, M.I.; Zhu, X.; et al. The Atomic Arrangement of Cr-rich Tourmaline from the #1 Mine, Balmat, St. Lawrence County, New York, USA. *Minerals* **2019**, *9*, 398.
3. Lupulescu, M.V.; Rowe, R. Al-rich chromium-dravite from the #1 Mine, Balmat, St. Lawrence County, New York. *Can. Mineral.* **2011**, *49*, 1189–1198.
4. Chiarenzelli, J.; Lupulescu, M.; Robinson, G.; Bailey, D.; Singer, J. Age and Origin of Silicocarbonate Pegmatites of the Adirondack Region. *Minerals* **2019**, *9*, 508. [[CrossRef](#)]
5. Martin, R.F.; Schumann, D. A Silicocarbonatitic Melt and Spinel-Bearing Dunite of Crustal Origin at the Parker Phlogopite Mine, Notre-Dame-du-Laus, Quebec, Canada. *Minerals* **2019**, *9*, 613. [[CrossRef](#)]
6. Van Velthuizen, J. The Parker mine, Notre Dame du Laus, Quebec. *Mineral. Rec.* **1993**, *24*, 369–373.
7. Peck, W.H.; Eppich, G.R. The Kilmar Magnesite Deposits: Evaporitic Metasediments in the Grenville Supergroup, Morin Terrane, Quebec. *Minerals* **2019**, *9*, 554. [[CrossRef](#)]
8. Wilson, M.E. *Magnesite Deposits of Grenville District, Argenteuil County, Quebec*; Geological Survey of Canada: Ottawa, ON, Canada, 1917; p. 88.
9. Osborne, F.F. Magnesite-dolomite deposits, Grenville Township. In *Quebec Bureau of Mines Annual Report; Part C Lachute Map-Area; Part III*; Quebec Bureau of Mines: Québec, QC, Canada, 1938; pp. 65–87.
10. Darling, R.S.; Gordon, J.L.; Loew, E.R. Microscopic Blue Sapphire in Nelsonite from the Western Adirondack Mountains of New York State, USA. *Minerals* **2019**, *9*, 633. [[CrossRef](#)]
11. Dymek, R.F.; Owens, B.E. Petrogenesis of apatite-rich rocks (nelsonites and oxide-apatite gabbro-norites) associated with massif anorthosites. *Econ. Geol.* **2001**, *96*, 797–815. [[CrossRef](#)]
12. Chamberlain, S.C.; Lupulescu, M.V.; Bailey, D.G. Mineralogy of Chub Lake-Type Hematite Deposits in St. Lawrence County, NY. *Minerals* **2019**, *9*, 567. [[CrossRef](#)]
13. Volkert, R.A. Constraints from Geochemistry and Field Relationships for the Origin of Kornerupine-Bearing Gneiss from the Grenvillian New Jersey Highlands and Implications for the Source of Boron. *Minerals* **2019**, *9*, 431. [[CrossRef](#)]
14. Lonker, S.W. An occurrence of grandidierite, kornerupine, and tourmaline in southeastern Ontario, Canada. *Contrib. Miner. Petrol.* **1988**, *98*, 502–516. [[CrossRef](#)]
15. Darling, R.S.; Florence, F.P.; Lester, G.W.; Whitney, P.R. Petrogenesis of prismatic-bearing metapelitic gneisses along the Moose River, west-central Adirondacks, New York. *Mem. Geol. Soc. Am.* **2004**, *197*, 325–336.
16. Bailey, D.G.; Lupulescu, M.V.; Darling, R.S.; Singer, J.W.; Chamberlain, S.C. A Review of Boron-Bearing Minerals (Excluding Tourmaline) in the Adirondack Region of New York State. *Minerals* **2019**, *9*, 644. [[CrossRef](#)]

17. Emproto, C.; Alvarez, A.; Anderkin, C.; Rakovan, J. The Crystallinity of Apatite in Contact with Metamict Pyrochlore from the Silver Crater Mine, ON, Canada. *Minerals* **2020**, *10*, 244. [[CrossRef](#)]



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).