

MINING, GEOLOGY, AND GEOLOGICAL HISTORY OF GARNET AT THE BARTON GARNET MINE, GORE MOUNTAIN, NEW YORK

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ABSTRACT

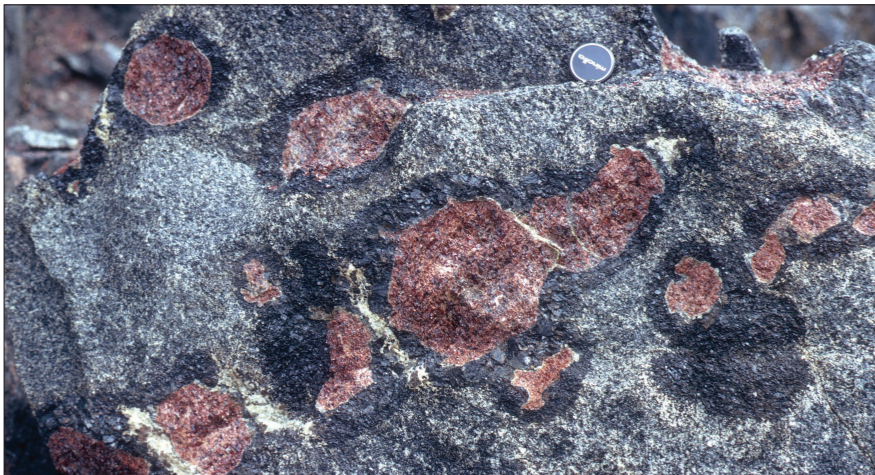
Garnet megacrysts commonly 30 centimeters (cm) ranging up to 1 meter (m) in diameter occur at the summit of Gore Mountain, Adirondacks, NY and were mined there for abrasives for more than a century. The mine, owned by Barton Mines Co., LLC, is roughly 2 km x 150 m and is located in a hornblende-rich garnet amphibolite at the southern boundary of a metamorphosed olivine gabbro body that is in fault contact with charnockite. Barton supplies garnet, a chemically homogeneous pyrope-almandine, to the waterjet cutting, lapping, and abrasive coatings industries. The garnet megacrysts are reliably dated at 1049 ± 5 Ma. The growth of the garnet megacrysts was facilitated by an influx of hydrothermal fluid emanating from the ore body's southern boundary fault. The fluids were most probably associated with the intrusion of the Lyon Mountain Granite (1049.9 ± 10 Ma) and/or associated pegmatitic rocks late in the tectonic history of the Adirondacks.

INTRODUCTION

The Adirondack Mountains in upstate New York are a small outlier of a larger body of rocks of similar age and geologic history that is located to the north in Canada. The Adirondack region can be loosely divided into amphibolite metamorphic facies Lowlands, in the northwest, and the granulite facies Central Highlands, which are

separated by a very large, northwest-dipping fault zone. The rocks that comprise the Barton Mine, Gore Mountain and environs are in the Central Highlands. Gabbroic rocks in the Central Highlands commonly contain garnets, often as crystals of unusual size (i.e., megacrysts up to 1 m in diameter). The garnet deposit at Gore Mountain is the most spectacular (Figure 1), but megacrystic garnets, similar to but smaller than Gore Mountain, occur elsewhere such as at Cranberry Lake, Warrensburg, and Speculator. For discussion of these latter and other Adirondack megacrystic garnet occurrences, the reader is referred to McLelland and Selleck (2011). Typically, the Gore Mountain garnets are roughly dodecahedral single crystals encompassed by an enveloping shell, up to 4 cm thick, of hornblende. On roughly flat surfaces, the hornblende appears as a rim on the garnet.

Figure 1: Garnet megacrysts in metamorphosed gabbroic anorthosite, Barton Mine, Gore Mountain. Lens cap is 55 mm. Photo by author.



THE MINE

The Barton Mines Corporation open pit mine is located at an elevation of about 800 m on the north side of Gore Mountain. For 105 years, until mining operations were moved to Ruby Mountain in 1982, this was the site of the world's oldest continuously operating garnet mine and the country's second oldest continuously operating mine under one management. The community at the mine site was the highest self-sufficient community in New York State, capable of housing about 11 families and supplied with its own water, power, and fire protection. The 16 km company-built road from NY State Route 28 rises 91 m per mile and, like other roads in the vicinity, was surfaced with coarse mine tailings. Currently extant on the property are residences, some of the original mine buildings, and *Highwinds*, built by Mr. C.R. Barton in 1933 as a family residence (Figure 2).

Figure 2: Barton Mine at the summit of Gore Mountain looking west to east, 1956. Mine buildings center foreground, waste piles, foreground, residences in trees, center. Photo courtesy of the Adirondack Museum.



The early history of the Barton garnet mine has been compiled by Moran (1956) and is paraphrased here from that source. Mr. Henry Hudson Barton came to Boston from England in 1846 and worked as an apprentice to a Boston jeweler. While working there in the 1850's, Barton learned of a large deposit of garnet located in the Adirondack Mountains. Subsequently, he moved to Philadelphia and married the daughter of a sandpaper manufacturer. Combining his knowledge of gem minerals and abrasives, he concluded that garnet would produce better quality sandpaper than that which was currently available. He was able to locate the source of the Adirondack garnet stones displayed at the Boston jewelry store years before. Barton procured samples of this garnet, which he pulverized and graded. He then produced his first garnet-coated abrasive by hand which was tested in several woodworking shops near Philadelphia. It proved to be a superior product and Barton soon sold all he could produce.

H.H. Barton began mining at Gore Mountain in 1878 and in 1887 bought the entire mountain from the State of New York. Early mining operations were entirely manual. The garnet crystals in Barton's mine were commonly 30 cm in diameter and rarely up to 1 m with an average diameter of 9 cm (Hight 1983). The garnet was hand cobbled (i.e., separated from the waste rock by small picking hammers and chisels). Due to the obstacles in moving the ore, the garnet was mined during the summer and stored on the mountain until winter. It was then taken by sled to the railroad siding at North Creek, whence it was shipped to the Barton Sandpaper plant in Philadelphia for processing. The "modern" plant at Gore Mountain was constructed in 1924. Crushing, milling, and coarse grading was done at the mine site. In 1983, the Gore

Mountain mining operation closed and mining was relocated to the Ruby Mountain site, approximately 6 km northeast, where it continues at present. The mine at Gore Mountain is approximately 2 km in length in an ENE-WSW direction. The ore body varies from 15 m to 122 m and is roughly vertical. Mining was conducted in benches of 9 m using standard drilling and blasting techniques (Figure 3). The ore was processed through jaw and gyratory crushers to liberate the garnet and then concentrated in the mill on Gore Mountain. Garnet concentrate was further processed in a separate mill in North River at the base of the mountain. Separation of garnet was and is accomplished by a combination of concentrating methods including heavy media, magnetic, flotation, screening, tabling, and air and water separation. Processes are interconnected and continuous or semi-continuous until a concentrate of 98% minimum garnet for all grades is achieved (Hight 1983). Finished product ranges from 0.6 cm to 0.25 micron in size.

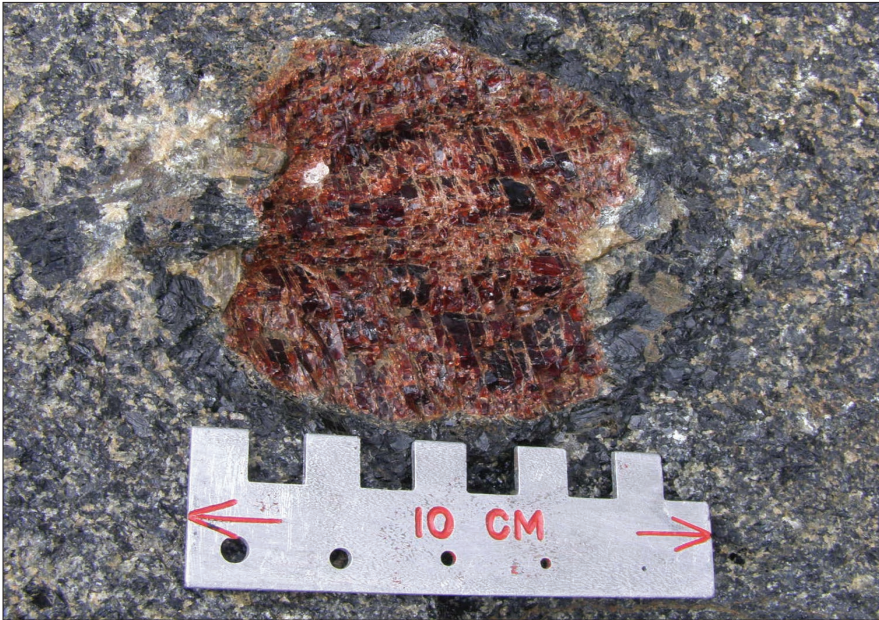
Figure 3: West end of Barton Mine, c. 1995. Ore here is garnet amphibolite. Note people, left center, for scale. Photo by author.



Garnet in general is used in waterjet cutting (35%), abrasive blasting (30%), water filtration (20%), abrasive powders (10%), and other processes (5%) (Olson 2013) such as to remove the red hulls from peanuts and as an anti-skid additive to aircraft carrier deck paint. Garnet is non-toxic, lacking crystalline silica, and is chemically inert, and it provides greater cutting speed, less dust, and lower volume requirements than competing abrasives. Overall, however, garnet comprises only a small portion (~2%) of the abrasives market. The garnet mined at Gore Mountain was a very high-quality abrasive. Although garnet does not normally exhibit cleavage, the garnets from Gore Mountain and those from the

surrounding region exhibit a tectonically induced “pseudo-cleavage” that produces sharp, angular fragments and greatly enhances the cutting ability of the final product (Figure 4). Present at a macro scale, this pseudo-cleavage is exhibited in all of Barton’s products. The markets currently served by Barton Mines Co. LLC are, in decreasing order, waterjet cutting, glass lapping, finishes, and abrasive coatings. Abrasive air blasting and water filtration media are minor. The value of garnet varies widely depending on a number of factors from \$75 to \$325 per ton (Olson 2015). Barton’s products fall into the upper price range.

Figure 4: Tectonically induced “pseudo-cleavage” in Gore Mountain garnet. This fracture pattern is present to 0.25 micron scale. Photo by Bruce Selleck.



Although the garnet crystals in the ore zone at Gore Mountain are atypical in size, the modal amount of garnet is not unusually high for Adirondack garnet amphibolites. Garnet amphibolite that is texturally and mineralogically similar occurs elsewhere in the Adirondacks, usually on the margins of gabbroic rock bodies. The ore at the currently operating Barton Corporation mine at Ruby Mountain, for example, is of the same tenor, but the garnets rarely are larger than 2.5 to 5 cm (Figure 5). The composition of the garnet at Gore Mountain is roughly 43% pyrope, 40% almandine, 14% grossular, 2% andradite, and 1% spessartine (Levin 1950; Harben and Bates 1990). Chemical zoning, where present, is very weak and variable (Luther 1976). The garnet has been so well analyzed isotopically that it is frequently used as an $^{18}\text{O}/^{16}\text{O}$ standard (Valley et al. 1995). Typical chemical analyses of the garnet are presented in Table 1. Hardness of the garnet is 7.5 and the average density is 3.95 gm/cm^3 .

Figure 5: Garnet ore (garnet amphibolite) at Barton's Ruby Mountain mine. Knife – four inches. Photo by author.

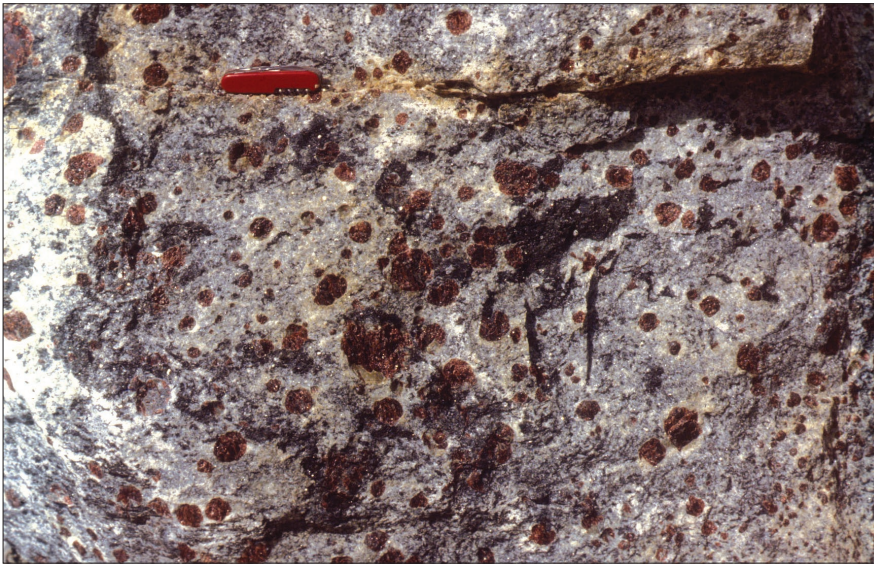
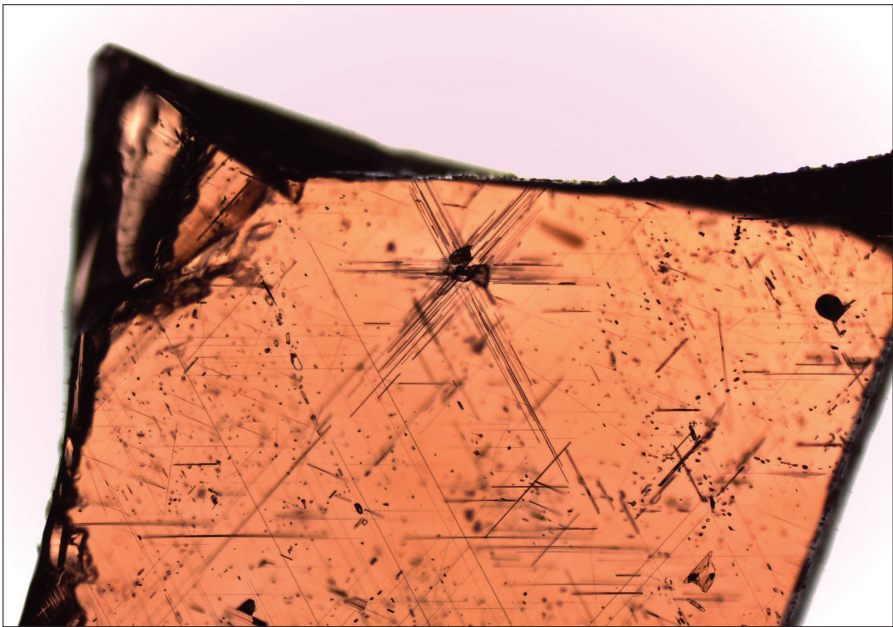


Table 1: Electron Microprobe analyses of Gore Mt. garnet (almandine-pyrope) normalized to 8 cations and 12 anions (Kelly and Petersen 1993). *Calculated by charge balance.

OXIDE WEIGHT PERCENT	#29	#41
SiO ₂	39.43	39.58
Al ₂ O ₃	21.40	21.20
TiO ₂	0.05	0.10
FeO*	22.80	24.45
Fe ₂ O ₃ *	1.44	0.72
MgO	10.65	9.60
MnO	0.48	0.74
CaO	3.85	3.97
Na ₂ O	0.00	0.00
K ₂ O	0.00	0.00
Total	100.09	100.36

Gore Mountain garnet hosts a number of inclusion types, the most common of which is acicular rutile. Other common solid inclusions include pyrite, plagioclase, pyroxene, hornblende, ilmenite, apatite, and biotite (Valley et al. 1995). Garnet has been legislatively designated as the official New York State gemstone. Barton Mines LLC itself produces no gem material but collectors are able to find rough material of gem quality. Stones cut from Gore Mountain rough material generally fall into a range of one to five carats. A small number of stones displaying asterism have been found. Many included rutile needles that are crystallographically controlled, and the asterated specimens may be due to the orientation of these inclusions parallel to $\{111\}$ of the garnet (Figure 6). Garnets from this locality are a dark red color with a slight brownish tint. Special cutting schemes have been devised for this material in order to allow sufficient light into the stone.

Figure 6: Crystallographically-controlled rutile needles in garnet which impart asterism to faceted garnet gemstones. The field of view for the star garnet image is 3.25 mm wide. Photo by R. Darling.

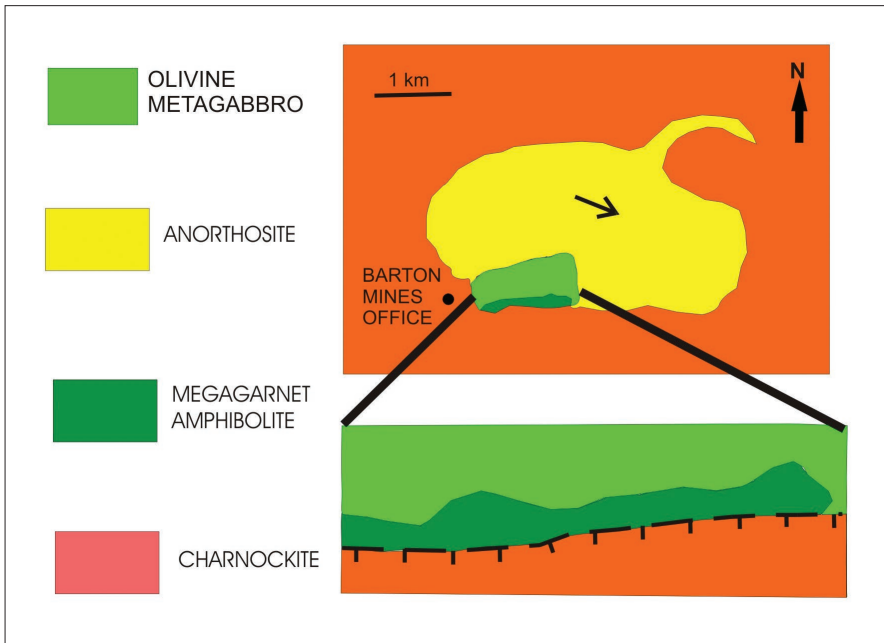


GEOLOGY

The garnet mine is entirely hosted by a hornblende-rich garnet amphibolite unit along the southern margin of an olivine meta-gabbro body (Figure 7). The garnet amphibolite grades into garnet-bearing gabbroic meta-anorthosite to the east. To the south, the garnet amphibolite is in contact with charnockite; a fault forms this southern contact. The ore zone is a granulite facies lithology with a relict subophitic texture. Preserved igneous

features, faint igneous layering, and a xenolith of anorthosite have been reported in the meta-gabbro (Luther 1976). Prior to metamorphism, the rock was composed of plagioclase, olivine, clinopyroxene, and ilmenite. During metamorphism, coronas of orthopyroxene, clinopyroxene and garnet formed between the olivine and the plagioclase and coronas of biotite, hornblende, and ilmenite formed between plagioclase and ilmenite (Whitney and McLelland 1973, 1983). The contact between the olivine meta-gabbro and the garnet amphibolite ore zone is gradational through a narrow (1 to 3 m wide) transition zone. Garnet size increases dramatically across the transition zone from less than 1 mm in the olivine meta-gabbro, to 3 mm in the transition zone, to 5 to 35 cm in the amphibolite (Goldblum and Hill 1992). This increase in garnet size coincides with a ten-fold increase in the size of hornblende and biotite, the disappearance of olivine, a decrease in modal clinopyroxene as it is replaced by hornblende, and a change from green spinel-included plagioclase to white inclusion-free plagioclase (Goldblum and Hill 1992). Mineralogy in the garnet amphibolite ore zone is mainly hornblende, plagioclase and garnet with minor biotite, orthopyroxene, and various trace minerals. In both the olivine meta-gabbro and the garnet amphibolite, garnet content averages 13 modal percent, with a range of 5 to 20 modal percent (Luther 1976; Hight 1983; Goldblum 1988).

Figure 7: *Geologic map of Barton garnet mine and surrounding area. The ore zone is megagarnet amphibolite. From McLelland and Selleck (2011).*



The garnet amphibolite unit is thought to be derived by granulite facies metamorphism of the southern margin of the olivine meta-gabbro. At the west end of the mine, a garnet hornblendite with little or no feldspar is locally present. This rock may represent original ultramafic layers in the gabbro (Whitney et al. 1989). In the more mafic portions of the ore body, the large garnet crystals are rimmed by hornblende up to several centimeters thick. Elsewhere, in less mafic ore, the rims contain plagioclase and orthopyroxene. Chemical analyses of the olivine meta-gabbro and garnet amphibolite show that the garnet ore was derived by isochemical metamorphism, except for an increase in the H_2O and fO_2 of the olivine meta-gabbro (Table 2; Luther 1976). Very coarsely approximated, the reaction olivine + plagioclase + (clinopyroxene + ilmenite) + fluid \rightarrow garnet + hornblende + (less calcic plagioclase + orthopyroxene + biotite) occurred during the formation of the ore body.

Table 2: Chemical analyses of olivine metagabbro and garnet amphibolite (ore), Gore Mountain (Luther 1976).

	OLIVINE METAGABBRO	GARNET AMPHIBOLITE
SiO ₂	47.14	45.68
Al ₂ O ₃	16.98	17.32
TiO ₂	0.18	0.78
Fe ₂ O ₃	0.69	1.30
FeO	11.13	9.67
MnO	0.16	0.15
MgO	11.04	10.97
CaO	8.05	8.58
Na ₂ O	2.54	2.85
K ₂ O	0.56	0.59
P ₂ O ₅	0.01	0.10
H ₂ O	0.44	1.16
Total	99.64	99.15

A strong, consistent lineation and weak planar fabric coincide with the zone of large garnet crystals and are an important feature of the garnet ore zone (Goldblum and Hill 1992). The lineation is defined by parallel alignment of prismatic hornblende crystals, elongate segregations of felsic and mafic minerals, plagioclase pressure shadows, and rare elongate garnet. The foliation is defined by a slight flattening of the felsic and mafic aggregates.

Darling et al. (1997) report a most unusual type of multiple solid inclusion containing the low pressure, very high temperature SiO_2 polymorph, cristobalite. This phase is accompanied by albite and a small quantity of ilmenite. The cristobalite is recognized by its fractures, formed by the 5% volume decrease upon a phase transformation occurring at temperatures between 260 and 270 °C. Darling et al. (1997) propose the cristobalite + albite + ilmenite inclusions began as small water-rich melt inclusions which then experienced diffusive loss of water. This led to an internal pressure decrease (under nearly isochoric, isothermal conditions) to the point where cristobalite, instead of quartz, crystallized in the melt inclusions. It should be noted that identical cristobalite-bearing multiple-solid inclusions also occur in garnet amphibolites at the former Hooper and North River Mines (Charles et al. 1998), so their formation is not unique to Barton Mine garnet. The most remarkable outcome is that the cristobalite never reconstructively transformed to quartz even during protracted cooling from starting conditions of approximately 800 °C. Darling et al. (1997) infer the absence of water was the primary reason for the preservation of cristobalite.

Fluid inclusions are rare in Gore Mountain garnet despite the importance of water in the formation of garnet amphibolite as well as large crystal sizes. Ironically, the most common fluid inclusion in Gore Mountain garnet is CO_2 -rich and is texturally secondary. These inclusions, like those in many other Adirondack rocks, most likely formed along the retrograde path following peak metamorphic conditions. Precisely how CO_2 -rich inclusions can form in garnet (or more commonly quartz) is unknown as neither mineral is soluble in liquid CO_2 . Two possible explanations include: 1) low temperature mineral growth from the aqueous portion of an immiscible H_2O - CO_2 fluid while trapping CO_2 , or 2) diffusive loss of H_2O from an original mixed H_2O - CO_2 inclusion.

GEOLOGIC HISTORY

Petrologic studies (Buddington 1939, 1952; Bartholome 1956, 1960; Luther 1976; Sharga 1986; Goldblum 1988; Goldblum and Hill 1992; McLelland and Selleck 2011) have concluded that the growth of the large garnets is related to a localized influx of water along the margin of the granulite facies olivine meta-gabbro body. The Gore Mountain garnets are chemically homogeneous suggesting that a) the garnets grew under conditions in which all chemical components were continuously available, and b) the temperature and pressure conditions were uniform during the period of garnet formation. A zone of high $f_{\text{H}_2\text{O}}$ along the southern margin of the original gabbro body may have enhanced diffusion and favored growth of very large garnets and thick hornblende rims at the expense of plagioclase and pyroxene. Luther (1976) speculates that physical and chemical conditions were favorable for the growth of garnet but poor for the nucleation of garnet so that the garnet crystals that did nucleate grew to large size. The presence of hydrothermal fluids provides a steady supply of chemical components promoting the growth of large crystals.

Newton and Manning (2008, 2010) have shown that the transport of Al_2O_3 necessary to form garnet is greatly enhanced by hot, saline fluids under the peak metamorphic conditions of the Adirondacks (8 kbar, 800 °C). McLelland (2002) demonstrated the presence of saline fluid inclusions in the rocks involved.

Recognition that the garnet ore body and deformation fabric coincide with the southern margin of the olivine meta-gabbro body led Goldblum and Hill (1992) to hypothesize that the high fluid flow required for growth of large garnet crystals was the result of ductility contrast at a lithologic contact during high-temperature shear zone deformation. The olivine meta-gabbro is a granulite facies rock with a poorly developed foliation and little evidence of ductile deformation. In the transition zone between the olivine meta-gabbro and the garnet amphibolite, increased ductile deformation resulted in grain-size reduction of plagioclase and pyroxene. Microstructures in plagioclase in the transition zone indicate plastic deformation, and the concurrent modal increase in hornblende indicates an influx of fluid. Fabric development and hydration are most apparent in the garnet amphibolite of the ore zone. According to Goldblum and Hill (1992), the olivine meta-gabbro remained competent and initially deformed by brittle processes along its southern margin, while the adjacent feldspar-rich charnockite and gabbroic meta-anorthosite deformed by ductile processes during deformation at amphibolite facies conditions. Initial grain-size reduction by cataclasis along the margin of the meta-gabbro allowed hydration and metamorphism to produce the garnet amphibolite. During metamorphism, the garnet amphibolite was likely a high-strain zone of reaction-enhanced ductility. Eventually, metamorphic reactions apparently outpaced the rate of deformation and grain coarsening impeded ductile deformation processes (Goldblum and Hill 1992).

It is not currently possible to specify the ultimate origin of the hydrothermal fluids responsible for the growth of garnet megacrysts at Gore Mountain and elsewhere in the Adirondacks, although a mantle source is possible. However, the formation of the garnets has been dated at 1059 ± 19 Ma (Basu et al. 1989), 1051 ± 4 Ma (Mezger et al. 1992), and 1046.6 ± 6 Ma (Connelly 2006). McLelland and Selleck (2011) conclude, based upon an average of previous dates, that the garnets formed at 1049 ± 5 Ma. The youngest major intrusive rock in the Adirondacks is the abundantly distributed Lyon Mountain Granite, which is reliably dated at 1049 ± 10 Ma (McLelland et al. 2010). Numerous pegmatites, granite dikes, and quartz veins, generally undeformed, are intrusive into all other lithologies. The average age of these pegmatitic rocks falls at the younger end of the range of ages available for the Lyon Mountain Granite. McLelland and Selleck (2011) conclude that the pegmatite represents the termination of the intrusion of the Lyon Mountain Granite. Pegmatite occurs at Gore Mountain in the fault contact between the garnet ore zone and the charnockite to the south. Therefore, it is probable that megacrysts of garnet, such as those found at Gore Mountain and elsewhere in the Adirondacks, are the result of the reaction between hydrothermal fluids and upper

amphibolite-grade gabbroic rock. The fluids were derived from the Lyon Mountain Granite or pegmatite derived therefrom and achieved access to the gabbroic rocks through steeply dipping faults or ductile shear zones.

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LITERATURE CITED

- Basu, A.R., B.E. Faggart, and M. Sharma. 1989. “Implications of Nd-isotopic study of Proterozoic garnet amphibolites and wollastonite skarns from the Adirondack Mountains,” *International Geologic Congress*, 28(I): 95-96.
- Bartholome, P.M. 1956. *Structural and petrologic studies in Hamilton County, NY*. Unpublished Ph.D. thesis, Princeton University, 188 pp.
- Bartholome, P.M. 1960. “Genesis of the Gore Mt. garnet deposit, New York,” *Economic Geology*, 55(2): 255-277.
- Buddington, A.F. 1939. “Adirondack igneous rocks and their metamorphism,” *Geological Society of America Memoir*, 7, 295 pp.
- Buddington, A.F. 1952. “Chemical petrology of metamorphosed Adirondack gabbroic, syenitic, and quartz syenitic rocks, New York,” *American Journal of Science*, Bowen Volume: 37-84.
- Charles, M.A., J.J. Gordon, Jr., P.J. Walter, and R.S. Darling. 1998. “More cristobalite in Adirondack garnet,” *Geological Society of America, Abstracts with Programs*, 30: 10.
- Connelly, J.N. 2006. “Improved dissolution and chemical methods for Lu-Hf chronometry,” *Geochemistry, Geophysics, Geosystems*, 7. Q04005, 9, doi: 10.1029/2005GC001082.
- Darling, R.S., I-M Chou, and R.J. Bodnar. 1997. “An occurrence of metastable cristobalite in high pressure garnet granulite,” *Science*, 276: 91-93.
- Goldblum, D.R.. 1988. *The role of ductile deformation in the formation of large garnet on Gore Mountain, southeastern Adirondacks*. Unpublished M.A. thesis, Temple University, 108 pp.

- Goldblum, D.R. and M.L. Hill. 1992. "Enhanced fluid flow resulting from competency contrasts within a shear zone: the garnet zone at Gore Mountain, NY," *Journal of Geology*, 100: 776-782.
- Harben, P.W. and R.L. Bates. 1990. "Garnet," in *Industrial Minerals: Geology and World Deposits*, Metal Bulletin Plc., London, 120-121.
- Hight, R.P. 1983. "Abrasives," in *Industrial Minerals and Rocks*, S.J., LeFond (Ed.), I (5), Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 11-32.
- Kelly, W.M., and Petersen, E.U., 1993, Garnet ore at Gore Mountain, NY: in *Selected Mineral Deposits of Vermont and the Adirondack Mountains*, E. U. Peterson, ed., Soc. Econ. Geol. Guidebook Series, v. 17, 1-9.
- Levin, S., 1950, Genesis of some Adirondack garnet deposits: *Geological Society of America Bulletin* v.61, 516-565.
- Luther, F.R., 1976, *The petrologic evolution of the garnet deposit at Gore Mountain, Warren County, NJ*: Unpublished. Ph. D. Thesis, Lehigh University, 224 pp.
- McLelland, J.M., J. Morrison, B.W. Selleck, B. Cunningham, and C. Olson. 2002. "High-temperature hydrothermal alteration of late- to post-tectonic Lyon Mountain Granitic Gneiss, Adirondack Highlands, New York: Origin of quartz-sillimanite nodules, quartz-albite facies and associated low-Ti, Fe oxide Kiruna-type deposits," *Journal of Metamorphic Petrology*, 20: 175-190. DOI: 10.1046/j.0263-4929.2001.00345.x.
- McLelland, J.M., B.W. Selleck, and M. Bickford. 2010. "Review of the Proterozoic evolution of the Grenville Province, its Adirondack outlier and, and the Mesoproterozoic inliers of the Appalachians," in R. Tollo et al. (Eds.), *From Rodinia to Pangea: The lithotectonic record of the Appalachian region*. *Geological Society of America Memoir*, 206: 1-30. DOI:10.1130/2010.1206(02).
- McLelland, J.M. and B.W. Selleck. 2011. "Megacrystic Gore Mountain-type garnets in the Adirondack Highlands, origin and tectonic implications," *Geosphere*, 7(5): 1194-1208.
- Mezger, K., E. Essene, and Halliday. 1992. "Closure temperatures of the Sm---Nd system in metamorphic garnets," *Earth and Planetary Letters*, 113: 397-409.
- Moran, R. 1956. "Garnet Abrasives: An 80 year history of the Barton Mines Corporation," *Business Biographies*, 47 pp.
- Newton, R., and C. Manning. 2008. "Stability of corundum in the system $\text{Al}_2\text{O}_3\text{-SiO}_2\text{-H}_2\text{O-NaCl}$ at 800 °C and 10 kbar," *Chemical Geology*, 249: 250-261. DOI: 10.1016/j.chemgeo.2008.01.002.

Newton, R., and C. Manning. 2010. "Role of saline fluids in deep crustal and upper mantle metasomatism: Insights from experimental studies," *Geofluids*, 10: 58-72.

Olson, D.W. 2015. "Garnet, industrial," *Mineral Commodities Summaries*. Accessed January 2016 from <http://minerals.usgs.gov/minerals/pubs/commodity/garnet/mcs-2015-garne.pdf>.

Olson, D.W. 2013. *Garnet, industrial, advanced release*. USGS 2012 Minerals Yearbook Vol. 1: Metals and Materials. Accessed January 2016 from <http://minerals.usgs.gov/minerals/pubs/commodity/garnet/myb1-2013-garne.pdf>.

Sharga, P.J. 1986. *Petrologic and structural history of the lineated garnetiferous gneiss, Gore Mountain, New York*. Unpublished M.S. thesis, Lehigh University, 224 pp.

Valley, J.W., N. Kitchen, M.J. Kohn, C.R. Niendorf, and M.J. Spicuzza. 1995. "UWG-2, a garnet standard for oxygen isotope ratios" Strategies for high precision and accuracy with laser heating," *Geochemical et Cosmochimica Acta*, 59: 5223-5231.

Whitney, P.R. and J.M. McLelland. 1973. "Origin of coronas in metagabbros of the Adirondack Mountains," *Contributions to Mineralogy and Petrology*, 39: 81-98.

Whitney, P.R. and J.M. McLelland. 1983. "Origin of biotite-hornblende-garnet coronas between oxides and plagioclase in olivine metagabbros, Adirondack region, NY," *Contributions to Mineralogy and Petrology*, 82: 34-41.

Whitney, P.R., S.R. Bohlen, J.D. Carl, W. deLorraine, Y.W. Isachsen, J.D. McLelland, J.F. Olmsted, and J.W. Valley. 1989. *The Adirondack Mountains - a section of deep Proterozoic crust*. 28th International Geological Congress Field Trip Guidebook T164, American Geophysical Union, Washington, D.C., 63 pp.