Geological Significance of Blue Quartz in the United States of America

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Abstract

Figure 1: Blue quartz xenolith in an outcrop near Old Rag Mountain, VA

Blue quartz has been identified in literature dating as far back as 1884. However, few studies have been conducted to discern the geological significance of its occurrence. Although rarely reported in the world, it is not uncommon to find blue quartz in certain regions of the United States. Nine samples of blue quartz were analyzed from localities in: Old Rag Mountain, VA (2), Flint Hill, VA (2), Roseland, VA, Cape Ann, MA (2), Oracle, AZ, and Llano, TX. Scanning electron microscope images revealed the presence of rutile needles in quartz in all six localities. However, the size of these needles (2-30 μm) makes them unlikely candidates for the Rayleigh scattering of light. Thus, the origin of blue color remains unresolved. Thin sections of blue quartz from Old Rag Mountain showed rutile needles predominantly oriented at 60° to each other, which is consistent with the hexagonal crystal system of quartz suggesting rutile exsolved from the quartz. Blue quartz occurs in host rocks of varying composition (quartz monzonite to anorthosite to syenogranite gneiss) and age (1450 m.y. to 388 m.y.) amongst the studied localities. Some researchers suggested that blue quartz could be used an indicator for regional metamorphism, while others suggest that blue quartz is restricted to granitic rocks. Our research revealed that blue quartz is more closely associated with anorogenic granite magmatism. Further studies should aim to resolve the geologic conditions at which rutile can exsolve from quartz. Recent studies have suggested titanium substitutions in quartz are temperature dependent (Wark and Watson, 2006); thus, attention should be given to the titanium-bearing blue quartz as a potential geothermometer.

Introduction

Due to the chemical simplicity of quartz, differences in the environmental conditions such as radiation and impurities can greatly influence its color. While some of its varieties are well-known such as rose and smoky quartz, others are less known such as blue quartz. Blue quartz is rarely reported in the world. However, it is not uncommon to find this mineral in certain regions of the United States (Figure 2). This research study was undertaken to better understand the significance of blue quartz in rocks found in differing geologic environments through optical and chemical studies of blue quartz. Nine samples of blue quartz were analyzed from localities in: Old Rag Mountain, VA (2), Flint Hill, VA (2), Roseland, VA, Cape Ann, MA (2), Oracle, AZ, and Llano, TX (Figure 3). The host rocks of blue quartz vary amongst the different localities in both composition and age. In Virginia, the host rocks are the Old Rag Granite (garnetiferous leucogranite, 1065 m.y. old), Flint Hill Gneiss (syenogranite gneiss, 1144 m.y. old), and the Roseland anorthosite (1045 m.y. old). The Cape Ann Granite in MA is a perthitic alkali feldspar granite that is roughly 388 m.y. old (Figure 4). The Oracle Granite in AZ is 1450 m.y. old and is a quartz monzonite. In Llano, blue quartz occurs in rhyolitic dikes (also known as llanite) and is 1093 m.y. old.

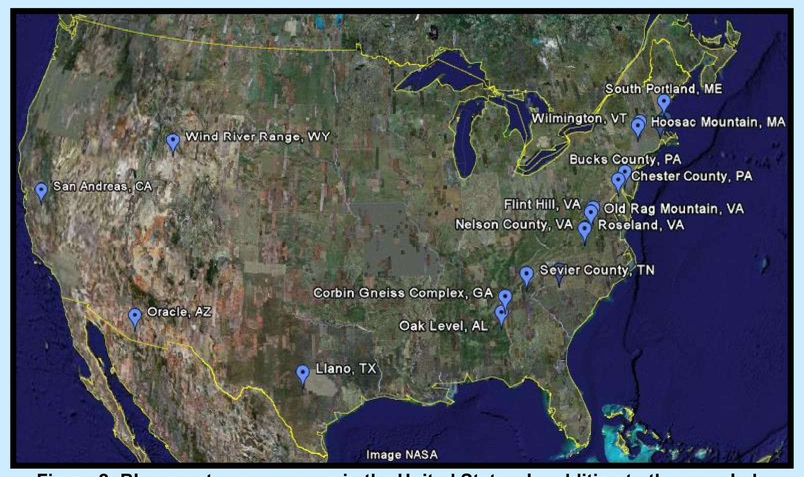

Figure 2: Blue quartz occurrences in the United States. In addition to the sampled localities, blue quartz has been cited in other regions along the Blue Ridge Mountains and in Wyoming.

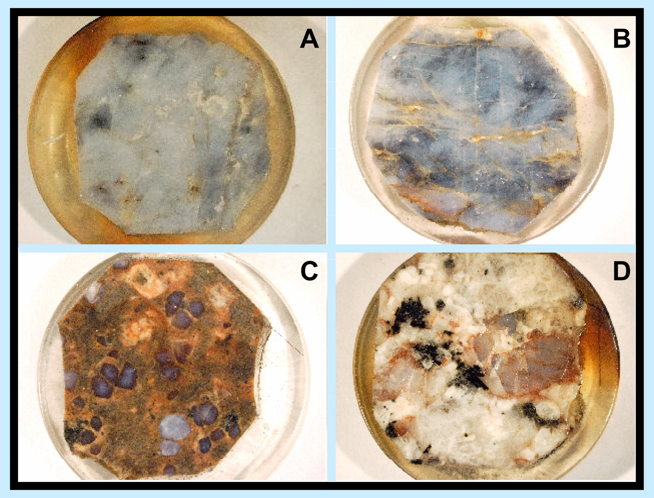

Figure 3: One-inch mounts of the nine samples were prepared, polished, and carbon coated for analysis. (A) Old Rag Mountain, VA. (B) Old Rag Mountain, VA. (C) Llano, TX. (D) Oracle, AZ.

Figure 4: Outcrop of Cape Ann Granite, MA with blue quartz segregations.

Results

Why is Blue Quartz Blue?

Unlike smoky quartz which derives its color from natural radiation, the origin of the distinctive blue color in blue quartz remains uncertain. Some researchers have hypothesized that the blue color arises from Rayleigh scattering of light by microscopic rutile needles. Rayleigh scattering is the elastic scattering of visible radiation from the sun by particles much smaller (<1/10) than the wavelength of the light. The wavelength of blue light is 475 nanometers.

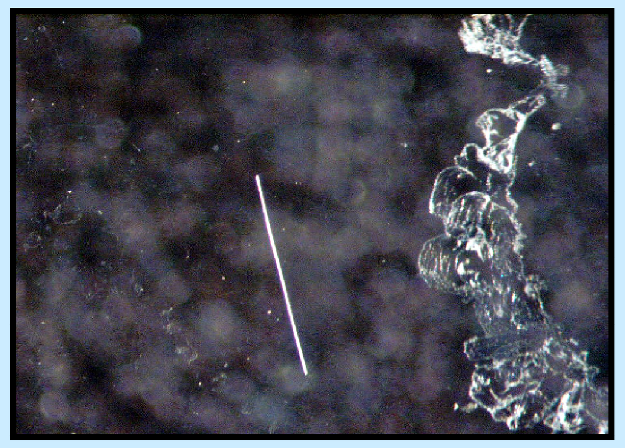

Figure 5: Acicular needle of rutile viewed under reflected light under a binocular microscope. Field of view approximately 1.55 mm.

The nine quartz samples were analyzed under a scanning electron microscope (SEM). Acicular needles (Figure 5) were present in eight of the nine samples. An energy dispersive X-ray spectroscopy (EDS) analysis revealed the needles were composed of Ti and O (Figure 6). Thus, these needles are most likely rutile, which is TiO_2. The size of the observed needles, however, were on the order of 2-30μm making them an unlikely candidate for Rayleigh scattering. It is possible, however, that nanometer-sized rutile needles present in the samples were beyond the detection level of the scanning electron microscope (SEM). Consequently, the origin of the blue color in blue quartz remains unresolved.

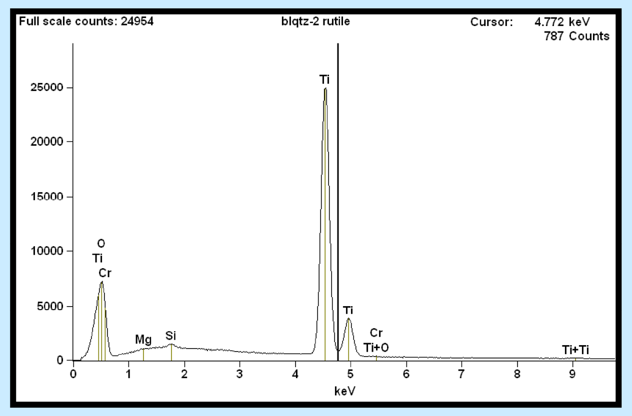

Figure 6: EDS scan of acicular needle identified in Blqtz-2, a sample from Roseland, VA.

Orientation of Rutile Needles

Thin sections of quartz samples from two localities: Old Rag, VA and Roseland, VA were examined in the petrographic microscope. Under transmitted light, the rutile needles are oriented at 60° to each other, consistent with the hexagonal crystal system of quartz (Figure 7). This orientation suggests that the rutile needles exsolved from the quartz after the quartz started crystallizing.

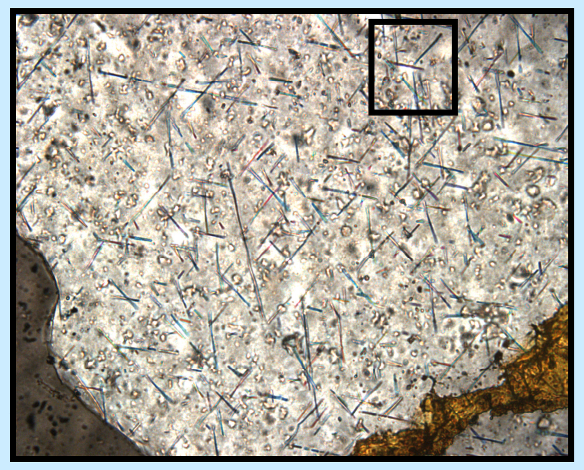

Figure 7: A thin section of blue quartz from Roseland, VA was photographed under transmitted light. Note the 60° orientation of the needles. Field of view 855 μm

Variation in Blue Color of Quartz

Other inclusions identified in the blue quartz samples included ilmenite, titanite, zircon, plagioclase feldspar and apatite. These minerals were typically consistent with the mineralogy of the host rock. In the VA samples, "wispy" strands of ilmenite often darkened areas in the blue quartz (Figure 8).

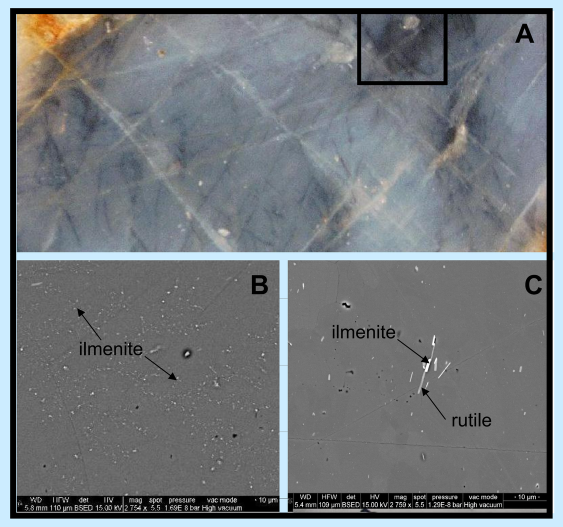

Figure 8: (A) Sample from Old Rag Mountain, VA; note insert with "wispy" strands of ilmenite. Field of view 0.51 cm. (B) SEM image of "wispy" ilmenite features on blue quartz sample from Flint Hill, VA. (C) Ilmenite rods were often associated with needles of rutile in all of the VA samples. Sample from Old Rag Mountain, VA.

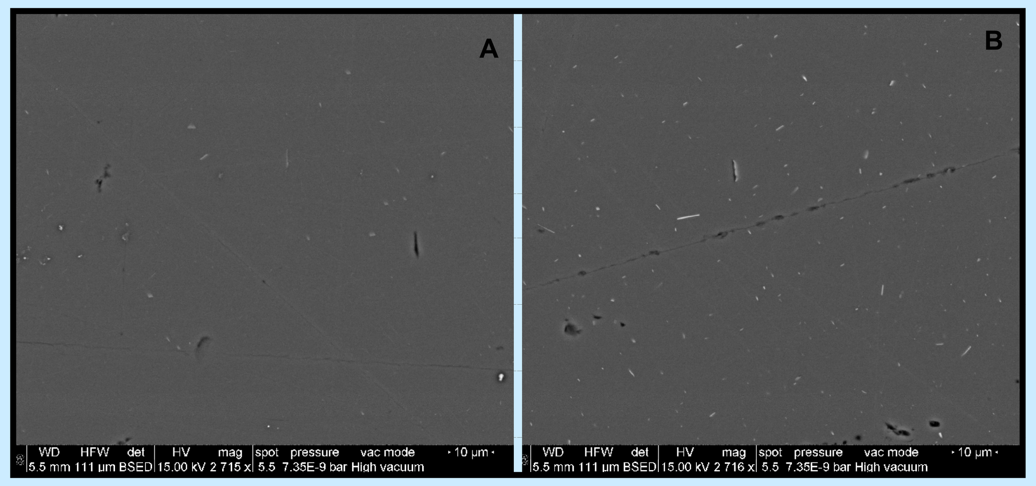

Figure 9: Phenocrysts in the blue quartz sample from Llano, TX were dark blue at the grain border and light blue at the center of the grain. (A) Center of a blue quartz grain. (B) Edge of the same grain boundary. Note the difference in the density of rutile needles.

In addition to varying in color amongst the different localities, blue quartz also varied in coloration within the same sample (Figure 3b). SEM imaging consistently revealed a higher density of rutile needles in the darker blue regions relative to the lighter blue regions (Figure 9).

Related Granite Magmatism

Blue quartz occurs both as phenocrysts and in the matrix in a variety of igneous rocks such as anorthosites, quartz monzonites, and charnockites. It also occurs as xenoliths, veins, and phenocrysts in many Precambrian gneissic metamorphic rocks. As previously mentioned, the host rocks in which blue quartz occurs vary in both composition and age. At least one similarity exists amongst these rocks; researchers have determined that each of these rocks were generated as a result of anorogenic or A-type magmatism (Figure 10).

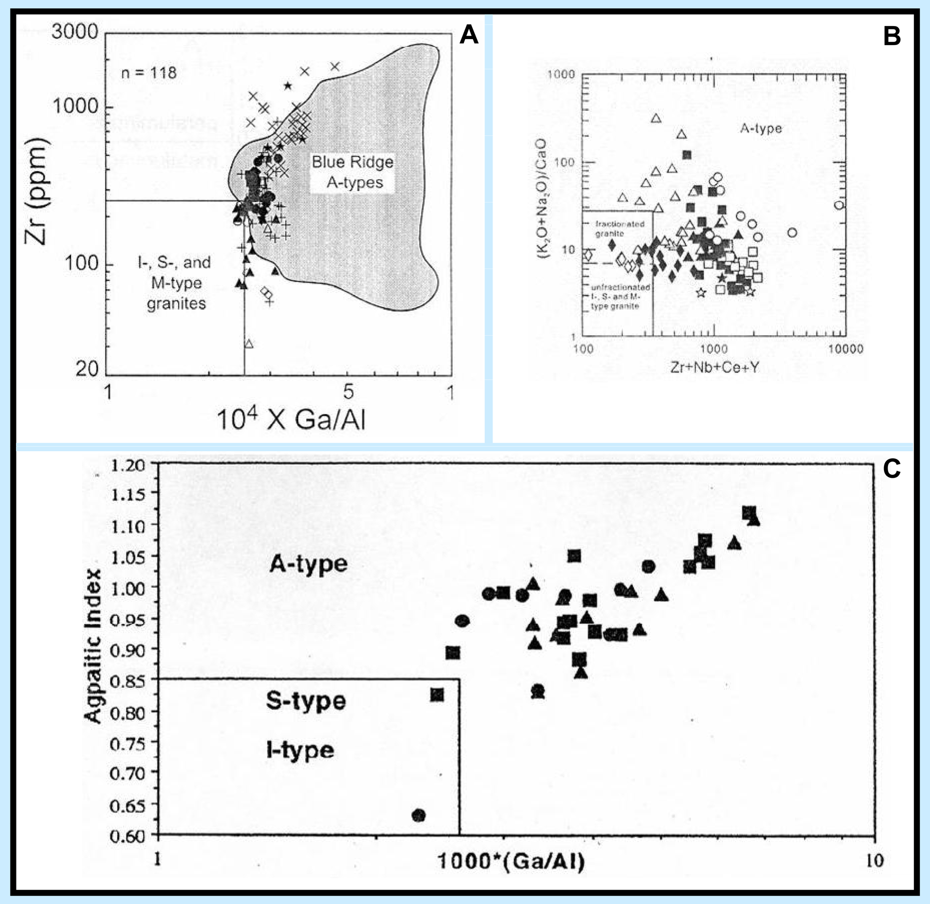

Figure 10: Discrimination diagrams of blue-quartz-bearing rocks represented in this study, (A) Basement rocks of the Blue Ridge Province including Old Rag Granite and Flint Hill Gneiss (Tollo et al, 2004). (B) Possible tectonic setting for Grenville-age felsic samples for the Potrillo maar xenoliths, 'Abilene' granite, Red Bluff Granitic Suite and Enchanted Rock Batholith (which contains the Llano rhyolite) (Li et al, 2007). (C) Plot of Cape Ann granites and syenites (Hon et al, 2001). Oracle Granite (not plotted) is also an A-type granite (Anderson and Morrison 2006).

Conclusions

- Origin of blue color in quartz remains unresolved.
- Orientation of observed rutile needles at 60° to each other is consistent with the hexagonal crystal system of quartz. Thus, these rutile needles most likely exsolved from quartz.
- Darker blue quartz regions have a higher density of rutile needles relative to the lighter blue quartz regions.
- Blue quartz found in both igneous and metamorphic rocks is closely associated with anorogenic magmatism.
- Further studies should aim to resolve the geologic conditions at which rutile can exsolve from quartz.
- Recent studies have suggested that titanium substitution in quartz is temperature dependent (Wark and Watson, 2006); thus, attention should be given to the titanium-bearing blue quartz as a potential geothermometer.

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