Heat Treatment of Amethyst from Brazil to Green Quartz

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Abstract

The main objective of this study is to find the optimum temperatures from heating experiments for changing the purple of amethyst samples from the Federal Republic of Brazil to green. This study also focuses on the gemological properties of the samples from this deposit. A total of 30 amethyst samples were divided into 3 groups according to the apparent colors, including the dark purple, medium purple, and light purple groups. The sample weighed in the range of 1.03 to 4.88 carats. The specific gravity value ranged from 2.62 to 2.64. The refractive indices ranged from 1.542 to 1.553 with birefringence between 0.007 and 0.011. They showed the phenomenon of double refraction and were inert under ultraviolet radiation in both the short and long wavelength ranges. These properties were unchanged after heating experiments. The amethyst samples were heated 3 times, using an electric furnace, under reduction conditions at 400°C and 420°C, maintaining at each temperature for 1 hour. The heating results revealed that at 400°C, the dark purple samples changed to a slightly yellowish green color, some of the medium purple samples turned pale yellow, and the light purple samples turned slightly lighter color. At 420°C, the dark purple samples changed from a slightly yellowish green to yellow-green with a shade of yellow, some of the medium purple samples turned nearly colorless, and the light purple samples turned colorless or developed a slight yellow shade. And at 440°C, the dark purple samples changed to At 440°C, the dark purple samples changed to a brighter yellowish-green, the medium purple samples changed to a clear to colorless pale yellow, and some samples changed to a pale purple. and the light purple samples changed to a pale yellowish-green. Absorption spectra investigated by UV-Vis-NIR spectrophotometry revealed absorption bands at approximately 345 nm and 545 nm before heat treatment. These bands are associated with the purple coloration in amethyst. After the heat treatment, the absorption intensity at 545 nm decreased as the purple color. The inclusions observed under the microscope revealed an increase in fractures, expansion of healed fractures, and enlargement of liquid inclusions after heat treatment. From this study, it can be concluded that the dark purple samples were the most suitable initial colors to transform amethyst into a green color, and the optimum temperature is 420°C. However, their transparency commonly decreased by fracture increases during heating experiments.

Introduction

Amethyst is the name of a purple quartz (SiO_2). In the gemstone market, amethyst is often valued by heating to change the color of amethyst into other more expensive quartz colors, such as yellow quartz or citrine, and green quartz or prasiolite. In particular, green quartz is rarer than citrine. Therefore, this study is an experiment to improve the quality of Brazilian amethyst by heating it with an electric furnace under oxidizing condition to study the optimum temperature range (between 400 - 440 ° C) that is expected to change the color of amethyst to green, and to compare its gemological properties using basic and advanced tools.

Materials & Methods

- Thirty amethyst samples (Figure 1) claimed to be from Brazil were studied for gemological characteristic, chemical compositions, cause of color and study the optimum temperature range for changing purple to green.
- The amethyst samples were heated using an electric furnace under reducing condition. Heating at 400°C involved heating for 2 hours followed by holding for 1 hour. At 420°C, the process involved heating for 2 hours and 30 min, holding for 1 hour, and at 440°C, heating for 3 hours and holding for 1 hour.
- The CIE program was used to compare the colors before and after the enhancement.

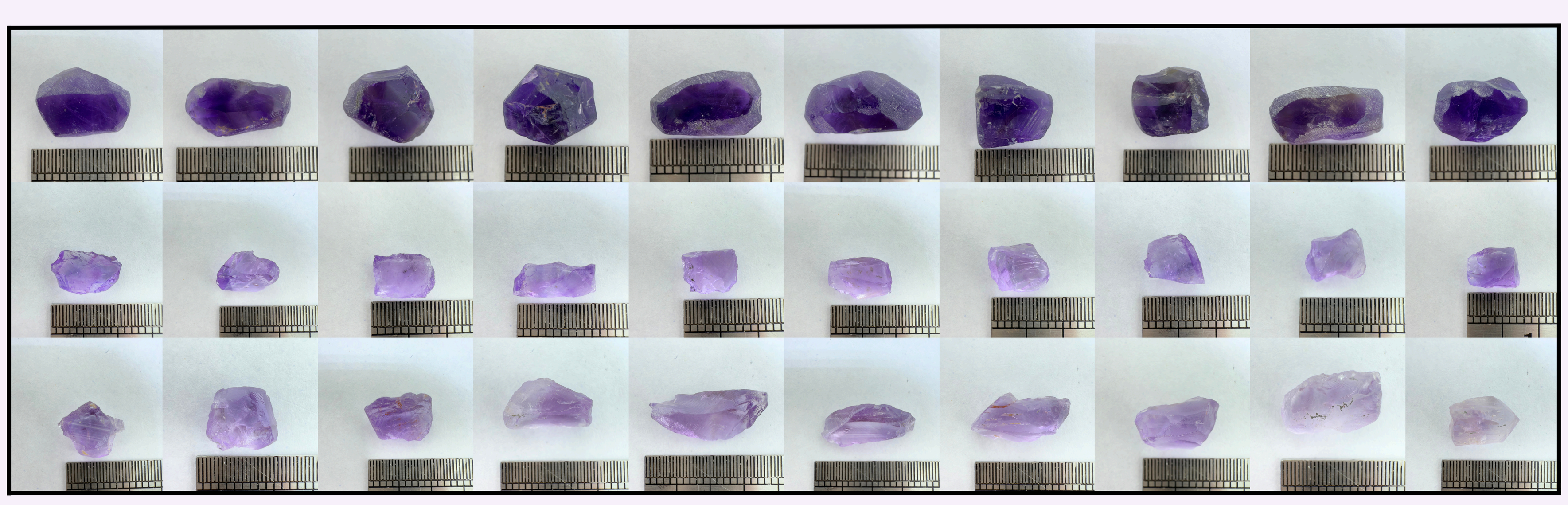


Figure 1. The studied 30 amethyst samples claimed from Brazil.

Result and Discussion

Gemological properties

The comparison of the basic gemological properties of the samples analyzed using standard instruments showed no significant changes.

Chemical compositions

From taking samples to analyze with SEM-EDS at The Central Science Laboratory, Chiang Mai University. It was found that the only major element detected was Si. The other elements were under detection limit

Inclusions

The inclusions after quality enhancement revealed an increase in fractures (Figure 2), expansion of healed fractures, and enlargement of liquid inclusions. There were also changes in the coloration of stains within healed fractures (Figure 3).

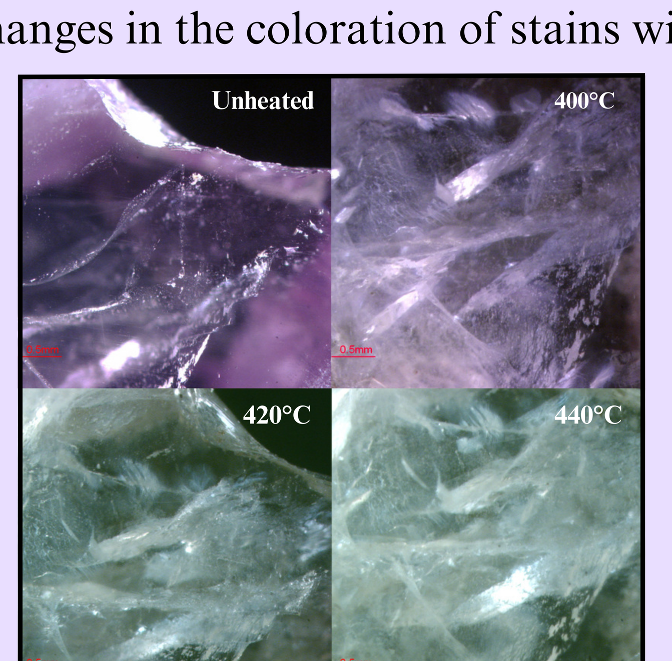


Figure 2. The inclusions after quality enhancement revealed an increase in fractures.

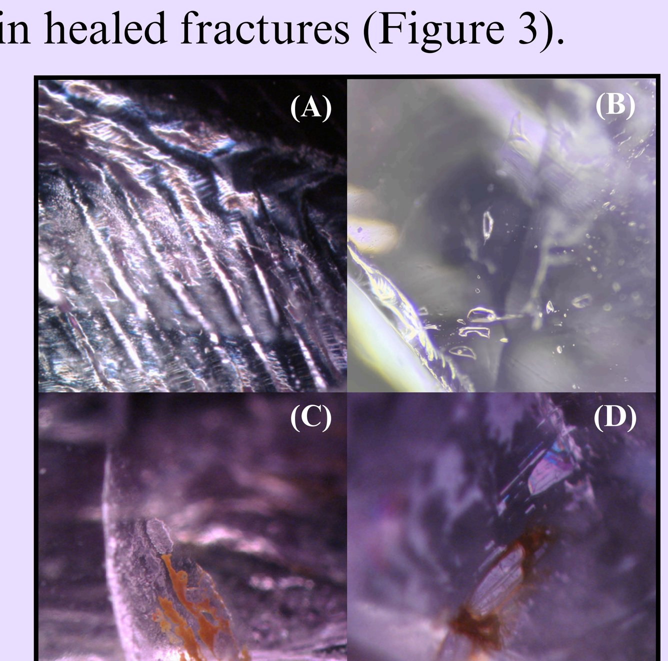


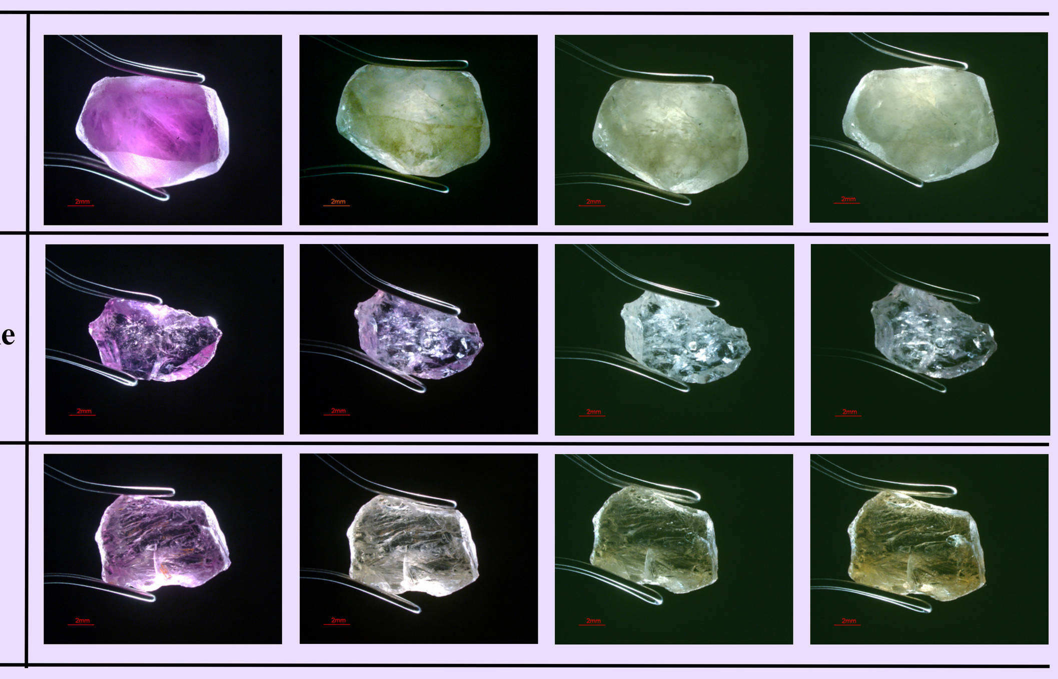
Figure 3. The zebra stripe (A) 2-phase inclusions (B) stains within healed fractures (C) and fractures (D) in amethyst samples.

Heat Treating Experiment

The heating results revealed that at 400°C, the dark purple samples changed to a slightly yellowish green color, some of the medium purple samples turned pale yellow, and the light purple samples turned slightly lighter color. At 420°C, the dark purple samples changed from a slightly yellowish green to yellow-green with a shade of yellow, some of the medium purple samples turned nearly colorless, and the light purple samples turned colorless or developed a slight yellow shade. And at 440°C, the dark purple samples changed to At 440°C, the dark purple samples changed to a brighter yellowish-green, the medium purple samples changed to a clear to colorless pale yellow, and some samples changed to a pale purple. and the light purple samples changed to a pale yellowish-green (Table 1).

Table 1. The change of colors after heat treatment at different temperatures

	Unheated	400°C	420°C	440°C
Dark purple				
Medium purple				
Light purple				



UV-Vis-NIR

UV-Vis-NIR spectrophotometric studies prior to heat treatment revealed absorption bands at approximately 345 and 545 nm, which were absorption sites associated with the formation of the purple hue in amethyst, caused by the replacement of silicon (Si^{4+}) with iron (Fe^{4+}) in the color center after heat treatment. The absorption band at 545 nm shows a decreasing absorption band as the purple color fades (Figure 4), as Fe^{4+} is converted to elemental Fe^{2+}, which gives it the green color.

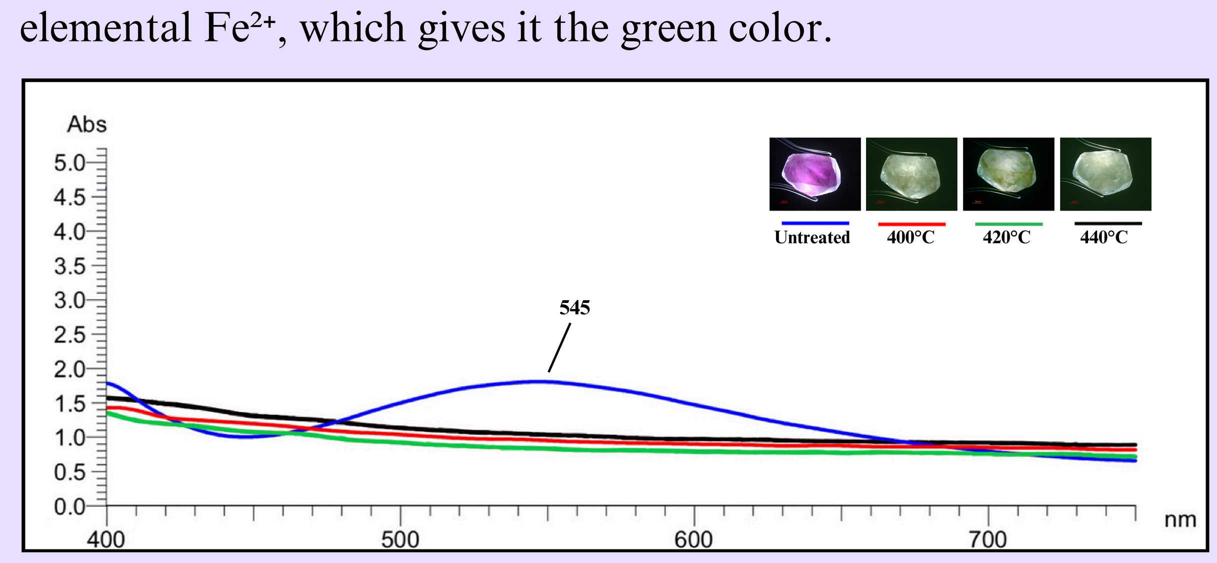


Figure 4. The UV-Vis-NIR absorption results of amethyst from Brazil before and after enhancement.

CIE Color space

The purple color of the sample before enhancement, and when it is enhanced at 400 and 420 degrees (Figure 5), it is in the green color, and at 440 degrees, it starts to turn more towards the yellow color.

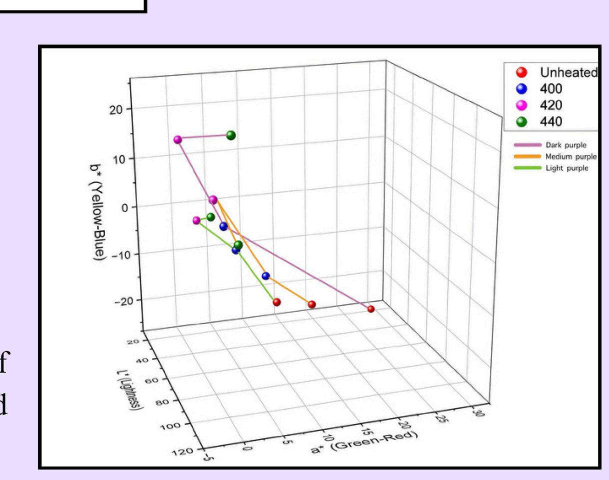


Figure 5. The CIE color space of the amethyst samples before and after enhancement

Conclusions

This study concluded that the optimal temperatures for heat treatment to transform amethyst into a green color were 420°C, based on the intensity of the color in the samples. Dark purple samples were more likely to turn green compared to medium and light purple samples. However, the transparency of dark purple samples decreased with increased fractures during heat treatment, while medium and light purple samples became more transparent with additional heat treatment.

Reference

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Acknowledgement

The authors would like to thank 50th Geological Anniversary Chiang Mai University and Faculty of Science, Chiang Mai University for providing the financial support for this research. Thanks are extended to Mr. Siwakon Chimnakphant and staff at the Department of Geological Sciences, Faculty of Science, Chiang Mai University, and Gems and Geological Items Analysis Section, Department of Mineral Resources, Bangkok, for providing the fascicles.