# NOTES · AND · NEW TECHNIQUES

## AMETHYSTINE CHALCEDONY

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*A new amethystine chalcedony has been discovered in Arizona. The material, marketed under the trade name "Damsonite," is excellent for both jewelry and carvings. The authors describe the gemological properties of this new type of chalcedony, and report the effects of heat treatment on it. Although this purple material is apparently a new color type of chalcedony, it has the same gemological properties as the other better-known types. It corresponds to a microcrystalline form of amethyst which, when heat treated at approximately 500°C, becomes yellowish orange, as does some single-crystal amethyst.*

Chalcedony is a microcrystalline form of quartz that occurs in a wide variety of patterns and colors. Numerous types of chalcedony, such as chrysoprase, onyx, carnelian, agate, and others, have been used in jewelry for thousands of years (Webster, 1983). These several kinds of chalcedony owe their coloration in part to finely disseminated mineral impurities, particularly the oxides and hydroxides of iron, that originate in the environments of chalcedony formation.

In the near future, a significant quantity of massive purple chalcedony mined in Arizona will be marketed in the form of cabochons and carvings under the trade name "Damsonite" (figures 1 and 2). Our examination of this material demonstrates that it is a microcrystalline form of amethyst quartz. Although it is likely that purple chalcedony has been found previously, a survey of the mineralogical and gemological literature indicates that this is one of the few reported occurrences where an amethyst-like, or amethystine, chalcedony has been found in quantities of gemological importance (see Frondel, 1962). Popular gem hunters' guides, such as MacFall (1975) and Anthony et al. (1982), describe minor occurrences in Arizona of banded purple agate, but give no indication of deposits of massive purple chalcedony similar to that described here. This article briefly summarizes the occurrence, gemological properties, and reaction to heat treatment of this material.

### LOCALITY AND OCCURRENCE

The purple chalcedony described here has been found at a single undisclosed locality in central Arizona. It was first noted as detrital fragments in the bed of a dry wash that cuts through a series of sedimentary rocks. A subsequent search of the adjacent hillsides uncovered the major in-situ de-

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*Acknowledgments: The authors thank J. D. Porter of Boulder City, Nevada, for supplying the purple chalcedony used for our examination, and Richard T. Liddicoat, Jr., for suggesting this study. The authors drew in part on an earlier unpublished study of this material carried out by W. John McLean of the Colorado School of Mines Research Institute in Golden. We also acknowledge the assistance of Randy Heuser for use of the electron microprobe at the California Institute of Technology in Pasadena.*

Figure 1. This purple chalcedony cabochon (approximately 21 × 8 × 5 mm) is set in yellow gold and accented by diamonds and pearls. Photo © Tino Hammid.

posit of the chalcedony. The material occurs in veins and massive blocks up to 1 m thick enclosed in the weathered sedimentary host rock. Massive pieces (up to 100 kg each) of purple chalcedony have been removed from this area. Hot springs and deposits of opalized silica in the immediate vicinity suggest that the veins of massive purple chalcedony were deposited from low-temperature silica-bearing solutions by normal depositional processes similar to those that typically form chalcedony in other sedimentary environments (for further general information, see Frondel, 1962). At the present time, all of the readily accessible purple chalcedony has been removed from this locality and mining has stopped. However, the total tonnage reserves on hand are sufficient to supply the jewelry market with several thousand carats of purple chalcedony per year for the foreseeable future. Current plans call for distributing the material only in finished form through a marketing company.

## DESCRIPTION OF THE MATERIAL

As with most other chalcedony, the purple material is a tough microcrystalline aggregate that occurs in dense, compact masses with a wax-like appearance (figure 3). In thin section under the microscope, the chalcedony is seen to consist of tightly packed microcrystalline (typically five micrometers across) grains of quartz in random arrangement. In thin pieces (less than 1 mm), the chalcedony is semitranslucent to translucent with a reddish cast, but almost all thicker pieces are opaque. It displays a dull conchoidal fracture on broken surfaces, but takes a vitreous luster when polished. The color of the chalcedony can best be described as a grayish, slightly reddish purple, but the tone, saturation, and sometimes the hue of the material vary within the deposit (figure 4). Approximately one-half of the chalcedony mined thus far reportedly is the darker purple, while the remainder represents the lighter shades. Some of the purple chalcedony is veined by thin seams of a reddish brown material that appears to be either an iron oxidation product such as hematite or goethite, or

Figure 2. This 5-in. (12.5-cm) high "kuan yin" figure was carved from a single piece of purple chalcedony. Photo © Tino Hammid.

*Figure 3. A large block (20 × 10 × 10 cm; 8 × 4 × 4 in.) of rough purple chalcedony. Photo © Tino Hammid.*

an iron-stained type of chalcedony (jasper). Also noted on a few pieces were black dendritic plumes of what appear to be one of the manganese oxides such as pyrolusite. The chalcedony displays no particular tendency to fracture along these veinlets nor along other features such as color boundaries.

## GEMOLOGICAL PROPERTIES

The gemological properties of this material, as determined by standard tests, were found to correspond closely to those of both chalcedony and amethyst. These are summarized in the insert box. A comparison of the visible absorption spectra of both purple chalcedony and amethyst is shown in figure 5.

Several cabochons of the purple chalcedony were examined with the microscope. At relatively low magnification (approximately 40×) all of the samples studied showed clusters of tiny dark brownish red to orange, slightly irregular, spherules of secondary iron compounds, possibly hematite or goethite (figure 6). The color in the chalcedony appeared to be slightly darker around the clusters, giving the material a mottled appearance at this magnification. The reddish color of these inclusions is quite reminiscent of the red-orange spots seen macroscopically in the type of chalcedony known as bloodstone.

## ORIGIN OF COLOR

Electron probe microanalyses performed on this material by C. M. Stockton showed that it contains 0.2–0.4 wt.% iron as $Fe_2O_3$. Iron as a trace element is responsible for the color of amethyst (Holden, 1925). The iron, in the form of $Fe^{3+}$, substitutes for $Si^{4+}$ in the quartz crystal structure and produces several kinds of color centers. Irradiation of these color centers causes the absorption of light, resulting in a purple coloration (see Cohen, 1956; Nassau, 1983). The depth of the purple color is directly related to the iron content (Frondel, 1962).

To test for the presence of dye in the purple chalcedony, we placed fragments of the rough material in a variety of solvents. Using a standard procedure for dye extraction (Kumar, 1981), we found no evidence of dye in the purple chalcedony.

*Figure 4. A selection of purple chalcedony cabochons showing the range of color of the material. Photo © Tino Hammid.*

**GEMOLOGICAL PROPERTIES OF PURPLE CHALCEDONY**

**Refractive index**
Spot method: 1.54
Flat surface: 1.535–1.539 (birefringence 0.004)

**Specific gravity**
Heavy liquid: 2.61 (average of measurements of 7 stones)
Hydrostatic method: 2.60 (average of 4 measurements on 1 stone)

**Visible-light spectroscopy**
No sharp bands noted in either transmitted or reflected light

**Visible-light spectrophotometry**
Increasing absorption toward the ultraviolet, with a superimposed broad absorption band centered about 540 nm

**Ultraviolet fluorescence**
Inert to long-wave and short-wave ultraviolet radiation

**Hardness**
Near 7 on the Mohs scale

**Microscopy**
Abundant dark brownish red spherules scattered throughout material

**Color**
Reddish purple to red-purple hues with low saturation (1–2) and low to moderate tone (2–5), according to the terminology of GIA's Colored Stone Grading system

## HEAT-TREATMENT EXPERIMENTATION

Samples of the chalcedony were heated to see if a color change would take place similar to that known to occur in single-crystal amethyst (Nassau, 1984). It has long been recognized that the heating of amethyst will produce citrine, and that subsequent re-irradiation will reinstate the purple color. Several cabochons, ranging from light to dark purple, were selected for heating and were then sawed in half to provide test and control samples. The test halves were heated using a Blue M Labheat muffle furnace with a temperature range up to 1000°C. For this heating, the test samples were placed in pure quartz sand in an alumina crucible. Heating was done in 100° increments, each lasting one hour. The test halves were compared to the control halves at the end of each heating increment. A change in appearance was first noted at 500°C. At approximately this temperature, the heated halves took on a grayish orange to brown tone that, after heating another 50°C to approximately 550°C, brightened in the case of the

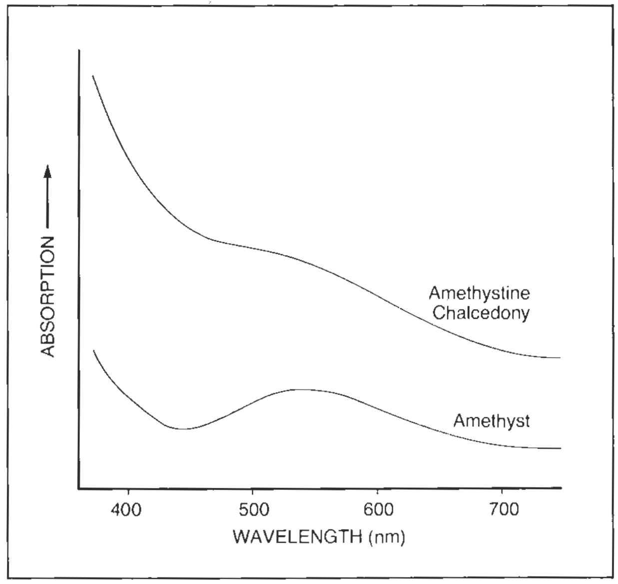


*Figure 5. Visible absorption spectra of purple chalcedony and amethyst. Both spectra show increasing absorption toward the ultraviolet and a broad region of absorption (centered around 540 nm) that is more pronounced in the amethyst spectrum. Samples were thin slices of purple chalcedony (0.59 mm thick) and amethyst (2.82 mm thick) with parallel-polished windows.*

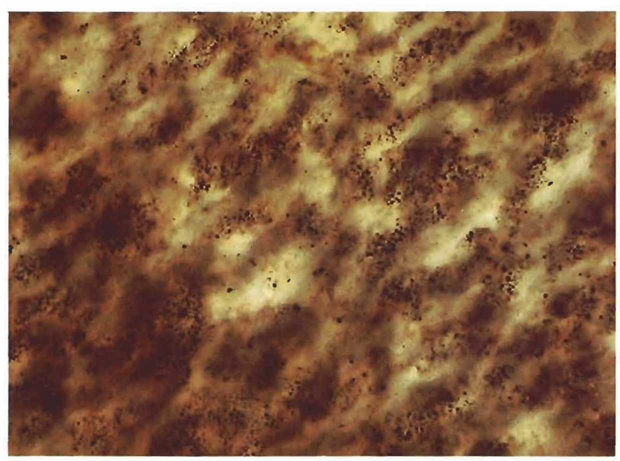

*Figure 6. Tiny spherules of secondary iron compounds concentrated in color-rich areas in the purple chalcedony. These spherules rarely occur as large as 0.1 mm. Note the orange "iron-stained" color of the chalcedony around these spherules. Transmitted light, magnified 40×. Photo by John Koivula.*

darker purple cabochons to an orange color similar to that of most citrine. The stones held this color to 800°C, at which point they began to bleach out. At 1000°C many of the stones had bleached to a grayish white; only those that originally had been the darkest purple still retained any orange coloration. It was also noted that pale-colored purple cabochons when heated never attained any orange body color but instead took on a brownish gray tone. Only those stones that possessed a dark purple color to begin with showed a color change to orange (figure 7).

These results are generally consistent with data on the heat treatment of amethyst reported by Neumann and Schmetzer (1984). In their study of amethyst from over 20 localities, they documented the color-change behavior for amethyst heated between 300° and 560°C for several hours. They found that amethysts with a preponderance of color centers associated with interstitial iron atoms (iron atoms located between silicon and oxygen atoms) turned green when heat treated (i.e., "greened" amethyst). Only amethysts that contained small amounts of iron, presumably in the form of small particles of hematite ($Fe_2O_3$), became orange on heating. We have already noted the abundance of tiny, reddish brown spherules of secondary iron oxides in the purple chalcedony. We believe that the color change of this purple chalcedony to orange with heating can be attributed to the presence of these hematite or goethite spherules. The intensity of the orange color produced by heat treating amethyst seems to be related to the intensity of the original purple color (Frondel, 1962; Neumann and Schmetzer, 1984). We observed a similar change in the purple chalcedony, with only the darker purple test samples taking on an orange color with heating.

*Figure 7. Deep purple amethystine chalcedony cabochon before (left) and after (right) heat treatment to 550°C. Photo by John Koivula.*

**CONCLUSION**

This new type of chalcedony from Arizona is very tough and durable and comes in a wide range of purple shades. It is easily identified by standard gemological testing procedures, and appears to be colored by the same color-center mechanism as amethyst. There is enough material to amply supply the market. Thus, many possibilities exist for its use in jewelry and carvings.

While the occurrence of purple chalcedony in Arizona appears to be unusual, we do not believe this occurrence to be unique, considering the relative abundance of chalcedony in many areas of the world. It is somewhat surprising, however, that other occurrences have not been more widely publicized.

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