A glass imitation of blue chalcedony

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ABSTRACT: A new artificial product on the Taiwan gem market, light blue translucent glass, is described and compared to natural blue chalcedony, blue opal and stained chalcedony. The gemmological characteristics of the materials are given and compared. Chemical ED-XFA tests indicate relatively high Na, Ca and low Al values in the glass compared with gemstones of the silica group, and also with such contents in natural glasses. IR spectra of the artificial glass and chalcedony are also quite different. Wollastonite was identified by Raman spectroscopy as a devitrification product forming fine felty fibres or small crystals up to 1 mm thick; they define the degree of translucency of this artificial calcium glass.

Keywords: Taiwan, blue chalcedony, glass imitation, wollastonite, ED-XFA

Introduction

Blue chalcedony is one of the most precious local gemstones in Taiwan. It occurs as irregular small veins in andesitic agglomerate north of Taitung, eastern Taiwan. After having been mined for decades, the deposits are now almost exhausted. Supplies therefore are scarce and many imitations of blue chalcedony are on the market, such as dyed blue chalcedony, dyed blue quartzite and blue opal. In 1998 we found another material resembling blue chalcedony on the market which was declared to originate from China. In the course of our study it turned out to be an artificial blue glass (Figure 1). Natural glasses have been encountered as obsidians, tektites and moldavite (see, for example, Tsai and Wu, 1997).

Figure 1: A 12.5 ct cabochon-cut glass imitation of blue chalcedony from Taiwan. The 17 mm long sample shows horizontal banding and perpendicular fibrous pattern. Photo by H.A. Hänni, SSEF.
The properties of blue chalcedony

Chalcedony is described as a fibrous aggregated form of silica which merges into agate when the banding becomes prominent (Webster, 1983). The microstructure of the sheaf-like fibre array (botryoidal structure) of silica allows some porosity in which natural or artificial pigments can impart colour. The whole structure of this cryptocrystalline material produces, depending on the direction of view, a more or less easily visible banded or polygonal pattern when inspected in transmitted light.

The properties of blue chalcedony from Taiwan have been widely studied by, for example, Huang (1965 and 1982), Chen (1969) and Chen and Zen (1982). So far we have not found any western reference for Taiwan blue chalcedony. The papers conclude that the colour of the Taiwanese blue chalcedony is usually homogeneous sky blue to greenish-blue, the material being semi-transparent to opaque, with a conchoidal fracture. The RI is 1.539, and SG is 2.58. A copper content of 0.01 to 0.02% has been reported, and a small uranium content of 0.002 to 0.0035 %wt gives rise to minor radiation (Huang, 1965).

Imitations

Imitations are substances that may substitute a given gemstone and may be natural gemstones or artificial products. Usually imitations are of lesser value than those that they imitate. The most popular imitations of natural blue chalcedony are dyed blue chalcedony, dyed blue quartzite and blue opal, but the new product described in this paper may also be convincing. Other substances to substitute for blue chalcedony are imaginable such as pectolite (Woodruff and Fritsch, 1989) or hemimorphite (Moses et al., 1998), both of sky-blue colour with a definite structure. The properties of these imitations are listed in Table 1 and some examples in comparison are shown in Figure 2.

Most of the dyed blue chalcedony is free of inclusions and has a homogeneous colour distribution besides a faint 'agate' banding. Such a weak banding structure can be found in most chalcedony (Figure 3). Under a Chelsea filter the dyed material appears

![Image: Figure 2: From left to right: (back) imitation blue chalcedony (glass), dyed blue quartzite, dyed blue chalcedony (front) natural blue chalcedony (Taiwan), natural blue chalcedony (Taiwan), blue opal (Peru). Photo by H.A. Hänni, SSEF.]

Table 1: The properties of blue chalcedony and its imitations.

<table>
<thead>
<tr>
<th>Gemstone</th>
<th>RI (spot reading)</th>
<th>SG</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue chalcedony</td>
<td>1.53</td>
<td>2.58</td>
<td>6.5</td>
</tr>
<tr>
<td>Dyed blue chalcedony</td>
<td>1.53</td>
<td>2.60</td>
<td>6.5</td>
</tr>
<tr>
<td>Dyed blue quartzite</td>
<td>1.54</td>
<td>2.65</td>
<td>7</td>
</tr>
<tr>
<td>Blue opal</td>
<td>1.45</td>
<td>2.15</td>
<td>6</td>
</tr>
<tr>
<td>Sky-blue glass</td>
<td>1.54</td>
<td>2.57</td>
<td>5</td>
</tr>
<tr>
<td>(chalcedony imitation)</td>
<td>1.60</td>
<td>2.81</td>
<td>5</td>
</tr>
<tr>
<td>Pectolite</td>
<td>1.60</td>
<td>3.45</td>
<td>5</td>
</tr>
<tr>
<td>Hemimorphite</td>
<td>1.62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

reddish-brown. Since RI and SG are the same for the natural and treated blue chalcedony, we cannot distinguish them on the basis of these two properties.

Blue opal usually shows jelly-like inclusions (Figure 5) which may look similar to some inclusions in natural blue chalcedony (Figure 6), but with its RI of 1.45 and SG of 2.15 it can be distinguished from chalcedony. Blue opal appeared on the market some years ago and has been reported from Chile (Koivula and Kammerling, 1991) and Peru (Milisenda, 1995).

![Figure 3: Banding structure of dyed blue chalcedony. The banding of chalcedony is usually finer and more homogeneous, whereas bands in the imitation (Figure 1) appear more structured by parallel fibres. Photo by S.T. Wu.](image1)

![Figure 5: Jelly-like inclusions in blue opal from Peru. Length of the stone is 8.6 mm. Photo by S.T. Wu.](image2)

Dyed blue quartzite possesses a slight porosity which allows the staining to penetrate along grain boundaries. Such material shows concentrations of dye between the quartz grains which are easy to detect when a penlight is used (Figure 4). The SG of quartzite is 2.65 which is distinctly higher than that of blue chalcedony (2.58).

![Figure 4: In dyed blue quartzite the colour is always concentrated on grain boundaries and along fractures. Length of the stone is 8 mm. Photo by S.T. Wu.](image3)

![Figure 6: Jelly-like inclusions in natural blue chalcedony from Taiwan. Length of the stone is 14 mm. Photo by S.T. Wu.](image4)

Artificial blue glass

Artificial blue glass as an imitation for opaque or semi-transparent stones, such as lapis lazuli (Bosshart, 1983) or blue chalcedony could only be a convincing imitation when it is not transparent but has
the same degree of translucency as the substance it is imitating. In order to make a glass translucent rather than transparent, its composition has to include some components that will oversaturate the melt and form crystals when the glass cools down. The process of devitrification may then allow the formation of, for example, devitrite, apatite, wollastonite, or fluorite and cristobalite, in the glassy groundmass (Hammer et al., 1999). Such crystals can render a glass milky through to opaque (Bosshart, 1983; Harding et al., 1989). The range of SG and RI values of artificial glass were shown by Webster (1983) in a diagram modified after Bannister.

**Macroscopic description**

The pieces of rough glass are up to 20 cm across (Figure 7); they are inhomogeneous and consist of massive glass with what appears to be a slaggy top zone. Most of the glass is dark or sky blue, but next to the slaggy zone it is green. The degree of transparency is also not uniform. Most of the material is cut into cabochons or bangles. They vary in colour from light sky blue to dark sky blue and range from semi-transparent to semi-translucent (Figure 8).

The raw material available for investigation consisted of three different
Glass imitations of blue chalcedony

Figure 9: Sample A: Partially devitrified, and containing relatively coarse wollastonite crystals. Magnification approximately 15x. Photo by H.A. Hänni, SSEF.

Figure 10: Sample B: Partially devitrified, with medium sized wollastonite crystals. Magnification approximately 15x. Photo by H.A. Hänni, SSEF.

Figure 11: Sample C: Partially devitrified with very fine wollastonite crystals in a banding pattern. Magnification approximately 15x. Photo by H.A. Hänni, SSEF.

types, varying in their degree of transparency.

Sample A is semi-transparent and of darker blue colour than the other two types. It contains needle-shaped crystals in random orientation, which are clearly visible at 10x magnification (Figure 9).

Sample B is lighter in colour and more milky than sample A. Its inclusions cannot be resolved individually at 10x, but a few oddly shaped bubbles may be visible (Figure 10).

Sample C is light blue and almost opaque. Patterns of white banding are eye-visible and are confined to sectoral areas (Figure 11).

Microscopic description

With a magnification of 10x to 50x the imitation stones display features not expected from their macroscopic appearance. The darker blue and semi-transparent material A contains needle-shaped crystals and inclusions, randomly oriented. They have a four-sided cross-section and may be hollow or filled with glass (Figure 9). The medium blue variety of glass B shows similar but finer needles (Figure 10); gas bubbles are not common. The light blue variety C is almost opaque and contains dense aggregates of very fine needles. They are arranged as radiating bunches or form a kind of zebra banding (Figure 11). Gas bubbles or swirl marks may be hidden by the dense pattern of these inclusions.

Physical data

The RI of 1.54 and SG of 2.57 are values close to those of blue chalcedony. These data are shown in Table 1 with comparable data from other imitations.

The semi-transparent variety A of the glass showed a homogeneous aggregate structure under the polariscope. Under the Chelsea
filter, the imitation stones appear green. With a hand-held spectroscope no spectral lines were observed. The UV-VIS spectrum recorded with a Varian Cary 500 Scan spectrophotometer is shown in Figure 12. It is characterized by general transmission between approximately 350 and 550 nm, and a weak absorption at 378 nm.

**UV-reaction**

In long-wave UV, the glass imitation stones showed weak bluish-white to

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**Figure 12:** Blue glass chalcedony imitation absorption spectrum from 300-800 nm recorded on a Varian Cary 500 Scan spectrophotometer. The main transparent area is between approximately 400 and 500 nm (blue colours).

**Figure 13:** Infrared absorption spectra of blue chalcedony and its glass imitation recorded on solid samples. The spectra show characteristic differences.
yellowish-green luminescence, and moderate to strong yellowish-green luminescence in short-wave UV.

**Infrared spectroscopic determinations**

The infrared spectrum of natural blue chalcedony is shown in *Figure 13 upper*. The curve indicates complete absorption from 400 cm⁻¹ to 2398 cm⁻¹, and strong absorption between 2689 cm⁻¹ and 3758 cm⁻¹ with two absorption bands at 4434 cm⁻¹ and 5231 cm⁻¹.

The sky-blue glass imitation stones (B and C) have two absorption bands at 2927 cm⁻¹ and 3464 cm⁻¹ (*Figure 13 lower*) and lack peaks in the 4-5000 cm⁻¹ region, a spectrum clearly different from that of blue chalcedony.

With a powder method where imitation glass is ground and mixed with KBr, we also found that the most important features of the infrared spectrum are the same as those of artificial glass (*Figure 14*): both have strong absorption in the ‘fingerprint’ area at 1053 cm⁻¹ and pairs of small absorbance bands at 651, 776 cm⁻¹, and 2932, 3450 cm⁻¹.

**Chemical analyses**

In order to obtain further information about the blue glass imitations, their chemical composition was investigated with a Tracor ED-XFA. The chemical analysis had first a qualitative character and helped to rule out the claim that the blue stones were chalcedony. A standardization for a semi-quantitative major element determination was done with artificial glass reference samples from the glass industry by conventional wavelength dispersive X-ray fluorescence spectrometry WDS-XFA.

*Figure 14*: Infrared absorption spectra of chalcedony imitation and window glass using a powder method with KBr tablets. The spectra show no significant differences.

*A glass imitation of blue chalcedony*
<table>
<thead>
<tr>
<th>Oxide (%wt)</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>MgO</th>
<th>CaO</th>
<th>K$_2$O</th>
<th>Na$_2$O</th>
<th>TiO$_2$</th>
<th>Fe$_2$O$_3$</th>
<th>MnO</th>
<th>Cr$_2$O$_3$</th>
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<tr>
<td><strong>Industrial glass references (WD-XRF analyses by J. Cerny)</strong></td>
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<tr>
<td>Olive standard</td>
<td>71.68</td>
<td>1.96</td>
<td>2.88</td>
<td>10.1</td>
<td>0.51</td>
<td>12.44</td>
<td>0.05</td>
<td>0.10</td>
<td>n.a</td>
<td>0.01</td>
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<tr>
<td>Brown standard</td>
<td>69.65</td>
<td>2.15</td>
<td>3.03</td>
<td>9.73</td>
<td>1.35</td>
<td>13.64</td>
<td>0.05</td>
<td>0.30</td>
<td>n.a</td>
<td>0.03</td>
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<tr>
<td>Green standard</td>
<td>71.57</td>
<td>1.65</td>
<td>2.12</td>
<td>10.29</td>
<td>0.67</td>
<td>12.71</td>
<td>0.06</td>
<td>0.33</td>
<td>n.a</td>
<td>0.22</td>
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<tr>
<td>Dark brown standard</td>
<td>78.02</td>
<td>2.27</td>
<td>2.45</td>
<td>10.43</td>
<td>1.09</td>
<td>12.38</td>
<td>0.06</td>
<td>0.29</td>
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<tr>
<td>Obsidian Mexico</td>
<td>75.13</td>
<td>12.46</td>
<td>n.d.</td>
<td>0.25</td>
<td>4.75</td>
<td>5.24</td>
<td>0.08</td>
<td>2.01</td>
<td>0.08</td>
<td>n.d.</td>
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<tr>
<td>Obsidian USA</td>
<td>74.61</td>
<td>12.77</td>
<td>n.d.</td>
<td>1.12</td>
<td>5.74</td>
<td>4.50</td>
<td>0.15</td>
<td>1.04</td>
<td>0.08</td>
<td>n.d.</td>
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<tr>
<td>Tekrite Thailand</td>
<td>75.13</td>
<td>12.93</td>
<td>0.96</td>
<td>2.32</td>
<td>2.51</td>
<td>0.29</td>
<td>0.61</td>
<td>5.09</td>
<td>0.15</td>
<td>n.d.</td>
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<tr>
<td>Moldavite CS</td>
<td>76.59</td>
<td>9.80</td>
<td>2.07</td>
<td>5.22</td>
<td>4.02</td>
<td>n.d.</td>
<td>0.27</td>
<td>1.75</td>
<td>0.29</td>
<td>n.d.</td>
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<tr>
<td><strong>Taiwanese blue glass (ED-XRF analyses by P. Giese)</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Imitation rough (Sample A)</td>
<td>73.30</td>
<td>0.34</td>
<td>3.85</td>
<td>9.11</td>
<td>0.26</td>
<td>12.98</td>
<td>0.02</td>
<td>0.14</td>
<td>0.01</td>
<td>n.d.</td>
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<tr>
<td>Imitation rough TL (Sample B)</td>
<td>73.01</td>
<td>0.33</td>
<td>3.86</td>
<td>8.54</td>
<td>0.26</td>
<td>13.83</td>
<td>0.02</td>
<td>0.14</td>
<td>0.01</td>
<td>n.d.</td>
</tr>
<tr>
<td>Imitation rough TL (Sample C)</td>
<td>72.97</td>
<td>0.45</td>
<td>3.86</td>
<td>9.13</td>
<td>0.31</td>
<td>13.09</td>
<td>0.02</td>
<td>0.17</td>
<td>0.01</td>
<td>n.d.</td>
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<tr>
<td><strong>Natural samples (ED-XRF analyses by P. Giese)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyed chalcedony</td>
<td>99.98</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0.02</td>
<td>0.03</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0.01</td>
<td>n.d</td>
<td>0.06</td>
</tr>
<tr>
<td>Blue opal</td>
<td>98.71</td>
<td>0.10</td>
<td>0.03</td>
<td>0.33</td>
<td>0.09</td>
<td>0.73</td>
<td>0.01</td>
<td>n.d.</td>
<td>0.01</td>
<td>n.d.</td>
</tr>
<tr>
<td>Taiwanese blue chalcedony</td>
<td>99.62</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0.07</td>
<td>0.03</td>
<td>0.24</td>
<td>0.01</td>
<td>n.d.</td>
<td>0.04</td>
<td>n.d.</td>
</tr>
<tr>
<td>Taiwanese blue chalcedony</td>
<td>99.68</td>
<td>n.d.</td>
<td>0.11</td>
<td>0.11</td>
<td>0.05</td>
<td>n.d.</td>
<td>n.d.</td>
<td>0.01</td>
<td>0.04</td>
<td>n.d.</td>
</tr>
</tbody>
</table>

n.a. = not analysed  
n.d. = not detected  
Chemical data analysed by WD-XRF and ED-XRF are semi-quantitative; EMP data are quantitative.
Raman spectroscopic identifications

The Raman microspectrometer system (Renishaw 1000) is an excellent instrument for the mineralogical distinction of materials of similar appearance such as the blue chalcedony, stained quartzite, pectolite (larimar), blue hemimorphite, opal or glass (see also Hänni et al., 1997). It is also excellent for identifying inclusions, so the method was used to identify the devitrification products in the blue glass (Figure 15). The Raman spectrum of a crystal inclusion (Figure 16) was matched with that of natural wollastonite in the SSEF Raman Data Search File, and confirmed its identity.

Figure 15: Surface of blue glass showing devitrification texture indicated by the wollastonite crystals. Some slender crystals are hollow. Magnification approximately 30x. Photo by H.A. Hänni, SSEF.

![Raman spectrum of wollastonite crystal in blue glass.](image)

SSEF Swiss Gemmological Institute

Raman spectrum

A glass imitation of blue chalcedony
traces of As are recommended in the manufacturing to reduce gas bubbles. It is possible that the blue glass is an industrial waste or slag, as proposed by Johnson et al. (1999). The relatively small amount of this product in the market is consistent with such an origin.

Conclusions

The described glass imitation of natural blue chalcedony is a convincing substitute which may intrigue gemmologists because of the similarity of their properties. When mounted, the identification of such stones could create difficulties. However, observation of microscopic features such as radiating fine or irregularly displaced coarser fibres of devitrification products, UV reaction and chemical differences, allow a safe identification. The sky blue stone is richer in Ca, Na and poorer in Al than natural glasses and indicates that it is artificial glass.

Acknowledgements

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