Chrysoberyl: a gemstone with many faces

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Chrysoberyl, BeAl₂O₄, is a mineral that often forms in pegmatite dykes but also in metamorphic rocks such as mica schists and marbles. It crystallises as orthorhombic crystals and often appears in twins and trillings. Chrysoberyl owes its name to the content of beryllium (Be), a light chemical element that is also a constituent of the mineral beryl. Besides of this common feature there is no link between the two different minerals. A great number of chrysoberyl sources lie in secondary deposits and stones are found as rounded pebbles in gravel. As the mineral has a high hardness (8.5) and no cleavage it serves as a durable and resistant gemstone. The crystal structure and simple chemical composition allows little atomic substitution, and the values of refractive indices and density vary in a small range only. The refractive indices are nD 1.74 - 1.75, and nω 1.75 - 1.757. Densities are 3.70 - 3.75 g/cm³. Figure 1 gives a survey on crystal shapes and colour range of chrysoberyls.

Chromophore trace elements encountered are Fe³⁺, Cr³⁺, V⁴⁺ and Ti⁴⁺, substituting for Al³⁺. This range of traces allows chrysoberyls to appear in different colours. Sn and Ga are also often found but have no chromophore (colour-giving) effect. Chrysoberyl is found in five varieties up to now. They appear under different names:

- Chrysoberyl, colourless to yellow and brown, transparent
- Chrysoberyl cat's-eye, yellow to brown and greenish, translucent
- Alexandrite, blue-green, colour changing, transparent
- Alexandrite cat's-eye, blue-green, colour changing, translucent
- Venadium-Chrysoberyl, light blue-green, transparent

Chrysoberyl (sensu stricto) is colourless, but usually yellowish, greenish to brown due to traces of iron. Major sources are in Sri Lanka, Zimbabwe, Brazil, Madagascar, and Tanzania. Inclusions found are zircon, apatite, fine tubes and healing fissures (finger-print type). Recently we have met heat-treated chrysoberyl of greenish yellow colour (Figure 2). They contain small discoid and strongly reflecting tension fissures, similar to what is found in other heated stones such as ruby, sapphire, demantoid, etc.

Chrysoberyl cat's-eye is always cut in cabochon, the higher the dome, the sharper the line. Responsible for the chatoyancy are thousands of very fine parallel channels, perpendicular to which the light line will appear. With lesser dense set of channels the light line will be less pronounced, and the stone more transparent. The base of the cabochon must be oriented parallel to the channels, that run along the shorter axis of an oval stone. A term often used to describe a perfect cat's-eye is "milk and honey" what means that half of the cabochon is milky white, and the other half is yellow-brown and transparent (Figure 3).

Quite rarely we have met chrysoberyl star stones (four rays) with two interacting light lines. Major sources of chrysoberyl cat's-eyes are in Sri Lanka, Zimbabwe, Brazil, Madagascar, Tanzania, thus same as for transparent stones.

In 1987 brown cat's-eyes have been reported that were found to be radioactive. These stones got their chocolate brown colour upon artificial irradiation. It is worth mentioning imitations of chrysoberyl cat's-eyes. A number of yellow natural stones may also show chatoyancy, as e.g. quartz, benyl, scapolite, apatite. Further there have been imitations in fibreglass and quartz-ulexite doublets.

Figure 1. Rough chrysoberyl crystals as twins and trillings, and a variety of colours and effects found with chrysoberyl.

Figure 2. Faceted chrysoberyls improved by a heat treatment. Largest stone is 5 ct.

Figure 3. Chrysoberyl cat's-eye of 46 ct showing strong chatoyancy effect.
**Alexandrite** is the most valuable variety among the chrysoberyls (Figure 4). They owe their colour to chromium traces.

We know chromium as colour giving ingredient in emerald (green) and ruby (red). In the chrysoberyl crystal lattice Cr$^{3+}$ gives rise to an absorption band at 570 nm. Absorption spectra recorded with a spectrophotometer of ruby, alexandrite and emerald show strong similarity. The maximum position for alexandrite is just between that of emerald and ruby (Figure 5).

It is then a matter of the spectral composition of the illuminant light whether the stone appears blue-green or red. In cold light, such as daylight or cold artificial light, alexandrites appear blue-green. This light is rich in shorter wavelengths like violet, blue and green. In warm light such as incandescent light the stones appear reddish violet. This light is rich in longer wavelengths like yellow and red. The quality of this change of colour is not only depending of the amount of Cr, but also its position in the lattice. As there are two different Al sites that may be occupied by Cr, it is a matter of the distribution of present Cr$^{3+}$ ions on the two sites, how good the colour change comes. The quality of colour change also depends on the orientation of the crystal when cut as only the b-vibration shows a colour change. The term alexandrite is attributed to stones with visible colour change only in major gem labs.

Chrysoberyls may possess Cr traces but still not display a change of colour. Such stones are not called alexandrites, but chrysoberyl only. Most important is that the evaluation of the quality of the colour change is done under two different lighting conditions: warm light and cold light.

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**Figure 4.** An alexandrite of 7.52 ct from Sri Lanka with excellent colour change. In this picture the distinct pleochroism is well visible, a feature that is sometimes mistaken for colour change.

**Figure 5.** Absorption spectra of Cr-bearing gemstones in comparison. The position of the main absorption moves from right to left from emerald to ruby. The transmission left of this maximum (emerald) or right of the maximum (ruby) leaves the necessary transmission that makes the colour appearance. As in alexandrite the maximum is at 570 nm, it quasi forms a balance between the cold colours and the warm colours. The spectral supply of the illuminant thus makes the colour appearance of the alexandrite.

**Figure 6.** A cluster of alexandrite from the Malysheva Mine, Ural Mountains, Russia, in a mica matrix. The crystals show cyclic twinning (trillings). Length of sample approx. 3 cm.
Alexandrite as an expensive stone is predestined to be imitated or produced synthetically. Synthetic chrysoberyls are in the trade since the 1980’s as flux-grown crystals. Later pulled crystals from Russia and Japan have reached the gemstone markets. The oldest imitation of alexandrite is, Verneuil synthetic corundum doped with vanadium. Many tourists were misled and bought synthetic alexandrite in Alexandria during their holiday trip to Egypt. Alexandrite imitations have also been identified as Cr-doped synthetic olivine or rare earth doped glass. Colour changing garnet has also been mistaken for alexandrite.

**Alexandrite cat’s-eye** from Brazil is another variety of chrysoberyl, pretty rare and beautiful. Their colour in cold light is rather bluish but not greenish (Figure 7). We realise thus that with chrysoberyl two effects are possible: chatoxyancy and change of colour.

**Authenticity** of chrysoberyl can be easy when inclusions are present. Veils of fluids are frequent in Russian alexandrite, some show two phase fillings (Figure 8).

Flux grown crystals may show fine networks of residual flux very similar to fluid veils. The fingerprints contain, however, fine polycrystalline flux (Figure 9).

Lamellar colour zoning may be present in flux-grown, but not in Czochralski pulled crystals. Natural chrysoberyls are often very pure. In the laboratory, FTIR-spectroscopy offers discrimination. Trace element analysis by ED-XFA or LA-ICP-MS shows a clear pattern of trace elements (Ti, Ga, Zn) that are absent in synthetic stones. Flux grown material on the other hand may show presence of crucible or flux elements (Pt, Mo).

**V-chrysoberyl** is rather a novelty among the chrysoberyl varieties. In 1995 the author has reported a set of gemstones from the secondary deposit in the area of Tunduru, Songas District, Southern Tanzania. Among the enumerated gemstones chrysoberyl and alexandrite were listed.

Since the beginning of the mining activities in the area, light bluish green chrysoberyl was sporadically found that might resemble some lime green grossular garnet. These stones occurred in sizes up to some carats and do not present any colour change. We were very much surprised however, to receive a faceted intense bluish green gem of eleven carats (Figure 10).

The stone was apparently free of inclusions and because of the colour it was hard to believe that it was a chrysoberyl. When we took a short look on the qualitative chemical constituents by EDS-XRF we remarked with astonishment that the colour-giving element was vanadium. It was never before reported that natural blue-green chrysoberyls coloured by V do exist.

Quantitative microprobe analysis of blue-green chrysoberyl (measured by Dr. Michael Krzemnicki, SSEF) contained an average of 0.4 wt-% V₂O₅ and 0.2 wt-% Fe₂O₃ and traces of Cr, Sn and Ga.

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**Recommended reading**


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**About the Author**

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