

Chrysoberyl: A Gemstone with Many Faces

Prof. Dr H.A. Hänni, Basel

金綠寶石常以偉晶岩及變質岩形式出現，主要產地為斯里蘭卡、津巴布韋、巴西、馬達加斯加及坦桑尼亞等。作者描述不同產地及不同形態的金綠寶石，並附以樣品圖片。

Chrysoberyl, BeAl_2O_4 , 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 drillings (cyclic twinning). Chrysoberyl owes its name to its beryllium Be content, a light chemical element that is also a constituent of the mineral beryl. Apart from this common feature there is no link between the two different minerals. Chrysoberyl is mainly formed in the late pegmatitic and pneumatolytic phase in pegmatites, but also in marbles, mica schists and gneisses. 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 n_α 1.74 – 1.75, and n_γ 1.75–1.757. Densities are 3.70 – 3.75 g/cm^3 .



Fig. 1 Rough chrysoberyl crystals as twins and drillings, and a variety of colours and effects found with chrysoberyl.
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Chromophore trace elements encountered are Fe^{3+} , Cr^{3+} , V^{3+} and Ti^{4+} ; substituting for Al^{3+} . This range of traces allows chrysoberyl to appear in different colours. Sn and Ga are also often found but have no chromophore (colour-giving) effect.

Chrysoberyl has been 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

Vanadium-Chrysoberyl, light blue-green, transparent

Chrysoberyl (*sensu stricto*) is colourless, but usually yellowish or greenish to brown due to traces of iron. Major sources are 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 (Fig. 2). They contain small discoid and strongly reflecting tension fissures, similar to features found in other heated stones such as ruby, sapphire, and demantoid etcetera.



Fig. 2 Faceted chrysoberyls improved by heat treatment. Largest stone is 5 ct.
Photo © H.A. Hänni

Chrysoberyl Cat's Eye is always cut en cabochon, the higher the dome, the sharper the line. Responsible for the chatoyancy are thousands of very fine tube-like inclusions in parallel array, perpendicular to which the light line will appear. With less dense sets 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" which means that half of the cabochon is milky white, and the other half is yellow-brown and transparent (Fig. 3).



Fig. 3 Chrysoberyl cat's eye of 46 ct showing strong chatoyancy effect.
Photo © H.A. Hänni

Chrysoberyl also forms as star stones (four rays) with two intersecting light lines, but these are quite rare. Major sources of Chrysoberyl Cat's Eyes are Sri Lanka, Zimbabwe, Brazil, Madagascar and Tanzania - the same as for transparent stones.

In 1997 there were reports of brown cat's eyes that were found to be radioactive. The chocolate brown colour of these stones was caused by artificial irradiation. It is worth mentioning imitations of Chrysoberyl Cat's Eyes. A number of natural yellow stones may also show chatoyancy, as e.g. quartz, beryl, scapolite and apatite. In addition there have been imitations made in fibre-glass as well as quartz-ulexite doublets.

Alexandrite is the most valuable variety of chrysoberyl (Fig. 4). It owes its colour to chromium traces.



Fig. 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.

Photo © H.A. Hänni

We know chromium as the 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 (Fig. 5).

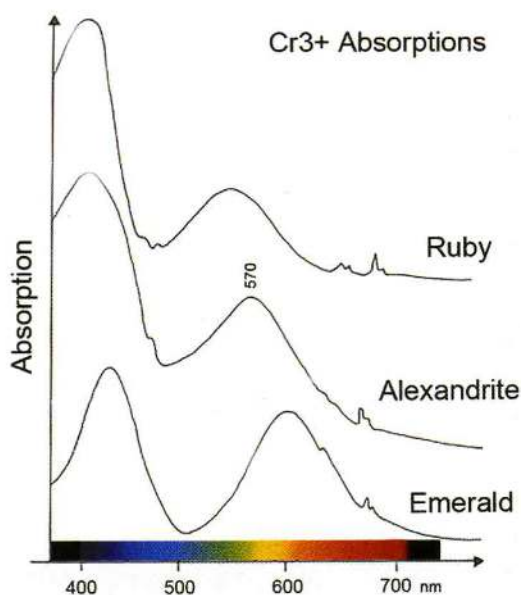


Fig. 5 Absorption spectra of Cr-bearing gemstones in comparison. The position of the main absorption moves from right to left from emerald to ruby. The transmission left of this maximum (emerald) or right of the maximum (ruby) leaves the necessary transmission that causes the colour appearance. As in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

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It is, therefore, the spectral composition of the illuminant light that determines 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 not only depends on the amount of Cr in a given stone, but also its position in the lattice. As there are two different Al sites that may be occupied by Cr, it is the distribution of Cr³⁺ ions present in the two sites that will determine how good the colour change will be. The quality of colour change also depends on the orientation of the crystal when cut as only the b-vibration shows a colour change. In major gem labs the term alexandrite is only attributed to stones with visible colour change. Chrysoberyls may possess Cr traces but still not display a change of colour. Such stones are not called *alexandrites*, but only *chrysoberyl*. It is most important that evaluation of the quality of the colour change in alexandrite is done under two different lighting conditions: warm light and cold light.

Russian alexandrites (Fig. 6) have been discussed in an excellent new book (Schmetzer, 2010) that may serve as further reference. This originally Russian variety of chrysoberyl, named to honour Tsar Alexander II, is now known to have further sources, the material of which may vary considerably in aspect.

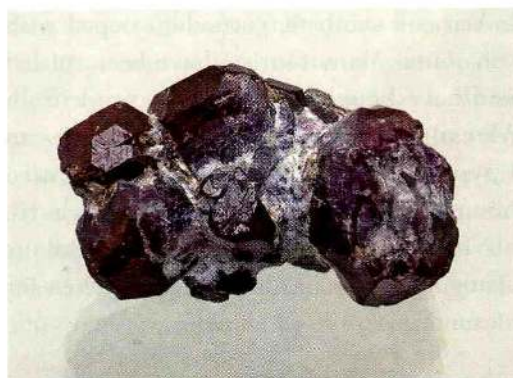


Fig. 6 A cluster of alexandrite in a mica matrix, from Malischewo, Ural Mountains, Russia. The crystals show cyclic twinning (drillings). Length of sample approx. 3 cm.

Photo © H.A. Hänni

Sri Lankan alexandrites are usually quite free of inclusions, but show a colour change from khaki to brown; exceptions are rare. Alexandrite from Zimbabwe (Novello) is usually dark and purplish, with little colour change. Tanzanian (Lake Manyara, Tunduru) material is lighter in tone and may show a moderate to good change of colour. Brazilian material (Hematita) is highly saturated and on the blue side with a change to purple. Indian stones (Orissa) may be quite attractive. Burmese alexandrites are also reported, but the author has seen none so far.

Alexandrite as an expensive stone is predestined to be imitated or produced synthetically. Synthetic chrysoberyls have been in the trade since the 1960's as flux-grown crystals. Later pulled crystals from Russia and Japan reached the gemstone markets. The oldest imitation of alexandrite

is Verneuil synthetic corundum doped with vanadium. Many tourists have been misled and have bought synthetic Alexandrite in Alexandria during their holiday trips 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. Its colour in cold light is rather bluish than greenish (Fig. 7).



Fig. 7 An Alexandrite cat's eye of 7.60ct from Hematita, Brazil.
Photo © H.A. Hänni

We realise, therefore, that two effects are possible with chrysoberyl: chatoyancy and change of colour

Verifying the authenticity of chrysoberyl can be easy when inclusions are present. Veils of fluids are frequent in Russian alexandrite; some show two phase fillings (Fig. 8).



Fig. 8 Fluid inclusions in an alexandrite from the Ural Mountains, Russia. The larger ragged inclusion shows gas bubble in liquid CO₂. Magn. 60x
Photo © H.A. Hänni

Flux grown crystals may show fine networks of residual flux very similar to fluid veils. However, the fingerprints contain fine polycrystalline flux (Fig. 9)

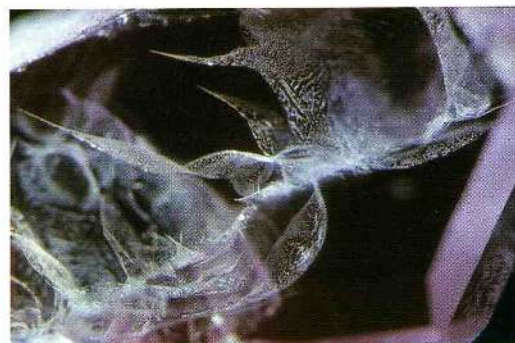


Fig. 9 Veils of residual flux in a synthetic alexandrite. Magn. 30x.
Photo © H.A. Hänni

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 a means of distinguishing between the two. Trace element analysis by ED-XFA or LA-ICPMS show a clear pattern of trace elements (Ti, Ga, Zn) that are absent in synthetic stones. Flux grown material, on the other hand, may show the presence of crucible or flux elements (Pt, Mo).

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

Since mining activities commenced in the area, light bluish green chrysoberyl has sporadically been 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 Fig. 10).

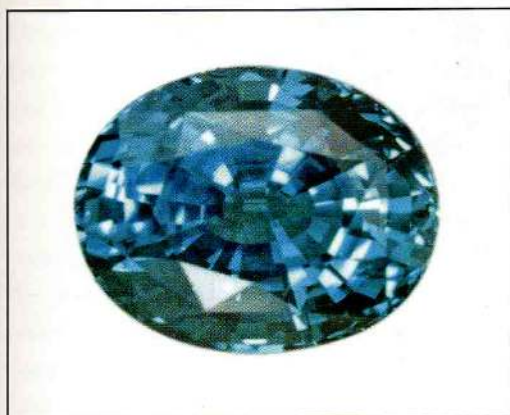


Fig. 10 An outstanding blue-green Vanadium-Chrysoberyl of 11.14 ct from Tunduru area in Southern Tanzania.
Photo © H.A. Hänni

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 at the qualitative chemical constituents by EDS-XRF we saw with astonishment that the colour-giving element was vanadium. It had never before been reported that natural blue-green chrysoberyls, coloured by V, existed.

Quantitative microprobe analysis of blue-green chrysoberyl (measured by Dr Michael Krzemnicki, SSEF) contained an average of 0.4 wt-% V_2O_3 and 0.2 wt-% Fe_2O_3 and traces of Cr, Sn and Ga.

Acknowledgements:

SSEF Swiss Gemmological Institute provided access to the stones shown in Figs. 3, 5 and 10 that had been submitted by clients for test reports. All other stones are part of the Prof. H.A. Hänni Gemstone Collection. Thanks go to Dr M.S. Krzemnicki for the quantitative microprobe analysis of a V-chrysoberyl sample.

Recommended reading:

Schmetzer, K. (2010): Russian Alexandrites. Stuttgart, Schweizerbart Science Publishers, 141 pp. ISBN 978-3-510-65262-4

The author may be contacted on:
www.gemexpert.ch