Asterism in beryl, aquamarine and emerald – an update

Dr Karl Schmetzer[1], Dr Lore Kiefert[2] and Professor Dr Henry A Hänni[2]

1. *Taubenweg 16, D-85238 Petershausen, Germany*
2. *SSEF Swiss Gemmological Institute, Falknerstr. 9, CH-4001 Basel, Switzerland*

Abstract: *An overview about present knowledge of asterism in beryl, aquamarine and emerald is presented. A bronze-brown beryl from Brazil and several aquamarines from Madagascar revealing six-rayed asterism were examined. An emerald specimen from Madagascar showing four- and six-rayed stars is studied in detail. The asterism of this specimen is due to a combination of a six-rayed star emerald and an emerald cat's-eye. Three causes for six-rayed stars in various members of the beryl family are known: (a) needle-like mineral inclusions, (b) elongated thin fluid films and (c) elongated negative crystals.*

Introduction

Recently, a German dealer purchased a rough emerald specimen in Madagascar, which was – according to the information given by a local gem merchant – most probably originating from the well-known Mananjary emerald mining area. Due to the visual appearance of the rough, it was assumed that the sample could yield another six-rayed star emerald similar to a specimen obtained in 2001[1]. However, after cutting as a cabochon, the emerald showed a weak four-rayed star in the centre of the convex surface. Examining this four-rayed star emerald, we took the opportunity to compare the sample with a six-rayed star beryl from Brazil and several star aquamarines from Madagascar, and to review and summarize the present knowledge about asterism in members of the beryl family.

Beryl with mineral inclusions

Beryl, aquamarine and emerald showing asterism are among the rarer gem materials. Gemmological literature dealing with asterism in beryl and its varieties is presented in *Table I*. In the 1950s, rough beryl with a specific type of inclusion was discovered in Brazil[2,3,4]. Cabochons with six-rayed asterism were cut and found their way onto the international market and into public or private collections (*Figure 1*). Examination of the cut sample in *Figure 1* and some rough material available to the present authors confirmed the descriptions published in the 1950s. The samples frequently quoted in textbooks and articles dealing with asterism in beryl or other minerals[5,6,7], have been described as almost colourless beryl to very light green aquamarine. The body colour of these specimens, however, is a much more intense bronze or bronze-brown when viewed in a direction parallel to the *c*-axis. This impression is due to a dense pattern of mineral inclusions which are located on planes parallel to the basal pinacoid, i.e. on planes perpendicular to the *c*-axis (*Figure 2*). A mineralogical

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Table 1: Asterism in aquamarine, beryl, and emerald.

Locality	Host	Asterism	Inclusions	References
Minas Gerais, Brazil	almost colourless beryl to light green aquamarine, with a dark brown or bronze-brown colour in a view parallel to the *c*-axis	six-rayed	skeletal elongated ilmenite crystals on planes parallel to the basal pinacoid	2, 3, 4, 5, 6, 7, this study
Brazil	greenish-grey, almost opaque beryl	six-rayed	tabular plates or flakes of pyrrhotite parallel to the basal pinacoid, other mineral inclusions without specific orientation	7, 8, 9
Sri Lanka	aquamarine	six-rayed	thin fluid films on planes parallel to the basal pinacoid	7, 10
unknown	emerald	six-rayed	channels parallel to prism faces consisting of two-phase inclusions	7, 11
Nova Era, Minas Gerais, Brazil	emerald	six-rayed	needle-like channels	7, 12
Santa Terezinha, Brazil	emerald	six-rayed	not mentioned	13
Santa Terezinha (?), Brazil	emerald	six-rayed	channels parallel to the *c*-axis, three series of elongated particles perpendicular to the *c*-axis	14
Brazil	aquamarine	six- or four-rayed	thin films on planes parallel to the basal pinacoid, hollow channels parallel to the *c*-axis	15
Mananjary area, Madagascar	emerald	six-rayed	tabular birefringent inclusions parallel to the basal pinacoid	1
Madagascar	aquamarine	six-rayed	three series of elongated channel-like inclusions (thin fluid films) perpendicular to the *c*-axis	this study
Mananjary area, Madagascar	emerald	six- and four-rayed	channels parallel to the *c*-axis, three series of elongated channel-like inclusions (negative crystals) perpendicular to the *c*-axis	this study

N.B.: The items are arranged chronologically in order of their discovery or reporting in the literature.

Figure 1: Bronze-brown six-rayed star beryl from Minas Gerais, Brazil. Diameter of the sample 6.0 mm, weight 1.41 ct.

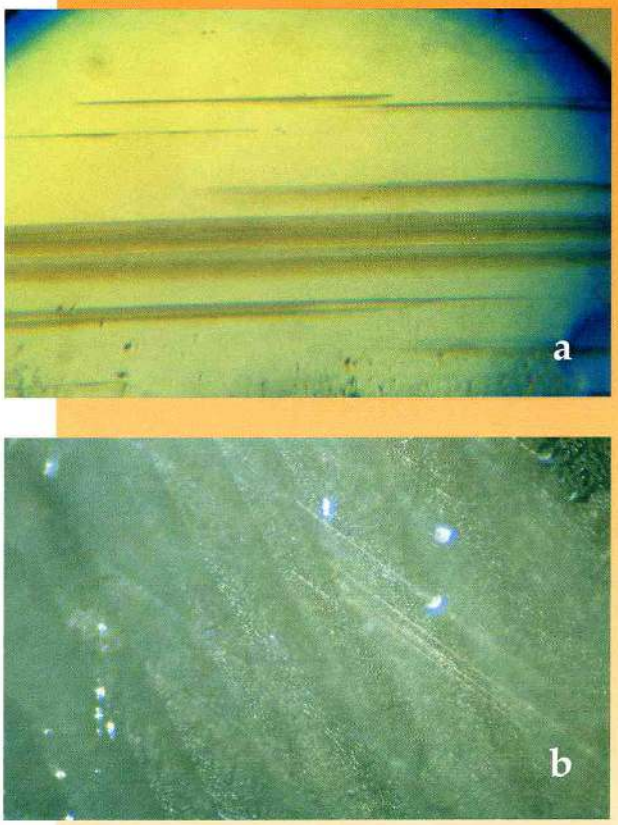


Figure 2: Bronze-brown six-rayed star beryl from Minas Gerais, Brazil; layers parallel to the basal pinacoid with a dense pattern of skeletal crystals, (a) view perpendicular to the c-axis, immersion, 40×, (b) view oblique to the c-axis, 100×.

examination of these inclusions described them as skeletal ilmenite crystals (*Figure 3*), the elongated directions of which were oriented parallel to prism faces of the beryl host[4], in this way causing the six-rayed star of the beryl cabochons.

A piece of an almost opaque, greenish-grey beryl originating also from Brazil, was described by Eppler (1960)[8]. Asterism in this sample is caused by plates or flakes of pyrrhotite, which are oriented parallel to the basal pinacoid of the host[8,9]. This specimen shows a number of extraordinary inclusions[9] and since no similar material has been described in the gemmological literature, it seems to be unique.

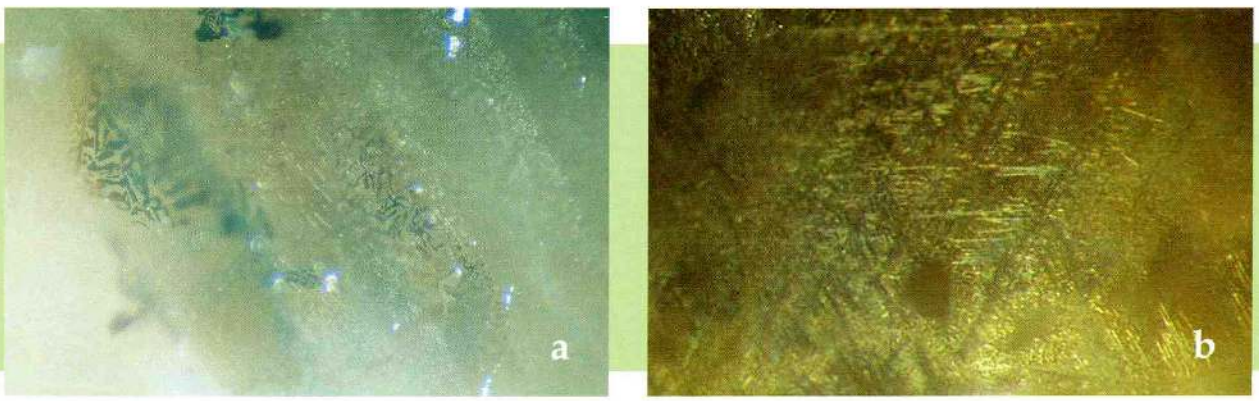


Figure 3: Bronze-brown six-rayed star beryl from Minas Gerais, Brazil; dense pattern of oriented ilmenite skeletal crystals, (a) view oblique to the c-axis, 100×, (b) view parallel to the c-axis, 100×.

Figure 4: Six-rayed star emerald from Brazil. Diameter of the specimen 12.5 mm, weight 10.03 ct. Photo by Tino Hamid, © GIA (reproduced by permission).

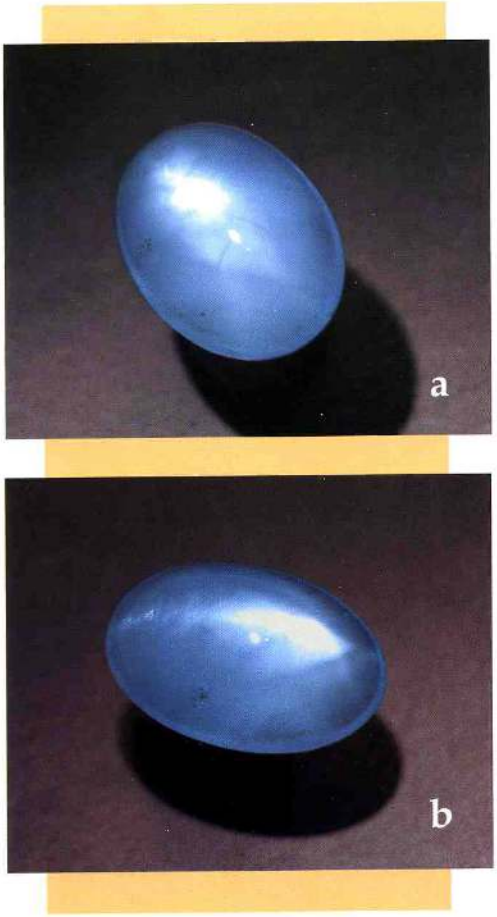
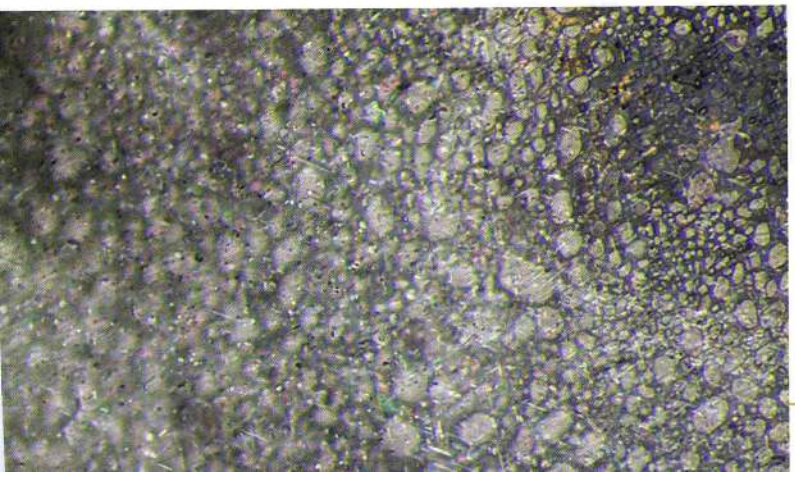


Figure 5: Six-rayed star aquamarine from Madagascar; in different orientations (a, b), an intense white sheen in the centre of the aquamarine and the weaker arms of a six-rayed star are visible. Size 18.4 × 12.6 mm, weight 9.53 ct.

Aquamarine with thin fluid films

Several cabochons of asteriated emerald (*Figure 4*) or aquamarine have been reported since the 1980s. These have come from different localities in Brazil as well as from Sri Lanka and Madagascar [1,7,10,11,12,13,14,15]. Microscopic examination commonly reveals that the star emeralds and aquamarines contain three series of small elongated particles[14], needle-like channels[7,12] or channels consisting of two-phase inclusions[7,11]. These inclusions are oriented perpendicular to the *c*-axis and parallel to prism faces of the host. In some samples, thin fluid films on planes parallel to the basal pinacoid[7,10,15] or tabular birefringent inclusions in the same orientation[1] are also present in asteriated beryl cabochons. Asterism has also been attributed to such fluid films[7].

Figure 6: Six-rayed star aquamarine from Madagascar; thin disc-like fluid films and channel-like or needle-like inclusions, view parallel to the c-axis, 100×.



Fluid films similar to those described by Henn and Bank[7] are also present in four star aquamarines from Madagascar which were available for the present study. In three specimens, the six-rayed star is weak and best seen when moving the cabochons back and forth. The specimen with the most intense star was examined in detail and showed a strong white sheen as well as the somewhat weaker arms of a six-rayed star (*Figure 5*). The asteriated aquamarine contains both disc-like fluid films and oriented channel-like or needle-like inclusions (*Figure 6*). The fluid films are located on planes perpendicular to the *c*-axis (*Figure 7*). Parts of the fluid discs show irregular outlines, but also

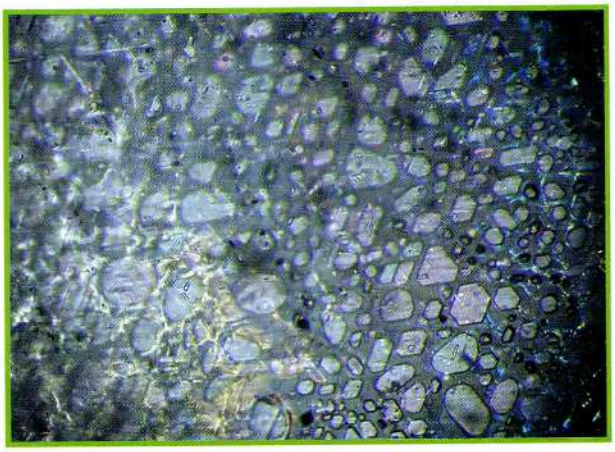


Figure 7: Six-rayed star aquamarine from Madagascar, thin fluid films on planes parallel to the basal pinacoid, the films show irregular and hexagonal or trigonal forms, view parallel to the c-axis, 200×.

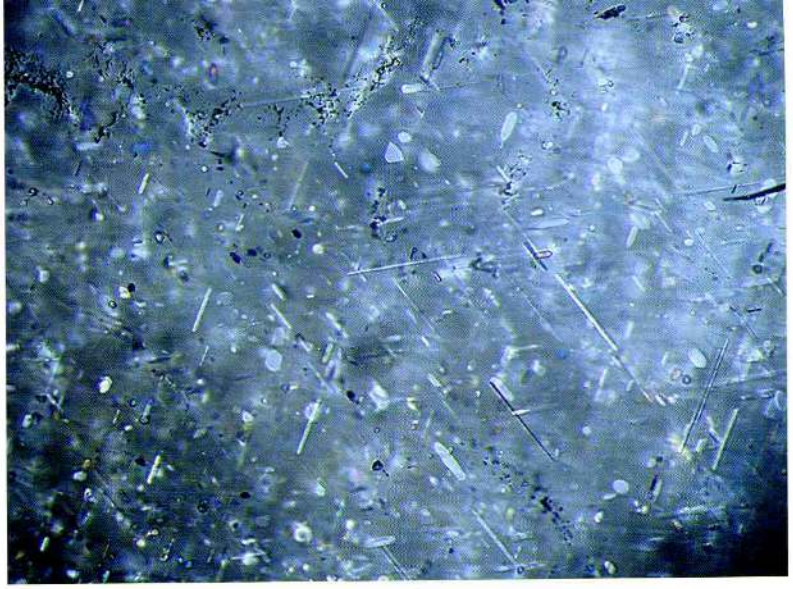


Figure 8: Six-rayed star aquamarine from Madagascar; three series of oriented channel-like or needle-like inclusions are responsible for the asterism; view parallel to the c-axis, 200×.

clear hexagonal or trigonal forms with boundaries parallel to prism faces are seen. In addition, three series of minute, channel-like or needle-like inclusions are present, which are oriented perpendicular to the *c*-axis in directions parallel to prism faces (*Figure 8*). In other words, the orientation of these minute elongated channels or elongated flat fluid films is parallel to the hexagonal boundaries of the flat fluid discs. In this specimen, an examination of the tiny oriented channels with the Raman microprobe did not show any characteristic Raman lines other than those of the beryl host.

Although the fluids on planes parallel to the basal pinacoid reflect at a certain angle to the incident light and cause a white sheen at the centre of the cabochon, they cannot be responsible for the six-rayed asterism of the aquamarine. The star is caused by three sets of elongated channel-like or film-like inclusions oriented in three different directions perpendicular to the *c*-axis. Because both types of inclusion are present, the white sheen of the sample is superimposed on the star and causes a pattern consisting of both optical phenomena. According to the results of the microscopic examination, both types of inclusion are disc-shaped and channel-like thin negative crystals (fluid films) showing boundaries parallel to basal and prism faces.

Multi-star emerald with negative crystals

A four-rayed star aquamarine from Brazil was recently described by Hyrsl (2001)[15]. The specimen was cut from the same type of rough as another cabochon, which yielded a star aquamarine with the ordinary six-rayed asterism but in another orientation. It is assumed that the four-rayed star is caused by a combination of the inclusions that are responsible for the six-rayed asterism and hollow channels which normally cause chatoyancy in beryl[15].

The four-rayed emerald from Madagascar (*Figures 9 and 10*) mentioned above belongs to the same type of beryl, i.e. the sample combines the inclusions causing the ordinary six-rayed asterism with chatoyancy in beryl due to channels parallel to the *c*-axis. The sample shows an absorption spectrum which consists of the absorption bands of Cr^{3+} in emerald superimposed on a strong aquamarine component. This spectrum is consistent with spectra reported for other emeralds from the Mananjary area in Madagascar[1].

The *c*-axis of the emerald is more or less parallel to the elongation of the cabochon which weighs 7.78 ct and measures 12.3 × 10.5 mm. Although the specimen is only semitransparent

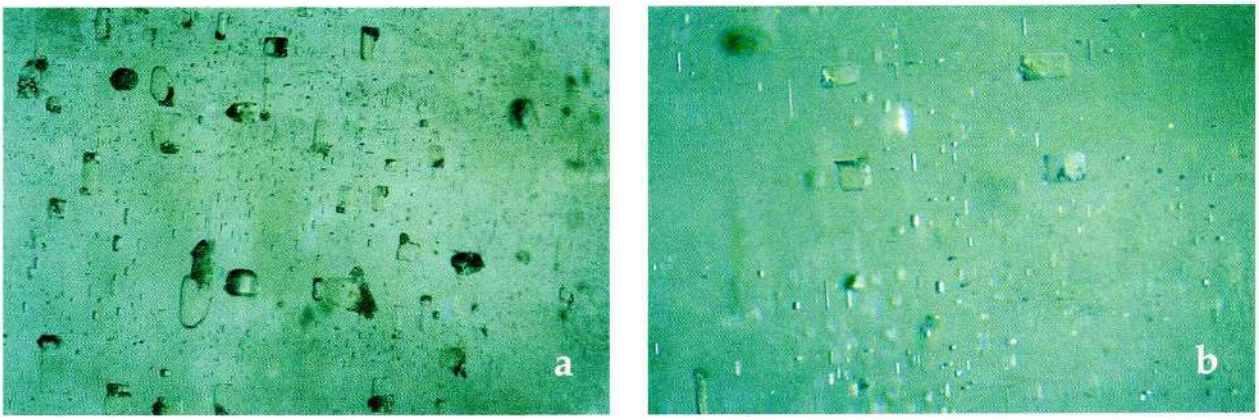


Figure 9: *Emerald from Madagascar with six- and four-rayed asterism; short prismatic negative crystals and elongated channels parallel to the c-axis, view perpendicular to the c-axis. (a) 50×, (b) 100×.*

(due to numerous inclusions and healing fissures), we observed a series of short prismatic negative crystals or elongated channels in a direction parallel to the *c*-axis with birefringent solid, liquid and two-phase fillings (*Figure 9*). At high magnification, it was also observed that three series of channel-like or needle-like inclusions are present in directions perpendicular to the *c*-axis (*Figure 10*). These channels are negative crystals elongated perpendicular to the *c*-axis and confined by basal and prism faces. An examination with the Raman microprobe showed only the spectrum of the beryl host.

According to the orientation of the different types of channels in this emerald (*Figure 11*), the centre of the four-rayed star in the middle of the dome of the cabochon is observed in a view perpendicular to the *c*-axis. Turning the cabochon towards a view along the *c*-axis, i.e. in a view parallel to the curved surface of the sample, one weak six-rayed star is seen at each end of the elongated cabochon. Consequently, the asterism of the emerald is caused by four light bands. The two six-rayed stars, which are observed in views parallel to the *c*-axis (at both ends of the elongated cabochon), consist of three light bands intersecting at angles of 60° to each other. The four-rayed stars, which are observed in views perpendicular to the *c*-axis, are formed by intersections of one of the three light bands of the six-rayed star with a fourth light band oriented perpendicular to the *c*-axis.

This interpretation is confirmed by the results of the microscopic examination described above. The six-rayed stars are formed by three light bands due to three sets of channel- or needle-like inclusions (negative crystals) which are oriented perpendicular to the *c*-axis intersecting at angles of 60° to each other. These are the light bands of the 'ordinary' six-rayed star in this beryl. Because additional channels or elongated channel- or needle-like inclusions parallel to the *c*-axis are present, a fourth light band can be observed. This is the light band of an 'ordinary' beryl cat's-eye. The intersection of each of the three 'six-rayed star light bands' and the 'cat's-eye light band' causes the four-rayed stars observed.

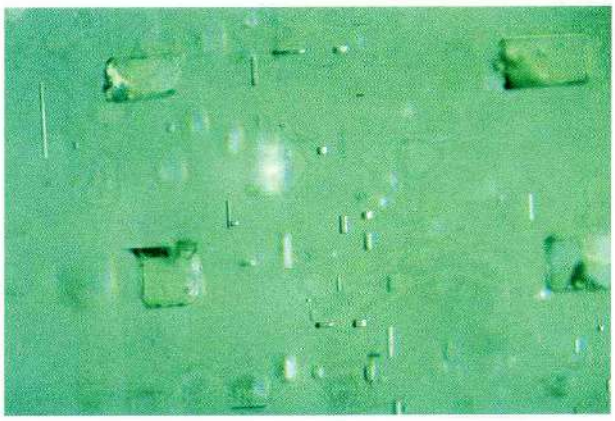


Figure 10: *Emerald from Madagascar with six- and four-rayed asterism; short prismatic negative crystals and two series of elongated channels in directions parallel and perpendicular to the c-axis, view perpendicular to the c-axis. 200×.*

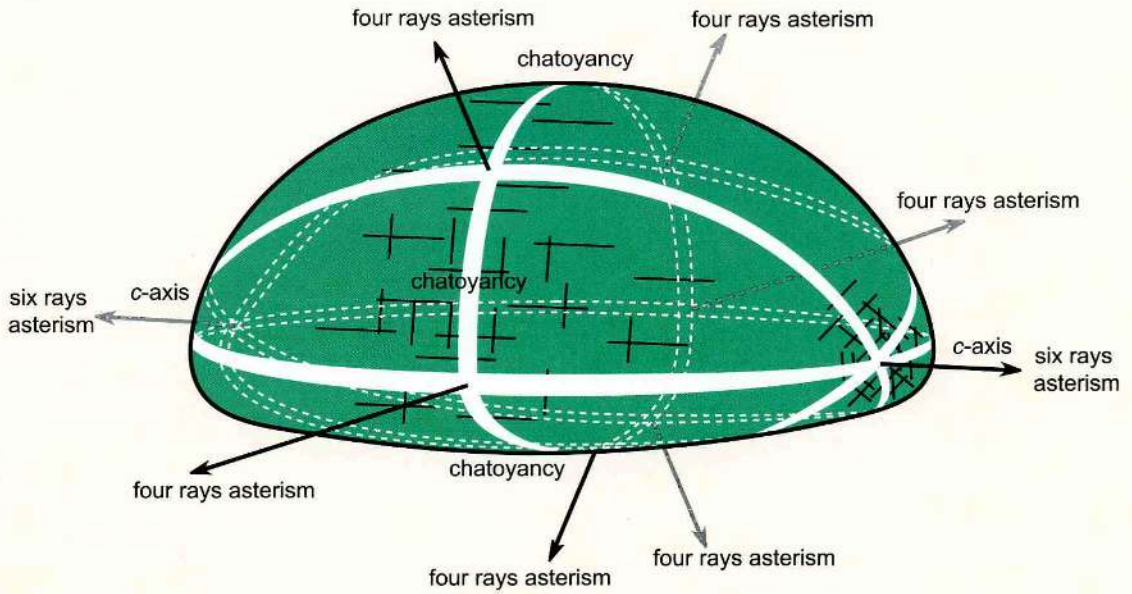


Figure 11: *Schematic drawing of the orientation of the four sets of parallel inclusions in the emerald from Madagascar producing four intersecting light bands and a four- and six-rayed multi-star network (artwork by M.S. Krzemnicki).*

Conclusion

In summary, asterism in members of the beryl family is caused by oriented solid and fluid inclusions. If three sets of elongated particles (e.g. ilmenite or elongated channel-like fluid films or elongated channel-like negative crystals) oriented perpendicular to the *c*-axis are present, a six-rayed star can be observed. With additional channels parallel to *c*, four- and six-rayed stars are formed. The mineral inclusions causing asterism in beryl which have been determined so far are ilmenite and pyrrhotite. The elongated channel-like inclusions are thin fluid films or negative crystals, both of which are terminated by basal and prism faces. The inclusions are elongated parallel to one of the three equivalent directions parallel to the prism faces of the host.

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