The orientation and symmetry of light spots and asterism in rose quartz spheres from Madagascar

Dr Karl Schmetzer[1] and Dr Michael Krzemnicki[2]

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

Abstract: *The orientation of light spots on the surface of four asteriated rose quartz spheres from Madagascar is described. The up to 50 different light spots form similar patterns on all samples examined with respect to their orientation, but are somewhat different according to their relative intensity. They are represented by the poles of six groups of symmetry equivalent quartz crystal forms, related to prismatic, rhombohedral and basal crystal faces. The phenomenal light spots are caused by reflection at plane phase boundaries with an orientation parallel to crystal faces of the rose quartz host and are due to inclusions of tiny minerals or negative crystals and/or oriented reflecting plane fluid cavities or mineral platelets.*

Introduction

Phenomenal quartzes are known from various localities. Specimens with needle-like inclusions orientated parallel to one direction are known as quartz cat's-eyes. Asteriated quartzes or rose quartzes with six-rayed stars reveal three groups of needle-like inclusions orientated in a plane perpendicular to the *c*-axis. Rarely twelve-rayed stares are seen which show six groups of needles in the same plane. Multi-star quartzes revealing numerous stars on the surface of cabochons or complete spheres are mainly known from Sri Lanka. The multi-star network is due to numerous intersecting light bands which are caused by various groups of needle-like inclusions (Kumaratilake, 1997; Schmetzer and Glas, 2003).

Occasionally, asteriated rose quartzes reveal – in addition to the three ordinary light bands forming the six-rayed star – several more or less sharp light spots. Such additional light spots have already been described by Goldschmidt and Brauns (1911) and by Kalkowsky (1915) in rose quartz spheres from Brazil and Madagascar as 'Lichtknoten' (light knots). This optical phenomenon has rarely been mentioned in gemmological textbooks (see for example Bauer and Schlossmacher, 1932).

On asteriated rose quartz spheres or cabochons seen on various occasions at mineral or gem shows, the authors have also observed such additional light spots, mainly in material from Brazil or

 ISSN: 1355-4565

Madagascar. The present study, however, started when we received two extraordinary rose quartz spheres, weighing 421 and 159 grams, diameters about 6.7 and 4.9 cm. The specimens originated from Madagascar and were submitted by the Swiss gem merchant A. Leuenberger to the SSEF Swiss Gemmological Institute, Basel, Switzerland. Leuenberger had noticed that in addition to their ordinary six-rayed asterism, the rose quartz spheres showed numerous light spots distributed over the complete surface, a phenomenon that he had not seen in any of the numerous spheres he had cut or seen in the past.

Stimulated by the initiative of Mr Leuenberger, the authors ~~went through~~ a large number of asteriated and non-asteriated rose quartz spheres that were offered by several Malagasy dealers at the Munich mineral fair. Most of these samples showed only the ordinary six-rayed star of asteriated quartz *(Figure 1).* However, we were able to select two additional spheres of 138 and 113 grams in weight, diameters 4.6 and 4.3 cm, respectively, for the present study, which showed the optical phenomenon mentioned above. Rose quartz is found in many localities on the island of Madagascar and at all of these is of pegmatitic origin (Pezzotta, 2001). Such pegmatitic origin has also been reported for Brazilian asteriated and non-asteriated rose quartz by Cassedanne and Roditi (1991).

Visual appearance and macroscopic observation

All four rose quartz spheres showed a similar phenomenal pattern consisting of a complete six- or twelve-rayed star and additional light spots. The central star in spheres A,C and D (see a summary of observed light effects in *Table I*) revealed three intersecting light bands and was not very strong (*Figures 2a, 4, 5a*). In B, three additional, even weaker light bands were present forming, together with the three somewhat more intense light bands, a twelve-rayed central star (*Figure 3a*). The intersection points of these stars are called north and south poles of the spheres.

In all four spheres, it was possible to follow the six arms of the star (in B to follow the six stronger arms of the twelve-rayed star) from the north to the south poles of the spheres. Turning the spheres to follow these light bands along the arms of the star, i.e. from the first intersection point (north pole) to the second intersection point (south pole), five additional light spots are located on each of these light bands (*Figures 2b, 3b*). From the positions of these light spots, i.e. from the pole distances of the different spots on the arms of the star, it is obvious that these light spots form symmetry equivalent groups (designated groups 1,3 and 4 in *Table I, column 1*). The light spots designated as group 1 were located at a distance of 90° to the poles of the spheres, i.e. at the equator of all samples (*Figure 2b*). The light poles of groups 3 and 4 were on the upper and lower hemispheres of the rose quartz spheres (*Figure 3b*). It was also observed that the patterns of spots observed on the upper and lower half of the spheres are identical with respect to pole distances and intensities.
A schematic drawing of all the patterns of light bands and light spots observed on the four spheres is given in *Figure 6*.

Figure 1: *Ordinary six-rayed asterism in a rose quartz from Madagascar. This sphere weighs 81 grams and measures 3.9 cm in diameter; the light spot left of the intersection point of the six arms of the star is the reflection of the fibre optic spot light used for illumination.*

Table I: Phenominal light effects in four rose quartz spheres from Madagascar..

Sphere						A	B	C	D
Weight [grams]						138	113	159	421
Diameter [cm]						4.6	4.3	4.9	6.7
Central star						six-rayed	twelve-rayed	six-rayed	six-rayed
Other light bands									$[0\bar{1}11]$
Group of faces	**Designation of faces**	**Symbol**	**Miller indices (hkil)**	**Angle of light spots versus c-axis**	**Number of symmetry equivalent crystal faces and light spots**	**Intensity of light spots, relation to the central star***			
1	hexagonal prism	m	$(10\bar{1}0)$	90°	6	strong	strong	moderate	strong
2	trigonal prism	*a* *a′*	$(11\bar{2}0)$ $(2\bar{1}\bar{1}0)$	90°	3	weak	moderate	n.o.	weak
3	rhombohedron	*r* *z*	$(10\bar{1}1)$ $(01\bar{1}1)$	51.8°	2x3	strong	strong	moderate	strong
4	rhombohedron	π π ′	$(10\bar{1}2)$ $(01\bar{1}2)$	32.4°	2x3	weak	moderate	moderate	weak
5	trigonal dipyramid	*s* *s′*	$(11\bar{2}1)$ $(2\bar{1}\bar{1}1)$	65.6°	2x3	moderate	strong	moderate	moderate
6	basal pinacoid	*c*	(0001)	0°	2x1	moderate	strong	strong	moderate

* Light spots related to the arms of the central six- or twelve-rayed star are indicated in red, light spots not related to the central star are indicated in blue. n.o. = not observed

Following the arms of the central stars from the north pole to the south pole, on spheres A and D (see again *Figure 6*), the sequences of light spots on the arms of the star showed the following intensities: a first spot of low intensity (group 4), three subsequent light spots of high intensity (belonging to group 3, to group 1 and again to group 3) and another light spot of low intensity (again group 4). As already mentioned, the middle light spot of high intensity (group 1) was located exactly half way between the north and south poles of the sphere, i.e. at its equator. In spheres B and C,

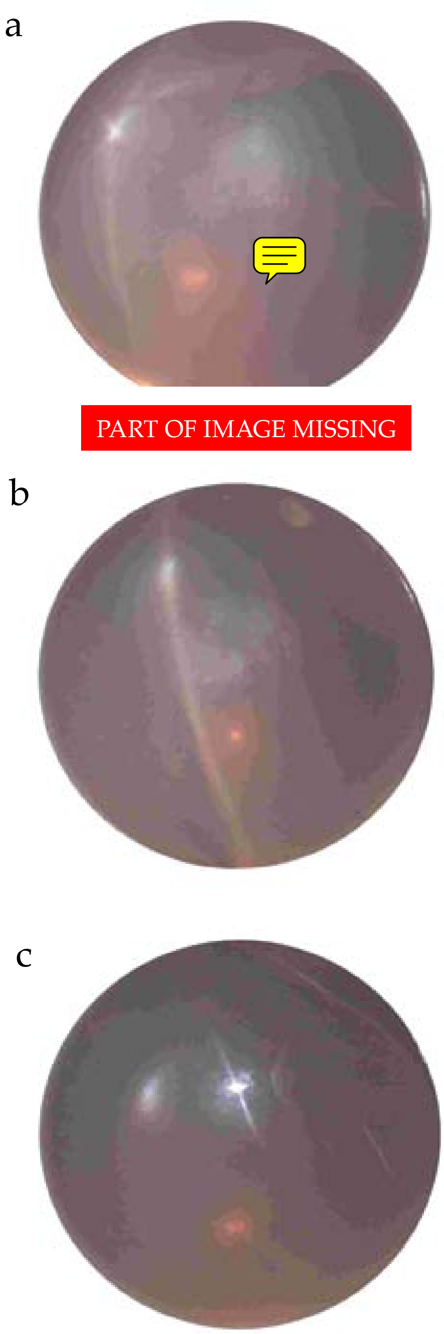

Figure 2: *Rose quartz sphere from Madagascar showing six-rayed asterism and numerous light spots on its surface; (a) six-rayed central star with a light spot at the intersection point of the arms of the star, (b) light spot located on one of the arms of the six-rayed star at the equator of the sphere, the light spot is related to the pole m; (c) light spot located between the equator and one of the poles of the central star, but not on one of the arms of the star, the light spot above left is related to the pole s; the light spot above right is the reflection of the fibre optic spot light used for illumination. This sphere (sample A) weighs 138 grams and measures 4.6 cm in diameter.*

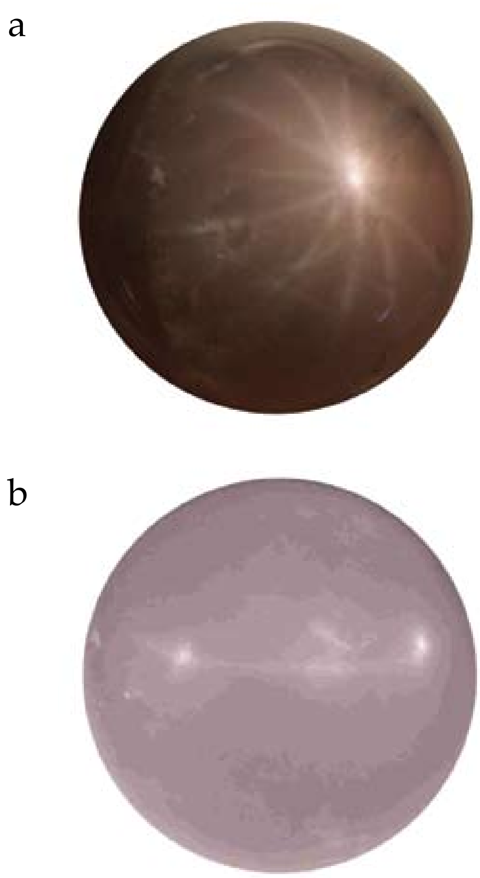

Figure 3: *Rose quartz sphere (sample B) showing twelve-rayed asterism and numerous light spots on its surface; (a) twelve-rayed central star with a light spot at the intersection point of the arms of the star, (b) two light spots located on one of the arms of the twelve-rayed star between the equator and one of the poles of the central star, the light spots are related to the poles r and π. This sphere weighs 113 grams and measures 4.3 cm in diameter.*

the same sequence and position of light spots belonging to groups 1, 3 and 4 was observed, although with different relative intensities (*Table I*).

Rotating spheres A and D to view their virtual equators, the six intense light spots (group 1) on the six arms of each star were clearly visible. In addition, six more light spots of lower intensity (group 2) were observed, equidistant from the light spots on the arms of the six-rayed star. Consequently, a total of 12 light spots (six of higher intensity on the arms, group 1, and six of the lower intensity, group 2) were located at the equator of the sphere. Finally, between each light spot

Figure 4: Rose quartz sphere (sample C) showing six-rayed asterism with a light spot at the intersection point of the arms of the star; the light spot at the right is the reflection of the fibre optic spot light used for illumination. This sphere weighs 158 grams and measures 4.9 cm in diameter.

of low intensity at the equator and the north and south poles of the sphere, one additional light spot of moderate intensity is present (*Figures 2c, 5c*). These symmetry equivalent light spots are designated as group 5.

In spheres B and C, in addition to the different relative intensities of the light spots belonging to groups 1, 3 and 4, the following differences were observed. In B, the light spots belonging to groups 2 and 5 were stronger in intensity than in A and D. They lie on the additional six light bands of the twelve-rayed central star (see *Figure 3a*). In sphere C, there was no evidence for 6 light spots of low intensity at the equator (group 2). The 12 light spots between the arms of the star (group 5), however, were present (see again *Table I*).

In all four spheres, additional light spots are present at the intersection points of the central star, i.e. at the north and south poles of the spheres (*Figures 2a, 3a, 4* and *5a*). They are of different sizes and intensities but this variation cannot be explained by intersection of the arms of the six- or twelve-rayed stars alone.

Sphere D contains distinct light bands forming the arms of the six-rayed central star, and additional light bands of low intensity (see *Figure 5b*), but it was extremely difficult to follow these light bands over the surface of the complete sphere. However, they appear to form a network between at least some of the light spots described above. The other three spheres, did not appear to show any similar networks of light bands.

Crystallographic orientation of light spots

Using the stereographic projection, a quick overview of the number and position of the various groups of light spots in relation to the six- or twelve-rayed central star is obtainable (*Figure 6*). In total, 48 light spots belonging to five groups (6 + 6 + 12 + 12 + 12 spots of groups 1 to 5) were observed (*Table I*). If we add the two spots at the north and south pole (group 6), the sphere shows 50 light spots distributed over its surface. It is evident that the positions of the spots at the equator (two groups with 6 spots each) are identical with the poles of the hexagonal prism *m* (group 1) as well as with the trigonal prisms *a* and *a′* (group 2) of quartz. The light spots at the intersection points of the central stars represent the position of the basal pinacoid *c*.

With this basic information, the angles between the remaining light spots which are not located at the equator of the sphere (three groups of 12 spots each) and the poles of the spheres were estimated. Using these data, the positions of the spots were found to be identical with the positions of the poles of four different rhombohedra, *r, z*, π and π ′ (groups 3 and 4), and two trigonal dipyramids *s* and *s′* (group 5). In summary, the positions of all 50 light spots observed on the surface of the sphere are represented by the pole positions of six groups of symmetry equivalent quartz crystal forms, namely basal pinacoid, prism, rhombohedron and dipyramid. Consequently, the oriented light spots are represented by the pole positions of known quartz crystal faces.

Crystallographic orientation of additional light bands

On the surface of sphere D, several light bands of low intensity were observed forming a special type of network. Although these weak reflections did not form complete light bands over the surface of the sphere, one network of six symmetry equivalent light bands was clearly established. Following one of these light bands from the equator at a light spot belonging to a pole of a trigonal prism (*a* or *a'*), this light band connects one light spot belonging to the pole of a first rhombohedron (*r* or *z*) with a light spot belonging to the pole of a second rhombohedron (π and π ') and a light spot belonging to the pole of a third rhombohedron (again *r* or *z*), running through the equator at a second prism (*a* or *a'* ; see *Figure 6D*). These light bands are inclined to the *c*-axis and are represented by the crystallographic zone symbol $[0\bar{1}11]$. The angle of these six light bands to the *c*-axis is calculated as 32.4°. Consequently, the needle axis of elongated particles forming these light bands is inclined at an angle of 57.6° to the *c*-axis.

Two of this group of six equivalent light bands intersect at each rhombohedral light spot belonging to a pole of group 3 (*r* or *z*) (*Figure 5b*). Combined with one light band of the central star, each rhombohedral light spot related to poles of group 3 also becomes the centre of a weak six-rayed star. In addition, the light spots belonging to poles of groups 2 and 4 become centres of weak four-rayed stars (see *Figure 6*).

Other groups of symmetry equivalent light bands (caused by additional groups of needle-like inclusions in different orientation) may also be present, but their intensity was too low to determine any orientation.

Microscopic observation

Without destroying the rose quartz spheres we were able to observe at high magnification extremely thin needles in all samples, especially by means of fibre optic illumination. These sets of needles are responsible for the six- or twelve-rayed asterism and for the additional light bands of sphere D. Such thin needles are commonly described as oriented rutile needles in quartz host crystals.

In C, we found numerous extremely small reflecting particles in all orientations of the sphere, in which distinct light spots were seen on the surface. However, we were unable to resolve the individual particles and to determine if they were mineral inclusions or

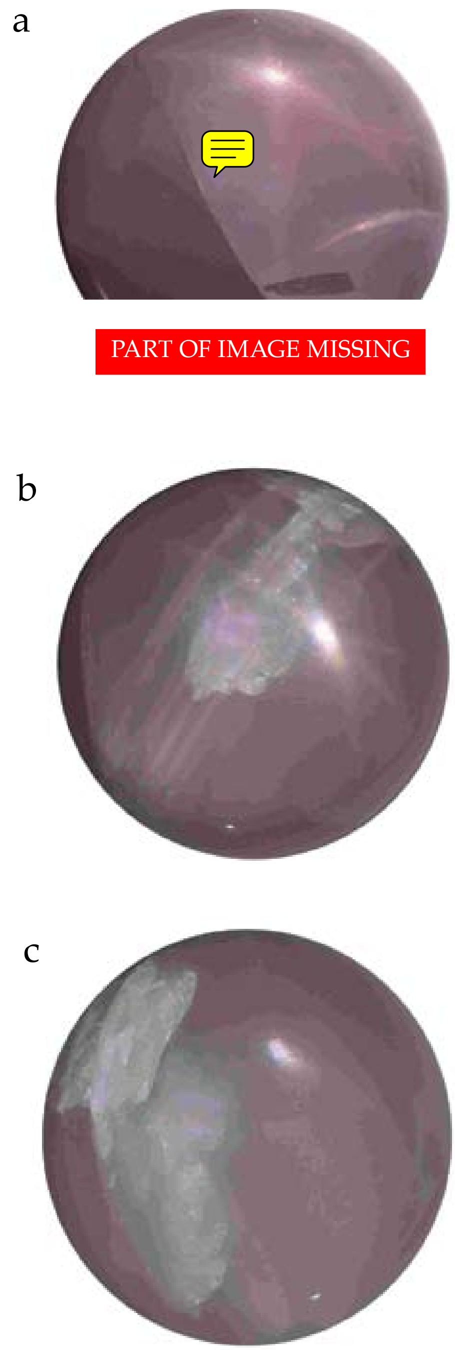

Figure 5: Rose quartz sphere (sample D) showing six-rayed asterism, numerous light spots and light bands on its surface; (a) six-rayed central star with a light spot at the intersection point of the arms of the star, (b) light spot located at the intersection point of one of the arms of a six-rayed star with two additional weak light bands, the light spot is related to the pole r; (c) light spot located between the equator and one of the poles of the central star, but not on one of the arms of the star, the light spot is related to the pole s. This sphere weighs 421 grams and measures 6.7 cm in diameter.

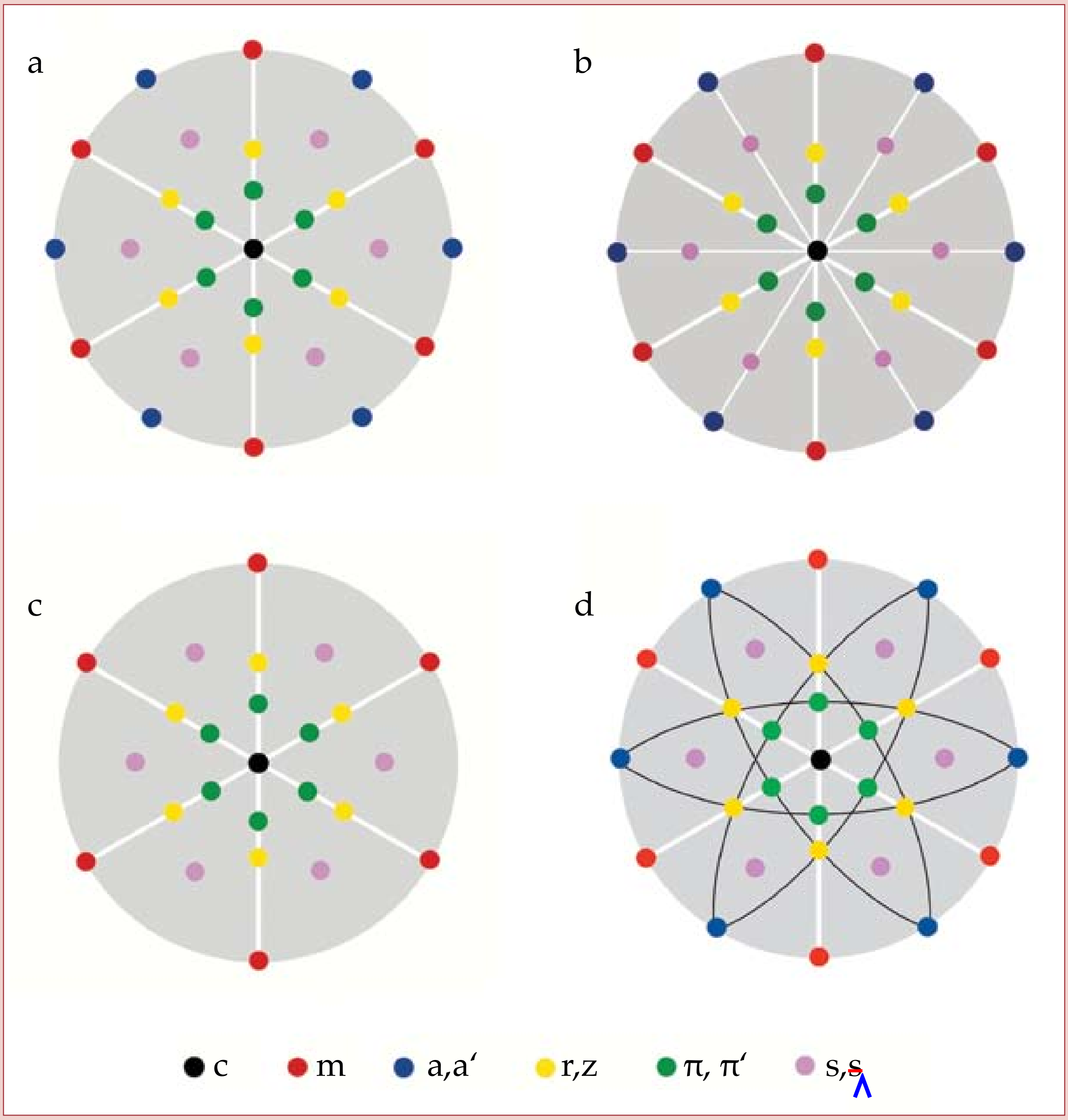

Figure 6: Stereographic projection of light poles on the surfaces of rose quartz spheres (samples A,B,C and D) from Madagascar and their orientation relative to the light bands of the central six- or twelve-rayed stars (only the upper hemispheres of the projection spheres are drawn). The light spots are related to several groups of symmetry equivalent poles of quartz crystal faces. In sample D, additional light bands perpendicular to $[0\bar{1}11]$ form four- and six-rayed stars at the positions of rhombohedral and prismatic light spots. Symbols at the bottom represent Groups 1-6 of faces detailed in Table I.

negative crystals. We were also unable to determine if individual particles reflect only in one orientation of the host crystal or if individual particles were related to several reflections and light spots.

In D, reflecting particles were present that were large enough to be resolved with the gemmological microscope. In detail, we observed a dense pattern of oriented reflecting plane faces, some hexagonally or trigonally outlined and commonly elongated parallel to a particular crystallographic direction (*Figure 7a, b*). This specific pattern of reflecting, mostly elongated plane faces was seen in each of the numerous orientations of the sphere in which a somewhat larger light spot (compared to C with the extremely small particles) was seen on the surface. Due to microscopic examination it

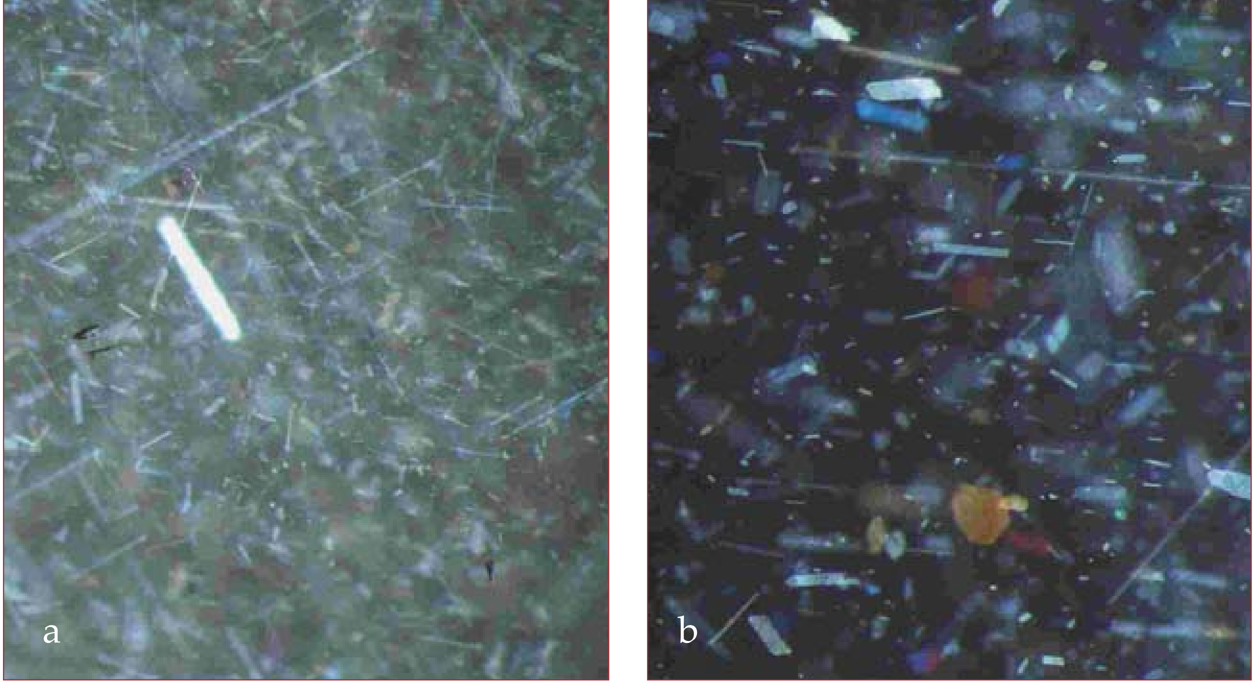

Figure 7: Numerous reflecting plane faces, some hexagonally or trigonally outlined and mostly elongated parallel to a specific crystallographic direction were seen in sample D in each orientation of the sphere in which light spots were seen on its surface; (a) magnified 40 ×, (b) magnified 80 × (photo by H. A. Hänni).

is, however, not clear if these reflecting plane faces represent solid or fluid-containing thin platelets or if they represent the surfaces of larger solid or fluid inclusions (mineral inclusions or fluid-filled negative crystals).

An investigation of the larger inclusions in sphere D by micro-Raman spectroscopy did not lead to any conclusive results. We obtained only the spectrum of the quartz host but no additional lines which could help to further identify the inclusions.

Spheres A and B contain both reflecting small particles and the somewhat larger plane faces that are present in C and D respectively. In A and B, however, the reflecting plane faces are smaller. At present we are unable to decide if we have one distinct type of inclusion with different sizes or if we really have two different types of inclusion present in the rose quartz spheres – in addition to the series of extremely thin needles which are assumed to cause the light bands of the more or less intense six- or twelve-rayed stars.

Further research is needed to identify all types of inclusions in rose quartz spheres showing asterism and additional light spots. This could be done with oriented thin sections (cut from similar phenomenal spheres) using a combination of microscopy, electron microscopy, electron diffraction, micro-Raman spectroscopy and electron microprobe analysis. This is a complex problem which was beyond the resources of the present study.

Discussion

The above orientations of light spots related to crystal faces of rose quartz spheres were determined at the beginning of the twentieth century by Goldschmidt and Brauns (1911) and Kalkowsky (1915), and they further indicated that the light forming the light spots is reflected from the faces of negative crystals within the rose quartz host or from series of oriented light-reflecting platelets of unknown nature. From our study of spheres A,B,C and D, it is evident that the different light spots are caused by reflected light originating from phase boundaries or planes which are orientated parallel to six different forms of symmetrically equivalent quartz crystal faces. In contrast, Maier (1943) suggested that the light spots in rose quartz originate from intersecting light bands, even if there are no intersecting light bands or no light bands at all are visible.

In seeking the reasons to explain our observations on four rose quartz spheres from Madagascar, especially

- the intensities of light spots related to light bands of the central stars,
- the intensity of isolated light spots not related to light bands of the central stars and

- the microscopic proof of light reflecting particles and/or platelets of different size,

Consequently, the idea that the observed light spots (related to the poles of quartz crystal faces) are caused by reflection of light from plane faces of negative crystals and/or oriented mineral platelets within the rose quartz singles crystal is more likely. This schematic model is consistent with the visual observation of the numbers and positions of all light spots. The dominant orientations of the reflecting faces are parallel to the dominant faces of quartz, e.g. parallel to the hexagonal prism *m* as well as the rhombohedra *r* and *z*, and produce the brightest spots. Light spots of lower intensity represent subordinate faces of quartz, i.e. the rhombohedra π and π' as well as the trigonal prisms *a* and *a'*.

However, the nature of the inclusions responsible for the light spots is not clear so far. It is evident that reflected light indicates phase boundaries between the host rose quartz crystal and additional solid or liquid phases. The solid phases might be mineral inclusions or mineral platelets. The liquid phases might be fluid-filled platelets or negative crystals outlined by the number of quartz crystal forms mentioned above. It is also not clear if there is any connection with the fibrous nanoinclusions of dumortierite (?), which were determined recently in rose quartzes originating from different deposits all over the world (see Goreva *et al*., 2001)..

The different intensities of light spots on the surface of different spheres could be caused by either liquid or solid inclusions. Different concentrations of the light reflecting faces of negative crystals would result in different concentrations of light reflecting mineral platelets in different rose quartz host crystals. The different sizes of the observed light spots might be due to different sizes of light-reflecting phase boundaries.

The rose quartz spheres contain also one or two groups of needle-like inclusions with an orientation perpendicular to the *c*-axis of the host crystals. These rutile (?) needles are responsible for the central six- or twelve-rayed stars of the samples. The larger sphere D contains at least one additional group of needle-like inclusions inclined to the *c*-axis, thus forming the six additional light bands which are, consequently, also inclined to the *c*-axis.

Acknowledgements

The authors are grateful to Mr. A. Leuenberger of ALine GmbH, Uetendorf, Switzerland, who initiated the present study. Prof. H.A. Hänni of SSEF, Basel, Switzerland, critically reviewed the manuscript and was helpful in discussing problems related to the present study.

References

Bauer, M., and Schlossmacher, K.,1932. *Edelsteinkunde. 3rd edn*. Verlag Bernhard Tauchnitz, Leipzig

Cassedanne, J.P., and Roditi, M.,1991. Crystallized and massive rose quartz deposits in Brazil. *Journal of Gemmology*, **22**(5), 273-86

Goldschmidt, V., and Brauns, R., 1911. Über Lichtkreise und Lichtknoten an Kristallkugeln. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, **31**. Beilage-Band, 220-42

Goreva, J.S., Ma, C., and Rossman, G.R., 2001. Fibrous nanoinclusions in massive rose quartz: The origin of rose coloration. *American Mineralogist*, **86**(4), 466-72

Kalkowsky, E., 1915. Opaleszierender Quarz. *Zeitschrift für Krystallographie und Mineralogie*, **55**(1), 23-50

Kumaratilake, W.L.D.R.A., 1997. Gems of Sri Lanka: a list of cat's-eyes and stars. *Journal of Gemmology*, **25**(7), 474-82

Maier, W. 1943. Experimenteller Asterismus. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie Abhandlungen, Abt. A*, **78**(3), 283-380

Pezzotta, F., 2001. Madagascar. A mineral and gemstone paradise. *ExtraLapis English No.1*, 51 pp

Schmetzer, K., and Glas, M., 2003. Multi-star quartzes from Sri Lanka. *Journal of Gemmology*, **28**(6), 321-32