# DOUBLE HELIX INCLUSIONS IN COLOMBIAN EMERALDS

By Pierre Vuillet & Jaime Rotlewicz

Translation from French to Spanish: David Goubert

English Translation: Ángela Echeverry

Key words: Colombia, emerald, double helix inclusions

In the series dedicated to the internal characteristics of Colombian emeralds, and followed by the article on pyrite inclusions (Rotlewicz, 2000), this study illustrates double helix inclusions. The authors wish to focus only on the description of these inclusions and emphasize on the role these imperfections play in the crystallization process. The analyses of the phenomena responsible for the formation of these inclusions is not addressed here since that would surpass the scope of this article. Nevertheless, some comments that may contribute to the explanation of the presence of these inclusions inside an emerald, may be presented.

Pierre Vuillet (pvuillet@yahoo.com) gemologist at C.I. StarEmerald Colombia Ltda., Bogotá.

Jaime (Jimmy) Rotlewicz (gemtec@elsitio.net.co), General Director at C.I. Gemtec Colombia Ltda., Bogotá.

See acknowledgements and cited references at the end of the article.

---

## Introduction

The inclusions and internal characteristics of the faceted stones are considered separately. For some, they are de defects that undermine the quality of a stone. For others, they represent the main appeal, both from the aesthetic point of view, as well as due to the information they are likely to provide. As a matter of fact, in some cases they offer identifying features about the nature of the stone; help differentiate natural stones from their synthetic counterparts and imitations; may characterize the nature of the deposit, or the growth method of the synthesis. Also, they may contribute to the determination and diagnosis of the origin site of the deposit, and identify any enhancements of the original stone wall. Additionally, they may well be the cause of optical phenomena, such as asterism, and reflection or sparkle.

But they may simply be fascinating under the microscope lens. Capturing the inclusions and internal characteristics of the stones may be a true challenge for the microphotography aficionado. The start-up and focusing demands a lot of patience, and is based on the binocular microscope and its accessories, such as clean and flat lighting, or dark background, polarization filters, immersion device, and others. The selection of the parameters for the photography is in itself linked to the photographer's expertise. Digital technology makes retouching trials easy and accessible.

## Double helix inclusions

This kind of inclusion is not exclusive to Colombian emeralds and is just the same found in other beryls such as Nigerian aquamarines (pers. Comm. E. Fritsch, 2001), hydrothermal synthesis emeralds of Biron manufacture (Currently Pool, Australia) (Guebelin y Koivula, 1986; Bosshart, 1991) and certain topaz specimens (pers. Comm. D.Gravier, E. Sternis y P. Dungler, 2001).

In English language gemological literature, this type of inclusions is called "spiral growth model" (Bosshart, 1991). It is actually a double helix whose axis is always a straight line parallel to the large z axis of the emerald's crystal. The overall shape of the inclusion is comparable to that of a slightly conical screw connected to two opposing nets rotating in the same direction. The steps are identical and constant throughout the inclusion's axis. The inclusion may be longer than 30 mm, its exterior diameter may be 1.5 mm, and the pathway of each helix may reach the 3.0 mm (figs. 1 and 2). The authors noted that these tracks are generally, but not exclusively, present in emeralds obtained from Chivor mines. It is difficult to determine the precise deposit where faceted stones and crystals come from. For the connoisseur, Chivor emeralds are sufficiently unique as to stand out; they present a number of special characteristics.

The properties that will be described next, allow the cuter or engraver, according to the design, to position the table of the faceted stone with faces parallel to the great z axis, which results in rectangular stones of a bluish hue, where the chamfering cuts are small in size. The active buyer in Bogota, who appraises over 5.000 Karats of small faceted stones per week, may find this kind of inclusion in the sales project of the goods two to three times a week.

In some cases, a solid inclusion is present in one of the extremities of the double helix where the diameter is the largest close to the inclusion, and gradually becomes smaller as it moves away from it. The double helix is located between the solid inclusion that always shows a well-developed crystal shape and the c pinacoid of the crystal (Figure 2). Pyrite (Figure 3).

In a carbonate (figure 4), two solid inclusions are often found in Colombian emeralds (Eppler, 1961; Sinkankas, 1989; Bosshart, 1991; Rotlewicz, 2000).

Some inclusions have a different structure. It is a case of continuous fracture in the shape of double helix that shows good symmetry, and the central nucleus of the fracture becomes visible (figure 5).

## Discussion

When a solid inclusion is present in the origin of the double helix, the general aspect of the figure brings to mind the drag marks caused by a fluid moving at high velocity, or the helicoidal movement of a body falling into air or into a fluid (a seed falling from a tree branch, for instance). The inclusion presents an obstacle that disrupts further growth of the emerald. These disturbances manifest under the shape of a frosty double helix, not completely cured, on a considerable distance along the z axis, the preferred direction of crystallization. If the solid inclusion is not visible, it could either be dissolved into the emerald after the growth of the crystal (especially if it is a carbonate), or, the double helix was born spontaneously. All the same, the inclusion may take the shape of a separation or fracture in double helix, more or less defined according to the degree of curation. At a lower degree of curation, the inclusion will be visible (figure 6).

It has been possible to establish the direction in which the crystal grows thanks to the presence of a solid inclusion (figures 3 and 4) where the decreasing shape of the double helix is (figures 1, 5, and 6). Figure 3 is quite confusing due to the determination of the direction of the twist of the double helix.

The reason for this frost taking the form of a double helix is yet unknown. Even though the phenomena related to the formation of this type of inclusion are beyond the scope of this study, it is interesting to point out the following:

* The growth of crystals and the conditions for their growth are not constant and may undergo brisk or regular variations; crystallization, partial dissolution and re-crystallization may alternate (Sunagawa 1998).

*Chemical and structural imperfections, including helicoidal dislocations, play a significant role in crystal growth (Bloss, 1994; Mercer, 1990. Please refer to the text box). Casey (1995) presents the simulation of the dislocation of two imbricated or embedded helixes that provides a constant source of places for crystals to grow.

*Corrosion figures on the faces or pinacoidal sides of beryls have a hexagonal contour that softens with distance or with the elongation of the point of origin of the corrosion figure (Sinkakas, 1989).

*Gubelin and Koivula (1986) illustrate a biotite inclusion twisted in double helix inside an emerald from Mozambique, which was oriented in accordance to the z axis of the stone.

* Rough crystals (usually called canutillos in the Bogota market) are very elongated, have a weak section, often with a pinacoid c combination finish (faces perpendicular to the large z axis) and display pyramidal faces.

*Low saturation green color (ordinary component, II ω) is modified by a strong low hue blue (extraordinary component, II ε).

*The concentration of color and crossing lines are perpendicular to the large z axis.

* The stones are well crystallized and the inclusions are rare.

Conclusions

The authors wish to call the attention on the aesthetics of the double helix inclusions of Colombian emeralds and give some hints about what causes their formation. Techniques like X diffraction topography (Topography – X rays) cathodic luminescence tomography (CL Tomography) (Sunagawa, 1998), inaccessible for this study, would very likely provide the necessary information that would explain the presence of these inclusions in elongated emerald crystals, and in their lower sections.

This study has unveiled the presence of a double helix in the place where a simple spiral has been previously reported. Four out of five inclusions presented here have “taken a step to the left”. It has not been possible to determine with precision the direction of the movement of the last sample. The low amount of the inclusions studied is not enough to establish the sinister character of the double helix in Colombian emeralds.

Translator’s note: the references to the figures and photographs are offered hereafter so the reader may find them in the original document.

Figure 1. Double helix inclusion “takes a step to the left” inside a Chivor emerald crystal. No solid inclusion is visible in the origin of the impression. The crystal is 4.5 cm long. Col Gemtec. Photo R. Giraldo CGIE.

Figure 2. Schematics of a Chivor emerald crystal that shows a double helix inclusion with presence of the origin of a solid inclusion.

Figure 3. Spectacular view of the disturbances caused by a deformed pyrite crystal inside a Chivor emerald. It is difficult to determine the direction of the passing of the helixes. The inclusion axis in double helix is perpendicular to the crossing lines of the emerald. X40. Photo J. Rotlewicz.

Figure 4. Double helix inclusion caused by a carbonate. The double helix “takes a step to the left”. The deposit of origin of the emerald is unknown. X35. Photo J. Rotlewicz.

Figure 5: Double helix frost created by detachment. The carver has placed the table on a plane parallel to z axis, in a faceting style typical of Chivor emeralds. X15 Photo J. Rotlewicz.

Figure 6: Depending on the curation degree, the frost shows a different definition. The diameters of the helixes decrease from left to right in the same direction as the growth of the crystals. A: double helix without a central nucleus as it “takes a step to the left” in a faceted stone of unknown deposit in Colombia. The curation of the frost is partial and only the outer edges of the helixes are visible. B: fracture in the shape of a double helix with central nucleus created by detachment as “it takes a step to the left” (partial magnification of figure 5). For enhanced clarity, the silhouette of the double helix is materialized. The minimal curation of the frost makes both the helixes and the nucleus clearly visible. A x 25; B x 30, Photo J. Rotlewicz.

**Comment [ÁE1]:** Aquí voy

### Imperfections in crystals (by F. D. Bloss)

The ideal structure of a crystal, just as it is described in literature, implies a perfect order, both in short and long distances. In short distance, the perfect order is realized if the ions located in the immediate environment of an A reference ion are identical in number, type and geometrical distribution to the ions present in the surroundings of ion A', corresponding to the reference ion, once the operations of symmetry passage and rotation that characterize the structure of the crystal are applied. In long distance, the perfect order is realized when the unitary vectors of the basic crystal mesh or net coincide in the place of an A reference in an A" place, once we multiply these vectors by a large whole number.

In real life, the X diffraction diagram of an ordinary crystal differs from the theoretical diagram of the ideal crystal. This is due to the imperfections in the structure and chemical composition of an ordinary crystal.

The imperfections in the chemical composition are mainly related to the substitution of ions for some other ones, with existing ionic radius and a similar valence. When the valence is different, it is compensated by the addition of interstitial ions or "holes". Sometimes, these imperfections are the cause for the color of the substance. The functioning of lasers and electronic circuits is directly related to the controlled introduction of impurities in the crystal mesh of the substrate.

Among the imperfections of the structure, the helicoidal type dislocation becomes apparent due to the introduction of a helicoidal axis crystal, which is not usually present. Then, the upper surface of the crystal looks like a ramp or helicoidal unevenness of which the incline (or passage) reached its maximum point immediately around the dislocation, and then diminished until it finally disappeared in distance; the crystal then finds its perfect order. These surfaces, in the shape of a helix ramp facilitate the growth of the crystal, because the atom and the ions that form the structure are subject to a much stronger attraction toward the front of the ramp or incline, particularly if this step has the height of one or several unitary cells.

The inclined growth of a crystal is much faster than the growth due to the consecutive addition of new layers of unitary cells underneath other existing layers, since it avoids the difficult task of the initial nucleation of new layers.

Acknowledgements

___________________________

The authors wish to thank: Emmanuel Fritsch (Emmanuel.fritsch@cnrs.imn.fr), Professor of the Continued Education Service at the University of Nantes and the Jean Rouxel Materials Institute (CNRS-IMN), Nantes, for his great cooperation; Philippe Monneret, Grand Chatel, who agreed to the edition of certain published documents; Denis Gravier (dgravier@aol.com) in Le Minéral Brut, Saint Jean Le Vieux, and is wife Daniele, who had the kindness of proofreading the original Microsoft® Publisher 98 composition.

## Références


Bloss F. D. (1994) *Crystallography and crystal chemistry*. Ed. Mineralogical Society of America, Washington DC. 545 p.

Bosshart G. (1991) *Emeralds from Colombia (Part 2)*. Journal of Gemmology, Vol. 22 No. 7, pp. 409-425.

Casey W. H. (1995) *Surface chemistry during the dissolution of oxide and silicate materials*. In Mineral Surfaces, (ed. D. J. Vaughan and R. A. D. Pattrick), The Mineralogical Society Series, 5, Chapman & Hall, London, UK, pp. 185-217.

Eppler W. F. (1961) *Growth marks in emerald*. Journal of Gemmology, Vol. 8 No. 2, pp. 72-77.

Fryer C., Ed. (1983) *Gem Trade Lab News: Emerald*. Gems & Gemology, Vol. 19, No 3, p. 173.

Gübelin E. J., Koivula J. I. (1986) *Photoatlas of inclusions in gemstones*. Ed. ABC, Zurich, Suisse, pp. 244-260, 461-475.

Mercer I. F. (1990) *Crystals*. Ed. Natural History Museum, London, UK. 60 p.

Rotlewicz J. (2000) *Les inclusions de pyrite dans l'émeraude de Colombie*. Revue de Gemmologie AFG, No. 140, pp. 16-17.

Sinkankas J. (1989) *Emerald and other beryls*. Ed. Geoscience Press, Prescott AZ. 665 p.

Sunagawa I. (1998) *Fingerprinting of two diamonds cut from the same rough*. Gems & Gemology, Vol. 34, No. 4, pp270-280