Made You Look • The Challenges of Identifying Inclusions at First Sight
挑戰一眼識別內含物

E Billie Hughes

E. Billie Hughes
Lotus Gemology Co. Ltd., Bangkok, Thailand
Website: www.lotusgemology.com
Email: billie@lotusgemology.com

作者分享在一些顯微儀器下觀察寶石內含物的經驗。

One of the joys of being a gemmologist is being able to venture through a new world each time one sits in front of the microscope. We never know where the journey through a stone will take us, or what we will see along the way. Like any traveller, as we peer into these vistas we start to wonder about the nature of what we are seeing. All features that interrupt the homogeneity of the host mineral are called inclusions. Inclusions can be solid, liquid or in gaseous form.

Many gemmologists would like to be able to identify the mineral inclusions we observe. This author is often asked about how to identify these features. Resources such as the Photoatlas of Inclusions in Gemstones series by Gübelin and Koivula, are a great place to start. Another way to learn about inclusions is to browse Hyperion, our free, searchable inclusion database available at https://www.lotusgemology.com/index.php/library/inclusion-gallery.

There are certain microscopy techniques that one can use, coupled with experience, to narrow down the possibilities. Adjusting the stone and viewing it from different angles and using a variety of lighting conditions and filters helps us learn more about each crystal. Through a process of elimination and careful microscopic observation we can narrow down the possibilities. However, observation alone doesn't provide definitive answers.

At Lotus Gemology as well as in other gemmological laboratories, we often use micro Raman to help with the identification of solid inclusions. By using confocal Raman spectroscopy, coupled with a microscope, we can dive into the stone, aiming the laser precisely at inclusions of interest. With this method we are able to identify inclusions with a much higher degree of accuracy than with observation alone.

Sometimes we find that our guesses regarding a mineral's identity are correct, but we are also often surprised by the results of the testing. Much like when we try to identify stones based solely on sight, it is only through thorough testing that we can be confident in our identification.

One of the problems with identification of inclusions by sight is illustrated in Fig. 1. In 1A we see a teardrop-shaped crystal in sapphire; in 1B a slim, elongated rod in zircon, and in 1C a rounded and a prismatic crystal that are attached in spinel. Analysis with micro Raman identified these different-looking inclusions as the same mineral: apatite. Inclusions like these may look different even though they are the same mineral.

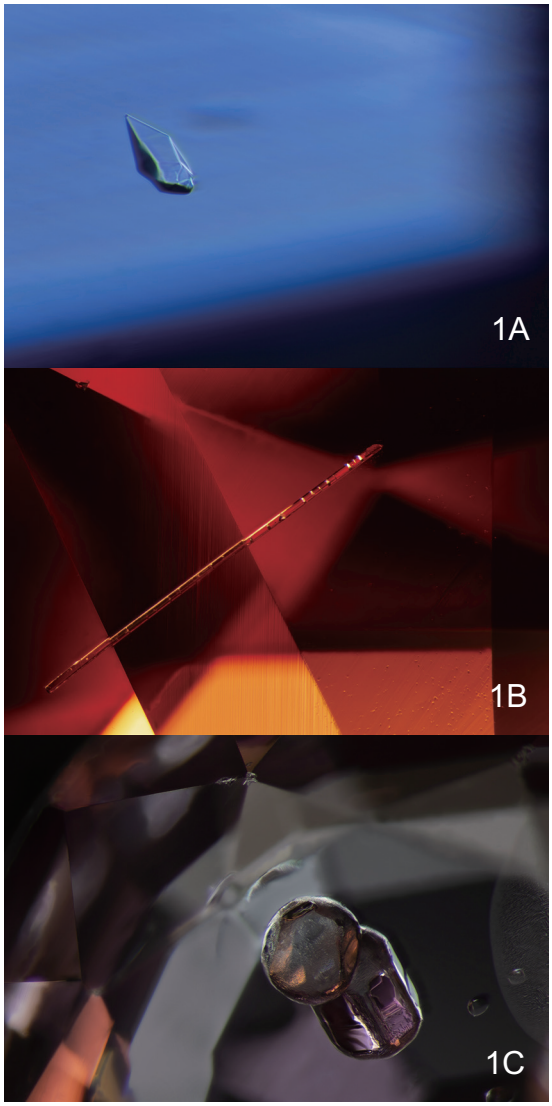


Fig. 1 In these images, we see inclusions that have a distinctly different appearance. In 1A there is an inclusion that is teardrop shaped, with one rounded and one pointed end in a blue sapphire host. 1B displays an elongated rod-like inclusion in a zircon host, and 1C displays a rounded and more angular prismatic inclusion that are attached and suspended in their spinel host. Analysis with micro Raman revealed that all three inclusions are apatite crystals. This demonstrates the difficulty of inclusion identification based on sight alone.
這些圖像中，具有明顯不同外觀的內含物。在 1A 中有一個淚珠狀的內含物，在藍色藍寶石主體中具有一個圓形和一個尖頭。1B 顯示了鋯石基質中的細長棒狀包裹體；而 1C 展示了附著並懸浮在尖晶石基質中的圓形且棱角更大的棱柱狀包裹體。微拉曼分析表明，所有三種包裹體都是磷灰石晶體。這證明了僅基於視覺識別內含物的難度。
***Photos**:*
1A: Richard Hughes/Lotus Gemology; FOV 1mm
1B: E. Billie Hughes/Lotus Gemology; FOV 1mm
1C: E. Billie Hughes/Lotus Gemology; Specimen courtesy Ayub Muhammad; FOV 4 mm

Sometimes we do observe inclusions with a more similar appearance. Take a look at Figs. 2A and 3A, for example. Both are transparent crystals in ruby, and both display a striking red colour. At first glance, they appear to be the same mineral. However, when we take a closer look and adjust our lighting setup, we notice an interesting feature. These inclusions are cut through on the surface, and we are able to view their lustre with reflected light. In 2B, we see that the first crystal displays a shiny, metallic lustre. Fig. 3B looks quite different, with a lower lustre that appears just slighter duller than that of the surrounding corundum. This is the first sign that we may be looking at different materials. By using micro

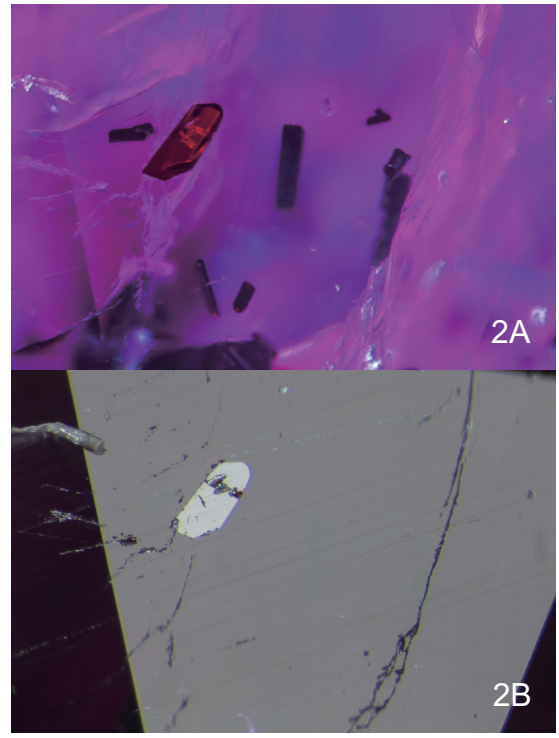


Fig. 2 A transparent, red crystal stands out in the inclusion scene in the ruby pictured in 2A, illuminated here in darkfield illumination. By adjusting our lighting conditions and using reflected light (2B), we learn more about it by discovering that it has a metallic lustre. This appearance, combined with micro Raman analysis, confirms that this crystal is primary rutile.
在暗域照明下，一個透明的紅色晶體在 2A 中的紅寶石的內含物中顯得突出。通過調整照明條件和使用反射光 (2B)，我們發現它具有金屬光澤，從而對它有更多了解。這種外觀與微拉曼分析相結合，證實該晶體是原生金紅石。
***Photos**:*
2A & 2B: Wimon Manorotkul/Lotus Gemology; FOV 2mm

Raman, we are able to confirm this hunch. The crystal in Fig. 2 is primary rutile, whereas the crystal in Fig. 3 is staurolite.

This example emphasises the importance of considering different aspects of the inclusions, including not just colour, but also transparency, shape, and lustre. Yet these, too, can be misleading. Fig. 2B is striking for the inclusion's metallic lustre. In Fig. 4, we see an inclusion with a similarly metallic appearance, reminiscent of the primary rutile in Fig. 2B. However, testing identified the crystal in Fig. 4 as hematite.

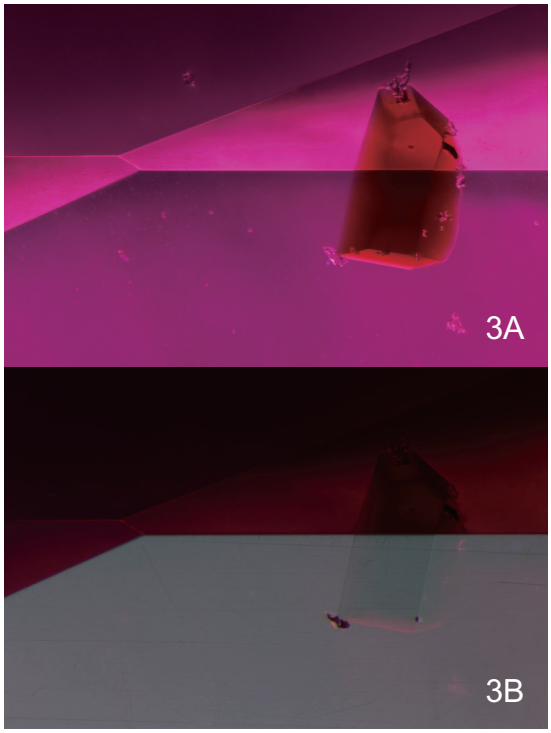


Fig. 3 At first glance in darkfield illumination, the inclusion pictured in 3A may look quite similar to that in Fig. 2A. Both of these crystals are transparent, both display a striking reddish colour, and both are present as inclusions in rubies. However, inspection of the surface where this crystal was cut through (3B) reveals a key difference: the inclusion in Fig. 3B displays a lustre lower than that of the surrounding corundum, while that in 2B displays a highly reflective, metallic lustre. This is an important clue to help us separate these materials. Analysis with micro Raman confirmed that the crystal in Fig. 3 is indeed different: it is the mineral staurolite.
在暗域照明下，3A 中的內含物看起來與 2A 中的非常相似。這兩種晶體都是透明的，也呈現出醒目的紅色，並且都以內含物的形式存在於紅寶石中。然而，對該晶體的切割表面 (3B) 的檢查揭示了一個關鍵區別：3B 中的內含物顯示出低於周圍剛玉的光澤，而 2B 中的內含物顯示出高反射性的金屬光澤。這是幫助我們分辨這些材料的重要線索。微拉曼分析證實，圖 3 中的晶體確實不同：它是十字石礦物。
***Photos**:*
3A & 3B: E. Billie Hughes/Lotus Gemology; FOV unknown

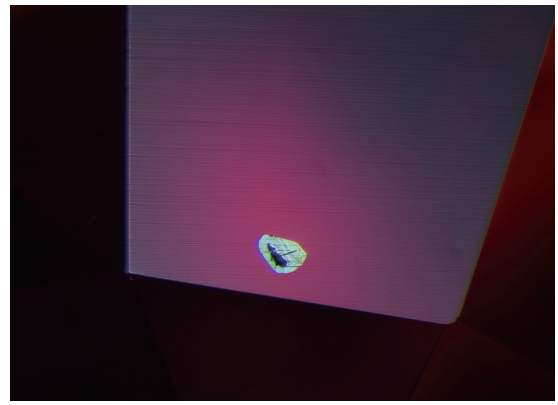


Fig. 4 With a quick look, this small crystal inclusion in a ruby shares a similar metallic lustre to what we see with the primary rutile crystal in Fig. 2B. However, Raman analysis identified this crystal as hematite. As with identifying all gemstones, identifying inclusions should be based on evidence and thorough observation and testing, since many inclusions can share similar (and sometimes misleading) characteristics.
紅寶石中的這種小晶體內含物與我們在圖 2B 中的原生金紅石晶體中看到的具有相似的金屬光澤。然而，拉曼分析鑑定為赤鐵礦。與識別所有寶石一樣，識別內含物應基於實證以及徹底的觀察和測試，因為許多內含物可能具有相似（有時會誤導）的特徵。
***Photo**: E. Billie Hughes/Lotus Gemology; FOV unknown*

In our next example, we also looked at surface-reaching inclusions. Figs. 5A and 5B both show rubies with cavities on the surface. These cavities are filled with a substance with a lower lustre than the corundum, suggesting these substances have a lower RI. In the first image, the substance is something gemmologists know well: glass filling. Although the inclusion in Fig. 5B has a similarly lower lustre, much like the glass, testing determined that these cavities were actually filled with the mineral dolomite. Unlike with the glass filled ruby, this was a completely natural occurrence.

While we have seen numerous examples of the challenges of identifying solid inclusions in gems, other features can be tricky to identify as well. One example is negative crystals which may contain liquids, gasses, or other solids. A helpful tool to use in separating negative crystals from solid crystals is a set of polarising plates. Double

refractive crystals will show interference colours in crossed polars, whereas a negative crystal will not. The caveat with this method is that singly refractive solid crystals will not show those interference colours either.

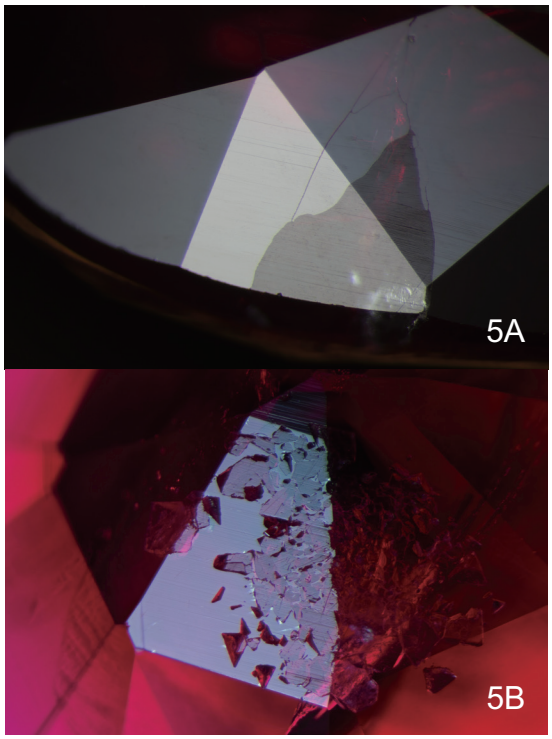


Fig. 5 Careful observation of the surface of these two rubies with reflected light reveals that both stones have inclusions cut through. These contain a substance that is, in both cases, of lower lustre than the surrounding corundum. In Fig. 5A, combining this observation with other features, we were able to determine that the stone was glass filled. The glass has a lower RI than the ruby, giving it a duller appearance. While Fig. 5B looks similar, after testing with micro Raman, we found that the inclusions were dolomite, a mineral naturally associated with this untreated ruby.
利用反射光仔細觀察這兩顆紅寶石的表面，發現兩顆寶石都有切面的內含物。在這兩種情況下，它們都含有一種比周圍的剛玉光澤低的物質。在 5A 中，將此觀察結果與其他特徵相結合，我們能夠確定此石是經玻璃填充的。玻璃的 RI 比紅寶石低，使其外觀更暗淡。雖然 5B 看起來很相似，但在用微拉曼測試後，我們發現內含物是白雲岩，是一種與未經處理的紅寶石天然相關的礦物。
***Photos**:*
5A & 5B: E. Billie Hughes/Lotus Gemology; FOV 3mm

Another feature to look for if you have a cluster of crystals is that negative crystals tend to form according to the symmetry of the host. This is why we often see strings of orderly octahedra in spinel, for example. One can notice that the light may bounce off a cluster of negative crystals all at the same angle. In Fig. 6A, we see strings of negative crystals in sapphire. Note how they are oriented, and how the light reflects off the different crystals at the same angle.

Furthermore, negative crystals may trap other substances inside, so one might see solid inclusions inside a negative crystal, or sometimes mobile bubbles (see Fig. 6B).

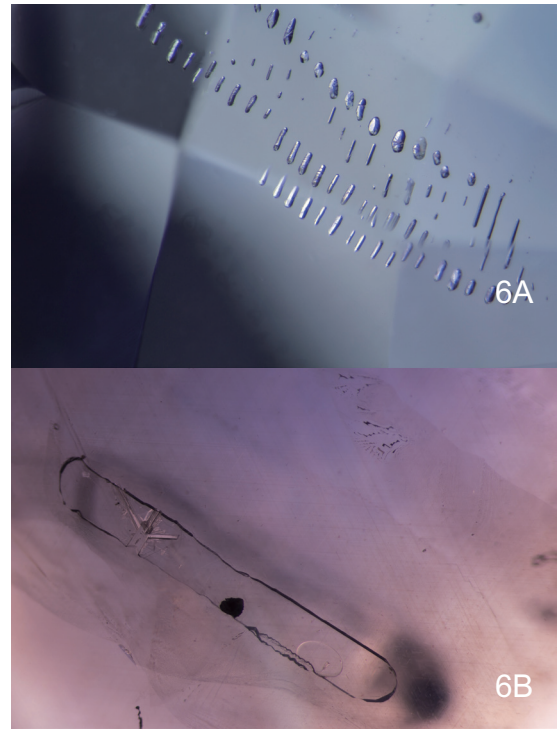


Fig. 6 6A We can observe a cluster of negative crystals in a sapphire from Madagascar. Note how the light reflects off the crystals at the same angle. In 6B, we see a close up view of a large negative crystal in a Sri Lankan sapphire. We can see how it contains other inclusions, including some needles on the left, a dark black platelet in the center (likely graphite), and also a gas bubble on the right. The gas bubble is likely the gaseous phase of liquid carbon dioxide that fills the cavity.
6A 我們可以在馬達加斯加的藍寶石中觀察到一簇負晶體光線以相同的角度從晶體反射。在 6B 中的斯里蘭卡藍寶石內的一個大型負晶體中，我們可以看到它如何包含其他內含物，包括左側的一些針狀物、中央的深黑色薄片（可能是石墨）以及右側的氣泡。氣泡很可能是充滿氣相的液態二氧化碳。
***Photos**:*
6A: Wimon Manorotkul/Lotus Gemology; FOV unknown
6B: E. Billie Hughes/Lotus Gemology; FOV unknown

Microscopy is one of the more traditional techniques used in gemmology, and still one of the most powerful. Yet, like any other gemmological test, it alone cannot offer all the answers. In analysing numerous specimens with micro Raman, we have seen first-hand how tricky it can be to identify inclusions based on sight alone. Whether we are focusing on testing the stone itself or the inclusions within, we must always keep our minds open to all of the possibilities while we wander through the micro world.

Further Reading

Gübelin, E.J. and Koivula, J.I. (1986) *Photoatlas of Inclusions in Gemstones.* Zürich, Switzerland, ABC Edition, revised Jan., 1992; German edition, 1986 (Bildatlas der Einschlüsse Edelsteinen), 532 pp.; RWHL*

Gübelin, E.J. and Koivula, J.I. (2005) *Photoatlas of Inclusions in Gemstones, Volume 2*. Basel, Switzerland, Opinio Publishers, 830 pp.; RWHL*. Vol. 2 for spinel

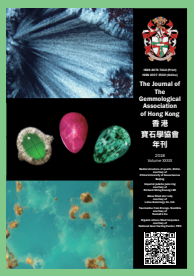
Gübelin, E.J. and Koivula, J.I. (2008) *Photoatlas of Inclusions in Gemstones, Volume 3*. Basel, Switzerland, Opinio Publishers, 672 pp.; RWHL*. Vol. 3 for corundum

Hughes, R.W., Manorotkul, W. and Hughes, E.B. (2017) Ruby & Sapphire: A Gemologist's Guide. Bangkok, Lotus Publishing, 816 pp.; RWHL*

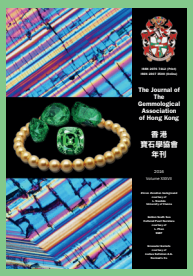
Nassau, K. (1981) Raman spectroscopy as a gemstone test. *Journal of Gemmology*, Vol. 17, No. 5, January, pp. 306–320

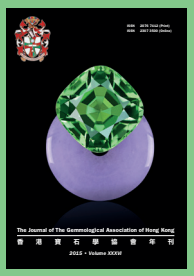

2020


2019


2018

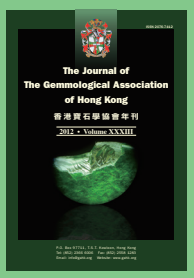

2017

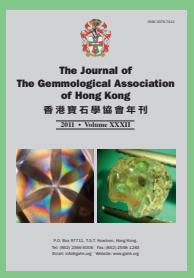

2016

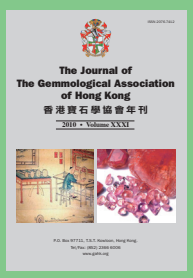

2015

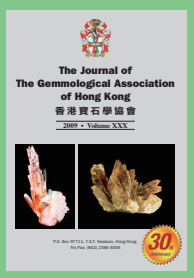

2014


2013


2012


2011


2010


2009

The Journal of The Gemmological Association of Hong Kong

Past copies, advertising and editorial guidelines are available for download from the GAHK website:

過往年刊、廣告及編輯指引可於香港寶石學協會網頁下載

http://www.gahk.org/en/journal.asp

ISSN 2076 7412 (Print) **ISSN 2307 3500 (Online)**

publication@gahk.org (852) 2366 6006 www.gahk.org