Are boehmite needles in corundum Rose channels?

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Crystallographically-oriented, rectilinear inclusions in corundum are often referred to as "boehmite needles" (Keller et al., 1985; Hughes, 1997; Stather, 2008; Kan-Nyunt et al., 2013). These inclusions are oriented along the edges of the rhombohedral faces "r" (10-11), that is edges [r - r'], [r' - r"] et [r" - r] (Figure 1). They form angles of 86.1° and 93.9° (Hughes, 1997). They are actually found at the intersection of twin lamellae, formed by twinning along the rhombohedral faces. These twin lamellae can be recognized by the interference colors seen in partially polarized light, or pleochroic colors, different in the lamellae and around it. In the following pages, "needles" refers to the volume created by the intersection of such twin lamellae, even if it is not strictly a needle.
These needles contain apparently polycrystalline material tentatively identified as boehmite, at least in some cases (Schmetzer, 1986). These are common in natural corundum and sometimes used as a criterion to separate natural from synthetic corundum. Twin lamellae observed in corundum most often form via deformation twinning (Belyaev, 1974; Schmetzer, 1986). They result thus from post growth events, and are the proof that strain was applied to the crystal. Hence comes their common occurrence in natural gems and scarcity in synthetic ones.

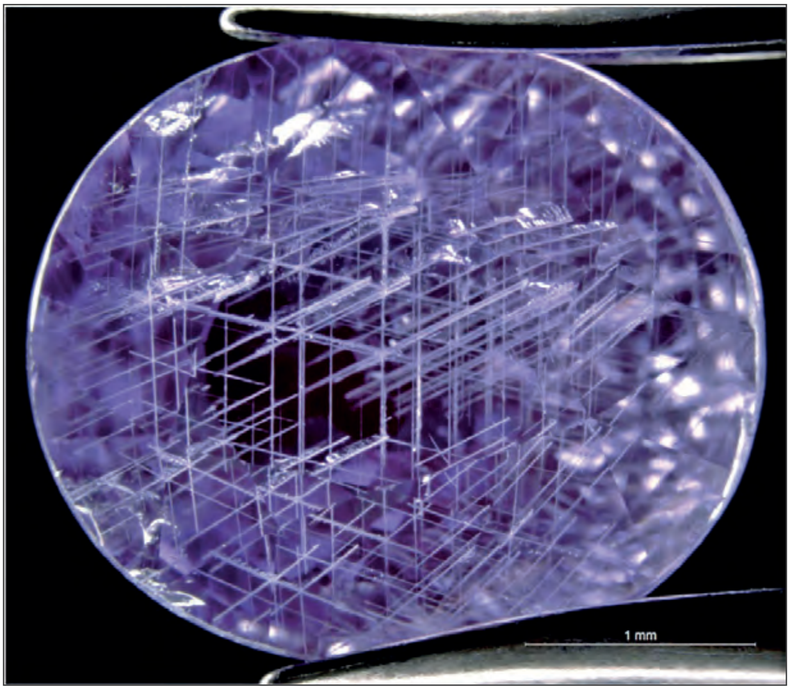

Figure 1. Purple sapphire (unheated) from the Umba valley in Tanzania with a large number of « boehmite needles », oriented in all three possible orientations (Ref. FN-1103; Field of view: 3.34 mm).

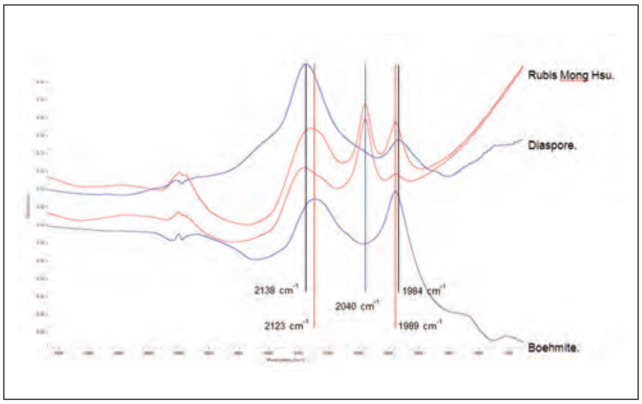

Figure 2. The infrared absorption spectra of boehmite, diaspore, and two Mong Hsu rubies with boehmite (and minor diaspore) inclusions.

Boehmite is the aluminum hydroxyde γ-AlOOH, and crystallizes in the orthorhombic system. It is found in corundum as a syngenetic inclusion, often also epigenetic, and finally as an exsolution product provoking parting (White, 1979). It can be identified through an easily recognizable infrared signal with two broad bands at about 2123 and 1989 cm^{-1}, differing only slightly in position from those of diaspore (Figure 2).

Materials and methods

Gemological observation and imaging was done using a variety of Leica microscopes, including the M205C and MZ6. Infrared spectra were obtained on a variety of Fourier Transform spectrometers, including a Bruker IFS and a Thermo Nicolet Nexus at a resolution of 4 cm^{-1} generally accumulating 100 scans. Hundreds of stones containing boehmite needles (as defined above) have been investigated by infrared absorption spectroscopy. Of particular interest is a Ramaura flux synthetic ruby containing a small number of such needles (Figure 3).

To investigate the nature and aspect of the material inside the needles, three samples from Vatomandry, Madagascar, were prepared with the needle axis near perpendicular to the plate, one with parallel windows (Figure 3). Scanning electron microscope (SEM) images were obtained on a Jeol-5800LV.

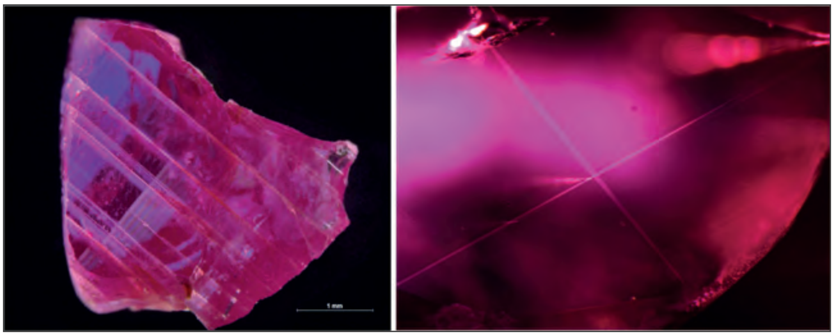

Figure 3. Some of the samples studied: (left) The parallel window Malagasy sample (Field of view, 4.83 mm) for SEM investigation with two series of twin lamellae (one dominates) and (right) a micrograph of the Ramaura synthetic ruby containing "boehmite needles" at the intersection of two twin lamellae (partially polarized light; Field of view 2.3 mm).

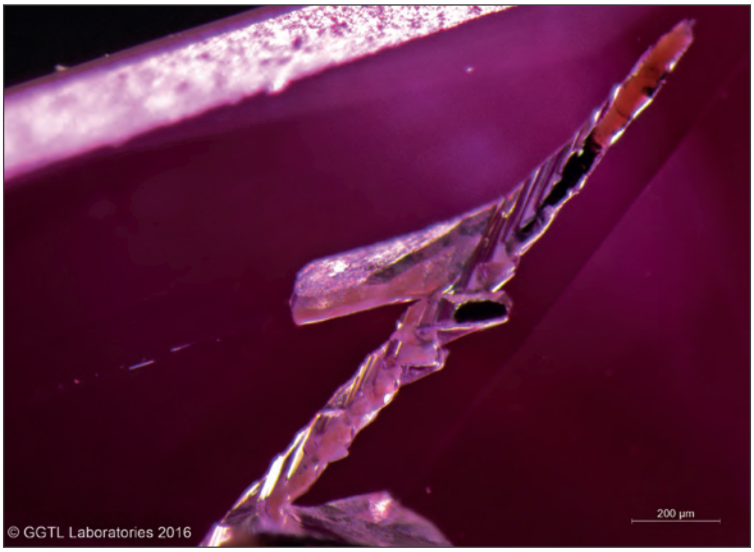

Figure 4. Unusually large "needles" in a purple sapphire from Ilakaka, Madgascar, demonstrate that these cavities are corundum negative crystals at intersecting twin lamellae (Field of view 1.65 mm).

Results

Observation with the microscope reveals two aspects for the boehmite needles: some are lath- or ribbon-shape. Others are clearly negative crystals (Figure 4). Figure 3 shows needles in a flux synthetic ruby, a gem with no boehmite infrared signal. The systematic infrared absorption approach did not always demonstrate the presence of boehmite absorptions when so-called boehmite needles are present. Over the years, this lead the authors to believe that there was no systematic relation between the „needles" inclusions and boehmite.

The SEM investigation turned out to be quite difficult, and often nothing was seen at the intersection of twin lamellae, even if visually there is the impression of a needle. Most of the time, there is a topographical depression at the intersection of twins. Sometimes, structures hard to explain are seen in the lamellae, which reveal an unexpected microstructure of what appears to be corundum, and not boehmite.

Discussion and conclusion

To reconcile observations and measurements, the view that needles are made of boehmite must be reconsidered. It is known in a small number of materials (some metals, calcite, diamond) that hollow channels may form at the intersection of twin lamellae (Seeger, 2007; Schoor et al., 2016), caused by deformation twinning. This was discovered by Rose (1868) in calcite, thus this feature is called "Rose channels". This is one of the possibilities offered by migration of vacancies created during deformation.

We believe that "boehmite needles" are Rose channels. Even when very small, these channels would explain the optical relief observed, without a change in chemistry or infrared absorption. They fit the crystallographic nature of the structures observed. It explains also the quick propagation of diffusion, and even glass filling, along these features.

It is possible that post deformation events created some dissolution or minor mineral transformation at the surface of these voids, reconciling this proposition with the variety of previous observations, including boehmite formation. This would account for the whitish appearance of this feature, created either by light scattering on a rough surface or mineral grains of a different index of refraction.

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