

INCLUSIONS IN AQUAMARINE FROM AMBATOFOTSIKELY, MADAGASCAR

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In January 2012, aquamarine crystals containing interesting inclusions were extracted from the Ambatofotsikely area northwest of Antsirabe, Madagascar. These specimens displayed various types of eye-visible and microscopic inclusions, and some had an unusual form. Raman microspectroscopy identified reddish brown platelets as hematite, while ilmenite was found as black platelets, black needles, and distinctive dark gray dendrites. Similar inclusions are known in beryl from Brazil, India, Mozambique, and Sri Lanka.

Mining activity near the central Malagasy village of Ambatofotsikely was first documented nearly a century ago, when Lacroix (1922) described monazite and columbite crystals from that area. In 1949, the French Atomic Energy Commission explored the region for beryl as well as minerals bearing uranium and niobium-tantalum. More recently, since about 1970, local farmers have sporadically dug shafts up to 20 m deep into a deeply weathered granitic pegmatite in search of gem aquamarine.

In December 2011, this deposit yielded a few kilograms of dark, translucent spessartine. A month later, the miners recovered some rather low-quality aquamarine. Some of this material showed a strong greenish blue color and contained dark, unusually prominent inclusions (figure 1). In March, that discovery led to a small rush of about 200 independent miners (figure 2). Additional aquamarine was produced that was more transparent, without the dark inclusions. In April, some inclusion-free colorless to very pale orange beryl was also recovered. As of June 2012, a few dozen miners continued to work the deposit with hand tools.

Between January and April, several hundred kilo-

grams of translucent to transparent beryl were produced, as well as several tonnes of opaque material for industrial use. While only a very small percentage was suitable for faceting, several hundred aquamarines in the 1–35 ct range have been cut. In April 2012, one of the authors (FD) traveled to the locality and obtained representative samples.

Location and Geologic Setting. The workings are located less than 1 km north of Ambatofotsikely (a village now locally known as Ambatofotsy Carole), 22 km north-northwest of Ankazomiriotra, and 74 km northwest of Antsirabe. The deposit is centered at coordinates 19°27.662'S, 46°27.450'E, at an elevation of 1,010 m. The site is accessed by a paved road (RN 34) from Antsirabe to a point 16 km west of Ankazomiriotra. From there, a trail extends 15 km to Ambatofotsikely.

The aquamarine deposit is part of the Betafo-Antsirabe pegmatite field (Pezzotta, 1999). This area is underlain by migmatite of the Precambrian crystalline basement of central Madagascar (Antananarivo Block). The pegmatites are related to a magmatic cycle

Figure 1. This 28.69 ct aquamarine from Ambatofotsikely, Madagascar, displays conspicuous dark inclusions. Photo by F. Danet.



See end of article for About the Authors.

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Figure 2. In early 2012, a minor gem rush occurred at this deeply weathered aquamarine-bearing pegmatite near Ambatofotsikely. Photo by F. Danet.



that took place 570–540 million years ago, during the late stages of the Pan-African orogeny. The Ambatofotsikely pegmatite is classified as a rare-element LCT (lithium, cesium, and tantalum) type body, of the beryl-columbite subtype. Beryl, biotite, clay-altered feldspar, and quartz are by far the most prominent minerals. Others include allanite, almandine-spessartine, anatase, columbite-tantalite, euxenite, fergusonite, ferrocolumbite, gahnite, hematite, ilmenite, monazite, muscovite, quartz (amethyst), rutile, samarskite, vermiculite, xenotime, and zircon (Lacroix, 1922; Behier, 1958).

Beryl from Ambatofotsikely occurs as hexagonal prisms, frequently more than one decimeter wide and several decimeters long. Most of the crystals are heavily fractured, and miners routinely break them while searching for transparent areas. The aquamarine is generally a moderate to strong greenish blue, though some crystals are simply green beryl.

Materials and Methods. Eight cut aquamarines (3.47–13.59 ct) and nine rough samples (1.1–4.1 g) were examined for this report. The samples ranged from medium blue to slightly greenish blue and contained various amounts of inclusions. Refractive indices were determined on the cut stones, and specific gravity was measured hydrostatically on the rough samples. Raman spectra of the inclusions in a faceted

stone were recorded at Pierre and Marie Curie University with a Renishaw inVia Raman microscope using 100× magnification and 514 nm argon-ion laser excitation. To interpret and correlate our results, we

In Brief

- Aquamarine with distinctive inclusions was found in the Ambatofotsikely area of central Madagascar in January 2012.
- Only a very small amount of the aquamarine was suitable for faceting, and several hundred stones weighing 1–35 ct have been cut.
- The inclusions consist of reddish brown platelets of hematite along with black platelets, black needles, and distinctive dark gray dendrites of ilmenite.
- Similar inclusions are known in beryl from Brazil, India, Mozambique, and Sri Lanka.

consulted the RRUFF database maintained by the University of Arizona.

Results and Discussion. Gemological examination of the samples gave the following properties: RI— $n_o = 1.580$ – 1.582 , $n_c = 1.573$ – 1.575 ; birefringence— 0.006 – 0.007 ; pleochroism—strong, in near-colorless and medium slightly greenish blue; hydrostatic SG— 2.69 –



Figure 3. A variety of inclusions were identified in the Malagasy aquamarine. Shown here are platelets composed of reddish brown hematite and black ilmenite, as well as dark gray dendritic inclusions and black needles of ilmenite. Photomicrograph by V. Bourgoïn; image width 1.0 mm.

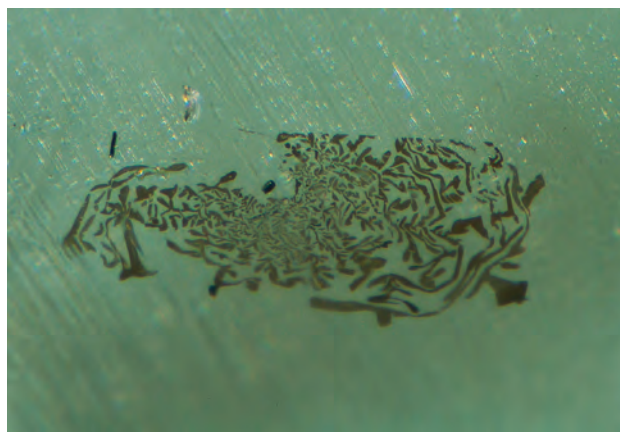


Figure 4. This close-up view shows a dendritic ilmenite inclusion in greater detail. Photomicrograph by V. Bourgoïn; image width 0.6 mm.

2.73 (no correlation with the concentration of inclusions); and some weak absorption at 456 nm visible with the desk-model spectroscope. These properties are consistent with beryl.

With magnification, numerous inclusions with varied forms, colors, and sizes were visible in both the rough and cut aquamarines. Hollow tubes were oriented in two directions, parallel and perpendicular to the c-axis. Some were filled with black material, while others appeared red, apparently because of oxidation. Rare translucent dark reddish brown platelets (sometimes with associated black platelets) were ori-

ented both parallel and perpendicular to the c-axis (figure 3). Also present were black needles, but the most common and noticeable inclusions were very thin plate-like reticulated dendrites (figures 3 and 4) oriented parallel to the basal plane c {0001}. They were typically ~0.1 mm wide, with a dark gray color. Their abundance varied considerably between samples and by location within a crystal, but did not vary systematically from the inner to outer portions of the crystals. In some areas, the ilmenite inclusions formed well-defined ladder-like bands elongated parallel to the c-axis. Where the inclusions were densely distributed, the stones appeared gray when viewed through the basal plane.

Raman spectroscopy (figure 5) identified the reddish brown platelets as hematite. The closely asso-

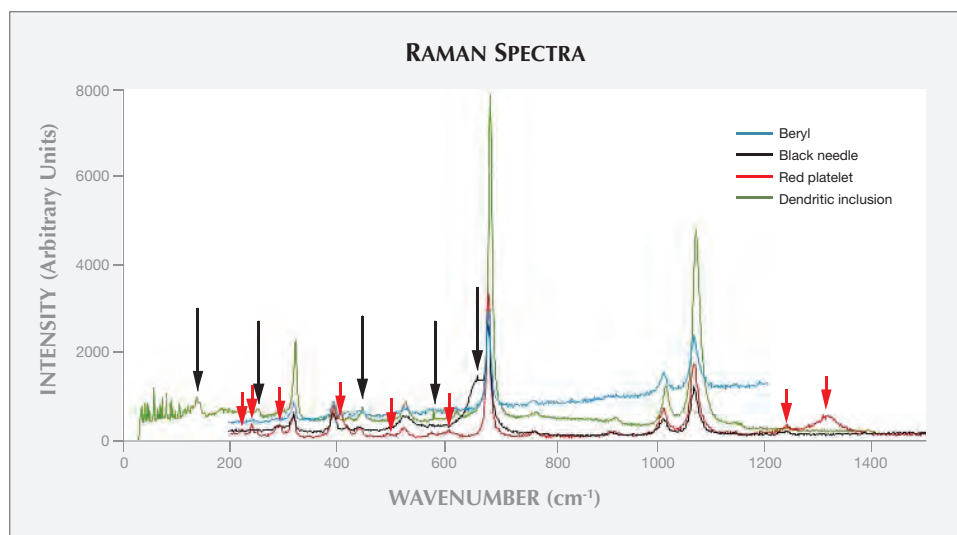


Figure 5. Raman spectra are shown for the host aquamarine and three types of inclusions. The black arrows correspond to ilmenite, and the red arrows are indicative of hematite. The dominant beryl peaks are also present in the spectra of the inclusions.

ciated black platelets were identified as ilmenite, as were the black needles and dark gray dendritic inclusions. Although ilmenite's characteristic 660 cm^{-1} peak was not clearly visible in the ilmenite spectra, its presence was detectable by the asymmetry of the 680 cm^{-1} beryl peak (particularly in the "purer" spectrum of the black needle).

Similar hematite and ilmenite inclusions have been documented previously in beryl from Brazil (Gübelin and Koivula, 1997); India (Koivula, 2006);

Alto Ligonha, Mozambique (O'Donoghue, 2006); and Balangoda, Sri Lanka (Gübelin and Koivula, 2005).

Conclusion. Raman analysis clearly identified the various inclusions in the aquamarine from Ambatofotsiky. The reddish brown platelets were hematite, whereas ilmenite was present as black platelets, black needles, and distinctive dark gray dendritic inclusions. This marks the first time these ilmenite dendrites have been documented in aquamarine from Madagascar.

ABOUT THE AUTHORS

The late Mr. Danet was owner of Style Gems in Antsirabe, Madagascar. Mrs. Schoor is a student at the National Institute of Gemology (ING) in Paris. Dr. Boulliard is director of the mineralogical collection of Pierre and Marie Curie – Sorbonne Universities in

Paris. Dr. Neuville is director of research at the National Centre of Scientific Research (CNRS) in Paris. Dr. Beyssac is a researcher at the Institut de Minéralogie et de Physique des Milieux Condensés (IMPMC) in Paris. Mr. Bourgoïn is a photomicrography specialist based in Paris.

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IN MEMORIAM FABRICE DANET (1966–2012)



Gems & Gemology contributor Fabrice Danet passed away on August 23 at the age of 46. Mr. Danet, owner of Style Gems in Antsirabe, Madagascar, had recently completed his article on inclusions in Malagasy aqua-

marine for this issue of *G&G*. He was also a regular Gem News International correspondent who provided important updates on gems from his adopted country.

Born in Brittany, France, Mr. Danet became passionate about minerals at an early age, collecting stau-

rolite "fairy crosses" in the neighboring countryside. He studied at the Nancy School of Geology, graduating in 1987. Following travels to Brazil and Pakistan, he established himself as a mineral dealer in 1989. He eventually relocated to Madagascar, where he met his wife. Their two sons have grown up immersed in gemology.

Mr. Danet enjoyed hiking throughout Madagascar and exploring for gem and mineral deposits. Each year at the Tucson gem shows he visited the *G&G* booth with interesting news and specimens to share. We extend our condolences to Mr. Danet's family and friends.