

FAPFH/GFF Treated Ruby from Mozambique

- a preliminary report -

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Figure 1: The three different powders used in the process, remnants of a ceramic crucible and some of the untreated and treated samples examined in this study. Photo: N. Sturman.

Introduction:

After the discovery of the Montepuez ruby mining area in Mozambique, during spring 2009 (Pardieu, *et al.*, 2009a), within few months, gemologists at the GIA Laboratory Bangkok started to see many stones originating from this new deposit. Many unheated stones were submitted for examination, but this was quickly followed by material that had been heated at high temperature using a “flux-assisted partial-fissure-healing” (FAPFH) process that appeared similar to that which has been used on the material from Mong Hsu (Burma) since the early 1990’s. In December 2009 the authors began to collaborate with Thawatchai Somjainuek, who had been developing a treatment process similar to that used on the Mong Hsu material for the material from Montepuez.

After studying numerous treated rubies from this new deposit the authors observed that in many cases in addition to the usual (for Mong Hsu material) partially-healed fissures, the stones also contained a variable number of surface reaching fissures that were not partially-healed and were simply filled with glass (GFF) – similar to the fissure filling seen in the so-called lead-glass-fissure-filled (LGFF) rubies and diamonds where fissures have been filled with glass. In the case of treated rubies from Mong Hsu that have undergone the FAPFH process, while the observation of glass-filled surface cavities is not unusual, unhealed fissures that are filled with glass (GFF) are.

While the glass that fills unhealed fissures in the Montepuez rubies does not contain significant quantities of lead as in the LGFF rubies, the intent of the treatment is the same and the results and effects are at least similar. Therefore, in many situations with these rubies the treatment process results in two separately defined treatment types within a single stone – FAPFH and GFF.

At the end of March 2010 the GIA laboratories in Bangkok, Carlsbad and New York, began to issue reports for these multiple-treatment rubies using where appropriate the TE scale (See LMHC Information Sheet# 1) to describe the effects of the FAPFH process together with the clarity enhancement statements also used for the effects of the LGFF process.

It is important to reiterate that the glass found in these GFF rubies does not contain a significant amount of lead or bismuth, nevertheless, it is still a glass and thus in comparison to the ruby itself, may be unstable at elevated temperatures and to chemical agents. Special care should be taken when cleaning or repairing jewelry items set with GFF or LGFF corundum.

Key acronyms:

FAPFH – Flux Assisted Partial Fissure Healing

GFF – Glass Fissure Filled

IS – LMHC Information Sheet

LGFF – Lead Glass Fissure Filled

LMHC - Laboratory Manual Harmonization Committee

Historical background:

Glass filling of cavities in Thai ruby and later sapphire was first reported during the early 1980's. (Hughes, 1984, Scarratt, *et al.*, 1984). In the ensuing years, glass filling was commonly seen in rubies from the Morogoro region in Tanzania and to a less extent in stones from Mogok (Burma) (Pardieu, *et al.*, 2006).

In the early 90's Thai ruby dealers placed most of their focus on the Mong Hsu deposit as a new treatment process, FAPFH, was able to transform this material from unsalable near opaque rough into wonderful transparent faceted red gems. The FAPFH process was clearly set out by Hänni in a diagrammatic form that is reproduced here (with permission) on the left side of Figure 2. In short; ruby is heated to temperatures that may reach as high as 1850°C in the presence of a molten flux. At these temperatures the surfaces of the ruby (alumina) in contact with the flux will slowly dissolve into the flux. During the gradual cool down period the alumina comes out of the flux and crystallizes on the nearest available surfaces. These surfaces may be those of the crucible in which the process is taking place or on the rubies being treated. If crystallization takes place on the rubies, this may be on the outer surfaces (facets) of the stones or on the inner surfaces of any fissures that may be present. If the crystallization is on the inside of fissures, the build-up of synthetic material will cause the fissures to gradually close or “partially heal” (Figure 2). These partially healed fissures have the appearance of intricate networks of fine tubules contained in undulating planes within the stone. The material that can be observed within these planes is mostly composed of a glass; the transparent spaces within the planes are where the fissures have been partially healed with synthetic corundum.

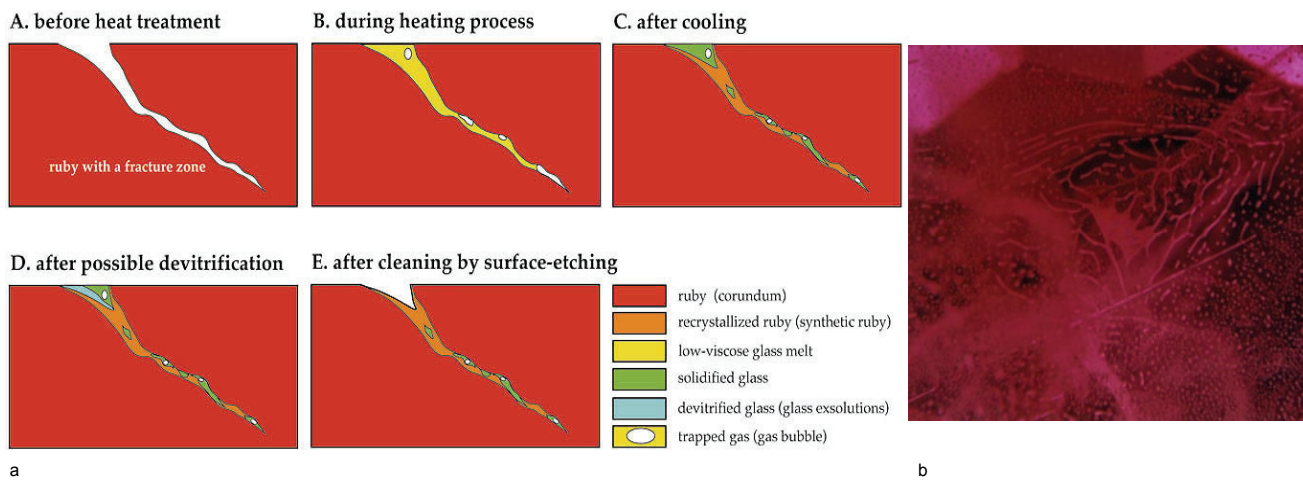


Figure 2: Flux assisted healing of a fissure during the heating process. A fissure that has been healed by the synthesis of corundum or other materials during the heat treatment or crystal growth processes. (Hänni, H.A., 1998) (a) schematic (b) actual

Upon formation one of the first tasks that the LMHC¹ undertook was to address the varied texts used to describe rubies that have undergone the FAPFH process. The LMHC Information Sheet #1 (IS1) sets out the agreed nomenclature. Table 1 sets out this the basic LMHC nomenclature for FAPFH treated rubies; readers are advised to download and read the entire IS1 for context.

Table 1: LMHC Residue Quantification terminology for flux healed rubies.

Condition →	No indications of heating	Indications of heating (no residue)	Indications of heating with residues in fissures				
Report Alpha numeric →	NTE	TE	TE1	TE2	TE3	TE4	TE5
Report Text →	No indications of heating	Indications of heating	Minor residue in fissures		Moderate residue in fissures		Significant residue in fissures
Condition →	Indications of heating with residues in cavities						
Report Alpha numeric →	C1		C2		C3		
Report Text →	Minor Residue in cavities		Moderate Residue in cavities		Significant Residue in cavities		

In 2000, Thai traders started to buy large quantities of rubies from Andilamena and Vatomaniry in Madagascar. After several years of experiments some Thai burners were able to adapt the clarity enhancement techniques developed by the Yehuda Company for Diamonds in the 1980's to rubies from Andilamena; a material with a good shape and color but usually heavily fissured. In 2004, large quantities of LGFF rubies from Andilamena appeared in the market (GAAJ, 2004, Pardieu, 2005). While FAPFH, LGFF and GFF stones all result in stones that have been “clarity enhanced”, the essential difference between the three types of treatment is that the fissures in FAPFH treated material are “healed” closed by synthesis while fissures in either LGFF or GFF are not, i.e., FAPFH fissures are stable (once any surface glass has been removed by HF) whereas LGFF and GFF treated fractures unstable (they will break down and become obviously visible),

¹ The Laboratory Manual Harmonisation Committee (LMHC) is comprised of representatives from the following gemmological laboratories located in Europe, America and Asia: CIGEM, GAAJ, GIA, GIT, Gübelin, SSEF

(McClure, 2006, Scarratt, 2009). In severe cases of LGFF treated rubies the LMHC laboratories developed severely worded descriptions; these are “ruby with glass” and “ruby-glass composite”.

Following the discovery of the Winza (Tanzania) deposit in November 2007 (Pardieu, 2008, Schwarz, *et al.*, 2008) two new ruby deposits in Mozambique were discovered. The first was near M’sawize village (Oct. 2008) in the Niassa province (Pardieu, *et al.*, 2009b) and the second was near the town of Montepuez (April 2009) in the Cabo Delgado province (Pardieu, *et al.*, 2009a). Large quantities of this latter material entered Thailand in 2009.

In September 2009 in Mozambique, one of the authors (VP) met Thai dealers familiar with the production from the two deposits (Niassa and Montepuez). They reported that the “best unheated material was coming from Niassa”, however, “most of the production from this deposit was only suitable for LGFF treatment”. On the other hand most of the production from Montepuez could be treated using a FAPFH process very similar to the process used for the heat treatment of rubies from Mong Hsu. Nevertheless in November while back in Thailand other Thai dealers expressed their concern that the average clarity of the FAPFH treated Mozambique material was lower on the TE scale compared to the average Mong Hsu material. They felt that this was “due to the material being more included and the presence of large fissures which are less common in the Mong Hsu material”.

In December 2009, while VP was visiting the Montepuez ruby deposit to collect reference samples at the mines, the other authors (NS, GD, SS, KT) began working in collaboration with Thawatchai Somjainuek (Khun Tai) who was treating Mozambique material using a derivation of the FAPFH process.

About Thawatchai Somjainuek:

Thawatchai Somjainuek (Khun Tai) is a Thai citizen who in the 90’s was very active in the treatment of corundum. He worked with yellow sapphire from Sri Lanka and then with sapphire from Madagascar. He is famous for the discovery in 1995 of the beryllium treatment process; however, he decided to suspend all his treatment activities after experiencing some ill feelings towards his involvement in this treatment process.

He recently decided to re-activate his treatment activities. However, in an attempt to ensure that he remains transparent about his processes, the materials and results, Somjainuek has taken the unusual and praiseworthy step of working with the GIA Laboratory, Bangkok, to ensure that each step in his treatment process is recorded and analyzed so as to avoid any ‘complications’ when the material is marketed. One of his main concerns was ensuring that no beryllium was involved in his process and that there were no additional “surprises”.

The Somjainuek treatment process:

The aim of the treatment carried out by Somjainuek is to turn rough low quality ruby with a commensurate lower market value into a more saleable product. Prior to treatment the rough is preformed and cleaned using a solution of dilute hydrofluoric acid (water 1:1) for 3 days. He then heats the material to stated temperatures of 1400°C for around 20 hours in a controlled oxidizing environment. Together with the rubies, which are held in ceramic crucibles during the process, are borax and silica. In the volatile atmosphere of the crucible the molten silica-rich flux covers every surface of the rubies and penetrates all the numerous surface reaching fissures. The process is therefore similar to that described for FAPFH above, however, the amount of added silica may be greater.

Materials and methods

Somjainuek loaned thirteen rubies for examination; six untreated rough stones weighing between 3.64 and 6.71cts (Figure 2), and seven treated stones weighing between 2.29 and 11.88cts (Figure 3). Two of the treated stones weighing 3.25 carats and 5.72 carats were in their final faceted end product form.

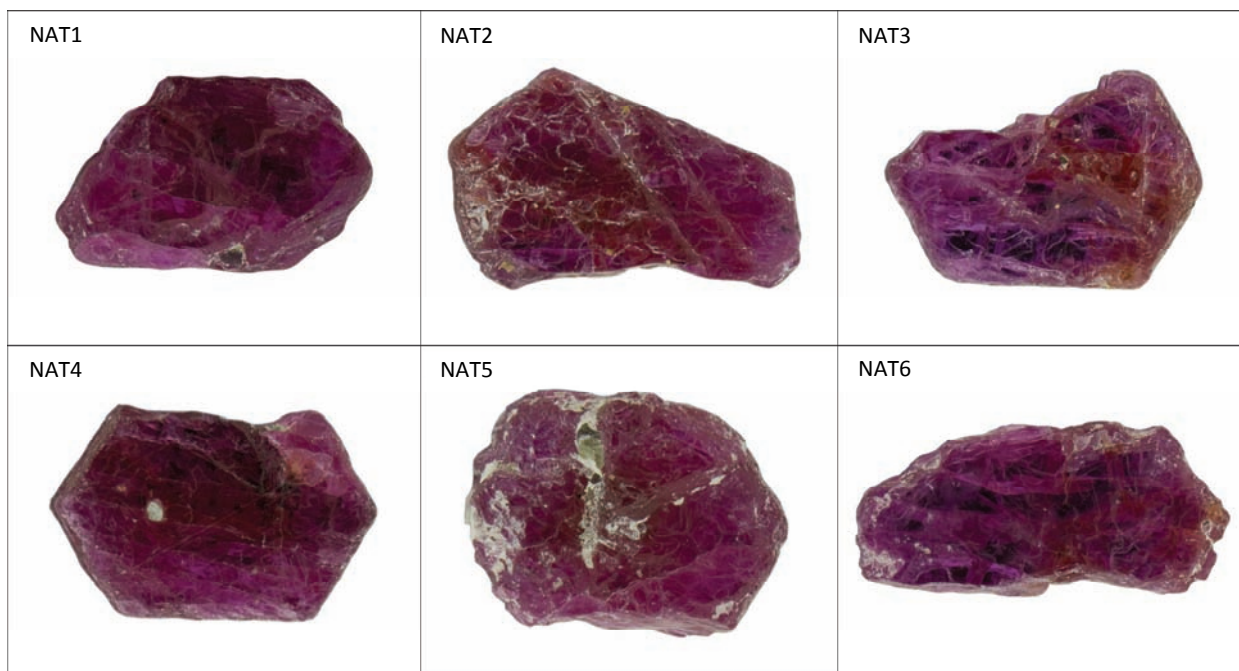


Figure 3: The six rough untreated samples loaned to the GIA by Mr. Somjainuek for this study. The largest sample weighs 5.72 carats and the smallest 3.25 carats. Photos: P. Adirote.

All the stones were examined using *Gemolite* microscopes with magnification ranging from 10 to 60x and the majority of the photomicrographs were recorded digitally using a Nikon system SMZ1500 with a Nikon Digital Sight Capture System and a variety of magnifications. The chemistry was determined with a Thermo X Series II LA-ICP-MS system with an attached New Wave Research UP-213 laser, and in some samples with a Quant'x Energy Dispersive X-ray Fluorescence (EDXRF) Spectrometer manufactured by Thermo Electron. Fourier Transform Infra-red (FTIR) spectra were collected using a Thermo Nicolet 6700 fitted with a 6x beam condenser accessory, and the UV-Vis-NIR spectra were collected using a Perkin-Elmer Lambda 950 Spectrometer. Microradiographic images were obtained using a Faxitron CS100-AC Real-Time system.

The untreated samples:

The starting material used by Somjainuek is reportedly from Mozambique, and indeed after examination the material was found to be similar to that collected in Mozambique by one of the authors (VP) near Montepuez.

The samples depicted in **Figure 3** have a purplish red color and have the appearance of coming from a primary deposit. All the samples were thin tabular crystals with etched pinacoids. The thickest sample measured only 3.37mm, at its thickest point whilst the thinnest sample measured 2.67mm, at its thickest point. The thin tabular form appears to be characteristic of this source. Basic gemological examination with a hand-held spectroscope revealed a characteristic ruby spectrum for all samples. The inclusions observed included dark opaque crystals **Figure 5**, yellowish opaque crystals, natural white surface/fracture filling material, twin planes commonly associated with intersection tubes, green and yellow amphibole crystals (**Figure 6** and **Figure 7**) fingerprints, numerous fine oxidized fractures (**Figure 8**), and bands of particles and needles (Figure 5). Since a number of the crystals were left exposed at or near the surface and the samples exhibited obvious unaltered features, the opportunity to identify some of these inclusions existed.



Figure 4: The seven treated samples loaned to the GIA by Mr. Somjainuek. The largest sample weighs 11.88 carats and the smallest 2.29 carats. Photos: P. Adirote.



Figure 5: Sample NAT2 showing a group of dark euhedral crystals and fine trails of minute white particles associated with needles. Photo: G. DuToit.

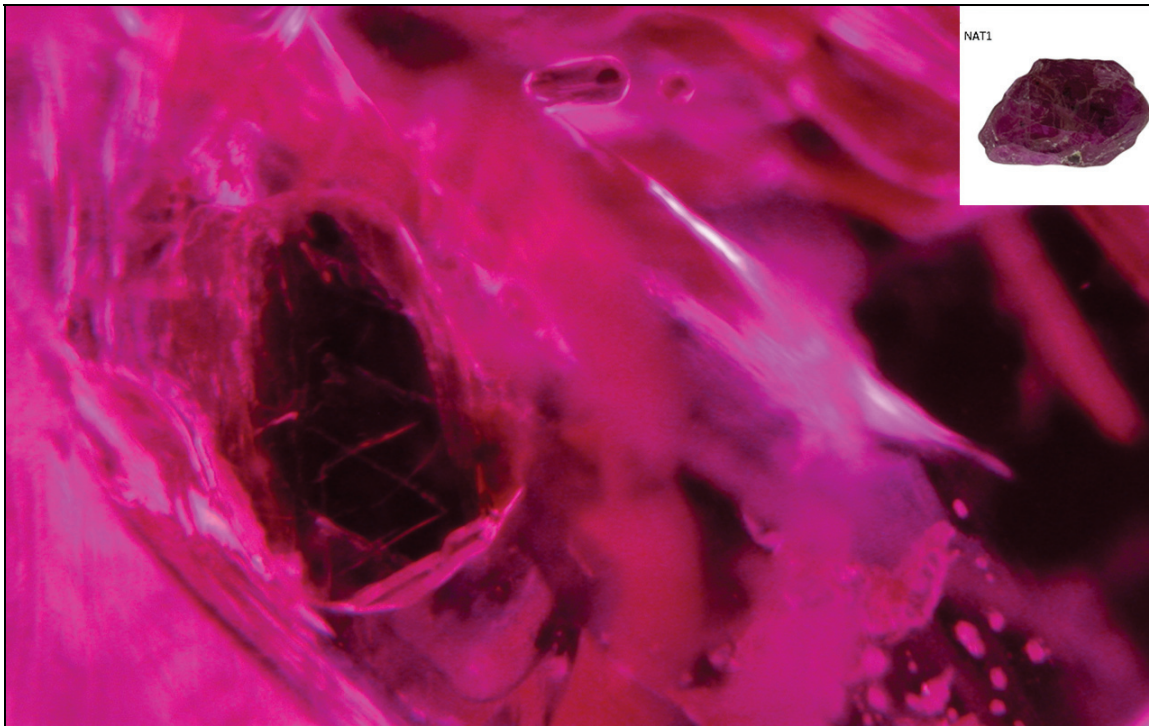


Figure 6: Sample NAT1 exhibiting several transparent greenish amphibole crystals. Photo: V. Pardieu.

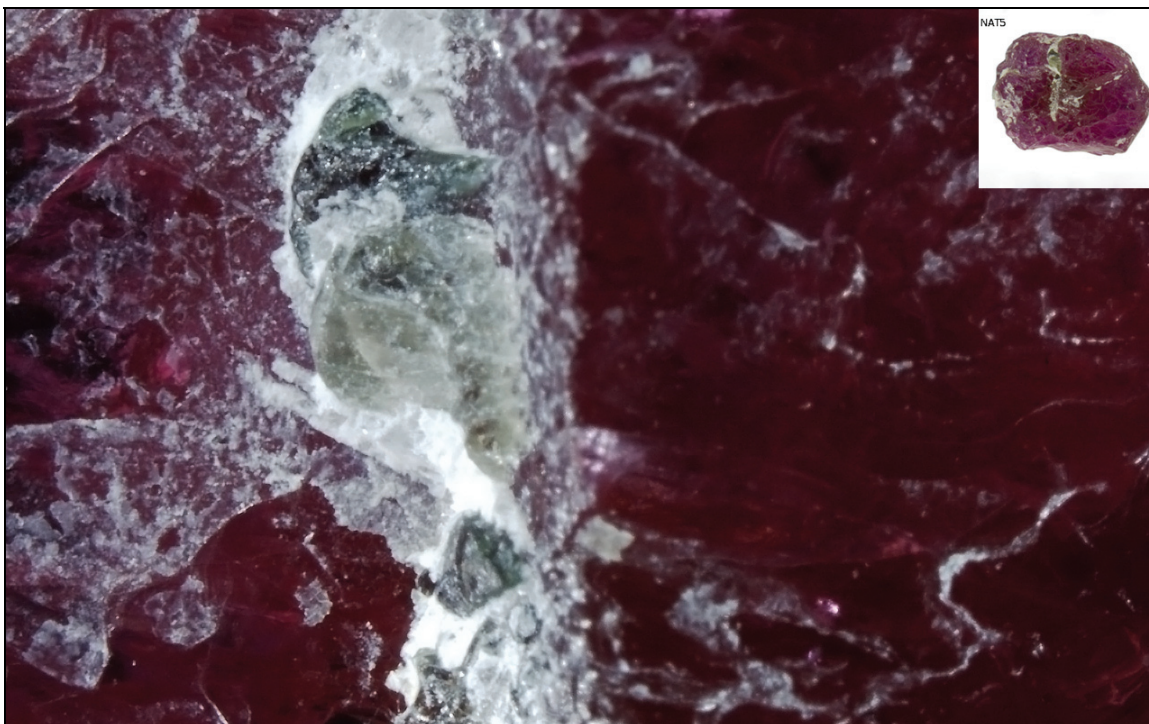


Figure 7: Surface reaching crystals of amphibole associated with white anorthite feldspar in sample NAT4. Photo: G. DuToit.

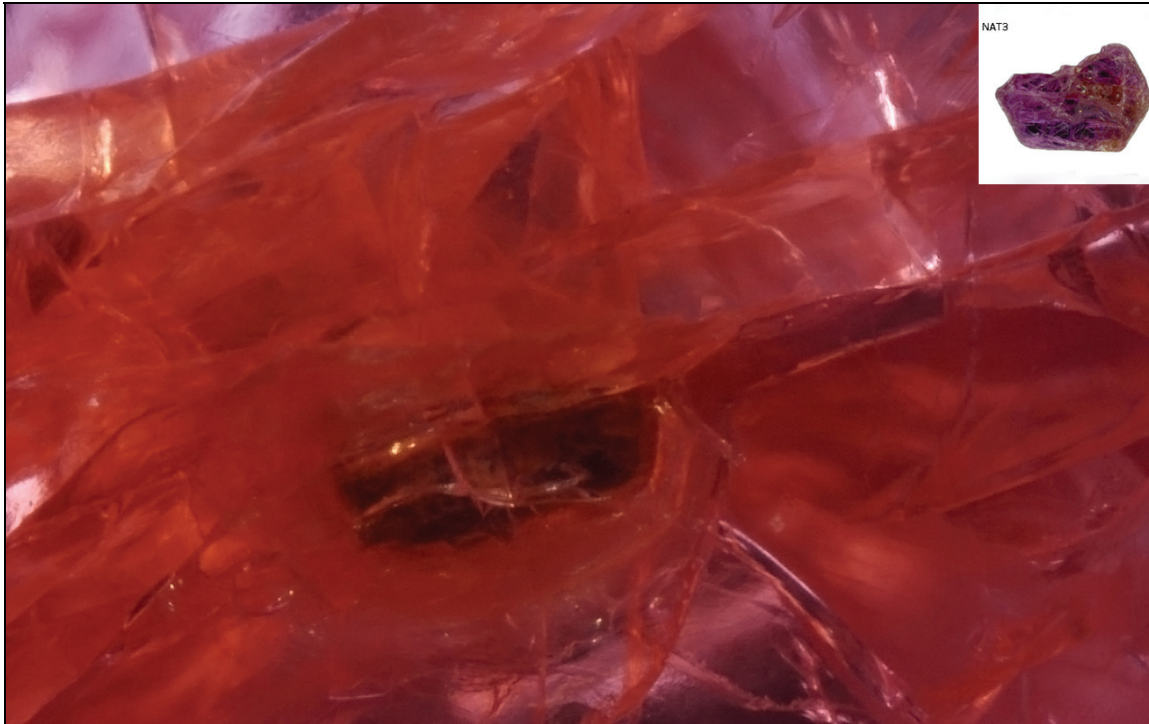


Figure 8: Pronounced oxidization within surface reaching fissures in sample NAT3. Photo: G. DuToit.

The treated samples

A close inspection of the treated rough with a simple hand loupe revealed that all the samples had a solidified near-colorless melt 'coating' most of their surfaces (Figure 9). Inclusions within the near-colorless material consisted of randomly positioned gas bubbles and in some cases white acicular inclusions were also seen along with the gas bubbles (Figure 10), both typical of glass.

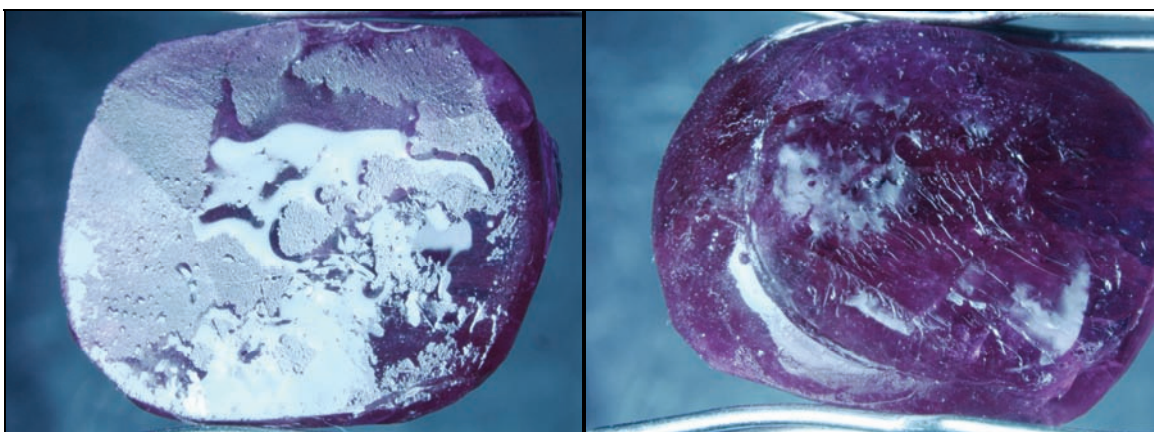


Figure 9: Sample TR3 as seen in reflected fluorescent overhead lighting showing the solidified molten patchy surface 'coated' areas over the surface of the stone. Photo: G. DuToit.

It is interesting to note that of-late devitrification features have been found in glass filled fissures within stones submitted for reports by GIA clients in Bangkok; These stones have also had FAPFH features, the devitrified glass being closer to the stone's surface and the FAPFH features being deep inside the stone (Figure 11).

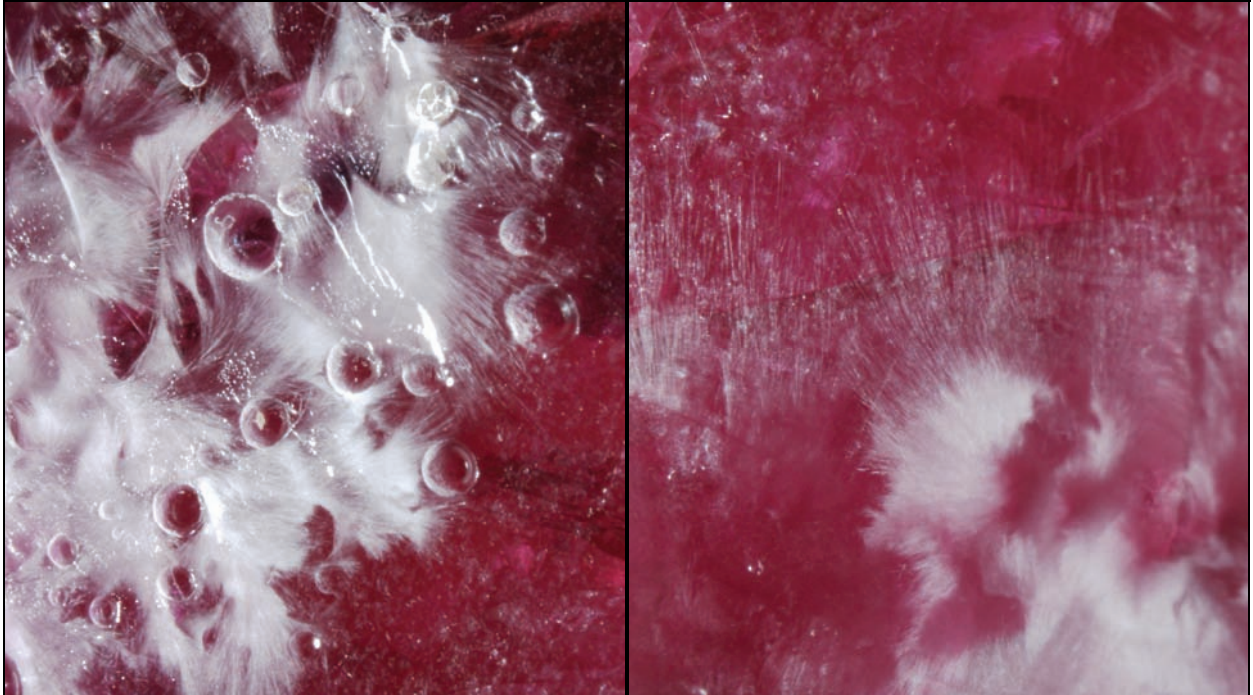


Figure 10: A close-up view of the white needles seen in sample TR3 shown in Figure 9. The numerous fine white needles in the flux 'coating' visible with the fluorescent overhead lighting in Figure 9 are much easier to see in these images. They form dense patches in areas (left) and reveal their finer form at the fringes (right). Numerous gas bubbles are also present. Photos: G. DuToit.

In treated samples, the rough appeared to be a slightly purer red with less of a purple component overall than the untreated samples. Inclusions, as would be expected, exhibited indications of heat treatment. The most useful and re-occurring indications of heating were altered crystals, naturally healed fractures with heat associated "fringes", numerous FAPFH healed fissures as well as GFF features. It was also no surprise that the white powdery mineral deposits were not present on any of the treated samples

The color appearance of the two faceted samples (TR1 and TR2) was a pinkish red for the pear-shape stone and a dark purplish red for the near-round stone. Inclusions in common with both specimens were altered (frosted or snowball-like) crystals (Figure 12), numerous FAPFH healed fissures (Figure 14) but also a large number of surface reaching GFF fissures (Figure 15, Figure 16). FAPFH and GFF fissures can be easily separated by their aspect: GFF fissures reaching the surface present a continuous line of exposed glass; whereas FAPFH healed fissures reaching the surface present only a dotted line as the fissure was partially closed during the FAPFH process.

Whilst no color flashes were observed in any of the treated samples, as might be expected for LGFF treated stones, the authors felt it important to characterize the composition of the glass on the surfaces of the treated rough and in the GFF fissures. An important part of the following LA-ICP-MS analysis was to also see if any artificially diffused beryllium was present in the treated samples.

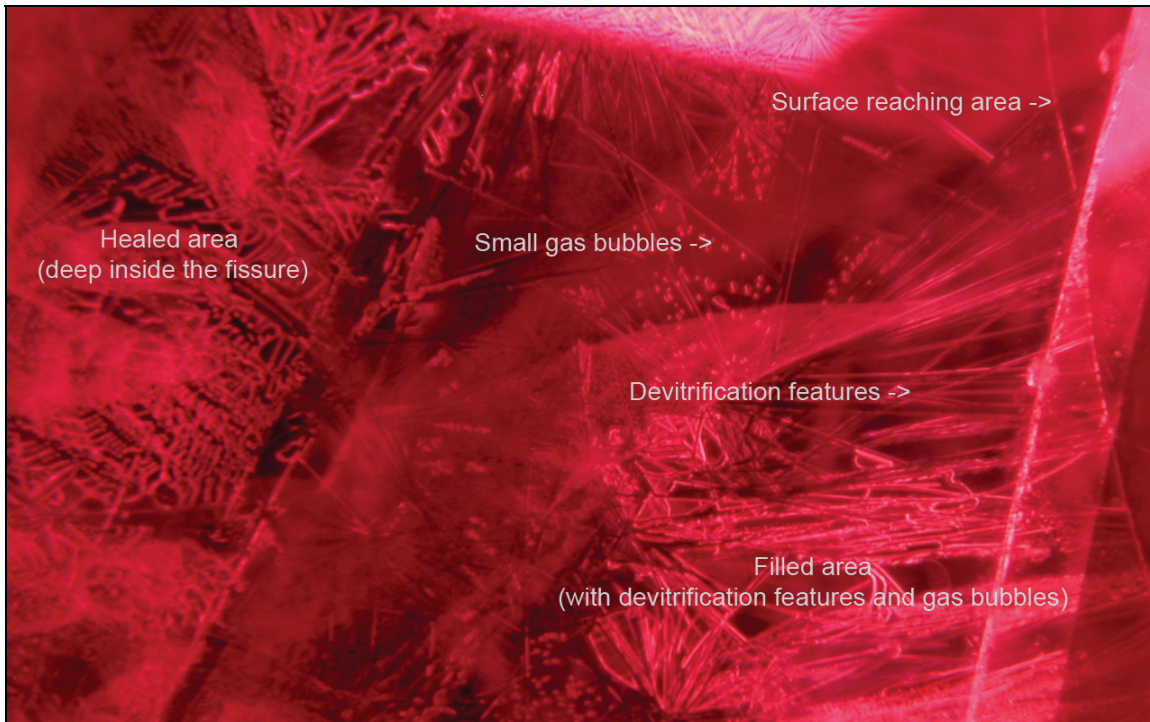


Figure 11: FAPFH features (left side) and GFF features (near the surface, right side) Photo: V. Pardieu

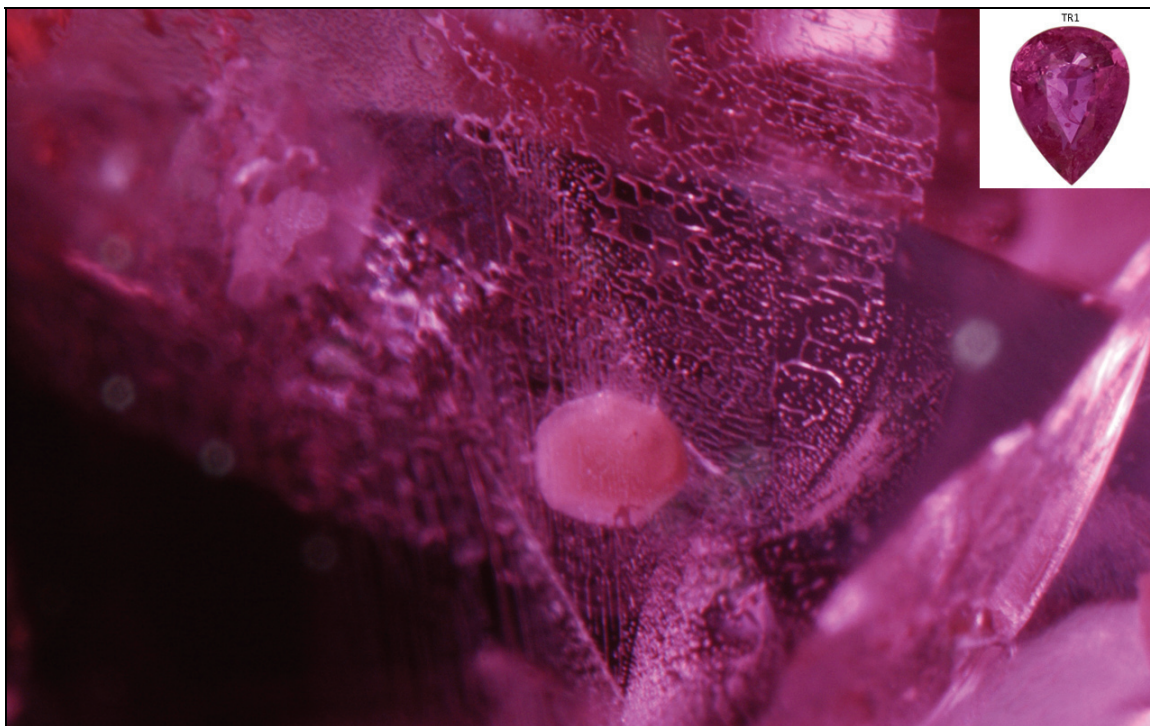


Figure 12: Sample TR1 revealed several frosted (heat affected) crystals such as the one shown here, numerous FAPFH features were also readily visible. Photo: G. DuToit.

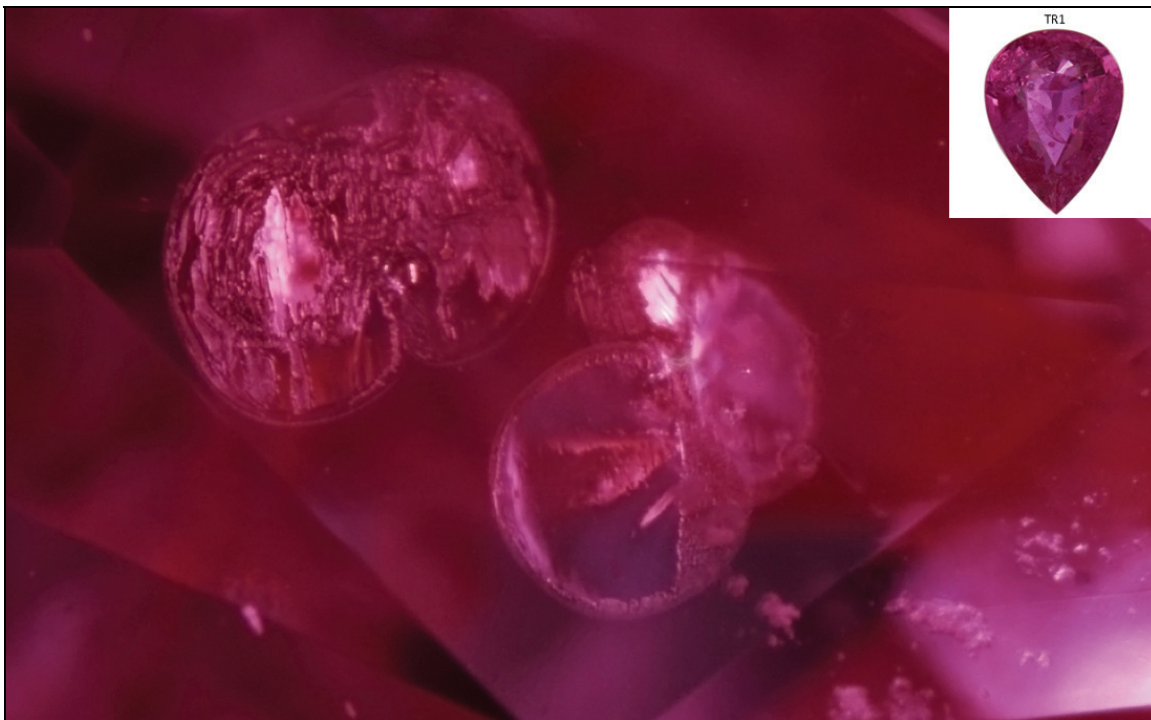


Figure 13: Melted crystals associated with discoid fractures are typically found in heat-treated rubies hosting mineral inclusions. Photo: G. Du Toit

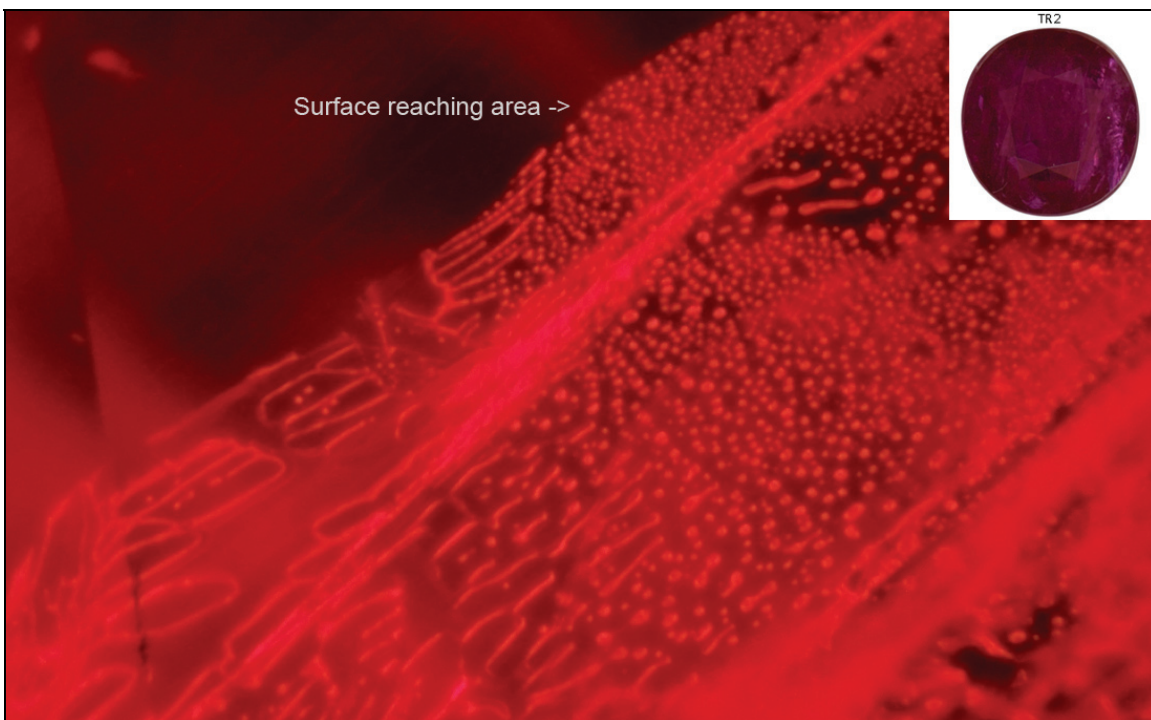


Figure 14: Surface reaching FAPFH features, trapped glass droplets and interconnecting or isolated tubules are giving the healed fissure a fingerprint like aspect. (Dark field illumination) Photo: V. Pardieu

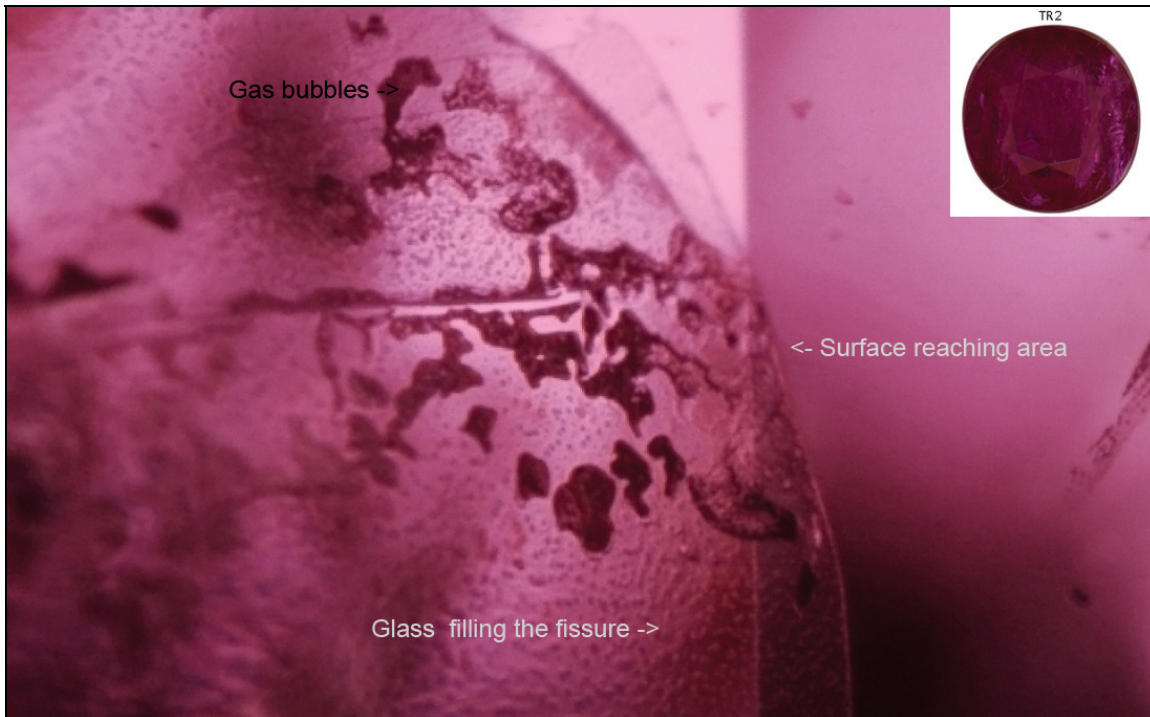


Figure 15: Surface-reaching glass filled unhealed fissure (GFF). Here the glass, unlike in partially healed fissures of the FAPFH process, is not trapped, the dark areas are gas bubbles trapped inside the glass. (Bright field illumination) See also Figure 16. Photo: G. Du Toit

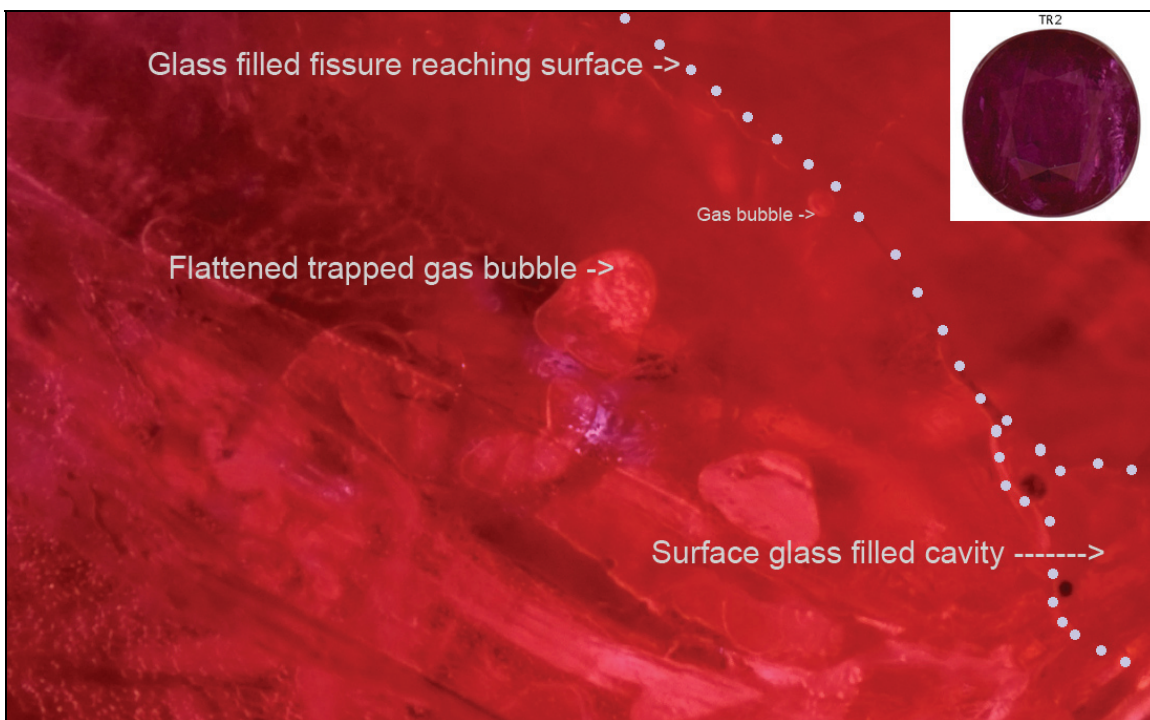


Figure 16: The same image as in Figure 15 but under dark field illumination; the surface reaching glass filled fissures (GFF) are less obvious, nevertheless the white dots denote the area where the fissure reaches the surface. Inside this fissure several large gas bubbles can be seen (bright, reflective): Photo: G. Du Toit

LA-ICP-MS Analysis

All stones were analyzed by LA-ICP-MS in a variable number of spots covering their surfaces. While the scenario was not perfect (before and after treatment of the same samples yielding truer results) for this preliminary examination the authors settled for a chemistry comparison between stones that were untreated (NAT 1-6) and separate stones that had been treated (TR1-7).

The general aim of the analysis was to see if any elements had been added during the processes applied. Somjainuek expressed concern was that he had not contaminated the specimens though the use of a furnace that had been previously used for beryllium treatment; a common problem in the heating of corundum. He felt that all measures to keep the heating environment free from any external impurities, such as beryllium, lead or bismuth, were undertaken, however as beryllium is very hard to remove from any furnace once it has become contaminated he needed to be sure that his precautions had been successful.

As would be expected the unheated samples (Table 2) showed no signs of artificially diffused beryllium or the presence of lead within their chemical composition.

Table 2: The average LA-ICP-MS results in ppmw obtained from each of the six untreated samples examined in this study.

Average Results Obtained (ppmw)	Li	Be	Mg	Ti	Cr	Fe	Ga	Nb	Ta	Pb
NAT1 (9 spots average)	BDL	BDL	38	53	2267	826	21	BDL	BDL	BDL
NAT2 (12 spots average)	BDL	BDL	43	74	1572	968	22	BDL	BDL	BDL
NAT3 (12 spots average)	BDL	BDL	37	59	1031	1098	22	BDL	BDL	BDL
NAT4 (12 spots average)	BDL	BDL	54	82	2782	1319	22	BDL	BDL	BDL
NAT5 (12 spots average)	BDL	BDL	51	64	2590	995	20	BDL	BDL	BDL
NAT6 (10 spots average)	BDL	BDL	53	79	2606	1030	21	BDL	BDL	BDL
Detection Limit Applied	0.39	0.17	0.86	0.58	2.13	3.70	0.05	0.04	0.14	0.01

Table 3 shows that Beryllium was also below detection limits for the two faceted stones treated by Somjainuek and that Lead was also not present in detectable amounts. However, in examining sample TR3 on the surface of which was a considerable amount of “solidified” glass, Be was detected (**Table 4**) but mostly in the glass itself rather than the ruby.

Table 3: The average LA-ICP-MS results obtained in ppmw from each of the two treated faceted samples examined in this study.

Average Results Obtained (ppmw)	Li	Be	Mg	Ti	Cr	Fe	Ga	Nb	Ta	Pb
TR1 (5 spots average)	BDL	BDL	17	21	647	550	13	BDL	BDL	BDL
TR2 (5 spots average)	BDL	BDL	22	30	2205	532	13	BDL	BDL	BDL

In this sample (TR3) analysis, points (spots) numbered 6, 8, 11, 13, 14, 16, 17, 19, 21, 22 and 23 are all located within glass covered areas on the surface whilst the remaining spots numbered 1, 2, 3, 4, 5, 7, 9, 10, 12, 15, 24 and 25 appear to be in areas relatively clear of glassy material (Figure 17). However, after studying the results it is obvious that spot 25 was also in a glassy area as it was found that same elevated levels of Li, Be, Si, Ca, and Pb, were present as in the glass covered areas.

There are clear differences in the normal (Ti, Cr, Fe, Ga.) elemental composition between the samples that are unheated compared with those that have been heated, however, such observations are not entirely valid given that the comparison is between two different stones rather than a single stone that was examined both before and after treatment. The presence of beryllium in the glass though indicates possible contamination of Somjainuek’s furnaces, crucibles or the borax / silica powders being used.

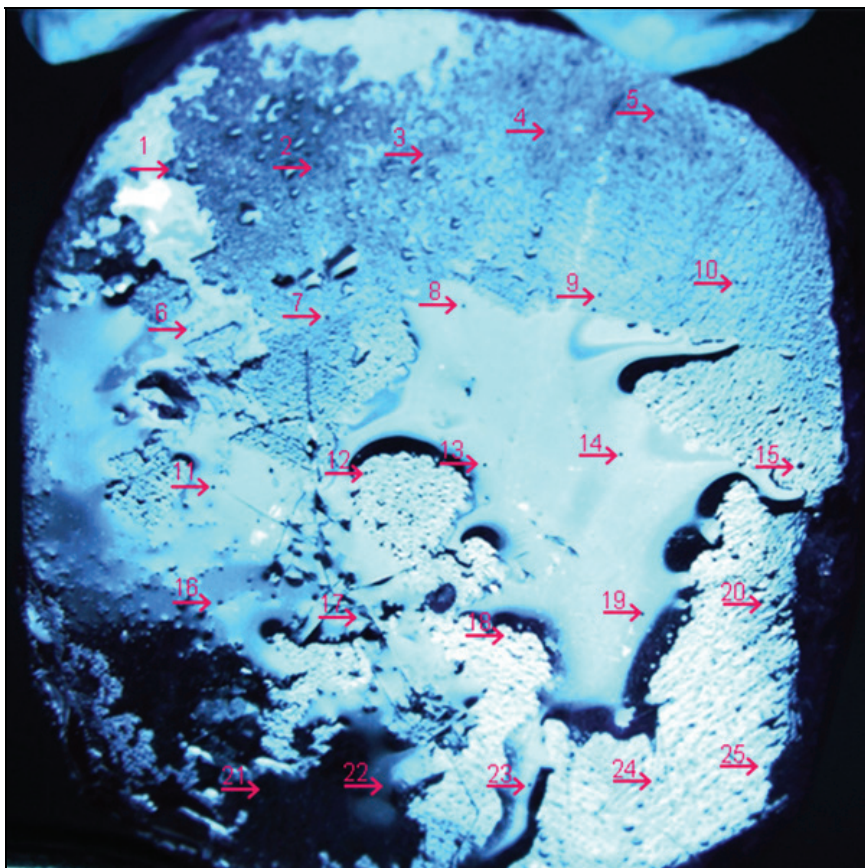


Figure 17: View of the surface of sample TR3 in reflected lighting showing the grid pattern of 25 laser ablation spots traveling across the stone from left to right and top to bottom. Photo: S. Saesaew.

Table 4: LA-ICP-MS results on sample TR3

Average Results Obtained (ppmw)	Li	Be	Mg	Si	Ti	Cr	Fe	Ga	Nb	Ta	Pb
Areas relatively clear of glassy material: Spots 1, 2, 3, 4, 5, 7, 9, 10, 12, 15 and 24 average	41	BDL to 1.18	71	N/A	10	714	178	4	BDL to 0.16	BDL	15
Glass covered areas: Spots: 6, 8, 11, 13, 14, 16, 17, 19, 21, 22, 23 and 25 average	2279	12	981	272575	114	BDL to 200	347.01	29	BDL to 5.6	BDL to 0.1	337
Detection Limit Applied	0.39	0.15	2.10	1.48	1.48	1.48	14.66	0.18	0.03	0.01	0.07

Another interesting observation on these results is that traces of lead (Pb) were found in sample TR3. The lead content on the surface of this sample was found to be ranging from about 15 ppmw in the non-glassy areas of the sample to about 330ppmw in the glassy areas. However, this number in comparison with the levels of lead found in the glass contained in LGFF rubies is very small.

In order to compare LGFF rubies with those treated by Somjainuek the authors turned to microradiographic analysis and examined the two Somjainuek treated rubies with the most obvious glass on their surfaces (samples TR3 and TR6) to see whether any evidence of heavy elements would result on the microradiographs. The results (Figure 18, Figure 19) show no traces any heavy element being present.

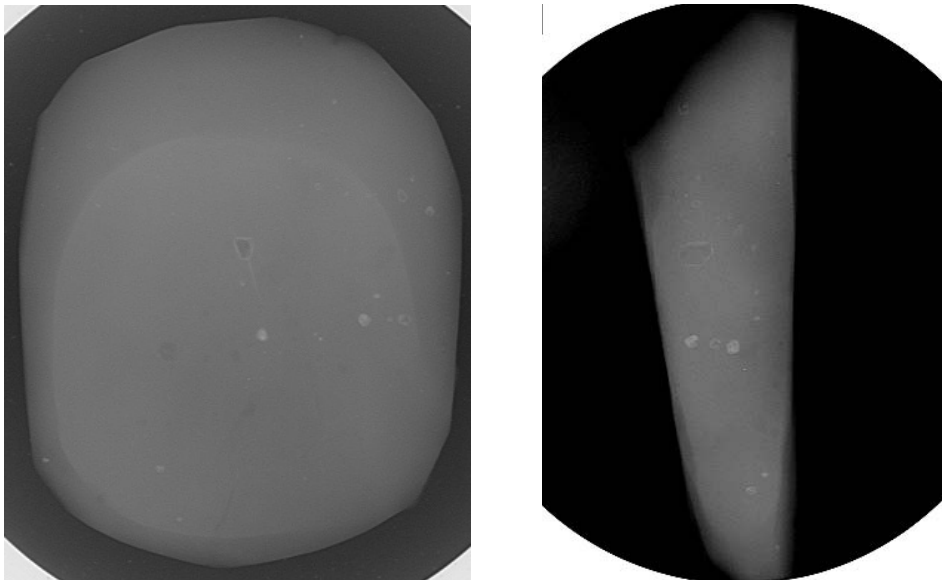


Figure 18: Microradiographic images of sample TR3, in two orientations, showing the lack of features usually associated with lead-glass filled corundum. The few random white spots that relate to elements with high atomic numbers within the periodic table are associated with natural crystalline inclusions within the samples and not from the treatment process. Images: N. Sturman

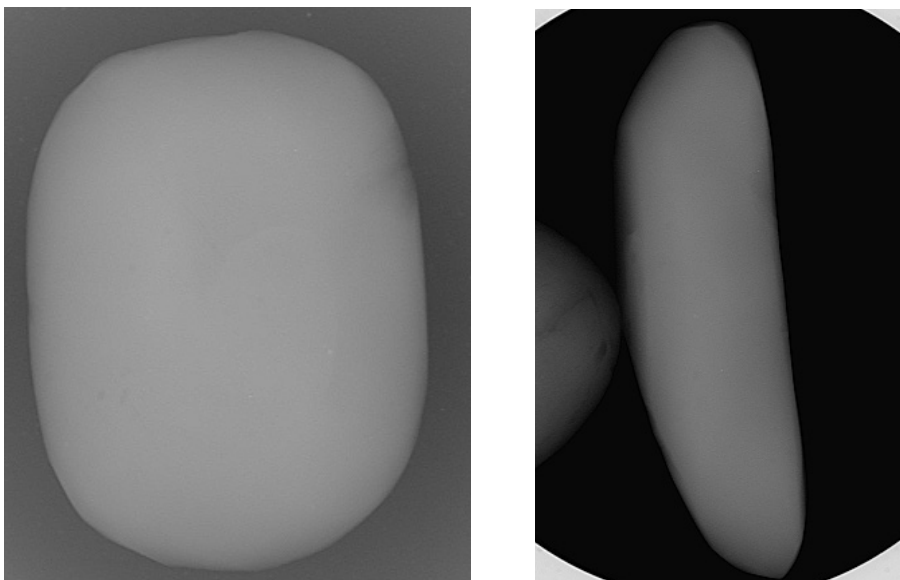


Figure 19: Microradiographic images of sample TR6, in two orientations, showing the lack of features usually associated with lead-glass filled corundum. Absolutely no features relating to any heavy elements within the periodic table are visible. Images: N. Sturman.

For comparison **Figure 20** displays microradiographs of a LGFF ruby taken from two directions. The lead rich glass is easily visible here, as white lines indicating filled fissures or white areas indicating filled cavities, thanks to the significant amount of lead in the glass composition.

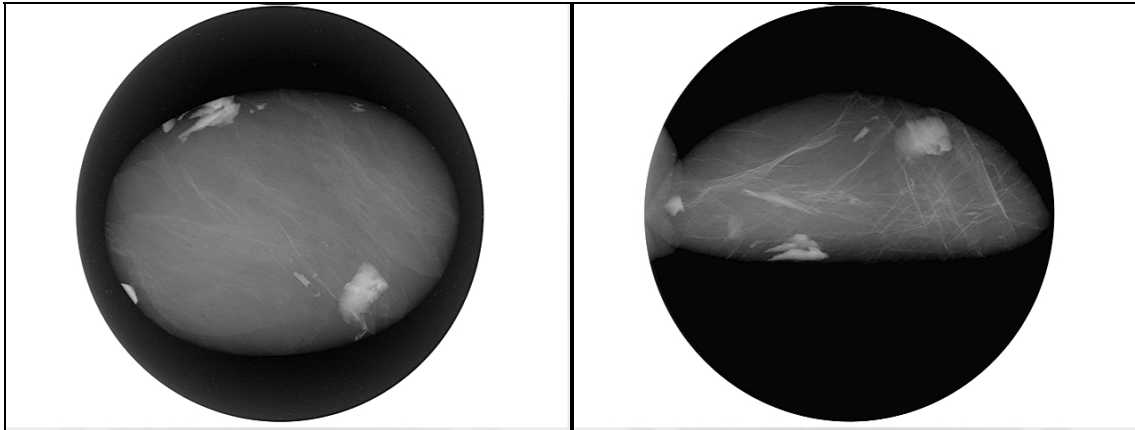


Figure 20: The stone has three main cavities filled with lead glass and from the side we can also see the lead glass filled fissures more clearly.

Discussion.

In accord with the claims, the untreated samples obtained from Tawatchai Somjainuek showed no indications of any treatment. The crystals all showed inclusion features consistent with untreated material and some of the useful advanced analytical data recorded also confirmed the visual examinations. Their gemological properties were found similar when compared to samples collected in the field in Mozambique by one of the authors (VP) in 2009.

In studying the Somjainuek treated samples it was simple to find indications of heat treatment using the microscope. As the stones were not cleaned with acid, the samples were covered with a glassy substance also found as a filler in unhealed fissures. Many fissures were (FAPFH) partially healed but some were just filled with glass. This is similar to observations made with FAPFH treated rubies from Mong Hsu over the last two decades (Peretti, *et al.*, 1995).

Nevertheless for FAPFH treated Mong Hsu ruby the stones are usually cleaned with hydrofluoric acid (which attacks silica) to remove the presence of surface reaching glass before being submitted to gemological laboratories and later traded. For the rubies from the new deposit in Mozambique, both in the cases of stones recently submitted for gemological reports as well as for the samples obtained from Tawatchai Somjainuek, the stones were not cleaned with acid before the laboratory examination. A possible reason for this is that if they were cleaned in hydrofluoric acid the glass (silica) would be removed from the (in some cases substantial) glass filled fissures (GFF) and this would destroy the effects of the treatment process.

However, leaving the glass in place may only temporarily retain the effects of the treatment process as the glass filler is softer than the host corundum and can therefore be comparatively easily damaged during wear and maybe during setting or some repair process. While the glass filler used in these FAPFH/GFF rubies may be marginally more durable than the glass used in the LGFF process, the presence of numerous unhealed glass filled fissures in these FAPFH/GFF rubies may impact the durability of the stone in a similar manner to LGFF rubies.

Previously cases where both FAPFH fissures and GFF fissures were associated in the same stone were rather rare, however, recently many such stones have been submitted for examination at all GIA Laboratory locations. Therefore, at the end of March 2010, GIA began to issue reports with a combination of comments that describe the FAPFH and GFF processes when they have occurred in the same stone.

Rubies from all origins found with a combination of healed fissures (FAPFH) and glass filled fissures (GFF) are currently described as follows (please note that these descriptions may be modified as research continues):

CONCLUSION

Species **NATURAL CORUNDUM**
Variety **RUBY**

Indication of heating with (minor/moderate/significant) residues in fissures (TE 1 to TE5 depending the case).

In addition, a (minor/moderate/significant) amount of clarity enhancement using a glass filler to reduce the visibility of fissures.

Comments:

The residues referred in the TE scale below are those trapped within fissures that have been repaired during a flux-assisted heating process. The higher the TE scale the greater the extend of repaired fissures.

Fissure filling material may be unstable to elevated temperatures and to chemical agents. Special care should be taken when cleaning or repairing jewelry items set with fissure filled corundum.

Important note: As this is an ongoing research project, this pdf will be updated when new elements are found. The authors would like to advise the reader to visit the GIA websites in order to be sure to have in hand an updated version of this study:

<http://www.giathai.net/lab.php>

<http://www.gia.edu/research-resources/news-from-research/index.html>

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References

GAAJ (2004), GAAJ Lab Alert:- lead glass impregnated ruby. GAAJ Research Laboratory http://www.gaaj-zenhokyo.co.jp/researchroom/kanbetu/2004/gaaj_alert-040315en.html

Hughes, R. W. (1984), New treatment surfaces for rubies. *Jewellery News Asia*. 6. 33.

McClure, S. F., Smith, C.P., Wang, W., Hall, H., (2006), Identification and durability of lead glass-filled rubies. *Gems & Gemology*. Vol. 42, No.1. spring 2006. 22 -34.

Pardieu, V. (2005), Lead glass filled / repaired rubies. www.aigslaboratory.com
http://www.fieldgemology.org/Ruby_lead_glass_treatment.pdf

Pardieu, V. (2008), A visit to the Winza ruby and Sapphire mining area, Mpwapwa district, Dodoma province, Tanzania. www.fieldgemology.org
<http://www.fieldgemology.org/Gemology%20tanzania%20ruby%20sapphire%20dodoma%20mpwapwa%20winza.php>

Pardieu, V., Jacquat, S., Senoble, J. B., Bryl, L. P., Hughes, R. W. and Smith, M. (2009a), Expedition report to the Ruby mining sites in Northern Mozambique (Niassa and Cabo Delgado provinces). http://www.giathai.net/Mozambique_Ruby_Special_Issue.php

Pardieu, V., Kaewen, S., Chinudompong, A., Somjainuek, T. and Juengsangun, M. (2006), Les alchimistes des temps modernes: A la rencontre des "chauffeurs de pierres thaïlandais" (in two parts). *Revue de Gemmologie a.f.g.* 156 and 157. 10-18 and 10-19.

Pardieu, V. and Thanachakaphad, J. (2009b), Rubies from Niassa province, Mozambique. www.giathai.net

Peretti, A., Schmetzer, K., Bernhardt, H.-J. and Mouawad, F. (1995), Rubies from Mong Hsu. *Gems and Gemology*. 31. 1. 2–26.

Scarratt, K. (2009), A Discussion on Ruby-Glass Composites & Their Potential Impact on the Nomenclature in use for Fracture-Filled or Clarity Enhanced stones in General. <http://www.giathai.net> http://www.giathai.net/pdf/Ruby-Glass_Composites.pdf

Scarratt, K. and Harding, R. R. (1984), Glass infilling of cavities in natural ruby. *Journal of Gemmology*. 19. 4. 293–297.

Schwarz, D., Pardieu, V., Saul, J. M., Schmetzer, K., Laurs, B. M., Giuliani, G., Klemm, L., Malsy, A., Erel, E., Hauzenberger, C., Du Toit, G., Fallick, A. E. and Ohnenstetter, D. (2008), Rubies and sapphires from Winza, Central Tanzania. *Gems & Gemology*. XLIV. Winter 2008. 322 - 347.