



| A Gemmological Approach to Distinguishing Natural from Synthetic Rubies: LA-ICP-TOF mass spectrometry provides new insights

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Price Comparison: Natural vs Synthetic Rubies

Natural Rubies

Natural rubies > \$3000 per carat
Good quality natural rubies ≈
\$10,000 to \$18,000 per carat

In 2012, a 6.04 ct
Burmese ruby sold
for \$551,000 USD
per carat



In 2014, the 8.62 ct
Burmese Graff Ruby
sold for \$8.6 Million =
\$997,679 per carat*

Synthetic Rubies

Flux	Verneuil	= \$1 to \$5 per carat
	Hydrothermal	≈ \$90 per carat
	Knischka	≈ \$90 per carat
	Chatham	≈ \$24 to \$400 per carat
	Kashan	≈ \$150 - \$500 per carat
	Ramaura	= \$150 to \$750 per carat

In the trade, prices would be
considerably lower



| Differences between Natural, Synthetic, and Treated Natural or Synthetic Rubies

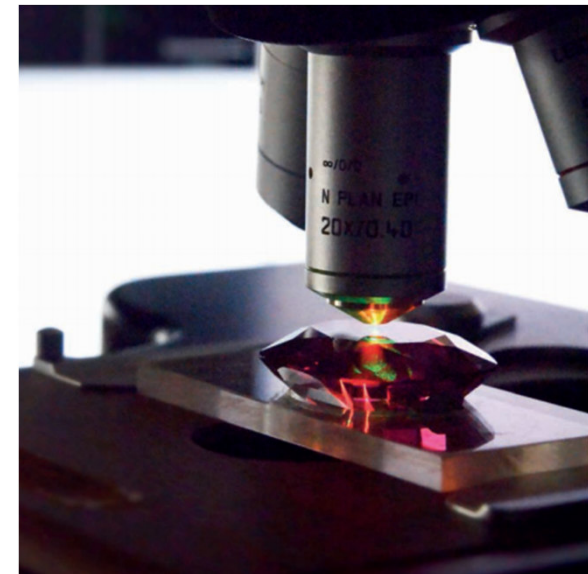
- Identifying the subtle differences can be difficult because of:
 - Overlapping physical properties and some trace elements
 - Presence of similar inclusions or growth features
 - Absence of inclusions or growth features
 - In addition, the setting of a gemstone may also interfere with analysing trace elements and observing internal features

| Analytical Techniques

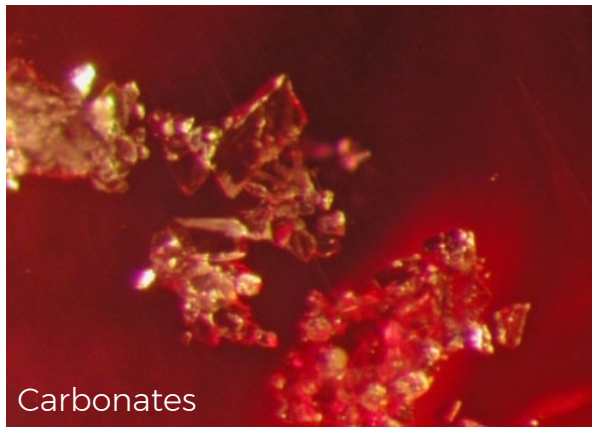
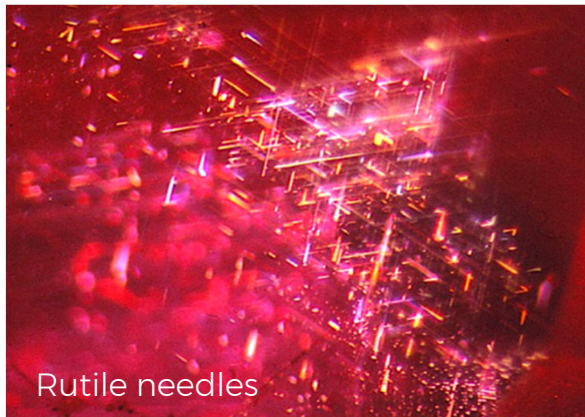
Optical Microscopy
-examine inclusions and
growth features



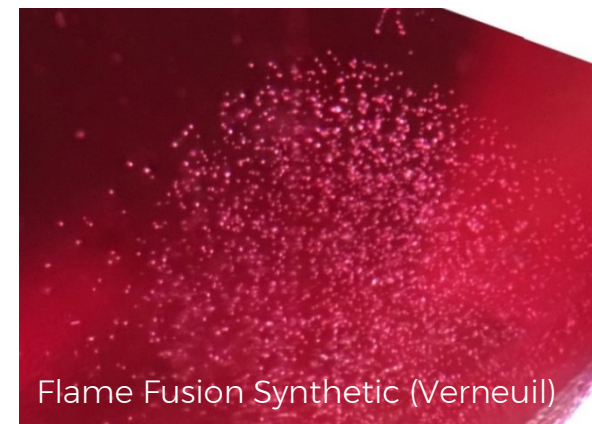
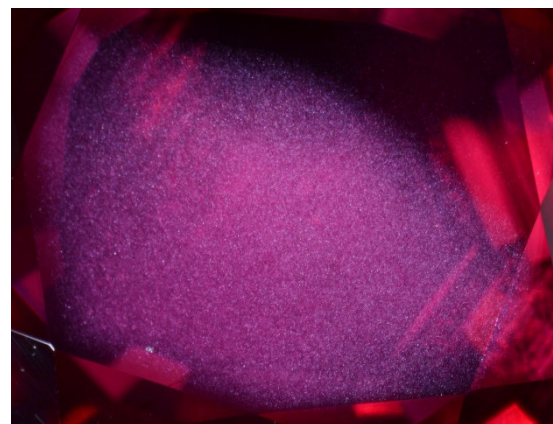
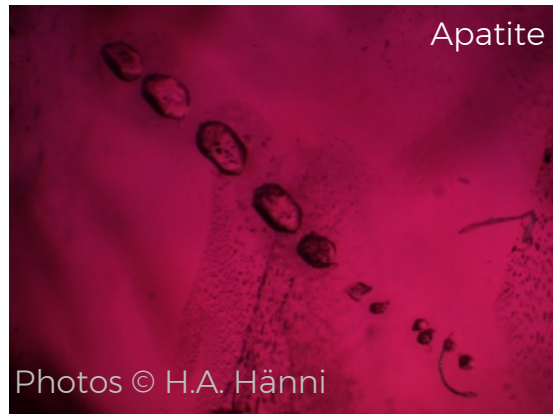
Raman Spectroscopy
-identify inclusions



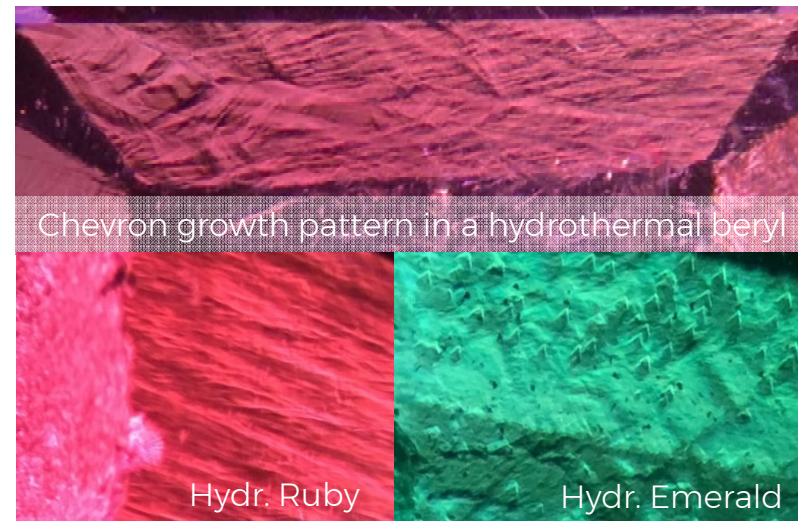
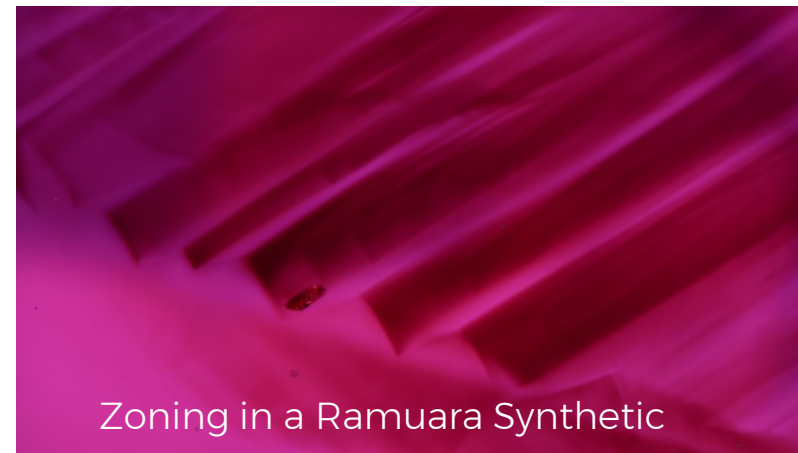
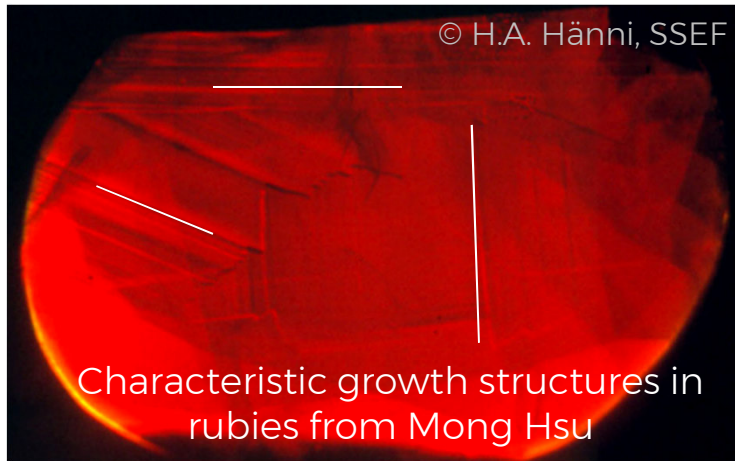
INCLUSIONS IN NATURAL RUBIES



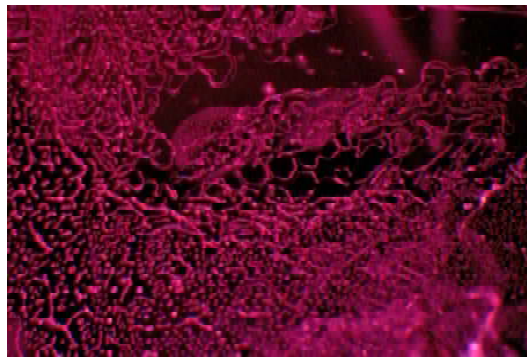
POSSIBLY CONFUSING INCLUSIONS IN NATURAL RUBIES vs SYNTHETIC RUBIES



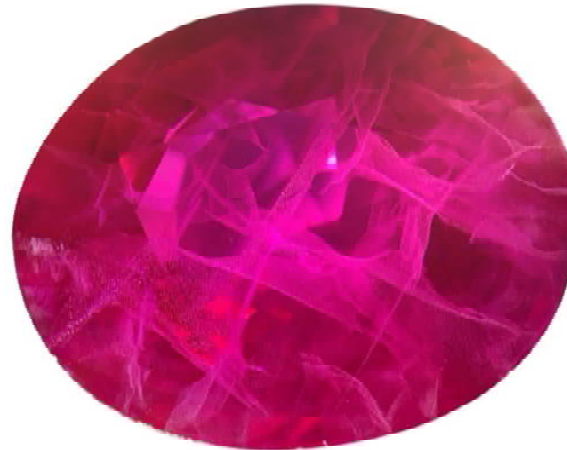
GROWTH PATTERNS IN NATURAL RUBIES VS SYNTHETIC RUBIES



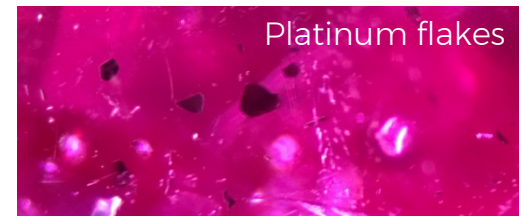
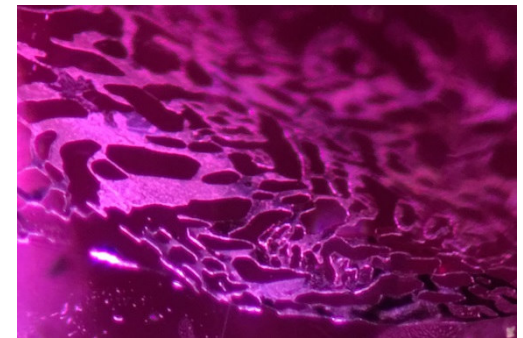
**Natural Ruby
Heated with Flux**



**Cracked Synthetic Verneuil Ruby
Heated with Flux**

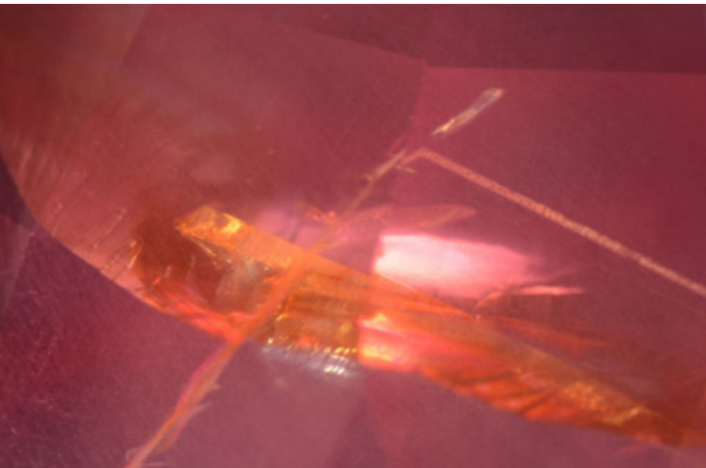
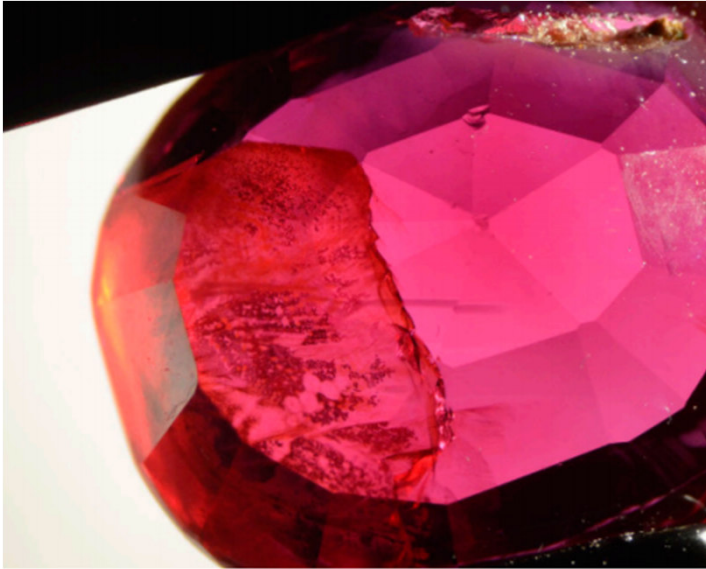


**Knischka Synthetic Ruby
with Flux Residue**

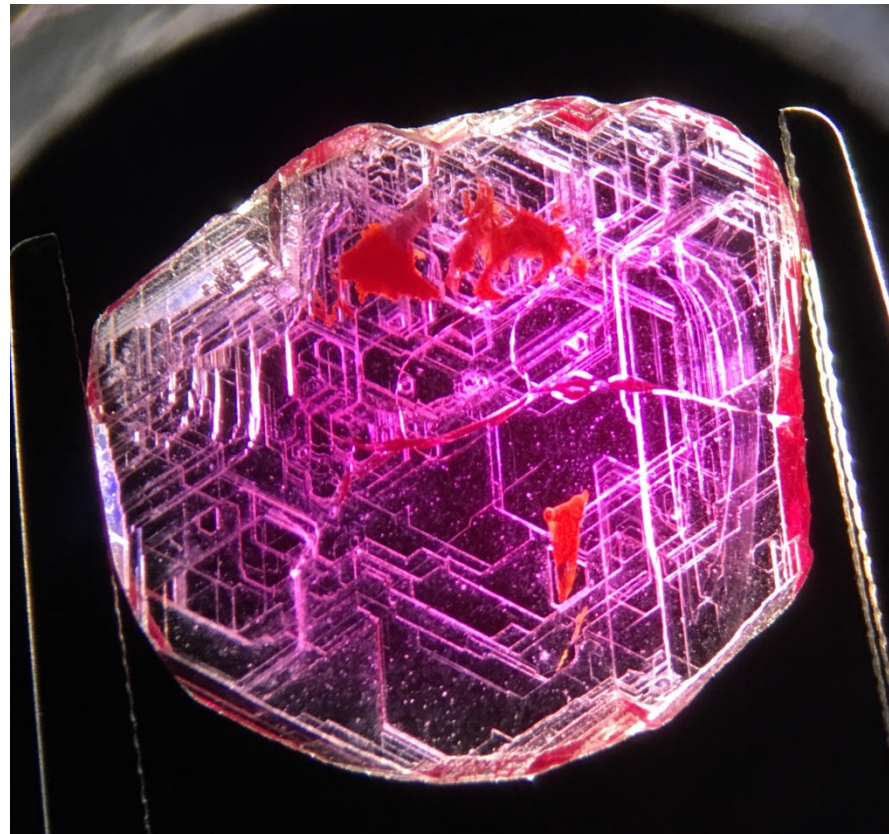


IRON STAINING VS FLUX RESIDUE

Iron Staining in Natural Ruby



Orange Flux in Synthetic Ruby (Ramaura)



| Possible Sources of Trace elements in Synthetic Rubies

Melt	Feed	Apparatus
Czochralski	Alumina and Cr_2O_3	Iridium Crucible
Flame Fusion	Alumina and Cr_2O_3	
Flux	Flux	
Chatham	$\text{Li}_2\text{O}-\text{MoO}_3-\text{PbF}_2$ and-or PbO	Pt Crucible
Kashan	Na_3AlF_6	Pt Crucible
Knischka	$\text{Li}_2\text{O}-\text{WO}_3-\text{PbF}_2$, PbO , $\text{Na}_2\text{W}_2\text{O}_7$, and Ta_2O_5	Pt Crucible
Douros	PbF_2 or PbO_4	Pt Crucible
Ramaura	$\text{Bi}_2\text{O}_3-\text{PbF}_2$, also REE dopant added to the flux La_2O_3	Pt Crucible
Hydrothermal	Alumina or aluminum hydrates partially dissolved in an aqueous medium with Cr compounds such as $\text{Na}_2\text{Cr}_2\text{O}_7$	Metal autoclave containing Fe, Ni, and Cu

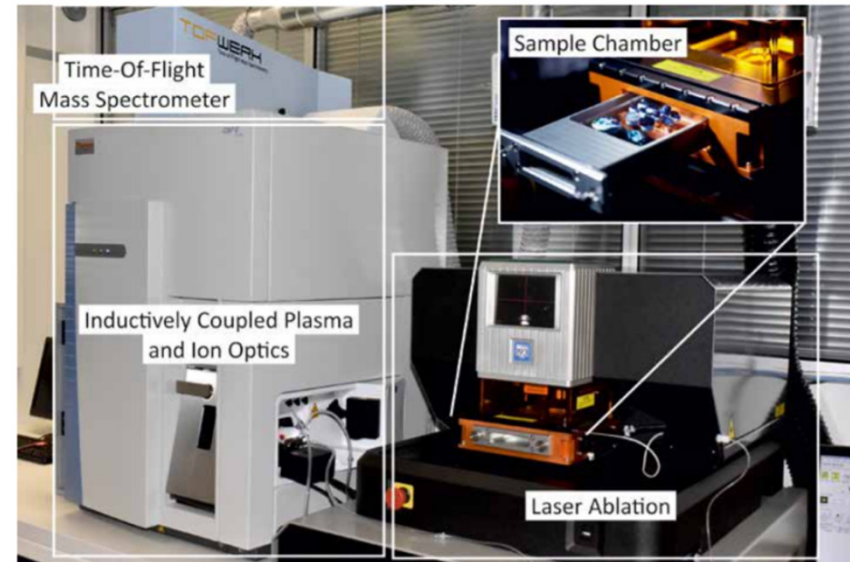
Reference: Muhlmeister et al. 1998 and sources within

Analytical Techniques

ED-XRF Spectroscopy

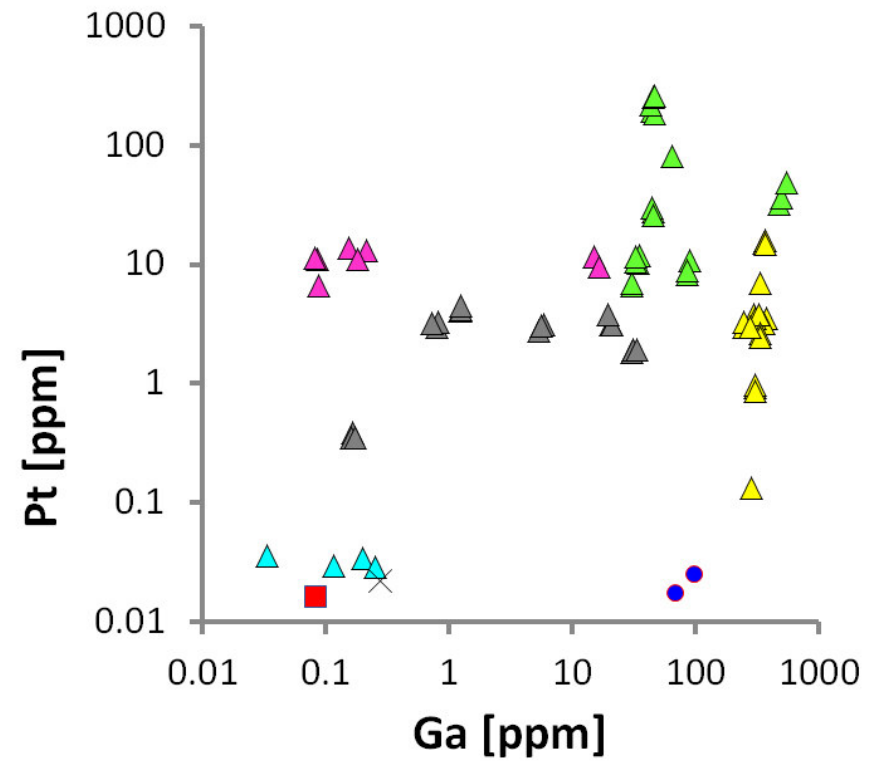
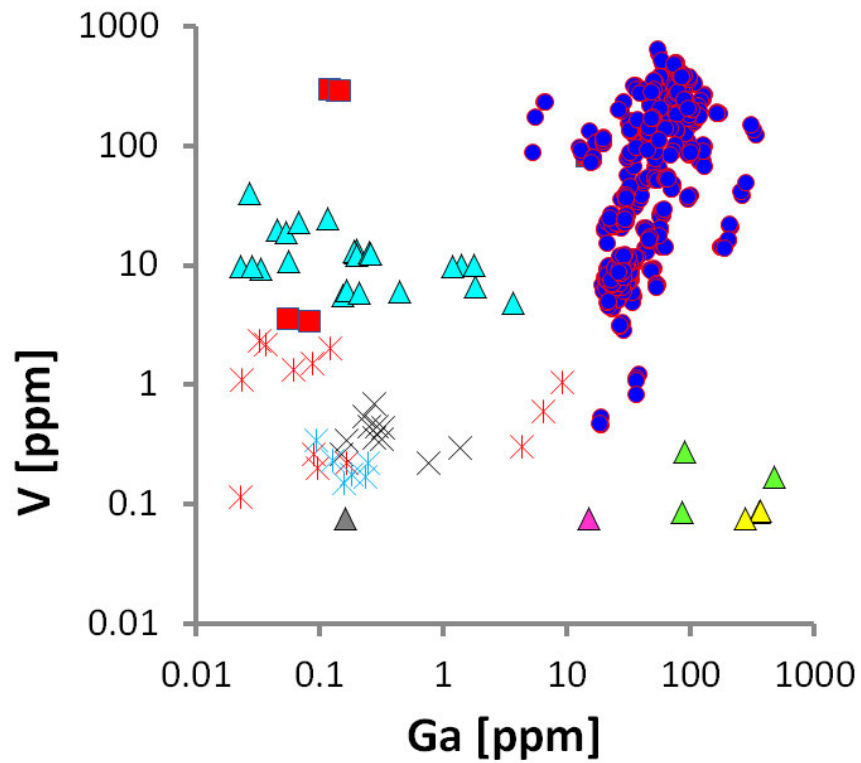
LA-ICP-TOF-MS

Major and Trace elements

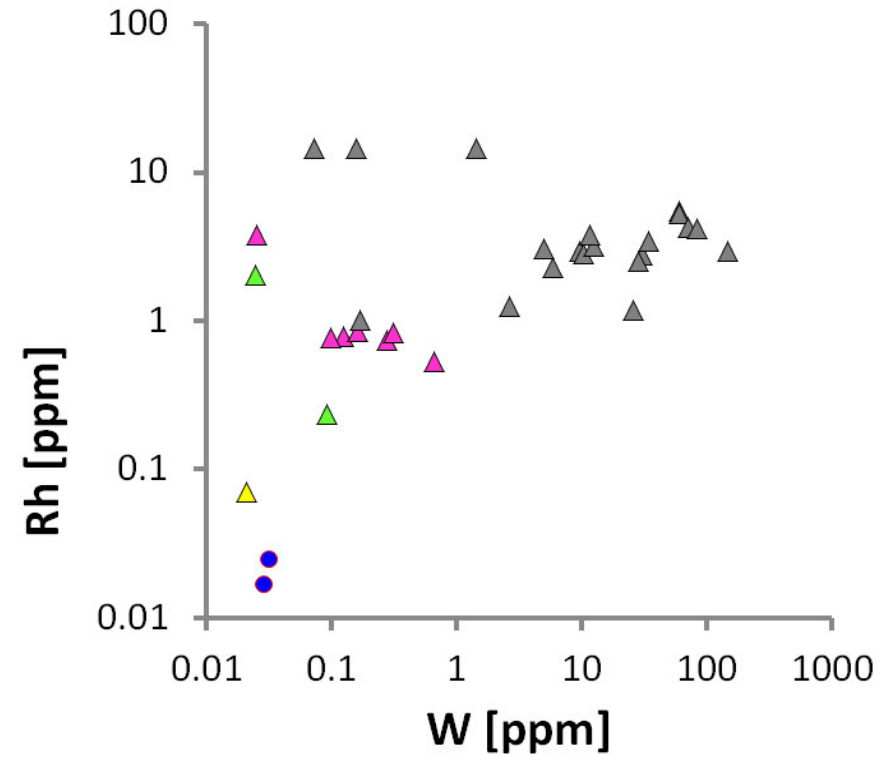
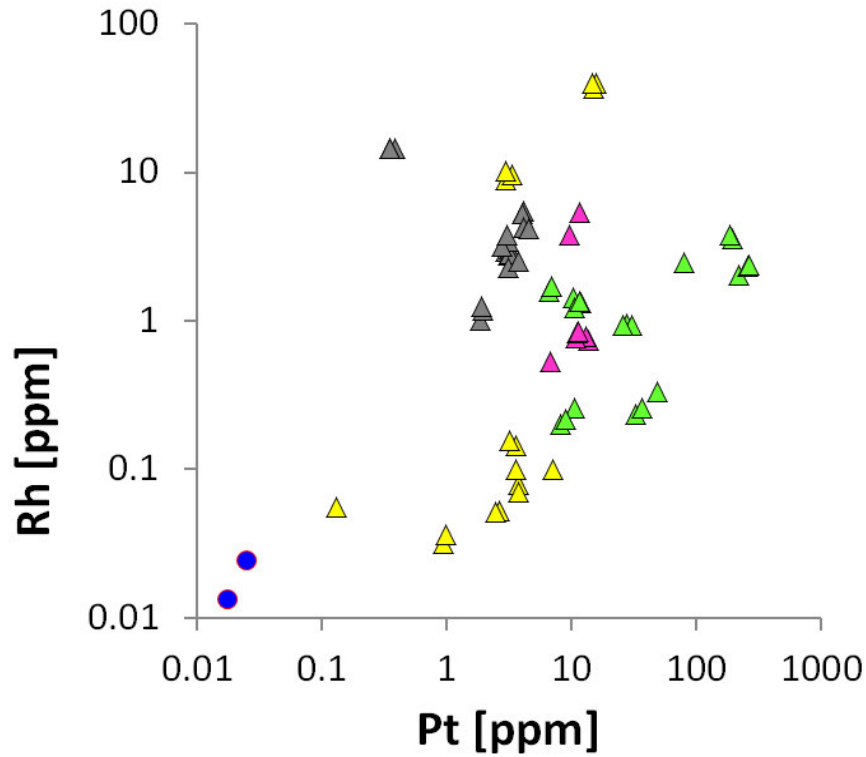


LA-ICP-MS detected:
Pt
elevated La, Bi, Pb





- Natural
- ▲ Synthetic, Flux, Chatham
- ▲ Synthetic, Flux, Douros
- ▲ Synthetic, Flux, Kashan
- ▲ Synthetic, Flux, Knischka
- ▲ Synthetic, Flux, Ramaura
- Synthetic, Crystal Pulling, Czochralski
- × Synthetic, Hydrothermal
- * Synthetic, Flame Fusion, Verneuil
- * Synthetic, Flame Fusion, Induced Fingerprint

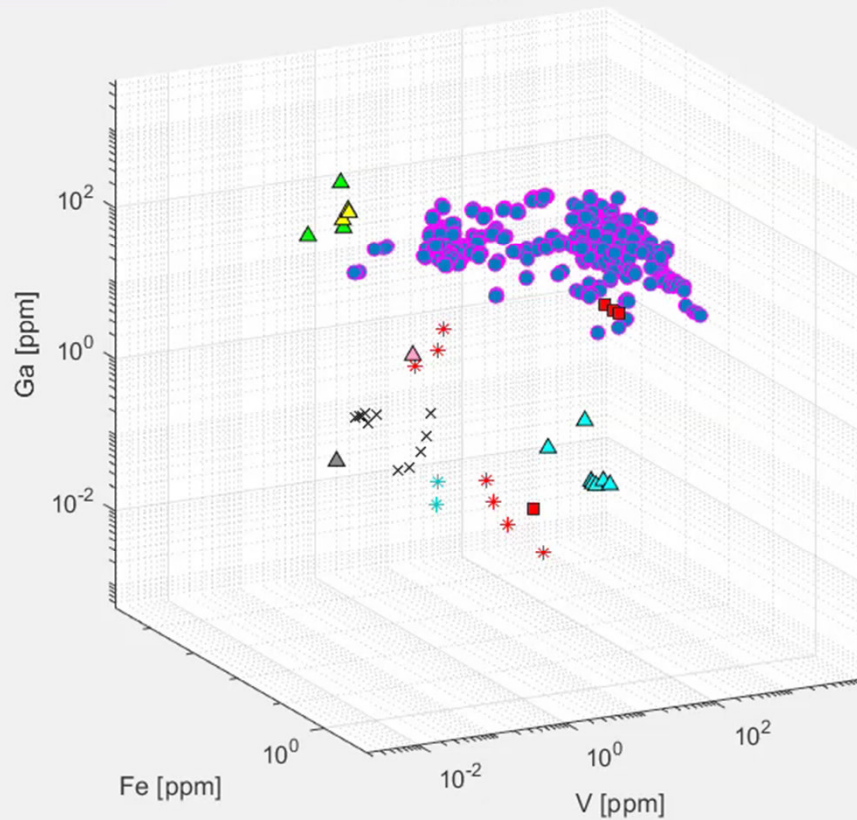


- Natural
- ▲ Synthetic, Flux, Chatham
- ▲ Synthetic, Flux, Douros
- ▲ Synthetic, Flux, Kashan
- ▲ Synthetic, Flux, Knischka
- ▲ Synthetic, Flux, Ramaura
- Synthetic, Crystal Pulling, Czochralski
- × Synthetic, Hydrothermal
- ✳ Synthetic, Flame Fusion, Verneuil
- ✳ Synthetic, Flame Fusion, Induced Fingerprint

Export Video

Export PDF

3D Scatter Plot



- Natural
- Synthetic, CrystalPulling, Czochralski
- * Synthetic, FlameFusion, InducedFingerprint
- * Synthetic, FlameFusion, Verneuil
- △ Synthetic, Flux, Chatham
- △ Synthetic, Flux, Douros
- △ Synthetic, Flux, Kashan
- △ Synthetic, Flux, Knischka
- △ Synthetic, Flux, Ramaura
- × Synthetic, Hydrothermal

Synthetic

Flame Fusion, Verneuil

Typically very pure

Hydrothermal

Typically very pure

Crystal Pulling, Czochralski

Typically very pure

Synthetic Flux (values in ppm)

Kashan

Na bd - 1371.13
Ni bd - 197.04
V 4.82 - 42.68

Knischka

Pt 0.35 - 4.49
W 0.07 - 146.58

Chatham

Pt bd - 13.68
Mo bd - 267.45
Ga 0.08 - 16.46

Douros

Pt 0.13 - 15.91
Rh bd - 39.70
Ga 244.80 - 380.61

Ramaura

Pt 6.57 - 262.95
La bd - 365.75
Pb bd - 2231.79
Bi bd - 837.98
Ni bd - 104.49
Ga 30.45 - 551.85

| SUMMARY AND CONCLUSIONS

- Natural rubies typically have many natural mineral inclusions
- It is important to always combine meticulous optical microscopic observations with elemental analyses
- In the presence of similar inclusions or the absence of any inclusions, LA-ICP-TOF-MS results may help differentiate natural from synthetic rubies
- Elevated levels of Pt, Rh, W, Ni, Mo, Na, La, Pb, and Bi can indicate a synthetic flux ruby

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Thank you for your attention