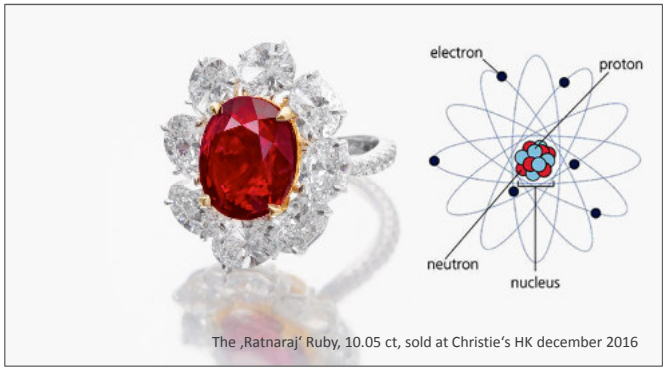
SSEF

SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT
SWISS GEMMOLOGICAL INSTITUTE
INSTITUT SUISSE DE GEMMOLOGIE

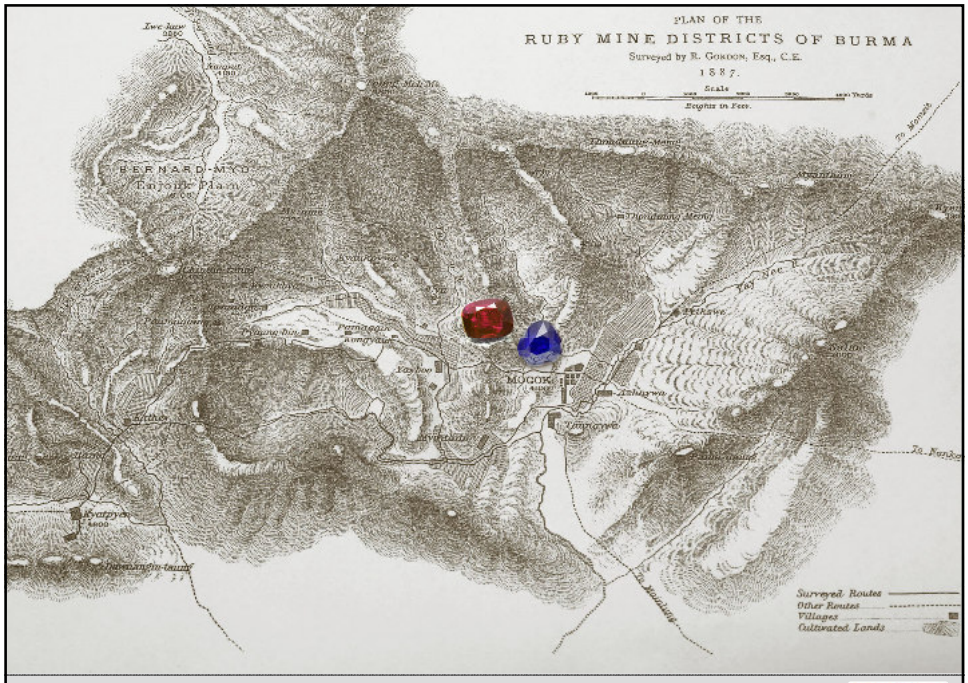
From classic inclusions to neutrons:

A 'fresh' look at modern gemmology



The ‚Ratnaraj' Ruby, 10.05 ct, sold at Christie's HK december 2016

PD Dr. Michael S. Krzemnicki, Swiss Gemmological Institute SSEF www.ssef.ch



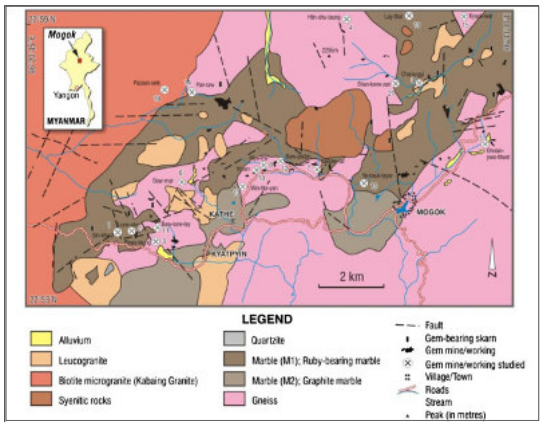
SGG Zermatt 30th June 2017 | Page 2

SSEF

From Geology to Gemmology

Mogok Gemstone Tract

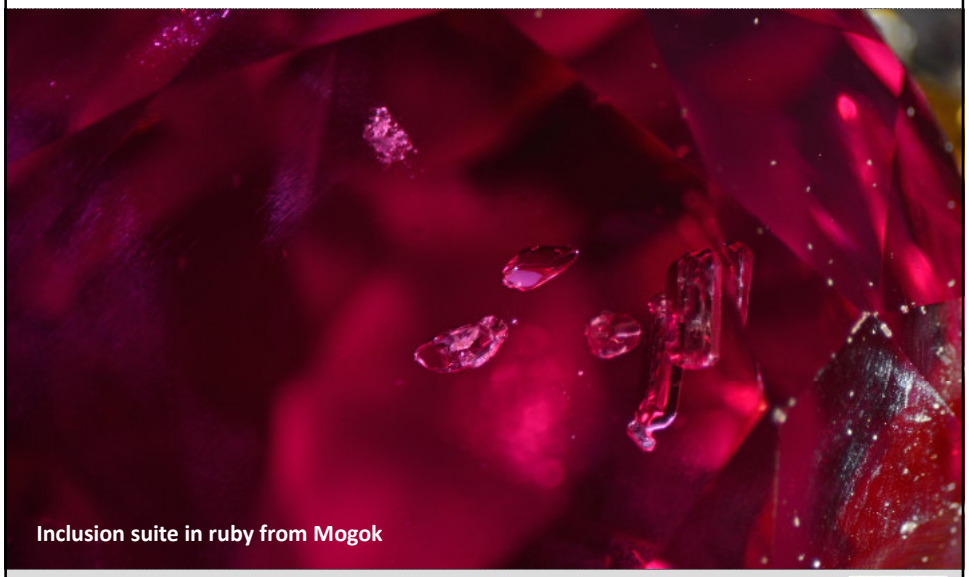
Metamorphic rocks (mainly marbles and gneisses) closely in contact with magmatic rocks (mainly granite and syenite).



Simplified geological map from Khin Zaw *et al.* 2014

From Geology to Gemmology

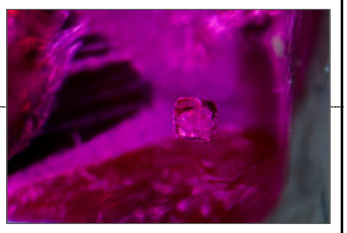
Inclusion paragenesis



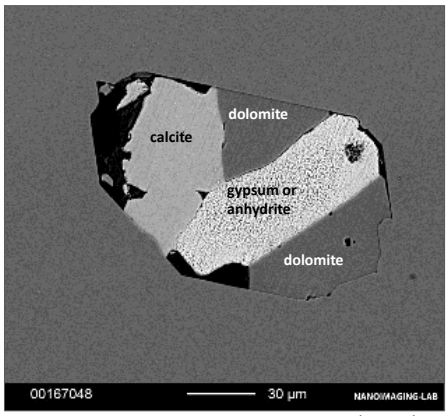
Inclusion suite in ruby from Mogok

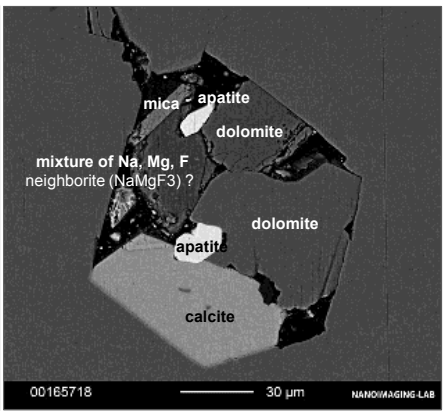
Inclusion studies

Inclusion paragenesis



What microscopically looks as one inclusion is quite often a mixture (intergrowth) of several mineral phases.



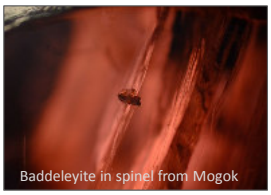


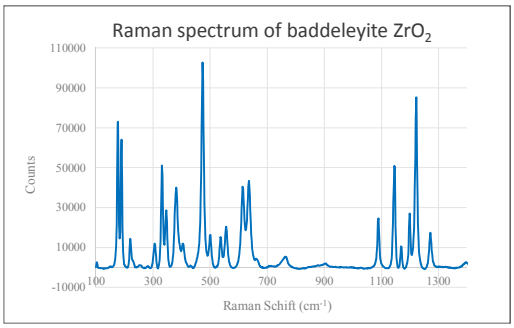
Photos: PhD cand. Myint Mya Phyo, SSEF

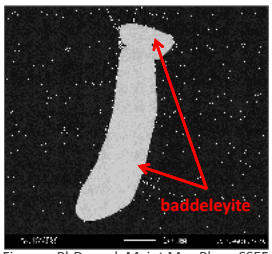
Inclusion studies

Baddeleyite ZrO_2

Tiny baddeleyite (ZrO_2) as accessory inclusions indicate magmatic contribution to gemstone formation in metamorphic marbles.



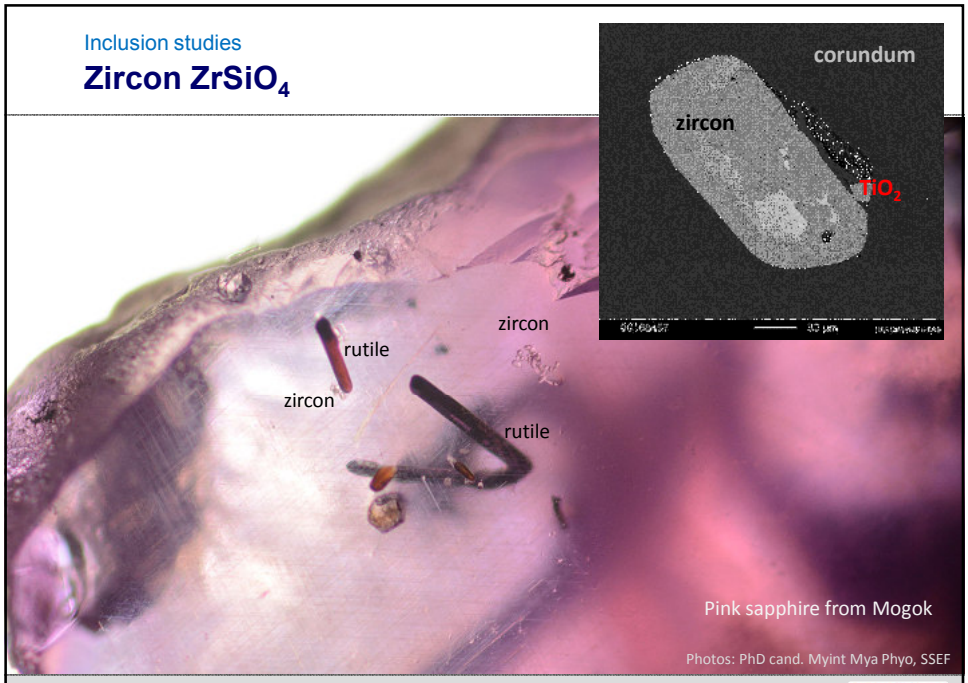




Figures: PhD cand. Myint Mya Phyo, SSEF

Inclusion studies

Zircon $ZrSiO_4$



WH1

GemTOF

Age dating of zircon inclusions

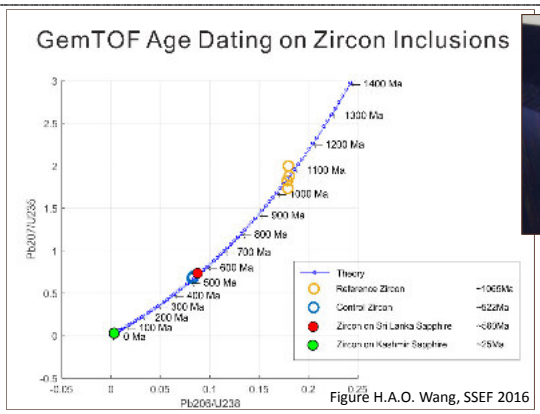
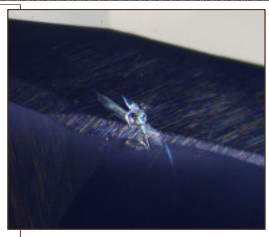
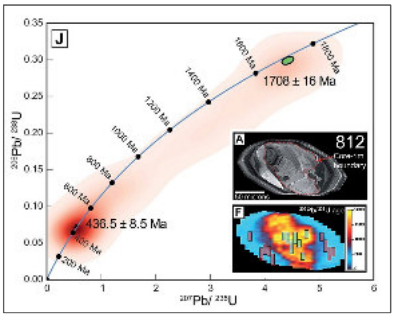


Figure H.A.O. Wang, SSEF 2016



Zircon at girdle of sapphire



Zircon inclusions (at the surface) enable us to carry out U-Pb age dating of gemstones, using the GemTOF (LA-ICP-TOF-MS).

Granitoid zircon (zoned)

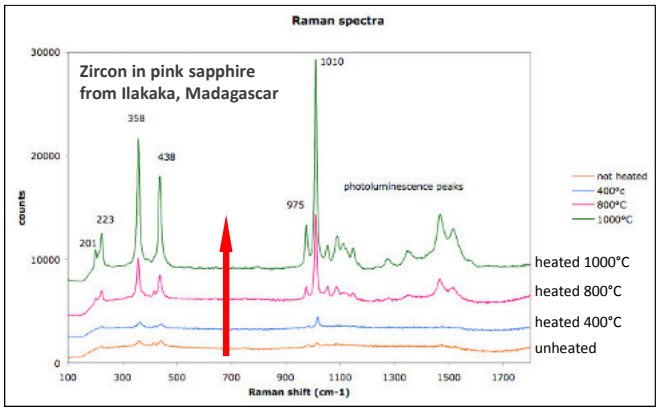
Figure (modified) from Chew et al. 2017

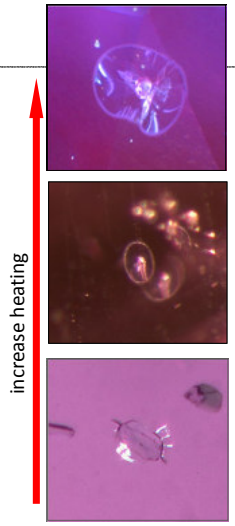
Slide 10

WH1 A new figure is attached, including two analyses of Zircons on SriLanka and kasmir sapphires.
Wang, Hao; 25.09.2017

Inclusion studies

Zircon $ZrSiO_4$

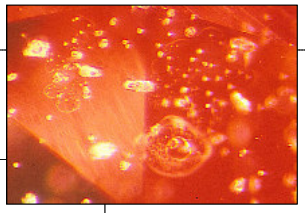




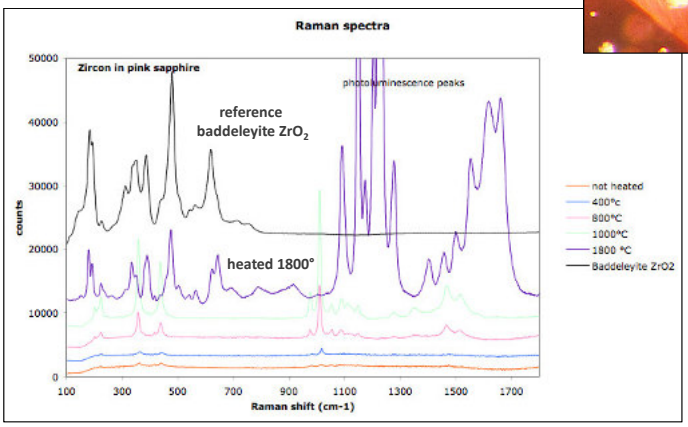
Raman spectra show the effect of heat treatment on the cristallinity of zircon inclusions in pink sapphires (from Ilakaka, Madagascar).

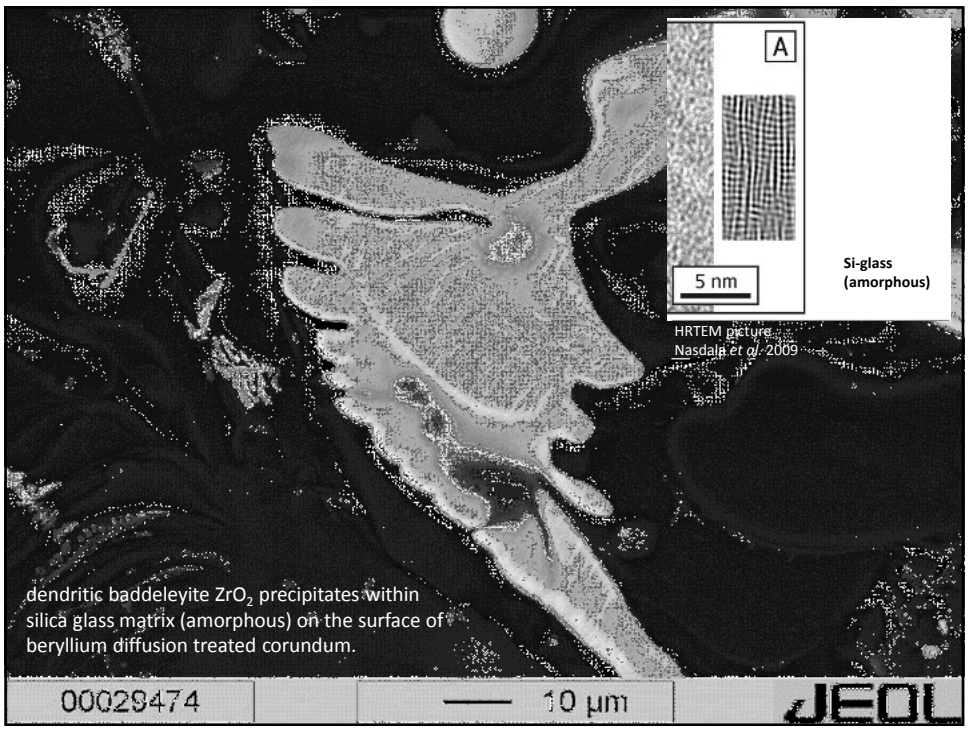
Inclusion studies

Zircon $ZrSiO_4$



High-temperature heating results in melting of zircon and precipitation of baddeleyite in silica glass matrix

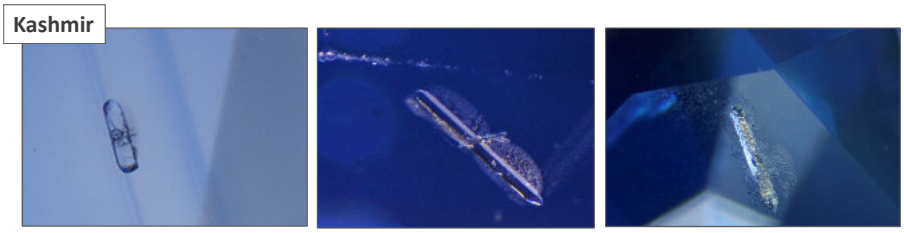




Inclusion studies

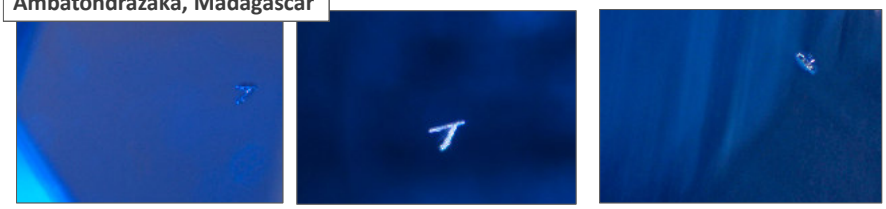
Zircon $ZrSiO_4$

Kashmir



prismatic zircon inclusions in **Kashmir** sapphires, often slightly corroded.

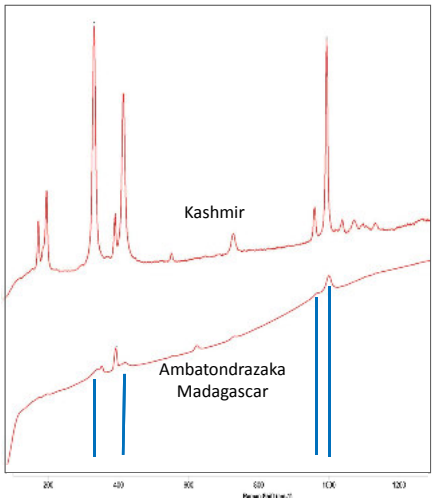
Ambatondrazaka, Madagascar



tiny prismatic zircon inclusions in sapphires from Bemainty near **Ambatondrazaka** (**Madagascar**), visually quite similar to zircons in Kashmir sapphire

Inclusion studies

Zircon $ZrSiO_4$



Raman spectra of zircon inclusions

non-metamict zircon inclusions

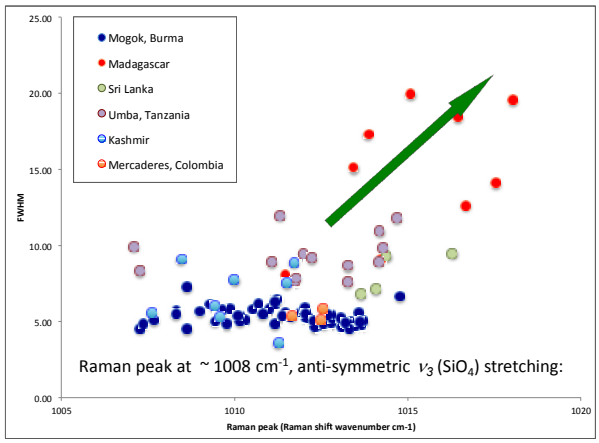
metamict zircon inclusions

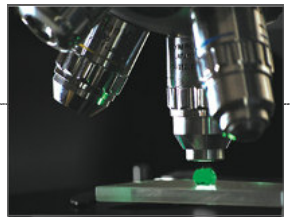
‚Kashmir-like' sapphires of excellent quality from new deposit at Bemainty near Ambatondrazaka, Madagascar.

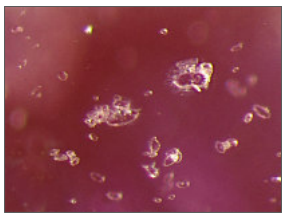
Inclusion studies

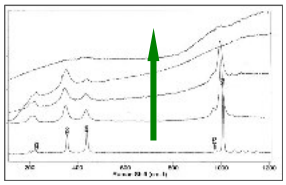
Zircon $ZrSiO_4$

Analysis of Raman spectra (position and peak width of 1008 cm^{-1} peak) of zircon inclusions of corundum (ruby/sapphire) specimens from different origins.





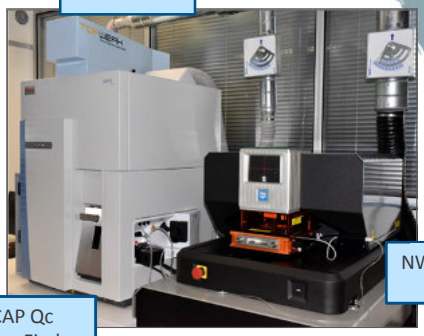




increase in metamictisation

New instrument

Time of Flight : GemTOF



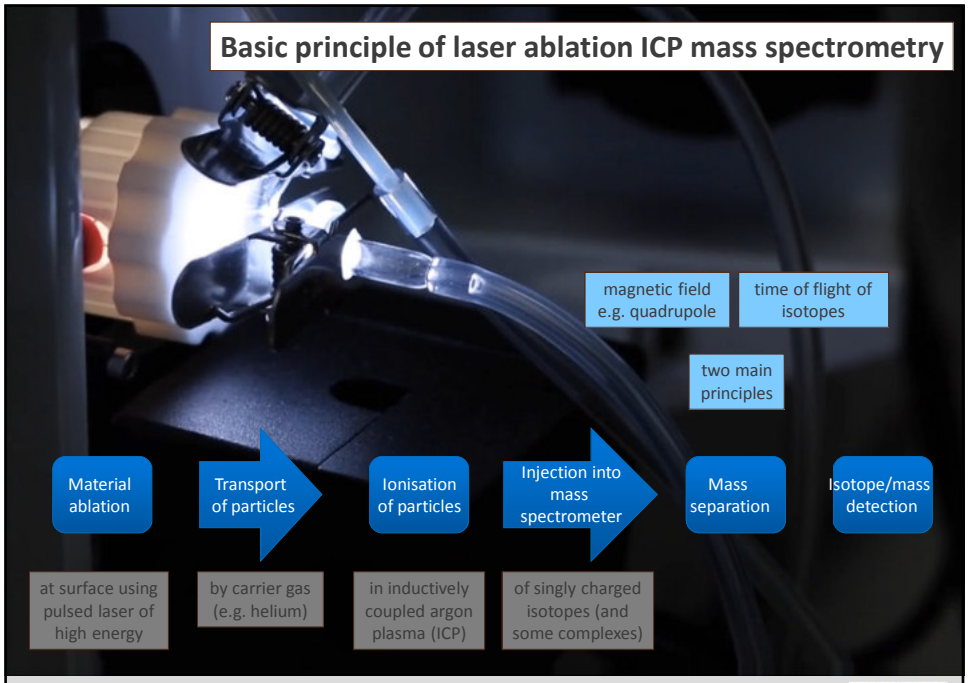
*icp*TOF
TOFWERK AG

NWR193UC
ESI

iCAP Qc
ThermoFischer

SSEF

Basic principle of laser ablation ICP mass spectrometry



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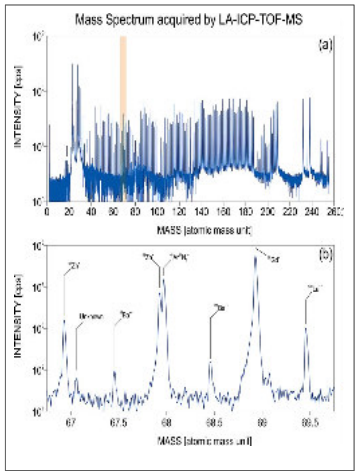
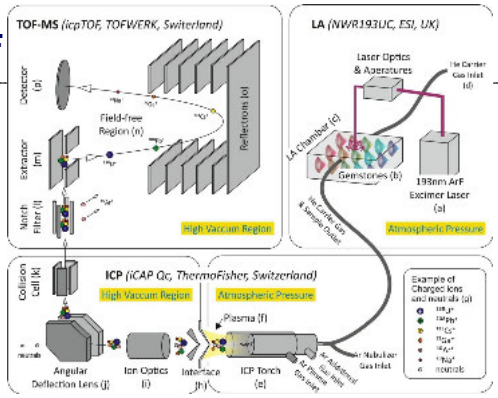
New instrument

Time of Flight : GemTOF

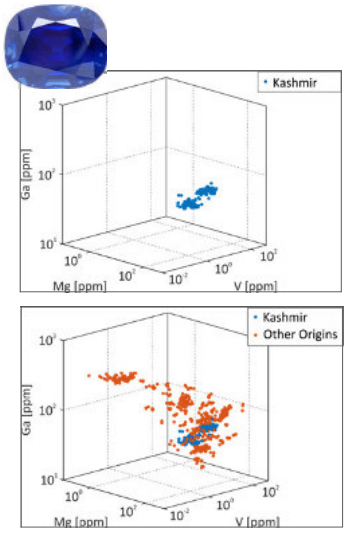


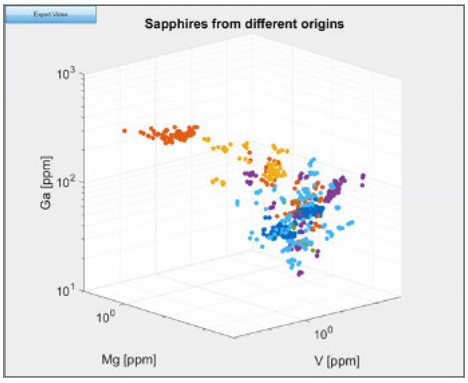


Through laser ablation, GemTOF can extract and analyse chemical information from a gemstone.

New Instrument

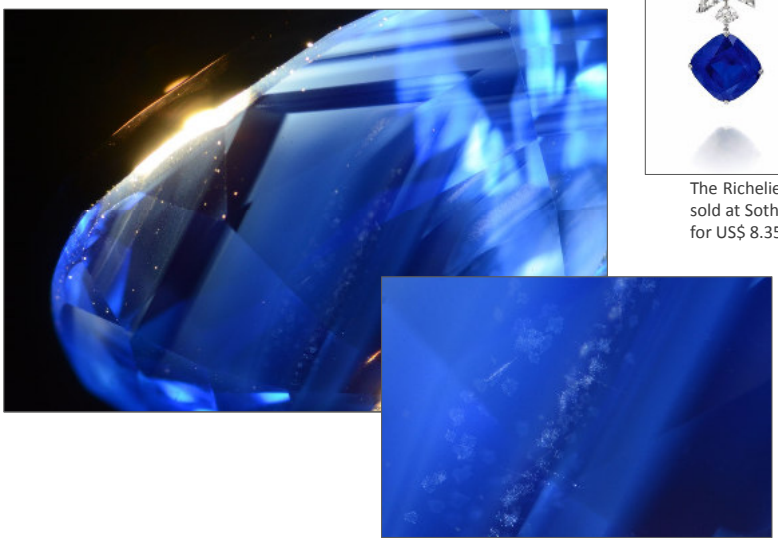
Time of Flight : GemTOF





Inclusion studies

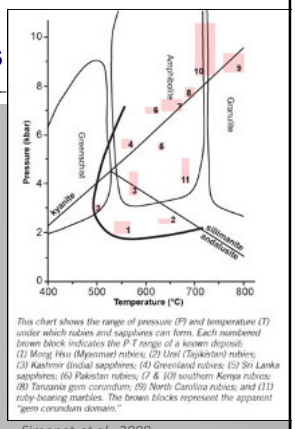
Kashmir sapphire



The Richelieu sapphires, sold at Sotheby's Geneva for US$ 8.35 mio.

From Geology to Gemmology

Corundum from amphibolite facies rocks



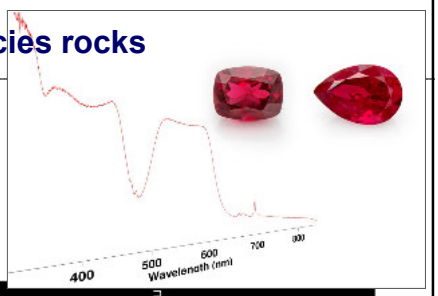
Simonet *et al.*, 2008

Ruby in amphibolite from Montepuez, Mozambique

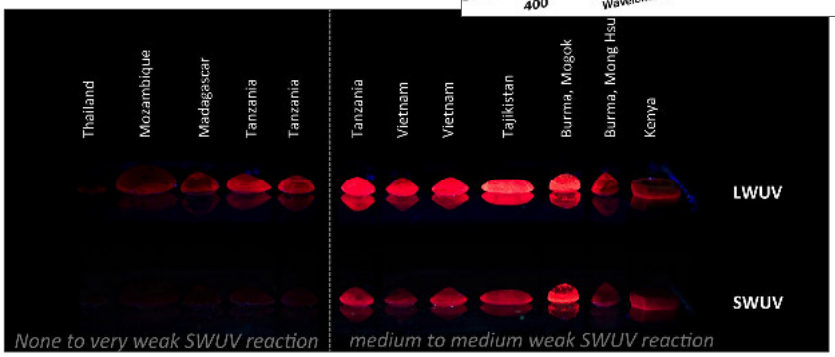
Photo: H.A. Hänni, SSEF

From Geology to Gemmology

Corundum from amphibolite facies rocks

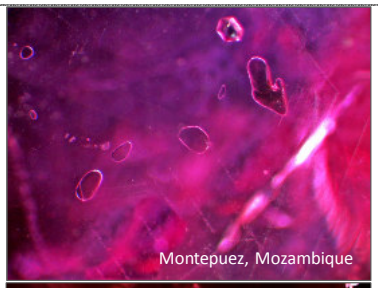


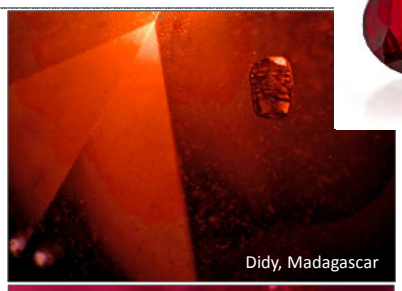
Rubies from amphibolite (metamorphic rock) are characterised by a distinct iron concentration, thus contributing to their colour and UV fluorescence reaction.

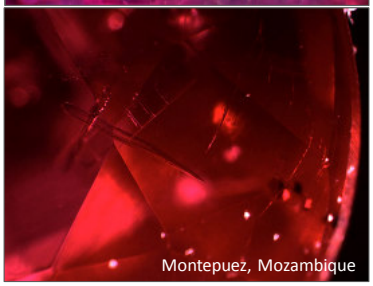


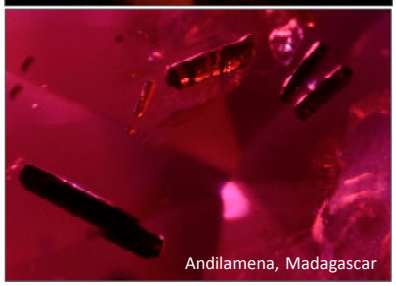
Inclusion studies

Amphibole in ruby









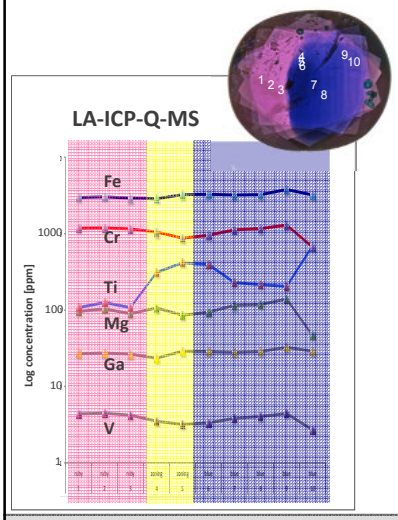
Inclusion studies

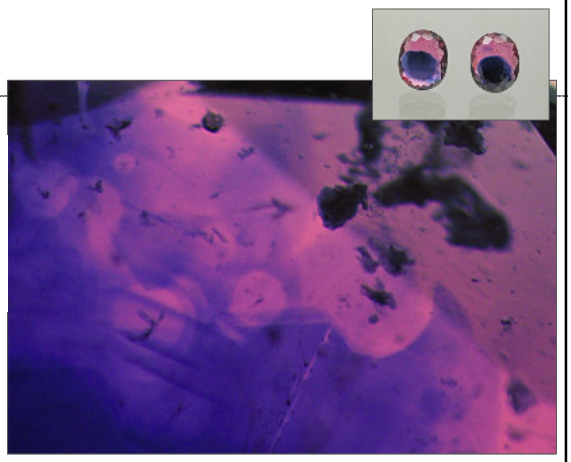
Amphibole in ruby

Ruby, fancy sapphires (ruby-sapphire mix) and sapphires from Winza, near Dodoma (Tanzania).

Inclusion studies

Amphibole in ruby



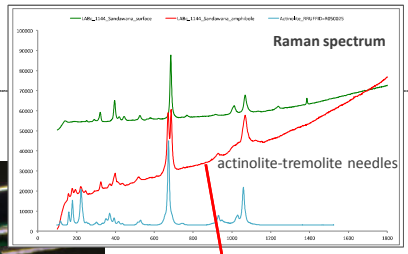


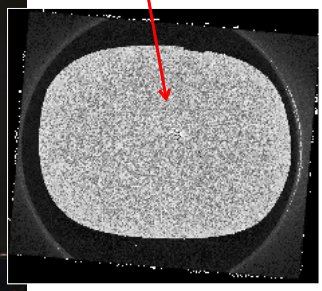
local change of the Ti^{4+} - Fe^{2+} intervalence charge transfer (IVCT) presumably caused by a reaction with the amphibole inclusion results in sperical colour „hole“ around these amphiboles.

Inclusion studies

Amphibole in emerald

Emerald sample – LABc_1144
Sandawana (Zimbabwe)





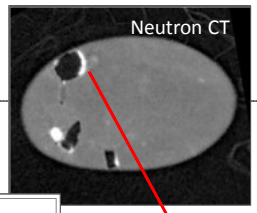
X-ray µ-tomography section

Inclusion studies

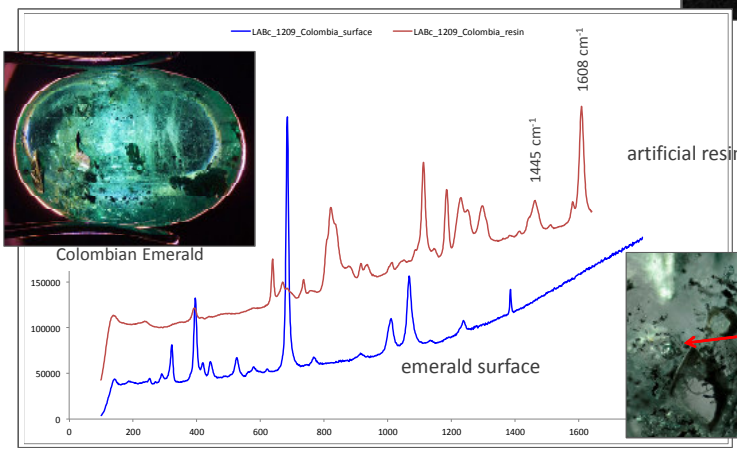
Using Neutrons and X-rays (PSI)

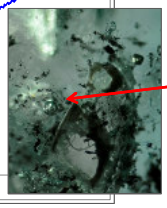
3D visualisation of inclusions and organic fillers in emeralds

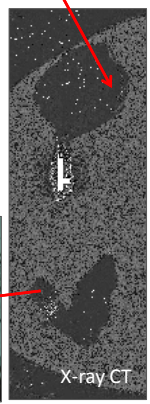
Project in collaboration with the Laboratory for Neutron Scattering and Imaging at PSI



Colombian Emerald

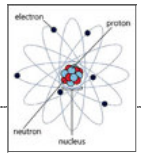




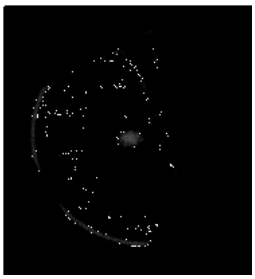


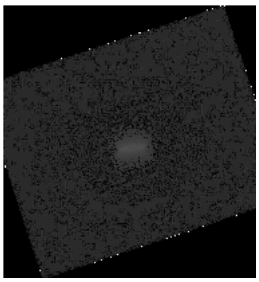
Inclusion studies

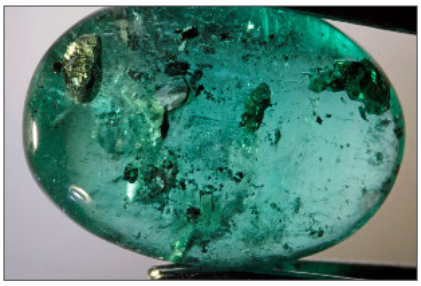
Using neutrons and X-rays (PSI)



Neutron µ-tomography **X-ray µ-tomography** Emerald sample – LABc_1209 Colombia







Neutron µ-tomography section		X-ray µ-tomography section	
White	=	± not seen	= cavity filling (epoxy)
Grey	=	white	= pyrite
Black	=	black	= cavity
Weak greyish lines	=	not seen	= fissure filling (epoxy)
± not seen	=	grey	= calcite

Conclusions

Inclusions in gemstones are highly important clues for a better understanding of (coloured) gemstones.

They reveal important information about formation processes, geological setting, and treatments.

The analysis of gemstones and their inclusions is based on a large range of methods from basic microscopy to advanced methods using laser light, X-rays, electrons and neutrons.

The aim is to characterize their chemical, isotopic, and structural state as far as possible.

Until today, meticulous **microscopic examination** of gemstones and their inclusions remains crucial, as it not only unveils their beauty, but also provides a wealth of information to gemmologists.

Thank you for your attention