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SWISS GEMMOLOGICAL INSTITUTE
INSTITUT SUISSE DE GEMMOLOGIE

On the Trail of New Gem Deposits:

Exciting for the Trade but Challenging for Gem Labs



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

Photos © M.S. Krzemnicki and SSEF, except where indicated otherwise

Coloured gemstones were formed during large-scale geological processes which have shaped the world as we know it today...

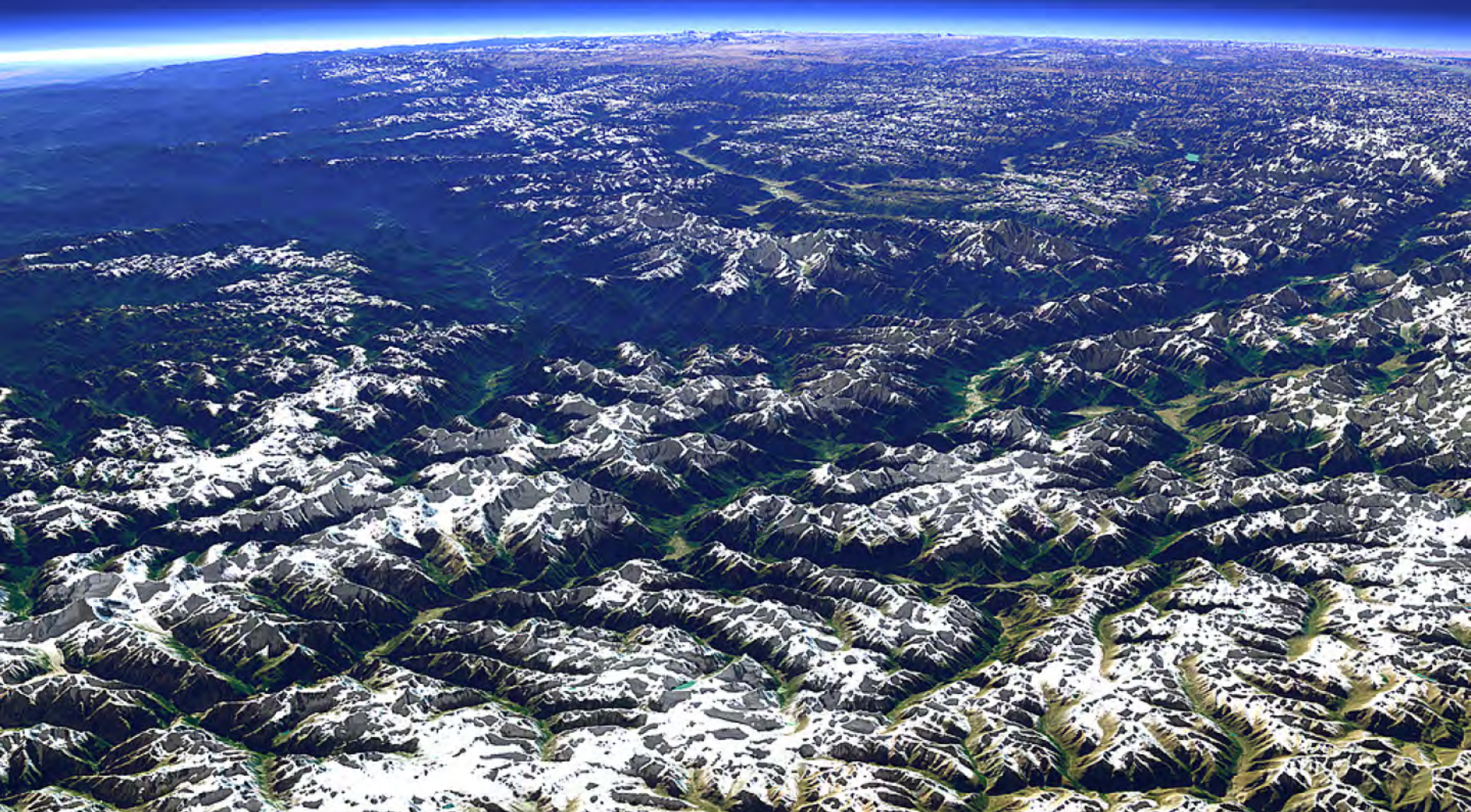




Foto: Baltoro-Glacier, Karakorum; Guilhem Vellut via, WikiCommons

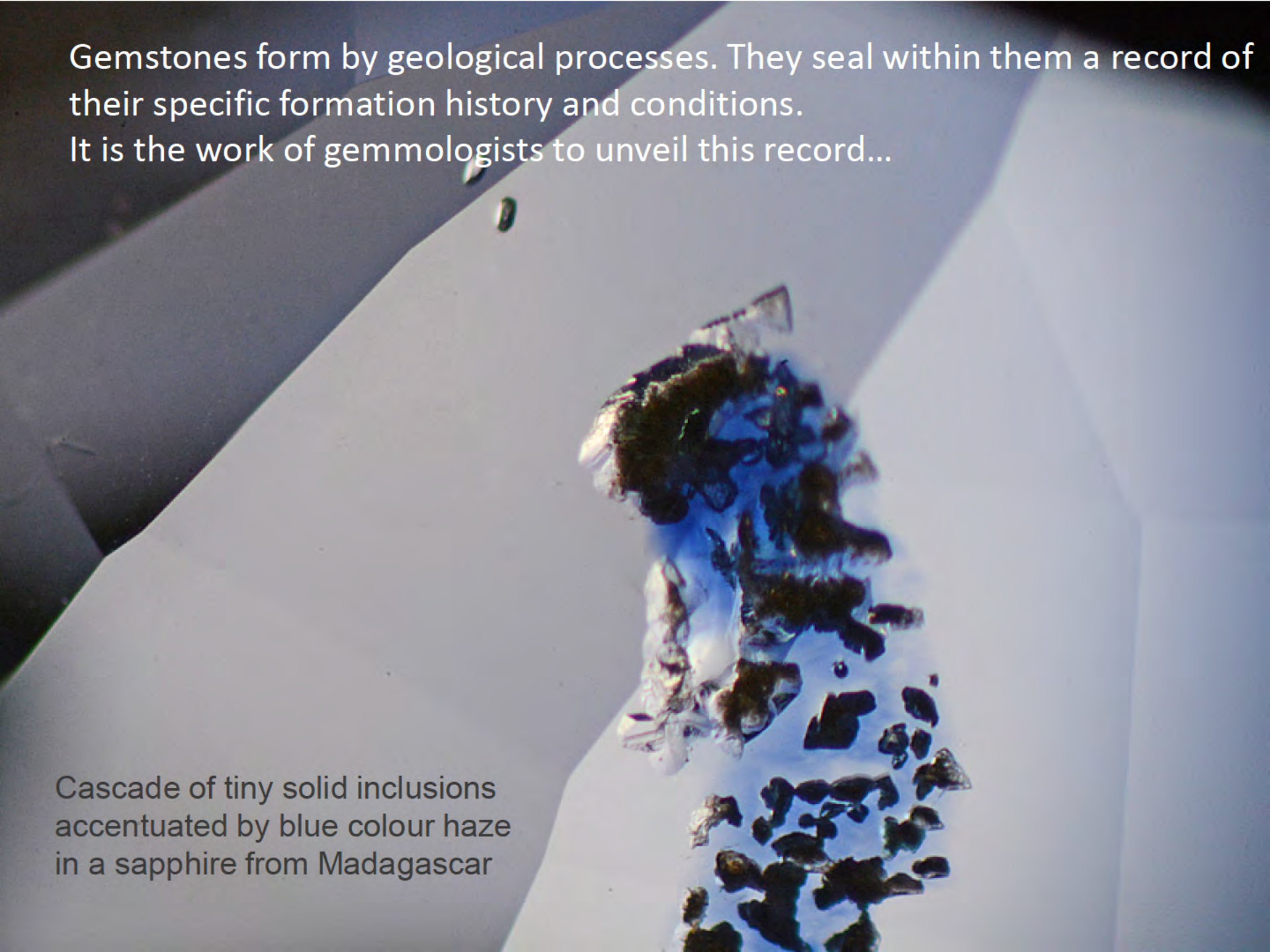


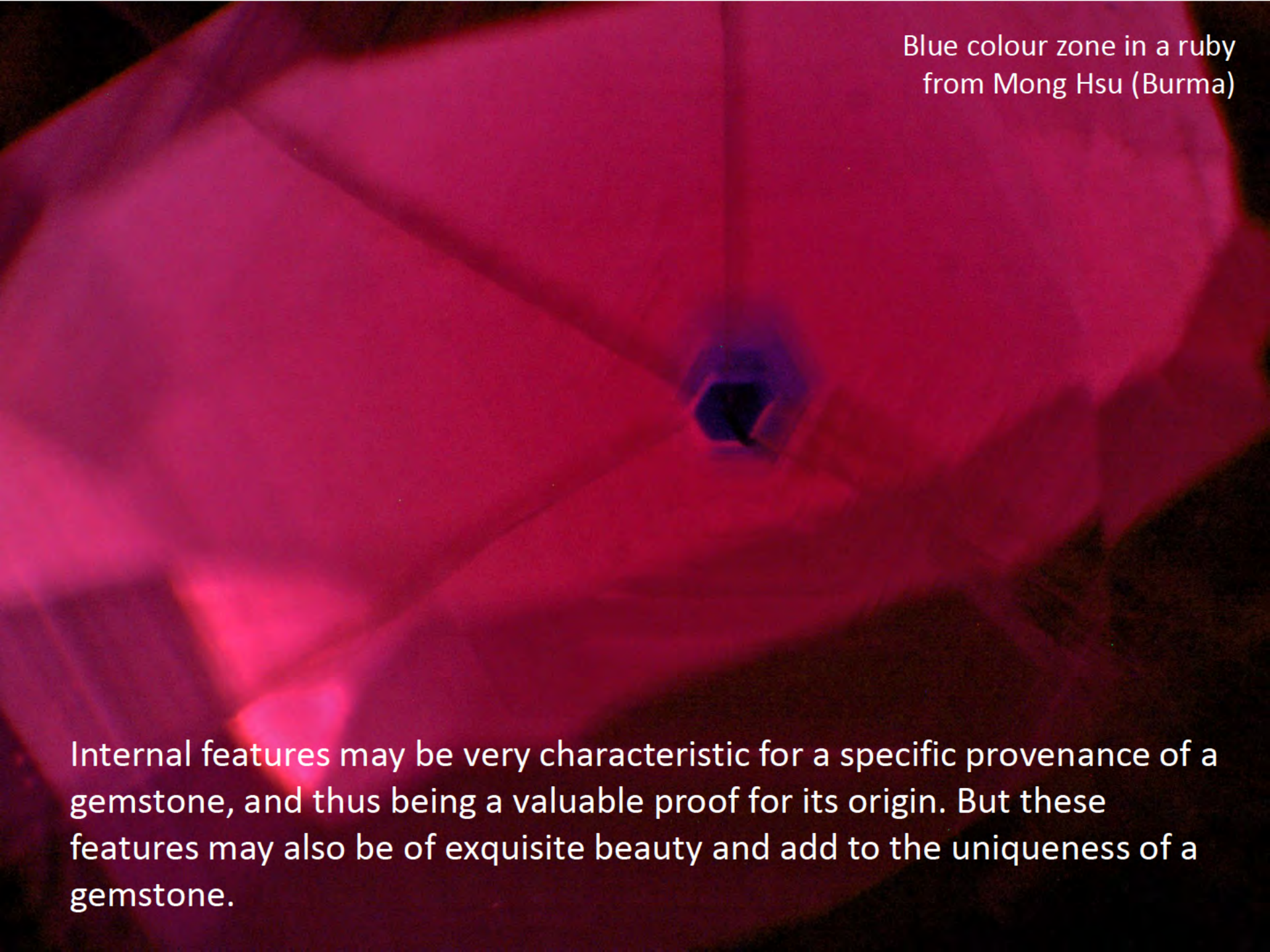
The collision of the Indian plate with the Eurasian plate has produced some of the most important deposits for coloured gems, such as in Kashmir (India) for sapphires, in the Pamir mountains (Tajikistan) for spinel, and in Mogok (Myanmar) for rubies and sapphires, to name a few.



Gemstones form by geological processes. They seal within them a record of their specific formation history and conditions. It is the work of gemmologists to unveil this record...

Cascade of tiny solid inclusions accentuated by blue colour haze in a sapphire from Madagascar





Blue colour zone in a ruby
from Mong Hsu (Burma)

Internal features may be very characteristic for a specific provenance of a gemstone, and thus being a valuable proof for its origin. But these features may also be of exquisite beauty and add to the uniqueness of a gemstone.

Some gem sources are known since historic times. Their gems have been treasured over centuries for their beauty and rarity, and they are thus highly sought after by the market today.



The King of Burma, circa 1885

But where do the stones come from...



Andranondambo in southern Madagascar

Gem Deposit Discoveries



historic
still active



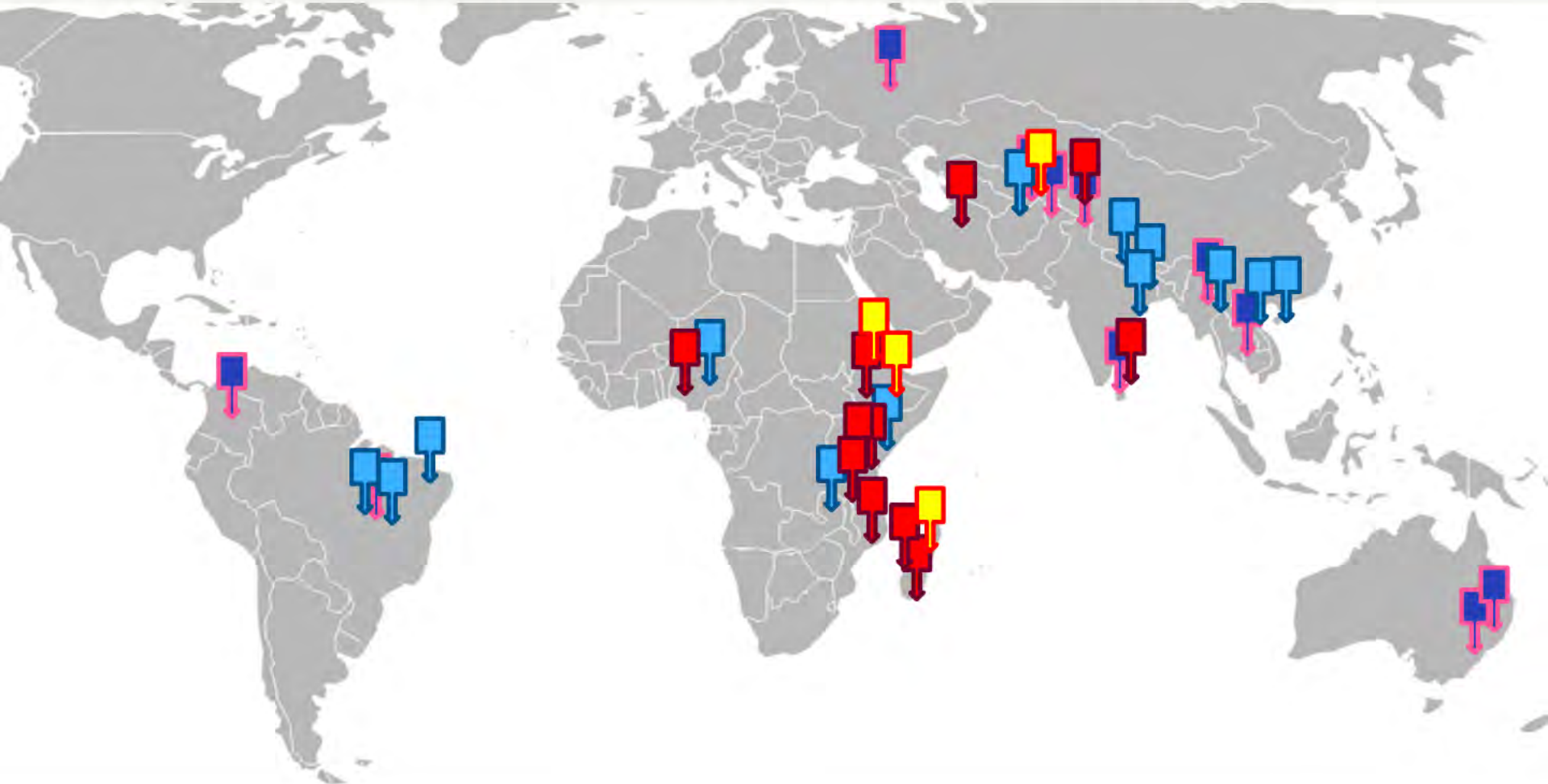
discovered
1960-2000



discovered
2000-2017



discovered in the
last few months





Small scale and artisanal mining:

Ruby deposit in marble rocks in
Mwarasi (Tanzania)



clip



clip



remote and adventurous...



Spinel deposit in marble rocks near Mahenge (Tanzania)



Only few large and mechanised mine operations

Emerald deposit in Zambia (Gemfields)



Photo courtesy Gemfields plc

Mining of Coloured Stones vs Mining of Diamonds:

Diamonds from different mines often show very similar range of colours and qualities. The diamonds from different mines are commonly and deliberately mixed, as they are only/mostly sold based on their quality (4C). There is commonly no price difference for diamonds from a newly found mine compared to diamonds from a established production.

There is not much incentive (so far) to separate diamonds from different sources.

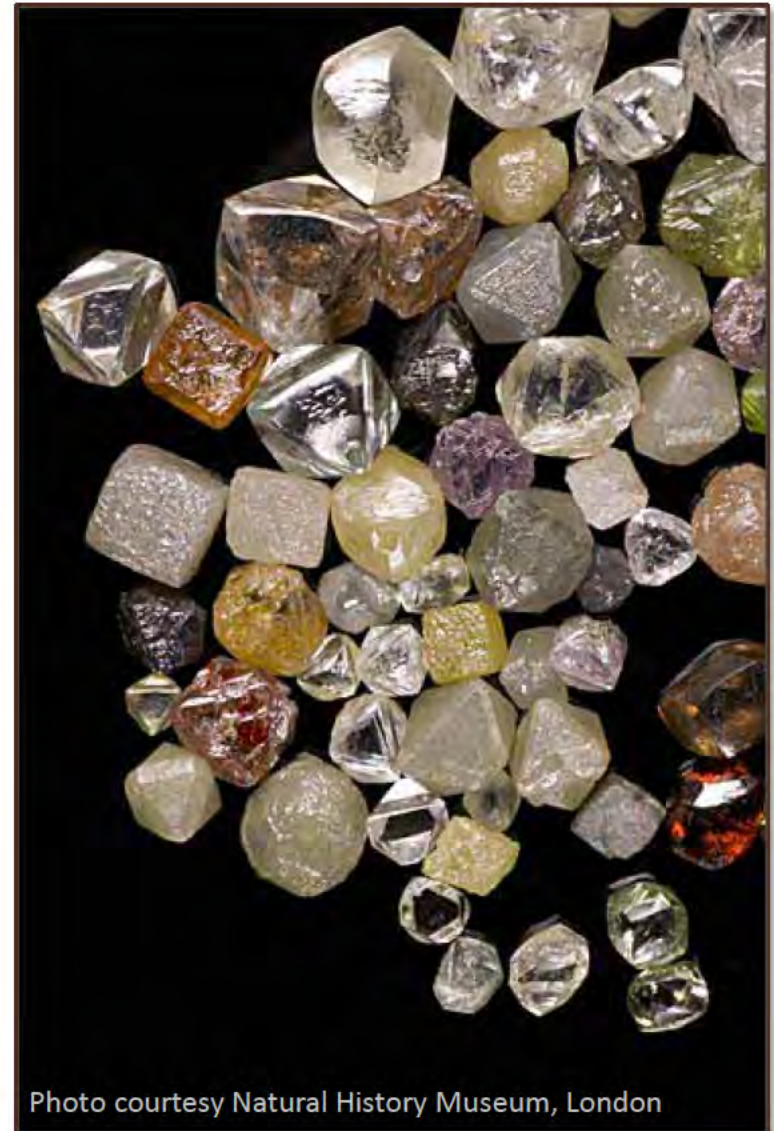


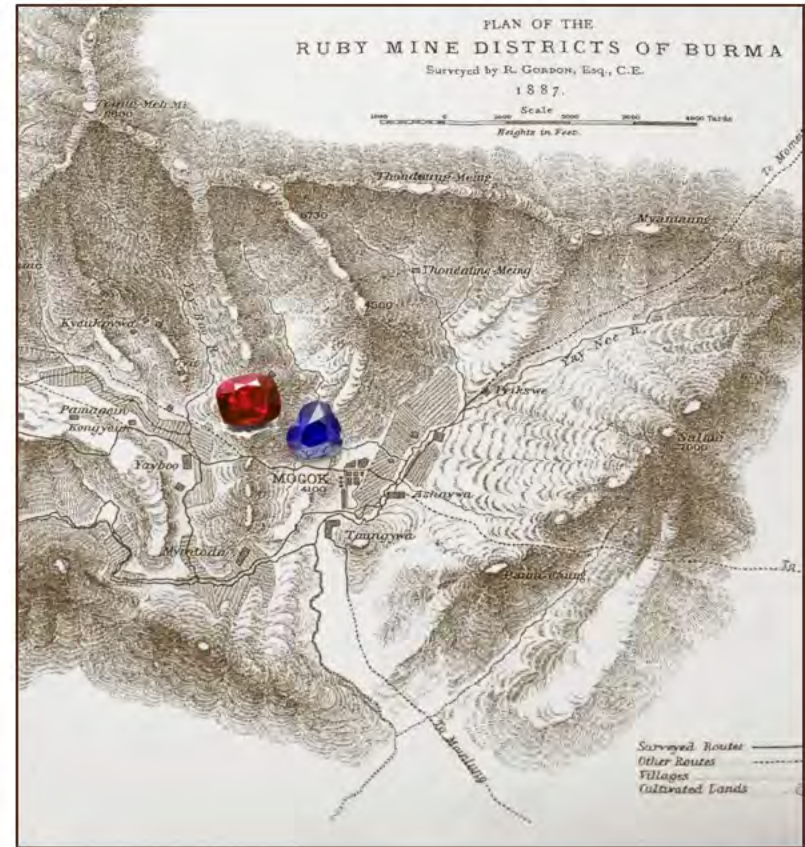
Photo courtesy Natural History Museum, London

Mining of Coloured Stones vs Mining of Diamonds:

Coloured gemstones often show **mine specific** colour shades or visual qualities. This makes every new find interesting, as even new colours or gem varieties (e.g. Paraiba tourmaline) may be discovered.

It brings very innovative aspects into the trade, as new deposits bring the chance to acquire gems at a substantially lower price (at least in the beginning of production) than from reputed and historic deposits. Thus it may provide the option for new stakeholders to enter the gem trade with only limited financial power; the only need is to be „among the first“ at a new gem discovery.

There is a strong demand for independent origin determination in the trade, as the origin of a gem may have a positive (or negative) impact on its price.



Sapphires of excellent quality
from a new deposit at Bemainty near Ambatondrazaka (Madagascar),
discovered October 2016



Such new gems may be comparable to...

...sapphires of finest quality from historically reputed deposits



The Star of Kashmir, 19.88 ct

Sold at **Christie's** in Geneva, May 2013 for 3'500'00 mio US\$

The Challenge to Determine the Origin of Gems

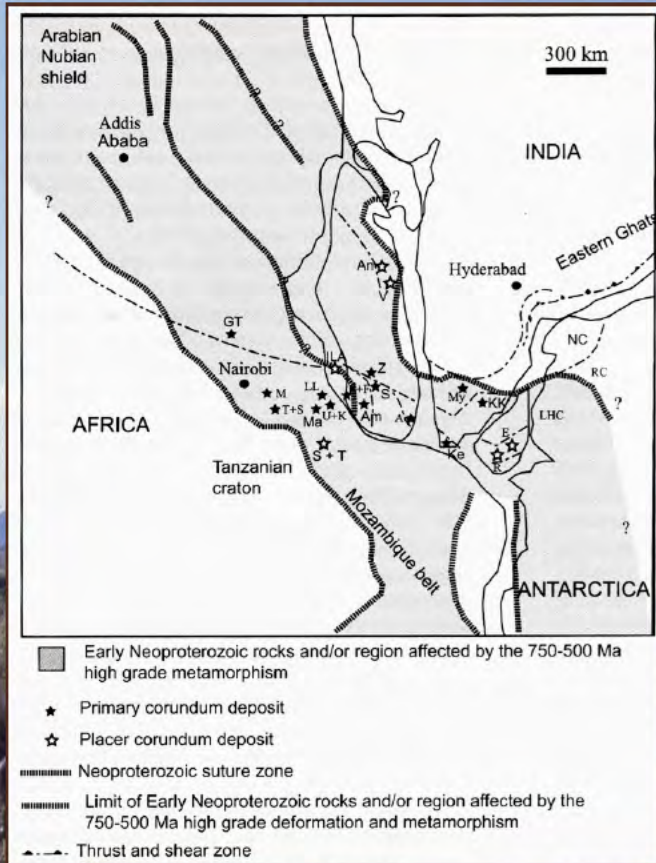
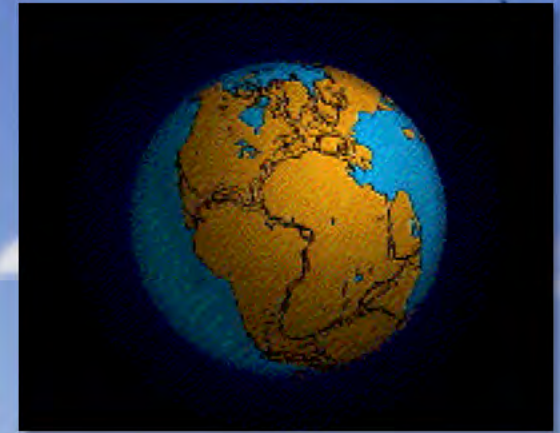
For gemmological laboratories offering the service of origin determination, it is thus crucial to quickly adapt to new developments and discoveries:

- Get first-hand reliable samples, and if possible directly from the mining site.
- Get an overview about production, quality, sizes, availability...
- Establish a catalogue of characteristic properties and internal features.
- Check for (geological and gemmological) similarities with existing gem deposits and develop methods to separate gems from a new deposit from existing ones.

Most important is to be able to separate gems of a new source from those originating from highly prestigious and classic sources.



The Challenge to Determine the Origin of Gems



Distribution of corundum deposits connected to Pan-African tectono-metamorphic events (750-450 ma) caused by the collision of eastern and western Gondwana.

In mid-Jurassic (about 160 ma), India started to drift towards north.

Guiliani et al. 2007

The Challenge to Determine the Origin of Gems



Formation of rubies in marbles



Mogok, 2016

Ruby testing at SSEF



Analytical instruments for origin determination at SSEF

- X-ray fluorescence (EDXRF)
- Raman microspectroscopy
- FTIR Infrared spectroscopy
- UV-Vis-NIR absorption spectroscopy
- Laser-induced photoluminescence
- GemTOF (laser ablation ICP time-of-flight mass spectrometry)

Rubies from Mozambique

the Eyes of the Dragon (11.26 ct and 10.70 ct)



the Eyes of the Dragon (11.26 ct and 10.70 ct)

© Burrard-Lucas.com

Rubies from Mozambique

Since their discovery in early 2009, the ruby deposits near Montepuez in Mozambique have produced an impressive number of exceptional-quality stones.



Scarlet Drop
(15.95 ct)



Rhino Ruby
(22.04 ct)

Detection of „Low-Temperature“ Heated Mozambique Rubies

In more recent years, an increasing number of rubies from Mozambique have come onto the market, after having undergone so-called “low-temperature” heating (below 1000 °C).

Unheated ruby from Mozambique showing a slight purplish zone which can be removed by low-T heating (< 1000°C).



Detection of „Low-Temperature“ Heated Mozambique Rubies

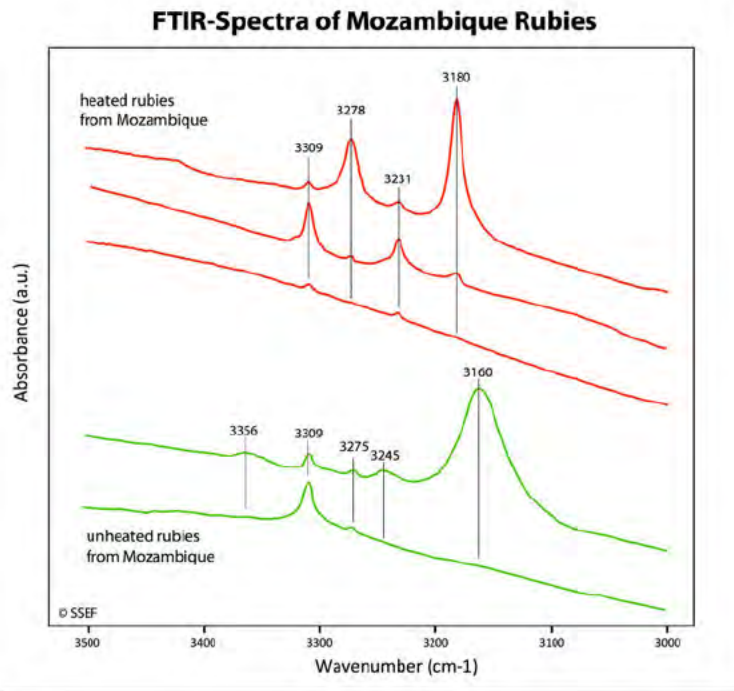


Characteristic microscopic features indicating a heat treatment such as a small disc-like expansion fissure (above) and a tiny heat-induced fissure at the surface (below) in heat treated Mozambique rubies.



But not all of these heated rubies show the microscopic features that commonly characterise heat treatments. This is a situation that challenges gemmologists and gemmological laboratories, and also, ultimately, the trade.

Detection of „Low-Temperature“ Heated Mozambique Rubies



FTIR spectra of unheated rubies from Mozambique (in green, below) and heated rubies (in red, above).

New research at SSEF on a large number of unheated and heated Mozambique rubies reveals that, rather than using individual FTIR peaks to determine if a ruby has been heat-treated or not, the focus should be on peak patterns.

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PRESS RELEASE

FOR IMMEDIATE RELEASE
CONTACT: Dr. Michael S. Krzemnicki FGA
gemlab@ssef.ch

New research by SSEF studies methods for detecting low-temperature heated rubies from Mozambique

BASEL, SWITZERLAND/SEPTEMBER 12, 2018 – Since their discovery in early 2009, the ruby deposits near Montepuez in Mozambique have produced an impressive number of exceptional-quality stones, including iconic unheated gems such as the Rhino Ruby (22.04 cts), the Scarlet Drop (15.95 cts) and the Eyes of the Dragon (a pair of rubies weighing 11.25 cts and 10.70 cts), all of which were analysed by the Swiss Gemmological Institute SSEF. But from the very beginning, there has been evidence in the market of lower-quality rubies from Mozambique that have been heated with or without a flux (borax), resulting in healed fissures with residue, and in some cases heavily-fractured material that has been lead-glass filled.

In more recent years, an increasing number of rubies from Mozambique have come onto the market, after having undergone so-called “low-temperature heating” (below 1000 °C). Presumably, the aim of this treatment is to enhance the colour slightly, by reducing subtle purplish zones which are sometimes present in rubies from this location (Figure 1).

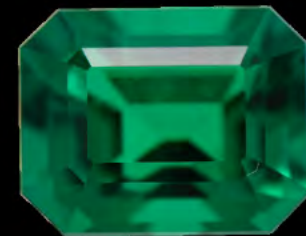


Figure 1: Slightly purplish zone in ruby from Mozambique. Photo: M.S. Krzemnicki, SSEF

SSEF Press Release Sept 2018
see www.ssef.ch

Emeralds from Afghanistan

Panjsheer Valley



Emeralds from a new „pocket“ in Panjeer valley, Afghanistan



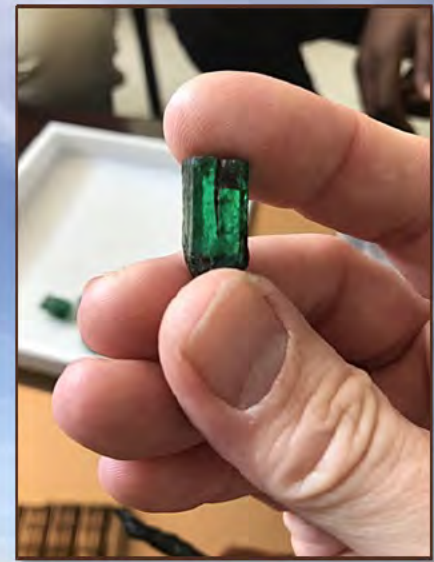
Discovered in early 2017, this new find has produced a small quantity of stones of partly exceptional quality

Emeralds from a new „pocket“ in Panjeer valley, Afghanistan



in many aspects very similar
to Colombian emeralds

A new source in Africa: Ethiopia



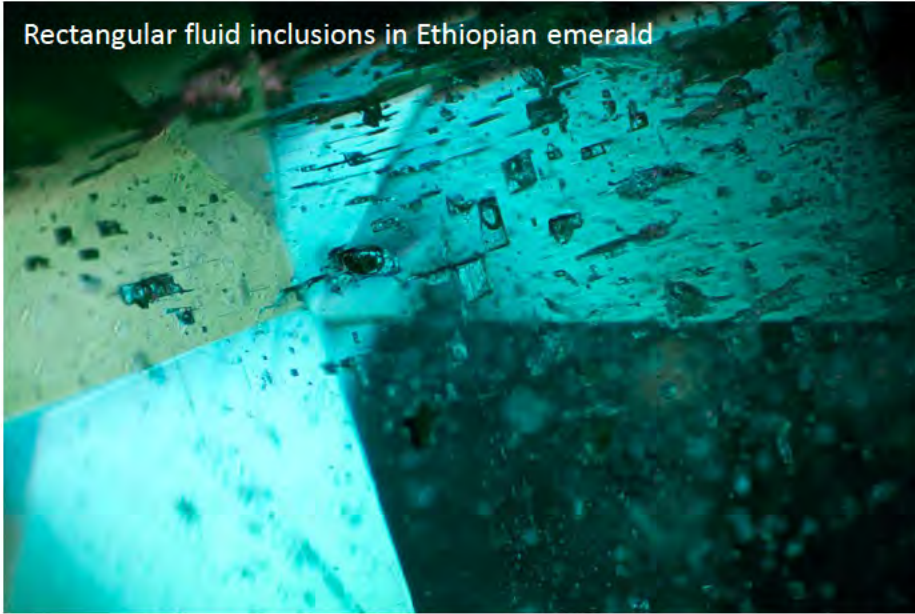
Emeralds from Shakiso in southern Ethiopia



Newly discovered in November 2016

Emeralds from Shakiso in southern Ethiopia

Rectangular fluid inclusions in Ethiopian emerald



Brown mica flakes (biotite) in Ethiopian emerald

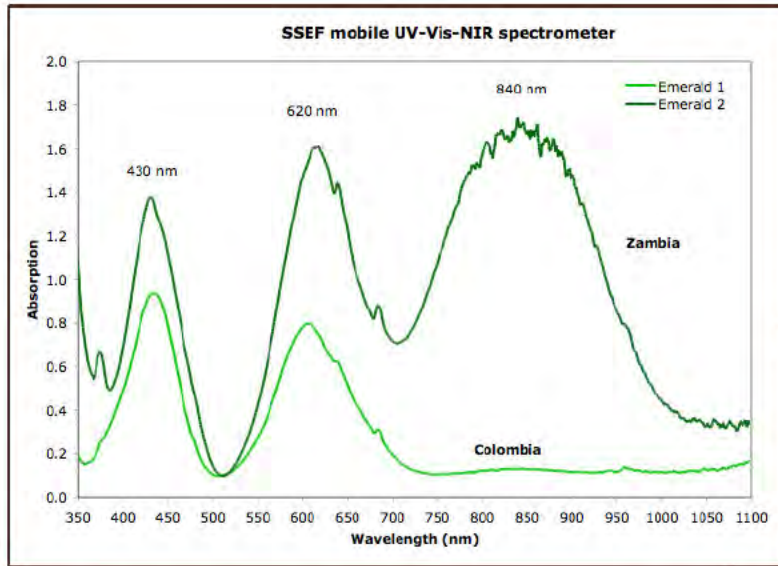


This new material from Ethiopia can be easily separated by microscope from emeralds originating from the classic mines in Colombia.

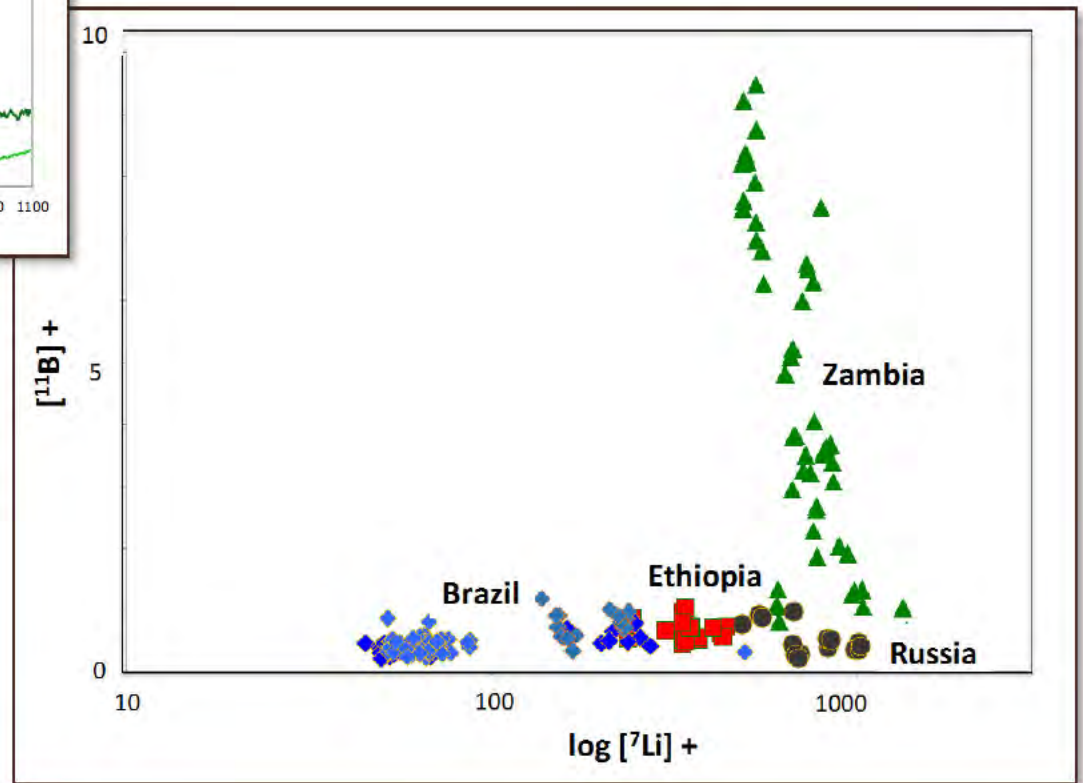
But is in many aspects - such as formation, properties and inclusions - very similar to emeralds from Zambia and therefore very difficult/impossible to separate from Zambian material just using the microscope.

Advanced instrumentation is necessary !

Emeralds from Shakiso in southern Ethiopia

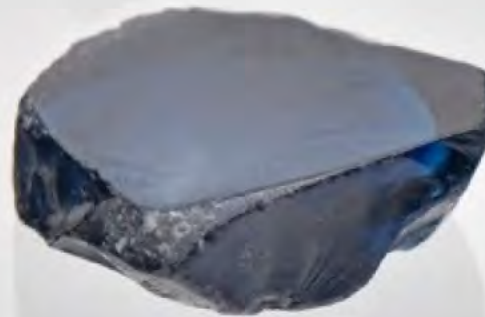
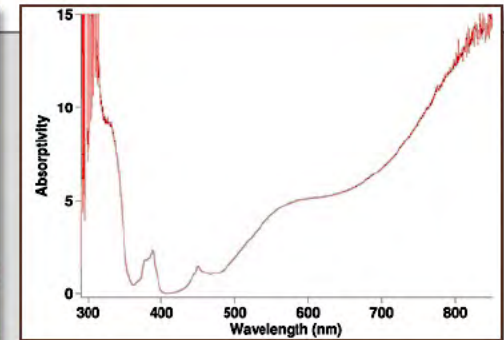
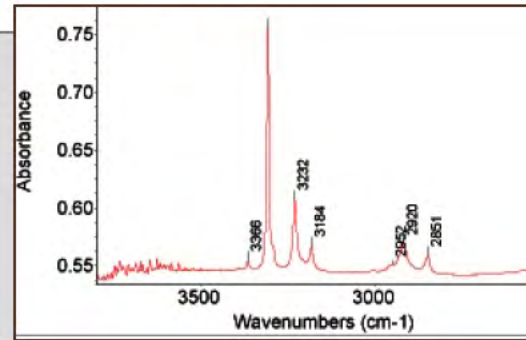


UV-Vis-NIR absorption spectrum and GemTOF trace element data plot to separate Ethiopian emeralds from Colombian emeralds (very different formation) and from Zambian and other biotite-schist related emerald deposits.



Recently in the spotlight

Sapphires from northern Ethiopia



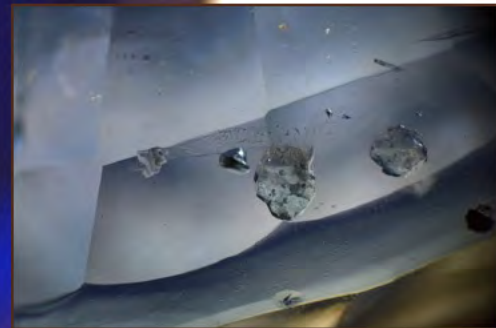
Ethiopian sapphires show features typical for sapphires from basaltic origin.

Recently in the spotlight

...and from Madagascar



U-Pb age dating may provide in certain cases important information about gemstone formation (and origin)

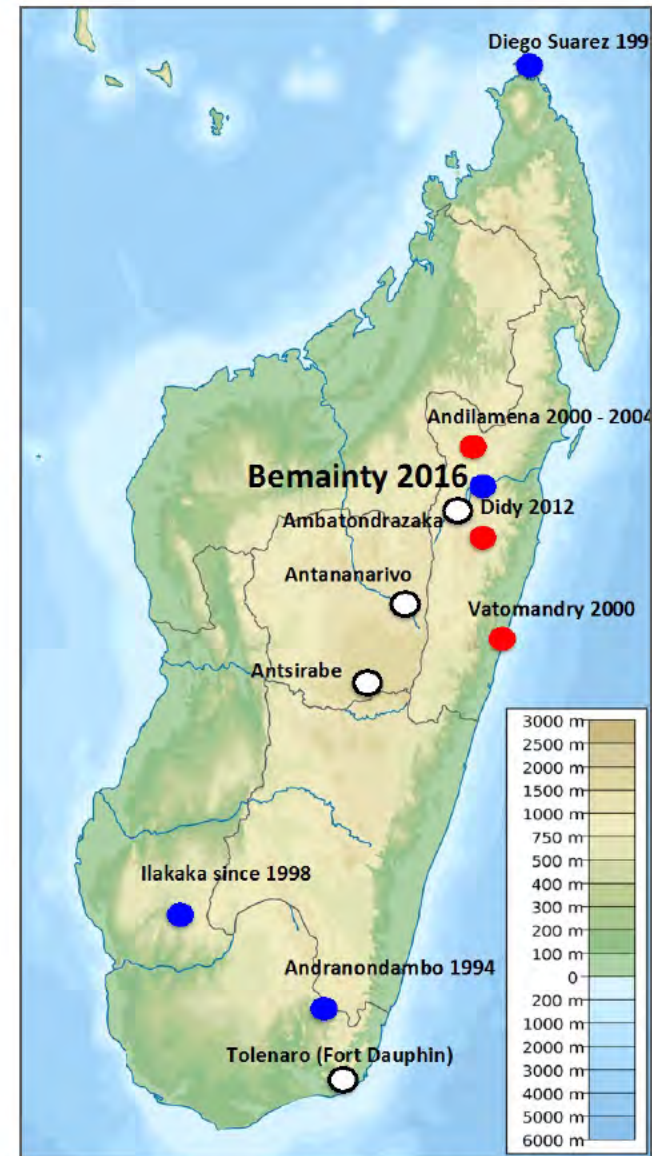
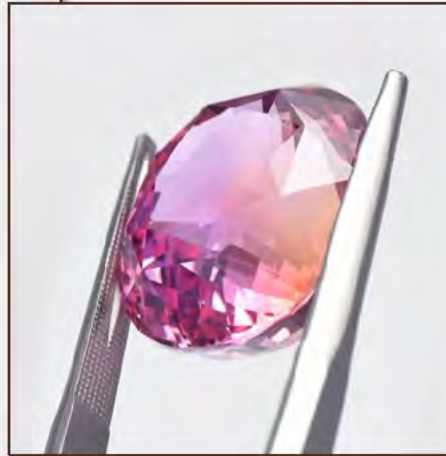


Recently in the spotlight

...and from Madagascar

New deposit discovered in October 2016 at **Bemainty**, near the small town **Ambatondrazaka**, Madagascar.

Mostly sapphires, but also fancy coloured varieties.



Some of the most productive ruby and sapphire mines of Madagascar (adapted from V. Pardieu 2017).

Recently in the spotlight

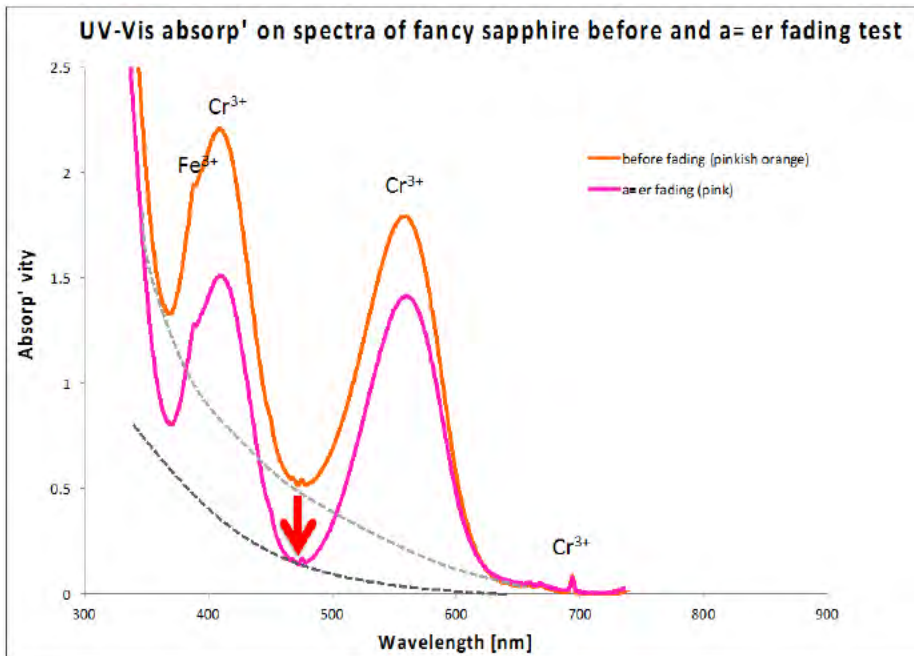
Fancy Sapphires with unstable Padparadscha-like colour



...so this fancy sapphire will be pink again after few weeks

Recently in the spotlight

Fancy Sapphires with unstable Padparadscha-like colour



Since mid 2017, SSEF applies colour stability test on padparadscha sapphires !

The colour of the stones are analysed before and after UV activation and fading test to determine their colour stability or instability !

In case the tested stone shows a distinct shift, SSEF will not identify these stones as padparadscha, but as **fancy sapphire**, adding a comment (and explanation letter) about their unstable colour.

Recently in the spotlight

New Sapphires of « Kashmir-like » appearance

See also:

www.ssef.ch/research-publications/press-releases/

and
ICA InColor
June 2017

GEMMOLOGY |


Sapphires from a New Deposit at Bemainty near Ambatondrazaka in Madagascar

By
Michael S. Krzemnicki, General J. Cohen, Bao AO
Wang, Wu, Chen, Hwang & Chen

Madagascar is noted for its gemstone resources. The island country has been a source of sapphires in the past for centuries. The most famous sapphire deposit in the world is the one at Ilakaka, which has been producing sapphires for centuries. The most famous sapphire deposit in the world is the one at Ilakaka, which has been producing sapphires for centuries. The most famous sapphire deposit in the world is the one at Ilakaka, which has been producing sapphires for centuries.

Abstract: new sapphires with a variety of colors and sizes.

Introduction: The Swiss Gemmological Institute (SGI) recently analyzed a large number of sapphires and many sapphires from the new deposit in the Bemainty area near Ambatondrazaka in Madagascar (Figure 1). The sapphires from this deposit are characterized by their color, clarity, and size. The sapphires from this deposit are characterized by their color, clarity, and size.



SSEF Newsletter March 2017-03-27

Trade alert:
'Kashmir-like' sapphires from Madagascar
are entering the gem trade in large sizes and quantities

by Dr. Michael S. Krzemnicki, SSEF

In the last few weeks, the Swiss Gemmological Institute SSEF analysed an important number of sapphires from a new deposit at Bemainty, near the small town of Ambatondrazaka in Madagascar, which were submitted to us by several reliable independent sources. This new gem-rush in Madagascar has produced in the last few months an impressive amount of sapphires, fancy coloured sapphires, and padparadschas of partly exceptional size and quality (Krzemnicki 2017 in *SSEF Facette* www.ssef.ch/research-publications/facette/ and upcoming *Journal of Gemmology*, Perkins 2016, Perkins & Pardieu 2016, Pardieu et al. 2017), and seems to be a new gem source more important than anything we have seen in recent years.



Figure 1: Exceptional quality and size (left 30 ct, right 13 ct) of 'Kashmir-like' sapphires from Bemainty near Ambatondrazaka in Madagascar. Photo: SSEF

The velvety blue of Kashmir sapphires



Photo © H.A. Hänni, SSEF

Sapphires from Kashmir contain sub-microscopic inclusions which scatter the transmitted light.

As a result, these stones often show a highly appreciated **velvety** blue colour.



The Maharaja of Jammu and Kashmir, circa 1900
www.kashmirphotos.org/history.html

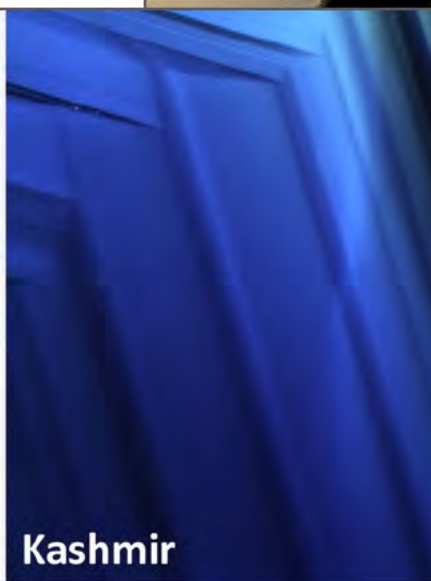
The Kashmir - Madagascar challenge !



The Kashmir – Madagascar Challenge

The newly discovered sapphires from Bemainty show a milkyness, resulting in an attractive velvety blue colour similar to Kashmir sapphires.

Fine milky zoning in sapphires from Bemainty compared to blocky zoning in Kashmir sapphires.

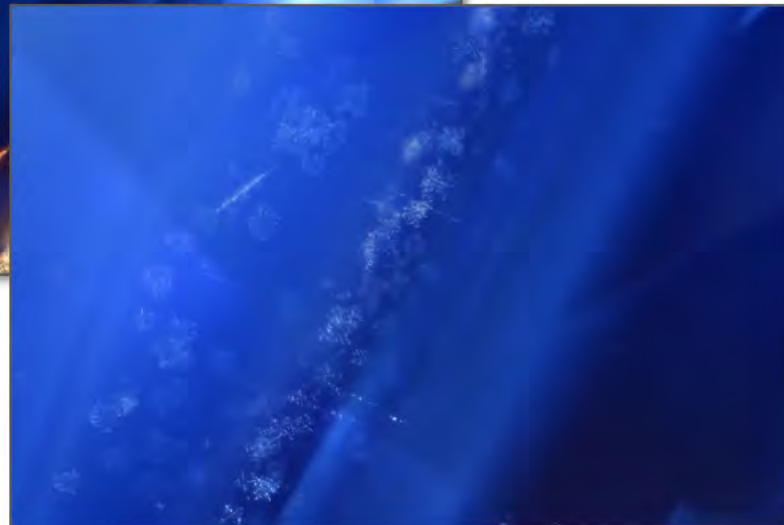




very regular zonation lines

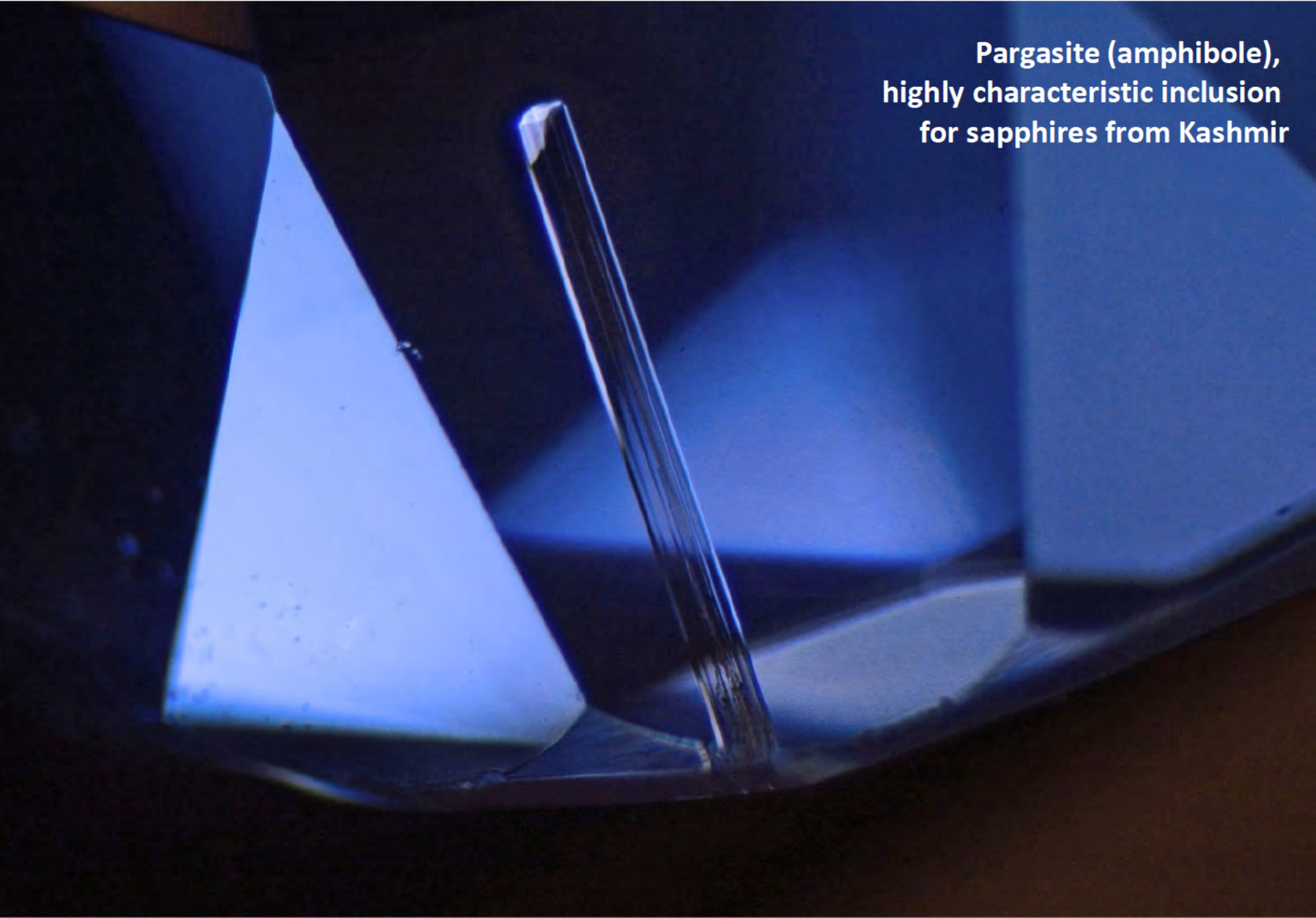
Distinct colour zonation in sapphire from new deposit at Bemainty (Madagascar)

Kashmir sapphire



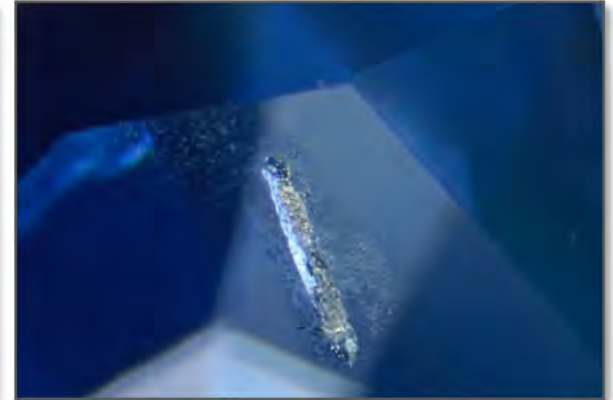
The Richelieu sapphires,
sold at Sotheby's Geneva
for US\$ 8.35 mio.

**Pargasite (amphibole),
highly characteristic inclusion
for sapphires from Kashmir**



The Kashmir – Madagascar Challenge

Kashmir



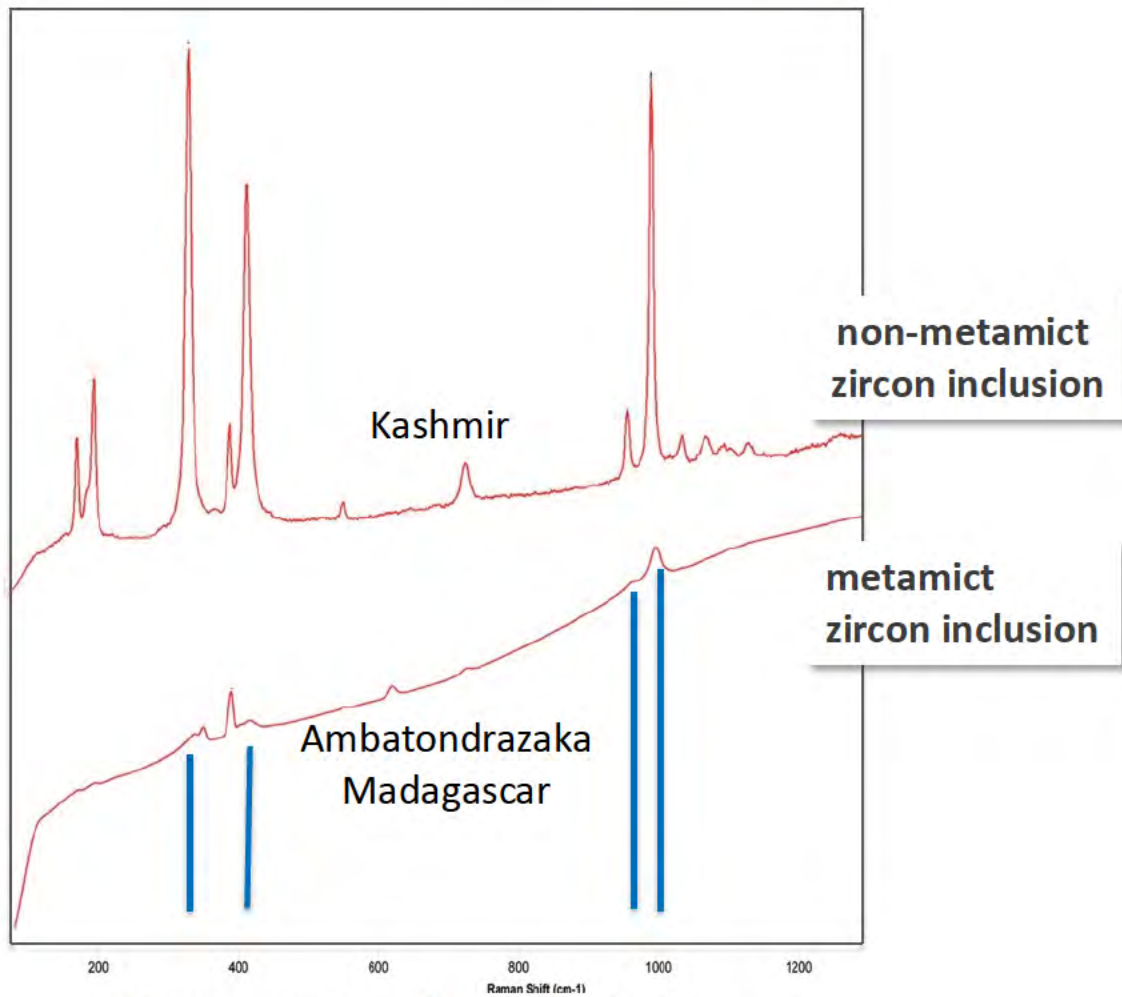
prismatic zircon inclusions in **Kashmir** sapphires, often slightly corroded.

Ambatondrazaka, Madagascar



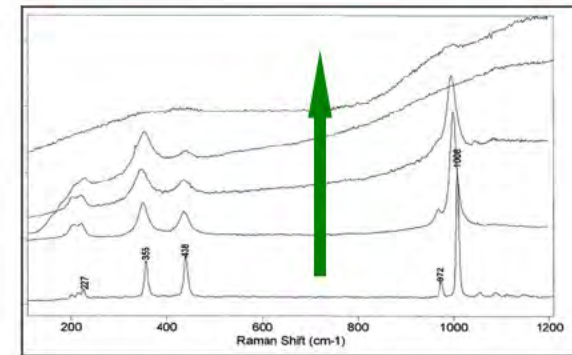
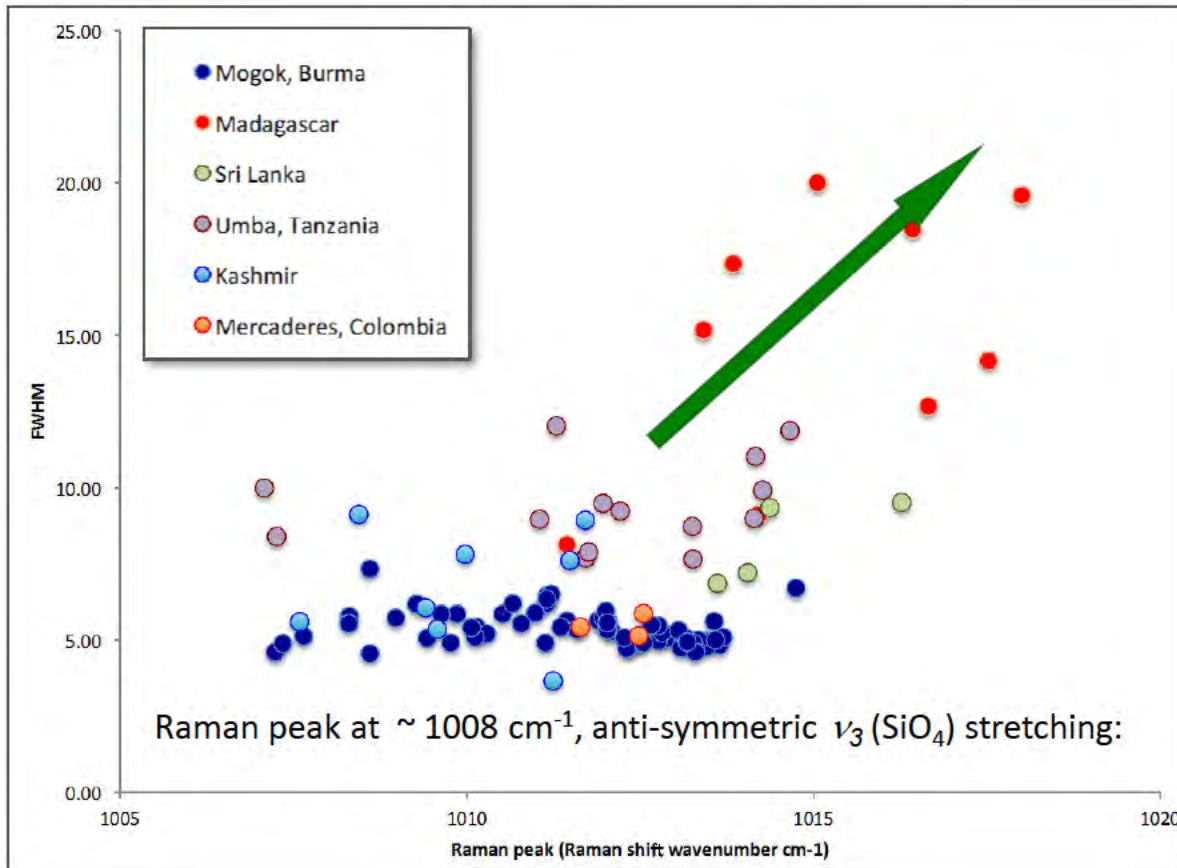
tiny prismatic zircon inclusions in sapphires from Bemainty near **Ambatondrazaka (Madagascar)**, visually quite similar to zircons in Kashmir sapphire

The Kashmir – Madagascar Challenge



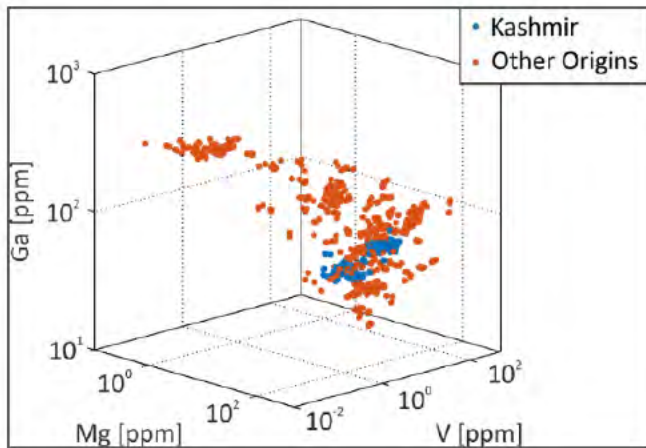
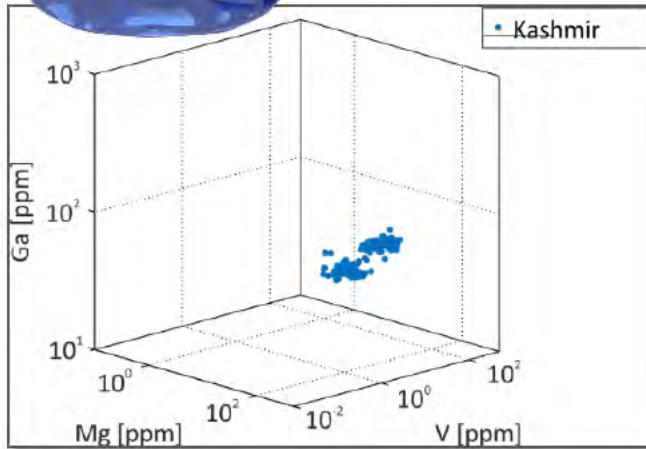
The Kashmir – Madagascar Challenge

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

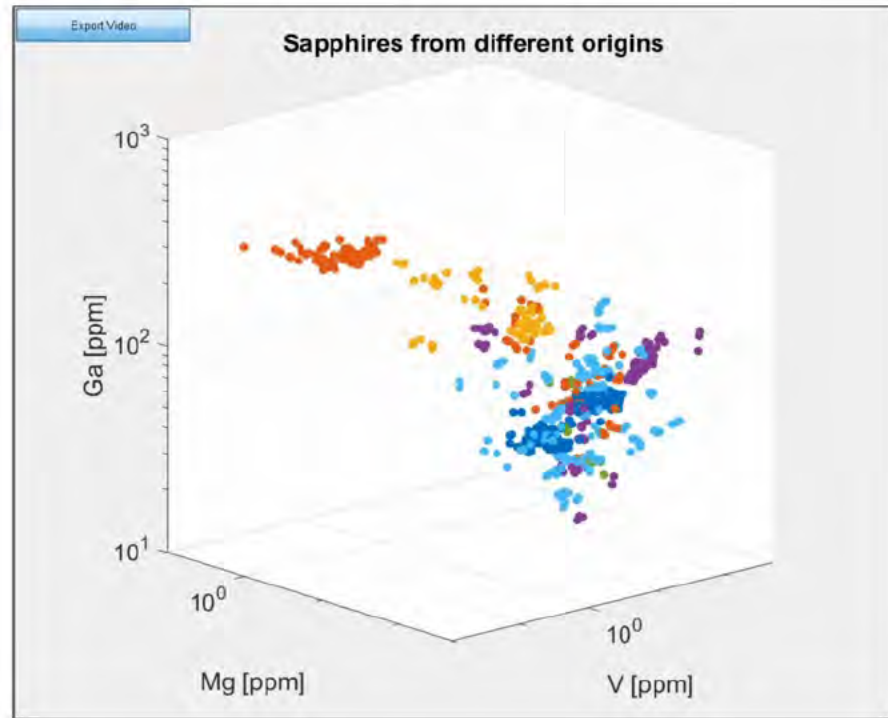


increase in metamictisation

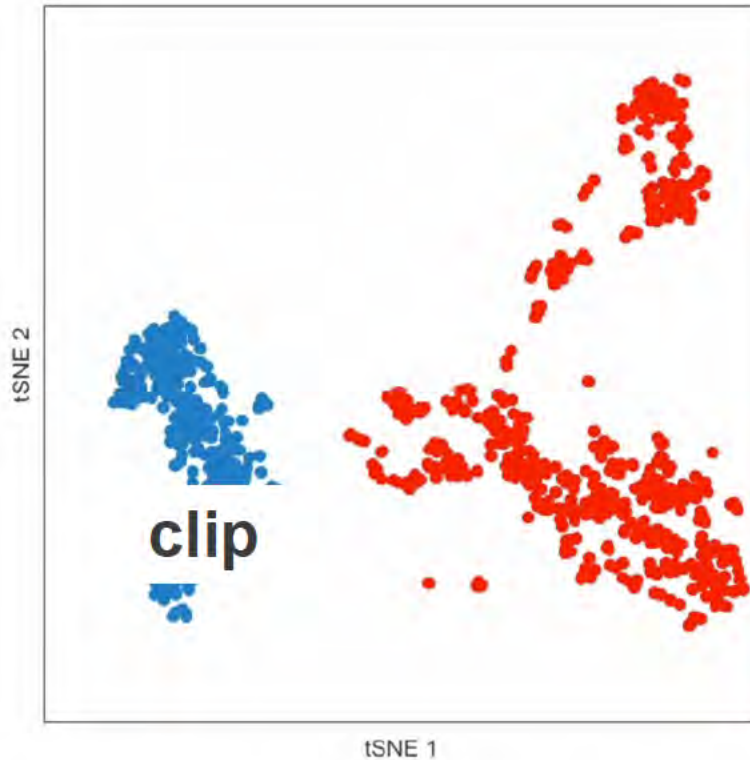
The Kashmir – Madagascar Challenge



GemTOF (Laser Ablation ICP Time-of-Flight Mass Spectrometry) is a very powerful tool to analyse trace elements of gemstones, thus supporting origin determination at SSEF.



The Kashmir – Madagascar Challenge



Trace Element Analysis for Gemstones using LA-ICP-TOF-MS and Its Application in Origin Determination using Machine Learning

Hao A.O. Wang, Michael S. Krzemnicki

Swiss Gemmological Institute SSEF, Aeschengraben 26, CH-4051, Basel, Switzerland
hao.wang@ssef.ch

Summary

We apply LA-ICP-TOF-MS (Pb:1000000 + Ag:1000) in quantitative trace element analysis of gemstones. Benefiting from fast mass spectral acquisition (from 100 to 300), a pre-defined list of interested isotopes is not required. This feature is particularly helpful when unexpected heavy appearing elements in gemstones shall be recorded, or when inclusion with unknown chemical composition shall be analyzed. A mass resolving power of 3000 (m/z for 238U) is sufficient to separate and allow correction of common interferences. Due to a low detector background, TOF MS increases its capability of detection (LOD) for heavy isotopes (e.g. 238U) to 100 ng/g LOD for light isotopes (e.g. Li+), which extends level of gemmological application research.

In an industrial case study, we compare performance of multivariate data visualization of blue sapphires from Kashmir and Madagascar using principal component analysis (PCA) and machine learning (ML). A clearer separation between sapphires from these two origins can be seen on data visualization using machine learning algorithm than PCA. Furthermore, subgroups are formed within origin of Madagascar samples in the machine learning plots. Detailed study of subgroups to extract common features in microstructure, physical and chemical properties, may help understanding gemstone formation mechanisms and trace gemmologists with complementary information in origin determination of sapphires.

Acknowledgement

We would like to thank the Board of the Swiss Foundation of Gemstone Research (SSEF) for their support in this project at the SSEF laboratory. The Swiss Association of gemstones dealers (ASG) is appreciated for their generous donation. Thanks also to the active SSEF team for their support of this project and for fruitful discussion.

Introduction

LA-ICP-TOF-MS has recently gained wide attention, mainly due to unique features of simultaneous full mass spectrum acquisition as well as ultra-fast data acquisition speed. As a result, it has shown strong capabilities in applications, which require multi-element detection within short transient signal events, for example high spatial resolution chemical imaging on biological and geological samples. In this work, we focus on the methodology development for routine analytical analysis, and show the capability of LA-ICP-TOF-MS in assigning origin determination of sapphires.

Characterizing fast gemstone changing tasks determining the origin of sapphires conventionally when they are not well understood. Often, sophisticated and existing characteristics indicators, or being overlap closely for conventional analytical methods, therefore trace element analysis is critical in providing complementary information. In our market case, it was negative result brought a gem deposit claim to Antananarivo, Madagascar into focus (Figure 1) (Pferber, 2016; Krzemnicki, 2017). Materials found in this area has shown similarities in quality and extraordinary trace (Figure 2). In addition, some of these materials may experience unusual behavior of trace element signatures, which is several times more expensive than the market. Careful mineralogical investigations are needed to appreciate these Kazakhstan materials. Stable isotope analysis, trace element analysis obtained from LA-ICP-TOF-MS, can bring better evidence and help gemmologists increase confidence of origin determination. Accurate origin determinations issued by independent gemmological testing laboratories is critical in maintaining sustainability and transparency of the gem trade market.



Instrument Settings

Parameter	LA-ICP-TOF-MS (Pb:1000000)	ICP-TOF-MS (Pb:1000000)
Laser wavelength	193 nm	193 nm
Laser fluence	5 J/cm ²	Mass resolving power (FWHM 238U)
Laser frequency	20 Hz	Mass spectrum range
Spot diameter	15 µm, 100 µm, 500 µm	238U + 232Th
Resolution	Spot analysis	232Th/190 + 232Th +
Pre-saltator	None	138U + 171Lu
Background + Ablation signal	30 s + 50 s	
Carrier gas	Helium 5.0-0.5/min	



Photo: DesiTOF platform at SSEF an LA-ICP-TOF-MS instrument see www.gemtest.ch

WinterPlasma Conference, January 2018

Using **machine-learning** algorithms, the statistical difference between the multivariate trace element data of "Kashmir-like" sapphires from Madagascar (**in red**) and those of Kashmir sapphires (**in blue**) can be visualized even more clearly.



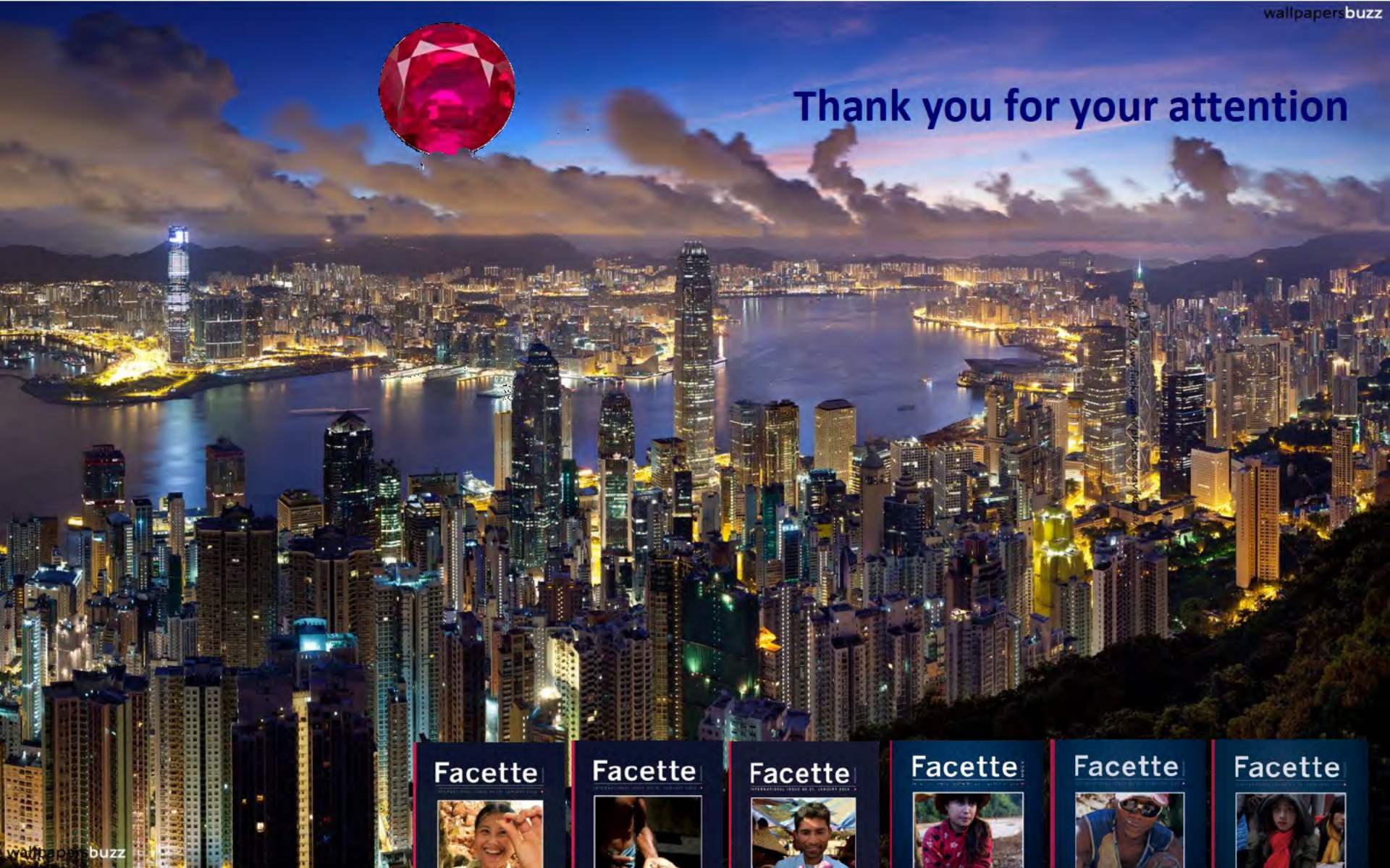
New gem deposits will be discovered in the future and provide exciting options for the trade but also challenges for gem labs.

But the trade has also a responsibility to strive for a respectful and sustainable mining and supply chain including a correct disclosure towards the consumers.

Gem Labs will assist the trade in these issues.



Thank you for your attention



wallpapersbuzz

A row of six Facette SSEF posters. Each poster features a different photograph of a child and includes the following text:

- Facette**
- International Trade Fair | January 2018
- SSEF**