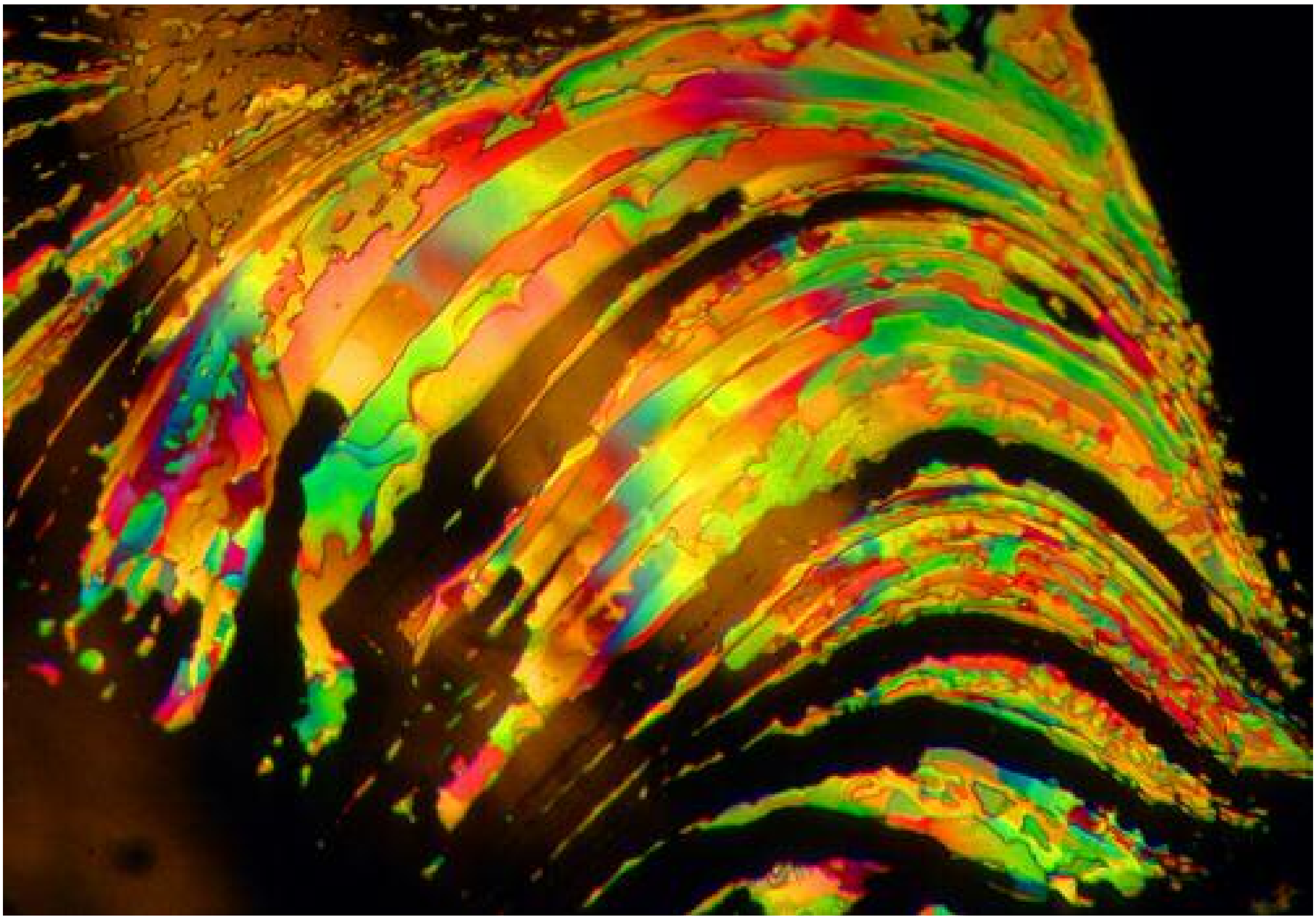


The Inside Story on Topaz

by H. Albert Gilg and Rainer Thomas

The internal features of a crystal, often microscopic, are a doorway to understanding its physical, chemical, and geological conditions of formation. Cavities containing fluid and/or mineral grains or exhibiting growth and deformation structures provide clues to the evolution of minerals that are intriguing and significant to gemologists and petrologists alike. The former group uses characteristic internal features to identify gem materials (or fakes), determine natural or synthetic origins, suggest a provenance (country, region, even a mine), and identify treatments or enhancements, such as irradiation, heating, or surface coating and diffusion (page 79). In contrast, petrologists study inclusions in topaz to understand topaz-forming processes in natural environments. They are interested in the type and composition of the media, such as magmas, hydrothermal solutions, supercritical fluids, or vapors, from which the topaz crystallized. With the help of inclusion studies, petrologists can determine pressures, temperatures, and mechanisms of topaz formation (page 14). Despite their different points of view, gemologists and petrologists both study the same minute objects with the same passion and precision.

Topaz is "less lavishly endowed with the variegated wealth of diagnostic and locally specific inclusions than some of the other gem minerals," said Eduard Gübelin and John Koivula in the second volume of their *Photoatlas of Inclusions in Gemstones* (2005), the "Bible" of gemstone inclusionists. Nevertheless, topaz forms in a range of geological settings, and the internal features of the mineral can thus be quite distinctive.

Methods of Study

The microscope has historically been the principal instrument used to study the internal world of minerals, and using it some characteristic minerals and fluids can be determined unambiguously. However, many inclusions cannot be conclusively identified using the microscope alone. More elaborate methods, such as X-ray diffraction (XRD) or electron microprobe analysis (EMPA), have been used for the past 60 years to enlarge the list of minerals included in topaz.

For XRD studies, the included mineral must be exposed to the surface, and a small sample must be scraped off for analysis. Although the method yields valuable information on crystal structure, it is of limited use to gemologists, as it requires that the sample be, at least to some degree, destroyed. An electron microprobe provides chemical information on solid inclusions at or just below the surface of the mineral, but it is unable to detect some of the critical light elements such as lithium, boron, and beryllium so common in the topaz environment. Thus, some of the topaz inclusions documented in earlier studies, such as those compiled by Hoover (1992), Menzies (1995) or Schwarz (1997), were wrongly identified and many of the minerals later found included in topaz were absent from their lists.

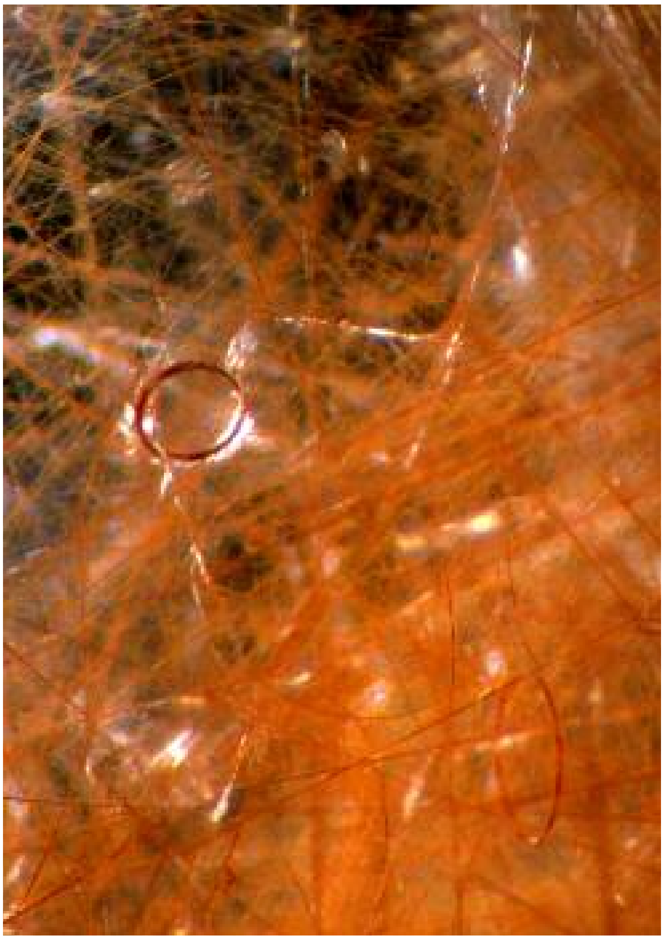
The advent of Laser micro-Raman spectroscopy at the end of the twentieth century has revolutionized not only the identification of solid and fluid inclusions but also the determinations of water content in silicate melt inclusions. The method is noninvasive, nondestructive, and precise. Raman spectroscopy does not require special sample preparation or a vacuum chamber, and it allows for a spatial resolution of about 1 cubic micrometer (μm^3). The downside is that some purely ionic crystals such as halite or sylvite show no Raman effects. Nevertheless, Raman studies have identified the surprisingly common presence of sassolite, the solid triclinic boric acid (H_3BO_3); zabuyelite, an otherwise rare lithium carbonate (Li_2CO_3); and beryllonite ($NaBePO_4$) in multiphase fluid inclusions of pegmatite-hosted topaz crystals. Solid inclusions in topaz were trapped as preexisting (protogenetic), simultaneously crystallizing (syngenetic), or subsequently formed (epigenetic) inclusions.

The list of solid mineral inclusions in topaz (page 90) shows the most recent update, although it may propagate some misidentifications from early studies. Many "rutile" inclusions in topaz have shown to be etched dislocation channels filled epigenetically by iron oxides, but rutile has unambiguously been identified in Schneckenstein (Germany) topaz. The list (page 92) of solid daughter minerals that crystallize from included fluids is based primarily on studies by one of the authors (RT) but includes results from a few other studies as well.

Topaz in Rhyolites

Two forms of topaz occur in fluorine-rich rhyolites: 1) tiny, unappealing phenocrysts, which grew in magma chambers in the Earth's crust prior to eruption and 2) beautifully colored and sometimes large crystals in cavities that condensed from hot magmatic vapors at the surface. The silicate melt inclusions in the former are studied by petrologists seeking the absolute contents of volatile species (water, fluorine, chlorine, sulfur, and carbon dioxide) in the magmas before eruption in an attempt to evaluate, for example, the environmental impact of past volcanic events or to determine the depth of the magma chamber. Very often the melt inclusions are glassy and can be analyzed directly, but they are sometimes crystallized and must be remelted and then quenched to a homogeneous glass for analysis.

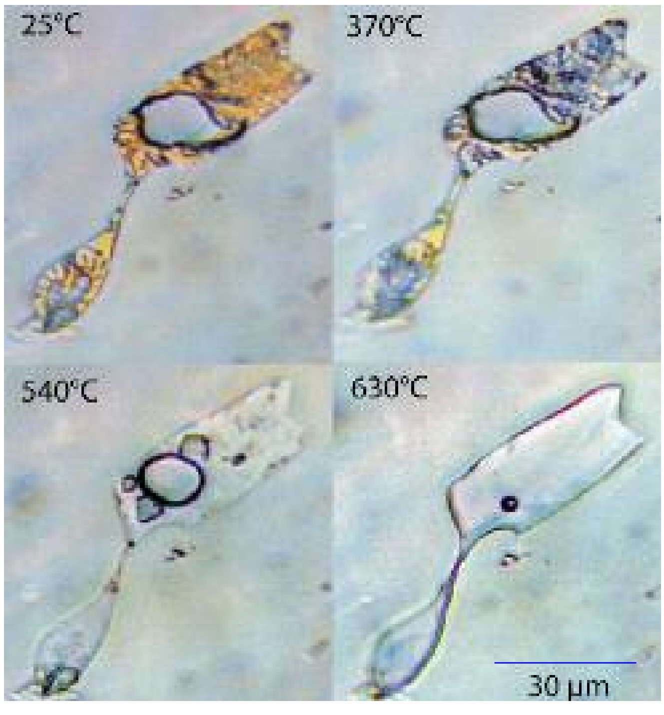
Gemologists, on the other hand, investigate the latter type of rhyolite-hosted topaz. These crystals typically accommodate inclusions of euhedral alpha-quartz, hematite, pseudobrookite, and very rarely bixbyite. The enclosed fluid phase is an aqueous vapor, sometimes with attached daughter minerals and rare silicate melt inclusions.

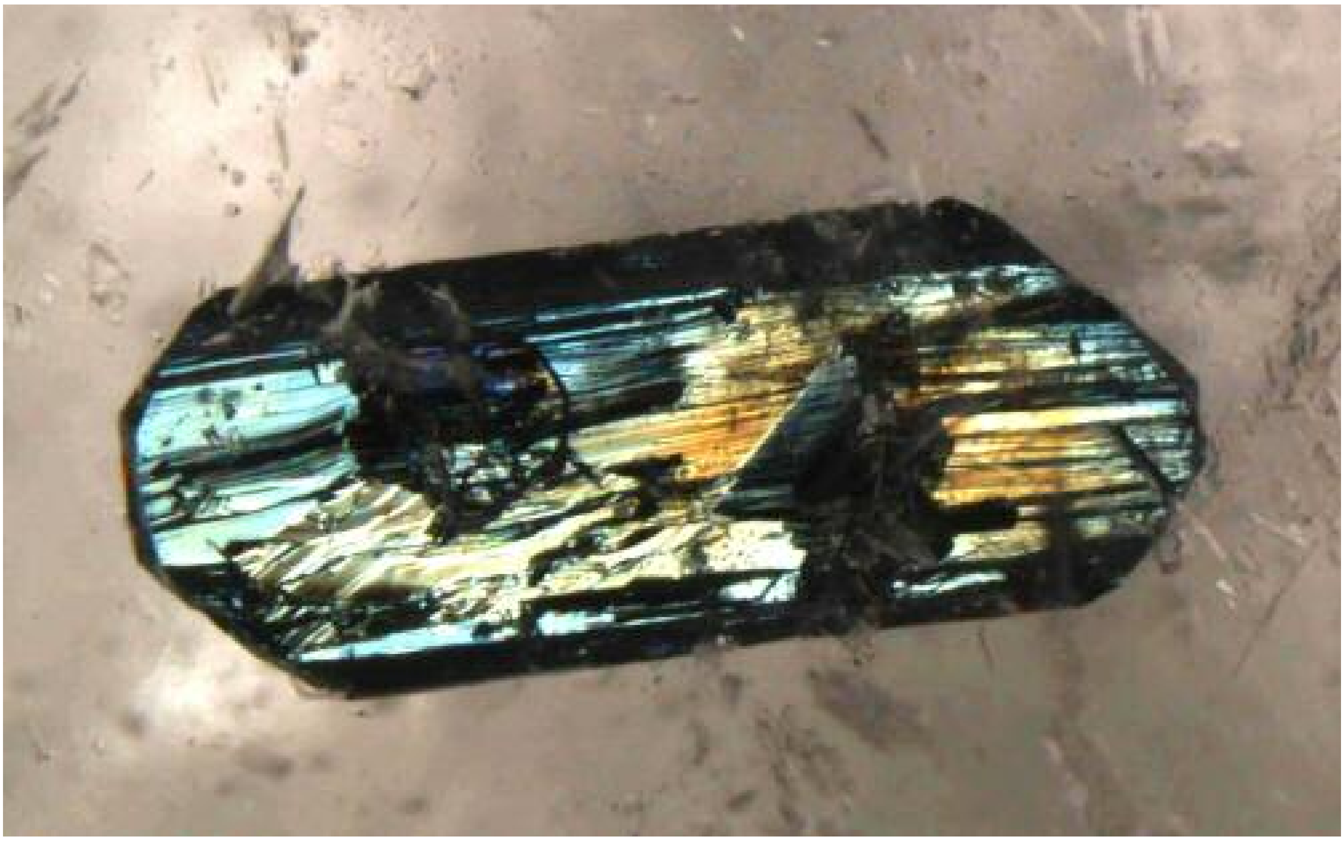


Above: Topaz with goethite alteration rings and etched dislocation channels (10x)
Tepetate, San Luis Potosí, Mexico; John Koivula photo

Below: Progressive heating of melt inclusions in rhyolite topaz
Thomas Range, Utah; Rainer Thomas photo

Facing page: A thin film on a partly healed cleavage in topaz, 30X
Tepetate, San Luis Potosí, Mexico; John Koivula photo





Topaz in Pegmatites and Granites

Most topaz comes from a pegmatitic or granite-related environment. Recent studies on fluid and melt inclusions in pegmatitic topaz have not only detected a bewildering diversity of accidentally trapped minerals, fluid inclusions, and daughter minerals but also shed light on the often puzzling origins of pegmatites.

Pegmatites appear to have crystallized from very water-rich and alkali-rich melts, which were often enriched in fluxing agents such as boron, fluorine, and phosphorus. Volatile-rich melts may show melt-melt immiscibility during cooling, with the formation of a water-poor, highly viscous, aluminum-rich silicate-rich melt, coexisting with a very low-viscosity, boron-, alkali- and water-rich melt. Both melt types may produce crystals in topaz-bearing rocks. They may further unmix during cooling, exsolving saline brines, low-salinity aqueous solutions, or even carbonic fluids. They may also react with and thus metasomatize earlier formed rocks or wall rocks and may even quench to gel-like bodies that crystallize slowly.

The complexity of these processes and their superposition makes the reliable classification of topaz types from the granitic-pegmatitic environment very difficult. For example, much topaz in granites is conventionally interpreted as a late-stage product, formed by processes such as greisenization or by autometasomatic fluid-rock interaction. However the observation of volatile-rich silicate melt inclusions indicates that such topaz often is formed from a hydrous silicate melt. Thus, petrologic terms commonly used to describe topaz such as “pegmatitic,” “greisen,” “vein,” or “pneumatolytic” should be used with caution unless the samples have undergone proper inclusion analysis.

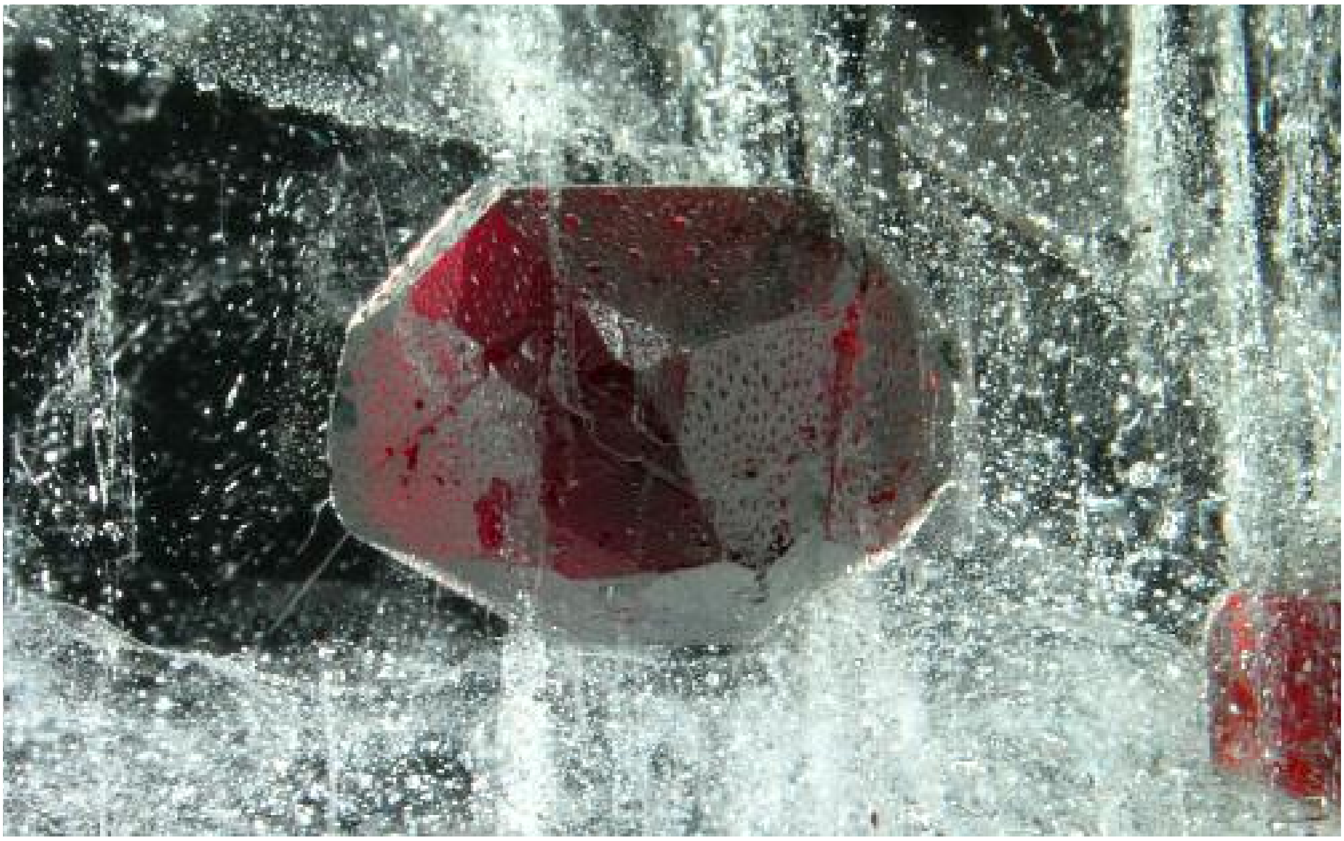
Solid Mineral Inclusions in Topaz

actinolite	fluorite	pyrochlore
albite	goethite	pyrophyllite
apatite	helvite	pyrrhotite
arsenopyrite	hematite	qitianlingite
biotite	hornblende	quartz
bismuth	ilmenite	rutile
bismuthinite	kaolinite	sanidine
bixbyite	kyanite	spessartine
brookite	lepidolite	sphalerite
calcite	magnetite	topaz
cassiterite	(mangano)columbite	tourmaline
chalcopyrite	(mangano)tantalite	tremolite
chlorite	monazite	varlamoffite
chloritoide	muscovite	wavellite
cubanite	phenakite	wolframite
dolomite	phlogopite	zinnwaldite
feldspar	protolithionite	zircon
(fluor)apatite	pseudobrookite	

Nevertheless, highly saline, multiphase aqueous fluid inclusions with associated vapor-rich, often carbon dioxide-bearing, inclusions are characteristic for topaz from shallow granites, pegmatites, and associated rocks. Some typical solid inclusions in topaz from this environment include feldspars (orthoclase and albite), muscovite and other, lithium-bearing white micas, biotite, apatite, columbite, tantalite, cassiterite, wolframite group minerals, fluorite, and spessartine.

Hydrothermal Topaz

Chromium- and vanadium-bearing, gem-quality, colored topaz occurs in veins from carbonate-rich metamorphic rock units near Kātlang (Ghundao Hill) in Pakistan and Ouro Prêto



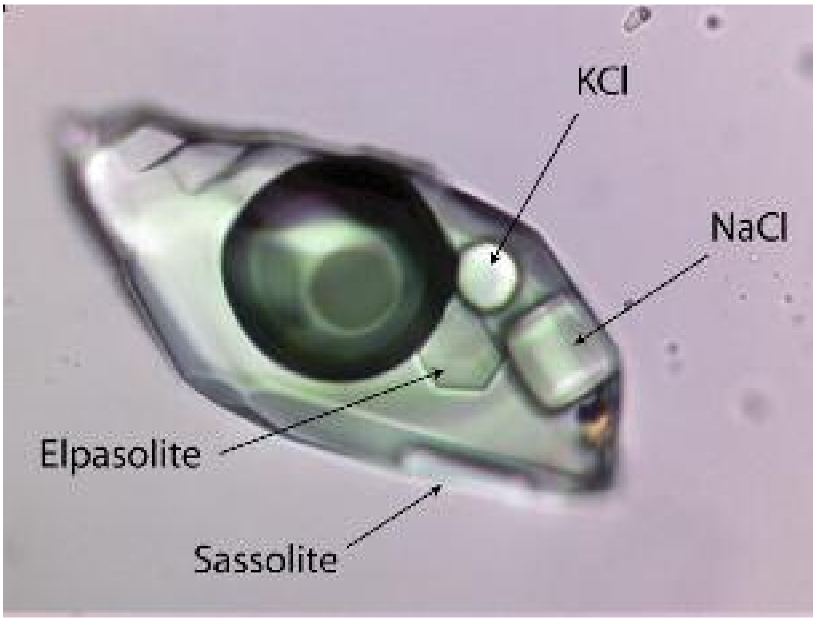
Above: Spessartine (5.07 mm long) inclusion in topaz from Brazil

Below left: Manganotantalite daughter crystal in a primary fluid inclusion in topaz from Pakistan (15x)

Below right: Fluorite in topaz from Nigeria (10x)

Facing page: Columbite (2.62 mm long) inclusion in a pegmatitic topaz from Gilgit-Baltistan Province, Pakistan

All of the photomicrographs on this spread are by John Koivula.



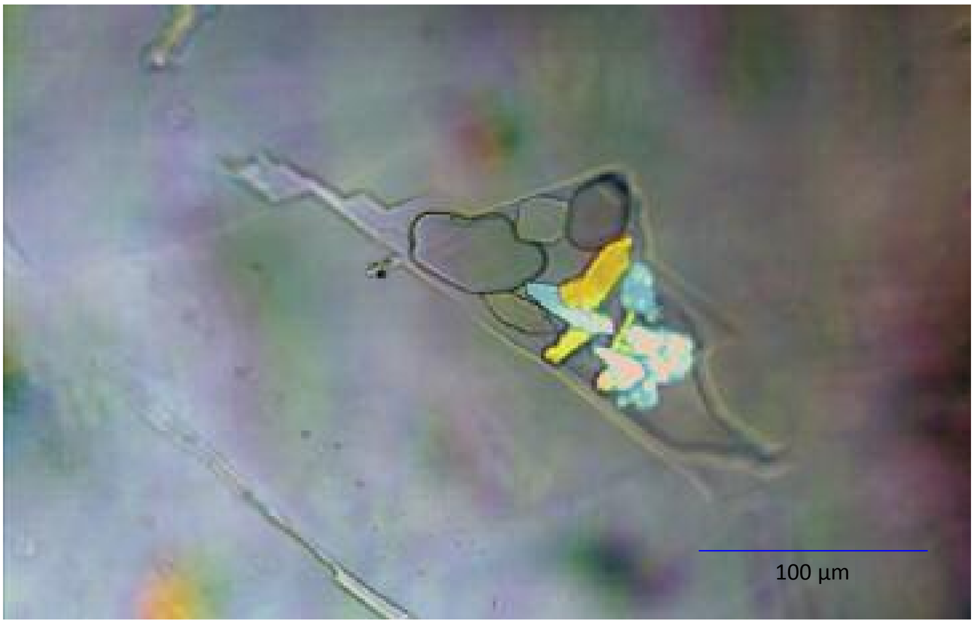
Daughter Crystals in Fluid and Melt Inclusions in Topaz

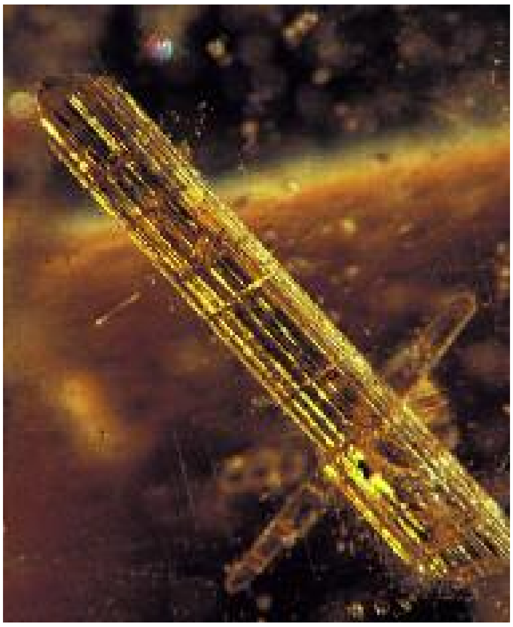
albite
amblygonite
anhydrite
apatite
avogadrite
bakerite
berborite,
bertrantite
beryl
beryllonite
borax
calcite
cassiterite
chondrodite
cristobalite
cryolite
cryolithionite
elpasolite
euclase
halite
hambergite
hematite
hieratite
K_2BeF_4
kaliophilite
kalsilite
lacroixite
muscovite
nahcolite
orthoclase
phenakite
protolithionite
pyrrhotite
quartz
ramanite-Cs
sassolite
siderite
sphalerite
sulphur
stannite
sylvite
teepleite
tungstite
ulexite
villiaumite
wavellite
zabuyelite

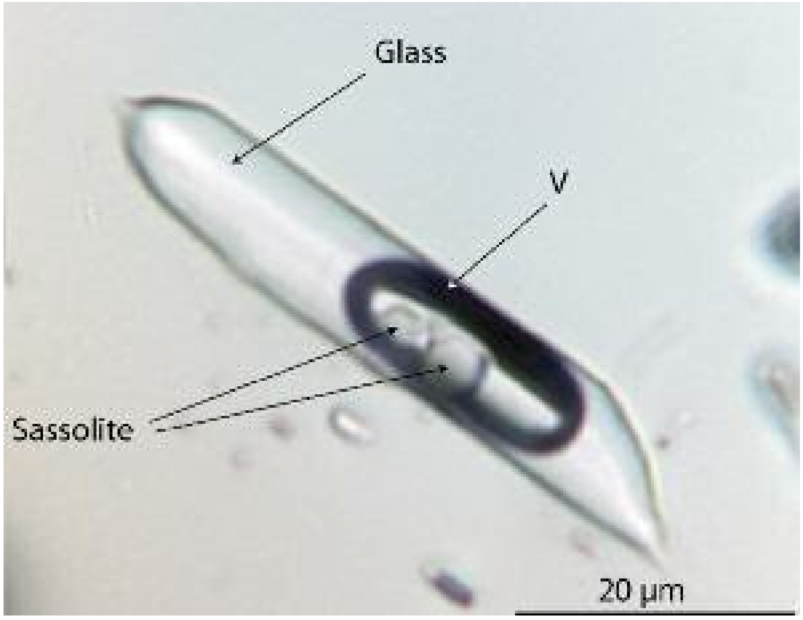
Top: Complex fluid inclusion in topaz with unknown birefringent daughter crystals (80x)
St. Anne's Mine, Zimbabwe
John Koivula photo

Middle: Complex fluid inclusion in topaz with sassolite, elpasolite, potassium chloride and sodium chloride daughter crystals
Rainer Thomas photo

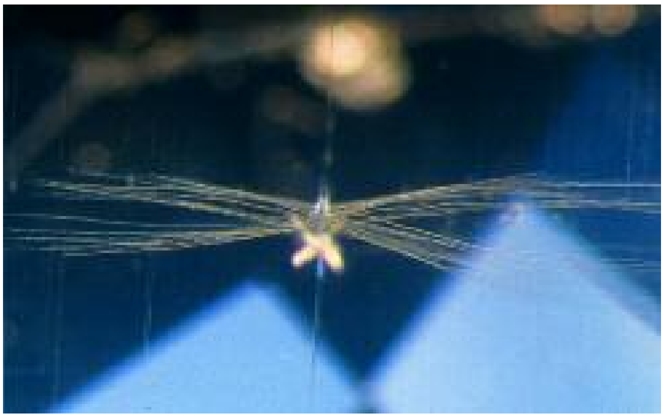
Right: Brine inclusion in topaz from the Schneckenstein (Saxony, Germany) greisen deposit
Rainer Thomas photo







in Brazil (page 60). Similar crystals are found along the Sanarka and Kamenka river valleys in the southern Urals of Russia (page 68). Topaz from these deposits contains typically three-phase aqueous-carbonic fluid inclusions with homogenization temperatures of less than about 320 degrees Celsius. Carbonates, such as dolomite or calcite, are characteristic solid inclusions, but fluorite is never observed. Some inclusions of low-grade metamorphic minerals, such as pyrophyllite or chloritoid, have been described from the Brazilian deposits. It has been, thus, suggested that these hydrothermal veins were formed during regional metamorphism, but further studies are warranted. Topaz from all of these environments formed at significantly lower temperatures than that from in rhyolitic or pegmatitic environments and thus shows higher hydroxyl (OH) contents (page 14).



Metamorphic Topaz

Topaz crystals with the highest hydroxyl contents (35 to 55 molecular percent) have been found in high-pressure (HP) and ultra high-pressure (UHP) metamorphic kyanite-quartzites of the Sulu orogenic belt in Eastern China. This metamorphic topaz frequently contains kyanite inclusions, while the associated kyanite contains coesite, a high-pressure polymorph of quartz. The metamorphic hydroxyl-rich topaz formed during subduction of continental crust to depths of more than 100 kilometers with pressures of about 3 gigapascals (GPa), 30 kilobars, and temperatures up to 800 degrees Celsius. Hydroxyl-rich topaz can be an important carrier of water into the mantle.

Treatments and Enhancements

Although topaz has been synthesized in the laboratory, synthetic topaz does not play an important role in the gem trade. Irradiation and heat, however, are often applied to artificially improve the color of natural topaz (page 79). In some cases, these treatments conspicuously alter the colors of fluid inclusions and daughter minerals. They also can cause acicular inclusions with fracture disks extending from them.

Just for fun (**upper left**): Topaz crystal in quartz from Ouro Prêto, Minas Gerais, Brazil (26x); Eduard Gübelin photo

Upper right: Melt inclusion in topaz from the Schneckenstein (Saxony, Germany) greisen deposit; Rainer Thomas photo

Middle right: Topaz showing irradiation and/or heat-treatment induced acicular inclusions extending from an internal cleavage plane (10x); John Koivula photo

Bottom right: Heat-treatment and/or irradiated-induced decrepitation disk (2.9 mm in diameter) surrounding a pyrochlore octahedron inclusion in topaz; John Koivula photo

Gilg, H.A. and Thomas, R. (2011) The inside story on topaz. In: Topaz, Perfect cleavage, Eds.: Clifford, J., Falster, A.U., Hanson, S., Liebetrau, S., Neumeier, G., Staebler, G., extra-Lapis No. 14, 88-93