



**In conjunction with the Mineralogical Society of America and the Tucson Gem & Minerals Society®, Friends of Mineralogy is pleased to announce the 44<sup>th</sup> Annual Tucson Mineral Symposium**

*Red, White, and Blue minerals: Let us celebrate*

**Saturday, February 14, 2026  
from 10 AM to 3:30 PM.**

**The 44<sup>th</sup> Tucson Mineral Symposium**

**West Meeting Rooms 102/103  
Tucson Convention Center, Tucson, AZ**



### **Acknowledgments**

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# **The 44<sup>th</sup> FM-TGMS-MSA Tucson Mineral Symposium**

**Theme " Red, White, and Blue minerals: Let us Celebrate"  
Saturday, February 14, 2026,**

**West Meeting Rooms 102/103  
Tucson Convention Center, Tucson, Arizona**

10:00 AM Opening of symposium

10:00-10:15 AM Introduction by symposium chair, **Mark Jacobson**

10:15 – 10:45 AM John Stuart McCloy, **Cuprorivaite: Egyptian Blue,  
humanity's first inorganic pigment.**

10:45 - 10:55 AM break

10:55 - 11:55 AM Johan Maertens, **Heaven and Hell in Ohio** [about Celestine].

**11:55 - 1:00 PM Lunch**

1:00 – 1:40 PM Donald A. Dallaire, **New Hampshire's Red, White & Blue  
Minerals .**

1:40 – 1:45 PM break

1:45 - 2:15 PM John Rakovan, **Pleochroism in minerals.**

2:15 - 2:20 PM break

2:20 – 2:50 PM Markus Raschke, **An ocean within – new insights into  
structure and phases of water in minerals.**

2:50 – 2:55 PM break

2:55 – 3:25 PM Bruce Kelley, **Finding Art in Minerals: How an interest in  
color and form ignited my passion for minerals.**

3:30 PM close of symposium

## Cuprorivaite: Egyptian Blue, humanity's first inorganic pigment

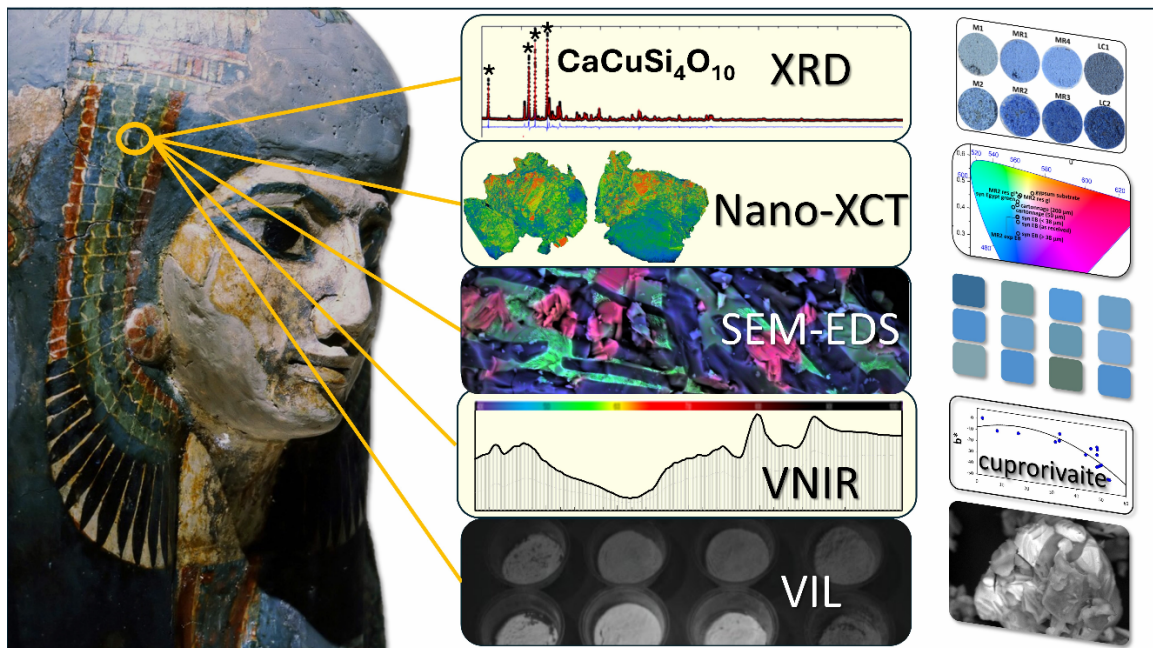
John S. McCloy,  
School of Mechanical & Materials Engineering,  
Washington State University

Egyptian Blue (EB), first made over 5,000 years ago, is the world's earliest synthetic pigment. It is based on the blue mineral cuprorivaite ( $\text{CaCuSi}_4\text{O}_{10}$ ), related to barium copper silicates (effenbergerite, colinowensite) also known from antiquity as Chinese blue and purple.

To fabricate EB, artisans heated sand, lime, copper minerals, and alkali to create a brilliant blue thought to symbolize eternity and the heavens, adorning tomb walls, statues, and pottery. Later, Romans used it in mosaics, frescos, and buildings. Its use declined after 600 CE but survived into the Renaissance. Rediscovered in the 19th–20th centuries, cuprorivaite was shown to have unique optical and magnetic properties, making it promising for modern applications in biomedicine, telecommunications, lasers, and security inks.

Recently, our group at Washington State University, with the Carnegie Museum of Natural History and the Smithsonian Museum Conservation Institute, recreated EB to uncover the science behind its color, ranging from gray or green to deep blue. We produced 12 versions of EB and compared them with artifacts, using advanced X-ray techniques, spectroscopy, and quantitative color measurements. We found EB is a complex mixture of phases, with hue controlled by particle size, glass content, and cuprorivaite–silica ratios. Even small changes in materials or heating could dramatically shift its color.

These findings reveal ancient craftspeople as skilled materials scientists. Beyond cultural insights and conservation, Egyptian blue's infrared glow continues to inspire modern technologies, linking past creativity with future innovation.



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### John S. McCloy, speaker biography



Dr. John S. McCloy is Professor and Director (Department Head) of the School of Mechanical & Materials Engineering and Lindholm Endowed Chair in Materials Engineering at Washington State University (WSU), and a joint appointee at Pacific Northwest National Laboratory (PNNL). His professional career includes academia (WSU, 12 y), national laboratory (PNNL, 5 y), and industry (Raytheon, etc., 10 y). At WSU, he leads the Nuclear, Optical, Magnetic, & Electronic (NOME) Materials Lab and the Crystals and SemiConductors (CASC) group, both within the Institute of Materials Research (IMR). These groups develop materials solutions for energy, environment, and security applications. Over his career, he has worked on diverse engineering problems, including cryogenics, composite structures, telescopes, optical ceramics, magnetic nanoparticles, ancient materials technologies, nuclear fuels, single crystal growth, and glass development for optics and immobilization of radioactive

waste. He holds degrees in Materials Science & Engineering (MSE) from the Massachusetts Institute of Technology (BS) and the University of Arizona (MS, PhD), as well as an MA in Anthropology from Arizona. He is co-author of over 300 journal articles, book chapters, conference proceedings, public reports, and patents. He is a Fellow of the American Ceramic Society, a Fellow of SPIE the optics and photonics society, an elected member of the Washington State Academy of Sciences, and a Fulbright Scholar. In whatever spare time there is left, he enjoys reading, hiking, music, mineralogy, foreign languages, and board games with his family.



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## Heaven and Hell in Ohio

Johan Maertens

Ohio

[Mr.Calcite@live.com](mailto:Mr.Calcite@live.com)

Attendees get to enjoy an audio-visual lecture about one of Ohio's common minerals. Celestine or celestite, is a mineral, the (anhydrous) sulfate salt of strontium. The mineral derives its name – for its occasional delicate blue color - from the Latin word caelestis meaning celestial, which in turn is derived from the Latin word caelum meaning sky or heaven. Celestine occurs as crystals, and also in compact massive and fibrous forms. It is mostly found in sedimentary rocks, often associated with the minerals gypsum, anhydrite, and halite. The mineral is found worldwide, usually in small quantities. Pale blue crystal specimens are found in Madagascar and in the Midwest USA.

Did you know that the bodies of Acantharea - a group of radiolarian protozoa - are made of strontium sulfate crystals, unlike those of other radiolarians which are made of silica. Celestine and the carbonate mineral strontianite are the principal sources of the element strontium, commonly used in fireworks and in various metal alloys. We descend from heaven and go underground to the largest known celestine geode located near the village of Put-In-Bay, Ohio on South Bass Island in Lake Erie.

Note: While the lecturer prefers the name celestite, celestine is the approved name for this mineral by the International Mineralogical Association Commission on New Minerals and Mineral Names (CNMMN). Although celestite finds frequent usage in some mineralogical texts, the name has been discredited as a valid mineral name by this organization.

### Johan Maertens, speaker biography

A lifelong naturalist and passionate collector, **Johan Maertens** is a citizen-scientist mineralogist based in Ohio, USA, best known for his specialization in calcite. His fascination with the natural world began in childhood and evolved to a focused interest in minerals, culminating in decades of collecting and studying calcite in all its diverse forms and crystal habits.

He is a dedicated member of the international mineral community since the late 1970s. His calcite inventory, ranging from micromounts to large cabinet specimens, reflects a lifelong pursuit of both beauty and crystallographic precision. Now in the “senior citizen” phase of collecting, he dedicates much of his time to curating the inventory to a collection and studying crystal forms, building 3D models, and applying a system he calls the “5 Ds” to responsibly downsize and refocus his extensive holdings. Beyond minerals, he is an active volunteer in several mineralogical and community organizations, a committed hiker, and a family cook.

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## New Hampshire's Red, White & Blue Minerals

Donald A. Dallaire

829 Candia Rd.

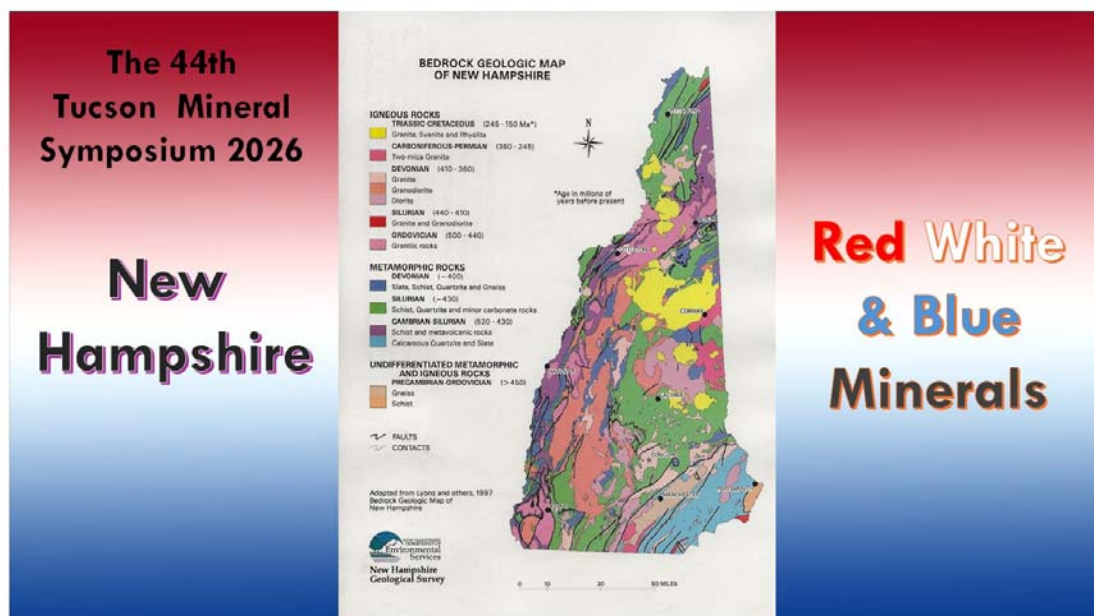
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New Hampshire is a small state but has 367+ confirmed mineral species (Mindat accessed 2025) placing it as the 33<sup>rd</sup> state with the most mineral species in the United States. The abundance of species can be attributed to past geological events including the formation of the super continent Pangea approximately 300Ma and subsequently as it broke up approximately 200Ma. The coalescence of Pangea was responsible for a number of orogenic granites and LCT (Lithium, Cesium, Titanium) class pegmatites and the subsequent breakup resulted in anorogenic granites and NYF (Niobium, Yttrium, Fluorine) class pegmatites as described in Černý and Ecrít's (2005) revision of pegmatite classification. Most of New Hampshire rocks are metamorphic and there are a

few hydrothermal veins that contain sulfide minerals, but pegmatites are the host of most mineral species. Consequently, in this review, the majority of the minerals presented are from pegmatites.



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### Don Dallaire, speaker biography



**Don Dallaire** was born in Manchester, New Hampshire and has lived in Chester, New Hampshire since 1971. He received a BA from St. Anselm's college in 1967 and an MBA degree from the University of New Hampshire in 1970. He had a career in banking for 38 years, retiring in 2008 giving more time to devote to his interest in minerals. His mineral collecting began in 1971 when a coworker showed him pictures of a recent vacation with a mine in the background. When told the vacation included collecting minerals at old mines his curiosity led him to join in on the next collecting trip. That began 55 years of collecting minerals. He has specialized in apatite and New Hampshire minerals. His

current collection of 5600+ catalogued specimens includes approximately 1000 apatites. Don has field collected in New England, New York, Michigan, California, Arizona, and Eastern Canada. He has written several articles for Rocks & Minerals magazine as well as other publications and has given many talks to mineral clubs in New England. Don is a member of the MP<sup>2</sup> Research Group at the Maine Mineral & Gem Museum in Bethel, Maine.



## Pleochroism in Minerals

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Pleo (many) chroic (colors), could be used to describe several phenomena mineralogy, however, the term pleochroic is used very specifically in mineralogy to describe the variation in color observed in a mineral when it is viewed along different crystallographic directions. Many minerals show pleochroism, and an excellent example is seen in the tanzanite variety of zoisite (Fig. 1). If one searches for a definition to the term pleochroism, however, they will find two



related but distinctly different definitions among reliable sources. The first is the definition given above. The second is the property of a crystal of showing different colors when viewed by light polarized in different directions (or something similar).

**Figure 1.** Tanzanite crystal (variety of zoisite), from the Merelani Hills, Tanzania; 3.8cm high. In this composite image, the crystal is seen along three different directions, all illuminated with unpolarized white light. In the upper left, you are looking along the *a* crystallographic axis, and the color is purple. In the middle right, you are looking along the *b*-axis, and it is distinctly blue. When looking down the *c*-axis, lower left, it appears red. This is an example of trichroic pleochroism, or simply trichroism. Mike Keim specimen. Jeff Scovil photo.

The term "pleochroism" was coined by the German mineralogist Wilhelm Haidinger (1795-1871) in his article "Ueber den Pleochroismus der Krystalle" (On the Pleochroism of Crystals) published in *Annalen der Physik und Chemie* in 1845. Haidinger therein introduces the term pleochroism for the first time, but in German, pleochroismus. In that paper Haidinger discusses pleochroism as the variation in a crystal's color when viewed along different crystallographic directions, and in unpolarized light.

Pleochroism, however, can be enhanced if polarized light is used in the observation of a crystal. In polarized light microscopy, especially using a polarizing light microscope, pleochroism is also used to describe a related, but subtly different, observation than the variation in the color of a crystal with varying directions of observation. When observing pleochroism in

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polarized light, especially in a thin section on a petrographic microscope, one is typically looking in only **one** direction relative to a crystal in the section. One then rotates the crystal relative to the fixed plane of polarization of the light source. In this context, we see a change in color as a function of polarization direction, not the direction of light propagation.

### John Rakovan, speaker biography



**Dr. John Rakovan** is a mineralogist and the Senior Mineral Museum Curator at the New Mexico Bureau of Geology and Mineral Resources, Socorro, NM, and an Adjunct Professor in the Department of Geology and Environmental Earth Science, Miami University, Ohio. John has been a mineral collector for more than fifty years, and it was collecting that opened his eyes to the science of mineralogy. His current collecting interests are heavily influenced by his research, much of which focuses on apatite and apatite supergroup minerals. John has been an executive editor of and regular contributor to *Rocks & Minerals* magazine since 2001. He is a fellow of the Mineralogical Society of America (MSA), a recipient of the Carnegie Mineralogical Award, and the eponym of the decavanadate mineral rakovanite.

## An ocean within – new insights into structure and phases of water in minerals

Markus B. Raschke

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We live in a water world. Seventy-one percent of the earth is covered by water. We humans are composed of approximately 60% water. When it rains, or snows, or does neither, a prominently visible hydrological cycle of surface and atmospheric water unfolds in front of our eyes every day. However, yet less visible, there is another *oceans'-worth of water* that lies beneath our feet. From the crust to the core the earth hosts an abundance of water. This deep water cycle controls from subduction and plate tectonics, to magmas and volcanism, and metamorphism. And with hydrothermal circulation giving rise to the formation of ore deposits, water plays a critical role in mineral formation, not only as a solvent, but also as agent controlling crystal growth, habit, and chemistry.

An associated process is *mineral hydration* which describes the incorporation of water into the crystal structure, either as OH<sup>-</sup> anions by, e.g., conversion of an oxide into a double hydroxide, or the incorporation of molecular water directly into the crystal lattice, either as integral part of the structure, or occupying vacancy sites. These processes control the formation, structure, composition, stability, and other properties of many mineral species.

Upon crystallization from a hydrous fluid, many minerals incorporate water into their crystal structure and typically in a well-defined stoichiometric ratio. Prominent examples are gypsum  $\text{CaSO}_3 \cdot 2\text{H}_2\text{O}$ , epsomite  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ , or borax  $\text{Na}_2[\text{B}_4\text{O}_5(\text{OH})_4] \cdot 7\text{H}_2\text{O}$ . Also, talc, zeolites, chlorite, muscovite, serpentine, and a range of biominerals contain variable amounts of water. Of technological importance is the hydration reaction giving cement its strength, and its intriguing ability to harden even when submerged in water.

However, many of the underlying processes of water in mineral formation are yet poorly understood [1]. This is associated with the yet poorly understood properties of water itself. This is exemplified by its many unusual properties that are fundamentally distinct from most other substances: Upon freezing water expands, rather than contracts. It has a very high heat capacity. It is one of the strongest polar liquids; for the

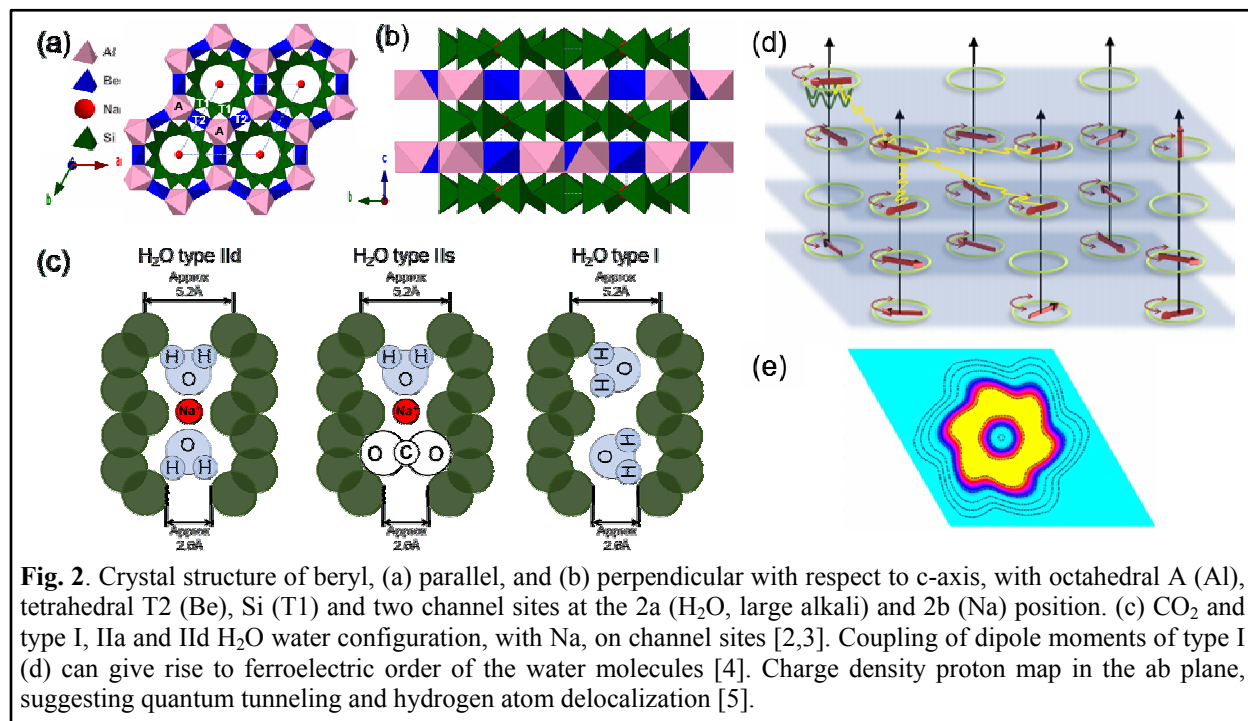


**Fig. 1.** Beryl (var. aquamarine) with cassiterite. Xuebaoding, 21.0 x 13.0 x 10.0 cm. Collection MIM museum. Photo James Elliott. The blue color is associated with Fe<sup>2+</sup> substitution. Beryl can contain several weight % water in its structure.

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molecular size it has a very high melting temperature; nearly universal solubility; and an exceptionally complex variety of thermodynamic phases.

These *anomalies of water* make water different from any other molecular substance. They result from its unique inter-molecular hydrogen bonded network. Conversely this highly fluctuating network and associated variations of local structure, make the study of elementary properties of water very difficult.



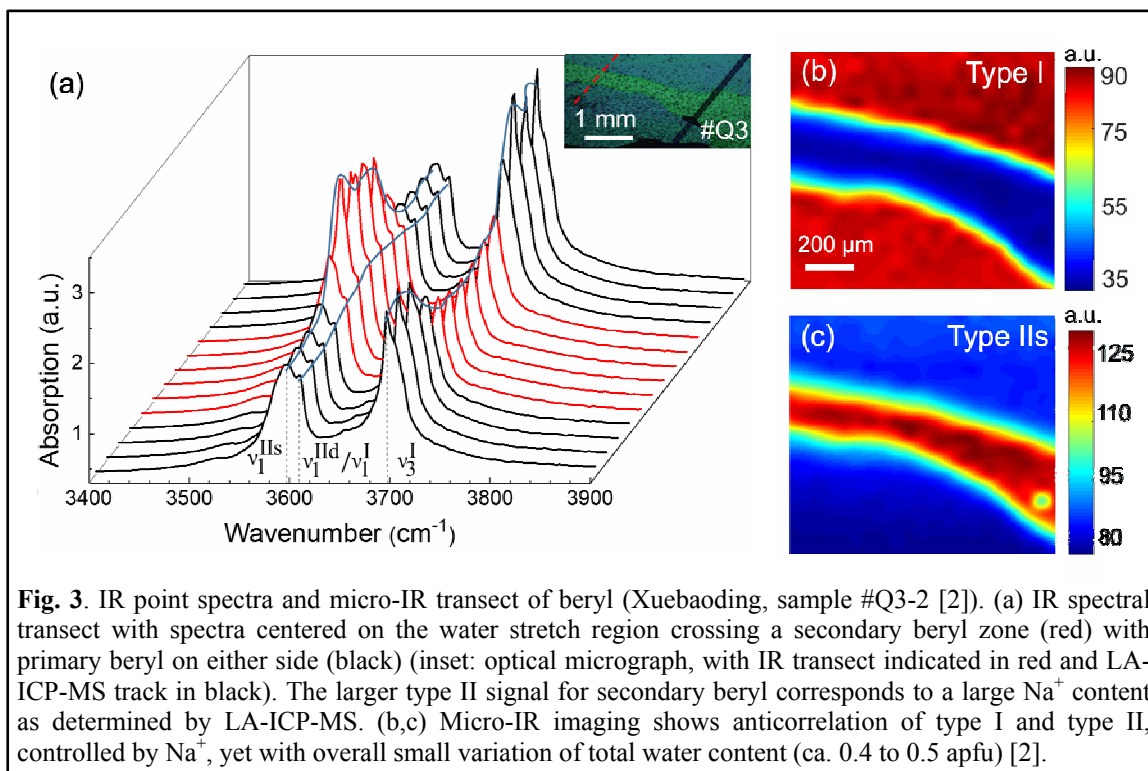
In this talk, I will provide both an overview of the field of water in mineral structures and discuss results from our studies of water in beryl Be<sub>3</sub>Al<sub>2</sub>Si<sub>6</sub>O<sub>18</sub> (**Fig. 1**). In beryl six-membered rings of Si tetrahedra form channels parallel with respect to the crystallographic c-axis (**Fig. 2a,b**). This open cyclosilicate framework of just the right dimensions provides for weakly bonded yet defined lattice sites for water molecules, thus prevented from hydrogen bonding in contrast to liquid water or ice. As shown in **Fig. 2c** water on the C1/2a sites has been defined as type I or type II with its molecular dipole moment orientated perpendicular or parallel with respect to the c-axis, respectively. The preference for each type, specifically, the amount of type II water is controlled by doping, where the oxygen ions of the silica tetrahedra bind, e.g., an alkali ion, which in turn defines the water molecular orientation by electrostatic interaction.

Providing a lattice of isolated water molecules, beryl has attracted considerable recent attention with the discovery of several exotic properties. In the absence of hydrogen bonding, yet with defined dipole interaction of the water molecules, a low-temperature ferroelectric ordering of crystal water was discovered based on the electric dipole-dipole interaction [4] (**Fig. 2d**). Even more unusual was the discovery that the hydrogen atoms of the water molecules do not behave classically as illustrated in **Fig. 2c** having defined spatial positions. Instead, quantum tunneling leads to a delocalization of the protons in the ab-plane over all six symmetrically equivalent channel positions around the c-axis (**Fig. 2e**).

I will discuss how we use this system of *isolated water molecules both as a laboratory to study elementary properties of water itself, as well as to advance our understanding of beryl hydration and hydrated minerals in general*. In this work we apply a combination of conventional

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vibrational infrared (IR) and Raman micro-spectroscopy and -imaging, with new nonlinear and coherent spectroscopy techniques. Probing the vibrational response of molecular vibrations of water, and using the symmetry selectivity of the IR and Raman response (similar to birefringence and dichroism in optical microscopy) we can determine molecular orientation and zoning in natural samples of beryl. As example **Fig. 3a-c** shows results from micro-IR spatio-spectral imaging of natural beryl from Xuebaoding. Based on IR absorption cross section and XRD a C1 site water content of 0.4–0.5 apfu is derived, i.e., close to 50% site occupancy. Secondary crystal phases with a decrease in Fe and Mg, yet increase in Na, suggest early crystallization of aquamarine, with goshenite being late [2].



In ongoing work, we combine electron microprobe analyses (EMP) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) with single-crystal X-ray diffraction (XRD), correlated with Raman and micro-infrared (IR) spectroscopy and imaging, to further quantify lattice position, molecular orientation, bonding state, and dynamics behavior of water in different natural and synthetic beryl crystals. For this work we introduce the application of the novel technique of infrared (IR) scattering scanning near-field microscopy (*s*-SNOM) for the study of water in mineral structures. IR *s*-SNOM extends spatial resolution of micro-IR spectroscopy and -imaging from the 10's micrometer to the 10's nanometer, resolving spatial heterogeneities of water type and content on the nanoscale [6]. Nano-IR spectroscopy using *s*-SNOM further extend selection rules and symmetry selectivity of IR spectroscopy with respect to the different crystallographic phases of water, and with femtosecond ( $10^{-15}$  seconds) laser excitation, we demonstrate active control of the molecular orientation through optical alignment.

In summary, this talk provides a tour about water from its fundamental properties in common mineral systems to the forefront of the field of mineral and nano-analytical instrumentation science.



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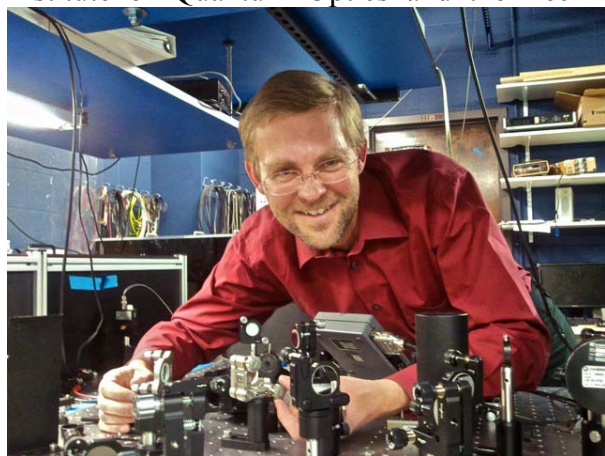
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## Markus Raschke, speaker biography

**Markus Raschke** is professor at the Department of Physics at the University of Colorado at Boulder. His research is on the development of novel nano-optical spectroscopy and microscopy techniques with applications to single molecules, quantum materials, and fundamental control of light matter interaction. Based on a long personal interest in field collecting minerals his research also ventured into geology and mineralogy, with projects in Washington, Colorado, and the Sichuan Mountains in Tibet/China. He received his PhD in 2000 from the Max-Planck Institute of Quantum Optics and the Technical University in



Munich,  
Germany.  
Following

research positions at the University of California at Berkeley, and the Max-Born-Institute in Berlin, he became faculty member at the University of Washington, followed by his appointment in Boulder in 2010. He is fellow of the Optical Society of America, the American Physical Society, the American Association for the Advancement of Science, and The Explorers Club.



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### Finding Art in Minerals: How an interest in color and form ignited my passion for minerals.

Bruce Kelley

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Objective: Illustrate how the fields of mineralogy and art overlap in the aesthetic space.

Outline:

1. Introduction
  - a. Why minerals?
  - b. My background
    - i. Science and technology
    - ii. Art study
2. Form
  - a. Form in art vs. form in mineralogy
  - b. Examples of interesting forms
3. Color
  - a. Slide show of colorful minerals with discussion of artistic considerations including depth of focus, composition, color, etc.

Conclusion: This is not a typical scientific talk, but more of an artistic appreciation of science. Expect eye candy!



**Caledonite** from **the** Rowley Mine, Painted Rock District, Maricopa Co., AZ  
FOV: 1.4 mm

## Bruce Kellley, speaker biography



**Bruce Kelley** is passionate about sharing his love of art and science. A retired software engineer, he has been exploring the micro-landscapes of tiny mineral crystals since 2008 and enjoys developing methods for photographing them. Bruce is a board member for the Pacific Northwest chapter of Friends of Mineralogy. He is also a classical musician, playing French horn in

the Port Angeles Symphony and Port Townsend Symphony and was one of the founders of the Northwest Mahler Festival. When those avocations aren't enough, Bruce works for the non-profit poetry publisher Copper Canyon Press. He is living his ideal "renaissance guy" life on Marrowstone Island in Washington State. You can see more of Bruce's photos at [LithoCat.com](http://LithoCat.com).

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# Notes



# Notes

