photo by Matt McGill

THE 40TH TUCSON MINERAL SYMPOSIUM

MINERALS OF THE APATITE SUPERGROUP AND MINERAL FLUORESCENCE

Saturday, February 12, 2022,
Tucson Convention Center, Tucson, AZ

ACKNOWLEDGMENTS

The Friends of Mineralogy executive board, including Alexander Schauss, Linda Vanegas-Smith, and Bruce Bridenbecker, has been very supportive of proceeding with this symposium, as have our co-sponsors, the Mineralogical Society of America represented by J. Alex Speer and Ann Benbow, and the Tucson Gem and Mineral Society, represented by Pat McClain. *Mineral News*, managed by Tony Nikischer, *Rocks & Minerals*, managed by Marie Huizing, and the *Mineralogical Record*, managed by Wendell Wilson, all helped with providing publicity for the symposium. Erin Delventhal and Matt McGill are appreciated with creating the publicity notices.

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SCHEDULE

▶ 10:00 AM • OPENING & INTRODUCTION

10:15 – 10:45 AM

DANIEL E. HARLOV

"Apatite and fluids: pseudomorphism, mineral inclusions, and mineral formation." (remote talk from Europe)

10:50 - 11:20 AM

JOHN RAKOVAN

"The Sauberg Mine, type locality of fluorapatite, and the recognition of apatite as a distinct mineral species."

11:25 – 11:55 AM

MADELINE MURCHLAND* AND JOHN RAKOVAN

"Fluorescence spectroscopy of apatite."

12:00 - 12:30 PM

EVAN SMITH

"Decoding the colors and patterns of fluorescence in Diamond."

▶ 12:30 - 1:30 PM • LUNCH

1:30 – 2:00 PM

PETER MEGAW

"The apatite supergroup minerals from Mexico."

2:05 - 2:35 PM

MARKUS RASCHKE

"The fluorescence of scheelite from Xuebaoding, Sichuan Province, China."

2:40 – 3:10 PM

RAY GRANT

"Vanadinite in Arizona."

▶ 3:10 – 3:25 PM • EXTENDED BREAK

3:25 – 3:55 PM

BILL STEPHENS

"Pyromorphite from the world-famous Phoenixville District lead mines, Chester County, Pennsylvania."

4:00 – 4:30 PM

THOMAS LOOMIS

"Apatite occurrences in the Black Hills, South Dakota."

4:35 - 5:05 PM

NICOLAS HEBERT

"Orange fluorescent minerals from Mogok: from the scapolite – feldspathoid bearing marbles to hackmanite." (remote talk from Australia)

5:10-5:40 PM

GLENN WAYCHUNAS*, GEORGE ROSSMAN, AND MICHAEL GAFT

"Electronic defects as activators of luminescence in minerals: overview and examples of novel fluorescence and tenebrescence."

APATITE AND FLUIDS: PSEUDOMORPHISM, MINERAL INCLUSIONS, AND MINERAL FORMATION.

DANIEL E. HARLOV

Apatite is the most common phosphorous- and fluorine-bearing mineral in the Earth's crust. It is found in sedimentary rocks, metamorphic rocks, igneous rocks, and various ore deposits – sometimes as a primary mineral. It is also a mineral that can be affected by fluids. This means that when apatite encounters various fluids in the Earth's crust its composition can be changed and other minerals, such as monazite, xenotime, and pyrrhotite, can form as inclusions in apatite from elements inherent in the apatite. In addition, apatite can replace other minerals as pseudomorphs as it can be replaced by these same minerals. In this talk I will be showing how apatite as fluorapatite and chlorapatite can be affected by fluids and what the results are. I will be using relatively sophisticated analytical equipment such as scanning electron microscopy and electron microprobe analysis to describe how apatite can be altered by fluids and how mineral inclusions can form in apatite.

Daniel E. Harlov is a research scientist at the Deutsches GeoForschungsZentrum, Potsdam, Germany, a visiting Professor in the Department of Geology, University of Johannesburg, Johannesburg, South Africa and a visiting Chair Professor in the Faculty of Earth Resources, China University of Geosciences, Wuhan, China. He has degrees from the University of Wisconsin-Madison and Purdue University. His research philosophy is to couple field observation with experimental replication and thermodynamic verification. Current field projects are worldwide and focus on the role of fluids during a wide variety of geological processes. Current laboratory projects focus on mineral-mineral and mineral-fluid equilibria and mineral alteration (apatite, monazite, xenotime, allanite, zircon, titanite, garnet, feldspars, scapolite, oxides, sulphides) under a broad range of P-T-X conditions.

THE SAUBERG MINE, TYPE LOCALITY OF FLUORAPATITE, AND THE RECOGNITION OF APATITE AS A DISTINCT MINERAL SPECIES.

JOHN RAKOVAN
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Because apatite is fairly common, it is not surprising that it has been collected and used since antiquity. Beads of apatite have been found at the Neolithic archeological site of Çatalhöyük that date to the 6th millennium BCE (Baysal 2016). What is surprising is that apatite was only recognized as a distinct mineral in the late 18th century (Werner 1788). This is in part because it is easily confused with other minerals, hence the name apatite (coined by Werner) that is derived from the Greek word απατάαο, which means "to deceive." The specimens Werner analyzed and described were fluorapatite from the Sauberg Mine, Ehrenfriedersdorf, Germany; making it the type locality for the species.

In Ehrenfriedersdorf mining for tin (cassiterite) dates back to the 13th century. Initially, miners exploited tin placers. This was followed by underground mining of hydrothermal vein, greisen, and skarn ores. These are associated with granites that were emplaced during the Variscan orogeny and date between 350 and 330 Ma.

The Sauberg mine played an important role in the history and technology of mining. It was the first and largest tin mine in Germany and the innovative water pumping system developed here, the Ehrenfriedersdorfer Kunstgezeug, was described by Georgius Agricola in his book *De re metallica* (1556), and went on to be used in mines worldwide, for more than two hundred years.

Several periods of mining occurred over the centuries, with the last being from August 1948 until October 3, 1990, when the Sauberg mine was closed. It is during this last period of mining that many specimens seen today were probably recovered. Today the mine is open for educational tours and museums focusing on the geology, minerals and history of the deposit occupy old mine buildings.

There are several different occurrences of apatite specimens in Ehrenfriedersdorf, including the pegmatites, greisen and veins of the Sauberg mine and the quartz veins and pegmatites of the Greifenstein Rocks area. Werner's description (1788) of the apatite specimens that he analyzed clearly indicate that they were from the Sauberg and not the Greifenstein Rocks area (Weiss 2012; Meier 2013).

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Fluorapatite, fluorite, quartz, Sauberg Mine, Ehrenfriedersdorf, Erzgebirgskreis, Saxony, Germany. 11.3 x 8.5 cm. Largest crystal is 3 cm. John Rakovan specimen and photo.

Dr. John Rakovan is a professor of mineralogy at Miami University in Oxford, 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.

FLUORESCENCE SPECTROSCOPY OF APATITE

MADELINE MURCHLAND AND JOHN RAKOVAN

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The two mineralogical themes of this year's FM-TGMS-MSA symposium intersect in apatite fluorescence. In addition to a wide variety of possible fluorescence colors apatite frequently exhibits fluorescence zoning, which can be scientifically informative as well as beautiful. We have collected apatite fluorescence emission spectra from samples from a wide variety of localities and deposit types. Many of these show distinct fluorescence zoning and regions of different emission colors have been isolated in the spectra.

Fluorescence is most often the result of specific elements substituting into the crystal structures of minerals that act as activators, coactivations, or quenchers. The interactions between these elements within the structure lead to a wide range of colors and intensities of emission. Apatite, which has the general chemistry $Ca_{10}(PO_4)_6(F,Cl,OH)_2$, is commonly luminescent under UV light. This is largely due to the crystal structure of apatite, which includes multiple cation sites that are incredibly accommodating of substitutions. The most common activators of apatite luminescence are Mn^{2+}, Eu^{2+}, Eu^{3+}, Ce^{3+}, Dy^{3+}, Nd^{3+}, Sm^{3+}, and Sm^{2+}, with Pb and Sb occasionally acting as coactivators of Mn^{2+} (Waychunas 2002). Combinations of these ions along with other substitutions will distort the structure and cause shifts in the crystal field; the exact color that results can depend on what ions are interacting, the presence or absence of quenching elements, and which sites are involved. Zoning is also observable in many fluorescent apatite crystals, most commonly concentric, sectoral, intrasectoral, and patchy zoning (Rakovan 2022).

Fluorescence emission spectra can vary from broad, continuous peaks over a wide range of wavelengths to multiple sharp, distinct peaks. Subtle differences in the relative intensity of different portions of emission spectra can lead to differences in observed colors, this is often the case with zoned crystals of apatite (Fig. 2). We see broad correlations between the colors of emission that are associated with different geologic occurrences, however the activators associated with those colors cannot simply be attributed by the color alone. For example, yellow fluorescence from Mn-rich apatites, like those found in the Harding pegmatite in New Mexico, look very similar to the fluorescence of apatites from the granitic pegmatites in Pakistan and Afghanistan, yet the latter's luminescence is dominated by REE activation. However, apatites from polymetallic hydrothermal deposits, which show pink-violet to blue emission, have essentially the same spectra resulting from rare-earth activators.

Figure 1. Fluorescent apatite (on nonfluorescent magnetite), South ore body, Three Peaks, Iron Springs Mining District, Utah. Largest crystal is 3.3 cm tall.

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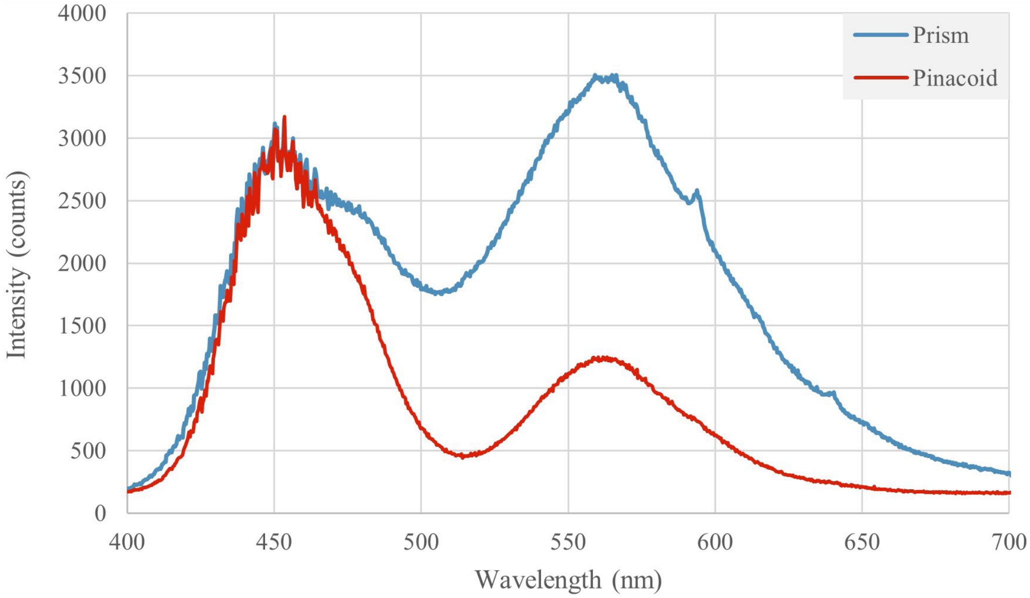

Figure 2. Emission spectra from the (001) pinacoid, blue, and (100) prism, orange, of a sector zoned fluorapatite from Llallagua, Bolivia.

Madeline Murchland is an undergraduate researcher and beginning collector. She is in her final year at Miami University in Ohio, where she is earning her B.A. in Political Science and B.S. in Geology. Madeline's research for the past three years has focused generally on mineralogy, and her most recent project is an investigation on fluorescence and zoning in apatites.

DECODING THE COLORS AND PATTERNS OF FLUORESCENCE IN DIAMOND

EVAN M. SMITH
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Diamond may not be a common specimen in fluorescent mineral collections, but it can exhibit a wide variety of luminescence characteristics. In its purest form, diamond is composed of carbon atoms alone and does not have any visible photoluminescence. However, diamond frequently has atomic scale defects that can lead to various colors of fluorescence and phosphorescence. By far the most common is blue fluorescence under long-wave UV light, caused by a nitrogen-containing defect called the N3 center. Additional colors sometimes observed span green, yellow, orange, and red. These colors are more than a curiosity, as the underlying defects responsible are a record of a diamond's geologic history and can change with the application of artificial color treatments. For this reason, quantitative spectroscopic analysis of diamond photoluminescence has become a common tool for advanced testing in gemological laboratories.

The spatial distribution of fluorescence can provide an additional layer of information to this record. With the aid of magnification, patterns in the fluorescence can reveal core-to-rim variations in defects or sectoral variations. Complex, oscillatory zonation is present in many natural diamonds, giving a sense of multiple growth episodes or pulses in the earth's mantle. Fluorescence patterns are also a useful guide for recognizing laboratory-grown diamonds. The two major technologies used to synthesize diamond, HPHT and CVD, both produce telltale growth patterns that are visible under deep UV excitation. This talk will explore some of the diverse fluorescence behaviors of diamond and their implications.

Dr. Evan M. Smith is a Research Scientist at GIA (Gemological Institute of America) who uses diamonds to explore the deep interior of the earth. With a background in geological engineering and mineral exploration, he became fascinated with the geology of diamonds in graduate school. His research demonstrates that diamonds are some of the most scientifically valuable samples of our planet. Chief among this work was the discovery that certain large and pure diamonds are formed at extreme depths, in pockets of molten metal. His findings have been published in the distinguished journals Science and Nature, as well as being featured by NPR, The Washington Post, and The Economist. Dr. Smith holds a Ph.D. in geology from the University of British Columbia and is a former GIA Liddicoat Postdoctoral Fellow.

THE APATITE SUPERGROUP IN MEXICO

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Mexico reports members of three of the five groups that comprise the apatite supergroup; with superb examples of the apatite group, decent examples of the hedyphane group and trace occurrences of the ellestadite group. No members of the belovite or britholite groups have been reported to date. Most Mexican "apatites" (s.l.) are found in hydrothermal iron or oxidized base metal deposits, but some are noted from geodes, cave deposits, fossils and meteorites.

Topping the list of the apatite group are the sharp yellow-green gemmy prismatic fluorapatites ("asparagus stone") from Cerro de Mercado in Durango. Known to the mineralogical and gemological world since the 1850s, these crystals were once so abundant that they were sold by the bucketful. When the Cerro de Mercado metallurgical plant converted from hand-sorting to magnetic separation in the 1990s, this abundant source for apatite specimens was eliminated, although large gemmy crystals continue to trickle out.

Next in importance are outstanding members of the mimetite-vanadinite-pyromorphite series. Mimetite from San Pedro Corralitos is arguably the world's best, with Ojuela and Santa Eulalia heading a long list of slightly lesser localities. Mexico's Zimapan District in Hidalgo is the type locality for vanadinite but the abundant specimens from San Carlos and Los Lamentos in Chihuahua are much better known. Pyromorphite is rare in Mexico, with the Guazapares District in Chihuahua providing the best examples.

Two localities in Mexico are important producers of apatite-related pseudomorphs. Stunning blue pseudomorphs of turquoise after stout prismatic apatite (sp) crystals up to 15 centimeters long and 7 centimeters across have come intermittently from the Cumobabi and Caridad Mines in Sonora and pale tan hydroxylapatite pseudomorphs after several unidentified but well-crystallized orthorhombic species come from the Astillero mine in Mapimi municipality. The latter are widely distributed in older collections with a wide range of amusing misidentifications of both the original and replacing species.

Members of the hedyphane group include unprepossessing hedyphane from Santa Eulalia, Ojuela and Bilbao, and attractive pale green botryoidal phosphohedyphane, associated with spectacular wulfenite, from the recently (and briefly) exploited La Morita mine in Chihuahua.

Fluorapatite, Cerro de Mercado, Durango Mexico, Peter Megaw specimen, Jeff Scovil photograph.

Dr. Peter K.M. Megaw is a *Consulting Geologist* (Ph.D. University of Arizona) and a dedicated mineral collector since first setting foot in Santa Eulalia in 1977. He moved to Tucson in 1979 and quickly joined the Tucson Gem and Mineral Society, taking on the job of Exhibits Chair for the TGMS Show in 1984. His mineral collecting has come to focus almost exclusively on Minerals of Mexico and he has spoken and written extensively on specimen localities there. A combination of the above led him to be awarded the Carnegie Mineralogical Award for 2009. More recently, his in-depth 2018 article for *Mineralogical Record* on the Santa Eulalia Mining District in Chihuahua, Mexico received the FM award for Best Article in *Mineralogical Record*. He is also a contributing editor for *Rocks and Minerals* and occasionally writes for *Mineralogical Monographs*.

FLUORESCENCE OF SCHEELITE FROM XUEBAODING, SICHUAN PROVINCE, CHINA

MARKUS B. RASCHKE

The fluorescence of scheelite ($CaWO_4$), with typically blueish-white emission under short wave UV excitation has long been known and used for its diagnostic characteristics. It is intrinsic and attributed to the $(WO_4)^{2-}$ anion itself and associated with its slight asymmetry of the WO_4 tetrahedron. However, in addition to the resulting broad spectral emission, the substitution of Ca^{2+} for REE gives rise to additional narrow spectral peaks characteristic for specific REE species, reflecting a relative abundance of different REE elements, which in turn can serve as an indicator of the environment of the scheelite formation, such as hydrothermal, pegmatite, or other origin.

In this project we perform fluorescence spectroscopy of scheelite from Xuebaoding and Pingwu to characterize their different trace element content and geochemical environments. The Xuebaoding greisen-type W-Sn-Be deposit in the Songpan-Ganzi orogenic belt in Sichuan Province, western China has long been known for scheelite, cassiterite, and beryl of exceptional size and gem quality. Together with quartz, fluorite, and minor apatite the mineralization is believed to have formed in a post-magmatic hydrothermal process associated with Mesozoic leucogranite intrusions. With the remote locality at elevations ranging from 3,900 to 4300 m in an area known for its extreme earthquakes, landslides, and vertical relief, this has long limited systematic field work and research of its geology and mineralogy. This includes mysteries of the actual number and location of, in fact, several and geographically widely distinct localities, which have traditionally been lumped together under the Xuebaoding label.

From several trips to the Xuebaoding and other localities in the vicinity since 2017, the actual origin of different species and mineral associations could be resolved. The scheelite ranges from rock and ore forming to large decimeter size crystals lining veins and cavities. With bright orange to deep red translucent crystals highly priced by collectors a wide variety, yet lesser-known range of colors from white, yellow, to grey and brown occurs, and with different crystal habits characteristic of distinct localities, some 10's km distant from the actual Xuebaoding locality group. Following our earlier work on beryl (Wang et al. 2021), I will discuss results from several field studies, and into the range of colors and fluorescence properties of scheelite from Xuebaoding and its neighboring localities.

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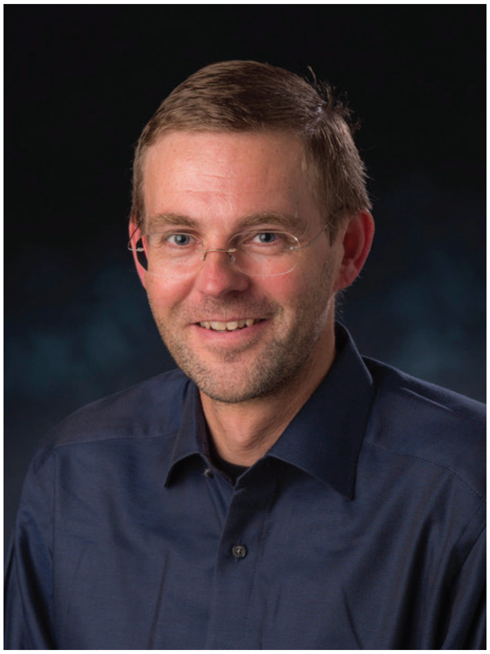
Markus Raschke is Professor of Physics and Materials Science at the University of Colorado. His research is on the development and application of new optical microscopy techniques to resolve the quantum nature of materials at the elementary scales of its atomic constituents. In parallel he pursues a scientific interest in earth sciences and mineralogy, with research in the Colorado Front Range, North Cascades of the Pacific Northwest, and the mountains of Sichuan of the Tibetan Plateau. He is also an active prospector and his combination of mineral field collecting and exploration with a scientific purpose earned him the honor of fellow of the Explorers Club.



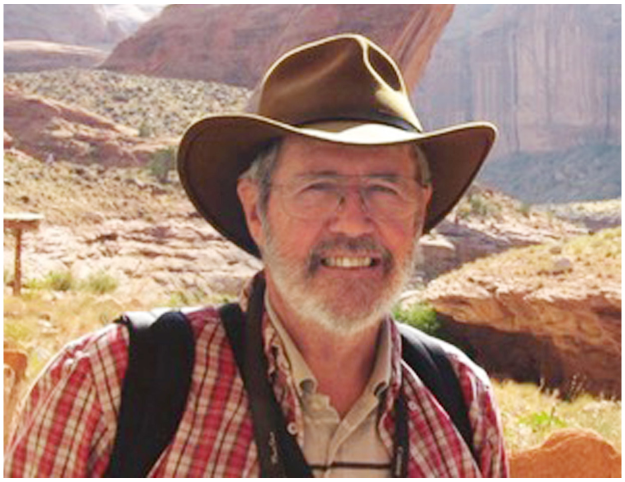
VANADINITE IN ARIZONA

RAYMOND GRANT

Vanadinite is found in 13 of the 15 counties in Arizona and well over a hundred localities have been reported. One of the earliest reports of vanadinite from Arizona is by Benjamin Silliman in the America Journal of Science in 1881. He writes about Arizona vanadinite: "I have obtained vanadinite of remarkable beauty of color and perfection of crystalline form..." and "This hitherto rare species promises now to be comparatively abundant." Geo. L. English & Co's Catalog of Minerals in 1890 has the following: "The specimens from the Hamburg and other neighboring mines in the Silver District, Yuma County, are unquestionably the most beautiful Vanadinites in the world. Mr. English visited this district in May 1889, and secured by far the largest and most varied lot of specimens ever shipped from Yuma County. As already noted our stock of Vanadinite is very large."

Over the next 50 years a large number of vanadinite localities were found and in 1942, Arthur Flagg wrote an unpublished report, Vanadium Report Book I to Book VIII for the Arizona Department of Mines and Mineral Resources. He described about a hundred localities for Arizona, essentially most of those known today. This was in response to the need for vanadium in World War II to make a hard steel alloy. Only a small amount of vanadinite has been mined in Arizona for vanadium ore.

The localities that have produced the best vanadinite specimens and are best known to collectors include the Apache Mine, Gila County; the Hamburg Mine and Pure Potential Mines, La Paz County; the Western Union Mine, Mohave County; the Old Yuma Mine, Pima County; the Grey Horse Mine, Pinal County; and the J. C. Holmes claims, Santa Cruz County. Good specimens have been found at many of the other localities but not in large amounts.



Raymond Grant is retired after teaching geology at Mesa Community College in Mesa, Arizona for 31 years. He is a co-author of the Mineralogy of Arizona, a past president of the Mineralogical Society of Arizona, past chair of the Flagg Mineral Foundation, and was cochairman of the Minerals of Arizona Symposium for 26 years. He has recently started the Pinal Geology and Mineral Museum in Coolidge, Arizona (pinalgeologymuseum.org).

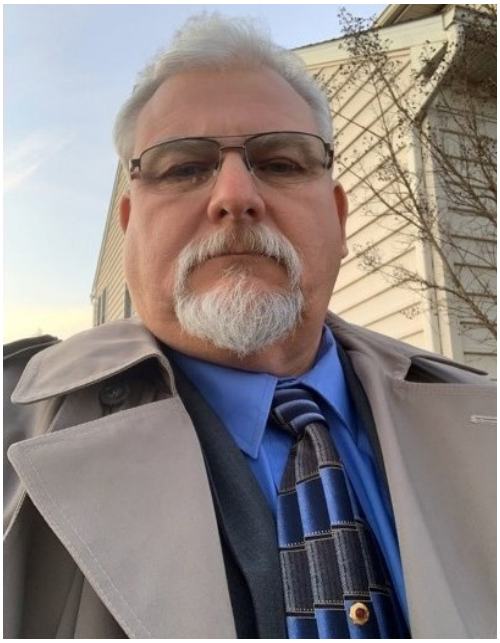
PYROMORPHITE FROM THE WORLD-FAMOUS PHOENIXVILLE DISTRICT LEAD MINES, CHESTER COUNTY, PENNSYLVANIA

BILL STEPHENS, PG

The orebodies were initially discovered by Charles Pickering who thought he had discovered silver ore and obtained a grant of 5,358 acres known as Pickering or Mine Hole Tract in 1682. Mining of lead ore, which included pyromorphite, began at the Wheatley Mine (most extensive and productive of the mines in the area) in 1850. The lead mining boom of the 1850's produced "some of the finest lead minerals the world had ever seen. Especially notable, and best known to collectors is the bright green pyromorphite from the Wheatley Mine." (Sloto, TMR, Volume 20, Sept.-Oct. 1989). Beneath the gossan, shallow zones of pyromorphite comprised the majority of the lead ore, which may account for the abundance of pyromorphite in the dumps. Many superior specimens of pyromorphite from the Phoenixville District reside in world class private and museum collections around the world.

The mines were essentially idle from the 1860's to 1917 when the Eastern Mining and Milling Company did additional mining (Southwest Chester Mine) that lasted until 1920. The Wheatley Mine was evaluated as a strategic mineral deposit in 1947-48, but no significant ore was encountered.

Today, the Wheatley dumps are on private property and are closed to collecting. The Brookdale and Chester mines reside on a Golf Course which does allow collecting. The Brookdale dumps around the old steam engine stack are picked over, but still produce micros. The Chester dumps, if one can find them, still produce nice thumbnail to small cabinet size specimens.



Bill Stephens is a licensed Professional Geologist, Current President of FM-PA Chapter and President of Stephens Environmental Consulting, Inc., a full-service environmental consulting, engineering and surveying company serving in the Mid-Atlantic Region since 1995. Bill is also a past VP of Programs for the Delaware Mineralogical Society. Bill started collecting about age 11, after being inspired by a National Geographic article on gems of the Eastern Appalachians. Family and later college buddy collecting trips focused on collecting mainly in North Carolina, with incidental trips to southeastern Pennsylvania locations including Phoenixville. More recently Bill has developed a passion for "machine digs," including Diamond Hill and Hogg Mines machine digs from which real knowledge of these deposits can be obtained. Bill uses his resources, including geological knowledge, GIS skills and drones to develop programs designed to inspire others and help provide them more tools to be more successful in their collecting adventures.

APATITE OCCURRENCES IN THE BLACK HILLS, SOUTH DAKOTA

THOMAS A. LOOMIS

The Black Hills are located in western South Dakota and are host to one of the most diverse geological environments in the world, especially when you consider their relatively small area of 100 x 50 miles. Near the center of the Laramide age uplift is Harney Peak (Black Elk Peak) at an elevation of 7,244 ft. Flanking Harney Peak are metamorphic slates and schists. Outward from and overlying the metamorphic rocks are Paleozoic to Tertiary age sedimentary formations. In the northern Black Hills are Eocene age intrusions. Historic mines can be found in nearly all of these rock formations and yield collector quality minerals from pegmatites, lode and roll front uranium deposits in the southern Hills to gold and silver mines in the northern Hills. Gold, silver, tungsten, iron, copper, tin, beryl, feldspar, lithium, mica, uranium, tantalum – niobium, and cesium have all been mined in the Black Hills. Gold and limestone are present day commodities.

Of particular interest to the collector are the many occurrences of apatite in not only the pegmatites but also in metamorphic and sedimentary rock types. Fluorapatite from the pegmatites rival those from other US localities. Purple, blue and green crystals from ¼ to 1 inch occur in the pegmatites. Primary apatite masses of over a thousand pounds were removed from one pegmatite. Yellow to dark green Fluorapatite can be found in the metamorphic rocks, while tiny, colorless crystals of perfection can be found in the mineralized Cambrian Deadwood Formation. Photos of all these localities, the many colors and forms of the fluorapatites and their mineralogy will be included in the presentation.

Tom Loomis owns and operates Dakota Matrix Minerals, a website based in Rapid City, which is devoted to collector quality mineral sales. Dakota Matrix has been online since 1998, and was one of the first mineral collecting websites on the Internet.

On a personal level Tom concentrates on the mineralogy of the Black Hills. His personal collection includes over 3,000 specimens from the Black Hills. He also maintains a large reference collection of worldwide species as well as display quality pyromorphites and minerals from Cornwall. Like many in the business, Tom started collecting in his youth at the age of 8. His love for mineralogy soon extended into geology in his early years. He enrolled at the South Dakota School of Mines in 1978 and graduated in 1982 with a BS in geological engineering. Although a native of the Chicago area, Tom was familiar with the Black Hills from several family vacations to the western states. At the School of Mines, he studied under Willard R. Roberts, professor of mineralogy, and became a serious collector of Black Hills minerals.

During the last 20 years he has discovered numerous new to the Black Hills minerals, including several from the famous Tip Top pegmatite mine, which he owns. In 1996 he re- discovered the Ross Hannibal sincosite deposit, which produced the best ever found. One of his recent discoveries includes the first authenticated sapphire corundum in the Black Hills. He has also discovered several new IMA approved mineral species. His work experience includes coal mining in Wyoming, gold mining in the Black Hills and Mexico and silver mining in Nevada.

ORANGE FLUORESCENT MINERALS FROM MOGOK, MYANMAR: FROM THE SCAPOLITE – FELDSPATHOID BEARING MARBLES TO HACKMANITE

NICOLAS HEBERT

The Mogok Metamorphic Belt is known for its strongly fluorescent rubies, however there are many more overlooked UV-reactive mineral species. The mechanism behind the orange fluorescence in scapolite and feldspathoids, and photochromism/tenebrescence (color darkens and becomes deep purple) of hackmanite has been ascribed in the literature(1) to $(S_n)^{x-}$ species (n = 2 or 3; x = 1 or 2), trapped in the host lattice concomitantly with chlorine vacancies. Current research predominantly explores the interaction of light with matter using recent advances in TD-DFT modeling. While theoretical physical chemistry studies provide a fertile ground to decipher the phenomenon behind these optical oddities, there is still room to gain understanding of the geological mechanisms required to form these minerals present across a wide range of paragenesis. From metacarbonates to syenite, the geology of the Mogok Gem Tract offers diverse lithologies. Impure spathic marble, present in Dattaw mine, hosts numerous neglected sulfur-bearing species, with either sulfur as sulfate groups as part of the structure (Cancrinite, Davyne, Haüyne), or as trace substitution in scapolite group minerals (Marialite – Meionite series, Balliranoite). Silica-deficient pegmatites in Pyant Gyi and Pain Pyit localities host sulfur-doped sodalite, known as hackmanite.

This presentation will explore the properties of these UV-reactive species from an ore genesis, petrological, geochemical and material science perspective. The discussion will cover: 1) How could meta-evaporite lenses in the protolith explain the presence of sulfate/chloride in the mineralogical assemblages lead by feldspathoids? 2) What are the genetic implications for the nearby ruby deposits? 3) What role for organic matter in enabling the reduction of sulfate to S_2^-, the activator dimer proven to be the cause of the yellow-orange fluorescence in scapolite? 4) What role for S_3^-, assumed to be responsible for the photochromism, and how can K^{40} radiation from neighboring micas and feldspars strengthen the intensity of the tenebrescence? 5) How do other mineral species in the paragenesis influence the optical properties of the S-doped sodalite? 6) How can Principal Component Analysis of multi-element data increase the understanding of this rare occurrence? 7) How is the daylight color of hackmanite linked to the intensity of its fluorescence? and 8) What influence thermal and irradiative treatments have on the luminescence/fluorescence/tenebrescence of natural hackmanite?

An extensive suite of these calc-silicate fluorescent minerals from the collection of the author will illustrate the findings and conclusions.

(1) see Stoliaroff et al. 2021, Blumentritt et al. 2020, Colinet et al. 2020, Norbo et al. 2018, 2016, and Curutchet et al. 2016.

Hackmanite, scapolite and apatite (respectively orange, yellow and colorless under UV while purple, colorless and sky blue under daylight) Pein Pyit, Myanmar, early 2020.

Corundum var. ruby/purple sapphire with yet-to-be identified bluish feldspathoid in spatic calcic marble. Dattaw, Mogok, Myanmar, found late 2019.

Nicolas Hebert is a geologist/engineer and mineral enthusiast. He graduated from Ecole Nationale Supérieure de Géologie, Nancy, France in 2018. Based in Perth, Western Australia, he presently works at the Dalgaranga gold mine, where his work encompasses exploration, resource development and production.

Previous conferences given include “The Mineralogy of the gem-bearing marbles of SE-Asia: a journey from Luc Yen to Mogok” where he discusses social, financial, legal, and logistical issues faced while undertaking field expeditions in artisanal gem-mining areas, before exploring the reasons behind similar mineralogy in those two locales, and “Blue spinels” for the 2020 Joint Mineralogical Societies of Australasia Seminar.

Even though primarily interested in mineral collecting in Vosges and Alpes massifs, he took part in paleontological collecting expeditions in Svalbard and Wyoming respectively for MHNF (Fribourg, Switzerland), and the Senckenberg museum (Germany). A significant part of Nicolas’ collection is focused on minerals from Mogok’s region and marble-hosted mineral associations.

ELECTRONIC DEFECTS AS ACTIVATORS OF LUMINESCENCE IN MINERALS: OVERVIEW AND EXAMPLES OF NOVEL FLUORESCENCE AND TENEBRESCENCE

GLENN WAYCHUNAS, GEORGE ROSSMAN AND MICHAEL GAFT

All luminescence in minerals is due to energy transfers within the electrons of specific activator elements or groups of atoms, but in some cases the activators are isolated electrons themselves. In the case of thermoluminescence, trapped electrons may be responsible for long delays in observation of luminescent activity, sometimes for years. A common example of trapped electrons controlling emission is found in willemite with trace Mn and As. The As ions can trap an electron from the excited activator Mn. When heat shakes loose the extra electron it returns to the Mn excited state, producing the green fluorescence emission. Such traps can hold electrons for minutes, hours or longer. Often electrons can be dislodged from normal sites and trapped at defect sites due to high energy radioactivity. These electrons can be thermally dislodged from the traps and excite nearby activators. Hence the well-known case of fluorite (chlorophane) thermoluminescence, and many other examples.

Fluorite can also contain defect sites with trapped electrons displaying both luminescence and tenebrescence. High Na content fluorites are particular candidates for defect electronic fluorescence (e.g., Mapimi, Mexico and MSH, Canada) as well as tenebrescence. Trapped electrons can also give rise to unusual “slow buildup” fluorescence that occurs with no observable afterglow, in hemimorphite from Skorpion mine in Namibia. Such hemimorphite may also show considerable tenebrescence. Such minerals may represent new classes of photochromic materials.

Glenn Waychunas is a Scientific Affiliate at Lawrence Berkeley National Laboratory in Berkeley, California and Visiting Scientist at the California Institute of Technology in Pasadena, California. At Berkeley, and previously at Stanford, he has been a leader in the application of synchrotron radiation techniques in mineralogy, especially with respect to sorption processes at mineral-water interfaces and the characterization of nanominerals. He has also used non-linear optical laser technology to probe mineral-water interface and aqueous solution-air interface molecular structure. His interests in luminescence stem from a trip to Franklin, New Jersey as a teenager after which he developed a passion for understanding how mineral luminescence worked. He is a fellow of the Mineralogical Society of America and has more than 200 publications related to mineralogical spectroscopy.

George Rossman is Professor of Mineralogy in the Division of Geological and Planetary Sciences at the California Institute of Technology, Pasadena, California. His principal research interests deal with the use of spectroscopic probes to study minerals and related synthetic materials. His work addresses problems relating to the origin of color in minerals, analytical methods for phase identification and spectroscopic methods for chemical analysis of minerals, particularly with regard to the role of low concentrations of water and hydroxide ion in nominally anhydrous solids. He has also studied X-ray amorphous minerals from bioinorganic hard parts of organisms and the effects of long term exposure of minerals to the background levels of radiation over geologic time. He is the recipient of the inaugural Dana Medal of the Mineralogical Society of America and Caltech's Feynman Prize for excellence in teaching. He has more than 380 publications in the mineralogical, gemological and chemical literature.

Michael Gaft is Professor and Senior Lecturer in the Department of Physics at Ariel University in Israel. He has previously held positions at the Open University in Israel as Physics lecturer, and in industry as CEO and Chief Scientist at Laser Detect Systems in Petach Tikva, Israel. He has studied the chemical characterization and spectroscopic examination of minerals his entire career, specializing in laser techniques including breakdown spectroscopy and time-resolved luminescence. His extensive luminescence studies form the basis for his textbook Modern Luminescence Spectroscopy of Minerals and Materials (with co-authors Reisfeld and Panczer), which is the largest compendium of luminescence information on minerals available.

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