DAISY MOUNTAIN ROCKCHIPS

The purpose of Daisy Mountain Rock & Mineral Club is to promote and further an interest in geology, mineralogy, and lapidary arts, through education, field experiences, public service, and friendship.

VOLUME 6, ISSUE 7 **JULY/AUGUST 2021**

Our own intrepid Stan Celestian stands at the pegmatite of the McDonald Mine, near Bancroft, Ontario, Canada. The huge orangish-pink crystals are K-Feldspar. The gray to clear mass is quartz crystals. Potassium (K) is an element that is radioactive, and whose final daughter is argon (Potassium-Argon decay). Note that there is a halo of smoky quartz around all the quartz-feldspar contacts. This is a color change caused by the radiation-induced disruption of the atomic structure of quartz. Read more about this phenomenon in the article on the Causes of Color in Minerals. *Photo by Susan Celestian*

CAUSES OF COLOR IN MINERALS

Color is probably the first thing we notice when we see a mineral specimen. But what causes those colors and their variations? We often simply say that the presence of a particular element (either integral to the mineral's composition, or as an impurity) imparts a particular color. And basically that is true, however……...

Fact: Beryl, Quartz, and Tourmaline are examples of minerals that would be clear, if not for impurities.

But technically, color is caused by the absorption of wavelengths of visible light*****, so that the light reflected back to our eyes is deficient in the wavelength absorbed. There are five main categories under which this occurs: metal ions in the chemical formula or as impurity, intervalence charge transfer, radiation, band gaps, and physical effects (diffraction, dispersion, interference, scattering). Additionally, heat could be entered as another catalyst of color change -- in association with other processes. And of course, often it is a combination of these processes that determines the color and/or depth of color. Plus the light source is a factor, as it determines what wavelengths of light are available. I'm afraid nothing is ever simple!

A mineral's color is dependent on

- **Interaction of light with atoms**
- **Wavelengths of light available**
- **Composition of the mineral**
- **Bonding strengths within the mineral**
- **Integrity of the crystal lattice**

The topic is complicated, and I've done my best to boil the processes down to their basics -- and yet it will probably remain mind-boggling in some parts. However, I'm sure some of it will stick, and I hope you gain an appreciation for the complexity of the causes of color in minerals.

* *Visible white light is composed of many wavelengths of light within the visible spectrum -- red, orange, yellow, green, blue, indigo, violet (ROYGBIV). And each wavelength represents a different energy level.*

Color continued on page 4…..

ZUNIITE

By Susan Celestian

Chemical Formula - $Al_{13}Si_5O_{20}(OH, F)_{18}Cl$
Crystal System - *Isometric (3 axes of equal length, at 90^o to each other).*
Growth Forms/Habits - *Crystalline: octahedral, tetrahedral, hexatetrahedral*
Hardness - *7*
Luster - *Vitreous*
Streak - *White*
Colors - *Clear, gray, white, pinkish*
Diaphaneity - *Translucent to translucent*
Specific Gravity - *2.88*
Cleavage - *One distinct to good*
Occurrence - *Metamorphosed alumina-rich shales and hydrothermal alteration of volcanic rocks*

Zunyite is named after the Zuni Mine, in Silverton, San Juan County, Utah, where it was discovered in 1884. In Arizona, the Big Bertha Mine (also known as Veta Grande Mine, Veta Granda claims, Crystal Caverns Claim, and Big Bertha claims), in the Dome Mountains, near Quartzsite, La Paz County has been the primary source of good large crystals in quartz. The first big rock to yield many good specimens is called the Electric Meatball Boulder.

Zunyite is quite uncommon. Localities include:

Zuni Mine, Silverton, San Juan Co., CO
Ruby Mountain, Juab Co., UT
Silver City, Juab Co., UT
Big Bertha Mine, Quartzsite, La Paz Co., AZ
San Manuel Mine, San Manuel, Pinal Co., AZ
Postmasburg Manganese Field, South Africa
Hormozgan Province, Iran
Yoji Mine, Japan
Ferdinand Adit, Banská Štiavnica, Slovakia

See Figures A-C.

Zunyite continued on page 20...

IN PERSON MEETINGS RESUME ON SEPTEMBER 7

INSIDE THIS ISSUE

Each item is now hyperlinked to the page on which it is found

Zoom Board Meeting Minutes
May 31, 2021

- In Attendance: Bill F., Bob E., Bob S., Cynthia B., Deanne G., Don R., Ed W., Howard R., Nancy G., Rebecca S., Sue C., and Tiffany P.
- Bill F. called the meeting to order
- May meeting minutes approved
- Cynthia B. went over the financials
  - Not finalized until end of month
    - (Executive meeting happened to land on the last day of May)
  - Refunds from cancelled show
    - In & Out – no way to contact
    - Royalty Rentals – no refund allowed
    - SW Barricade – will refund, possible fee
    - AZ Rentals – refund possible
  - $300 was spent for a new saw for our slab saw by Ed W.
- Tiffany P. discussed membership
  - 3 or 4 new members
  - New nametag vendor working well
    - About 1 week turn-around for orders
- Dave Haneline Mine was discussed
  - Ed W. will turn in Notice of Intent soon
- Tiffany P. gave an update to the wire wrapping class
  - 6 or 7 people showed to the first class
  - Another class will be June 8th at the Civic Building from 4:30-6:30pm
  - May have summer classes
    - Email Jennifer G. to let her know you are interested jennifer@eliteshuttersandblinds.com
- Bill F. discussed the field trips
  - Lynx Creek was successful
    - Everyone left with some gold flecks
  - Check your emails, the fires in the area are affecting our local trips
- Bob S. asked for the lapidary hours to be examined
  - The hours for lapidary and silversmithing are 8:30am-12:00pm
    - Mon (lapidary only), Thurs, and 1st 3rd and 5th Sat of the month
    - June dates - 3, 5, 7, 10, 14, 17, 19, 21, 24, 28
      - The center has limited capacity due to covid restrictions
      - The rest of the center closes at 9am, so don't be late
      - The center may require classes before using the machines
      - Contact Shirley Cote if you are interested in lapidary/silversmithing services Crystalc17@gmail.com
  - North Mountain Visitor's Center has specific hours for the club to have exclusive access to the *club's* equipment
    - A club approved monitor must be present while operating machines
      - This is an issue for changing lapidary schedule
    - Ed W. is going to analyze the schedule for any changes possible
- Do not forget to wear your name-tag on club events!

Respectfully submitted, Rebecca Slosarik, secretary

Zoom General Meeting Minutes
June 1, 2021

- In Attendance: 19 Zoom participants
- Bill F. called the meeting to order
- Mary Lou Ridinger discussed her spectacular Jade specimens from Guatemala
  - Check out the beautiful jewelry on their website! JadeMaya.com
  - Or email Mary Lou directly marylouridinger@jademaya.com
  - You can also check out Mary Lou's TedTalk – search her name
- Cynthia B. discussed the financials
  - Storage trailer fees coming soon
- Dave Haneline Mine was talked about
  - Yavapai County is missing $60 registration
    - We have registered with BLM
    - Ed W. will register in the near future
- Bill F. gave field trip updates
  - Check emails, newsletter, or website for current information
  - Always double check before coming on trips
    - Weather, fire, and availability permitting
  - The season will start again in September
- Tiffany P. talked about membership
  - If you need a nametag please email: dmrmclub@gmail.com
- Ed W. discussed an upcoming show
  - Still looking for location
  - Hopefully we can have a show in March 2022
- Jennifer G. will have another wire wrapping class
  - Tuesday June 8th 4:30-6:30pm at the civic building
- Do not forget you can always bring specimens for show-and-tell to the meetings
- The next general meeting will be September 7th at the Civic Building
  - See you then and please stay safe!

Respectfully submitted, Rebecca Slosarik, secretary

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METAL IONS

One can visualize atoms as a nucleus, surrounded by roughly concentric energy shells or orbits, and sub-shells/orbits. Figure 1. (This is a very simplified conceptualization, as in actuality electrons move in spherical, dumbbell, and cloverleaf pathways around the nucleus). It is within these orbits that electrons will stay, unless they absorb discreet packages of energy. And the amount of energy it takes to dislodge an electron varies, depending on the bonding type and pull of the nucleus.

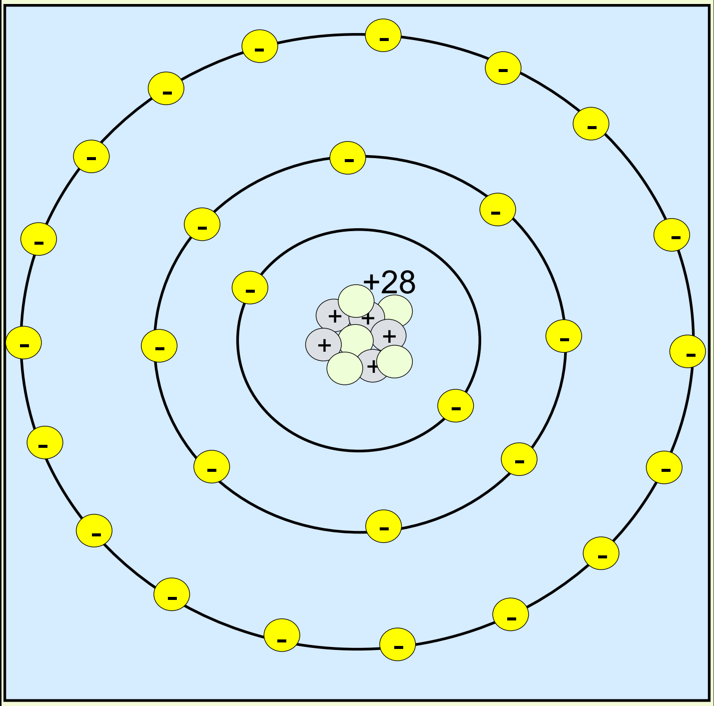

FIGURE 1 IDEALIZED SCHEMATIC OF AN ATOM The atom is composed of a positively-charged nucleus, surrounded by orbits of negatively-charged electrons. In this diagram, the green balls are neutrons (no charge), the blue balls are protons (positive charge), and the yellow balls are electrons (negative charge). Note that the negative and positive charges balance each other out, so that the atom has no net charge. *Diagram by Susan Celestian*

The positively-charged nucleus is composed of protons (+ charge) and neutrons (no charge). This is balanced by electrons (- charge). The ideal atom is neutral, with a balance of positive and negative charges. Electrons -- typically in pairs -- orbit the nucleus in these shells or orbits. Those in outer orbital, are far enough from the influence of the nucleus that they are vulnerable to interaction with visible light, and lone, unpaired electrons are wont to absorb energy, in search of a pairing. When light strikes some minerals, electrons in the outer orbits of metals (usually one of the transition metals -- Sc through Zn, in the first row of the periodic table, plus a few others such as uranium) may absorb some energy, and be kicked into higher energy levels. The wavelength that effected that change is subtracted from those of visible light, and the result is a particular color.

- For example, the presence of copper, intrinsic to the chemical compositions of azurite and malachite, results in the characteristic blue color of Azurite and the green of Malachite. Figure 2.
- Cavansite's color is due to VO^{2+} (vanadium oxide molecule). Figure 3.
- The atomic structure of minerals will help to determine what color is produced by a given ion, since the structure and bonding strengths will effect the energy needed to excite the electrons. Take Cr^{3+}, for example. It is the color-causing impurity in Ruby, Emerald, and Alexandrite. Wow! Those are 3 minerals with wildly different colors. However, the red of Ruby, green of Emerald, and purplish-red of Alexandrite are all the result of chromium ions as impurities, included in the mineral structure. Figure 4.

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Metal Ions continued:

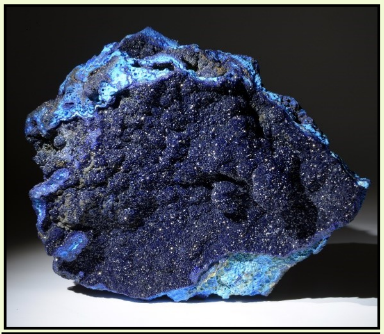
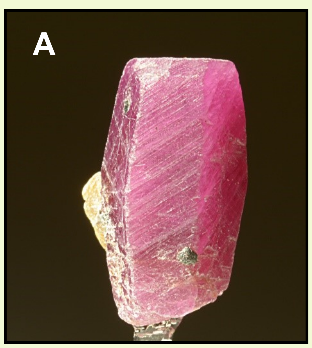
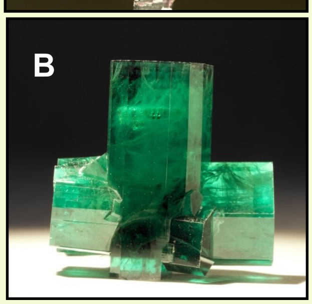


FIGURE 2 AZURITE AND MALACHITE Both copper carbonates, azurite and malachite have copper ions to thank for their very characteristics colors. *Photos by Stan Celestian*

FIGURE 3 CAVANSITE Wagholi Quarry, Wagholi, Pune District, Maharashtra, India *Photo by Stan Celestian*





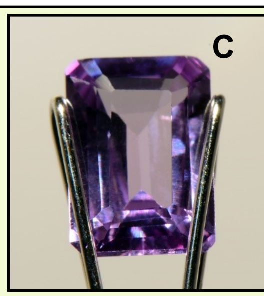


FIGURE 4 RUBY, EMERALD, AND ALEXANDRITE

Impurities of chromium ions (Cr^{3+}) are responsible for the red of Ruby (A), the green of Emerald (B), and the purplish-red of Alexandrite (C).

Different colors are caused by the same ion, because the atomic structures of the three minerals hold onto their electrons with varying strengths. Consequently, it takes different levels of energy to excite electrons in the outer orbits of the atoms. *Photos by Stan Celestian*

- Other examples of a given ion producing different colors (Figure 5):

Mn^{3+} red Beryl, green Andalusite, violet Tremolite, pink-red Tourmaline, Purpurite

Mn^{2+} pink Rhodonite, red Rhodochrosite, yellow-green Willemite

Fe^{2+} raspberry red Eudialyte, red Pyrope garnet, yellow-green Forsterite (olivine), bluish-green Phosphophyllite, blue Elbaite (tourmaline)

Fe^{3+} pale purple Strengite & Coquimbite, yellow-green Andradite (garnet), yellow Plagioclase, bright orange Diopside

Co^{2+} red Cobaltian Calcite, blue Spin

Cu^{2+} Paraiba Elbaite (tourmaline)

Cr^{3+} & V^{3+} green Tourmaline

Fe, Mn, Ti black Tourmaline

FIGURE 5 A-F MINERAL COLORS DETERMINED BY METAL IONS The following minerals are colored by an impurity or integral atom of a transition metal ion.
Photos by Stan Celestian

Purpurite Sandamap Farm, Kariib District, Erongo Massif, Namibia

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Andradite (garnet), Stanley Butte, San Carlos Reservation, Graham Co., AZ

Elbaite, Pederneira

Forsterite (olivine), San Carlos, Graham Co.,

Rhodochrosite, Capilitas Mine, Argentina

Schorl, Omaruru District, Erongo Massif, Namibia

Metal Ions continued:

- Pleochroism is the property of some minerals to exhibit different colors. This can happen for a couple of reasons.

  (A) One depends on in what direction one views the mineral. In other words, the atomic structure of these minerals exerts a strong influence on the absorption of light.

  (B) The other depends on the wavelengths available from the light source. For example, the source is deficient in red, then blues will dominate; if it is deficient in blue, then reds will dominate. Typically it is sunlight, candlelight, and fluorescent lights that induce these variations.

  Some examples of pleochroism due to atomic structure control are:

  - Andalusite: green brown/dark red/purple (Figure 6)
  - Beryl (Emerald): green/blue-green
  - Corundum: purple/orange; yellow-brown/orange; yellow/pale yellow
  - Hypersthene: purple/orange
  - Spodumene (Kunzite): purple/clear/pink
  - Tourmaline: pale purple/purple; light blue/dark blue; blue-green/ brown-green/yellow-green; pale yellow/dark yellow; light red/dark red

  Some examples of pleochroism -- often called 'color change', to distinguish it from the structure-controlled displays listed above -- due to light source variation are:

  - Chrysoberyl (Alexandrite): dark red/orange/green (Figure 7)
  - Zoisite (Tanzanite): blue/ purple/red
  - Some Garnets: most exhibit some variation of green to some variation of red

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Metal Ions continued:

- Diaspore (Zultanite): khaki green/ sage green/pink to raspberry/ champagne/canary yellow//ginger
- A rare Sapphire: blue/purple or green/pink or reddish-violet
- Fluorite, especially that from the Rogerly Mine, in England (Figure 7)

FIGURE 6 PLEOCHROISM DUE TO ATOMIC STRUCTURE CONTROL When viewed along different directions within the atomic structure, both Kunzite (A) and Andalusite (B) appear in different colors, or intensities of color. *Photos by Stan Celestian*

A Kunzite On the left, kunzite as viewed across the "C" axis; and on the right, as viewed down the "C" axis. Very different intensities of pink!

B Andalusite See how the color varies from brownish, olive, and reddish

FIGURE 7 PLEOCHROISM DUE TO LIGHT SOURCE VARIATION ***A*** Alexandrite appears green in daylight, because in the presence of the full light spectrum, the human eye is most sensitive to green; while in incandescent light (which is deficient in green and blue) it appears reddish/purplish. **B** Fluorite from the Rogerley Mine in England, actually fluoresces in Sunlight. *Photos by Stan Celestian*

A Alexandrite Left - in sunlight; right - in incandescent light

B Fluorite Rogerly fluorite is emerald green in incandescent light

B Fluorite Rogerly fluorite is very blue in sunlight

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INTERVALENCE CHARGE TRANSFER (IVCT)

Ions are atoms with a charge. In other words, there are either more protons than electrons (and the atom is positively-charged), or more electrons than protons (and it is negatively-charged). For example, common ions of iron are Fe^{2+} and Fe^{3+}. Another common element ion pair is titanium -- Ti^{3+} and Ti^{4+} Of course, there are many other ions that participate in this transfer.

Intervalence charge transfer (IVCT) occurs when an electron transfers between adjacent metal ions with different charges, or as described below -- between metal and non-metal ions. In the case of Fe^{2+} and Fe^{3+}, when an electron transfer occurs the Fe^{2+} becomes Fe^{3+}, and the Fe^{3+} becomes Fe^{2+} (Figure 8). This usually results from the absorption of red wavelengths of light, so the mineral is typically blue or green.

- In both Kyanite and blue Sapphire, Fe^{2+}- Fe^{3+} and Fe^{2+}- Ti^{4+} IVCT come into play, to create the blue colors. (Figure 9)
- In the case of Lazurite, it is IVCT between a triad of sulfur ions that cause its bright blue color. (Figure 9)
- Some of the many colors of tourmaline can be accounted for by IVCT Interactions (sometimes activated by radiation, and often in combination with metal ions as impurities):

Fe^{2+}- Fe^{3+}	Black
Fe^{2+}-Ti^{4+}	Amber to orange-brown, green
Mn^{2+}-Ti^{4+}	Yellow to yellow-brown

Absorption of Red Wavelengths

$$\mathbf{Fe^{2+}\ (position\ A) - Fe^{3+}\ (position\ B) \longrightarrow Fe^{3+}\ (position\ A) - Fe^{2+}\ (position\ B)}$$

FIGURE 8 Fe^{+2}- Fe^{+3} Intervalence Charge Transfer The absorption of energy, from the red portion of the light spectrum, causes an electron to jump from Fe^{3+} to Fe^{2+}. As the original Fe^{2+} loses an electron, it is altered to Fe^{3+}, and as the original Fe^{3+} gains an electron it becomes Fe^{2+}. (Positions A and B do not denote any particular site, they are just hypothetical sites, where the respective ions reside in the atomic lattice, of a given mineral.) That absorption of red light, causes the mineral to show in the blue part of the spectrum. *Diagram by Susan Celestian*

- An example of Fe^{2+}- Fe^{3+} IVCT can be found in Vivianite. It is naturally pale green, turning blue as IVCT occurs. (Figure 9)
- With Beryl, the result is aquamarine. (Figure 9)
- In Jade, the Fe^{2+}- Fe^{3+} IVCT may account for lavender color.

See Figure 9 for images of minerals whose color depends in Intervalence Charge Transfer.

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Intervalence Charge Transfer (IVCT) continued:

FIGURE 9 MINERALS WHOSE COLOR IS THE RESULT OF INTERVALENCE CHARGE TRANSFER All the minerals in this figure have been colored as a result of IVCT.

Photos by Stan Celestian

Kyanite, Barra do Salinas, Minas Gerais, Brazil

Lazurite $(Na,Ca)_8[S,Cl,SO_4,OH)_2]$ is a vibrant blue.

Blue Sapphire
(a variety of Corundum)

Vivianite, Bolivia This specimen was a translucent bluish green 25 years ago, when Stan & Sue first bought it. Exposure to light has caused it to darken over the years.

Beryl variety Aquamarine, Kala, Darrah Pech, Kunar Province, Afghanistan

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IONIZING RADIATION

Natural or artificial radiation can effect changes to minerals, that influence the color. The results vary -- color centers, intervalence charge transfers, molecular aggregates, and unknown (or in combination with some atomic substitutions).

Unknown**:** amber Calcite, blue Calcite, golden Beryl**,** lemon yellow quartz, pink quartz

Color Centers or F-Centers: Radiation (usually gamma rays) may damage the crystal lattice, and electrons may be dislodged from their normal positions. These unattached electrons may wander a bit and then settle into a space (trap) within the crystal lattice. And these electrons may absorb various wavelengths of light, changing the color of the mineral.

Heat or ultraviolet radiation may introduce enough energy to free the electrons from their traps, and the color will fade or return to its pre-radiation color.

- *Examples*: purple Fluorite, blue Fluorite, smoky Quartz, some amethyst quartz, green Kunzite, some brown topaz, laboratory-irradiated blue topaz (most blue topaz on the market), pink tourmaline Figures 10-14.
- Natural or laboratory-irradiated diamond (green) actually have color centers that are not occupied by an electron. The radiation has dislodged Carbon atoms from their original positions. These “holes” tend to absorb light in the red-orange range of the color spectrum.

FIGURE 10 GREEN KUNZITE *Photo by Stan Celestian*

FIGURE 11 FLUORITE AND COLOR CENTERS
The two blue specimens are from the Blanchard Mine, Socorro Co., NM, and the purple one is from Rosiclare, IL
Photos by Stan Celestian

FIGURE 12 QUARTZ MADE SMOKY BY RADIATION Radioactive minerals within alpine granites produced the energy to disrupt the atomic structure of these quartz crystals, and cause color center-induced darkening.
Photo by Stan Celestian

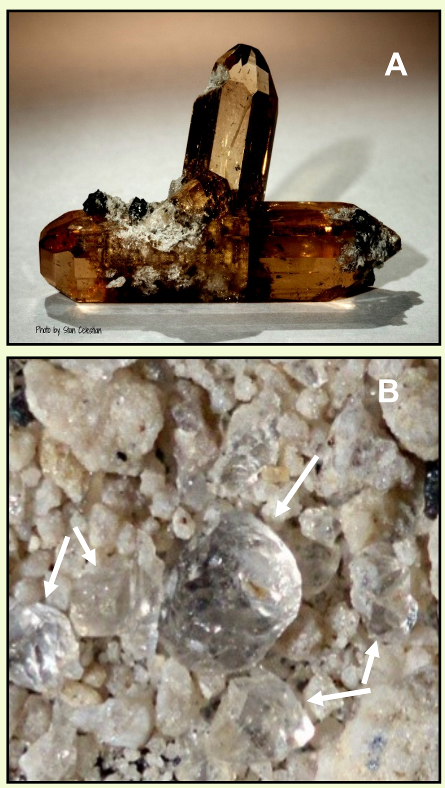

FIGURE 13 TOPAZ This sherry-colored topaz (A) from Topaz Mt., UT has been exposed to natural radiation. Exposure to the Sun causes the damaged atomic lattice to “heal”, and the color fades to clear, as indicated by arrows in the topaz sand grain (B) from a wash on the mountain.
Photos by Stan Celestian

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Ionizing Radiation continued:

***Intervalence Charge Transfer* (IVCT):** radiation (usually gamma rays) may supply the energy necessary to initiate an IVCT.

- This occurs when Fe^{4+} is created from Fe^{3+}, to produce Amethyst Quartz. In this case, ultraviolet (UV) light from sunlight supplies enough energy to reverse this process, and the purple color fades.
- Irradiation creates Fe^{3+} to produce golden Beryl. Heating golden Beryl will reduce Fe^{3+} to Fe^{2+}, and the result is blue Beryl. Figure 15.

FIGURE 15 Golden Beryl aka Heliodor Natural radiation induces the IVCT creation of Fe^{3+}, causing a golden yellow color. *Photo by Stan Celestian and used courtesy of the Natural History Museum of Los Angeles*

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***Molecular Aggregate (this is a bit of a permutation on Color Centers): Example*:** In the case of blue Halite, color centers, produced by radiation, turn the salt to an amber color. Given time, the electrons trapped in color centers may migrate and join with sodium ions (Na^+), to produce metallic sodium (Na). Those metal atoms will migrate and aggregate into colloidal-sized (very very small - .000000001 to .0000001 meter) particles --- and these cause the blue color. I know, it boggles the mind! Figure 16.

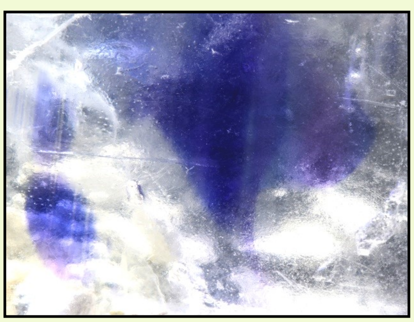

FIGURE 16 BLUE HALITE This blotch of inky coloration is stable -- it does not seem to fade. *Photo by Stan Celestian*

HEAT

Heat, either natural or laboratory facilitated, can contribute to color in some minerals. In fact, heat treatment (and irradiation, for that matter) are so common, that it is the norm in the realm of faceted gemstones.

The physics that causes color change is generally related to a) releasing color center electrons from their traps, or to re-arrangement of the atomic structure, thus removing "holes" in the atomic lattice; b) facilitating Intervalence Charge Transfers; c) the rise in temperature facilitating the mobility of atoms, and the subsequent "healing" of lattice defects (such as those created by irradiation). Some examples follow:

- Smoky Quartz can be lightened or turned clear. This probably is accomplished by releasing color center electrons from their traps.
- Amethyst Quartz can be lightened, or turned to Citrine (yellow, orange, orange-brown). In fact, Ametrine (part amethyst and part citrine) is created by heat treatment. This may be related to an IVCT interaction that converts Fe^{3+} to Fe^{2+}. Heating some amethyst to about 500° C, turns it green (a variety called Prasiolite) Figure 17.

FIGURE 17 PRASIOLITE CREATED BY HEATING AMETHYST. *Photo by Stan Celestian*

- Spodumene (Kunzite) is often treated to cause the pink color to darken or become more intense.
- Beryl (Morganite) is heated to change the color from orange-ish to pink-ish.
- Beryl (Aquamarine) is heated to remove green hues, and create a more blue-ish stone.

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FIGURE 14 BLUE TOPAZ For over 3 decades, nearly all commercial blue topaz has been irradiated to either enhance the blue color, or to change colorless topaz to blue.
Photo by Stan Celestian

Heat continued:

- Corundum's (Ruby) red color deepens, and inclusions and cracks are 'healed'.
- Corundum (Sapphire) is very commonly heated to improve the intensity and uniformity of the color.
- Zoisite (Tanzanite) is often a not-so-attractive purplish-gray or reddish-brown. heat treatment brings out the more desirable vivid violet-blue.
- Green and blue varieties of Tourmaline are color-enhanced by heating.
- Coupled with irradiation, heat can produce blue or pink colors in Topaz.
- Black Diamonds are rare, so most on the market are low quality diamonds that have been heated.

BAND GAPS

Very simply put, in minerals that are conductors (metals), semi-conductors (sulfides -- such as galena and pyrite, oxides, sulfosalts), and semi-conductors with impurities, the electrons in the outer shells (or bands) are shared by the whole mineral, rather than being bound to individual atoms or molecules -- they can be very mobile (hence the ability to conduct electricity, deform rather than break when impacted, and conduct heat). Inputs of various levels of energy can cause electrons to jump from their normal (or valence) band, into a higher energy band (conductive band), where they are quite mobile and able to move fairly freely. The energy difference between these two bands is the "band gap", and that gap determines the amount of energy necessary (light frequencies absorbed) to effect the jump of electrons to the higher state. Figure 18.

- For example, if the frequency absorbed is in the blue range of the color spectrum, the mineral will appear red to yellow, as in realgar, orpiment, cinnabar, sulfur, cuprite, and sphalerite. Figure 19.

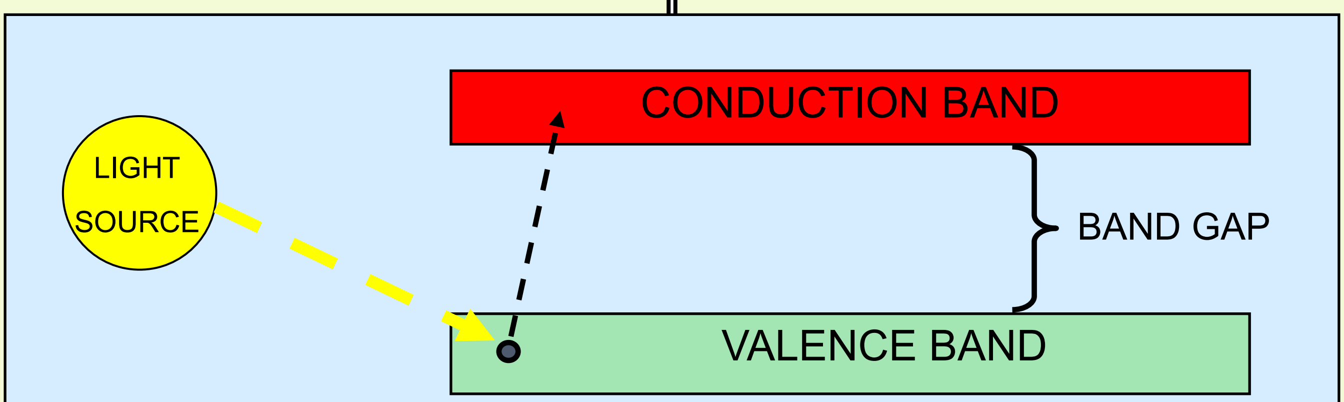

FIGURE 18 Band Gap In semi-conducting metals (and metals), there is a partially-occupied band of electrons that are not tied to any specific atoms. This is the Conduction Band. With the absorption of light energy, electrons, in outer shells of atoms in the Valence Band, may jump into the conduction band. The energy necessary for that jump is called the Band Gap. And a mineral's color will be depleted in the wavelengths absorbed. *Diagram by Susan Celestian*

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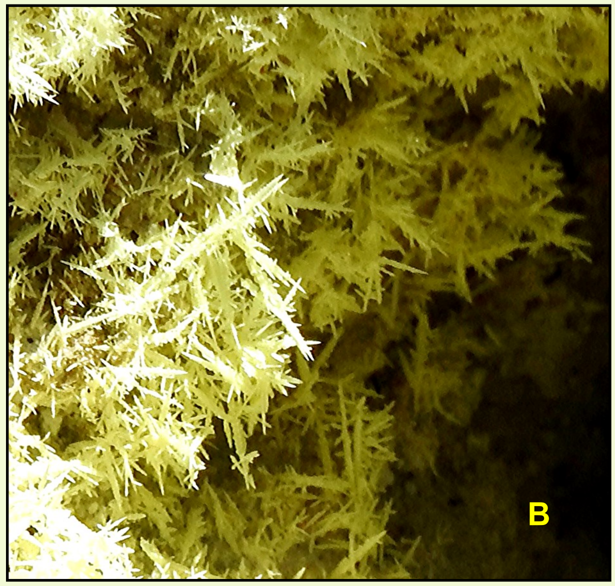
Band Gaps continued:



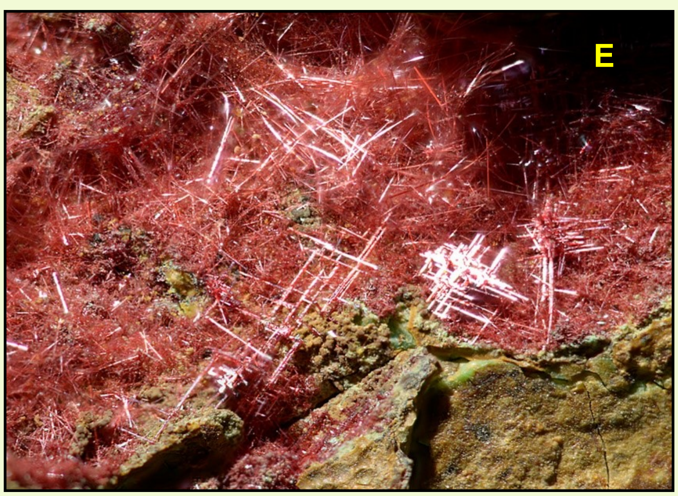


FIGURE 19 MINERALS COLORED BY BAND GAPS

These five minerals all owe their red to yellow colors to absorption of wavelengths in the blue end of the color spectrum. A - Realgar (red) and Orpiment (yellow), Getchell Mine, Humboldt Co., NV; B - Sulfur crystals at a fumarole in Bumpas Hell, Lassen NP, CA; C - Sphalerite, Silver Bell Mine, Pima Co., AZ; D - Cinnabar, Wanshan Mine, Guizhou Province, China; E - Cuprite (var. chalcotrichite), Ray Mine, Pinal Co., AZ. *Photos B-E by Stan Celestian, photo A with permission of Tom Loomis, Dakota Matrix Minerals https://www.dakotamatrix.com/*

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Band Gaps continued:

- Metals have characteristic opaque gold, silver, copper, and brassy metallic lusters because these band gap electrons absorb light energy, but then ***re-emit*** some of it, as they fall back to lower energy bands. How much is re-emitted determines the color of the metal. When the amount of energy re-emitted equals the amount absorbed, the color is silver; when the amount re-emitted is less than that absorbed, other colors are created. Figure 20.

FIGURE 20 NATIVE COPPER & NATIVE SILVER Copper and Silver owe their distinctive colors to the energy band-hopping of freely moving electrons. This is a "half-breed" specimen from Michigan. *Photo by Stan Celestian*

- And in diamonds (which are semi-conductors), a Nitrogen impurity produces a yellow color, while boron produces blue.

PHYSICAL OPTICS

Interference Iridescence in hematite, bornite, and chalcopyrite is caused by light passing through layers of oxidation, that are different thicknesses -- but all very, very thin. As light reflects off the oxidation layers, and the surface between the mineral and the tarnish, it is reflected back at different speeds, depending on the thicknesses of the layers. As the various reflected light rays interact with each other, they may be "in phase" with each other and reinforce the wavelength, or they may be "out of phase" and cancel each other out -- thereby causing a rainbow of colors to be displayed. This is also what causes an oil slick to display varying bands of color. See Figures 21-22.

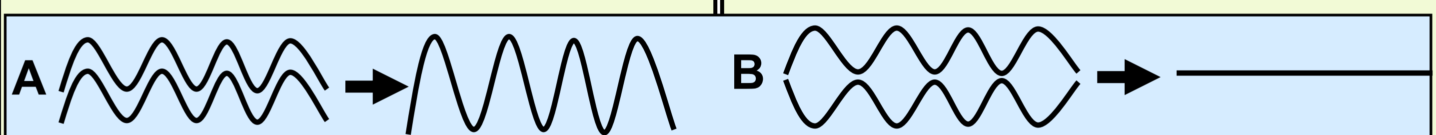

FIGURE 21 INTERFERENCE OF LIGHT WAVES In "A" above, two light waves are "in phase" with each other and effect constructive interference, reinforcing the wavelength in question. In "B" the two light waves are "out of phase" and effect destructive interference, cancelling out the energy. The amount that waves are "out of phase" determines what wavelengths will be cancelled by interference. *Diagram by Susan Celestian*

FIGURE 22 IRIDESCENCE OF FILMS & TARNISHES A thin, but irregular, film of Turgite (maybe a combo of Goethite and Hematite) on Hematite (on right) is colorful, because as light travels through layers of varying thicknesses, it is slowed at different rates, and bent, and as the rays emerge, they interfere constructively & destructively, creating a rainbow of colors. The same process occurs with the tarnish on chalcopyrite (on left).

Photos by Stan Celestian and Turgite used by courtesy of the Natural History Museum of Los Angeles NHMLA 40827

Color continued on page 15…..

...Color continued from page 14

Diffraction & Interference Diffraction occurs when light encounters an obstacle or opening. The light wave bends around the obstacle, or bends and emerges from the opening at a different angle, than it entered the opening. In the case of minerals, this phenomenon is often also influenced by interference.

- **Opal**: Opal is composed of tiny spheres of silica. When these spheres are uniform in size and regularly arranged, light is diffracted as it passes through, light waves interfere with each other, and the characteristic "fire" flashes before our eyes. See Figure 20. The color of the "fire" is determined by the size of the spheres, and of the spaces between them. Small spheres (< 150 nanometers) typically produce blue and violet; while larger spheres (150-350 nanometers) produce red and orange. Figures 23-24.

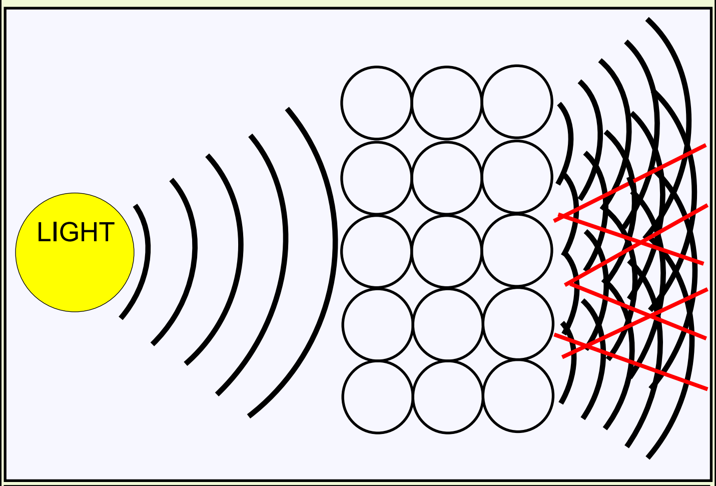

FIGURE 23 DIFFRACTION IN OPAL Opal's stack of spheres acts as a diffraction grating. As white light bends around the spheres making up opal, it exits the opal headed in different directions. As the exiting light waves overlap each other, both constructive and destructive interference occurs, resulting in the "fire" characteristic of Fire Opal. As one rotates an opal specimen in the light, and one observes light interacting with the spheres from different angles, the colors change.

The red lines represent areas of interference (they do NOT represent the color red).

Diagram by Susan Celestian

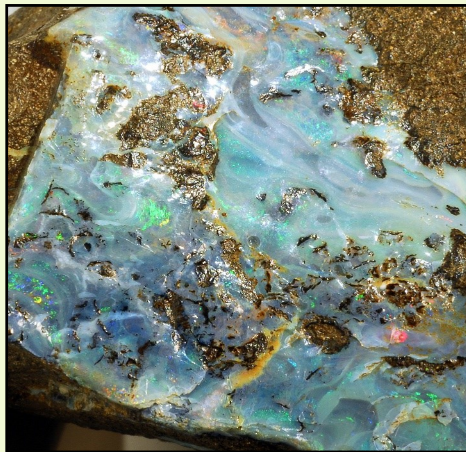

FIGURE 24 FIRE OPAL FROM AUSTRALIA Opal's gauntlet of spheres, causes diffraction of light. Interference of light waves creates "fire". The colors change like the Aurora, as a specimen is rotated, and exposes different angles of the stack of spheres. *Photo by Stan Celestian*

.**<u>Physical Optics continued:</u>**

- **Labradorite**: Labradorite $(Ca,Na)(Al,Si)_4)O_8$, is an intermediate member of the plagioclase series, within the feldspar group. When conditions are just right, the mineral is formed by often parallel lamellae (thin layers) of calcium-rich and sodium-rich varieties of plagioclase -- this is a from of twinning. Separations between the lamellae act as a diffraction grating, thus causing the play-of-colors, or *labradorescence*, so desired by lapidarists. Figure 25.

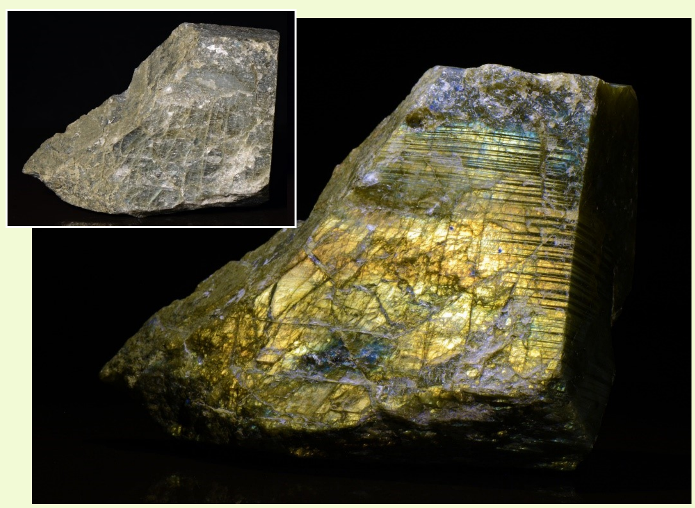

FIGURE 25 LABRADORITE Some Labradorite (and some Bytownite $(Ca,Na)[Al(Al,Si)Si_2O_8]$) display a play-of-colors, caused by diffraction off of internal lamellae. In this image, you can see the parallel striations, caused by polysynthetic twinning, characteristic of the plagioclase feldspars. Inset: specimen at a different angle. *Photo by Stan Celestian*

Color continued on page 16…..

...Color continued from page 15

Physical Optics continued:

Dispersion Dispersion is the process whereby white light is split up into its component wavelengths, i.e. colors. (This is the process by which rainbows are generated.) As light approaches a different medium (air, water, glass…..), at an angle, the light wave bends, or is refracted. For example, as a light wave encroaches upon a prism, the part of the wave that first encounters the prism, slows down. The rest of the wave proceeds at original speed. However, as each portion of the wave encounters the prism, refraction proceeds. The component wavelengths, are refracted at different angles; and thus the colors separate out. The waves refract again as they leave the prism and re-enter the air (See Figure 26).

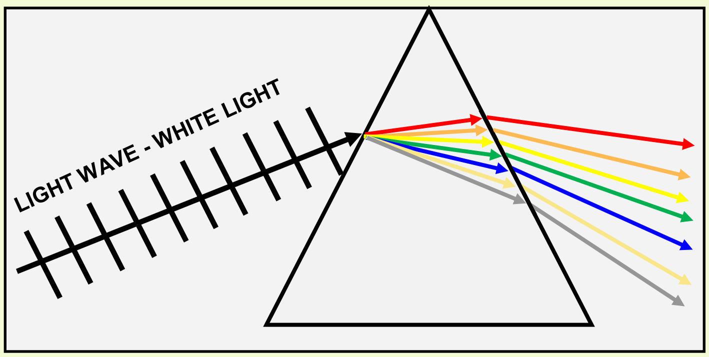

FIGURE 26 REFRACTION AND DISPERSION OF LIGHT THROUGH A PRISM As light waves slow upon entering a denser or less dense medium, the light wave bends or refracts. Each component wavelength (color) refracts at a different angle, thereby splitting out into a rainbow of colors. *Diagram by Susan Celestian*

- The faceting of gemstones results in the refraction and reflection of light, giving the stones their sparkle or 'fire'. (Facets cause light waves to be reflected back and forth inside the stone, to enhance the color separation). This is especially attractive in Diamonds. Figure 27.

---- *BOTTOM LINE* ----

There are many varied and complicated ways in which the atomic structures of minerals interact with light, to produce the kaleidoscope of colors we see in minerals.

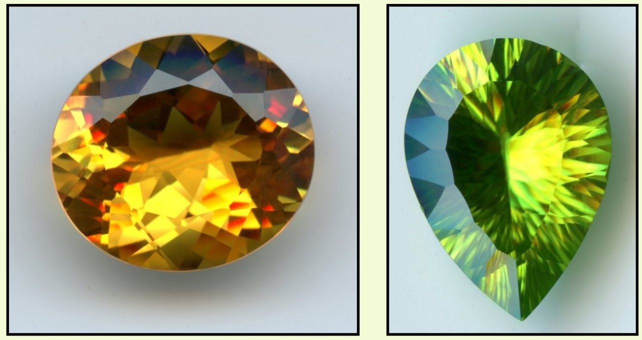

FIGURE 27 Gemstones Sparkle These faceted stones -- Citrine and Peridot -- sparkle with an array of colors as light rays penetrate faceted surfaces, refract, and break up into the colors of the rainbow. *Photos by Stan Celestian*

Scattering Scattering is the deflection of light from a straight path. This deflection occurs when the light wave encounters obstacles. If all wavelengths are scattered equally, the mineral appears white. Often the shorter wavelengths are selectively scattered, and a bluish tint will display.

- **Moonstone** - an intermediate variety of feldspar, called Adularia, that is composed of a mixture of Albite and Orthoclase. These 2 minerals are intergrown as alternating layers. As light encounters the interfaces between the different layers, it is bent and scattered in many directions. The effect is to produce a diffuse, glowing appearance called *adularescence*. It is often white or bluish. Figure 28.

FIGURE 28 MOONSTONE Scattering of light waves gives Moonstone (either Adularia, an orthoclase feldspar; or Oligoclase, a plagioclase feldspar) its cloudy white to blue sheen. *Photo by Stan Celestian*

Color continued on page 17…..

...Color continued from page 16

GENERAL RESOURCES FOR COLOR IN MINERALS

http://minerals.gps.caltech.edu/color_causes/index.html

http://www.minsocam.org/msa/collectors_corner/arc/color.htm

http://www.minerals.net/resource/property/Color.aspx

https://nature.berkeley.edu/classes/eps2/wisc/Lect7.html

https://www.gamineral.org/writings/color-daniels.html

https://www.researchgate.net/publication/291776755_Lavender_Jade_The_Optical_Spectrum_of_Fe3_and_Fe2_Fe3Intervalence_Charge_Transfer_in_Jadeite_from_Burma

https://www.gia.edu/doc/SP88A1.pdf

http://minerals.gps.caltech.edu/COLOR_Causes/Metal_Ion/index.htm

http://minerals.gps.caltech.edu/files/visible/tourmaline/index.html

https://en.wikipedia.org/wiki/Pleochroism

https://www.geologyin.com/2016/02/gemstones-that-change-color-in.html

https://www.gemselect.com/gem-info/heat-treatment.php

http://www.quartzpage.de/rose.html

Personal communication with Aaron Celestian, Mineral Curator Natural History Museum of Los Angeles County

MOLTEN MINI

In the June newsletter, I highlighted baked soils -- some of which display columnar jointing. Let's take a close look at *Columnar Jointing*.

Columnar jointing is a result of the cooling and shrinkage of a relatively homogeneous magma. Magma cools most quickly where it is in contact with cooler country rock, water (or air) -- in fact it is thought that the infiltration of water is a facilitating factor in the development of columnar jointing. Upon cooling, the rock contracts and fractures, generally in a 3-pronged crack. Intersecting crack triplets result in the formation of a broadly hexagonal pattern (may very from 4 to 8-sided polygons). And as the body of magma cooling continues, the cracks extend incrementally away from the cooling plane, forming long hexagonal columns. See Figure 1'.

For example: Imagine an intrusion of a large body of magma into a thick, cool sequence of sedimentary rocks. Assume that the cooling surfaces are parallel to the Earth's surface. Cooling is fastest nearer to the surface, where the intruded rocks are coolest; however the rocks in contact with the deepest part of the intrusion are still cooler than the magma.

Therefore, the intrusive body will cool from the top and from the bottom (and probably from the sides, as well). Contraction around cooling centers will begin the formation of a pattern of hexagonal cracking. As cooling progresses down from the top (and up from the bottom), vertical cracks produce ever-lengthening columns. Progression of the vertical cracks will be incremental, and cooling events will be marked by horizontal cracks produced by consequent stresses.

The columns will form perpendicular to the cooling plane. Stresses resulting from any variations to that plane will result in curved or bend columns.

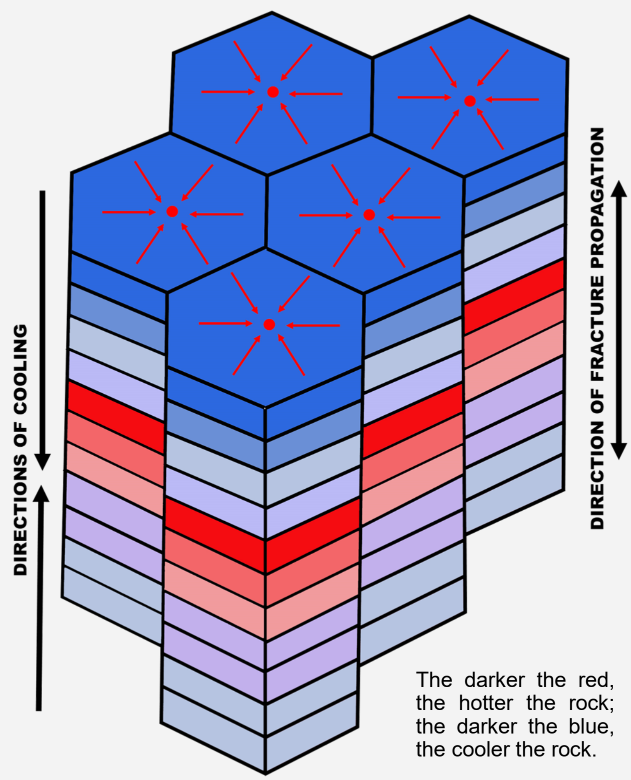

FIGURE 1' FORMATION OF COLUMNAR JOINTING
An intrusive body of magma will cool fastest where it is in contact with cooler rocks. Cooling results in contraction, represented by the red arrows. Contraction creates cracks that form a hexagonal (or at least polygonal) pattern, that propagates away from the cooling plane, creating hexagonal columns. The columns will be oriented perpendicular to the plane of cooling. *Illustration by Susan Celestian*

Columnar Jointing continued on page 18…..

...Columnar Jointing continued from page 17

Notable occurrences are displayed at Devil's Tower and Devil's Postpile (Figures 2'-5')

FIGURE 2' DEVIL'S TOWER in Wyoming. As a mass of intrusive magma cooled, large vertical columns -- columnar jointing -- formed. Note the curvature of the columns near the base of the tower *Photo by Susan Celestian*

FIGURE 3' DEVIL'S TOWER is composed of porphyritic phonolite (an intermediate rock containing nepheline) - see inset - and has some of the world's largest jointed columns, with hexagonal columns up to 10' across. *Photos by Stan Celestian*

FIGURE 4' BIG COLUMNS OF DEVIL'S TOWER
Look closely, the arrow points to some climbers on Devil's Tower, giving you a peek at the scale of the columns -- they are big! *Photo by Susan Celestian*

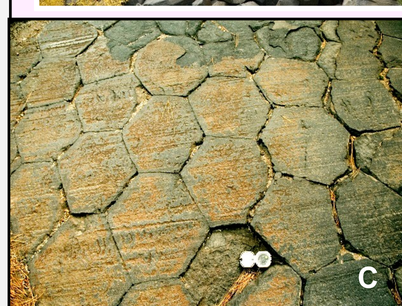

FIGURE 5' DEVIL'S POSTPILE Starting out, 100,000 years ago, as a lava lake, portions of the basalt fractured into crisp columns, with an average diameter of 2',and up to 60' long. During the last Ice Age, glaciers scraped across the top of the postpile, revealing the honeycomb-like pattern (C).
Photos by Stan Celestian

Columnar Jointing continued on page 19…..

...Columnar Jointing continued from page 18

While it seems that the majority of landscape columnar jointing is vertical to a general horizontal surface (the general Earth's surface), that is not always the case. In Figure 6', you can see columnar jointing along a road through Mt. Rainier NP. The jointing is perpendicular to the cooling plane, but is at an angle from the horizontal plane.

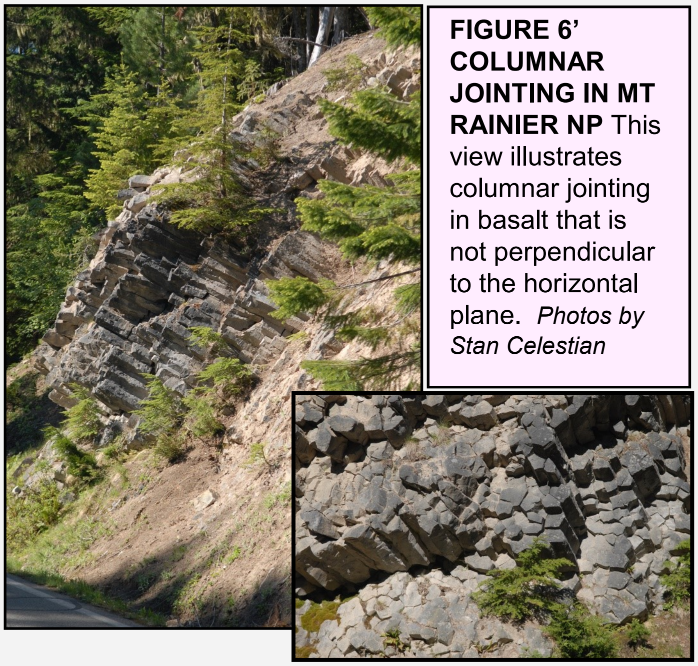

FIGURE 6' COLUMNAR JOINTING IN MT RAINIER NP This view illustrates columnar jointing in basalt that is not perpendicular to the horizontal plane. *Photos by Stan Celestian*

Columnar jointing is also seen commonly in Arizona -- even if it is not as picturesque as some of the globe's other landmarks. See Figures 7'- 10'.

FIGURE 7' COLUMNAR JOINTING IN ARIZONA This columnarly jointed lava flow is found along Dugas Road, Yavapai Co., Arizona. *Photo by Susan Celestian*

FIGURE 8' OAK CREEK CANYON is host to several outcrops of columnarly jointed basalt flows. This one is more crudely fractured than at sites in previous figures; however, this is probably more typical. *Photo by Susan Celestian*

FIGURE 9' COLUMNAR JOINTING IN ARIZONA I'm pretty sure this is a view of the top of a jointed basalt flow near where AZ Rt 89 crosses either Hell Canyon or Little Hell Canyon. This is not a view that is often available in Arizona. *Photo by Stan Celestian*

FIGURE 10' BASALT IN GRAND CANYON This is a view of columnar basalt veering off in many directions -- lots of cooling stresses here! Found in the Grand Canyon's Inner Gorge. *Photo "Columnar Jointed BasaltGrand Canyon Inner Gorge" by Ranger Robb is licensed under CC BY-NC-SA 2.0*

UPCOMING FIELD TRIPS & MEETINGS

At this time there are no field trips scheduled.

DATES SUBJECT TO CHANGE

Bill and the field trip committee will be actively looking for productive spots for field trips. If you have any suggestions, you are encouraged to contact him at bfreese77@cox.net

...Zunyite continued from page 2

FIGURE A ZUNYITE This sharp crystal 17mm on a side) is a tetrahedron modified by a cube. Locality: Qualat-e-Balat Saltdome, Bandar Abbas, Hormozgan Province, Iran *Photo by David Hospital and used with permission: Creative Commons Attribution-Share Alike 4.0 via Wikipedia Commons*

FIGURE B ZUNYITE This specimen is from Silver City, Juab Co., UT. The crystals are unmodified tetrahedrons.(3 mm on a side) *Photo by Rob Lavinsky, iRocks.com and used with permission: CC-BY-SA-3.0 via Wikipedia Commons*

FIGURE C ZUNYITE See these nice large crystals from the Big Bertha Mine, near Quartzsite, La Paz Co., AZ. The specimen is about 1"x1"x1". *Photo by Rob Lavinsky, iRocks.com and used with permission: CC-BY-SA-3.0 via Wikipedia Commons*

FACEBOOK

Visit and join the club page periodically. See what is happening, and boost our visibility on the web. Go to: The Daisy Mountain Rock and Mineral Club. It is set up so you can post photos of outings or related items. Share with friends!

AWARD-WINNING WEBSITE

http://www.dmrmc.com/

If you have comments, contact Nancy Gallagher.

INSTAGRAM

Follow the club on Instagram. Go to https://www.instagram.com/daisymountainrockclub/ and follow today. Share with friends!

Officers, Chairpersons, & Trustees

Meetings are held the **1st Tuesday of the month** at **the Anthem Civic Building**, 3701 W Anthem Way, Anthem, AZ 85086. General meeting at 6:30 pm. We **do not meet in July or August**.

DMRMCLUB@GMAIL.COM

Membership Dues:
First year $30, then $20.00 Adults per Person
First year $45, then $25.00 Family (2 people)

Meeting Dates for 2021

Jan 5, Feb 2, Mar 2, Apr 6, May 4, June 1, Sept 7, Oct 5, Nov 2, Dec 7

Words of Wisdom

passed along by our own

Bob Evans

UPCOMING AZ MINERAL SHOWS

August 21 - Gilbert, AZ 13th Annual Fine Mineral Sale; Gilbert Historical Society Museum; Sun 10-4; Admission: Free

September 17-19 - Payson, AZ Payson Rimstones Rock Club; Mazatzal Hotel & Casino, Highway 87, Mile Marker 251; Fri 2-7, Sat 9-5, Sun 10-4; Admission: adults $3; under 13 free. See poster on page 22.

September 24-26 - Tucson, AZ Minerals of Arizona Symposium; U of Alfie Norville Gem and Mineral Museum, 115 N Church St; Fee. https://flaggmineralfoundation.org/home/minerals-of-az-symposium/ See poster on page 23.

September 24-26 - Clarkdale, AZ; Mingus Gem & Mineral Club; Clark Memorial Clubhouse Auditorium, 19 N. 9th St; Fri-Sat 9-5, Sun 10-4; Admission: Free.

October 8-10 - Buckeye, AZ West Valley Rock & Mineral Club; 902 N 1st St (Miller Rd); Fri-Sat 9-5, Sun 9-2; Admission: $3, under 13 free.

October 16-17 - Sedona, AZ Sedona Gem & Mineral Club; Sedona Red Rock High School, 995 Upper Red Rock Loop Rd; Sat 10-5, Sun 10-4; Admission: ?.

October 9-10 - Sierra Vista, AZ Huachuca Mineral & Gem Club; The Mall, 2200 El Mercado Loop; Sat 9-5, Sun 10-4; Admission: Free.

November 27-28 - Wickenburg, AZ Wickenburg Gem & Mineral Society; Hassayampa School, Wrangler Event Center, 251 S Tegner St; Sat 9-5, Sun 10-4; Admission: Free. See poster on page 24.

If you are travelling, a good source of shows AND clubs is http://the-vug.com/educate-and-inform/mineral-shows/ **OR** http://www.rockngem.com/ShowDatesFiles/ShowDatesDisplayAll.php?ShowState=AZ **OR** https://www.rockandmineralshows.com/Location/?displayShows=true

NEEDED: QUALITY MINERALS (or OTHER) DONATIONS WITH LABELS -- for monthly raffle prizes; and for raffle, door prizes, and sales tables at the annual show. If you have specimens to donate, please see Robin Shannon. The Daisy Mountain Rock and Mineral Club is a 501(c)(3) non-profit organization, and will gratefully acknowledge your donation with a Tax Deduction Letter. Thank You!

NOTE FROM THE EDITOR

Have a geological interest? Been somewhere interesting? Have pictures from a club trip? Collected some great material? Send us pictures -- or write a short story (pictures would be great).

Deadline for the newsletter is the 22nd of the month.

Mail or Email submissions to:
Susan Celestian
6415 N 183rd Av
Waddell, AZ 85355
azrocklady@gmail.com

Visit http://rmfms.org/ for news about conventions, events, and associated clubs. If you are travelling, you might want to contact a club local to your destination. Maybe they have a field trip you could join, while in town.

NORTH MT OPEN STUDIO - SEPTEMBER

You are invited to return to NMVC Open Studio. Lapidary & Silversmithing on Thursdays and the first, third and fifth Saturdays in a month, from 8:30 to noon with cleanup starting at 11:45.

NMVC requires that everyone wear a mask while in the building. (Other NMVC requirements will be sent in a later email or on premises.)

Only four people can sign up, and must do so for the full three hours that the shop will be open each day. First come, first served.

Please arrive no later than 8:45 a.m. The center may close to the public at 10.

Email your request for the day(s) you are interested in participating ASAP. Email Shirley Cote at crystalc17@gmail.com

August – Thursday's dates are 5, 12, 19, 26
August – Saturday's dates are 7, 21
September – Thursday's dates are 2, 9, 16, 23, 30
September – Saturday's dates are 7, 21

If more than four people wish to participate on the same day, please expect to be bumped or rotated to another day as efforts to accommodate everyone will be taken.

We would also like to inquire as to anyone wishing to come in for **Lapidary Only Open Studio on Mondays.** Email Shirley at crystalc17@gmail.com

August - Monday's dates are 2, 9, 16, 23, 30
September - Monday's dates are 6, 13, 20, 27


Payson Rimstones
23nd Annual Gem
and Mineral Show
September 17th
through 19th, 2021
Event Center
Mazatzal Hotel & Casino
Admission $3 , Under 13 free
Hours: Friday 2-7 p.m.,
Saturday 9-5, Sunday 10-4
The Payson Rimstones Rock Club is a 501c3 Charitable Organization

FLAGG MINERAL FOUNDATION

28th Annual Minerals of Arizona Symposium

Friday September 24th, Saturday September 25th, and Sunday September 26th, 2021
Sponsored by the Flagg Mineral Foundation

"Daylight and Fluorescent Minerals"

to be held at the
UArizona Alfie Norville Gem and Mineral Museum
115 N. Church Ave., Tucson, AZ 85701

Saturday Program to include the following speakers:

7:45-8:30 AM – Registration & Check-in
8:30 AM to 5 PM – Program to include (with coffee breaks, snacks and lunch provided)

The University of Arizona Alfie Norville Gem and Mineral Museum – Brief Overview	Eric Fritz
The Significance of Donations to Museums	Anna Domitrovic
Fluorescence and the Zimmerman Collection	Mardy and Dick Zimmerman
Gallagher Mine and other Vanadium Localities around Charleston / Tombstone	Barbara Muntyan
Five Decades of Mineral Collecting in New Mexico	Mike Sanders
The World's Largest Silver Nugget	Chris Osterman
Minerals in the Movies	Dr. Wendell Wilson
Laser Fluorescence	Tom Kaye
Mineralogy of Arizona, 4th Edition	Ron Gibbs & Dr. Ray Grant
Fluorescent Petrified Wood, Who Knew?	Mike Fleeman

There will be mineral sales by the Flagg Mineral Foundation during the day on Saturday

Saturday Evening Activities:

TBD

Sunday Activities:

TBD

Go to flaggmineralfoundation.org for the latest information.


Wickenburg Gem and Mineral Show
Nov 27 & 28, 2021
Free Admission
Jewelry
Fossils
Minerals
Gems
Over 40 Vendors
Best Rock Contest
Raffle
Door Prizes
Kid's Area
Silent Auction
Hassayampa Elementary School
251 South Tegner Street Wickenburg, AZ
9am - 5pm Saturday • 10am - 4pm Sunday