AMBER

By Anita D. Westlake

Presented to Cotton Indian Gem and Mineral Society, March 2001; William Holland School of Lapidary Arts, June 2003; Gem Section: Georgia Mineral Society, Inc., November 2004

British poet Alexander Pope said of amber: *"Pretty! In amber to observe the forms of hairs, or straws, or dirt, or grubs, or worms! These things, we know, are neither rich nor rare, but wonder—how the devil they got there?"*

What is amber? It is resin that once seeped out of the bark of trees and has fossilized. Resin protects a tree by blocking gaps in the bark. It has antiseptic properties that protect the tree from disease. Resin is a natural polymer made up of carbon, hydrogen and oxygen. It is not the same as sap**,** however which transports nutrients through the heartwood of a tree.

Is amber considered a mineral? No. In order to be a mineral the following five criteria have to be true:
A mineral is defined as:

1. Naturally occurring (Amber: yes)
2. Homogeneous solid (Amber: yes)
3. Definite chemical composition (Amber: yes)
4. Ordered crystalline structure (Amber: no)
5. Inorganic origin (Amber: no)

HARDNESS:
Burmese amber is the hardest at 3.
Baltic amber is 2-2.5 (and is the most plentiful)
Dominican amber is 1-2 (2nd most plentiful) It is a geologically younger amber and tends to be softer than amber that has been buried for a long time.

FRACTURE: Conchoidal
LUSTER: Resinous
SPECIFIC GRAVITY: 1.05-1.2

FLUORESCENCE:
Some amber will fluoresce. Common fluorescent colors are blue, yellow, green, orange or white. In general, resins with higher sulfur content fluoresce more.

Amber is found in 12 states in the US: NJ, NC, Alaska, MT, AK, TX, TN, NM, Maryland, MA, WA, CA and at least 13 foreign countries.

AMBER NAMES:
Fatty, Bone, Foamy (or Frothy), Soily, Scoopstone, Sea Stone or Sea Amber, Pit Amber, Ambroid (pressed amber w/uniform color and consistency). Poland has over 200 folk names for amber.

COLOR AND INCLUSIONS:
Baltic Amber: Displays various colors, most notably a warm shade of orange. 1 in every 1000 pieces contains an inclusion. Baltic amber was produced by conifers 20-50mya. 750 documented distinct plant species have been found in Baltic amber.
Dominican Amber: Usually light honey-colored. 1 in every 100 pieces contains some kind of inclusion. Primarily of Oligocene Age.

Types of inclusions: Insects, insect droppings and eggs, spiders, butterflies, moths, plants, flowers, pinecones, seeds, mushrooms (found in NJ), feathers, silk, sawdust, pyrite crystals, bubbles, water, barnacles, crabs, frogs, lizards (rarely).

COLLECTING METHODS:
Riding on horseback through marshy areas with a net and scooping up the amber was one method. Another was to lie over the side of a boat and stir the sand, causing the amber to float to the surface. Other, less informal collecting methods are dredging, mining, and hydraulic mining.

CARE OF AMBER:
DON'T:
Put your amber jewelry on before you spray your hair or use perfume.
Store with other jewelry that can chip or scratch your amber.
Use ultrasonic or steam cleaners.
Get it near cleaning solutions, lard, salad oil, butter.
DO: String amber beads w/knots to separate each bead.
Store in a soft cloth.
Keep away from heat, open flame or direct sunlight.
Clean w/lukewarm water. Dry. Rub w/olive oil. Wipe excess off.

USES FOR AMBER PAST AND PRESENT:
Honey mixed with powdered amber – used for asthma, gout and the black plague
Pendants worn to preserve chastity
Talismans worn to protect against evil
Burned to chase away mosquitoes and sea serpents
Cigarette holders, mouth pieces for pipes
Ship decks
Early photography
Varnish for stringed instruments (nearly all varnishes today are synthetic)
Carvings, boxes, cups and dishes, rosaries, teething rings, etc.

COPAL VS. AMBER:
Copal: a few hundred to a few million years old. It is softer than amber. Most insects in copal belong to living species.
Amber: More than a "few million years old". Amber is harder than copal and can contain extinct species of insects.

DATING AMBER:
Amber is dated based on the fossils found in the associated sediments. If the amber has eroded from one deposit and was re-deposited somewhere else, it could be much older than the sediments suggest. Another way to date amber is by insect inclusions. If a modern housefly is found, it's not amber, it's plastic! (Although methods of fakery are becoming more sophisticated: forgers are now using real amber to surround their fake bugs.) Another test: true amber will powder when scraped with a knife, plastic will give off shavings.

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Websites for more info:
"Deadbugsinamber" society at:
http://members.tripod.com/snakefly/
"World of Amber"
http://www.emporia.edu/earthsci/amber/amber.htm
"The Amber Lady"
http://amberlady.com/

FUN FACTS TO KNOW AND TELL ABOUT AMBER

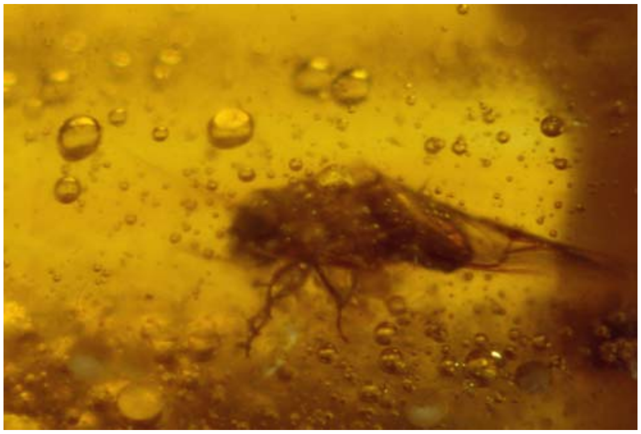
By Anita D. Westlake

- It has been poetically said of Amber that "Time has stopped inside it."
- Soft resin can be chewed as gum with disinfecting properties. It can be used to protect scabbed sores, preventing infectious bacteria and fungi from attaching to the wound.
- The ancient Greeks found that dissolving a little resin in the wine made it keep better. (I don't keep wine around long enough to worry about it spoiling.) This knowledge is still put to use today in the making of retsina wines, whose distinctive taste comes from the resin of the Aleppo pine.
- Succinite, the scientific term to describe authentic amber, comes from the Latin, meaning "juice stone."
- The parallel grooves sometimes found on larger amber pieces may be the result of ice movements.
- Yellow and brown are the most common colors of amber. Red develops over time through oxidation. Oxidation also causes crazing (shallow cracks along the surface).
- There are approximately 250 color variations of amber.
- White amber is less brittle than clear, and is therefore easier to sculpt and shape. Because of its many air bubbles, white amber can float in ordinary water: no salt needed!
- The world's largest piece of amber weighs 150 pounds and was found on the island of Borneo.
- The surface of amber is somewhat harder than the core which indicates that the hardening process occurs from the outside-in. Generally, the harder the amber, the older it is.
- Inclusions are almost always found in transparent amber and almost never in opaque stones. One theory is that clear amber is the result of a defense mechanism whereby the tree produced and released large amounts of resin in response to a threat.
- Amber inclusions of larger animals such as fish, lizards, etc. are almost always fakes. The local lizard population in Mexico is probably endangered from the amber forgers alone!
- Be careful when doing salt solution tests: Polystyrene has the same specific gravity as amber and will float.
- Amoebas have been found trapped in amber ***in the act of dividing.***
- Dinosaur DNA has not been extracted from the bellies of mosquitoes in amber, but in May 1995, Raul Cano revived bacterial spores from a sting-less bee entombed in amber 25-40 mya. If this feat can be substantiated, he will have been the first person to resurrect life from the past. Some say a modern strain of bacteria contaminated the experiment despite all precautions.
- Dominican amber is too young to house dinosaur DNA but NJ amber formed 30my before the dinosaurs became extinct.
- DNA is largely similar for most organisms: ***it contains around 90% inactive information*** (perhaps a reserve for future evolution?)
- Not all tree resins can form amber, as most get broken down and decay. Only 2 types of tree living today produce stable resins that could, with time, fossilize into amber.
- "Spangles" are artificially produced in real amber by heating the piece in sand.
- Pressed amber (ambroid) is commonly found in Victorian jewelry and as the stems of tobacco pipes. It is formed by fusing small pieces of amber together under high temperature and pressure.
- It was once believed by ancient people that amber was hardened lynx urine.
- In 1264 Teutonic kings tried to control the collection and sale of amber. If you were caught collecting amber w/o permission, you were hung.
- Phenolic resin (Bakelite) is the most common material to be encountered in fake amber jewelry.
- Insects in amber: If the specimen is perfectly centered in the piece, and its legs neatly stretched out and arranged, beware! Genuine spiders, for example, usually have their legs tightly curled up under their bodies in death.

In Mexico, green amber does occur naturally, but it's quite rare. Necklaces, rings, etc. are commonly made from green plastic and sold as amber. Amber can also be irradiated or heat-treated to produce the green color.

From "The Amber Book" by Ake Dahlstrom and other sources.

Insect in amber, Dominican Republic. 10 mm wide (the insect is 4 mm long). (Julian C. Gray, specimen and photo)



Now, <u>without looking back at the article</u>, take this AMBER QUIZ:

1. Is amber a mineral?
2. Can you get dinosaur DNA from amber?
3. How many names do Polish people have for amber?
4. Name two uses of amber.
5. Name three inclusions in amber.
6. What's the main difference between amber and copal?
7. In the 11th century, what was the penalty for collecting amber without permission?
8. What is the hardness of amber?
9. What's the difference between sap and resin?
10. What's the ratio of inclusions for Baltic amber? Dominican?
11. How many states in the US have amber?
    How is amber dated?

Color in Minerals

by Doug Daniels, GMS Member

(Note: this article is a brief version of a talk given to the Mineral Section in December 2003. There are some scientific ideas which are necessarily glossed over, in view of space. Hopefully, if anything seems a bit "over your head", you will search out the answers.)

Have you ever wondered what causes all those wonderful colors in your favorite specimens? Many have, and the causes have been the subject of many a study. Years ago, the explanations were simple – there were three causes. Idiochromatic minerals ("self-colored") were colored by some essential element (the "chromophore"), such as copper or iron. Allochromatic minerals ("other-colored") were colored by trace impurities (either chemical or mechanical in nature), or to defects in the crystal structure. Pseudochromatic minerals obtained their colors from the diffraction or scattering of light by structures within the mineral.

Simple, but the definitions satisfied many. But these definitions did not stop mineralogists and physicists from delving deeper into the causes of color. Current thoughts on the cause of color in minerals were summarized in an article in the American Mineralogist by Kurt Nassau (1978). He describes twelve separate causes, which can be placed in four main groups: 1) crystal field effects; 2) molecular orbital effects; 3) band gap theory; and 4) physical optics effects. More on each group later.

Before elaborating on the ideas above, we need to look at some color theory. Generally, the color we see for an object is the result of the interaction of white light with that object. White light is made up of red, orange, yellow, green, blue, indigo, and violet light (the spectrum, or "rainbow"). The color of an object is the result of that object absorbing certain colors of light; the color(s) seen is (are) the color(s) <u>not</u> absorbed. For example, if the blue/green/violet colors are absorbed, the color seen is red/orange. A final bit here: From physics, we know that each color has a frequency and a wavelength (actually, each has a narrow range). They also have an associated energy. Keeping things simple, the highest energy is in the violet end of the spectrum, decreasing towards the red end (part of the reason why the ultraviolet light [higher energy than violet light] in sunlight causes sunburn).

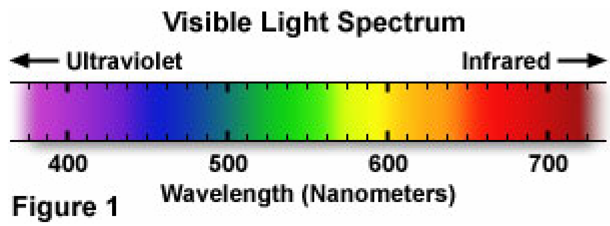


Figure 1

Theoretically, white light is made up of equal amounts of the aforementioned seven colors. However, we have a number of sources of "white" light, with minor differences that can be discerned using special instruments called spectroradiometers. Sunlight is actually a bit richer in the greenish-yellow part of the spectrum (our sun is a "yellow" star). "Daylight", the light obtained from a clear, northern, blue sky at noon (the photographic definition), is enhanced in the blue part. Incandescent bulbs are rich in the red end of the spectrum. Fluorescent bulbs tend to have "spikes" in the orange, green, and violet, due to the excitation of mercury atoms in the bulb; the actual "white" light comes from fluorescing phosphors. (The "spikes" result from the excitation of atoms, and add an overprint to the general white light.) Metal halide (halogen) bulbs have "spikes" in several color areas, depending on the elements used in the bulb. So why do they all appear "white"? Our brain processes what we see to tell us it is white; if you compare several side by side, you can perceive the ever-so-slight differences. However, the world of minerals gives us an example that shows the differences among light sources. Alexandrite, the gem variety of chrysoberyl, appears red under incandescent light (richer in red), but green under daylight or fluorescent light (richer in green-blue). The subtle differences in light sources results in a major change in appearance of the mineral.

Now we go back to the causes. The first main group of causes is due to <u>crystal field effects</u>. Within this group are two main causes – transition metal ions and color centers ("defects"). The metal ions include only a few of the 92 naturally-occurring elements, consisting of a few in Period 4 of the Periodic Table (vanadium, chromium, manganese, iron, cobalt, nickel, and copper), and some of the Lanthanide and Actinide series of elements. The cause of color due to these metals is related to the filling of the d- or f-shells of electrons (check your chemistry book….). Generally, electrons like to move about in pairs. When these metals form ions, a single, lone electron may be left in the orbital; in order to satisfy its need for companionship, it may absorb energy (i.e. color) from any incident light. The energies (wavelengths, frequencies) not absorbed causes the color seen. And, the "typical" colors seen may

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depend on the valence state (the electrical charge) of the ion. For example, copper with a +1 charge is typically colorless, whereas when it is in the +2 state it is green or blue. Iron in the +2 state is typically colorless to green, and in the +3 state it is yellow to orange. The color variations are explained by "coordination effects", that is, how the negatively-charged ions pack themselves around the metal ions (see, for example, Hurlbut and Klein for an explanation).

Visible Light Wavelength and Perceived Color

Wavelength Range (nanometers)	Perceived Color
340-400	Near Ultraviolet (UV; Invisible)
400-430	Violet
430-500	Blue
500-570	Green
570-620	Yellow to Orange
620-670	Bright Red
670-750	Dark Red
Over 750	Near Infrared (IR; Invisible)

Color centers are also referred to as defects. There are two types of color centers. An electron color center, also called an F-center (from Farbe – German for color), is due to unpaired electrons not on metal ions. Surprisingly, these electrons occupy positions within the crystal lattice with a missing ion; instead of an anion (a negatively-charged ion), there is only that poor, lonely electron. This source is often invoked to explain the colors in fluorite. The second type is called a "hole center", whereby an electron is missing from a metal ion (often an impurity metal) which usually has a pair of electrons. This type of color center appears to be formed mainly by the effects of radiation; an impurity metal having a different electrical charge than the "main" one is required in the structure to keep the electrical charges balanced. Such effects are thought to cause the colors of smoky quartz, amethyst, and blue topaz, to name a few. It should be noted that colors caused by this effect can be lost by heating, but reintroduced by irradiating the specimen.

The next group, molecular orbital effects, involves electrons not located on a single ion, but rather involved with a group of ions. And, there are three types: Metal-metal, metal-nonmetal, and nonmetal-nonmetal. In the metal-metal effect, there are two (generally transition, see above) metal ions, each of which can exist in two valence states (electrical charges). The absorption of light energy (the colors you don't see) causes an electron to transfer from one ion to the other; it then returns to the original ion, releasing heat (a very tiny amount). For example, on absorption of light, the pair iron +2/titanium +4 becomes iron +3/titanium +3, resulting in the blue color in sapphire.

The metal-nonmetal effect involves a multiple-ion anion (a negatively charged group), in which the ions are covalently bonded (again, see your chemistry text). The most obvious group here is the chromate group, consisting of a chromium ion surrounded by four oxygen ions. The electron transfers between the chromium and oxygen cause absorption of the blue end of the spectrum, yielding yellow to orange colors. As with the crystal field effect, the coordination of ions may also affect coloration.

The nonmetal-nonmetal effect involves, you guessed it, nonmetals, which are covalently bonded. In the mineral world, this is best exemplified by sulfur; the absorption of the blue end results in the yellow color. Interestingly, as you heat and melt sulfur, the coordination of the atoms changes, causing the color to change to orange, to red, then finally to black (the sulfur is absorbing all light at that point, assuming it hasn't burst into flames). This effect probably also contributes to the colors of those nasty halogen elements: chlorine and fluorine (both greenish gases), bromine vapor (red), and iodine vapor (violet); you would not want to try to collect these guys, even if they existed in nature.

The next beast, band gap theory, is the hardest to explain in simple terms. In the above two groupings, the electrons belong to either a single ion, or to a discrete grouping of a few ions. In this group, the electrons belong to the crystal (i.e., the mineral) as a whole; they are not constrained to a single atom or ion. This group includes conductors (metals), semiconductors (most sulfides, sulfosalts, oxides), and semiconductors with impurities (e.g., colored diamonds). This group gets into the ever-so-nasty quantum effects, wherein the energy levels occupied by the outermost electrons are stretched into "bands". There is a valence band, which is the normal energy level of the atom (the ground state). There is also a conduction band, which is a higher energy level where the electrons are more mobile. The energy difference between the two is termed the "band gap"; an electron within the valence band can absorb light energy and move into the conduction band. This is simply put.

In the metals, the outer electrons are in a common pool, that is, the valence band merges with the conduction band, allowing them to move rather freely throughout the crystal structure. This is the cause of the metallic luster, the high electrical conductivity, and other traits found in metals. The surface electrons can absorb light of any energy, but they reemit it; the efficiency of reemission produces the colors (i.e., copper, silver, gold).

Within the next subgroup, the minerals are covalently bonded, in which the average number of bonding electrons is four per atom. Light with energy greater than the band gap will be absorbed, moving electrons from the valence band into the conduction band. For example, if the ions absorb all the visible light energy, the color we see is gray or black (e.g., galena). If only the high-energy light (blue-violet) is absorbed, the color seen is red to yellow (cinnabar, cuprite, realgar, orpiment).

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Semiconductors with impurities are just that…..a semiconductor (such as carbon) with an impurity. In the mineral world, diamond is the best example, although this group is important in the electronics industry (but not for pretty, colored materials). For example, traces of nitrogen in diamond cause a yellow color, whereas traces of boron cause a blue color. Basically, this is similar to the color center effect, except that the electronic bonding between atoms/ions is different. The impurities lead to extra electrons, or "holes", within the structure; in this case electrons bandy about with the conduction band.

The final group includes the physical optics effects. Here, light is interacting with structures similar to the wavelength of light. These effects include scattering, dispersion, diffraction, and interference. Scattering involves the reflection of light off small particles, and includes chatoyancy (as in tigers eye), asterism (star sapphire), the luster of pearls and fibrous minerals, aventurescence (sunstone, some schiller), and adularescence (moonstone). For more details on these, consult your favorite reference, please.

Dispersion has to do with a material's index of refraction – simply put, different wavelengths (colors) bend differently when passing through a crystal at an angle; again, the explanation can be found elsewhere, and is not given here. This is what happens when white light is passed through a prism to produce a "rainbow" spectrum. This effect is used in faceting – you essentially are creating a complicated prism, which breaks the light into the colors (the "fire"). This is best seen in materials such as diamond, (pure) rutile, zircon, and cubic zirconia, to name a few.

Diffraction occurs when you have particles or layers with the same general dimension or thickness as the wavelength of light (or, at least of some of the colors). For example, precious opal has been examined under electron microscopes, and has been found to be composed of regular arrays of small spheres, all of roughly equal size; the size determines the color(s) of the "fire" seen. Labradorite, a variety of feldspar, has numerous very thin layers of differing composition, with differing optical properties; when oriented correctly, light diffracts through the layers producing incredible flashes of color.

Interference has to do with light passing through thin layers of differing refractive index. Examples include the tarnish layers on bornite and chalcopyrite (the "peacock coppers"), and the iridescent hematite (or whatever it is) found at Graves Mountain.

Thus I conclude my article on the causes of color in minerals. Is this simple and complete? No. I have deliberately kept a lot of stuff out. Hopefully, your interest is piqued enough to get you to dig a bit deeper, to learn more. You can do it. Just don't rush into it…. Even with a scientific background, many struggle with a lot of it (the band-gap, for example), but they work with it. That's how they learn.

Selected References

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Colors From Band-Gaps in Semi-Conducting Minerals. www.Minerals.gps.caltech.edu/COLOR_Causes/Band_Gap/index.htm

Colors From Metal Ions in Minerals. www.Minerals.gps.caltech.edu/COLOR_Causes/Metal_Ion/index.htm

Colors From Ionizing Radiation. www.Minerals.gps.caltech.edu/COLOR_Causes/Radiate/index.com

Colors in Minerals Caused by Intervalence Charge Transfer (IVCT). www.Minerals.gps.caltech.edu/COLOR_Causes/IVCT/index.htm

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Nassau, Kurt, 1978. *The Origins of Color in Minerals.* American Mineralogist, v. 63, pp 219-29. (also online at www.minsocam.org/msa/collectors_corner/arc/color.htm)

Why Do Things Look Colored?. www.lst-socrates.berkeley.edu/~eps2/wisc/Lect7.html

Below is a list of some coloring elements and the color they produce in at least one mineral:

- Cobalt, **Co**, produces the violet-red color in **erythrite**, *(cobalt arsenate)*.
- Chromium, **Cr**, produces the color orange-red color of **crocoite**, *(lead chromate)*.
- Copper, **Cu**, produces the azure blue color of **azurite**, *(copper carbonate hydroxide)*.
- Iron, **Fe**, produces the red color of **limonite**, *(hydrated iron oxide hydroxide)*.
- Manganese, **Mn**, produces the pink color of **rhodochrosite**, *(manganese carbonate)*.
- Nickel, **Ni**, produces the green color of **annabergite**, *(hydrated nickel arsenate)*.
- Uranium, **U**, produces the yellow color of **zippeite**, *(hydrated potassium uranyl sulfate hydroxide)*.
- Vanadium, **V**, produces the red-orange color of **vanadinite**, *(lead vanadate chloride)*.

From http://mineral.galleries.com/minerals/property/color.htm

MEMBERSHIP NEWS

I hope everyone will join me in welcoming the following new members to Georgia Mineral Society: Bill, Terri, Josh, and Nathan Adams of Clyde, NC; Sebastien, Sandrine, Sarah, and Samuel Fuchs of Decatur, GA; Douglas Green and Terri Chambers of Douglasville, GA; James H. and Judith A. Musick of Douglasville, GA; Jim, Mary Ann, and Jim O'Brien of Wheaton, IL; Christopher, Laura, Jennifer, and Sarah Ozment of Rome, Georgia; and Chip Miller of Scottdale, GA. We're glad to have you with us and hope to meet you soon.

Happy rockhounding!

Lizabeth McClain
Executive VP/Membership

GEM SECTION NEWS

Monday, March 28, 2005
7:30 pm, Kim Cochran's home
2605 Van Court
Snellville, GA, 30078

Last month we played with the dichroscope and refractometer. This month Martha Brown will demonstrate talc carving. Please bring a steak knife. Supper will be at 6:30pm.

Please RSVP to Kim at 770-979-8331

Hope you can make it,
Kim Cochran, Gem Section Chair

JUNIOR SECTION

There will be no meeting in March.

But save the date for:
April 10, Sunday
Providence Canyon, Lumpkin, GA
Meet at Providence Canyon State Park
12 Noon

In the April Tips and Trips, I will give more details about the outing. This is a three hour drive to the Canyon. We will have a picnic lunch and then go climbing into the canyon. This is not a collecting site since it is a state park, but a great place to have fun learning about erosion and finding fossils in the sedimentary layers. We will get dirty. We will leave the Canyon at 3 pm and be home by 6 pm. Call me for any other questions you may have.

Roxanne Lopez, Junior Section Chair
Home: 770-436-0387
Work: 404-814-4031

MICROMOUNT SECTION NEWS

There will be no Micromount Section meeting this month. The next meeting will be April 21, 2005 at the Fernbank Science Center.

Dave Babulski, Micromount Section Chair

SUNSHINE NEWS

Happy Birthday to the following GMS members:

Michelle Alber, 3/3
Julia Clark, 3/5
Susan Hanson, 3/16
Nia Riviears, 3/19
Kaitlynn Palmer, 3/23

Correction to last months article: Bill Waggener did not speak to the group of Elementary School science teachers at the "Extreme Science Day" in Rome, GA, on January 29th about teaching geology at the Elementary School level - it was cancelled due to inclement weather. Joan White represented GMS at the GSTA meeting in Columbus by handing out mini-grant application, club information and stickers for the students

Olin and Jeanette Banks celebrated their 46th wedding anniversary on February 14, 2005. They are true sweethearts.

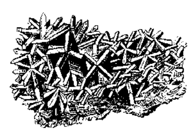
Luck to you on St. Patrick's Day,
Joan White, <u>Temporary</u> Sunshine Chair

FOSSIL SECTION NEWS

There will be no fossil section meeting this month. Please keep an eye on future issues of <u>Tips and Trips</u> for an announcement regarding the next meeting.

Friends, like fossils, are forever,
Harry Yingst, Fossil Section Chair

MINERAL SECTION NEWS



The next meeting of the Mineral Section is on Thursday March 24. Please note that we are meeting on a Thursday this month only because of my class schedule this semester; in May we'll go back to third Tuesdays on alternating months.

This month we'll be looking at the minerals occurring in everyone's favorite setting: *pegmatites!* Those minerals include tourmaline, beryl, microcline, mica, lepidolite, smoky and rose quartz, phenakite, bertrandite, to name only a few. The meeting will take place at 7:30 pm at my home at 524 Robin Lane SE, Marietta. To RSVP or if you're lost, call me at (770) 973-3632. I will feed folks who RSVP and show up at 6:30 pm, but I may need help with that unless you want Chinese food left over from the January meeting (or worse, graduate student food: bologna sandwiches, Doritos, etc.)

If you have an idea for a mineral related topic or would like to host a future meeting at your home, please contact me.

Thank you!
Julian C. Gray, Mineral Section Chair