Northwest
Micro Mineral
Study Group

MICRO PROBE

SPRING, 2011 **VOLUME XI, Number 3**

SPRING MEETING . . . . .VANCOUVER, WASHINGTON

May 7, 2011 9:00 am to 5:00 pm

Clark County P. U. D. Building
1200 Fort Vancouver Way
Vancouver, Washington

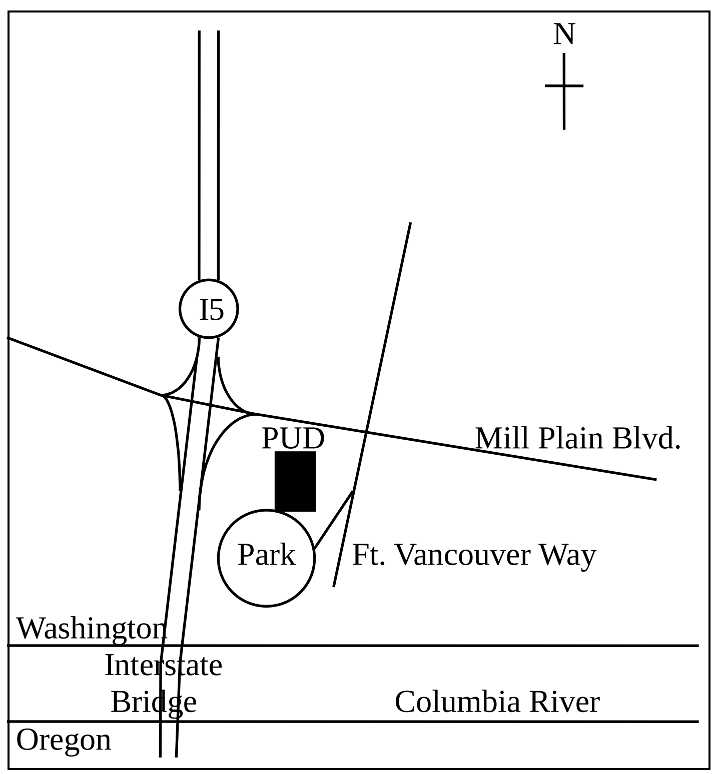
Come celebrate spring talking about your favorite minerals. Bring your microscopes and something for the free table to share with others. There should be plenty of time for sharing and swapping. We will have our usual brief business meeting in the morning, to be followed by our update session to find out what localities are actively producing material and are good bets for collecting trips.

In the afternoon:

Bob Meyers will be talking on *Micromineral Photography*,
Kelly Starnes will be making plans for a field trip to the Table Mountain Quarry, and
Don Howard will be showing pictures of "*What's Old in Minerals"* from things he found at last summer's NCMA meeting at El Dorado, California.
Others' pictures are always welcome.

The kitchen area is again available and we will plan on sharing lunch together. As always, the club will provide the basics for sandwiches, so bring goodies to make lunch special.

In the evening, many of us plan to go to a local buffet restaurant, so please join us if you can.



Presidents Message

Another year is here and changes are coming. The first change is I am retiring from the Rice NW Museum of Rocks and Minerals effective May 1st and I am now in the process of moving to Yakima, Washington. Why Yakima? The main reason is to be near Randy Becker who is building a new house in Yakima. Randy and I have been collecting partners for many years and we both need someone to study and talk about minerals.

The next big change for me is that I am changing the focus of my mineral studies from zeolites to minerals of the Golden Horn Batholith in northern Washington. Many of you have been studying these minerals for many years, so I have a lot of catching up to do. I hope to bring along the rest of the micro group to make a concentrated effort to study, describe, and add additional species and new species to the growing list of minerals found there. I hope the micro group will use some of its funds to pay for thin sections of rocks, microprobe chemical analysis, and x-ray work needed to identify the unusual minerals found in the Golden Horn Batholith. In time, I would like to see the micro group publish a book on the minerals from that area.

The agenda of the May 7th meeting:

- 9 am Doors open. Setup microscopes, talk to friends, and look at free minerals on tables
- 11 am Short Business Meeting
- Noon Potluck lunch
- 1 pm Talk on Building a micromineral photo unit by Bob Meyers.
- 2 pm talk on minerals from the coastal area of Oregon by Kelly Starnes.
- 2:30 Micromineral photos "What's Old in Minerals" by Don Howard
- 4 pm Clean up (help is needed in cleaning the kitchen, putting tables away, and vacuuming the rug).
- 5 pm Group supper at the Old Country Buffet in Vancouver

Rudy Tschernich, President

Micro-Minerals of Table Mountain Quarry, Lincoln County, Oregon

Kelly Starnes

Table Mountain forms a flat topped hill approximately 2700 feet in elevation in the central Coast Range in Lincoln County, Oregon. The mountain is capped by an nepheline syenite porphyry sill that intruded the middle Eocene Tyee Formation (Parker, D.F., et. al. (2010)). Snavely (1961) and the Oregon Department of Geology and Mineral Industries report the thickness of the sill to be approximately 250 to 400 feet. There are several quarries developed on the mountain, all within the nepheline syenite porphyry. The quarries (see Photo No. 1) were excavated primarily for jetty rock in nearby Yaquina Bay and crushed rock for road construction. The mountain is accessed via Highway 34 by traveling approximately 13.47 miles east of Waldport (or 50 miles West of Corvallis) to Forest Road 52. See Figure 1 for access map.

The main quarry (Photo 1) is located on "State of Oregon School Lands" and is not open for private mineral claims. There are private claims adjacent to the south and east of the school lands.

Photo 1 - Main collecting quarry, August 7, 2010.

Geology

Snavely (1961) described several alkalic intrusive bodies within the central Coast Range of Oregon in Lincoln County. He reported that nepheline syenite porphyry formed a stock at Blodgett Peak and sills capping Table and Cannibal Mountains. The sills may be the remnants of a larger intrusion that may have been approximately 200 square miles in area. The nepheline syenite at Blodgett Peak was described as being medium gray, composed of 50 percent albite laths in the groundmass, 10 to 15 percent each of albite phenocrysts, nepheline and analcime, and secondary minerals, 5 to 10 percent aegirine and aegirine-augite, 3 to 5 percent olivine and opaque minerals, and 1 to 2 percent riebeckite. Deuteric analcime partially replaced the nepheline and albite, and occurs as crystals in rare miarolitic cavities. The albite at Table Mountain has been almost completely altered to sericite and clay minerals.

The nepheline syenite porphyry at Table Mountain is light gray in color. Miarolitic cavities are more abundant here than at Blodgett Peak and range in size from 10 centimeters down to 0.5 millimeters. Field examination has found that the larger cavities are almost always completely filled with analcime. A higher percentage of the smaller cavities (1.0 centimeter or less) are found to be open, and it is within these smaller cavities that most of the interesting crystals have been found. Since the cavities are so small, I usually collect the most promising hand size specimens and do further trimming at home.

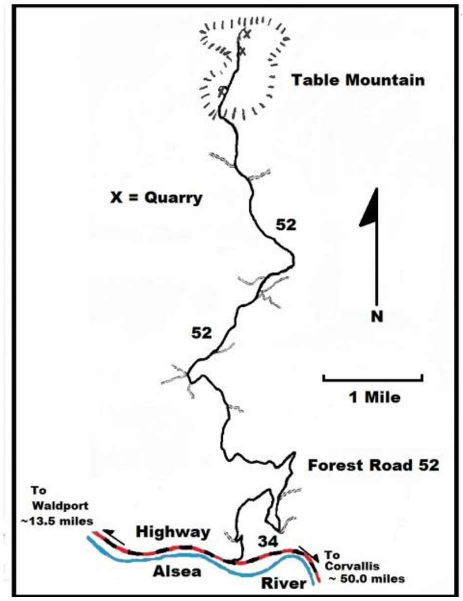


Figure 1 - Location map.

Mineral Descriptions

Albite

Transparent, tabular overgrowths on altered (sericitized) albite crystals occur in some of the cavities (Photo 2).

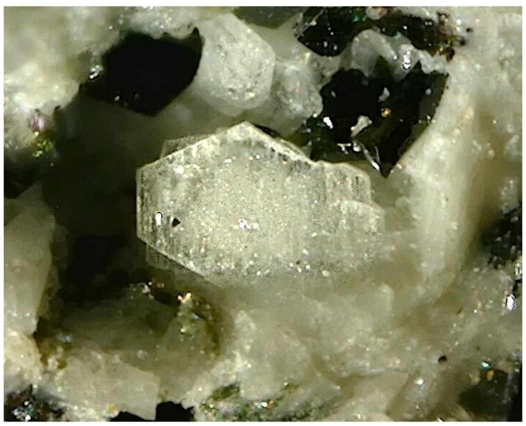


Photo 2 - Albite, crystal width ~0.4mm.
PKS Specimen No. 3304.

Analcime

Analcime is a common mineral found in the cavities at Table Mountain. The larger cavities are for the most part completely filled with milky analcime and the smaller cavities yield transparent crystal druses and rarely transparent single crystals (Photo 3). The analcime crystal in Photo 3 shows a cube crystal face.

Photo 3 - Analcime, ~1.2 mm in height, with cube face. PKS Specimen No. 4081.

Aegirine and Aegirine-augite

Aegirine and aegirine-augite are common minerals found in the cavities at Table Mountain. Every cavity examined contains at least one crystal of aegirine or aegirine-augite of varying form. The crystals range from short and blocky, of possible aegirine-augite composition (Photo 4), to thin, elongate blades (possibly aegirine composition) (Photo 5). The short and blocky crystals are very dark green to nearly black, transparent only along the edges. The bladed crystals are transparent green, with occasional color zoning. Corroded, black crystals of perhaps another pyroxene group composition mineral are occasionally found in the cavities. In some cavities, zeolite group minerals have preferentially grown on certain crystal faces. The aegirine crystal in Photo 5 has tiny acicular(?) crystals on the select prism faces.

Photo 4 - Intergrown aegirine-augite crystals to ~0.4 mm in height. PKS Specimen No. 3797.

Photo 5 – Aegirine crystal to ~0.9 mm in length with a zeolite group mineral overgrowth on select prism faces. PKS Specimen No. 3232.

<u>Calcite</u>

Calcite occurs as a rare late stage cavity filler mineral. Collected specimens are mostly massive with some crude rhombohedral faces in open cavities.

<u>Chabazite</u>

Chabazite is found as transparent, 0.2 to 0.5mm intergrown, pseudo-cubic crystals (see Photo No. 6).

Photo 6 – Transparent chabazite crystals ~0.5 mm in width. PKS Specimen No. 3211.

<u>Natrolite Group</u>

On a recent trip to the quarry, transparent, prismatic crystals up 0.5 mm in length and 0.1 mm in width were found (Photo 7). The prisms also form transparent, coarsely crystalline balls that show the terminations of the crystals. Upon exposure to the atmosphere, within 30 minutes to 72 hours (dependent upon temperature and humidity), the transparent crystals will dehydrate to opaque white crystals (Photo 8). The crystal form (see Figure 2) precludes laumontite. Further work should determine if the white mineral is gonnardite.

Photo 7 – Transparent natrolite group mineral. Crystal height ~0.4 mm.

Photo 8 - Natrolite group mineral after exposure to atmosphere. Crystal height ~0.4 mm. PKS Specimen No. 4111.

Unknown Minerals

Metallic – Brassy and bright silvery metallic minerals have been found in the cavities of Table Mountain. Two specimens of a brassy, metallic mineral have been found. The brassy crystals are frozen in matrix, but appear to be euhedral in form and range in size from 0.2 to 0.3 mm in size. (Photo 8). An interesting foil-like, hexagonal(?), bright metallic silver mineral has been found in the cavities (Photo 9). Very thin and fragile, these crystals are able to be bent even under the pressure of a breath of air.

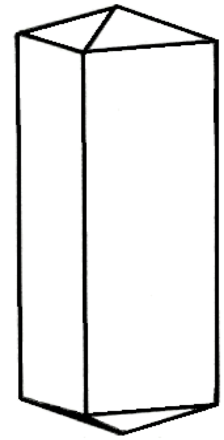


Figure 2 - Sketch drawing of a natrolite group crystal. Based upon natrolite drawing No. 425, Tschernich, 1992.

Photo 8 – Unknown, metallic crystal ~0.3mm in height. PKS Specimen No. 3727.

Photo 9 - Unknown, foil-like, metallic mineral, ~0.8mm in height. PKS Specimen No. 3802.

Zeolite Group – Unknown crystals or crystal groups that are transparent or white, equant, bladed or acicular crystals, are described under this group. All specimens were tested with hydrochloric acid to test for carbonate and no effervescence was observed. Further work should determine if the minerals are indeed zeolites. Photo 10 shows two intergrown, transparent dipyramidal crystals. Figure 2 is a sketch crystal form drawing of the crystals in Photo 10.

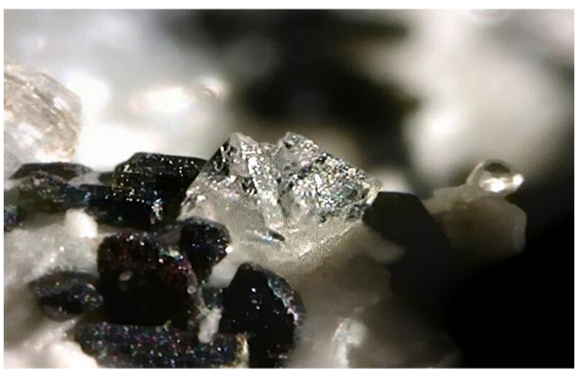


Photo 10 - Zeolite Group unknown. Crystal group ~0.4 mm in width. PKS Specimen No. 3305.

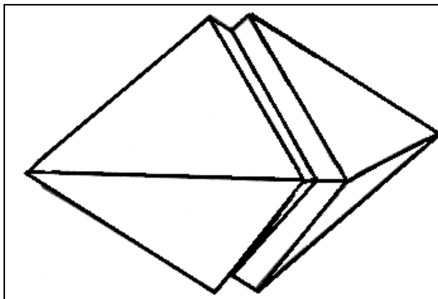


Figure 3 - Sketch drawing of crystal form in Photo 10. Based on gismondine drawing No. 234, Tschernich (1992).

White, semi-transparent, acicular crystals of a zeolite group mineral are found as radiating groups in cavities, on other mineral species (see Photos 11 and 17), or selectively coating crystal faces (see Photo 5). White, bladed, crystal groups that have been found can be roughly divided into two types; radiating groups of minute bladed crystals (Photo 12) or sheaf-like groups of bladed crystals (Photo 13). Radiating groups of transluscent crystals of undetermined form can also be found in the cavities (Photo 14).

Photo 11 – Acicular zeolite group mineral on aegirine-augite. Length of acicular crystal ~0.2 mm. PKS Specimen No. 2858.

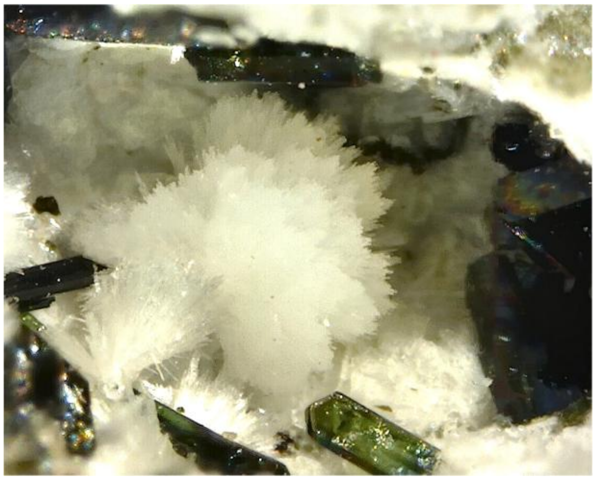


Photo 12 - Radiating, minute bladed crystals of a zeolite group mineral. Field of view ~1.0 mm. PKS Specimen No. 4124.

Photo 13 - Sheaf-like group of bladed zeolite group mineral. Sheaf height ~0.7 mm. PKS Specimen No. 4121.

Photo 14 - Zeolite group mineral, ~1.1 mm across. PKS Specimen No. 2857.

Pale green to yellow unknowns – Two types of yellow unknown crystals were found within the cavities. The first type can be described as minute tabular crystals and the second type as transparent, prismatic to bladed crystals. Photo 15 shows the tabular (hexagonal?) yellow unknown with natrolite group crystals. Photo 16 shows the transparent yellow, prismatic unknown. Pale green to pale yellow, possibly hexagonal, equant crystals have been found and are shown in Photos 17 and 18.

Photo 15 – Yellow, tabular (hexagonal?), unknown mineral. Crystal height ~0.1 mm. PKS Specimen No. 4201.

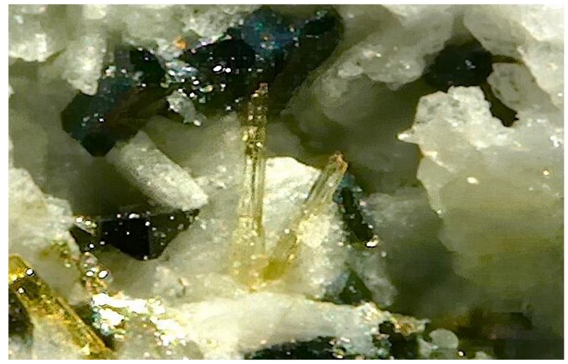


Photo 16 – Yellow prismatic unknown mineral. Crystal height for the center crystal is ~0.5 mm. PKS Specimen No. 3359.

Photo 17 – Yellow unknown mineral with acicular zeolite group overgrowth. Yellow crystal is ~0.3 mm wide. PKS Specimen No. 3216.

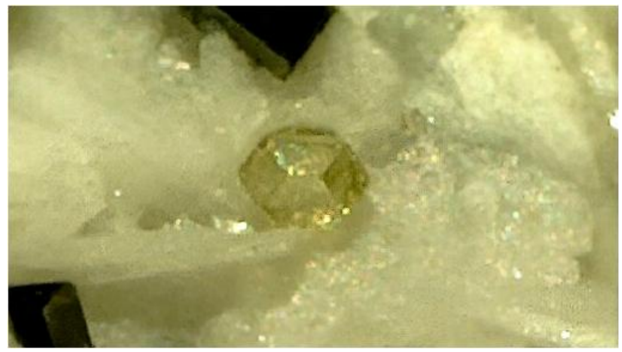


Photo 18 – Pale green unknown mineral. Crystal width ~0.2 mm. PKS Specimen No. 4201.

Pink unknown - Several specimens of a pale pink mineral have been found. Unfortunately, the crystals and partial crystals have been very minute (sub 0.1 mm), so identification of crystal forms has been difficult (see Photo 19).

<u>Chlorite or Mica Group</u>

A green to golden, micaceous mineral is present as distinct crystalline masses in many of the cavities. The green micaceous mineral usually forms minute, distinct crystalline spheres, whereas the golden micaceous mineral forms coarsely crystalline masses and films (see Photo No. 20).

Photo 19 - Pink unknown (center of photo), ~0.05 mm width. PKS Specimen No. 3302.

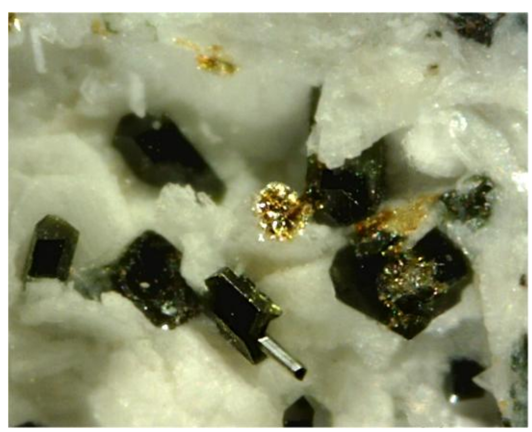


Photo 20 – Golden unknown mica(?) group

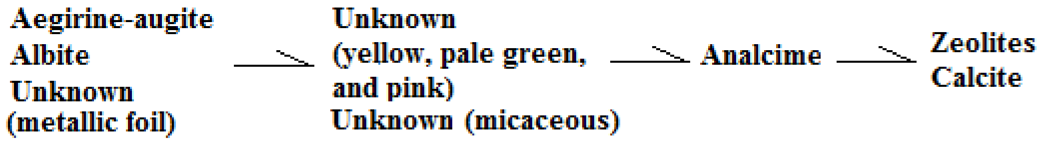


Figure 3 – General order of crystallization of minerals found within the cavities.

References:

Parker, D.F., Hodges, F.N., Perry, A., Mitchener, M.E., Barnes, M.A., and Ren, M., 2010, Geochemistry and petrology of late Eocene Cascade Head and Yachats Basalt and alkalic intrusions of the central Oregon Coast Range, U.S.A., Journal of Volcanology and Geothermal Research, 198 (3-4), pp. 311-324.

Snavely, Jr., P. D. and Wagner, H. C., 1961, Differentiated Gabbroic Sills and Associated Alkalic Rocks in the Central Part of the Oregon Coast Range, United States Geological Survey Short Papers in the Geologic and Hydrologic Sciences, pp. 156-161.

Tschernich, R.W., 1992, Zeolites of the World: Geoscience Press Inc., Phoenix, Arizona, 563 p.

Micro Mineral Photography using Image Stacking and a Machine Vision Lens

By Bob Meyer

Figure 1: A tapered 3.7 mm long crystal of Crocoite with Pyromorphite from the Kosminsky Mine, Dundas, Tasmania, Australia. An example of a photograph taken using image stacking through a machine vision lens.

Numerous forces are currently at play in the realm of micro mineral photography, largely due to the widespread acceptance and use of digital photography, the availability of a variety of equipment types for taking micro mineral photographs, the wonders of image stacking and image processing software, and the ability to easily share and transmit images with e-mail and the Internet. The purpose of this article is to explore some of the relevant issues pertaining to micro mineral photography, and particularly to discuss the production of high quality images using a machine vision lens and image stacking software. The issues covered will include a discussion of how one's purpose in attempting micro mineral photography will affect the type of investment in time and money required, a discussion of the elements required to produce high quality micro mineral photographs, a glance at the equipment required, and a brief discussion of some image processing methods, including image stacking.

What is Your Purpose in Wanting to Take Micro Mineral Photographs?

The question of purpose is the most central question you should ask before embarking on the road towards producing micro mineral photographs. If your purpose is primarily one of documenting your collection or being able to capture an image to e-mail it to others for discussion or attempts at identification, you can purchase equipment at a quite reasonable price that will enable you capture such photographs. Additionally, learning to use this equipment well enough to produce acceptable images for these purposes will not involve a huge investment in time or additional expenditures.

Figure 2: The Dino-Lite, an inexpensive digital microscope (Sunrise Dino, 2011)

Figure 3: An inexpensive microscope eyepiece camera (Digitals Microscope, 2011)

For the majority of micro mineral collectors, this purpose, and the investments required in time and money, will suffice. Although explaining the use and techniques involved with producing such images is not part of the scope of this article, a brief explanation of the methods and equipment required is warranted. The required elements are a camera, software, and expertise. Inexpensive camera options include small digital microscopes that capture images directly (figure 2), special "eyepiece" cameras that fit into one of the eyepiece openings of your existing stereo microscope (figure 3), and the taking of images with a normal digital camera though the eyepiece of a microscope or with the eyepiece removed. Some of these methods will allow the user to take a number of images of the same subject at varying focal planes, which can then be stacked using a stacking program, at least one of which is available as a free download on the Internet. The stacked output image can be cleaned up and further processed using digital photograph image processing software, and again, there are some that are free as downloads from the Internet. That takes care of the first two elements with only a small investment in money. The third element is expertise. As will be discussed further on, micro mineral photography can be frustrating. Producing acceptable images with this equipment will take a significant investment in time. Despite this, most micro mineral collectors should develop the ability to produce such images. With time, you will find that at least some of your photographs using such equipment and software rival those produced by those who possess systems that are far more expensive.

If instead, your purpose is to produce higher quality images suitable for publication, then the remainder of this article should prove to be pertinent. Before we go down that road, however, it is necessary to make a brief cautionary statement. Exploring micro worlds is an optical experience, and micro mineral collectors are often tempted to photograph the views they witness—one optical race a natural seeming extension of the other. Before you embark down that path, though, it is important to mention that studying minerals with a microscope is vastly different than photographing them through a microscope. Viewing minerals with a microscope is not particularly stressful, nor does it require great skill; actually, exploring micro worlds can be relaxing, even therapeutic. In contrast, photographing micro minerals can be quite frustrating, and achieving decent results will involve a large investment equipment, time, and patience. Every phase of the process involves skill. With that being said, if you have your heart set on photographing micro minerals, then go for it.

Elements of a High Quality Micro Mineral Photograph

Figure 4: Unlike mineral photographs, which rely on the availability of expensive specimens, photographs of natural scenery often just involve being there, having a camera, and shooting the picture. NWMMSG member Randy Becker at the Keystone Mine, near Challis, Idaho

Micro mineral photographs are like other photographs, only more so. It is not enough to have the equipment, software, and expertise; you must also have good stuff to photograph. While this is true of about any category of photography, some are more forgiving than minerals. For example, if you are a landscape or nature photographer, excellent quality photographic subjects can be obtained simply by visiting places such as National Parks. You can hardly go wrong with a camera while ensconced in photogenic places. Alternatively, if you enjoy taking photographs of people, you can wander around in large cities to capture interesting subjects. Of course, being in a national park is not by itself going to assure that perfect level of light, and hanging around cities is not going to give you access to professional models. Capturing the highest quality images always involves a sincere commitment to the art of photography.

If you peruse the Internet and observe the work of the best mineral photographers, you will note that either they have top quality specimens or they have access to them. The best photographs tend to be of exquisite specimens. Most of us are going to be shooting specimens from our own collections, and despite the cliché, it is difficult to make specimens appear better than they are—at least ethically. As an aside, you could retouch an image to make it better than it really is, but that opens up ethical issues, particularly in our scientific setting. Therefore, if you embark on a campaign to produce high quality images, you should keep in mind that you will also need access to high quality specimens. If these specimens are from your own collection, then you can add still another layer of investment. This added layer comes as an investment in time as a dedicated field collector, or an investment in money in purchasing specimens, or as both. Many of the best mineral photographers have large mineral budgets.

The second thing you will require is photographic equipment, which will include software for purposes of this discussion. These are *things* you must have to produce high quality images. The *higher the quality* of the equipment you have, *the higher the potential* you have to capture high quality images. However, with that being said, it is very easy to place undue importance on the equipment itself. The equipment is only a prerequisite to producing good images; it does nothing to produce them. There is an example that might be familiar to most of us. The first case is a person with an expensive camera, but who cannot seem to take decent photographs. Contrast this with a person possessing a modest camera, but who consistently turns out great images. Photographers tend to be extremely hardware conscious. Go to any photogenic place, such as a park at sunset, and you can observe this—the distain that photographers with tripods and large open lenses have for those with lesser gear. It is good to remember in these settings that the gear does not make the photographer.

Despite this admonition, you will never really be able to keep yourself as a photographer from centering on your gear. Ultimately, as you advance in your skills, the equipment that you have will define constraints on the level of the photographs you can produce. Your goal as a photographer should be to get to this point, but you will undoubtedly find this frustrating, because obtaining equipment that lifts these restraints might be prohibitively expensive, or it might simply not be available.

The final characteristics you will require are the potential and drive to become a good photographer.

Photography is an art, and photographers are artists. Think of what you know about artists, and the type mental traits required. Art is a driving force, and the mental pressures and frustrations involved in producing art often leads to eccentricity. Artists are often a bit crazy.

Photography is a science, and photographers are scientists. Photographers must have a strong technical knowledge of optics, color, lighting, and how various media, such as the sensor in a digital camera, captures and is limited by the interplay of light elements. Think of what you know about scientists and the type of mental traits required. Scientists must have highly developed powers of reasoning that should be free from aberration.

This dichotomy between the artist mentality and the necessity of possessing technical prowess exists in the production of most art forms, but nowhere is it as evident as it is in the field of photography. This conflict is magnified, if you don't mind the pun, when it comes to micro mineral photography. Mineralogy, our hobby, is a science. Studying and collecting minerals usually appeals more to the scientific side of our personalities than it does to our artistic sides. You could make the case that this is not necessarily true, as many collectors are only, or are predominantly, interested in aesthetics in their collecting habits. While this might be true of them, it is not true of micro mineral collectors. Although it is a bit of a generalization, most micro mineral collectors are firmly grounded in the scientific aspects of the hobby, and accessing their inner artists to become good photographers will involve facing and dealing with this internal conflict.

The Types of Equipment Used in Micro Mineral Photography

The types of equipment in use among the best micro mineral photographers generally fall into three camps. Each of these methods has its set of advantages and disadvantages, as will be discussed below.

The first type of equipment in use, and by far the most common among micro mineral photographers, centers on the use of a trinocular microscope, with the camera hooked up to the third light path. The second method uses luminars, photars, or special high quality macro lenses, hooked up to bellows and/or extension tubes, with the camera hooked up to the tube or bellows. The final method, which is the least common, is the use of a machine vision lens, which is essentially a single path zoom microscope, with the camera hooked up to that. This latter method will be described in depth below.

The most common method used by micro mineral photographers is to shoot through the third light path of a trinocular microscope. There are several advantages to this approach. For one, trinocular scopes are common and easy to obtain. Since all micro mineral collectors will have at the least a stereomicroscope, it involves little additional investment, in most cases, to purchase the trinocular version of the scope that you decide to purchase. With this approach, very little additional gear is required to begin taking micro mineral photographs. All that you would need in addition to the microscope is the camera and a camera adapter. There are, however, a number of problems with this approach. The foremost disadvantage is in the area of image quality. The manufacturers of these microscopes are primarily concerned with the quality of the stereo image that users obtain when looking through the eyepieces. Thus, the third light path, and the engineering around it, involves various compromises in optical quality. This is true of almost all trinocular microscopes. However, there are some trinocular scopes, notably the Zeiss Discovery.V20, that rival or surpass the quality of images that can be captured when using one of the other methods. This microscope is quite expensive, though, in the range of $40K, and so beyond the budget of most micro mineral photographers.

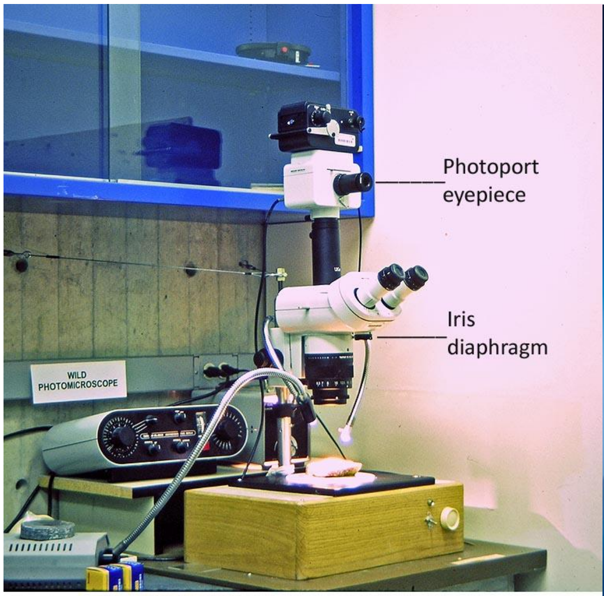


Figure 5: The Wild M420 “Macroscope” with Apozoom at the Western Washington University Geology Lab. This scope has an iris diaphragm and photoport eyepiece, and was state of the art in the 1970s when it was purchased for about $17K.

Figure 6: A Zeiss SteREO Discovery.V20 microscope, the ultimate micro mineral photography set-up, but beyond the budget of most photographers (Zeiss, 2011).

There are other problems that are unique to shooting through a trinocular scope, but these can be offset to some degree. A common problem concerns “shift” when focusing up and down for image stacking. The image shifts in one direction or another at each new focal plane. While all image stacking programs go through a process to align the images, the less alignment that is required the better. This problem can be offset by using a z-stage to move the subject up and down for image stacking. Some z-stages can be made to be automatic, even to driving the camera shutter, and this greatly simplifies the process of capturing image stacks. A second problem concerns the ease of use. Taking image stacks with a trinocular scope is somewhat difficult. Typically, the image is selected and composed while looking through the stereo eyepieces of the microscope. Then, there is usually a switch, which shuts off the light path to one of the eyepieces and changes it over to the third path and camera. Some high quality (and typically highly expensive) scopes will have built in iris diaphragms and another eyepiece set at a right angle to the third light path. This third eyepiece can be used to harmonize between the image as seen through the third light path and the image as seen through the primary eyepieces. This is important because the images will typically vary somewhat between what is seen through the third light path and the primary eyepieces. One way to offset this difficulty, especially if the microscope does not have the third eyepiece, is to use a camera that allows for a real-time preview, and to shunt that real-time preview to a remote display. This will be discussed in more detail below.

The second method that is growing in popularity among micro mineral photographs is also one of the oldest techniques. This is to use special macro lenses, especially Zeiss Luminars and Leica Photars, hooked up to bellows, and/or extension tubes, onto which the camera is mounted. Due to a lack of experience in using this method, the discussion here will be quite brief. The advantages to this approach seem to be in the area of cost and image quality. Systems can be put together for a relatively modest investment ($2K to $10K), and the proponents of this method claim to obtain superior image quality (Mindat, 2011). The disadvantages seem to be in the area of difficulty in putting together a system, the ability to achieve higher magnifications, and in ease of use. Unlike the trinocular microscope approach, putting together a system based on luminars will involve assembling elements from various sources. Proponents of these systems claim to achieve the best results with fields of view of 2.0 mm or more (Mindat, 2011), which is not a particularly high magnification when considering the other methods. Finally, the number of different lenses required to cover the range of magnifications, and the general configuration of the equipment make this method the least easy to use among the three methods we will discuss.

The final method, and the one that will be the subject of the remainder of this article, is the use of a machine vision zoom lens. A machine vision lens, or more specifically for our purposes, a micro inspection lens, is a single path zoom microscope that is primarily intended to be used in a high tech manufacturing environment for inspection or metrology. As electronic components become increasingly tiny and difficult to place correctly, the need for these versatile high quality instruments also increases. The primary advantage to using micro inspection lenses over the other approaches is that these lenses are designed to be object-space telecentric. This trait has particular relevance when attempting to stack images.

With typical optical systems that are not object-space telecentric, the magnification, shape, and perspective of objects will vary depending on their distance from the lens. In addition, out of focus objects that are close to the lens might obscure the in-focus elements that are farther away (Wikipedia, 2011). The problems that this would create in an inspection or measurement dependant industrial environment are obvious. Therefore, the micro inspection lenses are designed to be as telecentric as is possible. Additionally, this is a vital advantage when it comes to image stacking, as out-of-focus elements of the subject will tend to not distort or obscure information contained within the active focal plane.

Aside from telecentricity, the machine vision lens approach has further advantages. For one, since it is a single path microscope, the manufacturer can concentrate on engineering a product that does the job it is intended to do. Since that job is essentially identical with our intended use of the instrument, the compromises that occur when manufacturing trinocular microscopes do not exist. The manufacturers of machine vision lenses can achieve high numerical apertures and excellent resolutions that are surpassed only by a few traditional trinocular microscopes. Another advantage is cost. Since machine vision lenses are used widely in industry, they must also be cost effective. Machine vision lens systems with excellent optical characteristics can be assembled for much less money than systems with a trinocular microscope possessing comparable optics. A third advantage is the ease of use of these systems, especially when fitted with a camera that can output a real-time preview image that can be used for focusing and composing the image. The specific system that will be described below is very easy to use. Their wide zoom range prevents the necessity of changing auxiliary lenses in the majority of cases. The real-time preview allows one to quickly compose an image, make adjustments to the lighting, and take multiple images for stacking purposes.

There are some disadvantages to using a machine vision lens. For one, the primary purpose of these lenses is for use in an industrial setting. There are no pre-assembled systems that are configured for micro mineral photography. This is particularly true if you are on a budget and are attempting to find used components. It took 2 ½ years, and uncounted hours spent searching the Internet and corresponding with manufacturers to assemble the system that will be described below. Another disadvantage of machine vision lenses is the image quality. While these systems are very good, they are not the best available. If you build one of these systems and then spend the time to become a proficient and skilled photographer, you will encounter this limitation.

Hardware Components in a Specific Machine Vision Lens Based System

Save for the camera, the optical components of the system depicted in figure 7 were all manufactured by Thales Optem, now Qioptiq. Despite the name change, Qioptiq has kept the Optem brand name for their micro inspection lenses. The company produces five different zoom lens systems, any one of which can be used for micro mineral photography. The Optem website is a valuable reference for comparing the various systems. There are links to each of the systems, but a recent redesign of the website eliminated links to the brochures for each system. The brochures are valuable, not just in their description of the characteristics of each system, but also in that they contain a part number breakdown of individual components, as the various elements are not typically interchangeable between systems.

Figure 7: A Micro Mineral Photography setup centered on an Optem Zoom 125C micro inspection lens featuring an 8” diameter fiber optic ring light and a Nikon Coolpix 8400 camera with real-time preview and cordless remote control capabilities.

By far the most popular are the Zoom 65 (6.5 : 1) and Zoom 75 (7:1) systems. Both of these systems have been redesigned, with the Zoom 75, now being referred to as the Zoom75XL system (Thales Optem, 2004a). I have used both the Zoom 65 and Zoom 75 modules for micro mineral photography, and they are excellent for that purpose.

Next in the series is the Zoom 100 (10:1). These lenses seem to be popular in automated inspection and metrology settings. Most commonly on the surplus market they will be fitted with various stepper motors that probably make them unsuitable without modification for micro mineral photography. In about 2002, Optem upgraded the Zoom 100C system to the Telecentric Zoom 100 system. This new system has flat line telecentric performance over the entire magnification range, even surpassing the Zoom 125C system (Thales Optem, 2002). See figure 8. The Telecentric Zoom 100 module has not yet been seen on the surplus market.

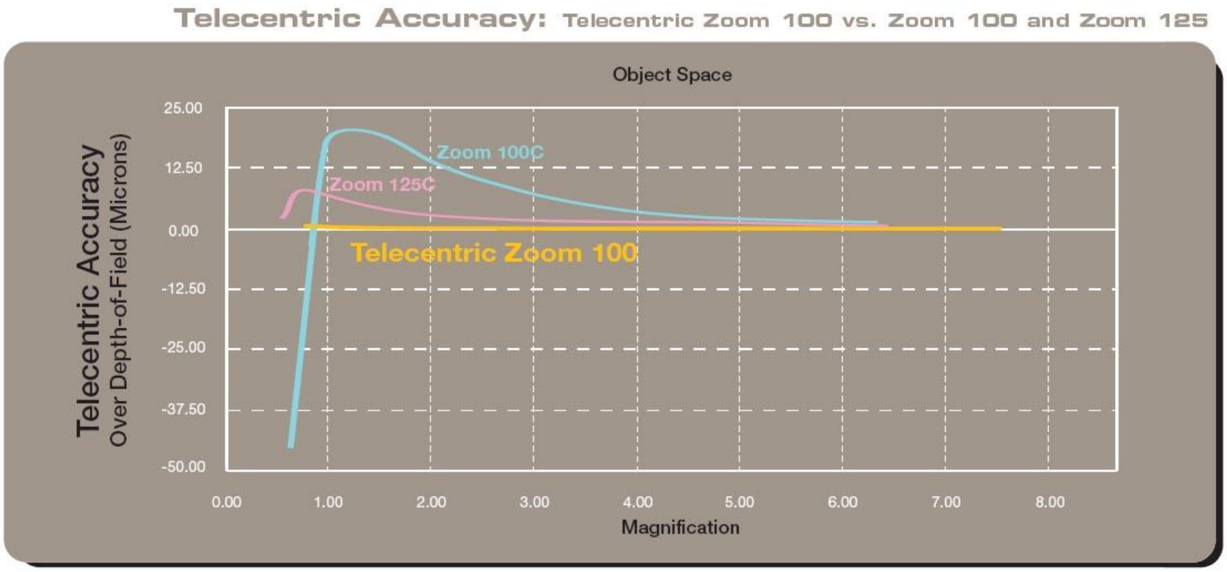


Figure 8: A comparison between the object space telecentric accuracy of three different Optem brand machine vision lenses (Thales Optem, 2002).

The zoom module being used in the system depicted in figure 7 is a Zoom 125C Module & Focus (part numbers [p/n] 30-61-20 & 30-13-10). The Zoom 125C is highly telecentric, has a 12.5 : 1 zoom range, and, when fitted with a 2.0x auxiliary lens (part number 29-20-41), has a numerical aperture (N.A.) of up to 0.20 (Thales Optem, 2004b). Occasionally, a Zoom 125C module will appear on the surplus market.

The final offering in Optem's line-up is their Zoom 160. The module from this system has an incredible 16 : 1 zoom range, when fitted with a 2.0x auxiliary lens has up a 0.30 N.A., and has a resolution of up to 900 lp/mm (Qioptiq, 2008). This compares favorably to the $40,000 Zeiss Discovery.V20, which has a resolution of 1000 lp/mm (Zeiss, 2007). This module is extremely rare on the surplus market.

In addition to the Zoom 125C Module with Focus attachment (p/n 30-61-20 & 30-13-10) and the 2.0x auxiliary lens (p/n 29-20-41) that is depicted in figure 7, there are other components in the system that are manufactured by Qioptiq. Directly above the zoom module is the TV tube, which is an extension with a C-Mount on the upper end. There are two different TV tubes available, one a 1x TV Tube (p/n 29-90-72) and the other being 2x (p/n 29-90-80). Depending on the magnification desired, either the 1x (most typical) or 2x TV Tube will be used. Above the TV tube is the camera adapter (p/n 25-84-00-02). The adapter that holds the TV tube in the microscope stand is Optem p/n 29-50-05. Finally, the large 8" diameter fiber optic ring light is manufactured by Optem (p/n RD5551), but the light source is a Dolan Jenner Fiber-Light PL-800.

The other components of the system are a large, extremely heavy microscope boom stand manufactured by Nikon, a Nikon Coolpix 8400 camera, and a small flat screen TV monitor.

A brief discussion of camera choice is warranted, although a thorough examination of camera options is beyond the scope of this article. The Nikon Coolpix 8400 was an excellent choice for this system when it was put together, but there are now undoubtedly better choices available for a reasonable cost. The advantages of the Coolpix 8400 were the large 8.0 megapixel image size, the availability of a low-resolution (640 x 480) real-time preview image, settings stability allowing numerous images to be taken using a cordless remote without having to reset image parameters, and white balance correction to offset the artificial light source. In addition, Optem makes a camera adapter that is specially designed for the Coolpix 8400. If choosing today, one would certainly look for a camera with larger image size, in the range of 12 to 14 megapixels, and one would look for models with built-in chromatic aberration correction. A major concern in any camera selection would be its compatibility with the Optem lens system, the availability of a camera adapter, and real-time preview.

One possible alternative might be a scientific grade camera designed specifically for use on a microscope. These cameras are extremely expensive ($5K to $10K) in comparison to consumer grade cameras, but have several potential advantages. Some of these cameras have much larger sensors featuring active pixels that directly produce the image size, rather than the firmware based interpolation from smaller sensors to produce large-sized images as in consumer-grade cameras. This is important in a scientific setting, because the image features are based more on direct observation, rather than interpolation by the camera’s firmware. Some of these cameras feature cooling for the CCD, which increases their sensitivity. Another major advantage of these cameras is the ability to have a high-resolution real-time preview of the image, directly on the computer.

Taking Photographs with a Machine Lens Based System

While taking the actual photographs is the most important, and it is certainly the most difficult, aspect of producing high quality micro mineral images, there is little concrete information that can be imparted in an article such as this that will help to turn you into a good photographer. This is where the twain meets—your scientific side and your inner artist. This is a path that you will have journey on alone, but there are some ideas that can be covered. The following section will describe two different artistic process approaches, and then will continue into a discussion of some of the difficulties that can arise in taking micro mineral photographs and a few ways to offset those difficulties.

Figure 9: The Road Not Taken—two approaches to producing art. A fork in the road between some of the collecting sites at the Black Pine Mine, near Philipsburg, Granite County, Montana—a source of many micros.

Two differing philosophies can govern how a piece of art is produced. A nice way to think about the two approaches is that the first concentrates on the road and the second concentrates on the destination. In practice, one can rarely produce a piece that does not have aspects of each approach. Some artists, notably poet Robert Frost, concentrated on the road (*The Road Not Taken*), seeing the act of creation of a piece as a process, and that this act of creation should determine the configuration of the final work. The second process is to envision the result you want, and to guide the process to producing what was envisioned. Problems emerge. When you concentrate on the road, you are never sure of your destination. This is difficult when considering the field of micro mineral photography. Alternatively, rarely is one skilled enough, the equipment good enough, and the subject cooperative enough to achieve the envisioned results. Therefore, with micro mineral photography, you might go down the road with a final destination in mind, but find that the road takes you somewhere a bit different from what you envisioned. This is where frustration occurs. Persistence can pay off in these situations. Trying several times while varying small elements of lighting, exposure, and composition might, or might not, get you closer to your envisioned destination. In the end, you will find that you are rarely completely satisfied with your images.

The mechanical act of taking photographs will depend to a great degree on your camera and other equipment. Get to know the manual of your camera and try the advanced features. When it comes to micro mineral photography, some universal problems warrant discussion. For one, your camera was not designed with the photographing of micro minerals in mind. Camera manufacturers do a good job of producing cameras that are versatile in many differing settings, but micro mineral photography is an esoteric setting at best. Some aspects of minerals as subjects pose a challenge to digital cameras. Some attributes are under your control and some are not. For example, at high magnification and using image stacking, various chromatic aberrations can appear as purple or green halos around brightly lit areas, particularly when the brightly lit area is directly adjacent to a dark area. Some newer cameras have settings to offset this. If your camera has this setting, you can do something about it. If not, you cannot. In the case of the Coolpix 8400, artifacts from the grinding of the lens begin to appear when shooting images with fields of view in the range of 0.5 mm. There is nothing that can be done about that. Nikon did not have 0.5 mm fields of view in mind when they designed the manufacturing process of the camera. In addition, camera lens of the Coolpix 8400 is a sealed assembly, but between the elements of the particular camera in figure 7 are some extremely minute dust particles that show up as artifacts on highly magnified image stacks. These dust particles would not be a problem with more typical photography.

Elements you do have control over include color and lighting. The highly saturated colors of some minerals are not handled well by digital cameras. In addition, despite the corrections you will make to adjust the white balance for your light sources, your camera will still most likely skew colors from actual color of the subject. The approach here is to allow the camera to do what it will with the colors and then to attempt to correct those colors using image processing software. This will be discussed further in the next section.

Lighting the subject will pose your single greatest challenge. Micro mineral specimens are typically very difficult photographic subjects. One major difficulty is due to contrast. This includes contrast between light and dark areas, contrasting colors, and most especially contrast created by brightly reflective crystal faces. Your camera, and this is especially so when considering image stacking, does not handle these forms of contrast well. When you light your subject, you find yourself constantly riding the fence between how much light you can get away with and producing subdued dimly lit images. In the case of brightly reflective crystal faces, the reflections will cause spectral flares, especially in focal planes where the reflective face is not in focus. Telecentric lenses do help to offset this issue, but only to a small extent. The spectral flares tend to obscure areas of the subject that are in focus, and the stack will lack information about the areas beneath the flares. To compensate for this, the image stacking software will typically deal with this by incorporating the flare into the output image. The resultant flare will not look right, however, and this leads to an effect that some refer to as "ice-like." Therefore, you will find yourself experimenting with various diffusing methods, blocking light from some directions, augmenting it from others, changing the intensity and direction of the light, and changing your exposure settings. The tools for this often include scraps of translucent white paper or plastic, black paper, foil—anything that can diffuse, reflect, or block the light.

When it comes to macro mineral photography, we are all familiar with the images we see on the covers of mineral magazines where the exact amount of light required to illuminate the different crystal faces was supplied. It is much harder to do this same thing with micro minerals. You might realize that there is a tiny face that you would like to get a reflection from, but the faces are often so tiny that this proves to be a practical impossibility. Any light source brought to bear will be too large, and will often illuminate things you do not want in addition to the face you do want. This is one area where input would be welcome.

Image Stacking and Image Processing

Image stacking software is amazing. The development of this software, along with digital photography, has removed the boundaries of depth of field and resolution dictated by the physical laws of optics. Images produced using such techniques are now capable of displaying features comparable to the magnification and depth of field produced by electron microscopes.

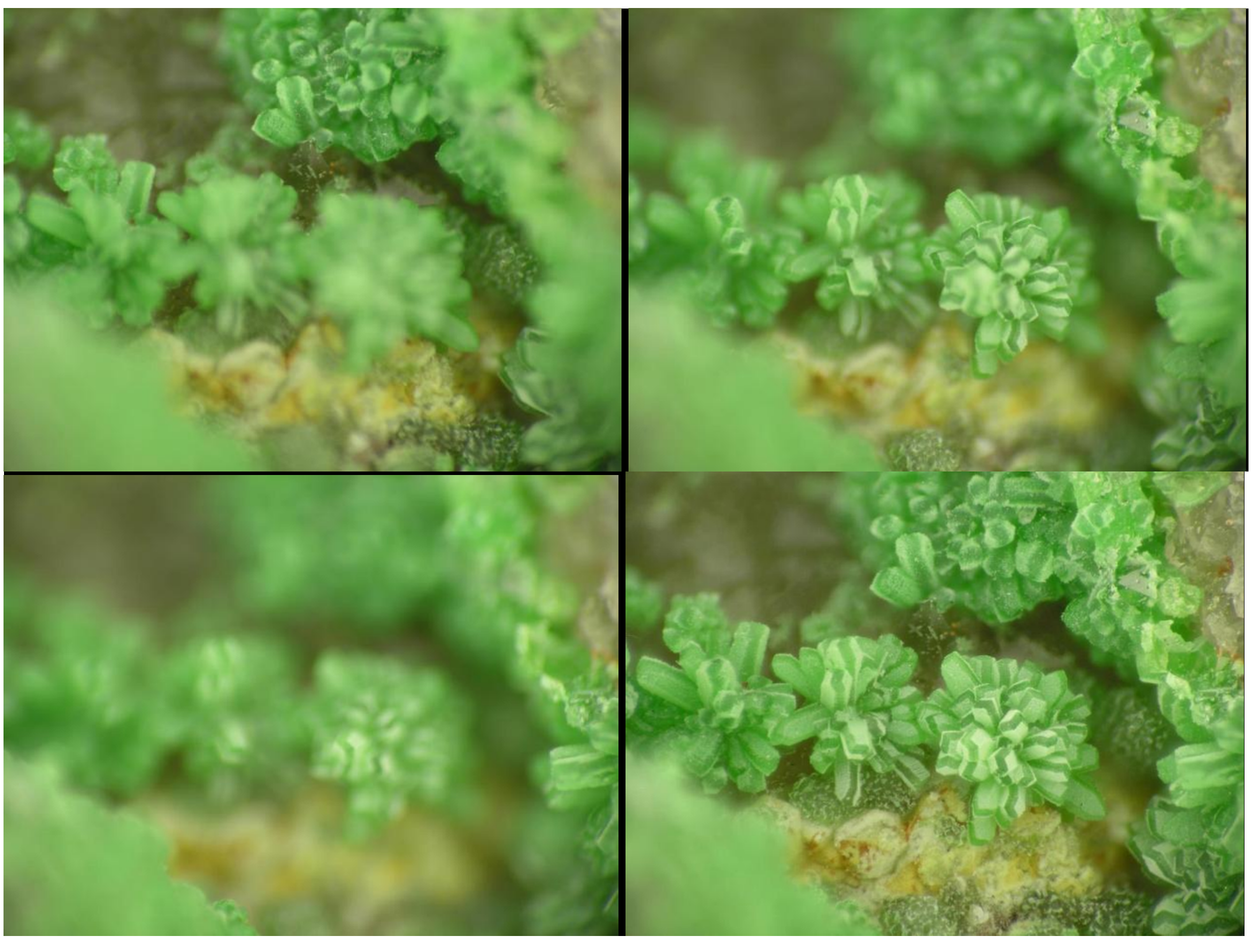


Figure 10: Three images from a stack of 39 individual images and the output image. The photograph on the upper left is the bottom layer, the image on the upper right is a middle layer, and the image on the bottom left is the top layer. The unprocessed output image from the stacking program is on the lower right.

Using image stacking software is highly intuitive and little instruction is required. One loads a stack of images into a job, and selects from a menu of macros, which will typically align and stack the images. Some programs allow for retouching, which is an override of the automatic decisions made by the stacking macro. With experience, you will become familiar with the idiosyncrasies of the programs—what turns out acceptably and what does not. At that point, you will begin to take into account these idiosyncrasies when you compose, illuminate, and take your individual images.

The author has used two different stacking applications, Combine ZP and Zerene Stacker. Combine ZP has the advantage of being free, but Zerene Stacker appears to do a better job 95 percent of the time. One suggestion is to keep an archive of your image stacks in case a better application is developed. This is not necessarily easy. A stack of 40 eight-megapixel images takes up a considerable amount of space on your storage media. Multiply that by thousands of stacks.

Much has been made of the recommended increments between focal planes or layers. Some of the German micro mineral photographers, being quite precise, insist that each layer should be exactly the same distance apart and, seem to universally use micrometer driven z-translation stages or a micrometer style of up and down adjustment on their microscope stands. The system depicted in figure 7 has none of these features, the up and down adjustments are all done by hand. While this technique took some practice, learning it was not difficult. The theory behind the manual approach is that the image stacking software looks for key elements that are in optimal focus. The goal in assembling a stack is to make sure that there are no gaps that are out of focus between layers, and to have layers that present key elements, such as the terminal face of a crystal, in their optimal plane of focus. With some practice, you can accomplish this without requiring a micrometer stage.

The final hint when it comes to image stacking concerns the height of the stack that is used in the output image. For relatively flat subjects, this might include stacking everything within the field of view so that the output image has no out-of-focus areas. For other subjects, however, this is not necessarily the best approach. Image stacking is essentially the conversion of a three dimensional stack of images into one two-dimensional plane. Thus, for very deep stacks, the image will be significantly flattened from its actual appearance. One approach to offset this is to keep the primary subject in focus, and to have the background, the foreground, or both out of focus to give an apparent illusion of depth.

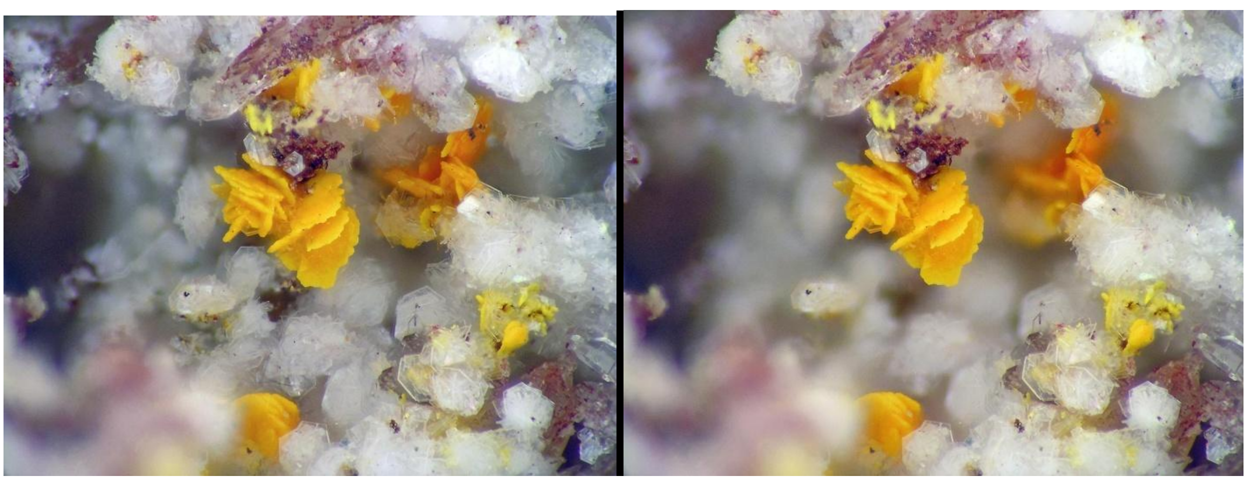


Figure 11: Two takes on the same image stack of an unknown species associated with white Wickenburgite from the Evening Star Mine, Tiger Wash, Maricopa County, Arizona. The image on the left is the full stack. On the right, the bottom portion of the stack was left out, and this has resulted in depth that is more apparent and three dimensionality in the output image. The FOV is 2.3 mm.

Once the stack is complete, the final step in producing your micro mineral image is to process it using an application such as Adobe Photoshop. In most cases, Adobe's inexpensive Photoshop Elements will be sufficient for most micro mineral photographers.

Figure 12: The processed image derived from the output image depicted in Figure 10. Color-zone cuprian Adamite crystals from the Centennial Eureka Mine, near Eureka, Juab County, Utah. FOV = 2.3 mm.

There is a mild amount of controversy concerning the use of Photoshop to correct images, especially with scientifically relevant subjects such as micro minerals. However, when it comes to correcting the images, in contrast with augmenting them, these objections are without much merit. First, it should be mentioned that almost total latitude to correct or augment photographs exists in traditional film and print based media, so the ability to adjust images is not a new development. Second, digital cameras have built-in firmware that processes and adjusts the photographs taken, and in many cases the automatic adjustments made by the camera's firmware need to be overridden and readjusted to conform to reality. Third, the various media that will be used to view the completed image vary widely. This specifically refers to computer monitors and printers. Two features of Photoshop that are helpful with this problem are monitor calibration and printer calibration. However, while you can be sure that your monitor is at least fairly close to being accurate, you have no control over any other monitor, and they do vary widely. Finally, when one considers the dramatic degree of image manipulation performed during the stacking process, the correction of such attributes as color pales in comparison. Thus, the argument that image processing dilutes the scientific value of the image is based on erroneous assumptions, but it unfortunately is responsible for a myriad of poorly lit, yellow-hued images rampant on sites such as Mindat.

So, where is the line between correction and augmentation? Like most things, there is no clear answer to that question that fits in all circumstances. In most cases, tools such as cropping, color correction, white balance correction, and lighting correction are well within the realm of correction rather than augmentation. Tools that can remove artifacts such as chromatic aberration halos and dust tracks are a bit more troublesome, but such image flaws are not natural in and of themselves. Finally, filters such as sharpening or despeckle undoubtedly introduce foreign elements to the image, but can still be useful in offsetting the loss of information that occurs when making low resolution versions of your images that are suitable for sending via e-mail or posting on the Internet.

Conclusion

Forces such as digital photography, image stacking, image processing software, and the ability to share images via e-mail or the Internet have revolutionized micro mineral photography. Most micro mineral collectors should develop some capability to take micro mineral photographs, at least to document their collections and to be able to share images for identification purposes. For most micro mineral collectors this should be sufficient, and would only involve a modest expenditure of time and money.

In those cases where a micro mineral collector has the purpose of producing high quality images, the collector should be ready to make a large investment in both time and money, and should expect that the route towards becoming a good micro mineral photographer will involve frustration and hard work.

Hardware is a prerequisite to producing high quality micro mineral photographs, but it is skill and knowledge that actually makes that possible. Owning an expensive photography setup does not make one a good photographer. There are three basic hardware types in use by the best micro mineral photographers. The first is photographing through the third light path of a trinocular microscope. The second method uses special macro lenses with bellows and/or extension tubes. The third uses a special single path microscope called a machine vision lens. All three methods have advantages and disadvantages.

The primary advantage of the machine vision lens approach is the property of telecentricity, which is particularly useful when used in concert with image stacking.

Once your micro mineral photography setup is complete, you will have to develop your own techniques in order to produce high quality images. Taking into account the difficulties presented by micro minerals as photographic subjects and then designing strategies to offset those difficulties will be your largest single obstacle.

Finally, once you have taken your stack of images, you will use an image stacking program to stack them and produce an output image, and you will use image processing software to correct and produce your final product, a high quality digital image of a micro mineral specimen.

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