

Northwest  
Micro Mineral  
Study Group



# MICRO PROBE

SPRING, 1999

VOLUME VIII, Number 9

SPRING MEETING . . . . .VANCOUVER, WASHINGTON

May 1, 1999

9:30 am to 6:30 pm

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

Bring your microscopes and prize specimens along with your special trading material and something for the free table to share with others. Be sure to include a box label that lists all the species present, give complete locality information, and includes your name so questions can be directed to the person bringing the material. Some people like to include the collector in their mineral data base.

**Morning program:**

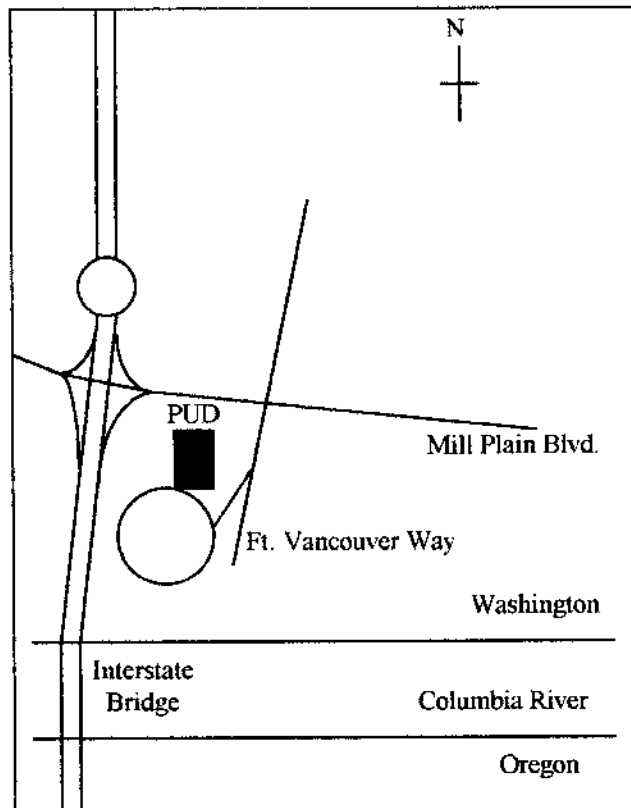
10:30 John Cornish will talk and show slides of the beautiful native copper specimens found at the Beaver Valley Quarry, Shine, Jefferson County, Washington. Specimens of the material will also be available for your inspection.

**Afternoon program:**

2:00 Our usual informal business meeting, including reports on the status of local collecting spots.

3:00 Don Howard will give an informal discussion of crystal structures for those interested. If you have slides of mineral specimens or collecting localities that you would like to share, bring them along; we will have a projector and screen available.

The kitchen area is available as usual and we will provide lemonade, coffee, popcorn, etc. There will be a snack table, so bring snacks to share with others for lunch and during the day. However, there will be no potluck dinner. Restaurants are available in the local area. Some of us will plan to eat together, so please join us.



## FIGURE CAPTIONS

*Micrograph Number is in the lower right corner of the front.*

- #846 Chalcocite on Chlinochlore** (x100)  
A flake showing multiple parallel growth and branching at approximately 60°. The pattern is similar to that seen in snowflakes.
- #855 Native Copper on Chlinochlore** (x 75)  
A filiform crystal whose structure is based on stacked octahedra. Numerous right-angle bends are present in the right-hand portion.
- #886 Native Copper on Chlinochlore** (x 18)  
A long and very torturous filiform crystal with right angle bends and abrupt doublebacks. The portions that appear curved were probably bent by physical processes after formation rather than grown in that form. The long nature of the filiform puts a great deal of strain on small cross-sections, and as-grown copper is soft and very susceptible to deformation.
- #887 Native Copper on Chlinochlore** (x 60)  
Close-up of the above crystal, showing the end portion that appears at center bottom. This portion is based primarily on stacked cubes, though it shows dodecahedral modifications on some of the corners.
- #888 Native Copper on Chlinochlore** (x 150)  
Another close-up of a portion of the crystal shown in #886, this time of a region in the upper right. This part of the crystal appears to be built up from stacked dodecahedra.

*All specimens from:* **Beaver Valley Quarry, Shine, Jefferson Co., Washington**

Micrographs,	Don Howard
Specimens,	John Cornish

Don't Forget!

**Pacific Northwest Chapter, FRIENDS OF MINERALOGY**

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## **In Memorium**

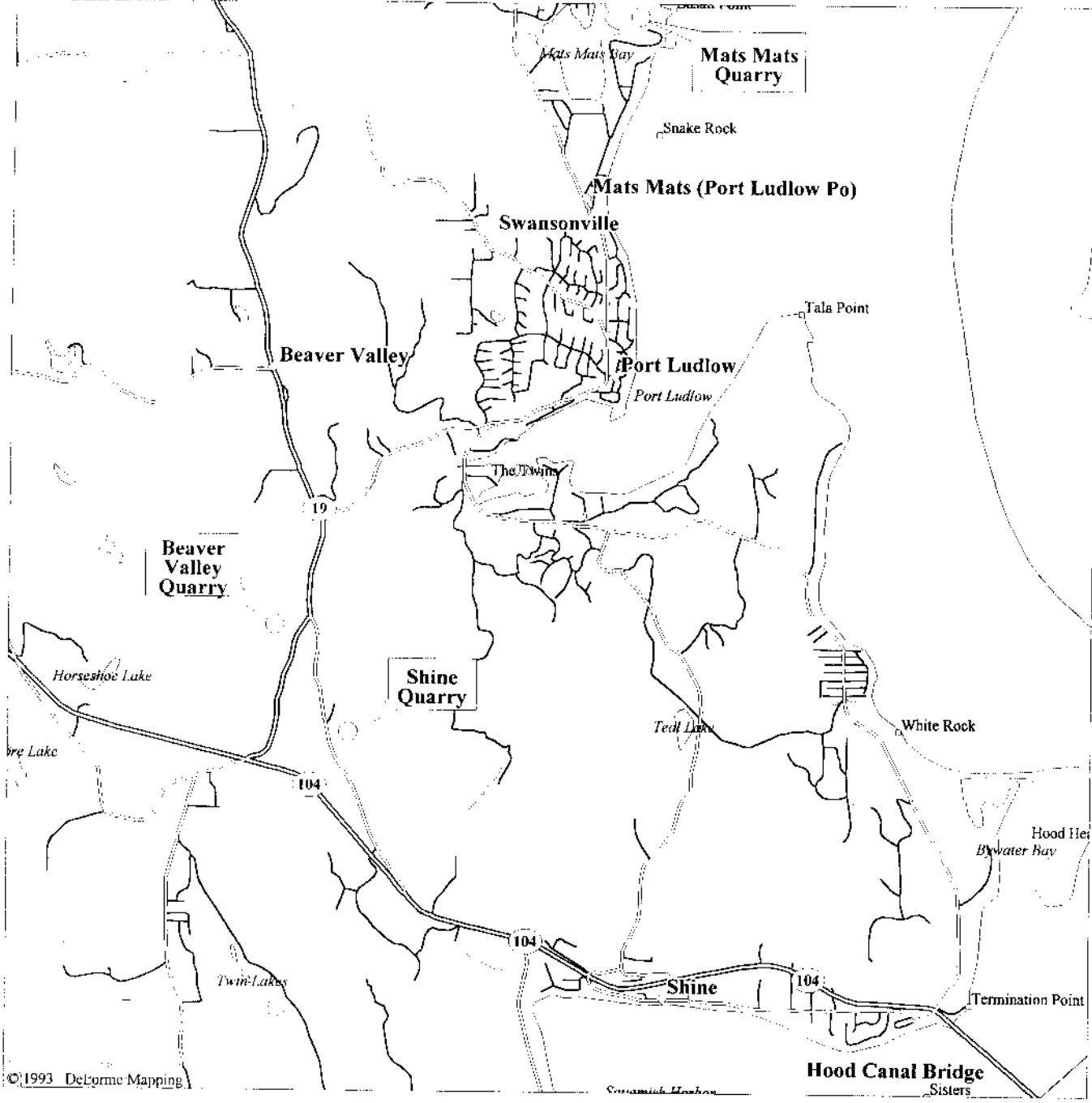
### **Evelyn Sweany**

It is with great sadness that we have to report the passing of Evelyn Sweany just before Christmas of last year. Her cheery countenance and quiet encouragement will be missed greatly. Our deepest sympathy goes out to Chuck.

Chuck and Evelyn have been active mineral collectors for many years, with a heart for interesting youngsters in mineral collecting and lapidary. They have spent numerous summers working at Camp Hancock. They have also been involved with OMSI through activities associated with the Oregon Agate and Mineral Club, always with the desire to see people, particularly the young, become interested in the mineral world around them.

Evelyn has always been a facilitator, helping to keep our field trips and meetings running smoothly. Her quiet encouragement and direction have played a large part in our group having satisfying meetings that appear to be running smoothly in spite of the frantic dithering of the president and secretary/treasurer. If you did not notice her very much, it was because she was in the kitchen helping with preparation of the food for our potlucks and noontime snacks. Wherever she went, she spread an atmosphere of calm and order. Her influence is greatly missed.

Evelyn has not been able to be present at the last few meetings because of declining health. But even then, it was a joy to visit with her because of her warm smile and positive attitude. We always came away from their home feeling blessed. And Genie felt that way again when she visited Evelyn just a couple of days before her death. Evelyn has been a wonderful role model, and knowing her has enriched our lives. Her memory will be carried in our hearts.



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- LEGEND**
- Population Center
  - State Route
  - Geo Feature
  - Town, Small City
  - County Boundary
  - Street, Road
  - Major Street/Road
  - State Route
  - River
  - Land Mass
  - Open Water
  - Intermittent River
  - Utility (powerline)

Scale 1:62,500 (at center)

1 Miles

2 KM

Beaver Valley Quarry  
 Mag 13.00  
 Thu Mar 11 09:45:00 1999

**COPPER, ZEOLITES, AND ASSOCIATED MINERALS FROM THE  
BEAVER VALLEY QUARRY, SHINE, JEFFERSON COUNTY,  
WASHINGTON**

John Cornish  
40 Cedar Glen Lane  
Port Angeles, Washington 98362

Rudy Tschernich  
526 Avenue A  
Snohomish, Washington 98290

**HISTORY:** The Beaver Valley quarry opened shortly after the relocation of Highway 104 in 1967 and the construction of a new section of Highway 19 connecting the old highway to Highway 104. At that time an old unnamed quarry which produced mordenite, clinocllore, and quartz was destroyed when Highway 19 passed right through it. Doug Merson (1990) was the first to report minerals from the Beaver Valley quarry and mentions quartz, calcite, laumontite, analcime, levyne, clay, and a fibrous zeolite.

The Beaver Valley quarry is located just west of the Hood Canal Bridge in an area of low rolling hills near the small community of Shine in Jefferson county, Washington at N 47° 54' 5.5" W 122° 43' 46.7" or SW1/4 of Section 19 T28N R1E. The quarry is reached by traveling on Highway 104 approximately 5 miles west of the bridge and then turning north onto Highway 19. After approximately 0.7 mile, a dirt road on the left side of the highway is seen descending down to a cable-gate. Park here without blocking the road, or if the gate is open, proceed into the quarry. Just beyond the gate, the quarry road splits. The right hand fork accesses the lower level of the quarry and the left-hand fork ascends to the quarry's upper level. An overgrown access road, partially buried by debris near the north end of the quarry, connects both levels.

The quarry is located on land owned by the Pope and Talbot Timber Company, which is managed by Olympic Management Resources (OMR). OMR personnel and lessees of the property have worked sporadically over time, and the quarry has never really seen a period of heavy activity. Recent years have seen lessees concentrating on crushing existing piles of rock in the quarry with no new blasting. This type of operation has reduced the dwindling collectable piles of rock in the quarry. Future work at the Beaver Valley quarry is quite possible and could include additional blasting.

The Beaver Valley quarry has been briefly mentioned by Merson (1990), Ream (1991), Tschernich (1992), and is referenced on the CD-ROM marketed by the Los Angeles County Museum of Natural History (1998). Ream, Tschernich, and the L.A.C.M.N.H. all give the name of the quarry as the Bear Valley quarry. The quarry is located in the Beaver Valley and is identified by OMR as the Beaver Valley quarry. The updated 1.1 version of the L.A.C.M.N.H. CD-ROM has been corrected to read the Beaver Valley quarry.

**GEOLOGY:** The most current theory for the origin of the rocks in the Beaver Valley area invokes lithospheric extension, which caused mantle upwelling, and decompressional partial melting, that caused an estimated 100,000 cubic kilometers of tholeiitic basalt, called the Crescent Formation, to erupt onto the sea floor (Babcock et al., 1992, 1994). This replaces an earlier theory of seamounts on oceanic plates that drifted into the North American continent proposed by Duncan (1982). Thick layers of pillow basalt, first formed on the ocean floor, interbedded with sediments eroding from the North American continent during the Eocene about 50 Million years ago (Babcock et al, 1994). In areas of intense activity, underwater seamounts formed, which later became oceanic islands. Broad shield volcanoes on the new islands formed a series of gently sloping vesicular flows, some of which are present in the Beaver Valley quarry. The Olympic Mountain core started to be uplifted to its present dome-shaped form about 10 to 12 million years ago (Babcock et al, 1994). No significant rotation or translation of the Crescent Formation in these rocks has been found since their extrusion, although rocks of similar age and type in the Black Hills and Willapa Hills of Washington and the Siletz River Formation of Oregon show a consistent post-Eocene rotation of 40 to 80 degrees clockwise (Babcock et al., 1994).

**MINERAL ASSEMBLAGES:** Two different mineral assemblages are recognized in the quarry. The first is clinochlore-quartz-rich cavities, commonly lined with dark black clinochlore, quartz, and calcite with minor amounts of stilbite, heulandite, mordenite, chabazite, copper, and chalcocite. The second is zeolite-rich cavities lined with analcime, natrolite/mesolite, stilbite, levyne, and small amounts of gonnardite, thomsonite, chabazite, calcite, and minor clay.

The Beaver Valley quarry exposes at least two basalt flows that dip to the northwest. The uppermost flow is massive without cavities. A sinuous thin red soil layer is seen running across the quarry, separating the upper massive flow from the lower vesicular flow. The flow located immediately below the red soil zone contains an abundance of small vesicles, commonly less than 2 cm in diameter, lined with zeolites. Deeper in the same flow, the number of vesicles decreases and the size increases to 2 to 4 cm, with a few larger. These cavities are lined with a thick dark black clinochlore, quartz, calcite, copper, and rarely zeolites. Distribution of the minerals in the cavities appears to be highly localized. Cavities lined with zeolites and calcite crystals are easy to spot. It is the pockets that contain the beautiful crystals of native copper and chalcocite that can be extremely difficult find. The finest collecting aid which you can have to find the copper is simply the sun. When working the rock on overcast or rainy days, these crystals just seem to blend into the clay linings of empty-appearing cavities. It is only the sunlight glinting off of their highly reflective surfaces that makes these crystals really stand out.

The loose rock strewn about the quarry represents material produced from several different areas. Many older exposures in the quarry are buried by rubble or are overgrown by vegetation. Some specimens cannot be traced to current exposures seen on the walls of the quarry today. However, many areas have been actively collected in recent years, where beautiful crystalline minerals have been found in place. Recent collecting in the walls of the quarry's upper level has produced beautiful specimens of copper, stilbite, quartz, chalcocite, natrolite, analcime, and calcite in cavities up to 20 centimeters in diameter.

**MINERALS PRESENT:** The minerals are described in the approximate order in which they first crystallized. Many of the species co-crystallized with other species, while others formed at several separate times in the two generalized crystallization sequences, one in silica-rich cavities, the other in silica-poor cavities.

Silica-rich cavities: celadonite > calcite > (dark green clinochlore > copper) > light green smectite > (quartz > heulandite-mordenite > stilbite > quartz > stilbite) > chabazite > (chalcocite > chalcopyrite-bornite > unknown #1) > (yellow calcite > colorless calcite).

Silica-poor cavities: calcite > (dark green clinochlore > copper) > light green smectite > (milky levyne > colorless levyne) > thomsonite-gonnardite > (natrolite-mesolite-natrolite) > analcime > trace of clinochlore > stilbite > chabazite > (chalcocite > chalcopyrite-bornite) > (yellow calcite > colorless calcite).

**CLAY/CHLORITE** are the most abundant minerals found in the quarry. They form in at least three distinct phases based on sequence of crystallization, color, and size of crystals, and may represent different species.

The first clay mineral to form, a fine grained, bright blue-green to light green, botryoidal clay layer only 1 millimeter thick, is likely an iron-rich celadonite. This clay layer is commonly covered by the low silica zeolites, natrolite/mesolite, thomsonite, analcime, gonnardite, levyne, and chabazite or a dark green, coarsely crystalline clay/chlorite mineral that represents the dominant second phase of clay growth.

The second clay mineral, forming a layer, up to 5 mm thick that consists of dark green to nearly black velvety delicate hemispherical aggregates, is likely an iron-rich clinochlore. It is the most common clay mineral and lines most of the cavities in the quarry. Aggregates are composed of tightly packed radial groups of thin hexagonal plates that crush easily and become silver colored. The clinochlore also forms stalactitic-like growths several centimeters long. These growths detach easily from cavity walls, accumulating in piles upon many pocket floors. Clinochlore is commonly overgrown by quartz and calcite, and rarely by stilbite, heulandite, mordenite, chabazite and copper. This beautiful clay mineral makes an exceptional background for these other species. The iron in the clinochlore commonly oxidizes when exposed to the air to a deep black color. The original color of the clinochlore was a deep green. In some cavities, the clinochlore is altered to a blue-green or brown, while in others, it is yellow or white due to a very thin coating of chalcedony or calcite. Energy dispersive x-ray (EDX), done by Don Howard, while taking scanning electron microscope (SEM) photographs for this paper, found the clinochlore to be extremely copper rich. So rich that the specimens used for SEM work did not need to be coated with a conductive material in order to conduct electricity. More work is being considered for this mineral.

The third, or last generation, of clay/chlorite is lustrous light to dark brown to greenish-black in color and is composed of hexagonal plates that form loosely grouped mounds, several millimeters in diameter. They are scattered over the earlier formed clinochlore in some cavities and are commonly included within or perched upon many of the quarry's other minerals.

**COPPER** at the Beaver Valley quarry is exceptionally attractive, with a wide array of fascinating habits. It forms magnificent wires, bars, and crystals in the black clinochlore-lined cavities and rarely in cavities containing zeolites. Native copper has been found rarely at several localities in the Crescent Formation. Cannon (1975) reports twinned crystals of copper, up to 12 mm across, with zeolites in basalt at the Pioneer quarry at Bremerton, Kitsap County. Tschernich (1992) reports native copper included in analcime at the Mats Mats Bay quarry at Port Ludlow in Jefferson County. Copper is also included within apophyllite and laumontite at the Shine quarry, a mile north of the Beaver Valley quarry. Currently, the Beaver Valley quarry is the best place to find native copper crystals within Washington state.

Copper is most often encountered in the vesicular basalt that contains a thick lining of clinochlore. Out of hundreds of clinochlore-lined pockets, only a few contain copper. Some of the copper preceded crystallization of the dark black clinochlore cavity-lining. In these cavities, the copper is well attached to the rock and can leave some copper on the rock surface when the cavity-lining is removed. Most of the copper crystallized during clinochlore crystallization, with the base of the copper wires and needles firmly attached within the clinochlore. Bright copper filaments, clearly enclosed within colorless transparent stilbite and analcime crystals, are seen to extend down to and into the clinochlore cavity lining. The copper can be a bright shiny copper color or can display a fascinating array of beautiful iridescent colors ranging from gold, yellow, green, blue, purple, orange, red, silver, gray and black, that are due to thin overgrowths of copper sulfides. Stilbite, heulandite, quartz, and calcite are infrequently perched on the copper filaments.

Three types of copper are recognized. The first type forms individual wires and attractive bundles of interwoven curved groups that form coils or nests of wires resembling wire silver. The curved wires are striated parallel to the length of the wire due to the alternating cube {100} and dodecahedron {110} crystal forms. Some of the wires can exceed 2 cm in length if straightened out. Very rarely nests of copper wires occur up to 1 cm across.

The second type of copper forms straight filiform needles that are composed of rectangular bars or elongated cubes. With magnification, this habit is commonly seen to be misaligned or to make numerous 90 degree turns that form amazingly complex grid-like structures, similar to those found on filiform pyrite (see Micrograph #886). The needles are often terminated by octahedral and hopper-like cavernous faces. Swarms of minute cubes with octahedral modifications are commonly found where bars make directional changes. This habit displays perfectly straight or curved-bowed crystals with an extremely high length to width ratio, which is often tens and even hundreds of times longer in one crystallographic direction. These crystals are commonly striated perpendicularly to the elongation resulting from the stacking of numerous cubes or octahedrons. Others are striated parallel to the elongation due to modifying {110} faces on the cubes; however, curved crystals can also be found which are perfectly smooth with mirror bright faces.

An uncommon third type of copper forms sharp single octahedra and groups of octahedra that are often flattened or distorted. Rarely, filiform chains of copper octahedra are found (see Micrograph #855).



Bright shiny copper is seen included within stilbite, analcime, quartz, calcite, and gonnardite and extends from these crystals into cavities. Ground water, which is found infrequently within cavities, is slightly acidic and slowly attacks the copper, keeping it bright and shiny. In time, bright copper crystals exposed to the atmosphere form a dark rich-brown patina. The late third generation of calcite is the only mineral that covers the colored copper crystals. This indicates the coloration is due to an overgrowth of copper sulfides such as bornite, chalcocite, or chalcopyrite, rather than from oxidation that occurred after all the minerals had formed. Chalcocite twins, overgrown by epitactic tetrahedra of chalcopyrite, are found on zeolites where native copper is included within analcime at the Mats Mats Bay quarry, near Port Ludlow (Tschernich, 1992). Tiny gray metallic masses, that are likely chalcocite, are found on laumontite rarely where copper is present at the Shine quarry. At both of these sites, the copper formed early in the cavities and was covered with zeolites, while the sulfides formed much later on top of the zeolites or exposed copper. The minerals coating the copper at the Beaver Valley quarry, formed near the end of the crystallization sequence and are described near the end of this paper.

**QUARTZ**-rich cavities are obvious in several areas within the quarry. Quartz forms several habits at this locality. Large geodes, up to nearly a foot in diameter, were found years ago lined with colorless pointed quartz crystals, up to 10 mm wide and tall, that lacked prism faces. Quartz more commonly forms tiny, colorless, transparent, hemispherical aggregates, up to 12 mm across, composed of minute swarms of quartz crystals that radiate from a common core on black clinochlore. This type of quartz is very similar to material found at the Mill Creek quarry near Buell, Oregon (Howard, 1995). Rarely, minute groups of quartz form attractive flat-lying star-shaped aggregates upon the black satiny clinochlore pocket lining. Quartz also forms doubly-terminated wheat-sheaf like groups and stalactitic columns. The quartz forms crystals that are terminated by three faces developed at the expense of the alternating three faces. Many terminations are incompletely formed, with hoppers or cavernous rounded pitted surfaces. Others crystals are terminated with a myriad of individuals projecting upward from within the cavernous center of the crystal. Quartz terminations and prism faces also display wavy irregular surfaces. Quartz crystals can have scattered clinochlore spheres partially or completely included within them. One of the most spectacular quartz specimens recovered from the quarry consists of a millimeter-sized spherical group perched dramatically atop a spiraled group of wire copper.

Some cavities contain thin, colorless, pointed or flat-topped stilbite blades found on the mounds of drusy quartz crystals and clinochlore. Other associated minerals found with quartz include copper, calcite, unknown #1, and heulandite, rarely included by minute doubly terminated quartz crystals.

Cryptocrystalline quartz forms green and lavender chert or a rather drab grayish-blue translucent fortified agate. Local lapidary artisans have fashioned jewelry from the green material. Rare vesicles contain smooth-surfaced, opaque, yellowish iron-oxide-stained chalcedony hemispheres, up to 7 mm across, on black clay. Other chalcedony-lined cavities are covered with colorless terminated drusy quartz crystals, that can completely fill the open space of a cavity with interlocking coarsely crystalline quartz.

**CALCITE** commonly forms a variety of attractive, colorless to golden-yellow rhombohedra scattered on a dark greenish-black clinochlore or as tiny crystals scattered on many of the zeolites. It is one of the more common minerals in the quarry. The color of the calcite varies from colorlessly clear to opaque white, with the most attractive colors ranging from soft shades of yellow to hot sulfur yellow, and orange-yellow. Iron oxides in some of the calcite crystals give them an orange hue and are responsible for the multi-colored iridescent pantina found on some crystals.

At least three generations of calcite are recognized in the quarry. A rare first generation of calcite precedes the dark black clinochlore. One well-formed rhombohedron of calcite, 15 mm across, is completely covered with clinochlore (Bob O'Brien, per. comm.). Generally, evidence of this generation of calcite is seen only in the form of rhombohedra-shaped pseudomorphs, up to 10 mm across, that are now composed of fine-grained needles of gonnardite, which are then covered by natrolite/mesolite, analcime, stilbite, chabazite, and a later generation of calcite.

The second generation of calcite forms crystals attractively scattered on black velvety-appearing clinochlore, quartz, and upon some of the zeolites. These crystals commonly form simple pseudocubic rhombohedra and penetration twins, up to 2 cm long, with rare individuals reaching 3 cm across. Calcite also forms light yellow and sulfur yellow extremely elongated, tapering, needle-like crystals. Twinned branches often shoot off at 60° angles from these main crystals. One boulder produced colorless transparent calcite crystals, up to 5 cm in diameter, that were covered with highly faceted faces. Many of the calcite crystals from this generation display phantoms and have clay inclusions, an exceptional cavity produced crystals under 1.5 cm with a black clay inclusion within the center of beautiful doubly terminated yellow calcite crystals.

The third generation of calcite forms tiny inconspicuous, colorless, simple rhombohedra that cover some of the second-generation calcite crystals and many of the zeolites. Crystals from this generation can be found formed along the cleavage planes of second generation crystals. Crystals of both the second and third generations of calcite can appear etched on their surfaces due to dissolution in ground water, producing crystals with rough prickly-appearing surfaces. This generation is one of the last minerals to crystallize.

**HEULANDITE** is rare in the quarry. It forms thin colorless crystals, up to 4 mm long, with two sets of characteristic triangular faces; rarely it forms thick coffin-shaped crystals. It occurs on dark clinochlore and on quartz crystals. Doubly terminated quartz crystals are seen included within some of the heulandite, yet drusy quartz fills spaces between heulandite crystals on other specimens, indicating co-crystallization of the two minerals. Mordenite needles cover some of the heulandite but are not included within them. In one clinochlore-lined cavity, colorless heulandite crystals contain included wires of copper.

**MORDENITE** very rarely forms thin, curved, white, matted needles, up to 5 mm long, that cover heulandite on black clinochlore-lined cavities at the Beaver Valley quarry. A roadcut along highway 19 about 0.25 mile north of the quarry produced mordenite needles up to 5 cm long in clinochlore-lined vesicles. This site was removed when highway 19 passed through it. The mordenite at both sites was positively confirmed by optics.

**STILBITE** is one of the few minerals that crystallized in both the clinocllore-quartz cavities and in the zeolite-rich cavities. It formed both before and after the crystallization of quartz. Colorless, transparent, thin blades of stilbite, commonly up to 5 mm long, with a few reaching 10 mm, clearly cover natrolite/mesolite needles and analcime.

Transparent, very thin, colorless stilbite blades, up to 8 mm in length, are commonly the only zeolite within elongated gas pockets that range in size from a few centimeters up to 80 cm long. Some of these elongated pockets also contain spectacular nests of native copper in twisting wires that have a bright, untarnished copper color. The copper clearly predates the crystallization of the stilbite. Copper wires are seen within and extending beyond stilbite crystals. Rarely, colorless doubly-terminated stilbite crystals are suspended on the copper strands. Both sharp, elongated, yellow calcite crystals and the needles of unknown #1 are infrequently encountered on the stilbite and copper in these cavities.

Stilbite commonly displays a pointed termination {111} at the Beaver Valley quarry. Rarely is stilbite found with flat top {100} terminations modified by triangular corners. Some thin, colorless, transparent, pointed stilbite blades are asymmetrical in crystal form. These crystals resemble the morphology of yugawaralite, but can be distinguished by the presence of 4 sets of intersecting striations on the broad {010} face which are characteristic of stilbite.

**LEVYNE** forms colorless, milky-white, and beautiful orange-red, thick, hexagonal plates, up to 5 mm in diameter, with large lustrous (0001) faces that are free of any epitactic offretite/erionite overgrowth. Levyne is rare at the Beaver Valley quarry, yet it was among the first minerals to be mentioned by Merson (1990). Levyne from the Beaver Valley quarry is included in the L.A.C.M.N.H. CD-ROM. Some of the levyne crystals contain phantoms that consist of a milky core and a colorless overgrowth that illustrates two periods of crystallization. An exceptional boulder found in April, 1995 produced crystals of levyne that are transparent with bright orange-red iron-oxide colored inclusions that are stunning under the microscope. Some of these colored inclusions outline the form of smaller, brightly colored phantom levyne crystals within the larger colorless crystals of levyne. Levyne crystals from this boulder formed upon a light green clay lining and are covered by thin reddish-orange natrolite/mesolite needles, brilliant colorless chabazite crystals, black spheres of clinocllore, and beautiful bright yellow colored calcite crystals.

**GONNARDITE** forms hard, tough, blue-white, fine grained, interwoven fibers that completely fill some of the vesicles. Gonnardite is a calcium/sodium zeolite with disordered Al/Si in a natrolite/thomsonite structure that is difficult to identify even with x-ray and optics, since all three of these species have overlapping properties. Identification of gonnardite at this site is based on its physical properties, optics, and x-ray, although it is very similar to thomsonite. In a few partially filled cavities, gonnardite masses, up to 10 mm across, are covered with natrolite/mesolite needles or analcime. Some gonnardite of these masses will display a rhombohedral morphology that quite possibly represents a pseudomorph after calcite.

**THOMSONITE** forms small, colorless to white, thin rectangular blades, under 2-mm long, that rarely line a few cavities. It is always covered with thin colorless to white natrolite/mesolite needles and colorless rectangular flat-topped blades of stilbite. Analcime covers both white thomsonite blades and natrolite/mesolite needles in completely filled cavities.

**NATROLITE/MESOLITE** overgrowths make up most of the colorless to white needles that are found in the cavities. Natrolite makes up the lower 25% of each needle with mesolite extending each needle approximately 70%. The mesolite is capped and covered on the sides by a very thin coating of natrolite. Some variation is noted within different cavities. Thicker prisms of natrolite/mesolite have a silky white appearance and a square cross section, and are terminated with a multitude of tiny fibers. These crystals resemble laumontite and account for reports of that mineral in the Beaver Valley quarry by Merson (1990). Most needles are straight, but some are branched or curved in the fashion described by Henderson and Garland (1986). The natrolite/mesolite overgrowths often extend from thomsonite blades, masses of gonnardite, or clay. Most of the natrolite/mesolite needles precede analcime growth and are surrounded by analcime at the base of the needles, or are totally included within analcime. Thin orange natrolite/mesolite needles are often covered with tiny colorless chabazite rhombohedra, flat-topped stilbite, black spheres of clinocllore, and yellow calcite crystals.

**ANALCIME** commonly forms simple, colorless, transparent trapezohedra, up to 4 mm across, with a few incomplete trapezohedra ranging up to 35 mm in diameter. Some of the analcime can appear green due to the reflected green color of the underlying clay minerals. Other specimens display an inner orange coloration due to included iron oxides or rare copper inclusions. Analcime commonly overgrows or completely includes levyne, natrolite/mesolite needles, and copper. Stilbite and calcite have been found covering crystals of analcime.

**CHALCOCITE** was first observed during research for this paper. Due to its minute size, it has been overlooked at this site for years. Chalcocite forms bright, shiny, silver-black flattened platelets, 0.2 to one millimeter across, usually scattered on a dark black, gray, or light green clinocllore in some of the cavities near those containing copper. Most of the chalcocite crystals require at least 30-power magnification to be seen and at least 70 power to clearly appreciate. They are very difficult to see in the field with a hand lens; therefore, bulk copper-bearing rock with numerous empty-appearing cavities must be collected, trimmed, and scanned with a microscope at home to find this mineral. Due to the tiny crystals' high luster, they reflect light like tiny silvered mirrors in otherwise empty appearing clay lined cavities.

The flattened plates of chalcocite have an asymmetrical six-sided shape, but they are not hexagonal. The forms are {001}, {113}, {023}, {111}, {110}, {010}, and {021}. They commonly combine to form unusual, flattened, parallel growth plates, resembling metal shavings, that are very weakly attached to the clinocllore (see Micrograph #846). Other crystals are spear-like. Many of the spears are twinned to form dendritic branches at an angle of 45° from the main spear-like crystal. Each of the branches is often branched by

# CHALCOCITE

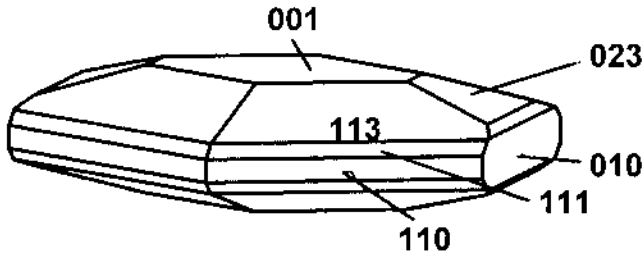


Fig. 1 Pseudo-hexagonal Habit

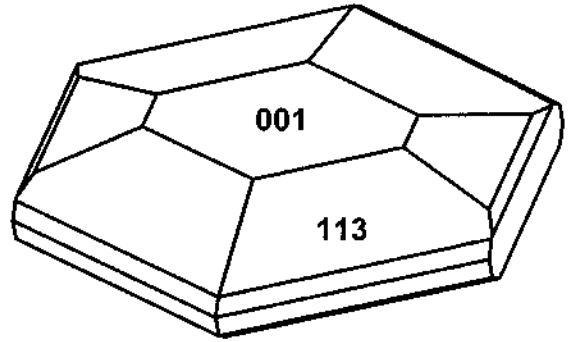


Fig. 2 Pseudo-hexagonal Habit

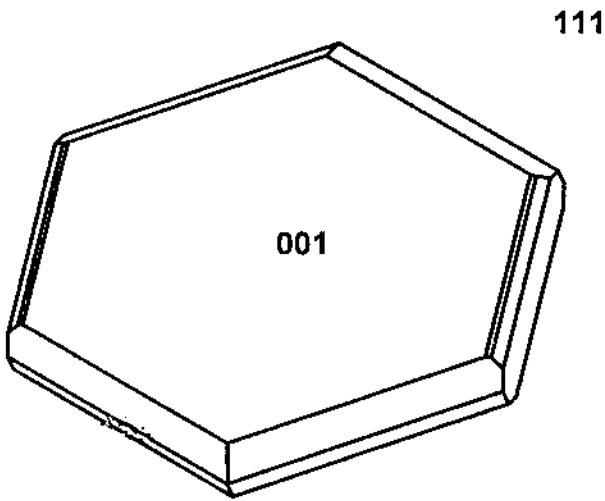


Fig. 3 Pseudo-hexagonal Habit

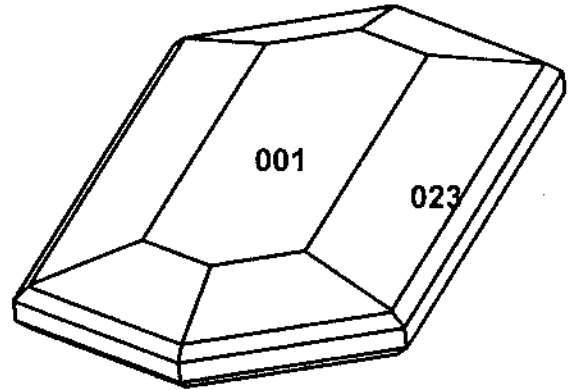


Fig. 4 Normal Habit

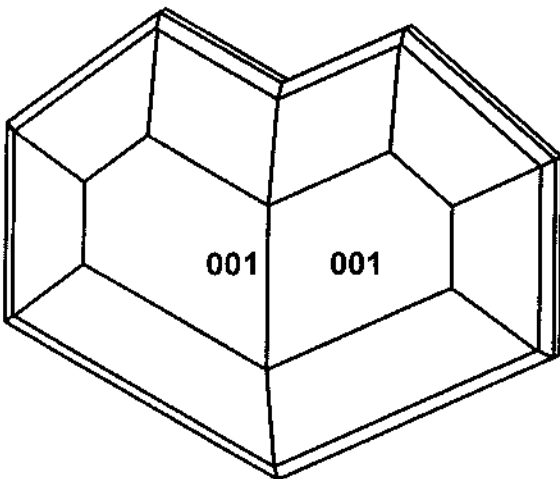


Fig. 5 Twinning on 110

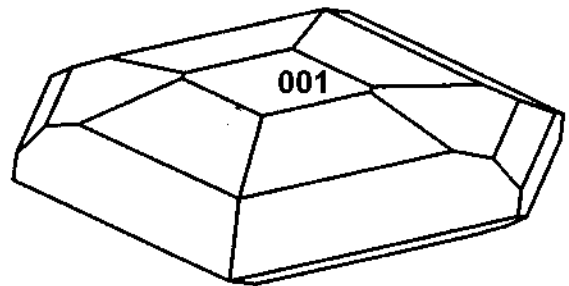


Fig. 6 Rounded Habit

the same kind of twinning. Some platelets are stacked on the broad {001} face to form shiny silver-black columns terminated by a larger pseudo-hexagonal plate. Less commonly, chalcocite forms rounded, highly striated crystals with many faces. Some of the thin platelets are striated across the c-face, which indicates they are not twinned. Tiny black chalcocite plates are rarely scattered on filiform needles of native copper. In other cavities the chalcocite plates rarely form chains, up to 15 mm long, that are covered with a beautiful dark blue coating of bornite. Both of these minerals are partially covered with light yellow calcite crystals.

Silver-black pseudo-hexagonal plates of chalcocite, and the black needles of unknown #1, have been observed included within the outer portions of analcime and on natrolite in one cavity. Rarely, minute chalcocite crystals can be mistaken for tiny rock fragments between natrolite/mesolite needles.

**CHALCOPYRITE** is rarely observed in a few cavities. It forms a very thin golden coating on chalcocite crystals and a thicker bright golden coating on some copper crystals. No distinct crystals of chalcopyrite have been observed.

**BORNITE** forms beautiful blue coatings on chalcocite and copper crystals in a few cavities. Jones et al. (1999) reports similar thin blue coatings of bornite on chalcocite from the Flambeau mine in Wisconsin. In some cavities at the Beaver Valley quarry, calcite clearly covers and includes bornite-coated crystals. Bornite appears to be one of the last copper-bearing minerals to form.

**UNKNOWN #1** forms straight black, silvery-gray needles, up to 10 mm long, scattered on quartz, stilbite, and copper in a few cavities. No radial groups of needles have been observed and no positive determination has been made to confirm this mineral. The mineral appears to be one of the last minerals to form in the pockets at about the same time as the copper sulfides. Most of the samples of this mineral have been found in stilbite-quartz-copper rich cavities from the upper level of the quarry. Tiny silvery-black needles were observed included within the outer portion of analcime along with chalcocite plates and native copper. SEM photographs of the mineral show it to resemble bundles of jointed bamboo with multiple tapering fibers at the termination. EDX indicates the mineral to contain copper and sulfur.

**CHABAZITE** commonly forms inconspicuous, tiny, colorless, transparent, pseudocubic rhombohedra and penetration twins, a few millimeters across, on most of the other minerals. Chabazite crystals are rarely scattered on the dark green clinocllore without other associations. The most spectacular specimens are those where the chabazite crystals are scattered on hexagonal levyne plates, long thin orange natrolite/mesolite needles, and colorless trapezohedra of analcime, along with a sprinkling of dark-green clay and yellow calcite crystals. Bright filiform copper is rarely seen within chabazite crystals. One cavity contained a twinned chabazite crystal, 8-mm across, with the phacolite habit.

**COPPER ALTERATIONS** are found in some cavities that have been exposed to surface water. Tiny, greenish-blue mounds composed of copper-stained caliche are rarely found on some of the native copper or in pockets containing copper.

**ORIGIN OF MINERALIZATION:** Different assemblages of minerals are found in the vesicles at the same level of the flows in the quarry. If the same amount of silica-aluminum fluid filled all the cavities, then the different species present may be explained by variations in the evolution of that fluid as the minerals crystallized. In the clinochlore-quartz pockets, much of the aluminum was used up to crystallize the clinochlore, leaving a high silica, low aluminum fluid, which favored crystallization of quartz. The small amount of aluminum present was used to form the trace amounts of zeolites found in a few of the clinochlore-quartz cavities. In cavities where the thick clinochlore did not crystallize, the silica and aluminum formed an abundance of zeolites and no quartz. In these cavities, high silica zeolites crystallized first, followed by progressively lower silica species. The crystallization of calcite is independent of the silica-aluminum ratio and can be found in any of the cavities.

Multi-colored floors are observed in some of the cavities. These floors formed by rapid crystallization and settling due to gravity of green, brown, or cream-colored clay minerals along with colorless quartz, in the clinochlore-quartz cavities, and clay and analcime, in the zeolite-rich cavities. If such floors could be observed in place and the angle of the floor measured from horizon, then the amount of tipping the basalt flows have undergone since the time the minerals crystallized could be determined.

**COLLECTING TODAY:** The once-abundant rock piles that were easily worked are rapidly dwindling away with each new lessee that works the property. Areas within the quarry are still very productive if one is willing to work the hard rock in the quarry walls. The managers of the quarry have the options of blasting the upper flows and the floor of the quarry to produce more rock for logging road re-surfacing and salmon stream rehabilitation, or purchase it from the nearby Shine and Matts Matts Bay quarries. We hope they make the right decision.

**ACKNOWLEDGEMENTS:** The authors would like to thank all of those who so graciously gave their time and shared their knowledge with us while we were working on this paper. Special mention is given to Dan Vandenberg, Bob O'Brien, Don Lown, and Dan Ice. Special thanks to Rod Maki of Olympic Management Resources for being so helpful while researching the history of the locality and to Bob Barrell for his incredible photographs. Thanks is given to Don Howard for the SEM microphotographs, EDX, and x-ray diffraction work required in this paper. Finally, J.C. would like to thank his wife, Gloria, for her patience and understanding as he pursues the other gems in his life.

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## ZEOLITE LASERS PROPOSED

Don Howard

Mineral collectors seldom read *Physical Review Letters*, but a recent article by a team of German researchers might be of interest to you. The report suggests that it might be possible to build a laser inside one of the channels of a zeolite crystal. The test system they report is only 8  $\mu\text{m}$  in diameter! If such systems can be perfected and developed, they might be very useful in making visual displays where each laser unit could form one pixel of a picture or text readout.

The reported system made use of an artificial aluminum phosphate crystal with a zeolite-like structure. Individual channels in this zeolite are about three-quarters of a nanometer across, just barely large enough to accommodate a particular dye molecule. Because the size fit is so close, the dye molecules end up being all oriented end to end in the channel. The dye is activated by optically "pumping" in energy from a laser operating at higher frequency. When the dye molecule relaxes, the light it emits is channeled along the pore of the zeolite and stimulates other excited molecules to add their light emission to the beam. This stimulated emission is the key to operating a laser. The zeolite channel with oriented molecules is an ideal system to accomplish this. The resultant light in this test experiment was in the yellow part of the spectrum. One added advantage turned out to be that because the molecules were aligned with each other, the resulting light was highly polarized.

Although in this experiment, the resulting light looked much like ordinary fluorescence (absorbing light at one frequency, say ultraviolet, and emitting a lower frequency in the visible part of the spectrum), it proved that such a system can act as a laser. Once the principle has been established, then experimentation in different ways to "pump" the system and different dye molecules will probably turn up systems that will function more like ordinary lasers.

In addition to the practical possibility for use in displays, systems such as this are expected to have some unusual properties, because the size of the channel is about the size of one wavelength of the light produced. Under these circumstances, quantum effects are possible that could lead to novel devices in the future. Perhaps someday, zeolites will be the key ingredient in a whole new generation of optical circuitry and communication devices.

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## CHALCOCITE – AN ODD ZEOLITE ASSOCIATE

Don Howard

The presence of copper in the basalt flows containing the zeolites we collect is not particularly unusual. Many of the locations produce at least sparing amounts of native copper – Goble and Beech Creek have produced some nice representative specimens to name only two. Other copper minerals tend to be very rare in this environment. Outside of oxide or sulfide coatings on the native copper that turn it black, or traces of carbonates that yield bluish surface stains, copper minerals are usually lacking. Sulfide minerals in this environment are usually restricted to pyrite (or marcasite), the sulfides of iron, since iron is a major constituent of the minerals decomposing in the basalts. It is interesting, therefore, to encounter sulfides of copper in the area around Shine in Jefferson Co., Washington.

Chalcocite has an interesting crystal structure. The sulfur ions are considerably larger than the copper ions, and govern the overall form of the crystals. The sulfur atoms form hexagonal close-packed sheets. In these sheets, each sulfur atom is surrounded by twelve other sulfur atoms. The largest spaces in the structure are where four sulfurs are arranged in a tetrahedron. There are eight such sites for every sulfur atom. If a copper atom occupies such a site, it sees the four sulfur atoms surrounding it. Thus, there is room for twice as many copper atoms in these sites as there are sulfur atoms. With everything filled, the overall composition would be  $\text{Cu}_2\text{S}$ . This is apparently the high-temperature structure of chalcocite – that is, the structure above about  $103^\circ\text{C}$ . This phase is truly hexagonal.

Below  $103^\circ\text{C}$ , a phase transformation takes place. Most of the copper atoms move away from one of the sulfur atoms to end up in trigonal rather than tetrahedral sites, and the lattice of sulfur atoms distorts slightly, so that the resulting crystal is close to hexagonal, but must be classified monoclinic. The angle between axes changes from  $120^\circ$  to about  $116^\circ$ , and the shifted copper atoms take on a complicated ordering that results in a much larger crystal cell size, about 4 by 3 times in the plane of the sulfur atoms, and with twice the repeat direction perpendicular to those planes.

The copper sulfide system has a further complication. Both copper and sulfur have a variety of valencies. In  $\text{Cu}_2\text{S}$ , the copper has a valence of one and the sulfur two. But copper can also be divalent. If some of the copper atoms take on the higher valence, fewer are needed for each sulfur atom, so the formula becomes copper deficient, rearranges ordering, and may take on other structures. The table on the next page summarizes seven recognized species based on crystal structure (Dana). All have closely related structures with varying amounts of distortion. For those that are cubic or near cubic, the sulfur planes stack slightly differently, yielding a structure related to face-centered cubic rather than hexagonal close-pack. In both structures, the sulfur atoms pack as closely together as allowed for spheres in a three-dimensional array.

The fact that the a-b interaxial angle is  $116^\circ$  rather than  $120^\circ$  means that twinning is possible in the low-temperature form of chalcocite. As indicated in the diagram in the previous article, the twinning will be on the (110) plane and lead to branching which is only a couple of degrees off of  $60^\circ$ . Hence, crystals such as the one shown in Micrograph #846 can result. Some of the chalcocite flakes found at Beaver Valley quarry are

## COPPER SULFIDES

Mineral	formula	system	a	b	c	$\beta$
Chalcocite(high T)	$\text{Cu}_2 \text{S}$	hexagonal	3.95		6.75	
Chalcocite	$\text{Cu}_2 \text{S}$	monoclinic	15.23	11.89	13.50	116.3°
Djurleite	$\text{Cu}_{1.97} \text{S}$	monoclinic	26.90	15.75	13.57	90.1°
Digenite	$\text{Cu}_{1.80} \text{S}$	cubic	5.57			
Roxbyite	$\text{Cu}_{1.78} \text{S}$	monoclinic	53.79	30.90	13.36	90.0°
Anilite	$\text{Cu}_{1.75} \text{S}$	orthorhombic	7.89	7.84	11.01	
Geerite	$\text{Cu}_{1.60} \text{S}$	cubic	5.41			
Spionkopite	$\text{Cu}_{1.40} \text{S}$	tetragonal	22.96		41.43	

unbranched – that is, appearing to be very close to simple hexagonal plates.

The copper sulfide minerals form when solutions containing copper ions encounter concentrations of sulfide ions in solution. Exactly which of the above minerals will form probably depends critically on temperature and degree of acidity, that is, on pH. Iron needs to be in short supply or one of the mixed sulfides, chalcopyrite for instance, will form instead. In highly mineralized environments, concentrations can be high and the chalcocite will form rapidly, normally forming finely crystalline masses in the vicinity of the water table. At some copper mines, these are important concentrations for commercial recovery of copper. As a result, distinct crystals of chalcocite are reasonably rare.

The presence of well-formed crystals in the basalts of the Olympic Peninsula probably means that concentrations of both copper and sulfide were rather low, and that the crystal formation was rather slow. The chalcocite is a late mineral in the formation sequence, while the native copper is early in the sequence. The copper was undoubtedly obtained from partial solution of the native copper already in place in the cavities. It would be interesting to know the source of the sulfide ions. There must also have been a very low concentration of iron in the solution; the iron being present in considerable abundance must have been tightly held in the clinocllore and clay phases. The colored blush mentioned on some of the native copper would indicate that enough iron was occasionally present to form a thin film of bornite. Bornite has a much higher ratio of copper to iron than does chalcopyrite.

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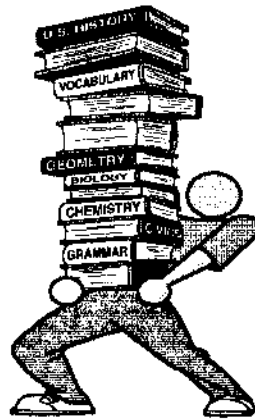
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