Northwest
Micro Mineral
Study Group

MICRO PROBE

FALL, 2012 **VOLUME XI, Number 6**

FALL MEETING . . . . .VANCOUVER, WASHINGTON

November 10, 2012 9:00 am to 5:00 pm

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

Schedule for the day;

9:00 am Doors open at the PUD building for table set up. Helpers needed.

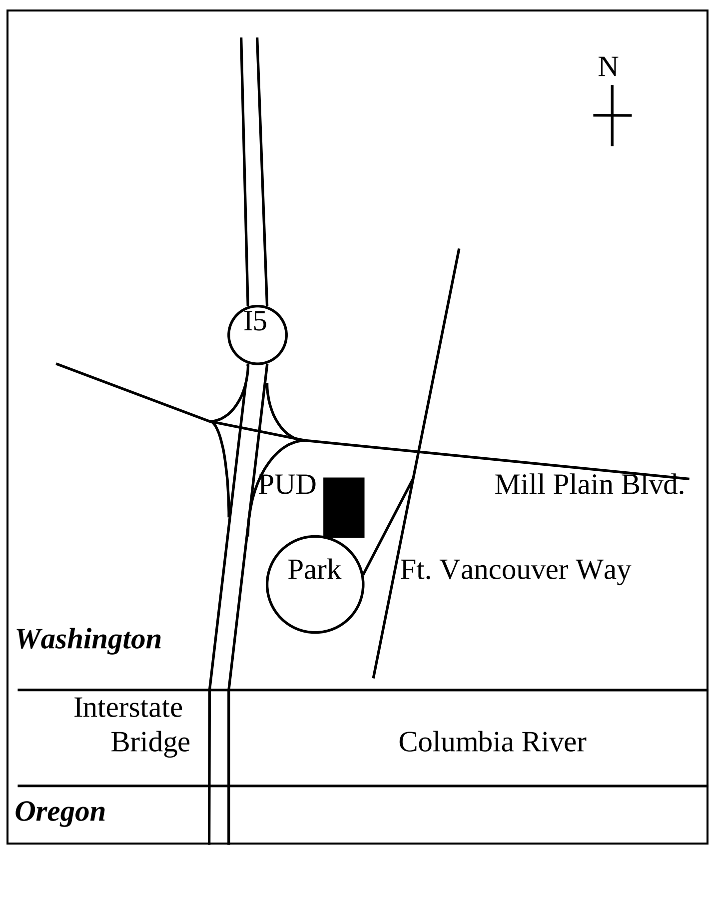
9:30 am Meeting starts: (trading, selling, free tables, viewing specimens, and visiting). Rudy is currently working on Zektzerite (see President's Page) and is requesting that you bring specimens, particularly those from known locations, for detailed examination.

11:00am Randy Becker will be talking about recent collecting at Washington Pass.

12:00 noon Lunch potluck: Club provides sandwich makings (bread, meat, lettuce, cheese, dressings, and coffee, tea, cocoa). Please bring salads, chips, pop, nuts, chili, cookies, pie, or cake to add to the lunch.

1:30pm Business meeting plus the group report on collecting spots. Rudy Tschernich will be talking about recent developments in the research on Washington Pass minerals.

5:00 pm Dinner will be at the County Buffet in Vancouver. Please join us if you can.



Presidents Page

by

Rudy Tschernich

It is time for the Fall 2012 meeting. I hope you have been either out collecting or studying some of your micro-minerals. Be ready to share with us your adventures during the **Trip Report**. A lot has been happening with study of minerals from the Golden Horn Batholith. Many samples have been studied with EDX for chemistry resulting with some results that have given us the identification of the mineral and a lot of results that only give us clues to what mineral might be present. This information will be presented at the meeting.

Some of the money from the **Mineral Research Fund** was used for thin sections of rocks reported in this newsletter. The remainder of the money in the Mineral Research Fund will be used for EDX of minerals from the Golden Horn Batholith.

Zektzerite is now being studied and I need your help in providing specimens. I would appreciate anyone with specimens of zektzerite from **known sites** in the Golden Horn Batholith to bring them to the meeting for my observation. I will make my observations and return them to you at the meeting. If you have extra specimens, even just broken crystals that could be used for research, please bring them along and donate them to the **Zektzerite Project**. They can be used for EDX to determine chemistry.

If you have any **unknowns** from the Golden Horn Batholith present them to Randy Becker for observation.

The programs for the meeting will be:

Collecting at Washington Pass by Randy Becker

Research progress on minerals from the Golden Horn Batholith by Rudy Tschernich.

THE MICROPROBE

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DUES: $15 per year per mailing address, payable at the Spring meeting or by mail to the Secretary/Treasurer:
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Geology of the Golden Horn Batholith

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The Cascade Mountain Range extends from southern British Columbia, where it is known as the Coastal Mountains, through Washington, Oregon, and into northern California. The Northern Cascades, which contains the Golden Horn batholith (GHB), is composed of the basement rocks of the Cascades that extend from north of Interstate 90 at Snoqualmie Pass to British Columbia. The Cascades south of I-90 are mostly younger volcanic rocks.

The origin of these rocks is explained by the theory of plate tectonics, which holds that the Earth's outer crust is made up of several large, relatively rigid plates floating on a denser layer of plastic rock. Where plates converge, some of the ocean-deposited sediments are scraped off, deformed, and transferred to the overriding plate, while some of the sediments and volcanic basalt is carried beneath the overriding plate in the subduction zone where increasing heat and pressure turn them into metamorphic rocks (Fig.1). Water, which is abundant in the sedimentary rocks, is driven off as the rocks move deeper and get hotter. The rising water lowers the melting point of the already hot upper mantle and lower crust, causing the rock to melt, expand, and become less dense than the rocks surrounding them. The molten rock rises buoyantly towards the surface along zones of weakness, such as faults. Where the molten rock reaches the surface, volcanoes form, expelling magma, gas, and water vapor. Other molten masses that never reach the surface slowly crystallize to form large masses called batholiths. Crystallization of the anhydrous minerals (quartz and feldspar) in the magma concentrates rare residual elements and volatiles into the remaining water-rich fluids that form fluid-filled areas within the batholith. When drained of fluid and exposed at the surface, these areas in the rock are called miarolitic cavities.

The North Cascades is a jumble of different rocks that record over 400 million years in geologic history. It is made of a mosaic of volcanic island arcs, deep ocean sediments, basaltic floor, parts of old continents, and even pieces of deep subcrustal mantle that have been faulted and moved in large slabs over each other. About 40 million years ago, a volcanic arc developed on the older terranes covering the older rocks with volcanic rock, a process that continues up to the present day. Due to thicker basement rocks, the North Cascades buoyant up higher than rocks in southern Washington and Oregon. Erosion from running water, landslides, alpine and continental glaciation exposed the complex basement rocks in the Northern Cascades, while the more southerly Cascades remained covered by volcanic rock.

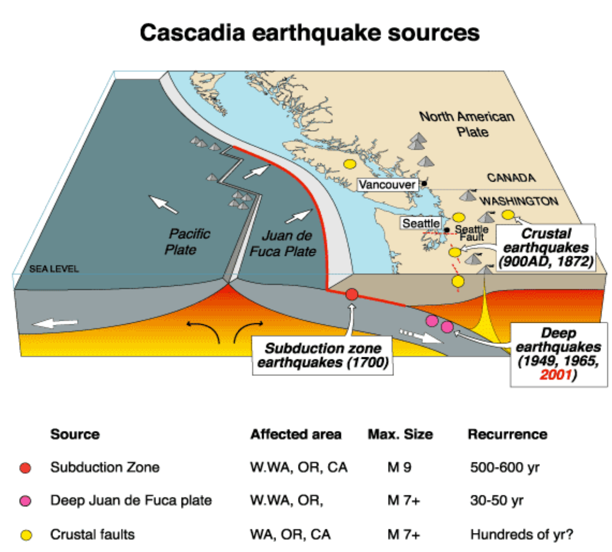

Figure 1 Subduction of the Juan de Fuca Plate. and the formation of magma

The Ross Lake fault system is 10 km wide and is part of a 500 km long zone of faults that run from northern California to the Northern Cascades. During the Eocene, a plume of magma, now called the Golden Horn Batholith, (GHB), rose into the weakened fault system and welded the Ross Lake fault in place (Fig. 2). The GHB is exposed for 120 square miles and is elongated northwest parallel to the Ross Lake Fault zone. Misch (1965) emphasized that the GHB granite is an anomaly. Other plutons in the region that predate and postdate the Golden Horn Batholith granite are calcium to alkaline diorites, quartz diorite, and granodiorite (Misch, 1966). No other true granite is

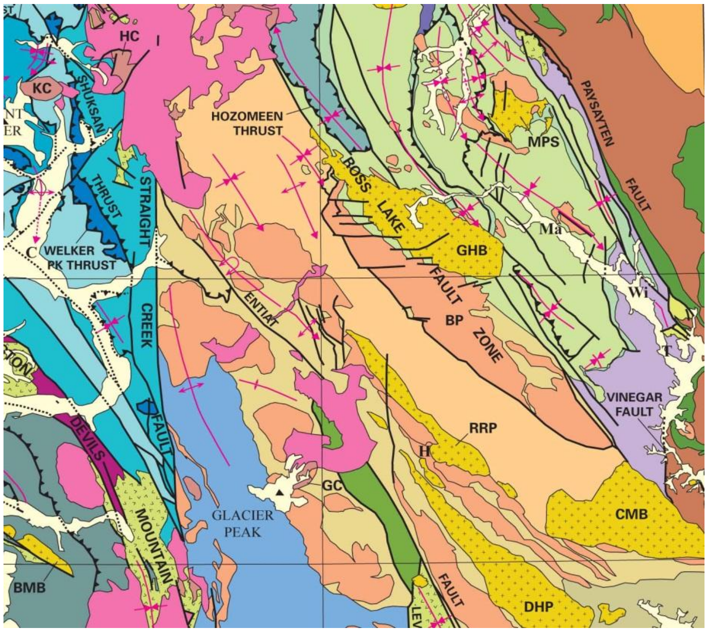

Figure 2 *GHB Golden Horn batholith, BP Black Peak batholiths MPS Monument Peak stock, CMB Cooper Mountain batholith, , RRP Railroad Creek pluton DHP Duncan Hill pluton (Haugerud, R.A. and Tabor, R.W. 2009).*

found in the Northern Cascades. $^{40}Ar/^{39}Ar$ age dating of arvfedsonite from the arfvedsonite-bearing granite in the GHB indicates Eocene, with an age 46.97 ± 0.23 mya, while annite taken from samples of annite-bearing granite of the GHB is 46.92 ± 0.04 mya (Petro, G. et al, 2002). This indicates the annite-bearing granite may have crystallized 50,000 years after the arvfedsonite-bearing granite.

The Monument Peak Stock, a small body of true granite located about 16 km north of the GHB and possibly related to it, has been K/Ar dated to be 47 mya (Tabor and others, 1968). The Black Peak granodiorite, Late Cretaceous age, 88-73 mya (Engels and others, 1976) and Ruby Creek Pluton predate the GHB, while the Horn Perry Creek intrusive postdates it. The GHB is in contact on the east and southeast sides by Cretaceous sandstone and shale. On the South and southwest sides it is in contact with the Black Peak Batholith and North Creek volcanics. To the north and northwest sides are found the Elzah Ridge Schist and Ruby Creek Pluton.

Emplacement of the GHB is shallow. It shouldered aside the Cretaceous strata on the north and east with magmatic stoping forming breccia at the contact with the Black Peak Batholith (Stull, 1969). Uplift of the rock surrounding the GHB produced fractures which filled with dike rock from the GHB. The contact of the GHB and the surrounding rock is extremely sharp, dips steeply, and shows little evidence of chilling. Contact metamorphism is absent beyond 100 yards from the contact (Stull, 1969).

Misch (1965) briefly described three types of granite in the GHB: 1) a 2-feldspar annite granite, 2) a 1-feldspar annite granite, and 3) an alkaline-arfvedsonite granite. Misch encouraged Stull to study the origin of the GHB.

Stull (1969) studied the southeast portion of the Tertiary Golden Horn Batholith. This pluton is unusual in the North Cascades, since it is rich in sodium and potassium, while other plutons in the area are typically calcium and sodium-rich with very little potassium (Stull, 1969). Stull (1969) mapped (Fig. 3) and defined the three rock types of Misch (1965). The two-feldspar annite granite grades into the one-feldspar granite while there is a sharp contact with the arfvedsonite granite. The arfvedsonite granite has no textural or mineralogical changes near the contact, although the one-feldspar granite is finer grained and severely altered at the contact. The contact of the one-feldspar granite and the arfvedsonite granite is vertical near Washington Pass and Silverstar Mountain, but becomes nearly horizontal or gently dipping to the southeast in the north. The two types of annite granites that are beneath the arfvedsonite granite have an elongated shape trending NW to SE (Stull, 1969). Dikes in the GHB are rare. A few consist of annite granite crosscutting the arfvedsonite granite, which demonstrates that the arfvedsonite granite is older than the annite granite. Xenoliths of diorite or granodiorite near the contact with the Silverstar Mountain are common in the two-feldspar annite granite, rare in the one-feldspar granite, and absent in the arfvedsonite granite (Stull, 1969). Field evidence shows large areas of two-feldspar annite granite east and north of Silver Star Mountain. Arfvedsonite granite was exposed south and west of Silver Star Mountain with one-annite biotite granite in the area between the other two granites (Stull, 1969).

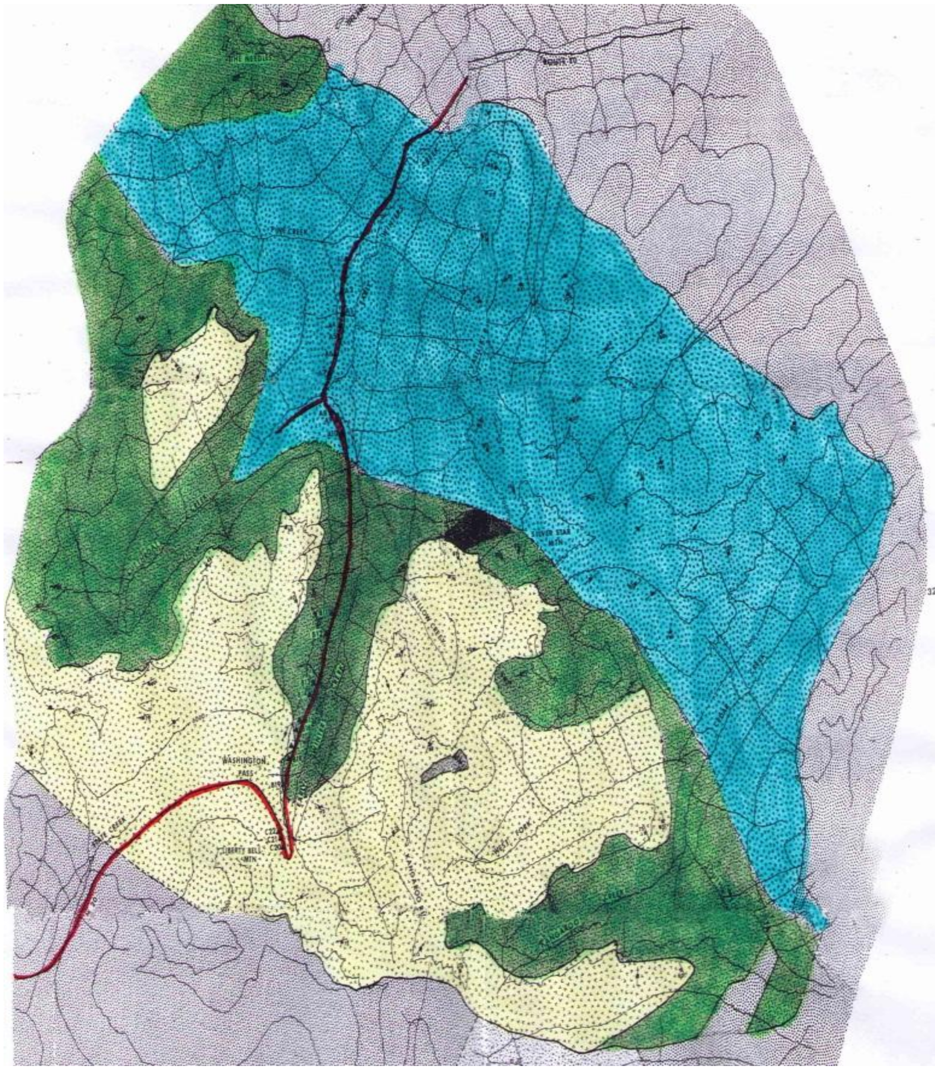

Figure 3 *Geologic map of SE portion of the Golden Horn Batholith (Stull, 1969).*
Yellow = arfvedsonite granite, Green = one-feldspar granite,
Blue = 2-feldspar granite

Miarolitic cavities are common in all rock types. The one-feldspar granite contains the most cavities (Stull, 1969). The average diameter of crystal-bearing cavities is only a few millimeters, up to several centimeters in size, with some tubes reaching 40 cm long and 10 cm in diameter. A few exceptionally large cavities occur in the arfvedsonite granite that are 7 to 10 meters in diameter, but none have been found to contain crystals.

Boggs (1984) divided the GHB into four units (Fig. 4):
1) subsolvses annite granite (now named two-feldspar annite granite),
2) hypersolvus annite granite (now named one-feldspar annite granite),
3) arfvedsonite granite,
4) border granite.

The border granite is defined only as a fine-grained granite deficient in dark minerals. It appears to be mapped from talus rather than bedrock exposures. The older arfvedsonite granite can be expected to occur high on the mountains with the younger annite granite below, somewhat like ice cubes floating on water. Rock collected in place along the road is annite granite, while loose boulders along the road can be from either annite or arfvedsonite granite. The border granite of Boggs (1984) is only found on the talus from Liberty Bell area and upper south part of Kangaroo Ridge. Granite of the GHB occurred from multiple intrusions at a shallow crustal depth, at 700-750^{o} C, when the water-vapor pressure was about two kilobars (Stull, 1969). Boggs (1984) extends the temperature range down to 200^{o}C to account for some of the low-temperature minerals in some of the miarolitic cavities. The older arfvedsonite granite was produced by partially melted metamorphic rocks in the area. From trace element comparison, the most likely source is the basement rocks of the Yellow Aster Complex (gneiss derived from sandstone, limestone, volcanic rocks, and xenoliths) (Misch, 1966, Stull, 1969). A small amount of Si-Al contamination of arfvedsonite granite magma with older diorite xenoliths produced the one-feldspar granite, and more advanced contamination produced the two-feldspar granite (Stull, 1969).

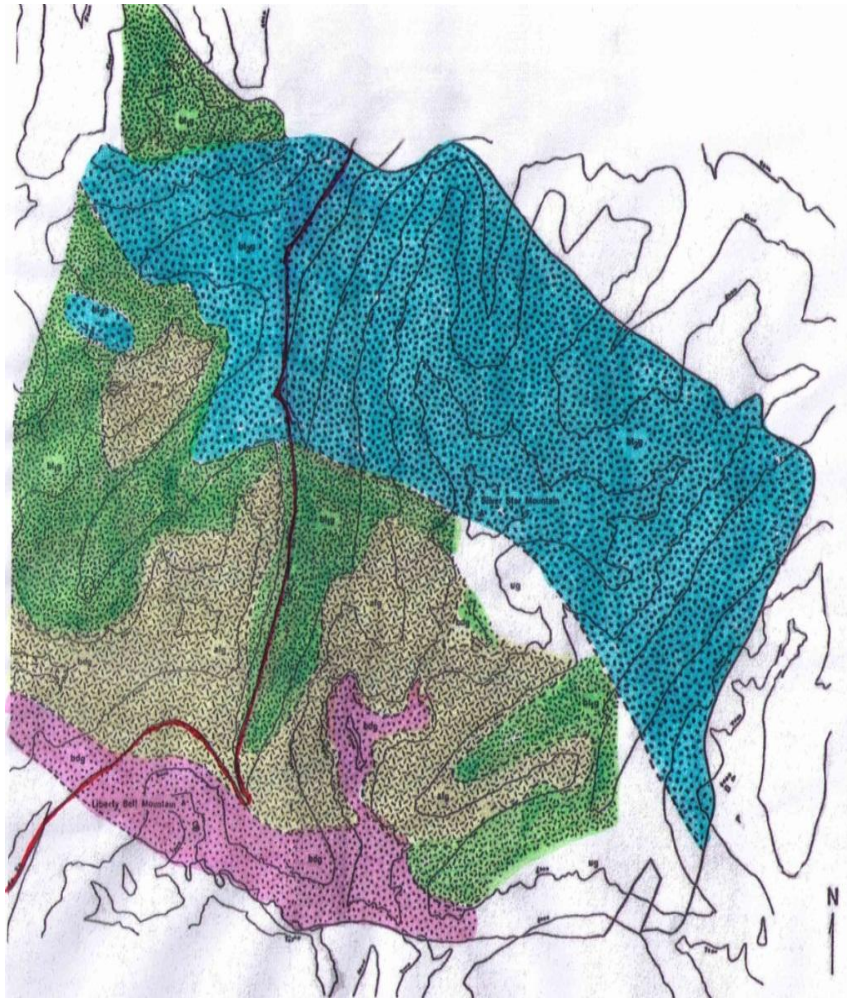

Figure 4 *Geologic map of SE portion of the Golden Horn Batholith (Boggs, 1984).*
Yellow = arfvedsonite granite, Green = one-feldspar annite granite,
Blue = two-feldspar annite granite, Pink = border granite.

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Rocks of the Golden Horn Batholith

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Introduction

Granite is a light-colored coarse-grained plutonic igneous rock that contains at least 20% quartz with two types of feldspar (35% K-feldspar and Na/Ca plagioclase) and less than 15% dark minerals (amphibole and biotite groups).

Alkali granite has over 20% quartz, two types of feldspar with orthoclase/microcline (K-feldspar) greater than Na/Ca plagioclase, and less than 10% dark minerals.

Granodiorite has over 20% quartz, like granite, but with roughly equal amounts of Na/Ca plagioclase and dark minerals and no K-feldspar.

Diorite is low in quartz, generally less than 5%, with about 50% Na/Ca plagioclase feldspar and up to 50% dark minerals (amphibole or biotite groups).

Golden Horn Rocks

The Golden Horn Batholith is composed of several types of granite:

The one-feldspar annite granite described by Stull (1969) is white, medium to coarse-grained rock containing quartz, perthite (K-feldspar intergrown with later-formed albite), and the dark minerals, annite with minor amphibole. It is the most severely altered of the rock types at GHB (Stull, 1969) and has the most cavities.

The two-feldspar annite granite is pinkish and white, medium to coarse-grained rock that contains quartz, two types of feldspar, orthoclase/microcline (pink) and plagioclase (white), and the dark minerals, annite and hornblende. The pink K-feldspar, orthoclase or microcline, is perthitic (intergrown with albite). The perthite often has a core of white Na-Ca plagioclase (oligoclase with a composition near albite). It is least affected by weathering (Stull, 1969).

The alkaline granite, also called the arfvedsonite granite, is a white, medium to coarse-grained rock with quartz, perthite feldspar made up of K-feldspar and albite, with black sodic amphibole, usually arfvedsonite, while annite is generally absent (Stull, 1969).

This Study

Rocks from 12 boulders that have produced interesting miarolitic cavity minerals from the GHB have been selected for study. A description in hand specimen and in thin section are given in order to understand the type of rock where crystal-bearing miarolitic cavities are present. The feldspar in the thin sections has been stained orange-green to clearly display the amount of feldspar minerals present. In general, the light orange-colored feldspar is sodium-rich albite while the darker orange to green color is potassium-rich microcline. Colorless quartz appears white in the photographs. Pleochroic or pleochroism is the property of a mineral to differentially absorb light that vibrates in different direction in passing through it. Sodium amphiboles, pyroxene, and biotite group minerals are pleochroic, which aids in their identification. Sodic amphiboles (arfvedsonite and riebeckite) are usually shades of blue, hornblende is shades of greenish-brown, aegirine is shades of green to brown, and biotite group minerals (annite) are shades of brown.

The rock samples for this study were provided by Randy Becker. Funding for making thin sections was from the Research Fund of the Northwest Micro Mineral Study Group. Thin sections and corresponding rock samples will be placed in the care of Randy Becker.

Figure 1 *arfvedsonite granite*

WP001 Arfvedsonite granite
Typical road cut rock at MP166

In hand specimen, the rock is a medium to coarse-grained granite with white to cream colored feldspar, colorless quartz, and about 5% black amphibole (Fig.1).

In thin section, the amphibole shows medium gray to dark blue pleochroism typical of arfvedsonite (Fig. 1b) while hexagonal plates of annite (Fig. 1c) which have dark brown pleochroism are scarce. The quartz is colorless. The feldspars are stained orange (albite) and green (microcline). They display parallel internal segregation and are overgrown with albite (Fig. 1a).

Miarolitic cavities are scarce in this sample but can be abundant in this rock type.

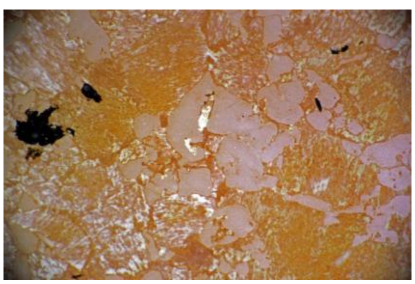

Figure 1a *quartz & feldspar (orange)*
(Field of view 10 mm)

Figure 1b *amphibole (blue-green)*
(Field of view 6 mm)

Figure 1c black annite (black)
(Field of view 5 mm)

Figure 2 *fine-grained arfvedsonite granitic aplite*

WP002 Arfvedsonite granitic aplite
Road cut aplite at MP166

In hand specimen, the rock is a white fine-grained granite with white feldspar, colorless quartz, and about 2% black minerals (black elongated amphibole).

Thin section shows strong graphic granite segregation of colorless quartz in feldspar (Fig. 2a). The feldspar (stained orange to green) consists of alternating albite and microcline often covered with a rim of albite (Fig. 2b,c). The microcline feldspar is filled with tiny, dust-like particles of clay as a result of low temperature alteration. The albite feldspar remains unaltered. The colorless quartz forms anhedral grains and segregations within the feldspar. The amphibole forms elongated black crystals that have light to dark blue pleochroism typical of arfvedsonite. Brown aggregates of astrophyllite blades are present. Opaque minerals are absent.

Miarolitic cavities are scarce but do contain colorless quartz, colorless albite on white microcline/albite, black arfvedsonite (some with green overgrowths of aegirine), bronze-colored astrophyllite, and zircon.

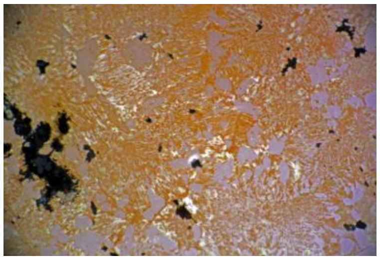

Figure 2a *microcline/albite stained with white quartz and black amphibole (Field of view 10 mm)*

Figure 2b *dark amphibole, quartz, feldspar (Field of view 6 mm)*

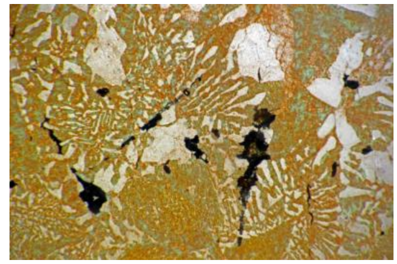

Figure 2c *graphic granite segregation (Field of view 6 mm)*

Figure 3 *arfvedsonite* granite

WP003 Arfvedsonite granite
Okanoganite Boulder

In hand specimen, the rock is a white to cream colored coarse-grained granite with feldspar, colorless quartz, 3% elongated black amphibole with no mica, and widely spaced miarolitic cavities.

In thin section, the mineralization is rather simple. The feldspar crystals are rather large, perthitic with an abundance of albite surrounding the perthite microcline/albite segregations (Fig. 3a,b). Small particles of clay gives a dust-like appearance to the microcline, while the albite is free of clay. The dark minerals are entirely large arfvedsonite crystals with a dark blue to greenish pleochroism (Fig. 3c). The quartz is colorless. No mica or opaque minerals were observed.

Miarolitic cavities contain microcline/albite, quartz, arfvedsonite, aegirine, REE carbonate, chevkinite, euxenite-(Y), pyrochlore, titanite, zektzerite, okanoganite, fluorite, rarely chamosite, and several unknowns (Becker, 1991).

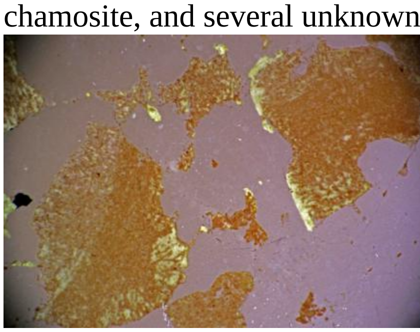

Figure 3a *feldspar stained orange/yellow surrounded by white quartz (Field of view 10 mm)*

Figure 3b *microcline stained orange surrounded by yellow albite with white quartz (Field of view 10 mm)*

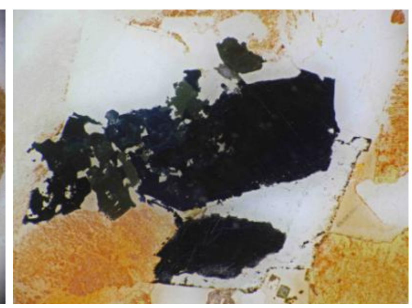

Figure 3c *blue/green arfvedsonite with white quartz and orange feldspar (Field of view 6 mm)*

Figure 4 *one-feldspar annite granite*

WP004 One-Feldspar Annite Granite
Amazonite Boulder at MP164

In hand specimen, the rock is tan to white colored, medium to fine-grained granite with white feldspar, small colorless quartz, 3% dark (black annite altered green).

In thin section, the feldspar is perthitic, composed of parallel segregation of albite (orange stain) and microcline (darker green stain) with an albite rim on crystals in cavities (Fig. 4,a,b). The feldspar is filled with a dust-like clay mineral. Quartz is colorless and anhedral.

Most of the dark minerals are dark to light green books of annite that are pleochroic from brown to light green (Fig. 4c). Tiny elongated crystals that are pleochroic dark to light green are probably a member of the hornblende group. No opaque minerals were observed.

Miarolitic cavities contain colorless to smoky quartz, white to blue-green microcline (amazonite), black to light colored annite, black amphibole, dark reddish-brown to yellow siderite, goethite, REE carbonate, zircon, anatase, gadolinite, fluorite, light green chamosite, β-fergusonite and magnetite (Becker, pers. comm.)

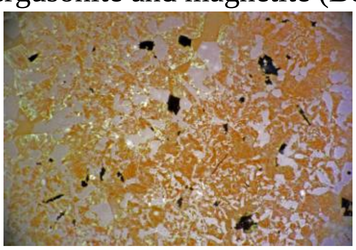

Figure 4a *orange/green stained feldspar (Field of view 10 mm)*

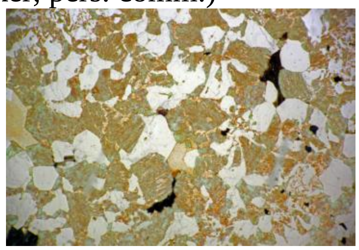

Figure 4b *white quartz colored feldspar (Field of view 6 mm)*

Figure 4c *black annite, quartz, feldspar (Field of view 4 mm)*

Figure 5 *one-feldspar annite granite*

WP005 One-feldspar annite granite. Genthelvite Rock at MP165

In hand specimen, the rocks is a white, medium-grained granite with small white to tan feldspar, colorless quartz, tiny widely scattered black minerals 5% (greenish-black to bronze-colored annite and black amphibole). The rock is scattered from MP164.5 to MP165.5. The rock appears blue-gray in color when wet. It has been hypothesized that the rock gets it color from tiny blue arfvedsonite needles.

In thin section, the feldspar microcline is perthitic with parallel segregations of albite. In cavities, a colorless albite rim covers the microcline/albite perthite (Fig. 5a). A gray-colored dusting of clay is present in the feldspar, which probably accounts for the change of color when wet. No blue sodic amphibole is present, although tiny amounts of pleochroic light green to brown amphibole, probably a hornblende member, is present. Books of annite (pleochroic brown to green) is the common dark mineral with some radial groups of pleochroic light green chamosite (Fig 5b,c). Quartz is colorless. A small amounts of opaque magnetite is present.

Miarolitic cavities contain colorless quartz, books of annite with greenish chamosite, anatase, bastnasite-(Ce), fluorite, zircon, gadolinite-Ce, okanoganite, and pink genthelvite (Krotki, 2012).

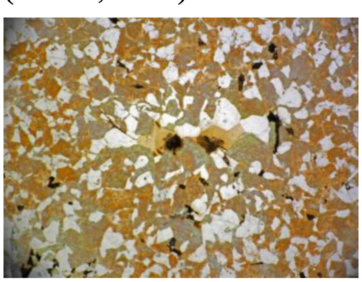

Figure 5a *feldspar (stained orange and and green) with white quartz (Field of view 10 mm)*

Figure 5b *light and dark brown books of annite with light brown chamosite (Field of view 6 mm)*

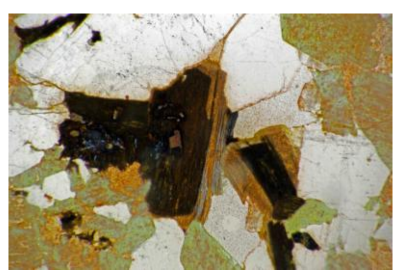

Figure 5c *brown books of annite with light brown chamosite and black magnetite (Field of view 5 mm)*

Figure 6 *one-feldspar annite granite*

WP006 One-feldspar annite granite
Culvert Rock at MP165 (apatite-bearing rock)

In hand specimen, the rock is tan colored medium-grained granite with white to tan feldspar, colorless quartz, small scattered black minerals 3% (black annite and elongated amphibole).

In thin section, euhedral perthitic microcline crystals with exsolved parallel zones of albite are surrounded by a graphic granite texture of feldspar and quartz (Fig. 6a,b). Albite also forms rims around microcline/albite in cavities. A dusting of clay is present in the microcline. Black to dark brown pleochroic books of annite is the main dark mineral. Green fans of chamosite occur on the books of annite. Quartz forms colorless anhedral grains intergrown with the feldspar. A small amount of light to dark greenish-brown pleochroic elongated crystals of amphibole (Fig. 6c) is present, which is probably of the hornblende group. Metallic opaque magnetite is associated with the amphibole (Fig. 6c).

The miarolitic cavities contain colorless quartz, colorless albite covering milky cream-colored microcline, green annite, brown chamosite, dark reddish-brown rhombohedra of siderite, colorless fluorite, anatase, hexagonal plates of REE carbonate, skeletal zircon, and unusual colorless hexagonal needles of apatite that have a “c” face termination.

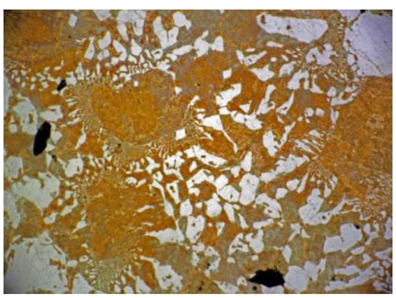

Figure 6a *graphic granite (quartz and feldspar)with white quartz (Field of view 10 mm)*

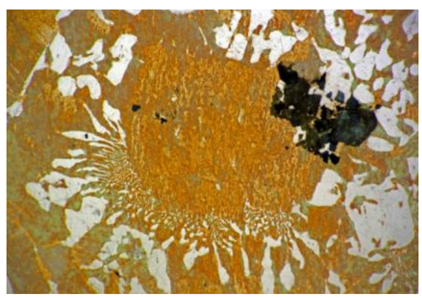

Figure 6b *microcline crystal surrounded by white quartz orange feldspar graphic granite (Field of view 5 mm)*

Figure 6c *hornblende and magnetite with white quartz and orange/green feldspar (Field of view 5 mm)*

Figure 7 *arfvedsonite aplite border granite*

WP007 Arfvedsonite aplite border granite
Blue Dike Rock, upper Liberty Bell talus

In hand specimen, the rock is a fine-grained bluish aplite dike rock crossing a coarser-grained granite. The dike is rich in colorless quartz and colorless transparent unaltered feldspar, which gives it a false blue or gray color. It contains only 5% black tiny minerals. The dike crosses a yellowish-white to tan-colored medium-grained granite of the same composition.

In thin section, the dike rock contains an abundance of irregular shaped microcline with patches of albite (Fig. 7c). Very little dusting from clay is present, which makes the feldspar and colorless quartz very transparent. Tiny equant patches of pleochroic dark blue to greenish arfvedsonite forms up to 5% of the dike, giving a blue color to the dike (Fig. 7b). Some fine-grained plates of annite are present. The coarse-grained granite (Fig. 7a) through which the dike cuts is similar in mineralization except that the crystals are larger and the feldspar is more altered with a dusting of clay minerals.

Miarolitic cavities contain arfvedsonite, aegirine, REE carbonate, quartz, microcline, astrophyllite, titanite, annite, and zircon (Becker, pers. comm.). Cavities are very small and concentrated near the contact zone of the fine-grained dike and the coarser arfvedsonite granite.

Figure 7a *fine-grained dike (upper part) cutting coarse-grained granite (lower part) (Field of view 10 mm)*

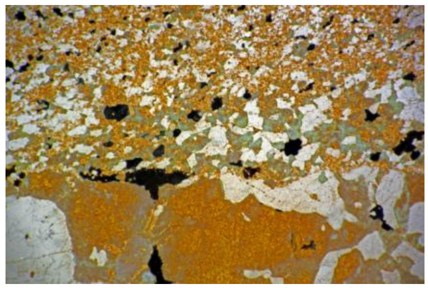

Figure 7b *contact of dike (upper part) with coarse-grained lower portion (Field of view 6 mm)*

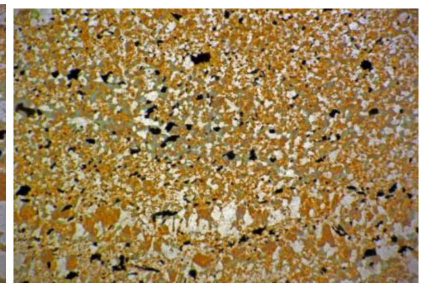

Figure 7c *fine-grained dike rock feldspar with feldspar stained orange and white quartz (Field of view 8 mm)*

WP008 one-feldspar annite granite Kainosite Type Rock, Liberty Bell talus

In hand specimen, the rock is a tan-colored, medium-grained border granite with dark tan colored feldspar, small colorless quartz, 3% brown chamosite mica with no black annite or amphibole. Characterized by presence of brown chamosite.

Figure 8 *one-feldspar annite granite*

In thin section, the microcline has strong segregations of albite (Fig. 8a). Albite forms a rim on the microcline. The microcline portion is heavily altered with dust-like clay. Books of brown annite with a light to dark brown pleochroism is abundant with some colorless radial chamosite blades (Fig 8b,c). Amphiboles are scarce. They are very irregular, have a dark blue to blue pleochroism, and form clusters with books of annite. Quartz forms irregular crystals between the feldspar.

Miarolitic cavities contain kainosite, allanite, fluorite, chamosite, quartz, feldspar and zircon (Becker, pers. comm.).

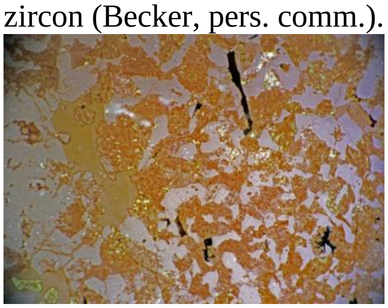

Figure 8a *feldspar stained orange, with white quartz (Field of view 10 mm)*

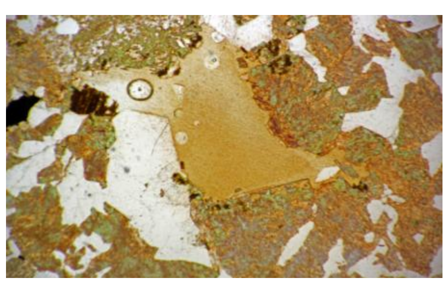

Figure 8b *cavity in center with brown annite, orange/green feldspar, and white quartz (Field of view 6 mm)*

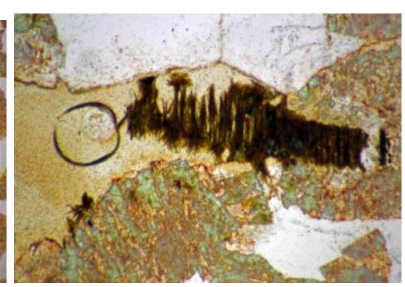

Figure 8c *parallel plates of annite with brown radial groups of chamosite in cavity (Field of view 5 mm)*

***Figure 9** one-feldspar annite granite*

**WP009 One-feldspar annite granite
Synchysite-(Ce) Rock 0.1 mile N of MP164**

In hand specimen, the rock is a tan medium-grained granite with colorless quartz, zoned colorless to white feldspar, and 10% black annite.

In thin section, the feldspar is zoned (Fig. 9a) with microcline and albite segregations. The perthite has a dusting of clay inclusions, while transparent albite also covers the perthite in cavities. Parallel plates or books of annite with a pleochroic greenish to brown color are common, while radiating brown blades of chamosite are only found in cavities (Fig. 9c). Brown to green pleochroic amphibole is scarce. Quartz forms colorless irregular grains. Less than 1% opaque magnetite is present within annite clusters.

The miarolitic cavities contain colorless quartz, deep green to black annite books, lustrous green fans of chamosite, fresh lustrous reddish-brown rhombohedra of siderite, complex fluorite crystals, and rarely stacked hexagonal light yellow REE carbonate, titanite, and white ball-like aggregates composed of thin hexagonal plates of synchysite-(Ce) (Friis, 2012).

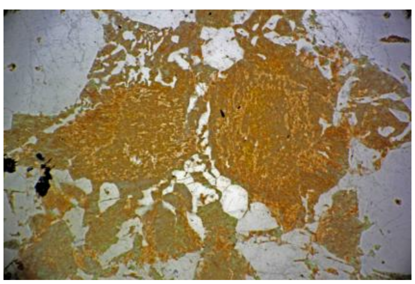

***Figure 9a** zoned perthic microcline/albite with white quartz (Field of view 10 mm)*

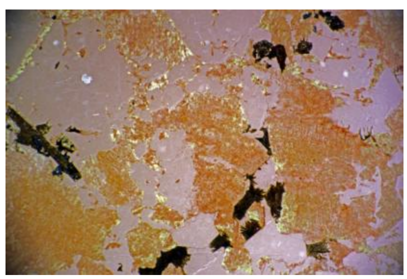

***Figure 9b** white quartz with feldspar stained orange and brown annite (Field of view 10 mm)*

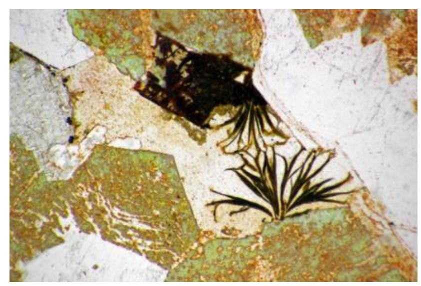

***Figure 9c** brown radial chamosite in cavity with green-orange stained feldspar and white quartz (Field of view 6 mm)*

***Figure 10** arfvedsonite granite pegmatite*

**WP010 Arfvedsonite granite pegmatite
Sogdianite pegmatite boulder MP164.5**

In hand specimen, the rock is a greenish cream-colored coarse-grained granite or pegmatite with white feldspar, colorless quartz, 15% large, long, 15 mm, black arfvedsonite, and white mica. Nearby rock in the same boulder contains feldspar and quartz of the same size as the pegmatite area, but contains only 2% small, equant arfvedsonite crystals, under 2 mm across.

In thin section, the feldspar is perthitic microcline with segregations of albite (Fig. 10a). Albite is abundant in cavities overgrowing the perthitic microcline/albite.

The microcline is filled with a dusting of clay particles. Colorless quartz is abundant. The characteristic dark mineral is arfvedsonite; it is pleochroic dark blue to greenish-blue and is always surrounded by light to medium green pleochroic aegirine (Fig 10b,c). Formerly, Boggs (1984) reported these dark crystals to be entirely aegirine.

Miarolitic cavities contain aegirine, microcline, quartz, zektzerite-sogdianite intergrowths, REE carbonates, polylithionite, titanite and unknowns (Becker, 1991).

Figure 10a *feldspar (stained orange/green) with white quartz and dark blue arfvedsonite (Field of view 10 mm)*

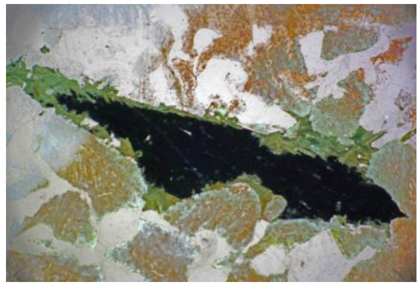

Figure 10b *blue arfvedsonite surrounded by green aegirine with quartz and feldspar (Field of view 6 mm)*

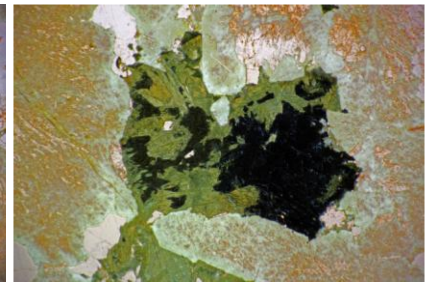

Figure 10c *dark-blue arfvedsonite surrounded by green aegirine and orange-green feldspar (Field of view 6 mm)*

Figure 11 *one-feldspar annite granite*

WP011 One-feldspar annite granite Calciohilairite Type Boulder, Liberty Bell talus

In hand specimen, the rock is a tan to cream-colored, medium-grained, one-feldspar annite granite. It has white to tan feldspar, colorless quartz, 7% large black annite books with bronze-colored chamosite.

In thin section, feldspar forms small irregular perthitic microcline with albite segregations intergrown with colorless quartz to form a micro graphic granite texture (Fig. 11a,b,c). There is a heavy dusting of clay particles in the microcline. Dark brown to black pleochroic books of annite are common with lesser amounts of brown-colored radial chamosite. The quartz is irregular and colorless.

Miarolitic cavities contain black annite, brown chamosite, cream-colored calciohilairite, microcline/albite, REE carbonate, fluorite, gadolinite, zircon and quartz.

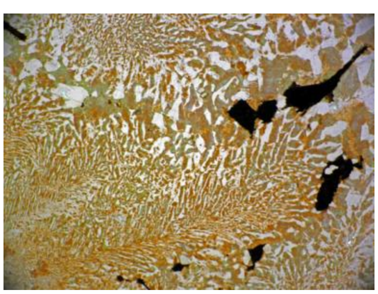

Figure 11a graphic granite, white quartz and black annite *(Field of view 10 mm)*

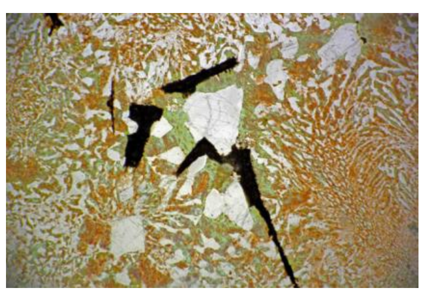

Figure 11b black annite with white quartz and feldspar stained orange/green *(Field of view 10 mm))*

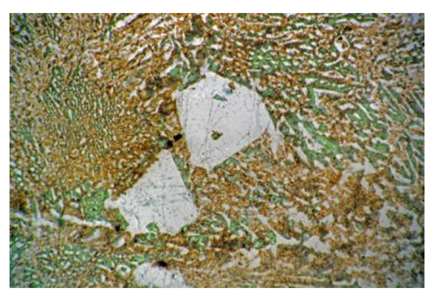

Figure 11c white quartz surrounded by graphic of quartz and feldspar (stained orange & green) *(Field of view 10 mm)*

Figure 12 *two-feldspar annite granite*

WP012 Two-feldspar annite granite, MP167.65

In hand specimen, this is a coarse-grained granite with both white and pink feldspars, colorless quartz, and 7% dark minerals consisting of black annite, black-brown amphibole and a gray metallic opaque mineral.

In thin section: Point count (2400 total) on four thin sections from this site yield K-feldspar 32.0%, plagioclase 30.0%, quartz 29.2%, annite 2.7%, amphibole 1.1%, opaque 0.4%, with a trace of zircon, apatite, titanite, chlorite (Stull, 1969). Quartz formed colorless, anhedral, equant crystals. Plagioclase (Ca-Na aluminosilicate) is euhedral to subhedral and is zoned (Fig 12b) from a (70-90% sodium, remainder calcium) core to an albite (100 to 90% sodium, remainder calcium) rim. Orthoclase (potassium-sodium aluminosilicate) is anhedral and was one of the last minerals to crystallize. It is commonly perthitic (intergrown with albite) with a high K/Na ratio. Orthoclase is consistently altered to a clay (kaolinite) or mica (sericite) mineral. Annite forms lustrous, hexagonal, euhedral books and plates that are strongly pleochroic from light yellow to very dark brown (Fig. 12c). Some of the annite is black with bronze-colored rims that is probably a chlorite mineral. The amphibole forms elongated crystals that are pleochroic light to medium green, probably a hornblende. Opaque metallic gray grains that are either magnetite or ilmenite are more plentiful than in the other granite samples studied.

No miarolitic cavities are seen in this specimen, but other rocks in the outcrop contain numerous miarolitic cavities with orthoclase, quartz, annite, prehnite, titanite, carbonates, apatite, epidote, and chabazite-Ca. Boggs (1984) reports cavities in aplite dikes cutting this rock. The presence of similar minerals in both the aplite dikes and surrounding rock indicates that the mineralization is due to residual fluids found in the cavities rather than from invading dikes.

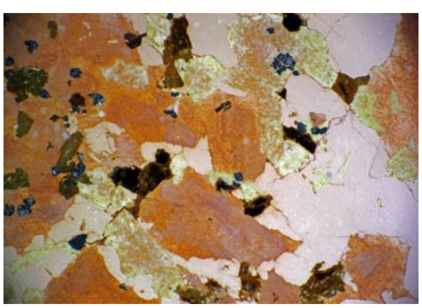

Figure 12a *orange and green stained feldspar white quartz, gray opaque, brown annite. (Field of view 10 mm)*

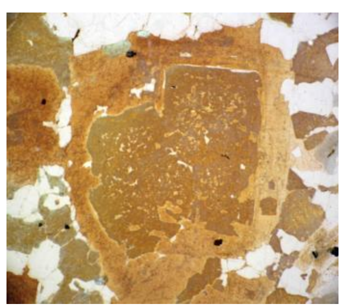

Figure 12b *zoned plagioclase with irregular grains of quartz. (Field of view 5 mm)*

Figure 12c *black annite with gray opaque white quartz, mineral and orange/green feldspar. (Field of view 6 mm)*

Conclusions

This study was to determine what type of rock makes up significant boulders that produce interesting minerals in their miarolitic cavities. Few if any conclusions about the geology can be drawn, since the boulders were not found in the bedrock. Many of the boulders found along the highway have fallen from higher above the road and do not represent the rock in place along the road. Those on the Liberty Bell talus also do not represent the bedrock under the talus.

The microcline in the perthite has been consistently altered to clay, which gives a white color to the normally colorless microcline, while albite in the perthite shows very little alteration and remains colorless. This alteration probably occurred a great deal of time after that minerals formed in the cavities. Therefore, it did not influence the types of minerals found in the cavities. Albite in the form of very thin layers or stacks of crystals has overgrown microcline in most of the cavities. Unaltered colorless feldspar and quartz in a rock often gives a false blue or gray appearance to the rock. Changes in color of the feldspar in rock when it is either dry or wet is probably due to the clay present in the feldspar and not due to the presence of fine-grained arfvedsonite. Arfvedsonite is the characteristic mineral in the arfvedsonite granite. From the few specimens studied, arfvedsonite is fresh and unaltered. An extensive overgrowth of aegirine was found on arfvedsonite only in the Sogdianite Boulder, but is probably present in other arfvedsonite granites in the Golden Horn Batholith. A brownish hornblende amphibole, which appears black in hand specimen, is present in some of the annite granites. Texture and intergrowth of quartz and feldspar does not appear to have any bearing on what minerals are found in the miarolitic cavities. Too few rocks were studied to make any conclusions about the relationship of the rock type and which miarolitic minerals should be present.

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Preliminary results of unknown WP-13 from the Golden Horn Batholith, Washington Pass, Okanogan County, Washington

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Introduction

Aggregates composed of thin white platelets that were removed from the top of a greenish-black micaceous chlorite group cavity lining (Fig. 1) were sent by Rudy Tschernich for identification. The samples were found near milepost 164.1 by Randy Becker in 2010 in a one feldspar annite-granite. The white aggregates were associated with a chlorite group mineral, quartz, albite/microcline, annite, fluorite, siderite, and zircon. The aggregates were damaged during transportation and smeared, either due to low hardness of the mineral or its platy nature.

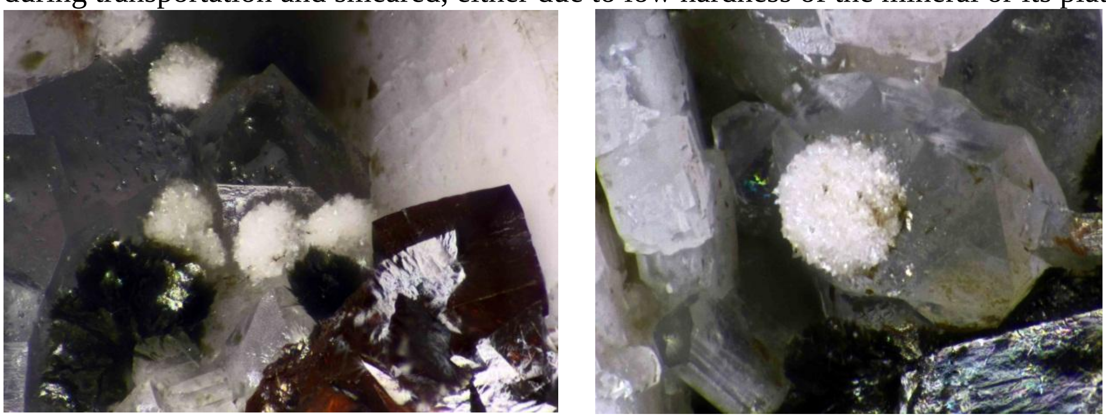

Figure 1. *Microphotograph of the unknown mineral on quartz. White aggregate 0.25 mm across. (R. Becker sample and R. Tschernich photo)*

Methodology

One of the aggregates was placed on a carbon disk and half the aggregate was separated into smaller pieces of which some were smeared over the surface. This was done to explore any chemical zonation and in the hope to isolate single crystals. The disk was coated with a thick layer of carbon prior to SEM analyses. A Philips XL30 SEM at UBC equipped with a Bruker Quanta 200 energy-dispersion X-ray microanalysis system and Xflash 4010 SDD detector was used for the analyses. As the sample was not polished or planar the EDS analyses are only semi quantitative.

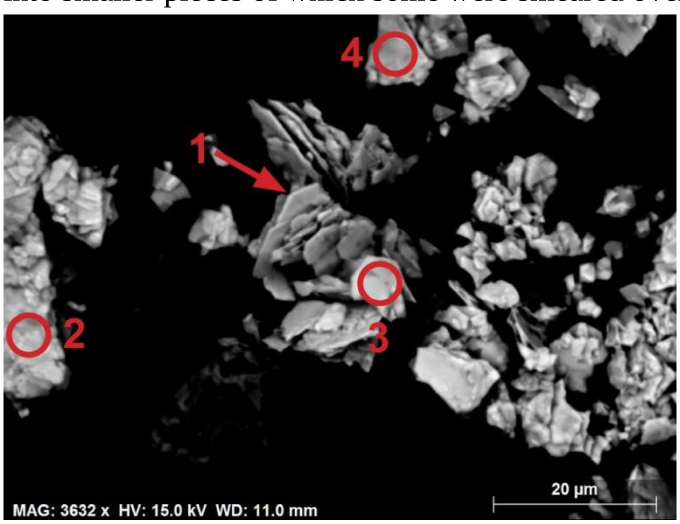

Figure 2. *BSI of the aggregates. The red numbers corresponds to the analytical points in Fig. 3.*

Results and Discussion

Figure 2 shows a backscatter image (BSI) of some fragments of the aggregate. Unfortunately, no crystals ended up in a position where it was possible to see a whole crystal and deduce a potential symmetry. However, the crystal group at the arrow in Fig 2. does appear to have 120° angles between crystal faces indicating a hexagonal symmetry. The combination of small crystal size and using carbon coating means it was not possible to get any higher resolution images.

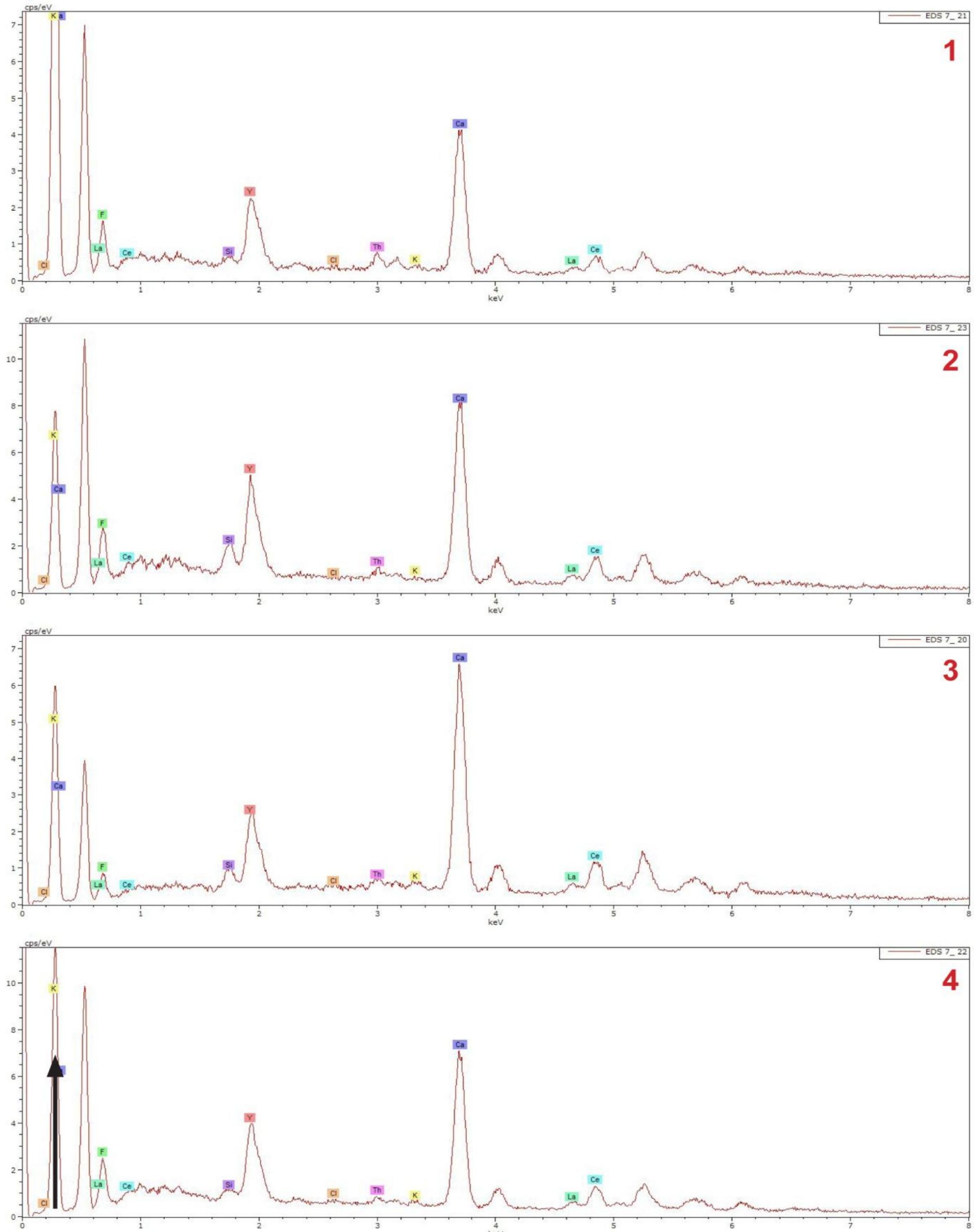

Figure 3. *EDS spectra of the unknown mineral. The numbers corresponds to the position on Fig. 2. The black arrow shows the position of the carbon peak.*

Figure 3 shows the EDS spectra of the four points on Fig. 2. The main elements are Ca, Y, REE and F, with minor Si, Th and K. Note that the Si peak is very low and somewhat overlaps Sr, so it could be that Si is actually Sr, or it could be sample contamination, since it is not found in all spectra. The detector cannot give reliable C values, especially as the sample was carbon coated. However, the carbon-peak seems higher for this material than other minerals tested at the same time, and hence samples having the same layer of carbon coating. This could indicate it is a Ce dominated REE+Y Ca-fluorocarbonate, e.g. synchysite or parisite. Although the Y-peak is higher than any of the REE peaks, the nature of these analyses means that a direct comparison of the height of the peaks does not translate directly into a ratio of elements in the formula. The approximate Ca:Y+REE ratio of 1.3 is in good agreement with synchysite ($CaREE(CO_3)_2F$), but the Ca:F of 7:1 is much too high. The potential 120° angles observed in Fig. 2 does support synchysite. The errors associated with the quantification means that WP-13 could also be parisite-(Ce).

Samples of WP-13 tested with Raman analysis by Lanny Ream indicated that the material is a carbonate, probably synchysite (Becker Unknown List, 2012).

Conclusions

It has not been possible to unambiguously identify the mineral, but EDS suggests that it is likely to be a fluorocarbonate, e.g. synchysite. The semi quantitative EDS shows that REE > Y, and that Ce is the dominating REE, so if it is synchysite it would be synchysite-(Ce) with the formula $Ca(Ce,Y)(CO_3)_2F$.

Ilmenite from the Golden Horn Batholith, Washington Pass, Okanogan County, Washington

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Background

Ilmenite was first reported in the Golden Horn Batholith by Cannon (1975). He described the crystals as rough tabular crystals several inches in length in quartz segregations. Boggs, (1984) found these crystals to be fayalite and states that ilmenite has not been found in the batholith. Boggs, (1984) did find small grains, less than 0.1 mm across, in the arfvedsonite granite that contained 65% TiO_2 and 35% FeO and proposed it was an unknown mineral. Boggs (1984) reported black tabular hexagonal hematite crystals, up to 4 mm across, in miarolitic cavities in the “border granite” and as red coatings on other minerals.

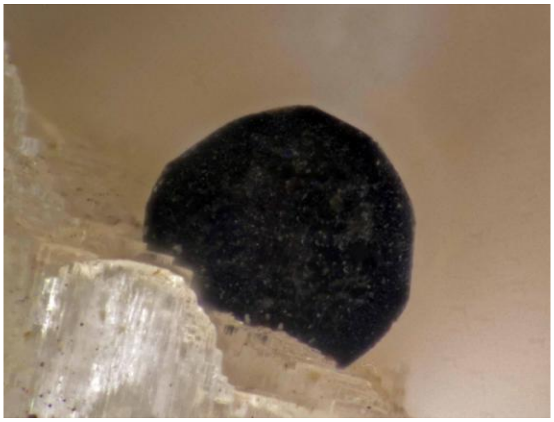

Figure 1 *A very thin black nearly rounded ilmenite plate, 0.95 mm across on colorless etched zektzerite from the "Basin", Randy Becker specimen RB456, Microphotograph by Rudy Tschernich*

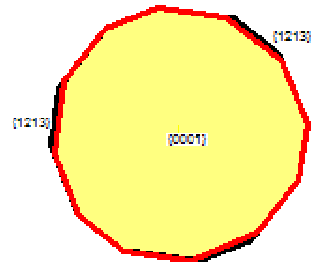

Figure 2 *Illustration of Fig 1 with complex edges*

This study

Grayish-black hexagonal-appearing metallic plates and flat-topped elongated prisms have been found in cavities at several sites in the Golden Horn Batholith. They give a gray streak, are brittle with a conchoidal fracture, and are weakly attracted to a magnet. These crystals, once thought to be hematite, have now been found to be ilmenite.

Grayish-black metallic plates of ilmenite are abundant on highly dissolved or etched zektzerite crystals with brownish-red zircons on microcline from a cavity in the "Basin" south of the Cutthroat Lake trail-head that were found by Randy Becker in 1980 (specimens RB426, Z6).

Excellent lustrous, metallic, grayish-black plates and rosettes of ilmenite, that resemble hematite, have been found on white albite/microcline with black crystals of arfvedsonite, and siderite in arfvedsonite granite in the "Cirque" south of MP166 that were collected by Randy Becker in 1984 (specimen RB318). Broken crystals have a grayish-black color, yield a gray streak, and are easily attracted to a magnet.

Figure 3 *Thick black ilmenite plate, 1.9 mm across, on colorless lustrous reddish-brown etched zektzerite from the "Basin". Randy Becker specimen Z6. Microphotograph by Rudy Tschernich.*

Figure 4 *Black ilmenite plates, 0.29 mm across, with zircons on colorless rods of etched zektzerite from the "Basin". Randy Becker specimen RB426. Microphotograph by Rudy Tschernich.*

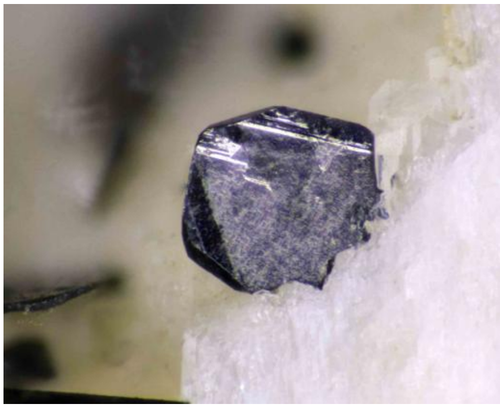

Figure 5 Thick plate of ilmenite, 0.49 mm across, with rhombo-hedral modifications on white albite/microcline from the "Cirque". Randy Becker specimen RB318. (Unknown list WP97). Microphotograph by Rudy Tschernich.

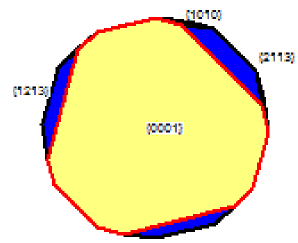

Figure 6 Illustration of Fig 5

Figure 7 Thick plates and rosettes of ilmenite, 1.5 mm across, with rhombohedral modifications, on white albite/microcline and arfvedsonite from the "Cirque". Randy Becker specimen RB318, (Unknown list WP97). Microphotograph by Rudy Tschernich.

Thin, black, hexagonal plates of ilmenite are found with micaceous polylithionite and colorless to orange zircons in a pocket within corroded zektzerite from the "Red Zircon Pocket" on Kangaroo Ridge collected by Randy Becker in the early 1990's (RB234).

Thin lustrous plates of ilmenite are found in one-feldspar annite granite with albite/microcline, greenish chamosite, and quartz, from the Ilmenite Boulder at MP164, found by Randy Becker in 1992 (RB102).

Thin plates of ilmenite are found on quartz and albite/microcline and as inclusions in colorless quartz from the Liberty Bell talus (RB239).

Figure 8 Black ilmenite plate, 0.25 mm across, with polylithionite and zircon from Kangaroo Ridge. Randy Becker specimen RB234, Mmicrophotograph by Rudy Tschernich.

Figure 9 *Very thin lustrous plates of ilmenite, 0.5 mm across, with albite/microcline and chamosite, from MP164. Randy Becker specimen RB102, Microphotograph by Rudy Tschernich.*

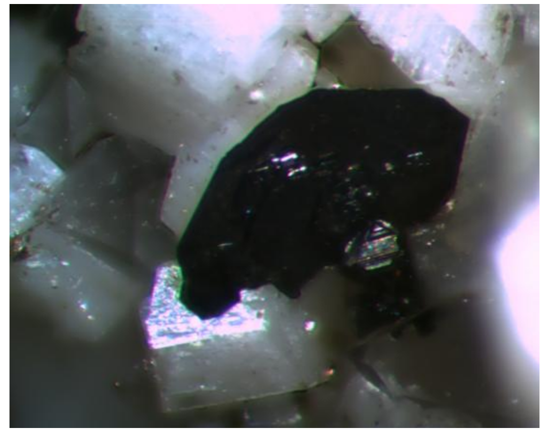

Figure 10 *Thin black ilmenite with complex faces similar to those seen in fig. 2. (Specimen and microphotograph by Don Howard.)*

Black plate of ilmenite were found along the highway, probably near MP164, in one-feldspar annite granite in a cavity with white albite/ microcline, colorless quartz, reddish-brown zircon, black books of annite, and magnetite (Don Howard, per. comm.). The ilmenite is shinny with parallel growth on the large "c" face and is almost round from complex faces occurring every 30^o on the edges. EDX was performed on this crystal.

Silver-black hexagonal barrel-shaped crystals of ilmenite on smoky quartz in one-feldspar annite border granite from Liberty Bell talus were found by Randy Becker in 1994 (RB150). Bob Boggs has found similar crystals on Kangaroo Ridge.

Blocky complex hexagonal ilmenite on white albite/microcline and colorless quartz from Liberty Bell talus displaying "c" face, prism faces, and small modifying rhombohedral faces, were found by Randy Becker in 1994 (RB239).

Silver-black, blocky, elongated, hexagonal prisms with "c" face modified with small rhombohedral faces are also found in the Liberty Bell talus with kainosite, quartz, and albite/microcline by Randy Becker 1994 (RB242).

Figure 11 *Silver-black hexagonal barrel-shaped crystals of ilmenite, 0.9 mm across, on smoky quartz from Liberty Bell talus. Randy Becker specimen RB150 (unknown WP78). Microphotograph by Rudy Tschernich.*

Figure 12 *Silver-black hexagonal blocky crystals of ilmenite, 0.5 mm across, on white albite/microcline and colorless quartz, from the Liberty Bell talus. Randy Becker specimen RB239 (unknown WP78). Microphotograph by Rudy Tschernich.*

Figure 13 *Barrel-shaped ilmenite, 0.45 mm across, on albite/microcline from Liberty Bell talus. Randy Becker specimen RB242 unknown WP78, Microphotograph by Rudy Tschernich.*

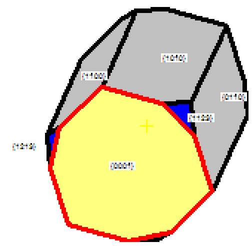

Figure 14 *Illustration of **Fig. 13.***

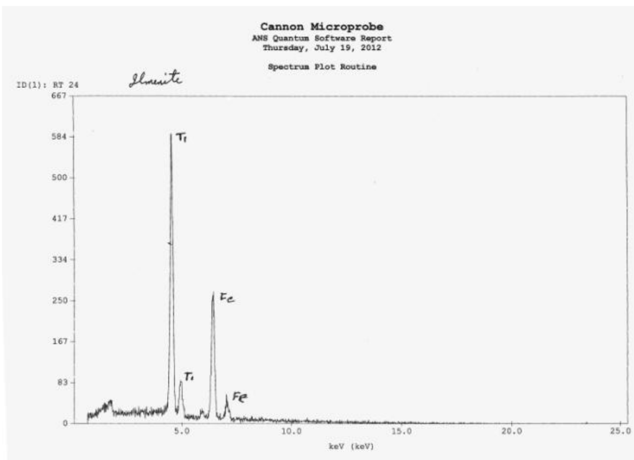

Figure 15 ***EDX spectra of ilmenite by Bart Cannon***

Chemistry

EDX or EDS (energy dispersive x-ray spectroscopy) was used to identify and roughly quantify the elements in a sample. The horizontal-axis is the energy in keV and the vertical axis is the counts given off by the element. The x-rays emitted from the elements in the sample always have the same energy and wavelength, therefore they always fall at the same position in the spectrum or on the horizontal axis. The x-rays from all the different elements with concentration above 2000 ppm are counted at the same time and appear simultaneously on the graph. EDX suffers from having poor spectral resolution. X-ray lines for different elements with similar energies may overlap or appear only as tiny shoulders on the side of a peak. Other elements with short wavelengths, such as H, Li, Be, C, N, O, cannot be detected. EDX is good in identifying which elements are present, but poor in telling you how much. The heights of the peaks are more related to the energy of the element than to how much of the element is present. A sample with equal amounts of Na, K, Ca, and Si would show tiny peaks of Na and K but high peaks for Si and Ca. Software programs are often used that are calibrated for a specific machine to determine the amount of the element present.

Four samples were selected for EDX analysis. Two were from etched zektzerite from the "Basin" south of Cutthroat Trailhead, one from the "Cirque" south of MP166, and one from the annite granite near MP164 along the highway. The first three samples were mounted and ground flat to yield a clean surface in order to remove surface impurities and coatings and to reflect the x-rays more precisely for better intensity readings of the peaks. These samples were coated with carbon to conduct electricity and analyzed with the EDX portion of a SEM by Bart Cannon. The fourth sample was done on a rough sample, coated with palladium-gold, and analyzed by Don Howard. The results seen in Fig. 15 are representative of all four samples. They all show the presence titanium and iron, which along with oxygen yields the formula $Fe^{2+}TiO_3$. The height of the peaks do not indicate amount of the elements present but are typical of ilmenite. Hematite would not contain Ti.

References:

Boggs, Russell C. (1984) Mineralogy and geochemistry of the Golden Horn batholith, northern Cascades, Washington. U of California, Santa Barbara PhD dissertation.

Cannon, Bart (1975) Minerals of Washington. Cordilleran, Mercer Island, WA p. 184.

Linarite from the Golden Horn Batholith, Okanogan County, Washington

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In August 2011 the author found a blue mineral on the surface of a very coarse-grained, nearly pegmatitic granite on the slope just south of the most northerly snow fan under Liberty Bell. The majority of the sample is feldspar with some areas of massive quartz. In addition, 8 mm zircons, showing both prism and pyramid faces, are present. The linarite occurs as blue masses on a flat surface, together with complex aggregates of malachite and galena (Fig. 1).

The linarite grains do not contain any other phases. The linarite and paragenesis was confirmed by means of SEM EDS analyses.

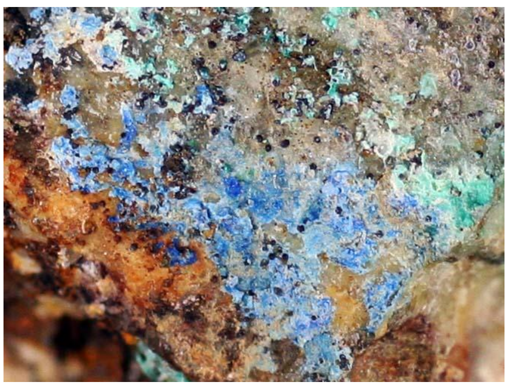

Figure 1. *Microphotograph of the area containing linarite and malachite (H. Friis sample and photo).*

The tested blue mineral contained copper, lead, and sulfur. It was not a sulfide; therefore, the following minerals are possible.

Caledonite $Pb_5Cu_2(SO_4)_3(CO_3)(OH)_6$	blue-green
Chenite $PbCu(SO_4)_2(OH)_6$	pale blue
Elyite $Pb_4Cu(SO_4)O_2(OH)_4{\cdot}H_2O$	purple
Lautenthalite $PbCu_4(SO_4)_2(OH)_6{\cdot}3H_2O$	green-blue
Linarite $PbCu(SO_4)(OH)_2$	dark blue
Steverustite $CuPb_5(S_2O_3)_3(OH)_5{\cdot}2H_2O$	white

Linarite seems to best fit the chemistry and color.

Blue minerals and coatings have rarely been observed in and on the granite of the Golden Horn Batholith for some time. Randy Becker found a blue mineral from the Liberty Bell talus that appears also to be linarite surrounding a galena crystal (Fig. 2, right). The linarite is not directly in contact with the galena; a zone of malachite exists between the two. In this aspect, the sample resembles the sample described above where malachite was found in aggregates with galena, whereas linarite was not observed with galena. In this sample, some euhedral linarite crystals are observed (Fig. 2, left).

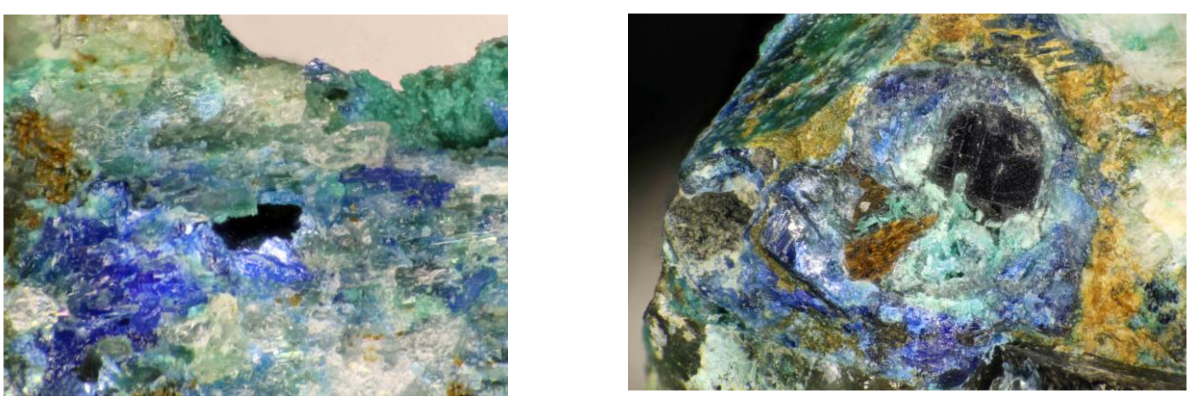

Figure 2. *Microphotograph showing an intimate intergrowth of blue linarite and green malachite. (left) RB211 and malachite and linarite surrounding a galena crystal (right) RB212. (R. Becker samples, photos by Rudy Tschernich).*