Northwest
Micro Mineral
Study Group

MICRO PROBE

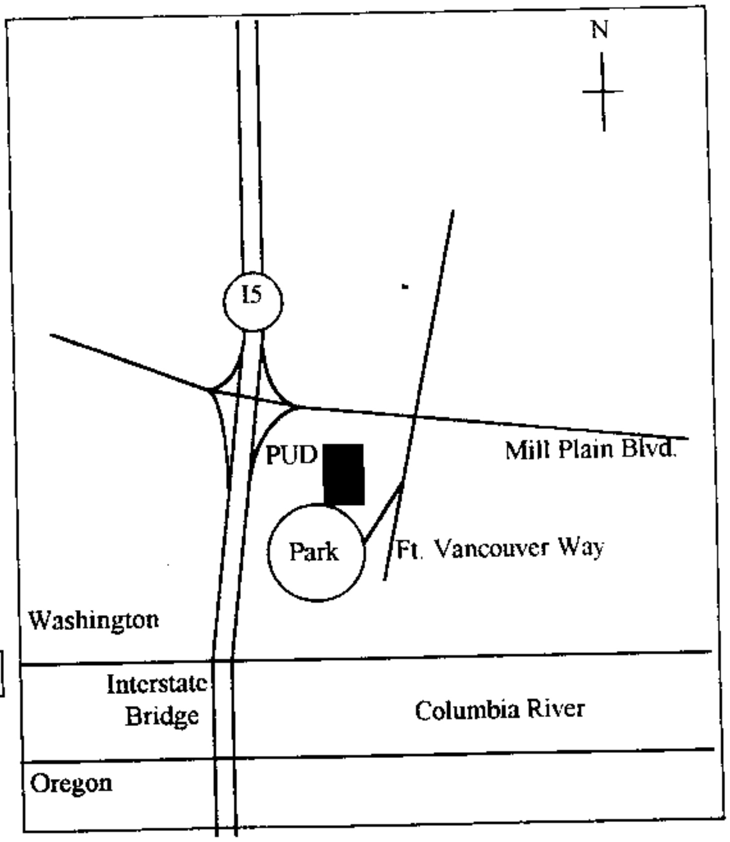
FALL, 1996 VOLUME VIII, Number 4

FALL MEETING ....VANCOUVER, WASHINGTON

November 9, 1996 9:30 am to 6:30 pm

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

The Fort Vancouver facilities have been renovated, so this will be our chance to see what they have done, and how well we fit into the new accommodations. Bring your microscopes and some material to share with others that can be put out on the free table. Good material should be available from Gordon Gilbertson's collection courtesy of Bill Leach. During the afternoon, after a very brief business meeting, we will be discussing new collecting areas. Rudy Tschernich will be showing slides of Yellow Lake, British Columbia. Minerals of Yellow Lake, and a sample of Tungusite from Los Angeles, will be available to look over. If you have slides of your own summer collecting, bring them to share with the group.



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 during the day. However, there will be

NO POTLUCK DINNER

in the evening. Restaurants are available in the local area.

THE OCCURRENCE OF TUNGUSITE IN THE SANTA MONICA MOUNTAINS, LOS ANGELES COUNTY, CALIFORNIA

Fred DeVito *with* Robert Housley and Donald Howard

Tungusite, a hydrated aluminum silicate of calcium and iron, has been an inadequately described species since it was first discovered in 1966 along the lower Tunguska River near Tura in central Siberia.[1] It was reported as plates up to 0.5 cm, forming crusts of radiating-fibrous structures on the walls of amygdules in spherulitic lava, associated with analcime, apophyllite, gyrolite, calcite, quartz and unspecified zeolites. The color ranged from dark green to grass green and greenish white with decreasing iron content. Again in 1978, tungusite was reported in the north-west Siberian platform in association with gyrolite, analcime, fluorapophyllite, reyerite, datolite, calcite and quartz.[2]

During the past ten years, here on the other side of the world, gyrolite and tacharanite were being found in the central Santa Monica Mountains of California[3] along with a green, chlorite-like mineral strongly resembling the Siberian tungusite. Other associated minerals include analcime, fluorapophyllite, pectolite, calcite and quartz. Confirmation of the California tungusite could not be made because of the inadequacy of the data based on the Siberian type material. Fortunately, with new data published in September, 1995 showing the structural relationship between gyrolite, reyerite and tungusite as well as new microprobe analyses[4], confirmation of the California tungusite has now been made, both from x-ray diffraction and microprobe analysis, by Robert Housley.

The three minerals that are closely related structurally are:

Reyerite	$Ca_{14}(Na,K)_2Si_{22}Al_2O_{58}(OH)_8 \cdot 6\ H_2O$
Gyrolite	$Ca_{16}NaSi_{23}AlO_{60}(OH)_8 \cdot 14\ H_2O$
Tungusite	$Ca_{14}Si_{24}O_{60}(OH)_8 \cdot Fe^{+2}_9\ (OH)_{14}$

All three minerals possess a layered structure. In reyerite, there are in effect five layers, and the mineral possesses overall rhombohedral symmetry. Gyrolite has an additional $(Ca,Na)O_2 \cdot 8\ H_2O$ that makes a sixth layer. The c-spacing is increased, and distortions are such that, while very nearly rhombohedral, the mineral is actually monoclinic. Tungusite has instead an additional $Fe^{+2}_9\ (OH)_{14}$ as the sixth brucite-like layer. In this case, the mineral appears rhombohedral but actually has a triclinic distortion. Since the ferrous ions are somewhat smaller than calcium ions, the c-spacing is slightly less than that of gyrolite, though by such a small amount that it is impossible to detect in x-ray diffraction without very high resolution. The similarity of the structures means that tungusite and gyrolite (and to some extent reyerite) can intergrow intimately, thus further confusing x-ray diffraction. Fortunately, iron does not easily substitute for calcium in gyrolite, so the color and presence of iron in a microprobe analysis serve to verify the presence of tungusite.

The tungusite locality is in the central Santa Monica mountains about 20 miles northwest of downtown Los Angeles, 4 miles north of Malibu and 3 miles south of the Ventura Freeway near the town of Agoura (location j on the map, figure 1). Geologically, this region is part of the middle Miocene Conejo Volcanics and consists of marine basalts and pillow basalts interbedded with minor amounts of calcareous marine sediments. The basalts are heavily mineralized, and long veins of gyrolite, fluorapophyllite and pectolite are exposed along Mulholland Highway just west of its intersection with Cold Canyon Road. At location j, the tungusite occurs in spherulitic basalt in nodules and cavities of gyrolite and analcime. When broken open, some of the nodules contain cavities showing well developed pseudo-hexagonal gyrolite crystals upon which are euhedral crystals of calcite, fluorapophyllite and several zeolites including analcime, chabazite, heulandite and rarely phillipsite. Tungusite has not yet been found crystallized in open cavities, but occurs in the rim or solid portion of the nodule intimately associated with gyrolite, tacharanite, pectolite, analcime and fluorapophyllite. Tungusite occurs here as dark green platelets, broken radiating spheres, or grading into white gyrolite (see figure 2). The distinct (001) cleavage is chlorite-like, but looking down on (001) the fibrous nature is more obvious.

The gyrolite bearing basalt extends from location j southeast for almost 7 miles. Robert Housley (of Pasadena) has found tungusite at two other locations south of Mulholland Highway, so future occurrences of tungusite in the Santa Monica mountains are quite probable. Reyerite may also be identified from this area in the future now that improved data is available.

A number of our zeolite collecting areas, particularly those in Grant County, Oregon, have considerable amounts of tacharanite, gyrolite, apophyllite and analcime. We need to be on the lookout for green bladed radiating material, particularly in the more thoroughly filled cavities that we are often wont to ignore. Tungusite is almost certainly a more common mineral than three occurrences would indicate. It could easily be passed off as some form of chlorite and ignored. We expect to see it, and probably also reyerite (which will be much harder to identify in the field) cropping up as additional zeolite associates in the near future.

ACKNOWLEDGMENTS; Many thanks are given to Dr. William Wise and Dave Yeomans of the University of California-Santa Barbara for their work confirming the identification of gyrolite and tacharanite; to Robert Housley of Pasadena, California for his microprobe and x-ray diffraction analyses, and for furnishing data for this report; and to William Rader of Santa Monica, California for taking me (FD) to this part of the Santa Monica mountains many years ago.

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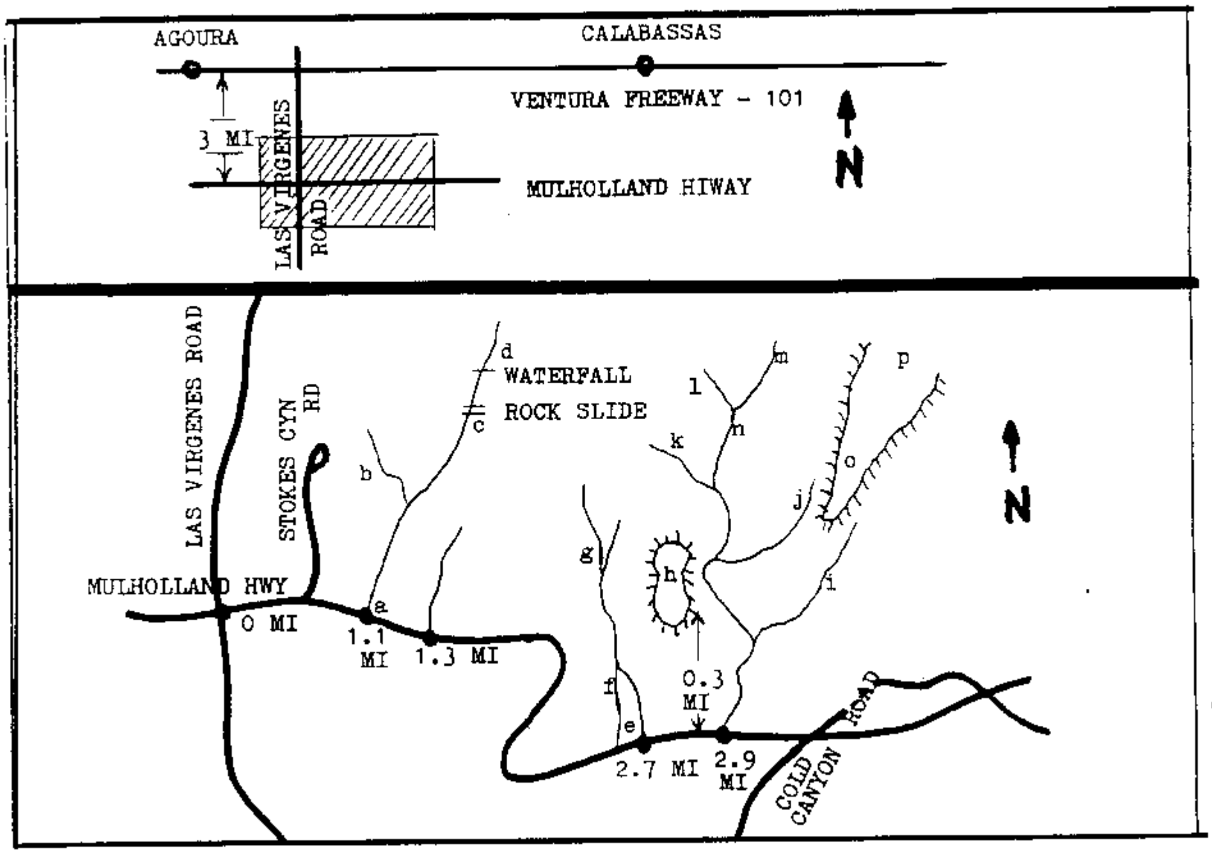

a. Natrolite,analcime,laumontite
b. Natrolite,analcime
c. Laumontite,analcime,prehnite,natrolite
d. Prehnite-slender fingers and crystals
e. Marine fossils-pectens in limestone,analcime
f. Gyrolite veins in hiway cut
g. Marine fossils,analcime
h. Prehnite,thomsonite,calcite,analcime,natrolite,chlorite,saponite
i. Marine fossils
j. Gyrolite,chabazite,apophyllite,analcime,pectolite,tungusite,tacharinite.
k. Natrolite,analcime
l. Natrolite,analcime
m. Natrolite,analcime
n. Apophyllite,chlorite,calcite,analcime,pectolite,natrolite
o. Thomsonite,analcime
p. Barite,dolomite,mordenite

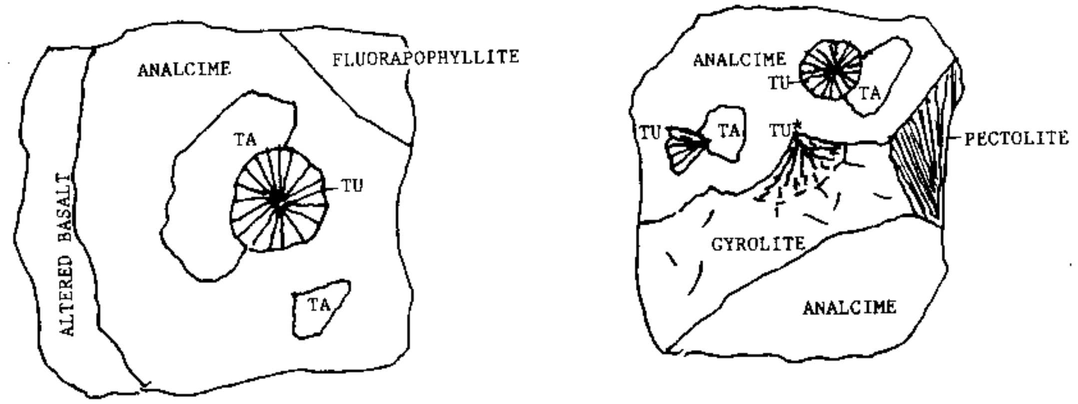

FIGURE 2. SPECIMENS OF TUNGUSITE ABOUT 1.5 CM ACROSS. (TA-TACHARINITE, TU-TUNGUSITE, TU*-DARK GREEN TUNGUSITE GRADING INTO LIGHT GREEN TUNGUSITE AND WHITE GYROLITE. SANTA MONICA MOUNTAINS, CALIFORNIA. NOTE: TUNGUSITE IS DARK GREEN. ALL OTHER SPECIES SHOWN ARE WHITE.

IN MEMORY OF:

Viola Sobolik

who passed away in October. Our condolences go out to Tony.

Charles Curtis

who passed away in January. Our condolences go out to Juanita.

Vi Frazier

who passed away in May. Founder of the Northern California Mineralogical Association.

Sid Sparhes

long-time collector from Vancouver, Canada.

THE MICROPROBE

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ZEOLITES FROM YELLOW LAKE, OLALLA , BRITISH COLUMBIA, CANADA

by
Rudy W. Tschernich
526 Ave. A
Snohomish, Washington 98290

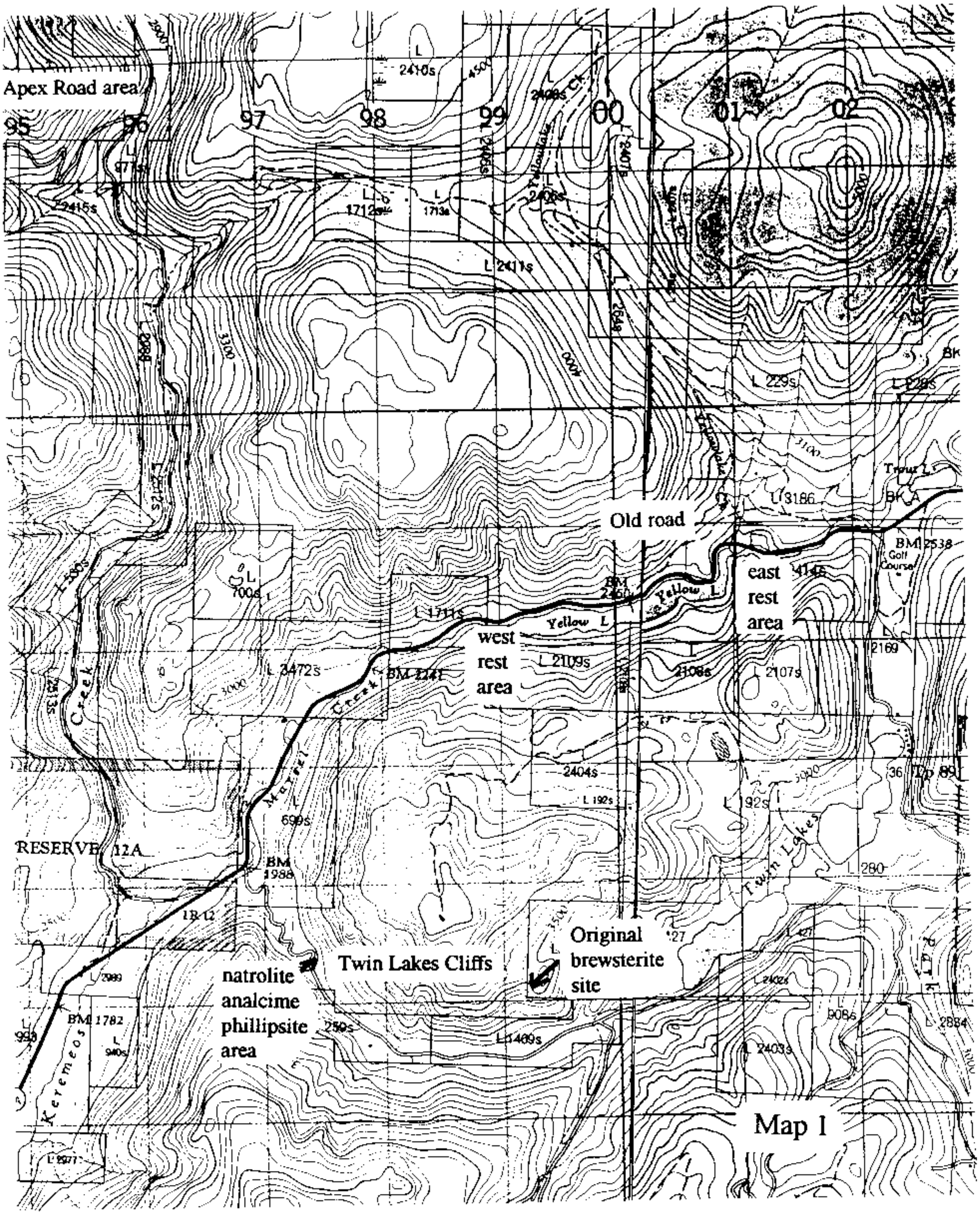
The volcanic rocks of the Eocene Marron Formation mapped by Church (1967) that surround Yellow Lake in southern British Columbia contain an unusual assemblage of strontium-bearing zeolites and other minerals. The Yellow Lake area is located along Highway 3 approximately 8 miles northeast of Keremeos and southwest of Penticton (Map 1). The small town of Olalla is located between Keremeos and Yellow Lake. In the Yellow Lake area the Marron Formation is 1500 to 2800 feet thick. It consists primarily of vesicular flows of the lower Yellow Lake Member that make up the middle and western area along the lake and the upper Kitely Lake Member found at the eastern end of the lake (Church 1967). The Kitely Lake Member typically forms slab-like pillars that account for many of the cliffs in the area. The rock is a clot-porphyry consisting of groups of feldspar phenocrysts in trachyandesite. In places the Kitely Lake Member is cut by veins lined with red heulandite, brewsterite, fluorite, laumontite, and an abundance of calcite. The Yellow Lake Member is a vesicular porphyritic trachyte to phonolite (extrusive equivalent of syenite and nepheline syenite respectively) with large augite, feldspar, and biotite phenocrysts. Along the west shore of Yellow Lake, the rock is porphyritic trachyte with large augite phenocrysts while at the middle of the lake shore the phenocrysts are predominately biotite. Amygdules in the Yellow Lake Member are commonly elongated due to movement of the flow during cooling and are commonly completely filled with zeolites. Only in one area near the middle of the north lake shore are open vesicles common. In addition to the vesicles, veins lined with brewsterite, heulandite, laumontite, and calcite are common in the Yellow Lake Member.

The cliffs west of Twin Lakes, southwest of Yellow Lake, consist of 350 feet of volcanic breccia overlain by about 600 feet of Yellow Lake Member lava (Church, 1967). Rare rhomb-shaped anorthoclase phenocrysts are present in the Twin Lake Cliff area. Veins and cavities lined with zeolites are scarce.

Individual flows are 40 to 200 feet thick, strike northerly and generally dip about 10° east near Yellow Lake. North-treading faults cut the gently dipping flows with displacements of more than 1500 feet (Church, 1967). In places fault blocks have been rotated and tilted that strike north 60 to 80° east and dip 10 to 50° northwest. Jointing with accompanying hydrothermal mineralization cut the rock in two directions at approximately 90° to each other. One set of joints is parallel to the major faults and is due north to 10° east and dip 80° northwest and the other is north 60 to 90° east dipping 45 to 70° northwest.

Four general mineralized areas are described. The main zeolite area is in roadcuts along Highway 3 on the north side of the lake. Zeolites are found throughout this section but are particularly abundant in the central section between the pump house used to aerate the lake and the main parking area next to the lake (Map 2). The highway area produces the best brewsterite, pink mesolite, complex thomsonite, heulandite, and wakefieldite.

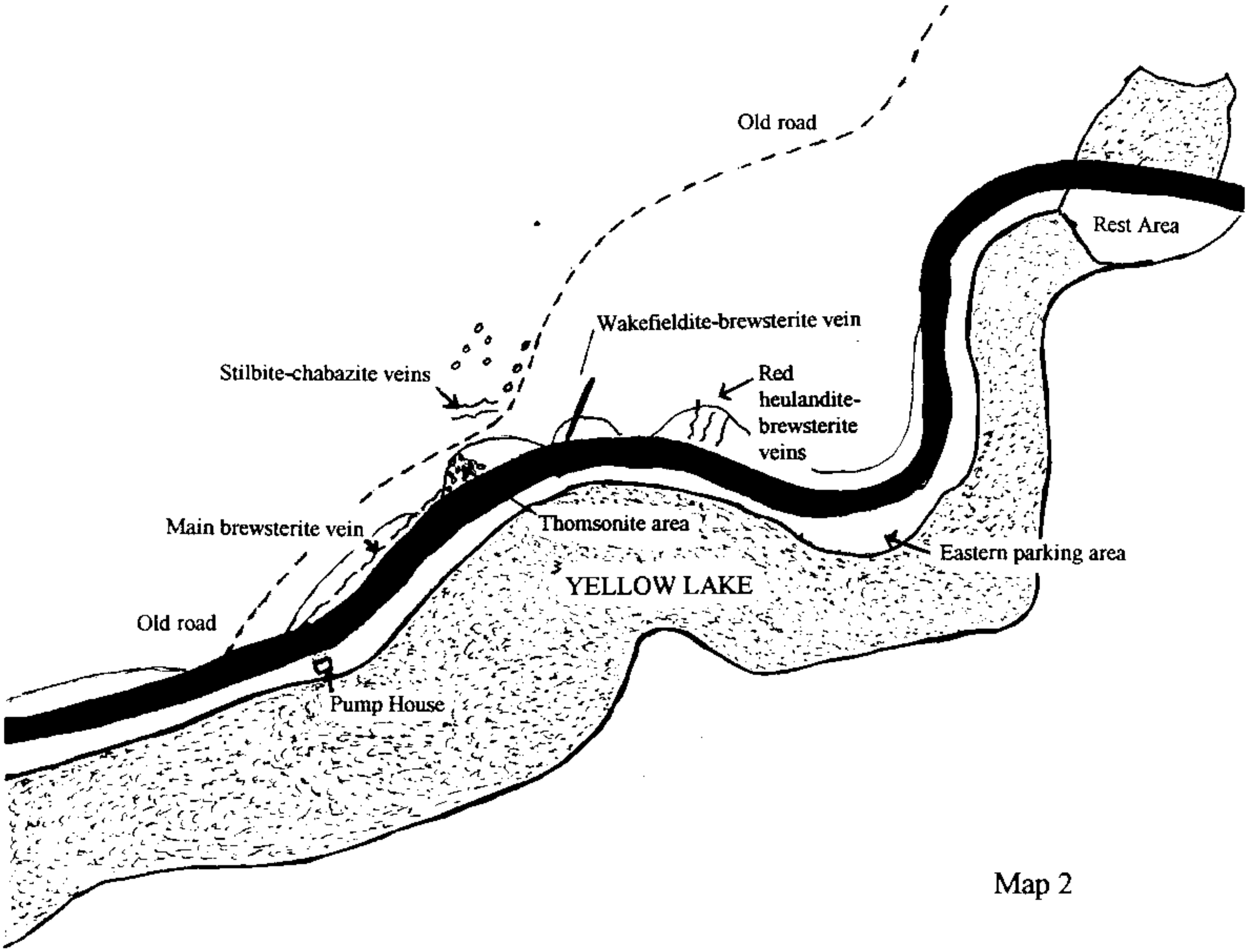
The second zeolite area is along an abandoned road leading from the pump house up hill above the main road. This area is noted for veins that contain stilbite, chabazite, laumontite, calcite, and amygdules filled with colored scolecite, heulandite, and stilbite. The third zeolite area is southwest of Yellow Lake in the steep Twin Lakes Cliffs. This is the site of the original discovery of brewsterite by Bird in 1965, as well as phillipsite, analcime, thomsonite, and natrolite. Most of the specimens recovered from this area are found in talus or large boulders that have fallen from the steep cliffs. The fourth site is several miles northwest of Yellow Lake along logging roads taking



off from the road leading to the Apex Ski area. This area produces small amounts of colored chabazite, analcime, mesolite, and blocky thomsonite.

Zeolites were first described at Yellow Lake by Bird (1965) in a masters thesis for the University of British Columbia. Although his paper was on the petrology of the rocks in the area, zeolites were part of the study. He was the first to note the presence of analcime, brewsterite, natrolite, thomsonite, laumontite, heulandite, and chabazite. The brewsterite site and other sample sites were plotted on a map in the pocket of his thesis. Unfortunately the map became lost or stolen from the thesis and the exact sites where the samples were collected were lost. After years of exploring, in 1985, the original site for brewsterite described by Bird was found in the cliff area west of Twin Lakes which is south of Yellow Lake (Map 1). The natrolite described by Bird is only found in the Twin Lakes Cliffs rather than along Yellow Lake as reported by later authors.

In 1968 Sinclair and Gower summarized Birds work but added no new information. Stan Leaming (1973) popularized the zeolites along Yellow Lake and finally brought this area to the attention of mineral collectors. Bob and Mary Hillsdon of Vernon, B.C. were the first to find the rare strontium-rich brewsterite in 1973 along the highway at Yellow Lake and were instrumental in exploration of this area. At first the tiny colorless octahedra found on the brewsterite were thought to be the rare zeolite faujasite which has the same morphology and optical properties but a X-ray pattern by Bill Wise indicated it was only fluorite. Several trips were made to the area in 1974.



Map 2

On May 25, 1975 a major field trip by the Northwest Micro Mineral Study Group was held at Yellow Lake over the Memorial Weekend. About 20 members attended. Most of the work was conducted in the thomsonite area along the highway. The vesicular rock is jointed into large, interlocked, stacked blocks in that area. Some of these blocks of rock can be barred loose from the wall of the roadcut but are still very difficult to break due to large phenocrysts in the rock that prevents the rock from fracturing. I brought along a Skill rotohammer to drill the hard rock and points were pounded into the holes to split boulders, some weighing several tons, into small chunks. One unusually large boulder was drilled in place high on the face of the roadcut and points were placed in the holes. Because none of the other rock had broken easily, we were prepared for a long hard time, braking this boulder. It surprised everyone and broke on the third hit and dropped down to the side of the road. Fortunately no one was beneath it. Due to all the activity along the highway cars slowed down or even stopped not because we were in the way but because they were curious about what we were doing. Naturally the most common question was "Are you finding gold?". One unpleasant person, noting that most of the cars were from the "States" threatened to call the Mounties because we were removing Canadian minerals. We watched over our shoulders for the rest of the day but no one showed up. However, Ingelson (1984) incorrectly reported "The Royal Canadian Mounted Police requested that a large group of collectors vacate the roadcut to prevent rock from the pocket excavations falling onto the highway." Never did any rock fall on the road although concern for traffic slowing down to see what we were doing was real. Never did all the "excavations" from 3-inch pockets present a threat to traffic.

Wise and Tschernich (1978) studied the thomsonite at Yellow Lake and found it to contain strontium in quantities up to 10% of its exchangeable cations, the highest amount known in the world. A brief description of the zeolites found at Yellow Lake and their morphology is found in Tealdi and Tschernich (1984a, 1984b, 1985). In 1986 Don Howard and the author explored the Twin Lakes Cliffs, found the original brewsterite site and found a vein containing an unknown black mineral along the highway. Howard, Tschernich, and Klein (1995) reported that mineral to be wakefieldite- (Ce), an unusual mineral never before found associated with zeolites. Crystal drawings of thomsonite and brewsterite, used in this paper, are found in Zeolites of the World by Tschernich (1992).

Much earlier a strontium-rich mordenite had been found several miles east of Yellow Lake in the Marron Formation (Poitevin, 1932; Reay and Coombs, 1971) but has not been found in the area reported in this paper.

ZEOLITE CRYSTALLIZATION EVENTS:

Mineralization at Yellow Lake is complicated because two zeolite-forming events have occurred. Low-temperature, low-silica zeolites first crystallized in vesicles throughout the Yellow Lake area often completely filling the cavities in the order: analcime > bladed thomsonite > scolecite > mesolite > analcime > calcite. Faulting and jointing of the rock probably occurred millions of years later up lifting and tipping the rock up to 60° and was followed by higher-temperature, medium-silica-rich, strontium-rich hydrothermal fluids that crystallized zeolites on the joints and fractures in the order heulandite > brewsterite > fluorite > wakefieldite > laumontite > calcite. In the rare case where a vesicle is cut by a fracture, bladed thomsonite from the early generation of minerals was covered by a sandstone-like layer of heulandite that formed a flat floor in the cavity followed by larger heulandite crystals, brewsterite, and calcite. Although the rock is tipped 60° the heulandite floor in the cavities is parallel to present day horizontal which indicates the vein minerals formed after the tipping of the rocks. In rare cases vesicles containing bladed thomsonite, that were not totally filled with zeolites or intersected by fractures, slowly enlarged to form simple blocky crystals that were later covered with complex crystal forms.

In the Apex Mountain area the sequence of crystallization appears to be pink chabazite > mesolite > analcime > thomsonite with on cavity containing heulandite on chabazite.

MINERALS IN VESICLES:

The first zeolites that crystallized at Yellow Lake formed in vesicles. They are described in the order in which they first appeared in the cavities with the exception of calcite which crystallized throughout this time period.

ANALCIME commonly forms tiny, 2-mm, colorless trapezohedra in most of the vesicles under one centimeter in diameter that are found along the highway. In larger vesicles the tiny analcime crystals are inconspicuously scattered on the walls of the cavity and are completely covered with a thick layer of thomsonite, calcite, and later-formed minerals. Along the highway, analcime appears to be the first zeolite to crystallize and is preceded only by a thin layer of a clay mineral. In some cavities, a second generation of analcime crystallized on the scolecite/mesolite needles or enlarged existing analcime crystals.

In the Twin Lakes Cliff area, small colorless, trapezohedra of analcime are preceded by phillipsite, a mineral absent along the highway. In this are analcime also forms a second generation that is usually light orange-colored, up to 8-mm across, on white thomsonite blades and natrolite needles.

Colorless to white trapezohedra of analcime, up to 8 mm across, are found on pink chabazite and thomsonite in the Apex Mountain area.

PHILLIPSITE is scarce at Yellow Lake. Only one cavity containing the mineral has been found along the old road 100 feet east of the stilbite-chabazite area. That cavity contained deep maroon, opaque, blocky phillipsite crystals, 3-mm long, on analcime and were covered with calcite. Phillipsite is much more common in cavities found in loose rock at the bottom of the canyon of the Twin Lakes Cliffs. The best phillipsite is found in a large boulder on the west edge of the road along the curves in the northern section of the Twin Lakes road. There it forms a druse of lustrous, bright orange to deep red, pointed crystals, up to 4 mm long, that line most of the cavities. The phillipsite is often covered with orange to colorless analcime and rarely thomsonite, natrolite, and a second generation of analcime. Calcite is scarce. The minerals in these boulders crystallized in the order: orange phillipsite > clay > small orange analcime > thomsonite > natrolite > large colorless analcime > calcite. Evidence of downed trees leading up the east side of the cliffs indicates the boulder along with many others came from the top of the eastern cliff area. Other boulders in that slide area produced little. Further up on the slope below the vertical cliffs nodules lined with highly decomposed orange phillipsite were found covered with analcime and calcite. In other nodules small white elongated prisms of phillipsite, up to 2 mm long, were rarely found on small colorless analcime that were covered by an amber-colored calcite followed by thomsonite, natrolite, and white bladed calcite-dolomite.

THOMSONITE at Yellow Lake forms some of the most complex crystals in the world. Some of the crystals have crystal forms found nowhere else. Common bladed thomsonite is found in the hills north of the old road along north of the highway and in amygdules filled with scolecite and mesolite but the most interesting thomsonite is found in a small vesicular area along the highway called the thomsonite area (Fig. 2). The cavities range from a few centimeters to over 4 inches across. Most of the cavities are elongated due to stretching of the gas cavities when the flow was still moving. The thomsonite is usually a light pink color from hematite inclusions and lines most of the cavities. Tiny colorless analcime actually predate the thomsonite but are completely covered. The core of the thomsonite is a opaque pink color and has the shape of simple bladed thomsonite (Figs. 1-3). As the crystals continued to grow blocky, simple, six- to eight-sided crystals with smooth flat tops developed with the forms {100}, {010}, {101}, {110}, {001}(Figs. 9-12). Calcite crystallized at the same time as the thomsonite often covering the thomsonite at different stages of growth preserving the crystal forms of these early stages of thomsonite growth when the thomsonite is revealed from the calcite with acetic acid. Where the blocky flat-topped thomsonite was not covered with calcite the thomsonite developed rough surfaced crystals composed of complex forms {502}, {301}, {801}, {410}, {012}, {021} as well as the forms of the early generation (Figs. 4-8, 13-16 & SEM photos 487,488, 490, 494, 496). The forms {502}, {301}, {410} are only found at Yellow Lake. Twinning by rotation of 90° around the c-axis is

THOMSONITE

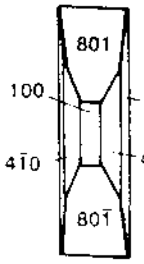


Fig. 1

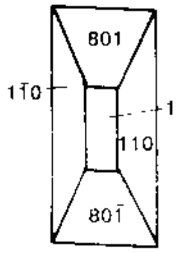


Fig. 2

COMPLEX BLADED HABIT FLATTENED ON (100)

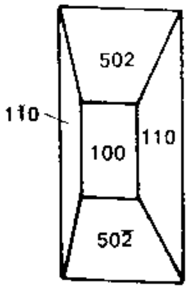


Fig. 3

THIN BLADED HABIT

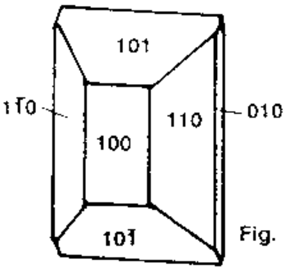


Fig. 4

CHISEL HABIT

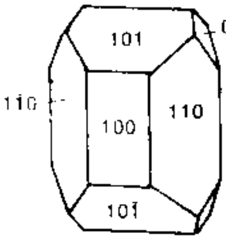


Fig 5

MODIFIED CHISEL HABIT

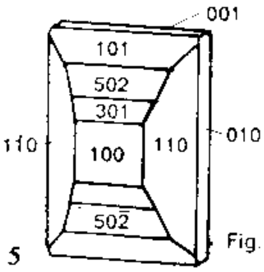


Fig. 6

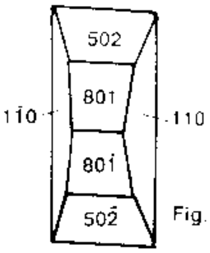


Fig. 7

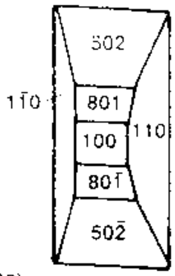


Fig. 8

COMPLEX BLADED HABIT FLATTENED ON (100)

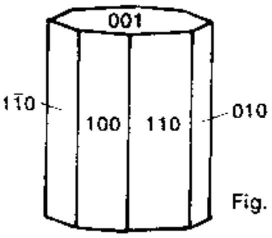


Fig. 9

SIMPLE BLOCKY HABIT

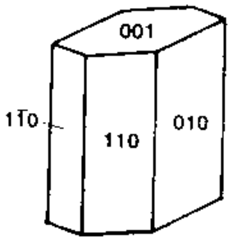


Fig. 10

SIMPLE BLOCKY HABIT FLATTENED ON (010)

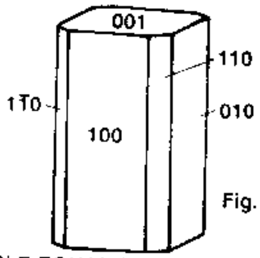


Fig. 11

SIMPLE EQUANT BLOCKY HABIT

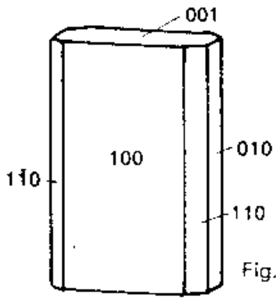


Fig. 12

MODIFIED BLADED HABIT

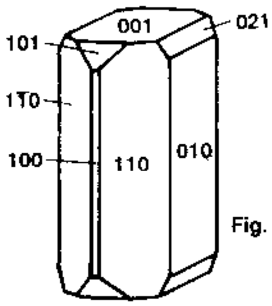


Fig. 13

BLOCKY HABIT FLATTENED ON (010)

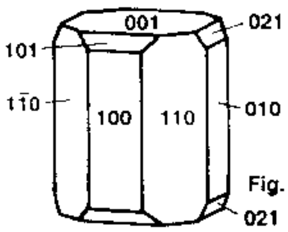


Fig. 14

COMPLEX EQUANT BLOCKY HABIT

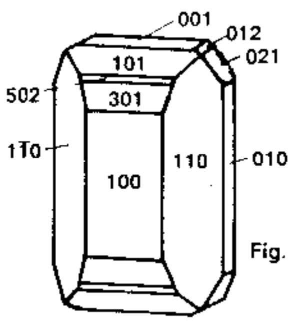


Fig. 15

COMPLEX PRISMATIC HABIT

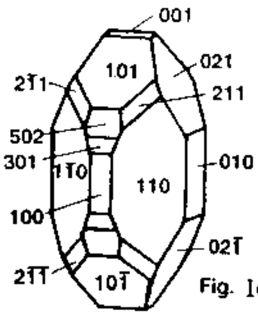


Fig. 16

COMPLEX PRISMATIC HABIT

common in the thomsonite (Fig. 17 & SEM photo 489). Study of this thomsonite by Wise and Tschernich (1978b) indicates the large blocky crystal habit is a result of slow crystallization which allow ordering of the aluminum and silicon in its framework in contrast to rapidly crystallization that produced less order of silicon and aluminum in the small thin blades of thomsonite. Chemical analysis of the thomsonite (Wise and Tschernich, 1978b) shows that it contains up to 10% strontium in its exchangeable cations, the largest amount known in the world.

THOMSONITE TWIN

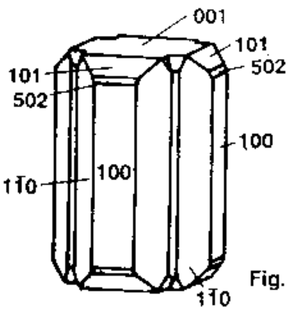


Fig. 17

TWINNING ON (110)

In the northern Twin Lakes Cliff area, thomsonite is commonly found on the slopes lining dolomite/calcite-filled nodules up to 4 inches across. The crystals range from thin tapered blades to blocky bundles with flat-topped terminations. All of the crystals are white, partly due to alteration before deposition of the carbonates and partly from the acid used in removing the carbonates. The thomsonite is found on tiny colorless analcime and is covered by either orange analcime or natrolite needles. In some of the cavities amber rhombohedral calcite precedes the thomsonite and in all of the cavities bladed white dolomite/calcite formed during the final stages of zeolite crystallization or after it. In boulders at the base of the cliffs white radiating groups of thomsonite blades, up to 10 mm across, are found on orange phillipsite and covered by orange analcime, natrolite, and calcite.

In the Apex Mountain area colorless chisel-shaped blades and blocky hexagonal-appearing prisms of thomsonite, up to 4 mm long, are found alone or on analcime.

SCOLECITE, MESOLITE, and NATROLITE are found in the Yellow Lake area. Zoned salmon, pink, and white needles of scolecite completely fill most of the nodules, up to 4 inches across, in the cliffs north of Yellow Lake and along the old upper road, although mesolite has been found on the terminations of some crystals. Similar scolecite fills vesicles along the western half of the road cuts along the highway. In these nodules white thomsonite blades commonly line the cavity and are covered by a thick growth of scolecite/mesolite needles. In some of the nodules the center is filled with calcite, heulandite, and analcime. Many of these nodules are attractively colored zoned light to deep orange, red, and white that would rival the so called "thomsonite" of Michigan if polished.

In the vesicular thomsonite area along the highway, attractive deep pink to maroon stout bundles of mesolite free growing needles, up to 15 mm long, are found on chisel-shaped thomsonite crystals in open cavities. Hematite inclusions give the to color the mesolite. Although scarce, these mesolite groups make exceptional specimens.

Natrolite has been recognized only in the Twin Lake Cliff area. There it forms colorless or light pink to orange needles, up to 8 mm long, as tufts of needles or aggregates, up to 15 mm across. The natrolite needles are either straight or form unusual curved, arched, and branched groups. The natrolite is found on small colorless analcime and is often covered by larger colorless trapezohedra of a second generation analcime which results in natrolite needles within analcime crystals and small analcime crystals scattered on the natrolite needles. Trace amounts of tiny laumontite crystals crystallized after the natrolite and analcime but before calcite filled the cavities. The calcite is removed with acetic acid to expose the zeolites. In cavities containing white thomsonite, colorless natrolite needles extend from bladed bundles of thomsonite and is covered by calcite. In some of these cavities the natrolite filled in spaces between calcite blades and appears to have crystallized in the order: analcime > amber rhombic calcite > white thomsonite > natrolite > white calcite blades > natrolite > heulandite > laumontite > calcite. In cavities containing orange phillipsite that are found in the boulder at the base of the cliffs, natrolite forms colorless to white radial groups, up to 8 mm across, on phillipsite and is covered by large colorless analcime crystals.

In the Apex Mountain area colorless mesolite needles, are found on pink chabazite and covered by analcime in only a few cavities.

APOPHYLLITE was found in one cavity in the talus up hill from the brewsterite boulder at the Twin Lakes Cliffs. The crystals were up to 10 mm across, colorless, and blocky with triangular corners.

YUGAWARALITE has been found in only one vesicle at Yellow Lake. It was found by Bob and Mary Hillsdon in the thomsonite area along the highway. The cavity, which measured over 2 inches across, contained tiny analcime crystals scattered on the walls that were covered with zoned light pink to colorless bladed thomsonite, 5 mm long, and plates of calcite. On the thomsonite and calcite plates were found light pink, translucent, rather thick yugawaralite crystals, up to 10 mm long. The forms {010}, {100}, {011}, {-111}, {120}, and tiny {032}, {110}, {140}, {-344}, {301}, {012}, {-102} were observed. Since the yugawaralite crystallized after the white bladed calcite in this single cavity it is possible that the yugawaralite crystallized from hydrothermal vein solutions introduced along a fracture in the rock rather being a vesicle-forming mineral.

MINERALS IN VEINS:

HEULANDITE is common only in the road cuts along the east half of the highway. There is forms reddish asymmetrical crystals, up to 5 mm long, that line the veins cutting the rock (SEM photo 387). It is usually covered by brewsterite, fluorite, laumontite, and calcite and rarely by wakefieldite. Heulandite is found on thomsonite, analcime, and mesolite only when a vein intersects a vesicle. Small veins of red heulandite are seen cutting the rock and passing across scolecite in many of the nodules along the upper old road. Normal coffin-shaped heulandite crystals, up to 4 cm long, are rarely present along the western part of the highway. Colorless to light red blocky heulandite crystals lined the main brewsterite vein that extends from the pump house to the thomsonite area.

In the northern Twin Lakes Cliff area one nodule was found on the talus containing reddish heulandite that co-crystallized along the planes of the dolomite/calcite both minerals covering white bladed thomsonite and natrolite. When the carbonates were etched away thin parallel layers of heulandite were exposed.

Colorless heulandite crystals, up to 5 mm across, are found on pink chabazite in the Apex Mountain area.

Chemical analysis by Bill Wise of the red heulandite in the eastern road cuts show up to 33% strontium in its exchangeable cations. This is one of the highest amounts of strontium known for heulandite.

BREWSTERITE is a rare strontium-bearing zeolite found in only a few places in the world. Some of the largest and finest specimens of brewsterite occur at Yellow Lake. Brewsterite is found only in veins that cut the rock along the highway from the pump house to the eastern parking area and in the talus of the Twin Lakes Cliffs.

Small near vertical veins at the eastern end of the highway contain colorless, blocky, lustrous prisms of brewsterite, up to 5 mm long, on bright red heulandite that are covered with fluorite, laumontite, and calcite. The crystals of brewsterite display a dominant flat {100} termination, with small to large {010} faces parallel to the cleavage, and numerous small faces on the sides of the prism (Figs. 18-23). Further west is a large vein that contains wakefieldite-(Ce) on a cream-

BREWSTERITE

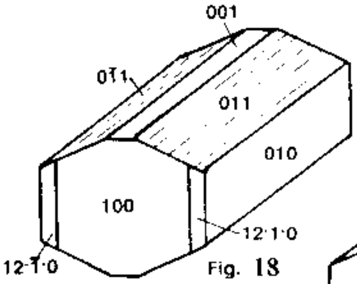


Fig. 18

FLATTENED ON (001)
ELONGATED ALONG (100)

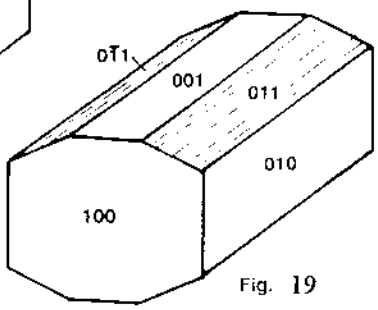


Fig. 19

COMMON HABIT

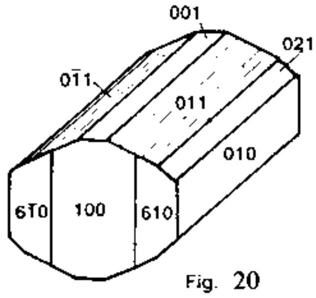


Fig. 20

COMMON HABIT

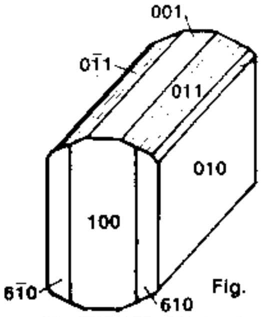


Fig. 21

FLATTENED ON (010)

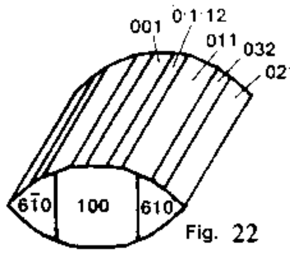


Fig. 22

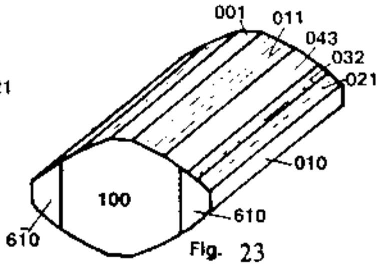


Fig. 23

COMPLEX STRIATED HABIT

colored to light pink opaque brewsterite crystals, up to 5 mm long. The brewsterite in this vein is commonly covered with fluorite, laumontite, calcite, and very rarely wakefieldite-(Ce).

In the vesicular thomsonite area small veins cut the rock that are lined with brewsterite crystals. Rarely one of these veins intersects a vesicle. When this happens heulandite and brewsterite crystallize on the earlier-formed analcime, thomsonite, and mesolite.

The largest and finest brewsterite crystals are found in a vein that has been intermittently traced over 100 yards roughly parallel to the highway from the pump house to the thomsonite area. The vein contains colorless, lustrous brewsterite crystals, up to 10 mm long. The vein pinches and swells allowing terminated crystals to occur in only a few places. One side of the vein contains large brewsterite crystals on red heulandite, while the other side of the vein, brewsterite is found covered with attractive complex calcite crystals, brownish-golden goethite sprays, and rarely pyrite. Brewsterite from this vein is regarded as the finest in the world.

In the Twin Lakes Cliffs, Bird (1965) originally found brewsterite in the center of small, 15-mm thick, calcite-filled veins. These veins consist of several alternating calcite and red heulandite layers with light pink, 3-mm long, brewsterite crystals in the center. Good specimens are rare. One carbonate-filled nodule found on the northern Twin Lakes Cliffs talus was lined with analcime covered with colorless brewsterite prisms and red heulandite crystals. At the base of the Twin Lakes Cliff talus, a large boulder was found by students at a UBC geology field camp that produced one open pocket, over 6 inches across, that was lined with colorless brewsterite crystals, up to 10 mm long. Search of the talus slope above the brewsterite boulder did not yield more specimens of brewsterite, therefore, it must have fallen from much higher on the vertical cliffs.

Chemical analysis of the brewsterite by Bill Wise, shows that strontium makes up 73 to 88% of the exchangeable cations with 3 to 20% sodium, 4 to 8 % barium, and 1 to 11% calcium. This chemical composition has a much higher strontium and sodium content than brewsterite at other localities where barium and calcium are the major cations.

FLUORITE is found on heulandite and brewsterite only in veins along east end of the highway at Yellow Lake. The fluorite forms simple colorless octahedra, 1-millimeter in diameter, on the surface of red heulandite and as inclusions within brewsterite and embayed in the surface of brewsterite. This indicates crystallization of fluorite started after small brewsterite crystals had formed and were partially or completely covered with brewsterite as it continued to enlarge.

One vesicle was found that contained chisel-shaped thomsonite, pink mesolite, and calcite covered with colorless octahedra of fluorite. Broken fragments of the thomsonite and mesolite in the cavity, that have been rehealed, indicate that this cavity was affected by faulting and jointing of the rock and the fluorite was probably the result of the cavity being intersected by a crack and addition of hydrothermal fluids.

CHABAZITE and STILBITE have not been found along the highway or in the Twin Lakes Cliff area but both species are present in filled veins along the old road cut above the highway. The veins are up to one inch thick and trend north 80° to 60° east and dip 60° northwest. They are lined with reddish-pink rhombohedra of chabazite, up to 4 mm across, and are covered with colorless, pointed stilbite, a few millimeters long, and finally filled with white laumontite and amber colored calcite. Terminated crystals are only exposed by removing the calcite with acid. Traces of chabazite and stilbite have been found on some of the scolecite needles in the same area.

Deep pinkish-red rhombohedra of chabazite, up to 8 mm across, line cavities up to 3 inches across in the Apex Mountain area. They are covered by mesolite, analcime, and heulandite.

WAKEFIELDITE-(Ce), the rare-earth vanadate, has rarely been found in only two veins along the highway between the thomsonite area and the red heulandite/brewsterite veins. The first vein containing the mineral was found in 1974 by the author. This vein was lined with colorless heulandite covered with colorless brewsterite on which was found three rather large, 1.5-mm, blocky, dark red to black, lustrous crystals with beveled edges that was unknown at that time. The forms {110}, {100}, {111}, and {001} were present on these crystals. Much later in 1985 Don Howard found the same mineral in a nearby large vein that contained an abundance of cream-colored brewsterite, colorless octahedral fluorite, laumontite, and calcite when the calcite was etched away. The mineral was identified as wakefieldite-(Ce) and reported by Howard, Tschernich, and Klein (1995). In this vein the wakefieldite-(Ce) forms dull, dark black, elongated simple prisms (110} terminated by {001} or {111}. Although the vein contained an abundance of fluorite on brewsterite, wakefieldite-(Ce) was only found in areas of the vein where fluorite was absent. Later Ty Blacko discovered a highly vesicular portion of the flow, that was cut by the wakefieldite-brewsterite-bearing vein, also contained wakefieldite-(Ce) in the vesicles adjacent to the vein. These cavities were all lined with colorless analcime rarely with pink mesolite, laumontite, and long prisms of wakefieldite-(Ce), some with pyramidal terminations {111}, others with a single flat {001} face. The crystals range from 52% cerium and 40% lanthanum in the core of the crystal to 63% cerium and 26% lanthanum at the surface with the remainder neodymium and samarium (Howard, Tschernich, and Klein, 1995).

GOETHITE has been found only in the main brewsterite vein along the highway near the pump house. It forms attractive golden-brown sprays of needles, up to 3 mm in diameter, on large colorless brewsterite crystals, heulandite, and pyrite. Calcite and laumontite are rarely found on some of the goethite sprays.

PYRITE forms small cubes, under 1 mm across, rarely on brewsterite in the main brewsterite vein near the pump house along the highway and in one vesicle in the thomsonite area that had been intersected by a heulandite-brewsterite-vein. Most of the pyrite has been replaced by goethite.

LAUMONTITE is very common in veins along the highway at Yellow Lake. It forms white square prisms, up to 5 mm long, with a single sloping termination and is commonly on brewsterite and heulandite along the highway and on stilbite and chabazite along the old road further up the hill. It is the last zeolite to crystallize and is commonly covered by calcite. Laumontite is found in vesicles only when they are intersected by a vein. In the Twin Lakes Cliff area laumontite is rare.

CALCITE is a very common mineral at Yellow Lake and crystallizes at many periods throughout the period of zeolite crystallization. In general amber colored rhombohedral calcite formed early and late in some of the cavities. This type of calcite is easily removed and reveals well formed zeolites which it covered. A second type of calcite formed stacks of thin white plates during the middle part of the zeolite crystallization. This type of calcite is much harder to remove, probably due to a magnesium content. It appears to have co-crystallized with the zeolites which results in the zeolites being malformed and restricted by the calcite plates. In the Twin Lakes Cliffs much of the white carbonate, that covers the zeolites, is dolomite and is very difficult to remove with acid.

FUTURE COLLECTING:

Collecting is still possible along the main road, along the old upper road, and in the cliffs north of Yellow Lake. In most places there is plenty of room between the highway and the roadcuts to work with the exception of the main brewsterite near the pump house. That site is located only 2 feet from the edge of the blacktop on the inside of a curve. Traffic is heavy and moving at high speeds. That site is very dangerous. Very little collecting has been done in the Twin Lakes Cliff area. The cliffs, talus, and boulders in that area need to be worked. Over half of the veins and nodules found in this area are filled with calcite/dolomite that requires removal with either hydrochloric acid for heulandite/brewsterite veins or hot acetic acid for thomsonite/scolecite/mesolite/natrolite nodules (see Zeolites of the World for the procedure). Highway 3 has been widened to 3 lanes up to each end of Yellow Lake. The narrow, windy road along the lake is a bottle neck for travel between the Okanagan Valley and Vancouver and needs to be widened to 3 or 4 lanes. The exposures created by such a road would yield of wealth of zeolites. The only problem is that we have been waiting for 20 years for the road to be widened and it still has not happened.

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Wise, W.S. and Tschernich, R.W. (1978b) Habits, crystal forms and composition of thomsonite. Canadian Mineralogist, V 16, pp 487-493. (Yellow Lake, British Columbia; Skookumchuck Dam, Washington; Goble, Beech Creek, Spray, Drain, Oregon)

PHOTO CREDITS

Specimen #16	*Fred DeVito*
Specimens #006 & 387	*Donald Howard*
All other specimens	*Rudy Tschernich*
Photograph and Micrographs:	*Donald Howard*

FIGURE CAPTIONS

Color Photograph Number is in the upper left corner on the back of the print.

#16 Tungusite with Tacharanite and Apophyllite **(x 8)**
Mulholland Highway, Santa Monica Mtns, Los Angeles Co., Calif.
Green radial cluster of platy crystals of tungusite in a completely filled cavity. The tacharanite is white while the apophyllite appears somewhat glassy.

Micrograph Number is in the lower right corner on the front of the print.

All micrographs are from: **Yellow Lake, Olalla, British Columbia, Canada**

#006 Fluorite on Brewsterite **(x 60)**
Two colorless octahedra embedded in the face of a brewsterite prism. Notice that, unlike the thomsonite, the top face of the brewsterite is smooth.

#387 Heulandite **(x 100)**
A highly asymmetric crystal based on a prism elongated along the a-axis, with a termination similar to fig. 319 of *Zeolites of the World*, page 247.

#487 Thomsonite **(x 90)**
Wedge-shaped crystals composed primarily of (502) face terminations on the end of a prism formed of (110) faces, similar to fig. 3. The crystal, upper center, shows beveling due to (021) faces. This group is actually forming a coating over earlier mesolite.

#493 Thomsonite **(x 50)**
Wedge-shaped crystals in parallel growth, composed primarily of (101) face terminations on the end of a prism formed of (110) and (100) faces, similar to fig. 4

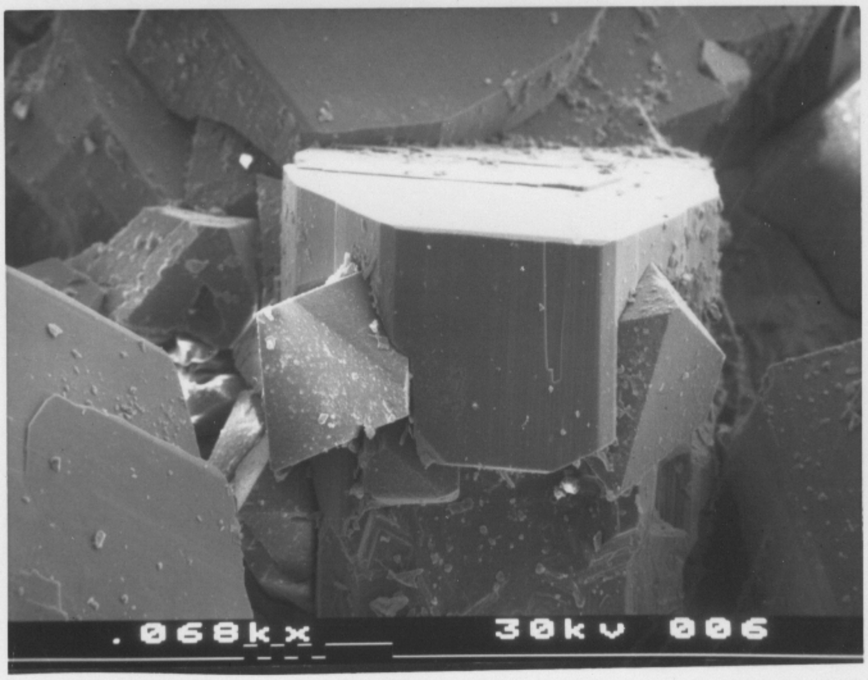
#488 Thomsonite **(x 150)**
Complex prismatic crystals featuring both (012) and (021) bevels, similar to fig. 15. Note the series of faces present on the wedge of the crystal at the extreme top.

#496 Thomsonite **(x 45)**
Equant blocky individuals with prominent (001) faces similar to fig. 13.

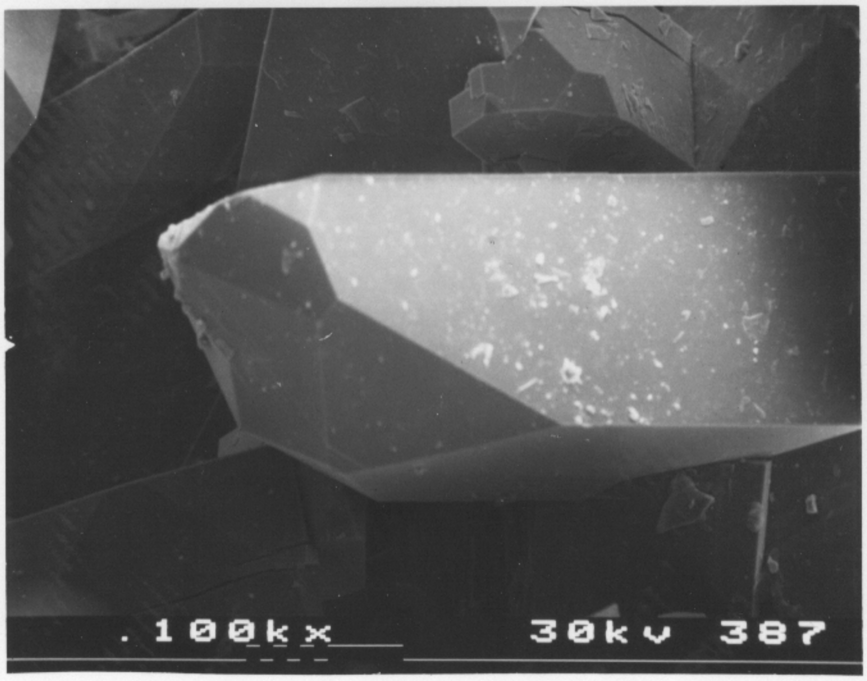
#490 Thomsonite **(x 40)**
Equant blocky individuals with c-faces, showing the more usual behavior of clustering due to parallel growth and twinning. The tops of these type of crystals show a great deal of segmenting where individual crystals meet.

#489 Thomsonite **(x 40)**
More segmented crystals, showing in particular a cyclic fourling caused by twinning at lower right.

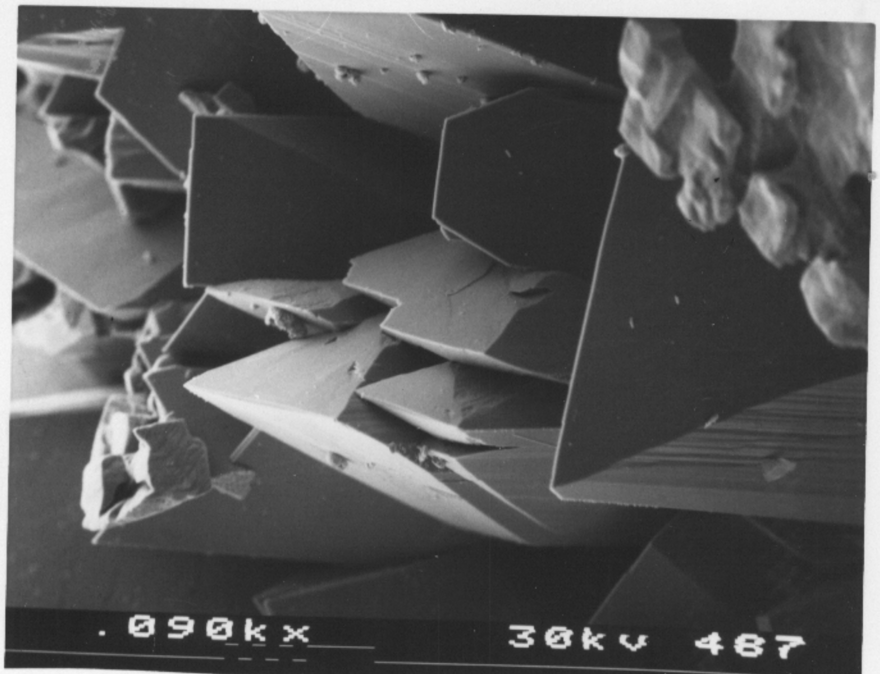
#494 Thomsonite **(x 60)**
Flat-ended crystals composed of many individuals, causing the end face to be very rough and irregular. Nearly parallel growth is very evident on the part of the crystal that extends beyond the rest.



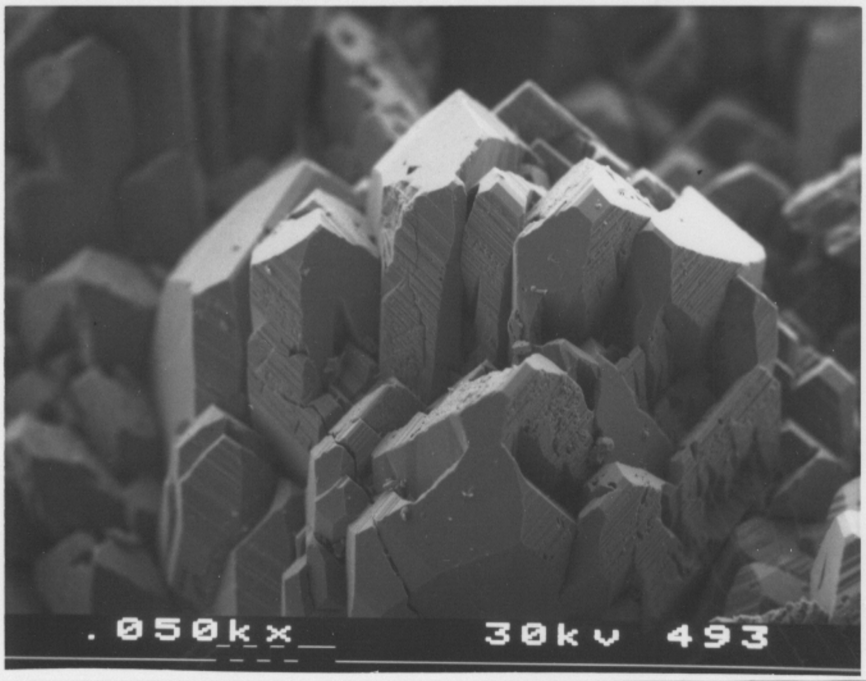
#006 – FLUORITE, BREWSTERITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 60X



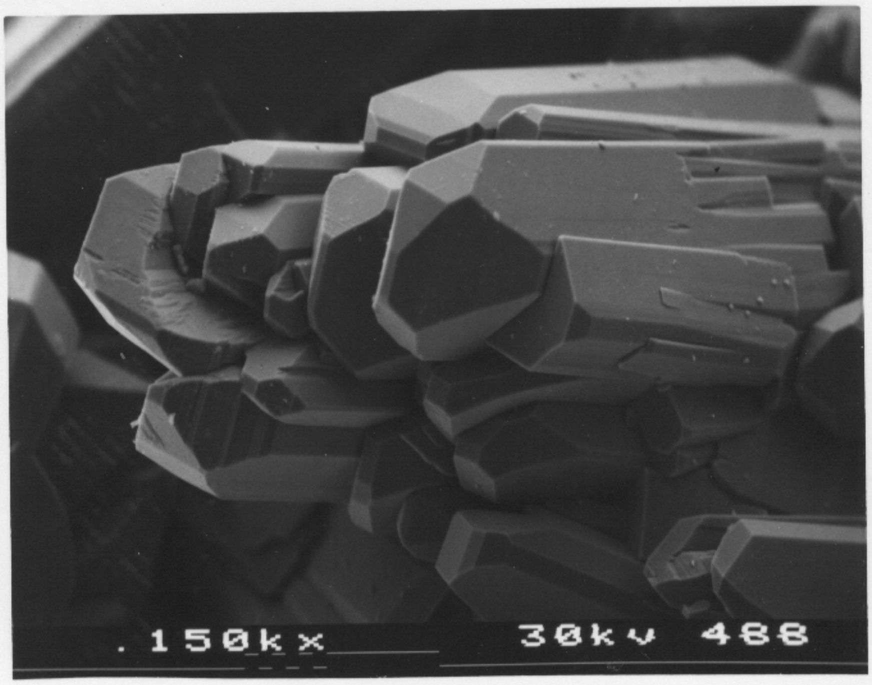
#387 – HEULANDITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 100X



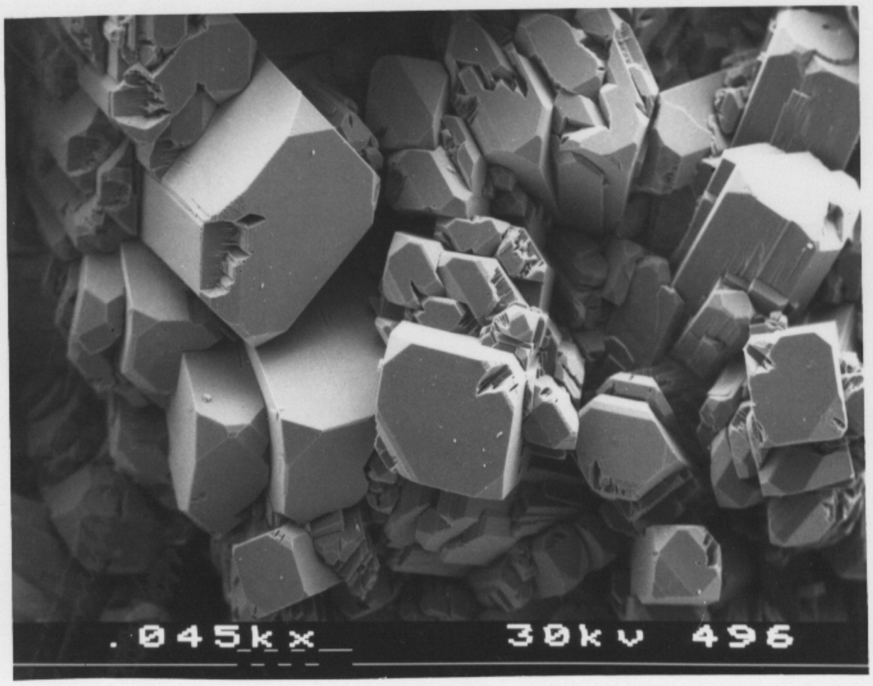
#487 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 90X



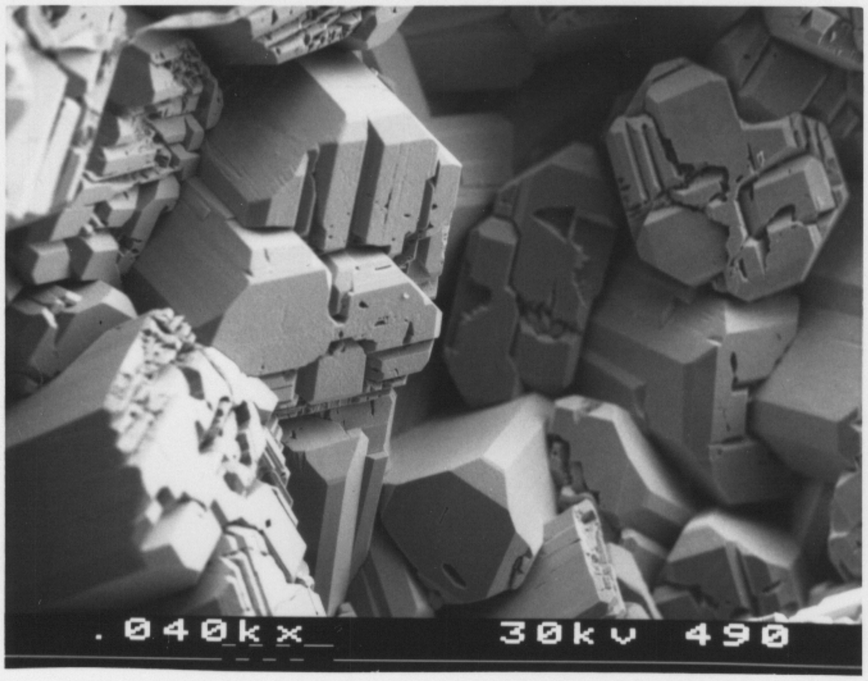
#493 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 50X



#488 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 150X

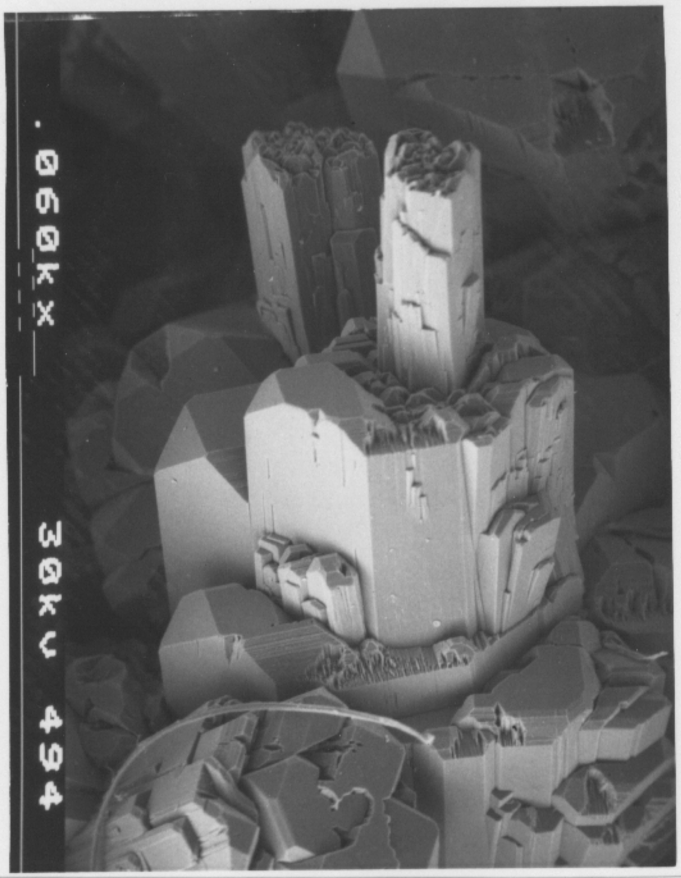


#496 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 45X



#490 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 40X

#489 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 40X



#494 – THOMSONITE – YELLOW LAKE, OLALLA, BRITISH COLUMBIA, CANADA – 60X