

Northwest  
Micro Mineral  
Study Group



# MICRO PROBE

SPRING, 1998

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SPRING MEETING . . . . .VANCOUVER, WASHINGTON

May 2, 1998

9:30 am to 6:30 pm

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

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

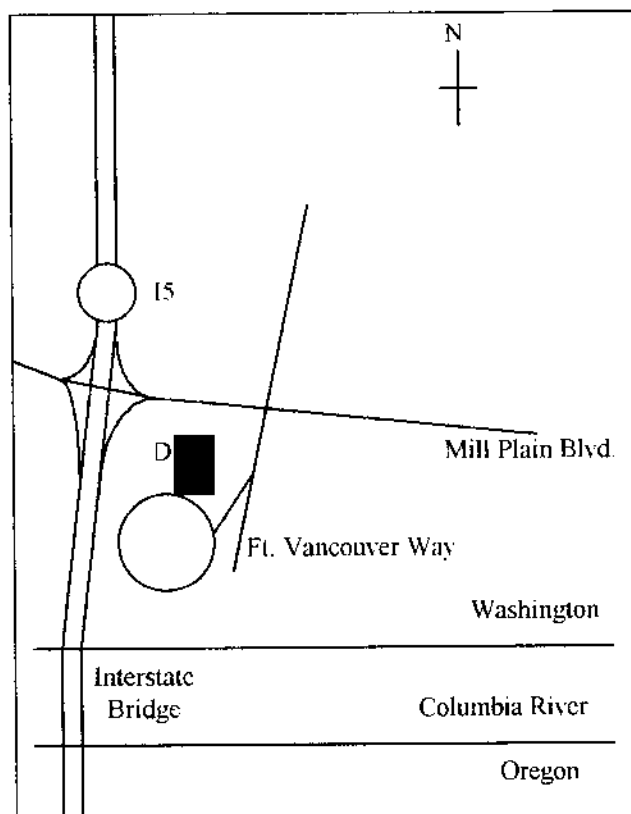
**Morning program:**

10:30 Rudy Tschernich will show slides of collecting at the Weyerhaeuser Lincoln Creek Quarry. Immediately following, 5 flats of material from the roof of the larger pocket will be placed on the free table. Bring your own tweezers and boxes to pick out beautiful groups of natrolite covered with apophyllite and calcite.

**Afternoon program:**

2:00 Our usual informal business meeting, including reports on the status of local collecting spots.  
3:00 Second slide program. Nothing has been planned, but if you have slides of mineral specimens or collecting localities that you would like to share, bring them along, we will have a projector and screen available.

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



## NEW NOMENCLATURE FOR ZEOLITE MINERALS APPROVED BY IMA

Rudy Tschernich  
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The zeolite group of minerals has been under revision by the Subcommittee on Zeolites for the International Mineralogical Association (IMA), Commission on New Minerals and Mineral Names since 1979. The first Subcommittee, chaired by William S. Wise (USA), included L. P. van Reeuwijk (Netherlands), G. Gottardi (Italy), Max Hey (Great Britain), Douglas Coombs (New Zealand), and Hideo Minato (Japan) with consultants J. V. Smith (USA), W. M. Meier, (Switzerland), Rudy Tschernich (USA), and V.A Frank-Kamenetskii (USSR). They completed a draft report in 1987 that recommended the changes published in *Zeolites of the World* in 1992 by Rudy Tschernich. By 1993, G. Gottardi, Max Hey, and V. A. Frank-Kamenetskii had died, and William Wise had resigned as chairman. Due to inaction, they were not replaced by IMA. Publication of *Zeolites of the World* brought to the attention of IMA the need to replace the Zeolite Subcommittee. Douglas Coombs was appointed chairman of the second Zeolite Subcommittee along with 18 others including A. Alberti, G. Artioli, C. Colella, E. Galli, E. Passaglia, S. Quartieri, R. Rinaldi, and G. Vezzalini (all from Italy), D. Peacor, M. Ross, and R. Sheppard (all from USA), E. Tillmanns (Austria), E. Nickel (Australia), H. Minato (Japan), J. Mandarino and J. Grice (Canada), F. Liebau (Germany), and T. Armbruster (Switzerland). The second Subcommittee was dominated by the Italian group, industrial natural zeolite promoters, and the synthetic zeolite industry. The voice of museum curators and mineral collectors was minimal. The new nomenclature for zeolite minerals developed by the second Zeolite Subcommittee and approved IMA has now been published in the *Canadian Mineralogist* and will also appear in other publications.

Zeolites have been considered hydrous aluminosilicate frameworks with loosely bonded alkali or alkali-earth cations since Max Hey of the British Museum published the definition in 1930. The Zeolite subcommittee found this definition too restrictive and formulated the following:

**New Definition of a zeolite: "A zeolite mineral is a crystalline substance with a structure characterized by a framework of linked tetrahedra each consisting of four O atoms surrounding a cation. This framework contains open cavities in the forms of channels and cages. These are usually occupied by H<sub>2</sub>O molecules and extra framework cations that are commonly exchangeable. The channels are large enough to allow the passage of guest species. In the hydrated phases dehydration occurs at temperatures mostly below about 400° C and is largely reversible. The framework may be interrupted by (OH, F) groups that occupy a tetrahedral apex which is not shared with adjacent tetrahedra."**

The new definition of a zeolite does not require aluminum, silicon, or water to be present. Certainly all the existing zeolites that do contain aluminum, silicon, and water are still included in the new group, but so are anhydrous minerals like leucite and ammonioleucite plus phosphate and beryllium minerals. As a result of this new definition, a zeolite can no longer be classed as a

hydrous tectosilicate, aluminosilicate, a silicate, or any other distinct chemical group since it includes phosphates, silicates (hydrous and anhydrous), and other elements. Classification of zeolites in works such as Dana's system, which is based on chemistry, is not possible. The unifying chemistry of the group is now lost.

The following rules have been made by IMA to help determine zeolite species.

**“Rule 1: (a) One or more zeolite minerals having a topologically distinctive tetrahedral framework and a composition that is distinctive for zeolites having that framework constitute separate species. (b) Zeolites having the same topologically distinctive tetrahedral framework constitute a series when they display a substantial range in composition in which differing extra-framework cations may be the most abundant in atomic proportions. These cations may occupy different extra-framework sites. Such series consist of two or more species that are distinguished on the basis of the most abundant extra-framework cation.”**

Part (a) of this rule indicates that a zeolite with a distinctive framework and composition is a separate species. This allows distinct minerals like laumontite, cowlesite, tschernichite and many others with little variation in their chemistry to be valid species. This rule also allows minerals such as natrolite, mesolite, and scolecite, which have the same framework but distinctly different compositions that do not form a series, to be separate species.

Part (b) creates all kinds of problems. It states that a zeolite with the same framework and a wide range in composition be considered a series with each species in the series named by adding the dominant extra-framework cation, connected by a hyphen, to the end of the name. The former species chabazite is now a series name. The chabazite series is composed of the species chabazite-Ca, chabazite-K, chabazite-Na, and chabazite-Sr. Other series include the analcime series, brewsterite series, clinoptilolite series, dachiardite series, erionite series, faujasite series, ferrierite series, gmelinite series, heulandite series, levyne series, paulingite series, phillipsite series, and stilbite series. Ideally, different names are not used for each member of a series. Exceptions have been made. Harmotome is retained as the barium member of the phillipsite series and the names analcime, pollucite, and wairakite are used as members of the analcime series because of the long usage. Several more series not defined by the Zeolite Subcommittee that will clearly be made in the future include the epistilbite series, mazzite series, mordenite series, and stellerite series. See Table 1 for a complete list of zeolite species and series.

As a result of part (b) in Rule 1, an accurate chemical analysis of each member of a zeolite series from each locality is required in order to correctly identify the species. The correct species name, not the series name, will be required in writing papers for most mineral publications, competition displays, and computer mineral databases. Formulas in *Zeolites of the World* are already listed with the dominant extra-framework cation first. In the formula  $\text{Na}_{1.45}\text{Ca}_{1.03}\text{K}_{0.38}\text{Sr}_{0.07}\text{Ba}_{0.02}[\text{Al}_{4.10}\text{Fe}_{0.01}\text{Si}_{7.90}\text{O}_{24}]12.5\text{H}_2\text{O}$  for a member of the chabazite series, sodium is dominant; therefore, the species name is chabazite-Na. Herschelite has been discredited by the Zeolite Subcommittee in favor of the name chabazite-Na. Wellsite, an intermediate member of the phillipsite series, has also been discredited. This rule greatly complicates the zeolite nomenclature, since a chemical analysis is now required in order to give a mineral a species name.

**“Rule 2: (a) Differences in space-group symmetry and in order-disorder relationships in zeolite minerals having the same topologically distinctive framework do not in general provide adequate grounds for recognition of separate species, but each case should be treated on its merits. (b) In assessing such cases, other factors such as relationship to chemical composition should be taken into consideration.”**

Fortunately this rule eliminates all the problems in the analcime series where differences in order/disorder could have resulted in many unneeded species. Other “factors” in the rule was the loophole where many obnoxious species that should not have been ever given species status were allowed to survive. Such examples are willhendersonite (ordered chabazite), garronite (disordered gismondine), gobbinsite (disordered amicitite), stellerite (ordered stilbite), and barrerite (ordered stilbite). Tetranatrolite, which has a disordered natrolite framework, is considered of doubtful species status by the Zeolite Subcommittee and now may be included in gonnardite.

**“Rule 3: Zeolite mineral species shall not be distinguished solely on the basis of the framework Si:Al ratio. An exception is made in the case of heulandite and clinoptilolite; heulandite is defined as the zeolite mineral series having the distinctive heulandite framework topology and the ratio Si:Al < 4.0. Clinoptilolite is defined as the series with the same framework topology and Si: Al >4.0.”**

Many zeolites have widely varying Si:Al ratios and are correctly not recognized as separate species by the Zeolite Subcommittee. An exception was made in the case clinoptilolite because of the entrenched usage of the name in natural industrial zeolites. As a result of separating clinoptilolite from heulandite and making them both a series, a total of seven new species have been made from heulandite.

**“Rule 4: Dehydration, partial hydration, and over hydration, whether reversible or irreversible, are not sufficient grounds for the recognition of separate species of zeolite minerals.”**

If a new framework arises from over-hydration or partial dehydration, separate species status would result from application of Rule 1. Leonhardite, the partially dehydrated form of laumontite, is not accepted as a separate mineral species. Paranatrolite, the overhydrated natrolite or tetranatrolite/gonnardite, is now of doubtful species status due to Rule 4 and probably will be eliminated as a species.

**“Rule 5: Individual species in a zeolite mineral series with varying extra-framework cations are named by attaching to the series name a suffix indicating the chemical symbol for the extra-framework element that is most abundant in atomic proportions, e.g., chabazite-Ca.”**

The first Zeolite Subcommittee recommended using optional adjective modifiers before the species name when the composition of the species, such as calcium chabazite, was known. The second Zeolite Subcommittee disregarded that proposal and added mandatory suffixes to the end of the formal name, therefore, making each one a new species. This action complicates naming and labeling specimens tremendously. See Table 1 for a list of the excepted new zeolite species.

**“Rule 6: (a) Space group variants of zeolite mineral species may be indicated by placing the space group symbol in round brackets (parentheses) after the mineral species name, e.g., analcime (*Ibca*); heulandite-Ca (*C2/m*). (b) Levels of ordering may be indicated by adjectival use of words such as “disordered” or “fully ordered” before the mineral name.”**

This rule is neutral and obvious. Any additional information about a mineral can be added as an adjective without changing the species name. Space group symbols and adjectival modifiers in Rule 6 are optional and not part of the mineral name. Such good sense should have been used rather than making Rule 1 part (b). Adding chemical information, such as calcium phillipsite, should have been optional, if it was known, without changing the mineral name to phillipsite-Ca which is a different species.

As a result of the new expanded definition of a zeolite and Rule 1, part (b), the world of zeolites has been needlessly complicated. Databases that keep track of museum and private mineral collections will have to be updated to add the new species. Since the chemical composition of most specimens in collections is not known, they will not be indexed correctly. Those that have been analyzed must be dug out of years of published literature. Both the old series name and the new species names will have to be retained on the database in order to index specimens. I have over 11,000 zeolite specimens on my database. Most of them will have to be changed in regard to both the major species name and all the associated minerals on each specimen. Competition mineral displays at shows require the species name to be given. Exhibitors will probably have to guess the most probable species of a series. In the field, collectors and mineralogists will ignore the suffixes and use old generic names. I personally would like to use the classic definition of a zeolite found in *Zeolites of the World*, ignore the suffixes, and call them CLASSIC ZEOLITES.

## NEW NOMENCLATURE FOR ZEOLITES APPROVED BY IMA IN 1998

### Analcime Series

- ✓1) Analcime
- 2) Pollucite
- 3) Wairakite

### Brewsterite Series

- 4) Brewsterite-Sr
- 5) Brewsterite-Ba

### Chabazite Series

- 6) Chabazite-Ca
- 7) Chabazite-Na
- 8) Chabazite-K

### Clinoptilolite Series

- 9) Clinoptilolite-K
- 10) Clinoptilolite-Na
- 11) Clinoptilolite-Ca

### Dachiardite Series

- 12) Dachiardite-Ca
- 13) Dachiardite-Na

### Erionite Series

- 14) Erionite-Na
- 15) Erionite-K
- 16) Erionite-Ca

### Faujasite Series

- 17) Faujasite-Na
- 18) Faujasite-Ca
- 19) Faujasite-Mg

### Ferrierite Series

- 20) Ferrierite-Mg
- 21) Ferrierite-K
- 22) Ferrierite-Na

### Gmelinite Series

- 23) Gmelinite-Na
- 24) Gmelinite-Ca
- 25) Gmelinite K

### Heulandite Series

- 26) Heulandite-Ca
- 27) Heulandite-Sr
- 28) Heulandite-Na
- 29) Heulandite-K

### Levyne Series

- 30) Levyne-Ca
- 31) Levyne-Na

### Paulingite Series

- 32) Paulingite-K
- 33) Paulingite-Ca

### Phillipsite Series

- 34) Phillipsite-Na
- 35) Phillipsite-K
- 36) Phillipsite-Ca
- 37) Harmotome

### Stilbite Group

- 38) Barrerite
- 39) Stellerite

### Stilbite Series

- 40) Stilbite-Ca
- 41) Stilbite-Na

### Gismondine Group

- ✓42) Gismondine
- 43) Amicite
- ✓44) Garronite
- ✓45) Gobbinsite

### Series to be made in the future

- 46) Mazzite Mg and Na
- 47) Mordenite Na and K
- 48) Epistilbite Ca and Na
- 39) Stellerite Ca and Na

### Separate Species

- 49) Bellbergite
- ✓50) Bikitaite
- ✓51) Boggsite
- ✓52) Cowlesite
- ✓53) Edingtonite
- ✓54) Gonnardite
- ✓55) Goosecreekite
- 56) Gottardiite
- ✓57) Laumontite
- ✓58) Merlinoite
- ✓59) Mesolite
- ✓60) Montesommaite

61) Mutinaite

- ✓62) Natrolite
- ✓63) Offretite
- ✓64) Scolecite
- 65) Terranovaite
- ✓66) Thomsonite
- ✓67) Tschernichite
- 68) Willhendersonite
- ✓69) Yugawaralite

### New IMA Zeolites

- 70) Ammonioleucite (anhydrous)
- 71) Chiavennite (Be silicate)
- 72) Gaultite (Zn silicate)
- 73) Hsianghualite (anhydrous Be silicate)
- ✓74) Leucite (anhydrous)
- 75) Lovdarite (Be silicate)
- ✓76) Maricopaite (PbAl silicate)
- 77) Kalborsite (anhydrous)
- 78) Pahasapaite (Be phosphate)
- 79) Partheite (Al silicate)
- 80) Roggianite (BeAl silicate)
- 81) Tschortnerite (CuAl silicate)
- 82) Weinebeneite (Be phosphate)

### Doubtful Status

- Paranatrolite
- Tetranatrolite
- Tvedalite

### Discredited as Species

- Herschelite
- Leonhardite
- Svetlozarite
- Wellsite

### Discredited as Zeolites

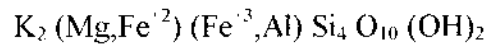
- Kehoeite
- Viseite

## Zeolite Associates --- CELADONITE

Don Howard and Jocelyn Thornton

From time to time we have featured articles about minerals that are often associated with zeolites which, for one reason or another, are not members of that group. It seems fitting, in light of Rudy's article on the proliferation of zeolite "species" based on chemical variations, to include another recent "group" designated in much the same way.

Fleischer's Glossary of Mineral Species gives the chemical formula for celadonite as:



This means that the mineral is a basic silicate of potassium, magnesium, and ferric iron. The quantities in the parentheses containing commas indicate that some ferrous iron can substitute for the magnesium, and that some aluminum can substitute for the ferric iron. The understanding is that the atomic percentage of magnesium exceeds that of ferrous iron, and the atomic percentage of ferric iron exceeds that of aluminum. In this sense, the ferrous iron and aluminum are considered possible impurities.

Recently, *Li, Peacor, Coombs & Kawachi* have reported chemical analyses on samples that show that the ferrous iron can indeed exceed the atomic percentage of magnesium, and aluminum exceed the atomic percentage of ferric iron. In keeping with current practices for all minerals, the name celadonite would then be considered a *group* name, and the name celadonite would be an *end-member*, consisting of pure potassium magnesium ferric silicate. Three other end-members should exist as limiting cases for a series of minerals. The above authors propose the names **ferroceladonite** and **ferroaluminoceladonite** for two of these end-members. The fourth member has not yet been detected. Since *two* sites are involved in the substitutions, putting chemical suffixes after the mineral, as Rudy has described for some of the zeolites, is not practical. These two new members would be considered new species.

Now before you rush out trying to find these new species for your collections, you need to know something of the "type locality" and the nature of the occurrence used to describe these new species. The type locality is in New Zealand, and Jocelyn Thornton has reported on it in the *Micro-Scope*, the Newsletter for the micro-mineral collectors of New Zealand:

*Celadonite is an old mineral, a fine-grained mica that when crushed is blue-green. It has been mined for centuries as a pigment from quarries near Verona, Italy, and in Cyprus. It occurs in hydrothermally altered volcanics from basalt to rhyolite, and also in sediments with volcanic ash that have been metamorphosed to the zeolite facies, one of Prof. Coombs' special fields.*

*In the 1970s he and James Boles reported celadonite and other minerals in altered crystal-vitric tuff in the Hokonui Hills east of Gore. Mineralogists knew that celadonite could have a range of compositions with varying proportions of magnesium, iron and aluminum, but these had never been properly analysed. Electron probe analysis of the Hokonui celadonite suggested varieties with iron and aluminum dominant, but also showed the presence of*

*intergrown chlorite, a major complication. Now, with much more sophisticated machines available, the old material has been re-analysed and the celadonite has been defined as three species:*

<i>Celadonite</i>	$K_4 Mg_2 Fe^{+2} Fe^{+3}_2 Si_8 O_{20} (OH)_4$
<i>Ferroceldonite</i>	$K_4 Fe^{+2}_2 Fe^{+3}_2 Si_8 O_{20} (OH)_4$
<i>Ferroaluminoceladonite</i>	$K_4 Fe^{+2}_2 Al_2 Si_8 O_{20} (OH)_4$

*The rock occurs in the bank of an old track as a hard wall about a metre long and high and much weathered. The paper describes the broken surfaces of a fresh hand-specimen, as being dark greyish-green in colour with reddish flecks and feldspars up to 1mm in length. Large dark fragments, 1 – 3mm in diameter, prove in thin section to be micro-pumiceous sharps and lapilli, somewhat glassy, with cusped fragments typically 0.2 – 0.6mm long. Glass in the shards and much of that in the pumiceous lapilli has been replaced by platy pink heulandite, which also fills some of the microvesicles. Other microvesicles contain celadonite family minerals, which also partially replace glass in the shards forming dark blue-green patches. Vesicles are commonly zoned with a film of celadonite family minerals lining the rims and larger celadonic flakes mixed with chlorite in the centres. Some vesicles only have chlorite, which also occurs in the matrix. Colour ranges from bright glaucous green celadonite through olive green to pale green chlorite. Other minerals grown in the sediment include micro-titanite, minor pyrite and quartz, fine-grained twinned albite and rare prehnite. The rock has detrital plagioclase, augite, magnetite, rare hornblende and lithic fragments.*

*Nice. Now for the bad news. Remember, we are looking at minerals that have grown in cavities inside bits of pumice that are 1 to 3mm across – the bits, not the cavities! In the paper there is a nice Back-scattered Electron image photo of the ferroceldonite and ferroaluminoceladonite to show the textural relation of the two minerals. Ferroceldonite forms layers about 1 – 2 microns thick of fibrous platy crystallites growing out from the vesicle walls (1 micron – one thousandth of a mm). Elsewhere, the ferroceldonite is described as sub-micrometer (approximately 200 – 300 nm thick) grains; 1mm – a millionth of a millimetre. Try and mount one of those in a box!*

*The type locality that we visited is on the farm of H.R.J. Eckhoff, in Waimea Valley Road. We drove past the woolshed to the deer enclosures where we parked to walk up the good track to a little quarry, and then went down the hillside to the old path closer to the stream. If anyone wants some of this rock I can share it – but I won't suggest you will see the minerals.*

*There is much better ferroceldonite in the bright green micaceous coatings round the vugs and filled vesicles in the Stew Point andesite. It is a fairly common mineral – it is real bad luck for us that the vital analysis was done with such care on such micro micro-minerals!*

As Jocelyn stated above, celadonite is a member of the mica group of minerals closely related to the mineral glauconite. It does not occur, however, in large, well-defined sheets, but rather as earthy masses, bluish green to green in color. These are often mixed with soil or ash, as in the feature called “haystack” and in several of the greenish road cuts along the road between Spray and the Burnt Cabin Creek site.

Lenses of pure celadonite of a rich green color several inches in diameter can be found in the banks along Fish Creek just above its junction with the Clackamas River. Some of the



heulandite in this area appears greenish because of a layer of celadonite directly beneath. Material from the lenses has been subjected to x-ray diffraction, verifying it to be celadonite. Mossbauer spectroscopy shows that most of the iron is in the ferric state, so that material would be the normal mineral celadonite. Indeed, it is rather bluish green in color.

Some specimens of heulandite collected in the Kalama area are green because of a layer of celadonite beneath the clear heulandite. Here as on the Clackamas, the celadonite formed before the heulandite.

The opposite condition, however, is usually observed for specimens from across the Columbia River in the basalts around Goble. Specimens from the Neer Road site show the celadonite as tufts of blades growing on top of the heulandite. Exposed clusters are usually a pale yellowish green, often rather orangy. Tufts that have been covered with another mineral – chabazite, thomsonite or phillipsite – are generally a much darker green.

There is a site just north of the Trojan plant (Little Jack Falls) where the celadonite is abundant. In fresh rock, almost every cavity is colored a rich green from a rather thick layer of celadonite. Being somewhat farther from Goble Creek, the only zeolite present in any of the cavities is heulandite, and most of the cavities have no zeolites at all. Those that do again show the celadonite as tufts on top of the heulandite. When freshly broken open, the celadonite tufts are a rich green color. They are usually wet (this being Oregon, after all). I have watched the green material turn to a dull rusty orange in a matter of minutes as the cavities dry, exposing the minerals to the air. That most clearly indicates oxidation of ferrous iron to ferric iron. This suggests that many of the celadonite specimens from this area may indeed be ferroceldonite.

To my knowledge, no one has done studies of the chemistry of material from the Goble area. Quantitative analysis (probably using a microprobe) would be necessary to establish which of the three minerals listed above is actually present. The observations also show that the valence state of the iron is not very stable when exposed to the air, so the original state of the iron would have to be deduced from the ratios of Mg:Fe:Al. Since none of these minerals make particularly attractive, showy specimens, no one is likely to go to the effort or expense of doing quantitative chemical analysis.

This is another case of the differences being too difficult to sort out to be of any interest to the normal collector. I am sure that most collections, should they even bother to have samples of these minerals, will simply label them *Celadonite* and be done with it.

#### REFERENCES:

Li, G., Peacor, D.R., Coombs, D.S. & Kawachi, Y., *Solid solution in the celadonite family: the new minerals ferroceldonite and ferroaluminoceldonite*. **American Mineralogist** 82, pp503-511(1997).

Thornton, Jocelyn, *Moonshine in the Hokonui Hills*. **Micro-Scope** #24 (Nov., 1997).

## **EXTRAORDINARY NATROLITE-LINED POCKETS AT THE WEYERHAEUSER LINCOLN CREEK QUARRY, DOTY HILLS, LEWIS COUNTY, WASHINGTON**

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Some of the finest natrolite specimens in North America are found in southwestern Washington State. The Robertson Pit near Dayton has been the premier site for natrolite specimens (Lasmanis, 1988). In 1996 an exceptional large 4x3x7 foot cavity containing natrolite was found in the Weyerhaeuser Lincoln Creek Quarry, in the Doty Hill, Lewis County (John Cornish, 1998). This year, exceptionally large plates of long white natrolite needles found in the Weyerhaeuser Lincoln Creek Quarry surpassed all those previously found.

Raymond Lasmanis, first reported attractive calcite crystals and zeolites in the Weyerhaeuser Lincoln Creek Quarry in January 1984. At that time the quarry was named the Section 23 Quarry due to its location in the center of Section 23, T14N R5W and to distinguish it from a nearby quarry that was named the Lincoln Creek Quarry by Lanny Ream in 1977 that is operated by the Department of Natural Resources (DNR). Unfortunately Weyerhaeuser also designates the name Lincoln Creek Quarry for their quarry in Section 23. The Dunn Creek Quarry is another alternative name formerly used for the quarry owned by Weyerhaeuser. We now use the long formal names Weyerhaeuser Lincoln Creek Quarry for the quarry in section 23 owned by Weyerhaeuser that produces the best zeolites and the DNR Lincoln Creek Quarry for the one owned by the state.

The quarry is reached by turning north from Highway 6 onto the Chandler Road leading to Dryad. After 0.5 miles turn right on the Kobe Road and follow it one mile to the Weyerhaeuser gate. If the gate is open, proceed along Road 550 for 2.5 miles, keeping to the left at the junction with road 554, and follow Road 550 for another 2 miles to the quarry (total of 7 miles from Highway 6). Access can also be made from the north along the Lincoln Creek Road. The gates are often locked. Collecting is allowed in the quarry if it is not in operation. Hard hats must be used and care must be taken not to work under loose rock or under over-hanging walls. If the quarry is in operation, collecting is only allowed after 4 p.m. weekdays and all day during the weekends. Camping is not allowed in the quarry.

In the early 1980's the quarry was only 100 feet long and occupied a space that is now in the middle of the present quarry. Ray Lasmanis found the first large pocket, 30 inches wide, 18 inches high, and over 24 inches deep, in the northwest end of the quarry on May 6, 1989. It produced flattened analcime crystals on the separated layers in the roof and on breccia plates in the bottom of the open cavity. Attractive long needles of natrolite were present along with a little calcite. Later, on October 21, 1993 Ray found another cavity in the southern portion of the quarry that contained very attractive dark golden colored calcite crystals. When the pocket was first encountered, it was a solid mass of calcite in the wall. After some work it opened up to a pocket 15 inches high and 24 inches wide and deep, lined mostly with beautiful calcite crystals, up to 5 inches across, with drusy analcime and pyrite. That cavity had a sloping floor that dipped to the east. In 1996 John Lindell found two breccia areas in the northern part of the quarry that, when the contents were removed, yielded two 24-inch spaces that were only a few feet above the 1989 Lasmanis Pocket. Whether these breccia areas and pockets were ever connected is not

known. The Lindell Pocket was totally filled with breccia covered with flattened analcime crystals and golden calcite, 1 to 2.5 inches across. The calcite crystals were mostly intergrown and often in contact on both sides with the breccia fragments.

The quarry wall was greatly extended to the southeast to form a large U-shape several hundred feet across. On Valentines Day 1996, John Cornish and Keith Ikerd discovered a 4x12 inch white area that, when dug into, exposed an unbreached 7-foot pocket high on the wall of the U-shaped area (John Cornish, 1996). It was filled with large plates of cream colored 1.5 inch long, natrolite needles, apophyllite, clay, and two exceptional calcite specimens. Additional work in the quarry was concentrated in the northwest section of the quarry in 1997 where the first large pockets were found. In that area, no more major pockets were encountered, only veins filled with massive amber-colored calcite, up to 7 inches thick, and areas of green chert

In 1998, additional blasting in the northwest and middle section of the quarry produced only traces of massive calcite but no zeolites. A rock fall in the U-shaped portion of the quarry in February 1998 removed the remains of the 1996 Cornish Pocket and exposed, 30 feet up on the wall, a small 12-inch opening lined with white material on the right and a small dark black hole a couple of inches across 10 feet to the left. On February 7th a ladder was made and these two spots were opened up and worked two feet into the rock by Warren Sorenson, the area engineer for Weyerhaeuser, and his son Dan. Both pockets contained excellent specimens of long white natrolite needles on a thick hard layer of apophyllite, but the left-hand pocket was the best. When first exposed, the left-hand pocket was only a couple of inches wide. It quickly opened up to a flattened pocket 18 inches wide, 8 inches high, and 2 feet deep with a barren roof and a floor covered with white natrolite needles, 2 to 3 inches long, on which were strewn tiny colorless apophyllite and calcite crystals. Both pockets had smooth flat floors that dipped 20° and appeared to pinch out after about 2 feet.

The next weekend on Valentines Day 1998 (exactly two years after the Cornish Pocket had been found) Warren Sorenson and I continued work in the pockets. By this time a rock pile had been made right up to the pockets so that ladders were not needed to reach them. The left-hand pocket had the best potential. As specimen after specimen was removed it was clear that the back of the pocket, which appeared to round off and taper off opened up again into a much larger chamber. The light from the flashlight showed the pocket extended into the solid rock over 8 feet. Loose natrolite needles that had fallen from the roof onto the plates on the floor made perfect packing material, but made the specimens initially look terrible. Fortunately the loose needles, black clay grains, and rock chips easily washed off when dipped in water. The roof, floor, and sides of the pocket were smooth, with strange black basalt stalactites and thin ribs, up to 3 inches long, hanging from the roof. Since the distance from the roof to the natrolite plates was only a few inches, great care had to be taken in order to remove the natrolite/apophyllite plates without hitting the stalactites. By this time the specimens were beyond reach and a modified shovel was used to hook the specimens and pull them up the 20° incline to the opening of the cavity. All of the plates of natrolite/apophyllite were loose in the pocket; therefore, no chiseling was required. Extraction was the problem. Modified long plastic tubing was later used with hooks, points, and hoe-like attachments to retrieve the specimens. The base of the pocket, which was now over 10 feet into the rock, branched both to the left and to the right. Two of the finest natrolite/apophyllite specimens, 30 inches long and 14 inches wide, came from the left and right branches at the base of the pocket. They were completely covered with 2 to 3 inch undamaged natrolite needles and ridges of coarse apophyllite that gave the specimens a unique character. Nearly all of the finest specimens came from the left-hand pocket.

After the main pocket had been cleaned out, several smaller side pockets were explored. One thin seam that first appeared to be only an inch high and 12 inches long was present only a few inches from the mouth of the left-hand pocket. The excavator was called in and its giant scoop quickly moved the face of the wall back several feet. The new face of the wall now exposed the middle pocket. It was at first several inches high extended 5 feet into the rock. It produced thin stiff natrolite needles 1.5 inch long, without a second generation of thin natrolite, on plates up to 10 inches across. When it became dark, Warren Sorenson left the middle pocket and John Cornish continued to explore it with a flashlight at night. He worked a white layered seam area on the left interior of the pocket. After removing a foot of collapsed material it opened up into another 5-foot long thin pocket. Nature had not been kind to this pocket. Six-inch thick slabs of roof basalt had collapsed, crushing the thin natrolite needles down to the apophyllite base. The next day Warren Sorenson returned to the middle pocket and explored the interior wall on right side. It also contained layered collapsed natrolite seams. After removing two feet of flatten rock and massive natrolite, it also opened into a 6-foot pocket. It too, was collapsed. The roof had fallen down onto the floor and ruined most of the crystals. One roof plate, 24x24 inches across and only 1.5 inches thick, was covered with basalt stalactites on top of which were attractive scattered needles of natrolite and apophyllite. The back of the plate contained two undamaged 3-inch colorless calcite crystals that had grown in an open space between the roof and the next layer of rock in the ceiling. After all the material had been removed from the middle pocket, it formed a large U-shaped cavity with two 6-foot legs. Unfortunately only a few clean undamaged specimens survived in this pocket.

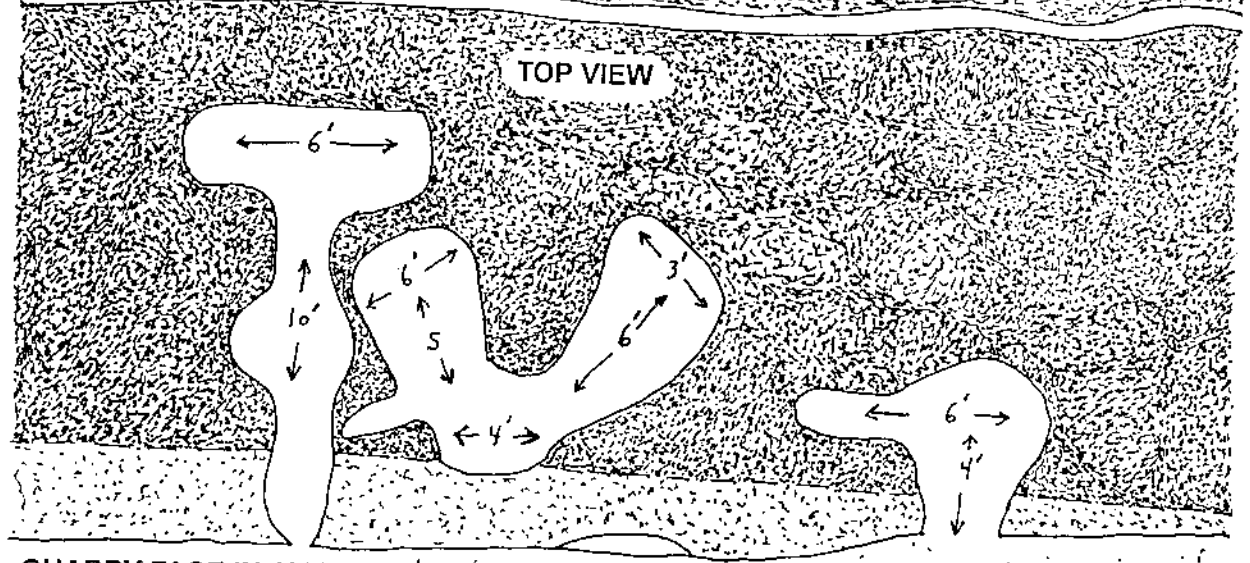
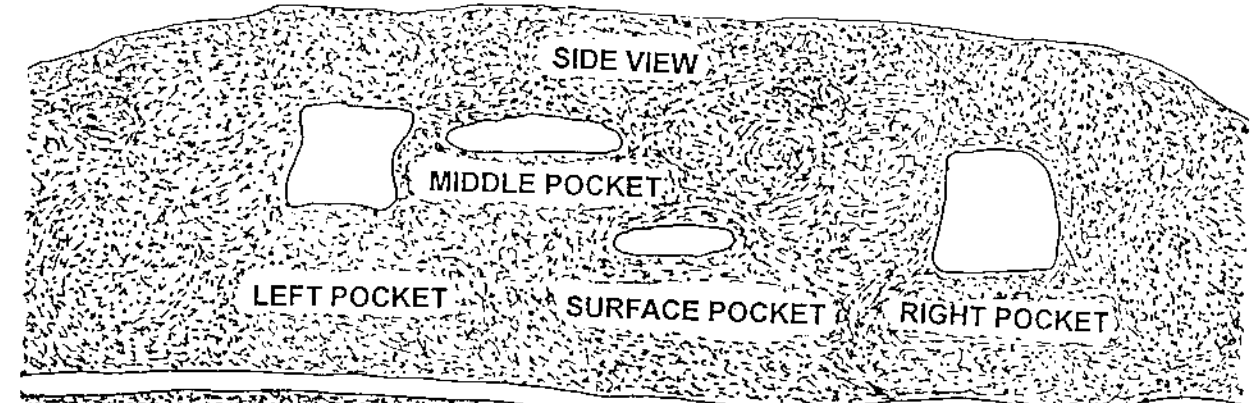
Over a period of three weeks, 3 major pockets with several side branches were found within a 12-foot area. Many interconnected with each other. All had basalt stalactites or ridges in the ceilings. From observations in the field, the swarm of pockets probably was the result of small lava tubes in the center of a flow. The surface and base of the flow had cooled first, allowing molten rock to flow through the center of the basalt flow. Ridges formed in the ceiling parallel to the direction of the flow. When the source of the lava was cut off, only the interconnecting tubes remained with basalt stalactites dripping down from the ceiling. Zeolites crystallized at a later time. If this scenario is true, the pocket swarm should extend into the quarry wall and more pockets could be encountered.

The rock is mapped as lower to middle Eocene Crescent Formation on the Geological Map of Washington, Southwest Quadrant (Walsh, et al., 1987). Oil/gas drilling 2.5 miles west of the quarry shows the rock lies above the Crescent Formation and probably belongs to middle to upper Eocene marine McIntosh Formation (Raymond Lasmanis, pers. comm., 1997). This unit is primarily sedimentary but is interbedded with the Pe Ell volcanic rocks exposed west of Pe Ell where natrolite, apophyllite, analcime, and calcite have been found in vesicular columnar basalt. Cavities are rare in the quarry. Vesicles are absent and veins containing calcite are rare. On a normal day in the quarry, no signs of zeolites are present. You would think it was barren. Very rarely large pockets or groups of pockets are exposed like those described in this paper. It is such pockets that will make this locality famous.

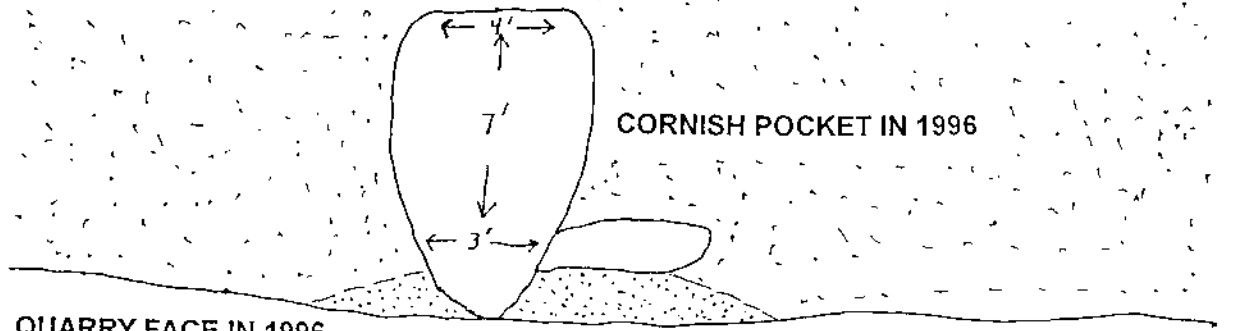
The number of minerals is limited to those commonly found in marine volcanic rocks, where sodium from the seawater determined their chemical composition. The sodium zeolites natrolite and analcime are the major zeolites present, with only traces of mesolite and thomsonite. Apophyllite, calcite, and clay are the other major minerals, along with some pyrite in the rock.

A dark green to black clay mineral, probably an iron-rich smectite, was the first mineral to crystallize in the pockets. The amount of clay present varies between pockets, ranging from a

NATROLITE/APOPHYLLITE POCKET AREA  
WEYERHAEUSER LINCOLN CREEK QUARRY,  
DOTY HILLS, WASHINGTON



QUARRY FACE IN 1998



QUARRY FACE IN 1996

thin black dusty layer generally found on the ceilings of the pockets to layers several centimeters thick on the floor. The layers are composed of tiny 1-mm diameter spherical aggregates made up of tiny, thin, hexagonal, platy smectite crystals. The round smectite aggregates piled up to form layers or unusual arched concave structures that resembled halves of ping-pong balls or tennis balls, 1 to 2 inches in diameter, with the curved surface attached to the wall of the pocket and the empty concave portion pointing into the center of the pocket. The concave smectite hemispheres were common in the large pocket found by John Cornish in 1996, but because of the weak attachment of the rounded surface of the smectite balls and the weight of the zeolites grown on it, the roof-lining of that pocket collapsed down to the floor. In most of the pockets the black clay has altered to a soft, loose, sooty material that separates the wall rock from the specimens; therefore, aiding in the removal of specimens. Tiny 1-mm cubes of pyrite are rarely found with the clay. More commonly, massive pyrite is found on the fracture surfaces of the broken basalt.

Analcime was the first zeolite to crystallize in the pockets. It first formed colorless to milky trapezohedra, less than 1 mm in diameter, that are inconspicuously scattered on the black smectite clay and breccia fragments. Natrolite later crystallized on some of the analcime crystals and was followed by additional analcime growth that enlarged existing analcime crystals to a diameter of 1 to 2 millimeters, and firmly attached the base of the natrolite needles within the analcime. The pockets found by Lasmanis and Lindell contained breccia that was covered with flattened analcime. The bottom of the 1996 Cornish Pocket was also filled with breccia fragments covered with flattened trapezohedra of analcime, some 2 mm thick and 10 mm wide. Phantoms commonly seen within the analcime crystals illustrate the two generations of growth.

In the pockets found in the northern portion of the quarry, smectite, analcime, and calcite were the major minerals present. Only a little natrolite was found. In the swarm of zeolite-bearing pockets in the southern portion of the quarry, natrolite was the major mineral. In the left and right-hand pockets, it formed in two generations. The first generation formed long, stiff, coarse, colorless needles 1.5 to 3 inches at random angles to the wall of the cavity rather than parallel needles perpendicular to the walls. Following the growth of the long needles, a distinct second generation of natrolite occurred that formed thin colorless to white hair-like fibers that attached to the sides and terminations of the coarse natrolite. Tiny segments of mesolite that make up less than 1 percent of a needle are present within some of the hair-like natrolite fibers. The middle pocket contained straight parallel natrolite needles that grew perpendicular to the walls. They were not covered with any second-generation fiber. Natrolite usually lined both the roof and floors of the pockets, although the floor had a denser population of natrolite needles.

Following both generations of natrolite, colorless blocky apophyllite crystals, up to 10 mm long, crystallized only on the bottom of the pockets, cementing the base of the natrolite needles together to form a rigid shell that allowed removal of large intact plates. The blocky apophyllite was slightly elongated along the c-axis and was terminated with small triangular {111} faces and {001} pinacoid. Following crystallization of the blocky apophyllite, a second generation of apophyllite formed tiny, colorless, highly elongated prisms, up to 3 mm long, also terminated by {111} and {001} faces, that were scattered on the blocky apophyllite and the upper portions of the natrolite needles. A very faint green zone is seen in some of the coarse apophyllite crystals in the 1996 Cornish Pocket.

Tiny, colorless to cream-colored, rectangular blades of thomsonite, up to 3 mm long, were very rarely found on analcime in the breccia area in the 1996 Cornish Pocket and very rarely on natrolite needles that are covered by apophyllite and calcite.

Calcite is abundant in veins and filled cavities in the quarry, but good complete undamaged crystals are scarce. They all too often grew completely across open spaces and cemented adjacent breccia plates together. At least four exceptional calcite specimens with crystals, up to 10 inches across, on plates up to 18 inches across, were found in the large open pockets, two in the 1996 Cornish Pocket and two in the left-hand pocket in 1998. Calcite crystallized at several times in the cavities. The sequence of crystallization and the color of the crystals can distinguish the different generations of calcite. All of the crystals are rhombohedral, and some are twins that range in size from a few millimeters to those 10 inches across. The first generation of calcite (and the rarest) formed beautiful deep brown crystals that precede zeolite crystallization. Later amber-colored calcite crystallized after the analcime, natrolite, and coarse apophyllite. A druse of elongated apophyllite crystals often covers it. After the drusy apophyllite, another generation of calcite formed very large medium to light yellow distorted crystals, up to 10 inches across. At the end of crystallization in these pockets, a tiny colorless calcite crystals formed a druse on all of the other minerals, particularly the natrolite needles. This colorless generation of calcite also formed many crystals, up to 1.5 inches in diameter, between breccia fragments.

The minerals appear to have crystallized in the order: clay-pyrite > dark brown calcite > analcime > natrolite > analcime > thomsonite > blocky apophyllite > amber-colored calcite > drusy apophyllite > colorless calcite.

Nearly all the pockets show evidence of collapse either before or after zeolite mineralization. All the large pockets found previous to 1998 contained a broken-up layer of thin basalt fragments, some over a foot across, that either partially or totally filled the pocket. These pockets were generally 2 to 4 feet high and 2 to 5 feet long with a smooth rounded roof, containing basalt stalactites or drippings and a breccia filled floor. These rocks were broken during cooling of the basalt flow previous to being mineralized by hydrothermal solutions. The pocket swarm found in 1998 contained pockets that were thin and wide with smooth floors and no breccia fragments. The arched basalt roofs in the best pockets were intact because the arching locked them in place and protected the crystals underneath. After the specimens were removed, the roof slabs were pried down to open up the cavity for easier access. In the middle pocket where the roof was not arched, 6-inch thick roof slabs fell down on the natrolite/apophyllite needles below crushing the natrolite crystals. The 1996 Cornish Pocket showed massive collapse. When the pocket was opened, all the roof zeolite/apophyllite/clay lining had fallen down onto the same lining on the floor of the pocket to form a sandwich 6 inches thick composed of black clay on both the top and bottom and a 4 to 5 inch thick mass of white natrolite needles in between. The long thin second-generation natrolite protected the stiffer first generation natrolite from damage from the fall just like cotton. In most of the thin pockets found in 1998, the roof lining and floor lining were not the same. The blocky apophyllite, which formed the base of the floor lining, was not present on the roof. Only attractive divergent sprays of needles covered with drusy apophyllite and calcite were present on the roof. They had been shaken loose from the roof and gently piled onto the floor plates, protecting most of the lower plates from further damage.

Tschernich (1997) and Cornish (1997) described the mineralization in the Gopher Valley Quarry, Sheridan, Oregon. The minerals present and age of the rock at the Gopher Valley Quarry are very similar to those at the Weyerhaeuser Lincoln Creek Quarry. Both sites are found in Upper Eocene marine volcanic rock that formed near the shoreline and contained large pockets lined with natrolite, analcime, calcite, and clay. Breccia is found at both sites. Several generations of calcite are present at both sites that decrease in color from dark brown to amber

and near colorless. Analcime is tiny at both sites. Pyrite is larger at the Gopher Valley Quarry but is still present at the Weyerhaeuser Lincoln Creek Quarry, while apophyllite is abundant at the Weyerhaeuser Lincoln Creek Quarry but absent at the Gopher Valley Quarry. Major disturbances have occurred at both quarries.

Prognosis for future collecting in the quarry does not look good. Pockets have always been scarce in the quarry. Several blasts in the northern and middle portions of the quarry have not exposed additional pockets. After the minerals were removed from the pocket swarm in the southern or U-shaped portion of the quarry, the excavator back filled the pockets with rock and removed the rock pile that was against the quarry wall, leaving the pocket area 30 to 40 feet from the floor. The pockets probably continue into the wall of the quarry, but without blasting, enough rock can not be removed to expose more pockets. A 20-foot layer of sediments that presently covers most of the basalt in the quarry has to be removed in order to obtain uncontaminated basalt for road surfaces. The basalt flows dip 20° to the east; therefore, the sedimentary rocks get deeper the further east the quarry is worked. Estimates of 40 feet of sediments behind the main pocket area makes continued work impractical.

#### ACKNOWLEDGEMENTS

I wish to thank Ray Lasmanis, John Lindell, and John Cornish for relating their collecting experiences in the quarry. Special appreciation is given to Warren Sorenson for calling me to collect in the open pockets and for photo documenting the collecting. Thanks is also given to Randy Becker for reviewing this paper.

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## Zeolites from the Getchell Mine, Humboldt Co., Nevada

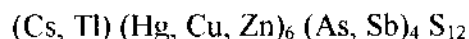
Don Howard

The Getchell Mine has long been a source of outstanding minerals. The most spectacular of these are the arsenic sulfides realgar and orpiment, which cover large portions of the dump. Many gorgeous crystals and groups have been found there. Craig Stolberg and Gail Dunning did a feature article on this material in the January/February, 1985 issue of the Mineralogical Record. This article included pictures of some of the rarer minerals, such as getchellite, lafittite, and galkhaite. A later article by Gail Dunning (July/August, 1988) added information about an array of secondary calcium arsenates, some of which are quite rare.

The Getchell Mine is an operating gold mine. Gold occurs there in micro-size grains throughout the sulfide-rich quartz matrix. It is quite difficult to obtain permission to collect anywhere in the mine. However, Joe Marty and Dick Thomssen were lucky enough to gain entry recently and collected some very interesting material from a small stope at about the 5000 ft. level.

The matrix is primarily a carbonaceous quartz material that is dark colored due to finely disseminated sulfide mineralization (marcasite, pyrite, arsenopyrite and magnetite). Fluorite, barite, and chabazite are also listed as being present. Until recently, chabazite was the only zeolite known to occur in the mine.

Joe and Dick worked an area where the openings in the rock were lined with small (up to a millimeter) crystals of stilbite. What was so unusual was that in many specimens, galkhaite crystals poked out through the interlocking layer of stilbite blades. Galkhaite is a rare sulfo-salt of cesium, thalium, and mercury:



The crystals are isometric, showing prominent cube (100) faces, often modified by (110) faces beveling the edges and (111) faces clipping the corners. Most galkhaite specimens found on the dump are black, since the mineral is light-sensitive like so many of the mercury minerals. In fresh material, the cubes are a rich dark red color. Since these specimens were taken from beneath the ground, the galkhaite retains its red color and contrasts nicely with the white stilbite. Late mineralization has added small sprays of shiny black needles of stibnite to some of the specimens. (Try saying that fast: *stibnite on stilbite*.)

It is unusual to find colored minerals associated with zeolites, and particularly unusual to find sulfo-salts and zeolites together. The specimens make attractive and unusual pieces to add to a collection. The location provides another really odd environment in which to find zeolites, and new associations that may very likely not be found anywhere else.

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## More Tungusite Localities in Southern California

Don Howard

In the fall, 1996 issue of the *Microprobe*, we reported on an occurrence of the mineral tungusite in upper Malibu Canyon near the town of Agoura, Los Angeles Co., California. Tungusite is a mineral closely related to gyrolite in which ferrous iron takes the place of the sodium and aluminum. Like gyrolite, it forms radial balls of bladed crystals. However, the mineral is a dark green color instead of the white of gyrolite.

Since the time of the first article, more and better material has been found in the same general vicinity. Basalts containing zeolites occur not only in the canyon described in the first article, but also across Mulholland Highway to the south, and for several miles south along Cold Springs Canyon Road. Various zeolites are also found in the basalts of this area.

In one place along Cold Springs Canyon Road, the rock bank is laced with numerous veins, varying from hairline thin to ones up to a half-inch across. Many of these veins are completely composed of gyrolite. In others, the gyrolite occupies both sides of the vein, while the center is filled with pectolite. The pectolite has a rather granular texture, while the gyrolite always shows platy partings. Tiny green radiating spheres of tungusite, a millimeter or two in diameter, sometimes line the very edges of these veins against the matrix rock. Occasionally, the green tungusite forms the center region that grades into whitish gyrolite in the outer portions of the rosettes. Much of the gyrolite has a greenish hue, indicating either intergrown tungusite, or more likely a percentage of iron substituting for the aluminum in the gyrolite crystal lattice. There do not seem to be any zeolites present in the rock associated with the veins.

All of the above sites are located in Los Angeles County. To the west, just across the county line into Ventura County, truly fine specimens of tungusite have been found just to the north of U.S. Highway 101. The locality is on the outskirts of the town of Newbury Park. In fact, it is comprised of a low hill directly behind a residential neighborhood and an industrial park. For some reason, the hill has a single terrace graded around it, and this has exposed the rock on the southern end.

Tungusite is a major constituent of this rock. It often forms rosettes up to a quarter of an inch in diameter that are a dark shiny green. In the showiest specimens, it forms in the vicinity of white cavity fillings, but many concentrations are virtually pure tungusite, showing as a lighter green in contrast to the rather bluish rock. Quartz regions are rather common, but only occasionally do they open up enough to show crystal faces; for the most part they are glassy and solid. Whiter regions appear to contain varying amounts of mordenite, much of which is so altered that the normal needle structure has been obliterated. In addition, cavities occasionally show crystals of apophyllite and chabazite, which may also be mostly altered, to quartz.

Tungusite, even the well-formed balls at the Newbury Park site, are always embedded and therefore do not show terminations on the surface of the balls. Very rarely a ball that is in the granular region of altered mordenite will show some of the roughened surface. The morphology of the crystals has not, therefore, been studied, but is assumed to be the same as gyrolite.

Weathered surface rock can be peeled off rather easily at Newbury Park, but a few inches down it is very tough and difficult to work. Almost every piece in this area contains tungusite,

and outstanding specimens can be removed with a little work. As long as the area remains undeveloped, it is an outstanding source of a rare mineral that can be very easily accessed. Where but in Los Angeles can you park on a city street in front of peoples' homes, walk a block, and scoop up unusual minerals?

The rock in both areas is believed to be a basalt that was poured into shallow, fresh-water basins. A distinct pillow structure is not present, and considerable altering has occurred. We need to be alert to similar situations, particularly in basalts of the coastal range of mountains that may have formed under similar conditions.

Tungusite clearly forms in areas deficient in aluminum. The associated minerals, such as apophyllite, are also aluminum deficient, and the zeolites such as mordenite are silica rich. Tungusite is almost surely a rare mineral mainly because it was originally poorly described. Green minerals in rocks can easily be overlooked on the assumption that they are a clay, a chlorite, or possibly celadonite. Since such minerals are seldom showy, we tend to ignore them and do not bother with an analysis of x-ray. At least at Newbury Park, the tungusite is showy enough to warrant a second glance.

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## FIGURE CAPTIONS

*Photograph Number is on the back in the upper left corner.*

- #31 Thomsonite on Celadonite on Heulandite (x10)**  
**Neer Road, Goble, Columbia Co., Oregon**  
Green tufts of needles, some free (left), some beneath the balls of thomsonite. The color is much more intense on the tufts that are embedded.
- #32 Celadonite (x1.5)**  
**Little Jack Falls, Columbia Co., Oregon**  
Every cavity is lined with a layer of bright green celadonite, giving the rock a polka-dot appearance.
- #33 Calcite on Natrolite (x0.5)**  
**Weyerhauser Lincoln Creek Quarry, Lewis Co., Washington**  
Brown calcite rhombs surrounded by long natrolite needles.
- #34 Apophyllite on Natrolite (x 3)**  
**Weyerhauser Lincoln Creek Quarry, Lewis Co., Washington**  
A close-up showing the tiny clear apophyllite frosting the natrolite needles.
- #35 Galkhaite on Quartz (x7)**  
**Getchell Mine, Humboldt Co., Nevada**  
Dark red interpenetrating cubes with slightly beveled edges.
- # 36 Stilbite on Galkhaite with Stibnite (x10)**  
**Getchell Mine, Humboldt Co., Nevada**  
Drusy of thin blades of stilbite coating quartz. The galkhaite cluster just to the left of Center has a small rosette of stibnite needles on the top of the front face..
- # 37 Tungusite in Quartz and Mordenite (x6)**  
**Newbury Park, Ventura Co, California**  
Radiating green sprays of tungusite, similar in form to gyrolite balls. The whitest areas are an altered mordenite, while glassy regions are quartz.

### PHOTO CREDITS

#31, 32 & 37	Photograph & Specimen	<i>Don Howard</i>
#33 & 34	Photograph & Specimen	<i>Rudy Tschernich</i>
#35 & 36	Photograph	<i>Don Howard</i>
	Specimen	<i>Joe Marty</i>

