NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

JUNE MEETING ANNOUNCEMENT

DATE: **Wednesday, June 27, 2001**

LOCATION: **Orinda Masonic Center, 9 Altarinda Rd., Orinda**

TIME: **6:30 p.m. Social; 7:00 p.m. talk (no dinner)**
Cost is $5.00 per person

RESERVATIONS: Leave your name and phone number at 925-294-7530 or by e-mail at dday@nrmc.com **before the meeting.**

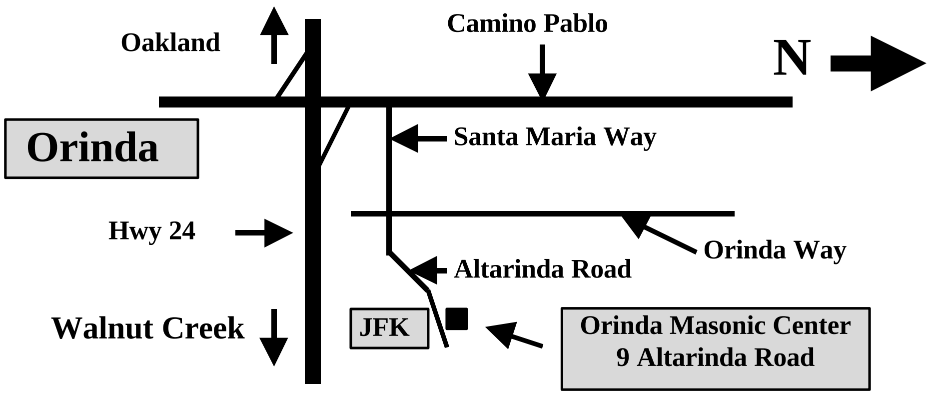
SPEAKER: Dr. Bruce E. Jaffe, U.S. Geological Survey Pacific Science Center, University of California, Santa Cruz

Mercury-Contaminated Sediments in the North Bay— A Legacy of the Gold Rush

A legacy of the Gold Rush is mercury-contaminated sediments in the Bay. Miners used mercury to extract gold from tailings during the gold rush. A large amount of this mercury (some estimates are as great as 10,000 tons) was lost during extraction to the watershed during the gold rush era. This mercury-contaminated hydraulic mining debris made its way to the Bay. Concentrations of mercury in this sediment are greater than 0.3 ug/g, which is a significant increase from the reported background level of 0.1 ug/g. The mercury in the debris was originally was elemental mercury, which is easily converted to a toxic form, methyl mercury. Questions remain about how much of this mercury is still in the Bay, where it is, and whether it is buried or is near or at the surface of the bay floor where it is potentially dangerous to fish, birds, and other wildlife.

These questions can be addressed using historical hydrographic surveys of the Bay and analyses of cores of the Bay's sediments. Surveyors repeatedly charted the Bay for to identify navigation hazards taking tens or hundreds of thousands of depth soundings during each survey. These detailed historical hydrographic surveys can be compared using surface modeling software to reconstruct patterns and quantities of deposition during the period when mercury-contaminated hydraulic mining debris was entering the Bay. In the North Bay alone, more than 400 million cubic meters of sediment was deposited during the hydraulic mining era. Over 75% of the North Bay was covered with these contaminated deposits, some thicker than 5 m. Reconstructing patterns of deposition or erosion subsequent to this influx using more recent hydrographic surveys identifies areas where the mercury-contaminated hydraulic mining debris is now capped by recent sediments (and presumably not bioavailable) or is at or near the surface. It can also identify potential mercury hot spots.

Continued on back page of the newsletter



A preliminary model animating the time-history of the 3-D distribution of the mercury-contaminated hydraulic mining debris in the North Bay will be presented. This and subsequent models will improve the understanding of mercury distribution and guide decisions about activities, such as dredging and wetland restoration, that could disturb and redistribute this material and worsen the mercury problem in the Bay.

Dr. Bruce E. Jaffe is with the U.S. Geological Survey Pacific Sciences Center at the University of California, Santa Cruz. He received his B.S. in Earth Sciences from U.C. Santa Cruz in 1980, an M.S. in Geological Oceanography from the University of Washington in 1983, and a Ph.D. in Earth Sciences from U.C. Santa Cruz in 1993. He has been a Research Oceanographer, U.S. Geological Survey, Western Coastal and Marine Geology, since October 1983, where he has conducted research on nearshore sediment transport, long-term coastal change, coastal erosion, nearshore processes, tsunami sedimentation, and landslide hazards. His research focus is coastal geologic and physical processes, emphasizing the use of modeling to better understand field data. In recent years Bruce has focused his research on modeling and understanding the geologic record of catastrophic events (e.g., hurricanes and tsunamis). He has studied coastal areas on the Pacific, Atlantic, Gulf, and Great Lakes coasts of the U. S., as well as areas in Puerto Rico, Samoa, Hawaii, Java, Papua New Guinea, and Guam. His current work stresses historical sediment transport, sedimentation, and coastal change; paleotsunami interpretation and sediment transport; and nearshore sediment transport and hydrodynamics.

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The Case of the Curious Student

It happens to instructors all the time. The field trip you are leading is coming to an end and the class has gathered on the final outcrop. You make your closing comments and nonchalantly utter that fateful phrase "Any questions?" As if prodded on by mischievous fellow students, a voice pipes up and asks "Professor, what is that?" pointing to some obscure feature on the outcrop. If you happen to be **Dr. David Mustart** of San Francisco State University you respond "Well, I really don't know…" and embark on a 16-year quest find out just exactly what that darned thing really is!

At the May 30th NCGS meeting, Dr. Mustart presented the audience with his findings in the talk ***"Hydrothermal Pipes in Three Granitic Plutons of the Tuolumne Intrusive Suite, Sierra Nevada Batholith, California."*** Dave's casual and often humorous presentation style provided a truly enjoyable glimpse at these rather unique and subtle plutonic rock features that are readily accessible to anyone traveling Highway 120 along Tenaya Lake in Yosemite National Park.

The background for this topic lies rooted in a classic study of the Tuolumne Intrusive Series in the eastern half of Yosemite National Park. The defining study of this plutonic sequence was done by Paul C. Bateman of the USGS, Menlo Park. For those not familiar with Bateman's work, he is one of a handful of geologists who have spent their lifetimes characterizing the geology and petrology of the Sierra Nevada Batholith. His contributions are many, and this particular work on the Tuolumne intrusive series that Dave used as his reference can be found in the article by Paul Bateman and Bruce Chappel (Australian National University) entitled *Crystallization, fractionation, and Solidification of the Tuolumne Intrusive Series, Yosemite National Park, California* in the Geological Society of America Bulletin, Part 1, vol. 90, pp. 465-482, May 1979. This outstanding work describes the various intrusive events that define the igneous units where the hydrothermal pipes were found. Dave used this treatise to locate the position of hydrothermal pipe features with respect to the regional geology.

Dave and his student assistants have described over the interim over 600 features that he has interpreted as hydrothermal conduits closely associated with pegmatite veining in the host granitoid rocks. These unique features consist of circular to subcircular concentric structures with raised, silica-rich rinds in sharp contact with the granitic host rock, and surrounding recessed, often strongly weathered mafic (containing iron and magnesium-rich dark minerals) cores. His observations have led to the conclusion that these features are NOT weathering pits, erosional features like potholes, or miarolitic cavities (segregation pockets in igneous rocks that are frequently lined with faceted crystals that grew inward from the walls of the cavity into a central void). Dr. Mustart's interpretations draw heavily on his graduate experiences with mentor Dr. Richard Jahns of Stanford University. Dick was a world-renowned expert on pegmatites, igneous dike rocks and segregations commonly but not exclusively associated with granitic rocks. Jahns concluded that pegmatites are formed from an aqueous fluid phase that separates from plutonic rocks late in their crystallization, and fills fractures or occurs as very coarse crystalline pockets that are sought after for their semi-precious and gem-grade minerals. Such a deposit is the famous Pala pegmatites in the Southern California Batholith that Jahns used to develop his theory of pegmatite genesis. Jahns invoked aqueous-rich fluids as the source of the pegmatites, whereas researchers at the University of Oklahoma thought these extremely coarse crystalline dike rocks were formed from a quenched glass phase that subsequently devitrified (precipitated crystals from the solid state). The association of very coarse crystalline hydrous minerals with the pegmatites would argue against the devitrification theory, and is favored by Dave's work on these zoned pipes.

The Tuolumne Intrusive Series consists of four approximately concentric and obviously genetically related plutonic events. The first and outermost intrusion is the more mafic Kuna Crest Diorite. It was intruded by the volumetrically largest intrusive, the Half Dome Granodiorite, followed by the Cathedral Peak Granite and the final stage (and smallest intrusive) Johnson Granite Porphyry (contains a population of coarse crystals--phenocrysts--in a much finer-grained groundmass). The Half Dome Granodiorite has 366 known pipe-structures, the Cathedral Peak Granite has 44, and the Johnson Granite Porphyry only 6. The initial work on these pipes was conducted between Olmstead Point and Tenaya Lake on Highway 120, where Dave and his students did detailed mapping of well-exposed granitic dome surfaces. Above Olmstead Point they found 35 pipe-shaped structures from 0.1 to 4.5 meters across, and mapped 15 small aplite (very fine-grained granite) dikes. At one location they found a small pegmatite dike and following it upslope, discovered two pipe structures. Ultimately 17 pipe structures were discovered in this area either directly on or with a meter of pegmatite dikes. When Dave and his students returned to make detailed maps of the pipe locations, an additional 47 were found, all associated with or in close proximity to pegmatite dikes. Another study area off Highway 120 yielded 55 pipes, but none were associated with the aplite dikes.

The pipe structures occur in a granitic host rock, such as the Half Dome Granodiorite, which has an average plagioclase feldspar composition of 30% anorthite ($CaAl_2Si_2O_8$) and 70% albite ($NaAlSi_3O_8$), categorized as oligoclase in the albite-anothite series. The outer rinds are usually less than a foot thick and are mostly quartz, sericite (fine-grained muscovite) mica, potash feldspar compositions with minor clinozoisite (epidote) and chlorite. The mafic cores have albite feldspar surrounded by a groundmass of epidote and spherulitic (minerals radiating outward from the center of a sphere) chlorite. The epidote/clinozoisite is a hydrated calcium aluminosilicate and the chlorite is a complex mafic micaceous mineral. This type of mineralogical zonation has been reported in the Bushveld Complex in South Africa, and exhibits the same spherulitic chlorite structure. Some of the mafic cores have a microbreccia texture (fine fragmented structure) that would imply forceful fluid flow through the orifice, as would be expected in a supercritical aqueous fluid streaming through a partially solidified "crystal mush." Look at a pan of rice being cooked when it is almost done, and note the little steam "fumaroles" escaping through the mass of rice grains. This simplistic analogy can be applied to Dr. Mustart's hydrothermal conduits in these granitoid rocks.

The Yosemite study indicated that the Half Dome Granodiorite contained over 85% of the identified hydrothermal pipes, the Cathedral Peak Granite about 12%, and the Johnson Granite Porphyry only 1.5%. This local distribution merited further examination on a regional scale. Fortunately, extensive work has been done on mineralogical geobarometry, an important depth-of-emplacement indicator, using chemical variations of key minerals. The aluminum-hornblende geobarometer (horneblende is a member of the amphibole silicate group) has been applied to numerous plutons in the Sierra Nevada and Southern California Batholiths. Results indicate that the Tuolumne Series is a very shallow (4 to 9 km. deep) intrusive complex (epizonal level), whereas the southern Sierra Nevada plutons were emplaced at depths of 14 to 19 km. And the Southern California Batholith was intruded at even greater depths of 18 to 23 km. The shallower epizonal level plutons allow aqueous fluid phases to accumulate and intrude the last crystallizing magma residua as volatile-rich pegmatite veins and dikes. Dave also discovered a few hydrothermal pipes in Joshua Tree National Monument granites. One of these structures was eroded in a fashion that exposed its 3-dimensional shape, which finally confirmed his hypothesis that these are indeed cylindrical pipes. He also envisions these structures as ultimately connecting with breccia pipes for volcanic eruptives and as feeders for shallower level hydothermal ore deposits. Unfortunately, erosional activity removes the overlying "plumbing system" and hence removes the evidence that would link these various vertically distributed zones of igneous activity. But Dave is still intrigued with the possible occurrence of these features elsewhere, and has looked for them in the granites of western Texas. An audience member recalled seeing similar structures in epizonal plutons of the Idaho Batholith, a terrain that Dr. Mustart has not yet explored. An interesting observation is the association of these pipes with I-type subduction-derived granites in these 86 million-year-old (Upper Cretaceous) Tuolumne series rocks.

So what began with a simple question has become an on-going study to better understand the subtle features of late stage granite crystallization. The ultimate goal is to discover how they are associated with volatile phase migration and the genesis of ore-bearing fluids. Good luck with your search, Dave! You now have several eager NCGS members who are keeping their eyes peeled for these pipes as they head for the central Sierras to escape the chaos of Bay Area life! We all wish to thank Professor David Mustart for discussing this intriguing igneous phenomenon that has been overlooked by Sierran geologists until recent times.

As a footnote, an excellent article on pegmatites in San Diego County appeared in the January/February 1999 issue of *California Geology*. To obtain a copy of this issue call the California Division of Mines & Geology, Publications and Information, at **(916) 445-5716**.

Scholarship Recipient Presents Research on Silicic Volcanics in Berkeley Hills

Year 2000 NCGS scholarship recipient **Lin Murphy** presented a poster exhibit update of her work on ***Silica-rich Volcanics of the Berkeley Hills*** at the May 30th NCGS meeting. Lin, a student of **Dr. Sue Hirschfeld** at California State University, Hayward, chose to study these problematic siliceous volcanics as part of her graduate research at CSUH. Lin was kind enough to share the status of her research with NCGS members.

The two key outcrops that she examined, the areally restricted Northbrae rhyolite outcrop and the more extensive Leona Rhyolite, are collectively part of silica-rich suite of volcanics scattered throughout the Berkeley Hills. These volcanics have been mapped as Tertiary or Quaternary by Dibblee (1980), Knox (1973), Radbruch (1969), and Robinson (1956), but are now considered Upper Jurassic (Jones and Curtis, 1991). California Division of Mines & Geology maps of the San Francisco-San Jose Quadrangle (1991) depicts the rocks as "rhyolite of uncertain age," and assigned them to the Coast Range Ophiolite. The work of Graymer et. al. (1996) at the USGS, Menlo Park, however, refers to them as volcanic keratophyre and quartz keratophyre overlying the Coast Range Ophiolite (see USGS Open File Reports 94-662 and 96-252). Early Bay Area geologist Lawson (1914) dubbed the Berkeley Hills rhyolites "Northbrae" and "Leona" rhyolites after the communities where they are exposed. Lawson had considered the Northbrae outcrop as a flow-banded subset of the essentially featureless Leona rhyolite and had assigned a Plio-Pleistocene age to them. The Leona rhyolite is difficult to characterize because it is highly fractured, weathered, lacks any distinctive textures, and is altered. The Northbrae Rhyolite of Indian Rock Park, Great Stone Face Park, and smaller outcrops in nearby neighborhoods has distinctive flow-banding and autobrecciated flow-banded and nonflow-banded clasts pointing to an origin as a lava flow or dome. Lin's chemical studies of the flow-banded Northbrae rocks and Leona Rhyolite samples from Tunnel Road and Alvarado Park show a distinctively higher potash (K_2O) content for the former, as well as trace element features that distinguish it from the Leona rocks.

The questions that Lin wished to address were: 1) Do the Northbrae and Leona Rhyolites share the same origin as keratophyres in the underlying Coast Range Ophiolite?; 2) What is the relationship between silica-rich rocks at Cragmont Rock Park and the Northbrae Rhyolite?; and 3) What are the implications for the tectonic history of California's Pacific margin if the Leona, Northbrae, and Coast Range Ophiolite keratophyres DO NOT share the same petrogenesis? Keratophyre samples from the Coast Range Ophiolite at Del Puerto Canyon south of Livermore and Tracy in the northern Diablo Range was used for comparison. Thin section examination supported the macroscopic interpretation of the Cragmont Rock and Indian Rock outcrops as autobrecciated flows, devitrified intrusive material, and silicic volcanic debris that has undergone intense silica alteration. None of the brecciation, flow-banding, spherulitic, or silica replacement textures was seen in the Leona Rhyolite from Tunnel Road and Alvarado Park outcrops, or in the Del Puerto Canyon keratophyres. These observations imply that the Northbrae and Leona Rhyolites in the Berkeley Hills may have had different petrogenetic histories.

Lin sampled the Northbrae Rhyolite in five locations, the Leona Rhyolite at Tunnel Road and Alvarado Park, the Del Puerto Canyon quartz keratophyre, and two samples representing clast and clast-matrix composite from Cragmont Rock Park. Geochemical data was plotted to determine tectonic setting and petrogenetic relationships between the samples (based on extensive databases of rock chemistries from known tectonic regimes). In situations like this, where field evidence and whole rock major element chemistries of samples are not definitive petrogenetic indicators, one has to rely on minor and trace element differences to determine origin. Lin plotted soda (Na_2O) versus potash (K_2O), rare earth element (REE) profiles, and selected trace elements (Hf, Th, Ta, Nb, Y, and Yb) for the Northbrae (Indian Rock), Leona (Alvarado Park and Tunnel Road sites), Cragmont clast and clast + matrix composite, and the Del Puerto Canyon quartz keratophyre (representative of Coast Range Ophiolite silicic volcanics. The soda versus potash plot showed the Northbrae (Indian Rock) site to contain roughly equal amounts (~4.5%) of K_2O and Na_2O, the Leona samples to be enriched in Na_2O but depleted in K_2O, the Del Puerto quartz keratophyre to be highly depleted in K_2O but to have the same soda content as Indian Rock, and the highly silicified Cragmont Rock samples to be very low in K_2O and Na_2O. The REE diagram plots the ratio of the whole rock lanthanum (La) through lutetium (Lu) series of fourteen elements to those values for chondritic meteorites. It is likewise considered a petrogenetic indicator. The Leona Rhyolite samples and the Del Puerto Canyon keratophyre have flat REE plots with 5 to 10 times enrichment of each element over the chondrites; the silicified Cragmont Rock is depleted in light REE (LREE) and approaches the Del Puerto Canyon keratophyre and Leona Rhyolite ratios in the heavy REE; and the Northbrae (Indian Rock) sample is enriched in LREE over the heavy REE, and shows a distinct dip in the Eu (europium) value, as does the Cragmont Rock clast + matrix. Lin suggests that the Cragmont LREE depletion is due to silica dilution of minerals that concentrate the LREE. The REE evidence points to a common petrogenetic origin for the Leona Rhyolite and Del Puerto Canyon quartz keratophyre, and a different but common petrogenetic origin for the Cragmont Rock and Northbrae (Indian Rock) specimens assuming the Cragmont REE profile was modified (LREE depleted) by silica alteration. Th-Hf/3-Ta plots for these rocks, based on extensive petrogenetic provenance analyses reported by Wood (1980) and Rollinson (1993), interpret the Leona sites as volcanic arc origin, but also reveal the Del Puerto Canyon quartz keratophyre to have some anomalous trace element signatures that differ from other published data of Coast Range Ophiolite silicic rock suites (Jones, 1981). Pearce et. al. (1984) developed Nb-Y and Ta-Yb trace element plots to distinguish granitoid rocks from ocean ridge, volcanic arc, within-plate, and plate collisional tectonic settings. The Coast Range Ophiolite (Del Puerto Canyon) has been interpreted as having a supra-subduction zone (SSZ) or volcanic arc origin by Shervais (1990), and this is confirmed by their extremely low (0.05 ppm) yttrium (Y) values. The Indian Rock site plots as an anomalous ocean ridge silicic volcanic.

Lin's work also indicates that the Northbrae outcrops are distinctive in terms of their alkali contents (Na_2O and K_2O), and are actually "sandwiched" between Leona-type silicic volcanics depleted in K_2O. Her REE and trace element analyses indicate the Leona Rhyolite and Coast Range Ophiolite keratophyre/quartz keratophyre silicic volcanics came from a plate collisional-volcanic arc tectonic origin. The different REE patterns for the Northbrae and Cragmont Rock samples could be due either to magmatic differentiation or to silicification (Cragmont Rock). If the silicic alteration is not the cause of the different REE features, then the hypothesis that both locations are part of the same silicic flow or eruptive must be dismissed. The trace element geochemistry is nevertheless consistent with the interpretation that these are Franciscan Complex rocks transported to the Berkeley Hills by subduction accretionary processes that predated the current Pacific Plate. A possible tectonic analogy for these rocks would be the marine rhyolites of the Izu-Bonin Arc/Sumisu Rift system. Future work will focus on clarifying some of the questions that raised by the results of this petrographic and geochemical study.

The NCGS sincerely thanks Lin Murphy and Dr. Sue Hirschfeld for displaying the results of this study at the May 30th NCGS meeting. Lin's work on these unique silicic volcanic rocks is an important piece to the tectonic puzzle of the Berkeley Hills. It is interesting to note that this kind of study has not been done on these outcrops even though they are physically recognizable features in several public parks. We wish Lin our best with her continuing research of these outcrops, and encourage members to visit her and Dr. Hischfeld's web site at **http://eqdoc.home.netcom.com** to see a more detailed description of this study including site photographs, photomicrographs, and trace element plots.

NCGS May Fieldtrip: The Golden B.E.A.R.* Tour 2001 (Blueschists, Eclogites, Amphibolites and Refreshments)

article by **Elizabeth A. Gordon**

Once again **John Wakabayashi** led geologists and friends on an interesting fieldtrip through some of the most beautiful terrane of central California, **The Golden B.E.A.R.* Tour 2001** was a two day trip sampling **Blueschists, Eclogites, Amphibolites and Refreshments** (brewpubs) in the Franciscan Complex of the central California. If you didn't make this tour, you missed something special. About 30 people came for the sites and tastes available from the spectacular Tiburon Peninsula to localities near Santa Rosa, Lake Sonoma, and Jenner. While the field guide discussed the importance of geology on flavoring local brews, John emphasized the necessity of drinking brew in order to fully comprehend the complex field relationships of these fascinating rocks. Wisely, John scheduled viewing and collecting stops at the first outcrops each morning, saving the more mundane outcrops and those most difficult to understand for study after appropriate refreshment.

Saturday's first stop on the Tiburon Peninsula involved a quick, steep hike to breath- taking views overlooking the Bay. Non-Californians were ecstatic over the blueschists and eclogites, having previously seen these rocks only in the lab. John gave a synopsis of the blueschist facies associations in the Franciscan complex, explaining how the rocks on this tour reflect unique aspects of the tectonic history of subduction in this region of California. He discussed two types of blueschists within the Franciscan Complex, each with different origin and history: relatively fine-grained "coherent" melange (metagraywackes, metashales, cherts, metabasalts, and serpentines, which constitute the basic mapable thrust sheets; and coarse- grained exotic blocks or "terranes" (metabasalts, metacherts), which represent garnet-amphibolite to granulite grade slabs that were later overprinted by blueschist to eclogite metamorphism. Blocks, frequently contained within melange, are particularly unusual because Franciscan blueschists are considered colder than most blueschist rocks; thus, any explanation of their origin must account for their original high temperature features.

John pointed out that Tiburon "blocks" are notable for their unusual history of counterclockwise metamorphism: amphibolite → blueschist → prehnite-pumpellyite facies. Originally formed at high grade, the garnet-hornblende schists yield hornblende age-dates of ~160 Ma, recording a high temperature thermal event at that time. Apparently equivalent coarse-grained blocks elsewhere in the Franciscan (Pacheco Pass, Clear Lake) contain xenoliths up to granulite grade. The coarse-grained blocks everywhere yield radiometric age-dates marking a major thermal event ~160 Ma. Since these oldest metamorphic ages are only a hair younger than the Coast Range ophiolite, they likely record the first gasp of subduction. Bluish glaucophane and green omphacite rims on hornblende grains at the Tiburon outcrops record post-thermal blueschist metamorphism, indicating a "refrigeration" effect during subduction and after the initial thermal event. Wide ranging age-dates on white micas from the blueschists record a long period of blueschist metamorphism from ~158 Ma to 80 Ma. Lack of greenschist overprinting on these rocks suggests temperatures remained cool, perhaps due to continuous rather than episodic subduction.

Hiking over the hill crest to examine more blocks of blueschist and eclogites, it was hard for some to not collect specimens from this fabulous nature preserve. Fortunately, the sunny, cool, windy hilltop quickly drew thirst, so that the group headed back to the bus and on into Larkspur to the **Marin Brewing Company**. Comments on the brews are absent, as the person writing this wasn't able to imbibe. The first pub stop seemed designed to help folks sleep through a very long, slow drive along crowded 101 to Healdsburg. Following lunch at the **Bear Republic Brewing Company**, another long drive led to roadside outcrops of the Skaggs Spring Schist high above beautiful Lake Sonoma.

The Skaggs Spring schist is part of a 70-km long belt of coherent blueschist facies, up to 3-4 km wide locally, that consists mainly of metagraywacke completely recrystallized to silvery gray and bluish gray rocks. Although nowhere near as impressive as the coarse-grained exotic blocks, this coherent blueschist outcrop nevertheless is distinctive: visible grains of glaucophane and lawsonite occur in outcrop and jadeite is reported in thin sections. A few float samples showed nicely weathered garnets, although there was some debate about the occurrence of garnets *in situ* within the outcrop. This particular roadcut lies structurally near the top of the pile, and is superimposed on much lower pressure rocks. John began discussion here by saying, "We see this stop after beer because it's more interesting this way." Perhaps beer also aids understanding of various complex structural theories proposed, which attempt to explain the existence of high pressure blueschist rocks on low pressure sequences, and the absence of expected intervening metamorphic units. A synopsis of
John's presentation:

<u>Interpretation of the Franciscan Blueschists</u>

In the beginning (150 to 160 Ma), eastward subduction occurred underneath a trapped piece of hot ocean crust, which later became the Coast Range Ophiolite. Initial subduction beneath hot, young ocean rocks overlying suboceanic mantle caused the subducting slab to heat to high temperatures resulting in metamorphism to amphibolite or granulite grade. Little sediment were associated with the young ocean crust, thus the earliest rocks subducted were likely basalts and cherts, which became heated to high grade due to residual heat from suboceanic mantle. As subduction continued, heat quickly dissipated so that a refrigeration effect controlled thermal regimes within the subduction zone. Refrigeration induced blueschist metamorphism at depth, overprinting the early-formed amphibolite rocks, which were later exhumed towards the surface. In time, graywackes, cherts and muds accumulated on the seafloor, which were dragged into the subduction zone and transformed into melange of the Franciscan coherent blueschist facies. As subduction continued refrigeration prohibited heating of these rocks at depth, resulting in the development of the distinctive high pressure blueschist minerals (glauconite, lawsonite, jadeite) which give these rocks their unique character.

John discussed several theories that have been proposed to explain how the high pressure (~30 km) rocks rose to the surface to become juxtaposed on low pressure (10 km) units. The high-P exotic blocks are widely assumed to move by diapirism along shales and serpentinites, or by sliding through melange channels. More difficult to explain is how relatively immobile coherent blueschist rocks moved to the surface. While field relationships show deep (30 km) blueschist rocks structurally superimposed on low pressure (10 km depth) rocks, perhaps more enigmatic is the absence of intervening units representing the 10 km to 30km facies. Since the high pressure rocks occur at all structural levels, any explanation of their origin must account for this apparent random distribution. Many of the blueschists occur within structural shear zones dated at ~90 Ma, related to uplift of the area. According to John, most previous studies of these rocks have focused on what happened to the blueschists after they got to their present positions. Thus John believes the problem of their origin has been incorrectly defined. "The Problem is: how do very deep rocks get up to the same locality as lower pressure rocks? how does an intact unit of high pressure rock get up to the surface? Rocks not down more than 10 km are directly on top of rocks that were metamorphosed at 30 km. What happened to rocks representing 10 km to 30 km depths?" An important (but not unique) aspect of the Franciscan is lack of any greenschist overprinting, which suggests that subduction was continuous rather than episodic. John proposes that the upward journey of blueschists from ~30 km deep occurred while subduction was active, although age-dates are still needed to better constrain the timing of structural deformation. John's idea requires simultaneous movement along opposing structural thrusts above and below the blueschists, which may be brought to the surface by underplating on overlying, westward-moving thrusts. Simultaneous thrusting in opposite directions above and below the blueschists therefore provides a new mechanism to "extrude" deep material towards the surface. An important aspect of this model is that it can account for the absence of intermediate (10 to 20 km) metamorphics at the surface, without having to evoke massive erosion, as other models suggest. John's model also precludes the need to explain absence of widespread ultramafics from the Franciscan, which would be expected if the rocks were pushed upwards by extension and normal faulting.

Perfect cool sleeping weather and an astounding banquet accompanied overnight camping at Spring Lake Campground in Santa Rosa. The generous efforts of **Keil Albert** and **Rob Nelson** resulted in a truly gourmet meal of barbecued chicken, hot dogs, garlic bread, seasoned roasted squash and tomato-halves, potato salad, cookies plus an assortment of beverages. Following dessert (who had room for it?), John broke out his private selection of homebrews for "The Brew Tasting Event." Plenty of sipping was enjoyed by all.

Sunday morning started strong with **Tridib Guha's** traditional boiled coffee, and doughnuts and pastries provided by **Phil Reed**. A relatively short drive through the winding Russian River Gorge led to Jenner, where the group scrambled down a seacliff to the shore, waking beach campers with the sound of rock hammers banging on exotic blocks. This stop was "The Crown Jewel" for most of us, being a place to actually collect specimens of these spectacular coarse-grained blueschists as well as sphene-bearing omphacite-garnet eclogites.

Exotic blocks at this locality near Jenner lie within a structurally low melange zone, opposite the situation at Tiburon. While some petrographic studies show the same counterclockwise P-T path preserved at Tiburon, there are additional, more complicated deformational and metamorphic crystallization events, which indicate a far more complex history. John cites studies that propose similar blocks may have been exhumed early on, eroded and resedimented into the trench, then later resubducted with the associated melange.

Following a short drive to Occidental, the group examined intact coherent blueschist facies rocks typical of Franciscan metabasalts. This outcrop probably correlates with undeformed blueschists near Ward Creek, At first glance these rocks appear to be simple metabasalts. Closer examination reveals thin purple-blue stringers, the only field evidence here of blueschist metamorphism. John reports that elsewhere, similar metabasalts contain pillow lavas with blue rims, where glaucophane developed in Na-rich reaction rinds that formed when the pillows originally erupted into seawater.

The **Powerhouse Brewing Company** in downtown Sebastopol renewed some of the energy sapped by rising temperatures. What began as a cool, breezy field excursion quickly turned hot. Following lunch, a stop at the Atherton Road Exit near Novato completed the picture of the great variety of Franciscan blueschists. The Atherton outcrop shows coherent blueschist facies rocks that are representative of most of the Franciscan. Not very impressive in the field, most of these rocks retain a primarily sedimentary character. Standing by the road, the rocks appear to be ordinary sandstones, A weak metamorphic fabric is visible only in fresh samples, where radiating lawsonite crystals can be seen with a hand lens, Thin sections show abundant jadeite pyroxenes, glaucophane and lawsonite. This locality typifies the majority of the Franciscan coherent blueschist facies, and underscores the necessity of careful field work on these rocks. When studying the Franciscan, it is imperative to recognize the signs of blueschist metamorphism on what, at first glance, may appear to be simple melange sequences. John notes: "most that is blueschist is not blue nor schist." Temperatures rose to the mid-90's, thus most probably welcomed the final stop at **Moylan's Brewery** in Novato**.**

The NCGS extends sincere thanks **John Wakabayashi** for putting together this dynamic field trip. Special thanks for the collection site at Jenner and for the thorough overview of a wide range of blueschist facies rocks. Kudos and thanks go to **Keil Albert** and **Rob Nelson** for an exceptional barbecue, and to **Tridib Guha** and **Phil Reed** for the coffee, breakfast treats, and organizational assistance.

Editor's note: I can appreciate the work that went into this excellent field trip write-up. A debt of gratitude goes out to NCGS member **Elizabeth Gordon** *for preparing this enjoyable narrative of the* **Golden B.E.A.R. Tour 2001**!