Dale Pendell: Tracing the Pluton

I. The Smell of Freshly Broken Rock

The rock was so hard that my first two blows had bounced off and my ears were ringing from the impact. I put down my rock pick and walked to the tool shed and pulled out my heaviest singlejack. The sample wasn't even that big—fist-sized, and pale and rounded and slightly oblate. It was from the Yuba River.

I wore gloves and safety goggles, cradled the sample into a depression in the bedrock, and then swung with both hands. It cracked, and small pieces flew off ten feet in several directions. I should have wrapped it in a cloth. And then I caught the smell.

It was a hot, burnt smell, maybe with a touch of ozone, like what one smells around electric trolley cars. Cast iron can have a similar smell, just when it begins to glow, but this was not a smoky smell. It was the smell of a fire locked in rock, a big and very hot fire—not the smell of hot lava but the smell of rock at the moment of its birth, when it cooled and crystallized, when high heat was still a fresh memory. And it was a smell I knew and remembered—one of my own earliest memories.

I went to grammar school in eastern San Diego, out near 54th St., and was allowed to walk home from school on trails through the canyons. The canyon trails were through chaparral: sumac and scrub oak, California sagebrush, California buckwheat, black sage, purple sage, white sage, and a few cacti, including some cholla—I learned the plant names when I was older.

In the 1950s the canyons were still pretty wild: owls, coyotes, roadrunners, rabbits, quail, tarantulas, trap-door spiders, and several kinds of lizards and snakes, including rattlers. I caught alligator lizards and king snakes and, once, a baby brush rabbit.

In the past fifty years, except for the very steepest slopes, those canyons have all been terraced and sub-divided and developed into cul de sacs. I don't think many kids have wild canyons to walk home through anymore. (Or, even if they did, parents who would allow them to walk a mile alone by themselves.) For me, though, they were a great gift. The "Canyon" was my favorite place to hang out, the inspiration for much of what I pursued in later life, and the source of my spiritual beliefs. It was a huge geography for a child, filled with distinctive places, most of which were named. There was The Cliff, The Slide, The Big Fort, The Six Cactuses, The Island, The Plateau, The Big Ravine, The Thicket, and a dozen others that I can't remember. At the bottom of the canyon was The Stream.

"The Stream" was a creek bed, dry unless it was raining, which was almost never. At a couple of places the floor of the canyon was wide enough for the streambed to split and flow around small terraces or alluvial beds--("The Island" was one of those terraces that lasted long enough to be named). A few small willows clung to a battered life, enduring the pelting and smashing of rocks during the handful of rainstorms that annually caused the stream to roar and overflow its banks.

The streambed was filled with rocks, and almost all of them were rounded. There were baseball-sized rocks, basketball-sized rocks, and pebble-sized rocks. A few of them were spherical, but mostly they were ovoid or ellipsoid. They had all been in riverbeds before.

About a hundred yards up-canyon from the “Six Cactuses” (they were prickly pears) where I was collecting, there was “the Cliff” –a place the stream had cut into the side of the canyon. It was like a smaller version of the road cuts in Mission Valley, and like them was a rusty yellow-brown cemented sandstone conglomerate, with layers of river cobble sticking out of the matrix. This was the source of the rocks now being rounded yet again in the streambed.

The housing tracts and the commercial districts near 54th St. are built on Quaternary alluvial deposits, but these mesas rest on much older terraces that the canyon cut through—sediments hundreds of feet thick deposited and cemented forty million years ago in the Eocene. And the hard rounded rocks within the conglomerate are older yet, from strata metamorphosed at great depth and pressure, then raised up and eroded. The igneous mother rock was even older--formed in a mountain range, long since disappeared, hundreds of miles away in Sonora and transported to San Diego by a great Eocene river.

From the time I could print I had known several things about rocks. I knew that there had been a “Stone Age,” when we’d made all the tools we needed out of rocks—a simplification I still find appealing. And I had heard that there was fire in rock, that you could make sparks by striking two of them together, and that it was possible to start fires with those sparks—a fact, or mis-fact, I hoped to replicate. (My father had told me that the best way to make sparks was with flint and steel, but when I had asked, my mother and father had disagreed on what flint looked like, and what color it was. And using steel seemed like cheating. So I just used rocks.)

Like other kids in the neighborhood, I knew the names of a few rocks. Quartz was the easiest, though some of what I called quartz, especially the rounded cobbles from the streambed, I'm now sure were quartzite. But there was real quartz—and some big pieces. We recognized two sub-varieties of quartz: milk quartz and rose quartz.

I also knew sandstone and granite, but granite was in the mountains—there was no granite in the stream rocks. And I knew what mica was—but that was something one found in granite. Very rarely, there would be an irregularly shaped rock that was layered and sparkly like mica, but those rocks were too soft to last long in the streambed. Because the rocks in the stream bed were hard. Very hard. I knew because I would break them, or try to.

Sometimes I would start out with a "hammer" stone—usually something white or light-colored that I could wield with two hands-- and use it to try to break smaller rocks. Oblong pestle-shaped rocks I would try to break by holding on to one end and smashing them as hard as I could against a larger boulder. Sometimes, in desperation, I would just throw a rock against bigger rocks. And sometimes, the rock would break. And somehow, the fairies that guard children protected me from serious injury, because rocks and rock fragments would ricochet in all directions.

When a rock broke, however, a new world opened. The inside of every rock was different and each one was a new surprise. Some were all one color, and some were speckled. And I knew that each one must have a name. There were greenish rocks, translucent orange-brown rocks, white rocks, and bluish gray rocks. The fresh surfaces were sugary, or sparkly, or frosty—very rarely dull. Almost all of them were glassy in some way, even if only like an extra fine sandpaper is glassy.

There was a comfort in rock, and a satisfying heft. A rock was as close as you could get to what we were standing on. It was the earth-stuff at the same time it was other-worldly. I knew the rocks carried stories, that rocks were objects of power and imagination, and that humans had once lived much more intimately with them than we do now.

And when a rock broke I could smell that cold fire smell that had been sealed inside the rock for thousands or hundreds of thousands of millennia —what the rock smelled like when it was first born, on some continent that no longer exists, and for which we now invent names such as Gondwana, Pangaea, Laurentia, or Rodinia.

II. **Some Kind of Granite**

Like many Californians, I live close to rock. There are, for sure, valleys and river bottoms in California where the country rock is deeply buried beneath hundreds or thousands of feet of sediments. But in most of the state—any place the topography isn't flat--the bedrock is near the surface.

My own house in the Sierra foothills rests on rock, and large boulders and outcrops poke out of the surrounding terrain in all directions. Most of the land is hilly, and some of the exposed outcrops are large enough to be suitable for bouldering.

Moss and at least five species of lichen compete for the surfaces wherever rock is exposed, and undergo spectacularly colorful transformations with even a modest rain—the lichens pale green or blue-gray or orange or black, and the moss a deep vibrant green. Where the rock is bare it has a rusty look, the color of burnt sienna tinted with a touch of Chinese white. The soil, what there is of it, is thin, red, rocky, and with enough clay to be, in some places, nearly impervious. In the summer it's so hard a pick barely dents it.

Where the rock has cracked and a piece has broken off the surface shows a creamy gray matrix heavily speckled with black minerals. It was, I knew, some kind of granite. So I began to wonder about this rock that I walked over and around every day. I broke off samples from half a dozen locations around my house, and inspected them first with my hand lens, and then with a dissecting microscope. Under magnification the freshly broken surface of the sample was a landscape of high cliffs and jagged plateaus. There was white stuff and dark stuff. And in some of the samples, gray beads and particles of greenish-brown glass. What was this stuff?

I wasn't entirely ignorant of geology—in the sixties I'd had a mining claim in the Trinities, and I'd studied mineralogy with Robert Webb—the man who wrote the book on California minerals. But petrology is different. In a rock sample the minerals are merely grains—and the old field techniques of testing hardness, heft, streak, and cleavage were almost impossible to apply. Professionals use thin sections and polarized light.

Rock taxonomy is different from botanical systematics: plant species, at least in theory, are discrete entities—even if, in certain families, hybrids and intergrading are maddeningly common in the field. Rocks are a complete continuum. Sandstones grade into siltstones and shale, metamorphism varies from mild to extreme, and igneous rocks are defined by percentages of the half dozen rock-forming minerals they contain.

Granitic rocks (plutonic rock—magma that has cooled and crystallized still inside the earth, as opposed to extrusive volcanics such as basalt, and andesite) are defined on a triangle, where the three axes correspond to the percentages of alkalai feldspar, plagioclase feldspar, and quartz. An incomplete list, from quartz-rich rock to quartz poor, includes quartzolite, syeno-granite, monzo-granite, granodiorite, tonalite, quartz syenite, quartz monzonite, quartz monzodiorite, quartz monzogabbro, quartz diorite, quartz gabbro, syenite, monzonite, monzodiorite, monzogabbro, diorite, and gabbro.

Another way to sort plutonic rocks is from light to dark, which, in its simplest form, goes granite → diorite → gabbro. This one dimensional mapping is often extended to include peridotite at the dark end, and varieties like quartz monzonite and granodiorite at the light end, and is much more effective than it has any right to be. The light to dark axis is simultaneously the “felsic” (feldspar-silica) to “mafic” (magnesium-ferric) axis, the light-in-weight to heavy-in-weight axis, and the low melting point to high melting point axis. This wonderfully simplifying physical and linguistic coincidence, which some might think proves the existence of God, seems to be accepted uncritically by geologists.

Coarse-grained granitic rocks that have roughly equal parts light and dark minerals are called diorite. My sample was a little darker than diorite, but maybe not dark enough to be gabbro. Trying to be like a real geologist, I called it gabbro-diorite. Except that in my notebook I followed the name with a question mark.

I needed more specimens to look at, for comparison--a lot more specimens. And I wanted to find some that were already labeled by a geologist. Thus began my studies.

The first thing I learned is that I lived on a named unit of rock, the Pilot Peak Pluton, part of the larger Smartville Block.

III. Where Are the Coconuts?

It turns out that the Pilot Peak Pluton has been carefully sampled and mapped several times. More, as part of the Smartville Block, it is not only the subject of a dozen papers, but also at the center of a major controversy in Northern California geology: are the magmatic and ophiolitic rocks of the Smartville block home-grown or far-traveled? And whether the Smartville block was grown *in situ* or floated in from the far western Pacific has tectonic implications for the other terranes further east—the Calaveras formation, the Feather River peridotite belt, and the Shoo Fly complex—as well as the tectonic terranes of the Coast Range and the Klamath Mountains—the whole Western Cordillera.

I'd read about the Smartville ophiolite in John McPhee's *Assembling California*. It's hard to write about the tectonics of California without mentioning John McPhee and his seductively coherent account of several hundred million years of

California geological history. McPhee visited Smartville with his geological guide, Eldridge Moores, father of the ophiolite “paradigm shift,” and McPhee begins his popular introduction to plate tectonics with the Smartville pillow lavas.

But it was one of Moores’s UC Davis colleagues, Howard Day (who makes a cameo appearance in *Assembling California*) who wrote, or co-authored, at least fourteen technical papers specifically, or partly, about the Pilot Peak Pluton and the Smartville Block. Moores is a co-author on four of the papers, and James Beard, who wrote his UC Davis doctoral dissertation on the stratigraphy of the Pilot Peak Pluton, is a co-author on three others.

Stratigraphy is the nuts and bolts of field geology. It’s been the core of the science for almost two hundred years, and the work of the early geologists is still used and referenced. Newer geologists mostly just add detail. Waldemar Lindgren, in 1896, mapped the western part of Nevada County as “amphibolites and gabbros,” and going over into “hornblende-diabases, augite-porphyrites, and hornblende-porphyrites.”

Beard and Day’s descriptions add finer detail and radiometric ages, subdividing Lindgren’s porphyrites into “olivine gabbro, gabbronorite, gabbronorite with hornblende oikocrysts, biotite hornblende diorite,” and “biotite-two pyroxene monzodiorite.”

I’m continually impressed by the skill of the early geologists. They didn’t have the theory of plate tectonics, or radiometric dating, or polarized light microscopy, modern analytical chemistry, or computers, but they knew their minerals, could visualize strata in three dimensions, and, considering that there weren’t very many of them, and that they literally had to start from scratch, they produced remarkably good maps.

If you are a person who likes maps, as I am, a geologic map is as good as they come. Each map is a maze of color, limited only by scale and resolution. A very large scale geologic map of California, highly simplified to fit on an 8 ½ x 11 inch piece of paper, is already wildly complex. Wavy colored bands and blobs wrap around and poke through each other. Eleven broad formations are each depicted by a separate color. Three curving bands of color delineate the Sierra Nevada: red for Mesozoic granite, green for Mesozoic sediments and volcanics, and blue for Paleozoic metamorphics. A few purple strips squeezed along faults denote serpentine and other ultramafics. The Klamath Range looks like a piece of the northern Sierra that was broken off and moved northwest, the space between covered over by the Cenozoic volcanics of the Modoc Plateau, which looks like a can of pink paint was spilled on the map. The Coast Ranges have their own colors: pale aqua for the late Mesozoic Franciscan Complex, olive green for Cretaceous marine deposits, all stretched along long faults. The largest and most coherent color on a California map is the long ecru oval of the Great Valley Formation, labeled as “Cenozoic nonmarine (continental) sedimentary rocks and alluvial deposits.”

A wall size geologic map of California depicts over four times as many rock units, each with its own color or shade, and each color subdivided with patterns: pale blue with brown speckles, blue-green with yellowish dots, yellow with small green dots, yellow with large green dots, blue with pale cross-hatching.

At even smaller, regional scales, such as the wall map of the Chico quadrangle, there are over fifty colored patterns, and some of these are further subdivided by letters: the sandy colored Miocene-Pliocene volcanic rocks (“MPv”) are suffixed with “b” for basalt, “a” for andesite, “af” for andesitic flows, “ap” for andesite pyroclastic rocks, and “t” for tuff-breccia. California geology seems to have a fractal quality, with equal complexity at any scale of magnification.

On the Chico Sheet the Smartville Complex alone is represented by eight colors: two greens, a pale blue for volcanics, an orange for quartz diorite and tonalite, blue cross-hatched with lavender for the dike complex, lavender cross-hatched with magenta for the massive diabase, dark purple for ultramafic rock, and a speckled lavender for gabbroic rocks. It is this last section, the gabbroic rocks, that James Beard and Howard Day further subdivide into their six named units on their even more magnified map.

Once one has identified the units of rock and named and dated them, has determined the strike of faults, measured the dip of the strata, and noted the unconformities where there is something missing, one must tell a story to explain how everything got to be the way it is. Geologists call their stories “models.”

Depending on which geological paper one reads, there are three, or maybe five, or maybe seven contending models for the accretionary history of northern California and western North America. This would be complicated enough, but every geologist’s list of the contending models seems to be different, so that the total number of models approaches the total number of geologists as a limit. In a general way the models divide into collisional versus non-collisional, or, another way, into *in situ* versus far-travelled, or another way, into eastward subduction versus westward subduction, and various combinations of all.

In Eldridge Moores's theory, first proposed over forty years ago, an island arc a thousand miles long rode the Pacific Plate east until it collided with the western edge of North America. In 2004, however, Howard Day and another petrologist, Marion Bickford, found that the Pilot Peak Pluton and surrounding areas contained Precambrian zircons, very much older than the parent rock of the Smartville Block, dated to 160 million years. Day and Bickford interpreted these zircons as detritus from the North American craton that was picked up by the rising Jurassic magma that formed the Pilot Peak Pluton, and that therefore the rifted arc that formed the Smartville ophiolite was offshore, but near to the continent. That is, we could say, that instead of finding coconuts from an exotic, far-travelled terrane, he found acorns.

Day admitted in his paper that his evidence was not conclusive—that the zircons could come from some other source—only that it was "most easily accomplished in proximity to the North American margin." Perhaps in response, Moores prefaced a 2006 paper with a quote from New Zealand geologist Douglas Coombs: "A vital lesson of plate tectonics is that there is no validity to any assumption that the simplest and therefore most acceptable interpretation demands a proximal rather than a distant origin."

In the last decade several major papers favoring a west-dipping subduction of North America beneath oceanic plates have appeared, as well as grand syntheses of the older "standard" east-dipping model. There is a Mojave-Sonora Megashear hypothesis, and even larger scaled giant shears reaching from South

America to British Columbia and Alaska. There is a SWEAT hypothesis, connecting southwestern North America with eastern Antarctica.

At least four geologists have proposed grandly unifying theories centered on a lost (subsumed) ribbon continent, resting on its own plate and stretching for thousands of miles. Though superficially similar, the models are not interchangeable. Robert Hildebrand named his ribbon continent "Rubia," Stephen Johnston named his "SAYBIA" (an acronym for Siberia-Alaska-Yukon-British Columbia), Eldridge Moores proposed "Cordilleria," and Richard Schweikert managed to get by with "Mezcalero."

In a general way, each of these models has the Sierra foothills, and, in more complicated ways, the California Coast Ranges, assembled into a unit far offshore of North America, with collisions of island arcs onto one or both sides of the ribbon continent, and subductions that at some point change polarity—that is, from eastward-dipping to westward-dipping, or vice versa.

Recent advances in seismic tomography of the mantle, such as that of Karin Sigloch and Mitchell Mihalynuk in 2013, with the ability to image deeply subducted plates now sunk a thousand miles into the earth, promise to add significant new constraints and tests on proposed movements and subduction of tectonic plates, perhaps heralding a second tectonic revolution.

Why is it so complicated? First, because it has been going on for such a long time. In geology, we might say, there is all the time in the world to get things done. If a continent is moving at ten centimeters per year, it can move 6,000 miles in a mere 100,000,000 years. The Mesozoic Era, where most of the action of adding

California to North America took place in the above theories, began 250,000,000 years ago, while the Precambrian super-continent of Rodinia began breaking up 750,000,000 years ago—enough time for any continent to circle the earth twice.

Secondly, there are now enough geologists doing skilled field work that the number of named "terranes" has doubled or even tripled since the early days of plate tectonics. Each of these terranes, stacked above or below other terranes, has to fit into a coherent story in space and time.

In the old geology mountain-building events were defined tautologically: mountains were made by "orogenies," by "mountain-building" events. Today any tectonic model of western North America has to account for the Antler Orogeny, the Sonoma Orogeny, the Nevadan Orogeny, the Sevier Orogeny, and several others in terms of specific collisions and subductions—and has to propose a suitable source for the momentum and kinetic energy needed to raise major mountain ranges thousands of feet into the air. Added to this there are the constraints of stratigraphy: explaining why and how each formation lies atop or beneath other formations, and, while at it, how they have to be older than the dikes or plutons that cut or intrude into them.

Reading geological reconstructions often seems like reading historical linguistics: a reconstructed continent or tectonic plate or island arc is then used to reconstruct even earlier configurations. And geological stratigraphies, like languages, are inherently messy. The problem in geology is that a block of rock that doesn't fit with its neighbors is harder to explain away as a "loan word." And thus accretionary models for the expansion of the western margin of Laurasia have become increasingly convoluted.

But cycles of complexity, followed by a revolutionary simplification, and then followed again by more complexity, are the way of science. There is even conflicting evidence, and interpretive debate, about the age of the Sierra Nevada. Did they arise to their present height four million years ago or forty million years ago? That's an order of magnitude of uncertainty, with supporting evidence for both theories, for one of the major mountain ranges on earth. And while it is frustrating not to have one rock-solid explanation, the depth of the mystery is in another way comforting. Such conundrums give geologists a modicum of humility.

Physicists ought to have this humility also, but often don't. The physicists problem has to do with the background energy of empty space, which differs from theory by an incomprehensible 122 orders of magnitude. And then there are the biologists—they might show some humility also: their conundrum, often denied, is the coexistence of matter and mind.

IV. Reading Rocks

The Pilot Peak Pluton, in western Nevada County, is two and a half miles wide and about seven miles long. It's shaped like a teardrop, the big end to the northwest and narrowing as it trends southeast. It's a magma chamber that never erupted onto the surface—that's why it cooled slowly and the crystals are big enough to see. Its namesake, Pilot Peak, is 2250 feet in elevation, sits astride the old California Trail used by wagon train emigrants, and is visible from Wheatland, where the California Trail ended at Johnson's Ranch.

James Beard and Howard Day called this pluton “reversely-zoned,” with the most mafic rock at the core and the quartz diorite at the extreme edge, where it contacts the massive diabase into which it had been emplaced. There are several theories as to how this came about, Beard and Day favoring the idea that settling of the minerals had already occurred in the magma chamber before the magma was intruded into the diabase above it.

James Beard had mapped my “some kind of granite” into six units, all of them intergrading. The rock where I lived was gabbro-diorite and another rock, gabbronorite, distinguishable by the presence of yellowish-tinted glassy grains of orthoclase. Between this rock and the olivine gabbro at he southern end of the pluton, the quartz content of the rock fell off from ten percent to zero, and levels of clinopyroxene, orthopyroxene, and amphibole generally increased, though not always together. The presence or absence of large hornblende or biotite crystals complicated the map, as did the topography: erosion exposes lower layers, elevation differences showing as concentric rings of exposed rock units.

I scanned the Beard/Day geologic sketch of the Pilot Peak Pluton, reduced the opacity, and after several scalings was able to layer it onto Google Earth, and was able to print out several 8 ½ x 11 maps.

I wanted to find some of their olivine gabbro, which would be about as close to mantle rock as I was going to get from an intrusive pluton. I lived at the other end of the pluton from the core, so I had to drive about five miles to get to the olivine zone. Some of the roads I traveled required low gear, all-wheel drive, and very careful steering. The one I was on would probably wash out with the next winter storm.

I was nearing the southeast end of the pluton, and stopped my car above a small reservoir where there was an outcrop exposed. It was a light-colored, fine-grained granite, with large plates of biotite mica. It wasn't rusty. Checking the geologic map I'd prepared, I decided this must be what James Beard had called "biotite-two pyroxene monzodiorite." My overlay was a little off.

I followed the winding road further up the mountain, and parked again when I saw rusty-colored boulders sticking up between the oaks. Breaking a piece off I could see it was a coarse-grained gabbro or gabbronorite—I was getting close.

I grabbed my collecting bag and started hiking up a steep firebreak. A hundred yards up I was suddenly surrounded by yerba santa, and I could smell camphor sage even before I saw it. In my mind I was transported to a serpentine ledge a thousand feet above the North Fork of the Trinity River, where a hermitic prospector named Red Barnes was showing me how he mixed *Salvia sonomensis* into his snoose, and into his smoking tobacco. Those two plants seem to love ultramafic rock.

I found a warty and rusty outcrop and sat down. There was a pile of bear shit not far from me full of berries. A lone golden yarrow (*Eriophyllum)* was in bloom. I broke off two chunks of rock, recorded the latitude and longitude, and examined the specimens with my hand lens.

The plagioclase was easy to spot—long striated palettes. The biotite was easy too—I'd known mica since I was a kid—here it was formed into little stacks of thin golden sheets. The rock was chock full of hornblende, shinier than the pyroxene, and I could even make out the 120 degrees between the cleavage planes on some of the crystals. The pyroxene was mostly whatever dark stuff was left that wasn't hornblende. Some of it had a powdery surface, and something that looked like a 90 degree cleavage. And then there were other tiny crystals, yellow-brown, and rusty oxidation showed even on the fresh surfaces.

I dropped the rocks into a numbered bag, recording the same into my notebook. I wanted some of Beard and Day's "quite fresh and unserpentinized" olivine. I wasn't sure I had it yet, so I drove deeper into the zone I had marked on my map. An undeveloped piece of land near the crest of the hill was for sale, so I felt free to hike over it. A dirt driveway led off to the left to an occupied parcel. The breeze changed slightly and I was enveloped by the heavy skunky air that surrounds every large California pot farm.

Another fifty yards along the dozer path I found more yerba santa and more camphor sage and some serpentine. But further, around the northwest side of the knoll, the rocks turned rusty again. I found a good outcrop where I could knock off a sample to get a fresh surface.

The rock was noticeably heavy—it had an extra heft. At first glance under magnification the crystals seemed to be packed together randomly—but with a closer look, in some areas, I could see that some of the long amphibole crystals were aligned and there was a hint of a curved outline, perhaps some obscure effect of convection or cooling.

I could see shiny terraces of hornblende, rusting ledges of dark pyroxene, a few bits of biotite mica, all embedded in a sea of feldspar crystals that were jammed together like piled-up ice bergs.

There were flashes from the striated cleavage planes of the plagioclase; and some tinted glassy stuff—probably the orthoclase. Some orthopyroxene had a metallic green and magenta sheen—the "Schiller luster." And there was this amber-colored stuff, little cubes of glass that turned completely to rust near the rim of the sample. Some of them had conchoidal fractures. If you want green olivine, I thought, don't look for it in 160 million year old rock.

I was still trying to decide if I really had the olivine gabbro as I was driving home. A thin section and polarized light and a petrographic compound microscope would reveal everything n a flash—that is what Beard and Day used--along with the electron microprobe lab at UC Davis. And eager graduate students to assist.

"Why am I doing this?" I thought, "I should be writing or painting or *something*." Or looking for pretty geodes like the rockhounds. I was never going to master petrology on my own. The sun was already low and I was getting hungry. Then I saw all this brown slatey rock exposed off in a field to my right. The road must have crossed the Wolf Creek Fault and put me off of the Smartville Block. I pulled over and stopped the car. And reached for my hammer.