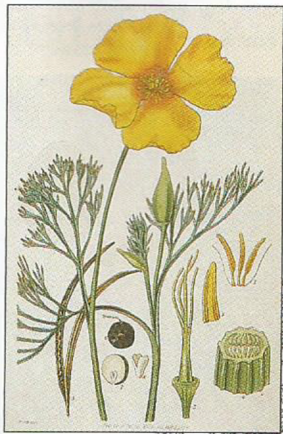
Some geologists, with a penchant for trees and wildflowers, are letting plants drill the test holes.



Organic Mining

BY TERRI HAAG

Every time I let it slip to someone at a cocktail party that I'm interested in geobotany and biogeochemistry, after the first admiring "No kidding?" my listener's interest tends to drop off sharply to: "Gee, look, they brought out a fresh baloney ring!" But see, that's before I get a chance to mention that little purple flowers led archeologists to the remains of ancient copper smelting sites left behind by a 500-year-old African civilization. Nor do I ever get the opportunity to drawl casually that, yes, I know Jim Erdman and that *he* knows about *Eschscholzia mexicana*, juniper berries, and bear poop. But I'm getting ahead of things.

Perhaps a better place to start a discussion of geobotany is with this definition by R.R. Brooks: (Geobotany is) "a visual survey of the vegetation cover in order to detect mineralization by means of plant distributions, presence of indicator plants and/or mutational or morphological changes induced by certain excess elements." Or, if you take a more populist, relaxed view of science: scope it out, see what's growing where, and if it's, like, *mutated*, then check the heavy metals, man.

ABOVE: A hand-colored engraving of Eschscholzia californica, California poppy, from Curtis's Botanical Magazine (1829, Plate 2887). E. californica is closely related to E. mexicana, the best known example of a southwestern copper indicator plant. Photo provided by Hunt Institute for Botanical Documentation. LEFT: California poppy and lupine invade this field at Organ Pipe National Monument in Arizona. Photo ©James Cowlin.

At first glance, using plants to point out geological features may seem obvious, but when a Roman engineer and architect named Vitruvius wrote in the year 10 B.C. that certain species of plants were restricted to marshy ground, he was actually pioneering the science of geobotany.

Parry's penstemon (Penstemon parryi), growing in the Verde River valley of central Arizona. Photo ©James Cowlin.

Throughout the following centuries, miners, prospectors, farmers, and herbalists looked for the presence or absence of various plants to point the way to mineral deposits. For instance, in the late 1800s prospectors scoured the Montana hills for the so-called "silver plant," *Eriogonum ovalifolium*, because it seems to grow on silver-rich soil.

The practice of using plants as signposts to buried mineral wealth has been traced back 1,400 years to a 6th century Indian philosopher named Varahamahira, who advocated looking at soil and plant relationships. Other early geobotanists like Agricola, a 16th century German mining engineer, noticed that the vegetation over lead deposits was often yellowed and stunted. In 1841 the Russian geologist A.L. Karpinsky recognized that whole plant communities could be linked to certain soil conditions. In fact, at today's cutting-edge of mining exploration, modern scientists are still refining techniques that have been used for centuries.

BOTANICAL EDGE. Furthermore, in the competitive, modern mining industry, any edge — or ledge, for that matter — no matter how dangerous to life, limb, and dignity, is a necessary edge. If that means squatting under an outcrop shouting, "Holy cow, here's a *Mielichhoferia*!" (one of a few, rare copper mosses known to grow almost exclusively on copper-rich rocks), so be it.

Unfortunately, for the copper industry, *Mielichhoferia* and other copper mosses are wildly elusive and generally prefer Alaska to Arizona, making them somewhat unsuitable as general copper indicators. Luckily, since a great deal of the North American copper reserves are in the southwestern United States and northern Mexico, there are a few copper indicator plants native to these latitudes, too.

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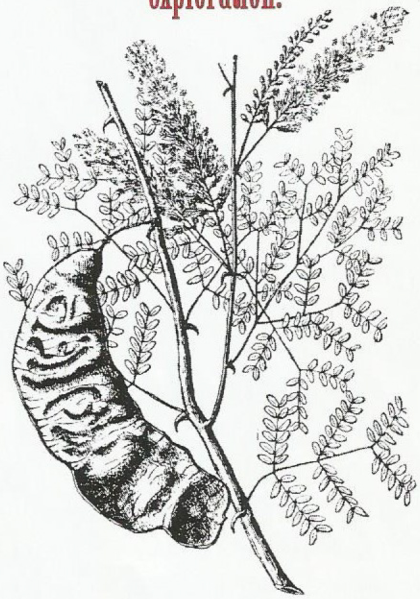

Texas cat claw, Acacia wrightii Bentham, has a deep taproot and is commonly used by geochemical mineral prospectors. Drawing from North American Trees, 1908. Photo provided by Hunt Institute for Botanical Documentation.

Probably the best-known example of a southwestern copper indicator plant is *Eschscholzia mexicana*, the bright, hardy, California poppy that often blankets large areas of Arizona in the spring. *E. mexicana* is known to grow lushly over copper-rich soils, much to the delight of geobotanists and tourists. Unfortunately, this plant is highly dependent on sufficient winter rainfall for germination, it sometimes grows where copper isn't, and it is too unpredictable for serious prospecting use.

The trick, at least for serious geobotanists, is to find an indicator plant that doesn't depend on weather fluctuations, is easily quantified, has a narrow and predictable preference range and is, essentially, well, *foolproof*. So far, there aren't any, making geobotanical exploration one of those earth sciences that can occasionally seem somewhat ethereal.

There are candidates that meet at least some of the above conditions — those of the *Eriogonum* genus in the buckwheat family. *Eriogonum* species have been found in close association with silver-rich soil in Idaho and with copper deposits in Montana and Sonora, Mexico, to list a few.

And while there are certainly plenty of inconsistencies and uncertainties associated with geobotanical prospecting, if *Eriogonum* is growing lushly on your little patch of heaven to the exclusion of most other plants, you might consider an immediate mineral assay and possibly an open-pit operation just behind the garage.

Another pretty wildflower, *Penstemon parryi*, belonging to the unlovely-sounding figwort family, has also been found in close association with mineral deposits. Jim Erdman, a geobotanist with the U.S. Geological Survey, found the red, spiky *P. parryi* growing in the Vekol Mountains of Arizona on an inhospitable mine dump containing 150 ppm copper, 3,000 ppm zinc, and 1,500 ppm lead, which, despite measuring in parts-per-million concentrations, are high enough at least to raise eyebrows in mineral exploration circles. (Not to take anything away from Dr. Erdman, but I have also seen *Penstemon* growing lushly beside freeways and roadside rest stops, perhaps seeking the high concentrations of brass shell casings, old hub-caps, and Pepsi cans in the surrounding soils.)

LESS CAN BE MORE. Naturally, geobotanists look for more than just the presence of certain plants when prospecting for mineable ore deposits. Sometimes, they look for *less*, since the presence of heavy metals in high concentrations is often just as toxic to plants as it is to people. Therefore, finding no plants where plants should be or finding deformed or chlorotic (yellowed) plants where everything ought to be healthy, may signal concealed ore bodies.

An example of using a lack of plant life to find buried geologic features occurred in Turkmenia, where extensive crustal faulting allowed salty, mineral-laden waters to surface, thereby poisoning vegetation along the fault lines. The subsequent absence of plant life was easy to spot from the air and in satellite imagery.

The discipline of biogeochemistry, as it pertains to mineral exploration, is a bit different from geobotany. This science involves analyzing parts of certain plants for anomalous (abnormal) concentrations of various elements, such as lead, molybdenum, silver, gold, and copper, among others. The plant parts most commonly analyzed are leaves and stems, but roots can also be analyzed. Using roots, however, involves a greater risk of skewed results due to the physical impossibility of washing *all* of the dirt off, as anyone who has ever tried to prepare fresh spinach will attest.

Dr. Maurice Chaffee, a geochemist with the U.S. Geological Survey, has had a long and illuminating association with plants and parts of plants. "You see these things growing in your backyard, and you don't really think of them with regards to mineral exploration," he said.

To me, using plants as ore-finders sounded cheap and easy — why spend millions on collecting rock samples and drilling test holes? "Ah, but plants are tricky," countered Chaffee. "You have to be thorough and you have to know which plants to sample."

I asked Dr. Chaffee how he came to be, well, outstanding in his, er, field. He began by citing the influence of pioneering American biogeochemical luminaries like Helen Cannon and Lyman Huff. Eventually he got around to talking about some of his landmark papers about the connections between plants and copper ore, including his now-famous study done on the Mineral Butte copper deposit in Pinal County, Arizona.

"Many years ago, when I first started out," Chaffee mused, "I'd just go and collect various kinds of plant samples that seemed to be growing in interesting places as far as mineralization went. I didn't always know what they were. I just called them 'plant X' and 'plant Y' in my notes. Then I'd have to go look them up later at the arboretum or in a field guide to plant species!"

ONE OF THE PLANT TYPES most commonly utilized by geochemical types are the phreatophytes. Deserts, by definition parched and scant of rainfall, are hostile to all but the wiliest of indigenous denizens. To survive, phreatophytes like the mesquite tree and the cat claw acacia devised the simple expedient of sending their taproots down sometimes as far as 175 feet, into a permanent or perched water table, thus essentially digging their own wells.

These exceptionally deep-rooted plants may tap into groundwater percolating through buried ore deposits or actually transect the ore body itself. In either case, unusually high concentrations of elements are often transported from the plant's roots to its leaves and stems, where toxic compounds and elements can be stored out of harm's way (much as the human body can remove small amounts of arsenic and mercury from the general system by storing it in fingernails and hair).

By exposing freshly collected vegetation samples to high temperatures and then performing spectral analysis on the ashes, geochemists can tell if there are unusual amounts of metal in the tree's immediate vicinity. In the desert southwest, this technique has been used successfully to locate buried copper ore deposits, much to the delight of geologists who love to let plants drill the initial test holes. Not only is it much, much cheaper, it's also politically correct.

Other plants are natural metallurgists, adept at leaching metals from the surrounding soils, and in fact, use an almost identical chemical agent to that used by their human counterparts. These plants excrete hydrocyanic acid into the soil from special cells in the roots and in doing so, solubilize metals, including gold! In this way, vital nutrients and trace elements are made available to the plant for uptake and growth. Biogeochemists can then analyze samples for these same metals in conjunction with mineral exploration.

Some conifers (cone-bearing trees like pines) let the neighbors do the work, with the same results. Fungal mats, called mycorrhizae, live on the tree's roots, forming a symbiotic relationship. It is the mycorrhizae that are suspected of making hydrocyanic acid in their cells. The tree takes advantage of the chemical factory at its roots while the fungus absorbs other needed nutrients from the tree.

DOWN AND DIRTY. I became personally conversant with terms like "phreatophyte" and "biogeochemist" after answering a local want-ad for a geology tech, which promised decent money and "travel opportunities." The travel opportunities turned out to involve jolting through the Arizona desert in July, 50 miles from the nearest convenience mart, while trying to read the little wavy lines on a 48-year-old topographic map and figuring out which of the roads still existed and whether or not I was on one.

Mostly, I carried a shovel, a huge metal dishpan, an enormous stainless steel strainer, and some pruning shears over hill and dale, looking for a place in nature that corresponded to the "X" on the map. Having located said X, my instructions were to strain 40 pounds of sand through the sifter until it was all of an easily inhalable size, and then to prune many small branches from the nearest mesquite tree and shove them, thorns and all, into a plastic bag. After that, sweating and chewing mesquite barbs out of my punctured fingers, I got to haul everything a mile or two cross-country through cactus, snakes, and hornets, back to the truck.

Sure, it was glamorous, but after I got the four-wheel drive pickup stuck three times in the same afternoon and had to back down a five-foot-wide circular track on the top of a 30-foot embankment, I decided that anything I still didn't know about *Prosopis juliflora* (mesquite), I could learn from a book.

Luckily, the "book" is a doozy. Entitled *Biogeochemical Exploration Simplified*, it is actually the study manual from a short course given by Colin Dunn and Gwendy Hall, of the Geological Survey of Canada, Jim Erdman, and S.C. Smith of Minerals Exploration Geochemistry in Carson City, Nevada. In it is more than most people want to know about using plants to find metals.

The authors remind us that different plants respond uniquely to the same soil, and while one species may take up and store potentially injurious elements in dead bark or leaves, another may have physiological barriers preventing uptake of that element in the first place. Unfortunately, the same cellular barriers do not exist in many of the animals that may graze on these concentrator plants. For instance, a disease of ruminants called "teart," is a form of molybdenosis, which occurs when the animals feed on plants that have accumulated large concentrations of molybdenum in their tissues. A sad situation for the animals but fortuitous for roving biogeochemists looking for "moly."

PIGS AND PROTOZOA. In addition to the reaction of separate genera or species to the same local conditions, any one individual plant of the same species may differ in its response to an element, depending upon temperature, available water, soil pH, time of year, and general health of the plant. And just to drive biogeochemists and their field personnel really berserk, sometimes only the leaves on one side of a tree will be positive for anomalous elements.

However, at least trees and shrubs tend not to move around by themselves or smell bad, unless you leave their parts in plastic bags in the sun for extended periods. Not so all biogeochemical test subjects. Some biogeochemists, for instance, find themselves elbow deep in fish livers. Like ancient soothsayers (Ah, Herodius, bring me the sacred trout!), these ingenius scientists discovered that heavy-metal poisoning isn't, maybe, always a *bad* thing: groundwater drains through an ore deposit picking up signature metals, fish drink the water, researchers analyze the fish, and everybody goes home and washes with Clorox.

Dogs have also been employed as biogeochemical researchers. By sniffing out sulfide-rich boulders in glaciated terrain, much as European pigs are used to find truffles, dogs have pinpointed potential mineral exploration targets in Scandinavia. Even bees have been put on the mineral exploration payroll. Toxic metals can accumulate in pollen and since bees collect pollen from within a few kilometers of their hives, by analyzing honey from various sites, a biogeochemist can, at least theoretically, discover a potential mine site.

The capper, however, is that researchers are now studying microorganisms in order to determine where their metal appetites lie. The presence of significant populations of certain fungi, bacteria, algae, and other protozoans are, in some instances, turning out to be even better indicators of metal-rich zones than plants or poodles. One bacteria strain, for instance, actually becomes more resistant to penicillin when raised on copper-rich substrates. Another bacterium, *Bacillus cereus*, has been used in the search for gold and copper reserves.

But back to Jim Erdman, one of the country's few exploration geobotanists. People listen to him at cocktail parties. Take the time he and a colleague were on a trail leading into Bronco Canyon in Arizona, after being dropped off by helicopter. Erdman was part of a multi-disciplinary team assessing the mineral potential of a large region. Suddenly, right in his path, was a large pile of fresh bear droppings. At this point, most people would think it a good idea to head in the other direction. Jim thought it a good idea to get down and examine the pile for interesting "berries" and plants. Just as he bent down for a scientifically significant closer look, the embarrassed bear, having forgotten to flush, returned. It was, "an interesting stand-off," says Erdman, "until my friend banged vigorously on a gold pan," and the bear, completely humiliated, sensibly ran away.

I dunno. Jim Erdman just tells better party stories than I do, I guess. ◆