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Some observations on plant assemblages and elemental content of plants in mineralized areas of the Walker Lake 1° x 2° quadrangle, California-Nevada

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ABSTRACT

A geobotanical study was undertaken in the Walker Lake 2^o quadrangle in conjunction with the Conterminous United States Mineral Appraisal Program (CUSMAP). Plant assemblages and plant growth habits were studied in areas mineralized with base metals, precious metals, uranium, and industrial minerals. Selected plant and soil samples were analyzed for key elements. The objective of the study was to determine whether plants could be useful in prospecting in the quadrangle.

Significant physiological changes in growth habits were observed in areas mineralized with molybdenum and also in areas of high radiation. Many species of Eriogonum grew in highly mineralized areas--particularly around copper and gold-silver deposits--and were found to accumulate excessive amounts of many metals. Uranium is accumulated in unusually high quantities by phreatophytes and aquatic plants, suggesting their usefulness in prospecting for uranium along drainage systems. The tendency of algae to accumulate arsenic could be useful in prospecting for gold-silver deposits.

INTRODUCTION

The study of plant species growing in mineralized areas located in the Walker Lake $1^o \times 2^o$ quadrangle, California-Nevada, was made at the request of Frank Kleinhampl in conjunction with the mapping of mineral deposits for the Conterminous United States Mineral Assessment Program. Areas of particular interest were suggested in order to determine the usefulness of plant species in delineating mineralized ground or areas for additional sampling. Photographs of plants were requested for help in field identification by Kleinhampl. The stations that were studied are shown on Plate 1. In each area we observed plant societies, collected plant specimens if needed for later identification, and at most stations collected soils and selected plants for analysis. In all, we visited 18 mines in different districts, five mineralized prospects, six areas of springs associated with hydrologically closed basins, and five lakes or marshes. Approximately 75 plants and 50 soils or sediments were submitted for analysis. Many of the 75 plants were divided into leaf, stem, and root components. The above-ground samples were cut off two inches above ground and all root samples were washed. Except for algae, the samples were dried in paper bags; algal samples were collected in cloth sacks, wrung out and dried. The plant samples were all analyzed by semiquantitative emission spectrography (Mosier, 1972) and, when specifically requested, for arsenic, gold, lithium, and molybdenum by atomic absorption spectrography (Nakagawa, Watterson, and Ward, 1975; Ward and others, 1969), uranium (Huffman and Riley, 1970) and selenium (Harms and Ward, 1975) by fluorimetry, tungsten colorimetry (Quin and Brooks, 1972), and total sulfur was determined turbidimetrically (Tabatabai and Bremmer, 1970). Sulfur and selenium, reported in dry weight of plant tissue, were converted to an ash weight basis for easy comparison on data tables. The soil samples were all analyzed by semiquantitative emission spectrography (Grimes and Marranzino, 1968), and selected specimens for other elements by methods described by O'Leary and Meier (1984). Some of the algal specimens were identified by Ellie Saboski of New England College, N.H. Identifications of the plants were made according to Munz and Keck (1963) and Abrams (1955). Timby also identified some plants in the Stanford herbarium.

The occurrence of plant species at different study localities and the analytical data are presented in tables 1-6 and discussed in connection with plant distribution in sections of the report grouped as Base-metal deposits; Precious-metal deposits; Uranium mines and radioactive areas; Industrial minerals; Springs; and a Mineralized well. The probable average contents of elements in plants compiled from the literature and from the files of the senior author are given in the appendix to aid in comparing our data with published values.

ACKNOWLEDGEMENTS

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Topography and plant zones

From east to west, the topography of the Walker Lake quadrangle is one of alternating desert basins and mountain ranges, culminating in the high Sierra Nevada on the west. Salt marshes and playas occur in the eastern valleys; Walker Lake fills the valley between the Gillis and Wassuk Ranges; the northern part of the evaporative Mono Lake lies along the southern edge of the quadrangle and smaller fresh-water lakes occur along the eastern flanks of the Sierra Nevada. Six distinct plant zones occur in the quadrangle characterized by particular plants.

Alpine, 10,000-11,000 ft. Species of Eriogonum (buckwheat), Arenaria (sandwort), Lupinus (lupine), Draba (rock-cress), Astragalus (milkwitch), Erigeron (fheobane).

Subalpine, 8,000-9,500 ft. Pinus albicaulis (white-barked pine), Pinus balforiana (fox-tail pine), Juniperus occidentalis (Sierra juniper).

Pinyon juniper, 5,000-8,000 ft. Juniperus osteosperma (Utah juniper), Pinus monophylla (pinyon), Cercocarpus ledifolius (Mtn. Mahogany).

Sagebrush scrub, 5,000-7,000 ft. Artemisia tridentata (big sagebrush), Purshia tridentata (antelope brush), Chyrsothammis nauseosus (rabbitbrush).

Shadscale scrub, 3,000-6,000 ft. Atriplex confertifolia (shadscale), Grayia spinosa (hopsage), Menodora spinescens (twinberry).

Alkali sink, less than 4,400 ft. Allenrolfea occidentalis (pickleweed), Atriplex polycarpa (cattle spinach), Kochia americana (red molly).

Plant tolerance and metal accumulation

Generally, the greatest edaphic effect on plant distribution is the presence of carbonate; plants are commonly listed as calcifuge or non-tolerant of carbonate soils, or calciphile or preferring carbonate soils (Marchand, 1973). The control is actually the interaction of all the soil constituents (including pH) on the amounts of water-soluble or exchangeable ions available in major amounts to the plants. Plants that grow around base-metal deposits in relatively acid iron-rich soils may tolerate large amounts of metal either by exclusion or by the evolution of tolerant ecotypes. Also, they may grow there because the iron increases the availability of phosphorus and potassium. According to Baker (1979), accumulator plants accumulate metals in the various plant parts from low or high background levels. Excluder plants, by differential uptake, restrict the metals from reaching the shoots below a critical level; above this level there is unrestricted transport. A high tolerance for metals is possible for grasses because their roots are adventitious and can be replaced continuously as the older roots become physically clogged with toxic elements. Ricegrass and ryegrass are common in metalliferous soils of the area. Accumulator plants are capable of accumulating large amounts of metal in the above-ground portion of the plant, usually in the cell walls, without harm to growth. In many cases, a tolerant variety or subspecies has evolved in metalliferous soils and is, if transplanted, unable to grow in normal soils. Many indicator plants are believed to have gone through such an evolution. A particular variety, Eriogonum ovalifolium var. ovalifolium grows only on high copper soils in Montana (Grimes and Earhart, 1975). This variety was not seen in Nevada, but two other varieties and 16 species of Eriogonum grew in mineralized soils. Two other calcifuge genera deserve mention--Lupinus and Phacelia. Species of Lupinus grew at several base-metal and gold-silver localities but none in calciferous soils. No lupine grew in areas of uranium mineralization nor was it observed near uranium deposits of the Colorado Plateau. Like Stanleya, reproduction of the genus may be affected by radiation. The lack of petals and stems in Stanleya was observed in radioactive areas where the levels were not sufficiently high to affect all spikes and the plant could continue to survive. Stanleya and other crucifers require sulfur, which is available near sulfide deposits. Plant species of possible geobotanical usefulness are given in Table 1.

Base-metal deposits

Plant relationships around mines from which copper (Cu), molybdenum (Mo), lead (Pb), zinc (Zn), tungsten (W), and chromium (Cr) had been produced, were studied, and selected plant specimens were analyzed for concentrations of certain elements (Table 2). No definite indicator plant of a particular metal was observed. Although various species of mints have been used in prospecting for Cu in Africa and China (Cannon, 1971), only one mint, Monardella odoratissima, occurred in Cu-rich soils. Eight species of Eriogonum, a genus known to be highly tolerant of metal-rich soils, occurred in Cu areas and in Pb-Zn soils. No subspecies or variety of Eriogonum ovalifolium is associated with Cu in this area, as has been the case in Montana, because the species is a calcifuge and the deposits studied were largely in carbonate rocks. However, the large number of species growing in highly mineralized soils is significant. The poppy indicative of Cu in Arizona was not seen in the Walker Lake quadrangle, but Argemone platyceras (thistle poppy) (fig. 3b) grew at both Yerington and the Santiago mine.

Effects on vegetative growth were noted in areas of high Mo content in the Pine-Nut district, Nevada. Juniper, pine, and Ephedra (all gymnosperms) were observed to have longer than normal internodes between leaf clusters; this caused the specimens to have a straggly or, in the case of pine, a pendulous appearance. As this effect was not noted at the Star City mine where the Mo is associated with Cu, the Cu may protect against anomalous growth effects. The latter association of elements is known to protect livestock. The pine samples contained more Mo and Cu than any plants analyzed from other Mo-rich areas. Warren and Delavault (1965) found that plants growing over commercial Mo deposits contained more than 500 and never less than 50 ppm Mo and plants growing in ground unmineralized with Mo contained less than 50 ppm. According to these figures, the Star City samples and those collected south of Luning suggest occurrences of economic value.

Lead poisoned soils in Norway have been reported by Låg and Bølviken (1974) to cause plants to be stunted, chlorotic, lack fruit or be absent entirely. Dwarfed and mishapen pine trees were noted by Mudge and others (1968) around the Elk Creek lead-poisoned soil in Montana. Samples of white-barked pine collected by the authors from Elk Creek contained as much as 30,000 ppm Pb in the ash of roots, 700 ppm in the wood and 500 ppm in the needles. At the Bertha Hall mine in California, no unusual growth was noted but an extremely healthy Eriogonum Lobbii with a tremendously large root system contained more than 5,000 ppm Pb and more than 20,000 ppm Zn in both leaves and roots. Possibly the vegetation at this locality is protected from growth damage by the high iron content of the soils.

Copper

Yerington copper pit, Lyon County, Nevada, elevation 4,300 ft. The porphyry Cu ore occurs in a contact metamorphic deposit. The ore of pyrite and chalcopyrite (Mo deficient) occurs as a replacement in limestone (Ferguson, 1929). The orebody has now been mined and the Anaconda Company is allowing the open pit to fill with water (fig. 1). Observations were made at only two stations.

Station 1. The plants near the edge of the open pit in an area that had been bulldozed did not include known Cu-indicator plants, but the S-loving crucifers, Lepidium perfoliatum and Sisymbrium altissimam, and the seleniferous Oryzopsis hymenoidis (rice grass) grew here. Dwarfing and red stems on Erodium cicutarium (alfileria) appeared to be related to the mineralization.

Station 2. The Cu diggings and outcrop on the hill by the main road, where the soil contained 2,000 ppm Cu, were covered with Chaenactis stevioides (false yarrow) (fig. 1 and 2). Other plants included Eriogonum sphaerocephalum, Malcothrix glabrata and Argemone platyceras (fig. 3b) of the poppy family. Oenothera clavaeformis (primrose) was dwarfed and had reddish leaves; the grizzly bear cactus and Grayia spinosa were also red. This reddening phenomenon has been observed at Cu deposits in Arizona.

Santiago mine, Copper Mountain, Mono County, California, elevation 8,600 ft (Station 61). Copper minerals occur in calcium carbonate veins. Eriogonum microthecum, E. Baileyi, E. inflatum, and E. umbellatum grew here, but not Eriogonum ovalifolium v. ovalifolium, the indicator of Cu that occurs in Montana. Because of the calcium carbonate, several calciphile plants such as Mentzelia were noted along with Eriogonum inflatum, known to be an indicator of gypsum. Eriogonum ovalifolium is listed by Marchand (1973) as a calcifuge. Because there are several mints that indicate Cu in different parts of the world, Monardella odoratissima (fig. 3a) and Scutellaria nana (skullcap) of the mint family were of particular interest. Monardella contained 300 ppm Cu, growing in soil containing 700 ppm Cu--this was the greatest amount detected in the above-ground portion of an herb on this project (Table 2).

A small digging for Cu in an altered zone of carbonates was examined in Mineral County, Nevada (Station 39) at an altitude of 4,600 ft. A value of 200 ppm Cu was reported in a rabbitbrush sample and 700 ppm Cu in soil in which the plant was rooted.

Figure 1. Mineralized outcrop in Yerington copper district with extensive cover of Chaenactis stevioides. Station 2.

Figure 2. Chaenactis stevioides (false yarrow) at Yerington copper outcrop. Station 2.

Figure 3a. Eriogonum umbellatum (sulfur buckwheat) and Monardella odoratissima (monardella) at Santiago mine, Copper Mountain. Station 61.

Figure 3b. Argemone platyceras (thistle poppy) at Santiago mine, Copper Mountain. Station 61.

Molybdenum-copper

Star City molybdenum mine in the Sweetwater Mountains, Mono County, California, elevation 8,100 ft (Station 53). The Star City mine in Green Creek Canyon was originally mined for Au and Ag but is now known to contain Mo and to occur within the large area of Mo mineralization associated with a quartz monzonite stock of the Sweetwater Mountains. The flora consists of a large number of genera including two sulfur-loving crucifers and three species of Eriogonum. One species, Eriogonum wrightii, commonly occurs around Cu deposits in Arizona. Samples of pine had values of 580 ppm Mo in the ash of needles, 380 ppm in the twigs, and 5,000 ppm in the roots. The soil contained 1,000 ppm Mo. The roots of pine appeared to concentrate Cr and Ni (300 and 200 ppm, respectively), whereas the amounts in the surface soil were negligible (<20 ppm). The Sweetwater Ranch at the foot of the mountains has had difficulty with stock being poisoned, first from cyanide when cyanide was used in the recovery of Au, and more recently from Mo. The cattle are now fed Cu to counteract the molybdenosis. Reports from USDA agricultural agents of metal poisoning in stock can be useful in prospecting.

Molybdenum

Pine-Nut Molybdenum district, Douglas County, Nevada, elevation 6,200 ft. (fig. 4a) (Stations 28, 29, 31). The molybdenum occurs as MoS_2 around the edge of a quartz monzonite stock in Alpine limestone and the Alpine volcanics. The ore is Cu deficient. The spectral reflectance of trees was studied by Kenneth Watson and Thomas Hessin, and geobotanical observations were made by H. Cannon in 1973 using as a guide, maps furnished by Climax Corporation, which showed the Mo content and location of tree and soil samples analyzed by the company. The district was revisited in 1978. Species observed in mineralized but not unmineralized areas included the S-loving Zygadenus venosus (death camas), Lepidium perfoliatum (peppergrass), and also Scutellaria nana (skullcap) and Mimulus longulus (monkey flower). Unusual growth changes were noted in Peraphyllum gracile (squaw apple), which had white flowers and smaller flowers and leaves when rooted in mineralized ground than those of normal plants with pink flowers (fig. 5a and 5b). The junipers were brighter green and had a strange growth habit on mineralized ground (fig. 4a and 6) in 1979. A pinyon with long internodes between needle clusters was observed (fig. 4b). A similar elongated growth in Ephedra viridis (joint fir) was observed in 1973 (fig. 7a and 7b). Leaves, stems, and roots of Peraphyllum and juniper at Station 28, and of Pinus monophylla at Station 31 along with soil samples, were collected in 1978 for analysis (Table 1). Amounts of 260 ppm Mo in the roots of squaw apple and 250 ppm in juniper twigs were greater than in any other plants that were sampled. A sample of mistletoe and the tree on which it grew were collected at Station 29. The mistletoe contained more Mo than the pine. Mineralization is extensive and junipers with irregular growth were noted along the drainage west toward the main highway, but the trees on high ground were normal. Possibly this growth pattern, if noted in stream drainages, could be used in prospecting for mineralization in the headwater areas.

Luning, Mineral County, Nevada, elevation 4,470 ft. Less than a mile south of Luning there is a large area of Stanleya pinnata extending from east of the railroad tracks (Station 36a) to 1/2 mile up the bajada on the west side of the road (Station 36b). The area is down drainage from several W mines. The samples taken of Stanleya east of the tracks and up the bajada

Figure 4a. Abnormal growth habit of Juniperus monosperma growing in soils of high molybdenum content. Alpine mill in background.

Figure 4b. Abnormal growth habit of pine growing in Mo-mineralized soils of the Pine-Nut molybdenum district.

Figure 5a. Normal Peraphyllum (squaw apple) growing in unmineralized soil of the Pine-Nut district. Station 28.

Figure 5b. Squaw apple with white flowers growing in Mo-rich soil. Station 28.

Figure 6. Abnormal juniper growing in Mo-rich soil, Pine-Nut district.

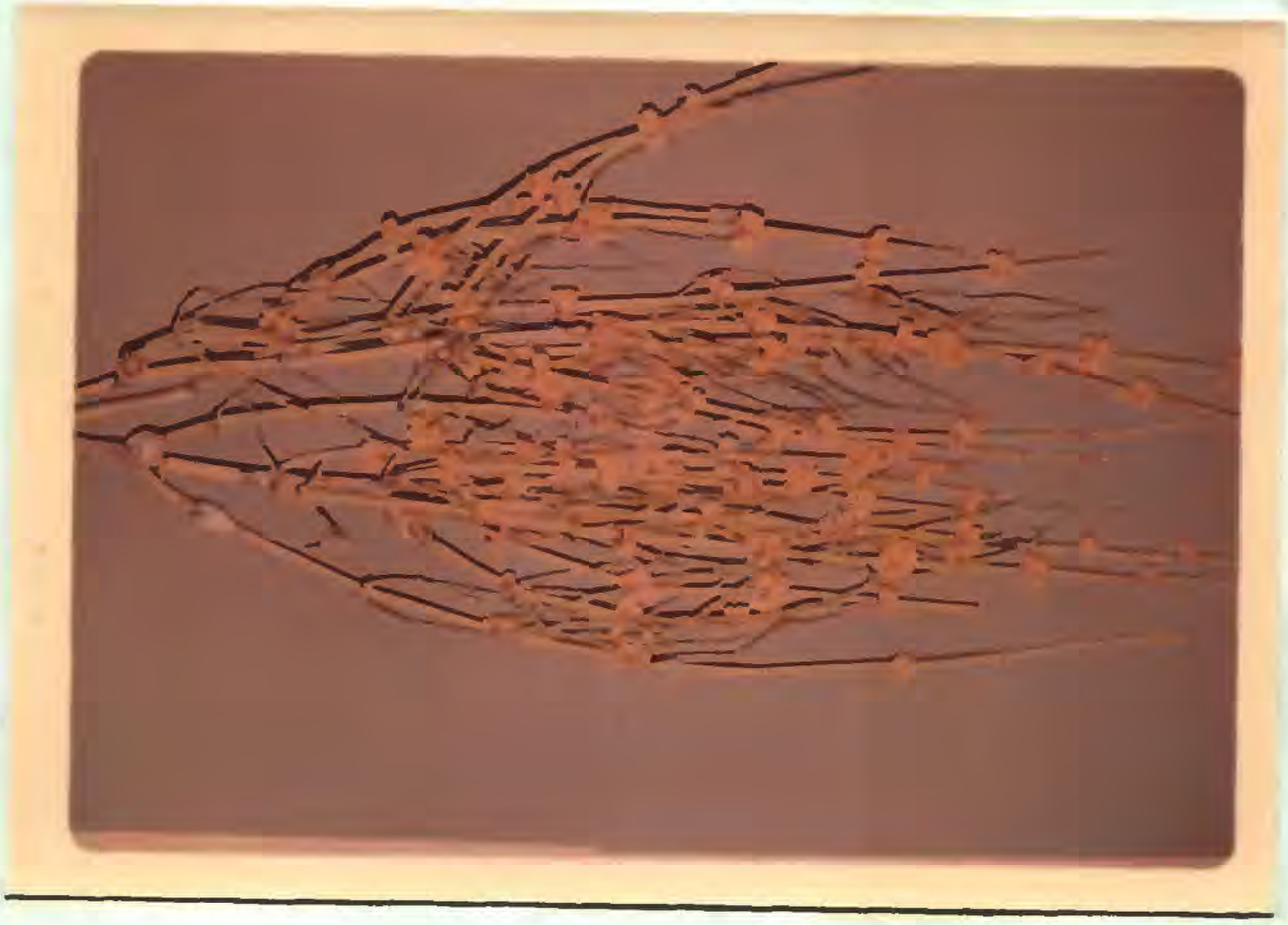

Figure 7a. Normal growth of Ephedra viridis (joint fir).

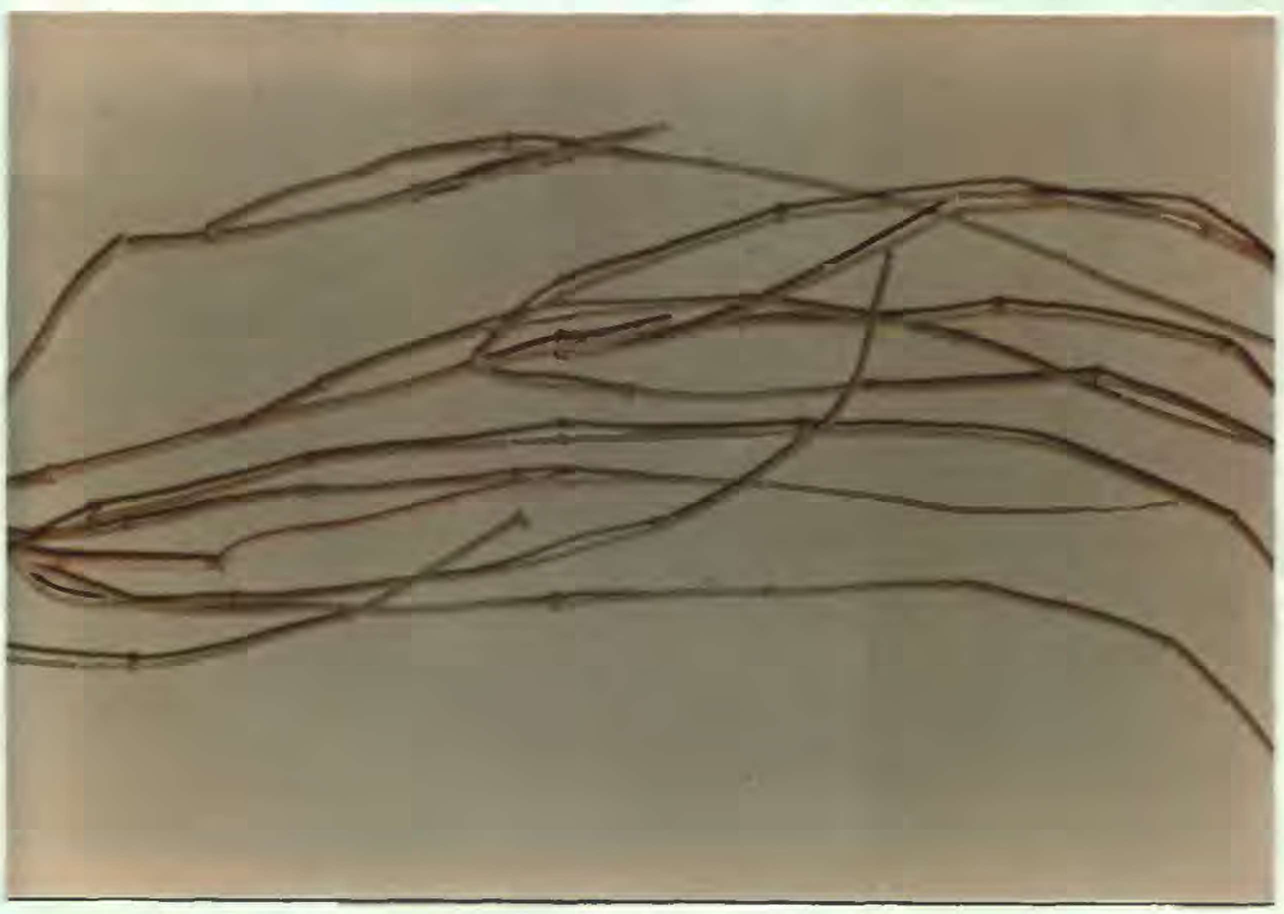

Figure 7b. Ephedra viridis with wand-like appearance growing in soils of high molybdenum content, Pine-Nut district.

were not analyzed for W, but contained 300 ppm Mo and 100 ppm Mo, respectively. They also contained 0.4 ppm U and the soils 2 ppm U. A radioactivity reading of 0.1 mr/hr was obtained on the bajada. The Mo values are high and the area should be investigated further.

Lead-zinc

Bertha Hall lead mine, Mono County, California, elevation 9,200 ft (Station 59). Lead-zinc ores occur in iron- and manganese-coated dolomite (fig. 8a). The significant plants associated with the Pb-rich soils included Eriogonum Lobbii, E. vimineum and the crucifer, Streptanthus tortuosus. The high Pb content may be balanced by the Fe in the soils, as no chlorosis was noted, although the tree growth (fig. 8a) appears to be affected. Eriogonum Lobbii previously observed only at the Frederick Au-Ag mine, grew vigorously with heavy, red-barked roots that were at least 32 inches long. The various parts of the plant contained from 5,000 ppm Pb in the stems to 10,000 ppm in the roots, and 2 percent or more Zn in the leaves and roots (Table 1). Both species of Eriogonum growing there are shown in figures 8b and 8c.

Tungsten

Divide tungsten mine, Douglas County, Nevada, elevation 7,200 ft (Station 30). As previously observed, the occurrence of dwarfed Lupinus caudatus on the dumps and the prolific stands of healthy lupine (fig. 9) down the drainage from the mines is unusual. The plant contained 30 ppm W rooted in soil containing 50 ppm W and 140 ppm Mo in soil that contained 36 ppm Mo. Lupine does not occur at the Alpine Mill or around the Mo mines on the other side of the mountain. The distribution may be related to the presence or absence of limestone because the genus is a strict calcifuge. The plant species that were observed in the area in 1973 and 1978 were not unusual, but did include two crucifers, Arabis pulehra and Descurainia sophia. The irregular growth of juniper observed at the Alpine Mo mill was also observed here. Observations made after dark with a mineral light showed W on the dump but no fluorescence in the vegetation.

Flying Cloud tungsten mine, Cottonwood Canyon, Mono County, California (Station 18), elevation 7,000 ft. Peraphyllum gracile (squawbush) grew around the mine and down the canyon. The only other locality where this plant was observed was in the Pine-Nut Mo district. Chrysothamnus nauseosus (rabbit-brush) sampled near the mine contained 50 ppm W, in soil containing 70 ppm W. Surprisingly, this sample contained 150 ppm Cr even though the soil contained only 10 ppm Cr (Table 2). Several species of Astragalus were identified but were not species known to be seleniferous.

Chromium-nickel

Belle mine, Candelaria district, Mineral County, Nevada, elevation 5,600 ft (Station 60). An outcrop of serpentine occurs near the Belle shaft. The serpentine is altered from ultramafic intrusive rock and contains magnetite and chromite. The serpentine was at one time shipped to the Gabbs area where it was used in the processing of magnetite (Ross, 1961). The plants observed at the site included the seleniferous Stanleya elata. A rare plant, Hecastocleis Shockleyi (a composite), grew on the serpentine and contained 200 ppm Cr and 50 ppm Ni--the maximum amount of Cr in a higher plant reported on this project (Table 2). This is the type locality for this species.

Figure 8a. Bertha Hall lead-zinc sampling station. Station 59.

Figure 8b. Eriogonum lobbii (granite eriogonum) sampled at lead-zinc mine. Station 59.

Figure 8c. Eriogonum vimineum (Broom eriogonum) at lead-zinc mine. Station 59.

Figure 9. Lupinus caudatus at Divide tungsten mine. Station 30.

Blue Noble mine, Mineral County, Nevada, elevation 6,000 ft (Station 13). This mine is reported to have mined turquoise and presumably copper, but is apparently down drainage from a serpentine area. Stream sediment below the mine had values of 1,500 ppm Co, 1,000 ppm Ni, 200 ppm Cu, and 0.10 ppm Au (Table 2). Stanleya elata occurred here and also several other S plants, Descurainia pinnata (tansy mustard), Lepidium montanum (peppergrass) (fig. 10a), and Eriogonum inflatum (desert trumpet). A shadscale sample contained only 7 ppm Cr and 20 ppm Ni but 17,500 ppm As (converted to ash).

Precious-Metal Deposits

Geobotanical relationships around Au and Ag deposits in nine districts were studied and selected samples were analyzed for key elements (Table 3). Eriogonum (wild buckwheat) was observed in eight of the districts; 13 different species were recorded. Of these, Eriogonum caespitosum, the mat-forming species was most common at high elevations of 8,200-10,400 ft. and E. umbellatum at 7,400-8,600 ft. Eriogonum ovalifolium was reported by Lidgey in 1897 to be an indicator of Ag in Montana. E. ovalifolium var. nivale occurred at the Montague and Frederick mines, both above 10,000 ft. in elevation. Arenaria Nuttallii v. gracilis (sandwort) grew with the latter species as in Montana. Species of Lupinus grew in six districts, and Phacelia in several. Shacklette and others (1970) suggest that Au in the soil is made soluble by cyanide excreted by plant root systems, which is derived from cyanogenic glycosides that occur in certain plant species. According to Girling and others (1979) Phacelia sericea, a cyanogenic plant, is an accumulator of Au. Unfortunately, none of our phacelias were analyzed for Au. Erdman and others (1985) found Douglas fir to be an accumulator of Au and to be useful in biogeochemical prospecting. This tree does not grow at any of our study sites. Monardella odoratissima, a mint, occurs on mineralized ground at four Au-Ag mines and two Cu mines. Reasons for the presence of certain genera near Au and Ag deposits may be the acidity of the soil, low Ca levels, or high Fe content, which increases the availability of phosphorus. Species of Eriogonum, Lupinus, Leptodactylon, and Oxyria grew around the Frederick mine on Fe-rich basic dike rock. Marchard (1973) mentions a similar association common on low Ca soils and related to exchangeable K.

Gold values as high as 2 and 2.3 ppm, respectively, were reported in Eriogonum caespitosum (fig. 10b) at the Chemung mine and Zannichella (poolmat) at a spring below the mine. The highest Ag contents (10 and 5 ppm) were found in the same plants.

Santa Fe mines, Mineral County, Nevada, elevation 5,700 ft (Station 5 and 34). The mines, six miles north of Luning in Santa Fe Pass, contain Ag-Pb minerals with tourmaline in a fissure vein cutting a quartz-hornblende diorite. Specular hematite is present (Clark, 1922). There is a 300 ft incline shaft and about 100 ft of workings. According to Ross (1961), $50,000 worth of Ag was produced. Stanleya elata (a S indicator) and Hymenoclea salsola (burrobush) grew along an altered zone that cropped out up the steep west side of the pass above an adit (Station 5). Stanleya, Eriogonum inflatum (S indicator) and E. nidularium grew all around the shaft entrance at Station 34.

Figure 10a. Lepidium montanum (peppergrass), Blue Noble mine. Station 13.

Figure 10b. Eriogonum caespitosum, sampled at the Chemung mine.

Samples of Stanleya elata and red oxidized hematite from Station 5 and Stanleya, soil, and a rock sample from the mine entrance at Station 34 were collected for analysis (Table 3). Stanleya does not appear to take up Au, Ag, or Pb, even as in this case, when growing in soil containing 30 ppm Ag and 700 ppm Pb. The rock sample collected at the shaft entrance had values of 500 ppm Ag and 20,000 ppm Pb.

Silverado-Kentuck mine, Mono County, California, elevation 9,000 ft (Station 50). The vein ores contain Au, Ag, Cu, and Pb. Plants growing around the mine included the S-loving crucifers, Draba subsessile and Arabis sp. Pinus albicaulis (white barked pine) and Holodiscus boursieri (rock spirea) were sampled directly above the portal for analysis. Silver was detected only in the roots of the pine, but 2 ppm Ag was reported in the twigs and leaves of Holodiscus that grew in soil containing 30 ppm Ag. Holodiscus that grew in a supposedly negative soil (0.2 ppm Ag) contained 1.5 ppm Ag. These amounts are greater than those reported in Holodiscus growing in other districts.

Montague mine, Mt. Patterson, Sweetwater Mountains, Mono County, California, elevation 11,000 ft (Station 56). The mine produced Ag, Au, Mo, and W (Kleinhampl and others, 1984), but the amounts are unknown.

Soils are not well developed above treeline on the crest of the Sweetwater Mountains, and the alpine plant communities, under stress from extreme climatic conditions, change abruptly at contacts of the various rock types that are exposed. Near the mine dumps, the Eriogonum ovalifolium var. nivale--Arenaria Nuttallii var. gracilis plant community is found on sediments containing 1,500-3,000 ppm Ca. Over rocks with less Ca (700 ppm), this community was replaced by the calcifuge Lupinus hypolasius (fig. 11a) growing on altered white clay. The Eriogonum absorbed more Ag and Pb than Lupinus. Phacelia frigida growing on a road cut contained 10,000 ppm Ba, whereas the soil contained only 700 ppm Ba.

Morning Star mine, Mono County, California, elevation 7,400 ft. (Station 45). The mine is in an area of Marklesville volcanics that contain quartz jasperoids. Geochemical sampling by Bruce Wachter (1969-70) showed the rocks to be enriched in Hg and W. The ores yielded Au, Ag, Cu, Ba, and Sb. The plants growing around the mine included many shrubs and herbs of the sagebrush scrub zone. A society of Eriogonum umbellatum, Arenaria Nuttallii v. gracilis (fig. 11b), Monardella odoratissima, Allium validum, and Mentha piperita (not seen elsewhere) may have geobotanical significance (Table 3). Prunus virginiana (elderberry), which was growing above the abandoned shaft, had a higher Au and Pb content in the stems than in the leaves or berries, but more Ag and As in the leaves. Holodiscus had considerably less Ag than Prunus.

Chemung mine, Masonic district, Mono County, California, elevation 8,200 ft (Station 46). Approximately $500,000 worth of Au and Ag have been taken from the mine (Kleinhampl and others, 1984). The main vein extends up a hill above the mill. Several species of Eriogonum (Table 3) and the mint Monardella odoratissima, are common around mines. The presence of Stanleya elata suggests that the ores contain selenium. Juniper, pinyon, and sage scrub cover the hillside. Eriogonum caespitosum had absorbed considerably more Au, Ag, and Pb than Holodiscus Boursieri (Table 3)--specifically 2 ppm Au, 10 ppm Ag, and 200 ppm Pb. Poolmat, Zannichella palustris, sampled in the large spring in the meadow below the mine (fig. 12) contained 2.3 ppm Au, 5 ppm Ag, 69 ppm As, and 70 ppm Pb. These Au levels are the highest of any reported in plants sampled on this project. The amounts of precious metals in the sludge in the bottom of the spring is not known.

Figure 11a. Lupinus hypolasius sampled at the Montague silver mine, Sweetwater Mountains. Station 56.

Figure 11b. Arenaria Nuttallii at Morning Star mine. Station 45.

Figure 12. Spring sampled below Chemung gold mine. Station 48.

Serita gold mine, Masonic district, Mono County, California, elevation 8,300 ft (Stations 47 and 48). About $500,000 worth of Au has been produced from this mine (Kleinhampl and others, 1984). Four species of Eriogonum grew at the unmineralized station (-) and only one in mineralized soil (+) around the mine. Samples of plant from both stations contained Au. Combined leaf and twig samples of Cercocarpus ledifolius contained the highest levels (ash basis) of Au (0.07 ppm), Ag (1 ppm), As (15 ppm), and Pb (70 ppm). An associated soil sample contained 1.0 ppm Au, 30 ppm Ag, 350 ppm As, and 1,500 ppm Pb (Table 3). Apparently As would be an excellent pathfinder element for prospecting in this area.

Frederick gold-silver mine, Sweetwater Mountains, Mono County, California, elevation 10,400 ft (Station 54). The Au occurs in a silicic porphyritic dike rock. An alpine flora that grew on the rock pavement 0.2 miles south of the mine included five species of Eriogonum and the sandwort Arenaria Nuttallii v. gracilis. This suggested possible mineralization and Eriogonum ovalifolium var. nivale and soil were analyzed, but contained no detectable Au. Moss collected from dike rock at the mine portal had values of 0.45 ppm Au, 50 ppm Ag, 500 Cr and 50 Ni. Possibly the Cr content of the dike rock should be investigated further. The Ag content of the moss was the highest reported in any plant analyzed on the project.

Aurora mining district, Mineral County, Nevada, elevation 7,600 ft (Station 20). Gold and silver occur in quartz veins cutting propylitized and seriticized andesitic flows of the Aurora formation (Payne, 1965). Two species of Astragalus, A. Purshii var. lectulus and A. malacus, not known to be Se accumulators, occurred around the old town site but were not observed on mineralized ground. A moss-like form of Eriogonum ovalifolium also grew in the town site. Eriogonum umbellatum (fig. 13) grew around prospects and mines on Last Chance Hill. A spring, precipitating calcareous tufa along a stream flowing north from the district, supported a growth of Ranunculus cymbalaria (Desert crowfoot) and ryegrass. The old tailings pond upstream was covered with rushes and algae.

Representative species and the soils or muck in which they were rooted were collected from the mine area, tailings, and spring for analysis (Table 3). The algae collected from the tailings had concentrated 0.15 ppm Au, 3 ppm Ag, and 100 ppm As--considerably larger amounts than those concentrated by Juncus. Payne (1965) has shown that As retained in the soil by coprecipitation with Fe can be used as a pathfinder element for the Au and Ag that have been leached from the soil. The buttercup and muck from the spring contained no Au, 5 ppm Ag, and the unexpected levels of 100 ppm Pb and 350 ppm W. The latter is the largest amount of W reported in a plant on this project. Possibly the chemistry of the spring plants reflect mineralization in the granite below the volcanics. The spring muck was not analyzed for W.

Bodie gold and silver district, Mono County, California, elevation 8,400 ft (Station 21). Gold and silver occur in quartz veins cutting the Bodie Canyon volcanics that overlie the Aurora volcanics, and thus were deposited later than the metals of the Aurora district (Payne, 1965). Mines and diggings pockmark the hills that surround the town of Bodie, which is now preserved as a State Historical Park (figs. 14a, 14b).

Six species of Eriogonum occurred in the study localities and were associated with Monardella odoratissima, Phacelia bicolor, and Lupinus caudatus. A sample of filamentous algae growing in the stream that drains the district had values of 0.55 ppm Au, 7 ppm Ag, and 196 ppm As (ash basis). A sample of sagebrush that was collected near a mine at Station 21d absorbed lesser amounts of all three elements, but the soil contained 50 ppm As (Table 3).

Figure 13. Eriogonum umbellatum growing in mineralized ground of the Aurora gold district.

Figure 14a. Mine workings of Bodie gold district, near algal sampling station.

Figure 14b. Mines and part of town, Bodie gold district.

Uranium mines and radioactive areas

Four uranium mines and three areas of possible uranium (U) or thorium (Th) mineralization were visited. The most important indicator plants that are useful in prospecting on the Colorado Plateau (Cannon, 1957) do not occur here because of the low levels of selenium, the Colorado Plateau pathfinder element. The plant most tolerant of radiation was the shrub Atriplex confertifolia (shadscale), which grew rooted in ore or dump material at all locations below 5,600 ft. Other species common on uraniferous soils were Oryzopis hymenoides (rice grass) requiring small amounts of Se, and Eriogonum inflatum (desert trumpet), a S-indicating plant. The largest amounts of U in the plants that were analyzed were found in the water-loving Carex abrupta (sedge) and Salix lemmoni (willow). These plants grew along the stream draining the Juniper open pit and had absorbed 200 ppm U and 100 ppm U, respectively; they showed no signs of radiation damage. Pinus albicaulis (white pine) growing on Juniper mine dump material and exhibiting chlorosis, contained 4.5 ppm U (Table 4). These concentrations in plants around autonite mines are extremely high compared to 2 ppm indicating carnotite ore on the Colorado Plateau. The samples of Eriogonum collected from the East Fork of Walker River, from the Rainbow rare earth mine and from Monitor Pass all contained a large quantity of U. The U contents of other plants and soils from these areas are not U-rich. Effects of radiation damage on the highly susceptible Stanleya were observed in areas of relatively low level radiation; the plant cannot reproduce in highly radioactive areas.

Holiday uranium-thorium mine, Mineral County, Nevada (Station 40), elevation 5,000 ft. Thorite, huttonite, and uranothorite occur in plagioclase in the hanging wall of a vertical fault, which separates a dike of plagioclase, epidote, mica, and apatite from the quartz monzonite country rock (Ross, 1961). The ore assays 0.22% U_3O_8 and 0.85% ThO_2. Russian thistle and shadscale grew on the most radioactive material at the mine entrance. Eriogonum deflexum, E. inflatum, and E. nidularium grew here but not E. ovalifolium v. multiscapum, which occurs in radioactive ground on east Walker Creek. No Stanleya grew around the mine because the high levels of radioactivity would prevent the development of seeds, but plants were observed at a distance down drainage from the mine.

Juniper uranium mine, Tuolumne County, California (Station 41), elevation 8,640 ft. Autonite occurs in a carbonized layer in claystone beds of volcanic andesite. Ore valued at $1,600,000 has been mined from the open pit shown in figure 15a. Springs issue from sides of the pit and furnish water for a small stream that flows from the pit. A sample of sedge growing along the stream contained an unusually large amount of 200 ppm U. A sample of stream sediment associated with the sedge contained 20 ppm. Values of 100 ppm U were reported in willow growing in soil that contained 30 ppm. Trees growing on dump material were yellowed or dead (fig. 15c, 15d). Chloratic white pine had a U content of 16 ppm and the dump material 35 ppm. The old Sierra juniper (fig. 15b) at the discovery stake above the open pit had only 0.4 ppm U in the end branches, but 2.8 ppm U in the roots (Table 4).

Nyemin uranium mine, Mineral County, Nevada (Station 8), elevation 4,400 ft. The outcrop and diggings are located on top of a small hill southeast of "Hot Springs" on the east side of Alkali Playa. The ore is meta-autonite in silicified rhyolitic tuff and registered 3,500 counts per minute on a scintillometer. No different plants were noted with the exception of Chaenactis steviodes, but the same remarkable tolerance for radiation was shown by plants of Atriplex confertifolia (shadscale), which were rooted in

Figure 15a. Juniper uranium mine. Station 41. Arrow shows carbonized beds of high U content.

Figure 15b. Juniperus occidentalis sampled at discovery stake of Juniper mine.

Figure 15c. The chlorosis in pine growing in dump material at Juniper uranium mine. Station 41.

Figure 15d. Unhealthy red fir near dump of Juniper uranium mine. Station 41.

the ore outcrop, as at the Ule-Ann claims. The shadscale had unusually reddish bracts. A value of 2 ppm U was reported in leaves and young twigs of shadscale growing above the cut and also rooted directly in ore. Old wood contained 4.5 ppm U (Table 4). Species of plants on the pediments below the mine showed no differentiation in plant distribution on barren or mineralized ground.

Garfield Hills, Mineral County, Nevada, elevation 5,200 ft (Station 9). Carnotite occurs in tuffs of the area which has been staked. Sagebrush and many commonly associated shrubs cover the hills. Eriogonum inflatum (desert trumpet) occurred all over the north-facing hillside (fig. 16a). The large assemblage of herbs also included Lepidium montanum, Phacelia gymnoclada and P. crenulata common around base-metal deposits. No plants were collected for analysis.

Ule-Ann claims, Mineral County, Nevada (Station 10), elevation 5,400 ft. The claims are located close to the road through the Garfield Hills pass (fig. 16b). The uranium occurs as carnotite on bedding planes in tuffaceous sandstone. A small amount of production has been reported. Shadscale grew on the mineralized exposure and was collected with soil for analysis. The soil had a value of 30 ppm U and the plant 2 ppm (Table 4). Eriogonum inflatum grew here as on the north-facing hill at Station 9 along with Oenothera and Chaenactis.

East Fork of Walker River, Lyons County, Nevada, elevation 6,100 ft (Stations 26, 27, and 42; fig. 17a and 17b). This is an interesting area in which plants may be useful in delineating U-rich ground. The presence of U was considered possible in the altered beds of volcanic rhyolitic or pyroclastic sediments on the south slope of east Walker River. The plant society included Eriogonum ovalifolium vs. multiscapum, which was associated with Cu mineralization in Montana (Grimes and Earhart, 1975), Eriogonum rupinum, Eriogonum wrightii ssp. subscapum, Arenaria nuttalii (also associated with Cu in Montana) Oenothera allysoides, Phacelia frigida, crucifers and many other calcifuge species. Shadscale, Oenothera, Eriogonum and blue altered material were collected for analysis. A second collection of Eriogonum ovalifolium var. multiscapum and blue clay was made at Station 27 near the Morgan Ranch. The Eriogonum contained from 7 to 30 ppm U, the other plants less than 0.4 ppm U and the soils 1.0 ppm (Table 4). The Cu value was low. A level of 5-15 ppb U was reported by Benson and Leach (1979) in well water at the Morgan Ranch. Their sampling of the Walker River drainage system showed high U levels in the central and western parts of the basin and concentration by evaporation in Walker Lake.

An area relatively bare of plants (particularly sage) with sharply defined boundaries was investigated at Station 42 (fig. 17b). There were claim stakes in the area. Eriogonum ovalifolium var. multiscapum grew in the area devoid of shrubs along with Lupinus pusillus and Cordylanthus Helleri. Values of 25 ppm U in Eriogonum and 0.9 ppm U in associated soil were reported. A scintillometer reading of 0.15 mr/hr was obtained.

Uranium in Walker Lake, Mineral County, Nevada, elevation 4,000 ft (Station 17). The waters of the closed basin of Walker Lake have been reported to contain U. The source is believed to be in areas of recharge west of the lake (Benson and Leach, 1979). A tamarisk growing on the shore of the lake and a biscuit-shaped algal specimen collected from the lake were submitted for analysis. The tamarisk twigs contained 1.2 ppm U and the alga 5.5 ppm U and 60 ppm Li. Levels of 2 ppm U were reported in a sample of the salt crust and surface soil at the edge of the lake (Table 4).

Figure 16a. Garfield Hills uranium area. Station 9.

Figure 16b. Ule-Ann uranium claims, Garfield Hills. Station 10.

Figure 17a. Altered blue beds along East Walker River. Station 26.

Figure 17b. Area bare of shrubs near East Walker River. Station 42.

Radioactive area north of Gillis Range, Mineral County, Nevada, elevation 5,600 ft (Station 33). Abnormal flower spikes on Stanleya pinnata were observed in a fairly large area with measurable radioactivity believed to be due to Th. On these spikes, the green sepals were enlarged, the yellow petals and stamens were absent and tiny asexual plants were developing from the pistil (figs. 18a, 18b). This phenomenon has been observed at the Nevada Test Site and also produced in plants grown in experimental plots, to which ground U ore was added to some and ground Th ores were added to others (Cannon and others, 1983). A sample contained 0.6 ppm U but was below the detection limit of 100 ppm Th. A scintillometer reading of 0.17 mr/hr was obtained.

Rainbow rare earth mine, Lyon County, Nevada, elevation 7,000 ft (Station 43). Here, rare earths occur in a pegmatite cutting a phyllite schist (Kleinhampl, pers. comm., 1978). This mine was visited by Frank Kleinhampl who collected specimens of the plants growing there and a sample of Eriogonum wrightii ssp. subscapum and soil from a bare spot for analysis. Only 10-15 ppm Y was reported in the plant and 30 ppm Y in the soil (Table 4). However, the plant contained 20 ppm U in the flower scapes and 8 ppm in the leaves. The soil was not analyzed for U. The mine should be checked for U levels.

Industrial Minerals

Several types of industrial minerals have been produced in the Walker Lake 1^{o} x 2^{o} quadrangle. Sulfur, talc, and diatomaceous earth are concentrated from volcanic sources; salt and borates in evaporative closed basins; and travertine from hot springs. Although Li is processed at Mina, the source of the Li is Clayton Valley to the south. No clear-cut association of species with the element or compound being produced could be seen. The three species of pine growing at the Leviathan sulfur mine were dwarfed, but perhaps owing to the high As content rather than that of S. Halophytes such as pickleweed, cattle saltbush, greasewood, saltgrass, and seepweed grew in the closed basins rich in salts, and calciphiles grew in the travertine springs. Analyses of samples that were collected are given in table 5. Algae appear to concentrate S, Ba, Sr, and As. In the Leviathan open pit, algae accumulated 50 ppm Tl.

Leviathan sulfur mine, Alpine County, California, elevation 7,200 ft (Station 52). Native S has been mined for H_2SO_4 production from an open pit in Tertiary volcanics by Anaconda Corporation. Springs issue from the base of the tailings or dump material on the side of the mountain. Trees growing in the high S soils are dwarfed (fig. 19). The large number of plant species growing on the hillside and around the springs did not include plants known to have indicator significance. Filamentous green algae and dogbane were collected in the pit for analysis. The dogbane had absorbed 4.0 percent S and 4.0 ppm As; the algae 1.7 percent S, 1.0 percent As, and an unusually large amount of tellurium (50 ppm) (Table 5). The high As content in the algae suggests a high level of As in the S ore.

Dover talc mine (Donnelly andalusite mine), Mineral County, Nevada, elevation 5,400 ft (Station 16). The ore consists of replacement bodies of aluminum minerals (andalusite and pyrophyllite) in metavolcanic rocks. There is a 400 x 230 ft open pit and a 200 ft shaft (Ross, 1961) (fig. 20a). There were selenite crystals on the dump. Several S-loving plants grow around the open pit and dump, including Stanleya elata, Eriogonum inflatum (all around open pit) (fig. 20d), and Lepidium lasciocarpum. The plant society also included Lycium andersonii (wolfberry), a Li accumulator (fig. 20b), and Phacelia gymnoclada (fig. 20c). Atriplex spinifera and stream sediment were

Figure 18a. Normal Stanleya pinnata (Prince's plume).

Figure 18b. Irradiated Stanleya lacking petals and stamens and producing asexual growth from pistils. Station 33.

Figure 19. Waste material from open pit of Leviathan sulfur mine, and dwarfed trees on hillside. Station 52.

Figure 20a. Dover talc mine. Station 16.

Figure 20b. Lycium andersonii (wolfberry) at Dover talc mine. Station 16.

Figure 20c. Phacelia gymnoclada (yellowthroat) at the Dover talc mine. Station 16.

Figure 20d. Eriogonum inflatum (desert trumpet), an indicator of gypsum, around Dover talc mine. Station 16.

analyzed but only by emission spectrography; the amounts of Al and S were not determined (Table 5).

Giraux barium mine, Candelaria district, Mineral County, Nevada, elevation 6,500 ft (Station 37). The barite occurs in a vein 40 ft wide and 300 ft long in Ordovician chert. The plants growing on the dump were not unusual. A wide-leafed variety of Eriogonum ovalifolium grew on some iron-rich dump material. A specimen of ore contained greater than 5,000 ppm Ba, 2,000 ppm Sr, 10,000 ppm Fe and very little else. Chrysothamnus collected along a traverse across the ore by Roberts (1949) had levels of $<$ 100 to 1,800 ppm Ba.

B and B group, Gabbs Valley Range, Mineral County, Nevada, elevation 5,400 ft (Station 35). A deposit of diatomaceous earth was being mined on a small hillside. An unidentified Eriogonum and selenium indicators, Stanleya pinnata, Stanleya elata, and Oryzopis hymenoides all grew in the diggings. The valley was being prospected for uranium. Radioactivity levels ranged from 0.12 to 0.75 mr/hr.

Rhodes Salt Marsh (Virginia), Mineral County, Nevada, elevation 4,400 ft (Station 15). According to Ross (1961) salt (NaCl) was first mined from the marsh, later borax, then thenardite (Na_2SO_4). The latter at a production rate of 150 tons a day with a reserve of 3,000,000 tons. The salt in the early days was shipped by camel to Comstock City for use in gold extraction. The cottonball borax (ulexite) was picked out by hand. The salts form halos from the center outward with NaCl in the center, then NaCl + borax, then Na_2SO_4 + $NaCO_3$. The water level is 4-5 ft below the surface. The brines are too low in potash to warrant extraction.

The Foote Mineral Company--Lithium Division, has a plant at Mina just north of Rhodes Salt Marsh, and are reportedly processing Li from Columbus Salt Marsh. Analyses of samples collected from the latter are reported in Cannon and others (1975).

The plants of Rhodes Salt Marsh consisted entirely of halophytes--Suaeda torreyana (seepweed), Allenrolfea occidentalis (pickleweed) (fig. 21b), Sarcobatus vermiculatus (greasewood), Distichlis spicata (saltgrass), Kochia americana (green molly), and Atriplex polycarpa (cattle spinach) (fig. 21a). 500 ppm B, 10,000 ppm Mg, and greater than 50,000 ppm Na were reported in pickleweed. No Li was detected, and the plant was not analyzed for Cl or S (Table 5).

Teel's Marsh, Mineral County, Nevada, elevation 4,912 ft (Station 38). Salt (NaCl) was first extracted from the playa commercially. In 1872, the first borax to be discovered in Nevada playas was found here and was produced from 1872-1892 at which time the Death Valley borates were discovered (Ross, 1961). Saltgrass, greasewood, and horsetails grew at a spring on the southwest edge of the playa. Greasewood and algae were collected for analysis (fig. 22). The blue-green algae, Coelosphaerium sp. and Oscillatoria sp., a green alga Sirogonium sp. and six species of diatoms were identified in the algal sample. The greasewood contained more than five percent Na and one percent Mg, surpassing the Na uptake of the algae. Calcium was not reported in the plants, but there was three percent Ca in the soil. The samples were not analyzed for S or Cl.

Travertine Springs near Bridgeport, Mono County, California, elevation 6,800 ft (Station 25b). These springs have precipitated large amounts of $CaCO_3$, which has been quarried as travertine stone. The hot water from the springs flows along a natural conduit in the top of an elevated mound of travertine and drops into a small pond of hot water (figs. 23a, 23b). Three

Figure 21a. Atriplex polycarpa (cattle spinach) at Rhodes Marsh. Station 15.

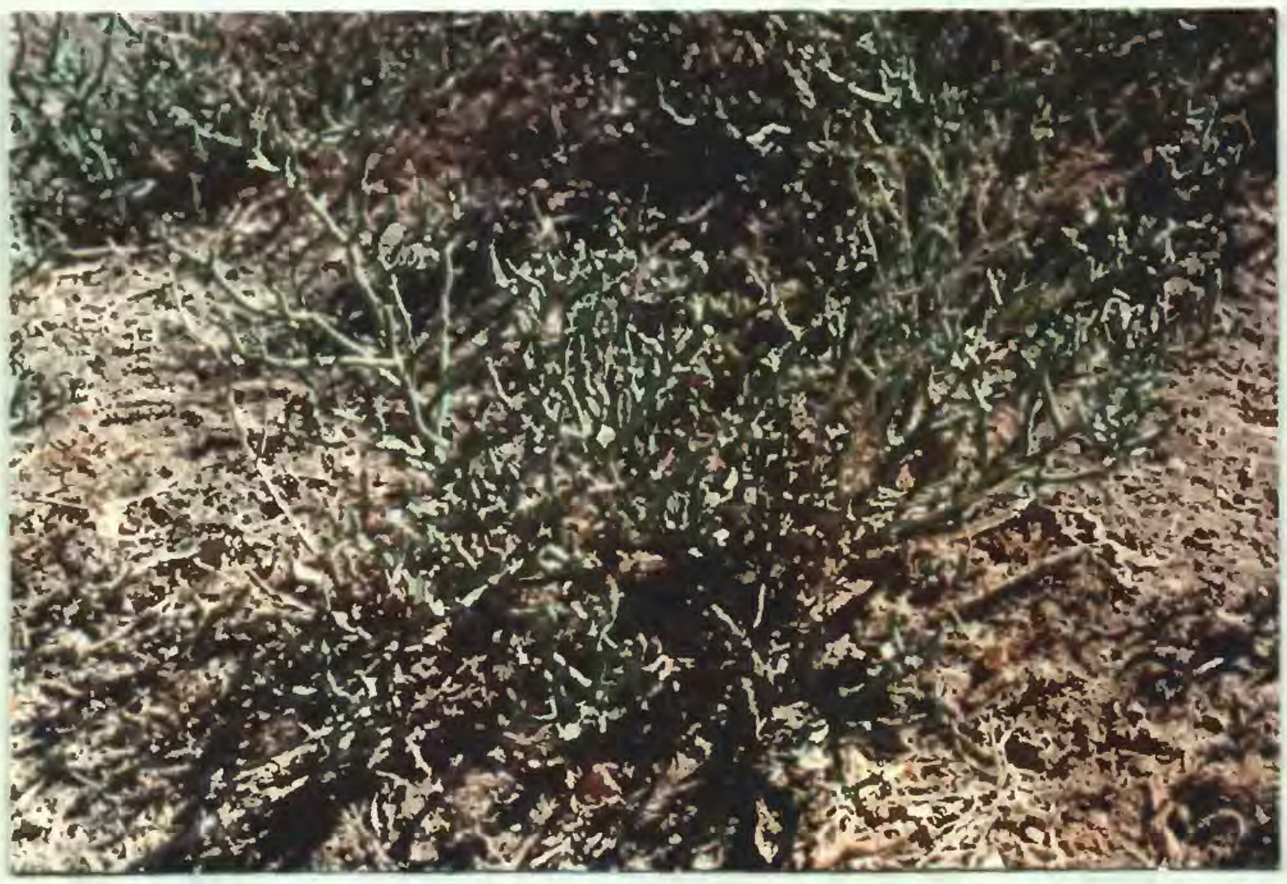

Figure 21b. Allenrolfea occidentalis (pickleweed) sampled at Rhodes Marsh. Station 15.

Figure 22. Spring in Teel's Marsh where greasewood and algae were sampled. Station 38.

Figure 23a. Travertine hot springs near Bridgeport where samples collected from ponded water. Station 25.

Figure 23b. Conduit from hot spring along travertine mound to ponded water at Bridgeport travertine springs.

genera of blue-green algae, Oscillatoria sp., Nostoc sp., and Hammatoidea yellowstonensis were collected from the ponded hot water. Oscillatoria and Nostoc are listed by von Linstow (1929) as preferring lime. The incrustations contained 15 percent Ca, greater than 5 percent Sr, 3 percent Mg, and 0.05 percent B. The Li level of 700 ppm is also high. The anion values are not known. The algae absorbed less than these amounts (Table 5), but bullrushes growing in a small nearby spring contained more than 0.1 percent B and more than 0.5 percent Sr. Concentrations of Ca, Mg, and Sr were considerably reduced at Station 25a, a half mile downstream, but the levels of Li and Sr in green algae and greasewood were high. A large number of plant species were recorded growing on the slopes of travertine, including Senecio crassulus, S. multilobatus, Pentstemon speciosus, several mustards, sedges and bushes. All of these are necessarily calcophile species; species of several genera such as Mentzelia (Blazing star) and Eriogonum (wild buckwheat) occurring at travertine springs have been reported as gypsum indicators in the literature (Cannon, 1971).

Garfield Flat, Mineral County, Nevada, elevation 5,500 ft (Station 12). The phreatophyte Sarcobatus vermiculatus, greasewood, grows on the playa called Garfield Flat and was sampled along with playa mud to determine whether Li occurred in quantity. Both plant and mud contained little Li, 1-1.5 percent Ca and Mg, and the greasewood contained greater than 5 percent Na (Table 5).

Mono Lake, Mono County, California, elevation 6,400 ft (Station 22). Mono Lake is a saline remnant of a much larger, deep fresh water glacial lake. The lake level has dropped rapidly since 1941 owing to diversion of water for Los Angeles consumption (1.5 feet per year). Salinity is caused by evaporation, which averages six times that of annual precipitation (Cloud and Lajoie, 1980). According to the Park Service signs, Ca-rich fresh-water springs along the edge of the lake coming in contact with salt water of high $NaSO_4$ and $Na(CO_3)_2$ salts causes precipitates of $CaCO_3$ and $CaSO_4$. Subvertical axial channels that carry water upward increase precipitation of the strange tufa mounds that presently extend above the level of the lake. Travertine has been mined, and evaporated salts have been sold for health purposes. The water of Mono Lake has been reported by Cleveland and others (1983) to contain in mg/l:

$CaCO_3$	26,300	Na	26,000
Ca	12	Sr	0.03
Fe	1	Cl	22,000
Mg	23	F	48
Mn	0.03	P	20
K	1,300	S	8,300

Green algae growing in a spring that issues from a mound at a height of several feet above the ground (fig. 24b) was collected for analysis. The spring issuing from the tufa mounds has created a small community of water-loving plants, Rorippa nasturtium-aquaticium (watercress), Ranunculus cymbalarius (buttercup), Mimulus, Arabis, and moss. A floating algae mat, biscuit-shaped with scalloped edges, probably Nostoc caeruleum, was collected from the lake along with the salt crust on the shore for analysis (fig. 24a). The algal specimen from the lake had considerably more Mg, Li, and Na than the algae from the spring (Table 5).

Figure 24a. Mono Lake at algal collection station 22.

Figure 24b. Spring issues from vent several feet above ground level in tufa mound left above level of receding Mono Lake. Station 22.

Springs and a mineralized well

Several hot or warm springs and a shallow mineralized well were sampled to determine whether they contained cations of economic value or suggested mineralization at depth. Lithium, which is one of the last ions to be deposited from evaporative brines, is easily redissolved by hot spring waters and brought to the surface where it may reflect Li at depth in the basins. Lithium occurs in commercial amounts in closed evaporative basins and, in particular, in lacustrine deposits of volcanic origin (Cannon et al., 1975). Lithium levels in plant and soil samples from several springs were relatively high; the unusually high W and Cu contents in the soil near Dead Horse Well may be attributed to milling contamination.

Hot Springs, Mineral County, Nevada, elevation 3,900 ft (Station 7). These very hot springs, reported to be 140^{o}F, are on the east side of Alkali Flat and a few miles northeast of the Nye-Min uranium deposit. Mucilagenous colonial algae float in mats on the surface of the springs and blue mud occurs at depth. The algae and mud both had levels 0.4 ppm U, 50-55 ppm Li and relatively high rare earths (Table 6).

Fales Hot Spring, Mono County, California, elevation 7,400 ft (Station 24). Analyses of the water by the Water Resources Division of the U.S. Geological Survey in Menlo Park show 1.5 mg/l Li. Collections were made of plants and soil in the stream directly below the hot spring pool. The levels of metals in green algae and *Mimulus guttatus* (fig. 25a) differ markedly. The algae concentrated the largest amounts of Be, Ge, Fe, As, and Mn; *Mimulus* had higher concentrations of Li and Cu than algae or soil (Table 6).

Warm Springs, east of Bridgeport, Mono County, California (Station 23). Eight springs issue along a ring fracture zone on the east side of a caldera. The springs have formed small rock screes with no soil development. Green algae, watercress, muck, and volcanic rock containing plagioclase phenocrysts were collected. Both plants contained 16 ppm Li and 1,000 ppm Ba. They were not analyzed for U (Table 6).

Long Doctor Spring, Lyon County, Nevada (Station 43) is piped into a trough for stock, one mile below the Rainbow rare earth claims. The area is east of the Sweetwater Range. The green filamentous algae, *Sirogonium* sp. from the trough had a value of more than 100 ppm Ge (Table 6).

Dead Horse Well, Mineral County, Nevada, elevation 4,163 ft (Station 32). The well, on the west side of Alkali Flat, is near ruins of what may have been a processing plant for W, because the Rawhide tungsten district is about five miles to the north. *Sarcobatus vermiculatus*, greasewood (fig. 25b), and soil were collected. The greasewood had concentrations of 160 ppm W, 500 ppm Li, and 100 ppm Cu; the soil contained 1,500 ppm W, 3,000 ppm Cu, and 7 ppm Ag (Table 6). Unfortunately, the soil was not analyzed for Li; the ratio of Li in seven samples of *Sarcobatus* to soil collected earlier in open and closed basins of the Basin and Range province averaged 1.1 or a little more Li in the plant than in the soil (Cannon and others, 1975). Further analyses of plants and soils for Li in this area may be warranted.

CONCLUSIONS

The purpose of this reconnaissance survey was to make geobotanical observations of plant assemblages and growth habits as related to various types of mineralization in the hope that these observations might be useful in suggesting areas for prospecting or for additional sampling. Selected samples were taken to determine the chemical controls of the observed effects on vegetation.

Figure 25a. Mimulus guttatus sampled at Fales Hot Spring. Station 24.

Figure 25b. Sarcobatus vermiculatus sampled at Dead Horse Well. Station 32.

Growth anomalies--Several growth differences have been noted in the Pine-Nut molybdenum district (high Mo, low Cu) which are not common in mining districts where both Mo and Cu are high. These include a lengthening of the internodes in Ephedra (joint fir), pine and juniper; smaller white, instead of pink, flowers on Peraphyllum; and a brighter green color in junipers growing on mineralized ground. The strange growth in juniper was also noted in trees growing along washes that drain the district. A reddening of the stems and bracts of certain plants was noted at Yerington copper pit and Nyemin autonite mine. Dwarfing is common on highly mineralized ground and was observed at the Bertha Hall lead mine and the Leviathan sulfur mine. The effects of radiation damage were observed in both species of Stanleya in areas of relatively low but measurable radiation. In highly radioactive areas, the plants cannot reproduce, and hence are not available as indicators of U deposits that contain Se.

Plant distribution--No strong indicators of Se were found near U mines or prospects. The species of Astragalus that were identified are not known to be seleniferous and did not appear to have a clear-cut association with ore. The two Stanleya species that grew in the quadrangle have different distribution patterns. Stanleya pinnata grows profusely on lake sediments or on fans at low elevations; Stanleya elata is commonly confined to mineralized ground at higher elevations. The genus requires S and also Se but not in great quantities. Eriogonum inflatum, the mustards, Lepidium and Descurainia, and Oenothera also indicate high S soils. Seventeen species of Eriogonum occur in mineralized areas of the Walker Lake quadrangle and are particularly prevalent near Cu, Au, or Ag deposits. Thus, an association of several of the above-mentioned species growing in the same area is highly suggestive of either the presence of sulfides or gypsum.

Ion accumulation in plants--Unusually high levels of Mo and Cu were reported in pine and Stanleya, the latter growing in soil not known to be mineralized. The largest values of Au and Ag were found in Eriogonum caespitosum and in a water plant Zannichella. Zanichella, a moss, and algae absorbed the largest amounts of As in Au districts, suggesting that the As content of plants in streams may be used as an indicator of Au deposits. Two varieties or subspecies of Eriogonum contained unusually high levels of U in dry areas of no known U mineralization. Species of Eriogonum occur in areas highly mineralized with Cu, Pb, Au, Ag, and U in the Walker Lake $1^{o} \times 2^{o}$ quadrangle; the genus is not only tolerant of metals, but accumulates them. One species of Eriogonum was shown by Grimes and Earhart (1975) to be an indicator of Cu in Montana; other species may be useful in prospecting for many metals. Similarly, phreatophytes along drainage courses may be used in prospecting for U, as shown by concentrations of more than 100 ppm U in willow and sedges below the Juniper mine. Industrial mineral deposits are usually self evident and the analysis of plants is of little value. An exception is the analysis of phreatophytes for Li at springs or deep wells, which may indicate the presence of economic amounts of Li at depth. Such is suggested by the Li content of greasewood at Dead Horse Well.

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APPENDIX--Estimated average elemental contents in the ash of vegetation growing in unmineralized soils (compiled from literature and from files of the senior author)*

[Leaders (--) mean insufficient data]

Element	All vegetation	Grasses	Legumes	Other forbs	Shrubs	Deciduous trees	Coniferous trees	Approximate number of analyses
				Parts per million				
As	--	3.1	41	9.6	--	8.5	--	62
Al	8500	3000	4000	4400	30,000	14,000	18,000	80+
Ag	0.1-5	<1	<1	<1	<1	1.6	<1	308+
Au	<0.007	--	--	--	--	0.015	<0.006	32+
B	580	200	360	600	1,200	730	570	702
Ba	1100	600	1300	500	1,140	1,900	1,300	250
Cd	9.1	22	<1	5	8	8	9	500+
Co	*7	<5	8	10	14	8	*7	1367
Cr	15	22	10	12	22	6	9	1450
Cu	150	120	125	120	220	250	150	3880
Li	--	1.5	2.9	18	20	7	8.6	350
Mn	3300	1680	1730	3270	10,000	6,900	6,700	1880
Mo	13	23	15	17	12	7	5	930
Ni	65	45	25	35	95	85	55	950
Pb	70	170	20	40	80	50	75	2040
Se	--	1.3	<4	4.5	--	1.7	--	87
Sr	1730	330	960	1920	1,935	2,080	2,500	216
U	0.62	2.8	0.8	1.7	0.4	0.7	0.7	610
V	20	20	12	20	30	15	20	320
Zn	1220	690	560	650	1,560	2,000	1,130	2150
				Percentages				
Ash yield	10.1	7.9	7.6	6.1	8.9	11.5	3.3	--
Ca	--	5	22	12	13	23	15	2880
S	2.4	2.6	2.1	3.6	1.5	1.6	2.0	500
Fe	0.7	0.9	0.5	1.0	1.1	0.7	1.4	790
K	23	26	23	26	17	12	20	1270
Mg	4.3	2.6	4.3	3.5	5.9	4.6	4.3	1300
Na	--	3.7	2.4	4.2	0.9	2.1	1.5	220
P	3	2.3	3.3	3.3	2.0	2.3	3.5	2620

One-half of the less than values as <500 (etc.) were used in the calculations. Arsenic, Se, and S values reported in dry weight were converted to values in ash for easy comparison.

*Approximate only