U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Analytical results from a greenhouse study of sagebrush grown in soils containing Carlin ore

by

*K.C. Stewart, D.M. McKown and D. L. Fey

Open-File Report 94-237

*U.S. Geological Survey, Denver Federal Center, Box 25046, MS 973, Denver, CO 80225 (all authors).

CONTENTS

TABLES

INTRODUCTION

Sagebrush has been proposed for use as a biogeochemical prospecting medium for gold in the Great Basin of Nevada because of its widespread growth in areas where Carlin-type disseminated gold deposits are known to exist (Erdman and Olson, 1985; Erdman and others, 1988; Busche, 1989). Because of its extensive root system, sagebrush may tap groundwater containing mobile ions associated with these deposits (Reynolds and Fraley, 1989; Weaver and Clements, 1938; West, 1983). In the desert environment, however, true anomalies in plant data resulting from internal uptake may be obscured by surface aeolian contamination of the plant material. This is especially true for plants such as sagebrush that have rough surface textures and secrete resins and oils which tend to trap dust particles (Cutter and Guyette, 1993; Wilt and others, 1992; Rosentreter and Kelsey, 1991; Fowells, 1965). In order to investigate the utility of sagebrush for biogeochemical exploration in the Great Basin, we designed a controlled greenhouse study to determine if sagebrush accumulates gold from soils containing Carlin-type disseminated gold ores.

GREENHOUSE METHODS

Growth Medium

Soil was collected from the Osgood Mountains in Humbolt County west of Preble, Nevada. Approximately 450 pounds of soil from several holes 2 feet in diameter by 18 inches deep was transported in 5-gallon buckets to the U.S. Geological Survey (USGS) laboratories in Denver. The soil was disaggregated with a mechanical mortar and pestle, sieved through a 10-mesh (2mm) sieve to break up large clods of dirt and to remove small rocks, and then mixed for 6 hours in a large V-blender to obtain a homogeneous mixture.

Carlin-type dissemminated gold ore was obtained from the Pinson and Getchell mining districts in Nevada. Gold is found in these ores as sub-microscopic elemental gold associated with quartz, pyrite, realgar and orpiment (Berger and Bagby, 1991; Kretschmer, 1984; Erickson and others, 1964). Ores were crushed with a jaw crusher, ground with ceramic plates to pass a 100-mesh (150 μm) sieve, and mixed to homogeneity in a V-blender. Soil and ores were combined in different proportions to obtain three different potting mixtures. Soil mixture (M1) was prepared without ore to represent a nonmineralized soil from Humbolt County. Two additional mixtures (M2 and M3) were prepared to contain anomalous levels of gold, arsenic, antimony and tunsten (Shacklette and Boerngen, 1984). Perlite was added to increase permeability (26 percent by weight).

Sagebrush

Seeds were collected in January, 1991 from a single basin big sagebrush plant (*Artemisia tridentata* ssp. *tridentata*) growing west of Preble, Nevada. Plants were germinated and grown to seedling stage (approximately 5 inches tall) by a commercial greenhouse. The 6-month old seedlings together with the root balls and supporting medium were transplanted into gallon pots with the soil mixtures, placed in a greenhouse, and grown for 4 months under ambient light conditions. Greenhouse temperatures were maintained between 21 and 30°C and soil moisture was kept at 20 percent by weight. A standard randomized block design was used for the study (Freese, 1967). Six plants potted in each mixture were randomly placed in each of three blocks.

SAMPLE PREPARATION

After 4 months, plants were harvested by cutting the stem approximately 1 inch above the soil level. Stems, twigs, and leaves were coarsely chopped into pieces and mixed to obtain one sample per plant. Samples were cleaned in dionized water containing Triton X-100® by sonication for 15 minutes, rinsed with deionized water, and air-dried at room temperature. A portion of each sample was reserved and the rest was dry-ashed in a muffle furnace overnight at 475°C. Samples and standard reference materials were submitted in a randomized order for analysis.

ANALYTICAL TECHNIQUES

Instrumental Neutron Activation Analysis (INAA)

Gold, arsenic, antimony and tungsten levels were quantitated in soils and unashed plant samples by instrumental neutron activation analysis (Baedecker and McKown, 1987). Samples were packed into pre-cleaned polythethylene vials and irridiated for 8 hours in the USGS research reactor. Following a decay period of 6 days, elements were quantitated from their individual spectral peaks of induced radioactivity with a high-resolution gamma-ray spectrometer. Lower limits for determination (LLD) are shown in Table 1.

Inductively coupled argon plasma-atomic emission spectroscopy (ICP-AES)

A 40-element determination was made on on the soils and ashed plant samples by inductively coupled argon plasma-atomic emission spectroscopy (Crock and others, 1983). Samples were decomposed at low temperature (100°C) with a mixture of concentrated hydrochloric, nitric, perchloric and hydrofluoric acids, taken to dryness, redissolved in aqua regia, and diluted with 1 percent nitric acid. Plant data were converted to a dry-weight basis for reporting. Elements reported and the LLD are shown in tables 1, 2, and 3.

RESULTS

Tables 4-7 show the analytical results for soil mixtures and plants. Splits of the original soil mixtures were analyzed as well as the soils from the pots at harvest. Table 8 lists the certified and noncertified values for the reference materials for comparison with the actual data obtained by the two methods of analysis. In the soil data, gold shows the poorest precision of all elements with a relative standard deviation (RSD) of 26 percent. Other elements show less than 5 percent RSD. All elements determined in the soil reference material fall within 2 standard deviations of certified values with the exception of arsenic, sodium, and zinc. Arsenic and zinc values are just below 2 standard deviations and sodium values are slightly higher than 2 standard deviations of the certified values.

In the reference sagebrush, gold by INAA was determined with a 15 percent RSD. Arsenic values for NBS 1575 are somewhat low, but those for NBS 1572 agree with the certified values. Values for antimony and tungsten in the reference materials are not certified, but values for NBS 1572 agree more closely with the noncertified values than do those for NBS 1575. Copper and iron by ICP-AES for one replicate and aluminum for both replicates of NBS 1572 fall outside 1 standard deviation, but other data for this reference material agree with the certified values. Elements in reference material NBS 1575 agree well with certified values except for manganese in both replicates and iron in one replicate which fall below the certified values. The good agreement of analytical data in the reference materials with certified values assured us of the accuracy in data obtained from this study.

Table 8 lists the means and standard deviations for gold, arsenic, antimony, and tungsten in five random samples taken from each soil mixture. Concentrations of gold, arsenic and antimony were significantly higher in soil mixtures M2 and M3 than in M1, but arsenic and antimony were not significantly different in mixtures M2 and M3. Tungsten was significantly higher in M3 than the other two mixtures.

Table 9 presents results of Duncan's test for multiple range and F tests (Duncan, 1955). Concentrations not joined by the same line are significantly different at the 0.05 probability level. The means for sagebrush gold among the various treatments are not significantly different. Mean arsenic and antimony concentrations in plants growing in M2 and M3, however, are significantly higher than for the control plants growing in M1. Mean plant tungsten levels for the two lowest levels of soil tungsten cannot be distinguished at the 0.05 probability level, but the concentration in plants growing in the highest soil tunsten is significantly greater than the other two. Tungsten values reported in the sagebrush, however, are only twice its LLD.

CONCLUSIONS

After 4 months of growth under controlled greenhouse conditions, sagebrush showed statistically significant uptake of arsenic, antimony, and tungsten from soils amended with Carlin-type disseminated gold ore. No significant uptake, however, was found for gold. Since gold uptake is not significant in a controlled environment, gold anomalies found in field studies may reflect aeolian gold rather than gold in the plant tissue. Gold in sagebrush from the Great Basin is therefore probably not the most sensitive indicator of concealed Carlin-type deposits. On the other hand, arsenic and antimony in sagebrush might be sensitive indicators of concealed gold deposits in the Great Basin since these elements are rapidly accumulated into above-ground tissue in a controlled environment to levels that are well above determination limits for INAA.

REFERENCES

Baedecker, P.A., and McKown, D.M., 1987, Instrumental neutron activation analysis of geochemical samples, *in* Baedecker, P.A., ed., Methods of Geochemical Analysis. U.S. Geological Survey Bulletin 1770, p. H1-H14.

Berger, B.R., and Bagby, W.C.D., 1991, The geology and origin of Carlin-type gold deposits, in Foster, R.P., ed., Gold Metallogeny and Exploration: Glasgow, Blackie & Son, 432 p.

Busche, F.D., 1989, Using plants as an exploration tool for gold: J. Geochem. Explor., v. 32, p. 199-209.

Crock, J.G., Lichte, F.E., and Briggs, P.E., 1983, Determination of elements in National Bureau of Standards Geologic Reference Materials SRM 278 obsidian and SRM 688 basalt by inductively coupled argon plasma-atomic emission spectrometry: Geostandards Newsletter, v. 7, p. 335-340.

Cutter, B.E., and Guyette, R.P., 1993, Anatomical, chemical and ecological factors affecting tree species choice in dendrochemistry studies: J. Env. Quality, v. 22, p. 611-619.

Duncan, D.B., 1955, Multiple range and multiple *F* tests, Biometrics, 11, p. 1-42.

Erdman, J.A., and Olson, J.C., 1985, The use of plants in prospecting for gold: A brief overview with a selected bibliography and topic index: J. Geochem. Explor., v. 24, p. 281-304.

Erdman, J.A., Cookro, T.M., O'Leary, R.M., and Harms, T.F., 1988, Gold and other metals in big sagebrush (*Artemisia tridentata* Nutt.) as an exploration tool, Gold Run District, Humboldt County, Nevada: J. Geochem. Explor., v. 30, p. 287-308.

Erickson, R.L., Marranzino, A.P., Oda, U., and Janes, W.W., 1964, Geochemical exploration near the Getchell Mine Humboldt County, Nevada: U.S. Geological Survey Bulletin 1198-A, 26 p.

Fowells, H.A., 1965, Silvics of forest trees of the United States: USDA Agric. Handb. 271, U.S. Gov. Printing Office, Washington, DC, 320 p.

Freese, F., 1967, Elementary statistics for foresters: U.S. Department of Agriculture Handbook 317, 87 p.

Grundy, W.D., and Miesch, A.T., 1988, 1988, Brief descriptions of STATPAC and related statistical programs for the IBM Personal Computer: U.S. Geological Survey Open-File Report 87-411-A, 34 p.

Kretschmer, E. L., 1984, Geology of the Pinson and Preble gold deposits, Humboldt County, Nevada: Ariz. Geological Soc. Dig., v. 15, p. 59-66.

Reynonds, T.D., and Fraley, L., Jr., 1989, Root profiles of some native and exotic plant species in southeastern Idaho: Env. Exp. Botany v. 29, p. 241-248.

Rosentreter, R., and Kelsey, R.G., 1991, Xeric big sagebrush, a new subspecies in the *Artemisia tridentata* complex: J. Range Management, v. 44, p. 330-335.

Shacklette, H.T., and Boerngen, J.G., 1984, Element concentrations in soils and other surficial materials of the conterminous United States: U.S. Geol. Survey Professional Paper 1270, 105 p.

Weaver, J.E., and Clements, F.E., 1938, Plant Ecology: New York, NY, McGraw-Hill Book Company, Inc., 601 p.

West, N.E., 1983, Great basin--Colorado Plateau sagebrush semi-desert, in West, N.E., ed., Ecosystems of the World, Temperate Deserts and Semi-deserts: Amsterdam, Elsevier Scientific Publishing Co., 522 p.

Wilt, M.F., Geddes, J.D., Tamma, R.V., Miller, G.C., and Everett, R.L., 1992, Interspecific variation of phenolic concentrations in persistent leaves among six taxa from subgenus *Tridentatae* of *Artemisia* (Asteraceae): Biochemical Systematics and Ecology, v. 20, p.41-52.

Table 1. Lower limits of determination (LLD) for elements reported by INAA. Two values are shown if LLD's are different for plants and soils. Values in ppm dry weight unless otherwise noted.

LLD	Element
1 ppb[1,2]	Au
0.1[1]	As, Sb, W
0.05[2]	As, W
0.01[2]	Sb

[1]soils; [2]plants

Table 2. Lower limits of determination (LLD) for elements in soil mixtures reported by ICP-AES. Values in ppm dry weight.

LLD	Element
1000	K
200	U
100	Al, Ca, Fe, Mg, Na, P, Ti
80	Ta
20	As, Bi, Sn
16	Au
8	Ce, Ga, Ho, Mn, Nb, Nd, Pb, Th
4	Ag, Cd, Eu, La, Li, Mo, Ni, Sc, Sr, V, Y, Zn
2	Ba, Be, Co, Cr, Cu, Yb

Table 3. Lower limits of determination (LLD) for elements in sagebrush reported by ICP-AES. Values are adjusted for percent ash by USGS STATPAC program GXFIXX[1] and reported in ppm dry weight.

LLD	Element
50	K
30	Al, Ca, Fe, Mg, Na, P
4.6	As
1	Li
0.6	Mo
0.5	Cr, Mn, Ni
0.2	Sr, Zn
0.1	Ba, Cu

[1]Grundy and Miesch, 1988.

Table 4. Analytical data listing for elements in soil mixtures reported by ICP-AES. Elements not detectable at determination limits shown in table 2 are omitted. First position in ID sequence represents soil mixture (M1, M2, M3 in table 3), second position represents block # in the randomized block design, and third position represents replicate. Samples of the original mixtures were taken as random splits, not from blocks.

ID	Al, %	As, ppm	Ba, ppm	Be, ppm	Ca, %	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Fe, %
					original mixtures					
101	6.6	<20	750	3	1.2	53	5	31	15	1.6
102	6.5	<20	750	3	1.2	53	4	26	10	1.6
103	6.5	<20	760	3	1.2	49	5	26	11	1.6
104	6.4	<20	800	3	1.2	51	5	25	10	1.6
105	6.5	<20	780	3	1.2	53	5	26	11	1.6
201	6.7	200	650	4	1.1	49	4	25	12	1.5
202	6.5	170	710	4	1.1	57	5	27	11	1.6
203	6.4	170	740	3	1.1	47	5	26	11	1.5
204	6.7	180	640	4	1.1	59	5	24	9	1.5
205	6.5	150	710	4	1.1	51	4	26	11	1.5
301	6.4	170	750	3	1.1	46	4	38	10	1.5
302	6.3	180	740	3	1.1	60	4	38	10	1.5
303	6.3	140	710	3	1.0	49	4	38	10	1.5
304	6.3	160	700	3	1.0	42	4	37	9	1.5
305	6.3	180	710	3	1.1	48	4	37	10	1.5
					pots after harvest					
111	6.5	<20	770	3	1.2	48	5	26	9	1.6
112	6.5	<20	720	4	1.1	44	5	27	6	1.6
121	6.6	<20	690	4	1.1	54	5	26	11	1.6
122	6.5	<20	720	4	1.2	45	5	26	11	1.6
131	6.6	<20	760	4	1.2	50	5	26	11	1.6
132	6.4	<20	710	4	1.1	59	5	29	11	1.6
211	6.5	180	720	4	1.2	46	4	29	11	1.6
212	6.5	180	720	3	1.2	64	5	30	11	1.7
221	6.6	160	640	4	1.1	47	3	24	2	1.5
222	6.5	190	740	3	1.2	62	6	28	10	1.7
231	6.6	170	720	4	1.1	52	5	27	10	1.6
232	6.6	160	700	4	1.1	55	5	27	13	1.6
311	6.3	150	670	4	1.0	44	3	36	11	1.4
312	6.4	180	680	3	1.1	49	5	40	11	1.5
321	6.3	170	680	4	1.0	52	4	37	9	1.5
322	6.4	170	730	3	1.1	54	4	39	11	1.5
331	6.4	170	660	4	1.0	41	4	38	9	1.5
332	6.4	240	700	3	1.1	48	4	38	10	1.5
					NIST standard reference material					
2711-1	6.5	88	700	2	3.0	69	11	45	110	3.0
2711-2	6.4	87	690	2	3.0	70	11	45	110	2.9

Table 4 cont.

ID	Ga, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %	Nb, ppm	Nd, ppm	Ni, ppm
					original mixtures					
101	21	2.6	30	42	.41	550	2.0	20	25	11
102	19	2.6	32	43	.41	580	2.0	18	22	11
103	19	2.6	30	41	.41	560	2.0	20	26	12
104	18	2.6	31	40	.42	540	2.0	20	25	11
105	20	2.6	30	43	.41	600	2.0	19	22	11
201	20	2.8	28	51	.38	660	2.2	24	23	11
202	19	2.6	35	45	.40	590	2.1	16	25	12
203	18	2.6	31	44	.39	570	2.0	22	21	11
204	19	2.8	37	51	.38	650	2.2	24	24	10
205	18	2.7	31	45	.39	590	2.1	24	21	12
301	17	2.5	28	44	.38	520	1.9	21	17	11
302	20	2.5	37	43	.38	560	1.8	20	28	11
303	18	2.5	29	46	.37	540	1.9	23	20	11
304	19	2.5	27	46	.37	540	1.9	23	18	12
305	20	2.5	28	45	.38	530	1.9	22	23	11
					pots after harvest					
111	20	2.7	29	44	.41	580	2.0	21	22	12
112	17	2.7	29	45	.49	610	2.0	21	21	12
121	20	2.7	32	47	.40	620	2.1	24	26	12
122	19	2.6	27	44	.47	590	2.0	22	22	12
131	20	2.7	31	45	.40	600	2.1	20	23	11
132	19	2.7	36	43	.60	590	2.0	20	27	14
211	19	2.7	29	45	.40	590	2.1	22	22	12
212	17	2.6	39	43	.57	580	2.0	19	26	13
221	17	2.7	28	49	.38	630	2.2	28	14	10
222	18	2.7	38	42	.57	570	2.0	20	26	14
231	22	2.7	28	47	.39	640	2.2	24	19	12
232	20	2.7	31	47	.45	620	2.1	25	22	13
311	18	2.5	27	49	.35	570	1.9	27	19	10
312	17	2.4	29	47	.42	550	1.9	22	21	12
321	20	2.5	30	48	.37	580	1.9	23	24	11
322	19	2.5	33	46	.44	530	1.9	22	21	13
331	19	2.5	24	50	.38	580	2.0	23	19	11
332	18	2.5	29	47	.41	550	1.9	24	14	11
					NIST standard reference material					
2711-1	16	2.4	40	27	1.10	650	1.2	9	29	20
2711-2	16	2.4	40	26	1.00	630	1.2	10	30	20

Table 4 cont.

ID	P, %	Pb, ppm	Sc, ppm	Sr, ppm	Th, ppm	Ti, ppm	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
					original mixtures					
101	.04	22	7	220	14	.21	47	25	3	57
102	.04	23	7	220	13	.21	46	26	3	56
103	.05	23	7	220	14	.21	47	25	3	54
104	.04	24	6	230	14	.20	48	24	3	54
105	.05	25	7	220	15	.21	47	26	3	56
201	.04	26	7	190	14	.20	42	30	4	59
202	.04	26	7	210	17	.21	46	28	3	57
203	.04	22	7	210	14	.19	43	26	3	54
204	.04	26	7	190	16	.19	43	30	3	59
205	.04	25	7	210	16	.20	44	26	3	55
301	.04	26	7	200	11	.23	51	26	3	52
302	.04	24	7	200	15	.22	51	26	3	51
303	.04	25	7	190	13	.21	49	26	3	51
304	.04	26	7	190	12	.21	48	25	3	52
305	.04	23	7	190	15	.22	48	26	3	52
					pots after harvest					
111	.04	22	7	220	16	.20	46	26	3	55
112	.04	23	6	200	15	.20	45	26	3	56
121	.04	24	7	200	16	.21	46	29	3	59
122	.04	24	6	210	13	.21	45	26	3	57
131	.04	26	7	220	15	.20	47	28	4	56
132	.04	21	7	200	17	.21	44	26	3	56
211	.04	25	6	210	16	.20	46	26	3	57
212	.04	26	6	210	16	.22	47	26	3	56
221	.04	25	7	190	10	.19	40	29	<2	59
222	.04	24	7	210	17	.21	47	25	3	57
231	.04	26	7	200	15	.21	45	28	3	58
232	.04	26	7	200	17	.20	44	28	3	59
311	.03	27	7	180	14	.21	45	28	3	52
312	.04	25	7	190	14	.23	50	27	3	53
321	.04	25	7	180	14	.21	47	29	3	53
322	.04	21	7	190	15	.23	51	26	3	52
331	.04	24	7	180	12	.23	47	28	3	54
332	.04	24	7	190	8	.22	46	26	<2	52
					NIST standard reference material					
2711-1	.09	1,100	9	250	13	.26	79	24	2	340
2711-2	.08	1,100	10	250	13	.27	77	25	3	330

Table 5. Analytical data listing for elements in soil mixtures reported by INAA. First position in ID sequence represents soil mixture (M1, M2, M3), second position represents block # in the randomized block design, and third position represents replicate. Samples of the original mixtures were taken as random splits, not from blocks.

ID	Au, ppb	As, ppm	Sb, ppm	W, ppm
		original mixtures		
101	<1.0	6.4	1.3	2.1
102	<1.0	6.6	1.2	2.3
103	2.0	6.3	1.2	2.2
104	1.8	8.5	1.3	3.0
105	1.9	6.7	1.4	2.0
201	37	230	15	3.3
202	33	220	12	2.6
203	33	220	13	3.2
204	38	230	15	3.2
205	38	220	11	3.3
301	180	270	11	13
302	190	230	11	13
303	210	240	12	13
304	180	230	11	13
305	190	240	14	14
		pots after harvest		
111	<1.0	6.4	1.5	2.5
112	1.5	6.4	1.2	2.1
121	<1.0	6.1	1.2	2.2
122	<1.0	5.9	1.2	2.7
131	1.2	6.7	1.2	1.9
132	<1.0	6.5	1.4	2.7
211	33	230	13	3.3
212	37	220	11	3.2
221	40	230	14	3.5
222	34	210	11	3.1
231	35	210	17	3.7
232	36	240	10	3.6
311	200	230	11	13
312	200	240	13	14
321	180	230	11	13
322	180	220	12	13
331	200	230	11	14
332	190	230	13	13
		NIST standard reference material		
2711-1	26	120	22	3.9
2711-2	38	120	22	4.2

Table 6. Analytical data listing for elements in sagebrush reported by ICP-AES on a dry weight basis. First position in ID sequence represents soil mixture of growth (M1, M2, M3), second position represents block # in randomized block design, and third position represents replicate.

ID	Al, ppm	As, ppm	Ba, ppm	Ca, ppm	Cr, ppm	Cu, ppm	Fe, ppm	K, ppm
				greenhouse sagebrush				
111	178	<4.6	18	4,981	.65	7.1	130	16,604
112	159	<4.6	16	4,934	.72	8.2	139	14,906
121	218	<4.6	13	3,717	.59	7.1	136	19,470
122	138	<4.6	15	4,379	.69	5.9	118	14,268
131	158	<4.6	19	5,736	.57	8.6	139	11,950
132	112	<4.6	17	4,730	.56	6.5	151	11,180
211	148	7.4	14	4,742	<.49	16.8	49	12,350
212	175	6.7	18	6,180	.62	8.2	191	12,875
221	155	8.3	17	4,963	.52	8.8	103	14,993
222	148	<4.6	17	4,813	.62	8.6	179	19,744
231	137	<4.6	15	5,470	.55	13.1	126	15,863
232	139	<4.6	13	3,889	<.49	6.0	139	12,964
311	167	5.9	17	5,003	.54	10.8	167	16,140
312	197	<4.6	20	5,412	.64	10.3	207	11,808
321	156	<4.6	16	6,115	.50	8.7	119	18,096
322	170	<4.6	13	4,454	.53	5.6	123	18,752
331	134	<4.6	15	4,104	.65	6.5	147	12,096
332	168	<4.6	18	5,250	.63	8.4	152	14,700
				reference materials				
1575-1	448	<4.6	6	3,776	2.60	2.8	168	3,304
1575-2	500	<4.6	7	4,170	2.56	2.8	195	3,614
1572-1	76	<4.6	20	31,750	.89	14.0	63	19,050
1572-2	76	<4.6	19	31,500	.88	16.4	88	17,640
CR21-1	1,918	<4.6	34	4,681	1.69	9.6	1,072	10,716
CR21-2	2,079	<4.6	36	4,811	1.84	8.3	1,188	11,286

Table 6 cont.

ID	Mg, ppm	Mn, ppm	Mo, ppm	Na, ppm	Ni, ppm	P, ppm	Sr, ppm	Zn, ppm	Ash, %
				greenhouse sagebrush					
111	1,720	83	1.8	231	1.1	2,550	23	36	5.9
112	1,439	134	2.3	139	1.3	4,369	21	27	5.1
121	1,062	53	2.1	159	.7	2,714	15	19	5.9
122	1,230	59	1.5	276	.8	2,854	23	26	4.9
131	1,482	115	2.5	124	1.0	3,203	24	33	4.8
132	1,419	189	.6	108	1.0	2,881	23	39	4.3
211	1,334	168	2.5	99	1.0	3,606	18	21	4.9
212	1,700	108	3.4	155	1.2	3,193	27	23	5.2
221	1,137	150	--	103	<.5	3,671	19	30	5.2
222	1,481	74	2.2	123	1.4	3,579	26	28	6.2
231	1,532	219	2.1	137	1.1	2,899	21	43	5.5
232	1,019	157	2.3	139	<.5	2,963	14	37	4.6
311	1,345	91	3.6	167	.8	3,228	23	23	5.4
312	1,624	98	3.9	148	2.0	3,050	23	28	4.9
321	1,685	243	1.7	137	1.2	3,682	22	44	6.2
322	1,289	100	2.3	164	.8	4,161	17	29	5.9
331	1,296	121	1.7	108	<.5	3,413	17	43	4.3
332	1,523	205	1.3	147	<.5	3,360	24	43	5.3
				reference materials					
1575-1	1,038	590	<.6	31	2.2	1,180	4	57	2.4
1575-2	1,140	584	<.6	39	2.3	1,279	5	83	2.8
1572-1	5,588	20	<.6	165	.6	1,524	100	27	12.7
1572-2	5,544	20	<.6	164	<.5	1,512	97	29	12.6
CR21-1	1,128	68	<.6	265	1.0	959	34	14	5.6
CR21-2	1,129	65	<.6	261	1.1	1,010	36	14	5.9

Table 7. Analytical data listing for elements in sagebrush reported by INAA on a dry weight basis. First position in ID sequence represents mixture of growth (M1, M2, M3), second position represents block # in the randomized block design and third position represents replicate.

ID	Au, ppb	As, ppm	Sb, ppm	W, ppm
		greenhouse sagebrush		
111	1.6	<.05	<.05	.06
112	2.1	1.2	<.05	<.05
121	<1	1.2	<.05	<.05
122	1.3	.05	<.05	<.05
131	<1	.07	<.05	<.05
132	3.3	.08	<.05	<.05
211	1.0	11	.33	.13
212	<1	8.4	.32	.08
221	1.7	8.7	.17	.06
222	<1	3.2	.11	<.05
231	<1	3.0	.12	<.05
232	<1	4.2	.17	.08
311	<1	6.4	.20	.14
312	1.5	4.5	.21	.09
321	1.0	3.8	.13	.06
322	6.4	5.0	.19	.14
331	4.2	4.7	.16	.10
332	1.9	1.9	.26	.08
		reference materials		
1575-1	<1	.13	.12	.09
1575-2	<1	.16	.15	<.05
1572-1	<1	3.3	.04	.07
1572-2	<1	2.9	.05	.06
CR21-1	2.1	.68	.13	<.05
CR21-2	1.7	.62	.10	.10

Table 8. Concentrations of gold, arsenic, antimony and tungsten in soil mixtures used for potting sagebrush. Calculations are based on the five replicates for each original mixture shown in table 5. Data less than determination limit (DL) is replaced by 0.7 times the DL for statistical calculations.

Mixture	Au, ppb	As, ppm	Sb, ppm	W, ppm
M1	1.4 ± 0.7	6.9 ± 0.9	1.3 ± 0.1	2.3 ± 0.4
M2	36 ± 3	224 ± 5	13 ± 2	3.1 ± 0.3
M3	190 ± 12	242 ± 16	12 ± 1	13 ± 0.4

Table 9. Concentrations of gold, arsenic, antimony, and tungsten in sagebrush grown in soil mixtures shown in table 8. Means not joined by the same line are statistically different at the .05 probability level as determined by Duncan's test.[1]

	M1	M2	M3
Au, ppb	1.6	.88	2.6
As, ppm	.44	4.4	6.4
Sb, ppm	.03	.19	.20
W, ppm	.04	.07	.10

[1]Duncan, 1955

Table 10. Certified, noncertified () and consensus values[4] on a dry weight basis for reference materials used in this greenhouse study. No value reported (---).

reference material	Al, %[1] ppm[2,3]	As, ppm	Au, ppb	Ba, ppm	Ca, %	Ce, ppm	Co, ppm	Cu, ppm	Cr, ppm	Fe, %[1] ppm[2,3]	Ga, ppm
NIST 2711[1]	6.5	105	(30)	730	2.9	(69)	(10)	114	47	2.9	(15)
NBS 1572[2]	92	3.1	---	21	3.2	(0.28)	(0.02)	16.5	0.8	90	---
NBS 1575[3]	545	0.21	---	---	0.41	(0.4)	(0.1)	3.0	2.6	200	---
CR21[4]	---	---	2.2	---	0.45	---	0.33	---	---	---	---

reference material	K, %	La, ppm	Li, ppm	Mg, ppm	Mn, ppm	Mo, ppm	Na, %[1] ppm[2,4]	Nd, ppm	Ni, ppm	P, %	Pb, ppm
NIST 2711	2.5	(40)	---	1.05	638	(1.6)	1.14	(31)	21	.086	1160
NBS 1572	1.82	(0.19)	---	0.58	23	0.17	160	---	0.6	0.13	13.3
NBS 1575	0.37	(0.2)	---	---	675	---	---	---	(3.5)	0.12	10.8
CR21	0.99	---	1.49	---	---	---	0.022	---	---	---	---

reference material	Sb, ppm	Sc, ppm	Sr, ppm	Th, ppm	Ti, %	V, ppm	W, ppm	Y, ppm	Yb, ppm	Zn, ppm	ash, %
NIST 2711	19	9	---	13.6	0.31	81.6	(3)	(25)	(2.7)	350	---
NBS 1572	(0.04)	(0.01)	100	---	---	---	---	---	---	29	---
NBS 1575	(0.2)	(0.03)	4.8	0.037	---	---	---	---	---	---	---
CR21	---	---	---	---	---	---	---	---	---	20	5.5

[1]National Institutes of Standards Technology, moderately contaminated soil, various methods
[2]National Bureau of Standards, citrus leaves, various methods
[3]National Bureau of Standards, pine needles, various methods
[4]inhouse sagebrush reference material, flame atomic absorption, n=12