

Baseline Elemental Concentrations for Big Sagebrush from Western U.S.A.

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Abstract

The analysis of samples of big sagebrush from 190 sites in 8 western physiographic provinces resulted in measurable concentrations of 30 elements. Except for Sb, U, and V, whose concentrations were generally below the analytical detection limits, the expected (baseline) concentration range of each element was defined. The variability in the concentration of Ba, Ca, Li, Pb, Se, Sr, and Zn among the 8 provinces was found to be nonsignificant and therefore a mean and deviation (for all provinces combined) for these elements was used to define their baseline. For concentrations of 20 of the elements (including the environmentally important metals As, Cd, Cr, Co, Cu, Hg, and Mo), significant variability was found among province populations so that baseline values are reported for each province or group of provinces. Physiographic provinces were incorporated in the study design as a convenient natural unit in presenting the element baselines and we anticipate that these data may be useful in assessing biogeochemical changes brought about by the activities of energy development, mineral processing, and other anthropogenic disturbances.

The major goal of this study is to establish baselines for the elemental composition of big sagebrush (*Artemisia tridentata* Nutt.) throughout the western U.S.A. Big sagebrush is one of the most widely distributed and easily recognized shrubs of this vast region and of southern British Columbia, Canada. The importance of this species as a component in natural ecosystems and in regions dominated by livestock production was the subject of a recent symposium (Utah State Univ., 1979).

At the beginning of this study, baseline elemental composition data were seen as being useful primarily in assessing the consequences of energy development in the western U.S.A. Such activities include the surface-mining of coal and the attendant geochemical and biogeochemical changes following land reclamation (e.g., Munshower and Neuman 1980) as well as point-source contamination from coal-fired power plants and mineral processing facilities (e.g., Connor et al. 1976, Severson and Gough 1976). Elemental composition data, however, may be equally useful in evaluating contamination from natural events (e.g., the Mount St. Helens eruption) or assessing the value of sagebrush as a browse plant for livestock or for wildlife (e.g., Alvarez-Cordero and McKell 1979, Welch and McArthur 1979). In addition, big sagebrush has had limited use as a sampling medium for geochemical exploration (Warren et al. 1949, Cannon 1952, Anderson and Kurtz 1956, and Erdman and Harrach 1981) and the data in the present report should be useful in helping to identify anomalous samples from potentially mineralized areas. The use of big sagebrush as a biogeochemical exploration medium is attractive not only because of its wide distribution but also because it grows in vast regions where alluvial and colluvial surfaces (as in the Basin and Range province)

may cover blind ore deposits (Lovering and McCarthy 1978).

Sampling Methods and Study Design

In the fall of 1975, big sagebrush samples were collected from 190 sites that were located in 8 western physiographic provinces (Fig. 1). All samples were collected between the end of August and the end of October when vegetative growth has generally ceased (DePuit and Caldwell 1973). Variation in the element concentrations of young big sagebrush tissue can be large (Gough and Erdman 1980). We showed that some differences in element concentration are likely due to intrinsic factors, such as a plant's genetic make-up, coupled with seasonal and climatic changes in element availability, and may not necessarily reflect environmental disturbance or underlying mineralization. In order to minimize these problems samples of sagebrush should represent a given plant part and be collected within a reasonably short period of time.

Each sample consisted of about 300 g of the current year's leaves and stems (approximately the terminal 20–30 cm of branches). A composite of this material was made from several shrubs within a

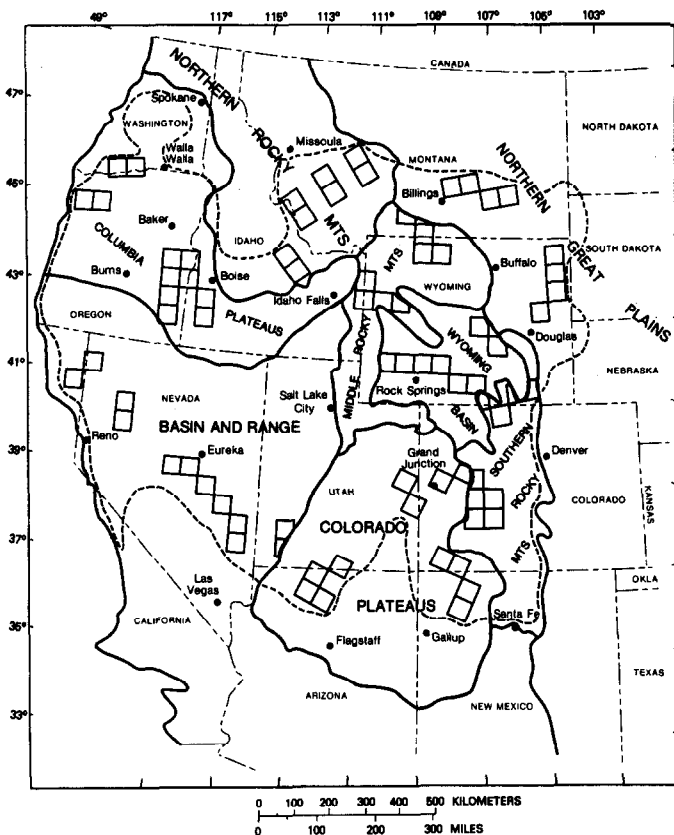


Fig. 1. Position of sampling locations 50 km on a side and the general distribution of big sagebrush (bold dashed lines, modified from Beetle, 1960) within 8 western physiographic provinces (province boundaries after Fenneman 1931).

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Table 1. The symmetrically nested, analysis-of-variance sampling designs.

Level	Two 200-km cells per province		Three 200-km cells per province	
	Number of samples representing level	Degrees of freedom	Number of samples representing level	Degrees of freedom
1. Province	5	4	3	2
2. 200-km cell	10	5	9	6
3. 100-km cell	20	10	18	9
4. 50-km cell	40	20	36	18
5. 25-km cell	60	20	54	18
6. 5-km cell	80	20	72	18
7. 0.1-km cell	100	20	90	18
8. Duplicate analyses	115	15	110	20
		Total = 114		Total = 109

small area (about 25 m²). Samples were a mixture of the 3 common subspecies: *tridentata* (basin big sagebrush), *wyomingensis* (Wyoming big sagebrush), and *vaseyana* (mountain big sagebrush).

Samples were collected according to a one-way, nested, analysis-of-variance (AoV) design (Table 1) similar to the ones diagrammed by Bainbridge (1963) and described in mathematical detail by Miesch (1976). The design had 8 levels and was unbalanced below the fourth level. The unbalancing meant that dichotomous branching was allowed on 1 of 2 possible legs resulting in the actual use of one-half of the total number of possible sampling sites. The unbalancing stabilized, to an acceptable number, the degrees of freedom used in the AoV (Table 1) and served to economize on field and laboratory time and expense without appreciably affecting the estimates of the variance components (Table 2).

The purpose of the design was to partition the variability in the concentration values of an element in plant tissue among distance

increments (natural variance) and analytical procedures (error variance). A proportion of the total variance (s^2_t) was measured at each AoV level as follows: s^2_p , among provinces; s^2_{200} , among cells 200-km on a side; s^2_{100} , between cells 100-km on a side; s^2_{50} , between cells 50-km on a side; s^2_{25} , between cells 25-km on a side; s^2_5 , between cells 5-km on a side; $s^2_{0.1}$, between samples 0.1 km apart; and s^2_a , between duplicate analyses of the same sample.

Because of the immense area occupied by the Columbia Plateaus (CbP), Colorado Plateaus (CIP), and Basin and Range (B&R) provinces, and because these 3 provinces contain a large proportion of the total big sagebrush distribution, an additional 200-km cell per province was included in the AoV design (Table 1). This addition increased the number of samples collected in these 3 provinces by one-third; therefore, 30 samples were collected in each of these 3 provinces, whereas 20 samples were collected in each of the other 5 Northern Rocky Mountains (NMR), Northern

Table 2. Distribution of variance in the concentration of elements in big sagebrush from eight western Physiographic Provinces.

Element or Ash	Total log ₁₀ variance	Percentage of total variance ¹							
		Among provinces	Among 200-km cells	Between 100-km cells	Between 50-km cells	Between 25-km cells	Between 5-km cells	Between 0.1-km cells	Between duplicate analyses
Ash	0.0041	*32	9	*12	3	2	22	*16	4
Aluminum	.0897	*34	<1	<1	22	<1	*24	*13	7
Arsenic	.1582	*49	5	*18	8	<1	2	*12	6
Barium	.0562	<1	9	10	<1	2	11	*55	14
Boron	.0365	*20	2	<1	12	<1	*27	*25	15
Cadmium	.1436	*26	2	*15	<1	15	8	*30	4
Calcium	.0090	<1	<1	*14	<1	24	8	*49	5
Chromium	.1160	*23	<1	3	*24	1	14	*19	16
Cobalt	.1020	*28	<1	*22	7	<1	*17	3	22
Copper	.0297	*15	<1	*17	<1	17	<1	*45	6
Fluorine	.0352	*99	<1	<1	<1	<1	<1	<1	<1
Iron	.1265	*44	1	<1	*23	<1	*15	*9	7
Lead	.0540	9	19	*20	10	<1	<1	*31	11
Lithium	.1251	11	4	*10	*33	<1	*29	*7	5
Magnesium	.0131	*23	7	*12	1	<1	13	*32	11
Manganese	.0500	*12	<1	6	17	<1	23	*30	12
Mercury	.0193	*21	4	<1	<1	<1	14	4	56
Molybdenum	.0684	*26	<1	3	1	*23	2	17	28
Nickel	.0891	*22	<1	4	11	4	16	*30	11
Phosphorus	.0162	*99	<1	<1	<1	<1	<1	<1	<1
Potassium	.0036	*13	3	<1	6	3	20	*35	18
Selenium	.2714	17	14	*14	17	6	9	*18	5
Sodium	.1566	*26	12	*11	<1	10	*23	*16	1
Strontium	.0909	<1	*17	<1	*18	<1	23	*22	20
Sulfur (total)	.0086	*34	2	*17	<1	12	4	*17	13
Titanium	.0922	*98	<1	<1	1	<1	1	<1	<1
Zinc	.0329	2	<1	<1	*31	<1	15	*50	2
Zirconium	.0804	*24	<1	8	*14	<1	*27	<1	26

*Significant at the 0.05 probability level.

¹Values are rounded to the nearest whole number.

Great Plains (NGP), Middle Rocky Mountains (MRM), Wyoming Basin (WB), and Southern Rocky Mountains (SRM).

The geographical position of sampling sites was determined by first superimposing the nested cells on base maps (scale of 1:250,000) and then randomly selecting cells, of successively smaller size, until a point was defined. Figure 1 shows the location of the randomly positioned 50-km cells.

Some restrictions as to the location of cells were imposed by the areal distribution of big sagebrush. Before going to the field, we also superimposed the cells on a map of sagebrush distribution in such a manner as to include as much of the distribution as possible. It is for this reason that the cells shown in Figure 1 appear in various orientations. Further, the random location of cells explains their truncated appearance when they occur near or on province boundaries.

Laboratory Methods

The unwashed samples from the 190 sites were dried at 38–40°C and ground to pass a 1.3-mm screen. Thirty-five random samples were split for the s^2_a measurement and the entire suite of 225 was submitted for analysis. The homogenized ground material was either ashed by dry ignition at about 500°C for 24 hr or subjected to acid digestion (Harms 1976) for the determination of As, F, Hg, Sb, Se, and S. Aluminum, B, Ba, Cr, Fe, Mn, Ni, Pb, Sr, Ti, V, and Zr were determined by semiquantitative d-c arc emission spectrography; As, Ca, Cd, Co, Cu, K, Li, Mg, Na, Sb, and Zn by flame absorption spectroscopy; Hg by flameless atomic-absorption spectroscopy; Mo and P colorimetrically; F by selective ion electrode; Se and U fluorometrically; and total S turbidimetrically.

Data Analysis

All concentration data are presented on a dry matter basis. These values were converted to logarithms because the frequency distributions of the transformed data were more symmetrical than those of the raw data. All statistical tests were performed on log-transformed data.

Some of the concentrations for As, Cd, Cr, Co, Li, Ni, Pb, Sb, U, V, and Zr were censored; that is, below (less than) the lower limit of determination (LLD) for the analytical method used, or not detected at all. Three of these elements (Sb, U, and V) had such a large proportion (>50%) of the values below the LLD that no statistical analyses were performed. The conversion of an LLD value, reported on an ash-weight basis, to a dry-weight equivalent, results in variable LLD values because of differences in the ash yield among samples. For this study we chose to handle the data as follows: (a) after dry-weight conversion, an average of the variable LLD values for each element was calculated; and (b) the censored values were then replaced with a value equal to 0.7 times the average LLD value. If censoring exceeds about one-third of the total number of values then our experience is that a substitution of some fraction of the LLD (in this case 0.7) will produce statistical tests that are compromised and uninterpretable. If substitutions with 0.7 times the LLD are made for censoring that occurs in less than about one-third of the values, then the statistical results can be used if they are interpreted with caution. Calculated average LLD concentrations (ppm) for those elements with censored values follows: As, .05; Cd, .019; Cr, .10; Co, .044; Li, .17; Ni, .48; Pb, .77; and Zr, .64.

Because our data were transformed to logarithms, our measure of the average is reported as the geometric mean (GM) and the spread (or scatter) as the geometric deviation (GD). The GM and GD are simply the antilogarithms of the mean and standard deviation, respectively, of the logarithms. A GD value of 1.0 means that there is no variability in the data. A "baseline," as first proposed by Tidball and Ebens (1976), was calculated and is defined as a concentration range bracketed by the GM/GD^2 to the $GM \times GD^2$. Element means for each province were compared using the Duncan test (1955) as modified by Natrella (1966) for means based on variable numbers of samples.

Results and Discussion

Biogeochemical Variability Among Individual Provinces

Table 2 lists the distribution of the variance as a percentage of the total among the 8 levels of the AoV design for 27 elements and ash yield. The GD for each element (where $n=225$ samples) can be calculated by taking the antilog of the square root of the total \log_{10} variance. A GD value calculated in this manner includes the variability associated with the 35 analytical splits (duplicate analyses).

We will confine our discussion to the 2 most important levels as defined by the distribution of the variance among the AoV levels (Table 2): the s^2_p level (broad regional component or variability among provinces) and the $s^2_{0.1}$ level (local component or variability at a distance of less than 100 m). Fourteen of the 28 constituents have more than 50% of their total variance at these 2 levels and an additional 10 have more than 40%.

In addition, the distribution of the variance in Table 2, for the concentration of an element in big sagebrush, shows that 78% of the constituents have a significant proportion of their variance at the s^2_p level and also at the $s^2_{0.1}$ level. This means that the concentration of most elements in big sagebrush differs among provinces but that within each province sagebrush individuals separated by about 0.1–5 km are likely to be as different chemically as are individuals separated by about 200 km. Sagebrush samples from the 3 Rocky Mountain provinces were mixtures of the 2 subspecies *vaseyana* and *wyomingensis* and samples from the other 5 provinces were uniformly composed of either *tridentata* or *wyomingensis*. We assume, therefore, that a real but undefinable contribution to the variability in sagebrush chemistry among provinces may be attributed to subspecies differences. A study was conducted in 1978 of the 3 recognized subspecies of *A. tridentata* at a uniform garden plot at the U.S. Department of Agriculture Gordan Creek Field Station near Helper, Utah. The results (J.A. Erdman, unpublished data) indicate that significant differences in concentrations of some elements, in unwashed leaf samples, do exist among the subspecies but that they seem to be minor compared with those differences among provinces observed in this study.

The distribution of the total variance at the s^2_a level (between analytical splits) is also of interest. If this value is large, then the observed scatter in the data measures mainly analytical error rather than natural variability. In our judgement, Hg is the only element with excessive analytical error (56%). Caution should be used, therefore, when interpreting the importance of the distribution of the variance of this element.

The elements Ba, Ca, Li, Pb, Se, Sr, and Zn do not show significant among-province differences. For these 7 elements, a grand geometric mean and deviation (calculated for samples from all of the provinces) is an appropriate measure of central tendency and spread (Table 3). These statistics may be used to assess the degree of uniqueness of a newly collected sample regardless of the province from which it was collected. For example, if a sample of sagebrush were collected in Nevada and had a Pb concentration of

Table 3. Summary statistics ($n=190$) for the concentration of seven elements in big sagebrush samples not having a significant regional variance component.

Element	Geometric mean	Geometric deviation	Expected 95 % range ¹
	ppm, dry material		
Barium	19	1.73	6.4 – 57
Calcium	5,000	1.21	3,400 – 7,300
Lead	1.1	1.77	.35 – 3.5
Lithium	.44	2.26	.086 – 2.3
Selenium	.11	3.23	.011 – 1.1
Strontium	58	1.85	17 – 200
Zinc	19	1.49	8.6 – 42

¹"Baseline" as proposed by Tidball and Ebens (1976).

2.6 ppm, it could be compared with the expected 95% range for all 190 samples of this study. A value of 2.6 ppm would be considered large but perhaps not unusual. A value greater than 3.5 ppm is unusual and probably represents an individual belonging to a population other than the baseline population.

Data for Sb, U, and V are not given in Table 2 because of excessive censoring. For these elements the number of values below the LLD was so great that statistical analyses would have had little meaning. Because of the importance of these elements in environmental and biogeochemical prospecting studies, however, we present the observed range of concentration values (ppm) for 190 samples as follows: Sb, <0.02-.25; U, <0.012-.25; and V, <0.42-7.9.

Biogeochemical Variability Among Province Groups

For the 20 elements and ash yield that did show significant regional trends (Table 2), a comparison test was performed in order to identify groups of similar means. Table 4 lists these groups. The last column in Table 4 uses symbols for each of the 8 physiographic provinces in order to illustrate these groupings. This display serves two basic functions: (a) it shows which of the provinces have sagebrush with concentrations of an element that are large or small (when compared to other provinces), (b) it allows for the presentation of summary statistics (GM, GD, and expected 95% range) based on the new province groupings, and (c) it lends itself to the construction of assemblages of elements with similar patterns in province groupings. Table 4 is divided into 3 arbitrary sections based on these element assemblages.

Summary statistics based on these groupings are illustrated by the data for Cr. Because the sagebrush samples from the Columbia Plateaus (CbP) had a GM for Cr significantly larger than the other 7 provinces, the CbP samples make up their own individual group

and the summary statistics are based on 30 samples. The second grouping consists of samples from both the Wyoming Basin (WB) and the Middle Rocky Mountains (MRM) and the summary statistics were calculated based on a total of 40 samples. The last grouping consists of the remaining 5 provinces (n=120).

Each of the 3 sections in Table 4 is composed of an assemblage of constituents that have similar province groupings when ordered from largest concentrations to smallest. In general, Section I constituents show the following province order: CbP > WB > Basin and Range (B&R) > Colorado Plateaus (CIP) and MRM > Northern Rocky Mountains (NRM) > Northern Great Plains (NGP) and Southern Rocky Mountains (SRM). The constituents in this section may be classified as the ash-forming elements and include the major-essential and the soil-resistate elements. The variables in Section II have the following general province order: CbP > WB > B&R and CIP > NRM > NGP, MRM, and SRM. Except for B, these elements are heavy metals; however, this assemblage does not appear to have any characteristics that make it particularly unique when compared with the 5 elements in Section III. This latter section has the following general province order: NRM > CbP and NGP > the remaining 5 provinces. The province order of Sections II and III differ most importantly in the position of the NRM province. In Section II (as in Section I) this province is usually in the fifth position (from left to right) whereas in Section III it is always first. This alteration in the position of the NRM province in Section III is due to the influence of a group of samples collected in the vicinity of Butte, Mont., and probably represents either the mineralization of the region or possible contamination related to ore processing.

Table 4. Summary statistics for the concentration of twenty elements (and ash yield) in big sagebrush samples with a significant regional (among provinces) variance component. Concentrations are in parts per million, dry matter basis, except ash yield and K which are in parts per hundred. Elements with similar patterns in province groupings are segregated into sections. The following symbols represent provinces: ● Columbia Plateaus; ▲ Basin and Range; ○ Colorado Plateaus; ▣ Northern Rocky Mountains; ■ Wyoming Basin; ○ Northern Great Plains; △ Middle Rocky Mountains; □ Southern Rocky Mountains.

Parameter	GM	GD	95% Expected Range	Provinces (overlap of symbols on successive lines indicates similarity of means)								Parameter	GM	GD	95% Expected Range	Provinces (overlap of symbols on successive lines indicates similarity of means)							
				Section I	Section II																		
Ash	5.6	1.17	4.1 - 7.7	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	4.8	1.09	4.0 - 5.7	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	4.6	1.11	3.7 - 5.7	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	4.3	1.16	3.2 - 5.8	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Al	1,600	1.74	530 - 4,800	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	860	1.51	380 - 2,000	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	580	1.73	190 - 1,700	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	520	1.78	160 - 1,600	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Fe	600	1.82	180 - 2,000	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	260	1.74	86 - 790	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	210	1.78	66 - 660	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	140	1.72	47 - 410	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Mg	1,600	1.20	1,100 - 2,300	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1,500	1.20	1,000 - 2,200	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1,100	1.29	660 - 1,800	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
P	1,800	1.17	1,300 - 2,500	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1,500	1.20	1,000 - 2,200	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1,400	1.21	960 - 2,000	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
K	1.4	1.14	1.1 - 1.8	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1.2	1.16	.90 - 1.6	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Na	120	1.54	51 - 280	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	78	2.68	11 - 560	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	50	2.07	12 - 210	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
S	1,600	1.15	1,200 - 2,100	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1,500	1.18	1,100 - 2,100	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1,300	1.19	920 - 1,800	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Ti	84	1.80	26 - 270	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	30	1.62	11 - 79	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	24	1.74	7.9 - 73	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Zr	2.5	1.80	.77 - 8.1	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1.5	1.81	.46 - 4.9	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.99	1.72	.33 - 2.9	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
B	26	1.41	13 - 52	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	22	1.40	11 - 43	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	14	1.35	7.7 - 25	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
				●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Cr	.66	1.71	.23 - 1.9	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.46	1.81	.14 - 1.5	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.26	1.92	.071 - .96	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Co	.16	1.78	.050 - .51	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.11	2.08	.025 - .48	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.086	1.49	.039 - .19	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Hg	.069	1.64	.026 - .19	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.054	1.64	.020 - .14	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
				●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Ni	.030	1.34	.017 - .054	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.025	1.31	.015 - .043	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.022	1.28	.013 - .036	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Mo	.88	1.66	.32 - 2.4	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.54	1.68	.19 - 1.5	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.43	1.85	.13 - 1.5	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Ni	1.9	1.58	.76 - 4.7	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	1.4	2.31	.26 - 7.5	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.93	1.78	.29 - 2.9	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.75	1.75	.24 - 2.3	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Section III	As	.97	3.38	.085 - 11	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△	
		.17	1.56	.070 - .41	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△	
		.10	1.73	.033 - .30	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△	
		.081	1.57	.033 - .20	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△	
Cd	.28	2.66	.040 - 2.0	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.15	2.00	.038 - .60	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	.098	1.73	.033 - .29	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
Cu	.063	1.96	.016 - .24	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	9.2	1.54	3.9 - 22	●	■	▲	○	□	△	○	■	▲	○	□	△	○	■	▲	○	□	△		
	8.4	1.32	4.8 - 15	●	■	▲	○	□	△	○	■	▲	○	□	△								

This type of data display also is useful when comparing the concentration of an element in a newly collected sagebrush sample with the proposed summary statistics for sagebrush from a given province. If, for instance, a sagebrush sample from the CIP province was found to have 1.0 ppm Cr, the conclusion would be that this value is unusually large when compared with the Cr summary statistics calculated from samples that included sagebrush from the CIP and 4 other provinces (Table 4). This is because 1.0 ppm is greater than the upper limit of the 95% expected range for samples from the group of provinces.

The means of groups of provinces were not always significantly different and some overlap occurred. The data for Cu (Section III, Table 4) are an example. A concentration value for Cu in sagebrush collected in the NGP could be compared with the summary statistics that include samples from the NMR or with statistics that include samples from the WB and the CbP. As a result, there are two sets of summary statistics that could be used to assess the degree of uniqueness of the Cu concentration in the new sample. A simplified approach would be to combine the 2 expected ranges from the 2 overlapping groups so that a somewhat larger data spread would result (3.9–15 ppm). The comparison of the Cu value from the new sample with the new range could then be made.

Conclusions

The alteration of the geochemical environment through natural (e.g., the eruption of the Mount St. Helens volcano) and anthropogenic sources (e.g., surface-mining and mineral-processing operations) can be anticipated over sections of the western U.S.A. energy regions. The degree to which these changes occur can be monitored only if reliable background or baseline biogeochemical estimates are known. Based on the distribution in the spatially related variability in the data we present baseline elemental concentrations for 27 elements (and concentration ranges for Sb, U, and V) in the young tissue (leaves and stems) of big sagebrush.

Concentrations of Ba, Ca, Li, Pb, Se, Sr, and Zn were found to possess an insignificant amount of the variability in their data at a regional scale (among the 8 western physiographic provinces). This meant that the variability in the data was distributed among samples more closely spaced and resulted in baselines for these elements that were calculated using samples from all 190 sites in the study. Concentrations of the 20 additional elements, however, were significantly different among the province sagebrush populations and baseline determinations for these elements were determined on samples from individual provinces or groups of provinces.

The manner in which the element baselines ordered themselves in relation to province groupings is interpreted as reflecting the basic geochemistry of these broad areas.

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