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Background Concentrations of Trace and Major Elements in California Soils

KEARNEY FOUNDATION OF SOIL SCIENCE
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Table of Contents:

Report	**Summary**
	Introduction
	Materials and Methods
	Results and Discussion
	References
Table 1A	Series and location of benchmark soils
Table 1B	Series and location of benchmark soils
Table 2	Total concentrations of elements in benchmark soils
Table 3	Ranges in concentration and summary statistics of 46 elements in 50 benchmark California soils
Table 4	Correlation coefficients between elements in California benchmark soils
Figure 1.	Soil sample numbers keyed to map of California
Figure 2	Distribution frequency of elements in California benchmark soils:

Figure 2. Distribution frequency of elements in California benchmark soils graphs available as Adobe Acrobat files at http://www.envisci.ucr.edu/downloads/chang/kearney/kearneytext.html

Aluminum-Antimony	Iodine-Iron	Silicon-Silver
Arsenic-Barium	Lanthanum-Lead	Sodium-Strontium
Beryllium-Bismuth	Lithium-Magnesium	Thallium-Thorium
Boron-Cadmium	Manganese-Mercury	Tin-Titanium
Calcium-Cerium	Molybdenum-Nickel	Tungsten-Uranium
Cesium-Chromium	Niobium-Phosphorous	Vanadium-Yttrium
Cobalt-Copper	Potassium-Rubidium	Zinc-Zirconium
Gallium-Germanium	Scandium-Selenium	

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Background Concentrations of Trace and Major Elements in California Soils

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Summary

The first comprehensive, scientific database on background concentrations of trace and major elements in California soils has been developed. Background total concentrations of 46 trace and major elements have been determined in 50 benchmark soils selected from throughout the state. The authors have received numerous requests from industries and public agencies to disseminate this information because it is necessary for environmental monitoring, remediation of contaminated soils, land use planning, and ecological evaluations. Reliable, comprehensive information about background levels of trace and major elements in California soils wilt facilitate accurate interpretations of experimental and field data and wilt facilitate scientifically defensible decisions by industries and policy makers.

Dissolution of soil samples with $HN0_3$-HCI-HF was followed by analysis with inductively coupled plasma optical emission spectrometry (ICP-OES) and mass spectrometry (lCP-MS). Statistical analyses of the data show that background concentrations of the elements vary by a factor of 3 to 150 times. Ranges in concentrations compare favorably with values reported in the scientific literature. Most elements show distinctly positively-skewed frequency distributions or concentrations less than median values. Highly significant ($p < 0.01$) positive correlation coefficients occur between several elements: Ce-La (r=0.96), Ni-Cr (r=0.95), Fe-V (r=0.92), Fe-Sc (r=0.92), Mo-U (r=0.82), V-Sc (r=0.86), Cu-Co (r=0.81), Co-Mg (r=0.63), Ni-Mg (r=0.71), Cr-Mg (r=0.65). These results suggest that chemical and physical factors control element associations in parent material and soil forming processes and that chemical and physical factors may be important in the distribution of elements in the soil. Coefficients of variation are greatest for Ag, Cr, Mo, Ni, Se, and W, and least for Zn, Al and Si.

This database is essential to systematic, accurate assessments of anthropogenic and natural causes of elevated trace element concentrations and should be particularly useful to industries attempting to monitor their own effects on trace element levels in soils and to public agencies charged with assessing the severity of trace element pollution problems.

Introduction

The term "trace element" is rather loosely used in the scientific literature to designate a number of elements that occur in natural systems in small concentrations (Page, 1974). As defined in many dictionaries, trace elements are those chemical elements, especially metals, used by organisms in minute quantities but believed essential to their physiology. However, the term is and has been used to designate elements with no known physiological function which, when present in sufficient concentrations, may be toxic to living systems.

Other terms that have been used, and which for all practical purposes can be considered synonyms for the term "trace elements," are "trace metals", "trace inorganics", "heavy metals", "micronutrients", and "microelements". The use of the term "micronutrient" usually has been restricted to those trace elements known to be essential for the growth of higher plants, e.g., Cu, Zn, Mo, B, Mn, Fe, CI, and Ni (Asher, 1991).The use of the term "heavy metals" in the scientific literature is usually, but not always, restricted to those metals that have densities greater than 5.0 g cm^{-3}. Trace elements are defined herein as those elements having less than 0.1 % average abundance in the earth's crust (Mitchell, 1964). Using this definition the elements AI, Ca, Fe, Mg, K, Na, Si and Ti are considered "major" elements in this manuscript.

Trace elements are ubiquitous in the earth's crust. Their natural levels in soil vary widely, depending largely on the nature of parent materials from which soils form and also on soil-forming processes (Adriano, 1986; Kubota, 1981; Lund et al., 1981; Heil and Mahmoud, 1978). Natural distribution patterns of trace elements in soil have been affected by a variety of anthropogenic activities, including mining, smelting, agriculture, energy generation, manufacturing, waste disposal, and transportation (Adriano, 1986; Munro, 1983; Page, 1974). Industrial effects are relatively well-documented and may be either largely concentrated on-site (e.g., mine tailings) or dispersed over large areas (e.g., stack emissions).

Adriano (1986) identified two major routes for input of trace elements into agro-ecosystems: aerial (e.g., aerosols, particulate matter, resuspended and airborne dusts, etc.), and land (fertilizers, pesticides, solid wastes, other soil amendments, etc.). The output pathways can be represented primarily by losses through plant tissue removal for food, feedstuff, and fiber, and by leaching and erosion. Both input and output fluxes are constancy changing whether soils are in agricultural production or not; therefore, the background concentrations of trace elements in soils are probably not significantly altered by short-term agricultural use. Harmason and de Haan (1980) calculated that it would take three centuries of phosphate fertilization at 100 kg P_20_5 per hectare per year to enrich the top 20 cm of soil by 1 mg/kg U, if the P_20_5 fertilizer contained 100 mg/kg U.

Most management activities that affect soil trace elements are very poorly documented; therefore, it is usually difficult or impossible to determine the anthropogenic influences on any specific site. Compounding this problem is a general lack of background data on natural trace element distribution patterns in soils.

Shacklette and Boemgen (1984) published results of an extensive sampling (1,218 samples) and analyses (35+ elements) in surficial materials in the United States as a whole. The samples were collected by U.S. Geological Survey personnel along their travel routes to other field studies or within their project areas. A sample site was selected about every 50 miles. Cultivated fields were included and congested areas avoided. They concluded that sampling to a depth of 20 cm may have avoided the effects of surface contamination. No gross contamination of samples was expected by a variety of methods. About 74 samples were collected in California.

When environmental problems related to high trace element levels in soils or groundwater are discovered, there has been a tendency for the public to blame the most visible industry first without proper technical assessment of other possible anthropogenic or natural causes (Letey et al., 1986).

By providing the first comprehensive, scientific database on background concentrations of trace and major elements in benchmark California soils, this study addresses serious shortcomings in assessment technology, to date. Previously, comparative data were not available because information compiled from different sources was incomplete and the methodologies used for soil sampling and analysis were incompatible. The results reported herein are the first cohesive data set available on background levels of trace and major elements in California. Such a database is essential to any systematic, accurate assessment of anthropogenic effects and natural causes of elevated or reduced levels of trace and major elements in California.

Materials and Methods

Sample Collection

Benchmark soil series sample locations for this study were selected from an extensive file of soil profile sample locations in the Department of Soils and Plant Nutrition, University of California; Berkeley (now known as the Department of Environmental Science, Policy and Management). These samples were accumulated by cooperative efforts of the University of California Division of Agriculture and Natural Resources and the U.S. Department of Agriculture soil survey teams during more than 50 years of soil survey work in California. A detailed discussion of the series is given by Stone and Weir (1953). R. J. Arkley, University of California, Berkeley, selected the 22 series for this and earlier studies (Bradford et al., 1967, 1971) as most representative of California soils. The series concept has changed since 1953, so current designations may be different. Contemporary methods have been used to determine total and water-soluble elements in soil profile samples from the Berkeley file and from separate collections in past studies (Bradford et al., 1967, 1971).

The 50 benchmark soil samples representing 22 soil series analyzed for this report were collected in 1967 (Bradford et al., 1967). The sampling sites (selected from the Berkeley file) were mostly from agricultural fields distant from known point sources of contamination; therefore, the trace element concentrations should be representative of background levels.

A 20-gallon soil sample was collected from the surface to 50 cm depth, excluding the organic debris at the surface. The soil was shoveled from the site onto a 10-mesh plastic fabric screen and sieved to exclude large rocks, etc. A plastic screen was used to avoid metallic contamination. The soil samples were air-dried, mixed and stored in 20-gallon plastic containers.

Soil series and their locations (longitude, latitude and county) are presented in Tables 1 A and 1 B. Soil family designations are not listed because of changes since 1953. Locations are also shown on a California map (Fig. 1). The authors emphasize that by identifying the soil samples as to a series designation in no way implies an attempt to correlate element concentrations within a series. Two or three samples of each series are too few to make such a study feasible. Furthermore, Bradford et al. (1967) concluded from a more extensive analysis of soil horizons from many of the same series studied in this report that there was no marked association of total essential trace element content with the series designation.

Sample Analyses

A 10-g subsample was ground with an agate mortar and pestle to pass a 60-mesh plastic screen. A 1-g portion was weighed into a 50-ml Teflon screw-cap centrifuge tube and treated with $HN0_3$, repeated portions of 6 N HCI and then dilute HF. Replicate analyses were not considered necessary because of low standard deviation values reported for 4 replicate analyses by the method used (Bakhtar et al., 1989). One in 500 (weight/volume) dilutions were analyzed with inductively coupled plasma optical emission spectrometry (ICP-OES) and mass spectrometry (ICP-MS). To avoid interferences from polyatomic chloride complexes in ICP-MS analyses, aliquots of dissolved sample solution in HCI were evaporated to dryness at a low temperature followed by redissolution in 1% $HN0_3$. Analyses were made with a VG Plasma Quad by following the manufacturer's recommended procedure with multielement calibration and scan acquisition of data.

In most cases, low concentration elements in the high atomic mass range were measured with ICP-MS and high-concentration elements in the low atomic mass range were measured with ICP-OES to minimize interferences. Gray (1986) estimated detection limits for multielement analyses using ICP-MS as shown in Table 2. Methods used for each element are shown in Table 3. Concentrations in Table 2 were set equal to one-half the detection limit in samples containing less than detectable levels of an element to permit statistical analyses (Gilbert, 1987).

Estimated detection limit for ICP-OES analyses is defined in this study as the concentration equivalent to a signal due to the analyte which is equal to three times the standard deviation of a series of 10 replicate measurements of a zero calibration blank.

Results and Discussion

Levels of trace elements in benchmark soils are the result of a combination of complex factors, including soil parent material, topography, climate, vegetation, management and time. High Cd has been identified with certain coastal marine sediments (Lund et al., 1981). High levels of oxyanions of U, V and Mo have been identified with evaporates in soils of the west side of the San Joaquin Valley and probably originate from West Side alluvial deposits (Bradford et al., 1990).

Table 2 shows total concentrations of 46 elements in each of 50 benchmark soils from California. Table 2 also lists the ranges in concentration for each element. Precision and accuracy are discussed in a published report of the method used (Bakhtar et al., 1989). In general, background elemental concentrations for these soils vary by factors ranging from about 150 times (P, W), about 80 times (B and Mo), about 60 times (Cr, Ni), about 15 times (Co), about 5 times (Pb, V) to about 3 times (Al, Ga, Zn). Summary statistics, which include the coefficients of variation (CV) for each element, are listed in Table 3. Coefficients of variation are greatest for Ag, Cr, Mo, Ni, Se, and W, and least for Zn, Al and Si. Ranges in concentrations compare favorably with those reported by Shacklette and Boerngen (1984), Kabata-Pendias and Pendias (1992) and Rose et al. (1979).

Correlation coefficients shown in Table 4 are significant at the probability level of 0.01. Examples of elements with high r values are Ce-La (r = 0.96), Ni-Cr (r = 0.95), FeV (r = 0.92), Fe-Sc (r = 0.92), Mo-U (r = 0.82), V-Sc (r = 0.86), Cu-Co (r = 0.81), Co-Mg (r=0.63), Ni-Mg (r=0.71), Cr-Mg (r=0.65). These high r values suggest that chemical and physical factors control element associations in parent material and soil forming processes. Data from analyses of other soil profile and topographic sequence samples from California also showed high r values between Ni-Cr, V-Sc, and Cu-Co (Marrett et al., 1992). The only significant negative r values observed were between Co-Th (r=0.39) and V-Th (r=-0.37).

Both our data and that from Shacklette and Boerngen (1984) show that samples from northern California often contain higher concentrations of Cr, Co, Cu, Ni, Fe and V compared to samples from southern California. An examination of a Geologic Map of California (Jennings, 1977) shows a predominance of volcanic and ultramafic rocks in northern California. Isolated areas of ultramafic rocks are also shown east of Porterville and in the Idria area to the west of the San Joaquin Valley. Ultramafic rocks are mostly serpentine, a magnesium silicate with associated Ni, Cr, etc. (Jennings, 1977). Soils formed from ultramafic parent material would likely show high r values between Mg and Ni and Cr as shown in Table 4. High concentrations of Cr, Co, Cu, Ni, Fe and V in northern California soils probably originate from high levels of these elements in the ultramafic and volcanic rocks in the area. Note that the concentrations of Ni, Cr, and Mg (Table 2) tend to be elevated in soil sample nos. 25 (Porterville area) and 48 (east of Idria).

Soil samples within a series (Table 2) most often show diverse concentrations of elements. Imperial clay loam samples (nos. 18, 19 and 20) are an exception. Concentration of most elements in the three samples of this series are closely grouped, suggesting thorough mixing of sediment imported by the Colorado River.

The above results emphasize the importance of parent material composition and soil forming processes on background concentrations of trace and major elements in soils. Bradford et al. (1967) observed in an earlier study that in general the distribution of trace element content of benchmark soils is reasonably consistent within groupings based on soil parent material. Frequency distributions are illustrated for each element in Fig. 2.

Moment coefficients of skewness and kurtosis express how the shapes of sample frequency distribution curves differ from ideal Gaussian (normal) curves. Skewness refers to asymmetry of the upper and lower halves of the curve around the mean. Kurtosis refers to deviations towards unusual flatness or pointedness of the curve peak. Perfect Gaussian (normal) curves have moment coefficients of skewness and kurtosis of 0 and 3, respectively. Log transformations (calculated but not shown) generally improve the data for most trace elements by helping to correct positive skew and stabilizing variance (which is proportional to the mean in untransformed data).

Analyses and reports were created by SAS software. Univariate statistics are summarized in Table 3. Distributions for each element were tested for normality using the W test (Shapiro and Wilk, 1965). Results of the W test for both untransformed and natural log-transformed data are given in Table 3. The W test produces a statistic for the null hypothesis such that the input data values are a random sample from a normal distribution. W must be greater than zero and less than or equal to one, with small values of W leading to rejection of the null hypothesis. The probability for testing the hypothesis that the data come from a normal distribution is given as PROB < W.

The hypothesis of normality (null hypothesis) is rejected at the a significance level if W is less than the a quartile, where, for example, the a quartile is 0.974 for a = 0.50 and n = 50. The significance level of a = 0.50 is the accepted level for testing the hypothesis of normality (Shapiro and Wilk, 1965). Tests for skewness, kurtosis, the W test and the related probability are also shown for the untransformed data in Fig. 2.

High concentrations of B, Mo and U observed in sample number 8, a Fresno Series from the Tulare Lake bed, led us to prepare and analyze a one-to-one soil-to-water extract. The water extract was high in Na (7,000 mg/L) and alkalinity (47.6 meq/L), and low in Ca and Mg. These chemical parameters favor high solubility of the oxyanions (Drever, 1988). Oxyanion analyses of sample number 8 showed P (21 mg/L), B (15 mg/L), V (8 mg/L), Mo (9 mg/L), U (1.8 mg/L) and As (1.8 mg/L). These high water-soluble concentrations of several toxic elements emphasize the importance of analyzing water extracts of soils in addition to total analyses for full and complete assessment of trace element impacts on the environment.

The principal objective of this study, to determine background concentrations of trace and major elements in benchmark soils from California, has been accomplished. Parent material and soil forming processes have a major effect on the chemical composition of soils. The data may have application to the identification of areas suspected of essential element deficiencies and/or trace element toxicity for plant growth and may also be useful in soil genesis studies.

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Table 1 A

Series and Location of Benchmark Soils'

Soil Series and Texture Phase	Soil No.	County	Longitude	North Latitude	Soil Taxonomy
Aiken scl	4	El Dorado	120°50'	38°39'	Clayey, oxidic, mesic, Xeric Haplohumufts
Aiken cl	5	El Dorado	120°57'	38°15'	
Aiken cl	6	Tehama	121°43'	40°26'	
Altamont cl	1	San Diego	117°13'	32°54'	Fine, montmorillonitic, thermic Typic Chromoxererts
Altamont cl	2	Glenn	122°22'	39°34'	
Altamont cl	3	Tehama	122°41'	40°14'	
Cajon fs	28	San Bernardino	117°40'	34°46'	Mixed, thermic, Typic Torripsamments
Coachella fs	7	Riverside	116°12'	33°42'	Sandy, mixed, hyperthermic Typic Torrifluvents
Fresno l	8	Kern	119°23'	35°23'	Fine-loamy, mixed, thermic Natric Durixeraffs
Fresno l	10	Merced	120°29'	37°10'	
Hanford sl	12	San Diego	116°47'	32°49'	Coarse-loamy, mixed, nonacid, thermic Typic Xerorthents
Hanford sl	11	San Joaquin	121°14'	38°11'	
Holland ls	14	El Dorado	120°41'	38°36'	Fine-loamy, mixed, mesic
Holland l	13	Fresno	119°22'	37°04'	
Holland ls	15	El Dorado	120°54'	38°49'	
Holtville sl	50	Imperial	115°23'	32°46'	Clayey over loamy, montmorillonitic (calcareous) hyperthermic Typic Torrifluvents
Hugo cl	17	Solano	122°00'	38°22'	Fine-loamy, mixed mesic dysrtic xerochrepts
Hugo cl	16	Humboldt	123°54'	40°45'	
Imperial cl	18	Imperial	115°34'	32°42'	Fine, montmorillonitic (calcareous), hyperthermic
Imperial cl	19	Riverside	114°36'	33°38'	
Imperial cl	20	Imperial	115°31'	32°56'	Vertic Torrifluvents
Kettlemen sl	21	Fresno	120°40'	36°35'	Fine-loamy, mixed (calcareous), Thermic Typic Torriorthents
Kettlemen sl	23	Fresno	120°20'	36°19'	
Kettlemen cl	22	Kern	119°22'	34°58'	

Soil Series and Texture Phase	Soil No.	County	Longitude	North Latitude	Soil Taxonomy
Lassen c	25	Tulare	119°00'	36°06'	Fine, montmorillonitic, mesic Typic Chromoxererts
Lassen c	24	Modoc	120°27'	41°32'	
Los Osos c	27	Santa Barbara	120°28'	34°35'	Fine, montmorillonitic, thermic, Typic Argixerolls
Los Osos cl	26	Lake	122°30'	38°53'	
Maymen sl	30	Lake	122°54'	39°16'	Loamy, mixed, mesic dystric Lithic Xerochrepts
Maymen sl	31	Tehama	122°41'	40°09'	
Maymen sl	29	Glenn	122°36'	39°34'	
Merced sl	9	San Joaquin	121°22'	38°05'	Fine, montmorillonitic, thermic Patchic Haploxerolls
Merced c	33	Fresno	120°12'	36°35'	
Merced cl	34	Merced	120°19'	37°28'	
Merced c	32	Kern	119°13'	35°12'	
Mojave l	36	San Bernardino	117°12'	34°32'	Not available
Mojave sl	35	San Bernardino	116°41'	34°58'	
Panoche cl	48	Fresno	Not available		Fine-loamy, mixed (calcareous), thermic Typic Torriorthents
Ramona sl	37	San Diego	116°54'	32°43'	Fine-loamy, mixed, thermic, Typic Haploxeraffs
Ramona sl	38	San Joaquin	121°13'	38°14'	
Redding cl	40	Tehama	122°12'	40°04'	Fine, mixed, thermic Abruptic Durixeralfs
Redding cl	39	Glenn	122°15'	39°41'	
San Joaquin sl	41	Merced	120°11'	37°10'	Not available
San Joaquin l	42	Tulare	119°05'	36°02'	
Venice	49	San Joaquin	121°31'	37°40'	Eric, thermic Typic Medihemists
Watsonville l	45	Santa Cruz	122°03'	36°57'	Fine, montmorillonitic, thermic Xeric Argialbolls
Watsonville l	43	Santa Barbara	120°27'	34°29'	
Watsonville l	44	Santa Cruz	121°42'	36°56'	
Yolo cl	46	Solano	121°47'	38°26'	Fine-silty, mixed, nonacid, thermic Typic Xerorthent
Yolo cl	47	Tehama	122°15'	40°03'	

[1]Table 1 A is alphabetical by soil series. Table 1 B is in numerical order by soil number.
[2]Texture phase abbreviations: l = loam, sl = sandy loam, ls = loamy sand, fs = fine sand, cl = clay loam, scl = sandy clay loam, c = clay (USDA-SCS classification scheme)

Table 1 B
Series and Location of Benchmark Soils[1]

Soil Series and Texture Phase	Soil No.	County	Longitude	North Latitude	Soil Taxonomy
Altamont cl	1	San Diego	117°13'	32°54'	Fine, montmorillonitic, thermic Typic Chromoxererts
Attamont cl	2	Glenn	122°22'	39°34'	
Alfamont cl	3	Tehama	122°41'	40°14'	
Aiken scl	4	El Dorado	120°50'	38°39'	Clayey, oxidic, mesic, Xeric HaplohumuRs
Aiken ci	5	El Dorado	120°57	38°15'	
Aiken ci	6	Tehama	121°43'	40°26'	
Coachella fs	7	Riverside	116°12'	33°42'	Sandy, mixed, hyperthermic Typic Torrifluvents
Fresno l	8	Kern	119°23'	35°23'	Fine-loamy, mixed, thermic Natric Durixeralfs
Merced sl	9	San Joaquin	121°22'	38°05'	Fine, montmorillonitic, thermic Pachic Haploxerolls
Fresno l	10	Merced	120°29'	37°10'	Fine-loamy, mixed, thermic Natric Durixeralfs
Hanford sl	11	San Joaquin	121°14'	38°11'	Coarse-loamy, mixed, nonacid, themnic Typic Xerorthents
Hardord sl	12	San Diego	116°47	32°49'	
Holland l	13	Fresno	119°22'	37°04'	Fine-loamy, mixed, mesic Ultic Haploxeralfs
Holland ls	14	El Dorado	120°41'	38°36'	
Holland ls	15	El Dorado	120°54'	38°49'	
Hugo cl	16	Humboldt	123°54'	40°45'	Fine-loamy, mixed mesic Dystric Xerochrepts
Hugo cl	17	Solano	122°00'	38°22'	
Imperial cl	18	Imperial	115°34'	32°42'	Fine, montmorillonitic (calcareous), hyperthermic
Imperial cl	19	Riverside	114°36'	33°38'	
imperial cl	20	Imperial	115°31'	32°56'	Vertic Torrifluvents
Kettlemen sl	21	Fresno	120°40'	36°35'	Fine-loamy, mixed (calcareous), thermic Typic Torriorthents
Kettlemen cl	22	Kern	119°22'	34°58'	
Kettlemen sl	23	Fresno	120°20'	36°19'	
Lassen c	24	Modoc	120°27	41°32'	Fine, montmorillonitic, mesic Typic Chromoxererts
Lassen c	25	Tulare	119°00'	36°06'	
Los Osos cl	26	Lake	122°30'	38°53'	Fine, montmorillonitic, thermic, Typic Argixerolls
Los Osos c	27	Santa Barbara	120°28'	34°35'	
Cajon fs	28	San Bernardino	117°40'	34°46'	Mixed, thermic, Typic Torripsamments
Maymen sl	29	Glenn	122°36'	39°34'	Loamy, mixed, mesic Dystric Lithic Xerochrepts
Maymen sl	30	Lake	122°54'	39°16'	
Maymen sl	31	Tehama	122°41'	40°09'	

Merced c	32	Kern	119°13'	35°12'	Fine, montmoriilonitic, thermic Pachic Haploxerolls
Merced c	33	Fresno	120°12'	36°35'	
Merced cl	34	Merced	120°19'	37°28'	
Mojave sl	35	San Bernardino	116°41'	34°58'	Fine-loamy, mixed, thermic Typic Haplargids
Mojave l	36	San Bernardino	117°12'	34°32	
Ramona sl	37	San Diego	116°54'	32°43'	Fine-loamy, mixed, thermic, Typic Haploxeraffs
Ramona sl	38	San Joaquin	121°13'	38°14'	
Redding cl	39	Glenn	122°15'	39°41'	Fine, mixed, thermic Abruptic Durixeralfs
Redding cl	40	Tehama	122°12'	40°04'	
San Joaquin sl	41	Merced	120°11'	37°10'	Fine, mixed, thermic Abruptic Durixeraffs
San Joaquin l	42	Tulare	119°05'	36°02'	
Watsonville l	43	Santa Barbara	120°27'	34°29'	Fine, montmorillonitic, thermic Xeric Argialbolls
Watsonville l	44	Santa Cruz	121°42'	36°56'	
Watsonville l	45	Santa Cruz	122°03'	36°57'	
Yolo cl	46	Solano	121°47'	38°26'	Fine-silty, mixed, nonacid, thermic Typic Xerorthent
Yolo cl	47	Tehama	122°15'	40°03'	
Panoche cl	48	Fresno	Not available		Fine-loamy, mixed (calcareous), thermic Typic Torriorthents
Venice	49	San Joaquin	121°31'	37°40'	Eric, thermic Typic Medihemists
Holtville sl	50	Imperial	115°23'	32°46'	Clayey over loamy, montmorillonitic (calcareous) hyperthermic Typic Torrifluvents

[1]Table 1 B is in numerical order by soil number. Table 1 A is alphabetical by soil series. [2]Texture phase abbreviations: I = loam, sl = sandy loam, Is = loamy sand, fs = fine sand, cl = clay loam, scl = sandy clay loam, c = clay (USDA-SCS classification scheme)

Table 2
Total Concentrations of Elements in Benchmark Soils

Soil No.	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr
	Mg/Kg	%	---	---	---	---	---	Mg/Kg	---	---	---	---
1	0.21	8.3	11.0	23	738	2.19	0.80	7360	0.11	305	8.8	36
2	0.37	8.1	8.3	17	654	1.20	0.38	5680	0.18	138	15.0	47
3	0.27	9.9	8.0	45	764	1.90	0.42	6948	0.44	121	24.1	110
4	0.37	9.7	3.9	16	659	1.90	0.25	6758	0.25	177	34.8	115
5	0.22	7.1	3.9	7	438	1.90	0.27	3782	0.95	217	38.8	242
6	0.22	9.6	1.2	1	260	1.10	0.24	6795	0.19	94	13.1	45
7	0.12	6.3	1.2	2	533	0.80	0.21	25090	0.16	292	6.9	35
8	0.28	7.6	4.2	74	526	1.25	0.39	22035	0.52	213	9.3	42
9	0.41	6.6	0.8	5	379	0.64	0.37	9587	0.05	161	4.3	26
10	0.80	6.3	1.1	13	517	1.38	0.29	17967	0.40	141	7.1	89
11	0.52	9.0	1.2	4	472	1.51	0.33	11081	0.31	184	7.6	27
12	4.30	8.3	0.6	10	250	0.60	0.24	24524	0.13	122	15.8	29
13	0.40	9.5	2.1	2	625	1.53	0.20	8592	0.36	208	10.8	26
14	3.30	8.7	6.9	34	358	1.43	0.34	16494	0.36	167	22.7	108
15	0.48	7.6	1.2	19	258	1.45	0.19	16658	0.56	85	18.3	107
16	0.42	6.8	5.7	27	375	1.70	0.39	2903	0.15	133	29.9	214
17	2.60	8.0	9.6	26	796	0.93	0.37	6488	0.20	173	15.9	73
18	0.16	6.4	5.2	36	371	1.48	0.45	36400	0.58	189	11.3	40
19	0.37	6.7	4.7	44	392	2.26	0.52	45577	0.43	216	10.0	52
20	0.43	5.9	5.4	33	385	1.76	0.41	41649	0.62	188	8.3	45
21	0.55	6.1	1.8	28	1400	1.14	0.34	15295	0.30	140	10.1	86
22	0.34	6.8	4.0	19	556	0.77	0.25	8243	1.70	115	8.1	50
23	8.30	6.9	4.4	19	677	0.83	0.31	20015	1.00	147	11.9	129
24	0.49	9.9	1.4	4	403	1.78	0.29	17812	1.10	154	26.6	92
25	0.18	8.5	1.7	5	248	0.66	0.28	24070	0.29	119	46.9	1579
26	0.22	10.6	1.4	3	525	1.17	0.33	9408	0.05	127	14.5	51
27	0.44	8.8	4.5	25	720	2.70	0.65	4559	0.44	240	14.2	102
28	0.28	5.8	1.0	5	576	0.68	0.60	15054	0.32	214	11.6	67
29	0.42	8.0	6.3	46	434	1.84	0.39	2777	0.31	153	26.4	181

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr
	Mg/Kg	%	-----------------------------------				--Mg/Kg--	-----------------------------------				
30	0.16	7.1	3.2	16	461	1.49	0.39	2451	0.13	107	12.9	70
31	3.80	7.7	6.8	30	440	1.47	0.30	2495	0.16	141	26.0	190
32	0.39	7.8	6.7	44	493	1.75	0.52	24853	0.14	234	8.7	38
33	0.27	8.3	3.9	26	552	1.45	0.58	11610	0.14	173	11.6	88
34	0.40	8.4	2.1	20	684	1.51	0.37	16160	0.05	158	16.0	68
35	0.12	6.9	3.8	11	571	1.10	0.39	16311	0.05	243	8.7	23
36	0.16	4.0	2.4	9	710	1.91	0.38	11229	0.14	239	8.0	47
37	2.50	10.4	1.7	17	221	0.86	0.64	29095	0.45	114	18.8	36
38	0.22	6.9	1.0	5	730	1.13	0.14	7653	0.05	155	7.9	49
39	0.63	5.0	2.1	8	158	0.92	0.25	2762	0.30	88	12.0	221
40	0.80	3.0	2.4	5	133	0.25	0.23	3422	0.11	83	8.8	102
41	0.13	7.0	1.4	8	531	0.50	0.29	14362	0.26	122	9.6	47
42	0.35	8.0	1.8	9	540	1.25	0.28	14131	0.24	167	10.8	50
43	0.16	5.2	1.4	7	571	1.42	0.35	3763	0.39	182	8.4	121
44	0.63	5.3	1.9	15	767	1.28	0.25	2570	0.18	148	9.2	129
45	0.22	4.9	1.1	9	565	0.68	0.11	6600	0.71	113	2.7	87
46	0.53	7.5	4.5	23	511	1.30	0.33	6076	0.21	114	22.1	397
47	0.58	7.5	3.0	22	361	1.03	0.20	10770	0.18	117	26.1	271
48	0.10	7.5	6.0	49	522	1.23	0.44	12531	0.18	139	17.8	147
49	0.20	3.5	4.7	25	324	0.25	0.34	24175	0.73	78	8.8	49
50	0.35	4.4	2.2	18	328	1.18	0.25	26824	0.58	121	4.3	29
AVG	0.80	7.3	3.5	19	509	1.28	0.35	14466	0.36	159	14.9	122
GEOM MEAN	0.41	7.1	2.8	14	468	1.14	0.33	10849	0.26	151	12.6	76
MAX	8.30	10.6	11.0	74	1400	2.70	0.80	45577	1.70	305	46.9	1579
MIN	0.10	3.0	0.6	1	133	0.25	0.11	2451	0.05	78	2.7	23
RANGE	8.20	7.6	10.4	73	1267	2.45	0.69	43126	1.65	227	44.2	1556
ESt.D.LiM.[1]	0.015	0.001	0.2	2	1	0.5	0.1	25	0.10	0.15	2.5	1

[1]Est.D.Lim. denotes the estimated detection limit for each element. In this table, concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Cs	Cu	Fe	Ga	Ge	Hg	I	K	La	Li	Mg	Mn
	-----mg/Kg-----		%	-------------------mg/Kg-------------------				%	--------------------mg/Kg--------------------			
1	7.3	36.6	3.2	22.0	1.6	0.90	1.24	3.00	38.5	33	7407	501
2	3.0	44.2	3.7	19.6	3.0	0.10	0.91	2.36	16.4	27	4913	549
3	4.5	66.9	5.7	27.6	3.5	0.70	0.94	1.48	13.0	90	11067	527
4	3.1	96.4	6.8	27.9	5.6	0.27	0.93	2.13	18.3	20	8745	1186
5	2.8	85.7	7.6	26.8	5.8	0.61	0.91	1.21	21.6	23	9586	1687
6	1.8	21.9	3.6	16.5	1.6	0.10	0.60	0.75	14.0	13	5888	618
7	1.8	14.8	2.9	18.0	2.0	0.10	0.72	2.48	39.3	21	11613	587
8	5.1	18.3	3.2	20.3	2.3	0.40	0.60	2.40	28.3	42	12928	682
9	1.5	13.7	2.0	11.5	1.9	0.27	0.49	1.78	20.4	11	5631	449
10	2.1	17.5	3.0	16.5	2.0	0.49	0.54	1.53	17.8	15	11000	598
11	1.9	24.4	3.0	14.3	2.8	0.10	0.49	2.91	24.6	13	6442	599
12	1.7	14.2	6.6	14:6	2.9	0.26	0.50	1.09	11.4	11	14345	1051
13	4.4	13.7	3.7	23.1	2.4	0.10	0.44	1.87	27.6	35	7920	911
14	3.2	21.6	5.3	18.7	2.5	0.22	0.43	1.51	18.6	50	12027	726
15	1.0	22.5	3.7	14.9	2.7	0.21	0.36	1.37	9.8	9	11364	584
16	2.8	34.5	4.0	15.0	1.9	0.10	0.33	1.03	18.2	40	15538	810
17	4.5	34.2	3.7	21.0	2.2	0.10	0.43	2.50	23.0	32	7147	574
18	5.5	16.5	2.6	15.4	2.2	0.10	0.34	2.38	25.6	23	12014	426
19	6.2	17.8	2.7	17.0	1.9	0.10	0.27	2.45	29.5	24	14305	480
20	5.1	17.7	2.3	15.3	3.0	0.10	0.33	2.16	25.4	18	12163	421
21	3.4	18.7	2.6	24.7	2.5	0.25	0.22	2.06	19.6	16	9628	456
22	2.6	11.8	1.8	13.7	2.6	0.29	0.25	2.25	16.3	7	4710	259
23	2.4	17.7	3.3	16.3	1.0	0.22	0.24	2.12	20.4	11	12036	542
24	2.1	45.2	5.8	19.3	3.7	0.10	0.27	0.57	16.5	8	11822	1217
25	2.2	52.7	4.5	13.3	2.1	0.57	0.26	1.05	15.5	8	32378	809
26	4.1	58.4	4.5	21.0	2.4	0.10	0.27	1.90	13.8	7	12014	768
27	8.7	28.7	4.3	24.5	3.9	0.39	0.25	2.93	32.3	14	9873	454
28	1.2	13.3	3.1	15.7	3.1	0.10	0.16	2.25	28.0	4	9678	470
29	3.5	50.3	5.0	20.0	4.8	0.75	0.28	1.72	17.3	13	12581	858

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Cs	Cu	Fe	Ga	Ge	Hg	I	K	La	Ll	Mg	Mn
	-----mg/Kg-----		%	-------------------mg/Kg-------------------				%	---------------------mg/Kg---------------------			
30	3.2	29.0	2.6	18.2	1.5	0.22	0.26	0.84	16.7	8	7497	961
31	2.5	55.6	5.1	19.2	5.1	0.10	0.23	1.33	16.0	32	12381	824
32	4.3	22.3	3.4	19.1	2.5	0.10	0.23	2.15	33.4	51	8370	285
33	3.9	23.6	3.5	18.9	2.6	0.45	0.23	1.74	23.4	33	8238	260
34	3.4	24.8	4.4	20.4	2.5	0.66	0.28	2.08	21.7	61	15918	768
35	2.4	11.3	2.5	16.5	2.2	0.32	0.20	2.47	31.8	32	7861	433
36	2.0	15.1	3.1	17.9	2.8	0.10	0.22	1.69	33.8	25	7410	439
37	1.6	35.6	8.7	20.9	5.2	0.10	0.27	0.51	10.9	11	13725	1205
38	1.6	16.1	3.3	15.3	2.1	0.10	0.20	2.49	20.1	9	3664	890
39	1.0	20.7	2.5	8.3	3.5	0.10	0.17	0.36	10.1	15	3003	480
40	1.0	20.0	2.1	8.5	4.1	0.10	0.15	0.21	9.7	9	2402	382
41	1.3	10.6	2.3	14.0	0.3	0.10	0.19	1.63	14.2	8	5436	638
42	3.9	18.6	3.5	18.5	3.8	0.10	0.27	2.06	21.5	20	8396	736
43	2.3	11.4	1.3	12.7	2.2	0.63	0.62	1.56	23.8	7	1970	445
44	2.1	16.6	2.0	17.7	1.5	0.10	0.42	1.99	20.4	10	2384	593
45	2.4	9.5	1.0	12.8	1.5	0.10	0.43	1.67	15.0	5	1456	268
46	3.3	41.5	4.5	18.3	4.4	0.34	0.32	1.66	13.3	27	15324	674
47	2.6	51.3	5.2	18.5	3.8	0.57	0.24	1.03	13.4	28	20568	720
48	4.1	37.6	4.2	20.8	3.3	0.10	0.35	2.01	18.8	52	18414	535
49	1.5	24.4	2.4	10.4	2.4	0.25	0.67	0.42	9.9	27	7393	436
50	2.8	9.1	1.4	10.7	1.2	0.10	0.27	1.57	16.0	20	7616	253
AVG	3.1	28.7	3.7	17.6	2.8	0.26	0.40	1.73	20.3	23	9923	646
GEOM MEAN	2.7	24.0	3.4	17.1	2.5	0.20	0.35	1.54	19.0	18	8492	592
MAX	8.7	96.4	8.7	27.9	5.8	0.90	1.24	3.00	39.3	90	32378	1687
MIN	1.0	9.1	1.0	8.3	0.3	0.10	0.15	0.21	9.7	4	1456	253
RANGE	7.7	87.3	7.7	19.6	5.6	0.80	1.09	2.79	29.6	86	30922	1434
Est.D.Lim.[1]	0.25	0.25	.00025	0.15	0.5	0.2	0.15	0.05	0.15	2	10	2.5

[1]Est.D.Lim. denotes the estimated detection limit for each element. In this table, concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Mo	Na	Nb	Ni	P	Pb	Rb	Sb	Sc	Se	Si	Sn
	--------	--------	--------	--------	mg/Kg	--------	--------	--------	--------	--------	%	Mg/Kg
1	1.4	14710	1.3	20	94	57.1	84.5	1.95	11.9	0.015	26.7	1.20
2	1.2	15620	0.9	25	231	29.7	48.0	1.46	11.6	0.015	31.0	1.25
3	0.4	8960	0.3	77	82	26.9	52.2	0.78	21.0	0.030	27.2	0.89
4	1.2	11790	0.8	51	359	22.4	53.1	1.15	18.0	0.015	23.7	0.75
5	0.7	10010	1.8	140	972	34.3	51.9	0.45	22.0	0.070	26.6	1.26
6	0.8	14400	1.3	25	13	15.6	19.5	0.29	12.0	0.015	22.4	1.13
7	2.4	16610	2.3	19	772	14.2	70.0	0.33	9.0	0.150	26.5	0.77
8	9.6	29000	3.4	21	807	18.4	81.5	0.73	7.5	0.015	27.0	1.38
9	0.6	15050	1.5	12	213	21.3	39.8	0.36	4.9	0.015	32.4	0.82
10	1.2	15270	1.3	26	107	14.8	43.2	0.32	7.6	0.015	28.9	0.86
11	0.5	22240	1.0	13	515	22.7	42.8	0.38	6.1	0.015	34.0	0.98
12	0.7	19560	1.1	10	74	15.6	31.9	0.26	20.0	0.015	24.3	1.38
13	1.4	73400	4.0	16	1150	97.1	86.0	0.47	5.7	0.015	24.4	2.16
14	0.6	18800	0.5	64	378	22.1	53.7	0.25	11.4	0.015	28.3	0.58
15	0.2	17400	0.5	49	142	12.4	25.9	0.35	9.5	0.015	30.1	1.14
16	0.7	13970	1.9	142	697	34.0	46.5	0.46	8.5	0 015	28.3	1.46
17	0.6	16230	0.8	40	539	30.9	54.7	1.03	10.5	0.050	31.2	1.01
18	0.8	9870	1.9	21	740	44.3	59.8	0.73	4.7	0.190	28.8	1.46
19	1.3	9490	2.1	25	873	37.0	66.8	0.77	5.9	0.220	26.3	1.12
20	0.8	10690	2.0	22	736	33.8	55.9	0.68	5.2	0.180	29.9	1.47
21	1.4	14620	1.0	53	342	19.7	53.5	0.66	5.6	0.170	32.6	0.57
22	3.7	10980	2.1	27	509	14.6	48.4	0.45	2.8	0.180	30.3	1.07
23	0.9	18380	1.0	62	560	22.5	41.7	1.50	5.1	0.160	32.1	1.00
24	0.4	14370	3.4	57	252	16.7	18.9	0.44	15.5	0.015	23.9	0.68
25	1.3	11340	1.8	509	41	17.9	33.4	0.73	11.7	0.015	25.2	1.91
26	0.8	11970	0.5	27	385	24.1	47.7	0.73	17.0	0.015	26.0	0.53
27	1.3	20970	3.5	52	293	39.1	107.9	1.52	7.8	0.430	30.0	1.85
28	0.1	15650	1.3	30	657	13.2	43.0	0.16	6.7	0.015	30.0	0.94
29	1.1	15580	0.5	116	664	23.9	57.2	0.75	12.8	0.230	30.2	0.85

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Mo	Na	Nb	Ni	P	Pb	Rb	Sb	Sc	Se	Si	Sn
	------------------------mg/Kg------------------------										%	Mg/Kg
30	0.6	15620	1.8	47	610	20.6	57.6	0.28	7.3	0.015	34.0	0.77
31	0.6	14270	0.7	104	487	18.1	41.7	0.59	17.1	0.040	32.8	0.85
32	4.5	15110	4.3	21	407	22.4	68.5	1.40	8.5	0.015	26.3	1.91
33	2.4	15650	2.7	56	63	24.5	61.4	0.68	7.9	0.015	28.8	1.35
34	1.7	16830	3.1	29	463	17.5	67.4	0.46	10.0	0.015	25.9	1.19
35	0.9	17260	1.3	12	301	21.3	55.1	0.33	5.3	0.015	30.4	1.22
36	1.0	7580	1.8	23	314	26.7	61.8	0.32	6.0	0.015	35.6	1.01
37	0.5	19540	1.4	15	33	17.0	28.5	0.42	24.0	0.015	27.9	1.38
38	0.5	13800	1.1	23	257	21.3	42.1	0.37	5.0	0.015	35.9	0.25
39	0.4	15550	0.8	50	194	12.7	16.3	0.24	5.0	0.015	39.4	0.64
40	0.7	6630	0.6	30	124	14.0	14.3	0.16	5.0	0.015	37.1	1.04
41	0.3	17410	0.9	17	65	14.2	30.2	0.15	6.8	0.015	33.5	0.99
42	1.0	13800	0.8	22	107	17.8	61.3	0.60	8.8	0.015	32.7	0.92
43	1.7	13570	4.9	20	387	13.4	41.7	0.50	2.5	0.110	36.7	2.44
44	3.1	10230	1.4	27	309	19.7	43.5	0.57	4.2	0.015	27.3	1.32
45	2.6	12290	2.9	9	360	16.0	28.9	0.48	2.6	0.015	34.7	1.77
46	0.7	17040	1.5	212	467	18.9	40.5	0.50	11.0	0.015	27.2	1.05
47	0.7	17890	0.6	196	351	14.9	34.4	0.40	15.3	0.015	28.1	0.65
48	1.5	19290	1.3	113	357	23.1	55.8	0.60	13.5	0.015	28.8	0.81
49	2.2	5580	1.7	41	1210	27.4	21.1	0.42	4.2	0.140	13.2	1.04
50	0.3	10010	0.9	12	524	16.8	31.9	0.31	0.8	0.015	35.6	1.35
AVG	1.3	15838	1.7	57	412	23.9	48.5	0.60	9.5	0.058	29.4	1.11
GEO. MEAN	0.9	14500	1.4	36	290	21.7	44.6	0.50	8.2	0.028	29.0	1.03
MAX	9.6	73400	4.9	509	1210	97.1	107.9	1.95	24.0	0.430	39.4	2.44
MIN	0.1	5580	0.3	9	13	12.4	14.3	0.15	0.8	0.015	13.2	0.25
RANGE	9.5	67820	4.6	500	1197	84.7	93.6	1.80	23.2	0.415	26.2	2.19
Est.D.Lim.[1]	0.025	100	0.25	5	25	1	0.15	0.15	0.2	0.03	0.0005	0.5

[1] Est.D.Lim. denotes the estimated detection limit for each element. In this table, concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim Descriptive statistics are calculated accordingly.

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Sr	Th	Ti	TL	U	V	W	Y	Zn	Zr
	mg/Kg									
1	84	36.2	4640	1.10	8.2	74	1.10	30.6	172	610
2	166	13.9	6463	0.62	5.7	134	0.22	22.6	165	232
3	38	10.1	6218	0.74	2.7	187	0.10	15.0	204	134
4	194	10.8	7337	0.85	3.8	236	0.16	31.2	149	151
5	47	8.8	12890	0.70	3.1	191	0.28	29.2	162.	230
6	155	9.8	5918	0.46	3.2	123	0.40	19.1	139	88
7	236	27.5	4351	0.62	8.5	60	0.36	43.2	170	32
8	210	25.4	4780	0.68	21.3	83	1.60	39.1	180	57
9	152	20.2	2885	0.34	4.6	55	0.33	29.4	182	51
10	151	12.8	4466	0.48	3.1	93	0.45	29.4	153	67
11	198	23.9	3864	0.41	5.1	80	0.28	26.6	97	56
12	92	11.0	5373	0.52	2.4	220	0.31	31.9	123	52
13	118	32.4	4650	0.87	10.7	89	0.74	23.4	236	53
14	84	18.0	5662	0.49	5.7	170	0.15	30.7	104	90
15	156	5.3	3590	0.29	1.9	123	0.19	26.8	141	29
16	68	8.1	4566	0.59	1.8	125	0.97	11.8	177	108
17	102	13.3	5225	0.57	3.2	133	0.42	22.8	193	99
18	169	15.8	3657	0.73	4.2	69	0.76	27.5	172	130
19	193	18.6	4778	0.75	4.4	84	0.73	31.8	179	180
20	197	15.9	3949	0.57	3.9	74	0.71	28.6	168	178
21	106	16.0	3740	0.42	3.4	92	0.60	25.3	165	81
22	176	13.7	2453	0.47	5.6	58	0.54	21.6	152	50
23	187	14.2	3963	0.47	2.9	113	0.47	25.0	107	92
24	182	8.2	6957	0.45	1.5	139	0.65	33:3	149	107
25	86	13.3	2757	0.36	4.3	77	0.95	16.8	133	45
26	231	9.8	3997	0.67	2.8	117	0.05	19.5	183	38
27	134	25.5	5683	0.90	5.8	133	1.20	24.8	144	105
28	116	19.5	3705	0.38	2.4	85	0.10	32.6	92	20
29	33	9.4	7096	0.69	1.6	185	0.22	15.6	157	164

Table 2 (continued)
Total Concentrations of Elements in Benchmark Soils

Soil No.	Sr	Th	Ti	TL	U	V	W	Y	Zn	Zr
	mg/Kg									
30	20	10.8	4814	0.63	3.0	102	0.44	8.5	144	68
31	24	7.3	7875	0.42	1.5	181	0.17	12.9	189	136
32	229	30.1	3499	0.79	17.3	77	6.50	36.9	164	43
33	172	23.1	3739	0.75	14.5	126	6.90	21.5	157	60
34	264	17.3	5178	0.68	6.4	115	1.20	33.9	176	48
35	179	25.1	3790	0.61	4.9	74	0.64	35.7	154	35
36	90	25.8	2950	0.77	3.9	75	0.72	30.6	94	19
37	158	5.9	7771	0.45	1.7	288	0.47	32.9	154	34
38	83	16.1	3644	0.42	3.4	96	0.28	20.9	91	58
39	23	6.0	4990	0.20	1.2	92	0.25	9.5	88	92
40	27	5.6	2388	0.17	1.2	76	0.24	10.8	136	24
41	65	10.4	3857	0.33	2.6	68	0.28	17.9	138	56
42	84	32.9	4565	0.81	6.7	94	0.28	24.4	155	60
43	87	17.3	4233	0.44	3.8	54	1.10	15.7	133	63
44	49	13.3	3454	0.58	4.3	88	0.50	15.6	100	56
45	69	11.3	2629	0.50	5.6	48	0.50	18.0	135	41
46	83	9.1	5539	0.50	2.1	139	0.48	16.4	119	100
47	74	7.2	6099	0.33	1.6	175	0.27	18.1	165	98
48	180	14.0	4913	0.59	4.0	138	0.37	25.7	132	111
49	271	9.8	2239	0.28	6.3	58	1.30	25.6	122	34
50	123	9.5	2012	0.49	2.5	39	0.36	18.1	150	95
AVG	128	15.7	4716	0.56	4.7	112	0.77	24.3	149	93
GEOM. MEAN	107	13.8	4419	0.52	3.8	101	0.45	22.9	145	72
MAX	271	36.2	12890	1.10	21.3	288	6.90	43.2	236	610
MIN	20	5.3	2012	0.17	1.2	39	0.05	8.5	88	19
RANGE	251	30.9	10878	0.93	20.1	249	6.85	34.7	148	591
Est.D.Lim.[1]	4	0.1	5	0.15	0.05	5	0.1	0.15	2.5	0.25

[1]Est.D.Lim. denotes the estimated detection limit for each element. In this table, concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

Table 3

Ranges In Concentration and Summary Statistics of 46 Elements in 50 Benchmark California Soils[a]

Parameter	Ag	AI	As	B	Ba	Be	BI	Ca	Cd	Ce
Mean	0.80	7.3	3.5	19	509	1.28	0.35	14466	0.36	159
Standard Deviation	1.43	1.7	2.5	15	210	0.52	0.14	10703	0.31	52
Coefficient of Variation (CV) (%)	178	24	71	79	41	41	39	74	88	33
Geometric Mean	0.41	7.1	2.8	14	468	1.14	0.33	10849	0.26	151
Geometric Deviation	2.64	1.3	2.1	2.6	1.54	1.79	1.46	2.25	2.27	1.38
Geometric CV (%)	636	19	76	19	0.30	157	448	0.02	876	0.9
Minimum	0.10	3.0	0.6	1	133	0.25	0.11	2451	0.05	78
Lower Quartile	0.22	6.3	1.4	7	375	0.92	0.25	6600	0.15	121
Median	0.37	7.5	2.7	17	519.5	1.265	0.335	11420	0.275	150.5
Upper Quartile	0.53	8.3	4.7	26	625	1.53	0.39	20015	0.44	188
Maximum	8.30	10.6	11.0	74	1400	2.70	0.80	45577	1.70	305
W:Normal[b]	0.4864	0.9761	0.8865	0.8935	0.9161	0.9883	0.9248	0.8848	0.7977	0.9426
Prob<W[c]	0.0001	0.5824	0.0001	0.0001	0.0015	0.9591	0.0039	0.0001	0.0001	0.0268
W:Ln Normal[d]	0.8708	0.9218	0.9556	0.9566	0.9562	0.8305	0.9816	0.9505	0.9764	0.9781
Prob<W	0.0001	0.0028	0.1021	0.1129	0.1082	0.0001	0.7863	0.061	0.5961	0.6564
Methods Reported[e]	1	2	3	2	2	1	1	2	1	1

[a]Please refer to Table 2 for concentration units for each element. Concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

[b]w:Normal: Normal test statistic
[c]Prob<W: Associated probability for testing the hypothesis that the data come from a normal distribution
[d]W:Ln Normal: Normal test statistic for Ln transformed data

[e]Methods Reported
1 = ICP-MS (Inductively Coupled Plasma-Mass Spectroscopy)
2 = lCP-OES (ICP-Optical Emission Spectroscopy)
3 - ICP-OES Hydride

Table 3 (continued)
Ranges in Concentration and Summary Statistics of 46 Elements in 50 Benchmark California Soils[a]

Parameter	Co	Cr	Cs	Cu	Fe	Ga	Ge	Hg	I
Mean	14.9	122	3.1	28.7	3.7	17.6	2.8	0.26	0.40
Standard Deviation	9.2	223	1.6	19.3	1.6	4.5	1.2	0.21	0.24
Coefficient of Variation (CV) (%)	62	183	53	67	43	25	43	80	60
Geometric Mean	12.6	76	2.7	24.0	3.4	17.1	2.5	0.20	0.35
Geometric Deviation	1.79	2.27	1.7	1.8	1.6	1.3	1.6	2.12	1.67
Geometric CV (%)	14	3	62	7	46	7	64	1059	476
Minimum	2.7	23	1.0	9.1	1.0	8.3	0.4	0.05	0.15
Lower Quartile	8.7	45	1.9	16.1	2.6	14.9	2.0	0.10	0.24
Median	11.6	69	2.6	21.6	3.3	17.9	2.5	0.19	0.30
Upper Quartile	18.3	115	3.9	36.6	4.5	20.3	3.5	0.34	0.49
Maximum	46.9	1579	8.7	96.4	8.7	27.9	5.8	0.90	1.24
W:Normal[b]	0.8510	0.3834	0.9001	0.8169	0.9396	0.9758	0.9410	0.8133	0.8138
Prob<W[c]	0.0001	0.0001	0.0003	0.0001	0.0194	0.5721	0.0226	0.0001	0.0001
W:Ln Normal[d]	0.9727	0.9265	0.9815	0.9544	0.9846	0.96	0.9379	0.9212	0.9372
Prob<W	0.4631	0.0047	0.783	0.0903	0.8799	0.1563	0.0162	0.0026	0.015
Methods Reported[e]	2	2	1	1	2	1	1	1	1

[a]Please refer to Table 2 for concentration units for each element. Concentrations less than the Est. D. Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

[b]w:Normal: Normal test statistic
[c]Prob<W: Associated probability for testing the hypothesis that the data come from a normal distribution
[d]W:Ln Normal: Normal test statistic for Ln transformed data

[e]Methods Reported
1 = ICP-MS (Inductively Coupled Plasma-Mass Spectroscopy)
2 = ICP-OES (ICP-Optical Emission Spectroscopy)
3 = ICP-OES Hydride

Table 3 (continued)
Ranges in Concentration and Summary Statistics of 46 Elements in 50 Benchmark California Soils[a]

Parameter	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni
Mean	1.73	20.3	23	9923	646	1.3	15838	1.7	57
Standard Deviation	0.69	7.5	17	5356	285	1.5	9309	1.1	80
Coefficient of Variation (CV) (%)	40	37	75	54	44	113	59	65	141
Geometric Mean	1.54	19.0	18	8492	592	0.9	14500	1.4	36
Geometric Deviation	1.77	1.4	2.0	1.80	1.5	2.23	1.5	1.9	2.4
Geometric CV (%)	115	7.5	11	0.02	0.3	239	0.01	141	7
Minimum	0.21	9.7	4	1456	253	0.1	5580	0.3	9
Lower quartile	1.33	15.0	10	6442	449	0.6	11790	0.9	21
Median	1.76	18.7	19	9166	590	0.85	15080	1.3	27
Upper Quartile	2.25	24.6	32	12036	809	1.4	17260	2	56
Maximum	3.00	39.3	90	32378	1687	9.6	73400	4.9	509
W:Normal[b]	0.9610	0.9350	0.8442	0.8978	0.9104	0.6126	0.5514	0.8747	0.5508
Prob<W[c]	0.1722	0.0118	0.0001	0.0002	0.0008	0.0001	0.0001	0.0001	0.0001
W:Ln Normal[d]	0.8352	0.9696	0.9776	0.92	0.9732	0.9849	0.904	0.9806	0.9388
Prob<W	0.0001	0.3634	0.6377	0.0023	0.4807	0.8873	0.0004	0.749	0.0178
Methods Reported[e]	2	1	2	2	2	1	2	1	2

[a]Please refer to Table 2 for concentration units for each element. Concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

[b]w:Normal: Normal test statistic
[c]Prob<W: Associated probability for testing the hypothesis that the data come from a normal distribution
[d]W:Ln Normal: Normal test statistic for Ln transformed data

[e]Methods Reported
1 = ICP-MS (Inductively Coupled Plasma-Mass Spectroscopy)
2 = lCP-OES (ICP-Optical Emission Spectroscopy)
3 = ICP-OES Hydride

Table 3 (continued)
Ranges in Concentration and Summary Statistics of 46 Elements in 50 Benchmark California Soils[a]

Parameter	P	Pb	Rb	Sb	Sc	Se	Si	Sn	Sr
Mean	412	23.9	48.5	0.60	9.5	0.058	29.4	1.11	128
Standard Deviation	290	13.8	19.0	0.39	5.3	0.084	4.6	0.42	67.62
Coefficient of Variation (CV) (%)	70	58	39	66	55	147	16	38.	53
Geometric Mean	290	21.7	44.6	0.50	8.2	0.028	29.0	1.03	107
Geometric Dev	3	1.5	1.5	1.80	1.7	2.89	1.2	1.48	1.97
Geometric CV (%)	0.9	7	3	360	21	10149	4	143	2
Minimum	13	12.4	14.3	0.15	0.8	0.015	13.2	0.25	20
Lower Quartile	194	16	34.4	0.33	5.3	0.015	26.6	0.85	83
Median	360	20.6	47.9	0.47	8.0	0.015	28.8	1.04	121
Upper Quartile	560	26.7	57.6	0.73	11.9	0.050	32.6	1.35	180
Maximum	1210	97.1	107.9	1.95	24.0	0.430	39.4	2.44	271
W:Normal[b]	0.9330	0.6712	0.9680	0.8210	0.8966	0.5860	0.9662	0.9444	0.9501
Prob<W[c]	0.0950	0.0001	0.3202	0.0001	0.0002	0.0001	0.2500	0.0322	0.0587
W:Ln Normal[d]	0.9101	0.9118	0.9538	0.9704	0.9712	0.626	0.7089	0.9708	0.9045
Prob<W[e]	0.0008	0.0009	0.0849	0.39	0.415	0.0001	0.0001	0.4015	0.0004
Methods Reported	2	1	1	1	2	3	2	1	2

[a]Please refer to Table 2 for concentration units for each element. Concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

[b]w:Normal: Normal test statistic
[c]Prob<W: Associated probability for testing the hypothesis that the data come from a normal distribution
[d]W:Ln Normal: Normal test statistic for Ln transformed data

[e]Methods Reported
1 = ICP-MS (Inductively Coupled Plasma-Mass Spectroscopy)
2 = ICP-OES (ICP-Optical Emission Spectroscopy)
3 = ICP-OES Hydride

Table 3 (continued)
Ranges in Concentration and Summary Statistics of 46 Elements In 50 Benchmark California Soils[a]

Parameter	Th	Ti	Tl	U	V	W	Y	Zn	Zr
Mean	15.7	4716	0.56	4.7	112	0.77	24.3	149	93
Standard Deviation	7.6	185	0.19	3.9	53	1.27	8.1	32	90
Coefficient of Variation (CV) (%)	49	39	34	83	47	166	33	21	97
Geometric Mean	13.8	4419	0.52	3.8	101	0.45	22.9	145	72
Geometric Deviation	1.6	1	1.46	1.9	2	2.51	1.45	1	2
Geometric CV (%)	12	0.03	280	51	2	553	6	0.9	3
Minimum	5.3	2012	0.17	1.2	39	0.05	8.5	88	19
Lower Quartile	9.8	3657	0.42	2.5	75	0.28	18.0	133	48
Median	13.5	4516	0.54	3.8	94	0.45	24.9	153	63
Upper Quartile	19.5	5539	0.69	5.6	134	0.73	30.6	170	107
Maximum	36.2	12890	1.10	21.3	288	6.90	43.2	236	610
W:Normal[b]	0.9028	0.8778	0.9846	0.7174	0.8974	0.4405	0.9793	0.9696	0.6261
Prob<W[e]	0.0004	0.0001	0.8775	0.0001	0.0002	0.0001	0.7026	0.3657	0.0001
W:Ln Normal[d]	0.9611	0.9843	0.9633	0.9657	0.9809	0.9589	0.9467	0.9401	0.9497
Prob<W	0.1731	0.8699	0.212	0.2633	0.7619	0.1415	0.041	0.0205	0.0561
Methods Reported[e]	1	2	1	1	2	1	1	2	2

[a]Please refer to Table 2 for concentration units for each element. Concentrations less than the Est.D.Lim. are reported as one-half of the Est.D.Lim. Descriptive statistics are calculated accordingly.

[b]w:Normal: Normal test statistic
[c]Prob<W: Associated probability for testing the hypothesis that the data come from a normal distribution
[d]W:Ln Normal: Normal test statistic for Ln transformed data

[e]Methods Reported
1 = ICP-MS (Inductively Coupled Plasma-Mass Spectroscopy)
2 = ICP-OES (ICP-Optical Emission Spectroscopy)
3 = ICP-OES Hydride

Table 4

Correlation Coefficients between Elements in California Benchmark Soils[1]

	Ag	Mo	Be	P	Si	Se
B	-	0.51	-	-	-	-
K	-	-	0.38	-	0.43	-
Pb	-	-	0.43	0.45	-	-
Zr	-	-	0.48	-	-	-
Rb	-	0.37	0.64	-	-	0.41
Nb	-	0.50	-	-	-	-
Cs	-	-	0.68	-	-	-
Sb	-	-	0.46	-	-	-
Bi	-	-	0.43	-	-	-
W	-	0.43	-	-	-	-
La	-	-	0.47	-	-	-
TI	-	0.51	0.37	-	-	-
Ga	-	0.51	0.60	-	-	-
Cd	-	0.51	-	-	-	0.36
As	-	-	0.39	-	-	-
U	-	0.82	-	-	-	-
AI	-	-	0.36	-	-	-
Ti	-	-	0.41	-	-	-
Ce	-	-	0.51	-	-	-

[1]Correlation significant at $p < 0.01$ if $r > 0.36$

	Ga	Sc	Hg	Ge	Ca
Sc	0.58	1.0	-	-	-
Ge	0.42	0.61	-	1.0	-
Cu	0.62	0.76	-	0.66	-
As	0.38	-	-	-	
AI	0.63	0.65	-	-	-
Fe	0.61	0.92	-	0.69	-
Mn	0.47	0.69	-	0.69	-
Ti	0.63	0.75	-	0.69	-
Mg	-	0.39	-	-	-
I	0.38	-	0.44	-	-
Ce	0.38	-	-	-	-
Sr	-	-	-	-	0.49

[1]Correlation significant at $p < 0.01$ if $r > 0.36$

Table 4 (continued)
Correlation Coefficients between Elements in California Benchmark Soils[1]

	B	Li	K	V	Co	Ni	Cr
Li	0.59	1.0	-	-	-	-	-
CO	-	-	-	0.63	1.0	-	-
Ni	-	-	-	-	0.76	1.0	-
Cr	-	-	-	-	0.65	0.95	1.0
Rb	0.41	0.39	0.71	-	-	-	-
Cs	0.55	0.38	0.56	-	-	-	-
Sb	-	-	0.52	-	-	-	-
Bi	0.39	-	-	-	-	-	-
Y	-	-	0.42	-	-	-	-
La	-	-	0.72	-	-	-	-
Zn	-	0.41	-	-	-	-	-
Ba	-	-	0.59	-	-	-	-
Tl	-	0.39	0.42	-	-	-	-
Ga	-	0.45	-	0.56	0.40	-	-
Sc	-	-	-	0.86	0.67	-	-
Ge	-	-	-	0.69	0.55	-	-
Cu	-	-	-	0.66	0.81	0.46	-
As	0.62	0.59	-	-	-	-	-
Th	-	-	0.65	-0.37	-0.39	-	-
U	0.41	-	0.39	-	-	-	-
Al	-	-	-	0.60	0.45	-	-
Fe	-	-	-	0.92	0.72	-	-
Mn	-	-	-	0.68	0.66	-	-
Ti	-	-	-	0.76	0.62	-	-
Mg	-	-	-	-	0.63	0.71	0.65
Ce	-	-	0.69	-	-	-	-

[1]Correlation significant at $p < 0.01$ if $r > 0.36$

	Bi	W	Y	La	Zn	Ba	Tl
W	0.38	1.0	-	-	-	-	-
La	0.47	-	0.58	1.0	-	-	-
Ba	-	-	-	0.39	-	1.0	
Tl	-	-	-	0.48	0.43	-	1.0
Ga	-	-	-	-	0.45	0.55	0.39
As	0.49	-	-	-	-	-	-
Th	0.42	0.47	0.49	0.83	-	0.37	0.55
U	-	0.69	0.45	0.53	-	-	0.39
Al	-	-	-	-	0.37	-	-
Ca	-	-	0.47	-	-	-	-
Ce	0.47	-	0.63	0.96	-	-	0.47
Sr	-	-	0.67	-	-	-	-

[1]Correlation significant at $P < 0.01$ if $r > 0.36$

Table 4 (continued)
Correlation Coefficients between Elements in California Benchmark Soils

	Pb	Zr	Rb	Nb	Cs	Sn	Sb
Zr	0.42	1.0	-	-	-	-	-
Rb	0.57	-	1.0	-	-	-	-
Nb	-	-	0.40	1.0	-	-	-
Cs	0.57	0.53	0.81	-	1.0	-	1.0
Sn	-	-	-	0.63	-	1.0	-
Sb	0.38	0.62	0.53	-	0.68	-	1.0
Bi	-	0.45	0.50	-	0.59	-	0.51
W	-	-	-	0.52	-	0.36	-
Y	-	-	0.38	-	-	-	-
La	0.41	-	0.78	0.46	0.51	-	0.39
Zn	0.50	-	0.42	-	0.48	-	-
Ba	-	-	0.48	-	-	-	0.39
TI	0.40	-	0.52	-	0.40	-	0.36
Ga	0.36	-	0.59	_	0.53	-	0.46
Hg	-	0.46	-	-	-	-	-
As	0.37	0.65	0.40	-	0.59	-	0.66
Th	0.44	-	0.74	0.44	0.47	-	-
U	-	-	0.57	0.57	0.38	-	-
Ca	-	-	-	-	-	0.38	-
Mg	-	-	-	-	-	-	-
Na	0.63	-	0.37	-	-	-	-
I	-	0.61	-	-	-	-	0.39
Ce	0.42	0.37	0.76	0.39	0.51	-	0.40

[1]Correlation significant at $p < 0.01$ if $r > 0.36$

	As	Th	U	Al	Fe	Mn	Ti
U	-	0.71	1.0		-	-	-
Fe	-	-	-	0.67	1.0	-	-
Mn	-	-	-	0.50	0.78	1.0	-
Ti	-	-	-	0.49	0.79	0.77	1.0
Mg	-	-	-	_	0.47	-	-
Na	-	0.36	-	-	-	_	-
I	0.38	-	-	-	-	-	-
Ce	-	0.78	0.47	-	-	-	-
Sr	-	-	0.43	-	-	-	-

[1]Correlation significant at $p < 0.01$ if $r > 0.36$

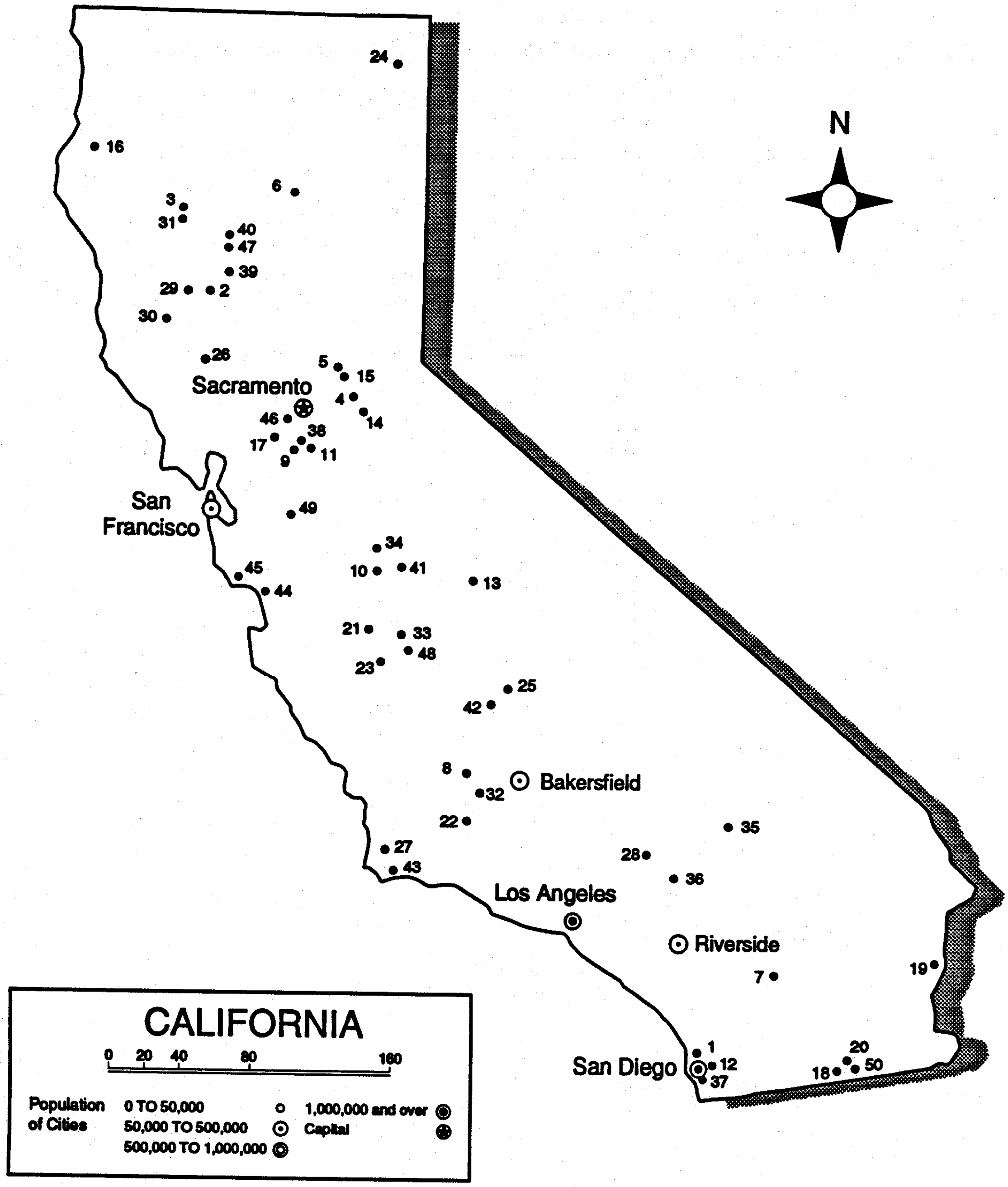

Figure 1. Soil sample numbers keyed to map of California