UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BASELINE GEOCHEMISTRY OF SOILS, WITH EMPHASIS ON SELENIUM, AT THE OAKES IRRIGATION TEST AREA, NORTH DAKOTA

By

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INTRODUCTION

Intensively-irrigated agriculture in the San Joaquin Valley of California is reported to have contributed to major environmental problems associated with the mobilization, transport, and concentration of selenium and other trace elements at Kesterson Reservoir. The Bureau of Reclamation is in the process of expanding irrigation from the Garrison Diversion into the James River basin. An approximately 15 square-mile area near Oakes, North Dakota is being used as an irrigation-test area. The present study is concerned with defining the concentration and distribution of selenium and other elements in soils of the Oakes test area prior to irrigation and drainage development. Once this "baseline" information is available and the existing geochemical processes are understood, then some judgements can be made as to the potential for mobilization, transport, and concentration of selenium and other trace elements as a result of irrigation and drainage at the Oakes test area.

METHODS

Field Sampling

Field sampling was conducted by scientists from the Bureau of Reclamation during the summer of 1986. Thirty-one sampling sites (fig. 1) were located adjacent to observation wells installed previously by scientists from the Bureau of Reclamation and the Water Resources Division of the U.S. Geological Survey. Soils were collected to depths of 20 feet (6.09 meters). The soil profile to 7 feet was obtained with a 4-inch diameter, 5-foot long soil tube, except where shallow ground water occurred. Samples from the beginning of the saturated zone to 20 feet were obtained using a 6-inch flight auger. Surface contamination on the auger was removed by scraping with a knife, and the soil was removed from the auger and placed in sequence on plywood boards. Soil characteristics were described and composite samples of various soil horizons were collected in kraft paper bags. In the office, the soil descriptions were reviewed, additional compositing was performed, and some samples were omitted by Bureau of Reclamation scientists to reduce the number of samples submitted for analysis to an acceptable number. A listing, identifying samples composited, sampling depths, soil horizons, and soil series is given in table 10.

Laboratory Methods

Soil samples were mailed to the U.S. Geological Survey laboratories in Denver for preparation and analysis. The soil samples were air dried under forced air at ambient temperatures. The dried samples were disaggregated with a mechanical mortar and pestle and the minus 10 mesh (2 mm) material sieved and saved for analyses. A split of the minus 2mm material was ground in a ceramic plate grinder to minus 100 mesh, and this material was used for all chemical analysis. Chemical analyses were performed by two main techniques, inductively coupled plasma atomic emission spectroscopy (ICP-AES) and continuous flow hydride generation atomic absorption spectroscopy (HGAAS).

Inductively Coupled Plasma Atomic Emission Spectroscopy

Samples were analyzed simultaneously for 38 elements using ICP-AES. Each sample (0.200g) was dissolved using a low-temperature digestion with concentrated hydrochloric, hydrofluoric, nitric, and perchloric acids (Crock

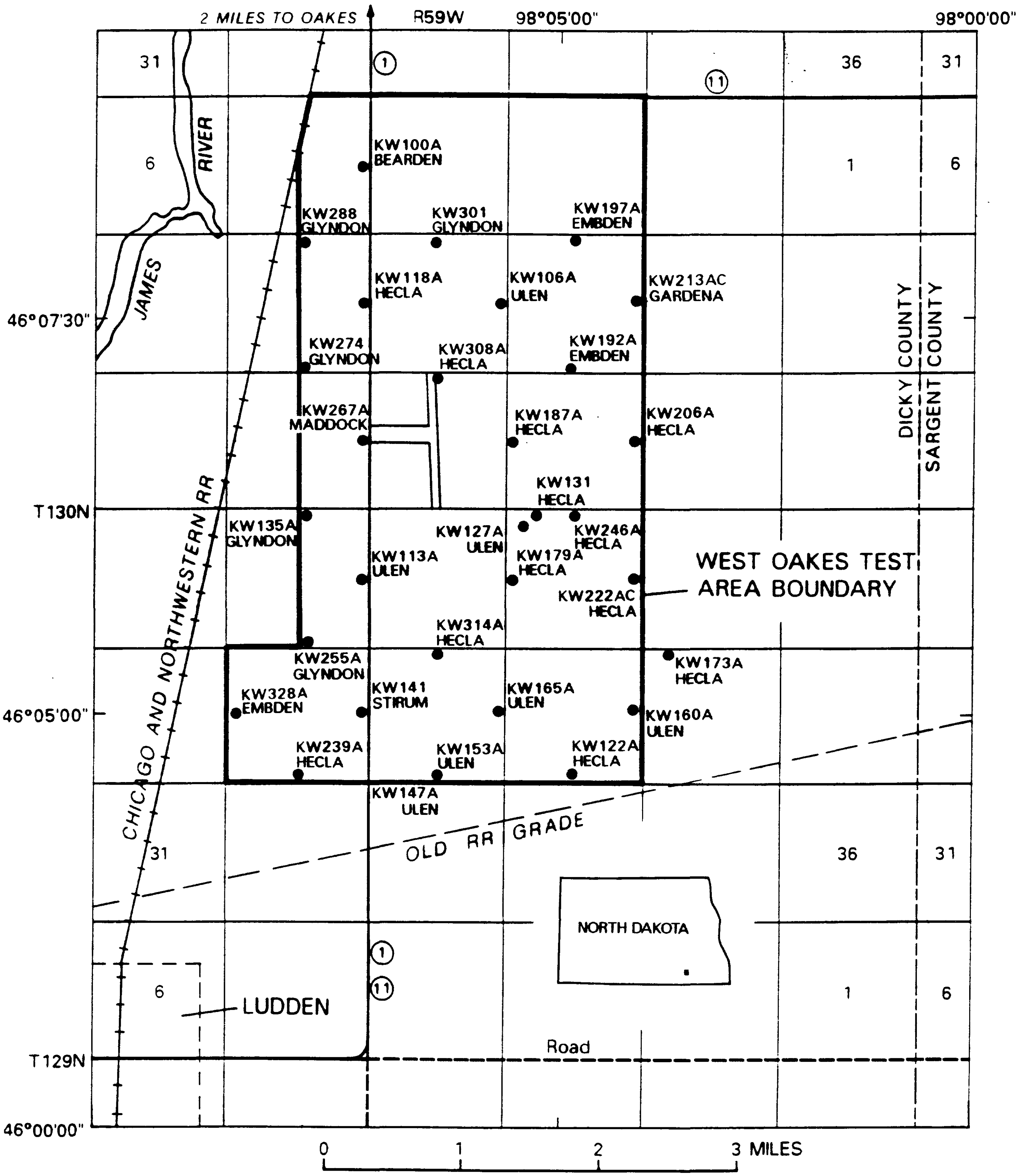

Figure 1. Index map showing location of the Oakes test area in North Dakota with sampling locations and soil series.

and others, 1983). The acidic sample solution was taken to dryness and the residue was dissolved with 1mL of aqua regia and then diluted to 10g. Reagent blanks, reference materials, and sample replicates were all digested by the same procedure and analyzed at the same time as the samples. The elements determined and their determination limits are shown in table 1. The elements Ag, Au, Bi, Cd, Ho, Sn, Ta, and U were below detection in all samples. The relative standard deviation (RSD) for replicate determinations of most elements is 5 percent or less.

Continuous Flow Hydride Generation Atomic Absorption Spectroscopy

Arsenic and selenium were determined by HGAAS (Crock and Lichte, 1982; Briggs and Crock, 1985). A 0.3 gram of sample was digested with nitric, perchloric, sulfuric, and hydrofluoric acids. After digestion, the sample was diluted to 30mL with 10 percent HCl. Arsenic and selenium were determined independently using specifically designed continuous flow systems. In the procedure, the sample solution was reacted with sodium borohydride in order to generate the gaseous hydrides which were swept into the heated quartz furnace of an atomic absorption spectrometer. Arsenic was determined using an aqueous standard calibration curve and selenium was determined using the method of standard additions. Determination limits for arsenic and selenium are shown in table 1. The RSD for the determination of both elements was about 10 percent.

RESULTS

Site and Analytical Variability

Site variability was to be evaluated by comparing the chemical properties of soil profiles collected adjacent to one another at four randomly selected locations. Because of the elimination of some samples for analysis, only two pairs of adjacent profiles were actually analyzed for their element composition. From each of the four profiles, after compositing and sample elimination, four depth zones (various combinations of soil horizons) were analyzed. Descriptive and analytical data for each profile (profile pairs KW147A-KW151A and KW153A-KW158A, KW222A-KW227A and KW230A-KW236A) are given in table 10. A one-way analysis of variance was used to partition the variation between horizons from all profiles and paired horizons (table 1). The variance components suggest that elements commonly redistributed within a profile by soil forming processes (Ca, Mg, Fe, Mn) exhibit most of their variation between horizons and the differences between horizon pairs is small. This suggests that soils are relatively uniform in soil formation across small distance intervals as indicated by element composition. For other elements that are more indicative of exchange, sorption, or precipitation reactions (As, Cu, Na, Ni, Pb, and Se), the greatest variation is between pairs of horizons. This suggests lack of uniformity between soil profiles over small distance increments. These interpretations must be viewed as tentative because of the small number of samples involved and the individual samples consisted of composites of horizons which were inconsistent from profile to profile.

Laboratory variation was estimated by selecting 12 samples at random and analyzing them in duplicate. Variation partitioned among samples and between analyses (table 1) shows that, for most elements, the laboratory error represents less than 5 percent of the total variation. The largest error is for As, and an examination of the data shows that this high value is due to a large difference for a single pair of samples (KW113A in table 10). Laboratory precision for all elements is sufficient so that trends in natural variation will not be obscured by laboratory error.

Soil Series Variability

Eight soil series, or variants of a soil series, were identified by the field soil scientist logging the core. The soil series sampled, with number of profiles of each in parenthesis, are; Bearden (1), Embden (3), Gardena (1), Glyndon (5), Hecla (13), Maddock (1), Stirum (1), and Ulen (5). The sampling locations for each soils series is shown in figure 1. Compositing of horizons and elimination of certain samples from analyses precludes the evaluation of differences within and among soil series on a horizon-by-horizon basis. Therefore, a weighted-average value was computed for each element for each of three soil zones; oxidized, mottled, and reduced. The weighted average was computed by multiplying the concentration by the depth increment represented by the sample and summing these values for the zone. The sum was then divided by the total depth of the zone to arrive at an average value for the zone. Where certain horizons, or depth zones, were not analyzed, the horizon above and below were averaged and this value was used for the missing depth increment. The oxidized zone was determined from field notes and consists of that zone which is freely drained and not saturated with water; the mottled zone is occasionally saturated with water and is indicated in the field notes as being mottled; the saturated zone is below the permanent water table. The permanent water table ranged in depth from 7 to 12 feet (2.1 to 3.7 meters) within the study area.

Only those soil series where more than one profile was sampled were included in the analysis-of-variance to estimate relative variation among and within soil series. The results of this analysis for the four soil series (Embden, Hecla, Glyndon, and Ulen) and the three zones (oxidized, mottled, and reduced) are shown in table 3. A separate, one-way, analysis-of-variance computation was used for each of the three zones. Differences among soil series are generally smaller than within samples from the same soil series, except for Li, Mg, P, and Sc in the oxidized zone, La, P, Sc, Ti, and Y in the mottled zone, and P in the reduced zone. This suggests that soil taxonomy reflects differences in total element concentration among taxonomic units for only those elements listed above in each zone. The differences in total element concentration within a soil series are generally greater than among soil series for most elements in each of the three zones. Therefore, extrapolations for chemical composition of a soil series, or the oxidized, mottled, or reduced zones from a soil series, can not be made across the study area where this same soil series is found.

Spatial Variability

An attempt was made to perform spatial-statistical analysis (kriging) for selenium in the oxidized, mottled, and reduced soil zones. Kriging expects the chemical data from the different sample locations to be autocorrelated, that is, the values from samples taken from nearby locations should be more nearly alike than those taken from greater distances apart. If autocorrelation exists, then it is quantitatively expressed by a variogram (a graph showing expected mean-squared difference of values taken at points a given distance apart). This technique, and its limitations are described by Tidball, Grundy, and Sawatzky, 1987.

Kriging was performed on each soil zone, oxidized, mottled, and reduced, by computing a selenium accumulation value for each sample location. This value was computed by multiplying the selenium value determined in a sample by the depth increment represented by the sample and then summing the products for the soil zone. Histograms of selenium accumulation and depth increments for each sample are shown in figures 2-4 for the oxidized, mottled, and reduced zones, respectively. Along with the histograms in each of these figures are variograms for selenium accumulation and depth increment. The variograms in figures 2-4 show that spatial autocorrelation was not found for any of the three soil zones. The variograms display an irregular generally horizontal pattern which fluctuates about the variance of the population. This lack of autocorrelation can arise from one of the following conditions, (1) the sample values are randomly distributed in space; (2) the samples were taken at locations too far apart to allow detection of any autocorrelation, or (3) sampling and analytical procedures may have introduced sufficient error into the data to obscure any spatial autocorrelation structure. Without further sampling and analysis, it is impossible to determine which condition is at fault.

Point plots showing the average selenium value in each of the three soil zones, oxidized (fig. 5), mottled (fig. 6), and reduced (fig. 7) support the results of the kriging. The average values are computed as described previously in the section on Soil Series Variability. These point plots show that the difference in selenium values from samples located close together are as different as from samples located far apart. Therefore, contour mapping of selenium concentration in soil is not appropriate.

Element Associations

R-mode factor analysis of the weighted-average values for the oxidized, mottled, and reduced zones was performed using an oblique solution with extreme variables as the reference axis. Correlations between the sample scores and the variables are presented in tables 4 through 6 for the three zones. Correlation coefficients quantify the relationship between an element and a factor. Positive coefficients indicate element enrichment, while negative coefficients indicate element depletion for a factor. Because an oblique solution was used, an element may be associated with more than one factor. Factor analysis is used as an aid in interpreting the relationships among a large number of variables (elements) by grouping them into a few factors. These associations of elements are then interpreted as processes.

Optimum models for the oxidized (table 4) and reduced (table 6) zones each had six factors. The optimum model for the mottled zone (table 5) had five factors. The soil matrix is represented by factor one for the oxidized and mottled zones, and by factor two for the reduced zone. Calcium and Mg carbonates are represented by factor two for the oxidized and mottled zones, and by factor three for the reduced zones. In the oxidized zone the carbonates are positively associated with P and Sr, and negatively associated with Mn. This contrasts with the carbonate factor in the mottled zone where Mn forms a positive association, while in the reduced zone there are no other elements associated with the carbonate factor. Factor 4 in the oxidized zone contains As associated with Ti; we do not have an explanation for this association. Arsenic associates with mainly transition metals in the mottled (factor 4) and reduced (factor 4) zones. Factor 5 in the oxidized zone and factor 4 in the mottled zone represent metals associated with Mn oxides, while the Mn factor in the reduced zone (factor 5) does not suggest these same

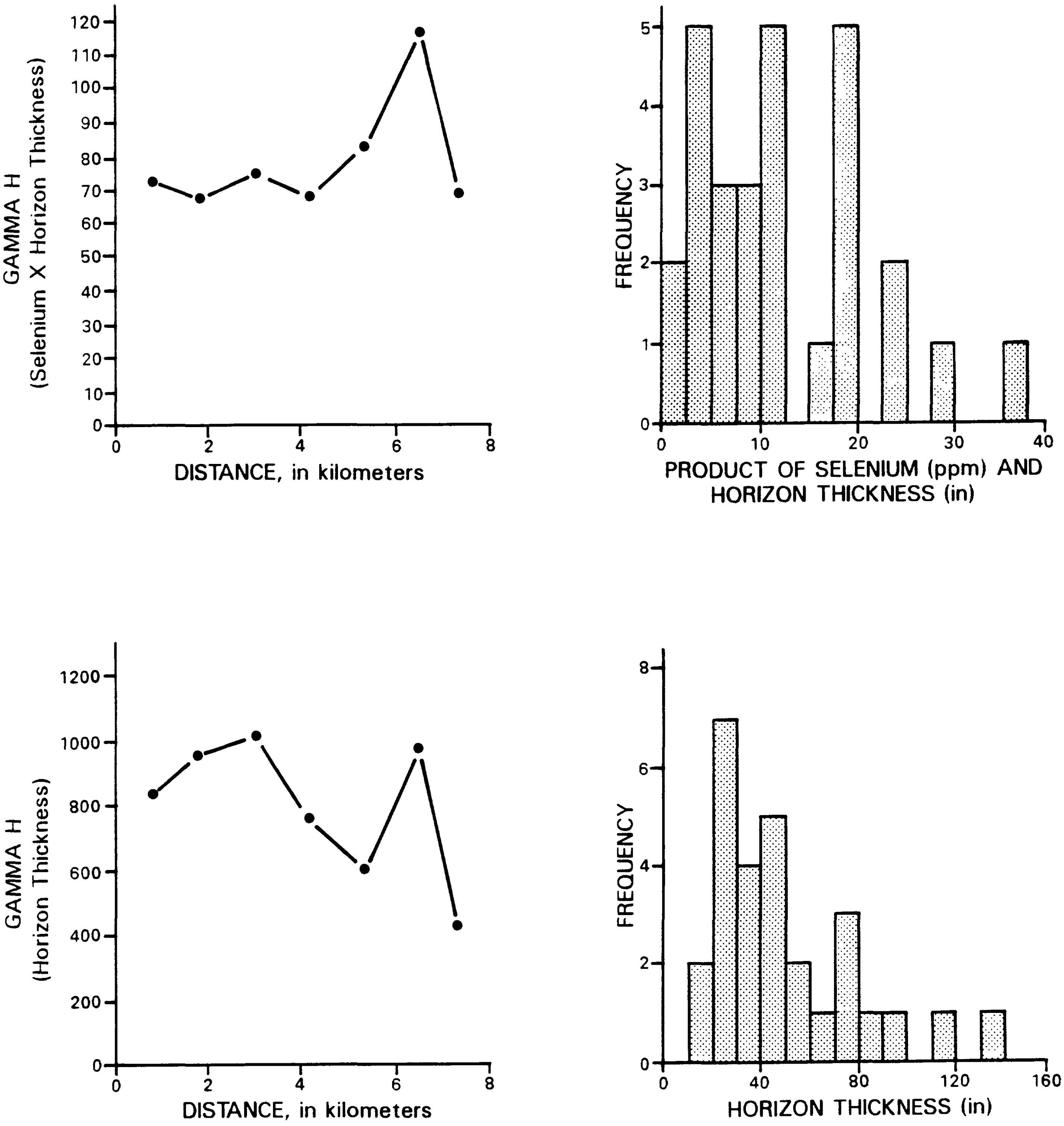

Figure 2. Variograms and histograms showing spatial variability for selenium in the oxidized soil zone.

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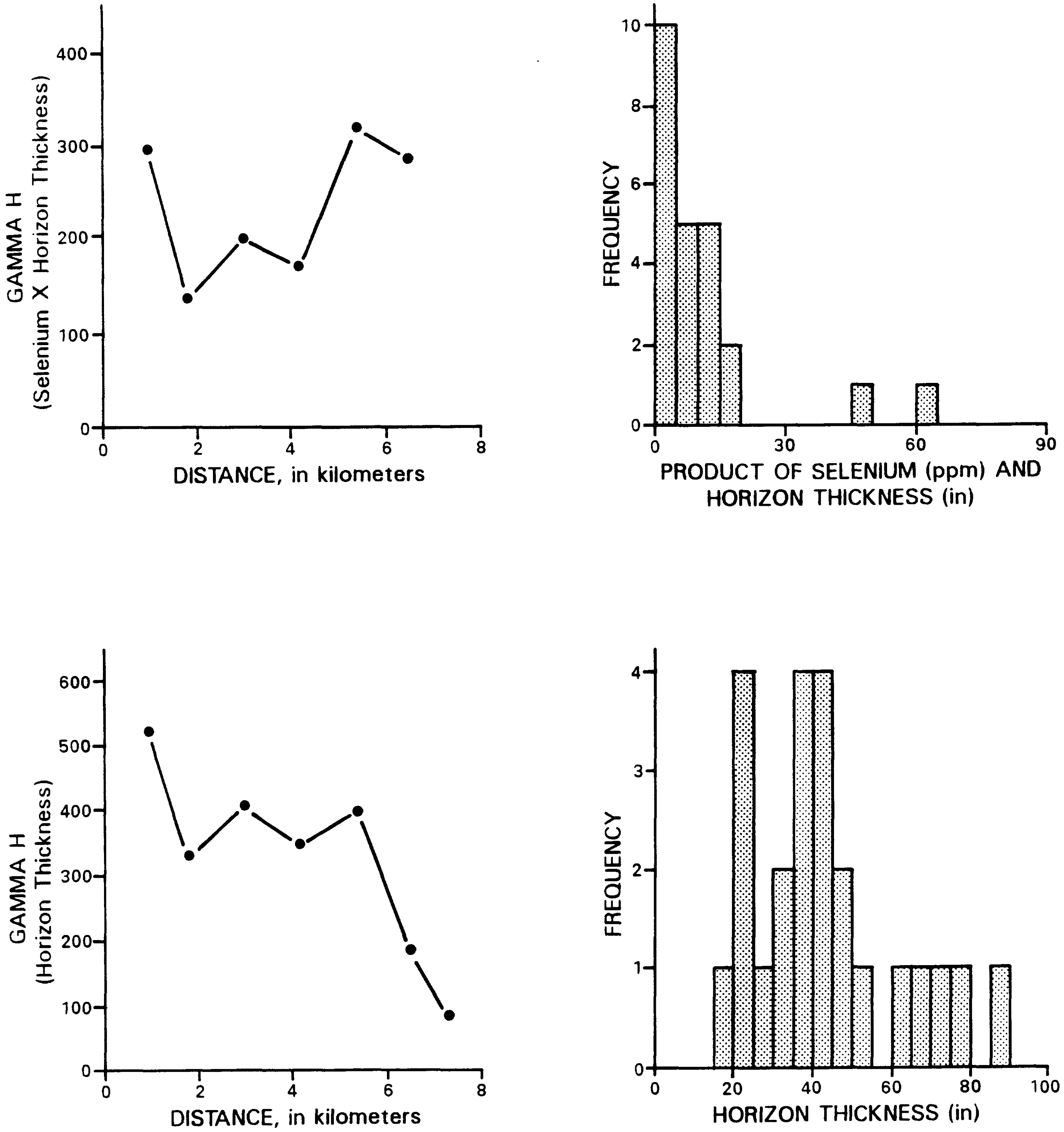

Figure 3. Variograms and histograms showing spatial variability for selenium in the mottled soil zone.

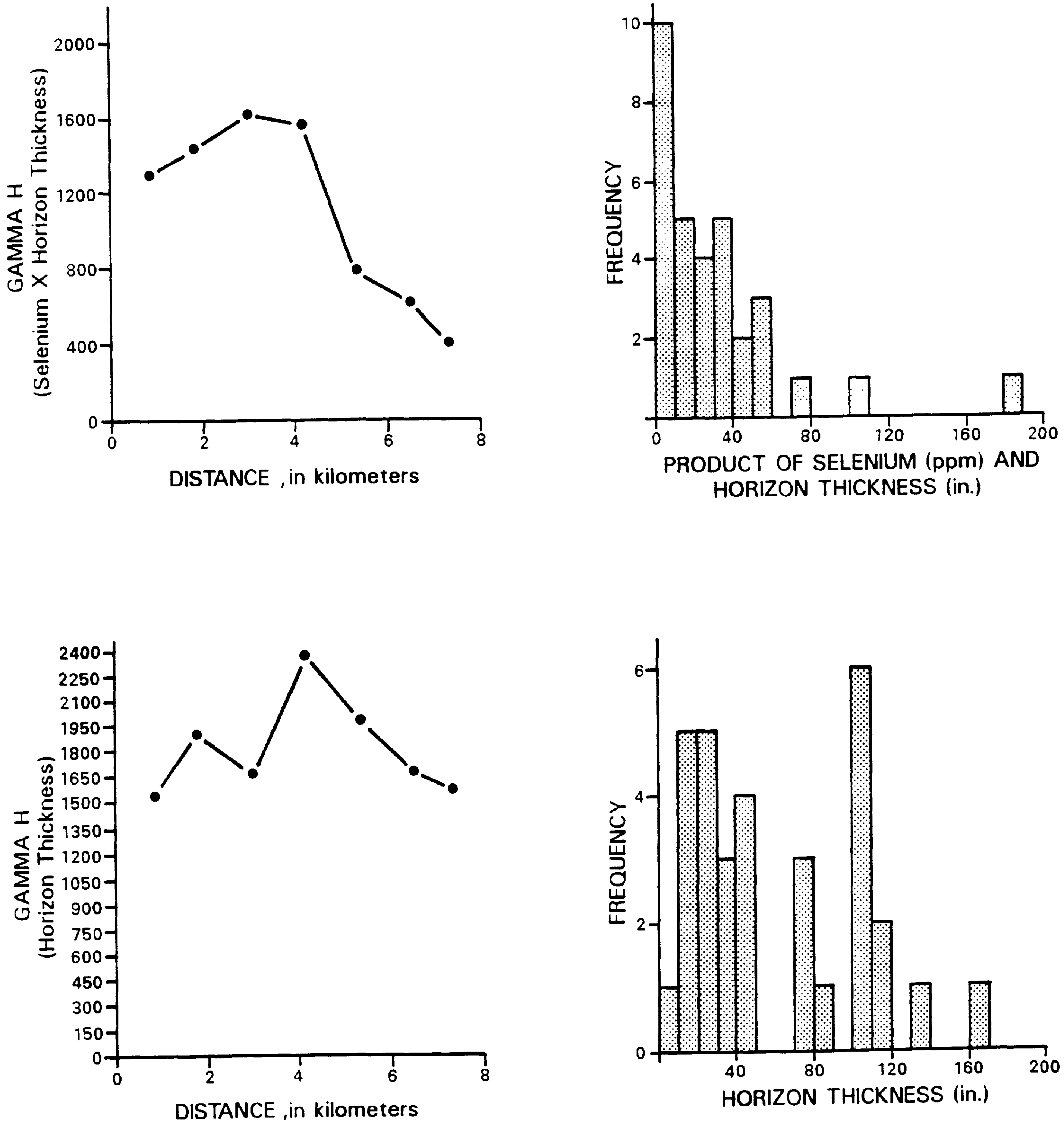

Figure 4. Variograms and histograms showing spatial variability for selenium in the reduced soil zone.

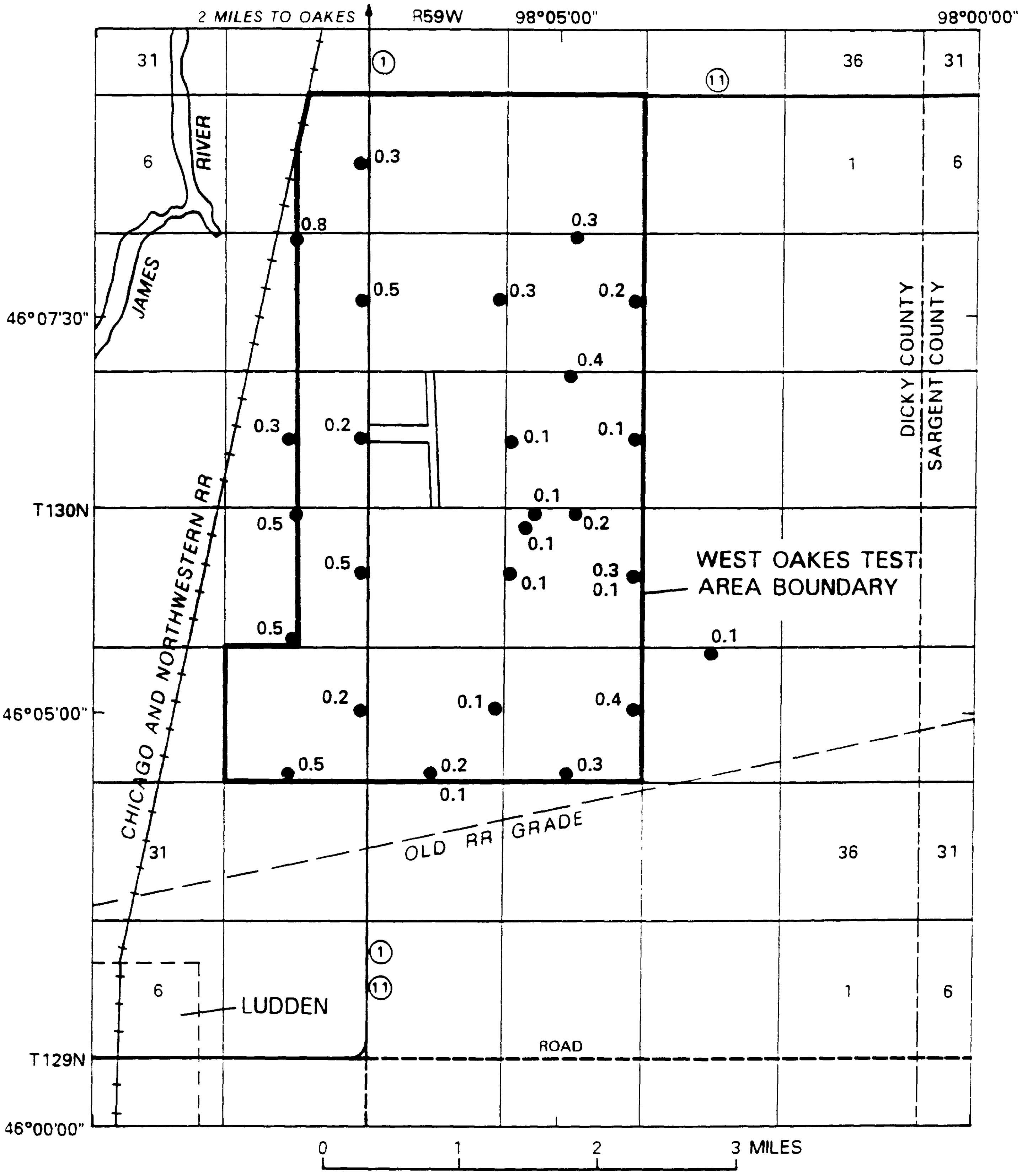

Figure 5. Map showing average selenium concentration in samples from the oxidized soil zone.

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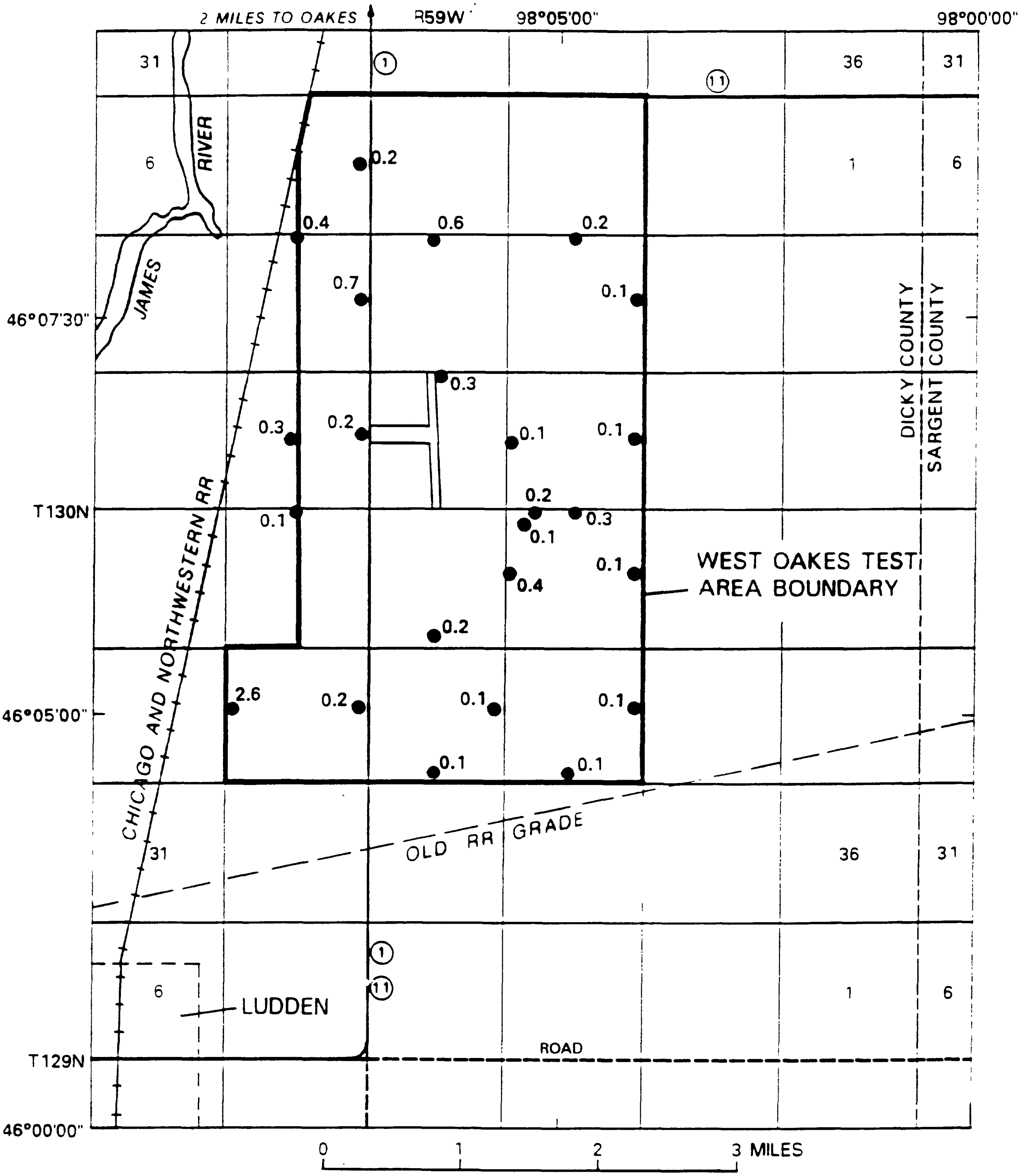

Figure 6. Map showing average selenium concentration in samples from the mottled soil zone.

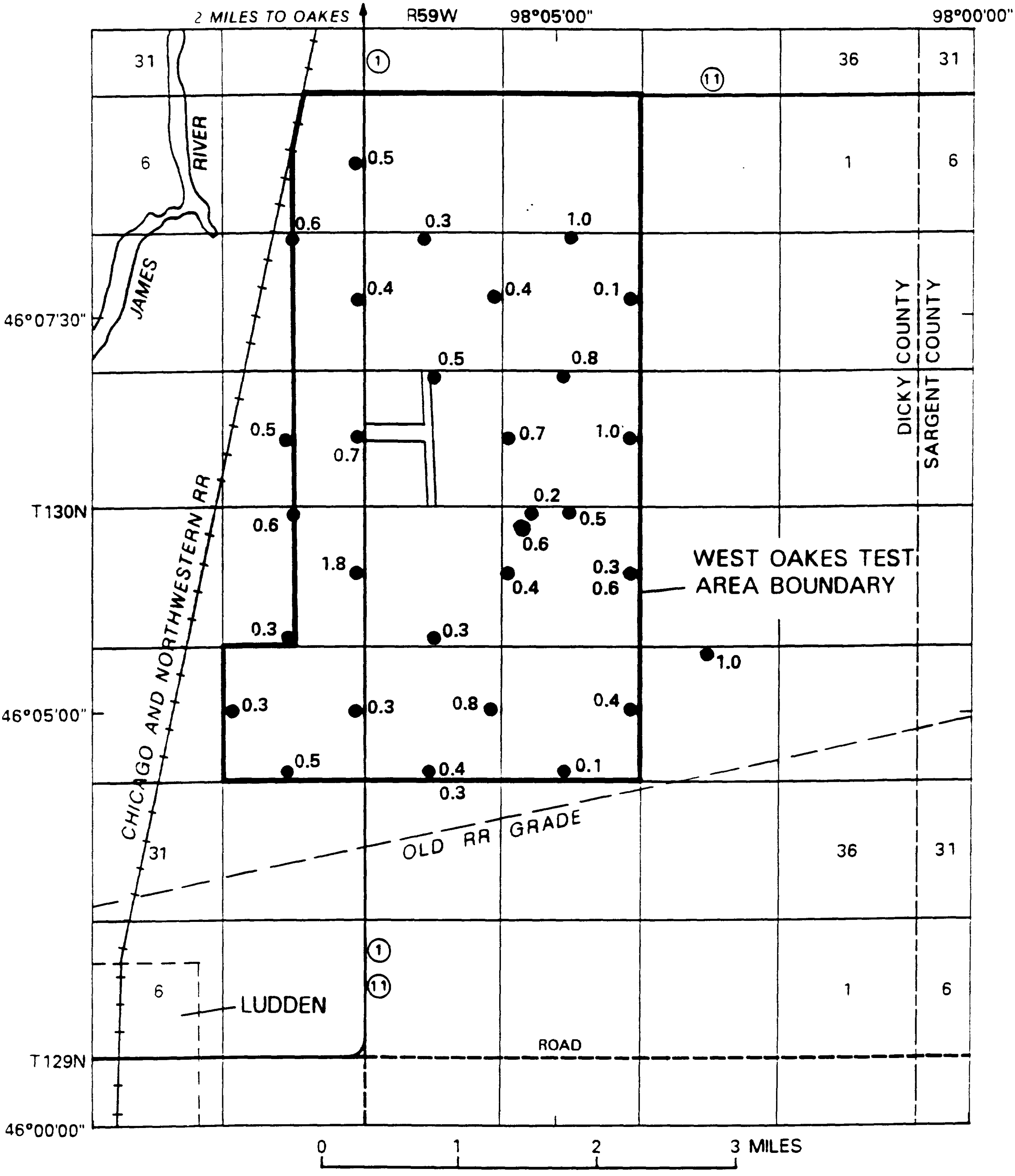

Figure 7. Map showing average selenium concentration in samples from the reduced soil zone.

associations. In the reduced zone these same metals are associated with Fe on the As factor (factor 4). A sodium factor (factor 3) in the oxidized zone has no counterparts in either of the other two zones. Factor 6 in the oxidized zone appears to be inversely related to factor 3; elements loading positive on factor 3 load negatively on factor 6, and vice verse. Factor 6, the Se factor has factor 5 (mottled zone) and factor 6 (reduced zone) as counterparts. However, Se is associated with different elements in the three zones. In the oxidized zone it is associated with Ca and Mg phosphates and probably carbonates, while in the mottled and reduced zones Se is associated with Sc and Co or Ni, Zn, and As, respectively. These differences in Se associations probably reflect differences in Se chemistry under oxidizing and reducing conditions.

Figures 8-10 are contour maps of factor scores for the selenium factor from the oxidized, mottled, and reduced zones, respectively. Each factor has a theoretical, or "end member composition", and a factor score indicates how closely the composition of the actual sample is to that end member composition. For each sample, there are as many factor scores as there are factors, and the scores define the mixture of end member compositions that make up that sample. A sample with a high score on any one factor indicates that the end member composition of that factor represents the sample composition fairly well. A score near zero for a sample on a factor indicates that the sample composition is not similar to the end member composition. A large negative score indicates that the composition of the sample opposes that of the end member; depletion of an element rather than enrichment is indicated. The three contour maps (figs. 8-10) suggest the same general patterns; samples become enriched in selenium and associated elements on that factor (tables 4-6) from east to west-northwest across the study area.

Factor analysis suggests that element associations in the oxidized zone differ from those in the mottled and reduced zone. These differences reflect the way in which element react to oxidizing or reducing chemical conditions. If the natural water table is altered by irrigation and drainage practices, then the element associations would be altered to reflect the changes, whether they be oxidizing or reducing. If the changes are toward more oxidizing conditions (lowering water table), then one would expect increased mobility of elements such as As and Se and decreased mobility of elements such as Pb, Zn, Cd, and Cu. If changes are toward more reducing conditions (rising water table), then the opposite trends in element mobility could be expected. The changes would be expected to be greatest in the western-northwestern part of the study area, especially for selenium, as indicated by the contour maps of factor scores (figs. 8-10)

Geochemical Summary

The previous discussions on kriging have shown that element distributions can not be reliably represented on a map because of excessive local variability. Differences in soil chemistry can not be assigned to soil series (taxonomic units) because they exhibit excessive variability within a series when compared to samples of that series collected throughout the study area. The most definitive way in which to describe the geochemistry of the soils of the Oakes test area is to present geochemical baselines for each of the three zones, oxidized, mottled, and reduced. Table 7 lists the observed range in concentration for all elements, and the mean and standard deviations for each of the three soil zones. This summary shows that, for most elements, the average concentration for each zone is the same. However, a few elements

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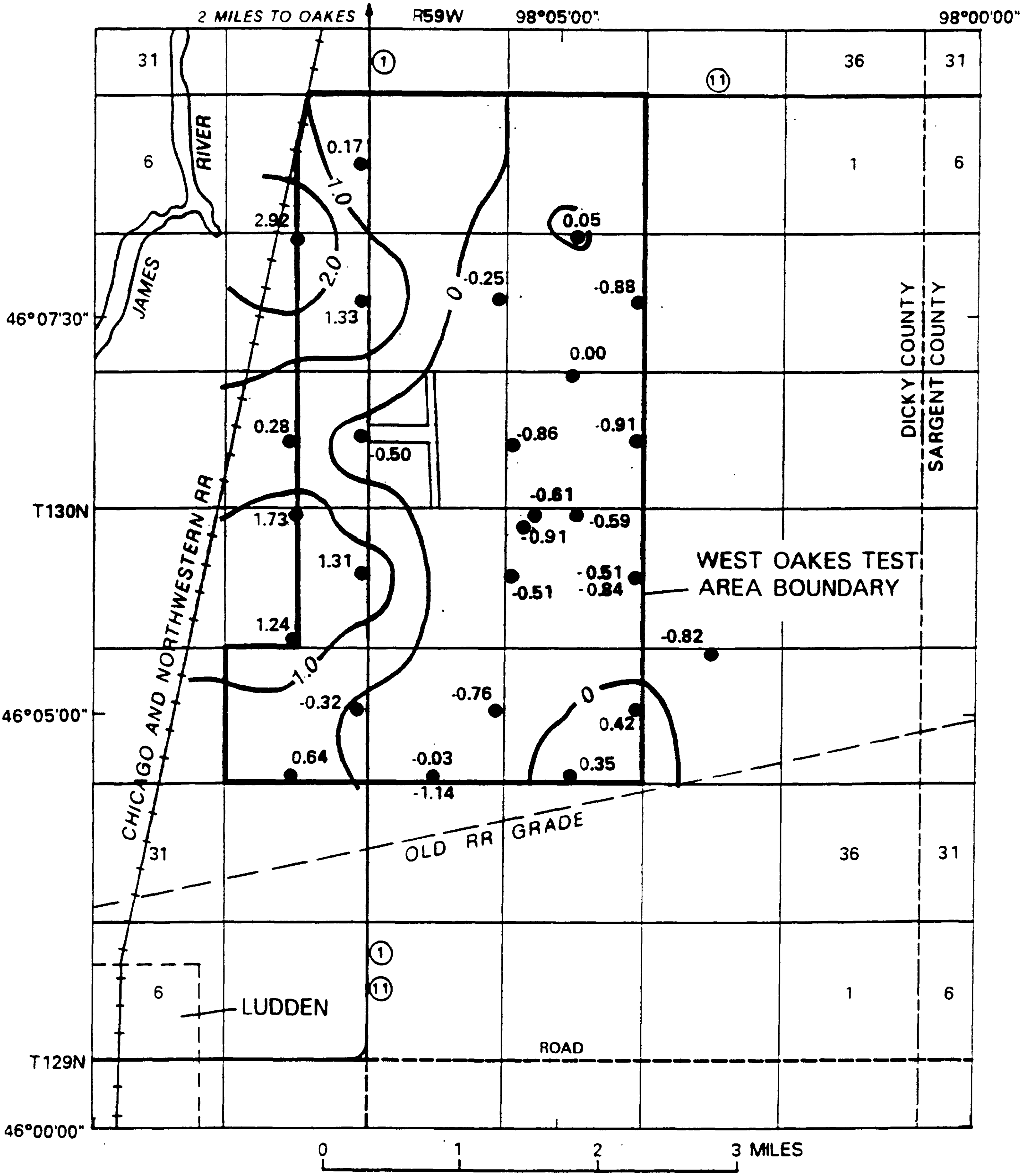

Figure 8. Contour map showing the distribution of factor scores for the selenium factor from the oxidized sampling zone.

Top

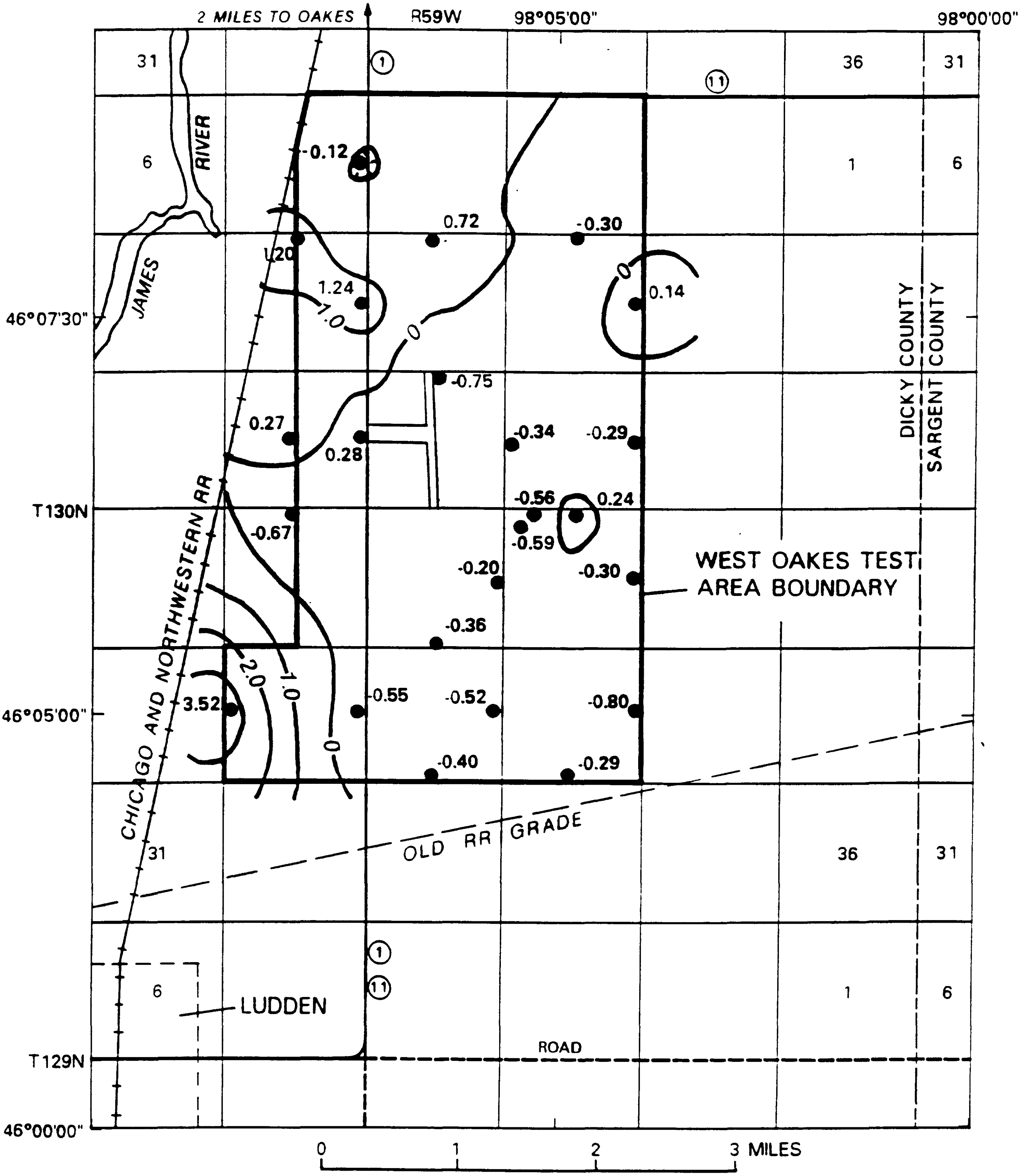

Figure 9. Contour map showing the distribution of factor scores for the selenium factor from the mottled sampling zone.

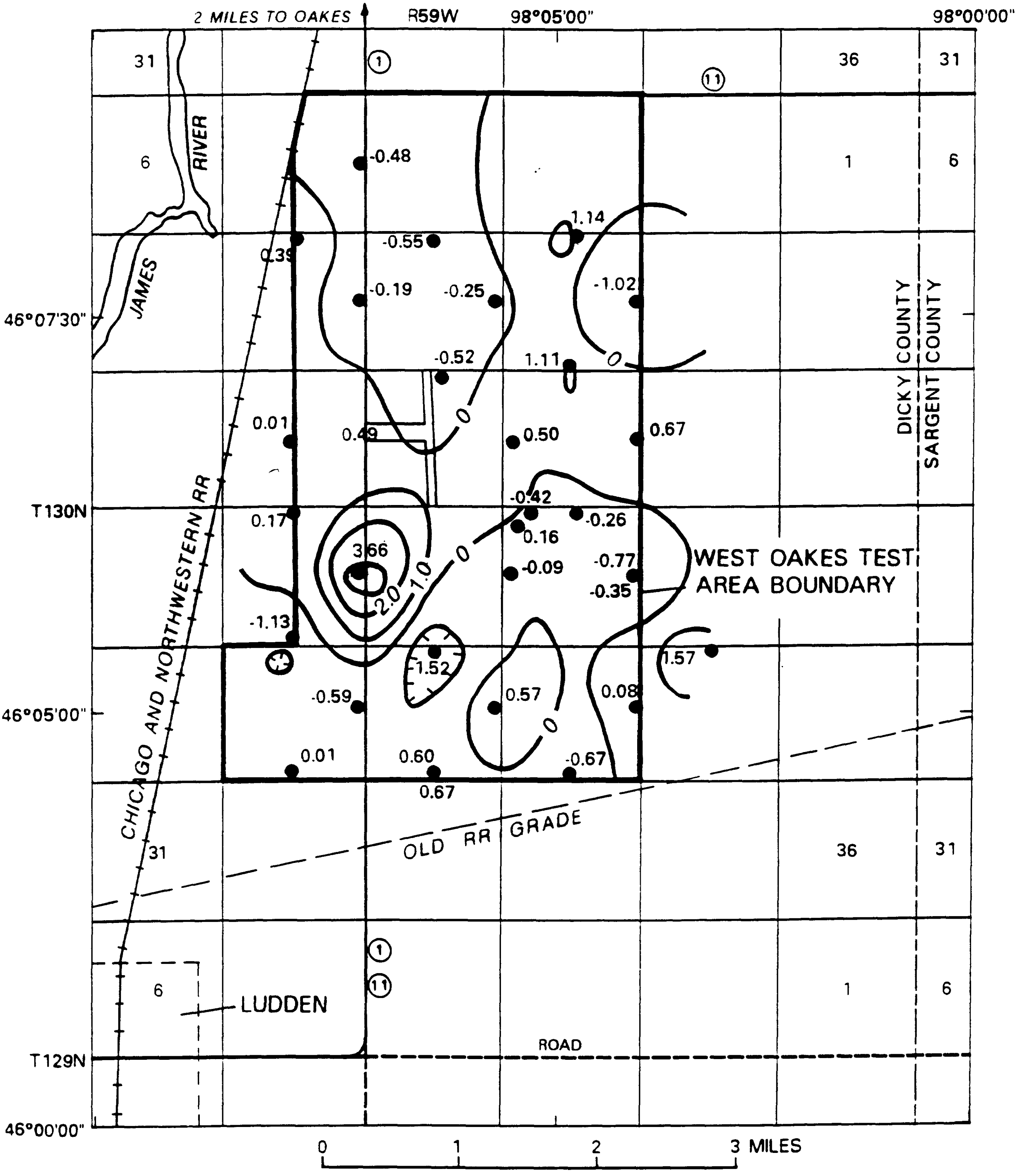

Figure 10. Contour map showing the distribution of factor scores for the selenium factor from the reduced sampling zone.

exhibit a tendency to increase (Co, Mg, Mn, and Se) or decrease (Ba, Ca, and Sr) in concentration with depth. These trends are probably not statistically significant, but do provide support to the analysis-of-variance discussion on site variability where some of the same elements were shown to exhibit most of their variation among different soil horizons reflecting soil forming processes. Factor analysis shows that the chemistry of oxidized, mottled, and reduced zones differ in their element associations. Therefore, even though the average compositions of the three zones are similar, differing geochemical processes within each zone have segregated elements into compounds whose susceptibility to mobilization and transport by irrigation water will differ.

Baseline data (table 8) is presented for the Northern Great Plains (Severson and Tidball, 1979) as a basis for making comparisons with a much larger adjacent area to determine whether the samples from the Oakes test site are unusual in their natural composition. The data in table 8 represent the surface, or A horizon and are, therefore most useful for making comparisons with the oxidized zone from the present study. Soils from the Oakes area tend to have lower average concentrations of trace elements when compared to the baselines in table 8. The soils in the Oakes area are derived from glaciofluvial sediments, whereas the soils used to construct the baseline were developed from materials ranging from marine shales and glacial lake clays to sandstone. The soils from the Oakes area are, in general, more sandy that the "average" soil from the Northern Great Plains, and the lower average concentration of trace elements probably reflects the lower amount of clay-size minerals present in these soils. There are, however, individual samples (table 10) from the Oakes test area which exceed the upper concentration limit of the baseline from the Northern Great Plains (table 8) by a large amount for As (KW116A), Ca (KW100A, KW161A, KW225A, KW256A, and KW288), Mg (KW255A), Mn (KW308), Ni (KW116A), Pb (KW314A), and V (KW101A, KW117A, and KW139A). Several of these samples (KW116A, KW117A, KW225A, and KW314A) were collected from soil profiles in which lignite was described as being present in one or more horizons. However, lignite was present in several profiles where elevated levels of trace metals were not measured. This aspect needs further investigation. All high Ca values were associated with horizons described as being zones of carbonate accumulation. Samples containing the high trace metal levels were from horizons described as being fine textured (silt loam or silty clay loam); however several other samples from fine-textured horizons did not contain elevated trace metal levels.

Geochemical baselines and observed ranges for selenium in soils from selected studies in the western United States are presented in table 9. The computed values are referred to as baselines because they represent the concentration measured at some point in time. Background values, in contrast, are intended to represent natural concentrations, which exclude man's influnce, and are rarely, if ever obtainable. Because the sampling media for each of the studies in table 9 differs from one study to another, some explanation is necessary. Samples from the western half of the United States (Shacklette and Boerngen, 1984) were collected from the B horizon, or below 20 cm where the B horizon was undefined. Surface, or A horizon samples were collected for the northern Great Plains study (Severson and Tidball, 1979). The surface 0-20 cm was collected for the San Joaquin Valley study (J.M. McNeal, U.S. Geological Survey, Reston, VA, unpublished data). Composite samples from 0-40 cm were collected from alluvial soils occurring on stream terraces for the Piceance and Uinta basin study in Colorado and Utah (Tidball and Severson, 1982). Samples of soils from a depth of 66-72 inches were collected from the Panoche Fan, located on the west side of the San Joaquin

Valley, California (Severson, Tidball, and Wilson, 1987). These baselines are valid for comparing analyses of the same kind of sample from within the area as the baseline was developed. They should be applied with caution to different sample media, or to samples collected outside of the baseline area. They are presented here to show what ranges in selenium values have been determined in soils from different parts of the western United States.

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Table 1. Site and analytical variance for elements measured in soils from the sampling locations at the Oakes test area, North Dakota.

Element, unit of measure	Percentage of variance		Percentage of variance	
	Among all horizons	Between pairs	Among samples	Between analyses
Al, %	14.6	85.4	97.5	2.5
As, ppm	21.8	78.2	59.2	40.8
Ba, ppm	24.2	75.8	97.2	2.8
Be, ppm	---[a]	---	---	---
Ca, %	70.3	29.7	99.0	1.0
Ce, ppm	59.1	40.9	96.3	3.7
Co, ppm	77.4	22.6	96.5	3.5
Cr, ppm	75.0	25.0	98.9	1.1
Cu, ppm	0.0	100.0	98.8	1.2
Fe, %	80.6	19.4	99.1	0.9
Ga, ppm	28.8	17.2	97.6	2.4
K, %	0.0	100.0	81.1	18.9
La, ppm	56.6	43.2	95.2	4.8
Li, ppm	83.9	16.1	99.0	1.0
Mg, %	75.5	25.4	99.0	1.0
Mn, ppm	79.5	20.5	99.6	0.4
Mo, ppm	---	---	---	---
Na, %	0.0	100.0	96.0	4.0
Nb, ppm	---	---	---	---
Nd, ppm	41.8	58.2	95.5	5.5
Ni, ppm	28.6	71.4	98.7	1.3
P, %	54.5	45.5	95.4	4.6
Pb, ppm	13.0	87.0	95.5	4.5
Sc, ppm	51.3	48.7	97.4	2.6
Se, ppm	36.0	64.0	88.7	11.3
Sr, ppm	77.2	22.8	91.2	8.8
Th, ppm	---	---	---	---
Ti, %	67.1	32.9	98.2	1.8
V, ppm	41.4	58.6	98.9	1.1
Y, ppm	77.3	22.7	96.4	3.6
Yb, ppm	---	---	---	---
Zn, ppm	51.5	48.5	99.0	1.0

[a] not determined

Table 2.--Listing of approximate limits of determination for elements reported.

Analytical method	Determination limit	Elements
Continuous flow hydride generation	0.1 ppm	As, Se
Induction coupled plasma	2.0 ppm	Ag, Cd, La, Li, Mo, Ni, Sc, Sr, V, Y
	0.05 %	Al, Ca, Fe, K, Mg, Na, P, Ti
	1.0 ppm	Ba, Be, Co, Cr, Cu, Yb
	4.0 ppm	Ce, Ga, Ho, Mn, Nb, Nd, Pb, Th, Zn
	8.0 ppm	Au
	10 ppm	Bi
	20 ppm	Sn
	40 ppm	Ta
	100 ppm	U

Table 3. Partitioning of variation among soil series and between samples within soil series for three zones; oxidized, mottled, and reduced.

Element unit of measure	Percentage of variance					
	Oxidized zone		Mottled zone		Reduced zone	
	Among series	Between samples	Among series	Between samples	Among series	Between samples
Al, %	0.0	100.0	35.0	65.0	44.1	55.9
As, ppm	0.0	100.0	12.1	87.9	0.0	100.0
Ba, ppm	14.1	85.9	28.2	71.8	36.9	63.1
Ca, %	35.6	64.4	0.0	100.0	16.6	83.4
Ce, ppm	10.6	89.4	38.2	61.8	37.5	62.5
Co, ppm	21.3	78.7	32.7	67.3	33.9	66.1
Cr, ppm	35.6	64.4	32.7	67.3	41.8	58.2
Cu, ppm	38.9	61.1	3.9	96.1	13.8	86.2
Fe, %	28.7	71.3	0.0	100.0	32.8	67.2
Ga, ppm	0.0	100.0	0.0	100.0	33.4	66.6
K, %	0.0	100.0	36.1	63.9	25.2	74.8
La, ppm	12.2	87.8	50.7	49.3	37.3	62.7
Li, ppm	61.3	38.4	26.2	73.8	32.1	67.9
Mg, %	72.7	27.3	0.0	100.0	31.0	69.0
Mn, ppm	0.0	100.0	0.0	100.0	0.0	100.0
Na, %	0.6	99.4	47.1	52.9	0.0	100.0
Nd, ppm	10.5	89.5	47.7	52.3	40.5	59.5
Ni, ppm	5.6	94.4	22.2	77.8	7.0	93.0
P, %	68.1	31.9	52.5	47.5	51.7	48.3
Pb, ppm	8.3	91.7	0.0	100.0	35.6	64.4
Sc, ppm	59.1	40.1	50.3	49.7	31.4	68.6
Se, ppm	33.4	66.6	43.7	56.3	0.0	100.0
Sr, ppm	45.2	54.8	34.5	65.5	24.9	75.1
Ti, %	26.0	74.0	52.9	47.1	32.6	67.5
V, ppm	25.9	74.1	0.0	100.0	18.7	81.3
Y, ppm	21.8	78.2	52.3	47.7	37.0	63.0
Zn, ppm	44.2	55.8	0.0	100.0	5.7	94.3

Table 4. Factor compositions, expressed as correlation coefficients, for the oxidized zone

Factors					
1	2	3	4	5	6
La .99	Sr .98	Na .98	As .99	Mn .98	Se .95
Y .98	Ca .70		Ti .55	Co .65	P .70
Nd .98	Mg .58			Ni .65	Mg .58
Ce .97	P .51			Fe .57	Ca .54
Ti .94				Ga .56	
Cr .91				Zn .55	
Al .89				V .53	
Sc .84				Pb .53	
Fe .83				Cu .51	
Ga .81					
Zn .80					
V .77					
Ba .75					
Li .75		Se -.50			
Ni .74		V -.50			
Co .73		Sc -.52			
Pb .72		Li -.56			
Cu .72		Ca -.62			
K .57		Mg -.62			
P .51	Mn -.50	Cu -.63		Sr -.50	Na -.51
Percentage of total variance explained by each factor					
59.9	15.8	9.9	4.3	2.9	1.9

Table 5. Factor compositions, expressed as correlation coefficients for the mottled zone

Factors									
1		2		3		4		5	
Na	.96	Mg	.95	V	.97	Mn	.95	Se	.91
Sr	.94	Ca	.90	Li	.89	Mg	.71	Sc	.62
P	.92	Mn	.71	Zn	.80	Ca	.69	Co	.53
Ti	.92	Ga	.51	Cr	.66	Ga	.55		
Y	.90	Pb	.51	Sc	.62	Ni	.55		
Nd	.89			Al	.59	As	.51		
La	.89			K	.59	Co	.51		
Al	.87			Cu	.50				
Ce	.87								
Ba	.87								
Sc	.75								
Cr	.71								
K	.67								
Ga	.62								
Zn	.52								
Cu	.51								
Co	.51			As	-.70				
Percentage of total variance explained by each factor									
50.9		15.4		8.9		5.6		5.2	

Table 6. Factor compositions, expressed as correlation coefficients, for the reduced zone

		Factors			
1	2	3	4	5	6
V .92	K .93	Ca .99	As .96	Mn .96	Se .94
Sc .92	Al .90	Mg .86	Ni .73	Ca .50	Ni .64
Cr .91	Ba .87		Zn .62		Zn .60
Fe .91	Y .71		Co .59		As .54
Li .88	La .70		Fe .56		
Zn .86	Ti .70		Li .55		
Ni .85	Ga .70		Ga .54		
Cu .83	Ce .69		Sc .54		
Y .83	P .69		Se .53		
Ga .81	Nd .68		V .53		
Ti .80	Sr .65		Y .50		
Co .78	Li .65				
Ce .77	Cr .59				
Nd .76	Sc .58				
La .75	Zn .52				
Pb .71	Fe .50				
Al .65					
P .54				Ba -.50	
As .51				Na -.56	
Mg .51				Sr -.57	Na -.58
Percentage of variance explained by each factor					
57.9	17.2	8.0	3.7	3.6	2.3

Table 7. Detection ratio and observed range for all samples, and arithmetic mean and standard deviation for elements in three zones from soils at the Oakes test area, North Dakota

Element, unit of measure	This study, all data		Oxidized zone		Mottled zone		Reduced zone	
	Detection ratio[a]	Observed range	Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation
Al, %	139:139	2.8 - 6.6	4.2	0.534	3.8	0.535	3.8	0.529
As, ppm	139:139	1.3 - 46	4.5	3.78	4.5	2.45	4.5	3.41
Ba, ppm	139:139	380 -1000	630	48.3	600	132	550	91.0
Be, ppm	10:139	<1.0 - 1.0	---[b]	---	---	---	---	---
Ca, %	139:139	0.80- 19	3.2	3.17	2.4	1.11	2.9	0.761
Ce, ppm	139:139	16 - 55	32	6.56	27	8.06	27	8.11
Co, ppm	139:139	4.0 - 18	6.1	1.81	6.6	0.877	6.9	2.32
Cr, ppm	139:139	15 - 79	30	10.1	26	8.13	28	10.8
Cu, ppm	139:139	3.0 - 26	6.4	3.75	5.4	1.47	6.6	4.49
Fe, %	139:139	0.61- 3.0	1.2	0.366	1.1	0.210	1.1	0.325
Ga, ppm	139:139	6.0 - 15	8.0	1.49	7.4	1.18	7.8	1.17
K, %	139:139	0.77- 1.8	1.3	0.139	1.3	0.141	1.3	0.124
La, ppm	139:139	9.0 - 30	17	3.57	15	4.44	15	4.26
Li, ppm	139:139	6.0 - 38	12	4.44	10	1.86	12	4.33
Mg, %	139:139	0.20- 2.3	0.67	0.464	0.72	3.21	0.85	0.281
Mn, ppm	139:139	130 -3400	540	256	1000	707	960	355
Mo, ppm	4:139	<2.0 - 7.0	---	---	---	---	---	---
Na, %	139:139	0.53- 1.6	1.2	0.134	1.2	0.169	1.1	0.151
Nb, ppm	9:139	<4.0 - 8.0	---	---	---	---	---	---
Nd, ppm	139:139	6.0 - 27	15	3.68	12	4.60	13	4.35
Ni, ppm	139:139	8.0 - 58	14	5.38	14	3.18	17	6.67
P, %	139:139	0.02- 0.09	0.044	0.0130	0.034	0.0118	0.034	0.00342
Pb, ppm	139:139	6.0 - 48	10	1.53	12	8.38	10	2.04
Sc, ppm	139:139	2.0 - 10	3.5	1.35	2.9	0.995	3.2	1.40
Se, ppm	114:139	<0.01- 3.0	0.28	0.181	0.32	0.514	0.53	0.330
Sr, ppm	139:139	120 - 340	230	38.6	200	31.8	190	26.8
Th, ppm	65:139	<4.0 - 9.0	---	---	---	---	---	---
Ti, %	139:139	0.05- 0.28	0.13	0.0360	0.096	0.0359	0.10	0.0430
V, ppm	139:139	18 - 140	39	17.8	37	8.77	43	19.9
Y, ppm	139:139	5.0 - 18	9.7	2.19	8.2	2.37	8.5	2.82
Yb, ppm	63:139	<1.0 - 2.0	---	---	---	---	---	---
Zn, ppm	139:139	15 - 80	32	10.9	25	5.45	30	13.4

[a] number of samples above the lower detection limit and total number of samples

[b] not determined

Table 8. Geochemical baselines for soils from the northern Great Plains.

[Detection Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed; *, values preceded by an asterisk are arithmetic means or standard deviations; GM, geometric mean; GD, geometric deviation; Baseline, expected 95-percent range; ---, not determined]

Element, unit of measure	Detection ratio	GM	GD	Baseline	Observed range
Ag, ppm	22:136	0.14	1.58	0.056-0.35	<0.22-0.49
Al, %	136:136	5.6	1.19	4.0-7.9	3.4-12
As, ppm	135:136	7.1	1.69	2.5-20	<0.1-26
B, ppm	135:136	41	1.59	16-100	<2.2-990
Ba, ppm	136:136	1,100	1.33	620-1,950	420-2,300
Be, ppm	135:136	1.6	1.42	0.79-3.2	<0.22-3.5
Ca, %	135:136	0.97	2.30	0.18-5.1	<0.014-7.0
Ce, ppm	99:136	38	2.08	8.8-164	<22-130
Co, ppm	135:136	6.4	1.48	2.9-14	<1.0-23
Cr, ppm	136:136	45	1.56	18-110	11-160
Cu, ppm	136:136	19	1.64	7.1-51	4.3-110
Fe, %	136:136	2.1	1.41	1.1-4.2	0.26-6.5
Ga, ppm	136:136	11	1.44	5.3-23	4.2-29
Hg, ppm	135:136	0.023	1.68	0.0082-0.065	<0.01-0.07
K, %	136:136	1.8	1.13	1.4-2.3	1.3-2.7
La, ppm	128:136	23	1.47	11-50	<10-49
Li, ppm	136:136	19	1.40	9.7-37	7.0-40
Mg, %	136:136	0.66	1.67	0.24-1.8	0.18-2.7
Mn, ppm	109:136	460	2.38	81-2,600	<200-3,800
Mo, ppm	118:136	3.8	1.68	1.3-11	<1.0-12
Na, %	136:136	*0.83	*0.36	0.11-1.6	0.22-1.6
Nd, ppm	11:136	---	---	---	<46-140
Ni, ppm	136:136	18	1.46	8.4-38	4.3-64
P, %	107:136	0.074	1.37	0.039-0.14	<0.044-0.13
Pb, ppm	136:136	16	1.54	6.7-38	5.1-41
Sc, ppm	114:136	5.4	1.67	1.9-15	<3.0-17
Se, ppm	104:136	0.45	2.72	0.061-3.3	<0.1-20
Sr, ppm	136:136	160	1.47	74-350	58-440
Ti, %	136:136	*0.2	*0.023	0.15-0.25	0.11-0.37
Th, ppm	136:136	8.4	1.23	5.6-13	3.0-13
U, ppm	136:136	2.3	1.25	1.5-3.6	1.1-4.9
V, ppm	136:136	54	1.35	30-98	20-96
Y, ppm	136:136	18	1.46	8.4-38	3.1-54
Yb, ppm	136:136	2.4	1.41	1.2-4.8	0.78-5.8
Zn, ppm	136:136	*63	*20	23-100	14-170

Table 9.--Geochemical baselines for selenium in soils from selected studies in the western United States.

[Detection Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed; GM, geometric mean; GD, geometric deviation; Baseline, expected 95-percent range]

Authors and general location of the study area	Detection ratio	GM	GD	Baseline	Observed range
Shacklette and Boerngen, 1984 western half of the United States	590:733	0.23	2.43	0.039-1.4	<0.1-4.3
Severson and Tidball, 1979 northern Great Plains, parts of Montana, Wyoming, and N. Dakota	104:136	0.45	2.72	0.061-3.3	<0.1-20
McNeal (unpublished) San Joaquin Valley, California	240:328	0.14	2.56	0.021-0.92	<0.1-2.8
Tidball and Severson, 1982 Piceance and Uinta basins, in Utah and Colorado	12:30	0.079	2.72	0.010-0.58	<0.1-0.57
Severson, Tidball, and Wilson, 1987 Panoche Fan, San Joaquin Valley	713:721	0.68	1.94	0.1-2.2	<0.1-4.5

Table 10. Listing of analytical data for individual samples and their locations, horizons composited, depths at which they were collected, and the name of the soil series assigned.

Sample ID (Soil Series)	Latitude	Longitude	Horizon(s)	Depth, in	Al, %	As, ppm	Ba, ppm	Ca, %
KW100A (Bearden)	460610	980527	Ap, A	0- 16	4.2	3.8	630	9.8
KW101A/KW102A			Bk1,Bk2,C1,C2	16- 74	6.6	8.9	700	4.4
KW101A/KW102A			Replicate	16- 74	6.5	8.3	710	4.2
KW104A			3C,4C	86-110	3.7	1.5	490	3.0
KW105A			5C	110-216	3.6	3.7	530	2.9
KW106A (Ulen like)	460518	980412	Ap,A	0- 18	4.3	1.6	620	1.5
KW107A/KW108A/KW109A			Bk,Ck,2-4C,5C1	18-106	3.9	2.5	600	2.7
KW110A			5C2	106-135	3.0	1.3	450	2.2
KW111A			5C3	135-180	3.8	1.6	530	1.9
KW113A (Hecla like)	460334	980528	Ap,A	0- 19	4.0	11	600	3.0
KW113A			Replicate	0- 19	4.2	1.8	610	3.3
KW114A			C1,C2	19-108	4.2	4.0	600	1.1
KW115A			2Cg	108-132	3.9	2.9	480	2.6
KW115A			Replicate	108-132	3.9	2.0	490	2.7
KW116A			3Cg	132-162	2.8	46	420	2.0
KW117A			4Cg	162-216	4.9	7.3	640	2.6
KW118A (Hecla like)	460518	980527	Ap,A	0- 24	3.6	2.4	550	.82
KW120A			C2,C3	55-144	3.1	5.2	410	3.0
KW120A			Replicate	55-144	3.1	4.8	420	2.9
KW121A			Cg	144-216	3.3	1.7	460	4.5
KW122A (Hecla like)	460216	980335	Ap,A	0- 24	4.0	1.6	580	.93
KW124A			C3k	66-105	3.4	4.9	590	2.3
KW125A			C	105-216	3.6	7.7	580	2.3
KW127A (Ulen like)	460356	980400	Ap,A,Ck1,Ab1	0- 40	4.3	3.2	670	3.7
KW128A			Ck2,Ab2,C	40-113	3.9	3.8	590	2.0
KW129A			Cg	113-144	3.2	3.5	470	2.5
KW130A			Cg	144-216	3.5	3.5	500	3.7
KW131A (Hecla like)	460400	980450	Ap,A,C,Ck	0- 61	3.7	2.4	540	1.5
KW132A			C2,C3	61-102	3.4	4.0	550	1.7
KW133A			Cg	102-133	3.1	2.8	460	2.4
KW135A (Glyndon like)	460358	980603	Ap,Ak,Ck1,Ck2	0- 46	4.2	12	660	4.4
KW136A			C	46- 72	4.5	3.8	690	2.4
KW137A			Cg	72-120	4.4	5.5	740	2.2
KW138A			Cg	120-180	4.6	4.3	740	2.7
KW139A			2Cg	180-210	6.3	4.5	740	3.8
KW140A			3Cg	210-336	4.8	8.4	570	5.1

Table 10. Listing of analytical data for individual samples and their locations, horizons composited, depths at which they were collected, and the name of the soil series assigned. (continued)

Sample ID (Soil Series)	Latitude	Longitude	Horizon(s)	Depth, in	Al, %	As, ppm	Ba, ppm	Ca, %
KW141A (Stirum)	460243	980527	Ap,A	0- 13	4.3	1.6	640	2.5
KW142A			Btn	13- 22	4.3	3.0	630	5.1
KW143A			Ckg,Ab,2C	22- 50	4.3	7.1	640	5.7
KW144A			3Ck,4C1,4C2,4C3	50-105	3.5	9.5	610	2.0
KW145A			4Cg	105-156	3.5	2.5	500	3.2
KW146A			4Cg	156-216	3.4	2.8	490	3.2
KW147A (Ulen)	460214	980450	Ap,Ak	0- 16	4.5	1.8	660	1.4
KW148A/KW149A			Ck1,Ck2,Ck3	16- 67	4.0	3.7	600	2.4
KW150A			C	67-115	4.2	11	640	2.0
KW151A			Cg	115-143	3.5	2.6	550	2.2
KW153A (Ulen like)	460215	980450	Ap,Ak	0- 25	3.6	2.1	540	5.1
KW154A/KW155A			Ck,C1	25- 74	4.0	2.3	570	1.6
KW156A/KW157A			C2,C3	74-116	4.0	2.8	650	1.2
KW158A			Cg	116-139	3.5	1.9	530	2.4
KW158A			Replicate	116-139	3.4	1.8	540	2.5
KW160A (Ulen like)	460240	980301	Ap,A	0- 18	4.2	1.7	600	.99
KW161A			Ck,2Ckg	30- 61	2.8	2.7	540	19
KW162A			3C	61- 84	4.4	4.2	800	1.2
KW163A			3Cg	84-121	3.5	8.5	520	2.8
KW165A (Ulen like)	460241	980411	Ap,A	0- 15	4.1	1.4	610	1.7
KW166A/KW167A			Bk,2Ck	15- 50	4.3	2.0	640	5.2
KW168A/KW169A			3C1,3C2	50- 97	3.5	7.8	560	2.1
KW170A			Cg1	97-118	3.6	5.0	560	2.2
KW173A (Hecla like)	460306	980236	Ap,A1,A2	0- 38	4.2	1.8	620	.92
KW174A/KW175A/KW176A			A3,C1,C2,C3	38-151	4.2	2.6	620	2.5
KW177A			Cg1	151-162	4.7	6.6	610	2.5
KW179A/KW180A (Hecla like)	460332	980411	Ap,A1,A2,Ck1	0- 46	4.4	10	680	2.2
KW181A/KW182A			Ck2,2Ck	46- 96	4.4	4.0	640	4.4
KW183A			3C,3Cg1	96-133	4.4	2.8	630	1.8
KW184A			3Cg2	133-156	3.5	5.1	490	2.6
KW187A (Hecla like)	460424	980411	Ap,A1,A2,C1	0- 60	4.4	2.0	660	.91
KW188A			Abk	60- 83	4.3	1.7	650	1.7
KW189A			C2,C3	83-153	3.6	4.5	550	1.9
KW189A			Replicate	83-153	3.6	4.6	550	1.9
KW190A			Cg1	153-200	3.4	2.3	500	2.9
KW192A (Embden)	460450	980336	Ap,A	0- 24	4.0	3.5	580	1.1
KW193A			C1,C2,C3	24- 81	3.7	6.5	660	2.3
KW194A			C4g	81-101	3.7	2.9	470	1.6
KW195A			Cg	101-144	3.2	1.6	400	4.6

Table 10. Listing of analytical data for individual samples and their locations, horizons composited, depths at which they were collected, and the name of the soil series assigned. (continued)

Sample ID (Soil Series)	Latitude	Longitude	Horizon(s)	Depth, in	Al, %	As, ppm	Ba, ppm	Ca, %
KW197A (Embden like)	460543	980336	A,AC	0- 40	4.8	2.1	680	1.0
KW198A/KW199A			C,Ab	40- 71	5.0	3.7	700	.96
KW200A/KW201A			C1,C2	71-120	5.3	9.0	700	1.9
KW200A/KW201A			Replicate	71-120	6.1	9.0	800	2.2
KW202A/KW203A			C3	120-160	3.7	2.2	590	2.2
KW204A			C4	160-183	2.8	6.1	400	3.2
KW205A			C5g	183-216	3.0	2.2	440	3.1
KW206A (Hecla)	460425	980258	Ap,A	0- 25	3.8	1.5	550	.80
KW207A/KW208A/KW209A			C1,C2,C3	25-102	3.8	3.8	570	2.0
KW210A			C4	102-139	3.4	3.0	490	1.6
KW211A			C5g	139-156	3.6	1.5	530	2.3
KW211A				139-156	3.5	1.8	500	2.1
KW213A/KW214A (Gardena like)	460516	980258	A1,AB	0- 26	4.5	2.3	650	.99
KW215A/KW216A/KW217A			B3,Cca,C1	26- 54	4.4	2.4	660	1.8
KW218A			C2	54-100	3.9	4.8	610	3.8
KW219A			C3g	100-144	3.9	2.4	570	1.7
KW222A/KW223A (Hecla like)	460333	980258	Ap,A1,AB	0- 27	4.0	6.4	600	.87
KW225A			C2ca	49- 97	4.1	2.8	650	8.3
KW226A			C3	97-128	3.4	10	560	1.5
KW227A			C4	128-159	3.9	2.4	600	3.2
KW230A/KW231A (Hecla like)	460333	980259	A,AC	0- 26	4.0	2.5	600	.92
KW232A/KW233A/KW234A			C1ca,C2,C3ca	26- 71	4.3	3.4	670	6.1
KW235A			C4	71-106	4.0	5.7	660	2.3
KW236A/KW237A			C5g	106-174	3.8	2.2	590	2.5
KW239A (Hecla like)	460215	980603	Ap,A	0- 24	4.5	17	670	1.0
KW240A/KW241A/KW242A			B,C1ca,C2	24-106	4.6	13	710	2.7
KW243A			C3	106-129	3.8	2.9	580	1.9
KW244A			C4g	129-147	4.3	2.5	670	2.8
KW245A			C4g	147-216	3.7	7.4	680	2.7
KW246A (Hecla)	460358	980336	Ap,A	0- 28	4.4	1.9	640	.95
KW247A/KW248A/KW249A/KW250A			C1,C1-3ca	28- 91	4.1	3.6	640	4.2
KW251A			C4	91-111	3.6	8.2	500	2.8
KW252A			C5	111-136	3.3	5.2	510	3.3
KW253A			Cg	136-154	3.8	5.1	560	2.7

Table 10. Listing of analytical data for individual samples and their locations, horizons composited, depths at which they were collected, and the name of the soil series assigned. (continued)

Sample ID (Soil Series)	Latitude	Longitude	Horizon(s)	Depth, in	Al, %	As, ppm	Ba, ppm	Ca, %
KW255A (Glyndon like)	460306	980605	Ap	0- 9	4.0	1.7	660	4.5
KW256A/KW257A			C1ca,C2ca	9- 34	4.0	5.0	700	8.9
KW258A/KW259A/KW260A			C3,C4,C5	34- 82	4.6	3.9	750	1.2
KW261A			C6g	82- 98	5.0	3.9	850	1.3
KW262A/KW263A/KW264A			C7g,C8g	98-201	4.8	6.1	750	2.1
KW265A			C9g	201-207	3.9	3.0	600	3.9
KW266A			C10g	207-216	5.8	6.0	880	4.2
KW266A			Replicate	207-216	5.9	5.1	920	4.3
KW267A (Maddock like)	460424	980528	A	0- 10	4.2	3.8	620	.91
KW267A			Replicate	0- 10	4.1	5.7	610	.90
KW268A/KW269A/KW270A/KW271A			AC,C1,C2,C3	10-133	4.3	2.9	650	2.9
KW272A			C4	133-213	2.8	4.8	380	3.1
KW273A			Cg	213-216	3.6	1.7	450	2.3
KW274/KW275 (Glyndon like)	460450	980605	A,B	0- 40	4.9	3.3	710	1.4
KW277/KW278			Cca,C1,C2	51-113	4.7	3.2	770	2.5
KW277/KW278			Replicate	51-113	4.7	3.5	780	2.5
KW279/KW280			C1g,C2g	113-216	4.6	3.7	760	4.3
KW288/KW289 (Glyndon)	460542	980604	Ap,Bk	0- 22	3.3	2.6	630	13
KW291			C1,C2	58- 82	4.8	2.8	1000	1.5
KW292			C1g	82- 96	4.6	2.8	720	1.6
KW294			2Cg	118-216	4.8	14	600	5.5
KW301 (Glyndon like)	460542	980452	2C3	108-132	3.4	3.0	500	3.3
KW302			2C4	132-216	3.6	3.1	520	3.0
KW308A (Hecla like)	460450	980451	C3	102-144	4.0	9.5	700	6.4
KW308A			Replicate	102-144	4.0	9.4	710	6.0
KW309A			C1g	144-155	3.4	2.0	490	3.3
KW314A (Hecla)	460306	980449	C	84-116	3.4	2.2	470	2.4
KW315A			Cg	116-140	3.4	2.0	480	3.0
KW328A (Embden like)	460240	980641	C4	138-156	4.6	2.0	640	1.2
KW329A			Cg	156-174	4.6	3.1	690	2.6

Sample ID	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Fe, %	Ga, ppm	K, %	La, ppm	Li, ppm	Mg, %
KW100A	38	7.0	40	12	1.5	9.0	1.3	21	20	1.5
KW101A	55	15	79	26	3.0	15	1.5	29	33	1.8
KW101A	55	15	77	26	2.9	14	1.8	30	34	1.7
KW104A	23	6.0	22	5.0	1.1	7.0	1.3	12	12	.79
KW105A	30	7.0	24	21	1.2	7.0	1.2	16	10	.83
KW106A	33	6.0	24	4.0	1.0	8.0	1.2	17	10	.40
KW107A	25	6.0	25	6.0	1.0	8.0	1.3	14	10	.55
KW110A	20	4.0	15	3.0	.70	6.0	1.1	11	7.0	.51
KW111A	28	7.0	28	5.0	1.1	8.0	1.3	14	13	.57
KW113A	35	5.0	30	6.0	1.0	7.0	1.2	20	12	.57
KW113A	29	6.0	26	5.0	1.1	8.0	1.2	15	11	.63
KW114A	32	8.0	25	6.0	.91	7.0	1.4	17	9.0	.37
KW115A	23	8.0	25	7.0	.83	8.0	1.3	12	11	1.1
KW115A	26	7.0	23	6.0	.78	8.0	1.4	14	12	1.2
KW116A	25	18	34	11	1.8	8.0	.77	14	12	.65
KW117A	40	13	54	19	2.0	11	1.4	21	26	1.2
KW118A	25	6.0	23	4.0	1.1	8.0	1.2	13	9.0	.27
KW120A	20	6.0	21	3.0	1.6	6.0	1.0	12	8.0	.81
KW120A	25	7.0	23	4.0	1.6	6.0	1.1	12	8.0	.83
KW121A	17	5.0	15	3.0	.89	7.0	1.2	10	8.0	1.2
KW122A	28	5.0	23	5.0	.95	7.0	1.0	16	9.0	.28
KW124A	22	6.0	18	5.0	.90	6.0	1.2	12	9.0	.61
KW125A	21	5.0	19	3.0	.91	7.0	1.2	12	9.0	.63
KW127A	35	6.0	31	6.0	1.2	8.0	1.4	18	12	.66
KW128A	30	6.0	23	4.0	.97	7.0	1.2	16	8.0	.52
KW129A	21	6.0	23	4.0	.95	7.0	1.0	12	9.0	.71
KW130A	22	6.0	21	5.0	1.0	8.0	1.2	13	10	.95
KW131A	26	6.0	25	6.0	1.1	7.0	1.3	14	10	.49
KW132A	23	6.0	20	7.0	.90	8.0	1.1	12	9.0	.53
KW133A	28	5.0	23	4.0	.97	6.0	1.0	15	7.0	.56
KW135A	38	6.0	37	6.0	1.3	8.0	1.3	21	14	1.2
KW136A	48	6.0	38	9.0	1.2	7.0	1.4	25	10	.72
KW137A	35	9.0	31	7.0	1.2	8.0	1.4	18	13	.65
KW138A	39	7.0	40	5.0	1.3	9.0	1.4	22	14	.76
KW139A	54	11	72	23	2.5	14	1.8	29	38	1.6
KW140A	40	9.0	49	13	1.9	9.0	1.4	21	24	1.6
KW141A	36	6.0	32	6.0	1.2	7.0	1.4	19	18	1.0
KW142A	41	6.0	31	4.0	1.1	7.0	1.4	21	16	1.1
KW143A	41	8.0	32	7.0	1.2	8.0	1.3	21	15	.86
KW144A	26	6.0	20	4.0	.88	7.0	1.2	13	8.0	.47
KW145A	21	7.0	18	5.0	.90	7.0	1.2	11	10	.82
KW146A	20	6.0	21	4.0	.92	8.0	1.3	11	11	.87
KW147A	36	5.0	30	4.0	1.1	7.0	1.4	20	11	.43
KW148A	31	6.0	27	4.0	.95	7.0	1.3	16	11	.53
KW150A	39	6.0	31	5.0	1.2	8.0	1.3	21	11	.71
KW151A	19	4.0	16	3.0	.61	6.0	1.2	11	8.0	.49
KW153A	27	4.0	23	3.0	.84	7.0	1.1	15	11	.60
KW154A	26	5.0	25	4.0	.89	7.0	1.3	15	10	.49
KW156A	30	6.0	28	6.0	1.2	7.0	1.4	16	12	.49
KW158A	22	5.0	17	5.0	.69	7.0	1.2	12	8.0	.61

Sample ID	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Fe, %	Ga, ppm	K, %	La, ppm	Li, ppm	Mg, %
KW158A	20	5.0	18	5.0	.71	7.0	1.2	11	8.0	.62
KW160A	31	4.0	26	4.0	.96	7.0	1.2	17	9.0	.27
KW161A	23	6.0	21	6.0	.80	6.0	.88	11	12	1.2
KW162A	29	6.0	24	5.0	1.0	8.0	1.5	16	10	.34
KW163A	20	5.0	18	3.0	.78	7.0	1.2	11	8.0	.73
KW165A	29	5.0	23	5.0	.92	7.0	1.3	16	10	.45
KW166A	30	5.0	30	5.0	1.1	8.0	1.4	17	14	.81
KW168A	25	6.0	20	5.0	1.2	7.0	1.2	13	9.0	.69
KW170A	21	5.0	18	4.0	.70	7.0	1.3	12	9.0	.61
KW173A	29	5.0	24	6.0	.97	8.0	1.3	16	9.0	.26
KW174A	28	7.0	26	6.0	.98	9.0	1.5	14	11	.65
KW177A	41	11	55	19	1.9	11	1.4	22	25	1.1
KW179A	31	6.0	32	6.0	1.2	9.0	1.4	18	13	.67
KW181A	33	9.0	39	10	1.7	9.0	1.3	18	17	1.2
KW183A	29	6.0	27	5.0	1.1	8.0	1.4	15	11	.70
KW184A	27	7.0	26	5.0	1.5	8.0	1.3	14	10	.74
KW187A	32	6.0	28	5.0	1.1	7.0	1.4	17	10	.27
KW188A	35	7.0	30	7.0	1.2	9.0	1.3	18	11	.50
KW189A	22	7.0	21	6.0	.89	8.0	1.1	12	9.0	.61
KW189A	23	7.0	20	5.0	.88	8.0	1.3	12	9.0	.62
KW190A	24	6.0	29	5.0	.86	7.0	1.2	14	9.0	.74
KW192A	25	5.0	23	4.0	.94	7.0	1.2	15	9.0	.30
KW193A	26	9.0	26	5.0	1.6	7.0	1.3	15	10	.93
KW194A	27	11	31	7.0	1.6	9.0	1.1	16	13	.78
KW195A	17	6.0	22	3.0	.97	7.0	1.1	9.0	9.0	1.3
KW197A	39	6.0	33	8.0	1.3	9.0	1.5	20	11	.33
KW198A	44	9.0	38	10	1.7	9.0	1.5	24	14	.43
KW200A	44	12	63	16	2.4	12	1.5	25	24	.95
KW200A	51	14	72	19	2.7	13	1.7	29	28	1.1
KW202A	21	7.0	20	6.0	.94	7.0	1.3	11	10	.69
KW204A	20	7.0	19	4.0	1.4	6.0	.94	11	7.0	1.0
KW205A	21	7.0	15	4.0	.93	7.0	1.1	10	7.0	.80
KW206A	25	4.0	22	3.0	.84	7.0	1.3	13	8.0	.20
KW207A	28	6.0	28	5.0	1.1	8.0	1.2	15	11	.40
KW210A	27	6.0	19	4.0	.82	6.0	1.2	14	9.0	.42
KW211A	25	6.0	22	5.0	.89	7.0	1.3	14	11	.58
KW211A	24	6.0	22	5.0	.85	7.0	1.2	12	10	.54
KW213A	33	5.0	29	7.0	1.1	8.0	1.4	19	11	.32
KW215A	31	7.0	29	6.0	1.1	8.0	1.4	16	13	.59
KW218A	22	8.0	26	5.0	1.3	9.0	1.4	13	12	1.2
KW219A	31	7.0	30	6.0	1.1	8.0	1.3	17	13	.68
KW222A	26	4.0	24	4.0	.92	7.0	1.3	15	9.0	.24
KW225A	32	7.0	32	5.0	1.2	9.0	1.3	17	14	.89
KW226A	23	6.0	20	3.0	1.1	7.0	1.1	12	8.0	.45
KW227A	23	5.0	19	3.0	.89	8.0	1.5	13	10	.79
KW230A	27	4.0	21	4.0	.89	8.0	1.3	15	8.0	.25
KW232A	35	7.0	29	6.0	1.1	8.0	1.4	18	13	.92
KW235A	24	6.0	25	4.0	1.2	8.0	1.4	14	10	.69
KW236A	25	6.0	20	7.0	1.0	7.0	1.2	13	11	.69
KW239A	34	5.0	34	4.0	1.1	9.0	1.4	19	11	.30

Sample ID	Ce, ppm	Co, ppm	Cr, ppm	Cu, ppm	Fe, %	Ga, ppm	K, %	La, ppm	Li, ppm	Mg, %
KW240A	38	6.0	37	5.0	1.2	8.0	1.4	21	13	.71
KW243A	29	6.0	27	5.0	.95	7.0	1.3	15	10	.63
KW244A	37	7.0	33	6.0	1.3	8.0	1.4	19	11	.83
KW245A	29	7.0	31	9.0	1.4	8.0	1.2	16	13	.81
KW246A	33	5.0	30	6.0	1.1	8.0	1.4	18	10	.29
KW247A	28	7.0	24	7.0	1.2	8.0	1.3	15	11	.54
KW251A	26	8.0	26	8.0	1.4	8.0	1.2	14	10	.78
KW252A	20	5.0	18	3.0	.89	6.0	1.2	11	9.0	.91
KW253A	27	6.0	27	6.0	1.1	8.0	1.3	15	12	.71
KW255A	34	5.0	34	8.0	1.1	7.0	1.3	18	22	2.3
KW256A	33	6.0	33	7.0	1.2	8.0	1.3	17	18	1.6
KW258A	40	6.0	33	4.0	1.3	8.0	1.4	21	11	.38
KW261A	34	7.0	27	6.0	.98	9.0	1.7	18	12	.43
KW262A	34	8.0	32	6.0	1.2	8.0	1.5	18	14	.61
KW265A	33	6.0	29	5.0	1.4	7.0	1.3	18	10	1.1
KW266A	50	13	66	24	2.6	12	1.7	26	30	1.9
KW266A	48	14	64	24	2.6	12	1.8	25	30	2.0
KW267A	31	6.0	27	8.0	1.2	8.0	1.3	17	10	.32
KW267A	34	7.0	26	7.0	1.2	8.0	1.4	19	10	.32
KW268A	30	8.0	25	6.0	1.2	9.0	1.5	15	10	.81
KW272A	20	6.0	15	5.0	1.1	6.0	1.0	10	6.0	.80
KW273A	25	6.0	29	4.0	.99	8.0	1.2	13	13	.77
KW274A	46	8.0	46	9.0	1.6	10	1.5	26	15	.72
KW278A	44	7.0	44	7.0	1.4	10	1.4	25	13	.96
KW278A	42	8.0	43	7.0	1.5	10	1.4	24	13	1.0
KW279A	50	9.0	52	11	1.7	9.0	1.4	27	17	1.7
KW288A	26	6.0	28	9.0	1.0	6.0	.98	14	16	1.9
KW291A	41	9.0	42	7.0	1.5	9.0	1.4	23	13	.58
KW292A	42	7.0	37	6.0	1.8	9.0	1.4	24	12	.65
KW294A	39	10	52	14	1.8	11	1.4	21	23	1.8
KW301A	16	7.0	21	4.0	.91	6.0	1.2	11	10	.87
KW302A	23	13	30	6.0	.99	9.0	1.2	13	12	.80
KW308A	21	8.0	29	8.0	1.4	10	1.3	11	11	1.9
KW308A	20	8.0	27	6.0	1.4	9.0	1.3	11	11	1.8
KW309A	19	5.0	16	5.0	.77	7.0	1.2	12	9.0	.84
KW314A	22	6.0	39	6.0	1.0	7.0	1.1	12	11	.76
KW315A	20	5.0	27	4.0	.98	7.0	1.1	12	9.0	.80
KW328A	36	8.0	35	6.0	1.2	8.0	1.4	21	13	.42
KW329A	41	8.0	35	7.0	1.3	9.0	1.4	23	13	.77

Sample ID	Mn, ppm	Na, %	Nd, ppm	Ni, ppm	P, %	Pb, ppm	Sc, ppm	Se, ppm	Sr, ppm	Ti, %
KW100A	700	.96	17	18	.07	11	5.0	.50	260	.18
KW101A	1200	.79	27	41	.06	16	10	.27	160	.26
KW101A	1100	.78	26	39	.06	15	10	.31	160	.26
KW104A	1100	1.0	9.0	12	.03	10	3.0	.20	170	.07
KW105A	1100	.98	13	16	.03	11	3.0	.45	170	.09
KW106A	280	1.2	14	11	.04	10	3.0	.25	230	.11
KW107A	570	1.3	11	15	.04	8.0	3.0	.40	210	.11
KW110A	640	1.0	8.0	10	.03	7.0	<2.0	.60	160	.06
KW111A	1300	.95	12	16	.03	9.0	3.0	.30	160	.09
KW113A	310	1.2	17	12	.05	10	3.0	.50	220	.14
KW113A	330	1.2	12	12	.05	11	3.0	.27	230	.13
KW114A	140	1.3	14	18	.04	10	3.0	.32	230	.11
KW115A	690	1.1	10	19	.03	12	3.0	3.0	180	.08
KW115A	660	1.1	11	19	.03	10	3.0	2.0	180	.08
KW116A	1100	.53	12	58	.02	11	5.0	2.1	120	.10
KW117A	1100	.71	19	38	.04	12	7.0	1.0	150	.19
KW118A	1200	1.1	11	14	.04	10	3.0	.50	170	.09
KW120A	770	.98	7.0	12	.02	10	3.0	.70	160	.08
KW120A	760	.99	9.0	13	.02	9.0	3.0	.80	160	.08
KW121A	1300	1.1	7.0	10	.03	9.0	<2.0	.40	180	.05
KW122A	380	1.2	14	10	.04	9.0	3.0	.30	220	.11
KW124A	970	1.1	10	17	.02	9.0	2.0	<.10	180	.07
KW125A	710	1.2	10	16	.03	8.0	2.0	<.10	190	.08
KW127A	680	1.3	16	15	.04	10	3.0	<.10	240	.14
KW128A	430	1.3	13	10	.04	9.0	2.0	<.10	240	.12
KW129A	970	.91	9.0	17	.03	8.0	2.0	.90	160	.09
KW130A	1600	1.1	10	15	.03	9.0	2.0	.40	180	.07
KW131A	890	1.1	12	17	.03	10	3.0	.10	170	.09
KW132A	1800	.99	10	16	.03	9.0	2.0	.23	170	.07
KW133A	530	1.1	12	11	.03	9.0	3.0	.20	180	.10
KW135A	360	1.3	18	14	.08	10	4.0	.50	270	.19
KW136A	200	1.5	21	11	.05	10	4.0	.10	250	.17
KW137A	450	1.2	16	16	.04	10	4.0	.43	240	.13
KW138A	500	1.3	18	16	.06	10	4.0	.60	240	.17
KW139A	1100	.73	25	35	.06	14	9.0	.76	170	.28
KW140A	940	1.0	17	30	.05	15	6.0	.90	210	.17
KW141A	380	1.2	16	13	.06	11	4.0	.30	280	.15
KW142A	310	1.3	18	13	.04	9.0	3.0	<.10	330	.14
KW143A	300	1.3	18	15	.05	12	4.0	.24	270	.15
KW144A	1400	1.2	11	14	.03	9.0	2.0	.20	200	.09
KW145A	1400	1.1	8.0	12	.03	9.0	2.0	.48	180	.06
KW146A	1400	1.0	10	15	.03	10	2.0	.20	170	.07
KW147A	270	1.4	15	12	.04	10	3.0	.10	250	.14
KW148A	400	1.3	13	13	.03	11	3.0	<.10	230	.11
KW150A	850	1.3	17	16	.04	10	4.0	.20	230	.14
KW151A	530	1.2	9.0	10	.03	8.0	<2.0	.50	200	.07
KW153A	360	1.1	11	9.0	.05	7.0	3.0	.60	230	.12
KW154A	480	1.3	13	11	.04	9.0	3.0	<.10	220	.12
KW156A	470	1.1	13	11	.03	12	3.0	.10	190	.10
KW158A	760	1.1	10	11	.03	9.0	<2.0	.35	200	.07

Sample ID	Mn, ppm	Na, %	Nd, ppm	Ni, ppm	P, %	Pb, ppm	Sc, ppm	Se, ppm	Sr, ppm	Ti, %
KW158A	770	1.1	8.0	11	.03	9.0	<2.0	.34	190	.06
KW160A	230	1.4	14	10	.03	12	3.0	<.10	220	.13
KW161A	460	.77	7.0	10	.04	6.0	<2.0	.57	340	.09
KW162A	1200	1.3	13	13	.04	11	3.0	.10	240	.11
KW163A	680	1.2	9.0	13	.03	8.0	<2.0	.40	190	.08
KW165A	310	1.3	12	9.0	.05	10	3.0	.31	250	.11
KW166A	420	1.3	14	13	.05	10	3.0	<.10	300	.15
KW168A	880	1.1	10	12	.03	10	2.0	<.10	180	.08
KW170A	440	1.2	9.0	14	.03	8.0	2.0	.80	190	.08
KW173A	410	1.3	14	10	.04	9.0	3.0	.10	220	.11
KW174A	800	1.1	11	14	.04	10	3.0	.70	210	.09
KW177A	1100	.71	19	37	.04	13	7.0	1.0	140	.20
KW179A	580	1.3	15	14	.05	9.0	3.0	<.10	250	.15
KW181A	930	1.1	15	23	.03	10	5.0	<.10	220	.14
KW183A	330	1.2	13	13	.04	12	3.0	.35	220	.10
KW184A	1000	1.0	11	19	.03	10	3.0	.40	170	.09
KW187A	600	1.3	14	14	.04	12	3.0	.10	220	.13
KW188A	570	1.2	14	16	.04	10	3.0	<.10	210	.12
KW189A	1200	1.0	10	16	.03	10	2.0	<.10	190	.07
KW189A	1200	1.0	10	16	.03	10	2.0	<.10	180	.07
KW190A	880	1.1	11	15	.03	8.0	2.0	.70	180	.08
KW192A	260	1.2	11	9.0	.03	11	3.0	.38	210	.10
KW193A	850	1.1	13	16	.03	12	3.0	<.10	180	.09
KW194A	530	.97	13	28	.03	13	4.0	.40	160	.10
KW195A	1600	1.1	6.0	13	.03	8.0	<2.0	.80	170	.06
KW197A	570	1.4	18	14	.05	11	4.0	.20	230	.16
KW198A	570	1.3	22	20	.05	11	5.0	.31	230	.17
KW200A	850	.87	22	34	.06	12	7.0	.40	160	.23
KW200A	1000	1.0	25	39	.07	15	9.0	.40	190	.27
KW202A	990	1.1	8.0	14	.03	11	2.0	.24	180	.07
KW204A	450	.94	8.0	15	.03	9.0	3.0	1.6	150	.07
KW205A	920	.98	8.0	13	.03	10	<2.0	.76	170	.06
KW206A	340	1.2	11	8.0	.03	8.0	2.0	.10	200	.10
KW207A	570	1.1	12	14	.03	8.0	3.0	<.10	180	.10
KW210A	660	1.0	11	12	.02	9.0	2.0	.10	170	.08
KW211A	920	1.0	11	13	.03	9.0	3.0	1.0	180	.08
KW211A	820	1.0	10	13	.03	9.0	2.0	.70	180	.08
KW213A	320	1.3	16	12	.03	10	3.0	.40	230	.14
KW215A	740	1.3	13	18	.03	12	3.0	<.10	220	.11
KW218A	1900	1.1	10	18	.03	11	3.0	<.10	190	.09
KW219A	670	.99	14	17	.03	10	3.0	.10	170	.09
KW222A	380	1.2	12	10	.03	9.0	3.0	<.10	210	.12
KW225A	910	1.2	14	17	.05	8.0	3.0	.40	270	.14
KW226A	960	1.1	10	12	.02	9.0	2.0	<.10	180	.08
KW227A	1100	1.2	10	14	.03	9.0	2.0	.60	210	.08
KW230A	340	1.3	14	9.0	.03	10	2.0	.26	220	.10
KW232A	610	1.3	15	13	.04	9.0	3.0	.27	280	.12
KW235A	1000	1.2	12	15	.03	8.0	3.0	<.10	200	.10
KW236A	1300	1.1	12	13	.03	9.0	3.0	.36	190	.08
KW239A	330	1.4	17	12	.04	10	3.0	.50	230	.16

Sample ID	Mn, ppm	Na, %	Nd, ppm	Ni, ppm	P, %	Pb, ppm	Sc, ppm	Se, ppm	Sr, ppm	Ti, %
KW240A	330	1.4	19	15	.05	9.0	4.0	.50	250	.18
KW243A	470	1.2	13	11	.03	11	3.0	<.10	190	.11
KW244A	460	1.3	16	13	.05	11	4.0	.65	240	.15
KW245A	1100	1.0	13	19	.04	9.0	4.0	.60	180	.14
KW246A	460	1.3	14	12	.03	11	3.0	.10	220	.14
KW247A	740	1.2	12	15	.04	9.0	3.0	.25	240	.11
KW251A	1100	1.1	11	28	.02	12	3.0	<.10	190	.09
KW252A	770	1.1	7.0	11	.03	10	<2.0	.50	170	.06
KW253A	920	1.1	13	18	.04	11	3.0	.50	190	.11
KW255A	470	1.2	16	13	.09	9.0	3.0	.80	320	.16
KW256A	440	1.1	14	13	.06	10	4.0	.40	340	.16
KW258A	310	1.5	18	12	.04	10	4.0	<.10	250	.16
KW261A	130	1.6	15	15	.04	12	3.0	.50	270	.12
KW262A	380	1.4	15	18	.04	12	4.0	.20	250	.14
KW265A	810	1.2	14	14	.05	7.0	3.0	.50	210	.13
KW266A	1100	1.0	23	37	.06	16	8.0	.70	200	.28
KW266A	1200	.98	22	35	.07	14	8.0	.84	210	.25
KW267A	730	1.2	15	13	.05	11	3.0	.30	200	.12
KW267A	740	1.1	15	13	.05	12	3.0	.35	190	.12
KW268A	1100	1.3	12	15	.04	12	3.0	.21	220	.10
KW272A	550	.95	6.0	8.0	.03	9.0	2.0	.22	160	.06
KW273A	1500	.87	11	19	.02	8.0	3.0	.70	140	.09
KW274A	710	1.2	24	18	.05	12	6.0	.30	220	.19
KW278A	500	1.4	23	14	.06	13	5.0	.30	250	.17
KW278A	520	1.4	23	15	.06	15	5.0	.20	240	.17
KW279A	590	1.3	26	19	.06	13	6.0	.50	230	.21
KW288A	490	.84	12	12	.07	7.0	4.0	.80	290	.11
KW291A	1800	1.5	22	19	.06	8.0	5.0	.40	250	.18
KW292A	1500	1.4	21	15	.06	8.0	5.0	.20	240	.17
KW294A	1500	1.0	20	28	.05	16	6.0	.70	200	.17
KW301A	1100	1.1	9.0	14	.03	8.0	3.0	.60	180	.07
KW302A	1700	.97	12	24	.03	10	3.0	.30	170	.08
KW308A	3400	1.3	11	19	.04	26	3.0	.30	220	.07
KW308A	3400	1.3	9.0	18	.03	26	3.0	.30	220	.07
KW309A	1000	1.1	11	13	.03	11	2.0	.50	180	.06
KW314A	430	.96	12	15	.02	48	3.0	.20	160	.08
KW315A	710	1.1	11	11	.03	16	3.0	.30	170	.08
KW328A	150	1.4	19	20	.05	10	5.0	2.6	240	.15
KW329A	390	1.4	21	16	.05	9.0	5.0	.30	250	.17

Sample ID	V, ppm	Y, ppm	Zn, ppm
KW100A	50	11	47
KW101A	140	18	80
KW101A	130	17	76
KW104A	50	7.0	27
KW105A	49	8.0	23
KW106A	33	9.0	29
KW107A	30	8.0	22
KW110A	20	5.0	17
KW111A	61	8.0	32
KW113A	34	10	34
KW113A	38	9.0	30
KW114A	35	10	29
KW115A	52	7.0	33
KW115A	46	7.0	33
KW116A	91	13	67
KW117A	110	14	76
KW118A	31	7.0	37
KW120A	32	7.0	24
KW120A	31	7.0	21
KW121A	19	5.0	17
KW122A	29	9.0	26
KW124A	29	7.0	21
KW125A	28	7.0	21
KW127A	38	10	31
KW128A	27	8.0	21
KW129A	38	7.0	28
KW130A	33	7.0	24
KW131A	42	8.0	27
KW132A	39	7.0	28
KW133A	24	7.0	19
KW135A	39	12	34
KW136A	37	12	28
KW137A	51	11	35
KW138A	48	12	37
KW139A	120	17	78
KW140A	79	12	56
KW141A	35	11	37
KW142A	40	11	26
KW143A	48	11	26
KW144A	22	7.0	20
KW145A	33	6.0	22
KW146A	38	6.0	25
KW147A	33	10	30
KW148A	36	9.0	23
KW150A	39	10	29
KW151A	18	6.0	18
KW153A	28	8.0	24
KW154A	27	9.0	21
KW156A	46	9.0	37
KW158A	23	6.0	18

Sample ID	V, ppm	Y, ppm	Zn, ppm
KW240A	41	12	31
KW243A	37	9.0	29
KW244A	41	11	30
KW245A	57	9.0	35
KW246A	36	10	32
KW247A	38	9.0	25
KW251A	40	9.0	29
KW252A	29	6.0	19
KW253A	45	9.0	31
KW255A	36	10	48
KW256A	36	10	41
KW258A	38	11	27
KW261A	39	10	37
KW262A	48	11	37
KW265A	33	9.0	26
KW266A	89	16	79
KW266A	95	16	80
KW267A	38	9.0	38
KW267A	39	10	39
KW268A	38	9.0	30
KW272A	21	6.0	15
KW273A	62	7.0	30
KW274A	51	15	50
KW278A	47	13	32
KW278A	49	14	34
KW279A	55	16	40
KW288A	34	8.0	35
KW291A	45	15	33
KW292A	43	13	32
KW294A	76	13	50
KW301A	32	7.0	19
KW302A	54	8.0	26
KW308A	34	7.0	23
KW308A	32	7.0	22
KW309A	28	6.0	18
KW314A	46	7.0	23
KW315A	35	7.0	18
KW328A	46	12	32
KW329A	46	13	31