U. S. DEPARTMENT OF THE INTERIOR
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Analytical results for As species and related elements in interstitial porewater and sediment from the Maurice River and Union Lake in Vineland, New Jersey

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INTRODUCTION

Union Lake, the Maurice River, and the Blackwater Branch , a tributary of the Maurice River, all parts of a small watershed near Vineland, New Jersey, are contaminated by arsenic (As) from a local chemical factory (fig. 1)(Faust and others, 1987). An in-depth study to be used for the design of the remedial action at the Vineland Chemical Co. Superfund site was initiated by the U.S. Environmental Protection Agency to determine the extent and severity of the contamination. The Vineland Chemical Co. site is located in Cumberland County, New Jersey. Organic As herbicides were manufactured there from approximately 1949 to the late 1980's. As part of the effort, core samples were collected in the Maurice River close to the chemical factory and from Union Lake, a reservoir approximately seven miles from the factory. This report summarizes the analytical results for As speciation and various constituents in the interstitial porewater and associated sediment from these cores. Because the U.S. Geological Survey has the analytical expertise and necessary equipment, the samples were analyzed in USGS laboratories in Denver, Colorado and Seattle, Washington.

SAMPLE COLLECTION

Five cores were collected between July 22 and July 24, 1992. Two of these cores were taken from the Maurice River, one near the confluence of the Blackwater Branch and Maurice River, and the other where Almond Road crosses the river (fig. 1). Samples from these sites are identified as BW and AR, respectively, in the tables containing the analytical results. Two of the cores were collected at a site behind a submerged dam near the north end of Union Lake (1UL and 2UL), and the final core was obtained near the existing dam at the south end of the lake (3UL). The reservoir cores were collected at depths of 20 to 25 ft. by divers using a Jahnke coring device (Jahnke, 1988). The river cores were collected in about three ft. of water using the same type of corer. Plugs were placed in both ends of the core liners while the cores were still underwater. Approximately 30 centimeters of sediment plus overlying water were collected in the core liner from each site.

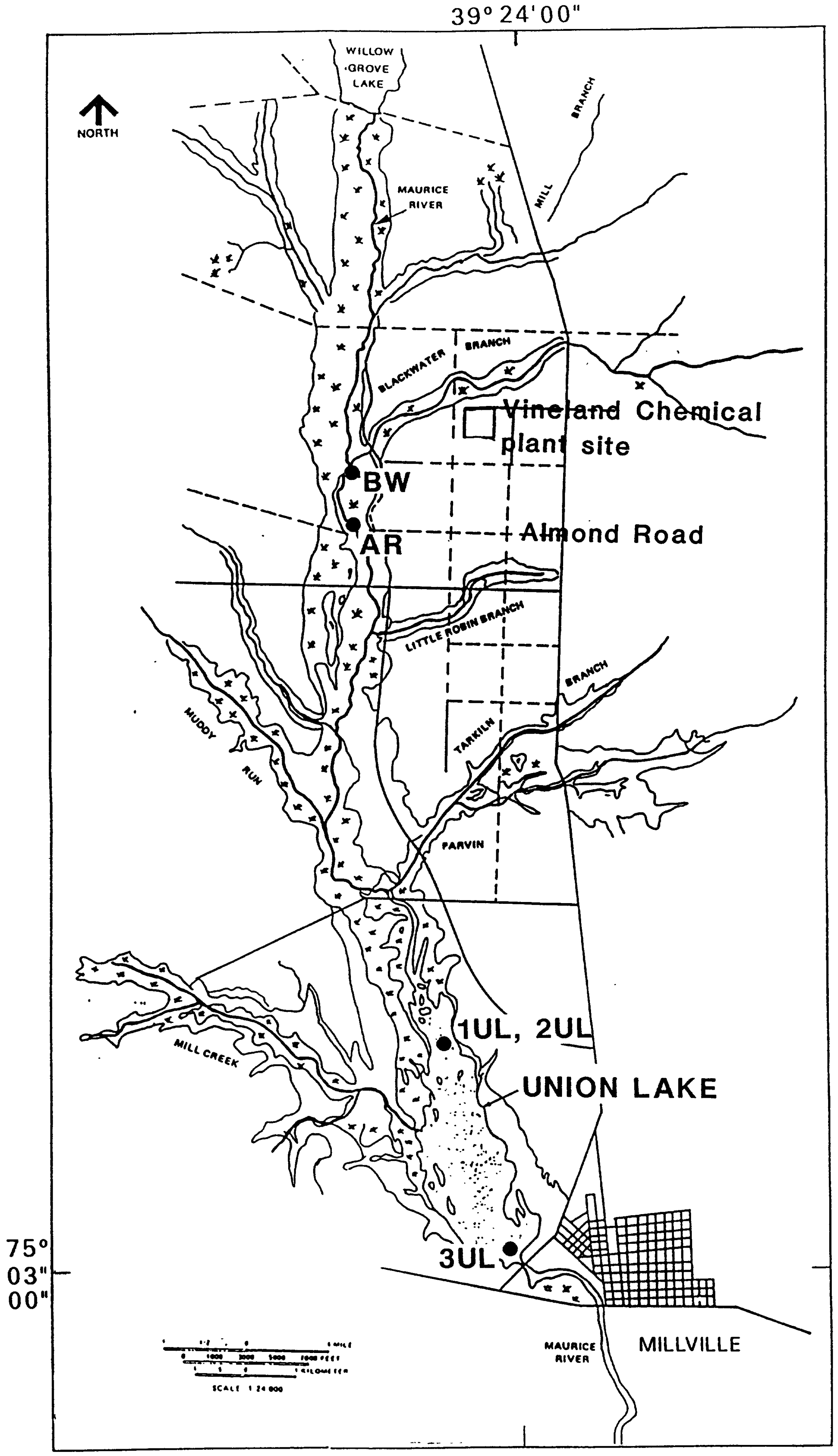
Cores were returned to a field laboratory located in Vineland within hours of collection and stored at 5^{0}C until porewater and sediment were extracted. The core liner had pre-tapped holes at various depths into which syringes were attached by Luer Lok fittings (fig. 2). The interstitial water was extracted into the syringes by applying pressure (60 psi) to the whole core. This system ensured that anoxic water samples were not contaminated by atmospheric oxygen. The material in the core was compressed and, hence, the level from which a given sample was taken changed during the extraction of the water. These depths are summarized in the tables containing the analytical information. The associated sediment was extruded in discrete intervals from the cores, packed in plastic bags, and frozen. Extraction of porewater and subsectioning of the cores occurred at the field laboratory within 12 hours of core collection.

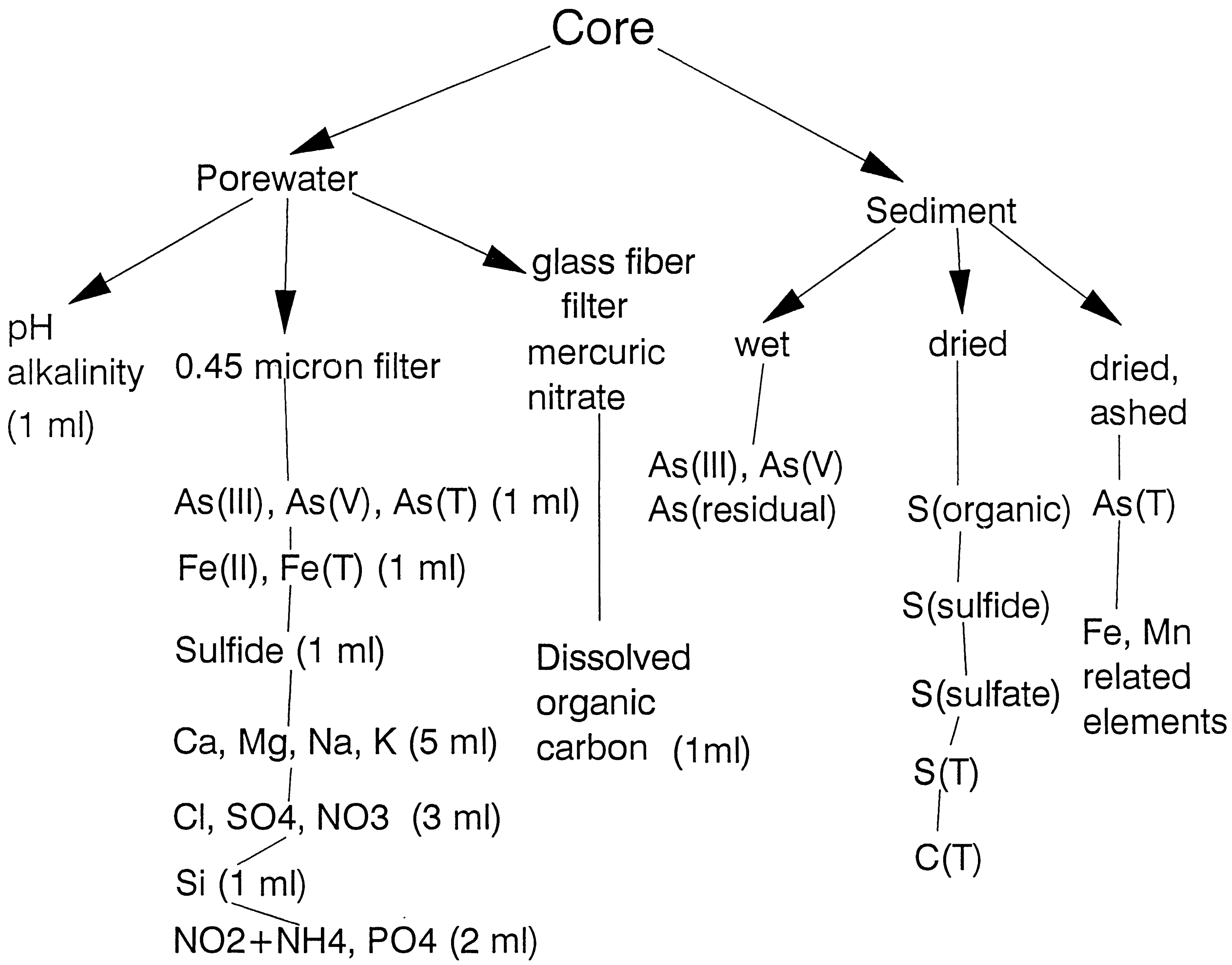
Captions for figures.

Figure 1--Map of the study area near Vineland, New Jersey. Adapted from Final Field Operations Plan, Vineland Chemical Co. site, by Ebasco Environmental.

Figure 2--The Jahnke corer in use during extraction of interstitial porewater.

Figure 3--Diagram showing the distribution of water sample during subsectioning of each core.


39° 24'00"
WILLOW GROVE LAKE
NORTH
MILL BRANCH
MAURICE RIVER
BLACKWATER BRANCH
Vineland Chemical plant site
BW
AR
Almond Road
LITTLE ROBIN BRANCH
MUDDY RUN
TARKILN BRANCH
PARVIN
1UL, 2UL
UNION LAKE
MILL CREEK
3UL
75° 03" 00"
SCALE 1:24 000
MAURICE RIVER
MILLVILLE


Core
Porewater
Sediment
pH
alkalinity
(1 ml)
0.45 micron filter
As(III), As(V), As(T) (1 ml)
Fe(II), Fe(T) (1 ml)
Sulfide (1 ml)
Ca, Mg, Na, K (5 ml)
Cl, SO4, NO3 (3 ml)
Si (1 ml)
NO2+NH4, PO4 (2 ml)
glass fiber
filter
mercuric
nitrate
Dissolved
organic
carbon (1ml)
wet
As(III), As(V)
As(residual)
dried
S(organic)
S(sulfide)
S(sulfate)
S(T)
C(T)
dried,
ashed
As(T)
Fe, Mn
related
elements

CHEMICAL ANALYSIS

The sectioning of the cores resulted in a total of 42 water samples and 37 sediment samples. All water samples, except those subsamples for pH, alkalinity, and dissolved organic carbon (DOC), were filtered through 0.45 µm disposable filters prior to any subsequent treatment. The flow diagram presented in fig. 3 indicates the subsectioning of each sample and the volume of water required for a particular analysis. In general, there was insufficient porewater available to do each of the chemical analyses more than once. The methods for the water and sediment determinations are summarized in Table 1. A description of the visual appearance of the cores is presented in Table 2.

Each water sample was analyzed for ferrous and total iron, hydrogen sulfide, and pH immediately following extraction from the core. A subsample of water was preserved for arsenic speciation by adding 10 µl of concentrated HCl to one ml of water. Subsamples of water for chloride, sulfate, and nitrate determinations were frozen and sent to Denver for analyses. Dissolved organic carbon samples were filtered through precombusted glass fiber filters, transferred to precombusted glass vials, preserved with mercuric nitrate solution, and refrigerated for shipment to Denver. Subsamples for alkalinity determinations were refrigerated before analysis, whereas samples for phosphorus, nitrite, and ammonia analyses were frozen for shipment to Seattle. The analytical results for the water immediately overlying the sediment and the interstitial pore water are summarized in Table 3. Hydrogen sulfide was not detected in any of the water samples and the results are not included in Table 3.

For some of the pore-water samples, the sum of the concentration of As(III) and As(V) do not add up to the concentration of total arsenic determined independently of the speciation. Because of the limited quantity of water available for the speciation, the speciation analysis could not be repeated in order to achieve better agreement. In these cases the results do reflect the presence or absence of one or both species.

Subsections of sediment were immediately frozen in order to preserve the speciation of arsenic in its original form and shipped to Denver for analysis. The samples were thawed just before analysis of the sediment. Arsenic was extracted from wet sediment samples using 4.0N HCl and separated into As(III) and As(V) according to the method of Ficklin (1990). The arsenic remaining in the sediment following extraction with 4.0N HCl was partially dissolved by adding potassium chlorate and concentrated HCl. This treatment dissolves sulfides and probably other forms of arsenic (Ficklin, 1990). Analyses of these leachates are identified as residual As (table 4). A subsample of the wet sediment was dried at 100°C to determine wet to dry weights and used for the determination of sulfur species and total carbon. Subsamples of the dried sediment were also ashed and then used for the determination of bulk sediment concentrations of arsenic, iron, and manganese by inductively couple plasma-atomic emission spectrometry (ICP-AES) (Briggs and others, 1990). Results for arsenic species and other constituents in the sediment are summarized in Table 4. Some elements are part of the ICP-AES scan but they were below the detection limit of the analytical procedure. These are listed below with the detection limit in parentheses following the element: gold (8 ppm), silver (2 ppm), bismuth (10 ppm), europium (2 ppm), holmium (4 ppm), tin (5 ppm), tantalum (40 ppm), and uranium (100 ppm).

The extraction of arsenic from the solid phase material also resulted in some concentrations of the three species that did not add up to the total concentration obtained by ICP-AES. There are several explanations for this: (1) The samples used for the ICP-AES analysis were dried and ashed before a sample was weighed, whereas the samples for the speciation were wet. (2) The samples used for the speciation may not have been homogeneous, and the small amount used for the analysis may not have been as representative as desired. (3) Some organic arsenic compounds may occur in the sediment and may not react with the reagents employed in the analysis of arsenic species.

DISCUSSION AND CONCLUSIONS

The oxidation of organic matter in recently deposited sediments occurs via a series of thermodynamically predictable reactions (Berner, 1980). These reaction are mediated by bacteria. Entrained oxygen is used first, followed by denitrification (i.e. the reduction of nitrate via nitrite and ammonia to nitrogen). When readily available oxygen is gone, the bacteria then obtain oxygen from manganese oxide, iron oxide, and sulfate. The final step is the dissociation of organic matter into carbon dioxide and methane. These reactions result in the sequential disappearance of oxygen, nitrate, and sulfate, and the appearance of dissolved Mn(II), Fe(II), sulfide, and methane in the interstitial pore waters of sediment.

Evidence for nitrate reduction in Union Lake pore waters is shown by decreases in nitrate concentration and increases in concentrations of combined nitrite and ammonia with depth in the upper portions of each of the cores (Table 3). The presence of dissolved Mn and Fe(II) in the overlying water and increases in these species in the upper portions of the cores indicate that reduction of Mn and Fe oxides is also occurring in the bottom waters and sediments of Union Lake (Table 3). No measurable concentrations of sulfide were observed in the interstitial pore waters of Union Lake.

Arsenic is also a redox sensitive element. The redox potential for the As(V)/As(III) couple is between the potential for Fe(III)/Fe(II) and SO_4^{2-}/S^{2-} in freshwater systems at pH 6 (Turner and others, 1981). However, the transformation of elements between their oxidation states may be sluggish so predictions of natural water concentrations and speciation based on thermodynamic principles may only indicate the direction the system is heading. Based on the Fe(II) data for the overlying water and pore water of Union Lake, we might expect As in the pore waters to be in its reduced state, and indeed, the As speciation data indicate that a significant portion of the total dissolved As occurs as As(III) (Table 3).

The mobility of As(III) and As (V0 in aquatic environments is also controlled by adsorption onto hydrous ferric oxyhydroxides (Ferguson and Gavis, 1972; Aggett and O'Brien, 1985). When oxygen is present Fe will primarily exist as insoluble oxyhydroxides capable of adsorbing dissolved arsenic species. However, for anoxic conditions, Fe oxyhydroxides may be reduced and any associated elements (e.g. As species) can be released. This process may be occurring in Union Lake as there is a positive correlation between Fe(II) and total As in the porewater (r^2=0.69). The large change in concentrations of dissolved Fe(II), As(III), As(V), and Mn across the sediment-water interface in the river and lake cores indicates that these species are diffusing out of the sediment and into the overlying water.

Despite the absence of sulfide in the pore water, sulfate reduction may be occurring in the sediments. Sulfide produced during the reduction of sulfate may be consumed in the precipitation reactions involving heavy metals and sulfide (e.g. CuS, PbS, and ZnS). Sulfate reduction in Union Lake may be occurring because decreases in sulfate concentration in the pore waters with depth are observed (Table 3) and a significant proportion of the solid sulfur exists as sulfide (Table 4). The large amount of arsenic in the sediments that was not dissolved by 4.0N HCL but dissolved by potassium chlorate and concentrated hydrochloric acid (Table 4) may be indicative of arsenopyrite, a mineral composed of As(III), Fe(II), and sulfide.

The cores from the river had a dark brown layer that occurred above a tan, sandy layer and the lake cores were all dark brown (Table 2). The dark brown layers were high in organic matter (7 to 23% total carbon), whereas the sandy layers had less than 2% total carbon (Table 4). The highest concentration of arsenic in the sediments occurred in the organic rich layers of the cores (Table 4). In fact, there is an excellent correlation between total carbon and total arsenic in the river sediments (r^2=0.71).

Summary

The widespread distribution of As in the area around and downstream of the Vineland Chemical Co. Superfund site is demonstrated by the data contained in Tables 3 and 4. The As occurs mostly as As(III) and As(V) in the interstitial pore water of cores collected from Union Lake and from the Maurice River. Bacterial mediated reactions occurring in the sediment are responsible for maintaining the speciation of As. As is relatively soluble in the interstitial water and it occurs in the overlying water, consequently As is diffusing from the sediment into the lake water. The organic rich parts of the sediment contain more arsenic than the sandy sediment.

ACKNOWLEDGMENTS

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Table 1--Analytical methods for analyses of interstitial pore water and sediment samples in the Maurice River-Union Lake arsenic study

Specie	Method	Reference
WATER SAMPLES		
As(III), As(V)	Ion exchange/GFAAS[a]	Ficklin (1983)
As(T)	GFAAS	Ficklin (1983)
Fe(II), Fe(T)	Colorimetric	Gibbs (1976)
Sulfide	Colorimetric	Cline (1969)
pH	Ross electrode	
Cl, SO_4, NO_3	Ion chromatography	Pfaff et al. (1989)
Mg, Ca, K, Na	AAS[b]	Fishman and Friedman (1989)
DOC	UV/persulfate oxidation	Standard Methods (1981)
NO_2+NH_4, Si, PO_4[c]	Colorimetric	Strickland and Parsons (1972)
SEDIMENT SAMPLES		
As(III), As(V), As(res)	Acid extraction/ ion exchange/GFAAS	Ficklin (1990)
Sulfur species		Unpublished method, USGS
Bulk As, Fe, Mn, and others	ICP-AES[d]	Briggs (1990)

[a] graphite furnace atomic absorption spectrometry

[b] flame atomic absorption spectrometry

[c] arsenic interferes with PO_4; results for PO_4 questionable

[d] inductively coupled plasma-atomic emission spectrometry

Core	depth	
AR1		Overlying water
AR2	1.9-3.8 cm	organic, sand mixture with stems and roots, brown
AR3	7.6-8.6 cm	organic, sand mixture with stems and roots, brown
AR4	10.2-11.4 cm	organic sand mixture with stems and roots, brown
AR5	14.6-15.2 cm	mostly sand , some clasts, roots, tan color
AR6	26-26.7 cm	mostly sand, gas pockets, clasts, tan color
BW1		Overlying water
BW2	.6-1.9 cm	organic rich, very little sand, fine grains, dark brown
BW3	3.8-5.1 cm	mix of organic and sand, fine grains, very dark brown
BW4	8.9-9.8 cm	sand with minor organic, few gas bubbles, tan
BW5	13.3-14.9 cm	sand with mnior organic, few gas bubbles, tan
BW6	23.5-24.1 cm	mostly sand, fine grains, light tan
1UL1		overlying water
1UL2	.6-1.9 cm	very fine organic, no visible sand, no roots, dark brown
1UL3	1.3-2.5 cm	very fine organic, no visible sand, no roots, dark brown
1UL4	4.5-5.7 cm	similar to above but with gas pockets
1UL5	5.1-6.7 cm	similar to above but with gas pockets
1UL6	8.3-9.5 cm	similar to above but with gas pockets
1UL7	9.5-10.8 cm	similar to above but with gas pockets
1UL8	14-15.2 cm	similar to above but with gas pockets
1UL9	16.5-17.1 cm	similar to above but with gas pockets
1UL10	23.5-24.8 cm	similar to above but with gas pockets
2UL1		overlying water
2UL2	.6 cm	very fine organic, no visible sand, no roots, dark brown
2UL3	1.3-1.9 cm	very fine organic, no visible sand, no roots, dark brown
2UL4	3.2-4.5 cm	similar to above but with gas pockets
2UL5	5.1-5.7 cm	similar to above but with gas pockets
2UL6	9.5 cm	similar to above but with gas pockets
2UL7	11.4-11.8 cm	similar to above but with gas pockets
2UL8	13.3-14 cm	similar to above but with gas pockets
2UL9	18.4-18.7 cm	similar to above but with gas pockets
2UL10	21.3-21.5 cm	similar to above but with gas pockets
3UL1		overlying water
3UL2	1.3-4.5 cm	organic very fine grains, dark brown
3UL3	1.9-5.1 cm	organic very fine grains, dark brown
3UL4	5.1-8.2 cm	organic very fine grains, dark brown
3UL5	8.3-11.4 cm	organic very fine grains, dark brown
3UL6	11.4-14 cm	organic very fine grains, dark brown
3UL7	16.5-19.4 cm	organic very fine grains, dark brown
3UL8	18.4-21.6 cm	organic very fine grains, dark brown
3UL9	24.1-27.3 cm	organic very fine grains, dark brown
3UL10	27.3-29.2 cm	organic very fine grains, dark brown

Table 2--Core descriptions for the two river cores and the three lake cores collected in the Maurice River-Union Lake study.

Explanation of chemical symbols used in Table 3.

As(III)=arsenic(III)
As(V)= arsenic(V)
Sum(III)(V)= the sum of As(III) and As(V)
As(total)= total arsenic (determined independently of the speciation
Fe(2)= ferrous iron , The field determination was in uM. the second column labelled Fe(2) is the conversion from uM to milligrams per liter
Fe(t)= total iron in uM.
Fe(T)= total iron in milligrams/L converterd from uM.
Mn= manganese
Cl= chloride
NO3= nitrate
SO4= sulfate
DOC= dissolved organic carbon
Alk= alkalinity
Ca=calcium
Mg= magnesium
Na= sodium
K= potassium
Si= silicon
P= phosphorus
NH4+NO2= nitrogen occurring as ammonium ion or nitrite ion
ug/L= micrograms per liter
uM= micromoles per liter
mg/L= milligrams per liter

Table 3--Analytical results for overlying water and interstitial porewater samples from five cores collected in the Maurice River and Union Lake. Sample descriptors are discussed in the text. The depths before and after squeezing of the core are listed in the column labeled depth. At levels where insufficient sample was available for all of the determinations the result is listed as "ins".

SAMPLE	depth	As(III) ug/L	As(V) ug/L	Sum(III)(V) ug/L	As(total) ug/L
AR1	overlying	24	73	97	110
AR2	1.9-3.8cm	15	190	205	330
AR3	7.6-8.6 cm	<5	170	170	210
AR4	10.2-11.4 cm	<5	350	350	410
AR5	14.6-15.2 cm	<5	130	130	110
AR6	26-26.7 cm	<5	32	32	50
BW1	overlying	930	360	1290	1090
BW2	0.6-1.9 cm	1000	2030	3030	3100
BW3	3.8-5.1 cm	3900	2170	6070	5900
BW4	8.9-9.8 cm	130	160	290	270
BW5	13.3-14.9 cm	80	70	150	180
BW6	23.5-24.1 cm	10	9	19	18
1UL1	overlying	30	100	130	170
1UL2	0.6-1.9 cm	110	210	320	330
1UL3	1.3-2.5 cm	90	100	190	250
1UL4	4.5-5.7 cm	590	1250	1840	1910
1UL5	5.1-6.7 cm	500	1330	1830	2110
1UL6	8.3-9.5 cm	1100	1610	2710	2910
1UL7	9.5-10.8 cm	1670	1200	2870	3100
1UL8	13.9-15.2 cm	680	1600	2280	2400
1UL9	16.5-17.1 cm	870	1130	2000	2110
1UL10	23.5-24.8 cm	390	390	780	720
2UL1	overlying	25	130	155	140
2UL2	0.6 cm	60	170	230	250
2UL3	1.3-1.9 cm	60	290	350	340
2UL4	3.2-4.4 cm	760	930	1690	1680
2UL5	5.1-5.7 cm	800	1270	2070	1960
2UL6	9.5 cm	510	1700	2210	2150
2UL7	11.4-11.7 cm	790	1100	1890	1750
2UL8	13.3-13.9 cm	1400	1190	2590	2480
2UL9	18.4-18.7 cm	480	930	1410	1450
2UL10	21.3-21.6 cm	120	330	450	560
3UL1	overlying	15	120	135	130
3UL2	1.27 cm	160	640	800	760
3UL3	1.91 cm	10	130	140	150
3UL4	5.1-8.3 cm	400	1200	1600	1660
3UL5	8.3-11.4 cm	230	850	1080	1040
3UL6	11.4-13.9 cm	670	860	1530	2200
3UL7	16.5-19.4 cm	50	900	950	920
3UL8	18.4-21.6 cm	310	790	1100	1260
3UL9	24.1-27.3 cm	160	610	770	900
3UL10	27.3-29.2 cm	150	330	480	500

Table 3--continued

SAMPLE	Fe(2) uM	Fe(2) mg/L	Fe(t) uM	Fe(T) mg/L	Mn ug/L	Cl mg/L
AR1	17.3	0.97	22.1	1.23	440	6.1
AR2	137	7.64	104	5.80	1260	6.3
AR3	177	9.90	242	13.4	ins	7.2
AR4	266	14.9	266	14.8	1680	7.0
AR5	177	9.90	148	8.28	370	7.3
AR6	156	8.72	293	16.3	360	6.8
BW1	86.2	4.82	77.5	4.33	360	8.6
BW2	220	12.3	233	13.0	ins	10
BW3	323	18.0	343	19.2	240	22
BW4	31.1	1.73	31.3	1.75	210	24
BW5	17.5	0.98	18.5	1.03	190	24
BW6	4.63	0.26	2.46	0.14	190	23
1UL1	11.9	0.66	16.8	0.94	90	11
1UL2	178	9.95	135	7.56	190	11
1UL3	95.7	5.35	77.6	4.34	140	11
1UL4	326	18.2	472	26.4	410	24
1UL5	337	18.8	472	26.4	350	11
1UL6	484	27.0	632	35.3	420	7.2
1UL7	418	23.3	632	35.3	ins	14
1UL8	257	14.3	499	27.9	ins	4.8
1UL9	359	20.0	436	24.3	290	3.8
1UL10	285	15.9	366	20.5	240	3.3
2UL1	19.0	1.06	27.4	1.53	90	11
2UL2	95.8	5.35	120	6.71	150	11
2UL3	115	6.45	156	8.71	190	11
2UL4	517	28.9	609	34.1	380	9.7
2UL5	382	21.3	519	29.0	380	11
2UL6	340	19.0	492	27.5	370	7.7
2UL7	504	28.1	627	35.0	350	7.3
2UL8	451	25.2	549	30.6	360	5.3
2UL9	371	20.7	479	26.8	300	5.2
2UL10	320	17.9	416	23.3	250	5.1
3UL1	13.9	0.78	21.7	1.21	460	7.9
3UL2	176	9.83	224	12.5	1110	8.2
3UL3	9.16	0.51	12.6	0.70	440	7.1
3UL4	223	12.5	321	17.9	1370	8.5
3UL5	192	10.7	270	15.19	1230	7.5
3UL6	335	18.7	474	26.4	1210	8.7
3UL7	192	10.7	260	14.5	900	9.2
3UL8	240	13.4	280	15.7	1000	8.9
3UL9	192	10.7	241	13.5	760	7.1
3UL10	184	10.3	207	11.5	510	7.4

Table 3--continued

SAMPLE	NO3 mg/L	SO4 mg/L	DOC mg/L	Alk meq/l	pH	Ca mg/L
AR1	4.9	8.6	5.6	0.247	6.03	4.9
AR2	1	5.9	7.6	0.474	5.53	2.6
AR3	<.1	5.1	14.3	1.518	5.59	12
AR4	<.1	5	12.1	0.502	5.62	17
AR5	<.1	5.1	0	0.907	5.49	4
AR6	<.1	5.2	ins	0.768	5.4	7.3
BW1	7.3	10	4.3	0.191		1.9
BW2	6.1	11	5.8	0.072	6.34	4
BW3		7.1	10	0.302	6.17	6.6
BW4	3.3	23	5.6	0.116	5.47	6.2
BW5	5	24	6.3	0.061	5.34	4.8
BW6	6.7	27	3.8	0.088	5.14	7.4
1UL1	6.2	8.4	6.8	0.257	6.37	4
1UL2	3.8	11	9.5	0.209	7.03	3.7
1UL3	5	12	6.6	0.121	6.55	3.3
1UL4	0.4	6	16	1.20	6.52	13
1UL5	1	5.7	13	0.722	6.67	9.2
1UL6	<.1	5.7	7.1	1.16	6.63	15
1UL7	<.1	5.7	ins	0.143	6.97	
1UL8	<.1	5.6	ins	0.272	6.82	7.9
1UL9	<.1	5.8	8.5	0.406	7.72	8
1UL10	<.1	5.7	7.5	0.597	6.59	6.7
2UL1	5.7	10	6	0.409	6.54	2.1
2UL2	5.4	11	8.4	0.170	6.71	3.2
2UL3	1.9	8.1	12	0.097	6.43	5
2UL4	<.1	5.1	9.5	0.111	7.03	8.5
2UL5	<.1	5	18	1.01	6.56	10
2UL6	<.1	5	14	0.274	6.54	7.2
2UL7	<.1	5	15	0.617	6.58	8.7
2UL8	<.1	5.1	13	0.556	6.58	12
2UL9	<.1	5	8.3	0.9458	6.54	8.1
2UL10	<.1	4.8	9.5	0.788	6.52	7.1
3UL1	1.3	6.7	7.4	0.432	6.92	5.1
3UL2	<.1	5.6	17	0.139	7.08	8.5
3UL3	0.9	9.2	7.7	0.174	6.75	5
3UL4	<.1	5.6	20	0.991	7.71	12
3UL5	<.1	5.5	15	0.890	6.73	11
3UL6	<.1	5.4	ins	ins	ins	11
3UL7	<.1	5.4	29	0.247	6.8	11
3UL8	<.1	5.5	47	0.660	6.75	12
3UL9	<.1	5.5	15	1.13	6.8	10
3UL10	<.1	5.5	31	1.01	6.75	11

Table 3--continued

SAMPLE	Mg mg/L	Na mg/L	K mg/L	Si uM	P uM	NH4+NO2 uM
AR1	2.5	5	2.2	63.8	0.00	32
AR2	0.7	1.1	0.8	164	0.00	56
AR3	4.2	7.6	7.9	420	0.00	84
AR4	5.6	7.1	5.4	128	0.00	71
AR5	1.3	2.5	1.3	638	4.0	77
AR6	2.9	6.5	3.3	658	0.50	59
BW1	0.6	1.9	0.6	114.9	0.00	35
BW2	2	9.8	2	112.9	0.50	38
BW3	2.9	15	1.2	89.1	9.3	36
BW4	2.5	15	1.4	80.3	0.00	33
BW5	1.8	12	1.4	75.7	0.00	33
BW6	2.6	16	1.9	81.3	0.00	34
1UL1	2.1	9.2	2.5	76.2	0.00	34
1UL2	1.8	8.4	2.4	106	6.0	41
1UL3	1.5	7.8	2.2	95.8	0.00	35
1UL4	4.4	12	3.3	202	6.0	60
1UL5	3.6	6.9	2.5	240	3.5	51
1UL6	7.6	8.5	3.7	237	1.3	57
1UL7				280	9.0	71
1UL8	3.9	6.8	3.4	286	0.2	66
1UL9	4.1	7.6	3.9	371	6.1	60
1UL10	3	6.4	3.6	442	5.5	50
2UL1	1.1	3.9	1	77.7	0.00	42
2UL2	1.7	8.9	2.3	1.25	0.00	39
2UL3	2.7	11	2.7	18.3	0.00	41
2UL4	3.9	10	3.1	218	0.00	53
2UL5	4.4	9.8	3.1	224	2.7	51
2UL6	3.2	5.4	1.9	305	6.8	54
2UL7	3.8	6.2	2.8	340	0.00	62
2UL8	5.8	8.9	3.8	290	0.00	64
2UL9	3.7	8.3	4.1	397	0.00	58
2UL10	3.4	5.8	4.8	57.6	1.2	57
3UL1	2.5	6.8	2.2	108	0.00	39
3UL2	3.8	7.2	2.6	27.1	11	50
3UL3	2.5	6.9	2.3	6.42	0.00	42
3UL4	5.7	7.2	2.8	183	5.5	53
3UL5	5.3	6.1	2.5	196	0.00	51
3UL6	4.8	7.6	3.2	243	17	58
3UL7	4.4	5.9	2.5	215	3.5	47
3UL8	5.5	11	4.4	28.6	0.00	43
3UL9	5.2	8.4	3.1	247	4.2	48
3UL10	5.5	9.1	3.3	256	0.00	43

Explanation of chemical symbols used in Table 4.

As(III)s= arsenic(III) from acid extraction of a sample of sediment
As(V)s=arsenic(V) from acid extraction of a sample of sediment
As(S)res= arsenic that was dissolved by hydrochloric acid and potassium chlorate following extraction of acid soluble arsenic
Sum As= sum of As(III)s+As(V)s+As(res)
As(total)= total arsenic determined by ICPAES
C(total)= total carbon
OrgS= sulfur that was chemically bound with organic material
SulfateS= sulfur that was chemically bound as sulfate
SulfideS= sulfur that was chemically bound as sulfide
S(total)= total sulfur regardless of chemical form
Fe(total)= total iron
Mn= manganese
Al=aluminum
Ca= calcium
K= potassium
Mg= magnesium
Na= sodium
P=phosphorus
Ti= titanium
Ba= barium
Cd= cadmium
Ce=cerium
Co= cobalt
Cr= chromium
Cu= copper
Ga=gasllium
La= lantnanum
Li=lithium
Mo=molybdenum
Nb=niobium
Nd=neodymium
Ni= nickel
Pb= lead
Sc=scandium
Sr= strontium
V= vanadium
Y= yttrium
Yb= ytterbium
Zn= zinc
%= concentration in per cent
ppm= concentration in parts per million

Table 4--Analytical results for sediment samples from five cores collected in the Maurice River and Union Lake. See text for sample descriptors. Blank spaces for sulfur species indicate that the sample was not run for that species because the total sulfur concentration was insufficient.

SAMPLE	As(III)s mg/kg	As(V)s mg/kg	As(S)res mg/kg	Sum As mg.kg	As(total) s mg/kg (ICPAES)	C(total) %
AR2	460	6	430	896	640	15.6
AR3	50	<.5	320	370	290	7.54
AR4	31	2.2	200	233.2	310	10.3
AR5	13	3.4	34	50.4	58	0.79
AR6	14	<.5	50	64	29	0.85
BW2	3000	550	860	4410	4100	23.3
BW3	120	59	48	227	100	0.80
BW4	1.5	11	5	17.5	24	0.16
BW5	3.5	42	15	60.5	43	2.06
BW6	<.5	7.3	<1	7.3	<10	0.05
1UL2	1600	70	200	1870	1600	21.9
1UL3	920	44	300	1264	1700	21.4
1UL4	990	1.2	240	1230	1500	22.8
1UL5	680	22	320	1022	970	17.6
1UL6	880	13	350	1243	1700	22.2
1UL7	650	24	430	1104	1300	20.7
1UL8	400	11	150	561	800	22.2
1UL9	190	<.5	330	520	680	20.6
1UL10	90	11	160	261	320	24.6
2UL2	960	95	360	1415	1600	21.1
2UL3	1000	32	330	1362	1700	22.3
2UL4	820	19	260	1099	1400	21.7
2UL5	660	10	410	1080	1300	22.1
2UL6	410	12	330	752	1000	20.9
2UL7	140	10	280	430	600	20.1
2UL8	140	12	200	352	490	21.0
2UL9	70	<.5	240	310	460	21.7
2UL10	40	16	360	416	500	23.0
3UL2	900	450	200	1550	1600	18.5
3UL3	940	150	260	1350	1300	17.7
3UL4	660	160	390	1210	1300	19.4
3UL5	440	11	250	701	1500	22.3
3UL6	430	30	160	620	530	17.6
3UL7	210	8.8	270	490	540	17.6
3UL8	300	38	ins	ins	550	16.3
3UL9	220	52	690	962	1100	17.2
3UL10	95	<.5	720	815	1300	17.2

Table 4--continued

SAMPLE	OrgS %	SulfateS %	SulfideS %	S(total) %	Fe(total) %	Mn mg/kg
AR2	0.12	0.01	0.21	0.34	1.7	510
AR3	0.09	0.03	0.11	0.23	0.78	190
AR4	0.06	0.01	0.12	0.19	0.81	210
AR5				0.04	0.19	63
AR6				0.03	0.17	59
BW2	0.16	0.03	0.24	0.43	5	460
BW3				0.02	0.21	36
BW4				0.01	0.10	23
BW5				0.04	0.13	26
BW6				<0.01	0.24	66
1UL2	0.18	0.05	0.23	0.46	9.4	340
1UL3	0.16	0.04	0.22	0.42	9.8	360
1UL4	0.14	0.04	0.28	0.46	9.4	360
1UL5	0.14	0.03	0.18	0.35	7.2	620
1UL6	0.29	0.05	0.19	0.53	9.4	300
1UL7	0.25	0.05	0.26	0.56	8.7	260
1UL8	0.22	0.08	0.34	0.64	7.0	230
1UL9	0.24	0.03	0.35	0.62	6.4	230
1UL10	0.20	0.04	0.35	0.59	3.3	160
2UL2	0.24	<0.01	0.21	0.43	9.6	340
2UL3	0.17	0.05	0.23	0.45	9.6	330
2UL4	0.14	0.04	0.24	0.42	9.2	320
2UL5	0.19	0.03	0.22	0.44	9.2	310
2UL6	0.25	0.05	0.22	0.52	8.5	260
2UL7	0.29	0.05	0.29	0.63	6.3	230
2UL8	0.32	0.05	0.25	0.62	5.5	200
2UL9	0.15	0.04	0.44	0.63	4.4	190
2UL10	0.18	0.05	0.42	0.65	3.7	160
3UL2	0.12	0.02	0.19	0.33	8.4	840
3UL3	0.12	0.02	0.19	0.33	8.1	820
3UL4	0.1	0.02	0.22	0.34	7.8	700
3UL5	0.13	0.05	0.36	0.54	9.1	310
3UL6	0.07	0.05	0.3	0.42	5.6	500
3UL7	0.1	0.03	0.34	0.47	5.3	460
3UL8	0.12	0.06	0.29	0.47	6.1	490
3UL9	0.12	0.05	0.33	0.5	4.0	370
3UL10	0.14	0.02	0.38	0.54	4.0	350

Table 4--Continued

	Al	Ca	K	Mg	Na	P
	%	%	%	%	%	%
AR2	1.2	.21	.16	.06	.04	.08
AR3	.60	.12	.10	.03	.02	.04
AR$	.61	.16	.11	.03	.02	.04
AR5	.14	.01	.05	.006	.005	.006
AR6	.16	.01	.10	.006	.01	<.005
BW2	2.8	.20	.30	.12	.12	.19
BW3	.16	.01	.04	.007	.008	.009
BW4	.09	<.005	.03	<.005	<.005	<.005
BW5	.11	<.005	.03	<.005	.006	<.005
BW6	.08	<.005	.04	<.005	<.005	<.005
1UL2	2.9	.43	.29	.17	.08	.32
1UL3	2.8	.43	.28	.16	.07	.32
1UL4	3.0	.40	.29	.16	.08	.32
1UL5	3.9	.43	.33	.20	.07	.28
1UL6	3.0	.39	.29	.16	.07	.34
1UL7	3.3	.37	.32	.17	.08	.34
1UL8	3.8	.36	.37	.19	.09	.31
1UL9	3.6	.36	.35	.18	.09	.30
1UL10	3.3	.38	.30	.16	.08	.25
2UL2	2.9	.44	.28	.17	.08	.33
2UL3	2.6	.40	.25	.15	.07	.31
2UL4	3.1	.37	.29	.16	.08	.34
2UL5	3.2	.36	.29	.16	.08	.34
2UL6	3.6	.36	.33	.18	.08	.35
2UL7	4.0	.38	.38	.21	.10	.29
2UL8	3.7	.38	.35	.19	.09	.28
2UL9	3.5	.37	.32	.18	.08	.27
2UL10	3.3	.37	.28	.16	.22	.27
3UL2	4.0	.44	.30	.19	.07	.27
3UL3	4.4	.42	.33	.20	.08	.25
3UL4	4.0	.47	.30	.20	.07	.26
3UL5	2.8	.39	.26	.15	.08	.32
3UL6	4.2	.43	.31	.21	.07	.26
3UL7	4.1	.44	.30	.21	.07	.25
3UL8	4.2	.41	.30	.21	.07	.27
3UL9	3.8	.44	.29	.20	.07	.22
3UL10	3.7	.43	.27	.19	.07	.22

Table 4--continued

	Ti %	Ba ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm
AR2	.33	240	<2	31	35	74
AR3	.22	130	<2	17	21	57
AR4	.26	170	<2	19	17	58
AR5	.21	38	<2	12	2	13
AR6	.23	57	<2	<4	1	22
BW2	.15	440	3	78	48	52
BW3	.13	34	<2	4	1	22
BW4	.12	22	<2	<4	<1	7
BW5	.13	22	<2	<4	<1	5
BW6	.36	27	<2	6	<1	18
1UL2	.18	470	3	62	31	160
1UL3	.16	470	3	59	28	150
1UL4	.18	460	3	58	28	140
1UL5	.17	450	2	69	42	200
1UL6	.17	460	3	63	29	160
1UL7	.19	450	3	67	29	190
1UL8	.22	490	3	65	29	250
1UL9	.23	470	3	64	28	260
1UL10	.21	460	4	70	20	310
2UL2	.20	470	3	61	26	160
2UL3	.18	450	3	55	26	140
2UL4	.19	440	3	61	27	150
2UL5	.21	420	3	61	29	150
2UL6	.17	420	3	69	29	190
2UL7	.20	470	3	69	29	290
2UL8	.22	460	4	69	26	320
2UL9	.22	470	3	66	26	450
2UL10	.19	450	4	71	22	330
3UL2	.18	460	<2	67	45	180
3UL3	.16	450	<2	68	45	170
3UL4	.14	460	<2	68	39	190
3UL5	.16	430	3	56	30	140
3UL6	.15	450	3	72	51	270
3UL7	.15	450	3	71	47	270
3UL8	.15	430	2	73	39	240
3UL9	.15	430	3	67	40	240
3UL10	.16	420	2	67	38	220

Table 4--contiinued

	Cu ppm	Ga ppm	La ppm	Li ppm	Mo ppm	Nb ppm
AR2	16	<4	23	5	<2	5
AR3	9	<4	12	3	2	<4
AR4	9	<4	13	3	<2	5
AR5	<1	<4	6	<2	<2	<4
AR6	2	<4	3	<2	2	<4
BW2	66	5	10	10	3	4
BW3	3	<4	<2	<2	<2	<4
BW4	<1	<4	<2	<2	<2	<4
BW5	<1	<4	<2	<2	<2	<4
BW6	<1	<4	2	2	<2	5
1UL2	39	4	40	13	4	6
1UL3	38	<4	40	12	3	5
1UL4	38	<4	39	13	3	5
1UL5	40	7	43	17	3	5
1UL6	40	4	42	13	3	5
1UL7	44	5	43	15	3	6
1UL8	50	6	41	18	2	5
1UL9	50	6	41	16	3	7
1UL10	45	7	41	14	2	4
2UL2	39	4	41	13	4	5
2UL3	35	<4	37	11	3	6
2UL4	39	4	39	14	3	6
2UL5	39	4	40	14	3	6
2UL6	44	6	44	16	4	6
2UL7	53	7	43	18	5	6
2UL8	51	8	42	16	3	6
2UL9	43	7	40	15	3	6
2UL10	45	7	42	14	3	5
3UL2	36	6	41	16	4	6
3UL3	36	8	42	17	4	5
3UL4	37	7	42	16	4	5
3UL5	35	4	38	18	4	6
3UL6	42	9	43	18	3	5
3UL7	43	8	43	18	3	5
3UL8	43	7	43	18	3	5
3UL9	42	8	40	16	3	5
3UL10	40	8	39	16	4	5

Table 4--continued

	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sr ppm	V ppm
AR2	28	28	69	<2	25	65
AR3	14	25	38	<2	15	41
AR4	15	21	41	<2	19	43
AR5	6	5	8	<2	6	10
AR6	6	8	6	<2	7	6
BW2	61	48	250	4	32	49
BW3	<4	12	12	<2	5	5
BW4	<4	4	5	<2	3	3
BW5	<4	2	6	<2	3	3
BW6	<4	7	<4	<2	4	7
1UL2	41	59	180	5	50	180
1UL3	42	51	170	5	50	160
1UL4	37	51	160	5	48	150
1UL5	43	61	180	6	50	210
1UL6	43	57	180	5	47	220
1UL7	44	54	230	5	49	210
1UL8	42	53	270	6	54	190
1UL9	41	54	290	6	53	210
1UL10	41	43	200	5	54	99
2UL2	43	49	180	5	49	160
2UL3	38	46	160	4	46	150
2UL4	41	51	180	5	46	170
2UL5	42	51	180	5	45	170
2UL6	48	60	230	6	49	190
2UL7	43	64	300	6	57	190
2UL8	43	60	300	6	55	180
2UL9	38	51	240	5	53	130
2UL10	42	45	200	5	54	100
3UL2	41	60	140	6	51	130
3UL3	41	61	140	7	51	150
3UL4	41	60	150	6	52	140
3UL5	40	54	160	5	46	150
3UL6	44	66	220	6	52	190
3UL7	42	62	220	6	54	160
3UL8	42	60	210	6	51	190
3UL9	41	60	190	6	56	110
3UL10	39	50	190	6	55	110

Table 4--continued

	Y ppm	Yb ppm	Zn ppm
AR2	28	3	92
AR3	14	1	50
AR4	14	1	44
AR5	<2	<1	8
AR6	<2	<1	6
BW2	56	4	220
BW3	<2	<1	6
BW4	<2	<1	<2
BW5	<2	<1	2
BW6	<2	<1	3
1UL2	46	4	310
1UL3	46	4	300
1UL4	46	4	290
1UL5	44	4	320
1UL6	47	4	320
1UL7	46	4	310
1UL8	43	4	290
1UL9	43	4	310
1UL10	41	3	370
2UL2	47	4	290
2UL3	43	4	280
2UL4	47	4	300
2UL5	47	4	300
2UL6	48	4	310
2UL7	43	3	310
2UL8	44	3	330
2UL9	39	3	300
2UL10	40	3	340
3UL2	42	4	290
3UL3	41	4	290
3UL4	42	4	300
3UL5	43	4	290
3UL6	43	4	360
3UL7	42	4	360
3UL8	45	4	320
3UL9	36	3	330
3UL10	34	3	300