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Analytical results for water, soil, and rocks collected near Granite Falls, Washington as part of an arsenic-in-groundwater study

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INTRODUCTION

The arsenic concentration in some domestic water supply wells in the vicinity of Granite Falls, Washington (fig. 1) greatly exceeds the maximum allowable concentration for safe drinking water (50µg/L) (David Frank, personal communication). We collected ground water samples from several of these wells and also solid phase material from sites adjacent to some of the wells. We also collected samples from in-place vein material that was exposed to the surface at a rock crushing operation near the Wayside mine (abandoned), a mine water sample and a vein sample from the Yankee Boy mine (abandoned), and two sediment samples and a water sample from Gardner Lake. The samples were collected to determine, if possible, the source of the arsenic in the groundwater. The location of samples is shown in figure 1 and 2. Figure 2 is a detailed sample location plot where several closely spaced wells contain very great concentrations of arsenic.

The surficial geology of the Granite Falls quadrangle is described by Booth (1985). Bedrock geology is described by Tabor and others (1982). The surficial geology of the Skyhomish River Quadrangle is described by Booth (1984). Some outcrops of volcanic rocks can be found in the vicinity of Granite Falls, however most of the samples were collected in areas where surficial alluvial material occurs.

SAMPLING TECHNIQUES

Ground water was sampled from domestic wells. Where ground water was being used as a domestic water supply, the well was pumped until constant temperature and specific conduction were obtained. Three wells, which had no pumps, were sampled by using a portable battery operated submersible pump. Wells A and B were sampled by bailing upon refill. Sample M was surface water collected from Gardner Lake. A portion of the water (50 ml) was filtered through a 0.45 micron filter and preserved with 0.5 ml of concentrated nitric acid. Another 50 ml sample used for arsenic speciation was filtered and preserved with 0.5 ml concentrated hydrochloric acid. A third portion of the water was sampled with no preservation.

The soil sample at well site B was collected from about 12 inches below the surface. The lake sediments were grab samples which were frozen until analysis for acid extractable arsenic. Rocks were collected from outcrops and in-place vein material.

ANALYTICAL TECHNIQUES

The rock samples and the soil sample were crushed and/or pulverized to -80 mesh. Each sample was digested in hydrofluoric, perchloric hydrochloric, and nitric acids and the concentration of 34 elements (table 2) was determined by inductively coupled plasma-atomic emission spectroscopy (Lichte and others, 1987). The major constituents were determined by X-ray fluorescence spectroscopy (Taggart and others, 1987).

In the water samples, the elements sodium, potassium, calcium, and magnesium were determined by flame atomic absorption spectrophotometry (AAS) (Aruscavage and Crock, 1987). Aluminum and silica were determined using nitrous oxide flame for AAS. Fluoride, chloride, nitrate, and sulfate were determined by ion chromatography (Fishman and Pyen, 1979). Alkalinity was determined within a few days by Gran's Plot Titration (Orion Research, 1978). The trace elements copper, zinc, iron, manganese, cadmium, selenium,

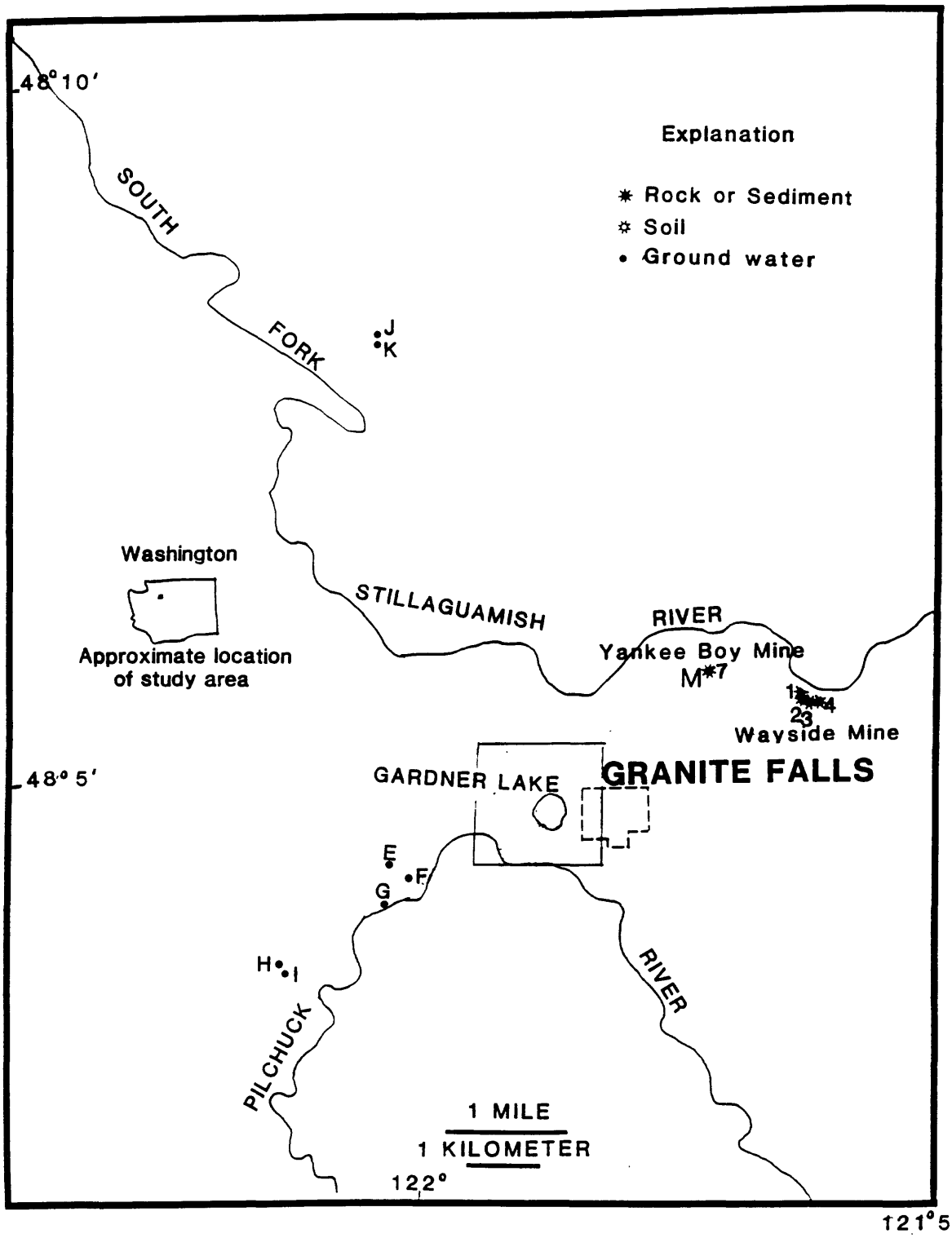

Figure 1. Location map of sample collection area, Granite Falls, Washington.

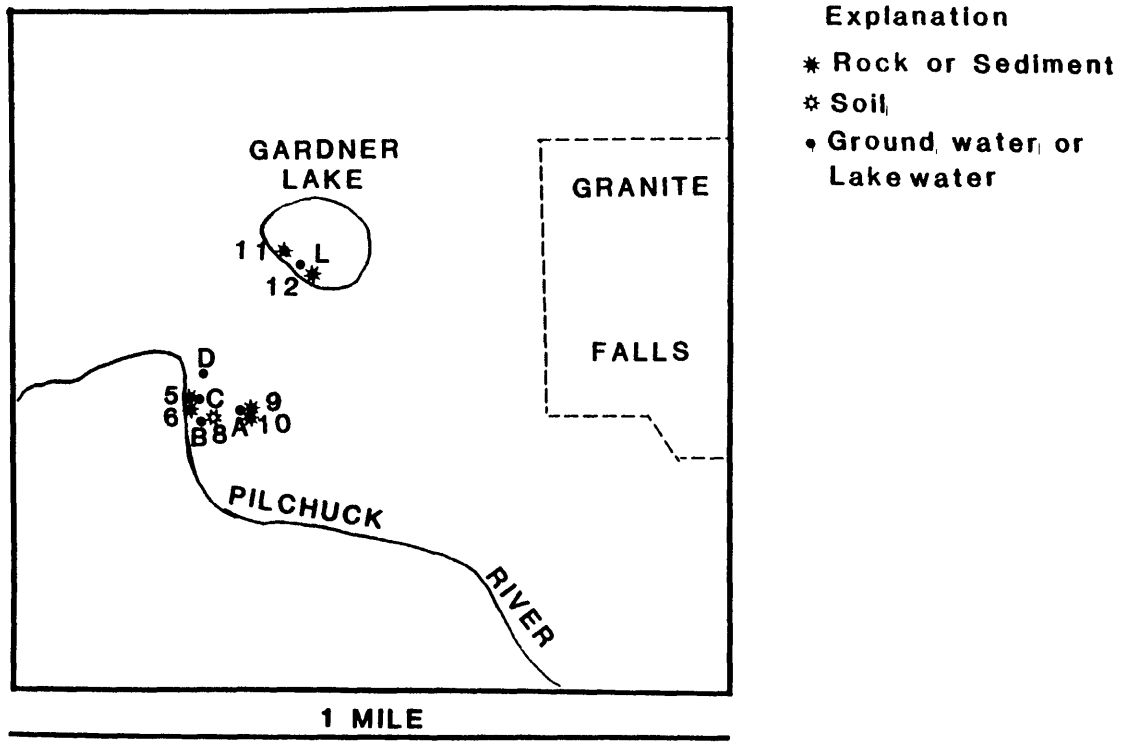

Figure 2. Detail of sample collection sites in area shown on figure 1.

molybdenum, and arsenic were determined by graphite furnace AAS. The arsenic species, arsenate (As(V)), arsenite (As(III)), monmethyl arsonate (MMA) and dimethyl arsinite (DMA) were determined using the ion exchange separation technique of Ficklin (1983). The method was extended to include MMA and DMA using an adaptation of the method of Pacey and Ford (1981) Oxidation-reduction potential was measured at the sample site using a Corning combination Redox electrode and a Beckman ϕ20 pH-mv meter. Temperature, pH, and conductivity were also determined at the time of sample collection.

RESULTS

The analytical results for the water samples are presented in table 1. Table 2 contains results for ICP-AES determination of elements in solid phase material and table 3 contains results for X-ray fluorescence determination of the major constituents of the solid material.

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Table 1. Analytical results for water samples collected in the vicinity of Granite Falls, Washington

Sample	As(III) µg/L	As(V) µg/L	DMA µg/L	MMA µg/L	As(tot) µg/L	Na mg/L	K mg/L
A	12,000	1,100	<5	<5	15,000	100	0.17
B	3,100	500	<5	<5	3,900	120	0.4
C	<5	2,300	<5	<5	2,500	150	0.41
D	7,600	7,200	<5	<5	13,000	140	0.36
E	60	130	<5	<5	190	21	0.75
F	<5	<5	<5	<5	<5	7	1.4
G	640	20	<5	<5	590	23	0.80
H	88	<5	<5	<5	100	31	1.4
I	180	<5	<5	<5	160	30	1.63
J	70	3,400	<5	<5	3,800	75	2.8
K	20	690	<5	<5	680	9	1.0
L	<5	<5	<5	<5	<5	6	1.0
M	<5	160	<5	<5	150	9	0.78

Sample	Ca mg/L	Mg mg/L	Li mg/L	F mg/L	Cl mg/L	NO_3 mg/L	SO_4 mg/L
A	2	0.4	0.14	4.1	44	<.1	18
B	4	0.2	0.14	3.2	56	<.1	17
C	19	0.7	0.2	1.0	184	0.4	19
D	7	0.3	0.23	2.2	69	<.1	8.3
E	22	0.9	0.06	0.2	11	<.1	4
F	16	5.4	<.01	0.09	4.3	1.9	8.6
G	13	2.7	0.07	0.6	22	<.1	4.4
H	6	2.4	0.04	0.1	15	<.1	0.5
I	12	3.5	0.01	0.2	23	<.1	1
J	9	2	0.2	3.5	8.1	0.4	23
K	39	5.2	<.01	0.1	2.3	<.1	20
L	29	6.4	<.01	0.1	2	<.1	1.9
M	25	2.5	0.06	0.2	3.8	0.1	9.3

Sample	Cu µg/L	Zn µg/L	Fe µg/L	Mn µg/L	Mo µg/L	Se µg/L	Al µg/L
A	3.9	<10	45	4	10	<5	<.1
B	4.4	<10	64	13	15	<5	<.1
C	1.5	<10	58	11	<1.0	<5	<.1
D	<1.0	<10	55	14	14	<5	<.1
E	<1.0	90	64	23	23	<5	<.1
F	16	440	<10	2	2	<5	<.1
G	<1.0	30	55	22	22	<5	<.1
H	<1.0	<10	200	20	20	<5	<.1
I	<1.0	<10	15	2	2	<5	<.1
J	2.8	420	11	<1	<1	<5	<.1
K	<1.0	1,510	20	36	3	<5	<.1
L	1.2	<10	2,600	470	<1	<5	<.1
M	68	30	22	5	<1	<5	<.1

Table 1. Analytical results for water samples collected in the vicinity of Granite Falls, Washington--Continued

Sample	Si mg/L	HCO_3 mg/L	Cd µg/L	Pb µg/L	pH	Redox mv	Cond us
A	10	177	<.5	<1	9.23	165	570
B	2	204	<.5	<1	9.3	126	720
C	14	144	<.5	<1	6.87	268	920
D	10	148	<.5	<1	8.3	201	970
E	13	117	<.5	<1	8.25	-119	290
F	18	77	<.5	<1	6.53	221	210
G	33	43	<.5	<1	8.07	-129	390
H	20	78	<.5	<1	8.72	-245	325
I	15	108	<.5	<1	8.38	17	340
J	8	201	<.5	<1	8.04	245	540
K	10	120	<.5	<1	7.6	184	330
L	8	33	<.5	<1	6.66	281	109
M	14	81	3.6	<1	7.33	264	293

Sample	T deg C
A	11
B	11
C	11
D	11
E	9.5
F	14
G	10.5
H	11.5
I	9.5
J	12
K	10.5
L	24
M	9.5

Table 2. Analytical results for rocks and soil samples as determined by multiacid digestion and inductively coupled plasma-atomic emission spectroscopy

Sample type	1 vein	2 vein	3 vein	4 vein	5 outcrop	6 outcrop	7 vein
Al%	8.9	6.8	7.5	6.9	5.5	7.6	5.3
Ca%	1.1	6.2	2.6	0.65	0.27	3.1	0.14
Fe%	3.8	4	4.8	2.4	0.85	3.5	4.9
K%	1.6	2.6	1.9	1.4	5.1	0.48	2.3
Mg%	0.64	1.1	1.2	0.31	0.2	1.3	0.94
Na%	2.1	0.58	0.46	2.2	0.49	2.5	0.05
P%	0.05	0.04	0.04	0.06	0.02	0.06	0.03
Ti%	0.43	0.34	0.41	0.31	0.11	0.38	0.24
Mn mg/kg	7500	1700	1100	240	190	700	1400
Ag mg/kg	<2	<2	<2	<2	<2	<2	<2
As mg/kg	110	30	50	300	30	20	110
Au mg/kg	<8	<8	<8	<8	<8	<8	<8
Ba mg/kg	530	340	410	56	1400	330	500
Be mg/kg	<1	<1	<1	<1	1	1	1
Bi mg/kg	<10	<10	<10	20	<10	<10	<10
Cd mg/kg	3	<2	<2	<2	<2	<2	<2
Ce mg/kg	25	28	18	45	51	33	54
Co mg/kg	39	14	20	16	4	17	17
Cr mg/kg	25	21	34	11	13	41	20
Cu mg/kg	140	17	28	28	8	74	1900
Ga mg/kg	21	16	16	13	13	17	17
La mg/kg	12	16	11	21	28	21	26
Li mg/kg	19	48	59	32	12	38	58
Mo mg/kg	4	<2	<2	<2	<2	<2	<2
Nb mg/kg	<4	<4	<4	<4	5	8	7
Nd mg/kg	20	19	13	37	21	15	22
Ni mg/kg	16	15	26	6	9	32	13
Pb mg/kg	89	<4	<4	19	6	5	38
Sc mg/kg	43	17	23	17	4	10	7
Sr mg/kg	320	130	160	120	120	310	45
V mg/kg	240	140	180	73	23	77	65
Y mg/kg	49	25	14	41	21	12	31
Yb mg/kg	5	3	2	3	2	1	3
Zn mg/kg	780	75	100	56	21	67	420

Table 2. Analytical results for rock and soil samples as determined by multiacid digestion and inductively coupled plasma atomic emission spectroscopy--Continued

Sample type	8 soil	9 cutting	10 cutting	11 lake sediment	12 lake sediment
Al%	7.7	8.6	8.1		
Ca%	1.2	3	2.5		
Fe%	4.2	4.3	3.7		
K%	0.9	1.2	0.84		
Mg%	1.6	1.4	0.97		
Na%	1.8	3	3		
P%	0.07	0.14	0.09		
Ti%	0.45	0.64	0.48		
Mn mg/kg	870	850	950		
Ag mg/kg	<2	<2	<2		
As mg/kg	10	140	400	10*	12*
Au mg/kg	<8	<8	<8		
Ba mg/kg	460	360	310		
Be mg/kg	1	1	1		
Bi mg/kg	<10	<10	<10		
Cd mg/kg	<2	<2	<2		
Ce mg/kg	33	46	39		
Co mg/kg	23	18	16		
Cr mg/kg	160	29	43		
Cu mg/kg	34	83	65		
Ga mg/kg	16	20	20		
La mg/kg	16	29	23		
Li mg/kg	33	100	110		
Mo mg/kg	<2	<2	<2		
Nb mg/kg	5	19	11		
Nd mg/kg	17	25	20		
Ni mg/kg	110	19	32		
Pb mg/kg	11	<4	7		
Sc mg/kg	15	13	12		
Sr mg/kg	190	430	320		
V mg/kg	130	120	90		
Y mg/kg	12	14	14		
Yb mg/kg	2	2	2		
Zn mg/kg	94	63	65		

*Acid extractable arsenic concentration determined by Graphite Furnace AAS

Table 3. Analytical results for rocks and soil samples as determined by X-ray fluorescence spectroscopy

[LOI is loss on ignition]

Sample No.	1	2	3	4	5	6	7
SiO_2%	58.5	54.5	62	68.9	78	65.6	73
Al_2O_3%	17.4	12.6	14.2	13.5	10.7	14.3	10.1
Fe_2O_3%	5.68	5.95	7.18	3.55	1.17	5.21	6.94
MgO%	1.08	1.85	1.98	0.56	0.38	2.05	1.49
CaO%	1.59	9.07	3.71	0.87	0.35	4.3	0.19
Na_2O%	2.94	0.74	0.66	3.11	0.72	3.33	<.15
K_2O%	2.11	3.28	2.39	1.88	6.66	0.59	2.94
TiO_2%	0.66	0.51	0.63	0.54	0.16	0.63	0.46
P_2O_5%	0.12	0.1	0.11	0.15	0.05	0.16	0.07
MnO%	1.09	0.24	0.15	0.02	<0.2	0.09	0.18
LOI 900C%	8.9	10.9	7.08	6.15	1.27	3.64	3.94

Sample No.	8	9	10
SiO_2%	61.2	58.9	62.3
Al_2O_3%	14.9	16.4	15.5
Fe_2O_3%	6.22	6.54	5.56
MgO%	2.59	2.38	1.58
CaO%	1.73	4.41	3.52
Na_2O%	2.37	4.07	4.01
K_2O%	1.15	1.48	1.05
TiO_2%	0.82	1.04	0.77
P_2O_5%	0.18	0.33	0.21
MnO%	0.11	0.11	0.12
LOI 900C%	8.58	4.37	5.26